UE OXBRIDGE-PREP

CAMBRIDGE NATURAL SCIENCES ADMISSIONS ASSESSMENT

NSAA

PAST PAPERS

2016-2023

Maths
Physics

Reproduced from Official Docs
On-line Complete Solutions

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Introduction

"NSAA Past Papers" is presented by UE International Education (ueie.com), which is designed as a companion to the ESAT Standard Course and the ESAT Question Practice. It aims to help students to prepare the Engineering and Sciences Admissions Test. It is also a useful reference for teachers who are teaching ESAT.

All questions in this collection are reproduced from the official past papers released by the University of Cambridge, with a few typos from the source files corrected. The 2024 Edition collects a total of **592** NSAA questions from 2016 to 2023.

In addition, subscribed users can access one more on-line ESAT mock papers, which are made up by our professional teachers based on the latest research on ENGAA/NSAA questions.

How to Access Full Solutions

Although this document is free for everyone to use, the detailed solutions to all questions are **only available for subscribed users** who have purchased one of the following products of the UE Oxbridge-Prep series (click on the link to learn more):

ESAT Standard Course

ESAT Question Practice

At least one of the official solution, hand-written solution or video solution is provided for each question. Hand-written solutions are provided if official solutions are unavailable. There are video solutions for some questions.

All solutions can be accessed **ON-LINE ONLY**.

NSAA Score Conversions

You may look up NSAA score conversions through the following page:

Cambridge NSAA Score Conversions

Statistics of Solutions (Maths and Physics ONLY)

Year	Number of Questions	Official Solutions	Handwritten Solutions	Video Solutions
2016	**56**	0	56	6
2017	**56**	0	56	5
2018	**56**	0	56	9
2019	**56**	0	56	6
2020	**60**	0	60	12
2021	**60**	0	60	2
2022	**60**	0	60	0
2023	**60**	0	60	0
Total	**464**	0 (0%)	464 (100%)	40 (8.6%)

简介

《NSAA 历年真题集》由优易国际教育（ueie.com）出品，是 ESAT 标准课程和 ESAT 刷题训练的配套资料之一。其主要用途是帮助学生提高备考 ESAT 考试的效率，以及为教授 ESAT 考试的同行老师提供参考。

真题集中的所有真题均由剑桥大学官方发布的真题重新排版制作而成，并修订了源文件中的若干印刷错误。2024 版收录了 2016 年至 2023 年共 **592** 道 NSAA 真题。

此外，我们还为付费订阅用户提供一套线上 ESAT 模考题。这些模考题是由我们的专业教师团队依据近几年 ENGAA/NSAA 考试命题趋势而命制的。

真题解析在哪里可以看到

所有用户均可免费使用真题集，但所有题目的解析仅向购买以下任意优易牛剑备考系列产品之一的**付费用户开放**：

ESAT 标准课

ESAT 刷题训练

所有真题都有详细解析，解析形式为官方解析、手写解析或视频讲解中的一种或多种。如果没有官方解析，则提供手写解析。部分题目提供视频讲解。

所有解析均**只能在线查看**。

NSAA 分数转换

你可以通过下方页面查询 NSAA 分数转换关系：

剑桥 NSAA 分数转换

解析数量统计(仅数学和物理题)

年份	真题数量	官方解析题量	手写解析题量	视频講解题量
2016	**56**	0	56	6
2017	**56**	0	56	5
2018	**56**	0	56	9
2019	**56**	0	56	6
2020	**60**	0	60	12
2021	**60**	0	60	2
2022	**60**	0	60	0
2023	**60**	0	60	0
总计	**464**	0 (0%)	464 (100%)	40 (8.6%)

簡介

《NSAA 歷年真題集》由優易國際教育（ueie.com）出品，是 ESAT 標準課程和 ESAT 刷題訓練的配套資料之一。其主要用途是幫助學生提高備考 ESAT 考試的效率，以及為教授 ESAT 考試的同儕老師提供參考。

真題集中的所有真題均由劍橋大學官方發布的真題重新排版製作而成，並修訂了源文檔中的若干印刷錯誤。2024 版收錄了 2016 年至 2023 年共 **592** 道 NSAA 真題。

此外，我們還為付費訂閱用戶提供一套在線 ESAT 模擬題。這些模擬題系我們的專業教師團隊依據近幾年 ENGAA/NSAA 考試命題趨勢而命製的。

真題解析在哪裡可以看到

所有用戶均可免費使用真題集，但所有題目的解析僅向購買以下任意優易牛劍備考系列產品之一的**付費用戶開放**：

ESAT 標準課

ESAT 刷題訓練

所有真題都有詳細解析，解析形式為官方解析、手寫解析或視訊講解中的一種或多種。如果沒有官方解析，則提供手寫解析。部分題目提供影片講解。

所有解析均**只能線上查看**。

NSAA 分數換算

你可以透過下方頁面查詢 NSAA 分數換算關係：

劍橋 NSAA 分數換算

解析數量統計(僅數學和物理題)

年份	真題數量	官方解析題量	手寫解析題量	影片講解題量
2016	**56**	0	56	6
2017	**56**	0	56	5
2018	**56**	0	56	9
2019	**56**	0	56	6
2020	**60**	0	60	12
2021	**60**	0	60	2
2022	**60**	0	60	0
2023	**60**	0	60	0
總計	**464**	0 (0%)	464 (100%)	40 (8.6%)

Answer Keys

NSAA 2016-2023

Only keys to multiple-choice questions are provided.

Full solutions can be accessed on-line by the links or scanning the QR codes provided.

2016 S1 Answer Keys									
Q1	G	Q21	H	Q41	C	Q61	B	Q81	D
Q2	B	Q22	F	Q42	D	Q62	B	Q82	B
Q3	C	Q23	C	Q43	D	Q63	H	Q83	G
Q4	E	Q24	D	Q44	E	Q64	E	Q84	G
Q5	C	Q25	E	Q45	C	Q65	G	Q85	D
Q6	B	Q26	D	Q46	A	Q66	E	Q86	E
Q7	F	Q27	E	Q47	C	Q67	D	Q87	G
Q8	E	Q28	H	Q48	F	Q68	B	Q88	A
Q9	B	Q29	F	Q49	F	Q69	D	Q89	E
Q10	C	Q30	F	Q50	A	Q70	C	Q90	C
Q11	A	Q31	D	Q51	F	Q71	H		
Q12	D	Q32	A	Q52	D	Q72	E		
Q13	D	Q33	A	Q53	C	Q73	C		
Q14	E	Q34	G	Q54	C	Q74	C		
Q15	B	Q35	D	Q55	C	Q75	C		
Q16	A	Q36	G	Q56	F	Q76	A		
Q17	C	Q37	D	Q57	A	Q77	C		
Q18	F	Q38	D	Q58	C	Q78	H		
Q19	B	Q39	C	Q59	E	Q79	A		
Q20	D	Q40	C	Q60	B	Q80	B		

2017 S1 Answer Keys									
Q1	F	Q21	E	Q41	D	Q61	B	Q81	E
Q2	E	Q22	E	Q42	C	Q62	D	Q82	A
Q3	B	Q23	D	Q43	D	Q63	G	Q83	A
Q4	G	Q24	D	Q44	D	Q64	B	Q84	A
Q5	E	Q25	B	Q45	D	Q65	C	Q85	C
Q6	C	Q26	F	Q46	E	Q66	C	Q86	B
Q7	D	Q27	A	Q47	E	Q67	F	Q87	A
Q8	B	Q28	A	Q48	D	Q68	H	Q88	H
Q9	D	Q29	E	Q49	E	Q69	A	Q89	B
Q10	F	Q30	C	Q50	B	Q70	H	Q90	B
Q11	C	Q31	C	Q51	A	Q71	C		
Q12	B	Q32	C	Q52	D	Q72	F		
Q13	B	Q33	C	Q53	C	Q73	E		
Q14	D	Q34	D	Q54	D	Q74	B		
Q15	C	Q35	E	Q55	A	Q75	C		
Q16	F	Q36	E	Q56	B	Q76	C		
Q17	G	Q37	F	Q57	C	Q77	B		
Q18	E	Q38	B	Q58	E	Q78	D		
Q19	B	Q39	H	Q59	A	Q79	D		
Q20	G	Q40	A	Q60	D	Q80	F		

2018 S1 Answer Keys									
Q1	E	Q21	G	Q41	B	Q61	H	Q81	C
Q2	B	Q22	E	Q42	E	Q62	G	Q82	D
Q3	H	Q23	E	Q43	F	Q63	A	Q83	C
Q4	D	Q24	C	Q44	A	Q64	B	Q84	F
Q5	C	Q25	C	Q45	E	Q65	F	Q85	D
Q6	E	Q26	A	Q46	C	Q66	E	Q86	A
Q7	A	Q27	A	Q47	A	Q67	A	Q87	E
Q8	C	Q28	C	Q48	D	Q68	C	Q88	A
Q9	E	Q29	E	Q49	B	Q69	H	Q89	C
Q10	D	Q30	C	Q50	A	Q70	G	Q90	B
Q11	C	Q31	B	Q51	C	Q71	F		
Q12	F	Q32	E	Q52	C	Q72	B		
Q13	E	Q33	H	Q53	B	Q73	A		
Q14	A	Q34	C	Q54	E	Q74	E		
Q15	C	Q35	E	Q55	F	Q75	D		
Q16	C	Q36	A	Q56	D	Q76	F		
Q17	G	Q37	C	Q57	E	Q77	C		
Q18	B	Q38	C	Q58	E	Q78	D		
Q19	B	Q39	A	Q59	E	Q79	E		
Q20	B	Q40	D	Q60	E	Q80	F		

2019 S1 Answer Keys									
Q1	F	Q21	F	Q41	H	Q61	G	Q81	B
Q2	H	Q22	A	Q42	F	Q62	D	Q82	C
Q3	E	Q23	C	Q43	E	Q63	A	Q83	A
Q4	C	Q24	D	Q44	B	Q64	C	Q84	D
Q5	E	Q25	A	Q45	H	Q65	H	Q85	E
Q6	D	Q26	A	Q46	D	Q66	B	Q86	F
Q7	B	Q27	E	Q47	D	Q67	B	Q87	D
Q8	F	Q28	F	Q48	A	Q68	E	Q88	D
Q9	A	Q29	C	Q49	D	Q69	A	Q89	F
Q10	D	Q30	C	Q50	B	Q70	H	Q90	B
Q11	E	Q31	C	Q51	D	Q71	D		
Q12	G	Q32	E	Q52	E	Q72	H		
Q13	D	Q33	F	Q53	B	Q73	C		
Q14	G	Q34	D	Q54	E	Q74	C		
Q15	C	Q35	B	Q55	D	Q75	B		
Q16	C	Q36	B	Q56	E	Q76	E		
Q17	C	Q37	F	Q57	C	Q77	D		
Q18	E	Q38	C	Q58	C	Q78	C		
Q19	B	Q39	E	Q59	D	Q79	E		
Q20	E	Q40	G	Q60	G	Q80	C		

2020 S1 Answer Keys							
Q1	D	Q21	B	Q41	E	Q61	H
Q2	G	Q22	C	Q42	F	Q62	F
Q3	A	Q23	A	Q43	F	Q63	G
Q4	A	Q24	F	Q44	B	Q64	D
Q5	C	Q25	D	Q45	E	Q65	F
Q6	B	Q26	A	Q46	B	Q66	G
Q7	B	Q27	D	Q47	F	Q67	F
Q8	F	Q28	E	Q48	A	Q68	E
Q9	A	Q29	F	Q49	D	Q69	F
Q10	E	Q30	C	Q50	C	Q70	B
Q11	F	Q31	C	Q51	D	Q71	F
Q12	B	Q32	B	Q52	E	Q72	C
Q13	E	Q33	E	Q53	D	Q73	H
Q14	A	Q34	D	Q54	G	Q74	A
Q15	F	Q35	H	Q55	C	Q75	A
Q16	E	Q36	C	Q56	E	Q76	C
Q17	B	Q37	D	Q57	G	Q77	C
Q18	D	Q38	G	Q58	D	Q78	F
Q19	C	Q39	A	Q59	F	Q79	C
Q20	D	Q40	G	Q60	F	Q80	F

2020 S2 Answer Keys					
Q1	E	Q21	G	Q41	B
Q2	D	Q22	G	Q42	C
Q3	C	Q23	B	Q43	C
Q4	E	Q24	C	Q44	H
Q5	G	Q25	E	Q45	C
Q6	D	Q26	C	Q46	G
Q7	B	Q27	E	Q47	D
Q8	F	Q28	D	Q48	B
Q9	F	Q29	H	Q49	B
Q10	C	Q30	A	Q50	G
Q11	D	Q31	F	Q51	A
Q12	D	Q32	D	Q52	D
Q13	F	Q33	B	Q53	F
Q14	A	Q34	B	Q54	F
Q15	E	Q35	B	Q55	A
Q16	E	Q36	D	Q56	D
Q17	D	Q37	C	Q57	E
Q18	B	Q38	E	Q58	D
Q19	C	Q39	B	Q59	D
Q20	D	Q40	C	Q60	A

2021 S1 Answer Keys							
Q1	E	Q21	B	Q41	F	Q61	F
Q2	B	Q22	E	Q42	C	Q62	B
Q3	D	Q23	F	Q43	B	Q63	B
Q4	A	Q24	A	Q44	E	Q64	D
Q5	C	Q25	G	Q45	D	Q65	C
Q6	E	Q26	H	Q46	E	Q66	H
Q7	A	Q27	C	Q47	F	Q67	D
Q8	F	Q28	D	Q48	D	Q68	G
Q9	D	Q29	E	Q49	C	Q69	B
Q10	E	Q30	H	Q50	E	Q70	A
Q11	F	Q31	B	Q51	B	Q71	A
Q12	D	Q32	G	Q52	C	Q72	D
Q13	F	Q33	C	Q53	A	Q73	H
Q14	E	Q34	E	Q54	E	Q74	C
Q15	B	Q35	D	Q55	A	Q75	B
Q16	G	Q36	B	Q56	B	Q76	E
Q17	A	Q37	C	Q57	C	Q77	C
Q18	F	Q38	D	Q58	F	Q78	A
Q19	H	Q39	G	Q59	E	Q79	A
Q20	F	Q40	E	Q60	A	Q80	D

2021 S2 Answer Keys					
Q1	D	Q21	C	Q41	E
Q2	C	Q22	B	Q42	D
Q3	G	Q23	C	Q43	E
Q4	D	Q24	F	Q44	C
Q5	F	Q25	D	Q45	E
Q6	A	Q26	B	Q46	B
Q7	D	Q27	A	Q47	G
Q8	B	Q28	D	Q48	D
Q9	D	Q29	D	Q49	F
Q10	C	Q30	E	Q50	B
Q11	E	Q31	E	Q51	D
Q12	F	Q32	G	Q52	A
Q13	C	Q33	C	Q53	G
Q14	E	Q34	F	Q54	H
Q15	H	Q35	B	Q55	E
Q16	E	Q36	E	Q56	F
Q17	G	Q37	D	Q57	B
Q18	C	Q38	H	Q58	G
Q19	A	Q39	F	Q59	C
Q20	C	Q40	C	Q60	B

2022 S1 Answer Keys					
Q1	E	Q21	A		
Q2	D	Q22	C		
Q3	D	Q23	E		
Q4	E	Q24	G		
Q5	D	Q25	E		
Q6	D	Q26	B		
Q7	C	Q27	A		
Q8	B	Q28	G		
Q9	B	Q29	B		
Q10	B	Q30	D		
Q11	G	Q31	E		
Q12	C	Q32	C		
Q13	G	Q33	G		
Q14	C	Q34	C		
Q15	E	Q35	D		
Q16	B	Q36	D		
Q17	E	Q37	F		
Q18	A	Q38	E		
Q19	D	Q39	E		
Q20	C	Q40	A		

2022 S2 Answer Keys					
Q1	E				
Q2	C				
Q3	C				
Q4	E				
Q5	B				
Q6	F				
Q7	D				
Q8	D				
Q9	B				
Q10	F				
Q11	C				
Q12	G				
Q13	F				
Q14	C				
Q15	E				
Q16	E				
Q17	A				
Q18	A				
Q19	D				
Q20	B				

2023 S1 Answer Keys					
Q1	A	Q21	G		
Q2	E	Q22	F		
Q3	C	Q23	D		
Q4	A	Q24	F		
Q5	F	Q25	B		
Q6	D	Q26	B		
Q7	D	Q27	E		
Q8	E	Q28	B		
Q9	D	Q29	E		
Q10	B	Q30	E		
Q11	B	Q31	A		
Q12	C	Q32	A		
Q13	H	Q33	B		
Q14	D	Q34	C		
Q15	B	Q35	E		
Q16	B	Q36	D		
Q17	E	Q37	H		
Q18	C	Q38	B		
Q19	C	Q39	C		
Q20	E	Q40	A		

2023 S2 Answer Keys					
Q1	A				
Q2	D				
Q3	F				
Q4	E				
Q5	C				
Q6	D				
Q7	D				
Q8	E				
Q9	F				
Q10	B				
Q11	C				
Q12	D				
Q13	E				
Q14	G				
Q15	A				
Q16	E				
Q17	C				
Q18	E				
Q19	D				
Q20	E				

NSAA 2016 S1

NSAA 2016 S1
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 80 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 80 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **five** parts: **A**, **B**, **C**, **D**, and **E**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **two** further parts chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology
Part E	Advanced Mathematics and Advanced Physics

Each part has 18 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **three** parts. Each question is worth one mark.

Questions ask you to show your choice between options. Choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You can use the question paper for rough working, but no extra paper is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators may NOT be used.

Part A

[NSAA, 2016S1Q1]

Find the complete set of solutions to $-8 < 6 - \frac{x}{2}$.

(A) $x < 4$

(B) $x > 4$

(C) $x < 20$

(D) $x > 20$

(E) $x < 22$

(F) $x > 22$

(G) $x < 28$

(H) $x > 28$

[NSAA, 2016S1Q2]

Which one of the following is a simplification of $\left(\sqrt{3} - \sqrt{2}\right)^2$?

(A) $1 - 2\sqrt{3}\sqrt{2}$

(B) $5 - 2\sqrt{2}\sqrt{3}$

(C) $2\sqrt{3} - 2\sqrt{2}$

(D) 1

(E) $5 - \sqrt{2}\sqrt{3}$

(F) $13 - 2\sqrt{2}\sqrt{3}$

(G) $5 + 2\sqrt{2}\sqrt{3}$

(H) 5

[NSAA, 2016S1Q3]

The ratio of $Q : R$ is $5 : 2$ and the ratio of $R : S$ is $3 : 10$.
Which one of the following gives the ratio $Q : S$ in its simplest form?

(A) $1 : 2$

(B) $2 : 1$

(C) $3 : 4$

(D) $3 : 25$

(E) $4 : 3$

(F) $25 : 3$

[NSAA, 2016S1Q4]

The mean age of the twenty members of a running club is exactly 28.

The mean age increases by exactly 2 years when two new members join.

What is the mean age of the two new members?

(A) 20 years

(B) 22 years

(C) 30 years

(D) 40 years

(E) 50 years

(F) 52 years

[NSAA, 2016S1Q5]

A medical scanner is bought for £15 000.

The value of the scanner depreciates by 20% every year.

By how much has the scanner reduced in value after 2 years?

(A) £600

(B) £3000

(C) £5400

(D) £6000

(E) £9000

(F) £9600

(G) £12 000

[NSAA, 2016S1Q6]

The point A is 4 km due East of the point B.

The bearing of the point C from A is 330° and the bearing of C from B is 060°.

Find the distance BC.

(A) 2 km

(B) $2\sqrt{3}$ km

(C) 4 km

(D) $2\sqrt{5}$ km

(E) $4\sqrt{2}$ km

[NSAA, 2016S1Q7]

The quantities x and y are positive.

x is inversely proportional to the square root of y.

When $x = 8$, $y = 9$.

What is the value of y when $x = 6$?

(A) $\frac{3}{2}$

(B) 2

(C) $\frac{81}{16}$

(D) $\frac{27}{14}$

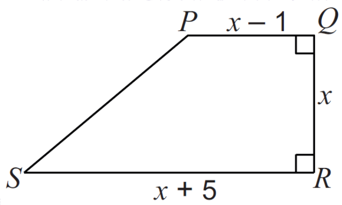
(E) 12

(F) 16

[NSAA, 2016S1Q8]

In a trapezium $PQRS$, the parallel sides are PQ and RS.

$PQ = (x - 1)$ cm, $RS = (x + 5)$ cm and the vertical height $QR = x$ cm.



[diagram not to scale]

The area of the trapezium is 120 cm².

What is the length of RS?

(A) 9 cm

(B) 10 cm

(C) 11 cm

(D) 12 cm

(E) 15 cm

(F) 17 cm

[NSAA, 2016S1Q9]

Make b the subject of the formula:

$$a = \frac{b^2 + 2}{3b^2 - 1}$$

(A) $b = \pm\sqrt{\left(\frac{a+2}{3a+1}\right)}$

(B) $b = \pm\sqrt{\left(\frac{a+2}{3a-1}\right)}$

(C) $b = \pm\sqrt{\left(\frac{2-a}{3a+1}\right)}$

(D) $b = \pm\sqrt{\left(\frac{2-a}{3a-1}\right)}$

(E) $b = \pm\sqrt{\left(\frac{3}{3a+1}\right)}$

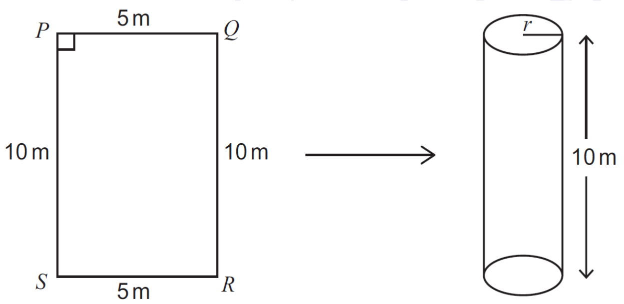
(F) $b = \pm\sqrt{\left(\frac{3}{3a-1}\right)}$

[NSAA, 2016S1Q10]

A thin rectangular sheet of metal 10 m by 5 m is made into an open ended cylinder by joining the edges PS and QR.

The height of the cylinder is 10 m.

What is the volume, in cubic metres, enclosed by this cylinder?



[diagram not to scale]

(A) $\frac{5}{2\pi}$

(B) $\frac{25}{4\pi}$

(C) $\frac{125}{2\pi}$

(D) 62.5π

(E) $\frac{125}{\pi}$

(F) 250π

[NSAA, 2016S1Q11]

Which one of the following is a simplification of $4+\frac{4-x^2}{x^2-2x}$?

(A) $3-\frac{2}{x}$

(B) $3+\frac{2}{x}$

(C) $4-\frac{2}{x}$

(D) $4+\frac{2}{x}$

(E) $5-\frac{2}{x}$

(F) $5+\frac{2}{x}$

[NSAA, 2016S1Q12]

During summer activities week 120 students each chose one activity from swimming, archery, and tennis.

46 of the students were girls.

36 of the students chose tennis, and $\frac{2}{3}$ of these were boys; 25 girls chose swimming, and 27 students chose archery.

A boy is picked at random. What is the probability that he chose swimming?

(A) $\frac{3}{20}$

(B) $\frac{9}{37}$

(C) $\frac{4}{15}$

(D) $\frac{16}{37}$

(E) $\frac{32}{57}$

[NSAA, 2016S1Q13]

Which one of the following expressions is equivalent to $\frac{9^{2n+1}\times 3^{4-3n}}{27^{2-n}}$?

(A) 3^9

(B) 3^{-2n}

(C) 3^{2-2n}

(D) 3^{4n}

(E) 3^{6n-2}

(F) 3^6

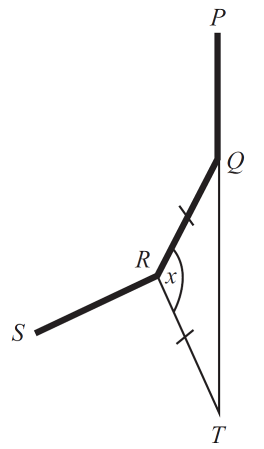
[NSAA, 2016S1Q14]

In the diagram below, $PQRS$ is part of a regular polygon.

The polygon has n sides.

The side PQ is extended to T such that PQT is a straight line.

The length of RQ is the same as the length of RT.



[diagram not to scale]

Find an equation for n in terms of x, where x is the size of angle $\angle QRT$ in degrees.

(A) $n = \frac{180}{x-90}$

(B) $n = \frac{180-x}{720}$

(C) $n = \frac{360-x}{90}$

(D) $n = \frac{360}{180-x}$

(E) $n = \frac{720}{180-x}$

(F) $n = \frac{720}{360-x}$

(G) $n = \frac{360}{360-x}$

[NSAA, 2016S1Q15]

In a population, $\frac{3}{5}$ of the adults are overweight.

The probability of an overweight adult having Type 2 diabetes is $\frac{9}{50}$; this probability is 6 times the probability of an adult who is not overweight having the disease.

An adult is chosen at random from the population.

What is the probability the chosen adult has Type 2 diabetes?

(A) $\frac{27}{250}$

(B) $\frac{3}{25}$

(C) $\frac{63}{500}$

(D) $\frac{37}{250}$

(E) $\frac{39}{50}$

(F) $\frac{21}{100}$

[NSAA, 2016S1Q16]

The graph of $y = x^2 + ax + b$ meets the straight line $y = x + 1$ when $x = 2$ and $x = 4$.

Find a and b.

(A) $a = -5, b = 9$

(B) $a = 5, b = 9$

(C) $a = -5, b = 11$

(D) $a = 5, b = 11$

(E) $a = -6, b = 11$

(F) $a = 6, b = 11$

(G) $a = -6, b = 13$

(H) $a = 6, b = 13$

[NSAA, 2016S1Q17]

A rhombus has diagonals of length 5 cm and 3 cm.

An enlargement of the rhombus has sides of length $\sqrt{68}$ cm.

What is the scale factor of the enlargement?

(A) $\sqrt{2}$

(B) 2

(C) $2\sqrt{2}$

(D) 4

(E) $4\sqrt{2}$

[NSAA, 2016S1Q18]

A straight line is drawn joining the points with coordinates $(7, 1-p)$ and $(2p+1, -1)$, where p is a constant.

What is the complete set of values of p for which the gradient of this line is finite and greater than zero?

(A) $p < -4, p > 0$

(B) $-4 < p < 0$

(C) $p < 0$

(D) $p < 2$

(E) $2 < p < 3$

(F) $p < 2, p > 3$

Part B

[NSAA, 2016S1Q19]

In the 1920s scientists discovered that the universe is expanding. One consequence of this expansion is that the intense gamma-ray radiation that filled the early universe has now been shifted to the microwave region of the electromagnetic spectrum.

Which line of the table describes how the expansion of the universe has affected the frequency and wavelength of these electromagnetic waves?

	effect on frequency	*effect on wavelength*
(A)	decrease	decrease
(B)	decrease	increase
(C)	increase	decrease
(D)	increase	increase
(E)	no effect	decrease
(F)	no effect	increase

[NSAA, 2016S1Q20]

A nuclide $^{214}_{82}\mathrm{Pb}$ changes by radioactive decay into the nuclide $^{210}_{82}\mathrm{Pb}$.

Which combination of emissions produces this change?

(A) 3 alpha

(B) 2 alpha and 1 beta

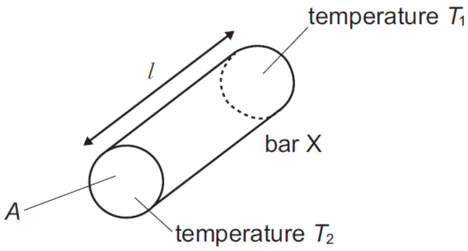
(C) 2 alpha and 2 beta

(D) 1 alpha and 2 beta

(E) 3 beta

[NSAA, 2016S1Q21]

A cylindrical copper bar X of length l has a cross-sectional area A. The colder end of the bar is kept at temperature T_1 and the hotter end is kept at temperature T_2.



The curved surface of the bar is perfectly insulated and thermal energy is conducted from the hotter end of the bar to the colder end.

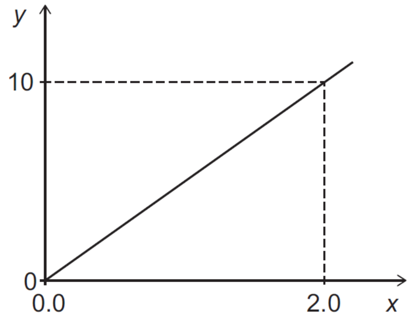
Changes in l, A, T_1 and T_2 may alter the rate at which thermal energy is conducted along the copper bar.

In which case is the rate of conduction of thermal energy along the insulated bar the same as for bar X?

	change in A	*change in l*	*change in T_1*	*change in T_2*
(A)	doubles	no change	no change	no change
(B)	halves	no change	no change	no change
(C)	no change	doubles	no change	no change
(D)	no change	halves	no change	no change
(E)	no change	no change	decreases by 10 °C	increases by 10 °C
(F)	no change	no change	decreases by 10 °C	no change
(G)	no change	no change	increases by 10 °C	decreases by 10 °C
(H)	no change	no change	increases by 10 °C	increases by 10 °C

[NSAA, 2016S1Q22]

The graph shown of quantity y against quantity x represents the motion of a body.



(The scales on both axes are in the appropriate S.I. units, and the gravitational field strength g is 10 N kg^{-1}.)

Which two of the following could the graph represent?

1 kinetic energy against velocity for an object of mass 10 kg undergoing free-fall.

2 potential energy against height for an object of mass 20 kg being lifted by a constant external force.

3 velocity against time for an object of mass 20 kg being accelerated by a resultant force of 100 N.

4 work done by an external force of 5 N against distance moved for an object of mass 12 kg being moved at constant speed by (and in the direction of) the external force.

(A) 1 and 2

(B) 1 and 3

(C) 1 and 4

(D) 2 and 3

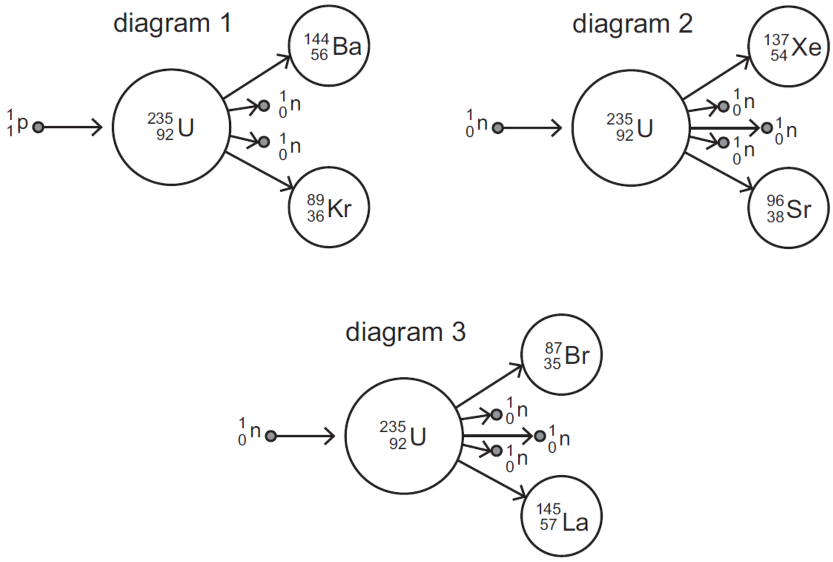
(E) 2 and 4

(F) 3 and 4

[NSAA, 2016S1Q23]

A uranium-235 nucleus can undergo fission to produce two smaller nuclei.

Which of the diagrams, if any, could represent this process?



(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2016S1Q24]

A circuit consists of a 5.0 Ω resistor and a variable resistor connected in series with a 24 V battery. The variable resistor has a minimum resistance of 3.0 Ω and a maximum resistance of 15 Ω. The battery and the connecting wires have negligible resistance.

What is the maximum power dissipated in the 5.0 Ω resistor?

(A) 7.2 W

(B) 18 W

(C) 27 W

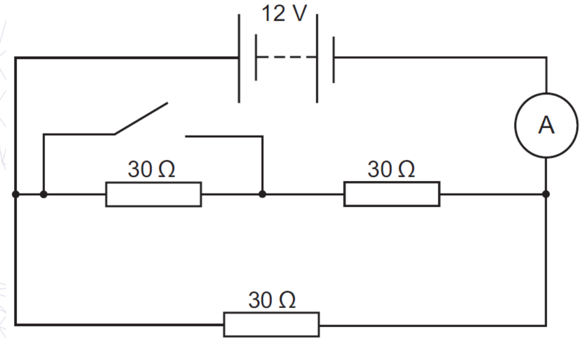
(D) 45 W

(E) 72 W

(F) 75 W

[NSAA, 2016S1Q25]

The diagram shows a 12 V battery, a switch and three resistors. Each resistor has a resistance of 30 Ω.



Initially the switch is open.

What happens to the reading on the ammeter when the switch is closed?

(A) It decreases by 0.20 A.

(B) It decreases by 0.40 A.

(C) It decreases by 0.60 A.

(D) It decreases by 0.80 A.

(E) It increases by 0.20 A.

(F) It increases by 0.40 A.

(G) It increases by 0.60 A.

(H) It increases by 0.80 A.

[NSAA, 2016S1Q26]

The total power P radiated by a star is given by:

$$P = kR^2T^4$$

where R is the radius of the star, T is its surface temperature and k is a constant.

The power currently radiated by the Sun is 4.0×10^{26} W. Towards the end of the Sun's life its radius will increase by a factor of a hundred and its surface temperature will decrease by a factor of two.

What will be the power radiated by the Sun when these changes have occurred?

(A) 2.5×10^{27} W

(B) 1.0×10^{28} W

(C) 2.0×10^{28} W

(D) 2.5×10^{29} W

(E) 1.0×10^{30} W

(F) 2.0×10^{30} W

(G) 2.5×10^{33} W

(H) 1.0×10^{34} W

[NSAA, 2016S1Q27]

A transverse wave travelling through a medium has a frequency of 5.0 Hz, a wavelength of 4.0 cm and an amplitude of 3.0 cm.

What is the total distance travelled by a particle of the medium in one minute?

(A) 900 cm

(B) 1200 cm

(C) 1800 cm

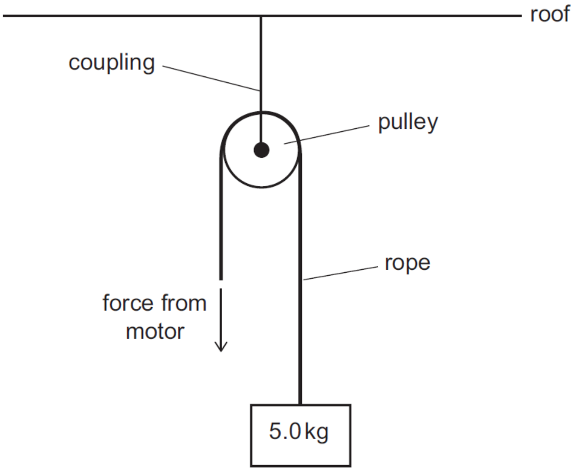
(D) 2400 cm

(E) 3600 cm

(F) 4800 cm

[NSAA, 2016S1Q28]

A motor is used to lift a mass of 5.0 kg using a pulley system as shown in the diagram. The pulley is secured to the roof using a coupling.



The motor needs to cause the mass to accelerate upwards at 0.80 m s^{-2}.

What is the minimum tension force that the coupling must be able to withstand without breaking?

(The gravitational field strength g is 10 N kg^{-1}. The pulley system is frictionless and has negligible mass. The rope has negligible mass and is inextensible.)

(A) 4.0 N

(B) 8.0 N

(C) 46 N

(D) 50 N

(E) 54 N

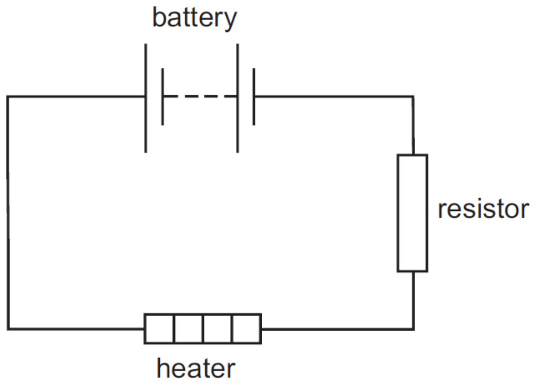
(F) 92 N

(G) 104 N

(H) 108 N

[NSAA, 2016S1Q29]

A heater is connected in series with a resistor and a 6.0 V battery in the circuit shown.



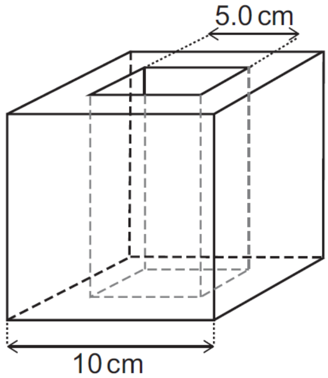
The total resistance of the circuit is 15 Ω. In 3.0 minutes, 180 J of electrical energy is transferred into other forms in the heater.

How much charge flows through the heater in the 3.0 minutes and what is the voltage across the heater?

	Charge / C	*Voltage* / V
(A)	1.2	150
(B)	1.2	216
(C)	7.5	0.041
(D)	7.5	24
(E)	72	0.40
(F)	72	2.5
(G)	450	0.40
(H)	450	2.5

[NSAA, 2016S1Q30]

A cubic block has a hole through it with a square cross-section. The dimensions are shown on the diagram. The weight of the block is 30 N.



What is the density of the material from which the block is made?

(The gravitational field strength g is 10 N kg^{-1}.)

(A) 0.30 g cm^{-3}

(B) 0.40 g cm^{-3}

(C) 0.60 g cm^{-3}

(D) 1.2 g cm^{-3}

(E) 3.0 g cm^{-3}

(F) 4.0 g cm^{-3}

(G) 6.0 g cm^{-3}

(H) 12 g cm^{-3}

[NSAA, 2016S1Q31]

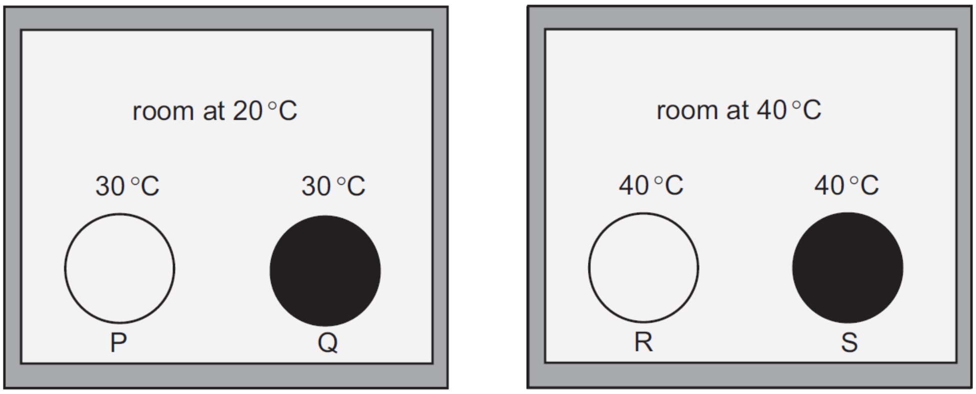
The diagram shows four solid steel balls P, Q, R and S which are of identical size.

Balls P and R have shiny surfaces. Balls Q and S have dull surfaces.

Balls P and Q are in a room at 20 °C.

Balls R and S are in a room at 40 °C.

The temperature of each ball at a given moment in time is shown on the diagram.

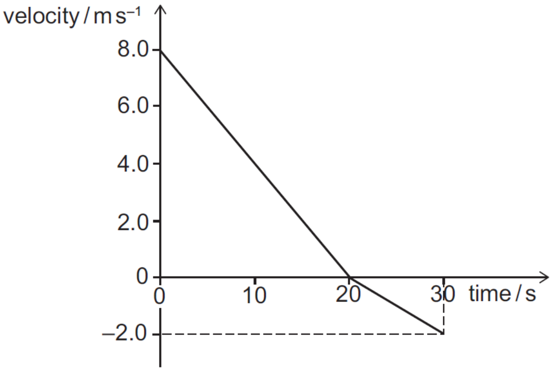


Which two balls lose thermal energy by convection, and which ball emits thermal radiation at the greatest rate?

	lose thermal energy by convection	*greatest rate of emission of thermal radiation*
(A)	P and Q	P
(B)	P and Q	Q
(C)	P and Q	R
(D)	P and Q	S
(E)	R and S	P
(F)	R and S	Q
(G)	R and S	R
(H)	R and S	S

[NSAA, 2016S1Q32]

The diagram shows the velocity-time graph for an object travelling in a straight line over a period of 30 s.



What total distance did the object travel in the 30 s, how far from its starting position was it at the end of the 30 s, and what was its average speed over the 30 s?

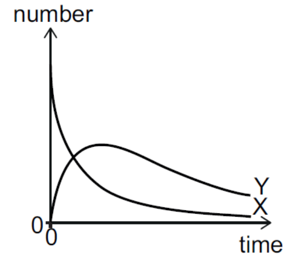
	total distance travelled / m	*distance from starting position* / m	*average speed* / m s^{-1}
(A)	90	70	3.0
(B)	90	70	5.0
(C)	90	90	3.0
(D)	90	90	5.0
(E)	180	140	5.0
(F)	180	140	6.0
(G)	180	180	5.0
(H)	180	180	6.0

[NSAA, 2016S1Q33]

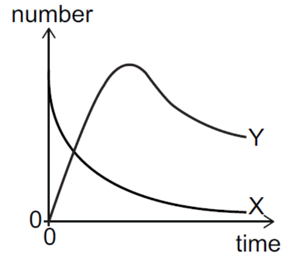
A sample of a radioactive isotope X decays to one other radioactive isotope Y. Y has a half-life that is double that of X. Initially only X is present.

Which graph could represent how the numbers of nuclei of X and Y that are present in the sample vary with time?

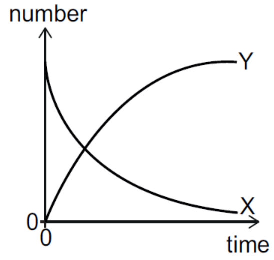
(All graphs cover the same period of time.)



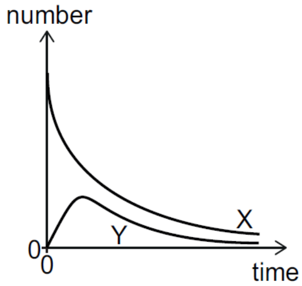
(A)



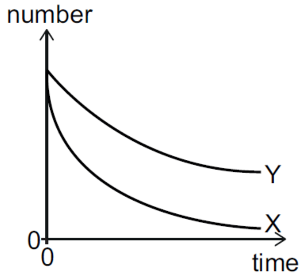
(B)



(C)



(D)



(E)

[NSAA, 2016S1Q34]

Bronze is a mixture of tin and copper.

A particular sample of bronze contains 10% tin by volume.(In other words, 10% of the total volume of the sample is tin and 90% of it is copper.)

What percentage of the mass of the sample is tin?

(Density of tin $= Y$ and density of copper $= X$.)

(A) $\frac{X}{9X-Y} \times 100$

(B) $\frac{X}{9Y-X} \times 100$

(C) $\frac{Y}{9X-Y} \times 100$

(D) $\frac{Y}{9Y-X} \times 100$

(E) $\frac{X}{9X+Y} \times 100$

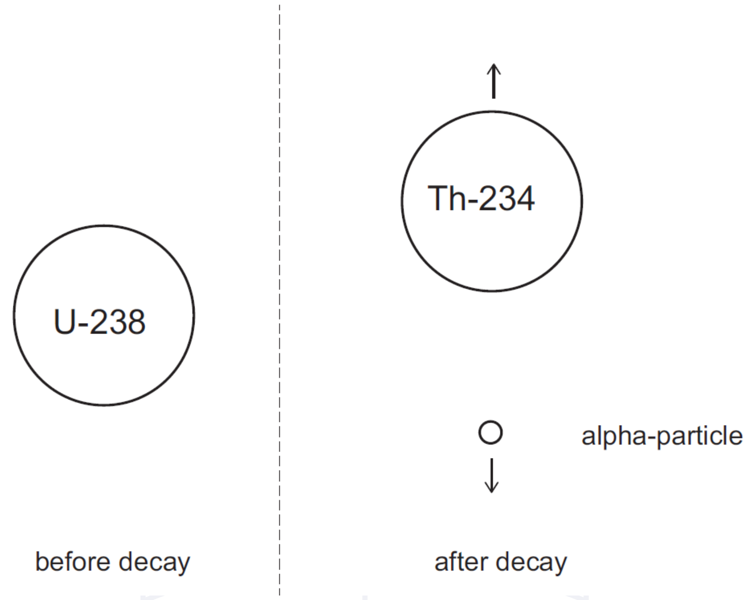
(F) $\frac{X}{9Y+X} \times 100$

(G) $\frac{Y}{9X+Y} \times 100$

(H) $\frac{X}{9Y+X} \times 100$

[NSAA, 2016S1Q35]

When a stationary uranium-238 nucleus decays by alpha emission it forms a nucleus of thorium-234. The total kinetic energy produced by the decay is E.



What is the kinetic energy of the alpha particle?

(A) $\frac{4E}{238}$

(B) $\frac{4E}{234}$

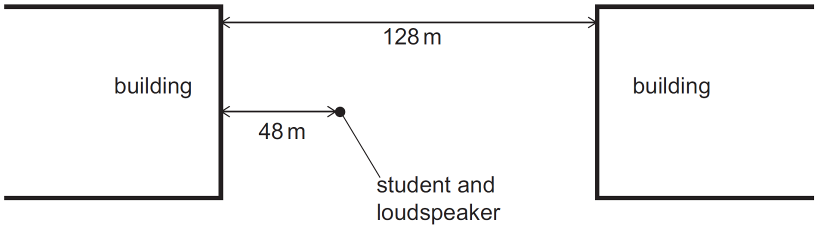
(C) $\frac{E}{2}$

(D) $\frac{234E}{238}$

(E) E

[NSAA, 2016S1Q36]

A student carries out an experiment to measure the speed of sound. A loudspeaker that emits sound in all directions is placed between two buildings that are 128 m apart as shown. The student and loudspeaker are 48 m from one of the buildings.



The loudspeaker is connected to a signal generator that causes it to emit regular clicks. The student notices that each click results in two echoes, one from each building. The rate at which the clicks are produced is gradually increased from zero until each echo coincides with a new click being emitted by the loudspeaker.

What is the frequency of emission of clicks when this happens?

(The speed of sound in air = 320 m s^{-1}.)

(A) 2.0 Hz

(B) 2.5 Hz

(C) 3.3 Hz

(D) 4.0 Hz

(E) 5.3 Hz

(F) 6.7 Hz

(G) 10 Hz

Part C

[NSAA, 2016S1Q37]

Which one of the following atoms or ions contains the same number of neutrons and electrons as ${}^{40}_{20}Ca^{2+}$?

(A) ${}^{35}_{17}Cl^{-}$

(B) ${}^{37}_{17}Cl$

(C) ${}^{40}_{18}Ar$

(D) ${}^{39}_{19}K^{+}$

(E) ${}^{39}_{19}K$

[NSAA, 2016S1Q38]

Solid titanium oxide does not conduct electricity and cannot be electrolysed.

When molten, titanium oxide is a conductor and can be electrolysed.

During electrolysis 7.2 g of titanium are formed for every 3.6 dm³ of oxygen at room temperature and pressure.

Which of the following statements, if any, are correct?

1 After electrolysis, the titanium atoms produced have a noble gas electron configuration.

2 When molten, titanium oxide electrons are delocalised and so they move to carry the charge.

3 The empirical formula of titanium oxide is TiO_2.

(A_r: Ti = 48; molar gas volume = 24 dm³ at room temperature and pressure)

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2, and 3

[NSAA, 2016S1Q39]

In which, if any, of the following reactions are covalent bonds both broken and formed?

1 burning sodium in oxygen

2 electrolysis of aqueous sodium chloride

3 displacement of iron from iron oxide by heating with aluminium powder

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2

(F) 1 and 3

(G) 2 and 3

(H) 1, 2, and 3

[NSAA, 2016S1Q40]

In a reversible reaction, gaseous reactants P and Q form gaseous products R and S.

An increase in temperature was found to increase both the rate of reaction and the yield at equilibrium.

An increase in pressure was found to increase the rate of reaction but the yield at equilibrium was unaffected.

Which equation could represent the reaction?

(A) $3P + Q \rightleftharpoons 2R + 3S$ ΔH is +ve

(B) $P + 3Q \rightleftharpoons R + 2S$ ΔH is +ve

(C) $P + 2Q \rightleftharpoons 2R + S$ ΔH is +ve

(D) $P + 2Q \rightleftharpoons 3R + S$ ΔH is −ve

(E) $P + 2Q \rightleftharpoons R + S$ ΔH is −ve

(F) $2P + Q \rightleftharpoons R + 2S$ ΔH is −ve

[NSAA, 2016S1Q41]

Several oxides of bromine have been identified. Analysis of 2.4 g of one of these compounds showed it to contain 1.6 g of bromine.

What is the empirical formula of this compound?

(A_r: bromine = 80; oxygen = 16)

(A) Br_2O

(B) BrO_2

(C) Br_2O_5

(D) Br_5O_2

(E) Br_4O_5

(F) Br_5O_4

[NSAA, 2016S1Q42]

The most common ion of antimony, Sb^{3+}, has 48 electrons.

Antimony has two isotopes. One isotope has 70 neutrons and has an abundance of 60%. The second isotope has 72 neutrons and has an abundance of 40%.

What is the relative atomic mass of antimony?

(A) 70.8

(B) 71.0

(C) 71.2

(D) 121.8

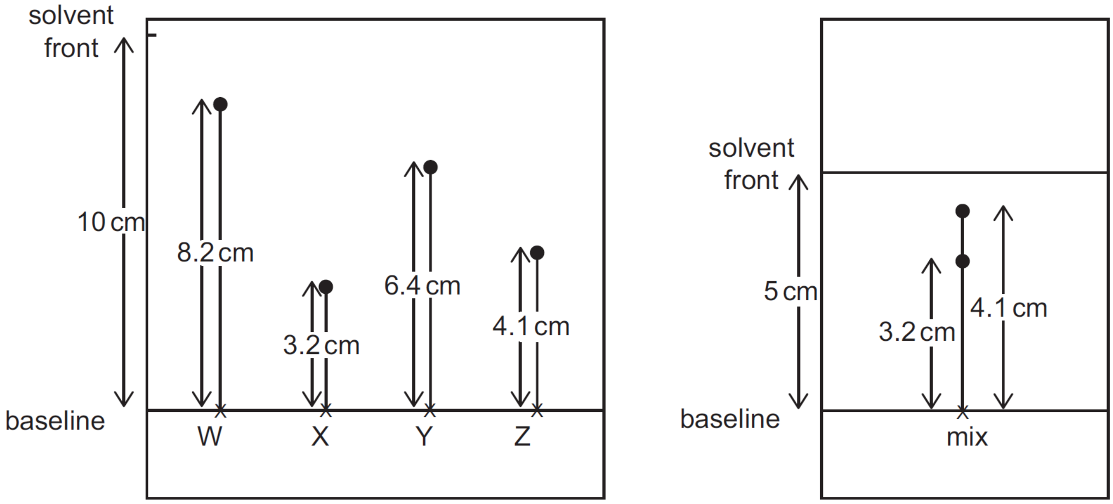
(E) 122.0

(F) 122.2

[NSAA, 2016S1Q43]

A chromatogram was produced for 4 separate dyes (W, X, Y and Z) using filter paper and a water solvent.

A second chromatogram was produced using a mixture of two of the dyes, again using filter paper and a water solvent:



Which of the following statements, if any, are correct?

1 The concentration of dye W must be twice the concentration of dye Z.

2 The mobile phase is the filter paper.

3 The mixture in the second chromatogram contained dyes W and Y.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

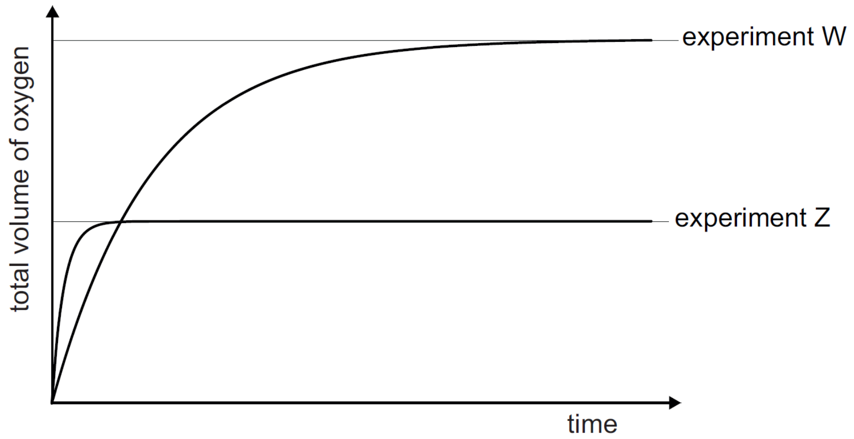
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2, and 3

[NSAA, 2016S1Q44]

The graphs show results of two experiments (W and Z) involving the catalytic decomposition of hydrogen peroxide.



Assuming all other conditions are kept constant, which one of the following options would lead to the results shown?

	experiment W	*experiment Z*
(A)	100 cm^3 of 1.0 mol dm^{-3} hydrogen peroxide	50 cm^3 of 2.0 mol dm^{-3} hydrogen peroxide
(B)	catalyst is in lumps	catalyst is finely divided
(C)	reaction carried out at 25 °C	reaction carried out at 50 °C
(D)	2.0 g manganese(IV) oxide used	1.0 g manganese(IV) oxide used
(E)	100 cm^3 of 1.0 mol dm^{-3} hydrogen peroxide	25 cm^3 of 2.0 mol dm^{-3} hydrogen peroxide

[NSAA, 2016S1Q45]

Two of the following equations represent redox reactions:

1 $Cl_2 + 2KI \rightarrow I_2 + 2KCl$

2 $Cl_2 + 2e^- \rightarrow 2Cl^-$

3 $HCl + AgNO_3 \rightarrow AgCl + HNO_3$

4 $Cl_2 + H_2O \rightarrow HCl + HClO$

Which two equations represent redox reactions?

(A) 1 and 2

(B) 1 and 3

(C) 1 and 4

(D) 2 and 3

(E) 2 and 4

(F) 3 and 4

[NSAA, 2016S1Q46]

Copper, Cu, reacts with concentrated nitric acid, HNO_3, to produce a solution of copper(II) nitrate, water and compound X.

Compound X does not contain copper or hydrogen.

The balanced equation for the reaction shows 3 moles of copper reacting with HNO_3 to produce 4 moles of water.

What is the identity of compound X?

(A) NO

(B) NO_2

(C) NO_3

(D) N_2O_5

(E) N_2O_8

[NSAA, 2016S1Q47]

During the electrolysis of a saturated solution of sodium chloride, 2.4 dm^3 of hydrogen gas was collected in time t at one of the electrodes.

Assuming no products dissolve, which row in the table correctly gives the mass or volume of the given product collected at the given electrode in time t?

(A_r: Na = 23; Cl = 35.5; H = 1, 1 mole of gas occupies 24 dm^3 at room temperature and pressure)

	mass or volume	*product*	*electrode*
(A)	0.1 g	hydrogen	negative
(B)	2.3 g	sodium	negative
(C)	2.4 dm^3	chlorine	positive
(D)	2.4 dm^3	chlorine	negative
(E)	2.4 dm^3	oxygen	positive
(F)	3.55 g	chlorine	positive
(G)	1.2 dm^3	oxygen	negative

[NSAA, 2016S1Q48]

The heat energy change for a reaction is −100 kJ mol^{-1}, and the activation energy is +150 kJ mol^{-1}.

What is the activation energy for the reverse reaction?

(A) −250 kJ mol^{-1}

(B) −150 kJ mol^{-1}

(C) −50 kJ mol^{-1}

(D) +50 kJ mol^{-1}

(E) +150 kJ mol^{-1}

(F) +250 kJ mol^{-1}

[NSAA, 2016S1Q49]

The following tests were carried out on separate samples of two monoprotic acids, HX and HY. HX is a strong acid and HY is a weak acid. Both acids had a concentration of 1 mol dm^{-3} .

1 Measure the time taken for a 1 cm strip of magnesium to react completely when added to 25 cm^3 of each acid.

2 Measure the volume of 1 mol dm^{-3} sodium hydroxide solution needed to completely neutralise 20 cm^3 of each acid.

3 Measure the electrical conductance of each acid using a conductivity meter.

Each test was carried out under the same conditions.

Which of the tests, considered independently, if any, would show that HX was a stronger acid than HY?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2, and 3

[NSAA, 2016S1Q50]

A 1.50 g sample of impure anhydrous sodium carbonate was added to 100 cm^3 of excess dilute hydrochloric acid. The impurity is unreactive.

The volume of gas released was 240 cm^3 at room temperature and pressure.

What is the mass of the impurity?

(A_r: Na = 23; C = 12; O = 16; molar gas volume = 24 000 cm^3 at room temperature and pressure)

(A) 0.44 g

(B) 0.53 g

(C) 0.67 g

(D) 0.83 g

(E) 0.97 g

(F) 1.06 g

[NSAA, 2016S1Q51]

0.35 g of lithium metal reacts with excess water at room temperature. Any gas produced in the reaction is collected and its volume measured at room temperature and pressure.

Assuming 1 mole of gas occupies 24.0 dm^3 at room temperature and pressure, what is the volume of gas collected?

(A_r: Li = 7)

(A) 0.00 cm^3

(B) 0.60 cm^3

(C) 1.20 cm^3

(D) 25.0 cm^3

(E) 50.0 cm^3

(F) 600 cm^3

(G) 1200 cm^3

[NSAA, 2016S1Q52]

Sodium sulfate was prepared by neutralising 25.0 cm^3 of 0.1 mol dm^{-3} sodium hydroxide with exactly 50.0 cm^3 of sulfuric acid.

What is the concentration of the sulfuric acid in g dm^{-3}?

(M_r: $H_2SO_4 = 98$)

(A) 0.025 g dm^{-3}

(B) 0.050 g dm^{-3}

(C) 0.250 g dm^{-3}

(D) 2.45 g dm^{-3}

(E) 4.90 g dm^{-3}

(F) 9.80 g dm^{-3}

[NSAA, 2016S1Q53]

During electrolysis of an aqueous solution of sodium sulfate the half equations for the electrode reactions are:

Anode (positive electrode): $2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$

Cathode (negative electrode): $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$

Which of the following deductions, if any, can be made from these equations?

1 The ratio by moles of hydrogen to oxygen produced at the electrodes is 1 : 1.

2 The sodium sulfate solution will become more concentrated as the electrolysis proceeds.

3 The whole solution will become acidic due to formation of H^+ ions at the anode.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

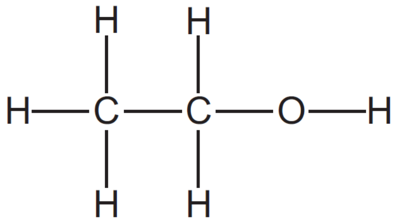
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2016S1Q54]

The structure of ethanol is given below:



Given the equation below and the overall enthalpy change for the reaction, which option correctly identifies the bond energy of the C– O bond in ethanol?

$H_2C{=}CH_2(g) + H_2O(g) \rightarrow C_2H_5OH(g)$ $\Delta H = -45$ kJ mol^{-1}

(Mean bond energy (kJ mol^{-1}): H– H = +436; C– C = +346; C– H = +413; O– H = +464; C=C = +611)

(A) 103 kJ mol^{-1}

(B) 316 kJ mol^{-1}

(C) 361 kJ mol^{-1}

(D) 707 kJ mol^{-1}

(E) 825 kJ mol^{-1}

Part D

[NSAA, 2016S1Q55]

Between 1954 and 1971 a mine in Northern Australia was releasing excess copper into the nearby Finnis River. Copper ions are poisonous and most of the types of fish living in the river died. The river still remains polluted with copper, but scientists have discovered one type of rainbow fish that is able to survive and live in the river.

A student wrote the following statements in order to explain this information.

1 One type of rainbow fish did not die out in the river because this type was able to adapt to the changing environment.

2 None of the other types of fish showed any type of genetic variation.

3 The presence of copper ions acted as a selective pressure.

Which of the student's statements could be correct?

(A) 1 only

(B) 1 and 2 only

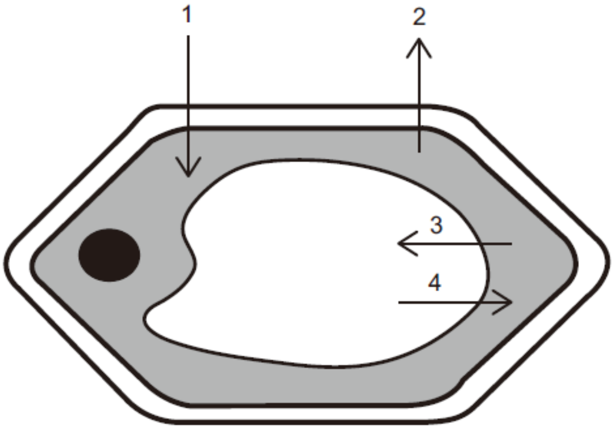
(C) 1 and 3 only

(D) 2 and 3 only

(E) 1, 2 and 3

[NSAA, 2016S1Q56]

The diagram shows a plant cell.



Which of the arrows on the diagram show the **net** movement of water molecules, by osmosis, when the cell is surrounded by a solution that is more concentrated than the solution in the cytoplasm?

(A) 1 only

(B) 2 only

(C) 1 and 3 only

(D) 1 and 4 only

(E) 2 and 3 only

(F) 2 and 4 only

[NSAA, 2016S1Q57]

A student described a population of organisms as having the following features

1 single celled

2 chloroplasts present

3 cell wall present

Using this information, which type of organism could this describe?

(A) algae

(B) bacteria

(C) ferns

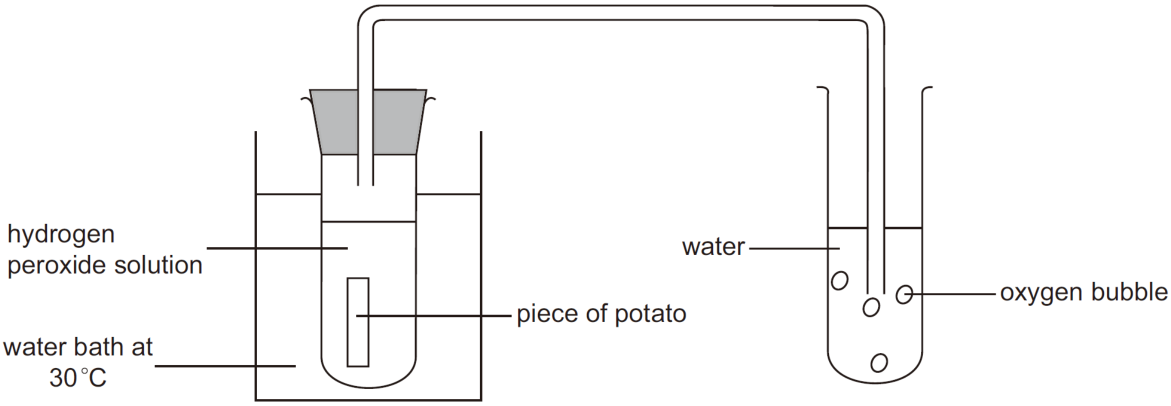
(D) fungi

(E) flowering plants

[NSAA, 2016S1Q58]

A student carried out an experiment to investigate how temperature affects the rate of activity of an enzyme found in potatoes. This enzyme breaks down the substrate hydrogen peroxide to produce water and oxygen.

The apparatus was set up as shown in the diagram and the experiment carried out at 30 °C.



The student counted the number of bubbles of oxygen produced in one minute.

The experiment was repeated at 40 °C, 50 °C, 60 °C, and 70 °C.

The table shows the results collected by the student.

temperature/°C	*number of bubbles of oxygen gas produced in one minute*
30	32
40	27
50	23
60	8
70	2

A group of students were given these results and asked to calculate the percentage decrease in the number of bubbles produced between 30 °C and 60 °C. Each student was also asked to write a conclusion to explain the results. These are shown in the table below.

Which student correctly calculated the percentage decrease in the number of bubbles between 30 °C and 60 °C and wrote an appropriate conclusion which explains the reason for this decrease?

	percentage decrease in the number of bubbles between 30 °C and 60 °C	*conclusion*
(A)	20	the high temperature causes the bonds maintaining the structure of the enzyme to break
(B)	20	the temperature of the environment is too hot and the enzyme dies
(C)	75	the high temperature causes the bonds maintaining the structure of the enzyme to break
(D)	75	the temperature of the environment is too hot and the enzyme dies
(E)	300	the high temperature causes the bonds maintaining the structure of the enzyme to break
(F)	300	the temperature of the environment is too hot and the enzyme dies

[NSAA, 2016S1Q59]

Albinism is a recessive genetic condition that results in the absence of the pigment melanin in the skin, hair and eyes. In a population of 580 000 people there were 29 albinos and 81 200 symptomless carriers. One living cheek cell was collected from every individual in the population.

What is the number of albinism alleles in these cells?

(A) 0

(B) 29

(C) 58

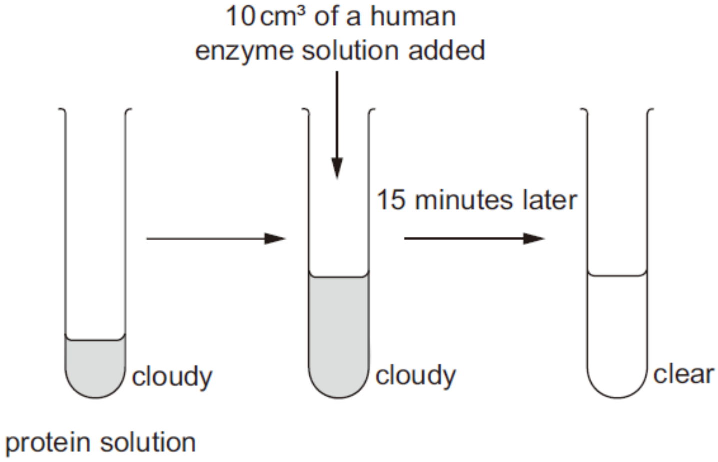
(D) 81 229

(E) 81 258

(F) 162 458

[NSAA, 2016S1Q60]

A student set up the following apparatus at a temperature of 25 °C and at pH 7.



What could the student change so that it would take less than 15 minutes for the solution to become clear?

(A) Carry out the experiment at p(H) 7, but increase the temperature to 70 °C.

(B) Carry out the experiment, stirring the mixture once every 30 seconds.

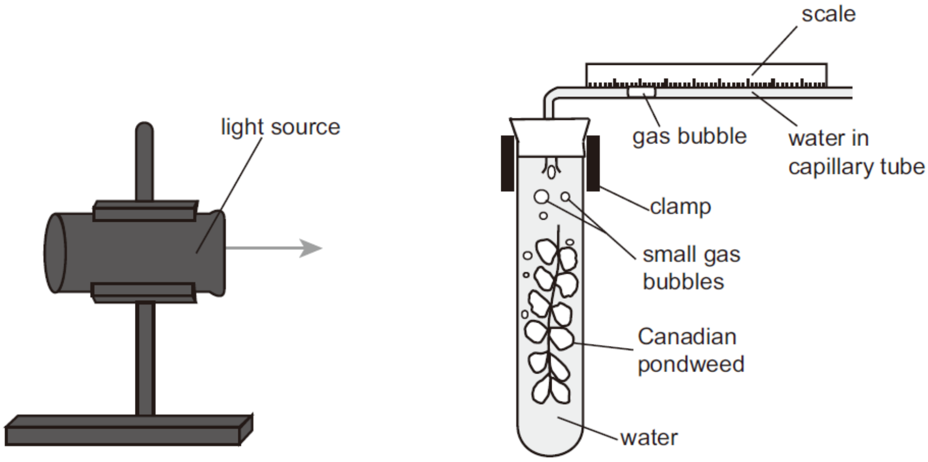
(C) Carry out the experiment at a temperature of 25 °(C)and a p(H) of 13.

(D) Double the volume of both the protein solution and the enzyme solution.

(E) Halve the volume of both the protein solution and the enzyme solution.

[NSAA, 2016S1Q61]

The diagram shows the apparatus used by a student to carry out an investigation into the rate of photosynthesis in pondweed.



The student measured the distance the gas bubble moved along the capillary tube in 3 minutes as 16 mm. The student calculated the volume of gas produced using the distance moved and the diameter of the capillary tube which was 1.0 mm. After 3 minutes the rate of gas production is reduced.

Which row represents the correct statements for this experiment?

	volume of gas produced / mm^3	*reason for reduction in rate of gas production after 3 minutes*
(A)	4π	all enzyme active sites are occupied
(B)	4π	carbon dioxide concentration is too low
(C)	16π	carbon dioxide concentration is too low
(D)	16π	photosynthesis enzymes denatured
(E)	16.5π	carbon dioxide concentration is too low
(F)	16.5π	photosynthesis enzymes denatured
(G)	34π	all enzyme active sites are occupied
(H)	34π	photosynthesis enzymes denatured

[NSAA, 2016S1Q62]

A student used a light microscope at a magnification of 40x to observe a slide of a stained non-dividing tissue. In the cells of this tissue, the student noted the presence of a large central vacuole and cytoplasm containing a single, stained, round structure.

Which of the following structures, if any, might the student also have seen in this tissue at this magnification?

1 cell wall

2 mitochondria

3 chromosomes

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

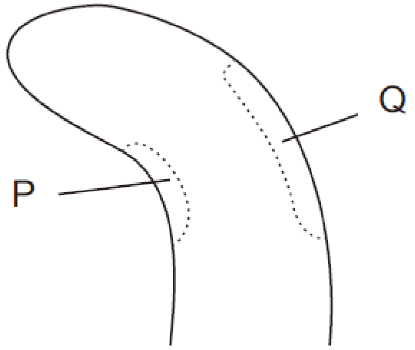
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2016S1Q63]

The diagram shows the tip of a plant shoot, with two areas labelled P and Q.



A student wrote the following statements to explain the growth of this shoot:

1 Cells at P are smaller than the cells at Q.

2 Concentration of plant hormone is higher at Q than P.

3 Unidirectional light has caused a change in the concentration of plant hormone at P.

Which of the student's statements, if any, could be correct?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2016S1Q64]

In an investigation, a molecule of DNA was extracted and separated into its single strands 1 and 2. The percentage of each base present in each strand was found.

The table shows some of the results for strand 1.

DNA sample	*base present (%)*			
	adenine[A]	*cytosine[C]*	*Guanine [G]*	*thymine[T]*
strand 1	26	?	28	14

P, Q, R and S are the percentages of each base in the complementary strand 2.

DNA sample	*base present (%)*			
	adenine[A]	*cytosine[C]*	*Guanine [G]*	*thymine[T]*
strand 2	P	Q	R	S

A student calculates the following percentages for P, Q, R and S:

P 14%

Q 28%

R 26%

S 28%

Which of the percentages is/are correct?

(A) P only

(B) Q only

(C) R only

(D) S only

(E) P and Q only

(F) R and S only

[NSAA, 2016S1Q65]

Cystic fibrosis is a condition of the respiratory system caused by abnormal ion transport in the lungs. It is a recessive genetic condition.

A female carrier has a child with a male who is also a carrier. What are the probabilities of the child having the characteristics described in the table below?

	probability that the child is a male with cystic fibrosis	*probability that the child is a female who does not have cystic fibrosis but carries the recessive allele*
(A)	$\frac{1}{4}$	$\frac{1}{8}$
(B)	$\frac{1}{4}$	$\frac{1}{4}$
(C)	$\frac{1}{4}$	$\frac{1}{2}$
(D)	$\frac{1}{6}$	$\frac{1}{8}$
(E)	$\frac{1}{6}$	$\frac{1}{4}$
(F)	$\frac{1}{6}$	$\frac{1}{2}$
(G)	$\frac{1}{8}$	$\frac{1}{4}$
(H)	$\frac{1}{8}$	$\frac{1}{2}$

[NSAA, 2016S1Q66]

Organisms interact with each other in many different ways, for example:

1 a tapeworm absorbing nutrients from a sheep intestine

2 a bacterial cell breaking down undigested food in a human gut

3 a leopard and a lion hunting an antelope

4 male deer fighting with each other to gain a mate

5 oak trees growing close to each other in a wood

Which of the statements is/are an example of intraspecific competition?

(A) 1 only

(B) 2 only

(C) 4 only

(D) 2 and 3 only

(E) 4 and 5 only

(F) 1, 2 and 5 only

(G) 1, 3 and 4 only

[NSAA, 2016S1Q67]

A diploid cell from a type of fly that contains 8 chromosomes, divides to form sperm cells.

Which row is correct for the number of strands of DNA in each sperm cell and the number of sperm cells produced?

	number of strands of DNA in each sperm cell	*number of sperm cells produced*
(A)	4	2
(B)	4	4
(C)	8	2
(D)	8	4
(E)	16	2
(F)	16	4

[NSAA, 2016S1Q68]

A healthy human is running a race over a distance of 1500 metres as fast as possible.

Which row shows molecules that would be in a higher concentration in a vein carrying blood away from an actively contracting leg muscle of the runner compared to an artery carrying blood to the capillaries in the muscle?

Key

✓ higher

X not higher

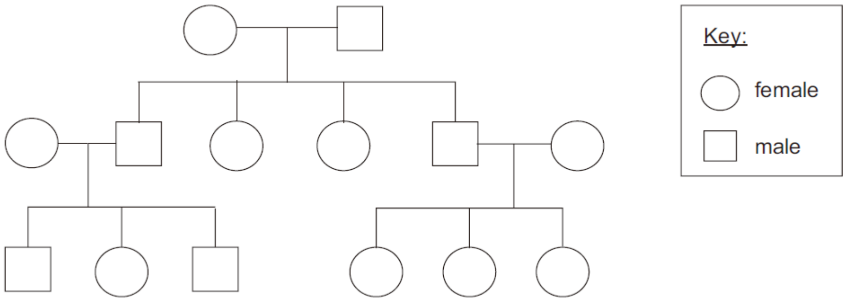
	glucose	*carbon dioxide*	*lactic acid*
(A)	√	√	√
(B)	×	√	√
(C)	×	×	√
(D)	×	×	×
(E)	√	√	×
(F)	√	×	×
(G)	×	√	×

[NSAA, 2016S1Q69]

The sex of species Q is controlled by two chromosomes X and Y.

The sex of females of species Q is controlled by inheriting the same combination of sex chromosomes as healthy **male** humans. The sex of males in species Q is inherited in the same way as healthy **female** humans.

The family tree for one population of species Q is shown.



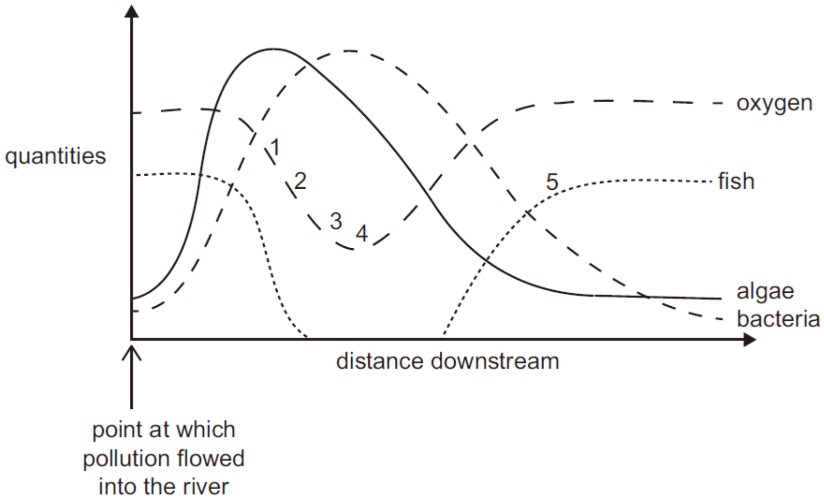
What is the ratio in its simplest form of males to females and the total number of Y chromosomes in this family tree?

	ratio	*total number of Y chromosomes*
(A)	1 : 0.5	9
(B)	1.8 : 1	9
(C)	5 : 9	5
(D)	5 : 9	9
(E)	9 : 5	9
(F)	9 : 5	19
(G)	1 : 2	19

[NSAA, 2016S1Q70]

The graph shows how a number of factors vary with the distance down a river, after a source of pollution flowed in.

(Assume the oxygen concentration is changing only based on the species present in the river.)



Which one of the statements below can be correctly concluded from the graph?

(A) At point 1, the oxygen concentration is decreasing because of increased anaerobic respiration.

(B) At point 2, the oxygen concentration is decreasing because high numbers of algae are photosynthesizing.

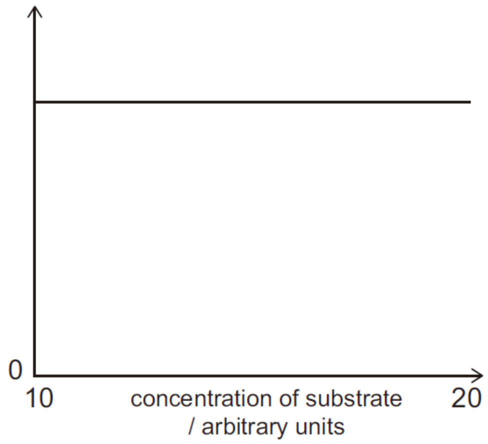
(C) At point 3, the oxygen concentration is decreasing because bacteria are using up more oxygen than the algae are producing.

(D) At point 4, the number of bloodworms and sludgeworms will be lowest because they lack oxygen.

(E) At point 5, fish numbers increase because there is less competition with algae for oxygen.

[NSAA, 2016S1Q71]

The graph shows the effect of increasing the substrate concentration on an enzyme-controlled reaction when all the other variables were kept constant.



Which of the following labels, if any, could be correct for the y-axis?

1 rate of substrate loss/mg min^{-1}

2 rate of enzyme-substrate complex formation/number of complexes s^{-1}

3 rate of product formed per enzyme molecule/mg min^{-1}

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2016S1Q72]

The table shows the DNA base triplet codes that are valid for this question and the amino acids that they code for.

DNA base triplet	*amino acid*
CGT	arginine
CGC	arginine
CGA	arginine
CGG	arginine
CTG	leucine
CCG	proline
CAG	glutamine
CAT	histidine
AGT	serine

Consider the part of the DNA sequence shown:

... CGC AGT ... →

Two mutations will occur in the DNA sequence. The initial mutation is an insertion of an additional base between the first and second bases in the sequence. The second mutation, which takes place some time after the first mutation, is a deletion that removes one base from the sequence.

Assuming that this DNA sequence is part of a longer sequence coding for a protein, and that no other mutations are occurring, what are the probabilities of the following?

	*probability that after the first mutation, the first triplet in this sequence does **not** code for arginine*	*probability that after the second mutation, both of the triplets in this sequence code for arginine*
(A)	$\frac{1}{4}$	$\frac{1}{28}$
(B)	$\frac{1}{4}$	$\frac{1}{24}$
(C)	$\frac{1}{4}$	$\frac{11}{28}$
(D)	$\frac{1}{4}$	$\frac{10}{24}$
(E)	$\frac{3}{4}$	$\frac{1}{28}$
(F)	$\frac{3}{4}$	$\frac{1}{24}$
(G)	$\frac{3}{4}$	$\frac{11}{28}$
(H)	$\frac{3}{4}$	$\frac{10}{24}$

Part E

[NSAA, 2016S1Q73]

When $x = 2$ is substituted in the expression $x^3 + px^2 + qx + p^2$ the result is 0.

When $x = 1$ is substituted into the same expression, the result is -3.5.

Find all possible value(s) of p.

(A) $p = -1 \pm \frac{\sqrt{6}}{3}$

(B) $p = 1$ or $p = -3$

(C) $p = 1$

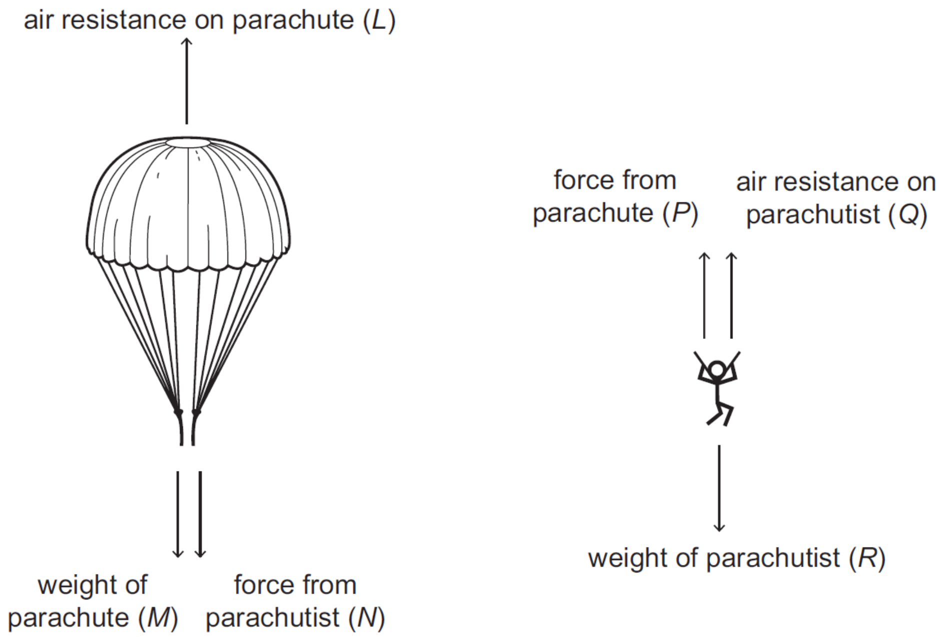
(D) $p = 1 \pm \sqrt{7}$

(E) there are no values for p

[NSAA, 2016S1Q74]

A parachutist is falling at terminal speed with his parachute open. The diagrams show, separately, the vertical forces acting on the parachute and the vertical forces acting on the parachutist.

The letters L, M, N, P, Q and R represent the magnitude of each force as indicated.



Consider the following equations:

Equation 1: $L = M + N$

Equation 2: $R = P + Q$

Equation 3: $L = Q$

Equation 4: $N = P$

Equation 5: $M + R = L + Q$

Which of these equations, if any, is/are the direct result of the application of Newton's Third Law to this situation?

(A) none of them

(B) 3 only

(C) 4 only

(D) 5 only

(E) 1 and 2 only

(F) 3 and 4 only

(G) 1, 2 and 5 only

(H) 1, 2, 3, 4 and 5

[NSAA, 2016S1Q75]

A square $PQRS$ is drawn above the x-axis with the side PQ on the x-axis.
P is the point $(-5, 0)$ and Q is the point $(1, 0)$.
A circle is drawn inside the square with diameter equal in length to the side of the square.
Which one of the following is an equation of the circle?

(A) $x^2 + y^2 - 4x + 6y + 4 = 0$

(B) $x^2 + y^2 - 4x + 6y + 9 = 0$

(C) $x^2 + y^2 + 4x - 6y + 4 = 0$

(D) $x^2 + y^2 + 4x - 6y + 9 = 0$

(E) $x^2 + y^2 - 6x - 4y + 9 = 0$

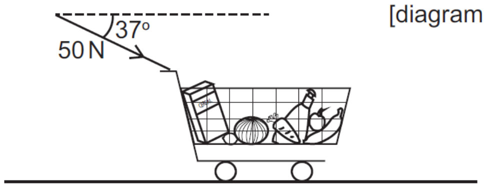
(F) $x^2 + y^2 - 6x + 4y + 4 = 0$

(G) $x^2 + y^2 + 6x - 4y + 4 = 0$

(H) $x^2 + y^2 + 6x + 4y + 9 = 0$

[NSAA, 2016S1Q76]

A shopper pushes a supermarket trolley a distance of 15 m in a straight line across a level, horizontal surface. The shopper applies a constant force of 50 N at an angle of 37° below the horizontal. The total weight of the trolley and its contents is 350 N.



[diagram not to scale]

What is the magnitude of the total vertical force that the surface exerts on the trolley and how much work is done by the pushing force?

(You may use the approximations $\sin 37° = 0.60$; $\cos 37° = 0.80$.)

	vertical force / N	*work done* / J
(A)	380	600
(B)	380	750
(C)	390	450
(D)	390	750
(E)	400	450
(F)	400	600

[NSAA, 2016S1Q77]

The first term of a convergent geometric series is 8.

The fifth term is 2.

The sixth term is real and positive.

What is the sum to infinity of this series?

(The sum to infinity of a convergent geometric series is given by $\frac{a}{1-r}$, where a is the first term and r is the common ratio.)

(A) $8(1+\sqrt{2})$

(B) $8(1-\sqrt{2})$

(C) $8(2+\sqrt{2})$

(D) $8(2-\sqrt{2})$

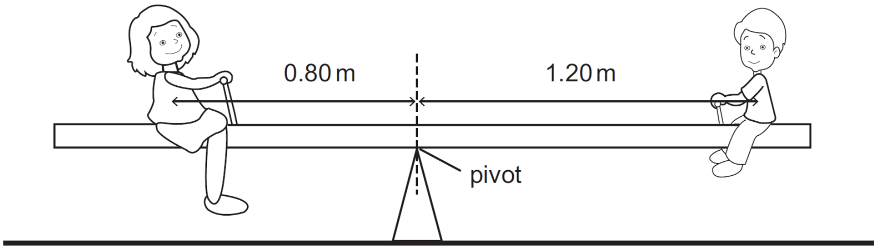
(E) 16

(F) $\frac{8\sqrt[5]{4}}{\sqrt[5]{4}-1}$

(G) $\frac{8\sqrt[5]{4}}{\sqrt[5]{4}+1}$

[NSAA, 2016S1Q78]

A plank of non-uniform density which has a mass of 15 kg is used to make a see-saw. A pivot is placed under the centre of the plank as shown on the diagram.



[diagram not to scale]

A boy of mass 35 kg sits at one end of the plank with his centre of gravity 1.20 m from the pivot. The see-saw balances when a woman of mass 60 kg sits on the plank on the other side of the pivot. Her centre of gravity is 0.80 m from the pivot.

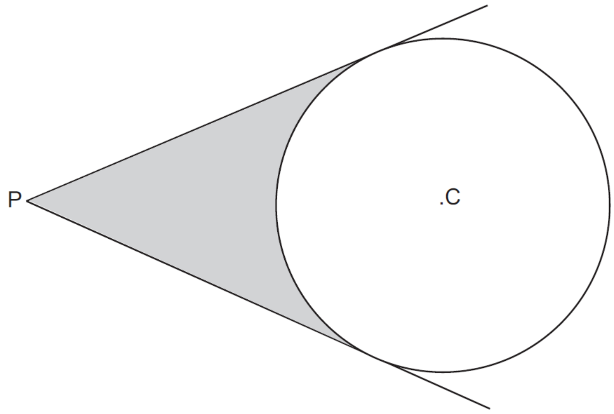
Where is the centre of gravity of the plank and what is the magnitude of the force between the pivot and the plank?

(The gravitational field strength g is 10 N kg^{-1}.)

	distance from pivot	*force* / N
(A)	0.40 m on left of pivot	100
(B)	0.40 m on left of pivot	1100
(C)	at the pivot	100
(D)	at the pivot	1100
(E)	0.20 m on right of pivot	100
(F)	0.20 m on right of pivot	1100
(G)	0.40 m on right of pivot	100
(H)	0.40 m on right of pivot	1100

[NSAA, 2016S1Q79]

Tangents are drawn from a point P to a circle of radius 10 cm.
The centre of the circle is C and the distance PC is 20 cm.



Which one of the following is an expression for the shaded area in square centimetres?

(A) $\frac{100}{3}(3\sqrt{3}-\pi)$

(B) $\frac{100}{3}(3\sqrt{5}-\pi)$

(C) $\frac{50}{3}(6\sqrt{3}-\pi)$

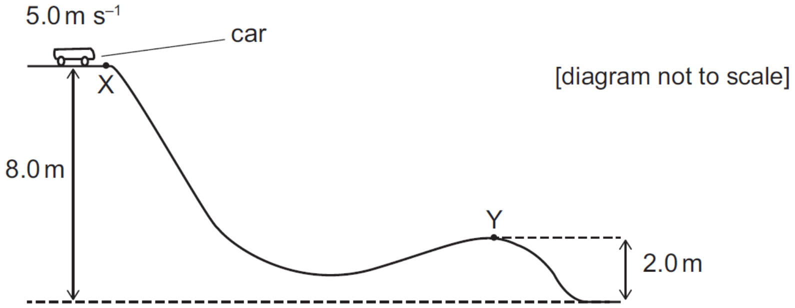
(D) $\frac{50}{3}(6\sqrt{5}-\pi)$

(E) $\frac{50}{3}(\sqrt{3}-2\pi)$

(F) $\frac{50}{3}(2\pi-\sqrt{3})$

[NSAA, 2016S1Q80]

A car of mass 200 kg on a fairground ride travels at a speed of 5.0 m s^{-1} at point X. The car is allowed to move down a sloping section of track without any energy input. The heights above the ground of points X and Y are shown. When the car reaches point Y its speed is 9.0 m s^{-1}.



How much energy is transferred in overcoming resistive forces as the car travels from X to Y?

(The gravitational field strength g is 10 N kg^{-1}.)

(A) 3900 J

(B) 6400 J

(C) 7900 J

(D) 10400 J

(E) 11200 J

[NSAA, 2016S1Q81]

Given that $7\cos\theta - 3\tan\theta\sin\theta = 1$, which one of the following is true?

(A) $\cos\theta = -\frac{3}{5}$ or $-\frac{1}{2}$

(B) $\cos\theta = -\frac{3}{5}$ or $\frac{1}{2}$

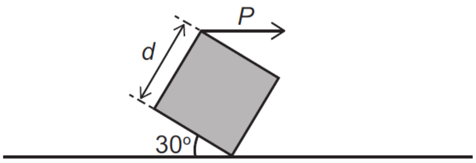
(C) $\cos\theta = \frac{3}{5}$ or $\frac{1}{2}$

(D) $\cos\theta = \frac{3}{5}$ or $-\frac{1}{2}$

[NSAA, 2016S1Q82]

The diagram shows a uniform, solid, heavy cube with side d. The cube rests with one of its edges in contact with a table that is perfectly level. A horizontal force P acts on another edge of the cube, and the cube is stationary.

[diagram not to scale]



Below are four statements about the forces on the cube.

1 It is possible that there is no frictional force between the cube and the table.

2 There must be a frictional force acting to the left between the cube and the table.

3 There must be a frictional force acting to the right between the cube and the table.

4 Force P has a clockwise moment about the edge in contact with the table equal to $P \times d$.

Which of the statements is/are correct?

(A) 1 only

(B) 2 only

(C) 3 only

(D) 1 and 4 only

(E) 2 and 4 only

(F) 3 and 4 only

[NSAA, 2016S1Q83]

The complete set of values of a for which the equation $3x^2 = (a + 2)x - 3$ has two real distinct roots is

(A) no values of a

(B) $-4\sqrt{2} < a < 4\sqrt{2}$

(C) $a < -4\sqrt{2}, a > 4\sqrt{2}$

(D) $-4 < a < 8$

(E) $a < -4, a > 8$

(F) $-8 < a < 4$

(G) $a < -8, a > 4$

(H) all values of a

[NSAA, 2016S1Q84]

An object is fired vertically upwards from the ground at time $t = 0$ s in still air at a speed of 8.0 m s^{-1}.

On the way up, what is the height of the object above the ground when it has a speed of 2.0 m s^{-1}, and at what time does it reach this height on the way down?

(The gravitational field strength g is 10 N kg^{-1}. Air resistance can be ignored.)

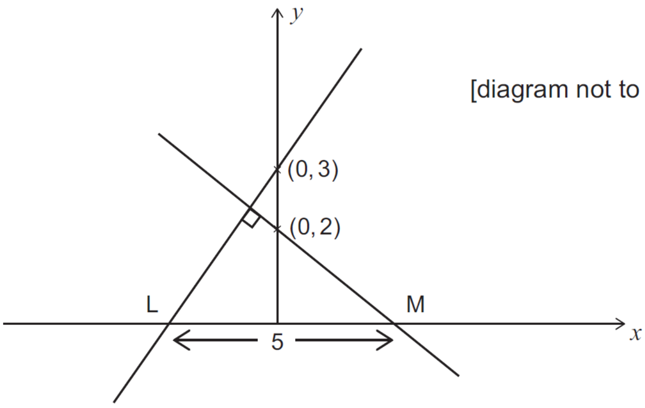
	height / m	*time* / s
(A)	2.4	0.60
(B)	2.4	0.64
(C)	2.4	1.0
(D)	2.4	2.0
(E)	3.0	0.60
(F)	3.0	0.64
(G)	3.0	1.0
(H)	3.0	2.0

[NSAA, 2016S1Q85]

The straight line with equation $y = mx + 3$, where $m > 0, m \neq 1$, is perpendicular to the line with equation $y = px + 2$.

The lines cut the x-axis at the points L and M respectively. The length of LM is 5 units.

What is the value of $m + p$ given that $m > 1$?



[diagram not to scale]

(A) $-\frac{8}{3}$

(B) $-\frac{13}{6}$

(C) $-\frac{5}{6}$

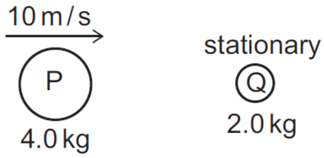
(D) $\frac{5}{6}$

(E) $\frac{13}{6}$

(F) $\frac{8}{3}$

[NSAA, 2016S1Q86]

The diagram shows a ball P, of mass 4.0 kg, moving to the right at 10 m s^{-1} directly towards a stationary ball Q, of mass 2.0 kg.



The balls collide but do not join together. Immediately after the collision ball Q moves at 10 m s^{-1} to the right.

What is the velocity of ball P immediately after the collision, and how much kinetic energy in total is lost during the collision?

	velocity of ball P after collision	*kinetic energy lost during collision / J*
(A)	0	50
(B)	0	150
(C)	10 m s^{-1} to the left	50
(D)	10 m s^{-1} to the left	150
(E)	5.0 m s^{-1} to the right	50
(F)	5.0 m s^{-1} to the right	150

[NSAA, 2016S1Q87]

$f(x) = x^3 - a^2x$ where a is a positive constant.

Find the complete set of values of x for which $f(x)$ is an increasing function.

(A) $x \leq -a, x \geq a$

(B) $-a \leq x \leq a$

(C) $x \leq -a, 0 \leq x \leq a$

(D) $-a \leq x \leq 0, x \geq a$

(E) $x \leq -\frac{a}{3}, x \geq \frac{a}{3}$

(F) $-\frac{a}{3} \leq a \leq \frac{a}{3}$

(G) $x \leq -\frac{a}{\sqrt{3}}, x \geq \frac{a}{\sqrt{3}}$

(H) $-\frac{a}{\sqrt{3}} \leq x \leq \frac{a}{\sqrt{3}}$

[NSAA, 2016S1Q88]

A point object of mass 2.0 kg is at rest on a level, horizontal surface. The coefficient of friction between the object and the surface is 0.25.

Two horizontal forces at right-angles to each other, with magnitudes 9.0 N and 12.0 N, are applied simultaneously to the object.

What is the magnitude of the acceleration of the object as it begins to move?

(The gravitational field strength g is 10 N kg^{-1}.)

(A) 5.0 m s^{-2}

(B) 7.25 m s^{-2}

(C) 7.5 m s^{-2}

(D) 8.0 m s^{-2}

(E) 10 m s^{-2}

(F) 10.5 m s^{-2}

[NSAA, 2016S1Q89]

The curve $y = x^2$ is translated by the vector $\binom{4}{3}$ and then reflected in the line $y = -1$.

Which one of the following is an equation of the resulting curve?

(A) $y = -3 - (x - 4)^2$

(B) $y = -3 + (x + 4)^2$

(C) $y = 3 - (x + 4)^2$

(D) $y = 3 + (x - 4)^2$

(E) $y = -5 - (x - 4)^2$

(F) $y = -5 + (x + 4)^2$

(G) $y = 5 - (x + 4)^2$

(H) $y = 5 + (x - 4)^2$

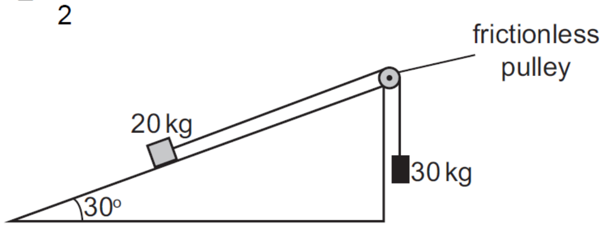
[NSAA, 2016S1Q90]

An object of mass 20 kg is pulled up a rough plane inclined at 30° to the horizontal by a light, inextensible cable attached via a frictionless pulley to a freely-falling 30 kg mass. The acceleration of the object along the plane is 2.5 m s^{-2}.

$$\cos 30° = \sin 60° = \frac{\sqrt{3}}{2}$$

$$\sin 30° = \cos 60° = \frac{1}{2}$$

[diagram not to scale]



What is the frictional force between the object and the plane?

(Air resistance and the mass of the pulley can be ignored. The gravitational field strength g is N kg^{-1}.)

(A) 25 N

(B) 50 N

(C) 75 N

(D) 100 N

(E) 150 N

(F) 175 N

(G) 250 N

NSAA 2016 S2

NSAA 2016 S2
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 40 MINUTES

This paper is Section 2 of 2.

There are six questions in this paper, of which you should answer any **two**.

There are 25 marks for each question. In total 50 marks are available.

You should write your answers in the spaces provided in this question paper. Please complete this section in **black pen**. Pencil may be used for graphs and diagrams only.

You can use the blank pages inside this booklet for rough working or notes, but no extra paper is allowed. Only answers in the spaces indicated in the paper will be marked.

Calculators may be used in this section. Please record your calculator model in the box below:

Calculator model	

Write the numbers of the questions you answer in the order attempted in the boxes below:

Question number

[NSAA, 2016S2Q1]

(a) A narrow beam of molecules with a range of different speeds passes through a molecular velocity selector.

The selector comprises two discs rotating in the same direction at the same frequency of rotation f on a common axis in an evacuated container.

The selector allows molecules with particular speeds to pass through.

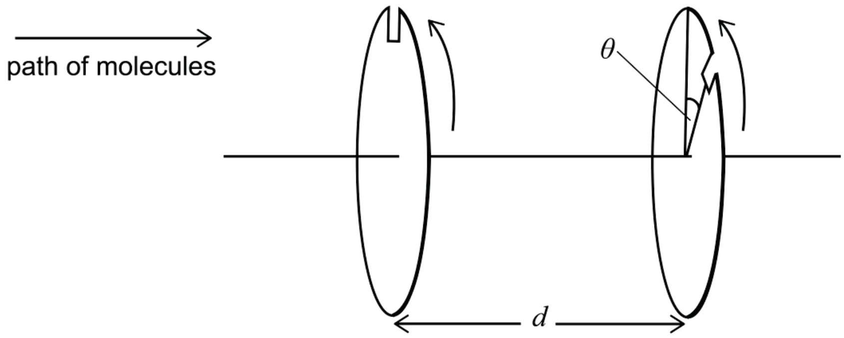


Fig. 2016Q1(a)

The speeds of the molecules, v, entering the selector vary over a very broad range. The molecules can pass through a very narrow slit on each of the two discs, as shown in Fig. 2016Q1(a). The slit on the right-hand disc is displaced by angle θ relative to the slit on the left-hand disc. The horizontal separation of the discs is d.

(The effects of gravity may be ignored and the speed of a molecule within the container remains constant.)

(i) For $f = 160$ revolutions s-1, how long does it take for the discs to rotate through 1.0°? [2]

(ii) If $\theta = 30.0°$, $d = 24.0$ cm and $f = 160$ revolutions s^{-1}, what is the highest speed of a molecule that will pass through both slits? [3]

(iii) When the speeds of the molecules are measured after they have passed through the two narrow slits, it is found that other molecular speeds are present. Explain why there is more than one speed in the outgoing beam. [3]

(iv) For the arrangement described in (ii), calculate the molecular speed, closest to your value in (ii), that will pass through both slits. [3]

(v) Each slit has an angular width of 0.3° either side of its centre, with the centres of the slits being θ apart. What is the range of speeds ($v_{\text{max}} - v_{\text{min}}$) for the set of molecules referred to in (ii) that pass through both slits? [3]

(b) A particle of mass m falls through height h on to a thin disc rotating at a rate f revolutions s^{-1}. The particle will just fit through a hole in the rotating disc (Fig. 2016Q1(b)).

(The effects of air resistance may be ignored; take the acceleration due to gravity as 9.81 m s^{-2}.)

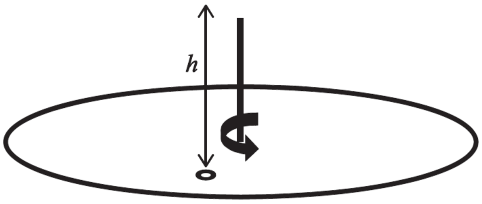


Fig. 2016Q1(b)

(i) The disc is rotating at frequency f revolutions s^{-1} when the particle is released from rest. Working in degrees, write down an expression for the angle θ through which the disc will have turned by the time the particle reaches it. [3]

(ii) If $f = 20$ revolutions s^{-1} and a particle, initially at rest, is released at the moment that the hole is vertically below it, what is the minimum height (greater than zero) from which the particle can be dropped so that it will pass through the hole? [2]

(iii) An identical disc with a similar hole is fixed to the same axis, but at a distance $h' = 0.15$ m below it. The two holes are aligned. When the particle is released from rest at a height $h = 0.10$ m above the top disc, it is able to fall through both holes in succession. What is the minimum frequency of rotation (greater than zero) of both discs which will allow this to occur? [6]

[NSAA, 2016S2Q2]

(a) Calculate the readings shown on the voltmeter and on ammeters A_1 and A_2 in the circuits shown in 2016Q2(a) (i) and (ii). [5]

(You may assume that the ammeters and voltmeters are ideal and that the cells have negligible internal resistance.)

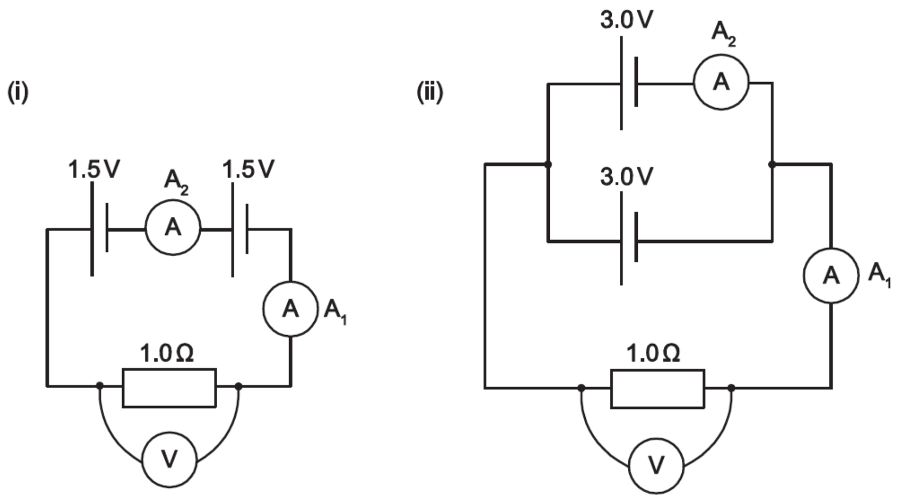


Fig. 2016Q2(a)

(b) In a more realistic model, the 1.5 V cell has an internal resistance of 0.10 Ω and the 3.0 V cell also has an internal resistance of 0.10 Ω. Calculate the new readings on the voltmeter and on the ammeters for the circuits shown in Fig. 2.1 (i) and (ii). [6]

(c) The 1.5 V and 3.0 V cells each store the same amount of energy. In which of the four arrangements described in (a)(i) and (ii) and (b)(i) and (ii) do the cells take the longest time to transfer all their energy into heat? Explain your reasoning. [2]

(d) A solar cell can be modelled as an ideal cell of 0.50 V in series with an internal resistor of 0.10 Ω. We want to operate a fan that consumes 0.96 W of power and requires a potential difference of 2.4 V. There are 10 identical solar cells available and all must be used. They are arranged as n identical parallel sections with each section consisting of N cells in series. How must they be arranged in the circuit, and what is the current in each solar cell? In both cases explain your reasoning. [4]

(e) A cell with a potential of 1.5 V and zero internal resistance is connected to two resistors in parallel, with values $R_1 = 1.0\ \Omega$ and $R_2 = 2.0\ \Omega$, as shown in Fig. 2017Q2(b).

(i) Calculate the current through the cell. [2]

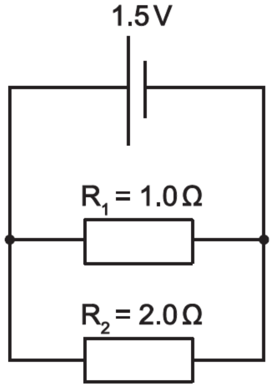


Fig. 2016Q2(b)

(ii) If the 1.5 V cell in the circuit shown in Fig. 2016Q2(b) is replaced with a 1.5 V cell with an internal resistance $r = 0.10\ \Omega$, how much power is dissipated in R_2? [2]

(iii) A third resistor $R_3 = 4.0\ \Omega$ is now added in parallel with the first two resistors with the cell from e(ii), as shown in Fig. 2016Q2(c). Calculate the current through the cell (which has an internal resistance of 0.10 Ω). [2]

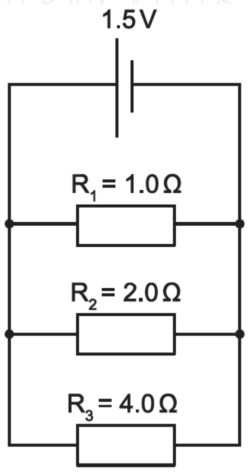


Fig. 2016Q2(c)

(iv) More and more resistors are now added, one by one, in parallel with the existing ones, each with double the resistance of the previous one. The final circuit consists of resistors with values of 1 Ω, 2 Ω, 4 Ω, 8 Ω, 16 Ω, 32 Ω, 64 Ω, ... connected in parallel with the cell. Calculate the total current through the cell if the number of resistors is infinite. [3]

[NSAA, 2016S2Q3]

Parts (a), (b) and (c) can be answered independently of one another.

(a) Draw two alternative 'dot and cross' diagrams to describe the bonding in the linear thiocyanate anion SCN^-. In one diagram place the negative charge on the sulfur, and in the other place the negative charge on the nitrogen. [5]

(b) Breakfast cereals frequently have elemental iron added to them as a dietary supplement. A method for making a quantitative measurement of the amount of iron is to use the reaction between $Fe^{3+}(aq)$ and thiocyanate, $SCN^-(aq)$, which gives the deep red complex $FeSCN^{2+}(aq)$.

$$Fe^{3+}(aq) + SCN^-(aq) \longrightarrow FeSCN^{2+}(aq)$$

The depth of the colour can be measured using a spectrophotometer which gives a value for the absorbance that is proportional to the concentration of the complex:

absorbance = constant × $[FeSCN^{2+}]$ **Equation 1**

The constant can be found by measuring the absorbance of a solution of known concentration.

(i) The absorbance of a solution of the complex with concentration 2.5×10^{-4} mol dm^{-3} was measured to be 1.85; determine the value of the constant in Equation 1. [2]

100 g of breakfast cereal was mixed with sufficient dilute acid to dissolve all of the iron. The solution was carefully filtered and mixed with sufficient oxidising agent to convert all of the iron to Fe^{3+}. The solution was made up to a total volume of 250 cm^3. 10.0 cm^3 of this solution was mixed with 10.0 cm^3 of a solution of thiocyanate; you may assume that all of the iron is converted to the complex. The absorbance of the resulting solution was measured as 0.519.

(ii) Using the value of the constant found in (i), calculate the concentration of Fe^{3+} in the solution for which the absorbance was measured. [2]

(iii) Hence calculate the concentration of Fe^{3+} in the solution prepared from the cereal. [2]

(iv) Hence calculate the mass of iron present in the 100 g of breakfast cereal (Ar: Fe = 55.85). [4]

(c) Hydrogen peroxide, H_2O_2, is used as the oxidising agent to convert Fe^{2+} to Fe^{3+} in the assay described in (b)(ii).

(i) Determine the oxidation state of oxygen in H_2O_2. [2]

(ii) When H_2O_2 acts as an oxidising agent in acidic solution, what is the oxygen-containing species that is produced and what is the oxidation state of oxygen in this species? [4]

(iii) Write a balanced chemical equation describing the oxidation of $Fe^{2+}(aq)$ to $Fe^{2+}(aq)$ by H_2O_2 in acidic solution.[4]

[NSAA, 2016S2Q4]

There are six isomers with the formula C_5H_{10} that are alkenes. The alkenes all have different enthalpies of formation, all of which are negative.

(a) Draw the structures of the six alkenes (skeletal or displayed structures are acceptable). [6]

Samples of the six alkenes, in a random order, are labelled **P**, **Q**, **R**, **S**, **T**, and **U**. You will be able to identify which isomer some of these correspond to using the information and data throughout the rest of the question.

Alkenes **P**, **Q**, and **R** react with hydrogen gas and a metal catalyst to give the same alkane **A**; alkenes **S**, **T**, and **U** react under the same conditions to give a different alkane **B**.

Both alkanes **A** and **B** react with chlorine gas under UV light to form chloroalkanes with the formula $C_5H_{11}Cl$. Under such conditions, alkane **A** forms four different structural isomers, whereas **B** gives three.

(b) Draw the structures of alkanes **A** and **B**. Also draw the structures of the four isomers arising from the chlorination of **A**, and the three isomers arising from the chlorination of **B**. [6]

The alkenes react with HBr to form bromoalkanes with the formula $C_5H_{11}Br$; the reaction proceeds via a carbocation intermediate. Alkenes **S** and **T** give a mix of two structural isomers, whereas alkene **U** gives only one.

(c) Give the structure of alkene **U**. [4]

A general rule for isomeric alkenes is that the more carbon atoms directly bonded to the double bond (or the lower the number of hydrogen atoms directly bonded), the more negative (that is, the more exothermic) the enthalpy of formation of the alkene.

(d) Out of **P**, **Q** and **R**, **R** has the most negative (most exothermic) enthalpy of formation. Give the structure of **R**. [1]

Consider the following thermodynamic data:

	value / kJ mol^{-1}
Standard enthalpy change of hydrogenation for alkene **P**	−113
Standard enthalpy change of hydrogenation for alkene **Q**	−119
Standard enthalpy change of combustion for alkane **A**	−3528
Standard enthalpy change of formation $H_2O(l)$	−286

(e) Use the data to deduce the structure of: (i) alkene **P**; and (ii) alkene **Q**. [4]

(f) Use the data to calculate the standard enthalpy change of combustion of alkene **P**. [4]

[NSAA, 2016S2Q5]

*Eco*RI is a restriction enzyme that cuts bacterial DNA into pieces at specific sequences.

(a) What type of biological molecule is *Eco*RI? [1]

(b) Name the type of bond between adjacent nucleotides that is cut by *Eco*RI. [1]

(c) *Eco*RI cuts at specific sites in the DNA, characterised by the sequence GAATTC. Other restriction enzymes cut at specific sequences like GGATCC or AGCT. What characteristic do these sequences have in common and how might this characteristic aid in cutting? [3]

(d) *Eco*RI is produced by bacteria. What role might it have in a bacterial cell? [1]

(e) We can use different restriction enzymes to cut DNA at different sites. Another restriction enzyme is *Bam*HI. By studying the fragments produced by different combinations of restriction enzymes we can produce a map of the cutting sites of these enzymes.

Use the data in the table below to produce a map of the cutting sites of restriction enzymes. This map should be drawn onto a circle of bacterial plasmid DNA, the total length of which is 18 kb.

Distances between the cut sites should be identified. [4]

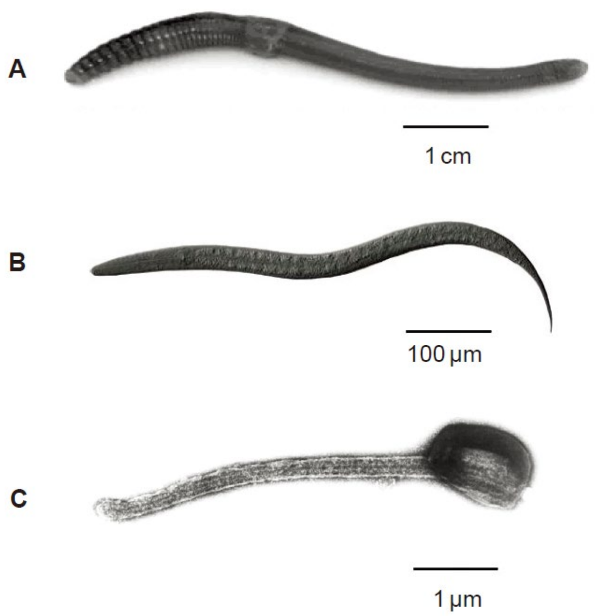
enzyme used	*fragment sized producd* / kb
*Eco*RI alone	6, 12
*Bam*HI alone	7.5, 10.5
*Eco*RI and *Bam*HI together	3, 3, 4.5, 7,5

(f) Suggest how enzymes like *Eco*RI could be used in genetic engineering. [3]

(g) *Eco*RI is produced by bacteria that often live harmlessly inside the human body. Explain how temperature and pH might affect the activity of *Eco*RI in bacterial cells, using diagrams if necessary. [10]

[NSAA, 2016S2Q6]

Below are images of three species of organism, all of which are vermiform (worm-like) in appearance.



(a) What is the approximate length of each species in mm? [3]

(b) What type of microscope has been used to produce the images of organisms B and C? [2]

(c) For organism A, treating it as a tube, estimate the surface area : volume ratio, working in mm. Show your working. [4]

(d) How will the surface area:volume ratio differ between the three organisms? [2]

(e) Identify four substances that organism A may need to exchange with the external environment. [2]

(f) Discuss how the size of organisms affects their ease of exchange of substances with the external environment. You should highlight at least two adaptations that help overcome the constraints of size. [10]

NSAA 2017 S1

NSAA 2017 S1

On-line Exam

Scan the QR code or click on the link to take an on-line exam.

Full solutions can be accessed after submission.

TIME ALLOWED: 80 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 80 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **five** parts: **A**, **B**, **C**, **D**, and **E**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **two** further parts chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology
Part E	Advanced Mathematics and Advanced Physics

Each part has 18 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **three** parts. Each question is worth one mark.

Questions ask you to show your choice between options. Choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again. You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators may NOT be used.

Part A

[NSAA, 2017S1Q1]

Evaluate

$$\frac{\left(\sqrt{12}+\sqrt{3}\right)^2}{\left(\sqrt{12}-\sqrt{3}\right)^2}$$

(A) 1

(B) 3

(C) $\frac{5}{3}$

(D) $\frac{7}{3}$

(E) $3\sqrt{3}$

(F) 9

[NSAA, 2017S1Q2]

Solve fully the inequality

$$2x^2 \geq 15 - x$$

(A) $x \leq -3$

(B) $x \geq 2.5$

(C) $x \leq -1.5, x \geq 5$

(D) $-1.5 \leq x \leq 5$

(E) $x \leq -3, x \geq 2.5$

(F) $-3 \leq x \leq 2.5$

[NSAA, 2017S1Q3]

The equation gives y in terms of x:

$$y = 3\left(\frac{x}{2} - 1\right)^2 - 5$$

Which one of the following is a rearrangement for x in terms of y?

(A) $x = 2 \pm 2\sqrt{\frac{y-5}{3}}$

(B) $x = 2 \pm 2\sqrt{\frac{y+5}{3}}$

(C) $x = 2 \pm 3\sqrt{\frac{y+5}{3}}$

(D) $x = -2 \pm 2\sqrt{\frac{y+5}{3}}$

(E) $x = -2 \pm 3\sqrt{\frac{y+5}{2}}$

(F) $x = 2 + 2\left(\frac{y+5}{3}\right)^2$

(G) $x = -2 + 2\left(\frac{y+5}{3}\right)^2$

[NSAA, 2017S1Q4]

A fruit stall sells apples costing £x each, and pears costing £y each.
Sam bought 2 apples and 5 pears, and the total cost of these was £P.
Lesley bought 3 apples and 2 pears, and the total cost of these was £Q.
Which of the following is an expression for the cost, in pounds (£), of a pear?

(A) $\frac{2Q-3P}{3}$

(B) $\frac{2Q-3P}{11}$

(C) $\frac{Q-P}{3}$

(D) $\frac{Q-P}{11}$

(E) $\frac{P-Q}{3}$

(F) $\frac{3P-2Q}{3}$

(G) $\frac{3P-2Q}{11}$

[NSAA, 2017S1Q5]

P is directly proportional to Q squared.

When P is 2, Q is 4.

Q is inversely proportional to R.

When Q is 2, R is 5.

What is P in terms of R?

(A) $P = \frac{5}{R}$

(B) $P = \frac{5}{4R}$

(C) $P = \frac{1}{800R^2}$

(D) $P = \frac{5}{4R^2}$

(E) $P = \frac{25}{2R^2}$

(F) $P = \frac{800}{R^2}$

(G) $P = \frac{R^2}{50}$

(H) $P = \frac{25R^2}{2}$

[NSAA, 2017S1Q6]

Two sequences are defined by the following rules:

In sequence S the nth term is $7n + 1$.

In sequence T the nth term is $99 - n^2$.

What is the smallest value of n for which the nth term of sequence S is greater than the nth term of sequence T?

(A) 6

(B) 7

(C) 8

(D) 13

(E) 14

(F) 15

[NSAA, 2017S1Q7]

Which one of the following is a simplification of

$$2-\frac{x^2(9x^2-4)}{x^3(2-3x)}$$

(A) $-1-\frac{2}{x}$

(B) $-1+\frac{2}{x}$

(C) $5-\frac{2}{x}$

(D) $5+\frac{2}{x}$

(E) $5-\frac{3}{x}$

(F) $5+\frac{3}{x}$

[NSAA, 2017S1Q8]

The parallelogram $OPQR$, labelled clockwise, is in the first quadrant ($x \geq 0, y \geq 0$) with O at the origin. The point R has coordinates $\left(\frac{3a}{2}, 0\right)$ and the point Q has coordinates $(2a, a+1)$. The area of $OPQR$ is 9 square units.

What are the coordinates of point P?

(A) $\left(\frac{\sqrt{3}}{2}, 1+\sqrt{3}\right)$

(B) $(1, 3)$

(C) $(1.5, 4)$

(D) $(2, 3)$

(E) $(3, 4)$

(F) $\left(2\sqrt{3}, 1+\sqrt{3}\right)$

[NSAA, 2017S1Q9]

What is the value of x that makes the following expression correct?

$$2^{3+2x}4^x8^{-x} = 4\sqrt{2}$$

(A) -2.25

(B) -1.75

(C) -1.5

(D) -0.5

(E) -0.25

[NSAA, 2017S1Q10]

There are 100 students in Year 10.

Each student studies exactly one of French, German, and Spanish.

X girls study French and there are $3X$ girls in total.

$2Y$ boys study German.

There are 35 students studying Spanish of which Y are boys.

Which of the following is an expression for the total number of students studying German?

(A) $X + 2Y$

(B) $X + Y + 35$

(C) $X + 3Y - 35$

(D) $2X + 2Y$

(E) $2X + Y - 35$

(F) $2X + 3Y - 35$

(G) $2X + Y + 35$

[NSAA, 2017S1Q11]

An exterior angle of a regular polygon with n sides is $4°$ larger than an exterior angle of a regular polygon with $(n + 3)$ sides.

What is the value of n?

(A) 10

(B) 12

(C) 15

(D) 18

(E) 21

(F) 24

(G) 27

[NSAA, 2017S1Q12]

The bearing of a ship R from a lighthouse L is 220°.

A canoe C is due North of R.

C is the same distance from the ship and the lighthouse.

What is the bearing of L from C?

(A) 070°

(B) 080°

(C) 090°

(D) 100°

(E) 140°

[NSAA, 2017S1Q13]

The hands of a 12-hour analogue clock move continuously. When the time on the clock is 4:00, the angle between the minute hand and the hour hand is 120°.

What is the angle between the two hands at 4:40?

(A) 80°

(B) 100°

(C) 110°

(D) 120°

(E) 140°

[NSAA, 2017S1Q14]

The cost of manufacturing a cake is directly proportional to the volume of the cake.

The baker makes a 70% profit when he sells a large rectangular cake.

The baker sells a large rectangular cake for £6.80.

The baker decides to sell smaller rectangular cakes. The length, width, and height of the smaller cakes are all half of those of the large rectangular cake.

He sells a pack of 6 of the smaller cakes for £6.50.

How much profit does he make on the pack of smaller cakes?

(A) £0.50

(B) £2.93

(C) £3.00

(D) £3.50

(E) £4.97

[NSAA, 2017S1Q15]

A pet shop has 4 female rabbits and x male rabbits for sale.

A customer buys 2 of the rabbits, chosen at random, and each rabbit is equally likely to be chosen.

The probability that both the chosen rabbits are male is $\frac{1}{3}$.

What is the value of x?

(A) 2

(B) 4

(C) 6

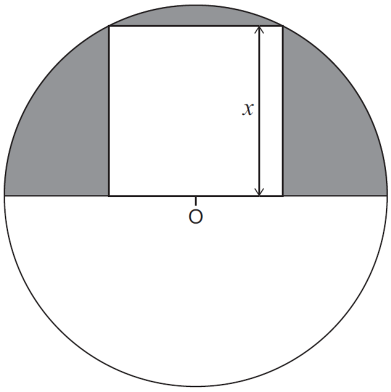
(D) 8

(E) 9

(F) 11

(G) 12

[NSAA, 2017S1Q16]



The diagram shows a square with side of length x cm. A circle is drawn with centre O which lies at the mid-point of one of the sides of the square. This side forms part of a diameter of the circle. The circle passes through two corners of the square as shown.

What is the area, in cm^2, of the shaded part of the semi-circle?

(A) $(\pi - 1)x^2$

(B) $\left(\frac{\pi-2}{2}\right)x^2$

(C) $\left(\frac{3\pi-2}{2}\right)x^2$

(D) $\left(\frac{3\pi-4}{4}\right)x^2$

(E) $\left(\frac{5\pi-4}{4}\right)x^2$

(F) $\left(\frac{5\pi-8}{8}\right)x^2$

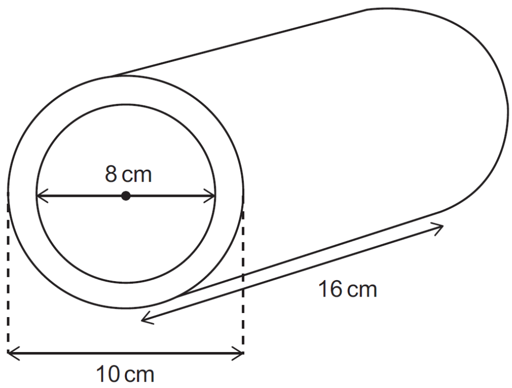
[NSAA, 2017S1Q17]

A cylindrical hollow metal pipe is 16 cm long.

It has an external diameter of 10 cm and an internal diameter of 8 cm.

The density of the metal from which the pipe is made is 8 grams per cm^3.

[diagram not to scale]



What is the mass of the pipe in grams?

(A) 8π

(B) 16π

(C) 18π

(D) 72π

(E) 128π

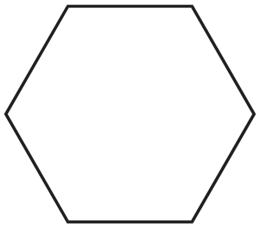
(F) 512π

(G) 1152π

(H) 4608π

[NSAA, 2017S1Q18]

The shortest distance between two opposite sides of a regular hexagon is 12 cm.



Find the area, in cm², of the regular hexagon.

(A) $36\sqrt{3}$

(B) 72

(C) $54\sqrt{3}$

(D) 108

(E) $72\sqrt{3}$

(F) 144

(G) $144\sqrt{3}$

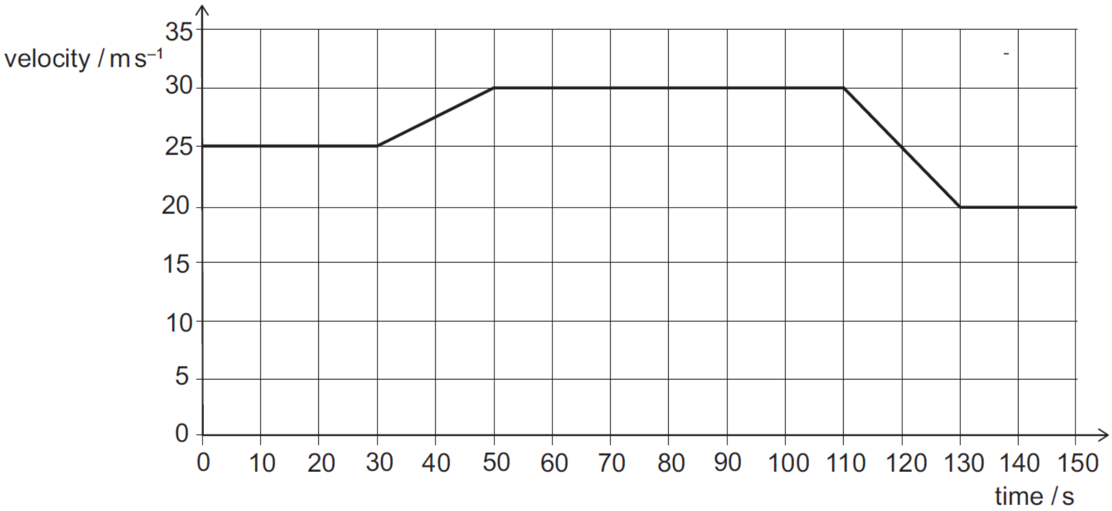
(H) $288\sqrt{3}$

Part B

[NSAA, 2017S1Q19]

A car is travelling along a horizontal road in a straight line.

The graph is a velocity–time graph for part of the car's journey.



During this part of the journey, what is the total distance that the car travels while it is decelerating?

(A) 400 m

(B) 500 m

(C) 550 m

(D) 600 m

(E) 750 m

(F) 1400 m

(G) 1800 m

(H) 1900 m

[NSAA, 2017S1Q20]

When a saucepan of water is heated from below, convection currents form and transfer heat through the liquid.

Here are three statements about the water as it is heated:

1 The mass of a fixed volume of the water increases.

2 The density of a fixed mass of the water decreases.

3 The volume of a fixed mass of the water increases.

Which of these statements help(s) to explain how convection currents are formed?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q21]

Table 1 gives the approximate frequency ranges of sections of the electromagnetic spectrum.

Table 1

type of wave	*radio waves*	*microwaves*	*infrared waves*	*visible light*	*ultraviolet waves*	*X-rays*	*gamma rays*
approximate frequency range / Hz	$< 3.0 \times 10^9$	3.0×10^9 to 3.0×10^{12}	3.0×10^{12} to 4.3×10^{14}	4.3×10^{14} to 7.5×10^{14}	7.5×10^{14} to 3.0×10^{17}	3.0×10^{17} to 3.0×10^{19}	$> 3.0 \times 10^{19}$

Table 2 gives information about two different types of wave in air.

Waves 1 to 3 are longitudinal waves formed by an object vibrating.

Waves 4 to 6 are electromagnetic waves.

The speed of sound in air is 300 m s^{-1}. The speed of light in air is 3.0×10^8 m s^{-1}.

Table 2

wave	*type of wave*	*wavelength* / m
1	longitudinal	1.0×10^{-4}
2	longitudinal	1.0×10^{-2}
3	longitudinal	1.0×10^{-1}
4	electromagnetic	5.0×10^{-7}
5	electromagnetic	5.0×10^{-1}
6	electromagnetic	1.0×10^{3}

A person detects only two of these waves unaided, using just their eyes and ears.

Which two waves does the person detect?

(A) wave 1 and wave 4

(B) wave 1 and wave 5

(C) wave 2 and wave 5

(D) wave 2 and wave 6

(E) wave 3 and wave 4

(F) wave 3 and wave 6

[NSAA, 2017S1Q22]

A charge of 60 C passes through an electrical component when a steady voltage of 10 V is applied across it for 30 seconds. The resistance of the component remains constant throughout.

What is the resistance of the component?

(A) 0.050 Ω

(B) 0.20 Ω

(C) 0.50 Ω

(D) 2.0 Ω

(E) 5.0 Ω

(F) 20 Ω

[NSAA, 2017S1Q23]

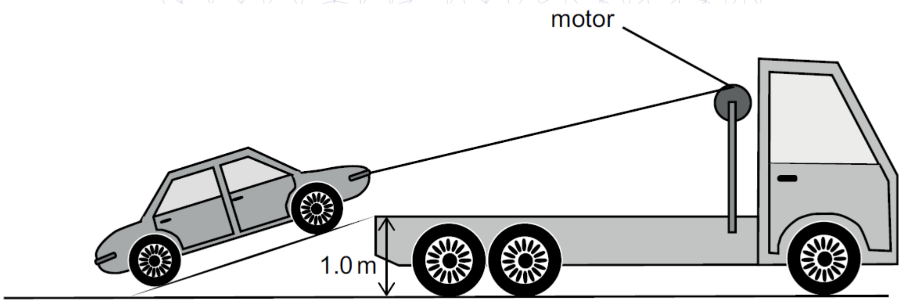
An electric motor is used to pull a broken-down car slowly from the road up a ramp on to the back of a breakdown truck.

The car has a mass of 1200 kg and is lifted through a vertical height of 1.0 m.

The total input energy to the motor is 28 kJ and it is 75% efficient.

In the process of lifting the car, energy is lost to the surroundings from the motor and from other causes.

What is the **total** energy lost to the surroundings?



(gravitational field strength = 10 N kg^{-1})

(A) 7.0 kJ

(B) 9.0 kJ

(C) 12 kJ

(D) 16 kJ

(E) 21 kJ

(F) 33 kJ

[NSAA, 2017S1Q24]

In one type of medical scanner a source is placed inside a patient's body. This source causes pairs of gamma-rays to be emitted simultaneously in opposite directions.

Detectors on each side of the patient are used to detect the gamma-rays. The distance between the two detectors is 3.0 m. When the source is at Q, half-way between the detectors, the two gamma-rays arrive at the same time. In a particular scan the gamma-rays arrive at the two detectors with a time difference of 4.0×10^{-10} s.

Assume that, inside the patient, the gamma-rays travel at a speed of 3.0×10^{8} m s^{-1}.

How far from Q, half-way between the detectors, is the gamma-ray source?

(A) 6.0 mm

(B) 12 mm

(C) 24 mm

(D) 6.0 cm

(E) 12 cm

(F) 24 cm

[NSAA, 2017S1Q25]

When a plutonium-239 nucleus absorbs a neutron it undergoes nuclear fission. One particular fission reaction results in the creation of xenon and zirconium as daughter nuclei. The nuclear equation for this reaction is shown but with some non-zero integers replaced by the letters w, x, y and z.

$$^{1}_{0}\text{n} + {}^{239}_{94}\text{Pu} \rightarrow {}^{w}_{54}\text{Xe} + {}^{y}_{x}\text{Zr} + z\,{}^{1}_{0}\text{n}$$

Which equation is correct?

(A) $w + y = 240$

(B) $z = 240 - (w + y)$

(C) $x = 40 - z$

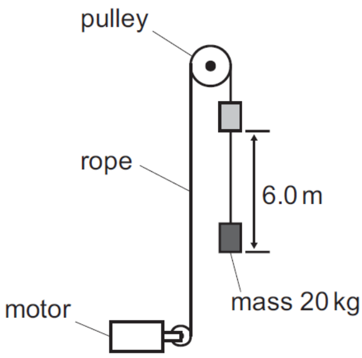
(D) $94 = 54 + x + 1$

(E) $240 = 54 + x$

(F) $94 = w + y + 1$

[NSAA, 2017S1Q26]

An electric motor is connected to a constant 12 V d.c. supply. The motor is used to lift a mass of 20 kg by means of a rope and pulley. The mass is lifted vertically through a height of 6.0 m in a time of 5.0 s. The complete lifting system (motor, rope and pulley) is 80% efficient.



What is the current in the electric motor?

(gravitational field strength = 10 N kg^{-1})

(A) 1.6 A

(B) 2.0 A

(C) 2.5 A

(D) 16 A

(E) 20 A

(F) 25 A

[NSAA, 2017S1Q27]

The nuclide ${}^{P}_{Q}X$ decays to the stable nuclide Y. During this process four particles are emitted: an α-particle and three β^- particles.

Which of the following is **not** a nuclide that could be formed at any stage during this process?

nuclide	*atomic mass*	*atomic number*
(A)	P	$Q-1$
(B)	P	$Q+1$
(C)	P	$Q+2$
(D)	P	$Q+3$
(E)	$P-4$	$Q-2$
(F)	$P-4$	$Q-1$
(G)	$P-4$	Q
(H)	$P-4$	$Q+1$

[NSAA, 2017S1Q28]

The radius of an iron-56 atom is 3.0×10^4 times greater than the radius of an iron-56 nucleus.

What is the value of $\frac{\text{densityof an iron atom}}{\text{density of an iron nucleus}}$?

(A) $(3.0 \times 10^4)^{-3}$

(B) $(3.0 \times 10^4)^{-2}$

(C) $(3.0 \times 10^4)^{-1}$

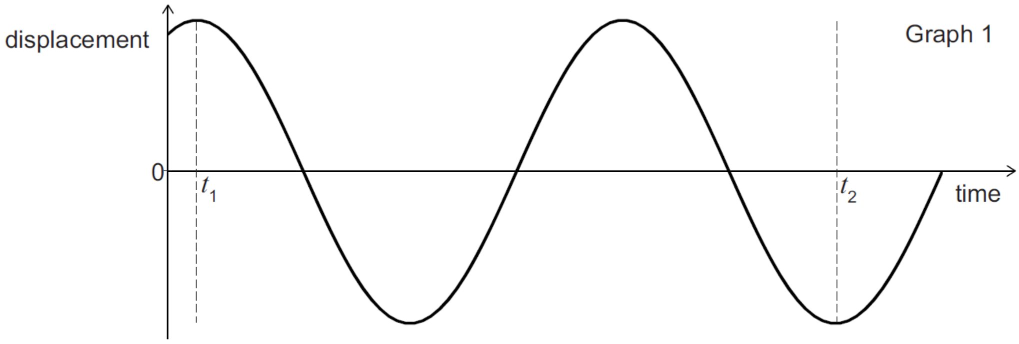
(D) $(3.0 \times 10^4)^{1}$

(E) $(3.0 \times 10^4)^{2}$

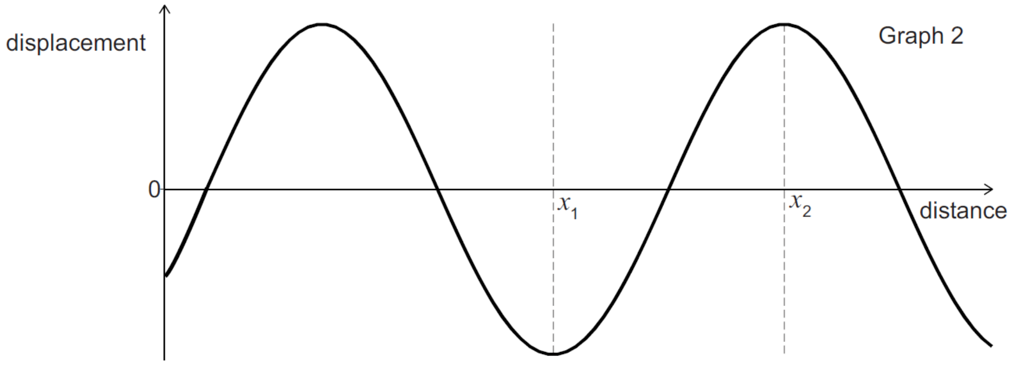
(F) $(3.0 \times 10^4)^{3}$

[NSAA, 2017S1Q29]

Graph 1 shows how the displacement of one of the particles of a medium varies with time in seconds as a wave travels through the medium.



Graph 2 shows how the displacement varies with distance in metres at one time for the same wave.



Which expression gives the speed in m s^{-1} of the wave?

(A) $\frac{4(x_2-x_1)}{3(t_2-t_1)}$

(B) $\frac{3(x_2-x_1)}{2(t_2-t_1)}$

(C) $\frac{2(x_2-x_1)}{t_2-t_1}$

(D) $\frac{8(x_2-x_1)}{3(t_2-t_1)}$

(E) $\frac{3(x_2-x_1)}{t_2-t_1}$

(F) $\frac{6(x_2-x_1)}{t_2-t_1}$

[NSAA, 2017S1Q30]

A kettle is designed to work from a car's power socket. The kettle has a power rating of 150 W when a constant voltage of 12.0 V d.c. is applied across its element.

How much charge passes through the element of this kettle when the voltage of 12.0 V is applied across it for 20 minutes?

(A) 96 C

(B) 250 C

(C) 15 000 C

(D) 36 000 C

(E) 900 000 C

(F) 2 160 000 C

[NSAA, 2017S1Q31]

A freight train travelling on a straight horizontal track at 2.0 m s^{-1} collides with a passenger train travelling at 5.0 m s^{-1} in the opposite direction. Both trains immediately come to a complete stop on the track.

The freight train has three locomotives of 130 tonnes each and seven container wagons of 30 tonnes each. The passenger train has two locomotives of 70 tonnes each and a number of passenger carriages of 10 tonnes each.

How many passenger carriages does the passenger train have?

(A) 7

(B) 9

(C) 10

(D) 24

(E) 46

[NSAA, 2017S1Q32]

Consider the following four calculations:

1 $(200\ \text{kg m s}^{-1}) \div (5\ \text{m s}^{-1})$

2 $(200\ \text{J}) \div (5\ \text{m})$

3 $(200\ \text{kg m}^{-3}) \div (5\ \text{m}^{3})$

4 $(200\ \text{N}) \div (5\ \text{m s}^{-2})$

Which two calculations result in the answer 40 kg?

(A) 1 and 2

(B) 1 and 3

(C) 1 and 4

(D) 2 and 3

(E) 2 and 4

(F) 3 and 4

[NSAA, 2017S1Q33]

Consider the following three statements about a parachutist of mass 72 kg falling vertically at a constant velocity of 5.0 m s^{-1} after the parachute has opened:

1 The parachutist has a constant kinetic energy of 1800 J.

2 The parachutist is losing gravitational potential energy at a rate of 3600 J s^{-1}.

3 Air resistance and the force of gravity acting on the parachutist are a Newton's third law pair of forces.

Which of the statements is/are correct?

(gravitational field strength = 10 N kg^{-1})

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q34]

Two radioactive sources X and Y have half-lives of 3.0 hours and 2.0 hours respectively. The product of the decay of both of the sources is a stable isotope of the element Z.

Six hours ago a mixture contained the same number of atoms of both X and Y, and no other atoms.

What fraction of the mixture is now made up of atoms of Z?

(A) $\frac{10}{16}$

(B) $\frac{11}{16}$

(C) $\frac{12}{16}$

(D) $\frac{13}{16}$

(E) $\frac{14}{16}$

(F) $\frac{15}{16}$

[NSAA, 2017S1Q35]

Car X passes car Y on a motorway.

Car X is travelling at 1.5 times the speed of car Y.

The mass of car X is $\frac{4}{5}$ of the mass of car Y.

How do the kinetic energies of the two cars compare?

(A) kinetic energy of car $X = 0.90 \times$ kinetic energy of car Y

(B) kinetic energy of car $X = 0.96 \times$ kinetic energy of car Y

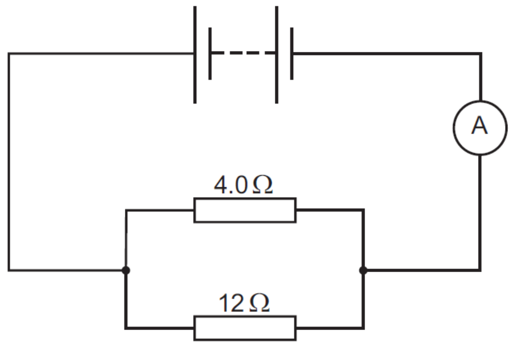
(C) kinetic energy of car $X = 1.20 \times$ kinetic energy of car Y

(D) kinetic energy of car $X = 1.44 \times$ kinetic energy of car Y

(E) kinetic energy of car $X = 1.80 \times$ kinetic energy of car Y

[NSAA, 2017S1Q36]

In the following circuit the ammeter shows a reading of 4.0 A.



The power dissipated in the 12 Ω resistor is 12 W.

What is the power dissipated in the 4.0 Ω resistor?

(A) 3.0 W

(B) 4.0 W

(C) 12 W

(D) 16 W

(E) 36 W

Part C

[NSAA, 2017S1Q37]

Consider the atoms/ions below:

$$^{24}_{12}Mg^{2+} \quad ^{16}_{8}O^{2-} \quad ^{18}_{8}O \quad ^{32}_{16}S^{2-}$$

Which of the following statements is/are correct?

1 Both $^{16}_{8}O^{2-}$ and $^{24}_{12}Mg^{2+}$ have the same electronic configuration.

2 $^{32}_{16}S^{2-}$ has double the number of neutrons that are in $^{18}_{8}O$.

3 The sum of the numbers of electrons in $^{16}_{8}O^{2-}$ and $^{18}_{8}O$ is equal to the number of electrons in $^{32}_{16}S^{2-}$.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q38]

Which two of the following reactions involve oxidation?

1 $Ca \rightarrow Ca^{2+} + 2e^-$

2 $Cl_2 + 2e^- \rightarrow 2Cl^-$

3 $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

4 $MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$

(A) 1 and 2 only

(B) 1 and 3 only

(C) 1 and 4 only

(D) 2 and 3 only

(E) 2 and 4 only

(F) 3 and 4 only

[NSAA, 2017S1Q39]

Hydrochloric acid (HCl) is a strong acid. Properties of a solution of 1.00 mol dm^{-3} hydrochloric acid include:

1 It turns blue litmus indicator red.

2 On reaction with sodium carbonate gaseous carbon dioxide is evolved.

3 25.0 cm^3 of this acid solution neutralises 25.0 cm^3 of 1.00 mol dm^{-3} sodium hydroxide solution.

Ethanoic acid (CH_3COOH) is a weak acid.
Which of the three properties is/are also correct for a 1.00 mol dm^{-3} solution of ethanoic acid?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q40]

Consider the following reactions:
Reaction Q :$CH_2 = CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$ ΔH is $-$ve
Reaction R: $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ ΔH is +ve
The following actions could be applied independently to each reaction (Q and R) above:

1 increase the pressure

2 increase the temperature

3 use a suitable catalyst

Assuming that all other conditions remain constant, which of these actions will increase the initial rate of reaction **and** increase the yield of products for **both** reactions Q and R?

(A) none of them

(B) 1 only

(C) 1 or 2 only

(D) 1 or 3 only

(E) 2 only

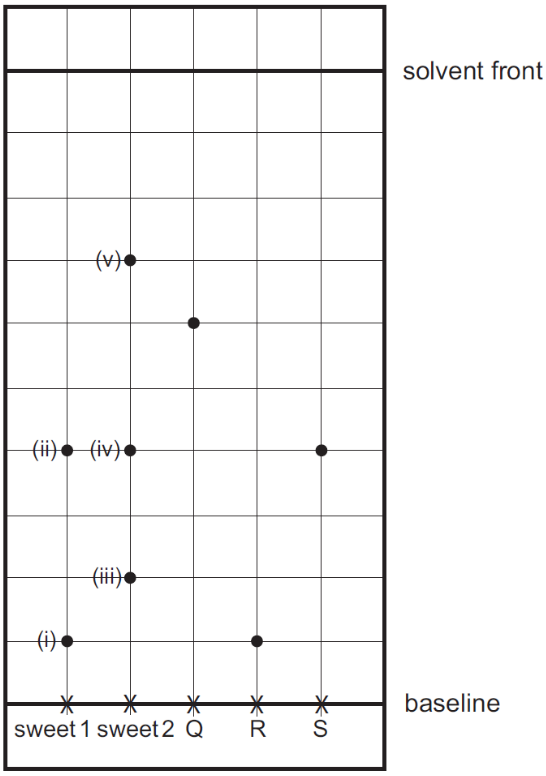
(F) 2 or 3 only

(G) 3 only

(H) 1, 2 or 3

[NSAA, 2017S1Q41]

Study the chromatogram below showing the spots obtained, labelled (i) to (v), from two sweets and pure samples of the food additives, labelled Q, R and S.



Which of the following statements about the chromatogram is/are correct?

1 Both sweet 1 and 2 contain additives R and S.

2 The R_f value for spot (iv) is half that for spot (iii).

3 The R_f value for spot (v) is 0.7.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q42]

Element X has atomic number 20. Consider only the **simple oxide** of X.

Which of the following options identifies the formula, the type of bonding and the acid-base character of the oxide of element X?

	formula of oxide	*type of bonding in oxide*	*acid-base character of oxide*
(A)	X_2O	ionic	basic
(B)	X_2O	covalent	basic
(C)	XO	ionic	basic
(D)	XO	covalent	acidic
(E)	XO_2	ionic	acidic
(F)	XO_2	covalent	acidic
(G)	X_2O_3	ionic	basic
(H)	X_2O_3	covalent	acidic

[NSAA, 2017S1Q43]

Solid copper(II) chloride contains Cu^{2+} ions and Cl^- ions only.

Solid lithium phosphate(V) contains Li^+ ions and PO_4^{3-} ions only.

Aqueous solutions of copper(II) chloride and lithium phosphate(V) are mixed to produce a precipitate of copper(II) phosphate(V) and an aqueous solution of lithium chloride.

Which of the following represents the balanced ionic equation for this process?

(A) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

(B) $2Cu^{2+}(aq) + 3PO_4^{3-}(aq) \rightarrow Cu_2(PO_4)_3(s)$

(C) $2Cu^{2+}(aq) + 5PO_4^{3-}(aq) \rightarrow Cu_2(PO_4)_5(s)$

(D) $3Cu^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Cu_3(PO_4)_2(s)$

(E) $3Cu^{2+}(aq) + 6Cl^-(aq) + 6Li^+(aq) + 2PO_4^{3-}(aq) \rightarrow Cu_3(PO_4)_2(s) + 6LiCl(aq)$

(F) $3CuCl_2(aq) + 2Li_3PO_4(aq) \rightarrow Cu_3(PO_4)_2(s) + 6LiCl(aq)$

[NSAA, 2017S1Q44]

Which of the following statements about the reaction of lithium with water are correct?

1 The reaction is a redox reaction.

2 7 g of lithium will react with excess water to produce 2 g of hydrogen gas.

3 The reaction produces a solution with a pH greater than that of water.

4 14 g of lithium will exactly react with 36 g of water.

(A_r values: H = 1; Li = 7; O = 16)

(A) 1 and 2 only

(B) 1 and 4 only

(C) 1, 2 and 3 only

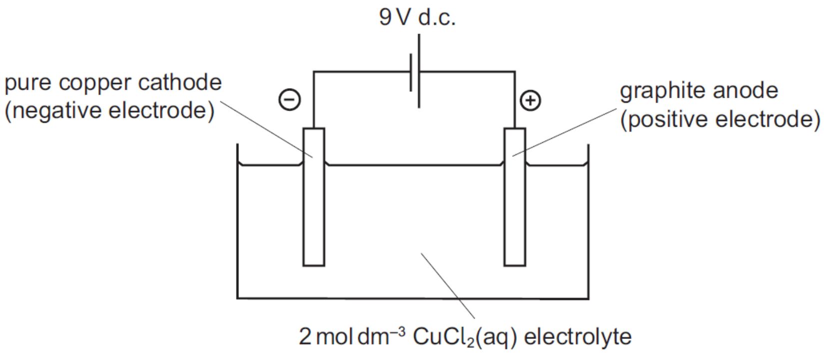
(D) 1, 3 and 4 only

(E) 2 and 3 only

(F) 3 and 4 only

[NSAA, 2017S1Q45]

Consider this electrochemical cell containing an aqueous copper(II) chloride electrolyte:



Which row in the following table identifies the reactions occurring at the electrodes?

	cathode (negative electrode)	*anode (positive electrode)*
(A)	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
(B)	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
(C)	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$
(D)	$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$
(E)	$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$	$2OH^-(aq) \rightarrow H_2(g) + O_2(g) + 2e^-$

[NSAA, 2017S1Q46]

A fluorocarbon has a relative molecular mass which is twice that of its empirical formula mass.

81 g of the compound contains 57 g of fluorine.

What is the molecular formula of the compound?

(A_r values: C = 12; F = 19)

(A) C_2F_3

(B) C_2F_5

(C) C_3F_6

(D) C_3F_8

(E) C_4F_6

(F) C_4F_{10}

[NSAA, 2017S1Q47]

In which of the following reactions is there a change in volume of 24 dm³, when measured at room temperature and pressure?

1 56 g of carbon monoxide completely reacts with an excess of oxygen $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

2 36 g of steam is fully decomposed $2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$

3 30 g of nitrogen monoxide completely reacts with an excess of oxygen $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

(A_r values: C = 12; O = 16; H = 1.0; N = 14. Assume that one mole of gas occupies a volume of 24 dm³ at room temperature and pressure.)

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q48]

Magnesium reacts with sulfuric acid according to the following chemical equation:

$$Mg(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2(g)$$

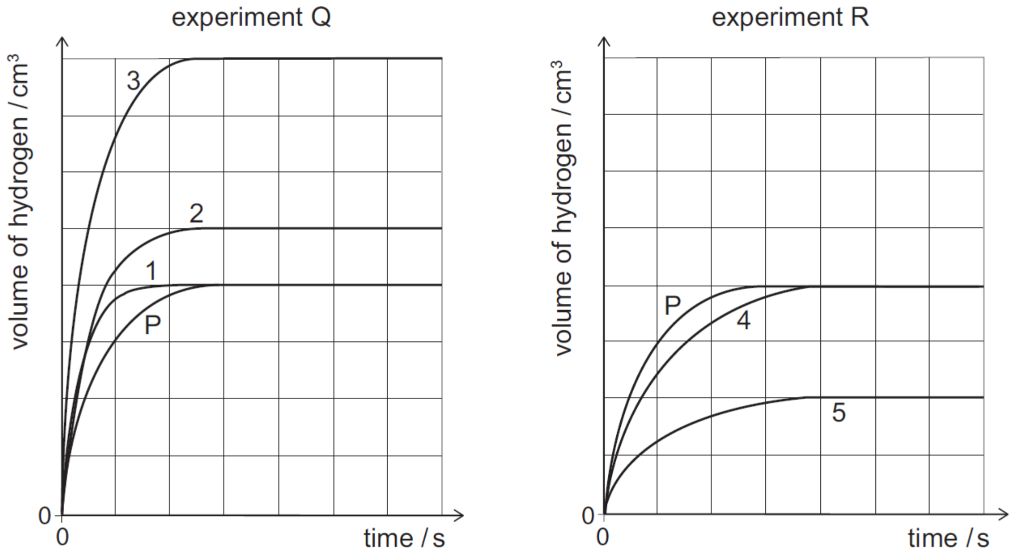
Line P on each graph shows how the volume of hydrogen formed changes with time when 1.2 g of magnesium reacts with 40 cm^3 of 1.0 mol dm^{-3} sulfuric acid at 20 °C.

(A_r value: Mg = 24)

Two further experiments were carried out and the volumes of hydrogen formed were plotted.

Experiment Q: 1.2 g of magnesium +40 cm^3 of 2.0 mol dm^{-3} sulfuric acid at 20 °C

Experiment R: 1.2 g of magnesium +40 cm^3 of 0.5 mol dm^{-3} sulfuric acid at 20 °C



Which lines show how the volume of hydrogen formed will change with time in each experiment?

	experiment Q	*experiment R*
(A)	1	4
(B)	1	5
(C)	2	4
(D)	2	5
(E)	3	4
(F)	3	5

[NSAA, 2017S1Q49]

Nitrogen and hydrogen react together to form ammonia as shown below:

$$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$$

The energy released by this reaction is 93 kJ mol^{-1}.

What is the bond energy in the nitrogen molecule?

(Bond energies: H– H = 436 kJ mol^{-1}; N– H = 391 kJ mol^{-1})

(A) 315 kJ mol^{-1}

(B) 513 kJ mol^{-1}

(C) 644 kJ mol^{-1}

(D) 864 kJ mol^{-1}

(E) 945 kJ mol^{-1}

(F) 1131 kJ mol^{-1}

[NSAA, 2017S1Q50]

Consider the following two electrolytic processes:

electrolysis of molten lead(II) chloride

electrolysis of brine (sodium chloride solution)

Which of the following statements is/are correct?

1 In both processes, reduction takes place at the negative electrode.

2 If 20.0 g of product is formed at the negative electrode in each process, then both processes produce the same volume of chlorine gas, measured at room temperature and pressure.

3 In both processes, a metal is produced at the negative electrode.

(A_r values: Cl = 35.5; H = 1.00; Na = 23.0; Pb = 207. Assume that one mole of gas occupies 24.0 dm^3 at room temperature and pressure.)

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

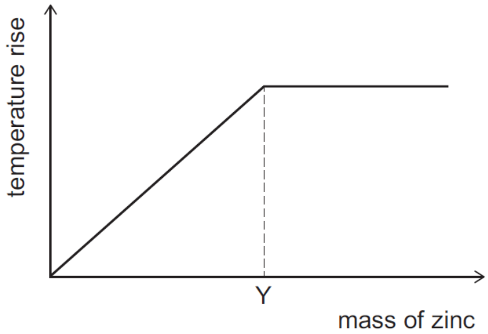
(H) 1, 2 and 3

[NSAA, 2017S1Q51]

Silver nitrate solution reacts with zinc powder in an exothermic reaction:

$$2AgNO_3(aq) + Zn(s) \rightarrow 2Ag(s) + Zn(NO_3)_2(aq)$$

The graph shows the maximum temperature rise as different masses of zinc react with separate 50.0 cm^3 samples of 0.100 mol dm^{-3} silver nitrate solution.



What is the mass of zinc at the position labelled Y?

(A_r value: Zn = 65)

(A) 0.163 g

(B) 0.325 g

(C) 0.650 g

(D) 1.63 g

(E) 3.25 g

(F) 6.50 g

[NSAA, 2017S1Q52]

Natural samples of copper contain two isotopes: ^{63}Cu which has a relative isotopic mass of 62.93, and ^{65}Cu which has a relative isotopic mass of 64.93.

The relative atomic mass of a sample of elemental copper is 63.55.

What is the percentage abundance of each of the two isotopes to the nearest whole number?

(A) 27% ^{63}Cu and 73% ^{65}Cu

(B) 73% ^{63}Cu and 27% ^{65}Cu

(C) 31% ^{63}Cu and 69% ^{65}Cu

(D) 69% ^{63}Cu and 31% ^{65}Cu

(E) 36% ^{63}Cu and 64% ^{65}Cu

(F) 64% ^{63}Cu and 36% ^{65}Cu

[NSAA, 2017S1Q53]

The reaction between calcium carbonate and hydrochloric acid was used to measure the effect of changing conditions on the mass of CO_2 produced and the rate of CO_2 production.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

The experiment was carried out five times with different conditions at a constant temperature.

The following conditions were varied:

$CaCO_3$ as chips or powder

mass of $CaCO_3$

volume of HCl

concentration of HCl

Which experiment (**A-E**) in the following table will produce 8.8 g of carbon dioxide in the shortest time?

(M_r values: $CaCO_3 = 100$; $CO_2 = 44$)

	$CaCO_3$		HCl	
	type	*mass / g*	*volume / cm³*	*concentration / mol dm⁻³*
(A)	chips	10	400	2.0
(B)	powder	20	100	2.0
(C)	chips	20	200	2.0
(D)	powder	10	200	2.0
(E)	chips	20	300	1.0

[NSAA, 2017S1Q54]

An atom of ^1_1H has a radius of 0.05 nanometres.

The radius of the nucleus of this atom is approximately 50 000 times smaller.

What is the approximate radius of the nucleus in femtometres?

(1 femtometre = 10^{-15} m)

(A) 1000

(B) 100

(C) 10

(D) 1

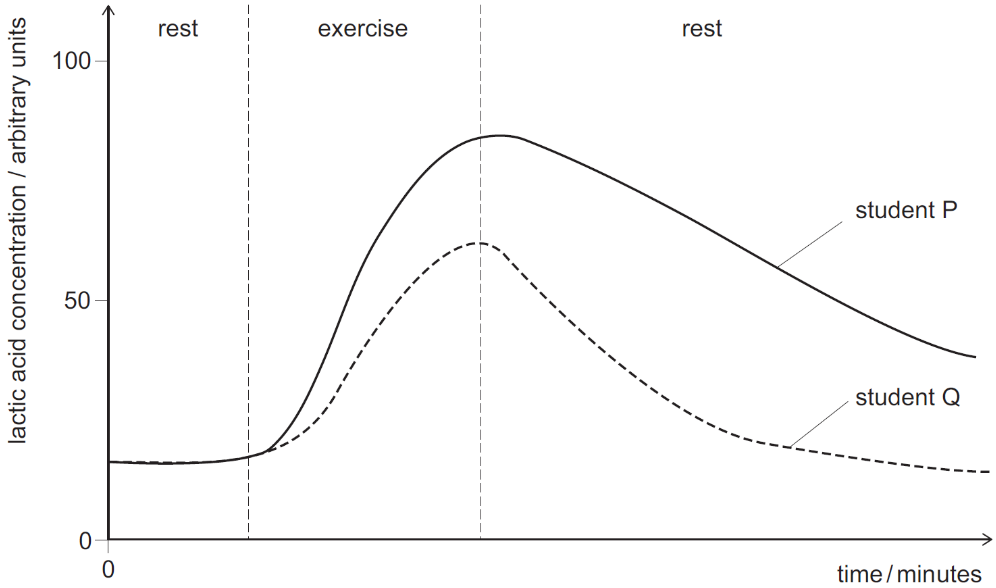
(E) 0.1

(F) 0.01

Part D

[NSAA, 2017S1Q55]

The graph shows the concentration of lactic acid in the blood of two students at rest, then carrying out the same level of exercise for 15 minutes, and then at rest again.



Which of the following statements correctly describe(s) the two students?

1 Student P's oxygen debt is repaid much quicker than student Q's .

2 Student P has a lower oxygen debt than student Q.

3 Student P has a higher level of fitness than student Q.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

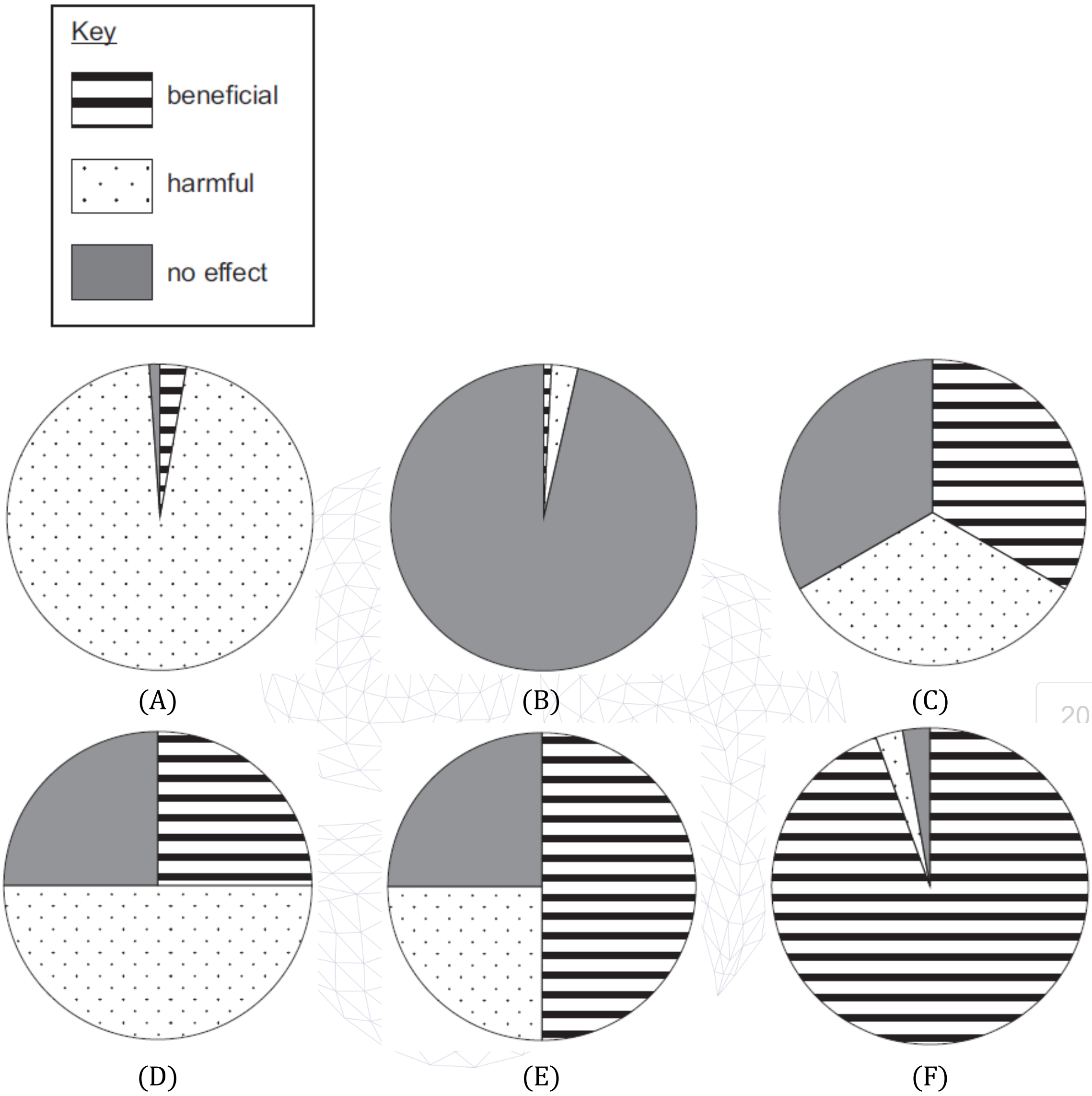
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q56]

Spontaneous mutations occur in the genetic material of all livingorganisms.

Which pie chart best represents the proportion of mutations that are beneficial, mutations that are harmful, and mutations that have no effect?



[NSAA, 2017S1Q57]

Ten randomly placed quadrats were used to estimate the frequency of occurrence of three plant species in a field.

	number of individuals of		
quadrat number	*Species X*	*Species Y*	*Species Z*
1	4	1	5
2	11	0	12
3	3	5	13
4	0	0	9
5	2	9	4
6	1	8	2
7	7	2	6
8	14	24	0
9	6	0	2
10	7	3	0

What was the correct lowest frequency of occurrence calculated from X or Y or Z?

(A) 0

(B) 0.2

(C) 0.7

(D) 1.0

(E) 1.4

(F) 5.2

(G) 52.0

[NSAA, 2017S1Q58]

Which of the following statements about stem cells in a healthy human female is/are correct?

1 An adult stem cell contains the same genes as an epithelial cell from that organism .

2 Stem cells from this human will all contain two X chromosomes.

3 When a stem cell divides it produces a new stem cell plus two specialised body cells.

(Assume that no mutations have occurred.)

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q59]

Which of the following will **always** lead to an increase in the size of a population?

1 removal of intraspecific competitors

2 supplying more of the nutrient that is at the lowest concentration

3 change in the organism's rate of reproductions.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

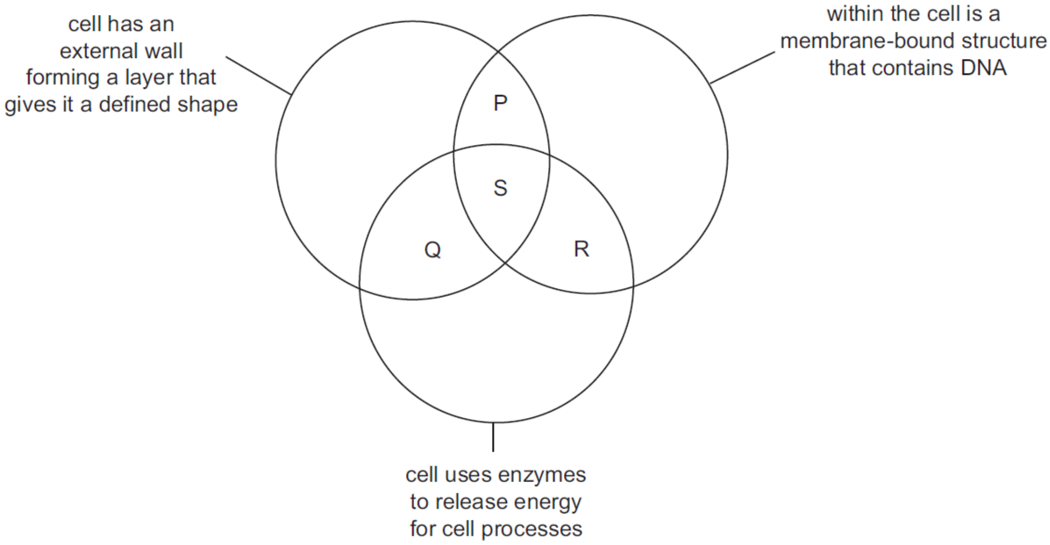
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q60]

The diagram shows three features which are used to group organisms.



Fungi, bacteria and animals can each be placed in one of the regions labelled P, Q, R or S on the diagram.

Which row in the following table is correct?

	fungi	*bacteria*	*animals*
(A)	P	S	R
(B)	P	R	S
(C)	Q	R	P
(D)	S	Q	R
(E)	S	S	S
(F)	R	P	Q
(G)	R	Q	P

[NSAA, 2017S1Q61]

A desert food chain is shown below.

cactus ⟶ rat ⟶ rattlesnake ⟶ hawk

Assume that 10% of the energy from each stage in the food chain is passed on.

If 150 000 units of energy are contained in the producer, how much energy will be lost in the transfer between the primary and secondary consumers?

(A) 1500

(B) 13 500

(C) 15000

(D) 135 000

(E) 148 500

[NSAA, 2017S1Q62]

Which of the following statements about bacterial cell division is/are correct?

1 Daughter cells show a large degree of genetic difference to the parent cell.

2 After each division, two daughter cells are produced by mitosis.

3 Chromosome replication occurs in the cytoplasm of the bacteria.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

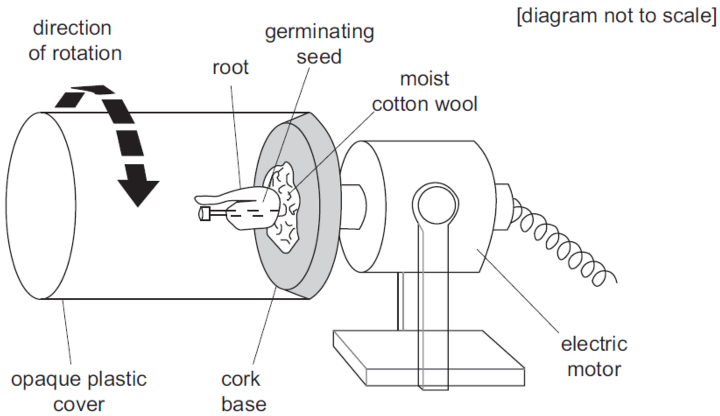
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q63]

Young plant roots show a similar positive response to the direction of gravity as their shoots do to the direction of light.

A clinostat, shown in the diagram, can be used to counter the effects of gravity on a plant. It has a motor which slowly rotates the plant. The cover is opaque to prevent light affecting the direction of root growth.



Two clinostats were set up using identical seedlings for two days:

Clinostat 1, with the motor running

Clinostat 2, with the motor stationary

In which direction would the root grow in each clinostat?

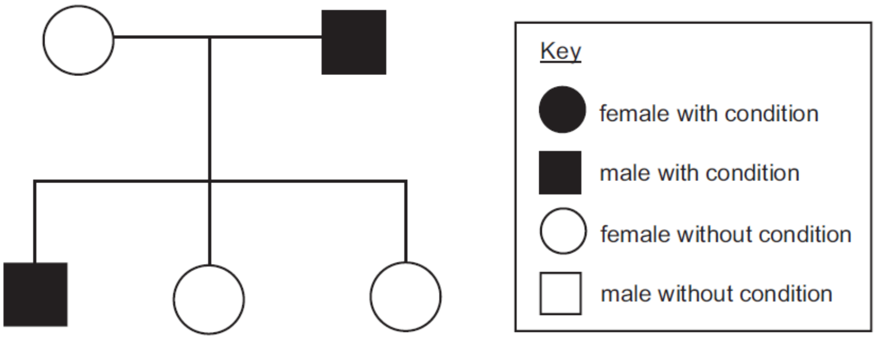
Key
⇓ downwards
⇑ upwards
⇐ horizontally

	results for clinostat 1	*results for clinostat 2*
(A)	⇓	⇑
(B)	⇓	⇐
(C)	⇓	⇓
(D)	⇑	⇐
(E)	⇑	⇓
(F)	⇐	⇑
(G)	⇐	⇓
(H)	⇐	⇐

[NSAA, 2017S1Q64]

An inherited condition is caused by a recessive allele.

The family tree shows the inheritance of this condition in one family.



One of the daughters in this family tree has children with a man who does not have the condition.

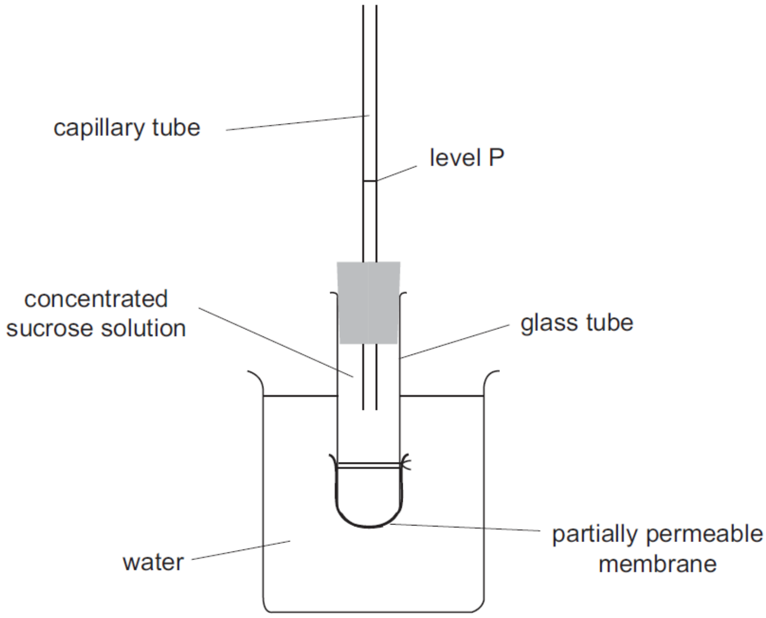
For the two situations described in the table, which row shows the probability that their first child will be a girl who has the condition?

(Assume no new mutations.)

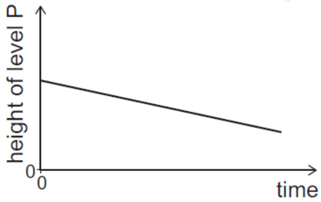
	father is homozygous dominant	*father is heterozygous*
(A)	0	0
(B)	0	0.125
(C)	0	0.25
(D)	0.5	0
(E)	0.5	0.125
(F)	0.5	0.25

[NSAA, 2017S1Q65]

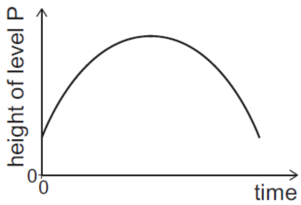
The diagram shows the apparatus used to investigate the movement of molecules across a partially permeable membrane. Sucrose is unable to cross the partially permeable membrane.



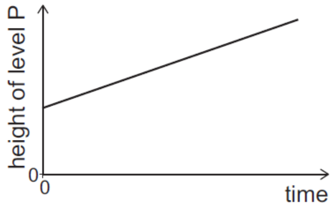
Which graph correctly shows how the height of solution in the capillary tube changes over 15 minutes?



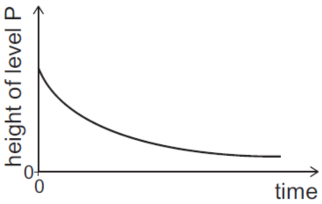
A



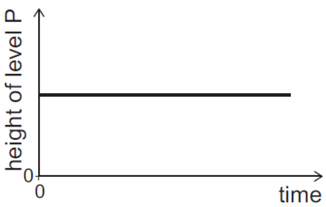
B



C



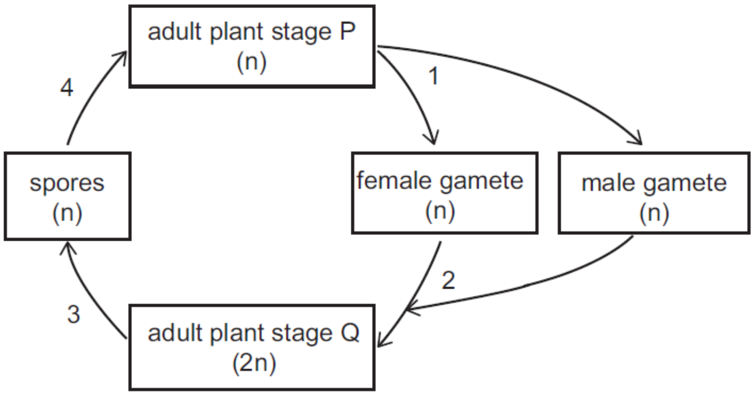
D



E

[NSAA, 2017S1Q66]

The diagram shows the life cycle of a simple type of plant.



Key
n = haploid number of chromosomes
2n = diploid number of chromosomes

At which two of the numbered stages does only mitosis occur?

(A) 1 and 2 only

(B) 1 and 3 only

(C) 1 and 4 only

(D) 2 and 3 only

(E) 2 and 4 only

(F) 3 and 4 only

[NSAA, 2017S1Q67]

Three different coloured leaves were collected: a dark green leaf, a light green leaf and a yellow leaf. Each leaf had 16 discs of 1 cm diameter cut from it.

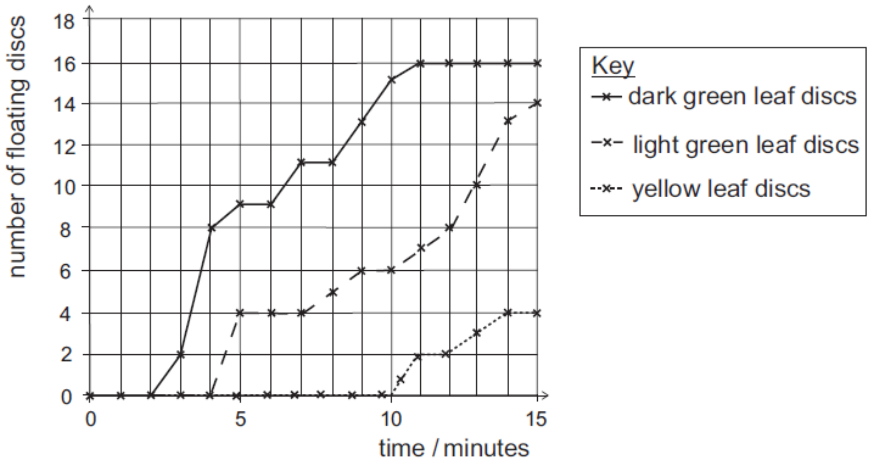
The discs were treated with sodium hydrogen carbonate solution to replace all the air from the spaces within the leaf. Sodium hydrogen carbonate solution is a source of carbon dioxide.

To start the experiment, each group of discs was then placed in a beaker of sodium hydrogen carbonate. At the beginning of the experiment all of the discs sank.

Each beaker was illuminated for 30 minutes by being placed 10 cm in front of a lamp that provided the same wavelengths of light as sunlight. It was observed that some of the leaf discs floated. The number of floating leaf discs was counted every minute for 15 minutes.

The results are shown in the graph.

(All other variables were kept constant.)



Which of the following statements is/are correct?

1 The average rate of photosynthesis was highest in the darkest leaves.

2 At 5 minutes 25% of the light green discs remained at the bottom of the beaker.

3 The reciprocal of the time taken for a quarter of the discs of a particular colour to float can be a measure of the relative rate of photosynthesis.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

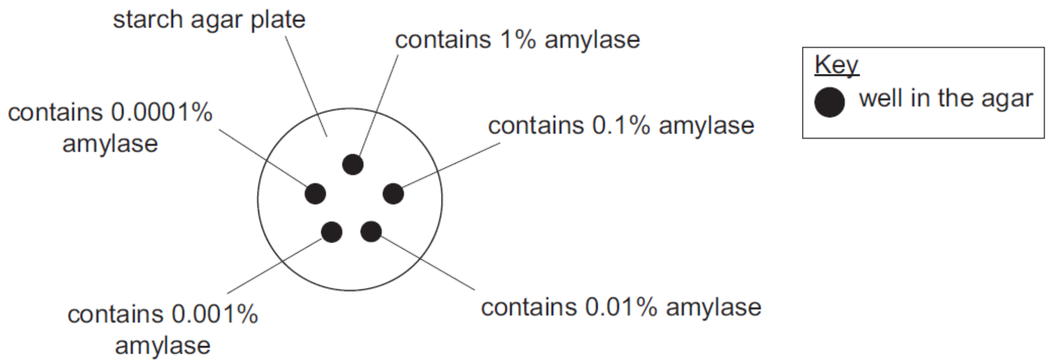
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q68]

A student carried out an experiment to investigate the effect of enzyme concentration on the rate of an enzyme-controlled reaction.

The student used a starch agar plate with five identically sized small wells cut into the agar. The wells were filled with identical volumes of different concentrations of amylase solution, as shown in the diagram.



The starch agar plate was incubated overnight and the plate was then flooded with iodine solution. Most of the agar stained blue, but there was a clear area around each well where starch had been digested by the amylase. The student measured and recorded the diameter of the clear area that formed. The results are shown in the table below.

Percentage concetration of amylase	*Diameter of clear area that forms around*
1.0	27
0.1	24
0.01	15
0.001	12
0.0001	9

Which of the following factors **could** have affected the diameter of the clear area around the wells containing amylase?

1 pH of the starch agar

2 concentration of the amylase solution

3 temperature at which the plates were incubated

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

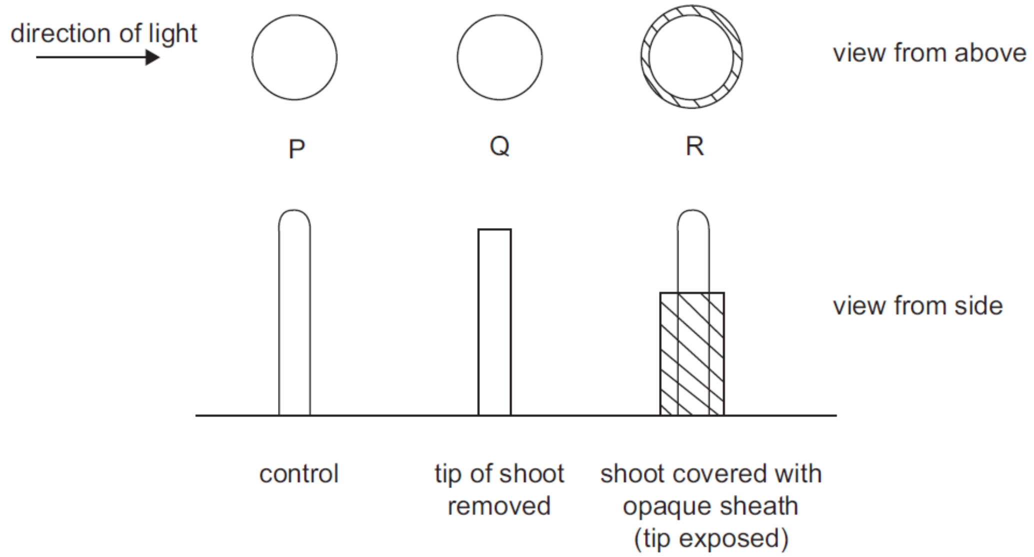
(G) 2 and 3 only

(H) 1, 2 and 3

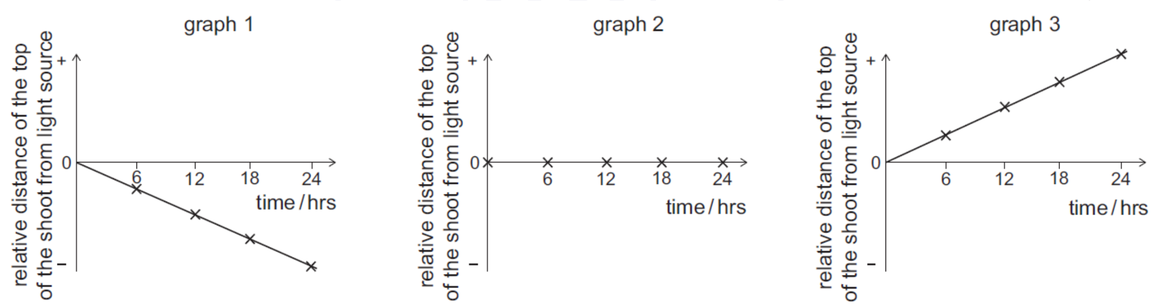
[NSAA, 2017S1Q69]

The diagram shows the start of an experiment on the effect of light direction on young shoots. All of the shoots were growing vertically. All of the shoots were the same distance from the light source. All of the shoots were continually exposed to the light from one side for 24 hours.

(All other variables were kept constant.)



Every six hours, the distance between the light source and the top of each shoot was measured. The distance from the light source relative to the position at the start of the experiment was plotted on the following graphs.



Which row represents the responses of the shoots to the light over 24 hours?

	P	*Q*	*R*
(A)	1	2	1
(B)	1	3	1
(C)	1	3	2
(D)	2	1	3
(E)	2	2	1
(F)	3	1	3
(G)	3	2	2

[NSAA, 2017S1Q70]

The table shows some of the genetic codes for amino acids:

genetic code	*Amino acid coded for (three-letter abbreviations)*
AGA	Arg
AGG	Arg
ATG	Met
CCC	Pro
CCG	Pro
CGA	Arg
CTG	Leu
GAC	Asp
GGA	Gly
GTC	Val
GTG	Val
TAG	Stop(ends protein synthesis)
TGG	Trp
TTA	Leu
TTG	Leu

The base sequence below shows the middle part of a gene coding for a protein:

A T G C G A G A C A T G T T A A G G T G G G A C C C C C G A G T C

Mutations took place in both the 4th and 20th base in this sequence.

Using **only** the information provided and reading the sequence from left to right, which of the following statements **could** be correct for the resulting amino acid sequence after the two mutations took place?

1 This sequence could be only six amino acids long.

2 The second amino acid in this sequence could be unaffected by the mutation.

3 This amino acid sequence could contain seven different amino acids.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

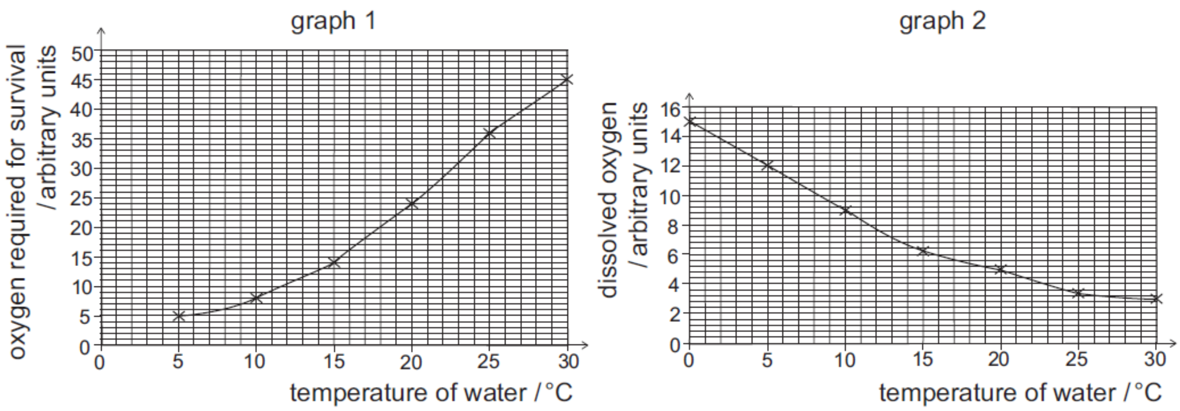
(H) 1, 2 and 3

[NSAA, 2017S1Q71]

A power station released warm water into a river. This is an example of water pollution because the temperature of the river water was increased.

A student was interested in the effects of the temperature increase on a pollution indicator species.

The student studied two graphs. Graph 1 showed the oxygen required by the pollution indicator species for survival and graph 2 showed the effect of temperature on the oxygen dissolved in the water.



The student wrote the following statements:

1 As the oxygen required by the pollution indicator species for survival increases, the water temperature rises.

2 There is less dissolved oxygen available to the pollution indicator species as the water temperature rises.

3 The pollution indicator species will survive better in water at 30 °C than at 5 °C because it has a greater oxygen uptake at 30 °C.

Which of the student's conclusions could be correct using only the information provided?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2017S1Q72]

In a monohybrid cross, two heterozygotes were allowed to mate and the resulting offspring showed a 2 : 1 phenotypic ratio.

Which of the following statements could explain this ratio?

1 The number of offspring produced was small.

2 The recessive condition was lethal prior to birth.

3 Being homozygous dominant was lethal prior to birth.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

Part E

[NSAA, 2017S1Q73]

Which one of the following is a simplification of

$$1-\left(\frac{3+\sqrt{3}}{6-2\sqrt{3}}\right)^2$$

(A) $-\frac{3}{4}$

(B) $\frac{3}{4}$

(C) $-\frac{3}{4}-\frac{\sqrt{3}}{7}$

(D) $\frac{3}{4}-\frac{\sqrt{3}}{7}$

(E) $-\frac{3}{4}-\sqrt{3}$

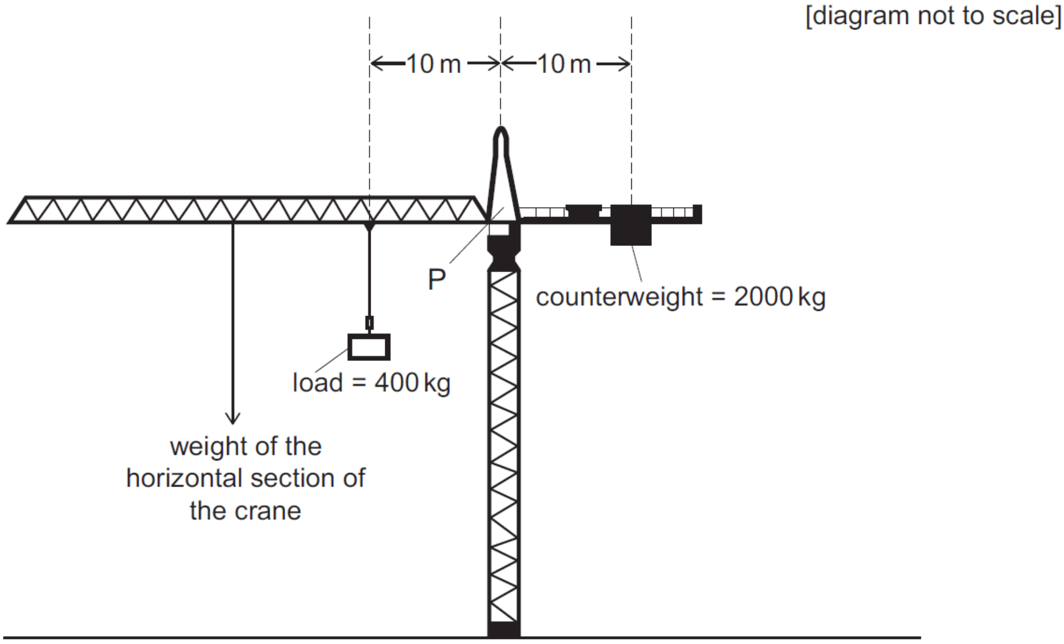
(F) $\frac{3}{4}-\sqrt{3}$

(G) $-\frac{\sqrt{3}}{2}$

(H) $\frac{\sqrt{3}}{2}$

[NSAA, 2017S1Q74]

The diagram shows a crane being used on a building site. The crane is perfectly balanced about *P*.



The load is now moved to the left by 5.0 m.

To keep the crane perfectly balanced about *P*, how far does the counterweight have to move, and in which direction?

(gravitational field strength = 10 N kg^{-1})

(A) 1.0 m to the left

(B) 1.0 m to the right

(C) 3.0 m to the left

(D) 3.0 m to the right

(E) 4.0 m to the left

(F) 4.0 m to the right

[NSAA, 2017S1Q75]

k is the smallest positive value of x which is a solution to **both** the equations $2\sin x + 1 = 0$ **and** $2\cos 2x = 1$.

How many values of x in the range $0 \leq x \leq k$ are solutions to at least one of these equations?

(A) 0

(B) 2

(C) 3

(D) 4

(E) 8

[NSAA, 2017S1Q76]

An aircraft is climbing at constant speed in a straight line at an angle of 10° to the horizontal. Which statement about the resultant force on the aircraft is correct?

(A) It is parallel to its motion.

(B) It is perpendicular to its motion.

(C) It is zero.

(D) It is equal to its weight.

(E) It is equal to the drag acting on the aircraft.

[NSAA, 2017S1Q77]

Which of the following is a solution to the equation $3^{(2x+1)} - 6(3^x) = 0$?

(A) $\log_2 3$

(B) $\log_3 2$

(C) 2

(D) $\log_{10} 2$

(E) $\frac{2}{3}$

[NSAA, 2017S1Q78]

A ball starts at a speed of 40.0 m s^{-1}. The ball is subject to a constant deceleration of 14.4 m s^{-2} as it travels a distance of 20.0 m in a straight line. What is the final speed of the ball?

(A) 16.0 m s^{-1}

(B) 20.0 m s^{-1}

(C) 25.6 m s^{-1}

(D) 32.0 m s^{-1}

(E) 36.2 m s^{-1}

(F) 39.3 m s^{-1}

[NSAA, 2017S1Q79]

The graph of the function $y = x^3 + px^2 + qx + 6$, where p and q are real constants, has a local maximum when $x = 2$ and a local minimum when $x = 4$. What are the values of p and q?

(A) $p = -3$ and $q = -8$

(B) $p = -3$ and $q = 8$

(C) $p = 3$ and $q = -8$

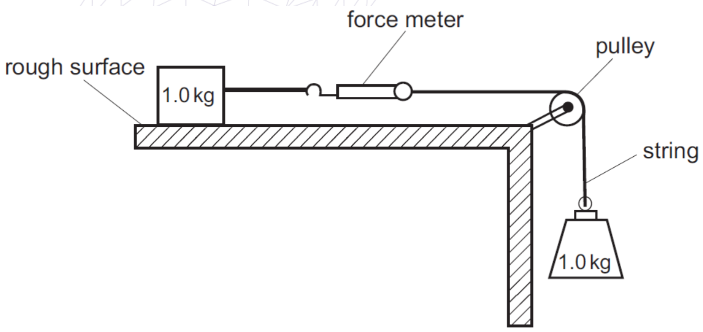
(D) $p = -9$ and $q = 24$

(E) $p = 9$ and $q = 24$

(F) $p = 9$ and $q = -24$

[NSAA, 2017S1Q80]

A block of mass 1.0 kg is at rest on a rough horizontal surface. The block is attached by a light inextensible string to a force meter. The other end of the force meter is attached by another light inextensible string via a frictionless pulley to a load of mass 1.0 kg. The block remains stationary.



What is the reading on the force meter?

(gravitational field strength = 10 N kg^{-1})

(A) 0.0 N

(B) 0.5 N

(C) 1.0 N

(D) 2.0 N

(E) 5.0 N

(F) 10 N

(G) 20 N

[NSAA, 2017S1Q81]

Given that $y = (2+3x)^6$, what is the coefficient of x^3 in $\frac{dy}{dx}$?

(A) 240

(B) 4320

(C) 4860

(D) 12 960

(E) 19 440

[NSAA, 2017S1Q82]

An apple of mass 100 g, growing on a tree, falls vertically from a height of 4.0 m above the ground. It hits the ground with a speed of 8.0 m s^{-1}.

How much work does the apple do against resistive forces during its descent, before it hits the ground?

(gravitational field strength = 10 N kg^{-1})

(A) 0.80 J

(B) 3.6 J

(C) 4.0 J

(D) 7.2 J

(E) 8.0 J

[NSAA, 2017S1Q83]

A geometric progression has first term equal to 1 and common ratio $\frac{1}{2}\sin 2x$.

The sum to infinity of the series is $\frac{4}{3}$.

Find the possible values of x in the range $\pi \leq x \leq 2\pi$.

(A) $\frac{13}{12}\pi, \frac{17}{12}\pi$

(B) $\frac{7}{6}\pi, \frac{4}{3}\pi$

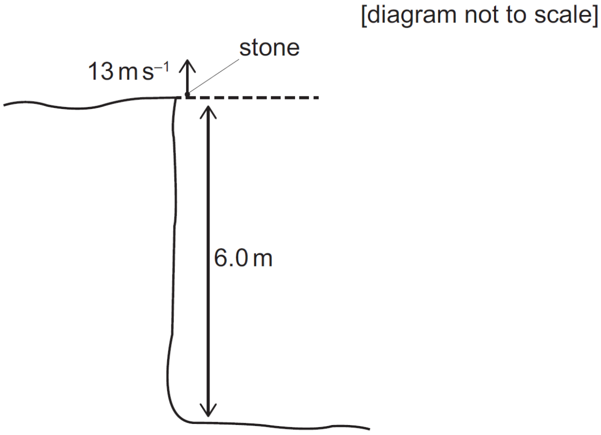
(C) $\frac{7}{6}\pi, \frac{11}{6}\pi$

(D) $\frac{5}{4}\pi, \frac{7}{4}\pi$

(E) there are no values of x in this range

[NSAA, 2017S1Q84]

A stone is fired vertically upwards at a speed of 13 m s^{-1} on a still day from the top of a 6.0 m high cliff. It then falls down and lands at the bottom of the cliff.



From when the stone passes the top of the cliff on the way down, how long does it take to reach the ground at the bottom of the cliff?

(air resistance can be ignored; gravitational field strength = 10 N kg^{-1})

(A) 0.40 s

(B) $\frac{6.0}{6.5}$ s

(C) 0.60 s

(D) $\sqrt{1.2}$ s

(E) 1.3 s

(F) 2.0 s

(G) 2.5 s

(H) 3.0 s

[NSAA, 2017S1Q85]

The sequence of numbers $u_1, u_2, u_3, \dots, u_n, \dots$ is given by

$$u_1 = 2$$
$$u_{n+1} = pu_n + 3$$

where p is an integer.

The fourth term, u_4, is equal to -7.

What is the value of $u_1 + u_2 + u_3 + u_4$?

(A) -10

(B) -2

(C) -1

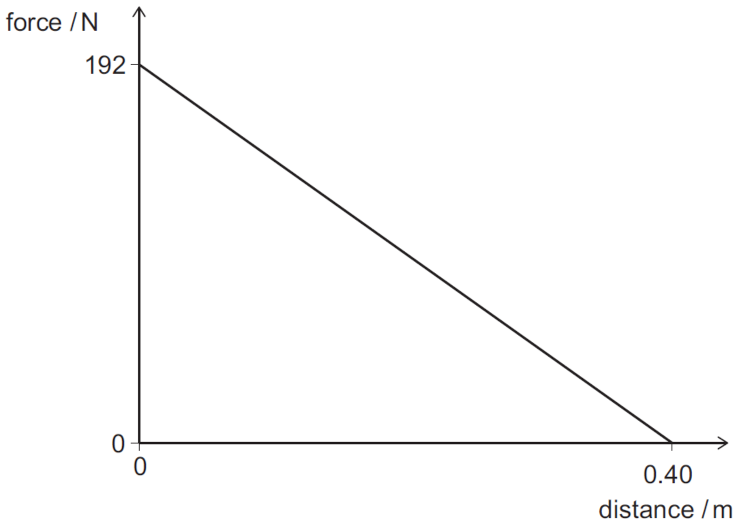
(D) 8

(E) 26

[NSAA, 2017S1Q86]

An archer fires an arrow of mass 0.024 kg vertically upwards from a bow.

The graph shows how the force of the bowstring on the arrow varies with distance as the arrow moves upwards.



The work done by the force of the bowstring is given by the area under the force-distance graph.

When the arrow leaves the bow, what is the kinetic energy of the arrow, and what is the maximum height that it gains from this point?

(Air resistance can be ignored. The effect of gravity as the arrow is fired is negligible compared to the force of the bowstring. The gravitational field strength = 10 N kg^{-1}.)

	kinetic energy / J	*height* / m
(A)	38.4	16
(B)	38.4	160
(C)	38.4	1600
(D)	38.4	16000
(E)	76.8	32
(F)	76.8	320
(G)	76.8	3200
(H)	76.8	32000

[NSAA, 2017S1Q87]

Find the complete set of values of x for which

$$\frac{x^3 - 6x^2 + 9x - 4}{x} > 0$$

(A) $x < 0, x > 4$

(B) $0 < x < 4$

(C) $0 < x < 1, x > 4$

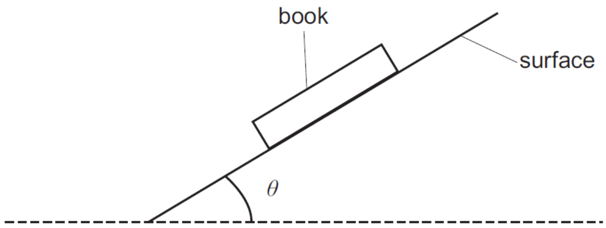
(D) $x < 0, 1 < x < 4$

(E) $x < 1, x > 4$

(F) $1 < x < 4$

[NSAA, 2017S1Q88]

A book of mass m rests on a rough horizontal surface. The surface is now tilted as shown:



When the angle of tilt θ is 20°, the book slides down the slope at a constant speed. What is the acceleration of the book down the slope when the angle of tilt is 25°?

(gravitational field strength = g)

(A) $g(\cos 20° - \sin 20° \tan 5°)$

(B) $g(\cos 20° - \sin 20° \tan 25°)$

(C) $g(\cos 25° - \sin 5° \tan 20°)$

(D) $g(\cos 25° - \sin 25° \tan 20°)$

(E) $g(\sin 20° - \cos 20° \tan 5°)$

(F) $g(\sin 20° - \cos 20° \tan 25°)$

(G) $g(\sin 25° - \cos 5° \tan 20°)$

(H) $g(\sin 25° - \cos 25° \tan 20°)$

[NSAA, 2017S1Q89]

The equations of two straight lines are $y = 3 + (2p^2 - p)x$ and $y = 7 + (p - 2)x$, where p is a real constant.

For certain values of p, the two lines are perpendicular.

Which of the following numbers is closest to the greatest such value of p?

(A) 2.00

(B) 1.75

(C) 1.50

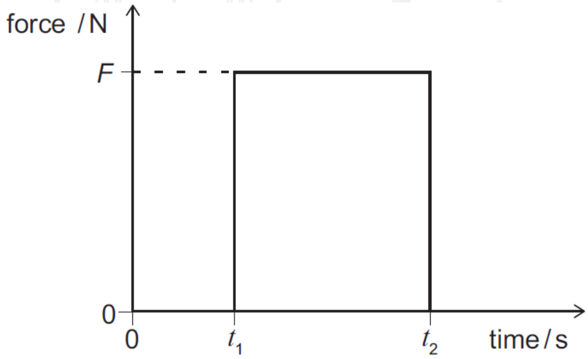
(D) 1.00

(E) -0.25

(F) -0.50

[NSAA, 2017S1Q90]

The graph shows how the horizontal force on a tennis ball of mass m varies during a shot in a tennis match. The ball is initially travelling horizontally toward the racket with speed u and leaves the racket horizontally travelling in the opposite direction with speed v.



Which expression gives the magnitude of the momentum of the ball as it leaves the racket?

(A) $F(t_2 - t_1)$

(B) $F(t_2 - t_1) - mu$

(C) $F(t_2 - t_1) + mu$

(D) $mv - mu$

(E) $Ft_2 - mu$

NSAA 2017 S2

NSAA 2017 S2
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 40 MINUTES

This paper is Section 2 of 2.

There are six questions in this paper, of which you should answer any **two**.

There are 20 marks for each question. In total 40 marks are available.

You should write your answers in the spaces provided in this question paper. Please complete this section in **black pen**. Pencil may be used for graphs and diagrams only.

You can use the blank pages inside this booklet for rough working or notes, but **no extra paper** is allowed. Only answers in the spaces indicated in the paper will be marked.

Calculators may be used in this section. Please record your calculator model in the box below:

Calculator model	

Write the numbers of the questions you answer in the order attempted in the boxes below:

Question number

[NSAA, 2017S2Q1]

In this question, assume the gravitational field strength = 10 N kg^{-1}, and neglect air resistance effects.

(a) State Hooke's Law, and briefly explain what is meant by elastic potential energy as applied to an elastic rope. [2]

(b) An elastic rope of negligible mass obeys Hooke's Law perfectly, and has an unstretched length of 10 m. When Alice, whose mass is 50 kg, hangs in equilibrium from its lower end, the rope has a total length of 26 m. [2]

Calculate the rope's elastic constant k (i.e. the ratio of the tension in the rope to its extension), and also the elastic potential energy stored in the rope.

Alice now uses the same elastic rope to do a "bungee jump": one end of the rope is attached to Alice, and the other end to a bridge over a very deep valley. Alice falls off the bridge, starting from rest, and moves vertically downwards.

(c) Describe in words Alice's acceleration until she reaches the lowest point of her fall. [2]

(d) Calculate Alice's vertical downward speed when she has fallen a vertical distance of 15 metres from the bridge. [2]

(e) Calculate the distance below the bridge where Alice is instantaneously at rest. [3]

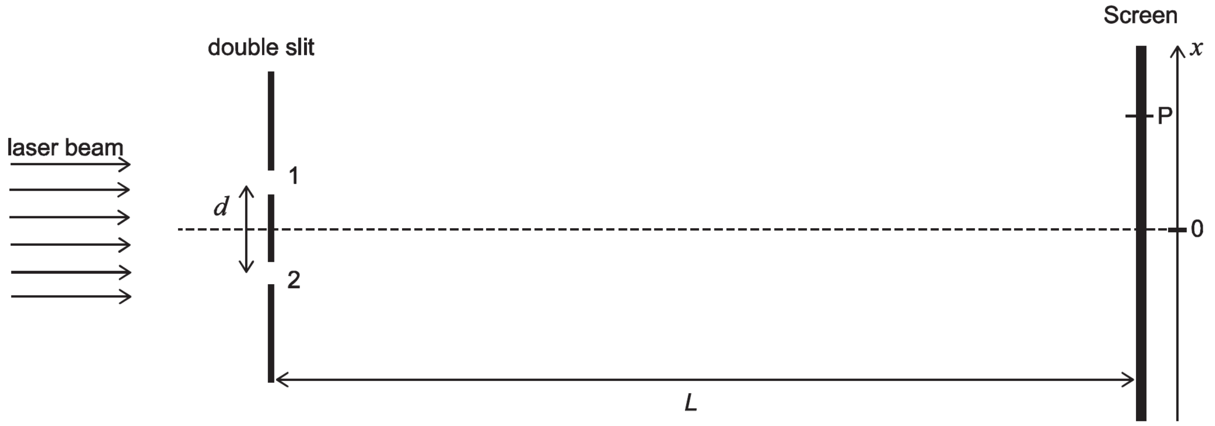
(f) Calculate Alice's maximum speed during her fall, and state where this occurs. [3]

(g) What is the magnitude and direction of the maximum acceleration that Alice experiences during her fall, and where does this occur? [3]

(h) Sketch a graph of Alice's vertical acceleration against distance fallen until she reaches the lowest point of her fall. Take the downwards direction as positive. [3]

[NSAA, 2017S2Q2]

In a double slit experiment, a laser beam of wavelength λ illuminates two narrow slits at normal incidence, as shown in the diagram. The two narrow slits are separated by a distance d and an interference pattern is seen on a screen a distance L away from the slits, where $L \gg d$.

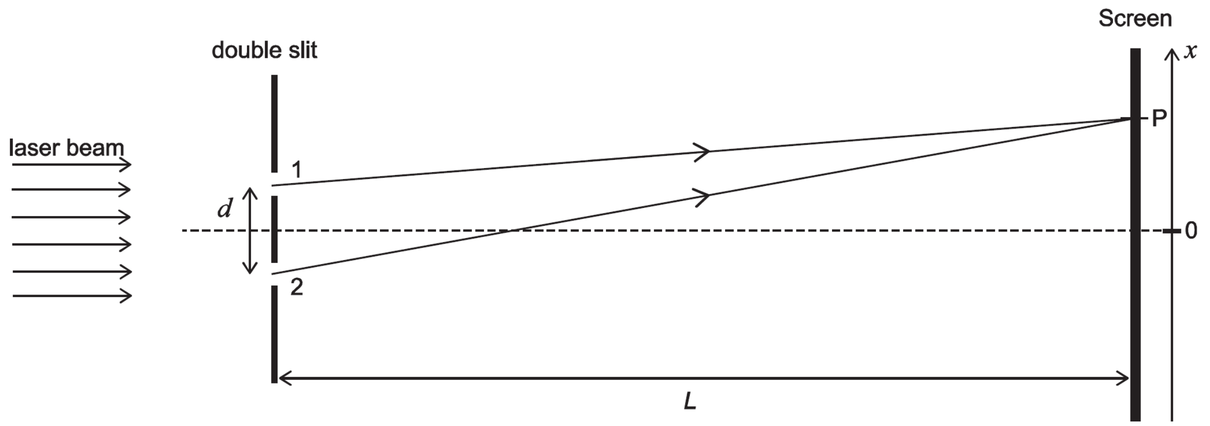


(a) Explain how this experiment is used to provide evidence for the wave nature of light. [2]

(b) The interference pattern that is seen on the screen can be sketched as a graph of light intensity against distance x measured from the central axis.

Sketch this graph for both positive and negative values of x. [3]

(c) Illustrate on the diagram below the path difference between two rays of light from the two slits arriving at point P on the screen. [1]



(d) By referring to the diagram in part (c), derive an expression for the x position of the first minimum (the minimum closest to $x = 0$) in terms of λ, d and L. [3]

The amplitude of the light wave from slit 1, arriving at point P, can be described mathematically by the function

$$A_1 = A_0 \cos\left(\omega t - \frac{2\pi(L - \Delta L)}{\lambda}\right)$$

Similarly, the amplitude of the light wave from slit 2 that arrives at point P can be described as

$$A_2 = A_0 \cos\left(\omega t - \frac{2\pi(L + \Delta L)}{\lambda}\right)$$

where A_0, λ, t and ω are constants.

(e) Using the trigonometric identity $\cos B + \cos C = 2\cos\left(\frac{B-C}{2}\right)\cos\left(\frac{B+C}{2}\right)$, derive an expression for the total amplitude of the light wave, $A = A_1 + A_2$ at point P. [3]

Give your answer in the form $A = F\cos(G)\cos(H)$ where F, G and H are expressions in terms of A_0, λ, t, ω, L and ΔL.

(f) Let $t = 0$ while L and λ remain constant. What are the two smallest positive values of ΔL for which $A = 0$? [4]

(g) If the first minimum at point P is at $x = 1.5$ cm when $d = 0.10$ mm and $L = 5.0$ m, what is the value of ΔL and what is the wavelength of the laser light? [4]

[NSAA, 2017S2Q3]

Data: Assume that the molar gas volume = 24.0 dm^3 mol^{-1} at room temperature and pressure (rtp).

(a) When lithium metal and hydrogen gas are heated together, a single substance, **A**, is formed as colourless crystals with a melting point of 688 °C. Molten **A** conducts electricity, and electrolysis of the molten substance re-forms the elements.

(i) Give an equation for the formation of **A**. [1]

(ii) Classify the structure of **A** as either molecular covalent, giant covalent, or ionic. Briefly justify your answer. [2]

(iii) During the electrolysis of molten **A**, which element appears at the positive electrode (the anode) and which appears at the negative electrode (the cathode)? [1]

(b) Substance **A** reacts with aluminium chloride to form lithium aluminium hydride ($LiAlH_4$) and one other by-product. [2]

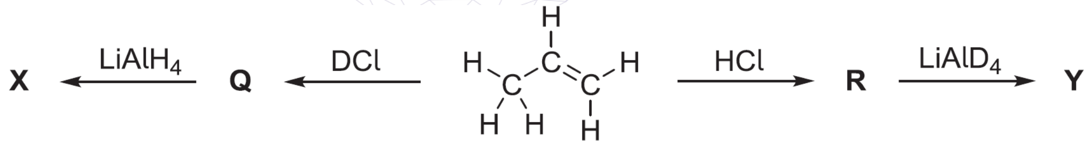
Give a balanced chemical equation for the formation of lithium aluminium hydride from **A** and aluminium chloride.

(c) When 3.8 g of lithium aluminium hydride is heated to 125 °C, it decomposes to give three substances: 1.8 g of aluminium metal, 2.4 dm^3 of a flammable gas (measured at rtp), and substance **B**.

Determine the formula for substance **B**. [5]

(d) Lithium aluminium deuteride can be prepared if deuterium gas is used in place of normal hydrogen. Deuterium, often given the symbol D, is the non-radioactive isotope of hydrogen, i.e. D = ^{2}H. The formula for lithium aluminium deuteride can be written $LiAlD_4$. Both $LiAlH_4$ and $LiAlD_4$ are common reducing agents and the latter is useful for preparing deuterium containing compounds.

Isomers of mono-deuterated propane, **X** and **Y**, may be prepared from propene according to the following scheme which also uses hydrogen chloride, HCl, and deuterium chloride, DCl. In the scheme, only the carbon-containing compounds are shown; other by-products are not.



Give the structures of **X** and **Y** and the intermediates **Q** and **R** formed during the syntheses. [4]

(e) 2,2-dideuterated propane may be prepared easily in two steps, from a mono-deuterated propene, **Z**. (The formula for **Z** is C_3H_5D.)

(i) Draw the structures of all the alkenes with formula C_3H_5D. [2]

(ii) Give a synthesis of 2,2-dideuterated propane starting from **Z** showing reagents and intermediates in each step, making sure to give the displayed formula for **Z**. [3]

[NSAA, 2017S2Q4]

Read the following carefully before proceeding to answer the question.

In their solid (crystalline) form many inorganic salts (such as NaCl or MgF_2) can be thought of as consisting of a giant lattice in which positive ions (e.g. Na^+, Mg^{2+}) and negative ions (e.g. Cl^-, F^-) are arranged in a regular pattern, called a lattice. The ions are held together by electrostatic forces arising from the favourable interactions between ions of opposite charge.

The lattice enthalpy is the enthalpy change for a process in which the solid material is formed from ions in the gas phase. For NaCl(s) this is the process

$$Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$$

and for MgF_2 the process is

$$Mg^{2+}(g) + 2F^-(g) \rightarrow MgF_2(s)$$

The lattice enthalpy is invariably large and negative.

The lattice enthalpy in kJ mol^{-1} can be estimated using the following expression:

$$\frac{-1.07 \times 10^5 \times n_{\text{ions}} \times z_+ \times z_-}{r_+ + r_-} \qquad \textbf{Equation 1}$$

In this expression, r_+ is the radius of the positive ion, in pm (1 pm $= 10^{-12}$ m), and r_- is the radius of the negative ion, also given in pm.

n_{ions} is the number of ions in the formula unit; for example, for NaCl $n_{\text{ions}} = 2$, but for MgF_2 $n_{\text{ions}} = 3$.

z_+ is the charge number on the positive ion; for example for Na^+ it is 1, but for Mg^{2+} it is 2. Likewise z_- is the **absolute value** of the charge number on the negative ion: for Cl^- it is 1 (**not** -1).

(a) Use Equation 1 to calculate the lattice enthalpy for CuF_2 given the following data: [3]

$$r_+ = 73 \text{ pm}, \qquad r_- = 133 \text{ pm}$$

(b) Use Equation 1 to calculate the lattice enthalpy for CuF_3 given the following data: [3]

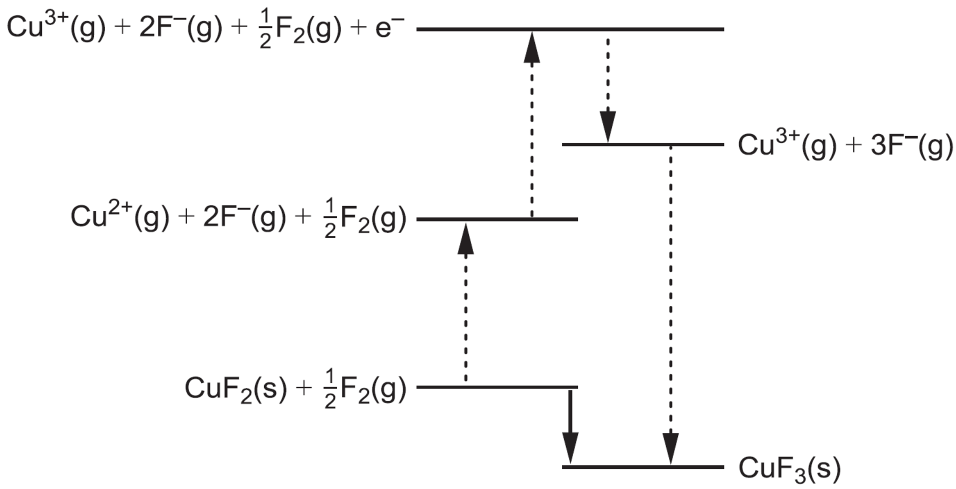
$$r_+ = 54 \text{ pm}, \qquad r_- = 133 \text{ pm}$$

(c) Calculated values of the lattice enthalpy can be used to estimate the enthalpy change of hypothetical reactions, such as [3]

$$CuF_2(s) + \frac{1}{2}F_2(g) \rightarrow CuF_3(s) \qquad \textbf{Equation 2}$$

Determine the oxidation state of copper in each of the species and hence classify what kind of reaction this is.

(d) The enthalpy change for the reaction in Equation 2 can be calculated using the following Hess's Law cycle.



Using your results from (a) and (b), and given the following enthalpy changes

$F_2(g) + 2e^- \rightarrow 2F^-(g)$ $\Delta H = -540$ kJ mol-1

$Cu^{2+}(g) \rightarrow Cu^{3+}(g) + e^-$ $\Delta H = 3555$ kJ mol-1

calculate the enthalpy change for: [5]

$$CuF_2(s) + \frac{1}{2}F_2(g) \rightarrow CuF_3(s)$$

(e) Use the data given below to calculate the enthalpy change for the following reaction (M is an unspecified metallic element). [6]

$$2MF_2(s) \rightarrow MF_3(s) + MF(s)$$

You may find it helpful to start by constructing an appropriate Hess's Law cycle.

$MF_2(s) \rightarrow M^{2+}(g) + 2F^-(g)$ $\Delta H = 3000$ kJ mol-1

$MF_3(s) \rightarrow M^{3+}(g) + 3F^-(g)$ $\Delta H = 7000$ kJ mol-1

$MF(s) \rightarrow M^+(g) + F^-(g)$ $\Delta H = 1000$ kJ mol-1

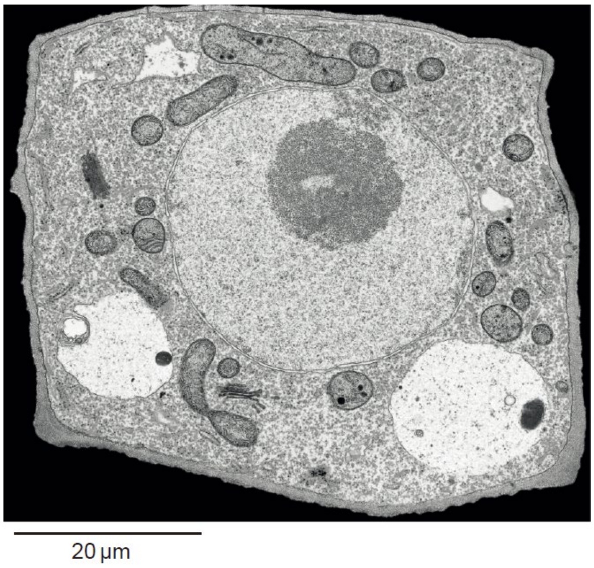
$M^+(g) \rightarrow M^{2+}(g) + e^-$ $\Delta H = 2000$ kJ mol-1

$M^{2+}(g) \rightarrow M^{3+}(g) + e^-$ $\Delta H = 3000$ kJ mol-1

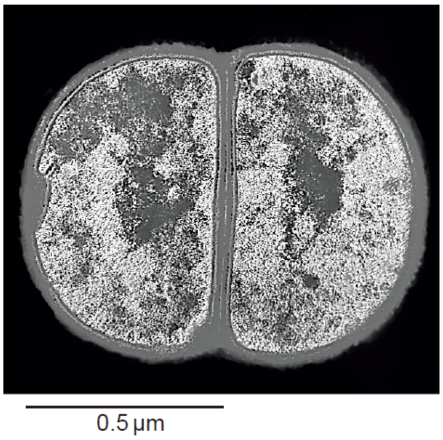
[NSAA, 2017S2Q5]

(a) Identify the types of cells that can be seen in Fig. (i) and (ii). [2]

Fig(i)



Fig(ii)



(b) Why was an electron microscope used to create these images? [1]

(c) Assume that the scale bar below each image is 3 cm long.

Estimate the magnification of each image. [2]

(d) Discuss the evolutionary order of appearance of the mitochondrion, chloroplast and ribosome, explaining your reasoning. [3]

(e) Estimate the percentage of the volume of the cell that the nucleus takes up in Fig.(i), assuming that the cell can be approximated as a cube and the nucleus as a sphere.

(The volume of a sphere is $\frac{4}{3}\pi r^3$ where r is the radius of the sphere.) [2]

(f) Discuss how differences in the structure of the cells shown in Fig.(i) and (ii) affect the locations of different processes within these cells. [10]

[NSAA, 2017S2Q6]

(a) From the following list of organisms identify one that can reproduce itself (i) without using mitosis or meiosis, and (ii) using either mitosis alone or meiosis. [2]

1 *Homo sapiens*

2 *Fragaria ananassa (strawberry)*

3 *Escherichia coli*

(b) For the processes of mitosis and meiosis, draw separate line graphs to show how the relative amount of DNA in a single healthy dividing cell changes with time. [3]

You should label the axes on the graphs.

(Assume that no mutations occur.)

Answer:

Mitosis Meiosis

(c) Calculate how many possible combinations of chromosomes could be produced in each gamete during sexual reproduction in humans (assuming no recombination). [2]

(d) A female has a recessive disease-causing allele on one of her non-sex-determining chromosomes. She mates with a male with the same disease-causing allele on one of his chromosomes. They have one child. Assuming that no mutations occur, what is the probability that:

(i) this child will have the disease? [1]

(ii) this child is male and does not have the disease? [2]

(e) Discuss: [10]

(i) how different mechanisms of reproduction affect the levels of variation in the next generation;

(ii) how variation affects the likelihood of survival in a changing environment.

NSAA 2018 S1

NSAA 2018 S1

On-line Exam

Scan the QR code or click on the link to take an on-line exam.

Full solutions can be accessed after submission.

TIME ALLOWED: 80 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 80 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **five** parts: **A**, **B**, **C**, **D**, and **E**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **two** further parts chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology
Part E	Advanced Mathematics and Advanced Physics

Each part has 18 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **three** parts. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators may NOT be used.

Part A

[NSAA, 2018S1Q1]

A group of drivers, consisting of 200 women and 300 men, was asked if they passed their driving test at the first attempt.

Altogether 167 of the group said they passed at the first attempt.

Of the women, 143 said they did not pass at the first attempt.

How many of the men said they passed at the first attempt?

(A) 10

(B) 24

(C) 33

(D) 57

(E) 110

(F) 133

(G) 157

[NSAA, 2018S1Q2]

A cuboid has sides of length x, $\sqrt{2}x$ and $2x$, measured in cm.

The volume, in cm^3, of the cuboid is numerically equal to twice the total surface area, in cm^2, of the cuboid.

What is the value of x?

(A) 10

(B) $6 + 2\sqrt{2}$

(C) 5

(D) $3 + \sqrt{2}$

(E) $\frac{5}{2}$

(F) $\frac{3}{2} + \frac{1}{2}\sqrt{2}$

[NSAA, 2018S1Q3]

The line joining the points with coordinates $(p, p-1)$ and $(1-p, 2p)$ is parallel to the line with equation $2x+3y+1=0$ What is the value of p?

(A) -1

(B) $-\frac{1}{7}$

(C) $\frac{1}{9}$

(D) $\frac{1}{8}$

(E) 1

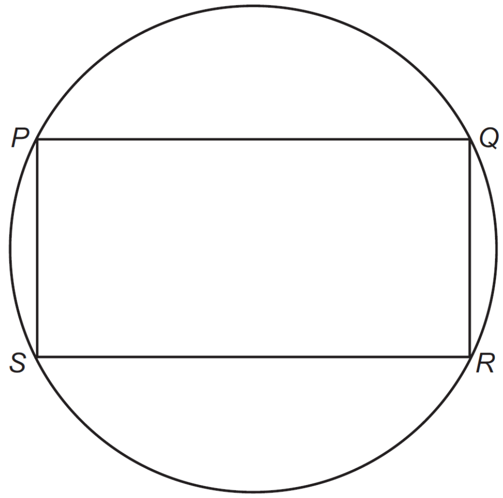
(F) $\frac{5}{4}$

(G) 2

(H) 5

[NSAA, 2018S1Q4]

A rectangle $PQRS$ is drawn inside a circle, with its vertices on the circumference of the circle.



[diagram not to scale]

The ratio of the length of PQ to the length of QR is $2 : 1$.

The area of the rectangle $PQRS$ is $96\ \text{cm}^2$.

What is the radius, in cm, of the circle?

(A) $\sqrt{6}$

(B) 3

(C) $3\sqrt{2}$

(D) $2\sqrt{15}$

(E) $4\sqrt{6}$

(F) 12

(G) $12\sqrt{2}$

(H) $8\sqrt{15}$

[NSAA, 2018S1Q5]

The expected number of bottles of water sold in a day at a sports ground is directly proportional to the square of the average outside temperature, in degrees Celsius, for that day.

On a day when the average outside temperature is 16 °C, 64 bottles of water, the expected number, are sold.

On a warmer day, when the average outside temperature is T °C, 256 bottles of water are sold, which is 31 bottles more than the expected number for that day.

What is the value of T?

(A) 7.5

(B) $\sqrt{450}$

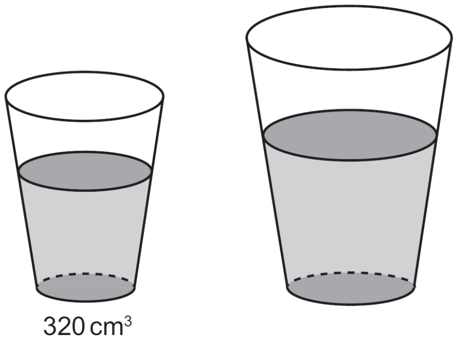
(C) 30

(D) 32

(E) $\sqrt{1148}$

(F) 56.25

[NSAA, 2018S1Q6]



[diagram not to scale]

At a cinema, drinks are sold in regular and large sizes.

The cups for these are mathematically similar.

The ratio of the heights of the cups and the ratio of the depths of the drinks are both 4 : 5.

The volume of drink in a regular size cup is 320 cm^3.

What is the volume, in cm^3, of drink in a large size cup?

(A) 384

(B) 400

(C) 500

(D) 576

(E) 625

(F) 640

[NSAA, 2018S1Q7]

The mean of n numbers is p.

The mean of two of these numbers is q.

The mean of the remaining numbers is 10.

Which of the following is a correct expression for n in terms of p and q?

(A) $\frac{2(q-10)}{(p-10)}$

(B) $\frac{2(q-10)}{(10-p)}$

(C) $\frac{2(q-10)}{(p+10)}$

(D) $\frac{2(10-q)}{(p+10)}$

(E) $\frac{2(10+q)}{(p-10)}$

(F) $\frac{2(10+q)}{(10-p)}$

[NSAA, 2018S1Q8]

The straight lines

$$5x + 2y = 20$$
$$y = 3x - 23$$
$$x = 0$$

enclose a region with area K square units.

What is the value of K?

(A) 39

(B) 78

(C) 99

(D) 129

(E) 198

(F) 258

[NSAA, 2018S1Q9]

A scale model of a cylindrical pillar is to be made.

The full-sized pillar has a volume of 12π m^3.

The model will use a length scale of 1 : 40.

The model is to be a solid cylinder made of a plastic which has a density of $\frac{4}{3}$ g cm^{-3}.

What is the mass of the model in grams?

(A) $\frac{9}{640}\pi$

(B) $\frac{1}{40}\pi$

(C) 40π

(D) $\frac{1125}{8}\pi$

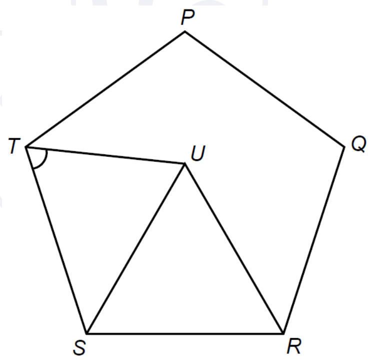
(E) 250π

(F) $10\,000\pi$

(G) $225\,000\pi$

(H) $400\,000\pi$

[NSAA, 2018S1Q10]



$PQRST$ is a regular pentagon.

RSU is an equilateral triangle.

What is the size of angle STU?

(A) 48°

(B) 54°

(C) 60°

(D) 66°

(E) 84°

[NSAA, 2018S1Q11]

The original price of an item is p.

The price is **increased by** 125%.

The increased price is then **decreased by** 40% to q.

The relationship between p and q can be expressed as $mp = q$.

What is the value of m?

(A) $\frac{7}{20}$

(B) $\frac{17}{20}$

(C) $\frac{27}{20}$

(D) $\frac{33}{20}$

(E) $\frac{37}{20}$

[NSAA, 2018S1Q12]

80% of a number is equal to two-thirds of a second number.

The whole number ratio of the first number to the second number in its lowest terms is $x : y$.

What is the value of $x - y$?

(A) 7

(B) 2

(C) 1

(D) 0.2

(E) -0.2

(F) -1

(G) -2

(H) -7

[NSAA, 2018S1Q13]

Q is 5 km away from P on a bearing of 065°.

R is 5 km away from Q on a bearing of 155°.

What is the bearing of P from R?

(A) 070°

(B) 110°

(C) 225°

(D) 270°

(E) 290°

(F) 315°

(G) 335°

[NSAA, 2018S1Q14]

With school lunch, students can select tomato sauce, or mayonnaise, or both, or neither.

n students selected both.

$3n + 1$ students selected tomato sauce.

$3n - 1$ students selected **only** mayonnaise.

There were $7n + 5$ students in the group.

The probability of a student, chosen at random, selecting **only** mayonnaise is $\frac{1}{3}$.

By finding n, what is the probability of a student, chosen at random, selecting **only** tomato sauce?

(A) $\frac{3}{11}$

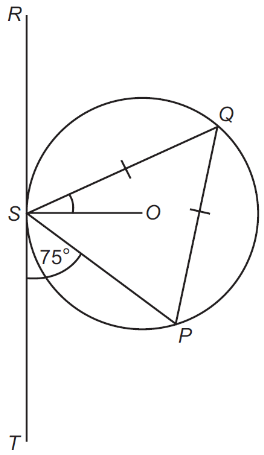
(B) $\frac{7}{26}$

(C) $\frac{13}{33}$

(D) $\frac{3}{8}$

(E) $\frac{7}{13}$

[NSAA, 2018S1Q15]



The line segment RT is a tangent at the point S to a circle with centre O.

Q and P are points on the circumference of the circle such that $QS = QP$.

Angle $PST = 75°$.

What is the size of angle QSO?

(A) 15°

(B) 30°

(C) 37.5°

(D) 45°

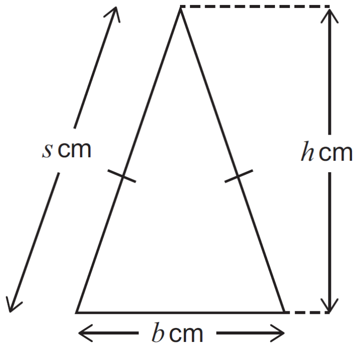
(E) 52.5°

(F) 60°

(G) 67.5°

(H) 75°

[NSAA, 2018S1Q16]



[diagram not to scale]

The vertical height h cm of an isosceles triangle is 3 cm longer than the base length of b cm.

The sloping side is of length s cm.

The area of the triangle is 14 cm^2.

There is one value of s which satisfies these conditions.

Within which range does this value of s lie?

(A) $5 < s < 6$

(B) $6 < s < 7$

(C) $7 < s < 8$

(D) $8 < s < 9$

(E) $9 < s < 10$

(F) $10 < s < 11$

[NSAA, 2018S1Q17]

The first five terms of a sequence in order are:

$$2 \quad 17 \quad 42 \quad 77 \quad 122$$

The nth term of this sequence is $pn^2 + q$ where p and q are integers.

What is the value of $\frac{p-q}{p+q}$?

(A) $\frac{1}{4}$

(B) $\frac{1}{2}$

(C) 1

(D) $\frac{23}{17}$

(E) $\frac{13}{7}$

(F) 2

(G) 4

(H) 14

[NSAA, 2018S1Q18]

A bag contains 6 red and 6 green sweets. The sweets are identical apart from their colour.

A child takes a sweet at random from the bag.

If the sweet is red, the child stops taking sweets.

If the sweet is green, it is not replaced and the child takes another sweet.

This continues until a red sweet is taken at which point the child stops taking sweets.

What is the probability that the child takes **more** green sweets than red sweets?

(A) $\frac{3}{22}$

(B) $\frac{5}{22}$

(C) $\frac{3}{11}$

(D) $\frac{1}{2}$

(E) $\frac{8}{11}$

(F) $\frac{17}{22}$

Part B

[NSAA, 2018S1Q19]

An unstable nucleus X becomes a stable nucleus Y after a succession of decays, during which a total of 5 alpha particles and 2 beta (β^-) particles are emitted.

How many fewer protons does nucleus Y contain than nucleus X?

(A) 6

(B) 8

(C) 10

(D) 12

(E) 14

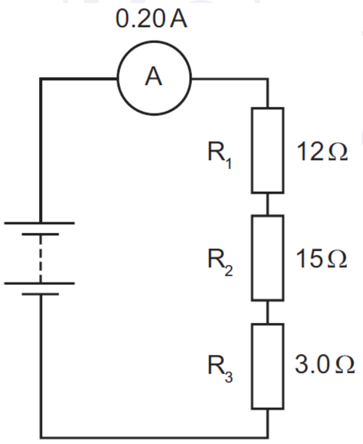
(F) 16

(G) 18

(H) 20

[NSAA, 2018S1Q20]

The diagram shows three resistors R_1, R_2 and R_3 connected in series with a battery of constant voltage. The resistance of each resistor and the corresponding current are also shown.



Resistor R_3 is now removed and the circuit is reconnected.

What is the new current in the circuit?

(A) 0.20 A

(B) 0.22 A

(C) 0.33 A

(D) 0.40 A

(E) 0.50 A

(F) 2.0 A

(G) 6.0 A

[NSAA, 2018S1Q21]

When travelling in a vacuum, visible light has a wavelength between 400 nm and 700 nm. The speed of light in a vacuum is 3.0×10^8 m s^{-1}.

What can be concluded about **ultraviolet** radiation from this information?

(A) It has a **maximum** frequency of 2.7×10^{14} Hz

(B) It has a **maximum** frequency of 4.3×10^{14} Hz

(C) It has a **maximum** frequency of 7.5×10^{14} Hz

(D) It has a **maximum** frequency of 1.0×10^{15} Hz

(E) It has a **minimum** frequency of 2.7×10^{14} Hz

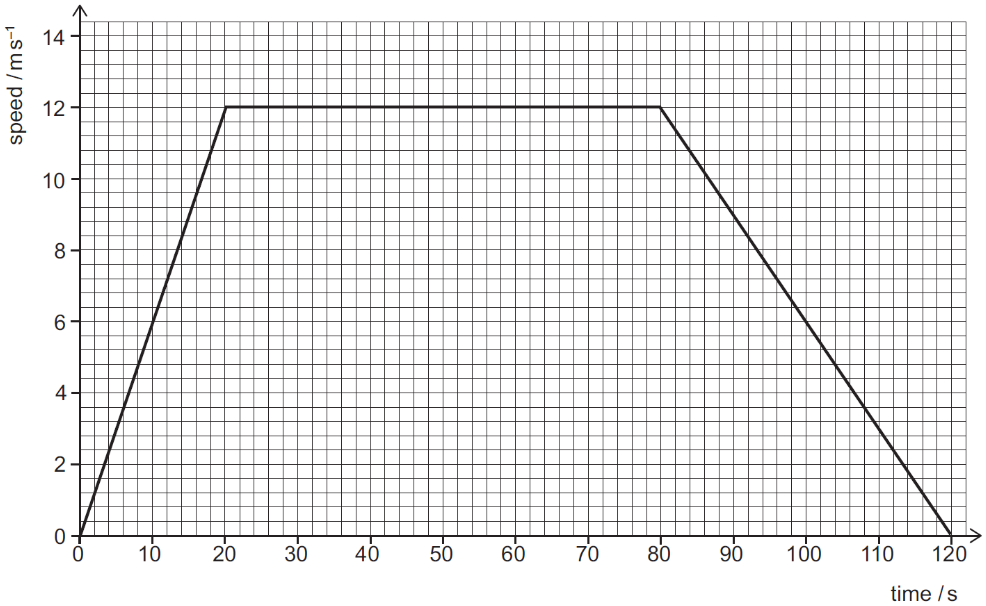
(F) It has a **minimum** frequency of 4.3×10^{14} Hz

(G) It has a **minimum** frequency of 7.5×10^{14} Hz

(H) It has a **minimum** frequency of 1.0×10^{15} Hz

[NSAA, 2018S1Q22]

The graph is the speed–time graph for a bus travelling in a straight line between two stops.



What is the average speed of the bus during this time?

(A) 3.0 m s^{-1}

(B) 4.5 m s^{-1}

(C) 6.0 m s^{-1}

(D) 8.0 m s^{-1}

(E) 9.0 m s^{-1}

(F) 11 m s^{-1}

(G) 12 m s^{-1}

[NSAA, 2018S1Q23]

A filament lamp working at its operating voltage converts electrical energy at a rate of 100 W.
The lamp has an efficiency of 5.0%.
How much energy is wasted by the lamp in 10 minutes?

(A) 50 J

(B) 950 J

(C) 1000 J

(D) 3000 J

(E) 57 000 J

(F) 60 000 J

[NSAA, 2018S1Q24]

A student is investigating heat flow along a solid uniform metal bar.
The bar has length l, cross-sectional area A, and has its ends maintained at temperatures T_1 and T_2 (where $T_1 > T_2$).
Which relationship represents the rate of heat flow P along the bar?
(Assume that there is no heat transfer through the sides of the bar.)

(A) $P \propto \frac{(T_1 - T_2)}{Al}$

(B) $P \propto \frac{(T_1 + T_2)}{Al}$

(C) $P \propto \frac{A(T_1 - T_2)}{l}$

(D) $P \propto \frac{A(T_1 + T_2)}{l}$

(E) $P \propto \frac{l}{A(T_1 - T_2)}$

(F) $P \propto \frac{l}{A(T_1 + T_2)}$

(G) $P \propto \frac{Al}{(T_1 - T_2)}$

(H) $P \propto \frac{Al}{(T_1 + T_2)}$

[NSAA, 2018S1Q25]

The potential difference across the motor in an electric car is 400 V and the current in the motor is 1250 A.

The car accelerates along a horizontal road from rest for 4.0 s.

The efficiency of the overall system is 45%.

What is the kinetic energy of the car at the end of the 4.0 s?

(Ignore energy losses due to air resistance and due to friction between the tyres and the road.)

(A) 225 000 J

(B) 500 000 J

(C) 900 000 J

(D) 1 250 000 J

(E) 2 000 000 J

[NSAA, 2018S1Q26]

The momentum of a small object moving in a straight line is 24 kg m s^{-1} and its kinetic energy is 96 J.

What is the mass of the object?

(A) 3.0 kg

(B) 4.0 kg

(C) 6.0 kg

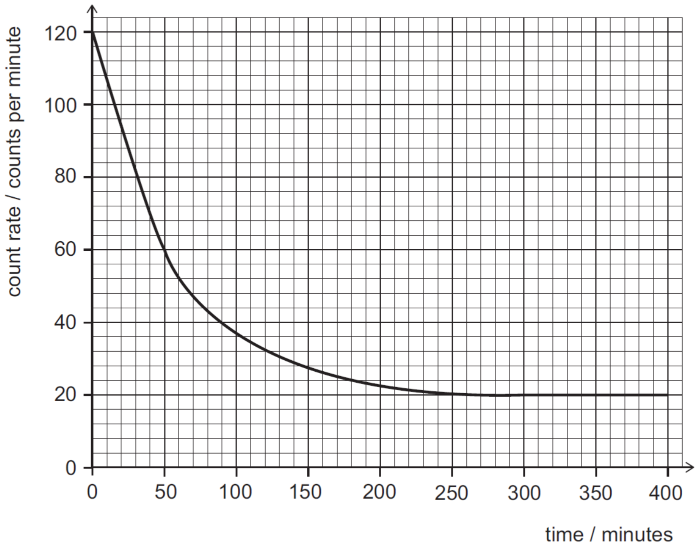
(D) 8.0 kg

(E) 12 kg

[NSAA, 2018S1Q27]

A radioactive isotope decays in a single step to a stable isotope.

A radiation detector is placed very near to a sample of the radioactive isotope in a laboratory. The count rate on the detector changes as time elapses. The graph shows how the measured count rate changes with time.



What is the background count rate and what is the half-life of the isotope?

	background count rate / counts per minute	*half-life of isotope* / minutes
(A)	20	40
(B)	20	50
(C)	20	60
(D)	20	65
(E)	120	40
(F)	120	50
(G)	120	60
(H)	120	65

[NSAA, 2018S1Q28]

A rock falling vertically experiences an air resistance force of 12 N at an instant when its acceleration is 2.0 m s^{-2} downwards.

What is the mass of the rock?

(gravitational field strength = 10 N kg^{-1})

(A) 1.0 kg

(B) 1.2 kg

(C) 1.5 kg

(D) 6.0 kg

(E) 10 kg

(F) 12 kg

(G) 15 kg

(H) 60 kg

[NSAA, 2018S1Q29]

A transverse wave with an amplitude of 4.0 cm and a frequency of 10 Hz travels along a rope at a speed of 2.4 m s^{-1}.

What is the total distance travelled by a particle in the rope in a time of 20 s?

(A) 2.4 m

(B) 4.8 m

(C) 8.0 m

(D) 16 m

(E) 32 m

(F) 48 m

[NSAA, 2018S1Q30]

A student places a measuring cylinder on a balance. She pours a volume V of water into the measuring cylinder, and finds that the mass of the measuring cylinder and water together is 290 g.

She then empties the measuring cylinder and dries it before putting it back on the balance.

She now pours the same volume V of olive oil into the measuring cylinder, and finds that the mass of the measuring cylinder and olive oil together is 270 g.

What is the mass of the measuring cylinder?

(densities: olive oil = 0.90 g cm^{-3}; water = 1.0 g cm^{-3})

(A) 18 g

(B) 20 g

(C) 90 g

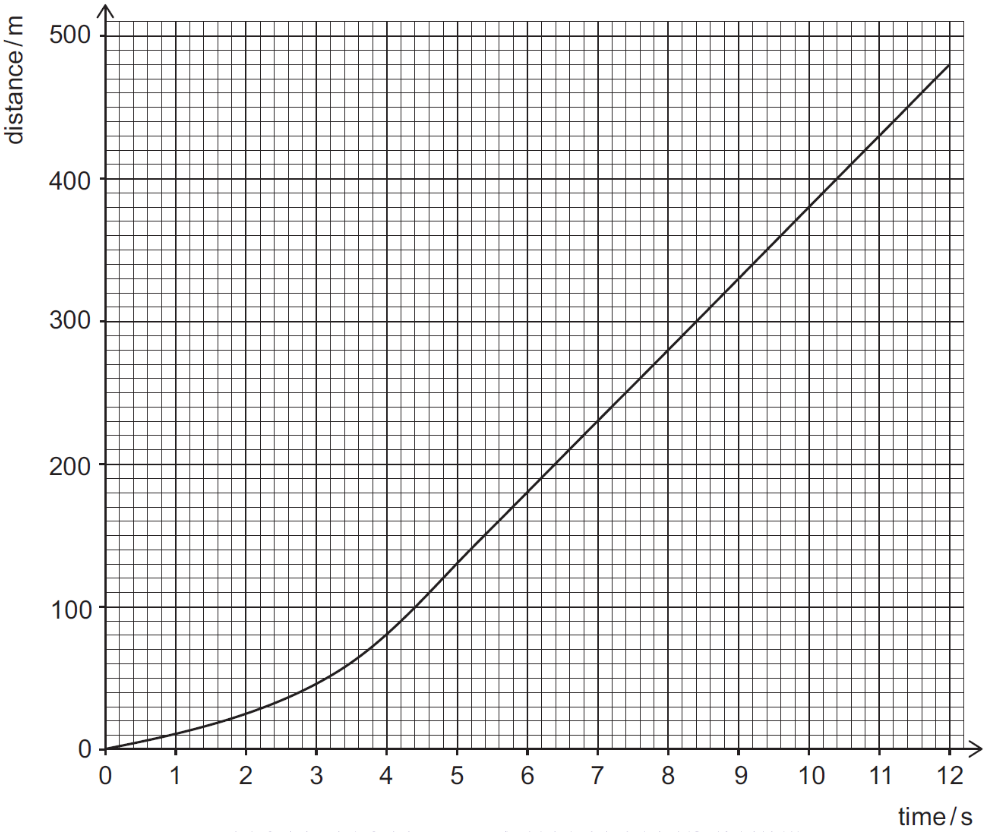
(D) 180 g

(E) 200 g

[NSAA, 2018S1Q31]

A skydiver of weight 1000 N falls vertically.

The distance–time graph for the skydiver is shown below.



The air resistance F (in N) acting on the skydiver travelling at velocity v (in m s^{-1}) is given by the equation

$$F = kv^2$$

where k (in N m^{-2} s^2) is a constant.

What is the numerical value of k for the skydiver?

(A) 0.050

(B) 0.40

(C) 0.63

(D) 2.5

(E) 20

[NSAA, 2018S1Q32]

A source generates water waves of fixed frequency that have a wavelength of 1.5 cm.

As they cross a boundary into shallower water their frequency does not change, but their speed is reduced by 18 cm s^{-1}.

The new wavelength is 1.2 cm.

What is the speed of the waves in the shallower water?

(A) 42 cm s^{-1}

(B) 50 cm s^{-1}

(C) 54 cm s^{-1}

(D) 60 cm s^{-1}

(E) 72 cm s^{-1}

(F) 90 cm s^{-1}

[NSAA, 2018S1Q33]

A neutron is absorbed by a uranium-235 $\left({}^{235}_{92}U\right)$ nuclide.

The resulting nuclide undergoes fission to produce a bromine-88 $\left({}^{88}_{35}Br\right)$ nuclide, a lanthanum-145 nuclide and some neutrons.

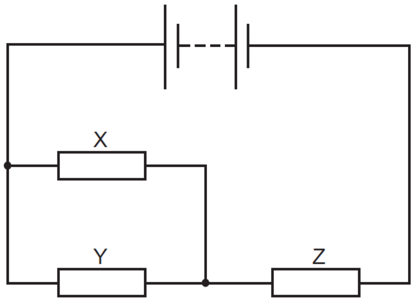
The lanthanum-145 nuclide is radioactive and emits a beta (β^-) particle.

How many neutrons are emitted in the fission reaction and how many protons are there in the nuclide formed by the decay of lanthanum-145?

	neutrons	*protons*
(A)	2	55
(B)	2	56
(C)	2	57
(D)	2	58
(E)	3	55
(F)	3	56
(G)	3	57
(H)	3	58

[NSAA, 2018S1Q34]

The diagram shows a circuit containing a battery and three identical resistors X, Y and Z.



The total power supplied by the battery is 18 W.

What is the power dissipated as heat in resistor X?

(A) 1.5 W

(B) 2.0 W

(C) 3.0 W

(D) 4.5 W

(E) 6.0 W

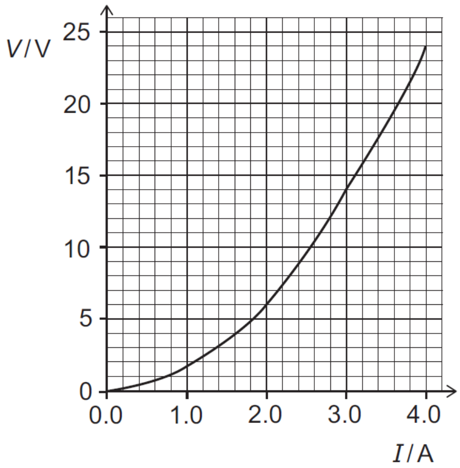
(F) 8.0 W

(G) 12 W

[NSAA, 2018S1Q35]

A filament lamp and a 0-10 Ω variable resistor are connected in series with a power supply of constant voltage.

The graph shows the voltage–current ($V-I$) characteristic of the filament lamp.



When the resistance of the variable resistor is 4.0 Ω, the current in the lamp is 2.0 A.

What is the power dissipated in the lamp when the resistance of the variable resistor is zero?

(A) 12 W

(B) 14 W

(C) 16 W

(D) 28 W

(E) 42 W

(F) 96 W

[NSAA, 2018S1Q36]

Three detectors X, Y and Z are separated by large distances.

Each of the detectors records a seismic wave from the same earthquake whose epicentre (source) is very close to the surface of the Earth.

The wave travels out from the epicentre at 4.0 km s^{-1}.

Detectors X and Y start to detect the wave at the same time, but detector Z starts to detect it one minute later.

Which of the following statements **must** be correct?

1 The epicentre is at the midpoint of the line XY.

2 Z is equidistant from X and Y.

3 Z is no more than 240 km away from X and from Y.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

Part C

[NSAA, 2018S1Q37]

Which row in the following table gives the numbers of protons, neutrons and electrons in $^{64}_{29}Cu^{2+}$?

	number of protons	*number of neutrons*	*number of electrons*
(A)	27	33	27
(B)	27	35	29
(C)	29	35	27
(D)	29	35	29
(E)	31	33	29
(F)	31	35	29

[NSAA, 2018S1Q38]

The following exothermic reaction reaches equilibrium at room temperature.

$$C_2H_5OH(l) + CH_3COOH(l) \Leftrightarrow CH_3COOC_2H_5(l) + H_2O(l)$$

Which of the following changes, when applied independently, will alter the position of the equilibrium?

1 increasing the temperature by 25 °C

2 adding 20 cm³ of water to the equilibrium mixture

3 adding a catalyst

4 adding an extra 0.5 mol of ethanol (C_2H_5OH)

(A) 1 only

(B) 1 and 3 only

(C) 1, 2 and 4 only

(D) 2 and 4 only

(E) 1, 2, 3 and 4

[NSAA, 2018S1Q39]

What is the overall process that takes place at the cathode (negative electrode) in the electrolysis of dilute aqueous sodium sulfate?

(A) $2H^+ + 2e^- \rightarrow H_2$

(B) $2O^{2-} \rightarrow O_2 + 4e^-$

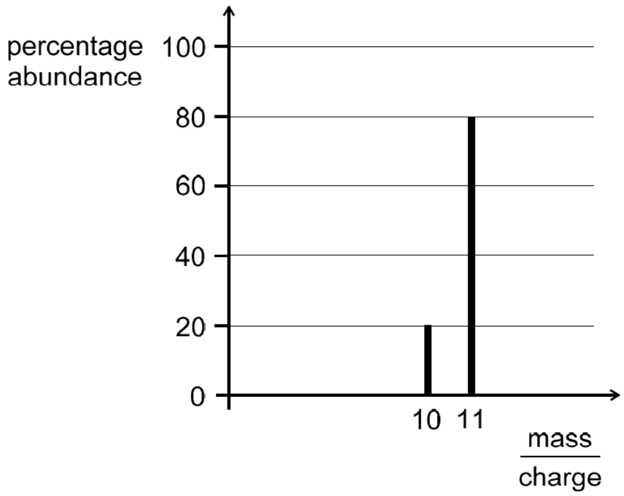
(C) $4OH^- \rightarrow O_2 + 2H_2O + 4e^-$

(D) $Na^+ + e^- \rightarrow Na$

(E) $SO_4^{2-} \rightarrow SO_2 + O_2 + 2e^-$

[NSAA, 2018S1Q40]

A mass spectrum of a sample of element X with atomic number 5 is shown.



Using the data, which row in the following table best describes the position of X in the Periodic Table and the relative atomic mass of this sample of X?

	Period	*Group*	*relative atomic mass*
(A)	1	15	10.2
(B)	1	15	10.8
(C)	2	13	10.2
(D)	2	13	10.8
(E)	3	2	10.2
(F)	3	2	10.8

[NSAA, 2018S1Q41]

The gases nitrogen, oxygen and argon can be separated from liquefied air by fractional distillation.

Given the data in the table, in which order would the gases be collected?

	Melting point / °C	*Boiling point / °C*
Nitrogen	−210	−196
Oxygen	−218	−183
argon	−189	−186

(A) nitrogen, oxygen, argon

(B) nitrogen, argon, oxygen

(C) oxygen, nitrogen, argon

(D) oxygen, argon, nitrogen

(E) argon, nitrogen, oxygen

(F) argon, oxygen, nitrogen

[NSAA, 2018S1Q42]

Concentrated aqueous sodium chloride was electrolysed. After a few minutes, the remaining electrolyte solution was tested with a pH probe at 25 °C.

The gases produced at the electrodes were collected and tested with a colourless aqueous solution of sodium bromide.

Which row in the following table best describes the observations in these tests?

	pH of the remaining solution	*test of gas from anode (positive electrode)*	*test of gas from cathode (negative electrode)*
(A)	2	no observable change	no observable change
(B)	2	no observable change	orange solution forms
(C)	7	orange solution forms	no observable change
(D)	7	orange solution forms	orange solution forms
(E)	12	orange solution forms	no observable change
(F)	12	no observable change	orange solution forms

[NSAA, 2018S1Q43]

The following equations show the main reactions that take place in a blast furnace during the extraction of iron and the removal of the impurities:

$$C + O_2 \rightarrow CO_2$$
$$\underline{CO_2} + C \rightarrow 2CO$$
$$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$$
$$\underline{CaCO_3} \rightarrow CaO + CO_2$$
$$\underline{CaO} + SiO_2 \rightarrow CaSiO_3$$

Which row in the following table correctly identifies whether the underlined substance is oxidised, or reduced, or neither?

	CO_2	$CaCO_3$	CaO
(A)	oxidised	reduced	neither
(B)	oxidised	neither	neither
(C)	oxidised	reduced	oxidised
(D)	oxidised	neither	oxidised
(E)	reduced	reduced	neither
(F)	reduced	neither	neither
(G)	reduced	reduced	oxidised
(H)	reduced	neither	oxidised

[NSAA, 2018S1Q44]

X, Y and Z have the **same** electron configuration.

X is an atom, Y is a monatomic anion and Z is a monatomic cation.

Which of the following statements is **always** correct?

(A) Anion Y has fewer protons than atom X.

(B) Cation Z has more electrons than protons.

(C) X, Y and Z are in the same group of the Periodic Table.

(D) X, Y and Z have consecutive atomic numbers.

(E) X, Y and Z have the same mass number.

[NSAA, 2018S1Q45]

In the Contact process, sulfur dioxide reacts with oxygen to make sulfur trioxide in a reversible reaction.

$$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$$

When 5.00 mol of SO_2 and 11.0 mol of O_2 are allowed to reach equilibrium at 450 °C, 80.0% of the SO_3 is converted to SO_3.

What is the volume of the resulting mixture?

(Assume that temperature and pressure are constant, and that at this temperature the volume of one mole of gas is 60.0 dm^3.)

(A) 240 dm^3

(B) 336 dm^3

(C) 600 dm^3

(D) 720 dm^3

(E) 840 dm^3

(F) 960 dm^3

[NSAA, 2018S1Q46]

The non-metallic element phosphorus forms two stable chlorides: PCl_3 (boiling point 76 °C) and PCl_5 (boiling point 161 °C).

Which of the following statements explain(s) the difference in boiling points?

1 There are more covalent bonds in PCl_5 so more energy is required to break them.

2 The forces between the molecules in liquid PCl_5 are stronger.

3 The covalent bonds in PCl_3 are weaker so less energy is required to break them.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q47]

A student calculated the mass of anhydrous copper(II) sulfate ($CuSO_4$) required to make 250 cm^3 of an aqueous solution of concentration 0.200 mol dm^{-3}.

However, the student mistakenly made the solution using the same mass of hydrated copper(II) sulfate ($CuSO_4 \cdot 5H_2O$) instead.

What is the concentration, in mol dm^{-3}, of the solution made with the hydrated copper(II) sulfate?

(A_r values: Cu = 64; S = 32; O = 16; H = 1.0)

(A) 0.128 mol dm^{-3}

(B) 0.160 mol dm^{-3}

(C) 0.180 mol dm^{-3}

(D) 0.200 mol dm^{-3}

(E) 0.223 mol dm^{-3}

(F) 0.313 mol dm^{-3}

[NSAA, 2018S1Q48]

Bromine is an element in Group 17 of the Periodic Table.

Which of the following statements is/are correct about the element bromine?

1 Bromine will oxidise chloride ions in aqueous solution to form chlorine.

2 Bromine has a lower boiling point than chlorine.

3 Bromine reacts with calcium (Group 2) to form a compound containing 80% bromine by mass.

(A_r values: Cl = 35.5; Ca = 40; Br = 80)

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

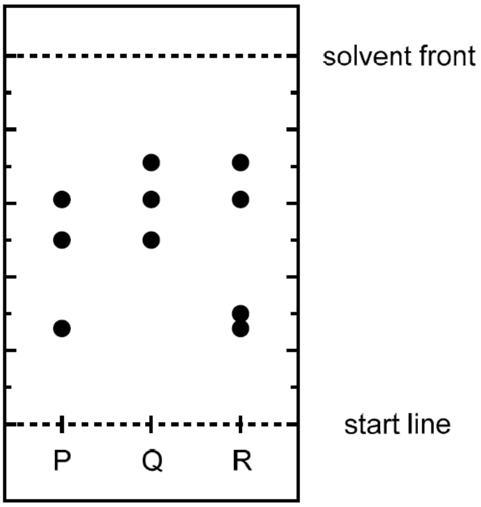
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q49]

Paper chromatography was used to separate three mixtures of amino acids. The mixtures were labelled P, Q and R.



Each mixture contains some of the five amino acids in the following table. The R_f values were measured for each amino acid with the solvent used to produce the chromatogram.

amino acid	R_f value
asparagine	0.50
glutamic acid	0.30
glycine	0.26
leucine	0.71
valine	0.61

Which of the following statements is/are correct?

1 Mixture P contains valine and glycine.

2 Leucine is found in all three mixtures.

3 Glutamic acid is the least mobile amino acid with this solvent.

4 Mixtures P and Q both contain asparagine.

(A) 1 and 2 only

(B) 1 and 4 only

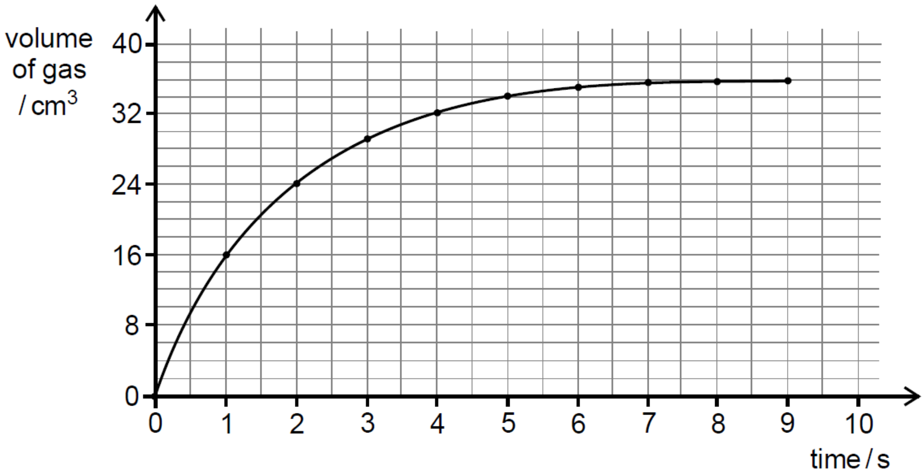
(C) 2 and 3 only

(D) 3 only

(E) 4 only

[NSAA, 2018S1Q50]

Dilute hydrochloric acid and magnesium were mixed and the total volume of gas released was measured over time.



What is the average rate of reaction, in g s^{-1}, with respect to the magnesium over the first **two** seconds?

(A_r value: Mg = 24. Assume that the volume of one mole of gas is 24 dm^3.)

(A) 0.012 g s^{-1}

(B) 0.024 g s^{-1}

(C) 0.048 g s^{-1}

(D) 12 g s^{-1}

(E) 24 g s^{-1}

(F) 48 g s^{-1}

[NSAA, 2018S1Q51]

Copper can react with concentrated nitric acid to form the gas nitrogen monoxide.

$$3\text{Cu} + a\,\text{HNO}_3 \rightarrow b\,\text{Cu(NO}_3)_2 + c\,\text{H}_2\text{O} + d\,\text{NO}$$

What is the value of a when the equation is balanced?

(A) 6

(B) 7

(C) 8

(D) 9

(E) 10

(F) 11

(G) 12

[NSAA, 2018S1Q52]

A small amount of a solid mixture, containing calcium carbonate and an inert substance, was added to 50.00 cm³ dilute hydrochloric acid of concentration 0.1000 mol dm⁻³.

$$CaCO_3 + 2HCl \rightarrow CaCl_2 + CO_2 + H_2O$$

After all of the calcium carbonate had reacted, the solution was heated to drive off the carbon dioxide.

The resulting solution was neutralised by 12.50 cm³ of 0.1000 mol dm⁻³ sodium hydroxide solution.

What was the mass of calcium carbonate in the mixture added to the hydrochloric acid?

(M_r value: $CaCO_3 = 100.0$)

(A) 0.06250 g

(B) 0.1250 g

(C) 0.1875 g

(D) 0.3750 g

(E) 0.6250 g

(F) 0.7500 g

[NSAA, 2018S1Q53]

2.80 g of lithium metal is placed in a closed system with 1.20 dm³ of pure oxygen gas (volume measured at room temperature and pressure).

If a complete reaction occurs between the lithium and the oxygen, what is the maximum mass of lithium oxide that can be formed?

(A_r values: $Li = 7$; $O = 16$. Assume that one mole of gas occupies 24.0 dm³ at room temperature and pressure.)

(A) 1.50 g

(B) 3.00 g

(C) 3.90 g

((D) 4.60 g

(E) 6.00 g

(F) 12.0 g

(G) 15.6 g

[NSAA, 2018S1Q54]

The following reaction between nitrogen oxide and oxygen releases 116 kJ of energy as heat for each mole of oxygen that reacts.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$$

An excess of NO and y moles of oxygen are mixed in a sealed container. The reaction reaches equilibrium in one hour.

At equilibrium, there are z moles of NO_2.

Assume that the pressure is constant throughout the experiment.

How much heat will be released over this hour?

(A) 0 kJ

(B) $58y$ kJ

(C) $116y$ kJ

(D) $232y$ kJ

(E) $58z$ kJ

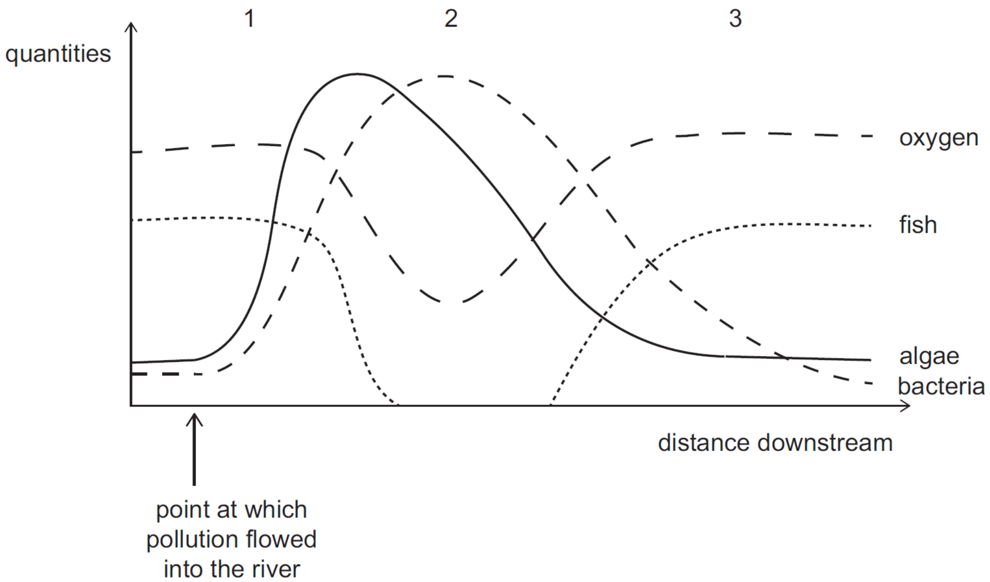
(F) $116z$ kJ

(G) $232z$ kJ

Part D

[NSAA, 2018S1Q55]

The graph shows how four variables change with the distance down a river, after a source of pollution flowed in.



Which indicator species could be expected to be found in large numbers at 1, 2 and 3?

	1	*2*	*3*
(A)	bloodworm	bloodworm	bloodworm
(B)	bloodworm	bloodworm	stonefly
(C)	bloodworm	stonefly	bloodworm
(D)	bloodworm	stonefly	stonefly
(E)	stonefly	bloodworm	bloodworm
(F)	stonefly	bloodworm	stonefly
(G)	stonefly	stonefly	bloodworm
(H)	stonefly	stonefly	stonefly

[NSAA, 2018S1Q56]

Sickle cell anaemia is a recessive genetic condition that results in abnormally-shaped red blood cells due to the production of a faulty type of haemoglobin. Children born with sickle cell anaemia rarely live to adulthood without significant medical intervention. Carriers, who only have one copy of the sickle cell allele, have greater resistance to the disease malaria than people with two copies of the allele for normal functional haemoglobin.

Using this information, which of the following statements is/are correct?

1 People with sickle cell anaemia would have reduced anaerobic respiration in their muscle cells.

2 In areas with malaria the percentage of people surviving with sickle cell anaemia increases.

3 In parts of Africa where malaria is more common you would expect to find more people with a sickle cell allele.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

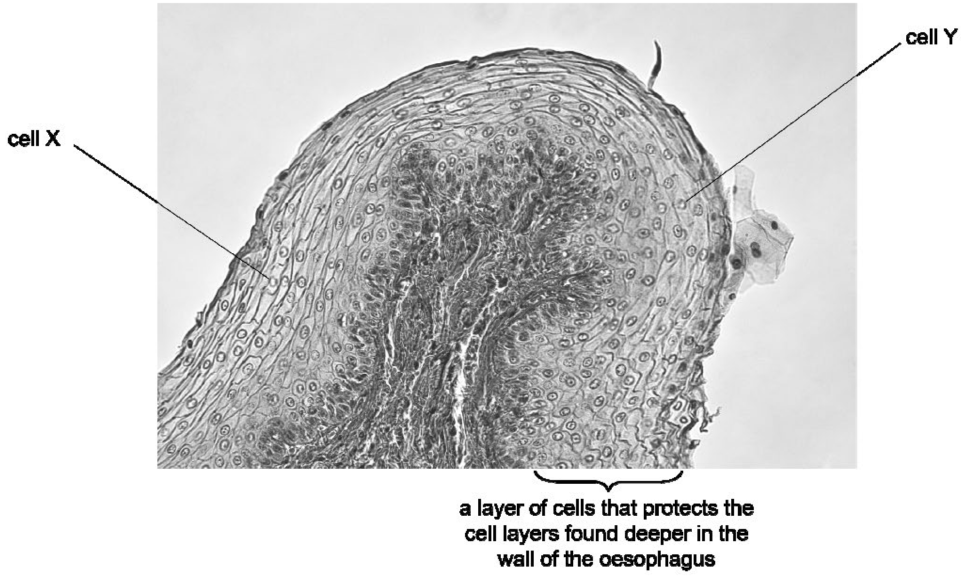
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q57]

A student studied this photograph of part of an organ.



The student drew the following conclusions about the two cells labelled X and Y.

1 Both cells X and Y are found in the same tissue.

2 Both cells X and Y were produced by mitosis.

3 Both cells X and Y have a cell wall.

Which of these conclusions is/are correct?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q58]

A student investigated the tadpole population in a large pond.

A net with a rectangular opening measuring 0.1 m × 0.2 m was swept through the water for a fixed distance of 1 m. This was repeated 10 times.

All the sweeps were made at the edge of the pond as the student had no waders or boat.

The number of tadpoles in each sweep was recorded in the table.

Sweep number	1	2	3	4	5	6	7	8	9	10
Number of tadpoles	20	12	32	0	4	8	4	8	12	20

The student made the following statements.

1 Each sweep sampled 0.02 m^3 of water.

2 The frequency of occurrence of the tadpoles was 90%.

3 An accurate estimate of the population size of tadpoles in the pond could be calculated using this data if the total volume of water was known.

Which of the statements about the investigation is/are correct?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q59]

A breeding experiment was carried out using rats.

A pair of rats has eight offspring per litter. The offspring breed freely amongst each other within the same generation. Each female is only allowed to have one litter of eight.

The expected ratio of male to female offspring in this breeding population is the same in rats as in humans, and is seen in every generation.

In the 4th generation of offspring, how many individuals would be expected to have the XY genotype?

(A) 16

(B) 32

(C) 64

(D) 128

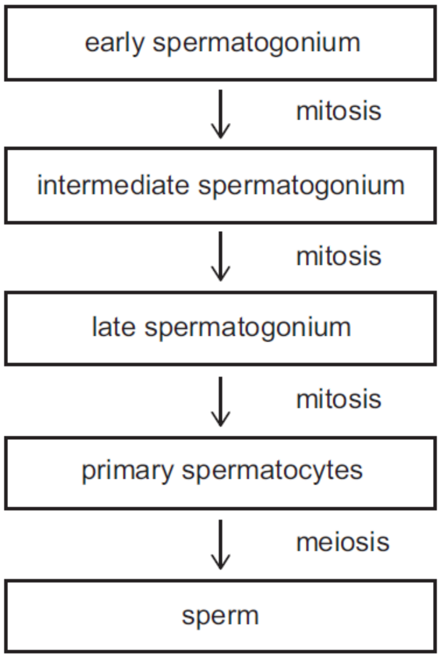
(E) 256

(F) 512

(G) 1024

[NSAA, 2018S1Q60]

The diagram shows four steps in the process of human sperm production. For each step only one complete division takes place.



Assuming no mutations and that all of the cells survive, what will be the maximum number of haploid cells originating from a single early spermatogonium?

(A) 1

(B) 2

(C) 8

(D) 16

(E) 32

(F) 64

[NSAA, 2018S1Q61]

Which of the following conditions is/are required by the cells near the tip of a plant shoot in order for the tip to grow towards light from one direction?

1 sufficient glucose

2 uneven distribution of plant hormone

3 sufficient oxygen

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q62]

A cell from the epithelium of an animal was removed. The cytoplasm of this cell can be considered as a 2% sugar solution. The living cell was placed in a 4% sugarsolution.

Which of the following statements is/are correct?

1 At equilibrium, the sugar concentration in the cell was 6%.

2 Water continued to move across the cell membrane after equilibrium was reached.

3 Osmosis was most rapid when the cell was first placed in the solution.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q63]

A piece of DNA is made up of two complementary strands, each 25 bases long.

14% of the bases are adenine.

Which two statements are correct?

1 Adenine and cytosine together make up 25 bases.

2 Adenine and guanine together make up 50% of the bases.

3 There are 14 thymine bases present.

4 36 of the bases are guanine.

(A) 1 and 2 only

(B) 1 and 3 only

(C) 1 and 4 only

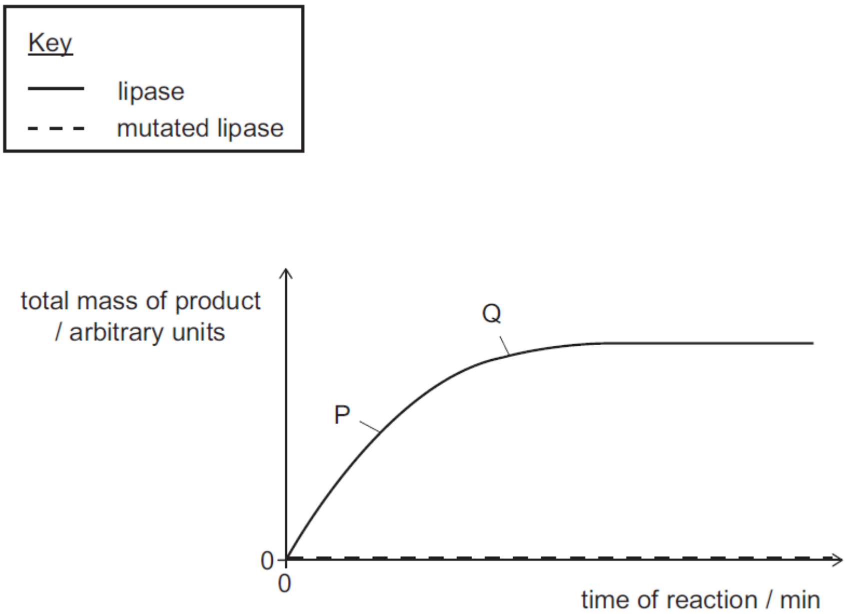
(D) 2 and 3 only

(E) 2 and 4 only

(F) 3 and 4 only

[NSAA, 2018S1Q64]

In a laboratory, the activity of two lipase enzymes on the same type of lipid was studied. One lipase enzyme was produced from a mutation in the gene that coded for the original enzyme. The mutation occurred in the sequence for three adjacent amino acids called serine, aspartic acid and histidine. The graph shows the results of this study.



Which of the following statements is/are correct?

1 The serine, aspartic acid and histidine amino acids could be in the active site of the enzyme.

2 All mutations affecting the region coding for serine, aspartic acid and histidine amino acids will be expected to have the same effect.

3 At point Q on the graph, the pH of the reaction mixture will be higher than at P.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

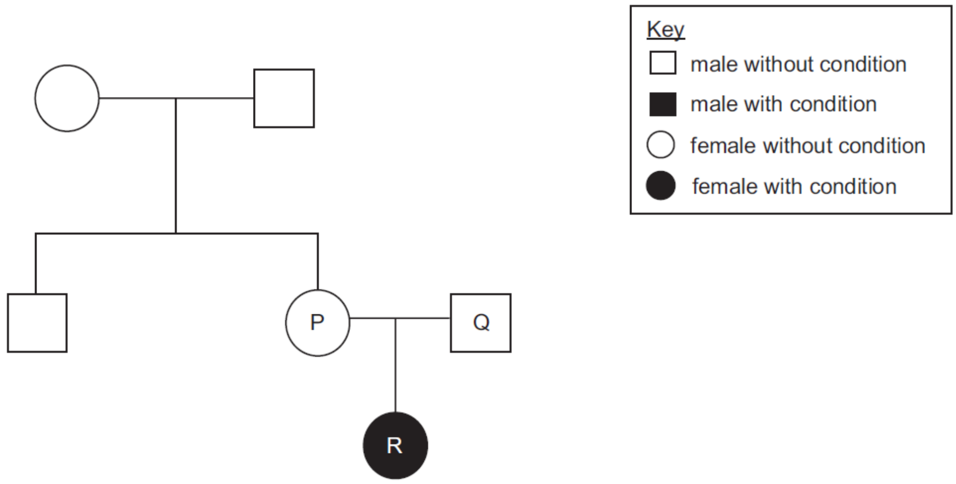
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q65]

The family tree shows a family affected by a dominant genetic condition. All people who carry the mutation show symptoms of the condition.



Which of the following statements could explain the presence of the dominant condition in female R?

1 The mutation occurs in P.

2 The mutation occurs in Q's father.

3 The mutation occurs in R.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

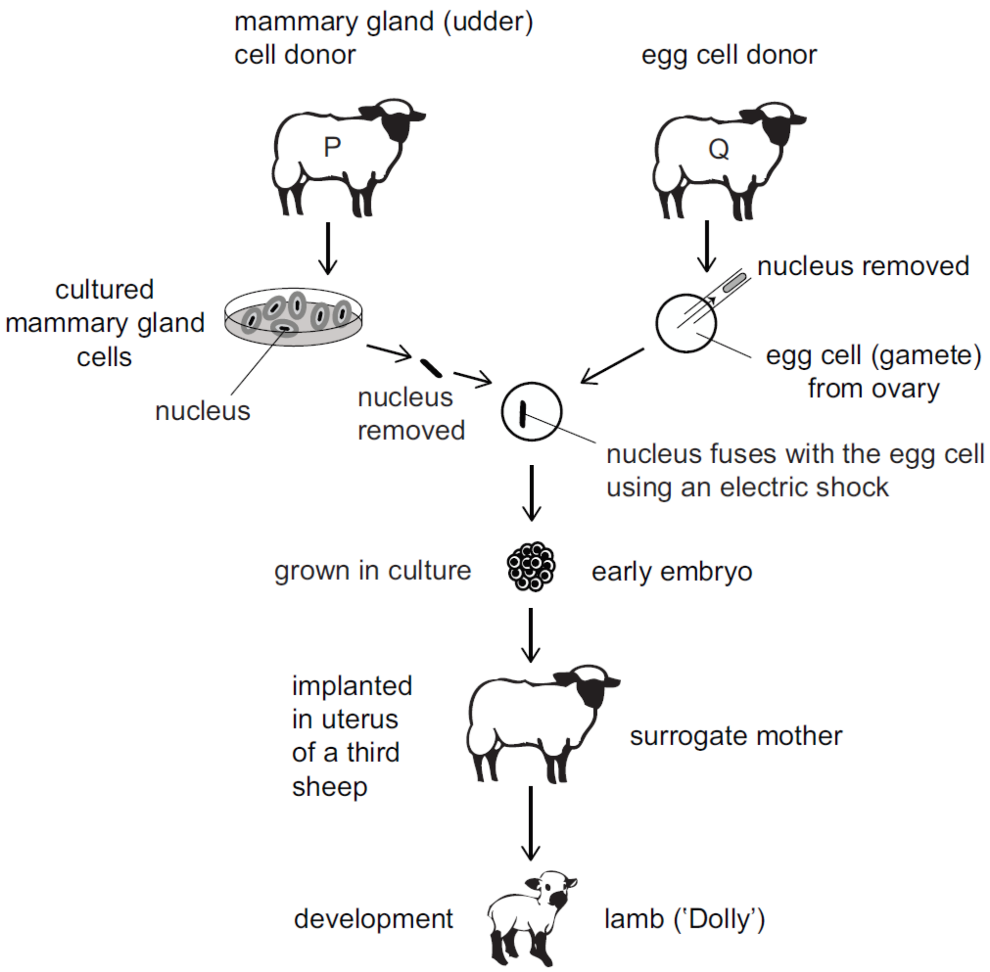
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q66]

Dolly the sheep was born in 1996. She was unusual because she had no biological father.

The diagram shows how she was produced.



Which of the following processes had to occur to produce Dolly?

1 genetic engineering

2 mitosis

3 meiosis

4 differentiation

(A) 1 and 2 only

(B) 2 and 3 only

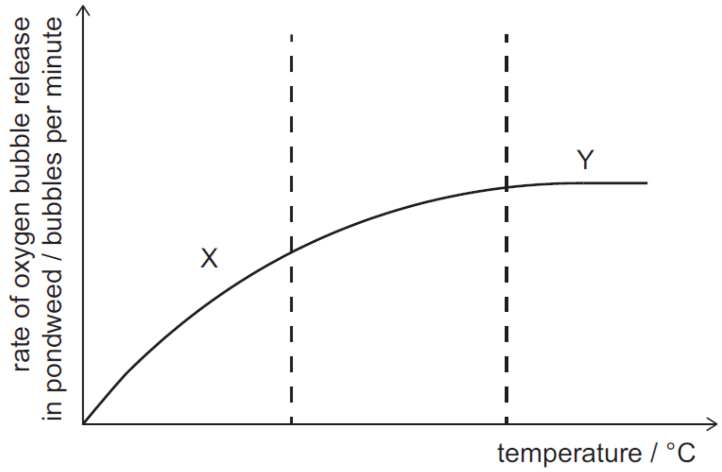
(C) 1, 2 and 4 only

(D) 1, 3 and 4 only

(E) 2, 3 and 4 only

[NSAA, 2018S1Q67]

A student investigated the rate of oxygen bubble release from a pondweed plant at different temperatures. The rates are shown below, with two sections of the graph marked X and Y. In each investigation all other factors were kept constant.



Which of the following statements about sections X and Y is/are correct?

1 In section X, the kinetic energy of the reaction molecules is increasing with increasing temperature.

2 In section Y, temperature is the factor which limits that rate of oxygen production.

3 In section Y, the plant's enzymes may have denatured.

4 Section Y represents the plant's maximum possible rate of oxygen production under any conditions.

(A) 1 only

(B) 2 only

(C) 3 only

(D) 4 only

(E) 1 and 2 only

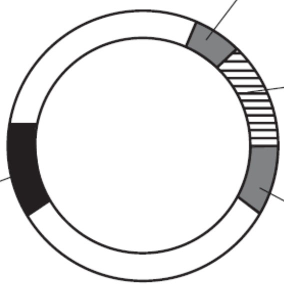
(F) 1 and 4 only

(G) 2 and 3 only

(H) 3 and 4 only

[NSAA, 2018S1Q68]

The diagram below shows a circular piece of bacterial DNA called a plasmid that has been made recombinant by the insertion of a plant gene for herbicide resistance.



Bacteria containing only the recombinant plasmid had to be identified from bacteria that contained only the original plasmid. The original plasmid contained a gene coding for resistance to the antibiotic penicillin and a gene coding for resistance to the antibiotic tetracycline.

These bacteria were grown on two sets of agar plates. One set used agar that contained the antibiotic penicillin and the other set used agar that contained the antibiotic tetracycline.

Which row in the table correctly shows the growth of these bacteria on the two sets of agar?

	bacteria containing only	*growth on agar containing penicillin*	*growth on agar containing tetracycline*
(A)	recombinant plasmid	yes	yes
	original plasmid	no	no
(B)	recombinant plasmid	yes	yes
	original plasmid	yes	no
(C)	recombinant plasmid	yes	no
	original plasmid	yes	yes
(D)	recombinant plasmid	no	no
	original plasmid	yes	yes
(E)	recombinant plasmid	yes	yes
	original plasmid	no	yes
(F)	recombinant plasmid	no	no
	original plasmid	no	no
(G)	recombinant plasmid	yes	no
	original plasmid	no	yes

[NSAA, 2018S1Q69]

A student analysed a gene sequence that had been identified in four different types of organism. The gene codes for a functional protein. A section of the gene's DNA is shown below. The rest of the DNA from this gene (not shown) is identical in all four different types of organism.

organism	*DNA sequence*					
human	ACG	CCT	CGT	CAC	GCT	AAA
oak tree	ACG	GAA	TAT	GTA	GCT	AAA
mushroom	ACG	GAA	CTC	TTA	GCT	AAA
E.coli bacterium	ACG	TAC	GAT	GGG	GCT	AAA

The student then made the following conclusions:

1 This gene does not code for chlorophyll.

2 This gene may be found in the nucleus or cytoplasm.

3 The protein that this gene codes for is likely to be more similar in plants and fungi than in the other organisms.

Which of these conclusions is/are correct?

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

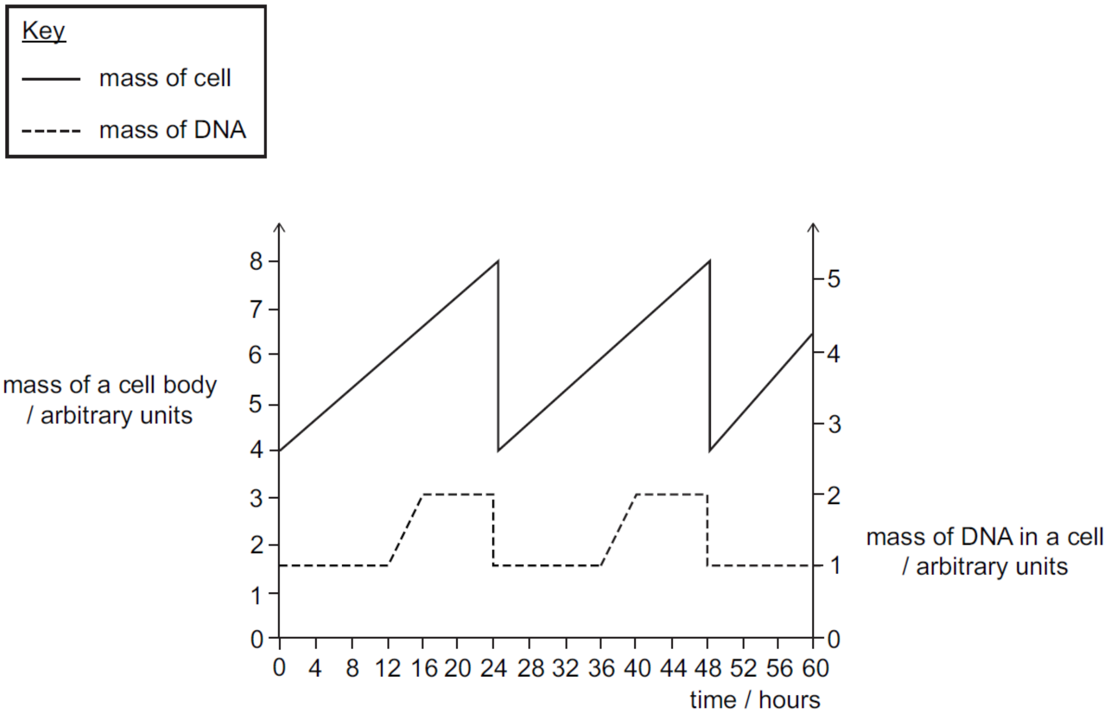
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q70]

The graphs represent the changes in the mass of a healthy human body cell and in the mass of the DNA of that cell over time.



Using the graph, which of the following statements is/are correct?

1 Mitosis takes place at 12 and 36 hours.

2 The graph shows two cell divisions.

3 The next cell division should take place at 72 hours.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q71]

Bt pesticide is used by farmers to kill insect pests. However, widespread use has resulted in the evolution of resistance to this pesticide. A recessive allele causes resistance.

Scientists have suggested that in areas where the Bt pesticide is used, a small number of fields are left untreated. These untreated fields are known as refugia. This method has been shown to slow down evolution of resistance to the pesticide.

Which of the following statements explain why refugia could slow down the evolution of resistance to Bt pesticide?

1 When resistant insects breed with pesticide-sensitive insects that do not have the allele for resistance, the offspring produced will be sensitive to the pesticide.

2 When fewer insects are exposed to pesticide, fewer mutations occur that produce alleles for resistance.

3 The refugia help to maintain genetic variation in the population of insect pests.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2018S1Q72]

A diploid plant cell divides by mitosis.

After mitosis of this cell, a mutation occurs that changes the genotype of **one** of the daughter cells. This mutant daughter cell produces a non-functional enzyme instead of the functional enzyme produced by the other daughter cell. This mutation has no effect on the phenotype of the plant or the number or length of chromosomes in the plant cell.

Which of the following statements describe the daughter cells after the mutation has occurred?

1 The chromosomes in the nucleus of each daughter cell will contain the same genes.

2 Both daughter cells will contain the same alleles for every gene.

3 The sequence of bases along each allele will be the same in each daughter cell.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

Part E

[NSAA, 2018S1Q73]

Curve C has equation $y = 9 - x^2$.

Line L has equation $y = 5$.

What is the area enclosed between C and L?

(A) $\frac{32}{3}$

(B) $\frac{62}{3}$

(C) $\frac{92}{3}$

(D) $\frac{122}{3}$

(E) $\frac{152}{3}$

[NSAA, 2018S1Q74]

An aircraft moves from rest with uniform acceleration along a horizontal runway. After travelling 1600 m it reaches a speed of 80 m s^{-1}.

What is the acceleration of the aircraft?

(A) 0.025 m s^{-2}

(B) 0.050 m s^{-2}

(C) 0.10 m s^{-2}

(D) 0.50 m s^{-2}

(E) 2.0 m s^{-2}

(F) 4.0 m s^{-2}

(G) 10 m s^{-2}

(H) 20 m s^{-2}

[NSAA, 2018S1Q75]

How many solutions of the equation $2\sin^3\theta = \sin\theta$ lie in the interval $-\frac{\pi}{2} \leq \theta \leq \pi$?

(A) 2

(B) 3

(C) 4

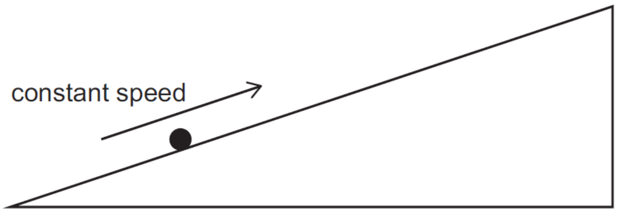
(D) 5

(E) 6

(F) 7

[NSAA, 2018S1Q76]

The diagram represents a mass that is moving in a straight line at constant speed up a slope of constant gradient.



Which statement about the forces acting on the mass **must** be correct?

(A) All the forces acting on the mass are equal in magnitude.

(B) Only three forces act on the mass.

(C) The force of friction on the mass is equal to the driving force.

(D) The weight of the mass acts in the opposite direction to the contact force.

(E) There is no air resistance acting on the mass.

(F) There is no resultant force acting on the mass.

[NSAA, 2018S1Q77]

The line $y = x + k$, where k is a constant, is a tangent to the curve $y = 3x^2 - 2x + 1$.

What is the value of k?

(A) -2

(B) -1

(C) $\frac{1}{4}$

(D) $\frac{1}{3}$

(E) $\frac{1}{2}$

(F) $\frac{3}{4}$

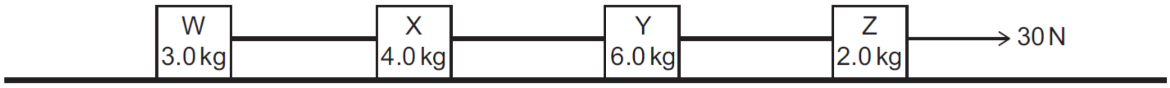
(G) 1

(H) 2

[NSAA, 2018S1Q78]

The diagram shows four objects W, X, Y and Z, of masses 3.0 kg, 4.0 kg, 6.0 kg and 2.0 kg respectively, connected by light, inextensible rods.

The objects are pulled along a smooth, horizontal surface by a constant force of 30 N in the direction indicated.



What is the tension in the rod connecting X and Y?

(A) 8.0 N

(B) 10 N

(C) 12 N

(D) 14 N

(E) 16 N

[NSAA, 2018S1Q79]

In a particular arithmetic progression:

1 the 13th term is six times the 1st term

2 the 11th term is 1 less than twice the 5th term

What is the 3rd term of the progression?

(A) -14.5

(B) -11

(C) $\frac{29}{19}$

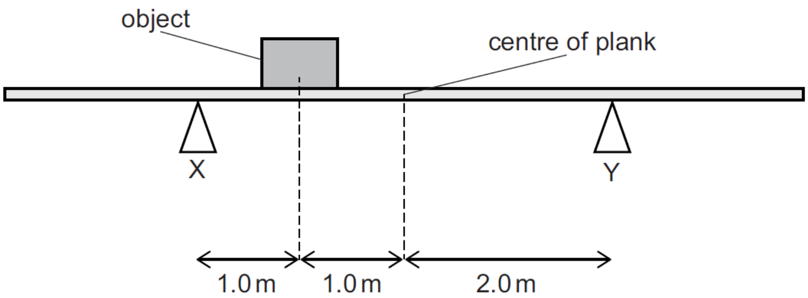
(D) 3.5

(E) 11

(F) 14.5

[NSAA, 2018S1Q80]

An object of mass 40 kg is placed on a uniform, horizontal plank of mass 10 kg between two supports X and Y as shown in the diagram.



What is the contact force at X?

(gravitational field strength = 10 N kg^{-1})

(A) 15 N

(B) 35 N

(C) 150 N

(D) 250 N

(E) 300 N

(F) 350 N

(G) 375 N

[NSAA, 2018S1Q81]

Evaluate

$$\log_2\left(\frac{5}{4}\right) + \log_2\left(\frac{6}{5}\right) + \log_2\left(\frac{7}{6}\right) + \cdots + \log_2\left(\frac{64}{63}\right)$$

(A) -2

(B) 3

(C) 4

(D) 6

(E) $\log_2(3!)$

(F) $\log_2 60$

[NSAA, 2018S1Q82]

An object X of mass 2.0 kg is initially moving at a speed of 4.5 m s^{-1} on a smooth, horizontal surface.

A 5.0 N force is applied to X in the direction of its motion for 3.0 seconds.

A short time later it collides head on with, and sticks to, a stationary object Y of mass 3.0 kg.

What is the speed of X and Y as they move off together after the collision?

(A) 1.8 m s^{-1}

(B) 3.0 m s^{-1}

(C) 3.6 m s^{-1}

(D) 4.8 m s^{-1}

(E) 5.4 m s^{-1}

[NSAA, 2018S1Q83]

Circle C has equation $(x+3)^2+(y-2)^2=5$. The length of the tangent from the circle C to the point P is $5\sqrt{3}$. What is the shortest distance from P to C?

(A) $5\sqrt{3}$

(B) $5\sqrt{3}+\sqrt{5}$

(C) $3\sqrt{5}$

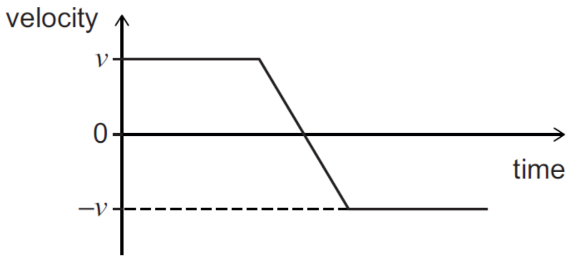
(D) 5

(E) 10

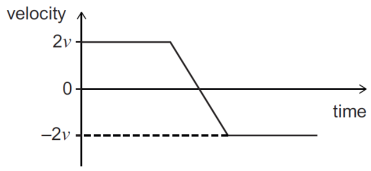
[NSAA, 2018S1Q84]

Two solid spheres X and Y have masses m and $2m$ respectively. They travel in opposite directions towards each other along the same line with speeds v and $2v$ respectively and collide head on.

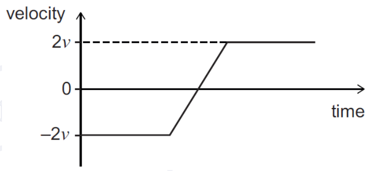
The graph shows the variation of velocity with time for sphere X before, during, and after the collision.



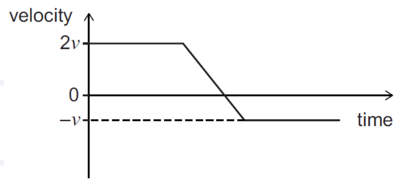
Which sketch shows the variation of velocity with time for sphere Y?



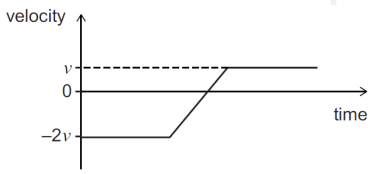
(A)



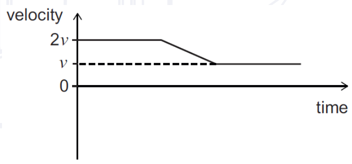
(B)



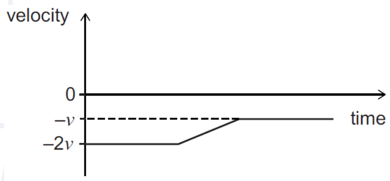
(C)



(D)



(E)



(F)

[NSAA, 2018S1Q85]

What is the coefficient of x^3 in the expansion of $(1-2x)^5(1+2x)^5$?

(A) -6400

(B) -640

(C) -80

(D) 0

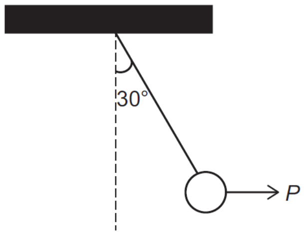
(E) 80

(F) 800

(G) 960

[NSAA, 2018S1Q86]

A metal ball suspended from a steel cable is held at rest by a horizontal force P. The cable makes an angle of 30° to the vertical as shown in the diagram. The cable exerts a force T on the ball.



What is the magnitude of P?

(A) $\frac{T}{2}$

(B) T

(C) $2T$

(D) $\frac{T}{\sqrt{2}}$

(E) $\frac{T}{\sqrt{3}}$

(F) $\frac{2T}{\sqrt{3}}$

(G) $\frac{\sqrt{3}T}{2}$

[NSAA, 2018S1Q87]

Given that

$$\int_0^2 x^m \, dx = \frac{16\sqrt{2}}{7}$$

and

$$\int_0^2 x^{m+1} \, dx = \frac{32\sqrt{2}}{9}$$

what is the value of m?

(A) $-\frac{11}{2}$

(B) $-\frac{9}{2}$

(C) $-\frac{22}{29}$

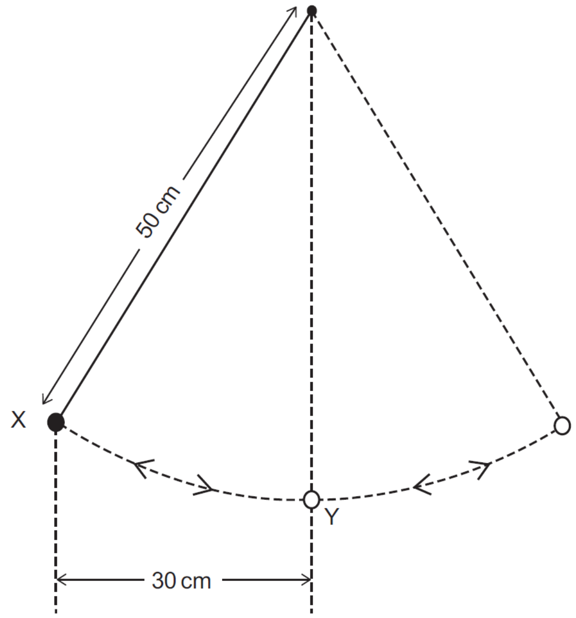
(D) $\frac{7}{22}$

(E) $\frac{5}{2}$

(F) $\frac{7}{2}$

[NSAA, 2018S1Q88]

A pendulum bob of mass 10 g is suspended by a light, inextensible string of length 50 cm. The bob is released from rest at position X.



What is the speed of the bob as it passes through position Y?

(gravitational field strength $g = 10$ N kg^{-1}; assume that resistive forces are negligible)

(A) $\sqrt{2}$ m s^{-1}

(B) $\sqrt{4}$ m s^{-1}

(C) $\sqrt{6}$ m s^{-1}

(D) $\sqrt{8}$ m s^{-1}

(E) $\sqrt{10}$ m s^{-1}

[NSAA, 2018S1Q89]

The dimensions of a solid cuboid, in cm, are x, $2x$ and y.

The volume of the cuboid is 576 cm^3.

At this volume, the surface area of the cuboid has its maximum value.

What is the area, in cm^2, of the face that has the largest area?

(A) $2(288)^{\frac{2}{3}}$

(B) 72

(C) 96

(D) 432

(E) $4(144)^{\frac{2}{3}}$

[NSAA, 2018S1Q90]

An object is thrown vertically upwards from ground level with an initial velocity of 40 m s^{-1}.

2.0 seconds later another object is released from a height above the ground and falls vertically from rest.

Both of the objects hit the ground at the same time.

From what height above the ground was the second object released?

(gravitational field strength $g = 10$ N kg^{-1}; air resistance can be ignored)

(A) 80 m

(B) 180 m

(C) 320 m

(D) 500 m

(E) 900 m

NSAA 2018 S2

NSAA 2018 S2
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 40 MINUTES

This paper is Section 2 of 2.

There are six questions in this paper, of which you should answer any **two**.

There are 20 marks for each question. In total 40 marks are available.

You should write your answers in the spaces provided in this question paper. Please complete this section in **black pen**. Pencil may be used for graphs and diagrams only.

You can use the blank pages inside this booklet for rough working or notes, but **no extra paper** is allowed. Only answers in the spaces indicated in the paper will be marked.

Calculators may be used in this section. Please record your calculator model in the box below:

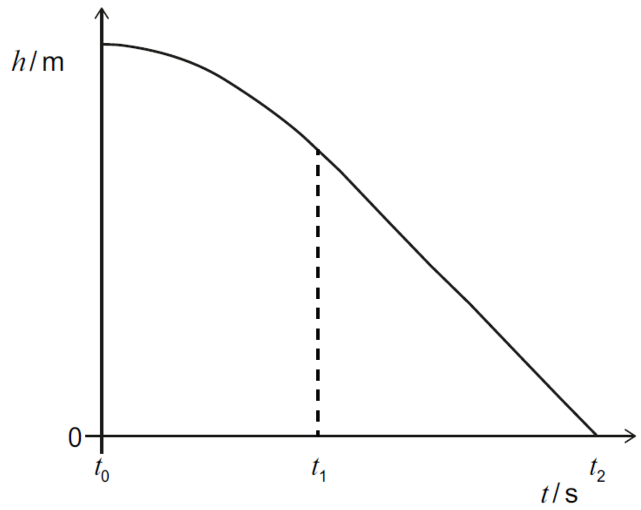
Calculator model	

Write the numbers of the questions you answer in the order attempted in the boxes below:

Question number

[NSAA, 2018S2Q1]

A ball of mass m is dropped and falls vertically from a high window. The graph illustrates the height of the ball above the ground, h, as a function of time t since the ball was dropped.



(a) In words, relate the speed of the ball to the gradient of the graph at time t_0, and in the two time intervals t_0 to t_1, t_1 to t_2. [6]

(b) The drag force on the ball caused by air resistance is given by F_d.

Using Newton's second law, find an equation for the acceleration a of the ball in terms of F_d, m, and g, where g is the gravitational field strength. [2]

(c) The drag force on the ball is given by $F_d = \frac{1}{4}\pi\rho r^2 v^2$, where ρ is the density of the air, r is the radius of the ball, and v is the instantaneous speed of the ball.

Find an expression for the terminal speed of the ball v_t in terms of m, g, r and ρ. [3]

(d) Calculate the value of the terminal speed of the ball given that it has a mass $m = 25$ g, a radius $r = 25$ cm, and that the density of the air $\rho = 1.2$ kg m^{-3}. (gravitational field strength = 9.8 N kg^{-1}). [2]

(e) Sketch a graph of the ball's speed against time, labelling the terminal speed of the ball. In words, relate the acceleration of the ball to the gradient of your speed–time graph. [4]

(f) The speed of the ball varies with height according to the equation. [3]

$$\left(\frac{v}{v_t}\right)^2 = \left(1 - 10^{-\frac{cy}{m}}\right)$$

where $m = 25$ g, $c = 0.051$ kg m^{-1} and y is the distance the ball has fallen from the window; $y = 0$ at the start of the fall.

Calculate the distance that the ball has fallen when its speed is equal to 99% of its terminal speed.

[NSAA, 2018S2Q2]

Assume throughout this question that the cells and batteries have no internal resistance.

A light-emitting diode (LED) has the ideal $I-V$ characteristic graph shown in Fig. 2a:

Figure 2a

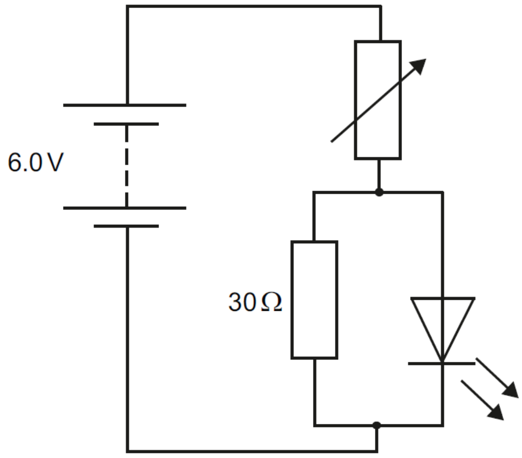


Figure 2b

If the potential difference across the LED is less than 1.4 V, no current passes through it. When a current does pass through the LED, the potential difference across it is always 1.4 V.

This LED is connected into the circuit shown in Fig. 2b, and the variable resistor is adjusted until there is a current of 8.0 mA through the LED. The battery has an emf of 6.0 V.

(a)

(i) What is the potential difference across the 30 Ω resistor? [1]

(ii) What is the current through the 30 Ω resistor? [1]

(b)

(i) What is the current through the variable resistor? [1]

(ii) What is the potential difference across the variable resistor? [1]

(iii) What is the resistance of the variable resistor? [1]

(c) The following circuit is constructed with a battery of emf 6.0 V, two fixed resistors, one variable resistor, and a voltmeter, as shown in Fig. 2c.

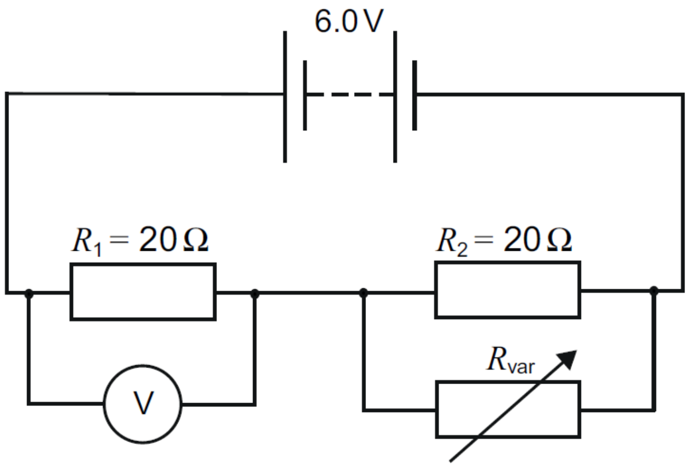


Figure 2c

$R_1 = R_2 = 20\ \Omega$, and R_{var} can be varied between 0 and 80 Ω.

(i) When R_{var} is set to 20 Ω, what is the voltage shown on the voltmeter? [1]

(ii) Sketch a graph of the voltage shown on the voltmeter against R_{var} for values of R_{var} between 0 and 80 Ω. Plot your result from part (i) on your graph. [3]

(iii) Calculate the potential difference across the variable resistor, and the power dissipated in the variable resistor, for $R_{var} = 0.0\ \Omega$, 5.0 Ω, 20 Ω, 50 Ω and 80 Ω. [5]

(iv) Using your results from part (iii), sketch a labelled graph of the power dissipated in the variable resistor against R_{var} from 0 to 80 Ω. [5]

(d) A potentiometer is a three-terminal device often used as a variable resistor by using only two of the three terminals (one end of the resistive track and the sliding contact). An example is shown schematically in Fig. 2d. In a logarithmic potentiometer the resistance varies with the angle of rotation, θ. [3]

The graph in Fig. 2e shows how the logarithm of the resistance R_{AB} varies linearly with angle θ. θ can vary between 0° and 270°.

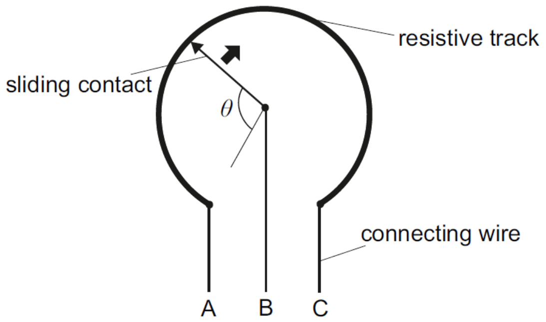


Figure 2d

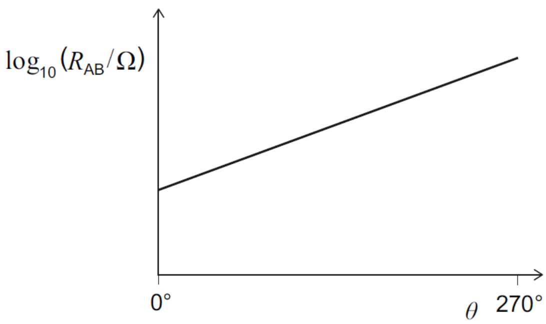


Figure 2e

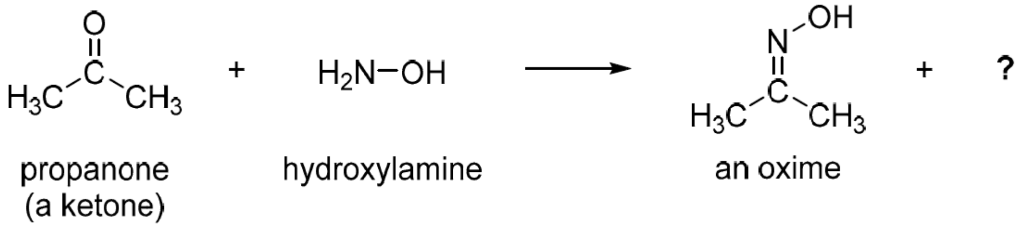
If the resistance when $\theta = 0°$ is $R_{AB} = 1.00\ \text{k}\Omega$, and when $\theta = 270°$ is $R_{AB} = 2.00\ \text{M}\Omega$, what is the value of R_{AB} when $\theta = 110°$?

H 1 1.008																	**He** 2 4.003
Li 3 6.941	**Be** 4 9.012						**symbol** atomic number relative atomic mass (A_r)					**B** 5 10.81	**C** 6 12.01	**N** 7 14.01	**O** 8 16.00	**F** 9 19.00	**Ne** 10 20.18
Na 11 22.99	**Mg** 12 24.31											**Al** 13 26.98	**Si** 14 28.09	**P** 15 30.97	**S** 16 32.06	**Cl** 17 35.45	**Ar** 18 39.95
K 19 39.10	**Ca** 20 40.08	**Sc** 21 44.96	**Ti** 22 47.87	**V** 23 50.94	**Cr** 24 52.00	**Mn** 25 54.94	**Fe** 26 55.85	**Co** 27 58.93	**Ni** 28 58.69	**Cu** 29 63.55	**Zn** 30 65.38	**Ga** 31 69.72	**Ge** 32 72.63	**As** 33 74.92	**Se** 34 78.97	**Br** 35 79.90	**Kr** 36 83.80
Rb 37 85.47	**Sr** 38 87.62	**Y** 39 88.91	**Zr** 40 91.22	**Nb** 41 92.91	**Mo** 42 95.95	**Tc** 43	**Ru** 44 101.1	**Rh** 45 102.9	**Pd** 46 106.4	**Ag** 47 107.9	**Cd** 48 112.4	**In** 49 114.8	**Sn** 50 118.7	**Sb** 51 121.8	**Te** 52 127.6	**I** 53 126.9	**Xe** 54 131.3
Cs 55 132.9	**Ba** 56 137.3	**La*** 57 138.9	**Hf** 72 178.5	**Ta** 73 180.9	**W** 74 183.8	**Re** 75 186.2	**Os** 76 190.2	**Ir** 77 192.2	**Pt** 78 195.1	**Au** 79 197.0	**Hg** 80 200.6	**Tl** 81 204.4	**Pb** 82 207.2	**Bi** 83 209.0	**Po** 84	**At** 85	**Rn** 86
Fr 87	**Ra** 88	**Ac†** 89															

***Lanthanides**	**Ce** 58 140.1	**Pr** 59 140.9	**Nd** 60 144.2	**Pm** 61	**Sm** 62 150.4	**Eu** 63 152.0	**Gd** 64 157.3	**Tb** 65 158.9	**Dy** 66 162.5	**Ho** 67 164.9	**Er** 68 167.3	**Tm** 69 168.9	**Yb** 70 173.0	**Lu** 71 175.0
†Actinides	**Th** 90 232.0	**Pa** 91 231.0	**U** 92 238.0	**Np** 93	**Pu** 94	**Am** 95	**Cm** 96	**Bk** 97	**Cf** 98	**Es** 99	**Fm** 100	**Md** 101	**No** 102	**Lr** 103

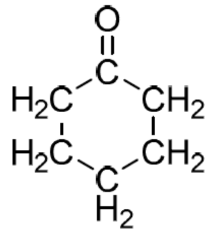
[NSAA, 2018S2Q3]

(a) Ketones react with hydroxylamine, NH_2OH, to give oximes. An example of such a reaction involving the ketone propanone is shown below:

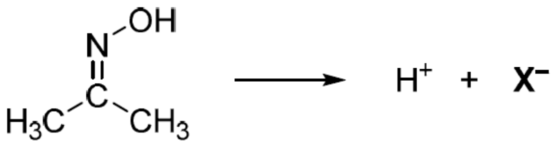


(i) In addition to the oxime, this reaction produces a second product. Suggest what this molecule might be. [1]

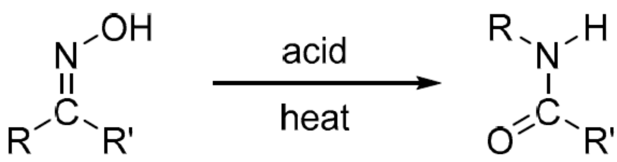
(ii) Draw the structure of the oxime that you would expect to be formed from the reaction of the ketone cyclohexanone with hydroxylamine. [2]



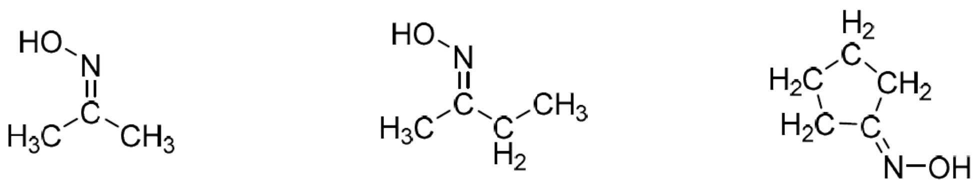
(iii) Oximes are weakly acidic. For the oxime below, explain which hydrogen atom will be the most acidic and draw the structure of the resulting anion **X**$^-$. [3]



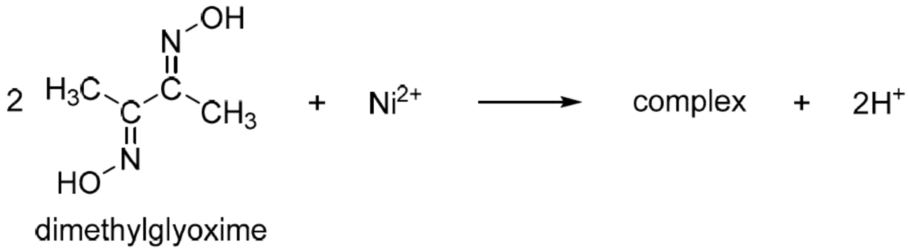
(b) Under acidic conditions, oximes undergo the following rearrangement reaction (note carefully that there are two different groups R and R′). [4]



Give the analogous structures into which each of the following oximes rearrange under the same conditions.



(c) Dimethylglyoxime reacts with Ni^{2+} ions in aqueous solution under mildly basic conditions to give a complex which is an insoluble red precipitate. The reaction involves two molecules of dimethylglyoxime and also results in the production of two H^+ ions. [4]



Assuming that the above equation is balanced, determine the **molecular formula** of the complex and its relative molecular mass; a structural formula is **not** required.

(Relative atomic mass data is given in the Periodic Table on page 14.)

(d) The reaction between dimethylglyoxime and Ni^{2+} ions can be used to determine the nickel content of alloys by weighing the amount of the red precipitate produced from a known mass of a sample of an alloy. [4]

A sample of mass 1.50 g of an alloy was dissolved in dilute acid and an excess of dimethylglyoxime was then added to the resulting solution. The pH was then adjusted to make the solution mildly alkaline, and this resulted in the formation of a red precipitate. The precipitate was carefully filtered off, dried and then weighed. The mass of the dry precipitate was 0.368 g.

Determine the nickel content of the alloy, expressed as a percentage by mass.

(e) Other metal ions, such as Pd^{2+} or Pt^{2+}, also react with dimethylglyoxime to give insoluble precipitates. What effect would the presence of palladium in the alloy have on the value of the nickel content determined using the method in part d)? [2]

[NSAA, 2018S2Q4]

(a) Write a balanced chemical equation for the reaction between $CO_2(g)$ and $OH^-(aq)$, giving $CO_3^{2-}(aq)$ as one of the products. [1]

(b) An organic molecule is known to contain C, H and O only. A sample of mass 0.100g is carefully burnt in the presence of excess oxygen. The resulting gases are passed over a desiccant (drying agent), and it is observed that the mass of the desiccant increases by 0.0931 g.

After passing through the desiccant the gases are bubbled through 25.0 cm^3 of a solution of 1.00 mol dm^{-3} NaOH. The solution is then titrated against 1.00 mol dm^{-3} HCl, and the end point is found to be when 14.7 cm^3 of the acid has been added.

(i) Calculate the amount in moles of H_2O produced by the combustion. [2]

(ii) Calculate the amount in moles of CO_2 absorbed by the NaOH solution. [4]

(iii) Hence determine the empirical formula of the organic molecule. [6]

(c) Determine the oxidation state of the metal atom or atoms in the following species.

(i) MnO_4^{2-} [1]

(ii) $K_2Cr_2O_7$ [2]

(d) Write a balanced chemical equation in which Fe^{2+} is oxidised to Fe^{3+} by MnO_4^- in an **acidic aqueous solution** and in which the Mn is reduced to a species with oxidation state +2. Your equation must balance for both atoms and charge, and you may **not** use free electrons (e^-) to achieve this. [4]

[NSAA, 2018S2Q5]

(a) Sketch a simple diagram of a eukaryotic cell, and label the locations where DNA transcription and RNA translation take place. [2]

(b) When RNA is translated into protein, it is read in triplets (codons). [2]

What proportion of codons might be viewed as redundant in the genetic code (i.e. in excess of the minimum needed to code for all amino acids)?

(c) What is an advantage of having more codons in the genetic code than there are amino acids? [2]

(d) A ribosome can translate 18 bases per second. How many seconds would it take to produce a protein that was 299 amino acids long? [2]

(e) Imagine that an alien organism is found that translates its RNA using pairs of nucleotides instead of triplets. [2]

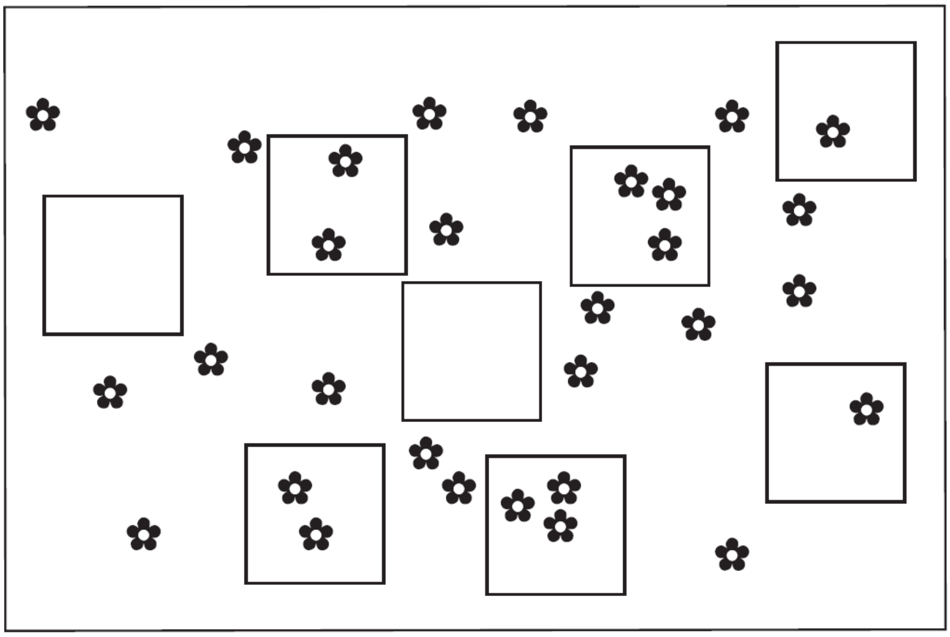
During translation, the alien organism can use 50 possible amino acids (rather than the 20 found in humans).

What is the minimum number of different types of nucleotides that would be needed to code for all of the possible amino acids?

(f) Using examples, describe the changes that can occur in DNA sequences and explain how these changes can lead to diseases. [10]

[NSAA, 2018S2Q6]

The diagram below shows eight 2 m × 2 m quadrats that have been placed into a 14 m × 10 m field that has recently been colonised by a small invasive plant (each plant is shown by a flower symbol).



(a) Describe one benefit **and** one problem associated with using quadrats in a study like this. [2]

(b) Calculate the frequency of occurrence of the species in the quadrats. [2]

(c) Calculate the mean number of plants found per square metre in the quadrats. [2]

(d) For the field as a whole, this population grows by 70 individuals per week. How long will the population take to reach an average density of two plants per square metre in the 14 m × 10 m field? [2]

(e) The invasive plant only produces flowers once every 5 years.

Explain why the plant produces flowers, and why flowers might be produced on this timescale. [3]

(f) Discuss the factors that may affect the spread and photosynthetic rate of the invasive plant. [10]

NSAA 2019 S1

NSAA 2019 S1
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 80 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 80 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **five** parts: **A**, **B**, **C**, **D**, and **E**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **two** further parts chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology
Part E	Advanced Mathematics and Advanced Physics

Each part has 18 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **three** parts. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators may NOT permitted.

Part A

[NSAA, 2019S1Q1]

Evaluate

$$\left(\sqrt{7}+\sqrt{3}\right)^2-\left(\sqrt{7}-\sqrt{3}\right)^2$$

(A) 0

(B) $2\sqrt{7}$

(C) $4\sqrt{7}$

(D) $2\sqrt{21}$

(E) 10

(F) $4\sqrt{21}$

(G) 20

[NSAA, 2019S1Q2]

Find the complete set of values of x which satisfy the inequality

$$\frac{1}{2}(3x-2)-\frac{2}{3}(x-4)<x$$

(A) $x<-22$

(B) $x>-22$

(C) $x<-2.5$

(D) $x>-2.5$

(E) $x<1.2$

(F) $x>1.2$

(G) $x<10$

(H) $x>10$

[NSAA, 2019S1Q3]

The equation gives y in terms of x:

$$y = 3 - 4\left(1 - \frac{x}{2}\right)^2$$

Which one of the following is a rearrangement for x in terms of y?

(A) $x = -2 \pm 2\sqrt{\frac{3-y}{4}}$

(B) $x = -2 \pm 2\sqrt{\frac{4-y}{3}}$

(C) $x = 1 \pm \sqrt{\frac{3-y}{4}}$

(D) $x = 1 \pm 2\sqrt{\frac{3-y}{4}}$

(E) $x = 2 \pm 2\sqrt{\frac{3-y}{4}}$

(F) $x = 2 \pm 2\sqrt{\frac{4-y}{3}}$

(G) $x = 2 \pm 2\sqrt{\frac{3+y}{4}}$

[NSAA, 2019S1Q4]

The resistance to the motion of a car is directly proportional to the square of the speed of the car.

The car increases its speed by 20%.

What is the percentage increase in the resistance to the motion of the car?

(A) 20%

(B) 24%

(C) 44%

(D) 120%

(E) 224%

(F) 240%

(G) 400%

[NSAA, 2019S1Q5]

The equation of a curve is $y = px^2 + qx$ where p and q are constants.

The curve passes through the points $(2, 6)$ and $(4, -4)$.

What is the value of $q - p$?

(A) 1

(B) 2

(C) 5

(D) 6

(E) 9

(F) 16

[NSAA, 2019S1Q6]

Which of the following is a simplification of

$$4 - \frac{x(3x+1)}{x^2(3x^2-2x-1)}$$

(A) $\frac{12x^3-8x^2-7x-1}{x(3x-1)(x-1)}$

(B) $\frac{4x^2+4x-1}{x(x+1)}$

(C) $\frac{4x^2+4x+1}{x(x+1)}$

(D) $\frac{4x^2-4x-1}{x(x-1)}$

(E) $\frac{4x^2-4x+1}{x(x-1)}$

(F) $\frac{12x^3-8x^2-x+1}{x(3x-1)(x-1)}$

[NSAA, 2019S1Q7]

The ball for a garden game is a solid sphere of volume 192 cm³.

For the children's version of the game the ball is a solid sphere made of the same material, but the radius is reduced by 25%.

What is the volume, in cm³, of the children's ball?

(A) 48

(B) 81

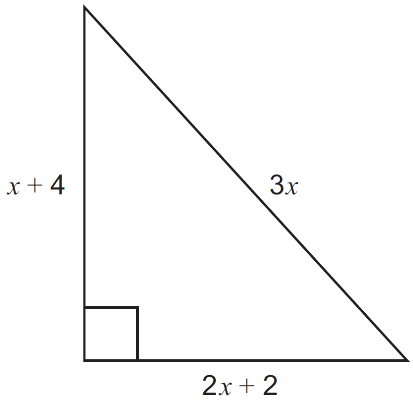
(C) 96

(D) 108

(E) 144

[NSAA, 2019S1Q8]

The diagram shows a right-angled triangle, with sides of length $x + 4$, $2x + 2$ and $3x$, all in cm.



[diagram not to scale]

What is the area, in cm², of the triangle?

(A) 10

(B) 12

(C) 28

(D) 36

(E) 40

(F) 54

(G) 70

[NSAA, 2019S1Q9]

Given that

$$9^{2x-1} \times \frac{1}{27^x} = 81^x$$

what is the value of x?

(A) $-\frac{2}{3}$

(B) $-\frac{2}{5}$

(C) $-\frac{1}{3}$

(D) $-\frac{1}{4}$

(E) $-\frac{1}{5}$

[NSAA, 2019S1Q10]

PR and QS are the diagonals of a rhombus $PQRS$.

$PR = (3x + 2)$ cm

$QS = (8 - 2x)$ cm

The area of $PQRS$ is 11 cm².

What is the difference, in cm, between the two possible lengths of PR?

(A) $2\frac{2}{3}$

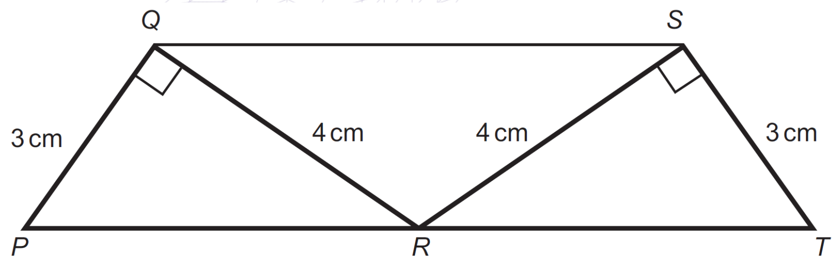
(B) $4\frac{1}{2}$

(C) $5\frac{1}{3}$

(D) 8

(E) 14

[NSAA, 2019S1Q11]



[diagram not to scale]

The diagram shows two congruent right-angled triangles PQR and TSR with right angles at Q and S, respectively.

$PQ = TS = 3$ cm

$QR = SR = 4$ cm

PRT is a straight line.

What is the length, in cm, of QS?

(A) 4

(B) $3\sqrt{2}$

(C) 5.2

(D) $4\sqrt{2}$

(E) 6.4

(F) 8.2

(G) 10

[NSAA, 2019S1Q12]

The total of three numbers p, q and r is 375.

The ratio $p : q$ is 5 : 7.

The ratio $q : r$ is 4 : 11.

What is the value of $p + r$?

(A) 16

(B) 60

(C) 97

(D) 125

(E) 144

(F) 231

(G) 291

(H) 315

[NSAA, 2019S1Q13]

The straight line P has equation $3y - 2x = 12$ and intercepts the y-axis at the point $(0, p)$.

The straight line Q is parallel to P, passes through the point $(6, -1)$ and intercepts the y-axis at the point $(0, q)$.

What is the value of $p - q$?

(A) -9

(B) -7

(C) 1

(D) 9

(E) 14

(F) 17

[NSAA, 2019S1Q14]

The vertices of a rectangle have coordinates:

$$P(4,5) \quad Q(4,8) \quad R(10,8) \quad S(10,5)$$

$PQRS$ is transformed by a clockwise rotation of 90° about P followed by a reflection in the x-axis.

What are the coordinates of the final position of R?

(A) $(-8,-10)$

(B) $(-7,-1)$

(C) $(-4,1)$

(D) $(-1,11)$

(E) $(1,-11)$

(F) $(4,-1)$

(G) $(7,1)$

(H) $(8,10)$

[NSAA, 2019S1Q15]

Box A contains exactly 10 balls, of which 6 are red and 4 are blue.

Box B contains exactly 15 balls, of which 3 are red and 12 are blue.

All the balls are identical in every respect, apart from colour.

One of the two boxes is chosen at random by tossing two fair coins, as follows:

“If **both** coins show heads, box A is selected. Otherwise box B is selected.”

One ball is then randomly taken from the selected box.

What is the probability that a red ball is taken?

(A) $\frac{9}{400}$

(B) $\frac{3}{25}$

(C) $\frac{3}{10}$

(D) $\frac{2}{5}$

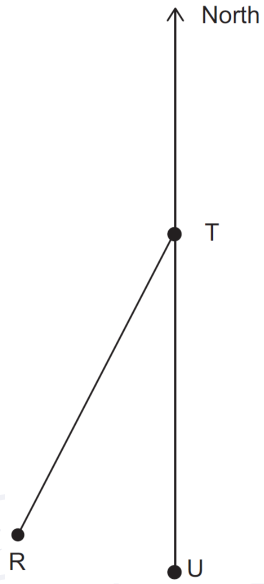
(E) $\frac{1}{2}$

(F) $\frac{4}{5}$

(G) $\frac{323}{400}$

[NSAA, 2019S1Q16]

Three towns Ryeton, Tonbridge and Uphampton are represented on the diagram by the points labelled R, T and U, respectively.



The distance from Tonbridge to Ryeton is the same as the distance from Tonbridge to Uphampton.

Uphampton is south of Tonbridge.

Ryeton is on a bearing of 210° from Tonbridge.

What is the bearing of Uphampton from Ryeton?

(A) 030°

(B) 075°

(C) 105°

(D) 150°

(E) 300°

(F) 345°

[NSAA, 2019S1Q17]

A list of five numbers has mean x, median y and range z.

A sixth number is added to the list. This sixth number is greater than x.

Which of the following statements **must** be true?

1 The median of the six numbers cannot be one of the numbers in the list.

2 The mean of the six numbers is greater than x.

3 The range of the six numbers is greater than z.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

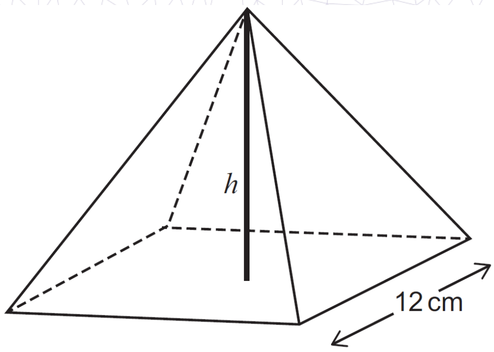
(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q18]



[diagram not to scale]

A solid pyramid has a square base of side length 12 cm and a vertical height of h cm.

The volume of the pyramid, in cm^3, is equal to the total surface area of the pyramid, in cm^2.

What is the value of h?

(volume of pyramid $= \frac{1}{3} \times$ area of base $\times$ vertical height)

(A) $\frac{72}{35}$

(B) $2\sqrt{3}$

(C) 6

(D) $\frac{144}{23}$

(E) 8

(F) $2\sqrt{21}$

Part B

[NSAA, 2019S1Q19]

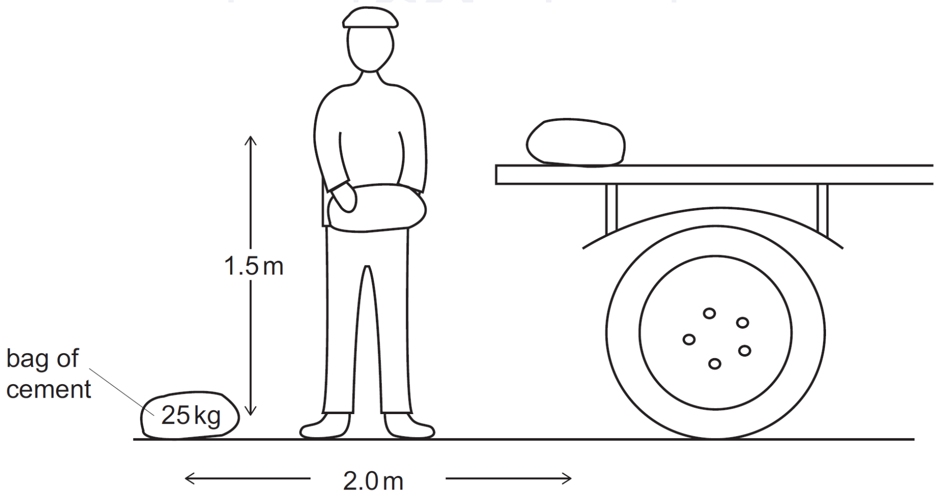
A transverse wave is travelling through a medium. The distance between successive wave peaks is 8.4 cm and the total distance travelled by a particle during one complete oscillation is 5.6 cm.

What is the amplitude and wavelength of the wave?

	amplitude / cm	*wavelength* / cm
(A)	1.4	4.2
(B)	1.4	8.4
(C)	2.1	2.8
(D)	2.1	5.6
(E)	2.8	4.2
(F)	2.8	8.4
(G)	4.2	2.8
(H)	4.2	5.6

[NSAA, 2019S1Q20]

A builder lifts bags of cement onto the back of a lorry. Each bag has a mass of 25 kg. It takes the builder 2.5 minutes to load ten bags.



[diagram not to scale]

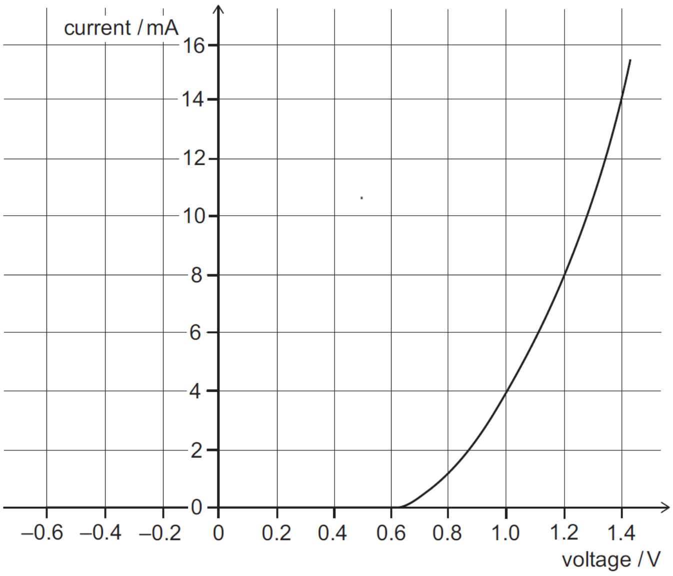
What are the total work done, T, on the ten bags and the average power required for T?

(gravitational field strength = 10 N kg^{-1})

	total work done T / J	*average power* / W
(A)	375	2.5
(B)	375	150
(C)	625	4.2
(D)	625	250
(E)	3750	25
(F)	3750	1500
(G)	6250	42
(H)	6250	2500

[NSAA, 2019S1Q21]

The current–voltage graph for a diode is shown.



The diode is connected in series with a resistor and a 6.0 V battery. The current in the circuit is 8.0 mA.

What is the resistance of the resistor?

(Assume that the battery has negligible resistance.)

(A) 0.15 Ω

(B) 0.60 Ω

(C) 0.75 Ω

(D) 4.8 Ω

(E) 150 Ω

(F) 600 Ω

(G) 750 Ω

[NSAA, 2019S1Q22]

Two electromagnetic waves P and Q travel in a vacuum and the ratio of their wavelengths is:

$$\frac{\text{wavelength of } P}{\text{wavelength of } Q} = 1.0 \times 10^{8}$$

Which row in the table shows the ratio of their speeds, the ratio of their frequencies, and identifies the possible natures of P and Q?

	$\frac{\text{speed of } P}{\text{speed of } Q}$	$\frac{\text{frequency of } P}{\text{frequency of } Q}$	*nature of P*	*nature of Q*
(A)	1.0	1.0×10^{-8}	microwave	X-ray
(B)	1.0	1.0×10^{-8}	microwave	radio wave
(C)	1.0	1.0×10^{8}	infrared	ultraviolet
(D)	1.0	1.0×10^{8}	visible light	infrared
(E)	1.0×10^{8}	1.0	gamma	X-ray
(F)	1.0×10^{8}	1.0	gamma	infrared
(G)	1.0×10^{8}	1.0×10^{16}	infrared	radio wave
(H)	1.0×10^{8}	1.0×10^{16}	visible light	ultraviolet

[NSAA, 2019S1Q23]

A block of aluminium of mass 0.80 kg, initially at a temperature of −21 °C, is supplied with 54000 J of thermal energy.

The specific heat capacity of aluminium is 900 J kg^{-1} °C^{-1}.

What is the final temperature of the block?

(Assume that there is no other transfer of energy between the block and the surroundings.)

(A) 27 °C

(B) 39 °C

(C) 54 °C

(D) 75 °C

(E) 96 °C

[NSAA, 2019S1Q24]

A light spring is used to support a range of loads.

The spring obeys Hooke's law. The system is in equilibrium.

Which of the following statements is/are correct?

1 The tension in the spring is directly proportional to the length of the spring.

2 The tension in the spring and the weight of the load it supports are a Newton's third law pair of forces.

3 When the extension of the spring is doubled, the energy stored in the spring increases by a factor of four.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q25]

A water-tight cylinder with a thin, freely moving piston contains 2.0×10^{-3} m^3 of trapped air at atmospheric pressure of 1.0×10^5 Pa.

When the cylinder is submerged in water of constant density 1000 kg m^{-3}, the volume of air in the cylinder decreases to 4.0×10^{-4} m^3.

The piston is at a depth h below the surface of the water and the water surface is open to the atmosphere.

What is the depth h?

(gravitational field strength = 10 N kg^{-1}; assume that the temperature of the air remains constant and that air is an ideal gas)

(A) 40 m

(B) 50 m

(C) 60 m

(D) 400 m

(E) 500 m

(F) 600 m

[NSAA, 2019S1Q26]

The secondary coil of an ideal, 100% efficient transformer is connected to a resistor by cables of total resistance 1500 Ω. The current in the primary coil is 4.0 A. There are 240 turns in the primary coil and 4800 turns in the secondary coil.

What is the power produced as heat in the cables?

(A) 60 W

(B) 300 W

(C) 6 000 W

(D) 24 000 W

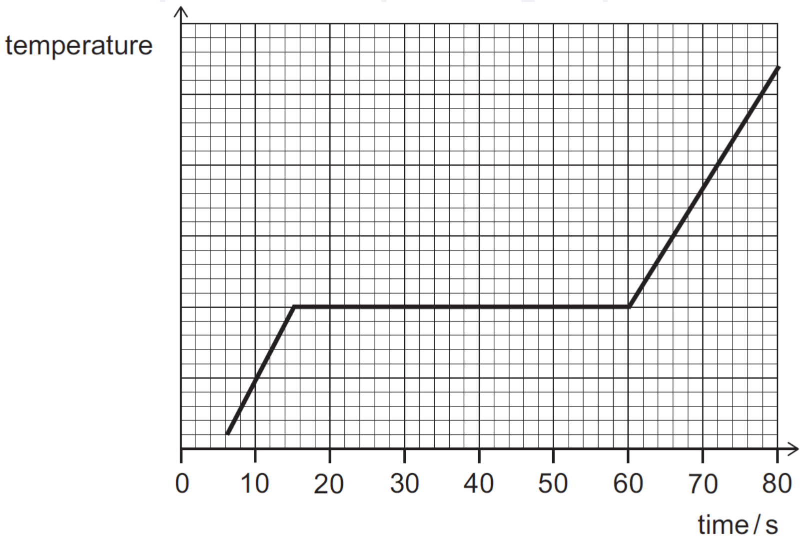
(E) 120 000 W

(F) 9 600 000 W

[NSAA, 2019S1Q27]

Heat is supplied to an initially solid substance at a rate of 60 W.

The graph shows the variation of the temperature of the substance with time.



What is the mass of the substance?

(specific latent heat of fusion of substance = 100 J g^{-1}; assume that there is no heat transferred to the surroundings)

(A) 0.013 g

(B) 0.60 g

(C) 3.0 g

(D) 9.0 g

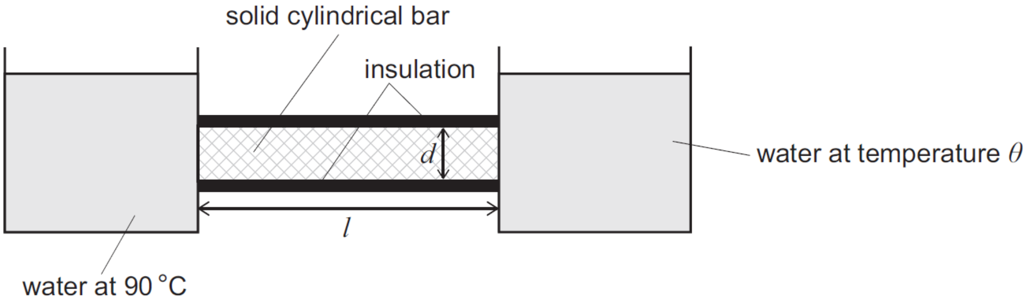
(E) 27 g

(F) 36 g

[NSAA, 2019S1Q28]

Two tanks of water are connected by a solid cylindrical copper bar of length l and diameter d. The bar is insulated.

One tank contains water at 90 °C and the other tank contains water at temperature θ.



For which of the following conditions is thermal energy conducted along the bar at the lowest rate?

	l / m	d / cm	θ / °C
(A)	0.40	4.0	20
(B)	0.40	4.0	40
(C)	0.40	8.0	20
(D)	0.40	8.0	40
(E)	0.80	4.0	20
(F)	0.80	4.0	40
(G)	0.80	8.0	20
(H)	0.80	8.0	40

[NSAA, 2019S1Q29]

A U-shaped permanent magnet rests on a balance.

A straight, horizontal wire of length 5.0 cm is fixed in position between the poles of the magnet, perpendicular to the horizontal magnetic field.

There is a current of 2.0 A in the wire and the reading on the balance is 202 g.

When the direction of the 2.0 A current is reversed, the reading changes to 198 g.

What is the strength of the magnetic field?

(gravitational field strength = 10 N kg^{-1})

(A) 0.020 T

(B) 0.040 T

(C) 0.20 T

(D) 0.40 T

(E) 200 T

(F) 400 T

[NSAA, 2019S1Q30]

The radioactive isotope X becomes the stable isotope Y after a succession of decays involving only the emission of alpha and beta (β^-) particles.

During the decay of one nucleus from X to Y, a total of seven particles are emitted. It is known that more of these particles are alpha particles than beta particles.

The atomic number of X is Z and the mass number of X is A.

Which row in the table could give the atomic number and the mass number of Y?

	atomic number of Y	*mass number of* Y
(A)	$Z-2$	$A-12$
(B)	$Z-5$	$A-8$
(C)	$Z-8$	$A-20$
(D)	$Z-10$	$A-24$
(E)	$Z-11$	$A-16$

[NSAA, 2019S1Q31]

The kinetic energy of an object of mass 4.0 kg, travelling in a straight line, increases from 32 J to 200 J in 3.0 seconds due to a constant resultant force.

What is the value of this resultant force?

(A) 2.0 N

(B) 4.0 N

(C) 8.0 N

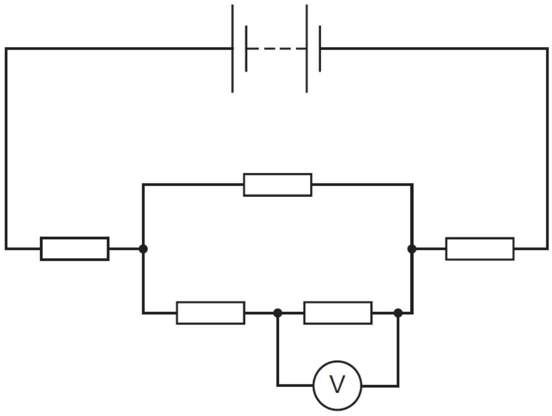
(D) 24 N

(E) 28 N

(F) 56 N

[NSAA, 2019S1Q32]

In the following circuit, all five resistors have the same resistance.



The reading on the voltmeter is 1.0 V.

What is the voltage across the battery?

(A) 4.0 V

(B) 5.0 V

(C) 6.0 V

(D) 7.0 V

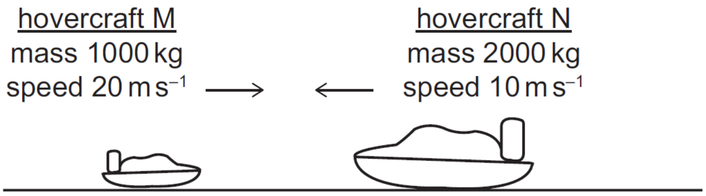
(E) 8.0 V

(F) 9.0 V

(G) 10 V

[NSAA, 2019S1Q33]

Two hovercraft travel horizontally in opposite directions along the same straight line. The mass and speed of each hovercraft are shown in the diagram. Horizontal resistive forces acting on each hovercraft are negligible.



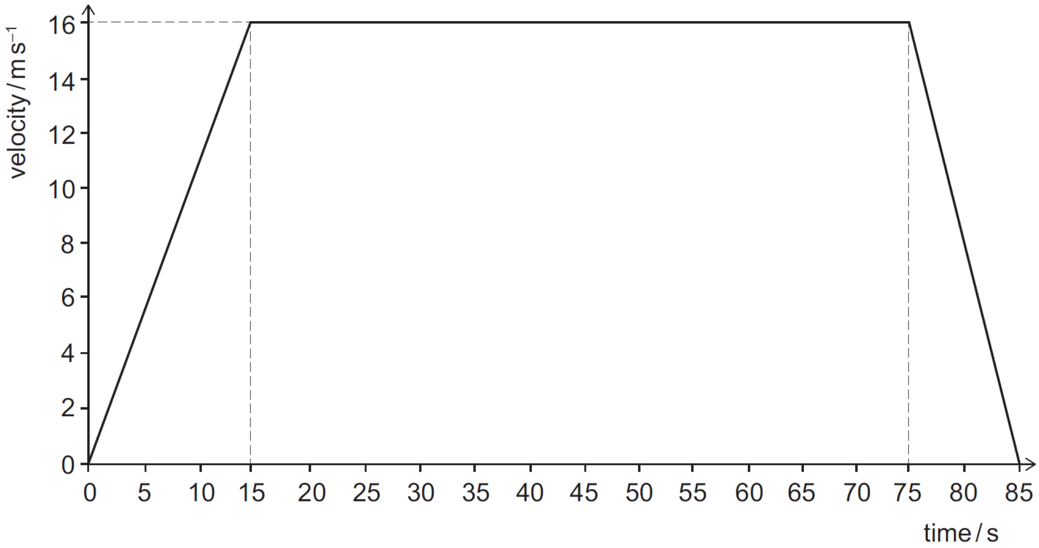
The hovercraft collide and stick together. The collision lasts for 0.10 s.

Just before the collision, what is the total kinetic energy and the magnitude of the total momentum of the two hovercraft, and what is the magnitude of the average force acting horizontally on each hovercraft during the collision?

	total initial kinetic energy / kJ	*total initial momentum* / kg m s^{-1}	*average force on each hovercraft* / kN
(A)	100	0	2.0
(B)	100	0	200
(C)	100	4.0×10^4	2.0
(D)	100	4.0×10^4	200
(E)	300	0	2.0
(F)	300	0	200
(G)	300	4.0×10^4	2.0
(H)	300	4.0×10^4	200

[NSAA, 2019S1Q34]

The graph shows how a car's velocity changes in 85 seconds.



What proportion of the total distance is travelled at constant velocity?

(A) $\frac{5}{29}$

(B) $\frac{5}{17}$

(C) $\frac{12}{17}$

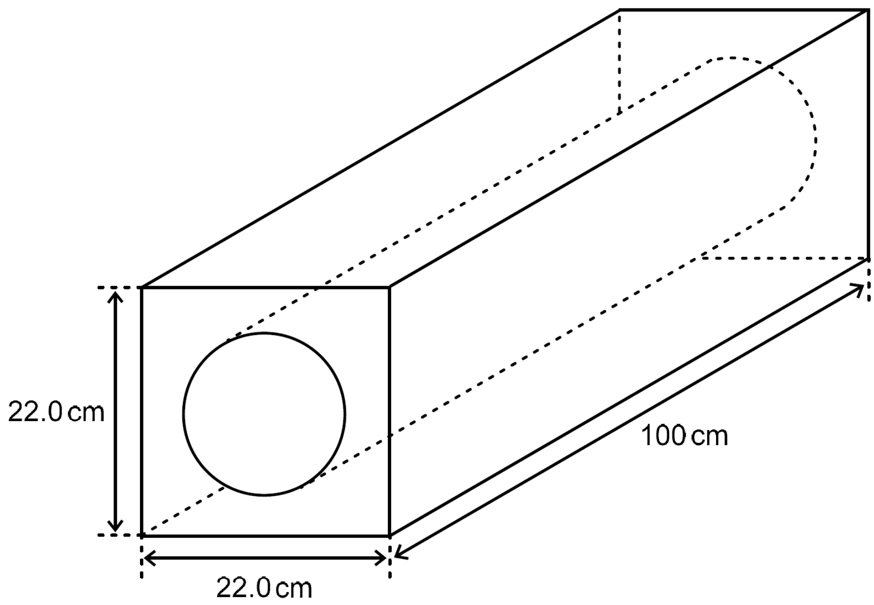
(D) $\frac{24}{29}$

(E) $\frac{8}{9}$

(F) $\frac{16}{17}$

[NSAA, 2019S1Q35]

A block is designed with a cylindrical channel to accommodate a hot-water pipe. The block is 100 cm long and it has a square cross-section of side 22.0 cm with a cylindrical hole in the middle, as shown in the diagram:



[diagram not to scale]

The diameter of the cylindrical hole is 14.0 cm and the density of the material from which the block is made is 0.100 g cm^{-3}.

What is the mass of the block?

(take π to be $\frac{22}{7}$)

(A) 1.32 kg

(B) 3.30 kg

(C) 13.2 kg

(D) 33.0 kg

(E) 132 kg

(F) 330 kg

(G) 1320 kg

(H) 3300 kg

[NSAA, 2019S1Q36]

A sample initially contains equal numbers of atoms of a radioactive isotope X and a stable isotope Y.

Isotope X has a half-life of 3 years and decays in a single stage to the stable isotope Y.

What is the ratio

$$\textit{number of atoms of } X : \textit{number of atoms of } Y$$

in the sample 6 years later?

(A) The sample contains only isotope Y.

(B) $1 : 7$

(C) $1 : 4$

(D) $1 : 3$

(E) $7 : 4$

Part C

[NSAA, 2019S1Q37]

HBr reacts with pent-2-ene in an addition reaction.

Which of the following products is/are formed in the reaction?

1 $CH_3CHBrCH_2CH_2CH_3$

2 $CH_2BrCH_2CH_2CH_2CH_3$

3 $CH_3CH_2CHBrCH_2CH_3$

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q38]

In which of the following solids does the bonding consist of single covalent bonds **only**?

1 graphite

2 SiO_2

3 Al_2O_3

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

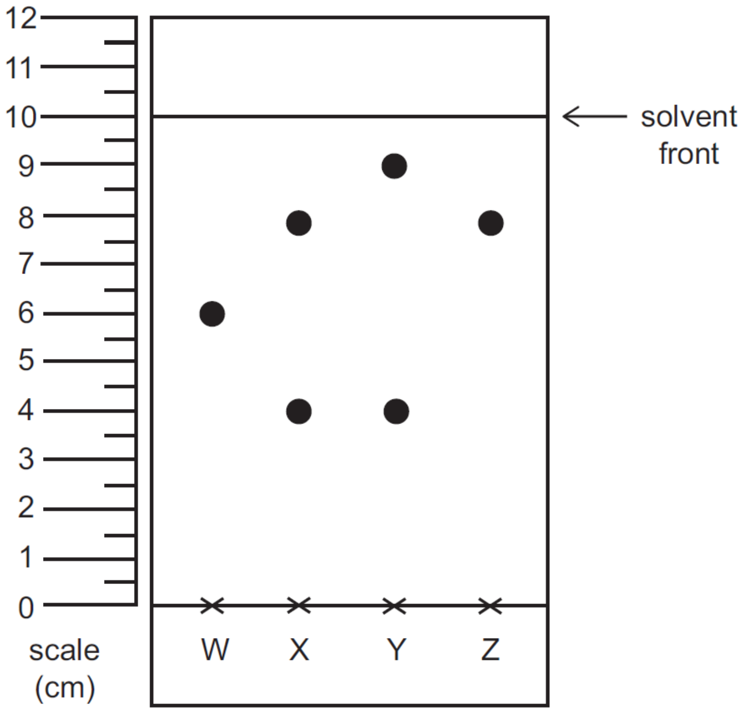
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q39]

Four samples, labelled W, X, Y and Z, were investigated using paper chromatography with a solvent that caused any mixtures present to be fully separated. The results are shown in the chromatogram.



What is the R_f value of the spot with the strongest attraction to the mobile phase relative to the stationary phase **and** that is from a sample containing only one substance?

(A) 0.50

(B) 0.60

(C) 0.67

(D) 0.75

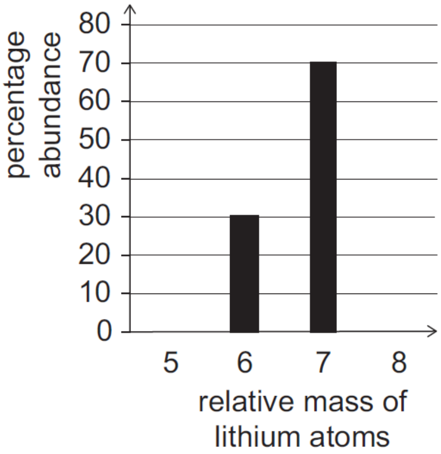
(E) 0.80

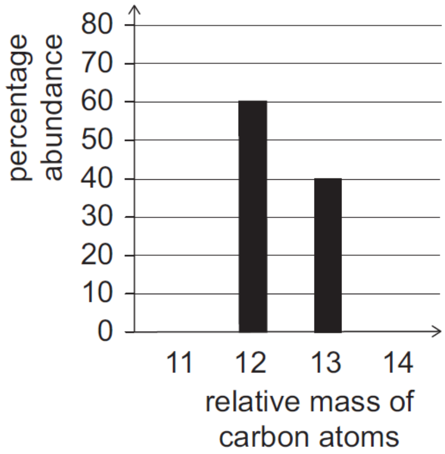
(F) 0.90

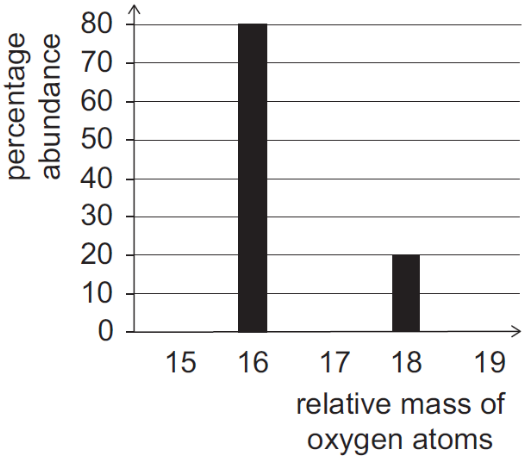
[NSAA, 2019S1Q40]

A mass spectrometer is a device that can measure the mass of isotopes. It shows this data as a spectrum, giving both the relative mass and the percentage abundance of each isotope.

The charts indicate the relative mass and percentage abundance for lithium atoms, carbon atoms and oxygen atoms found in a sample taken from a nuclear reactor.







Using this data, what is the largest possible relative molar mass of lithium carbonate?

(A) 35

(B) 38

(C) 45

(D) 67

(E) 74

(F) 75

(G) 81

[NSAA, 2019S1Q41]

The following information about metals labelled P, Q, R and S is given.

- Metals P and S can be extracted by electrolysis, but not by reaction with carbon.
- Metals Q and R can be extracted by reaction with carbon.
- Metal S forms positive ions more readily than metal P.
- Metal R reacts with the oxide of metal Q.

What is the order of reactivity of these four metals, starting with the most reactive?

(A) P, S, Q, R

(B) P, S, R, Q

(C) Q, R, P, S

(D) Q, R, S, P

(E) R, Q, P, S

(F) R, Q, S, P

(G) S, P, Q, R

(H) S, P, R, Q

[NSAA, 2019S1Q42]

A simple ion of an element with atomic number x has a mass number of $(2x + 2)$.
The ion has a charge of -2.
How many protons, neutrons and electrons are present in this ion?

	protons	*neutrons*	*electrons*
(A)	$x-2$	$x+4$	$x-2$
(B)	$x-2$	$x+4$	x
(C)	$x-2$	$x+4$	$x+2$
(D)	x	$x+2$	$x-2$
(E)	x	$x+2$	x
(F)	x	$x+2$	$x+2$

[NSAA, 2019S1Q43]

A 116 g sample of an oxide of iron contains 84 g of iron.

Which of the following is the empirical formula of this oxide of iron?

(A_r values: O = 16; Fe = 56)

(A) FeO

(B) Fe_2O_2

(C) Fe_3O_2

(D) Fe_2O_3

(E) Fe_3O_4

[NSAA, 2019S1Q44]

Which of the following chemical equations represent(s) a redox reaction?

1 $2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$

2 $Al^{3+} + 3e^- \rightarrow Al$

3 $2Ag^+ + 2OH^- \rightarrow Ag_2O + H_2O$

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q45]

X is an anhydrous salt of iron containing one type of cation and one type of anion.

An aqueous solution of X gives a white precipitate when aqueous barium chloride is added in the presence of hydrochloric acid.

On adding aqueous sodium hydroxide to an aqueous solution of X, a brown precipitate formed immediately.

The relative atomic mass of iron is 56, and its atomic number is 26.

What is the relative molar mass of X?

(A_r values: C = 12; N = 14; O = 16; S = 32; Cl = 35.5; Br = 80)

(A) 127

(B) 152

(C) 162.5

(D) 208

(E) 264

(F) 272

(G) 360

(H) 400

[NSAA, 2019S1Q46]

In the electrolysis of dilute sulfuric acid, hydrogen gas is formed at the negative electrode (cathode) and oxygen gas is formed at the positive electrode (anode).

If 100 g of hydrogen gas is formed in the electrolysis of dilute sulfuric acid, what mass of oxygen gas is also formed?

(A_r values: H = 1; O = 16)

(A) 50 g

(B) 100 g

(C) 200 g

(D) 800 g

(E) 1600 g

[NSAA, 2019S1Q47]

0.005 mol of a chloride of element X was dissolved in water and then reacted with excess silver nitrate solution to form a precipitate of silver chloride, AgCl. This precipitate is the only product of this reaction that contains chlorine.

After filtering, washing and drying, the mass of the precipitate was recorded to be 1.435 g.

Which of the following could be the formula of the chloride of X?

(M_r value: AgCl = 143.5)

(A) X_5Cl

(B) X_2Cl

(C) XCl

(D) XCl_2

(E) XCl_5

[NSAA, 2019S1Q48]

A chemical equation that represents the reaction of phosphorus with concentrated nitric acid is:

$$P_4 + w\,HNO_3 + H_2O \rightarrow x\,H_3PO_4 + y\,NO + z\,NO_2$$

What is the value of the sum $w + x + y + z$?

(A) 24

(B) 28

(C) 30

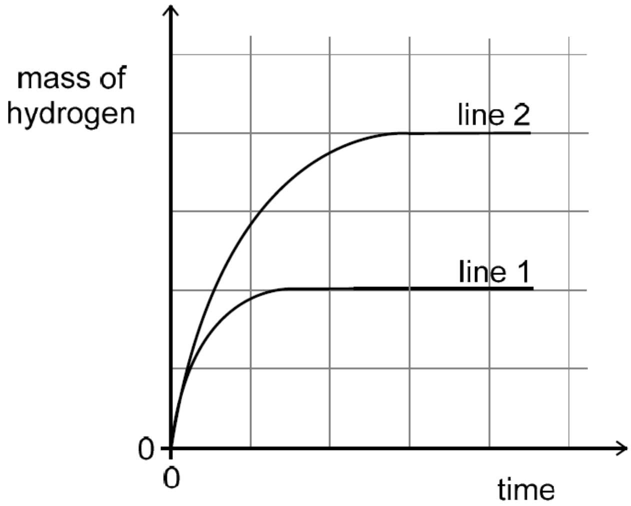
(D) 32

(E) 36

[NSAA, 2019S1Q49]

A 2.40 g lump of magnesium was added to 500 cm^3 of a 2.00 mol dm^{-3} solution of HCl in a conical flask that was on an electronic balance. The neck of the flask was plugged with cotton wool, and the decrease in mass of the flask and its contents was recorded at regular intervals.

The mass of the hydrogen released (equal to the mass loss recorded) was plotted against time. The result is line 1 on the graph.



Which of the following experiments performed under the same conditions would give line 2?

(A_r value: Mg = 24.0)

(A) a 2.40 g lump of magnesium added to 500 cm^3 of 2.00 mol dm^{-3} H_2SO_4

(B) 2.40 g of magnesium powder added to 500 cm^3 of 2.00 mol dm^{-3} HCl

(C) a 2.40 g lump of magnesium added to 1000 cm^3 of 2.00 mol dm^{-3} HCl

(D) a 4.80 g lump of magnesium added to 500 cm^3 of 2.00 mol dm^{-3} HCl

(E) 4.80 g of magnesium powder added to 500 cm^3 of 2.00 mol dm^{-3} HCl

[NSAA, 2019S1Q50]

A technician needs to separate three liquids (X, Y and Z) which have been accidentally mixed together. None of the liquids react with each other.

liquid	X	Y	Z
boiling point / °C	65	51	100
density / g cm^{-3}	0.79	0.68	1.00

X and Z are miscible, but Y is immiscible with both X and Z.

The technician uses a separating funnel to separate the upper and lower layers of the mixture.

What should the technician do next to maximise separation of the three liquids?

(A) distil the lower layer at 51 °C

(B) distil the lower layer at 65 °C

(C) distil the lower layer at 100 °C

(D) distil the upper layer at 51 °C

(E) distil the upper layer at 65 °C

(F) distil the upper layer at 100 °C

[NSAA, 2019S1Q51]

In each of the following procedures an excess of the metal is added to 1.0 dm^3 of a 1.0 mol dm^{-3} solution of the acid.

copper added to sulfuric acid

iron added to hydrochloric acid

magnesium added to sulfuric acid

zinc added to hydrochloric acid

Which row in the following table identifies combinations of metal and acid that will react and produce the largest, and the smallest, theoretical mass of anhydrous salt?

(M_r values: $CuSO_4 = 160$; $FeCl_2 = 127$; $MgSO_4 = 120$; $ZnCl_2 = 136$)

	reaction that produces the largest mass of salt	*reaction that produces the smallest mass of salt*
(A)	Cu and H_2SO_4	Fe and HCl
(B)	Cu and H_2SO_4	Mg and H_2SO_4
(C)	Fe and HCl	Zn and HCl
(D)	Mg and H_2SO_4	Fe and HCl
(E)	Mg and H_2SO_4	Zn and HCl
(F)	Zn and HCl	Mg and H_2SO_4

[NSAA, 2019S1Q52]

3.4 g of an impure sample of silicon tetrachloride is reacted with water. The mixture is then filtered and the resulting solution made up to 250 cm³.

$$SiCl_4(l) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$$

12.5 cm³ of this solution is neutralised exactly by 20.0 cm³ of 0.100 mol dm^{-3} sodium hydroxide.

What is the percentage purity of the silicon tetrachloride?

(M_r value: $SiCl_4 = 170$. Assume that the impurity does not react.)

(A) 1.7%

(B) 2.5%

(C) 10%

(D) 32%

(E) 50%

[NSAA, 2019S1Q53]

The Haber process is represented by the following chemical equation:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

What is the overall enthalpy change for the reaction?

(Bond enthalpies: $N \equiv N = 945$ kJ mol^{-1}; $H-H = 435$ kJ mol^{-1}; $N-H = 390$ kJ mol^{-1})

(A) +90 kJ mol^{-1}

(B) −90 kJ mol^{-1}

(C) +990 kJ mol^{-1}

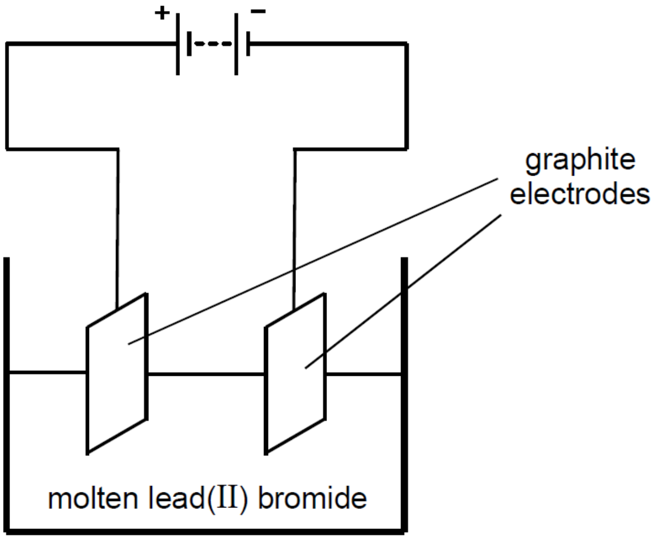
(D) −990 kJ mol^{-1}

(E) +1080 kJ mol^{-1}

(F) −1080 kJ mol^{-1}

[NSAA, 2019S1Q54]

The diagram shows the electrolysis of molten lead (II) bromide, $PbBr_2$, using graphite electrodes to separate the compound into its elements.



Which of the following statements about this electrolysis is/are correct?

1 Lead is formed at the negative electrode.

2 Electrons flow through the external circuit away from the positive electrode towards the negative electrode.

3 Bromine molecules and lead are produced in a 2 : 1 molar ratio.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

Part D

[NSAA, 2019S1Q55]

Which of the following statements is/are correct for both bacterial cells and sperm cells?

1 The cell can divide.

2 The cell contains DNA.

3 The cell has a cell wall.

4 The cell has a nucleus.

5 The cell can carry out respiration.

(A) 2 only

(B) 4 only

(C) 1 and 2 only

(D) 2 and 5 only

(E) 3 and 4 only

(F) 3 and 5 only

(G) 1, 2 and 5 only

(H) 1, 3 and 4 only

[NSAA, 2019S1Q56]

Which one of the following statements about cells or tissues is correct?

(A) Any adult stem cells can naturally give rise to all tissue.

(B) Endocrine glands secrete enzymes into the bloodstream.

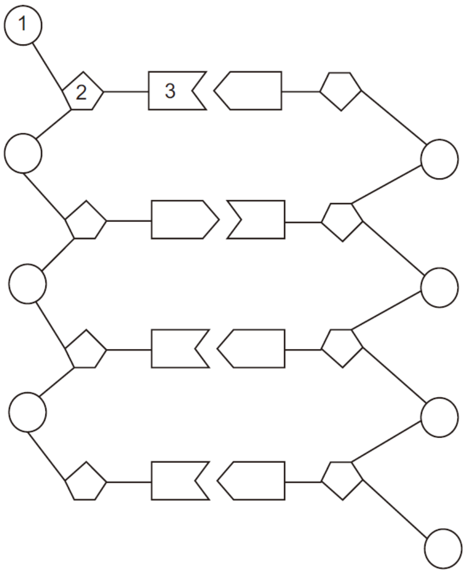
(C) Embryonic stem cells divide by meiosis to form all cell types.

(D) Receptor cells send chemical impulses along neurones.

(E) The stomach wall contains a tissue that enables movement of food.

[NSAA, 2019S1Q57]

The diagram represents a section of DNA.



What do the parts labelled 1, 2 and 3 represent?

	1	*2*	*3*	*1* and *2* and *3*
(A)	base	phosphate	glycerol	gene
(B)	base	sugar	amino acid	gene
(C)	phosphate	sugar	base	nucleotide
(D)	phosphate	sugar	base	DNA strand
(E)	sugar	phosphate	base	nucleotide
(F)	sugar	phosphate	fatty acid	DNA strand

[NSAA, 2019S1Q58]

Using the information in the table, which animal (**A-F**) is most at risk of extinction?

animal	*geographic range*	*habitat tolerance*	*population size*
(A)	restricted	broad	large
(B)	extensive	broad	large
(C)	restricted	narrow	small
(D)	extensive	narrow	small
(E)	restricted	broad	small
(F)	extensive	broad	small

[NSAA, 2019S1Q59]

An ecologist used a 50 cm × 50 cm square quadrat to estimate the number of meadow buttercups present in a field with an area of 50 m^2. The quadrat was distributed randomly on ten occasions in the field and the number of buttercups counted in each quadrat.

quadrat	*number of buttercups*
1	3
2	10
3	0
4	4
5	21
6	19
7	6
8	11
9	15
10	3

How many buttercups were there estimated to be in the 50 m^2 field?

(A) 368

(B) 460

(C) 920

(D) 1840

(E) 4600

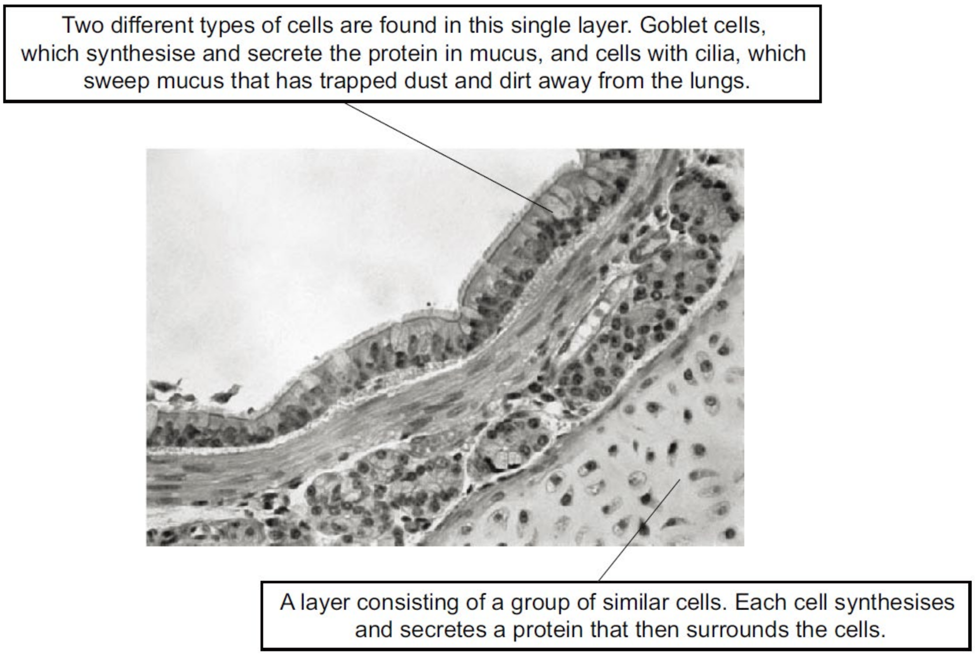
(F) 18 400

(G) 45 000

[NSAA, 2019S1Q60]

The photomicrograph shows a section through the wall of a human bronchus, one of the tubes which carries air towards the lungs.

A student studying this structure annotated the photomicrograph by describing the cells found in two different layers in the wall of the bronchus.



The student used these observations to write some conclusions.

Which of the following conclusions is/are correct?

1 The two different layers are both tissues.

2 The bronchus can be described as an organ.

3 Amino acids are found in the cytoplasm of cells in each layer.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 1, 2 and 3

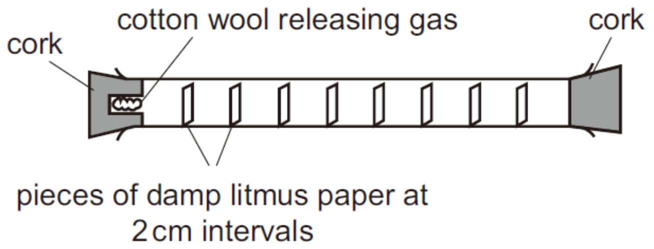
[NSAA, 2019S1Q61]

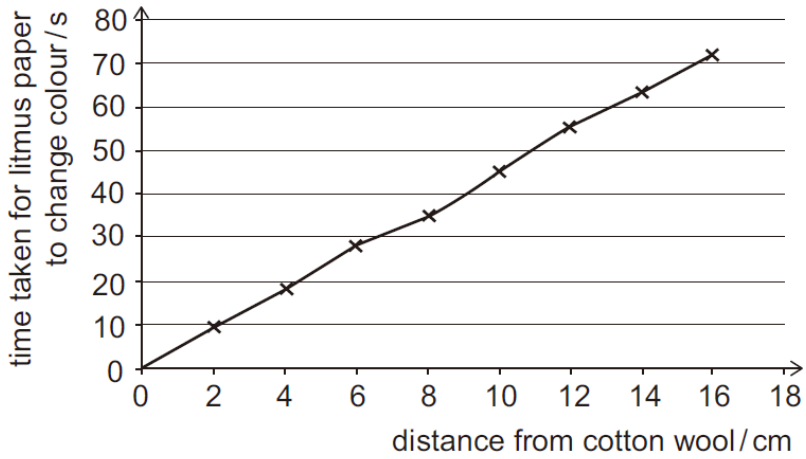
A student carried out an investigation using the diffusion of a gas along a tube to model movement of gases in the air space of a leaf. An alkaline gas was released from a solution that evaporated from the cotton wool.

As the gas diffused, it caused damp litmus paper to change colour.

The time was recorded when each piece of litmus paper changed colour.

The apparatus and a graph of the results are shown below.





Which of the following statements about the investigation is/are correct?

1 The dependent variable has been plotted on the x-axis.

2 If diffusion of the gas was slower, the graph line would become steeper.

3 If a more concentrated solution was used in an identical set of apparatus, the data collected would result in a line on the graph below the points plotted for the original gas.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

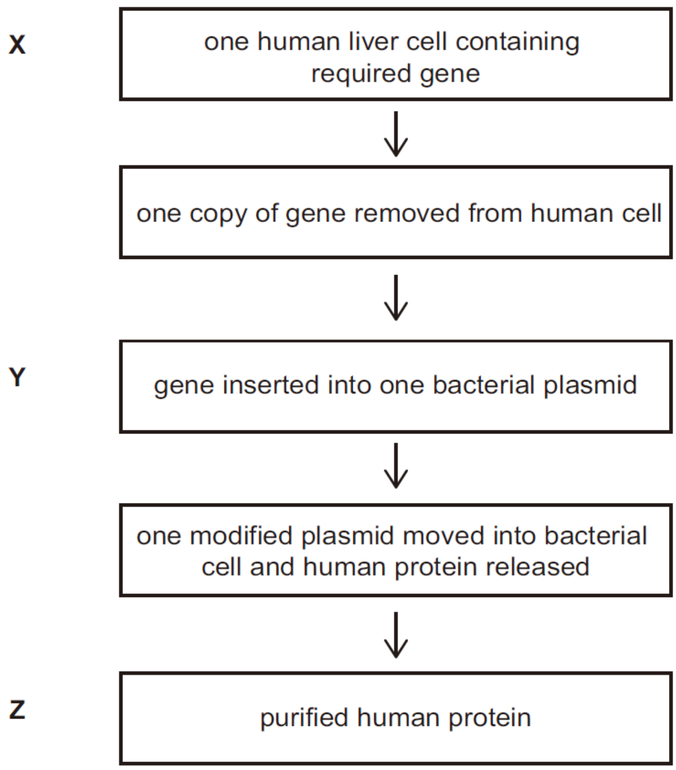
(F) 1 and 3 only

(G) 2 and 3 only

[NSAA, 2019S1Q62]

A bacterium was genetically modified by inserting a human gene into a plasmid. A plasmid is a small circle of DNA that can be used to transfer genes into bacterial cells. These modified bacteria then secrete the protein that the human gene codes for. The gene contains a sequence of bases that is not repeated anywhere else in its DNA and is not found in the DNA of other organisms. This sequence of bases is found in every allele of this gene.

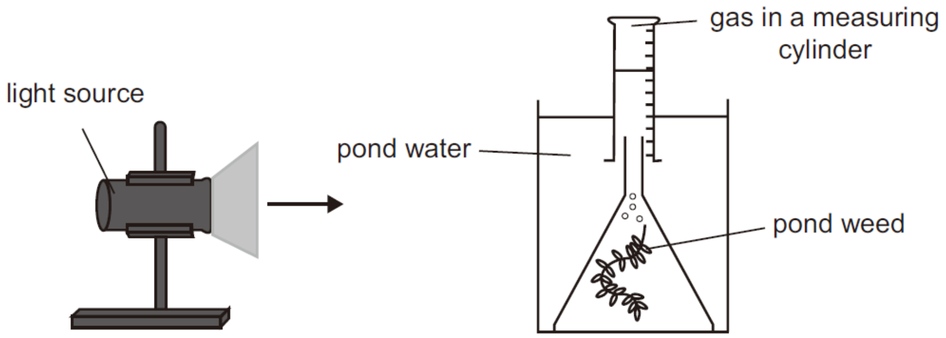
Assuming that no mutations occur, how many copies of this base sequence would you expect to find at each of the stages X, Y and Z?



	number of copies of DNA sequence found		
	stage X	*stage* Y	*stage* Z
(A)	1	1	0
(B)	1	2	1
(C)	1	1	1
(D)	2	1	0
(E)	2	1	1
(F)	2	2	0

[NSAA, 2019S1Q63]

A student set up an experiment to measure the rate of photosynthesis, as shown in the diagram.



Data was collected and plotted on a graph.

If plotted, which of the following variables would give a gradient that is directly proportional to the rate of photosynthesis?

(All other variables were kept constant.)

	x-axis	y-axis
1	time	volume of CO_2 released
2	time	number of gas bubbles released per minute
3	volume of oxygen released	time

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q64]

Bacteria reproduce asexually by dividing into two by binary fission.

Which of the following statements is/are correct about binary fission in bacteria?

1 As it is a form of asexual reproduction, there cannot be any variation in the offspring.

2 It can lead to a repeated doubling in population size if there are no limiting factors.

3 If binary fission occurs every 20 minutes, one bacterium would become 72^2 bacteria in 24 hours.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q65]

Which of the following may stay the same when a mutation occurs in a human gene that codes for a protein?

1 the genotype of the organism's offspring

2 the phenotype of the organism

3 the sequence of amino acids in the protein

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q66]

A child is affected by a dominant genetic condition. All of his cells have the same genotype. The allele associated with this condition is not present in either of his parents.

Which of the following statements could explain this?

1 A mutation occurred during meiosis in his father.

2 A random mutation occurred in his DNA after he was born.

3 Both of his grandmothers had the condition.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q67]

Phosphatase enzymes break the bond between a phosphate group and the rest of a molecule.

Phenolphthalein phosphate (PPP) is colourless and is a substrate for phosphatase enzymes.

1 The phosphate group of PPP can be removed by the phosphatase enzyme to produce the indicator phenolphthalein.

2 Phenolphthalein goes pink in alkaline conditions.

Five tubes were set up with equal concentrations of PPP and a plant phosphatase enzyme.

Each tube was at a different pH. The tubes were incubated at the same temperature. After 10 minutes Na_2CO_3 was then added to each tube until a pH of 9.5 was reached. The colour was observed immediately and then again after another 5 minutes.

tube	1	2	3	4	5
pH of the initial reaction	3.2	4.2	5.2	8.2	9.2
colour immediately after Na_2CO_3	pale pink	pink	dark pink	colourless	colourless
colour after another 5 minutes	pale pink	pink	dark pink	colourless	colourless

Which of the following statements is/are correct?

1 Na_2CO_3 solution inhibited the activity of the phosphatase enzyme.

2 More substrate was produced in conditions of high acidity compared to low acidity.

3 The optimum pH for this plant phosphatase must be 5.2.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

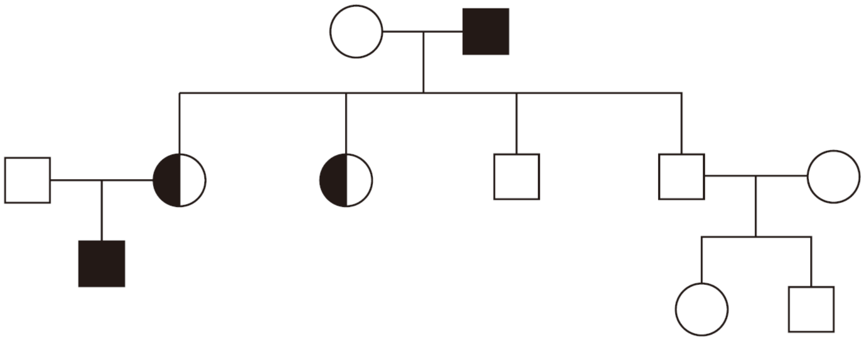
(H) 1, 2 and 3

[NSAA, 2019S1Q68]

A gene found on the X chromosome in humans has two alleles, dominant and recessive. Individuals who have only recessive alleles have a condition that affects their eyesight.

The inheritance of the condition in one family is shown in the family tree.

Key
- female without the condition
- female carrier
- male without the condition
- male with the condition



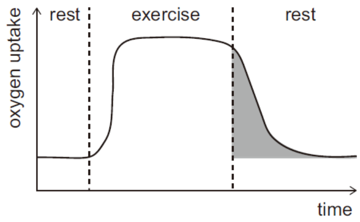
If one living skin cell from each member of this family were analysed, how many of the following alleles would be found?

	number of copies of the recessive allele	*number of copies of the dominant allele*
(A)	2	7
(B)	2	12
(C)	2	14
(D)	4	7
(E)	4	12
(F)	4	14
(G)	6	7
(H)	6	12

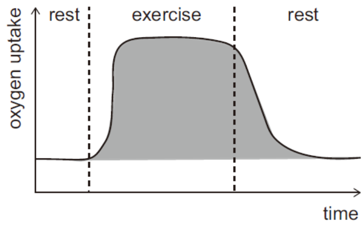
[NSAA, 2019S1Q69]

The graphs below show the oxygen uptake before, during and after a period of strenuous physical exercise.

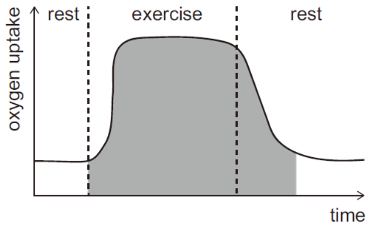
Which shaded area correctly represents the additional oxygen taken in to repay the oxygen debt acquired through anaerobic respiration?



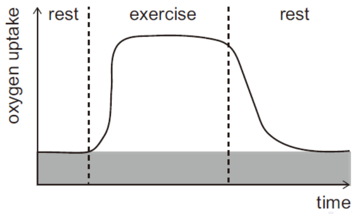
(A)



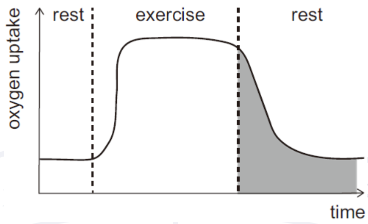
(B)



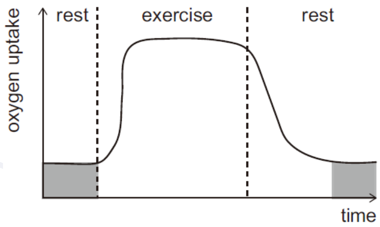
(C)



(D)



(E)



(F)

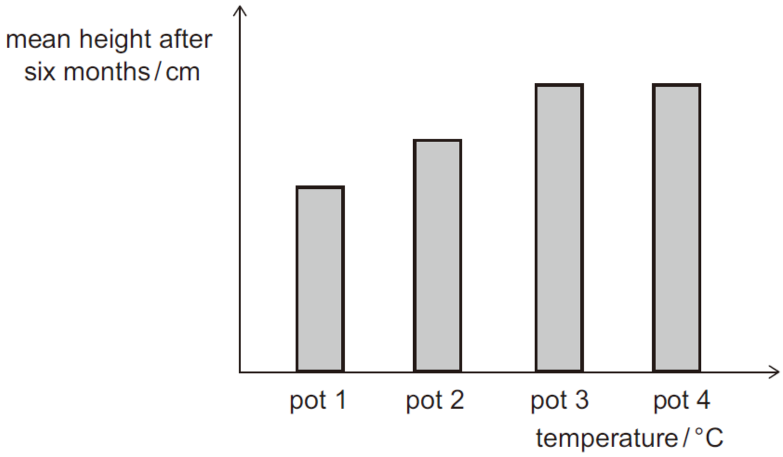
[NSAA, 2019S1Q70]

An investigation was carried out using clones of one plant.

Twenty plants of the same initial height were selected and divided into four equal groups. Each group was grown for six months and their environments were controlled as follows:

- kept at a different temperature to each other
- grown in a pot with an equal mass of soil with the same nutrients
- watered with an equal volume of water
- kept in the same light intensity

After six months, the height of the plants was measured. The mean height of the plants in each pot was calculated. The results are shown in the chart.



Which of the following statements could explain the results?

1 The difference in mean height between plants in pot 1 and plants in pot 2 could be due to the environment.

2 The mean height of plants in pot 4 equals that of plants in pot 3 because of another environmental factor in addition to temperature.

3 The mean height of plants in pot 3 equals that of plants in pot 4 because of the genotype of the plants.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

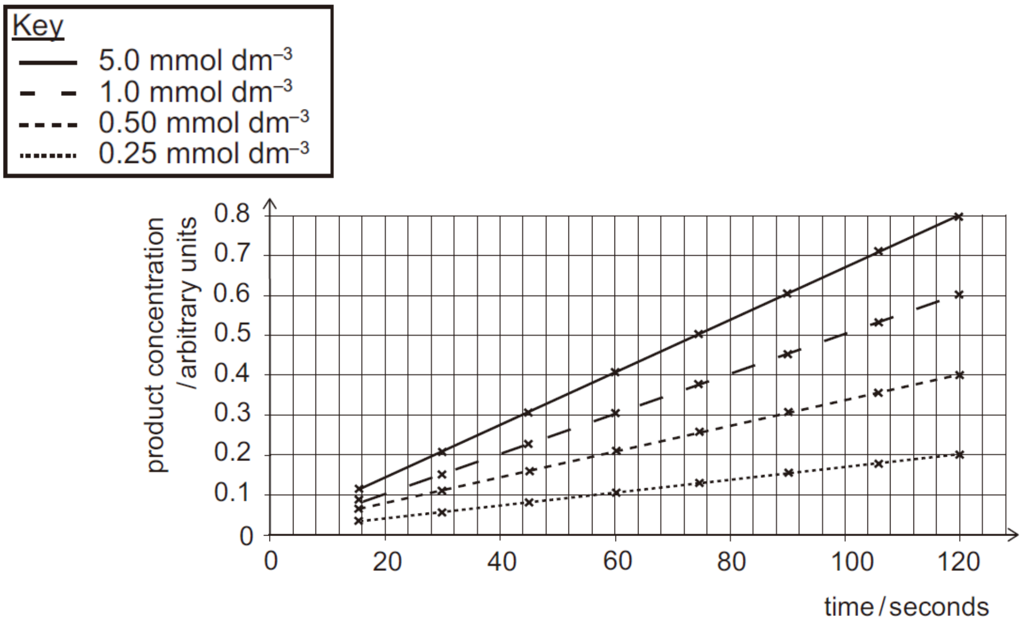
[NSAA, 2019S1Q71]

An investigation was carried out on the effect of substrate concentration on an enzyme-controlled reaction.

Four different concentrations of substrate were tested. In each case, the concentration of product was measured at regular intervals following the introduction of the substrate.

All the other variables were kept constant.

The results obtained are shown on the graph.



Which of the following statements is/are correct?

1 As substrate concentration increases, the time taken to produce 0.2 arbitrary units of product increases.

2 Doubling the substrate concentration always doubles the rate of the reaction.

3 The average rate of reaction for a substrate concentration of 1.0 mmol dm^{-3} is 0.005 arbitrary units per second.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2019S1Q72]

The sequence of a coding section of DNA is shown below.

CTAGTCTGGTGGCTACGTCCTCCTCTACTATGGCTAGTCGTCTGGTGGCTA

The number of each type of amino acid coded for by this sequence of DNA bases is shown in the table.

Amino acid coded for	*Number of this type of amino acid present*
Arg	1
Leu	6
Pro	2
Trp	5
Val	3

What is the correct sequence of amino acids coded for by this sequence of DNA?

(A) Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Val-Leu-Val-Val-Trp-Trp-Trp

(B) Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Trp-Val-Val-Val-Val

(C) Leu-Val-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp

(D) Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Val-Leu-Val-Val-Trp-Trp-Trp-Leu

(E) Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Trp-Val-Val-Val-Val-Leu

(F) Leu-Leu-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp-Val

(G) Leu-Val-Trp-Trp-Leu-Leu-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp-Leu

(H) Leu-Val-Trp-Trp-Leu-Arg-Pro-Pro-Leu-Leu-Trp-Leu-Val-Val-Trp-Trp-Leu

Part E

[NSAA, 2019S1Q73]

Find the area of the shape bounded by the four lines:

$$2y + x = 4$$
$$x = -6$$
$$x = 0$$
$$y = 0$$

(A) 4

(B) 12

(C) 21

(D) 25

(E) 27

(F) 30

[NSAA, 2019S1Q74]

A hydroelectric power station uses the water in a reservoir to power the generators. The water falls through a vertical height of 150 m to the turbines which power the generators.

The efficiency of the power station is 90% and the output power of the power station is 1800 MW.

The gravitational field strength is 10 N kg^{-1} and the density of water is 1000 kg m^{-3}.

What volume of water passes through the turbines in one minute?

(A) 6.48×10^4 m^3

(B) 7.20×10^4 m^3

(C) 8.00×10^4 m^3

(D) 6.48×10^7 m^3

(E) 7.20×10^7 m^3

(F) 8.00×10^7 m^3

[NSAA, 2019S1Q75]

The curve

$$y = x^3 + px^2 + qx + r$$

has a local maximum when $x = -1$ and a local minimum when $x = 3$.

What is the value of p?

(A) -9

(B) -3

(C) -1

(D) 1

(E) 3

(F) 9

[NSAA, 2019S1Q76]

A car P of mass 1000 kg is travelling north at 30 m s^{-1} along a straight, horizontal road when it hits another car Q which is directly ahead of P and travelling in the same direction. Car Q has a mass of 500 kg and is travelling at 20 m s^{-1}.

The collision lasts for 0.20 s and immediately after the collision car Q is moving north at 30 m s^{-1}.

What is the speed of P immediately after the collision and what is the size of the average resultant force that acts on Q during the collision?

(Assume that no external forces act on the cars during the collision.)

	speed of P / m s^{-1}	*average force on Q* / N
(A)	20	25000
(B)	20	50000
(C)	20	100000
(D)	20	125000
(E)	25	25000
(F)	25	50000
(G)	25	100000
(H)	25	125000

[NSAA, 2019S1Q77]

It is given that

$$7\cos x + \tan x \sin x = 5$$

where $0° < x < 90°$.

What are the possible values of $\tan x$?

(A) $\frac{1}{2}$ or $\frac{1}{3}$

(B) $\frac{1}{\sqrt{3}}$ or $\frac{1}{2\sqrt{2}}$

(C) $\frac{\sqrt{3}}{2}$ or $\frac{2\sqrt{2}}{3}$

(D) $\sqrt{3}$ or $2\sqrt{2}$

(E) 3 or 2

[NSAA, 2019S1Q78]

A metal wire of length 0.50 m has a uniform cross-sectional area of 4.0×10^{-7} m^2.

There is a current of 4.0 A in the wire.

What is the potential difference across the ends of the wire?

(resistivity of the metal 1.6×10^{-7} Ω m)

(A) 0.05 V

(B) 0.20 V

(C) 0.80 V

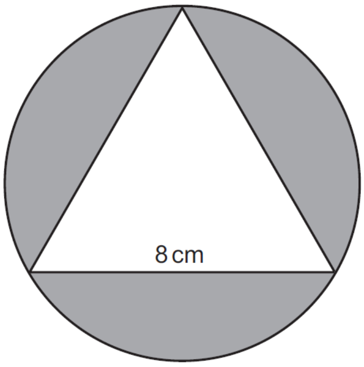
(D) 3.2 V

(E) 5.0 V

(F) 20 V

[NSAA, 2019S1Q79]

An equilateral triangle of side 8 cm is drawn so that its vertices lie on the circumference of a circle, as shown in the diagram.



What is the total of the three areas shaded in the diagram, in cm²?

(A) $8(2\pi - 3)$

(B) $24(\pi - \sqrt{3})$

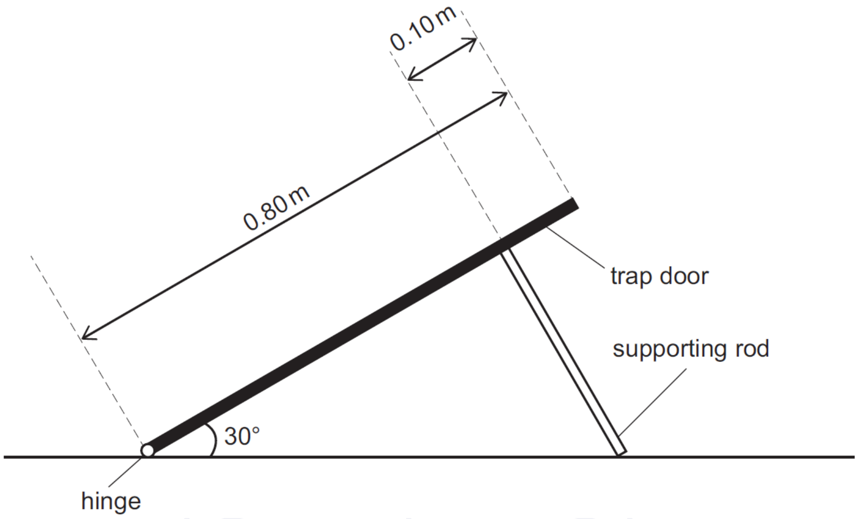
(C) $48(4\pi - \sqrt{3})$

(D) $\frac{16}{3}(4\pi - 6 - 3\sqrt{3})$

(E) $\frac{16}{3}(4\pi - 3\sqrt{3})$

[NSAA, 2019S1Q80]

A uniform square trap door of side 0.80 m and mass 14 kg has a smooth hinge at one edge and is held open at an angle of 30° to the horizontal. It is supported by a single rigid rod placed so that it meets the surface of the trap door at 90° at a distance 0.10 m from the top edge of the trap door, as shown.



What is the normal contact force exerted on the trap door by the rod?
(gravitational field strength = 10 N kg^{-1})

(A) 40 N

(B) $35\sqrt{3}$ N

(C) $40\sqrt{3}$ N

(D) 80 N

(E) $80\sqrt{3}$ N

(F) $280\frac{\sqrt{3}}{3}$ N

[NSAA, 2019S1Q81]

Which one of the following is the real solution of the equation

$$3 \times 5^{2x+1} - 5^x - 2 = 0$$

(A) $x = \log_5\left(\frac{1}{3}\right)$

(B) $x = \log_5\left(\frac{2}{5}\right)$

(C) $x = \log_5\left(\frac{3}{5}\right)$

(D) $x = \log_5\left(\frac{2}{3}\right)$

(E) $x = \log_5\left(\frac{5}{3}\right)$

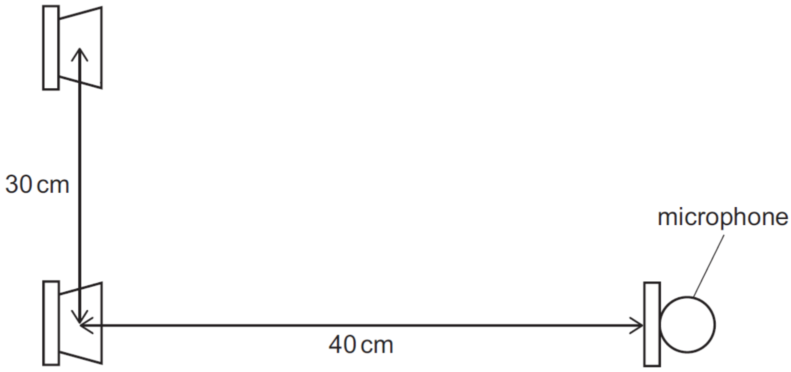
(F) $x = \log_5\left(\frac{5}{2}\right)$

[NSAA, 2019S1Q82]

Two small loudspeakers are placed side by side 30 cm apart.

They are connected to the same signal generator so that they emit sound of frequency 400 Hz in phase with one another.

The sounds both reach a microphone placed 40 cm directly in front of one of the two loudspeakers as shown.



What is the phase difference between waves from the loudspeakers as they arrive at the microphone?

(speed of sound = 320 m s^{-1})

(A) 30°

(B) 36°

(C) 45°

(D) 60°

(E) 72°

(F) 90°

(G) 120°

[NSAA, 2019S1Q83]

For a particular function $f(x)$, it is given that:

$$\int_{-2}^{2} 2f(x)\,dx + \int_{2}^{4} f(x)\,dx = 4$$

and also:

$$\int_{-2}^{2} 5f(x)\,dx - \int_{-2}^{4} f(x)\,dx = 7$$

Find the value of $\int_{2}^{4} f(x)\,dx$.

(A) $\frac{1}{3}$

(B) $\frac{11}{7}$

(C) $\frac{11}{6}$

(D) $\frac{13}{6}$

(E) $\frac{13}{3}$

[NSAA, 2019S1Q84]

An astronaut on the Moon throws a ball vertically upwards. The ball has a mass of 2.0 g and is thrown upwards at 80 m s^{-1}.

What is the maximum height gained by the ball?

(gravitational field strength close to the Moon's surface = 1.6 N kg^{-1})

(A) 25 m

(B) 50 m

(C) 320 m

(D) 2000 m

(E) 3200 m

(F) 4000 m

[NSAA, 2019S1Q85]

Given that

$$f(x) = \int_0^x (3 + 2t)^7 \, \mathrm{d}t$$

what is the coefficient of x^4 in the expansion of $f(x)$ in powers of x?

(A) 70

(B) 162

(C) $\frac{2835}{4}$

(D) 3024

(E) 5670

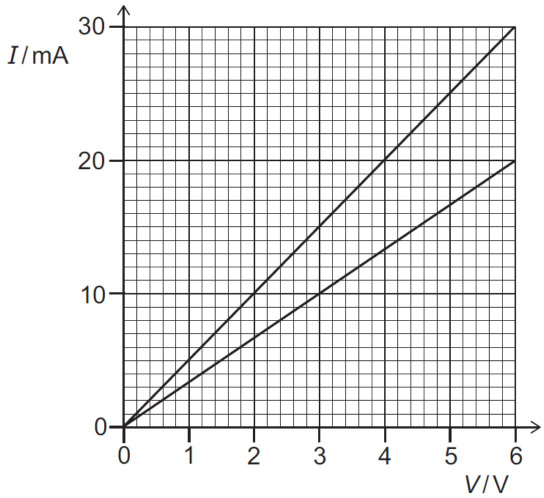
(F) 15 120

(G) 22 680

[NSAA, 2019S1Q86]

A student has one 300 Ω resistor and another resistor of resistance R.

The student plots a graph of current I against potential difference V for the 300 Ω resistor and then for both resistors connected in parallel.



What is the resistance R?

(A) 3.3 Ω

(B) 5.0 Ω

(C) 10 Ω

(D) 100 Ω

(E) 200 Ω

(F) 600 Ω

(G) 1000 Ω

[NSAA, 2019S1Q87]

The three internal angles in a triangle are α, β and θ, and

$$3\tan\alpha - 2\sin\beta = 2$$
$$5\tan\alpha + 6\sin\beta = 8$$

What is the value of θ in degrees?

(A) 15

(B) 45

(C) 75

(D) 105

(E) 135

[NSAA, 2019S1Q88]

A light, vertical, copper wire of length 2.4 m and uniform cross-sectional area 2.0×10^{-6} m^2 supports a load of mass 4.0 kg.

The Young modulus of copper is 1.2×10^{11} Pa.

What is the strain energy in the wire?

(gravitational field strength = 10 N kg^{-1}; assume that the wire obeys Hooke's law and that the cross-sectional area remains constant)

(A) 8.0×10^{-5} J

(B) 1.7×10^{-4} J

(C) 4.0×10^{-4} J

(D) 8.0×10^{-3} J

(E) 4.0×10^{-2} J

(F) 1.6×10^{-2} J

[NSAA, 2019S1Q89]

Find the complete set of values of x for which

$$x^3 - 2x^2 - 7x - 4 > 0$$

(A) $x < -1$

(B) $x > -1$

(C) $-1 < x < 4$

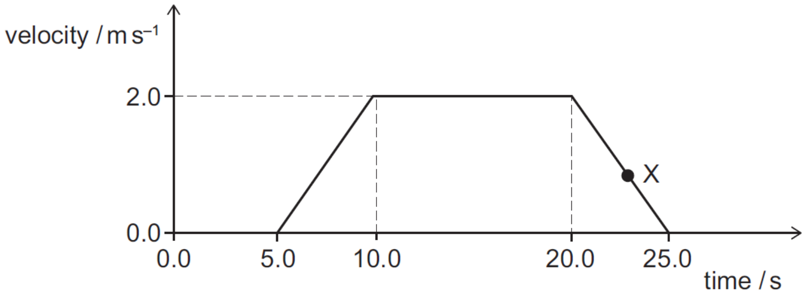
(D) $x < -1$ or $x > 4$

(E) $x < 4$

(F) $x > 4$

[NSAA, 2019S1Q90]

The velocity–time graph is for an 80 kg person in a lift that is moving vertically upwards.



What is the magnitude of the contact force between the person and the lift floor at the time corresponding to X?

(gravitational field strength = 10 N kg^{-1})

(A) 640 N

(B) 768 N

(C) 800 N

(D) 832 N

(E) 960 N

NSAA 2019 S2

NSAA 2019 S2
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 40 MINUTES

This paper is Section 2 of 2.

There are six questions in this paper, of which you should answer any **two**.

There are 20 marks for each question. In total 40 marks are available.

You should write your answers in the spaces provided in this question paper. Please complete this section in **black pen**. Pencil may be used for graphs and diagrams only.

You can use the blank pages inside this booklet for rough working or notes, but **no extra paper** is allowed. Only answers in the spaces indicated in the paper will be marked.

Calculators may be used in this section. Please record your calculator model in the box below:

Calculator model	

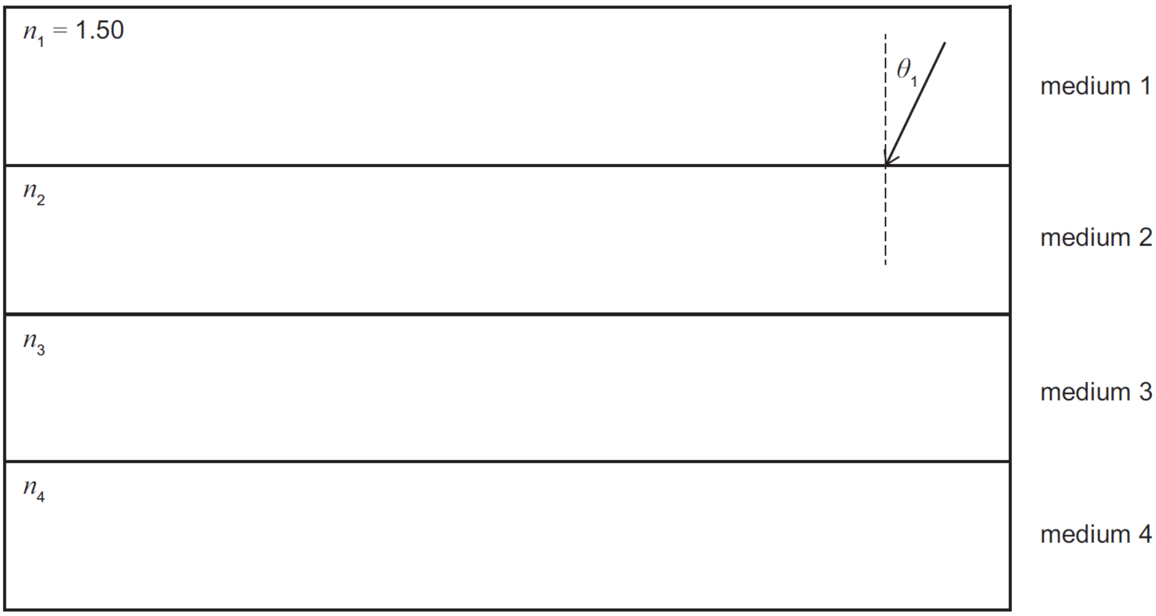
Write the numbers of the questions you answer in the order attempted in the boxes below:

Question number

[NSAA, 2019S2Q1]

(a) Four sheets of transparent material are placed on top of each other. A ray of light propagates through medium 1 and is incident at the boundary between medium 1 and medium 2 at an angle θ_1 to the normal. The refractive index of medium 1 is $n_1 = 1.50$.

(i) Given that $n_1 > n_2 > n_3 > n_4$ and n_4 is such that the ray of light does not enter medium 4, complete the diagram to show the path of a ray of light through the different mediums. Label the angles to the normal at the boundaries between medium 1 and 2, medium 2 and 3, and medium 3 and 4. [2]

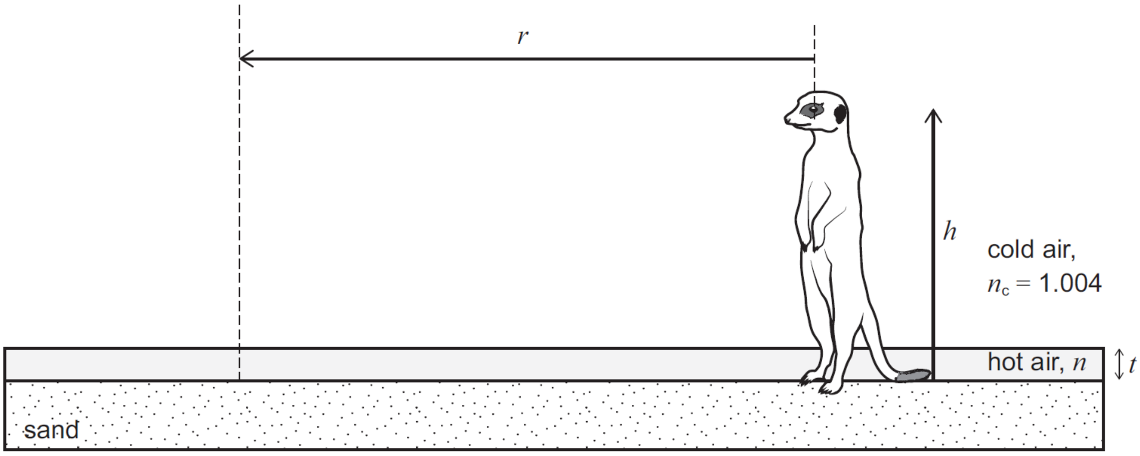


(ii) If the angle at which the light meets the normal to the boundary between medium 3 and medium 4 is the critical angle, find an expression for θ_1 in terms of n_1 and n_4. [3]

(iii) If the refractive index of each medium is given by $n_m = 1.50 \times (0.99)^{m-1}$, where m has values 1, 2, 3, and 4, find the minimum value of θ_1 for total internal reflection to occur at the boundary between medium 3 and medium 4. [2]

(b) A meerkat is in a desert on a hot day with a clear blue sky above the sand. A thin layer of air, of thickness t, above the sand is so hot that it has a lower refractive index, n, than the cold air directly above it. The cold air has a refractive index, $n_c = 1.004$.The meerkat has height h where $h \gg t$. The meerkat believes that he is standing on an "island" of sand of radius r, with what appears to be water all around him. He thinks that there is water because at distances greater than r away from him he sees a reflection of the blue sky when he is looking below the horizon towards the ground.

(i) On the diagram, draw rays to show how light reaches the meerkat's eyes from the sky, by reflection, and from the sand, by refraction. [2]



(ii) Add to the diagram a critical ray showing the path of the light reaching the meerkat's eye from the edge of the "island". Find an expression for the angle this ray makes with the normal in terms of n_c and n. [3]

(iii) A giraffe stands at the same position as the meerkat. The giraffe has height H, where $H \gg h \gg t$. The giraffe thinks the edge of the "island" is at a distance R. Find an expression for $\frac{R}{r}$ in terms of H and h. [1]

(iv) Using your result from (ii), show that the radius of the meerkat's "island" is given by $r = \frac{anh}{\sqrt{bn_c^2 + kn^2}}$ and find the integer values of a, b and k. [3]

(v) As the day progresses the hot air warms up and its refractive index n reduces, but the cold air remains at the same temperature and with the same refractive index, n_c. By considering the expression for r from (iv), explain what happens to r as the hot air warms up. Does the meerkat think that the water is **getting closer, staying the same, or getting further away**? [2]

(c) The camera that took this photograph was placed at the bottom of a swimming pool. The area labelled A is a window above the pool. The area labelled B is the top surface of a step. Describe the path that the light has taken to reach the camera from A and from B. [2]

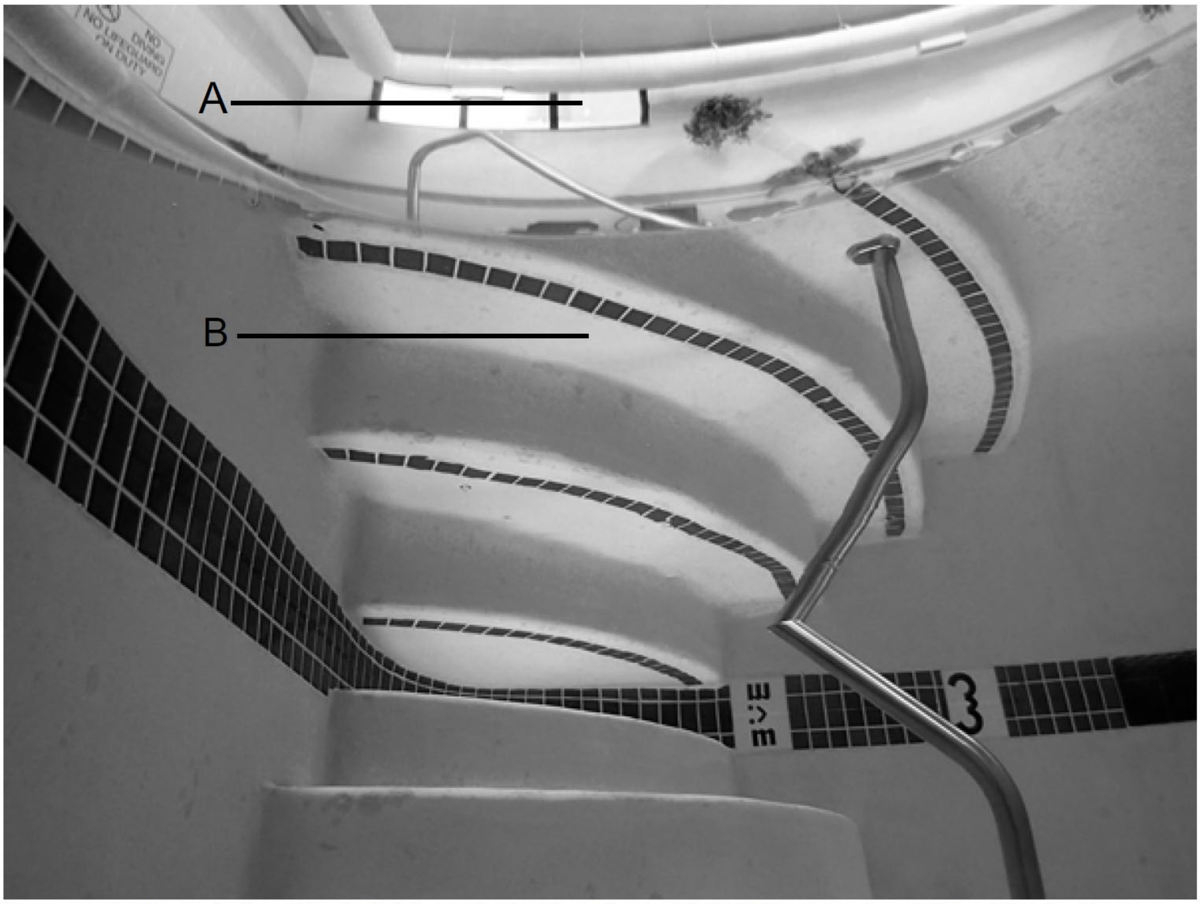
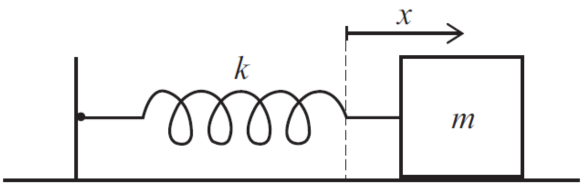


Image used with permission of the High School Physics Photo Contest © 2019 American Association of Physics Teachers

[NSAA, 2019S2Q2]

A mass m is placed on a frictionless horizontal surface and attached to the end of a light spring of spring constant k, and the spring is attached to a wall as shown in the diagram.



When displaced from equilibrium the mass oscillates with a frequency f. At time t the mass is at a displacement, x, from equilibrium and is moving with velocity, v.

(a) Write down an expression for the elastic potential energy, E_p, stored in the spring at time t. [1]

(b) Write down an expression for the kinetic energy, E_k, of the mass-spring system. [1]

(c) The rate of change of displacement, $\frac{\mathrm{d}x}{\mathrm{d}t} = v$ and the rate of change of velocity, $\frac{\mathrm{d}v}{\mathrm{d}t} = a$. [3]

Using the formula $\frac{\mathrm{d}E_p}{\mathrm{d}t} = \frac{\mathrm{d}E_p}{\mathrm{d}x} \times \frac{\mathrm{d}x}{\mathrm{d}t}$ show that $\frac{\mathrm{d}E_p}{\mathrm{d}t} = kxv$.

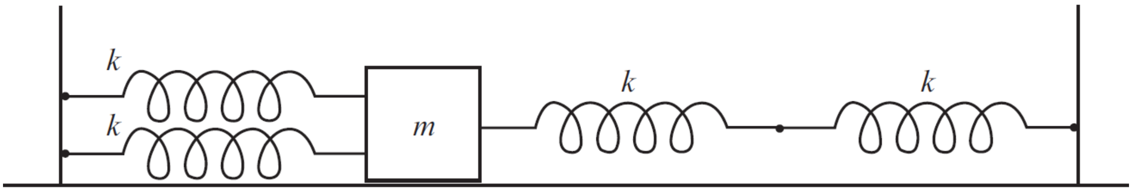
Using a similar method, find an expression for $\frac{\mathrm{d}E_k}{\mathrm{d}t}$ in terms of m, v and a.

Show all of your working.

(d) Give the physical reason in words why $\frac{\mathrm{d}(E_k+E_p)}{\mathrm{d}t} = 0$ [1]

(e) A formula for the acceleration of the mass is $a = -(2\pi f)^2 x$. Using your answers from part (c), the expression given in part (d) and this formula, find an expression for the frequency of the oscillation, f, in terms of m and k. Show all of your working. [3]

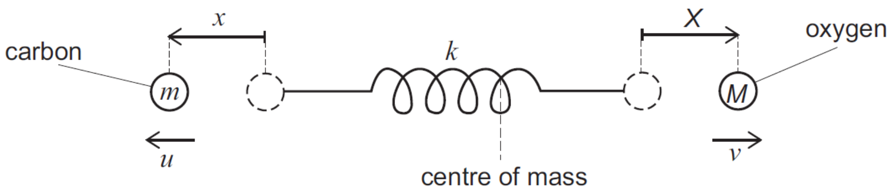
The mass is now placed on a frictionless surface between two walls. It is attached to the left wall by **two** identical, light springs in **parallel**, each of spring constant k and to the right wall by **two** identical springs in **series**, each of spring constant k.



(f) What is the new oscillation frequency, f_{new}, of this new system? [2]

A carbon monoxide molecule can be modelled as two different masses, m and M, each on one end of a light spring of spring constant, k.

When the molecule vibrates it does so such that the centre of mass of the molecule does not move. At time t the spring is extended and the masses are displaced from their equilibrium positions as shown in the diagram. The carbon atom, mass m, has moved a distance x to the left and is moving with a speed u to the left. The oxygen atom, mass M, has moved a distance X to the right and is moving with a speed v to the right.



(g) What is the total elastic potential energy stored in the spring in terms of k, x and X? [1]

(h) What is the total kinetic energy of the whole system in terms of m, u, M and v? [1]

(i) Explain in words why $MX = mx$. Hence deduce an expression for the acceleration, a_M, of mass M, in terms of the acceleration, a_m, of mass m. [2]

(j) Given that the total energy of the carbon monoxide molecule is constant, find an expression for the acceleration, a_m, of mass m, in terms of k, m, M and x. Hence deduce the frequency of the oscillation, f. [3]

(k) Calculate the frequency f of the vibration of the carbon monoxide molecule if the mass of the carbon atom is $12m_u$, the mass of the oxygen atom is $16m_u$ and $k = 2.0 \times 10^3$ N m^{-1}.

If this vibration was caused by an electromagnetic wave incident on the molecule, which part of the electromagnetic spectrum would this wave correspond to?

($m_u = 1.66 \times 10^{-27}$ kg. The wavelength of visible light ranges from 400 nm to 700 nm.) [2]

[NSAA, 2019S2Q3]

Data: Assume that the molar gas volume = 24.0 $dm^3\ mol^{-1}$ at room temperature and pressure (rtp).This question concerns the chemistry of tellurium, an element in Group 16 of the Periodic Table.

(a) What do you expect will be the maximum and minimum oxidation states of tellurium? Briefly explain your answer. [3]

(b) How do the electronegativities of the elements vary on descending Group 16? [1]

(c) Which hydride, H_2O or H_2Te, has the higher boiling point? Briefly explain your answer.[2]

Tellurium reacts directly with fluorine gas to form a dense gas, **A**, in which each molecule contains a single tellurium atom bonded to several fluorine atoms. In an experiment, 50 cm^3 of gas **A** is formed from 150 cm^3 of fluorine and a certain mass of tellurium, with all measurements made at room temperature and pressure.

(d) Calculate the formula of the gas **A**. [2]

(e) Predict the value(s) of the F– Te– F bond angles in **A**. [1]

(f) Calculate the minimum mass of tellurium needed to produce 50 cm^3 of **A**. [2]

(g) Calculate the density of gas **A** in g cm^{-3} at room temperature and pressure. [2]

(h) Calculate how many times denser gas **A** is than oxygen gas at room temperature and pressure. [1]

In another experiment, 5.0 g of tellurium is oxidised and dissolved in water to form 9.0 g of an acid with general formula $H_m TeO_n$. On neutralisation with aqueous KOH, 18 g of a salt is formed with general formula $K_m TeO_n$.

(i) Give an expression, in terms of m and n, for the oxidation state of the tellurium in the acid $H_m TeO_n$. [1]

(j) Calculate the relative molecular mass of the acid $H_m TeO_n$. [1]

(k) Calculate the values of m and n, and hence the formulae of the acid $H_m TeO_n$ and the salt formed on neutralisation. [2]

(l) Calculate the volume of a 2.0 mol dm^{-3} aqueous solution of KOH that would be needed to neutralise the 9.0 g of acid formed from 5.0 g of tellurium. [2]

[NSAA, 2019S2Q4]

Trifluoroethanoic acid, TFEA, is a carboxylic acid often used in organic chemistry and has the formula CF_3COOH. The density of TFEA is 1.489 g cm^{-3}.

(a) Draw the structure for trifluoroethanoic acid (TFEA). Indicate on your structure the approximate bond angles around each carbon. [2]

An aqueous solution of TFEA is made up by mixing 0.0700 mol of the pure acid with water and making the solution up to 100.0 cm^3.

(b) Calculate the volume of pure TFEA needed to make the solution. [3]

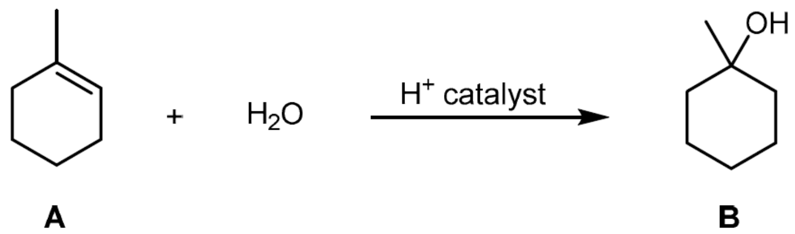
(c) Give an equation for the ionisation of TFEA in water. [1]

(d) Give an expression for the equilibrium constant for the ionisation of TFEA in water. [2]

(e) Given that the measured concentration of H^+ ions is 0.4119 mol dm^{-3}, calculate the value of the equilibrium constant. You may ignore the self-dissociation of water. [3]

A mixture of TFEA and trifluoroethanoic anhydride, $CF_3COOCOCF_3$, was used as the solvent system in a series of experiments to determine the standard enthalpy changes of hydration of various alkenes.

1-methylcyclohexene, **A**, may be hydrated in an acid-catalysed reaction as shown below:

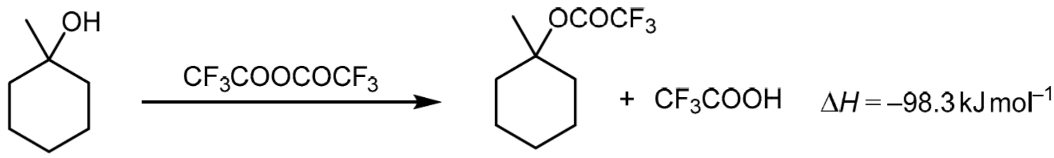


(f) How may this reaction be classified? Choose from: *addition*, *elimination*, *substitution*, *oxidation*, *addition polymerisation*. [1]

(g) Draw the structure of the intermediate initially formed when the H^+ catalyst reacts with alkene **A**. [1]

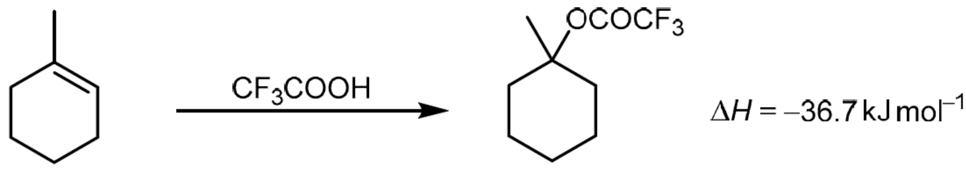
(h) The same product **B** is formed when an alkene isomer of **A** is treated under identical conditions. Suggest a structure for this isomer. [1]

In a mixture of TFEA and trifluoroethanoic anhydride, **B** reacts with the trifluoroethanoic anhydride to form **C** and TFEA as shown below. The standard enthalpy change for this reaction is −98.3 kJ mol^{-1}.



B **C**

Compound **C** may also be formed in the same mixture of TFEA and trifluoroethanoic anhydride from the reaction between 1-methylcyclohexene and TFEA. The standard enthalpy change for this reaction is −36.7 kJ mol^{-1}.



A **C**

The standard enthalpy change for the reaction between one mole of water and one mole of trifluoroethanoic anhydride is – 75.6 kJ mol^{-1}.

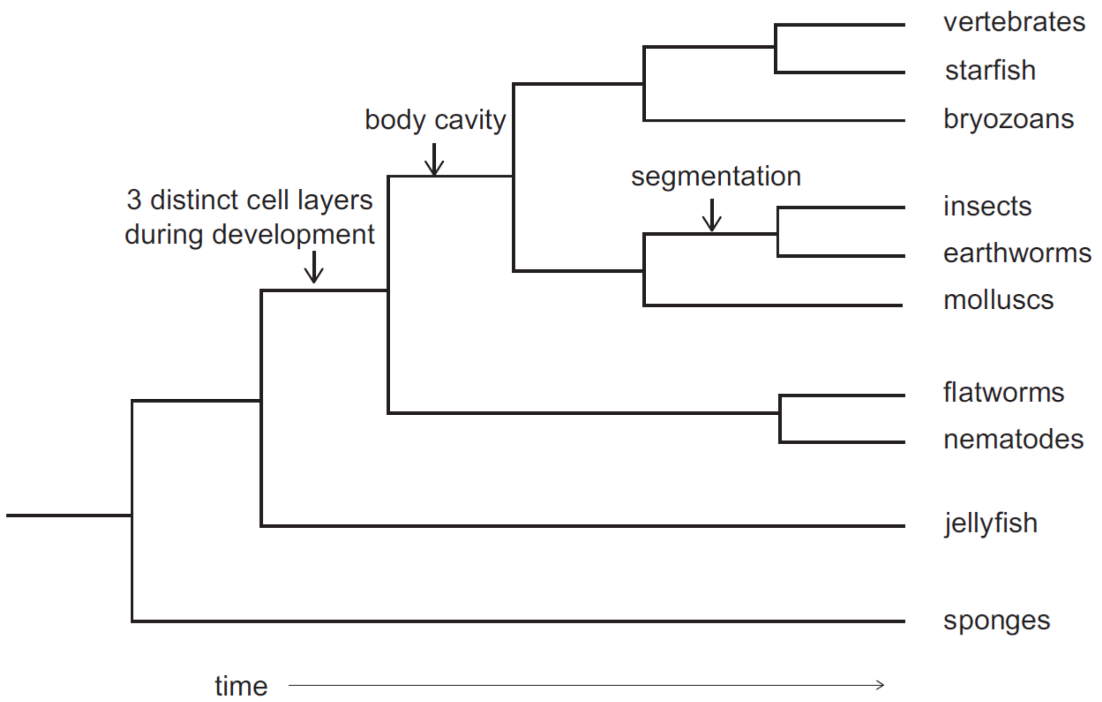
(i) Draw the structure of trifluoroethanoic anhydride. [1]

(j) Give the equation for the reaction between one mole of water and one mole of trifluoroethanoic anhydride. [1]

(k) By constructing an appropriate energy cycle, calculate the standard enthalpy change for the hydration of alkene **A**. [4]

[NSAA, 2019S2Q5]

The diagram shows an evolutionary tree for a kingdom of organisms. This tree was constructed over 20 years ago using shared observable features to group these organisms into smaller groups. The time at which three of these shared features first appeared is shown on the evolutionary tree. Each branching point in the tree indicates the time at which groups of organisms diverged from a common ancestor.



(a) Identify the kingdom represented in this evolutionary tree. [1]

(b) Recently, molecular evidence has changed our understanding of these relationships. Based upon each of the three findings below, what conclusions about evolution can you draw?

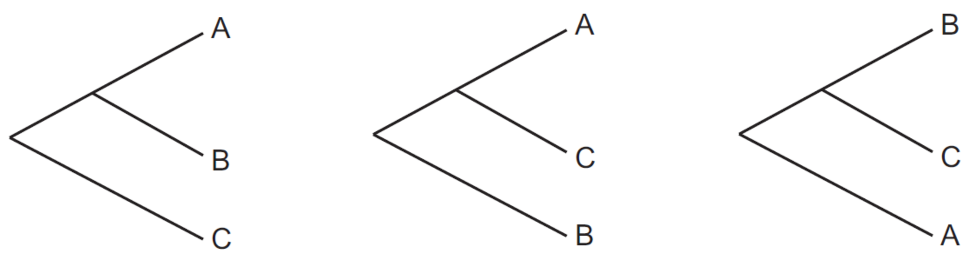
(i) Insects and earthworms are not closely related to each other. [1]

(ii) Nematodes and insects, both of which undergo moulting, are very closely related. [2]

(iii) Flatworms, which all lack a true body cavity, are not actually a single group. Some diverged at the base of the tree, some are related to the molluscs, and some are related to starfish and vertebrates. [2]

(c) Briefly describe two benefits of using molecular evidence, rather than visible characteristics, to construct trees. [2]

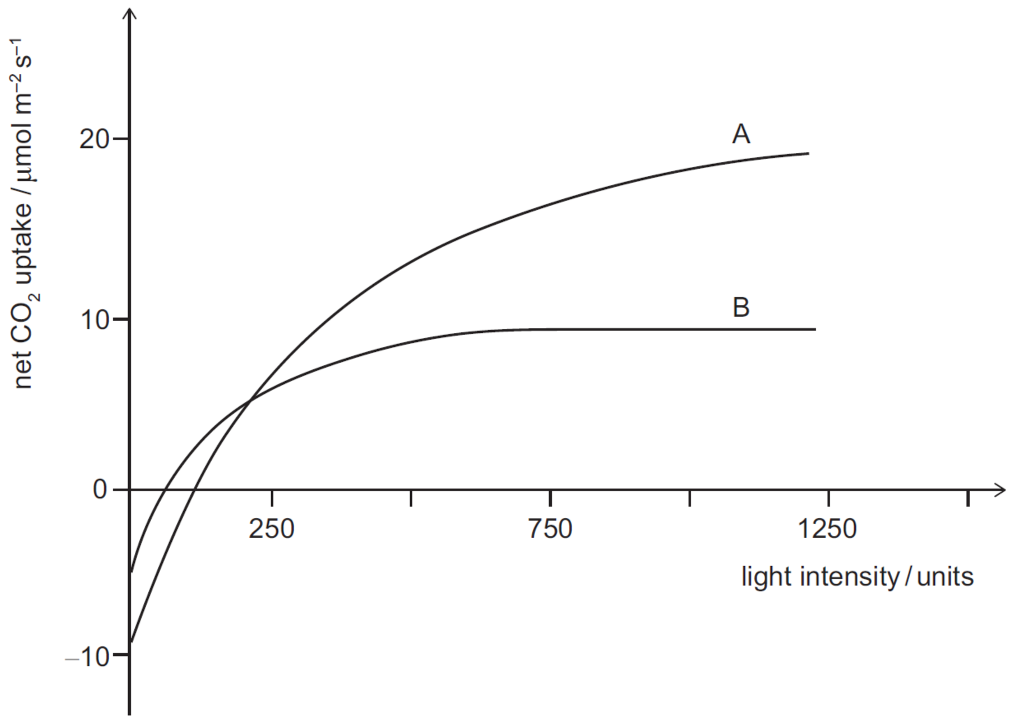
(d) The following three tree diagrams show **all** of the possible relationships between 3 different organisms. How many possible tree diagrams are there with 4 organisms? [2]



(e) Using examples, discuss the different ways by which we can measure biodiversity. [10]

[NSAA, 2019S2Q6]

The graph shows net CO_2 uptake of two different plants, A and B, when exposed to increasing light levels.



(a) Name two physiological processes that affect the net CO_2 uptake in plants. [1]

(b) State what can be concluded when the net CO_2 uptake in each plant is zero. [1]

(c) For plant B, estimate the value at which increasing light intensity no longer affects CO_2 uptake. [1]

(d) Estimate the number of micromoles of CO_2 that would be taken up by a 50 cm^2 leaf of plant B in one minute at light intensity of 750 units. [2]

(e) Propose two explanations for the existence of a plateau in the curve for plant B. [2]

(f) Describe the differences in the curves for plants A and B and suggest why these differences might occur. [3]

(g) Discuss how temperature might affect net CO_2 uptake in plants, with reference to the effects of temperature on enzymatic activity. Use graphs to illustrate your answer. [10]

NSAA 2020 S1

NSAA 2020 S1
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 60 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **four** parts: **A**, **B**, **C** and **D**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **one** further part chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **two** parts. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators are NOT permitted.

Part A

[NSAA, 2020S1Q1]

The admission charge to a cinema is different for adults and children.

Admission for 2 adults and 3 children costs £20.

Admission for 4 adults and 4 children costs £34.

What does admission cost for 6 adults and 2 children?

(A) £27

(B) £29

(C) £33

(D) £39

(E) £44

(F) £48

(G) £72

[NSAA, 2020S1Q2]

The nth term of a sequence is $2n - 5$.

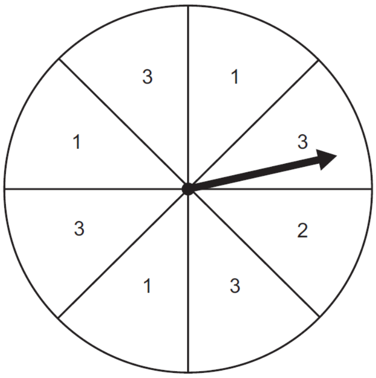
Which row in the table is correct for this sequence?

	term-to-term rule	*term which has a value of 17*
(A)	subtract 5	11th
(B)	subtract 5	29th
(C)	subtract 2	11th
(D)	subtract 2	29th
(E)	add 5	11th
(F)	add 5	29th
(G)	add 2	11th
(H)	add 2	29th

[NSAA, 2020S1Q3]

A fair spinner has eight equal sections.

Each section has one number written on it, as shown.



The spinner is spun twice, and the two numbers scored are added.

What is the probability that the sum of the two numbers is 5?

(A) $\frac{1}{8}$

(B) $\frac{5}{8}$

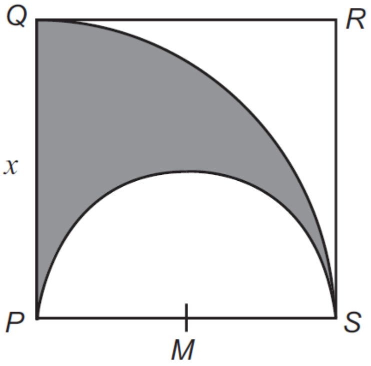
(C) $\frac{1}{16}$

(D) $\frac{3}{16}$

(E) $\frac{25}{64}$

(F) $\frac{55}{64}$

[NSAA, 2020S1Q4]



$PQRS$ is a square with side length x.

M is the midpoint of side PS.

A circular arc, with centre M, is drawn inside the square from S to P.

Another circular arc, with centre P, is drawn inside the square from S to Q.

What is the area of the shaded region in terms of x?

(A) $\frac{1}{8}\pi x^2$

(B) $\frac{3}{16}\pi x^2$

(C) $\frac{1}{4}\pi x^2$

(D) $\frac{5}{16}\pi x^2$

(E) $\frac{3}{8}\pi x^2$

(F) $\frac{7}{16}\pi x^2$

(G) $\frac{1}{2}\pi x^2$

[NSAA, 2020S1Q5]

A balloon contains 5000 cm³ of gas.

The gas in the balloon gradually escapes so that the volume of the balloon decreases.

60% of the volume of the balloon is lost each week.

What is the volume of the balloon, in cm³, after 3 weeks?

(A) 0

(B) 128

(C) 320

(D) 800

(E) 1080

[NSAA, 2020S1Q6]

Consider the four lines with the following equations.

1 $2x + 6y = 3$

2 $9y = 3x - 4$

3 $2y = 6x + 3$

4 $4x + 6y - 9 = 0$

Which two lines are perpendicular?

(A) 1 and 2

(B) 1 and 3

(C) 1 and 4

(D) 2 and 3

(E) 2 and 4

(F) 3 and 4

[NSAA, 2020S1Q7]

The equilateral triangle PQR has sides of length 8 cm.
A circle, centre O, passes through each of the vertices of the triangle.
Find an expression for the circumference of the circle, in cm.

(A) $\frac{\sin 60°}{8\pi}$

(B) $\frac{8\pi}{\sin 60°}$

(C) $\frac{\cos 60°}{8\pi}$

(D) $\frac{8\pi}{\cos 60°}$

(E) $\frac{\tan 60°}{8\pi}$

(F) $\frac{8\pi}{\tan 60°}$

[NSAA, 2020S1Q8]

Find the sum of the solutions of

$$2\left(\frac{x}{4}+3\right)^2-\left(\frac{x}{4}+3\right)-36=0$$

(A) 2

(B) $\frac{3}{2}$

(C) $\frac{1}{2}$

(D) -4

(E) -13

(F) -22

(G) -26

(H) -34

[NSAA, 2020S1Q9]

When the expression

$$(2x+3)^2-(x-3)^2$$

is written in the form $p(x+q)^2+r$, where p, q and r are constants, what is the value of r?

(A) -27

(B) -9

(C) 0

(D) 3

(E) 15

[NSAA, 2020S1Q10]

Which one of the following expressions is equivalent to

$$\frac{a}{b/c} - \frac{a/b}{c}$$

(A) 0

(B) $\frac{a(b^2-1)}{bc}$

(C) $\frac{a(b^2-c^2)}{bc}$

(D) $\frac{a^2b^2-c^2}{abc}$

(E) $\frac{a(c^2-1)}{bc}$

(F) $\frac{a^2c^2-b^2}{abc}$

(G) $\frac{b^2-a^2}{abc}$

[NSAA, 2020S1Q11]

The table shows statistics relating to the test marks of two groups of students.

	number of students	*mean*	*range*
group X	10	36	16
group Y	20	48	21

The results for the two groups of students are combined.

What can be deduced about the mean and range of the combined results?

(A) mean $= 40$, range ≤ 16

(B) mean $= 40$, $16 <$ range < 21

(C) mean $= 40$, range ≥ 21

(D) mean $= 44$, range ≤ 16

(E) mean $= 44$, $16 <$ range < 21

(F) mean $= 44$, range ≥ 21

[NSAA, 2020S1Q12]

The number of pairs of winter boots sold on a day is inversely proportional to the cube of the outside temperature on that day, measured in °C.

On a day when the outside temperature is 8 °C, 250 pairs of boots are sold.

The next day, when the outside temperature is x °C, the number of pairs of boots sold is 700% more than on the previous day.

What is the value of x?

(A) 2

(B) 4

(C) $\frac{8}{\sqrt[3]{7}}$

(D) $8\sqrt[3]{7}$

(E) 16

[NSAA, 2020S1Q13]

In a sale, all prices are reduced by 25%.

A customer calculates the pre-sale price of a bicycle incorrectly by increasing the marked sale price by 25%.

The customer's calculated pre-sale price is incorrect by £15.

What is the correct pre-sale price of the bicycle?

(A) £180

(B) £195

(C) £210

(D) £225

(E) £240

[NSAA, 2020S1Q14]

A paint colour is a mixture of red paint, blue paint and yellow paint.

The ratio of red paint to blue paint in the mixture is $18 : 5$.

The ratio of blue paint to yellow paint in the mixture is $p : 3$.

The ratio of red paint to yellow paint in the mixture is $12 : 5$.

What is the value of p?

(A) 2

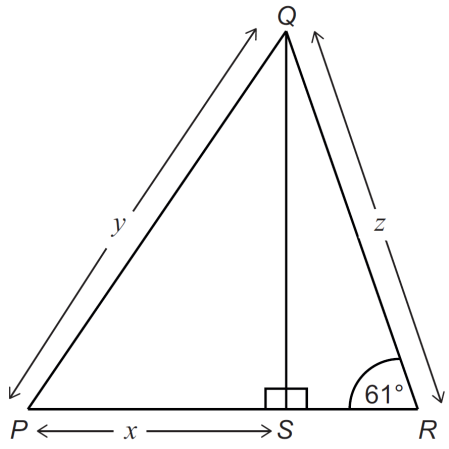
(B) 4.5

(C) 5

(D) 7.5

(E) 12

[NSAA, 2020S1Q15]



[diagram not to scale]

In the diagram, QS is perpendicular to PR.

$PS = x$ cm

$PQ = y$ cm

$QR = z$ cm

angle $QRS = 61°$

PSR is a straight line.

Which one of the following is an expression for the length z, in cm?

(A) $\sqrt{y^2 + x^2}\sin 61°$

(B) $\sqrt{y^2 - x^2}\sin 61°$

(C) $\sqrt{y^2 + x^2}\cos 61°$

(D) $\sqrt{y^2 - x^2}\cos 61°$

(E) $\frac{\sqrt{y^2+x^2}}{\sin 61°}$

(F) $\frac{\sqrt{y^2-x^2}}{\sin 61°}$

(G) $\frac{\sqrt{y^2+x^2}}{\cos 61°}$

(H) $\frac{\sqrt{y^2-x^2}}{\cos 61°}$

[NSAA, 2020S1Q16]

Two identical fair six-sided dice each have their faces numbered from 1 to 6, with one number on each face.

Both dice are thrown, and the number on each of the dice is recorded.

They are then both thrown again, and the number on each of the dice is recorded.

What is the probability that at least one of the four recorded numbers is even?

(A) $\frac{1}{4}$

(B) $\frac{1}{2}$

(C) $\frac{9}{16}$

(D) $\frac{3}{4}$

(E) $\frac{15}{16}$

[NSAA, 2020S1Q17]

The quadratic equation $2x^2 - px - 4 = 0$, where p is a positive constant, has two solutions that differ by 6.

What is the value of p?

(A) 2

(B) $4\sqrt{7}$

(C) 12

(D) $4\sqrt{11}$

(E) $4\sqrt{34}$

(F) $6\sqrt{30}$

[NSAA, 2020S1Q18]

Two vertices of a square are at $(1, 1)$ and $(3, 5)$.

What is the difference between the perimeters of the largest and smallest possible squares that can be drawn with these points as two of their vertices?

(A) 0

(B) $4\sqrt{3}(2-\sqrt{2})$

(C) $4\sqrt{3}(\sqrt{2}-1)$

(D) $4\sqrt{5}(2-\sqrt{2})$

(E) $4\sqrt{5}(\sqrt{2}-1)$

(F) $4\sqrt{13}(2-\sqrt{2})$

(G) $4\sqrt{13}(\sqrt{2}-1)$

(H) $4\sqrt{3}\sqrt{5}(2-\sqrt{2})$

[NSAA, 2020S1Q19]

The point M is $(2, 5)$ and the point N is $(-3, -1)$.

The line segment MN is transformed to the line segment TU by two transformations:

MN is rotated $90°$ clockwise about the origin to give the line segment RS.

RS is then translated by the vector $\begin{pmatrix} p \\ q \end{pmatrix}$ to give the line segment TU.

The coordinates of the midpoint of TU are $(7, -2.5)$.

Find the vector $\begin{pmatrix} p \\ q \end{pmatrix}$.

(A) $\begin{pmatrix} 2 \\ 0.5 \end{pmatrix}$

(B) $\begin{pmatrix} 0.5 \\ 2 \end{pmatrix}$

(C) $\begin{pmatrix} 5 \\ -3 \end{pmatrix}$

(D) $\begin{pmatrix} -3 \\ 5 \end{pmatrix}$

(E) $\begin{pmatrix} 9 \\ -2 \end{pmatrix}$

(F) $\begin{pmatrix} -2 \\ 9 \end{pmatrix}$

[NSAA, 2020S1Q20]

A solid cone has a base radius x cm.

The ratio of the perpendicular height of the cone to the radius of the cone is 5 : 2.

A solid hemisphere of radius $\frac{y}{2}$ cm is made from the same material as the cone.

Which one of the following is a correct expression for

$$\frac{\text{volume of the cone}}{\text{volume of the hemisphere}}$$

(Volume of a cone $= \frac{1}{3}\pi r^2 h$ where r is the radius and h is the perpendicular height.)

(Volume of a sphere $= \frac{4}{3}\pi r^3$ where r is the radius.)

(A) $\frac{5x^3}{y^3}$

(B) $\frac{5x^3}{4y^3}$

(C) $\frac{8x^3}{5y^3}$

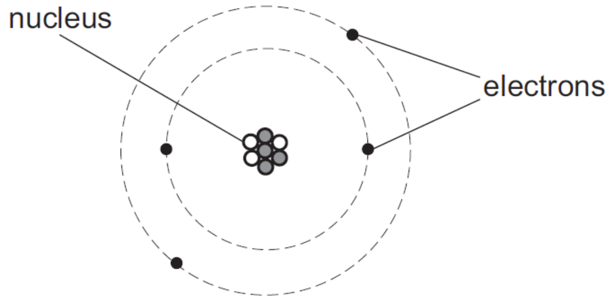
(D) $\frac{10x^3}{y^3}$

(E) $\frac{14x^3}{y^3}$

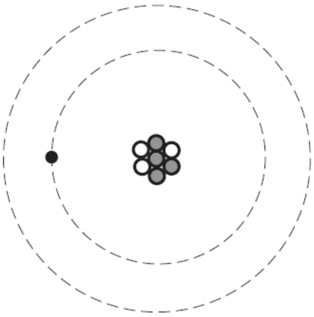
Part B

[NSAA, 2020S1Q21]

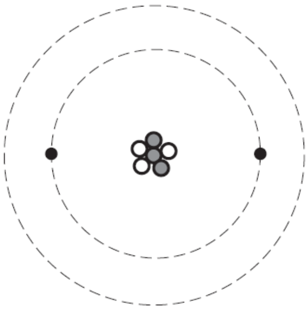
The diagram represents the structure of a charged atom (ion) of one isotope of an element.



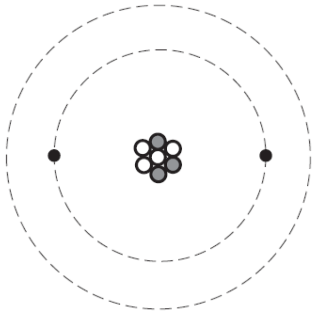
Which diagram represents the structure of an oppositely charged ion of a different isotope of the same element?



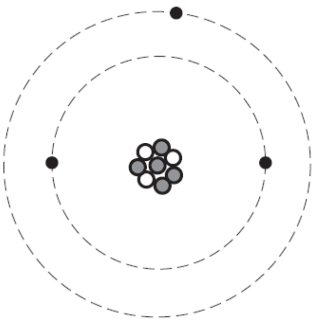
(A)



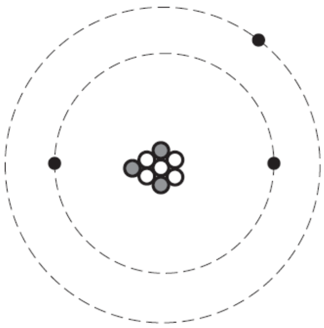
(B)



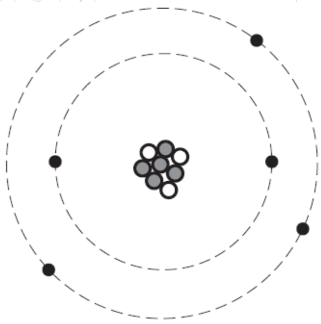
(C)



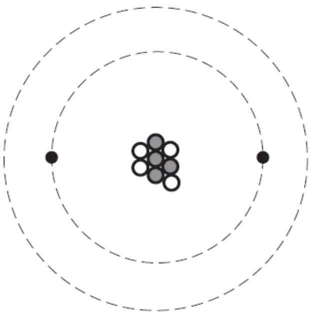
(D)



(E)



(F)



(G)

[NSAA, 2020S1Q22]

A soldering iron has a copper tip of mass 2.0 g.

The tip is heated with 30 W of thermal power. In 50 s, the temperature of the tip increases by 200 °C.

How much energy is transferred from the tip to the surroundings in this time?

(specific heat capacity of copper = 400 J kg^{-1} $°C^{-1}$)

(A) 160 J

(B) 500 J

(C) 1340 J

(D) 1500 J

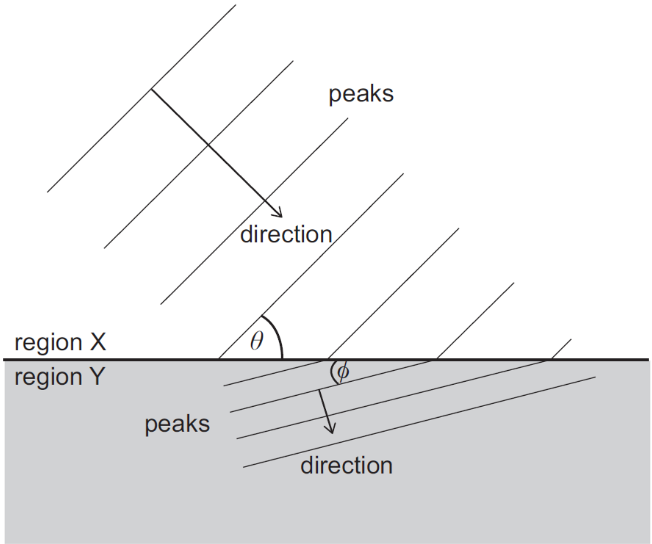
(E) 1660 J

(F) 1840 J

(G) 2500 J

[NSAA, 2020S1Q23]

A water wave is travelling in a shallow tank of water. The wave passes from region X into region Y where the speed of the wave differs from that in region X. The diagram shows the directions of travel in the two regions and peaks of the wave that are separated by one wavelength.



In region X, the angle between the wave peaks and the boundary between the regions is θ.

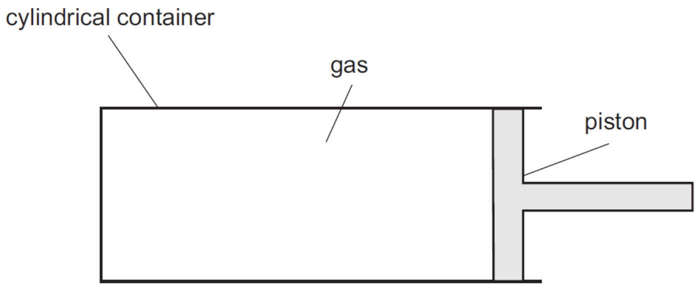
In region Y, the angle between the wave peaks and the boundary is ϕ.

What are the angle of incidence and the angle of refraction, and in which region is the speed of the wave greater?

	angle of incidence	*angle of refraction*	*speed greater in region*
(A)	θ	ϕ	X
(B)	θ	ϕ	Y
(C)	θ	$90° - \phi$	X
(D)	θ	$90° - \phi$	Y
(E)	$90° - \theta$	ϕ	X
(F)	$90° - \theta$	ϕ	Y
(G)	$90° - \theta$	$90° - \phi$	X
(H)	$90° - \theta$	$90° - \phi$	Y

[NSAA, 2020S1Q24]

A sample of an ideal gas is sealed in a cylindrical container by a piston as shown in the diagram.



The particles of the gas are moving with an average speed v, and collide with the surface of the piston with a frequency f.

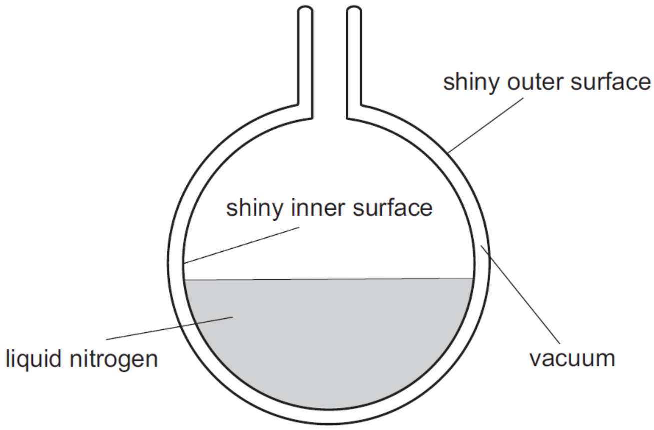
The piston is now slowly pushed into the cylinder until the gas occupies half of its original volume, but the gas remains at the same temperature.

What is the new average speed of the particles of the gas, and at what frequency do they now collide with the surface of the piston?

	average speed	*frequency*
(A)	$2v$	$\frac{1}{2}f$
(B)	$2v$	f
(C)	$2v$	$2f$
(D)	v	$\frac{1}{2}f$
(E)	v	f
(F)	v	$2f$

[NSAA, 2020S1Q25]

In a laboratory, liquid nitrogen is stored at a very low temperature in the vessel shown in the diagram.



The vessel has a double wall made from a poor thermal conductor. There is a vacuum in the gap between the two walls.

The inner surface of the inner wall is shiny. The outer surface of the outer wall is shiny.

These features insulate the liquid nitrogen by reducing the rate at which thermal energy is transferred to the liquid nitrogen.

Which of the following statements explain(s) why these features help to insulate the liquid nitrogen?

1 The shiny inner surface of the inner wall is a good emitter of thermal radiation.

2 Thermal radiation cannot travel in a vacuum.

3 The shiny outer surface of the outer wall is a poor absorber of radiation.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q26]

Uranium-238 ($^{238}_{92}U$) decays by a series of alpha and beta (β^-) emissions to become the stable isotope lead-206 ($^{206}_{82}Pb$).

How many beta (β^-) particles are emitted in the decay of one uranium-238 nucleus to lead-206?

(A) 6

(B) 8

(C) 10

(D) 12

(E) 14

(F) 16

[NSAA, 2020S1Q27]

A dc electricity transmission system uses an undersea cable to send electricity from one country to another. On a particular day, the first country supplies electricity at a voltage of 400 kV and 2000 A to the transmission system. The second country receives electricity from the transmission system at 160 kV and 4000 A.

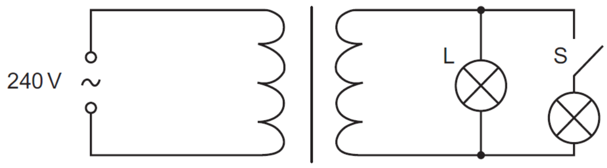
What is the percentage efficiency of the system and how much energy is wasted every minute?

	efficiency%	*energy wasted every minute* / J
(A)	20	9.6×10^{9}
(B)	20	3.84×10^{10}
(C)	20	4.8×10^{10}
(D)	80	9.6×10^{9}
(E)	80	3.84×10^{10}
(F)	80	4.8×10^{10}

[NSAA, 2020S1Q28]

The primary coil of an ideal, 100% efficient transformer is connected to a 240 V mains supply.

A lamp *L* that is connected to the secondary coil has a voltage of 12 V across it. An identical lamp and a switch *S* are also connected to the transformer as shown in the diagram.



With the switch open, the current in the primary coil is 0.10 A.

The switch is now closed.

What is the current in the primary coil now and what is the current in lamp *L*?

	current in primary coil / A	*current in lamp L* / A
(A)	0.10	1.0
(B)	0.10	2.0
(C)	0.10	4.0
(D)	0.20	1.0
(E)	0.20	2.0
(F)	0.20	4.0

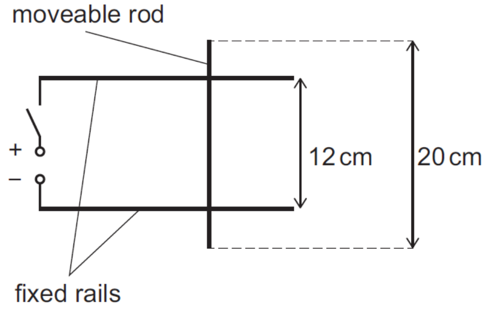
[NSAA, 2020S1Q29]

Two fixed horizontal metal rails are side by side and 12 cm apart. The rails are connected to a dc power supply by a switch that is initially open.

A freely moveable metal rod of length 20 cm is placed on the rails as shown in the diagram.

The diagram shows the arrangement seen from above.

The angle between the rod and the rails is 90°.



The whole arrangement is placed in a uniform magnetic field of magnitude 0.50 T that is directed perpendicularly into the page.

The moveable rod has a weight of 0.40 N.

The switch is now closed. As a result, there is a current of 2.4 A in the circuit and the rod moves.

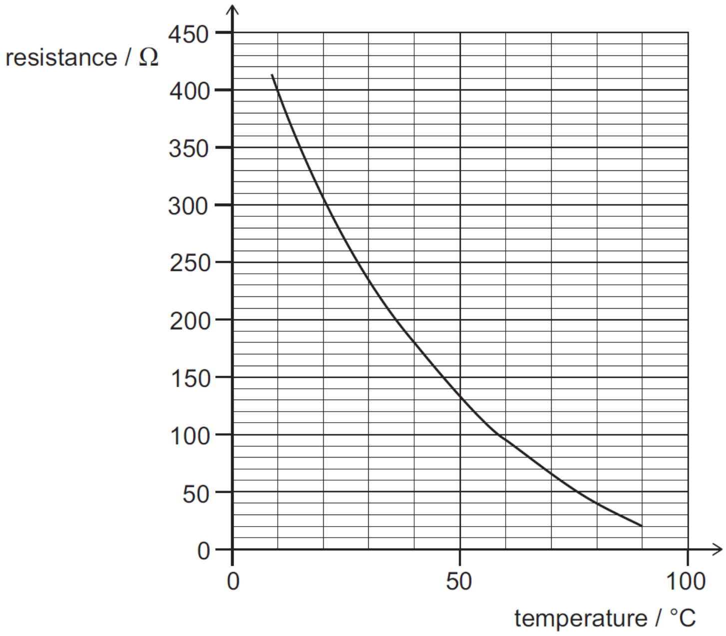
What is the initial magnitude of the acceleration of the rod and what is its direction?

(gravitational field strength = 10 N kg^{-1})

	acceleration / m s^{-2}	*direction*
(A)	0.36	to the left
(B)	0.36	to the right
(C)	0.60	to the left
(D)	0.60	to the right
(E)	3.6	to the left
(F)	3.6	to the right
(G)	6.0	to the left
(H)	6.0	to the right

[NSAA, 2020S1Q30]

A circuit contains a 12 V battery, a thermistor and a fixed resistor connected in series. The graph shows how the resistance of the thermistor varies with temperature.



When the temperature of the thermistor is 10 °C the current in the circuit is 25 mA.

What is the current when the temperature of the thermistor is 80 °C?

(A) 30 mA

(B) 80 mA

(C) 100 mA

(D) 120 mA

(E) 150 mA

(F) 300 mA

(G) 480 mA

[NSAA, 2020S1Q31]

Two trolleys are moving towards each other along a straight horizontal track.

One trolley has mass 8.0 kg and is travelling to the right at 4.0 m s^{-1}.

The other trolley has mass 2.0 kg and is travelling to the left at 1.0 m s^{-1}.

When the trolleys collide they stick together.

How much kinetic energy is transferred to other forms of energy in the collision?

(A) 2.0 J

(B) 18 J

(C) 20 J

(D) 28 J

(E) 35 J

(F) 40 J

(G) 45 J

(H) 65 J

[NSAA, 2020S1Q32]

Visible light waves are electromagnetic waves that travel through a vacuum at 300 000 km s^{-1} with wavelengths that range from 400 nm to 750 nm.

The electromagnetic waves emitted by a source are all at frequencies between 6.0×10^{12} Hz and 6.0×10^{14} Hz.

Which statement about the waves emitted by the source is correct?

(A) Infrared waves are emitted, but not ultraviolet or visible light waves.

(B) Infrared and visible light waves are emitted, but not ultraviolet waves.

(C) Infrared, ultraviolet and visible light waves are all emitted.

(D) Ultraviolet waves are emitted, but not infrared or visible light waves.

(E) Ultraviolet and visible light waves are emitted, but not infrared waves.

[NSAA, 2020S1Q33]

Cubes of side 2.0 cm are tightly packed into a rectangular box with internal dimensions 12.0 cm × 10.0 cm × 6.0 cm.

Each cube is either solid concrete or solid steel. There are twice as many steel cubes as concrete cubes.

What is the total mass of the cubes in the box?

(density of concrete = 2.0 g cm^{-3}; density of steel = 8.0 g cm^{-3})

(A) 2880 g

(B) 3240 g

(C) 3600 g

(D) 3840 g

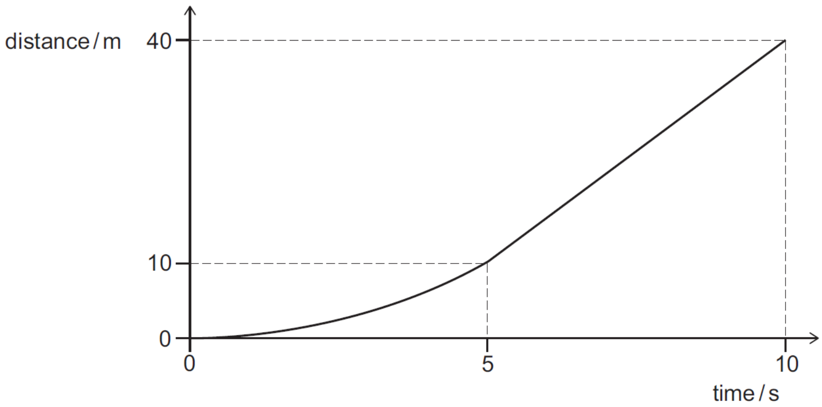
(E) 4320 g

(F) 4800 g

[NSAA, 2020S1Q34]

A car of mass 800 kg travels in a straight line along a horizontal road.

The car accelerates **non-uniformly** from rest for 5.0 seconds and then moves at constant speed, as shown in the distance–time graph:



What is the average resultant force acting on the car over the time for which it is accelerating?

(A) 320 N

(B) 480 N

(C) 640 N

(D) 960 N

(E) 1600 N

(F) 3200 N

(G) 4800 N

[NSAA, 2020S1Q35]

A sample contains only one radioactive isotope. This isotope decays in a single step with a half-life of 120 minutes to a stable isotope.

The sample is placed near to a radiation detector which measures the count rate. The count rate reading is 910 counts per minute (cpm).

After 240 minutes the measurement is repeated. The count rate reading is now 238 cpm.

After a further 360 minutes have elapsed, a third measurement of the count rate is made.

What is the count rate due to background radiation and what is the expected reading in the third measurement?

	background count rate / cpm	*third measurement* / cpm
(A)	224	148
(B)	224	226
(C)	142	28
(D)	142	148
(E)	142	154
(F)	14	14
(G)	14	28
(H)	14	42

[NSAA, 2020S1Q36]

P and Q are two fixed points on the surface of the ocean which are 6.0 m apart.

An ocean wave travels in the direction P to Q.

The wave has a frequency of 0.50 Hz and travels at a constant speed.

A wave peak passes Q at time $t = 0$ s.

The next wave peak travelling towards Q passes P at time $t = 0.80$ s.

What is the speed of the wave?

(A) 2.1 m s^{-1}

(B) 3.4 m s^{-1}

(C) 5.0 m s^{-1}

(D) 7.5 m s^{-1}

(E) 20 m s^{-1}

[NSAA, 2020S1Q37]

A parachutist of mass 80.0 kg drops from a plane travelling at 40.0 m s^{-1}, 2000 m above the Earth's surface.

The parachutist hits the ground at a speed of 5.00 m s^{-1}.

How much work is done by the parachutist against drag forces during the fall?

(Take the Earth's gravitational field strength to be 10.0 N kg^{-1}.)

(A) 1 535 000 J

(B) 1 624 000 J

(C) 1 649 000 J

(D) 1 663 000 J

(E) 1 726 000 J

[NSAA, 2020S1Q38]

A solid uniform sphere is made of metal of density ρ_S and has radius r and volume V. It falls vertically through a viscous liquid of density ρ_L.

Three forces act on it: its weight, a drag force D and an upthrust U. The magnitude of the upthrust force is equal to the weight of the liquid displaced by the sphere.

The magnitude of the drag force is given by:

$$D = krv$$

where v is the speed of the metal sphere and k is a constant.

What is the terminal speed of the metal sphere as it falls through this liquid?

(gravitational field strength $= g$)

(A) $\frac{\rho_L g}{Vrk}$

(B) $\frac{\rho_S g}{Vrk}$

(C) $\frac{g(\rho_S - \rho_L)}{Vrk}$

(D) $\frac{g(\rho_S + \rho_L)}{Vrk}$

(E) $\frac{V\rho_L g}{rk}$

(F) $\frac{V\rho_S g}{rk}$

(G) $\frac{Vg(\rho_S - \rho_L)}{rk}$

(H) $\frac{Vg(\rho_S + \rho_L)}{rk}$

[NSAA, 2020S1Q39]

A rocket travelling in space is burning its fuel at a constant rate. By expelling the burnt fuel through a nozzle, the engine is applying a constant force to the rocket.

What is happening to the magnitude of the acceleration of the rocket?

(A) It is increasing at an increasing rate.

(B) It is increasing at a constant rate.

(C) It is increasing at a decreasing rate.

(D) It is not changing.

(E) It is decreasing at an increasing rate.

(F) It is decreasing at a constant rate.

(G) It is decreasing at a decreasing rate.

[NSAA, 2020S1Q40]

A light spring of unstretched length 0.10 m has a spring constant of 20 N m^{-1}. The spring is suspended so that it is vertical and a load of mass 0.050 kg is attached to the end of the spring.

The load is pulled vertically downwards until the length of the spring is 0.30 m. The load is then released.

What is the speed of the load at the instant that the spring returns to its unstretched length?

(gravitational field strength = 10 N kg^{-1}; assume that resistive forces are negligible)

(A) 0 m s^{-1}

(B) 4.0 m s^{-1}

(C) 6.0 m s^{-1}

(D) 12 m s^{-1}

(E) 16 m s^{-1}

(F) $\sqrt{6}$ m s^{-1}

(G) $\sqrt{12}$ m s^{-1}

(H) $\sqrt{30}$ m s^{-1}

Part C

[NSAA, 2020S1Q41]

Use the following data table to answer the question.

gas	melting point / °C	boiling point / °C
hydrogen	−259	−253
nitrogen	−210	−196
oxygen	−219	−183
neon	−249	−246
argon	−189	−186

Water and carbon dioxide were removed from a sample of air and the remaining mixture was cooled to −260 °C.

The three most abundant remaining elements are to be separated by fractional distillation.

In which order would these three elements be collected?

(A) hydrogen, neon, nitrogen

(B) hydrogen, neon, oxygen

(C) neon, nitrogen, argon

(D) neon, nitrogen, oxygen

(E) nitrogen, argon, oxygen

(F) nitrogen, oxygen, argon

(G) oxygen, nitrogen, argon

(H) oxygen, argon, nitrogen

[NSAA, 2020S1Q42]

Consider **only** the first three metals in Group 1 (Li, Na, K) and **only** the first three elements in Group 17 (F, Cl, Br).

Which of the following statements is/are correct for the compound lithium bromide?

1 It is formed from the least reactive of the three Group 17 elements.

2 It is formed from the least reactive of the three Group 1 elements and the Group 17 element (of the three) with the lowest boiling point.

3 It is formed from the Group 1 element (of the three) with the highest melting point.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q43]

Which of the following tests could be used, on its own, to distinguish between all three of the following white solids: potassium carbonate, calcium chloride and sodium sulfate?

1 Add a small amount of each solid separately to a platinum wire and hold in a colourless flame.

2 Dissolve a small amount of each solid separately in deionised water and add a few drops of sodium hydroxide solution.

3 Dissolve a small amount of each solid separately in deionised water and add a few drops of hydrochloric acid, followed by barium chloride solution.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q44]

Molecule J is a straight-chain hydrocarbon containing one carbon-carbon double bond.

The relative atomic mass (A_r) of hydrogen is 1 and carbon is 12.

What is the **minimum** additional information that is needed in order to determine the molecular formula of molecule J?

1 The percentage by mass of carbon in the molecule.

2 The percentage by mass of hydrogen in the molecule.

3 The relative molar mass (M_r) of the molecule.

(A) 1 only

(B) 3 only

(C) 1 and 2 only

(D) 1 and 3 only

(E) 1, 2 and 3

[NSAA, 2020S1Q45]

Iodic acid, HIO_3, can be made from iodine in the following reaction:

$$I_2 + w\,H_2O + x\,Cl_2 \rightarrow y\,HIO_3 + z\,HCl$$

What is the value of x when the equation is balanced?

(A) 1

(B) 2

(C) 3

(D) 4

(E) 5

(F) 6

[NSAA, 2020S1Q46]

Which one of the following formulae is correct for the compound given?

(A) aluminium sulfate, $Al(SO_4)_3$

(B) ammonium carbonate, $(NH4)_2CO_3$

(C) calcium hydroxide, CaOH

(D) magnesium nitrate, $MgNO_3$

(E) potassium bromide, KBr_2

[NSAA, 2020S1Q47]

Which of the following statements about elements in the Periodic Table is/are correct?

1 When the element in Period 5, Group 2 reacts with the element that is in Period 3, Group 17, a redox reaction occurs.

2 In each Group, the elements from Period 2 are more reactive than the elements from Period 5.

3 The compound formed between the element in Period 2, Group 14 and the element in Period 3, Group 17 will have a simple molecular structure.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q48]

Some dilute aqueous solutions were electrolysed using graphite electrodes.

Which of the rows in the table show(s) the correct products of electrolysis?

	aqueous electrolyte	products of electrolysis	
		at the cathode (negative electrode)	at the anode (positive electrode)
1	potassium hydroxide	potassium	oxygen
2	copper(II) chloride	chlorine	copper
3	sodium sulfate	hydrogen	sulfur

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q49]

A paper chromatogram is set up with an orange food colouring spotted on the baseline.

Ten minutes after the start, the solvent front has moved 15.0 cm up the paper from the baseline and a yellow spot is 12.0 cm above the baseline.

Five minutes later, the solvent front has moved up a further 10.0 cm.

How far from the baseline will the yellow spot be 15 minutes after the start?

(A) 8.0 cm

(B) 12.0 cm

(C) 15.0 cm

(D) 20.0 cm

(E) 22.0 cm

(F) 25.0 cm

(G) 31.3 cm

[NSAA, 2020S1Q50]

Which of the following equations represent(s) a redox reaction?

1 $K_2Cr_2O_7 + 2KOH \rightarrow 2K_2CrO_4 + H_2O$

2 $8HNO_3 + 3C_2H_6O + K_2Cr_2O_7 \rightarrow 2KNO_3 + 3C_2H_4O + 7H_2O + 2Cr(NO_3)_3$

3 $H_2O + SO_2 \rightarrow H_2SO_3$

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q51]

100 cm^3 of ethane is mixed with 1400 cm^3 of oxygen and the mixture is ignited.

All volumes are measured at atmospheric pressure and a temperature of 150 °C.

What will be the **total** volume of gas after the complete combustion?

(Assume that equal amounts of any gas at the same temperature and pressure occupy the same volume.)

(A) 500 cm^3

(B) 1250 cm^3

(C) 1500 cm^3

(D) 1550 cm^3

(E) 1700 cm^3

(F) 2000 cm^3

[NSAA, 2020S1Q52]

10 g of a mixture of solid magnesium hydroxide, $Mg(OH)_2$, and solid sodium hydroxide, NaOH, is added to an excess of water and stirred.

One of the components of the mixture dissolves. Assume that the other is completely insoluble.

The mixture is filtered to remove the insoluble component of the mixture.

50 cm^3 of 1.0 mol dm^{-3} sulfuric acid exactly neutralises the remaining solution.

What is the mass of magnesium hydroxide in the original mixture?

(M_r values: $Mg(OH)_2 = 58$; $NaOH = 40$)

(A) 2.0 g

(B) 2.9 g

(C) 4.0 g

(D) 5.8 g

(E) 6.0 g

(F) 8.0 g

[NSAA, 2020S1Q53]

Calcium carbonate reacts with hydrochloric acid according to the following chemical equation:

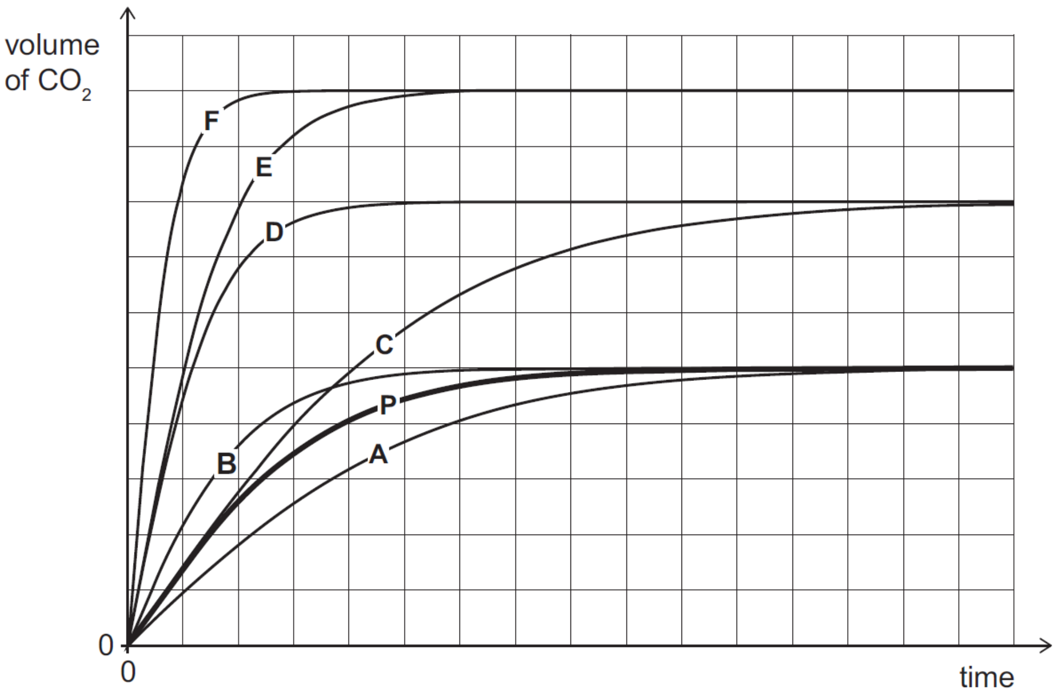
$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Line **P** on the graph shows how the volume of carbon dioxide formed changes with time when 4.0 g of calcium carbonate reacts with 50 cm^3 of 1.0 mol dm^{-3} hydrochloric acid at 20 °C.

A second reaction was carried out under identical conditions with the same mass of calcium carbonate but using 50 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

Which line (**A-F**) best represents how the volume of carbon dioxide formed changes with time in the second reaction?

(M_r value: $CaCO_3 = 100$)



[NSAA, 2020S1Q54]

Hydrochloric acid, sulfuric acid and phosphoric(V) acid are inorganic acids.

Phosphoric(V) acid, H_3PO_4, ionises in water in the following series of reactions:

$$H_3PO_4 \rightleftharpoons H^+ + H_2PO^{4-}$$
$$H_2PO^{4-} \rightleftharpoons H^+ + HPO_4^{2-}$$
$$HPO_4^{2-} \rightleftharpoons H^+ + PO_4^{3-}$$

0.1 mol dm^{-3} hydrochloric acid has a pH of 1.0 at room temperature.

Which of the following statements about these acids is/are correct?

1 The pH of 0.1 mol dm^{-3} sulfuric acid is greater than 1.0 at room temperature.

2 H_2PO^{4-} can act as an acid or as a base.

3 30 cm^3 of calcium hydroxide solution exactly neutralises 20 cm^3 phosphoric(V) acid solution when both solutions are the same concentration.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q55]

Complete combustion of 1 mol of hydrocarbon X requires exactly 8.5 mol of oxygen.

Incomplete combustion of 1 mol of hydrocarbon X, to form carbon monoxide and water only, requires exactly 5.5 mol of oxygen.

How many hydrogen atoms are there in one molecule of hydrocarbon X?

(A) 6

(B) 8

(C) 10

(D) 12

(E) 14

[NSAA, 2020S1Q56]

An element Z forms an ionic compound ZSO_4 which has $M_r = 120.4$.

The ion of Z in ZSO_4 has 10 electrons.

Element Z has three isotopes, labelled L, M and N, which contain the following numbers of neutrons.

isotope	L	M	N
number of neutrons	12	13	14

The percentage abundances of isotopes M and N are the same.

What is the percentage abundance of the isotope L in the element Z in ZSO_4?

(M_r value: $SO_4^{2-} = 96.1$)

(A) 4.10%

(B) 10.0%

(C) 13.4%

(D) 43.3%

(E) 80.0%

(F) 91.8%

[NSAA, 2020S1Q57]

An experiment is carried out using the first three metals in Group 1: lithium, sodium and potassium.

The initial masses of three open beakers each containing 100 g samples of an alcohol are recorded.

In three separate experiments, equal small masses of lithium, sodium and potassium are added to the three beakers, which are on electronic balances.

Each metal reacts in a similar way and after the reaction is complete, the final mass of each beaker and its contents is recorded.

In each case, the final mass of the beaker and its contents is compared to the recorded initial mass before the alkali metal was added.

Which of the following statements is correct?

(A) The beaker with lithium added would decrease in mass the most.

(B) The beaker with sodium added would decrease in mass the most.

(C) The beaker with potassium added would decrease in mass the most.

(D) All three beakers would show the same decrease in mass.

(E) The beaker with lithium added would increase in mass the most.

(F) The beaker with sodium added would increase in mass the most.

(G) The beaker with potassium added would increase in mass the most.

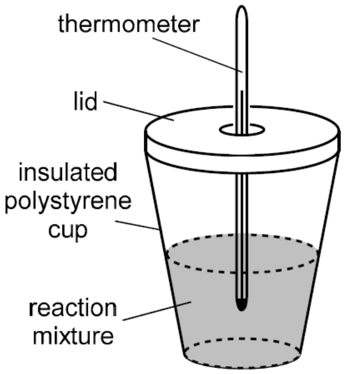
(H) All three beakers would show the same increase in mass.

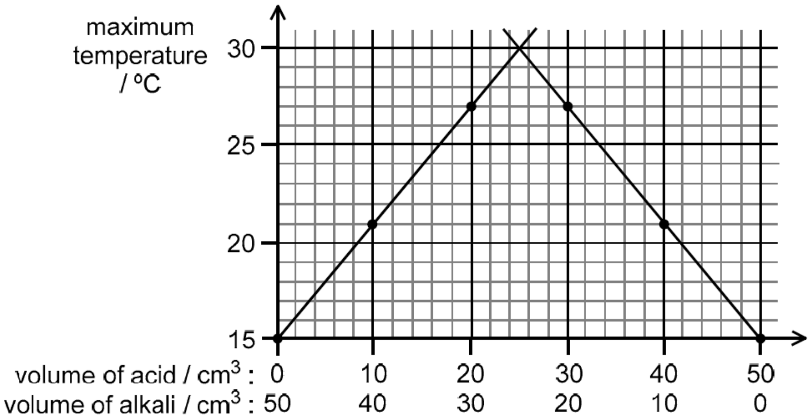
[NSAA, 2020S1Q58]

Four separate experiments were carried out using different quantities of 2 mol dm^{-3} hydrochloric acid and 2 mol dm^{-3} sodium hydroxide in insulated polystyrene cups.

After stirring, the maximum temperature was recorded and the results plotted on a graph as shown.

The temperatures of the acid and alkali on their own were also plotted on the graph. Two straight lines were drawn and extrapolated as shown.





What is the molar enthalpy change for the neutralisation reaction, in kJ mol^{-1}?

(Assume that the specific heat capacity of the solutions is 4 J g^{-1} $°C^{-1}$, the density of dilute solutions is 1 g cm^{-3}, and all heat is transferred to the solution.)

(A) 3 kJ mol^{-1}

(B) 6 kJ mol^{-1}

(C) 30 kJ mol^{-1}

(D) 60 kJ mol^{-1}

(E) 120 kJ mol^{-1}

(F) 3000 kJ mol^{-1}

[NSAA, 2020S1Q59]

An electric current is the flow of charged particles.

In an electrolysis of aluminium oxide using inert electrodes, the current flows at 5.00×10^{-6} moles of electrons per second.

Assume that only aluminium oxide is present and the aluminium is a single isotope $^{27}_{13}Al$.

What mass of aluminium is produced in 48 seconds?

(A) 0.04 mg

(B) 0.09 mg

(C) 0.52 mg

(D) 1.04 mg

(E) 1.08 mg

(F) 2.16 mg

(G) 3.12 mg

(H) 6.48 mg

[NSAA, 2020S1Q60]

X is a solution of sulfuric acid.

20.0 cm^3 of X is diluted by adding distilled water to produce 500 cm^3 of solution Y.

10.0 cm^3 of Y is exactly neutralised by 40.0 cm^3 of 0.0500 mol dm^{-3} aqueous potassium hydroxide.

What is the concentration of sulfuric acid in X?

(A) 0.00100 mol dm^{-3}

(B) 0.100 mol dm^{-3}

(C) 0.200 mol dm^{-3}

(D) 0.400 mol dm^{-3}

(E) 1.25 mol dm^{-3}

(F) 2.50 mol dm^{-3}

(G) 5.00 mol dm^{-3}

(H) 10.0 mol dm^{-3}

Part D

[NSAA, 2020S1Q61]

Which of the following **could** lead to phenotypic variation between a father and his son?

1 time spent in sunlight

2 their genomes

3 their diets

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q62]

Which of the following cells do not contain mitochondria?

1 bacterial cells

2 embryonic stem cells

3 mature red blood cells

4 potato cells

(A) 1 only

(B) 2 only

(C) 3 only

(D) 4 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 1 and 4 only

(H) 2 and 4 only

[NSAA, 2020S1Q63]

A section of double-stranded DNA contains 4500 base pairs. 10% of the bases present are adenine.

Which of the following statements is/are correct?

1 There are 450 thymine bases present.

2 40% of the bases present are cytosine.

3 There are 3600 guanine bases present.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

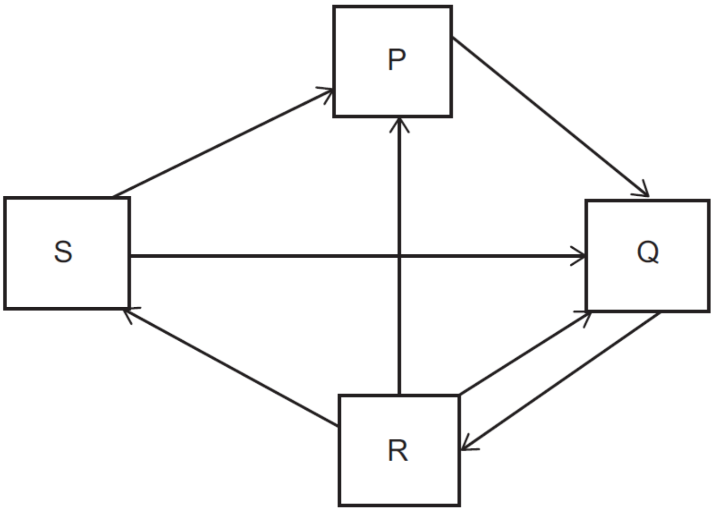
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q64]

The diagram shows part of the carbon cycle.



Which row identifies the correct descriptions for boxes P, Q, R and S?

	CO_2 in atmosphere	*carbon-rich compounds in animals*	*carbon-rich compounds in decomposers*	*carbon-rich compounds in plants*
(A)	P	Q	R	S
(B)	Q	P	S	R
(C)	S	Q	R	P
(D)	Q	S	P	R
(E)	S	R	Q	P
(F)	R	S	P	Q
(G)	P	R	Q	S
(H)	R	P	S	Q

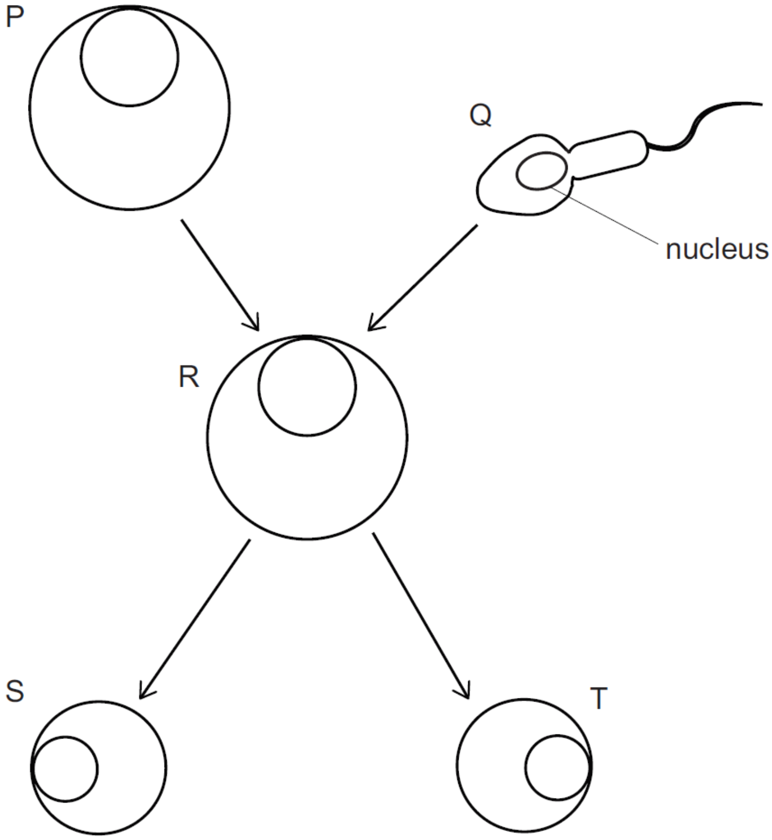
[NSAA, 2020S1Q65]

The diagram shows two human gametes, cell P and cell Q, fusing to form cell R.

Cell P carries an additional copy of one of its chromosomes so that it has one more chromosome than cell Q.

Cell R divides to form two cells S and T.

S and T grow into two separate individuals.



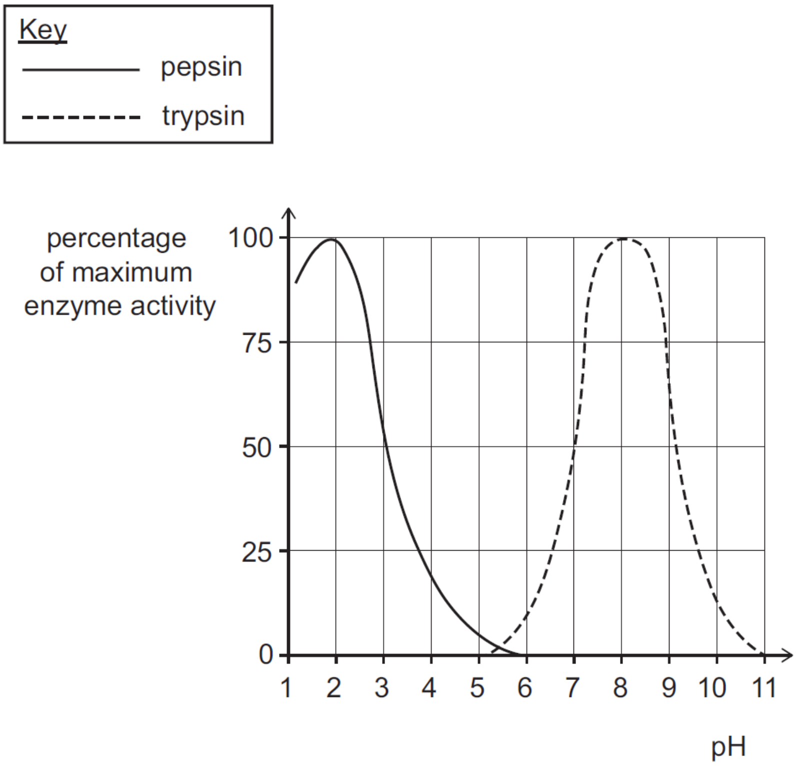
Using this information, which row shows the correct number of chromosomes in the nucleus of cell R and in the nucleus of cell T?

	cell R	*cell T*
(A)	23	24
(B)	24	47
(C)	24	48
(D)	46	46
(E)	47	24
(F)	47	47
(G)	92	47
(H)	93	93

[NSAA, 2020S1Q66]

Pepsin and trypsin are both protease enzymes found in the human digestive system.

The graph shows how the activity of both enzymes varies with pH.



In the human digestive system:

1 pepsin is most active in the stomach.

2 trypsin would be inactive in the stomach.

3 pepsin could be a substrate for trypsin.

4 pepsin is most active at low acidity and trypsin most active at high acidity.

Which statements are correct?

(A) 1 and 2 only

(B) 1 and 3 only

(C) 1 and 4 only

(D) 2 and 3 only

(E) 2 and 4 only

(F) 3 and 4 only

(G) 1, 2 and 3 only

(H) 2, 3 and 4 only

[NSAA, 2020S1Q67]

The table shows concentrations of substances in blood entering and leaving three different organs of a person:

- kidney
- small intestine
- chambers of the right side of the heart

The blood sample was taken 10 minutes after the person had eaten a carbohydrate-rich meal.

organ	*concentration in blood entering the organ*			*concentration in blood leaving the organ*		
	glucose / mg dm^{-3}	*oxygen / arbitrary units*	*urea / mg dm^{-3}*	*glucose / mg dm^{-3}*	*oxygen / arbitrary units*	*urea / mg dm^{-3}*
1	9.0	65	3.0	9.0	65	3.0
2	9.0	85	3.0	9.0	70	2.4
3	9.0	85	3.0	12.0	70	3.0

Which row in the following table identifies the organs?

	organ 1	*organ 2*	*organ 3*
(A)	kidney	small intestine	chambers of the right side of the heart
(B)	kidney	chambers of the right side of the heart	small intestine
(C)	small intestine	kidney	chambers of the right side of the heart
(D)	small intestine	chambers of the right side of the heart	kidney
(E)	chambers of the right side of the heart	small intestine	kidney
(F)	chambers of the right side of the heart	kidney	small intestine

[NSAA, 2020S1Q68]

SCID is an inherited condition in humans.

In one type of SCID, the white blood cells are unable to make the functional enzyme ADA, which is necessary for these cells to divide by mitosis during an immune response.

Scientists have developed a gene therapy treatment whereby a gene is inserted into the DNA of stem cells taken from the bone marrow of a person with this condition. These cells can then be returned to the body of the person, and can divide and differentiate into white blood cells. If this gene therapy is successful, the number of white blood cells should increase significantly.

Which of the following statements correctly describe(s) how this method of gene therapy might work to help a person with this type of SCID?

1 Genetically altered stem cells differentiate into white blood cells that are able to produce functional ADA.

2 Genetically altered stem cells can differentiate into gametes so that offspring will not inherit SCID.

3 The sequence of the bases in the DNA of the white blood cells, derived from the genetically altered stem cells, has changed.

(A) 1 only

(B) 2 only

(C) 3 only

(D) 1 and 2 only

(E) 1 and 3 only

(F) 2 and 3 only

(G) 1, 2 and 3

[NSAA, 2020S1Q69]

Which of the following could be a result of the addition of a large amount of organic material into a slow flowing river?

1 A decrease in biodiversity in the river.

2 A reduction in the oxygen concentration gradient between the air and the water.

3 An increase in the size of at least one aquatic population.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q70]

The table shows information about a human genetic condition called sickle cell anaemia and an infection called malaria. Both sickle cell anaemia and malaria can be fatal.

genotype	*phenotype*	*comment*
MM	does not show sickle cell anaemia	can be infected with malaria
Mm	does not show sickle cell anaemia	shows sickle cell anaemia
mm	shows sickle cell anaemia	shows more resistance to malaria than Mm

Which of the following statements is/are correct?

1 In areas without malaria, human populations are likely to have a low number of people with the m allele.

2 In areas with malaria, only those individuals that are heterozygous will be able to pass on their alleles to the next generation.

3 Presence of malaria has caused a mutation of the M allele to the m allele leading to an increased chance of survival in the heterozygous state.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q71]

The table shows the concentration of potassium ions in several different locations.

location	*concentration of potassium ions*
bacterial cell cytoplasm	30 mmol dm^{-3}
mammalian blood plasma	4000 μmol dm^{-3}
mammalian heart cell cytoplasm	1.0×10^2 mmol dm^{-3}
sea water	3.0×10^4 μmol dm^{-3}
yeast cell cytoplasm	300 mmol dm^{-3}

Which of the following statements is/are correct?

1 A mammalian heart cell needs energy from respiration in order to obtain more potassium ions from blood plasma.

2 If a yeast cell is placed in sea water then it will lose potassium ions by osmosis.

3 There is no concentration gradient for potassium ions between a bacterial cell and sea water.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

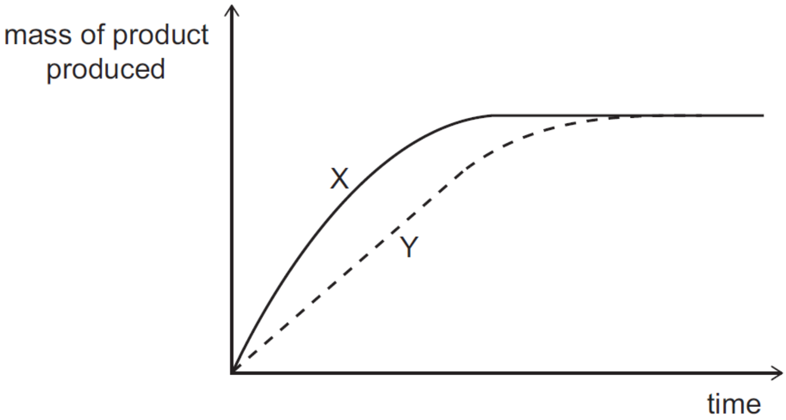
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q72]

The graph shows the mass of product produced over time for an enzyme-controlled reaction in two different conditions, X and Y. All other variables were kept constant.



Which of the following could be correct for this graph?

1 Condition X is a higher pH than condition Y.

2 Condition X has less substrate supplied than condition Y.

3 Condition X is a lower pH than condition Y.

4 Condition X has more substrate supplied than condition Y.

(A) none of them

(B) 1 and 2 only

(C) 1 and 3 only

(D) 1 and 4 only

(E) 2 and 3 only

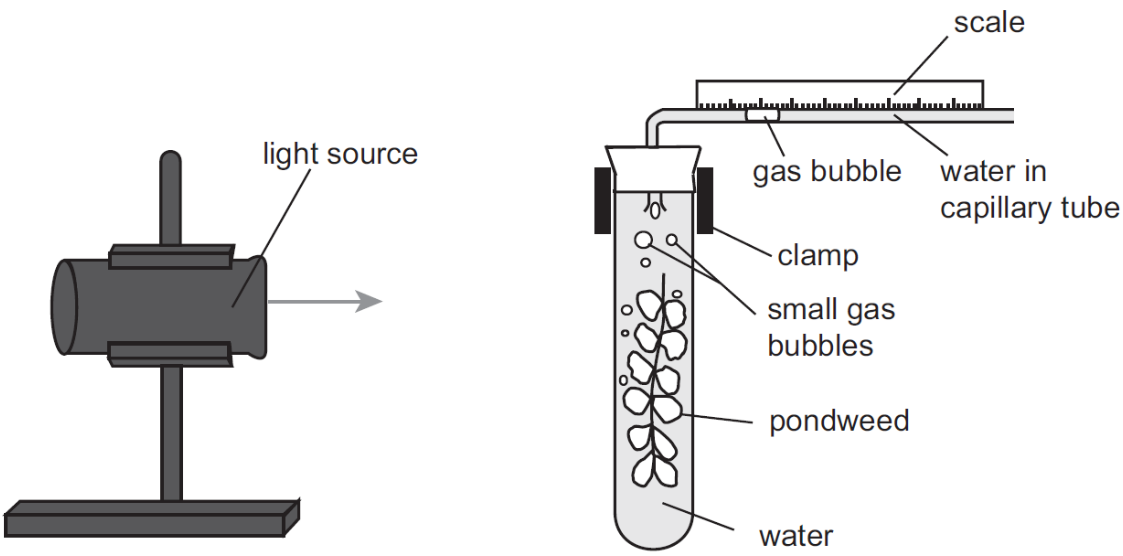
(F) 2 and 4 only

(G) 3 and 4 only

(H) 1, 2, 3 and 4

[NSAA, 2020S1Q73]

A student investigated the endothermic reaction of photosynthesis in pondweed. The student set up the apparatus as shown in the diagram.



The experiment was left for 5 minutes and the distance moved by the gas bubble along a capillary tube of 2 mm diameter was recorded. Using these values, the rate of gas production is 2π mm^3 per minute.

Which row of the table is correct?

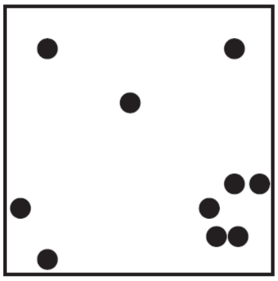
	total distance moved by the gas bubble during the experiment / mm	*total distance moved by the gas bubble during the experiment / mm*	*observations if the light source was moved further from the pondweed*
(A)	0.5	the reaction releases energy	the gas bubble moves more slowly to the right
(B)	0.5	the reaction takes in energy	the gas bubble moves more slowly to the left
(C)	2.0	the reaction releases energy	the gas bubble moves more slowly to the left
(D)	2.0	the reaction releases energy	the gas bubble moves more slowly to the right
(E)	2.5	the reaction takes in energy	the gas bubble moves more slowly to the left
(F)	2.5	the reaction takes in energy	the gas bubble moves more slowly to the right
(G)	10.0	the reaction releases energy	the gas bubble moves more slowly to the left
(H)	10,0	the reaction takes in energy	the gas bubble moves more slowly to the right

[NSAA, 2020S1Q74]

The abundance of a plant species in a habitat can be measured in different ways:

- the density (the number of that plant species per m^2)
- the frequency (the number of quadrats in which the plant species occurs)

The abundance of a plant species in a 100 m^2 area of grassland was measured. The diagram below represents this area of grassland. Each black circle represents one individual of the plant species in this area of grassland.



Two different size quadrats were used to sample the area:

- large quadrat (50 cm × 50 cm)
- small quadrat (10 cm × 10 cm)

The area is sampled randomly, first using 10 large quadrats and then a second time using 10 small quadrats.

Which of the following statements is/are correct?

1. The overall density in the grassland calculated from sampling with either size quadrat will always be the same.
2. The overall density in the grassland calculated from sampling will always be 1 plant per m^2.
3. The frequency obtained using the small quadrat will always be lower than that obtained with the large quadrat.

(A) one of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

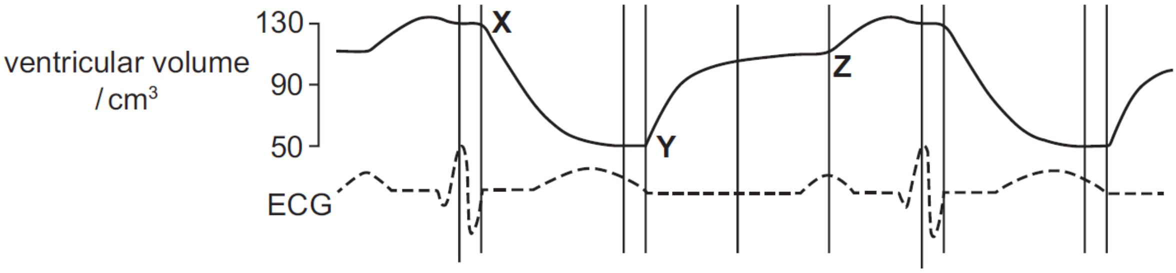
(F) 2 and 3 only

(G) 1 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S1Q75]

The diagram shows the changes in the volume of the ventricles, and the ECG trace that accompanies those changes, during two consecutive heart beats.



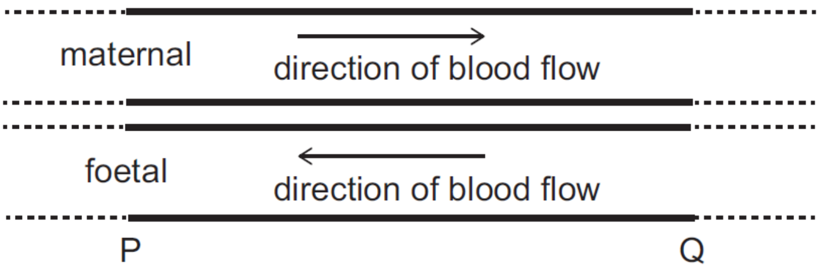
Which row is correct about the events happening at X, Y and Z?

	at X blood is being pumped into	*at X blood is being pumped into*	*at X blood is being pumped into*
(A)	aorta	open	atria
(B)	aorta	closed	atria
(C)	atria	open	ventricles
(D)	atria	closed	ventricles
(E)	pulmonary artery	open	ventricles
(F)	pulmonary artery	closed	ventricles
(G)	pulmonary vein	open	atria
(H)	pulmonary vein	closed	atria

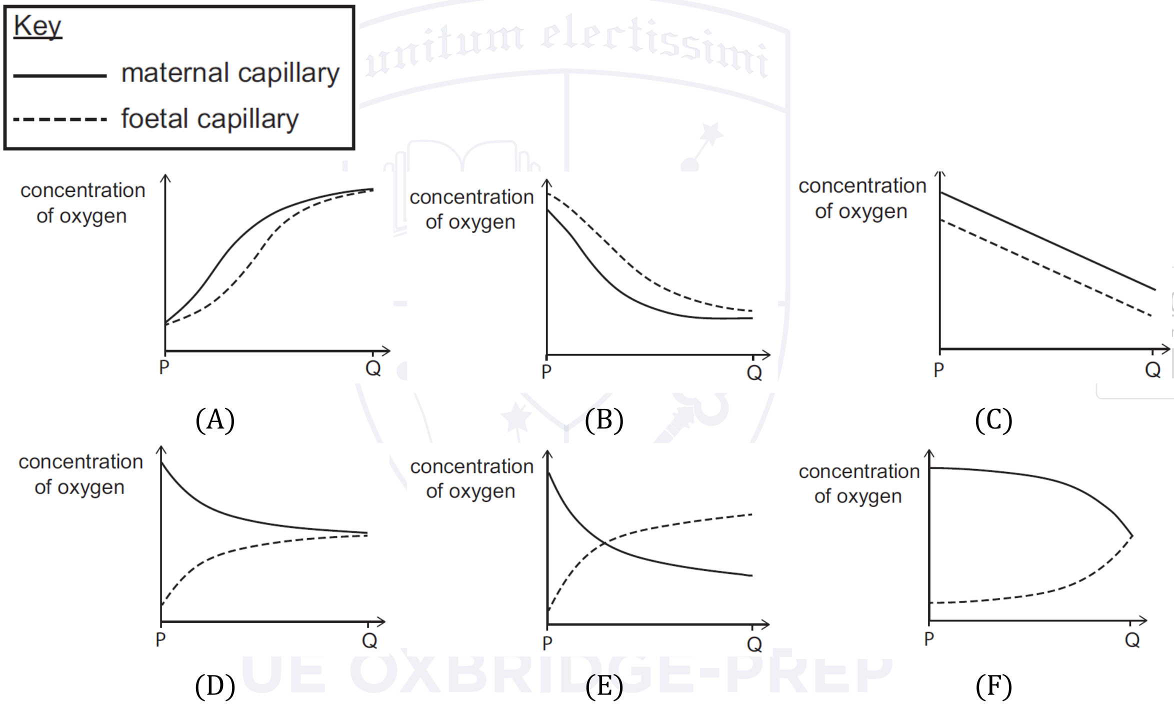
[NSAA, 2020S1Q76]

The placenta is an organ that develops during pregnancy. One function of the placenta is to allow the exchange of gases between the mother and the developing foetus.

The diagram represents the maternal and foetal blood flow between P and Q in a section of the placenta of a healthy small mammal. The concentration of oxygen in both maternal and foetal blood was measured at regular distances along this section.



Which graph illustrates the concentration of oxygen in both maternal and foetal blood between P and Q?



[NSAA, 2020S1Q77]

Catalase is an enzyme found inside plant and animal cells. When catalase is added to hydrogen peroxide, bubbles of oxygen gas are formed.

Red blood cells were placed into either water or plasma, and were placed in the dark.

Plant cells were placed into either water or 0.5 mol dm^{-3} sucrose solution, and were placed in the dark.

Assume that hydrogen peroxide and catalase do not cross the cell surface membrane.

Which row shows the results when hydrogen peroxide was added?

Key

✓ = oxygen bubbles will form

x = oxygen bubbles will not form

	when hydrogen peroxide was added to			
	red blood cells in plasma	plant cells in a 0.5 mol dm^{-3} sucrose solution	red blood cells in water	plant cells in water
(A)	√	√	×	×
(B)	×	×	√	√
(C)	×	×	√	×
(D)	×	×	×	√
(E)	√	√	√	×
(F)	√	√	×	√

[NSAA, 2020S1Q78]

Three different methods, X, Y and Z, of controlling pathogens in the human body are compared in the table.

method of controlling the pathogen	*affects bacterial pathogens*	*affects viral pathogens*	*requires the movement of human cells to have an effect*	*uses a molecule released from human cells*
X	yes	yes	yes	no
Y	yes	no	no	no
Z	yes	yes	no	yes

Which row in the following table is correct?

	method of controlling the pathogen		
	X	Y	Z
(A)	may be stimulated by injections of inactivated pathogen	taking an antibiotic	may work by cells engulfing pathogens
(B)	may be stimulated by injections of inactivated pathogen	may work by cells engulfing pathogens	taking an antibiotic
(C)	taking an antibiotic	may be stimulated by injections of inactivated pathogen	may work by cells engulfing pathogens
(D)	taking an antibiotic	may work by cells engulfing pathogens	may be stimulated by injections of inactivated pathogen
(E)	may work by cells engulfing pathogens	may be stimulated by injections of inactivated pathogen	taking an antibiotic
(F)	may work by cells engulfing pathogens	taking an antibiotic	may be stimulated by injections of inactivated pathogen

[NSAA, 2020S1Q79]

In rabbits, there are two alleles concerned with dark pigment in the fur:

- the dominant allele, B, for black colour
- the recessive allele, b, for brown colour

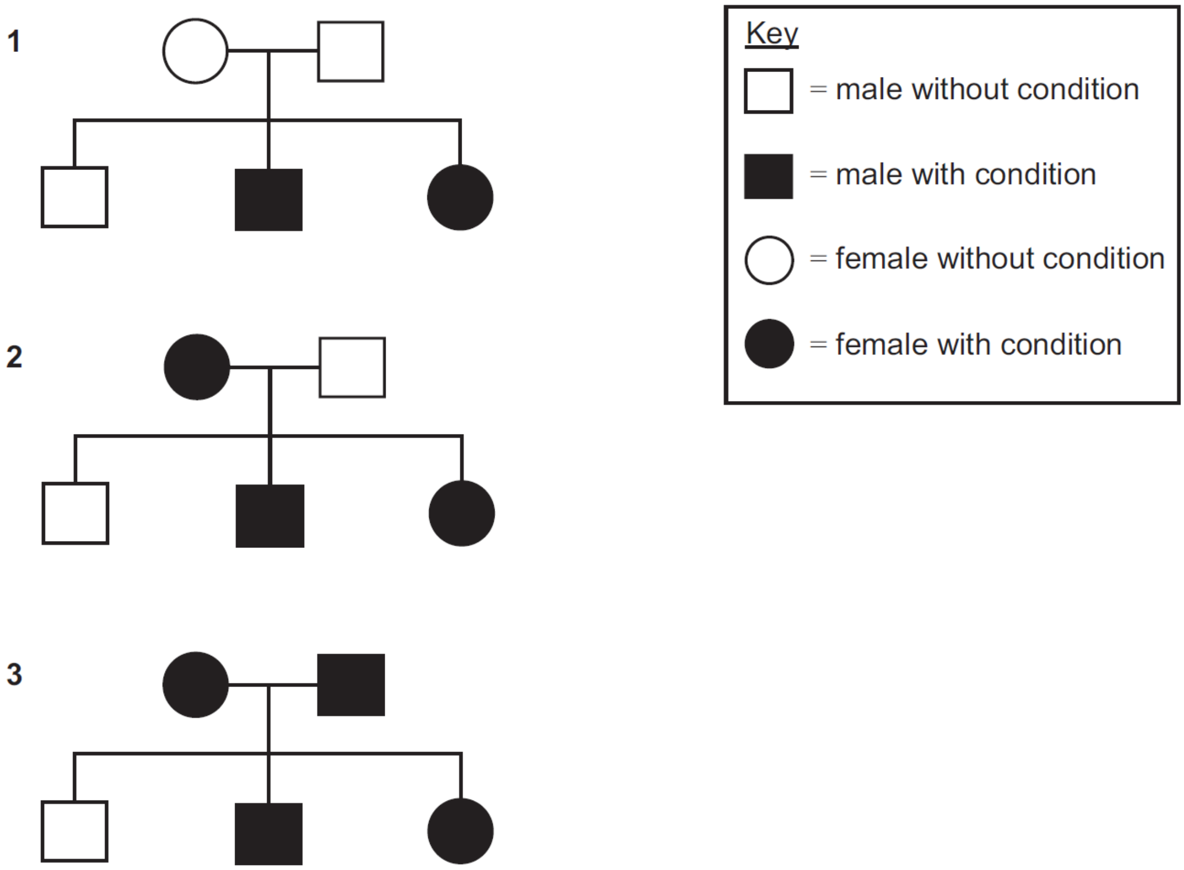
Two male black rabbits of unknown genotype each mated with a different female brown rabbit.

What is the expected proportion of brown offspring if both male rabbits are heterozygous, and what is the expected proportion of brown offspring if only one male rabbit is heterozygous?

	expected proportion of brown offspring	
	if both male rabbits heterozygous	*if only one male rabbit heterozygous*
(A)	0.25	0.5
(B)	0.25	1
(C)	0.5	0.25
(D)	0.5	1
(E)	1	0.25
(F)	1	0,.5

[NSAA, 2020S1Q80]

The three family trees show the inheritance of three different genetic conditions, each controlled by one gene with one dominant and one recessive allele.



In which of the family trees **must** the male parent be heterozygous?

(Assume that no new mutations occur and that the genes are not found on the X chromosome.)

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

NSAA 2020 S2

NSAA 2020 S2

On-line Exam

Scan the QR code or click on the link to take an on-line exam.

Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 2 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

This paper contains **three** parts: **X**, **Y** and **Z**.

All candidates should complete only **one** part chosen from:

Part X	Physics
Part Y	Chemistry
Part Z	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt **all** 20 questions in your chosen part. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

A Periodic Table is included.

Dictionaries and calculators are NOT permitted.

Part X

[NSAA, 2020S2Q1]

Spring P has spring constant 1.0 N cm^{-1} and spring Q has spring constant 3.0 N cm^{-1}.

The two springs are connected in series.

The springs are stretched by 6.0 cm in total.

What is the extension of spring P?

(The springs have negligible mass and obey Hooke's law.)

(A) 1.5 cm

(B) 2.0 cm

(C) 3.0 cm

(D) 4.0 cm

(E) 4.5 cm

[NSAA, 2020S2Q2]

A single strand of wire has a radius of 2.0×10^{-4} m and length 15 m. The resistivity of the material from which the wire is made is 4.8×10^{-7} m.

Twelve strands of this wire are connected in parallel to make a cable.

What is the resistance of the cable?

(A) $\frac{\pi}{2160}\,\Omega$

(B) $\frac{\pi}{180}\,\Omega$

(C) $\frac{\pi}{15}\,\Omega$

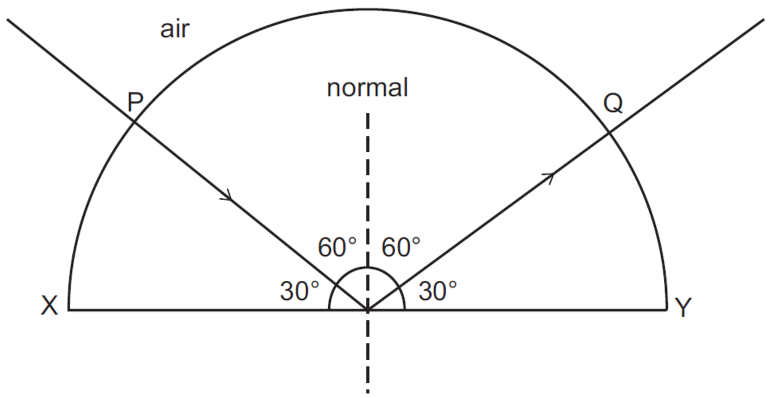
(D) $\frac{15}{\pi}\,\Omega$

(E) $\frac{180}{\pi}\,\Omega$

(F) $\frac{2160}{\pi}\,\Omega$

[NSAA, 2020S2Q3]

A ray of light is directed into a semicircular transparent block, entering at P. The direction of the ray is adjusted until it strikes the centre of the flat face XY of the block at the critical angle and reflects to Q as shown.



The length of XY is L.

The speed of light in air is c.

What is the time taken by the light to travel from P to Q in the block?

(A) $\frac{L\sqrt{3}}{2c}$

(B) $\frac{L}{c}$

(C) $\frac{2L}{c\sqrt{3}}$

(D) $\frac{L\sqrt{3}}{c}$

(E) $\frac{2L}{c}$

(F) $\frac{4L}{c\sqrt{3}}$

[NSAA, 2020S2Q4]

A solid cube with sides of length 20 cm is made from material with density 2000 kg m^{-3}. The cube is suspended, in equilibrium, from an initially unstretched spring, and this results in the spring gaining strain energy of 3.2 J.

What is the spring constant of the spring?

(gravitational field strength = 10 N kg^{-1}; the spring obeys Hooke's law)

(A) 40 N m^{-1}

(B) 80 N m^{-1}

(C) 400 N m^{-1}

(D) 800 N m^{-1}

(E) 4000 N m^{-1}

(F) 8000 N m^{-1}

[NSAA, 2020S2Q5]

A projectile is fired upwards from the ground at an angle of 60° to the vertical at a speed of 20 m s^{-1}.

It travels a horizontal distance d and lands with a downwards vertical component of velocity of 4.0 m s^{-1} on ground that is height h above the starting point of the projectile.

What are d and h?

(gravitational field strength = 10 N kg^{-1}; assume that air resistance is negligible)

	d / m	h / m
(A)	$6.0\sqrt{3}$	4.2
(B)	$6.0\sqrt{3}$	5.8
(C)	$10\sqrt{3} - 4.0$	4.2
(D)	$10\sqrt{3} - 4.0$	14.2
(E)	$10\sqrt{3} + 4.0$	5.8
(F)	$10\sqrt{3} + 4.0$	14.2
(G)	$14\sqrt{3}$	4.2
(H)	$14\sqrt{3}$	5.8

[NSAA, 2020S2Q6]

Diagram 1 shows the positions of nine equally spaced particles in a medium.

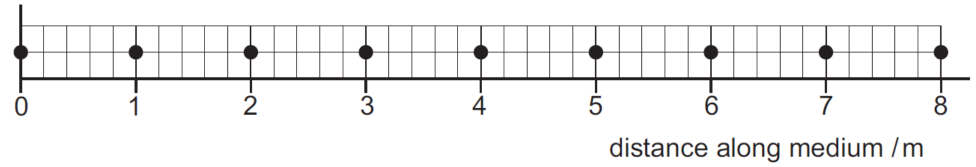


Diagram 1

Diagram 2 shows the positions of the same nine particles, at a particular time, while a longitudinal wave is travelling through the medium.

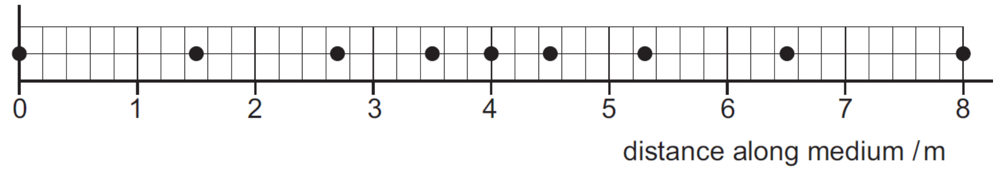


Diagram 2

What is the amplitude of the wave?

(A) 0.4 m

(B) 0.5 m

(C) 0.6 m

(D) 0.7 m

(E) 2.0 m

(F) 4.0 m

(G) 6.0 m

(H) 8.0 m

[NSAA, 2020S2Q7]

A spaceship with mass 8.0×10^4 kg travels at constant velocity and has 1.0×10^{12} J of kinetic energy.

An external impulse of 8.0×10^7 kg m s^{-1}, lasting for 2.0 s, is applied to the spaceship acting in the opposite direction to the motion of the spaceship.

What is the average rate of loss of kinetic energy of the spaceship during the application of the impulse?

(A) 9.5×10^{10} W

(B) 1.8×10^{11} W

(C) 2.2×10^{11} W

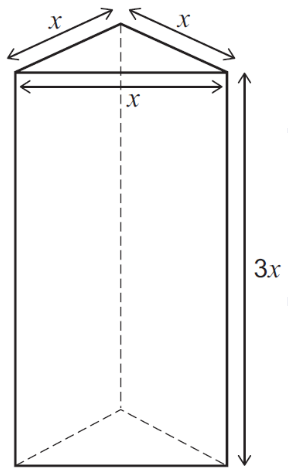
(D) 3.2×10^{11} W

(E) 3.6×10^{11} W

(F) 7.2×10^{11} W

[NSAA, 2020S2Q8]

The diagram shows a solid triangular prism.



The sides of the triangular cross section of the prism are of length x.

The height of the prism is $3x$.

The uniform density of the prism is ρ.

The gravitational field strength is g.

What is the minimum pressure the prism can exert when it rests on level ground?

(A) $3\rho g$

(B) $3\rho g x$

(C) $\frac{\rho g}{4}$

(D) $\frac{\rho g x}{4}$

(E) $\frac{\sqrt{3}\rho g}{4}$

(F) $\frac{\sqrt{3}\rho g x}{4}$

[NSAA, 2020S2Q9]

An apple of mass m_a is placed on a uniform metre rule with the centre of gravity of the apple at the 10 cm mark. The rule is balanced on a pivot placed at the 35 cm mark.

The apple is replaced with an orange of mass m_o. The rule now balances with the pivot at the 40 cm mark.

What is the ratio $\frac{m_a}{m_o}$?

(A) $\frac{5}{9}$

(B) $\frac{4}{5}$

(C) $\frac{5}{6}$

(D) $\frac{6}{5}$

(E) $\frac{5}{4}$

(F) $\frac{9}{5}$

[NSAA, 2020S2Q10]

A cyclist travels at a constant speed of 12 m s^{-1} on level ground. During this time the power needed to maintain a constant speed is 900 W. The total weight of the cyclist and bicycle is 850 N.

The cyclist now cycles up a slope at the same constant speed. The slope is at an angle of 30° to the horizontal.

What is the driving force on the bicycle as it travels up the slope?

(Assume that the magnitude of the resistive forces is constant.)

(A) 75 N

(B) 350 N

(C) 500 N

(D) $(425\sqrt{3} - 75)$ N

(E) 775 N

(F) $(425\sqrt{3} + 75)$ N

(G) 925 N

[NSAA, 2020S2Q11]

Three identical resistors can be combined in four different arrangements.

One of the arrangements has a resistance of 18 Ω.

A different arrangement has a resistance of 8.0 Ω.

What are the resistances of the other two arrangements?

(All three resistors contribute to the total resistance in all arrangements.)?

(A) 2.0 Ω and 4.0 Ω

(B) 2.0 Ω and 9.0 Ω

(C) 4.0 Ω and 12 Ω

(D) 4.0 Ω and 36 Ω

(E) 36 Ω and 162 Ω

(F) 81 Ω and 162 Ω

[NSAA, 2020S2Q12]

A 4.0 kΩ fixed resistor is connected in series with a light dependent resistor (LDR) across a 100 V dc power supply.

The current in the LDR is 5.0 mA.

The intensity of light falling on the LDR now decreases and the voltage across the fixed resistor changes by 50%.

What is the change in the resistance of the LDR as a result of the change in intensity?

(A) 8.0 kΩ

(B) 1 2 kΩ

(C) 1 6 kΩ

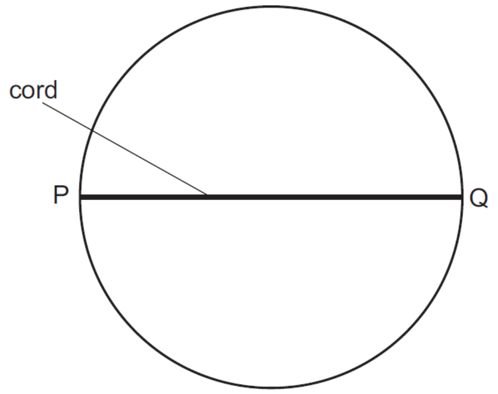
(D) 2 0 kΩ

(E) 3 2 kΩ

(F) 3 6 kΩ

[NSAA, 2020S2Q13]

An elastic cord with spring constant k is fixed to two points P and Q on the diameter of a ring so that the cord is taut but unstretched. The radius of the ring is r.



The midpoint of the cord is then pulled and fixed to a point on the ring halfway between P and Q.

What is the energy stored in the elastic cord?

(A) $\frac{1}{2}kr^2$

(B) $2kr^2$

(C) $\frac{1}{2}(\sqrt{2}-1)kr^2$

(D) $2(\sqrt{2}-1)kr^2$

(E) $\frac{1}{2}(3-2\sqrt{2})kr^2$

(F) $2(3-2\sqrt{2})kr^2$

[NSAA, 2020S2Q14]

An object of mass M experiences a resultant force of magnitude F. The force acts in a single horizontal direction with a magnitude that varies with time t according to

$$F = X + Y\sqrt{t}$$

where X and Y are constants.

The object is at rest at $t = 0$.

What is the magnitude of the momentum of the object at time $t = T$?

(A) $T\left(X + \frac{2}{3}Y\sqrt{T}\right)$

(B) $T(X + Y\sqrt{T})$

(C) $\frac{T}{M}\left(X + \frac{2}{3}Y\sqrt{T}\right)$

(D) $\frac{T}{M}(X + Y\sqrt{T})$

(E) $\frac{Y}{2\sqrt{T}}$

(F) $\frac{Y}{2M\sqrt{T}}$

[NSAA, 2020S2Q15]

A trolley of mass 3.0 kg is moving horizontally along a smooth track. Its displacement x from a point at time t is given by the equation:

$$x = 8 + 4t + 2t^2$$

where x is in metres and t is in seconds.

How much work is done on the trolley between times $t = 0$ and $t = 5.0$ s?

(A) 12 J

(B) 24 J

(C) 78 J

(D) 270 J

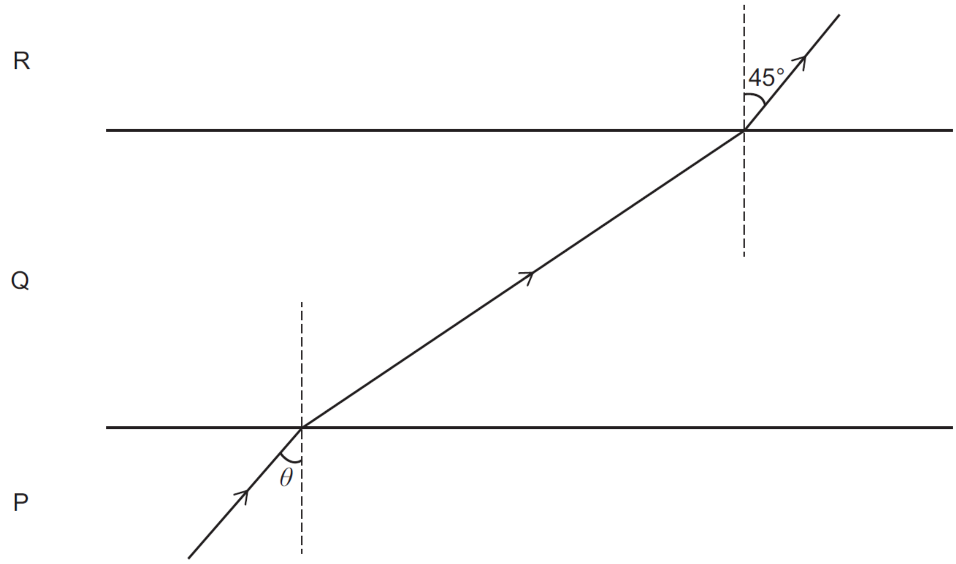
(E) 840 J

(F) 864 J

(G) 936 J

[NSAA, 2020S2Q16]

The diagram shows a ray of light passing through three mediums, P, Q and R. The boundaries between the three mediums are parallel.



The ratio of the speed of light in medium P to the speed of light in medium Q is $2 : \sqrt{5}$.

The ratio of the speed of light in medium Q to the speed of light in medium R is $3 : \sqrt{6}$.

What is the value of $\sin\theta$?

(A) $\frac{\sqrt{2}}{2}$

(B) $\frac{\sqrt{3}}{2}$

(C) $\frac{\sqrt{3}}{6}$

(D) $\frac{\sqrt{5}}{5}$

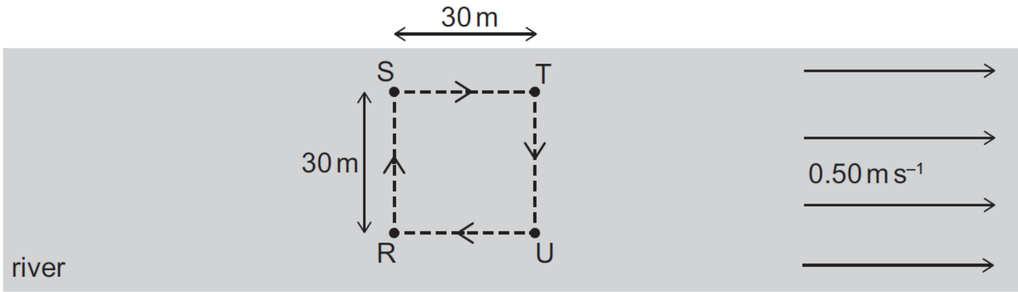
(E) $\frac{\sqrt{15}}{5}$

(F) $\frac{\sqrt{15}}{6}$

[NSAA, 2020S2Q17]

Water in a wide river flows at a constant speed of 0.50 m s^{-1}. A swimmer swims around a square path of side 30 m marked out by 4 posts R, S, T and U which are fixed to the river bed, as shown.

The swimmer has a constant speed of 1.0 m s^{-1} relative to the water.



How long does it take for the swimmer to swim around the square path once?

(A) $(60 + 24\sqrt{5})$ s

(B) $(60 + 40\sqrt{3})$ s

(C) $(80 + 24\sqrt{5})$ s

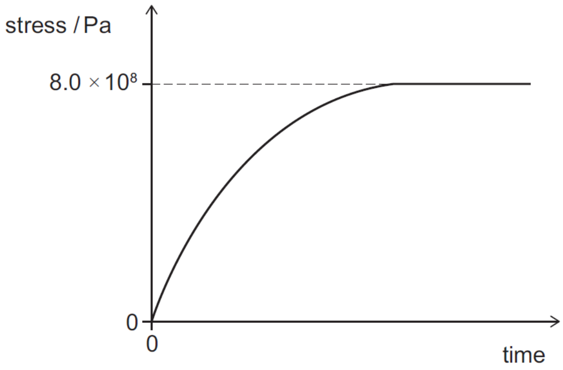
(D) $(80 + 40\sqrt{3})$ s

(E) 120 s

(F) 140 s

[NSAA, 2020S2Q18]

The stress in a steel cable increases with time and is then maintained at a constant value, as shown. The wire does not reach its limit of proportionality.



The table shows properties of the steel used in the cable and the dimensions of the cable.

length / m	*cross-sectional area* / m^2	*Young modulus* / Pa
4.0	2.0×10^{-4}	2.0×10^{11}

How much work was done to stretch the cable?

(A) 320 J

(B) 1.28 kJ

(C) 2.56 kJ

(D) 320 kJ

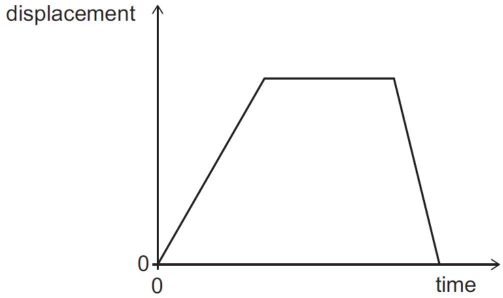
(E) 640 kJ

(F) 1.60 MJ

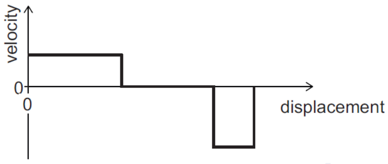
(G) 6.40 MJ

[NSAA, 2020S2Q19]

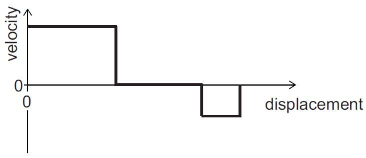
The following graph shows how the displacement of an object travelling along a straight, horizontal track varies with time.



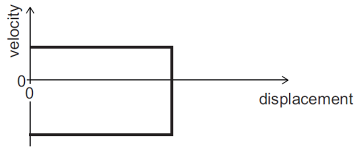
Which graph shows the velocity of this object against displacement?



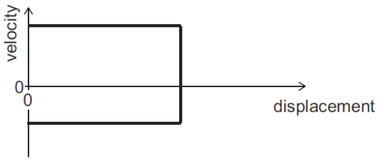
(A)



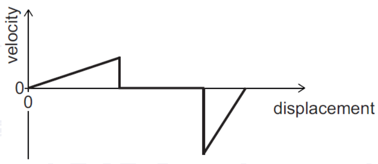
(B)



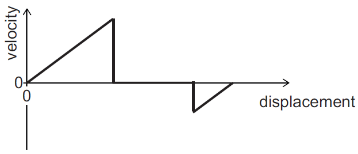
(C)



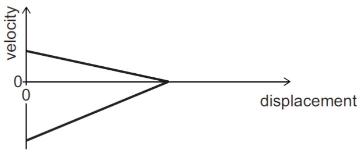
(D)



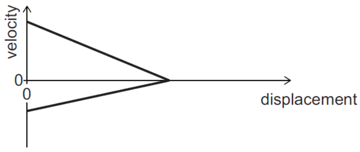
(E)



(F)



(G)



(H)

[NSAA, 2020S2Q20]

A cell has emf E and internal resistance r that varies with current I according to:

$$r = kI^2$$

where k is a constant.

A variable resistor is connected to the terminals of the cell. The resistance of the variable resistor is adjusted.

Which expression gives the resistance of the variable resistor, in terms of k and E, that causes maximum power dissipation in it?

(A) $3\left(\frac{kE^2}{2}\right)^{\frac{1}{3}}$

(B) $3\left(\frac{kE^2}{4}\right)^{\frac{1}{3}}$

(C) $3\left(\frac{kE^2}{9}\right)^{\frac{1}{3}}$

(D) $3\left(\frac{kE^2}{16}\right)^{\frac{1}{3}}$

(E) $(2kE^2)^{\frac{1}{3}}$

(F) $(4kE^2)^{\frac{1}{3}}$

(G) $(9kE^2)^{\frac{1}{3}}$

(H) $(16kE^2)^{\frac{1}{3}}$

Part Y

[NSAA, 2020S2Q21]

The table gives standard enthalpy change data measured at 25 °C.

reaction	standard enthalpy change / kJ mol^{-1}
$H(g) + Br(g) \rightarrow HBr(g)$	−366
$H(g) + Br(g) \rightarrow H^+(g) + Br^-(g)$	+968
$HBr(g) \rightarrow H^+(aq) + Br^-(aq)$	−92

What is the standard enthalpy change for the following reaction at 25 °C?

$$H^+(g) + Br^-(g) \rightarrow H^+(aq) + Br^-(aq)$$

(A) −510 kJ mol^{-1}

(B) +510 kJ mol^{-1}

(C) −694 kJ mol^{-1}

(D) +694 kJ mol^{-1}

(E) −1242 kJ mol^{-1}

(F) +1242 kJ mol^{-1}

(G) −1426 kJ mol^{-1}

(H) +1426 kJ mol^{-1}

[NSAA, 2020S2Q22]

Alpha-linolenic acid is a polyunsaturated straight-chain carboxylic acid.

0.001 mol of the acid reacts exactly with 15 cm^3 of 0.2 mol dm^{-3} aqueous bromine.

Alpha-linolenic acid contains 18 carbon atoms per molecule.

Which of the following is a formula for the acid?

(A) $C_{17}H_{35}COOH$

(B) $C_{17}H_{34}COOH$

(C) $C_{17}H_{33}COOH$

(D) $C_{17}H_{32}COOH$

(E) $C_{17}H_{31}COOH$

(F) $C_{17}H_{30}COOH$

(G) $C_{17}H_{29}COOH$

(H) $C_{17}H_{28}COOH$

[NSAA, 2020S2Q23]

25.0 g of compound X contains 9.75 g of potassium, 0.25 g of hydrogen and 12.0 g of oxygen.

When heated strongly, compound X produces a gas that turns limewater cloudy.

The chemical formula of X is the same as its empirical formula.

Compound X is the only product formed between substance Y and two further substances. One of these is the fourth most abundant gas in clean dry air, and the other changes the colour of anhydrous copper(II) sulfate from white to blue.

Which of the following could be the identity of substance Y?

(A_r values: H = 1; C = 12; O = 16; K = 39)

(A) K

(B) K_2CO_3

(C) K_2O_3

(D) $KHCO_3$

(E) CH_3COOK

[NSAA, 2020S2Q24]

Strontium (Sr) is a Group 2 metal.

Strontium hydride is an ionic compound made up of strontium and hydrogen only.

When a small mass of strontium hydride is added to 180 g of water in an insulated container and stirred, the temperature of the water rises by 25 °C and hydrogen gas is given off.

Assume that:

- the standard enthalpy change of the reaction is − 360 kJ mol^{-1} of strontium hydride.
- the specific heat capacity of water (and the solution formed) is 4 J g^{-1} $°C^{-1}$. Ignore any change in mass of the water due to the reaction.
- all heat is transferred to the water only.
- all measurements are made at atmospheric pressure, with all reactants and products in their standard states.
- one mole of a gas occupies 24 dm^3 at room temperature and pressure.

What is the maximum volume of hydrogen (measured at room temperature) that could be released?

(A) 1.20 dm^3

(B) 1.80 dm^3

(C) 2.40 dm^3

(D) 240 dm^3

(E) 480 dm^3

(F) 2400 dm^3

[NSAA, 2020S2Q25]

Element X forms the most soluble hydroxide of the hydroxides of the Group 2 elements in the range Mg to Ba.

50 cm^3 of a 0.2 mol dm^{-3} aqueous solution of an acid Y is exactly neutralised by 400 cm^3 of a 0.05 mol dm^{-3} aqueous solution of potassium hydroxide.

100 cm^3 of a 0.1 mol dm^{-3} aqueous solution of Y is titrated with an aqueous solution of the hydroxide of X until the acid is exactly neutralised.

Which statement about one product of the titration could be correct?

(A) 0.005 mol of barium chloride is formed.

(B) 0.05 mol of barium chloride is formed.

(C) 0.005 mol of magnesium chloride is formed.

(D) 0.05 mol of magnesium chloride is formed.

(E) 0.01 mol of barium sulfate is formed.

(F) 0.1 mol of barium sulfate is formed.

(G) 0.01 mol of magnesium sulfate is formed.

(H) 0.1 mol of magnesium sulfate is formed.

[NSAA, 2020S2Q26]

In the presence of a suitable catalyst, 30.0 cm^3 of a 0.10 mol dm^{-3} aqueous solution of $Na_2C_2O_4$ reacts exactly with 40.0 cm^3 of a 0.15 mol dm^{-3} aqueous solution of $Ce(SO_4)_2$.

The only products of the reaction are another cerium salt, a different water-soluble salt and carbon dioxide.

What is the cerium ion formed by this reaction?

(A) Ce^{+}

(B) Ce^{2+}

(C) Ce^{3+}

(D) Ce^{4+}

(E) Ce^{5+}

[NSAA, 2020S2Q27]

Consider all of the structural isomers of C_4H_9Br and the ways that they could react with hydroxide ions from aqueous sodium hydroxide.

How many different organic products (including all structural and E/Z isomers only) containing four carbons could be made?

(A) 4

(B) 5

(C) 6

(D) 7

(E) 8

(F) 9

[NSAA, 2020S2Q28]

In which of the following conversions does the stated bond angle decrease?

1 hydrogen–nitrogen–hydrogen bond angle in the conversion from NH_3 to NH_4^+

2 fluorine–iodine–fluorine bond angle in the conversion from IF_4^- to IF_6^+

3 chlorine–aluminium–chlorine bond angle in the conversion from $AlCl_3$ to $AlCl_4^-$

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q29]

Ethanol combines with ethanoic acid to form ethyl ethanoate according to the following reaction.

$$C_2H_5OH(l) + CH_3COOH(l) \leftrightarrows CH_3COOC_2H_5(l) + H_2O(l) \qquad \Delta H = -6 \text{ kJ mol}^{-1} \text{ at } 25\ °C$$

A mixture of 9.2 g ethanol, 12 g ethanoic acid and 8.8 g ethyl ethanoate is allowed to react and reach equilibrium.

The resulting equilibrium mixture is found to contain 4.8 g ethanoic acid at 25 °C and K_c was calculated.

What will happen to the value of K_c when the temperature is increased from 25 °C to 45 °C?

(M_r values: $C_2H_5OH = 46$; $CH_3COOH = 60$; $CH_3COOC_2H_5 = 88$; $H_2O = 18$)

(A) It increases from an initial value of 0.242

(B) It decreases from an initial value of 0.242

(C) It increases from an initial value of 1.833

(D) It decreases from an initial value of 1.833

(E) It increases from an initial value of 2.750

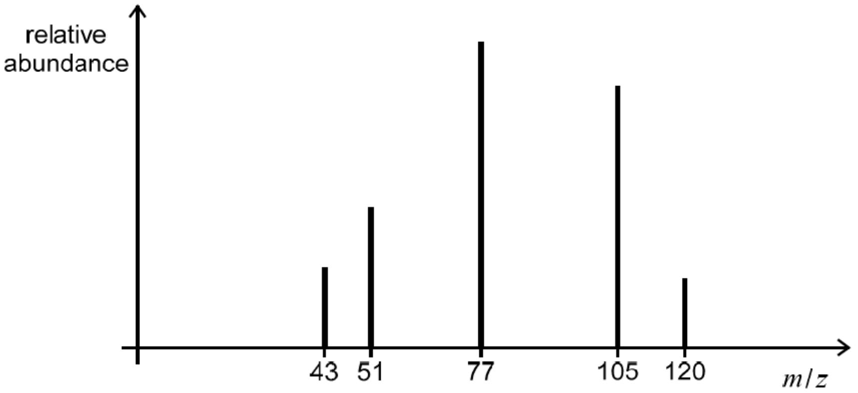
(F) It decreases from an initial value of 2.750

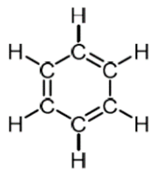
(G) It increases from an initial value of 4.125

(H) It decreases from an initial value of 4.125

[NSAA, 2020S2Q30]

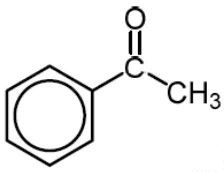
Compound Z is known to have percentage composition by mass C: 80.0%, H: 6.7%, O: 13.3%. The mass spectrum of compound Z is given showing the mass-to-charge ratio (m/z) of the molecular ion and its fragments.

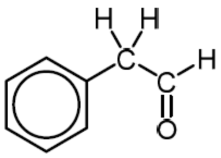


 and  are representations of the same molecule

Which of the following could be the structure of Z?

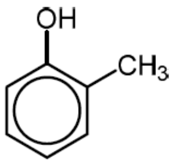
(A_r values: C = 12; H = 1; O = 16)

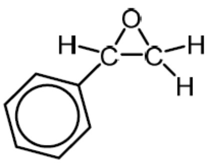
(A) 

(B) 

(C) $CH_3CH_2CH_2CH(OH)CH(OH)CH_3$

(D) $CH_2 = CHCH = CHCH = CH - CH = C = O$

(E) 

(F) 

[NSAA, 2020S2Q31]

The time it takes the ion ${}^{1}_{1}H^{+}$ to travel through the flight tube in a time of flight mass spectrometer is t.

How long would it take the ion ${}^{2}_{1}H^{+}$ to travel through the same flight tube?

(A) $\frac{1}{4}t$

(B) $\frac{1}{2}t$

(C) $\frac{1}{\sqrt{2}}t$

(D) $\sqrt{\frac{2}{3}}t$

(E) $\sqrt{\frac{3}{2}}t$

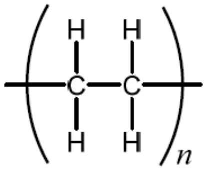
(F) $\sqrt{2}t$

(G) $2t$

(H) $4t$

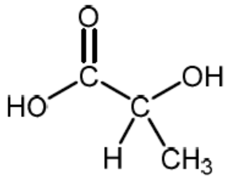
[NSAA, 2020S2Q32]

A paper coffee cup is lined with a thin layer of plastic to make it waterproof. This plastic makes up 5% of the mass of the cup and has the following molecular structure.



960 dm³ of a gaseous hydrocarbon monomer (measured at room temperature and pressure) was used to make a certain number of plastic-lined cups.

It is proposed that a more environmentally-friendly, biodegradable plastic, poly(lactic acid), could be used instead in the same proportions by mass (5%). Assume that any polymerization reaction has a 100% yield.



lactic acid

What mass of lactic acid ($M_r = 90$) is required to make the same number of biodegradable cups?

(A_r values: H = 1; C = 12; O = 16. Assume that one mole of a gas occupies 24 dm³ at room temperature and pressure.)

(A) 896 g

(B) 1120 g

(C) 1200 g

(D) 1400 g

(E) 1500 g

(F) 3000 g

(G) 3600 g

[NSAA, 2020S2Q33]

In which of the following pairs do **both** molecules possess permanent dipoles in the gaseous state?

1 methylamine (CH_3NH_2) and dichlorine monoxide (Cl_2O)

2 difluoroethyne (C_2F_2) and sulfur hexafluoride

3 phosphorus trichloride and xenon tetrafluoride

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q34]

At high temperatures, carbon dioxide reacts partially with solid carbon and forms the following equilibrium.

$$CO2(g) + C(s) \rightleftharpoons 2CO(g)$$

In an experiment, 1.0 mol of carbon dioxide is placed in a flask of capacity V dm^3 containing no air and an excess of carbon. It is then heated to a high temperature where an equilibrium between carbon dioxide and carbon monoxide is established. At this temperature, x mol of carbon dioxide converts to carbon monoxide and the value of the equilibrium constant, K_c, is 2.0 mol dm^{-3}.

As it is a solid, carbon is not included in the equilibrium constant expression.

What is the relationship between the value of x and V?

(A) $x = \frac{-V+\sqrt{V^2+32V}}{16}$

(B) $x = \frac{-V+\sqrt{V^2+8V}}{4}$

(C) $x = \frac{-2+\sqrt{4V^2+8V}}{4}$

(D) $x = \frac{-2V+\sqrt{4V^2-2V}}{2}$

(E) $x = \frac{-2+\sqrt{4-32V}}{4V}$

[NSAA, 2020S2Q35]

A student carried out an experiment to find the mass of the active ingredient calcium carbonate ($M_r = 100$) in an indigestion tablet. The student crushed the tablet and placed it in a beaker.

The student added 20.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid, an excess, to the tablet. When the reaction was complete, the reaction mixture was all transferred to a volumetric flask and deionised water added to make the solution up to 250 cm^3.

25.0 cm^3 samples of the solution in the volumetric flask were titrated against 0.100 mol dm^{-3} sodium hydroxide solution. The mean titre was 26.40 cm^3 of sodium hydroxide solution.

Assuming that all other ingredients in the tablet are inert, what is the mass of calcium carbonate in the tablet?

(A) 0.264 g

(B) 0.680 g

(C) 1.36 g

(D) 1.87 g

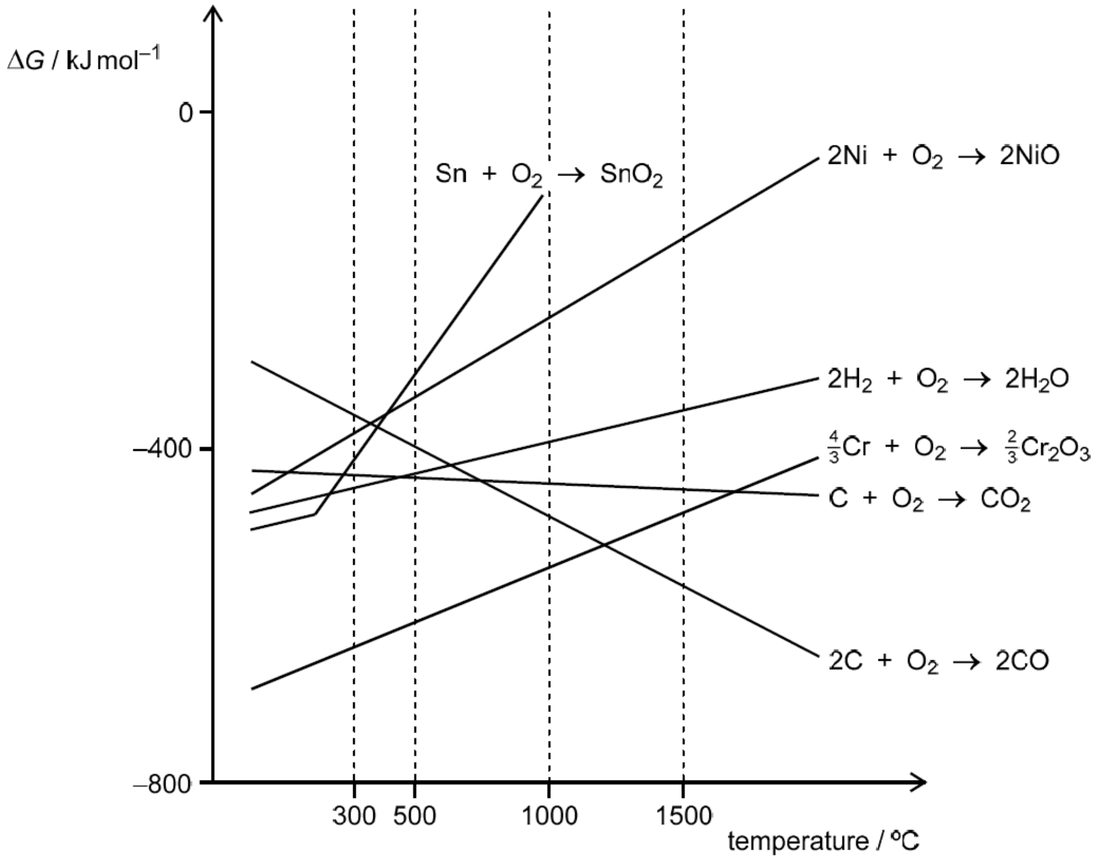
(E) 2.72 g

[NSAA, 2020S2Q36]

Ellingham diagrams show how the quantity ΔG for a reaction varies over a range of temperatures.

The ΔG values for different reactions can be combined using Hess's law.

For a reaction to be able to occur, the overall value of ΔG must be less than zero.



Using the Ellingham diagram shown, which one of the following statements is correct?

(A) Nickel can reduce tin(IV) oxide at 300 °C.

(B) Carbon can reduce chromium(III) oxide at 1500 °(C) forming carbon dioxide and chromium.

(C) Chromium(III) oxide and nickel oxide will decompose to their elements at all the temperatures shown.

(D) Chromium will react with steam at all the temperatures shown.

(E) Nickel oxide can be reduced by carbon at 300 °(C) forming carbon monoxide and nickel.

[NSAA, 2020S2Q37]

SO_3^{2-}(aq) ions can cause the reduction of VO_3^-(aq) ions to VO^{2+}(aq) in acidic solution. During this process, the SO_3^{2-} (aq) ions are oxidised to SO_4^{2-} (aq) ions.

What is the minimum volume of 1.00 mol dm^{-3} sulfuric acid required to provide sufficient hydrogen ions to allow Na_2SO_3(aq) to reduce 40.0 cm^3 of 0.100 mol dm^{-3} VO_3^-(aq) ions completely to VO^{2+}(aq)?

(A) no sulfuric acid is required

(B) 4.0 cm^3

(C) 6.0 cm^3

(D) 6.6 cm^3

(E) 8.0 cm^3

(F) 12.0 cm^3

(G) 13.2 cm^3

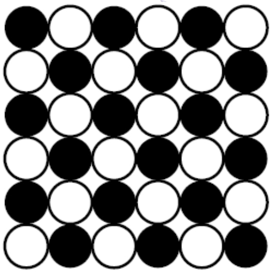
[NSAA, 2020S2Q38]

Sodium chloride is an ionic compound which forms highly ordered crystals of ions when in the solid state. This is called a lattice.

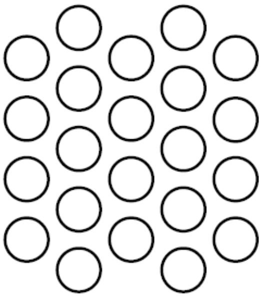
A lattice can be thought of as a stack of layered planes of ions.

In the following diagrams, the shaded and non-shaded circles represent sodium and chloride ions, respectively.

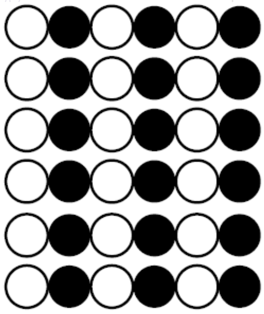
Which of the following is **not** a representation of a plane present in a sodium chloride lattice?



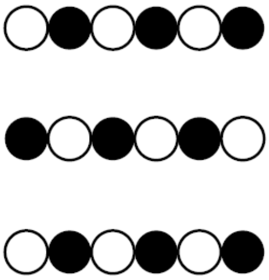
(A)



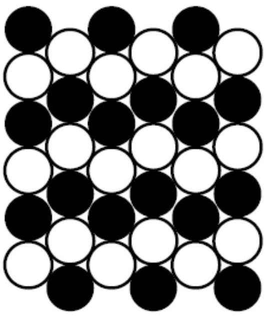
(B)



(C)



(D)

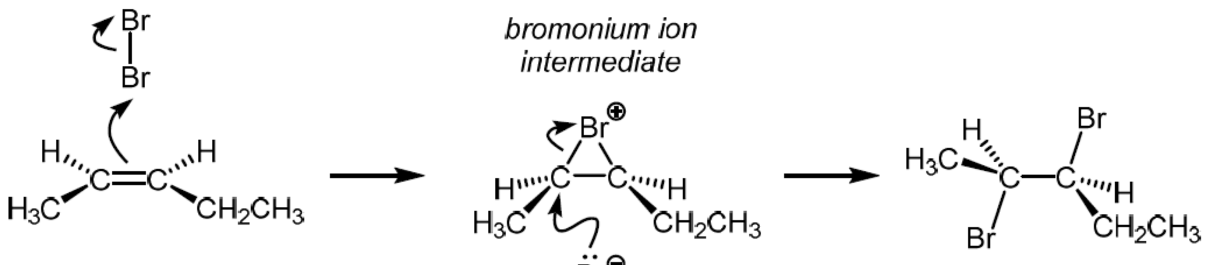


(E)

[NSAA, 2020S2Q39]

When bromine reacts with (Z)-pent-2-ene, an intermediate called a bromonium ion forms. This is then attacked by the bromide ion to give the 2,3-dibromopentane addition product.

The mechanism is shown:

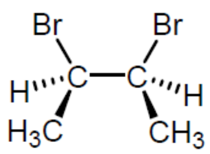


(Z)-pent-2-ene

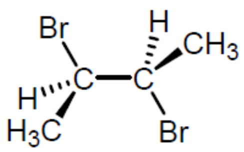
2,3-dibromopentane

In a different reaction **(E)-but-2-ene** is reacted with bromine in an addition reaction. This reaction also occurs via a bromonium ion intermediate.

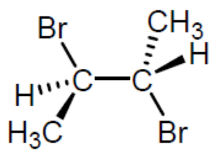
Which of the following structures show the final product of the reaction of **(E)-but-2-ene** with bromine?



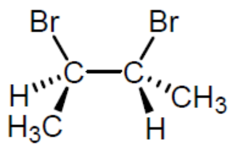
1



2



3



4

(A) structures 1 and 2 only

(B) structures 1 and 3 only

(C) structures 1 and 4 only

(D) structures 2 and 3 only

(E) structures 2 and 4 only

(F) structures 3 and 4 only

(G) structures 1, 2, 3 and 4

[NSAA, 2020S2Q40]

Both oxygen and carbon monoxide bind reversibly to haemoglobin.

For the purposes of this question, assume that only one molecule of either oxygen or carbon monoxide can bind to haemoglobin at any one time.

Within the human body, carbon monoxide is 200 times more effective than oxygen in binding to haemoglobin available in human blood. The binding efficiency is the equilibrium constant for this process and you may assume that the system is at equilibrium.

The effects of carboxy-haemoglobin in humans can typically be observed when it reaches 5% of the concentration of oxy-haemoglobin in their blood.

Assume that oxygen and carbon monoxide have the same molar solubility in blood.

What is the minimum proportion of carbon monoxide molecules in dry air, expressed as parts per million (ppm), that will result in a 5% ratio of carboxy-haemoglobin molecules to oxy-haemoglobin molecules in blood?

(A) 10 ppm

(B) 21 ppm

(C) 52.5 ppm

(D) 210 ppm

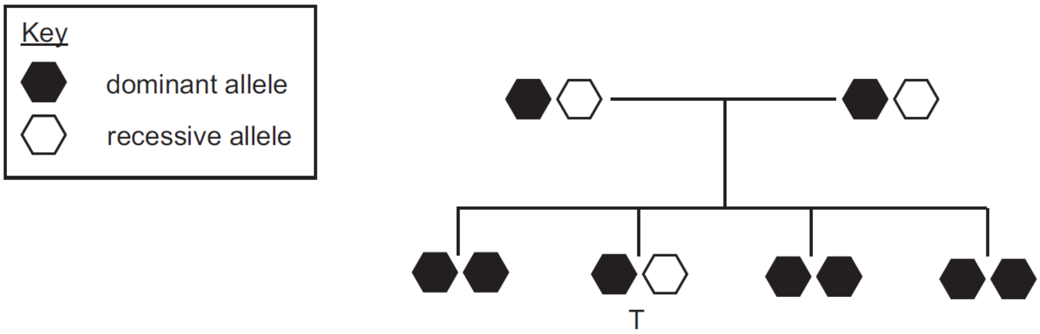
(E) 1000 ppm

(F) 5250 ppm

Part Z

[NSAA, 2020S2Q41]

The diagram shows the inheritance of a characteristic controlled by a single gene. Two organisms reproduce sexually and have four offspring, one offspring at a time.



Individual T goes on to have a single offspring with an unrelated individual who has a recessive phenotype. The offspring of T has a dominant phenotype.

What is the ratio of dominant to recessive alleles for all of the individuals in this diagram, as well as T's mate and their one offspring?

(A) 3 : 5

(B) 5 : 3

(C) 7 : 1

(D) 1 : 7

(E) 3 : 1

(F) 1 : 3

(G) 2 : 1

(H) 1 : 2

[NSAA, 2020S2Q42]

The average healthy mature red blood cell contains 200 000 000 molecules of haemoglobin.

If a red blood cell is saturated with dissolved oxygen, each haemoglobin molecule carries a total of 4 molecules of oxygen.

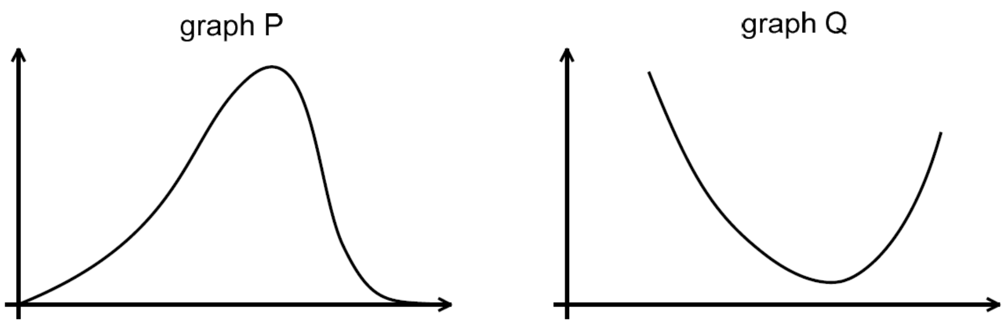
Haemoglobin molecules in red blood cells in the pulmonary artery are on average 65% saturated with oxygen.

How many oxygen molecules are carried by the average red blood cell in the pulmonary artery, and is the level of oxygen saturation greater in the aorta or the pulmonary artery?

	number of oxygen molecules carried	*level of oxygen saturation*
(A)	8.0×10^8	aorta > pulmonary artery
(B)	8.0×10^8	aorta < pulmonary artery
(C)	5.2×10^8	aorta > pulmonary artery
(D)	5.2×10^8	aorta < pulmonary artery
(E)	2.8×10^8	aorta > pulmonary artery
(F)	2.8×10^8	aorta < pulmonary artery
(G)	1.3×10^8	aorta > pulmonary artery
(H)	1.3×10^8	aorta < pulmonary artery

[NSAA, 2020S2Q43]

Graphs P and Q were plotted using data collected in an investigation into the effect of temperature from 0 to 60 °C on an enzyme-controlled reaction. All other variables were controlled.



Which two rows correctly identify the variables plotted on the horizontal and vertical axes of these graphs?

row	*graph*	*horizontal axis*	*vertical axis*
1	P	temperature	time taken for reaction
2	P	temperature	rate of reaction
3	P	time taken for reaction	temperature
4	P	time taken for reaction	rate of reaction
5	Q	temperature	time taken for reaction
6	Q	temperature	rate of reaction
7	Q	time taken for reaction	temperature
8	Q	time taken for reaction	rate of reaction

(A) 1 and 6

(B) 1 and 7

(C) 2 and 5

(D) 2 and 6

(E) 3 and 5

(F) 3 and 8

(G) 4 and 7

(H) 4 and 8

[NSAA, 2020S2Q44]

A recessive condition is found within a human population. There were 5000 births in this population within one year. Of these births, 8% had the condition and 32% were homozygous dominant.

One healthy cheek cell is analysed from each person born in this year.

How many recessive alleles and dominant alleles are present?

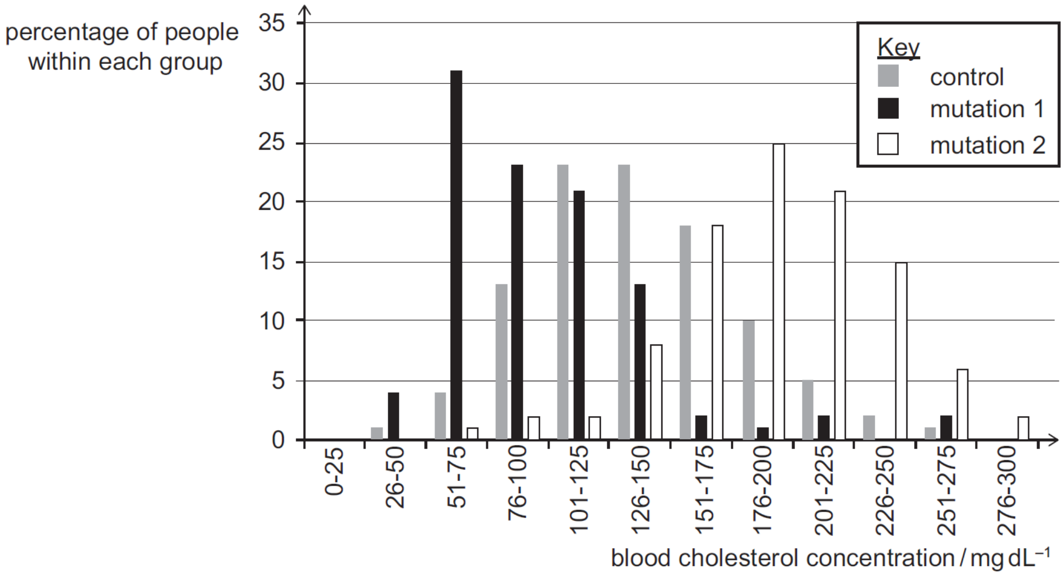
(Assume that no new mutations occur.)

	recessive alleles	*dominant alleles*
(A)	400	1600
(B)	400	4600
(C)	3400	1600
(D)	3400	4600
(E)	3400	6200
(F)	3800	1600
(G)	3800	4600
(H)	3800	6200

[NSAA, 2020S2Q45]

A study was carried out into the effect of liver protein Z on the risk of developing coronary heart disease, which is often associated with high blood cholesterol. Z binds to another protein in the membrane of liver cells that transports cholesterol from the blood into cells. This binding blocks the function of the transport protein.

Blood cholesterol levels were measured in three different groups of people. One group was a control group and contained no mutations in the gene for Z. The second group all had the same mutation in the gene (called mutation 1). This mutation occurs in the final section of the gene. A third group all had a different mutation in the gene (called mutation 2), but this was in the first section of the gene. The results are shown in the graph.



Which of the following can be correctly concluded from these results?

1 Changes in the first section of protein Z stop it from binding to the cholesterol transport protein.

2 Mutation 1 could result in an increase in the concentration of cholesterol inside liver cells.

3 Of the three groups, people in the control group are least likely to develop coronary heart disease.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

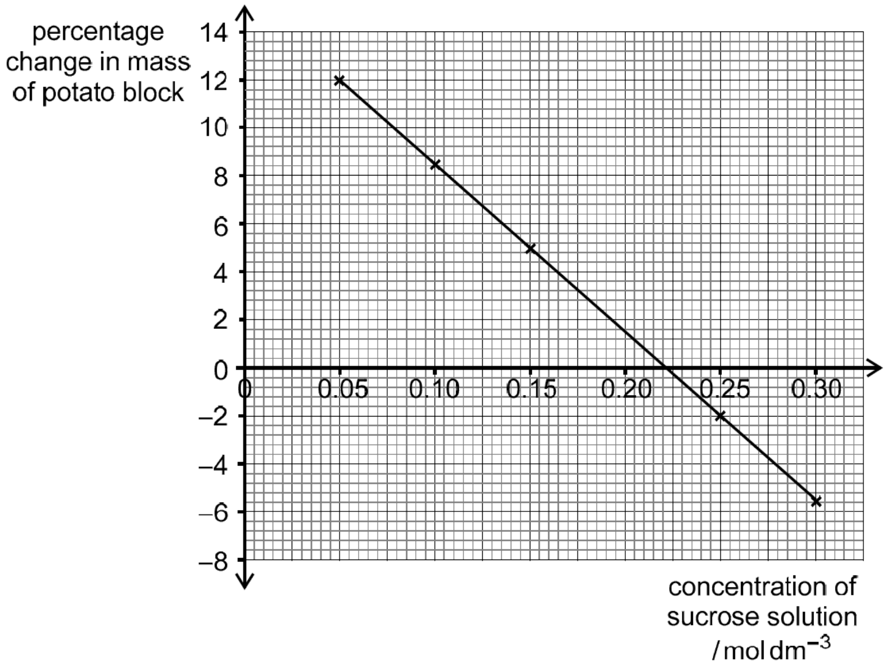
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q46]

Equal-sized, rectangular blocks of a raw potato were cut and their mass measured. The blocks were then placed in equal volumes of different concentrations of sucrose solutions for the same length of time. All other variables were kept constant.

After this time, the blocks were blotted on paper and then their masses were measured again. The percentage change in mass of each block was calculated and the results are shown in the graph.



Which of the following statements is/are correct?

1 In 0.10 mol dm^{-3} sucrose solution, there was some movement of sucrose molecules by osmosis across the membrane out of the potato block.

2 If the initial mass of the block in 0.25 mol dm^{-3} sucrose solution is 1.800 g then its final mass will be 1.764 g.

3 Repeating the experiment at a temperature that was 10 °C lower should not affect the point at which the graph crosses the x-axis.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q47]

The table shows the sources of water lost in one particular day from a healthy human.

percentage of the water that is lost	source
16	exhaled air
4	faeces
20	sweat
60	urine

On another day, the percentage of water lost in urine decreased by a sixth.

The percentage of water lost in exhaled air and in faeces remained the same.

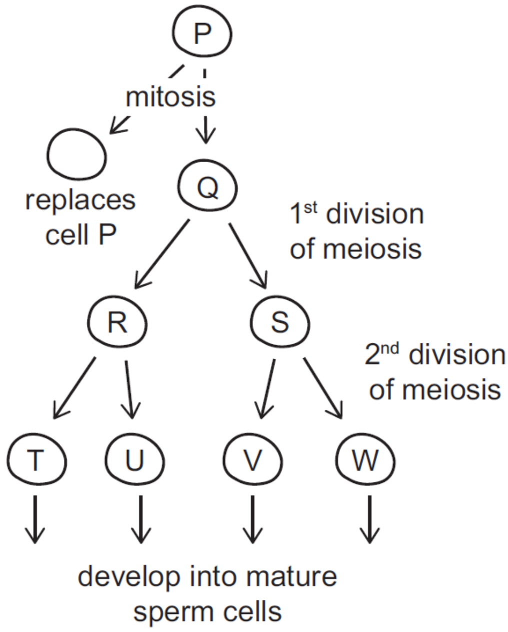
The total volume of water lost was 2500 cm^3 on both days.

What is the percentage increase in the volume of sweat produced and the reason for the decrease in the volume of urine?

	percentage increase in the volume of sweat	*reason for the decrease in the volume of urine*
(A)	33	a decrease in ADH
(B)	33	an increase in ADH
(C)	50	a decrease in ADH
(D)	50	an increase in ADH
(E)	150	a decrease in ADH
(F)	150	an increase in ADH

[NSAA, 2020S2Q48]

The diagram shows the production of sperm cells in a healthy mammal. Cell P divides. One daughter cell goes on to replace cell P, and the other daughter cell is called Q in the diagram.



Each mitotic cell cycle takes 14 hours.

The diploid number of chromosomes in this mammal is 68.

Which of the following statements is/are correct?

1 Cell P is a type of stem cell.

2 Cells T, U, V and W each contain 23 chromosomes.

3 In 112 hours, 128 replacements of cell P are made.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

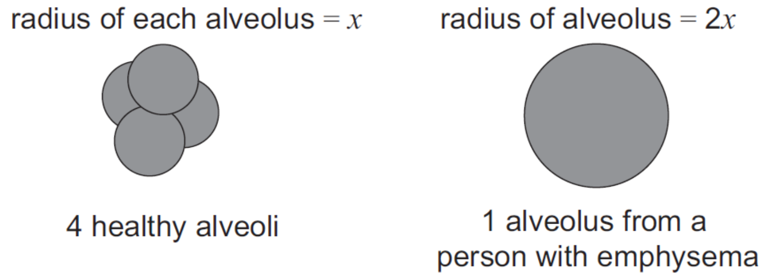
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q49]

In the disease emphysema the walls of the alveoli break down so that several smaller alveoli fuse to form a single large alveolus.

The diagram shows a model of the effect of emphysema on spherical alveoli.



Which of the following statements is/are correct?

1 The surface area-to-volume ratio of the four healthy alveoli is twice that of the single emphysema alveolus.

2 For the same concentration gradient, the rate of diffusion of oxygen into the blood from a single healthy alveolus will be greater than for a single emphysema alveolus.

3 Oxygen molecules will only move across the alveolus wall from the inside to the outside of an alveolus.

(surface area of a sphere = $4\pi r^2$; volume of a sphere = $\frac{4}{3}\pi r^3$, where r is the radius)

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

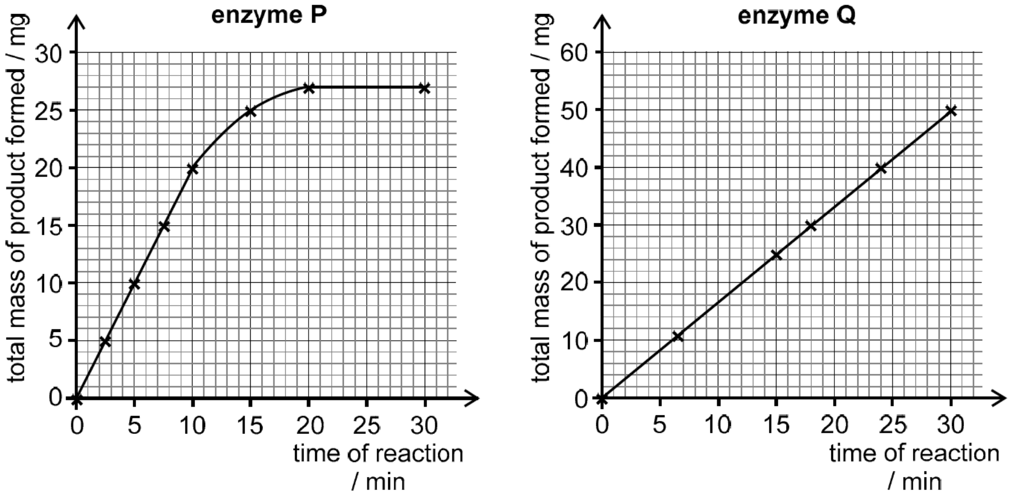
(H) 1, 2 and 3

[NSAA, 2020S2Q50]

Experiments were carried out to investigate the rate at which products were formed by two digestive enzymes, P and Q over a period of 30 minutes.

P and Q have similar optimum conditions for function. Only the enzyme and its substrate were changed between each reaction.

The results are shown in the graphs.



Which of the following statements is/are correct?

1 During the first 10 minutes, the rate of reaction (mg min^{-1}) with enzyme P is double the rate with enzyme Q.

2 A possible explanation for the difference in the shape between the graphs is that the product of the reaction catalysed by P significantly alters the pH of the solution.

3 The percentage change in mass of product formed by enzyme Q is more than 5 times greater between 6.5 and 15 minutes than it is between 24 and 29 minutes.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

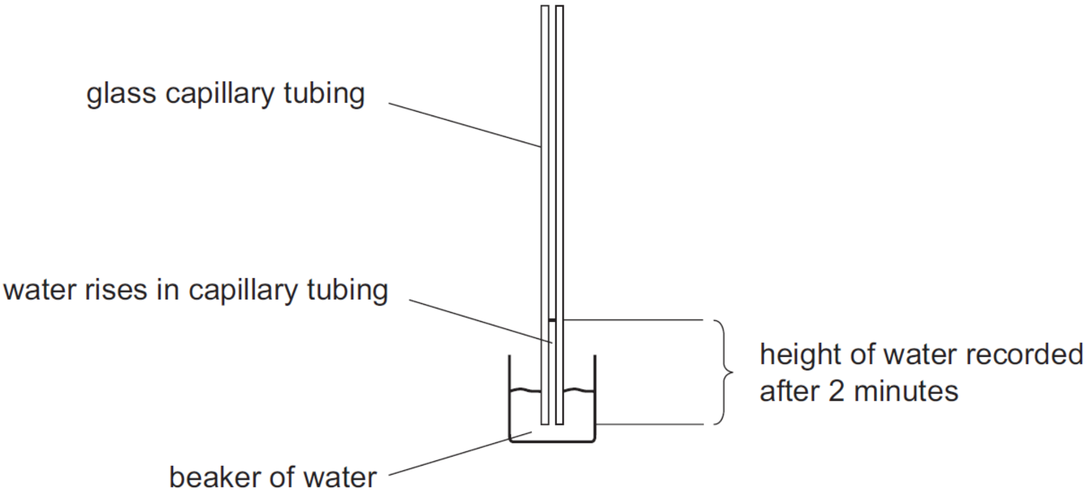
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q51]

An experiment was performed to investigate whether capillary action could account for the movement of water from roots to leaves in a plant.

The diagram shows apparatus used to model this effect using narrow glass capillary tubing. The inner diameter of the capillary tubing is 0.5 mm.



The initial height of the water in the tubing was recorded as 0.2 cm. After 2 minutes the height was recorded as 1.8 cm.

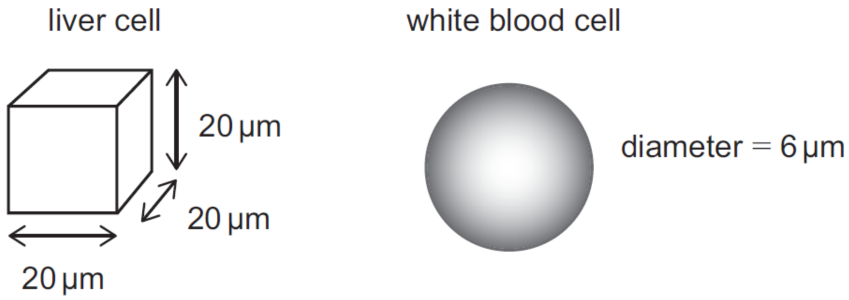
The model assumes the rate of movement is constant.

What is the rate of water movement in $mm^3\ min^{-1}$ and what vessel type transfers water from roots to leaves in a real plant?

	rate of water movement / $mm^3\ min^{-1}$	*vessel type*
(A)	0.5π	xylem
(B)	0.5π	phloem
(C)	π	xylem
(D)	π	phloem
(E)	2π	xylem
(F)	2π	phloem
(G)	4π	xylem
(H)	4π	phloem

[NSAA, 2020S2Q52]

Two healthy human cells with no mutations were modelled as shown in the diagrams below. The cells were not dividing. Both cells contain a single nucleus and are diploid.



A study estimates that mitochondria account for 12% of the volume of both types of cells. Using this estimate for all cells, which of the following is/are correct?

(The volume of a sphere is given by $\frac{4}{3}\pi r^3$, where r is the radius. Use the value 3.14 for π)

1 The larger number of mitochondria in the liver cell will produce more lactic acid than those in the white blood cell.

2 The liver cell is larger and so will contain a greater mass of nuclear DNA than the white blood cell.

3 The mitochondria in the white blood cell occupy 14 μm^3 to the nearest whole number.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

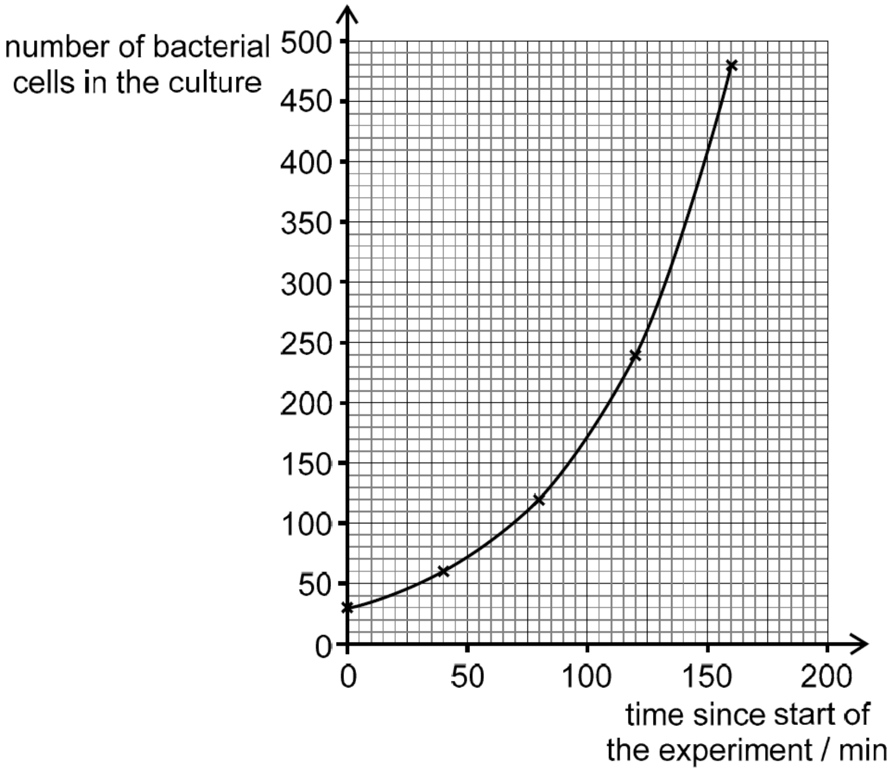
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q53]

Bacterial cells were grown in a laboratory experiment and the number of cells was recorded at regular intervals. The bacteria in this experiment reproduced asexually using a form of cell division. The growth medium was sterilised before it was used and the vessel containing the bacterial cells was sealed so that no other cells could enter.

The graph shows the results of the experiment.



Which of the following statements is/are correct?

1 After 4 hours, assuming that the rate of growth continues on the same curve, the predicted number of cells in the experiment is 1920.

2 During the 80 minutes after the start of the experiment there was a 400% increase in the number of cells.

3 The growth curve is of the form $y = 30k^x$.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q54]

Three samples of cells were taken from the same healthy human: one sample from the blood, one sample from a kidney, and one sample from a testis.

Each sample contained five cells, three of one type and two of a different type. None of the cells were dividing.

In each sample, the mean number of chromosomes per cell was calculated. The results are shown in the table.

Sample	*mean number of chromosomes per cell*
1	18.4
2	32.2
3	46.0

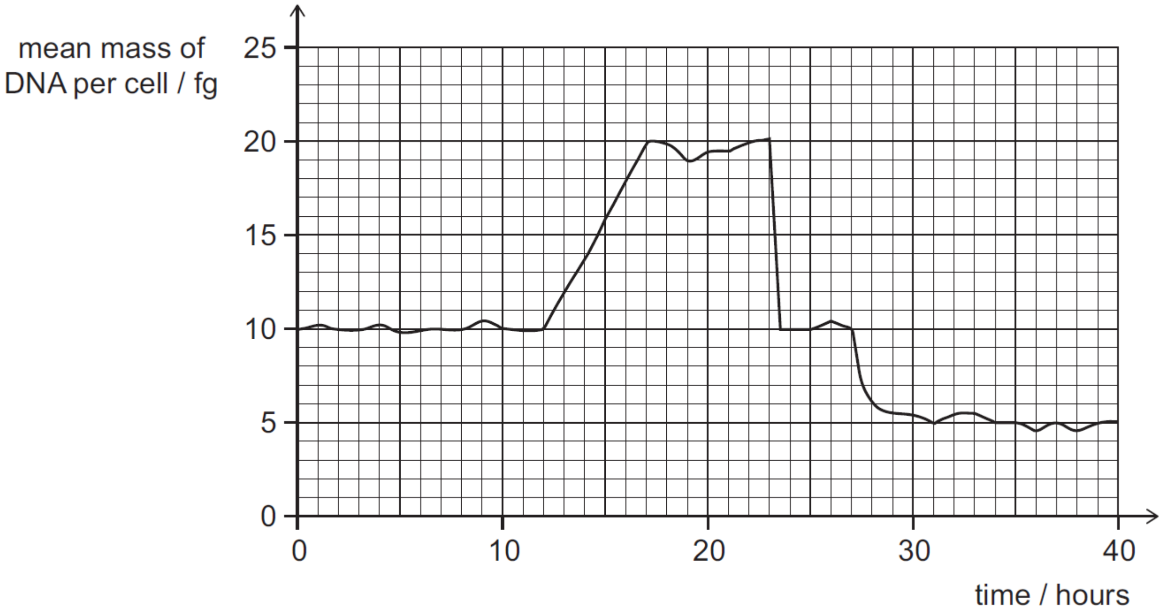
Which row in the following table identifies the samples from the kidney and the testis?

(Assume that no mutations occur in any of the cells in the samples.)

	kidney	*testis*
(A)	1	2
(B)	1	3
(C)	2	1
(D)	2	3
(E)	3	1
(F)	3	2

[NSAA, 2020S2Q55]

The graph shows the mean mass of DNA of a population of cells dividing at the same time, measured in femtograms (10^{-15} g) per cell.



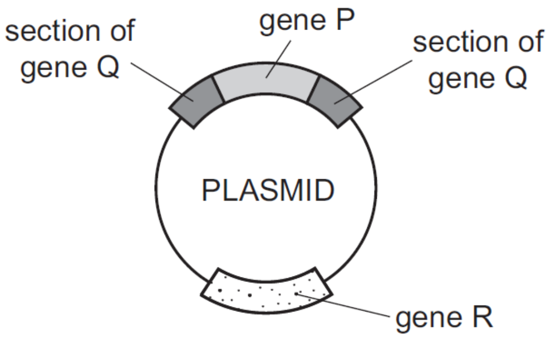
Which row in the table is correct?

	type of cell division taking place	*rate of DNA synthesis per cell between 12 and 17 hours / fg h⁻¹*	*period that could be part of interphase*
(A)	meiosis	2	0 to 17 hours
(B)	meiosis	0.5	0 to 17 hours
(C)	meiosis	2	12 to 24 hours
(D)	meiosis	0.5	12 to 24 hours
(E)	mitosis	2	0 to 17 hours
(F)	mitosis	0.5	0 to 17 hours
(G)	mitosis	2	12 to 24 hours
(H)	mitosis	0.5	12 to 24 hours

[NSAA, 2020S2Q56]

A plasmid contains genes Q and R. Gene Q codes for resistance to the antibiotic q. Gene R codes for resistance to antibiotic r.

The plasmid was genetically engineered to contain the human gene P. This gene was inserted into gene Q in the plasmid preventing gene Q from working.



A mixture of the original plasmid and the genetically-engineered plasmid were available to be taken up by bacterial cells. The bacterial cells took up either the original plasmid, or the genetically-engineered plasmid, or neither of the plasmids.

All these bacteria were allowed to grow and form colonies on agar plates in the absence of both antibiotics.

40 colonies formed.

Cells from each of the 40 colonies were grown on three agar plates with different contents.

The table shows the number of colonies that grew on each of the three plates.

contents of agar plate	*number of bacterial colonies able to survive on the agar plate*
no antibiotic	40
antibiotic q only	8
antibiotic r only	24

What percentage of the original 40 bacteria now contain gene P?

(Assume that no mutations occur.)

(A) 16%

(B) 20%

(C) 33%

(D) 40%

(E) 60%

(F) 80%

[NSAA, 2020S2Q57]

One form of genetic variation within a population depends on the number of alleles per gene.

Four populations of the same animal species each have the same gene in the same position on a chromosome.

Each population has a different number of alleles for this gene as shown in the table.

population	*number of alleles for the same gene*
P	3
Q	4
R	5
S	6

Assume that in the heterozygous state, the genotype is the same whether an allele is inherited from the mother or the father.

Which of the following is/are correct for this gene?

(Assume that no mutations occur in this gene.)

1 The theoretical number of different genotypes in population S is 6 more than in population R.

2

theoretical number of different homozygous genotypes in population			
P	Q	R	S
3	4	5	6

3 In populations P, Q and R, there are more different homozygous combinations than there are different heterozygous combinations.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

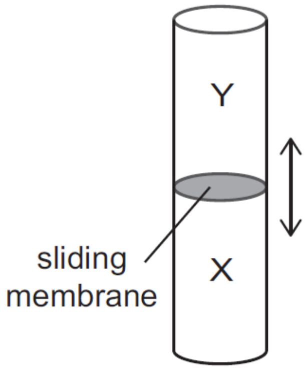
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q58]

The diagram shows a cylinder with two compartments, X and Y, separated by a sliding partially permeable membrane which is impermeable to glucose.



Compartment X contains 100 mmol dm^{-3} glucose solution and compartment Y contains 200 mmol dm^{-3} glucose solution. The initial volume of the solution in each of the two compartments is the same, 10 cm^3.

After three hours, there is no further change in the volumes of X and Y.

Which of the following statements describe(s) the results of the experiment?

1 The volume of Y increases during the first three hours.

2 During the first three hours, the average rate of osmosis is $\frac{10}{9}$ cm^3 per hour.

3 During the first three hours, the average rate of change in glucose concentration in compartment X is 50 mmol dm^{-3} per hour.

(A) 1 only

(B) 2 only

(C) 3 only

(D) 1 and 2 only

(E) 1 and 3 only

(F) 2 and 3 only

(G) 1, 2 and 3

[NSAA, 2020S2Q59]

A fertilised egg cell is spherical and has a volume of 0.12 μm^3.

In the initial stages of development, the fertilised egg cell undergoes several rounds of cleavage. During cleavage, cells divide by mitosis but do not grow. Assume that when cells undergo cleavage, the daughter cells are spherical and are identical to each other.

Which of the following statements about the cells present after three rounds of cleavage is/are correct?

1 Each cell will contain $\frac{1}{8}$ of the DNA present in the fertilised egg cell.

2 The volume of each cell will be 0.03 μm^3.

3 The diameter of the cells is 50% of that of the fertilised egg cell.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

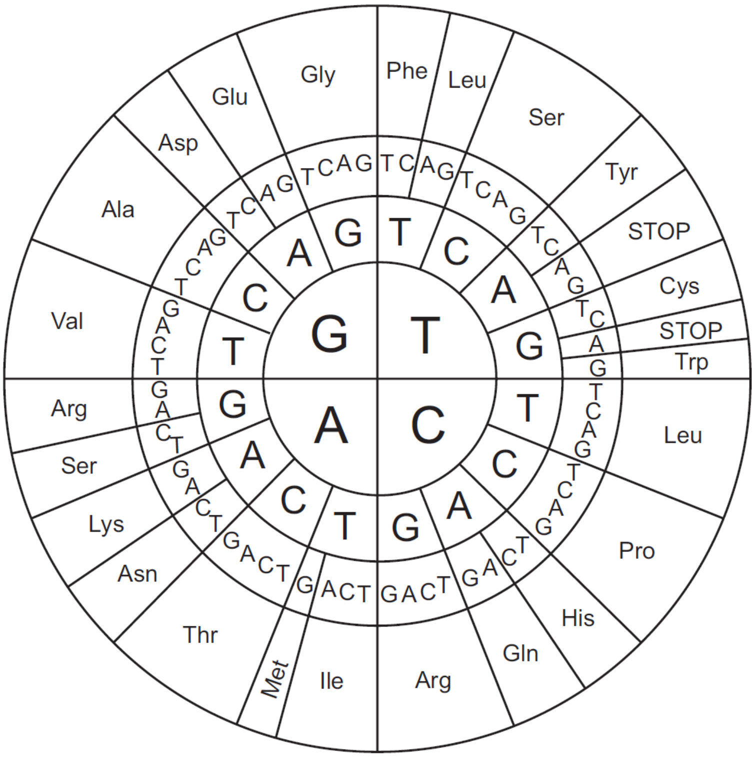
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2020S2Q60]

The genetic code is read in groups of three bases when coding for the synthesis of a protein. The diagram shows the base triplets within DNA that correspond to specific amino acids.

The diagram is read from the inside out. For example, the base triplets CAT and CAC both code for the amino acid histidine (His).



Assume that it is equally likely that mutations can change any base to any other base, and that the probability of this resulting in a change in any particular base during one cell division is 2×10^{-9}.

What is the probability that a triplet that codes for **Met** changes to code for **Pro** in one round of division?

(A) $\frac{4}{9} \times 10^{-18}$

(B) $\frac{4}{9} \times 10^{-9}$

(C) $\frac{2}{3} \times 10^{-18}$

(D) $\frac{2}{3} \times 10^{-9}$

(E) 4×10^{-18}

(F) 4×10^{-9}

NSAA 2021 S1

NSAA 2021 S1

On-line Exam

Scan the QR code or click on the link to take an on-line exam.

Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 60 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **four** parts: **A**, **B**, **C** and **D**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **one** further part chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **two** parts. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators are NOT permitted.

Part A

[NSAA, 2021S1Q1]

Simplify fully

$$5xy^2 \times (5x^2y)^{-3} \times 5x^2y$$

where x and y are positive.

(A) $\frac{1}{125x^7y^2}$

(B) $\frac{1}{125x^6y^2}$

(C) $\frac{1}{25x^6y}$

(D) $\frac{1}{25x^4y}$

(E) $\frac{1}{5x^3}$

(F) $\frac{1}{5x^2}$

(G) $\frac{y}{x^2}$

(H) $5xy^2$

[NSAA, 2021S1Q2]

Which of the following is a simplification of

$$2 - \frac{x + 3x^2}{12x^2 + x - 1}$$

where $x > 1$?

(A) $\frac{7x-1}{4x-1}$

(B) $\frac{7x-2}{4x-1}$

(C) $\frac{7x+1}{4x+1}$

(D) $\frac{7x+2}{4x+1}$

(E) $\frac{9x-1}{4x-1}$

(F) $\frac{9x-2}{4x-1}$

(G) $\frac{9x+1}{4x+1}$

(H) $\frac{9x+2}{4x+1}$

[NSAA, 2021S1Q3]

Which of the following is a rearrangement of

$$\frac{p}{2}+\frac{3}{q}=\frac{4}{r}$$

so that q is the subject?

(A) $q=\frac{2r}{24-3pr}$

(B) $q=\frac{3r}{2r-p}$

(C) $q=\frac{6r}{4-p}$

(D) $q=\frac{6r}{8-pr}$

(E) $q=\frac{r-2}{12p}$

(F) $q=\frac{3r-6}{4p}$

(G) $q=\frac{pr-8}{12p}$

(H) $q=\frac{3pr-24}{4p}$

[NSAA, 2021S1Q4]

A circle has its centre at $(0,0)$.

What is the equation of the tangent that touches the circle at the point $(4,3)$?

(A) $3y+4x=25$

(B) $3y-4x=25$

(C) $3y-4x=-7$

(D) $3y-4x=7$

(E) $4y+3x=24$

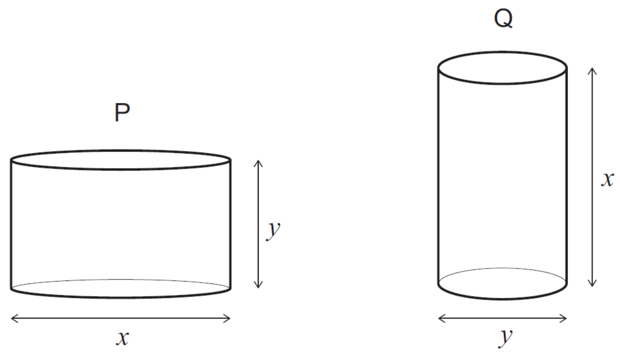
(F) $4y-3x=24$

(G) $3y+4x=24$

(H) $3y-4x=24$

[NSAA, 2021S1Q5]

Two solid cylinders, P and Q, are shown, where $x > y$.



Cylinder P has diameter x and height y.

Cylinder Q has diameter y and height x.

What is the positive difference between the total surface areas of P and Q?

(A) 0

(B) $\frac{\pi}{4}(x^2 - y^2)$

(C) $\frac{\pi}{2}(x^2 - y^2)$

(D) $\pi(x^2 - y^2)$

(E) $2\pi(x^2 - y^2)$

(F) $\frac{\pi}{4}xy(x - y)$

(G) $\pi xy(x - y)$

[NSAA, 2021S1Q6]

Given that

$$8^x + 27^x = \frac{13}{36}$$
$$8^x - 27^x = \frac{5}{36}$$

what is the value of x?

(A) -4

(B) -3

(C) -2

(D) $-\frac{3}{2}$

(E) $-\frac{2}{3}$

(F) $-\frac{1}{2}$

(G) $-\frac{1}{3}$

(H) $-\frac{1}{4}$

[NSAA, 2021S1Q7]

The price of item P is reduced by 10%. The next day, the new price is increased by 10%.
The price of item Q is increased by 10%. The next day, the new price is reduced by 10%.
How does the final price of each item compare to the original price of that item?

	item P final price	*item Q final price*
A	lower than original	lower than original
B	lower than original	higher than original
C	higher than original	lower than original
D	higher than original	higher than original
E	the same as original	the same as original

j

[NSAA, 2021S1Q8]

Here is a pattern of numbers:

1						
2	3	4				
5	6	7	8	9		
10	11	12	13	14	15	16

The pattern of numbers is continued in the same way.

What number will appear directly below 196?

(A) 218

(B) 219

(C) 220

(D) 221

(E) 222

(F) 223

(G) 224

(H) 225

[NSAA, 2021S1Q9]

SQT is a right-angled triangle with the right angle at Q.

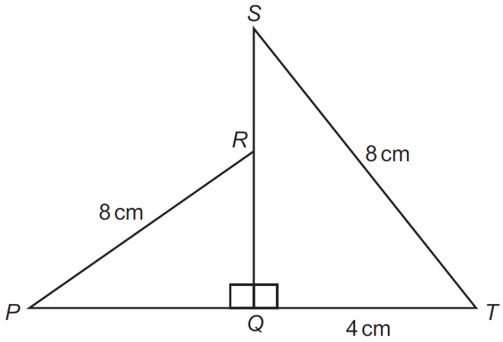
The point R is on SQ such that $SR : RQ = 1 : 3$.

QRP is a right-angled triangle with the right angle at Q.

$PR = ST = 8$ cm

$QT = 4$ cm

What is the length of PQ, in cm?



[diagram not to scale]

(A) $2\sqrt{3}$

(B) $4\sqrt{3}$

(C) $\sqrt{19}$

(D) $\sqrt{37}$

(E) $\sqrt{55}$

(F) $\sqrt{61}$

[NSAA, 2021S1Q10]

Pat and Alex have a combined total of £63.

The ratio of Pat's money to Alex's money is $5 : 2$.

They each spend an equal amount on sweets.

The ratio of Pat's money to Alex's money is now $3 : 1$.

How much did Pat spend on sweets?

(A) £0.50

(B) £2.00

(C) £2.25

(D) £3.00

(E) £4.50

(F) £6.75

[NSAA, 2021S1Q11]

The curve with equation $y = x^2 - 4x + 5$ meets the straight line with equation $y = 2x + c$ at two points, which have x-coordinates p and q, where $q > p$.

Given that $q - p = 8$, what is the value of the constant c?

(A) -43

(B) -12

(C) -2

(D) 0

(E) 2

(F) 12

(G) 43

[NSAA, 2021S1Q12]

An online company sells storage containers.

The following items are available:

capacity of container	*number available*
2 litres	2
3 litres	3
7 litres	4
8 litres	1

A customer orders two containers at random from those available.

What is the probability that the two containers will have a combined capacity of exactly 10 litres?

(A) $\frac{7}{25}$

(B) $\frac{14}{25}$

(C) $\frac{7}{45}$

(D) $\frac{14}{45}$

(E) $\frac{7}{50}$

[NSAA, 2021S1Q13]

Given that

$$y = \frac{\sin 60° - 1}{\cos 60°}$$

what is the value of y^3?

(A) $-\frac{\sqrt{3}}{9}$

(B) $-5\sqrt{2} + 10$

(C) $3\sqrt{3} - 8$

(D) $6\sqrt{3} - 10$

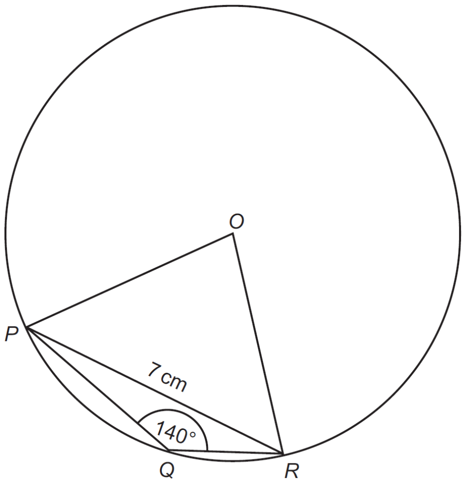
(E) $14\sqrt{2} - 20$

(F) $15\sqrt{3} - 26$

(G) $21\sqrt{3} - 38$

[NSAA, 2021S1Q14]

P, Q and R are points on the circumference of a circle with centre O as shown in the diagram.



[diagram not to scale]

Angle $PQR = 140°$

$PR = 7$ cm

Which of the following expressions gives the radius of the circle, in cm?

(A) $7 \sin 10°$

(B) $3.5 \sin 55°$

(C) $3.5 \sin 70°$

(D) $7 \sin 55°$

(E) $\frac{3.5}{\sin 40°}$

(F) $\frac{7}{\sin 80°}$

(G) $\frac{3.5}{\sin 20°}$

(H) $\frac{7}{\sin 40°}$

[NSAA, 2021S1Q15]

Charlie has a bowl containing red sweets and green sweets only. The sweets are identical in all respects except colour.

There are nine sweets in total in the bowl.

Charlie eats two sweets from the bowl at random.

The probability of Charlie not eating any green sweets is $\frac{5}{12}$.

What is the probability that Charlie eats two green sweets?

(A) $\frac{2}{27}$

(B) $\frac{1}{12}$

(C) $\frac{1}{9}$

(D) $\frac{4}{27}$

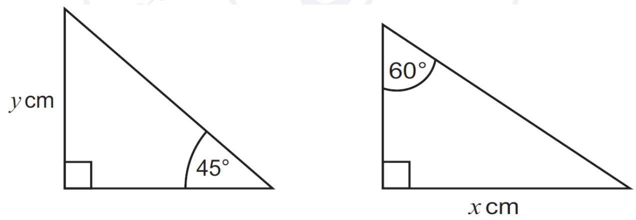
(E) $\frac{1}{6}$

(F) $\frac{1}{4}$

(G) $\frac{7}{12}$

[NSAA, 2021S1Q16]

The following right-angled triangles have the same hypotenuse length.



[diagram not to scale]

Which of the following is a correct expression for y in terms of x?

(A) $y = \sqrt{2}x$

(B) $y = \frac{\sqrt{2}x}{2}$

(C) $y = \frac{\sqrt{2}x}{3}$

(D) $y = \frac{\sqrt{2}x}{6}$

(E) $y = \sqrt{6}x$

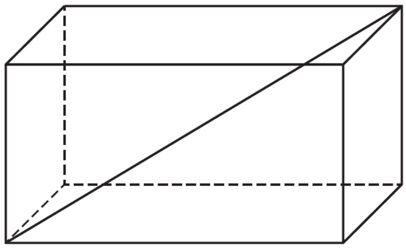
(F) $y = \frac{\sqrt{6}x}{2}$

(G) $y = \frac{\sqrt{6}x}{3}$

(H) $y = \frac{\sqrt{6}x}{6}$

[NSAA, 2021S1Q17]

The greatest diagonal distance between the two vertices of a cuboid, as shown in the diagram, is $\sqrt{77}$ cm.



A similar cuboid has all its lengths exactly half the lengths of the original cuboid.

The sides of this smaller cuboid are 2 cm, 3 cm and x cm.

What is the value of x, in cm?

(A) $\frac{5}{2}$

(B) 5

(C) $\frac{5\sqrt{2}}{2}$

(D) $5\sqrt{2}$

(E) $\frac{\sqrt{102}}{2}$

(F) $\sqrt{102}$

[NSAA, 2021S1Q18]

Alex, Cameron and Sam are all taking part in a 400 m race.

They are each running at a different constant speed.

Alex is running 12% faster than Cameron, whilst Sam is running 2% slower than Cameron.

When Alex crosses the finish line, how many metres is Sam from the finish line?

(A) 9.6

(B) 14

(C) 24

(D) 25

(E) 28

(F) 50

(G) 56

[NSAA, 2021S1Q19]

A car journey is m miles long.

One kilometre is equivalent to x miles.

The car uses one litre of fuel to travel a distance of f kilometres.

Fuel for the car costs p pence per litre.

Which of the following expressions gives the cost of fuel for this journey, in pounds?

(There are 100 pence in one pound.)

(A) $100fmpx$

(B) $\frac{100fmp}{x}$

(C) $\frac{100mpx}{f}$

(D) $\frac{100mp}{fx}$

(E) $\frac{fmpx}{100}$

(F) $\frac{fmp}{100x}$

(G) $\frac{mpx}{100f}$

(H) $\frac{mp}{100fx}$

[NSAA, 2021S1Q20]

How many solutions are there to the equation

$$\tan x = 100x$$

where $-360 \leq x \leq 360$?

(A) 0

(B) 1

(C) 2

(D) 3

(E) 4

(F) 5

(G) infinitely many

Part B

[NSAA, 2021S1Q21]

A resistor has a constant voltage of 9.00 V across it.

A total charge of 180 C passes through the resistor in 4.00 minutes.

What is the power dissipated in the resistor?

(A) 0.750 W

(B) 6.75 W

(C) 12.0 W

(D) 81.0 W

(E) 108 W

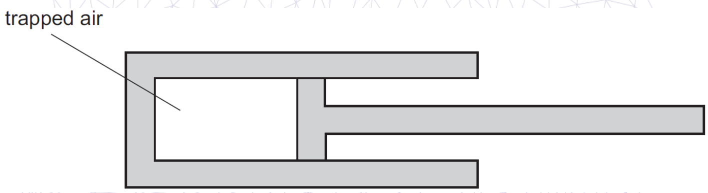
(F) 405 W

(G) 1620 W

(H) 6480 W

[NSAA, 2021S1Q22]

Air is trapped in a cylinder by a piston. The density of the air in the cylinder is ρ.



The piston is moved so that the pressure of the trapped air increases by 20%. The temperature of the trapped air does not change.

What is the new density of the trapped air?

(Assume that air is an ideal gas.)

(A) 0.69ρ

(B) 0.80ρ

(C) 0.83ρ

(D) 1.00ρ

(E) 1.20ρ

(F) 1.44ρ

[NSAA, 2021S1Q23]

A **non-ideal** transformer has 100 turns on the primary coil and 25 turns on the secondary coil.

It is provided with 3.0 kW of electrical power at a current of 12.5 A.

The voltage output is the same as for an ideal transformer, but the current in the output coil is 40 A.

What is the efficiency of the transformer?

(A) 20%

(B) 25%

(C) 31%

(D) 69%

(E) 75%

(F) 80%

(G) 91%

(H) 100%

[NSAA, 2021S1Q24]

A car of mass 1400 kg is towing a caravan of mass 1000 kg along a straight horizontal section of road at a constant speed.

The driving force from the engine is increased by 3000 N, causing the car and caravan to accelerate.

At one moment during this acceleration, the resistive force on the car has increased by 200 N and the resistive force on the caravan has increased by 400 N.

What is the acceleration of the car and caravan at this moment?

(A) 1.00 m s^{-2}

(B) 1.25 m s^{-2}

(C) 1.50 m s^{-2}

(D) 2.00 m s^{-2}

(E) 2.60 m s^{-2}

[NSAA, 2021S1Q25]

A star is moving away from a space telescope positioned above the Earth. The star emits light of frequency f and wavelength λ at the speed of light c.

This light travels towards the space telescope through the vacuum of space until it is detected on the space telescope.

The frequency, the wavelength and the speed of the light measured at the telescope are f_T, λ_T and c_T respectively.

How do f_T, λ_T and c_T compare with f, λ and c?

	f_T	λ_T	c_T
A	equal to f	equal to λ	equal to c
B	equal to f	equal to λ	less than c
C	equal to f	greater than λ	equal to c
D	equal to f	greater than λ	less than c
E	less than f	equal to λ	equal to c
F	less than f	equal to λ	less than c
G	less than f	greater than λ	equal to c
H	less than f	greater than λ	less than c

[NSAA, 2021S1Q26]

Q is an element with several isotopes.

The nuclide ${}^{(3x-7)}_{x}\text{Q}$ contains 6 neutrons more than the nuclide ${}^{(2x+3)}_{x}\text{Q}$.

Another isotope of Q is the nuclide ${}^{(3x+1)}_{x}\text{Q}$.

How many neutrons does the nuclide ${}^{(3x+1)}_{x}\text{Q}$ contain?

(A) 9

(B) 16

(C) 19

(D) 21

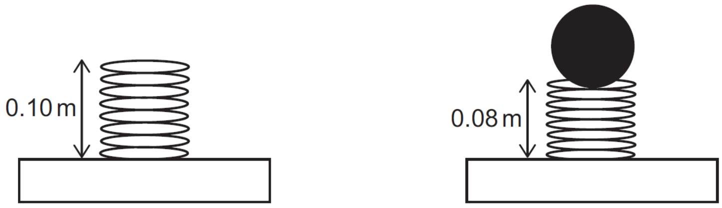
(E) 25

(F) 33

(G) 49

[NSAA, 2021S1Q27]

A light spring has an uncompressed length of 0.10 m. When an object of mass 0.5 kg rests in equilibrium on top of the spring, the length of the spring reduces to 0.08 m as shown.



What is the energy stored in the spring due to the compression?

(gravitational field strength=10 N kg^{-1}; the spring obeys Hooke's law)

(A) 0.005 J

(B) 0.02 J

(C) 0.05 J

(D) 0.1 J

(E) 0.2 J

(F) 0.4 J

[NSAA, 2021S1Q28]

A set of decorative lights consists of 20 lamps connected in series to a dc supply of constant voltage.

The total power transferred by all the lamps is P.

The set is designed so that if one of the lamps fails, that lamp becomes short-circuited and it then has zero resistance. The remaining lamps are still lit.

If this happens, with the set connected to the same supply, what is the new total power transferred by the remaining 19 lamps?

(Assume that the resistance of each functioning lamp remains constant.)

(A) $\left(\frac{19}{20}\right)^2 P$

(B) $\left(\frac{19}{20}\right) P$

(C) P

(D) $\left(\frac{20}{19}\right) P$

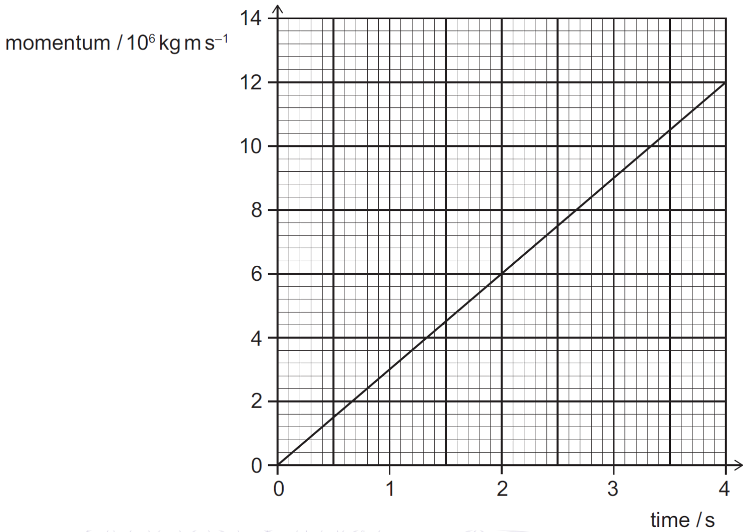
(E) $\left(\frac{20}{19}\right)^2 P$

[NSAA, 2021S1Q29]

A train accelerates from rest along a straight, horizontal section of track.

The force exerted on the train due to its motors is constant and there is a constant friction force of 1.8×10^7 N.

The graph shows how the momentum of the train changes with time.



What is the force exerted on the train due to its motors?

(A) 3.0×10^6 N

(B) 6.0×10^6 N

(C) 1.2×10^7 N

(D) 1.5×10^7 N

(E) 2.1×10^7 N

(F) 2.4×10^7 N

(G) 3.0×10^7 N

(H) 4.2×10^7 N

[NSAA, 2021S1Q30]

A ship travels into a wave that is travelling in the opposite direction to the ship.

The ship has a horizontal speed of 8.0 m s^{-1}. The speed of the wave is 3.0 m s^{-1}.

The front of the ship rises and falls with a time period of 8.0 s.

What is the wavelength of the wave?

(A) $\frac{3}{8}$ m

(B) $\frac{5}{8}$ m

(C) 1.0 m

(D) $\frac{11}{8}$ m

(E) 24 m

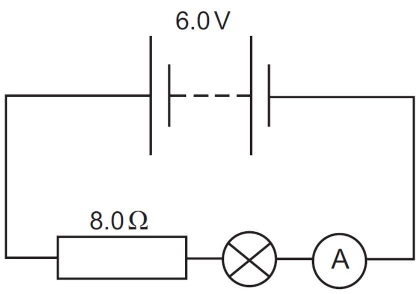
(F) 40 m

(G) 64 m

(H) 88 m

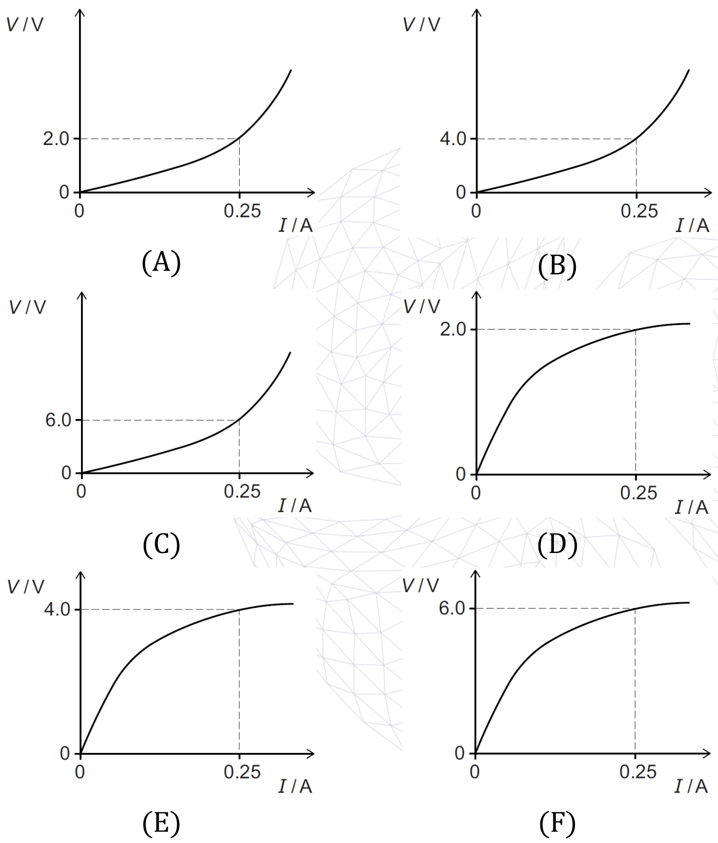
[NSAA, 2021S1Q31]

A 6.0 V battery is connected to an 8.0 Ω resistor and a filament lamp as shown in the circuit diagram.



The reading on the ammeter is 0.25 A.

Which graph is a possible $V-I$ graph for the filament lamp?



[NSAA, 2021S1Q32]

A uniform, horizontal magnetic field has magnetic field strength 0.60 T and a direction from west to east.

A horizontal wire is placed in a north–south direction, so that it is at 90° to the magnetic field.

The wire carries a constant current.

The wire has length 0.40 m and mass 0.018 kg.

The resultant force acting vertically on the wire is zero.

What are the magnitude and direction of the current in the wire?

(gravitational field strength=10 N kg^{-1})

	magnitude of current /A	*direction of current*
A	0.012	from north to south
B	0.012	from south to north
C	0.075	from north to south
D	0.075	from south to north
E	0.12	from north to south
F	0.12	from south to north
G	0.75	from north to south
H	0.75	from south to north

[NSAA, 2021S1Q33]

The wavelength range of visible light is 400-700 nm.

Light with a frequency of 6.0×10^{14} Hz is green.

Microwaves used in cooking have a wavelength of 12 cm.

Which of the following statements is/are correct?

1 Light with a frequency of 7.5×10^{14} Hz is red.

2 Microwaves used in cooking have a frequency of 2.5×10^{9} Hz.

3 Electromagnetic radiation with a frequency of 2.5×10^{15} Hz can be used in thermal imaging of a building.

(speed of light=3.0×10^{8} m s^{-1})

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q34]

There is a high-speed straight railway line between two cities that are 60 km apart. The train stops at both cities.

The train accelerates at a uniform rate of 1.5 m s^{-2} to a maximum speed of 120 m s^{-1}.

When braking, it decelerates at a uniform rate of 2.0 m s^{-2}.

What is the minimum time taken by the train to travel from one city to the other?

(A) 140 s

(B) 355 s

(C) 430 s

(D) 500 s

(E) 570 s

(F) 860 s

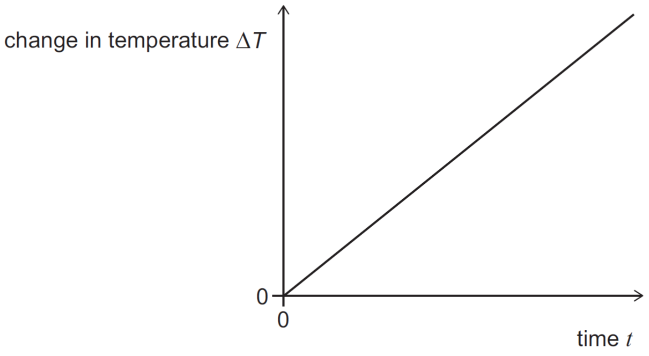
(G) 1000 s

[NSAA, 2021S1Q35]

A metal block has mass M.

Heat is transferred to the block at a constant rate P.

The graph shows how the change in temperature ΔT of the block from its initial temperature varies with time t.



The gradient of the line is k.

Which expression gives the specific heat capacity of the metal from which the block is made?

(Assume that no heat is transferred out of the block during the time interval shown by the graph.)

(A) $\frac{1}{MPk}$

(B) $\frac{M}{Pk}$

(C) $\frac{Mk}{P}$

(D) $\frac{P}{Mk}$

(E) $\frac{PM}{k}$

(F) $\frac{Pk}{M}$

(G) $\frac{k}{MP}$

(H) MPk

[NSAA, 2021S1Q36]

A skydiver of mass 80 kg is accelerating vertically downwards through the air. At one instant in time the skydiver has a speed of 5.0 m s^{-1}. After travelling a further distance of 20 m downwards the skydiver's speed has increased to 10 m s^{-1}.

What is the average force of air resistance acting on the skydiver over the 20 m?

(gravitational field strength=10 N kg^{-1})

(A) 600 N

(B) 650 N

(C) 750 N

(D) 790 N

(E) 950 N

[NSAA, 2021S1Q37]

A radioactive nuclide X decays in a single stage to a stable nuclide R.

A radioactive nuclide Y decays in a single stage to a stable nuclide S.

When a rock formed it contained equal numbers of atoms of all four nuclides X, Y, R and S.

The half-life of X is T years and the half-life of Y is $2T$ years.

What is the value of $\frac{\text{number of atoms of R}}{\text{number of atoms of S}}$ at a time $4T$ years after the rock has formed?

(Assume that no other processes add or remove X, Y, R or S from the rock during this time.)

(A) $\frac{1}{4}$

(B) $\frac{17}{20}$

(C) $\frac{31}{28}$

(D) $\frac{6}{5}$

(E) $\frac{5}{4}$

(F) 2

[NSAA, 2021S1Q38]

A beaker containing 180 g of water at 25 °C has a 20 g ice cube at 0 °C added to it.

No heat is transferred between the water and the surroundings (including the beaker).

What is the final temperature of all the water in the beaker after all the ice has melted?

(Take the specific heat capacity of water to be 4 J g^{-1} $°C^{-1}$ and the specific latent heat of fusion of water to be 300 J g^{-1}.)

(A) 2.5 °C

(B) 8.3 °C

(C) 10.0 °C

(D) 15.0 °C

(E) 16.7 °C

(F) 22.5 °C

[NSAA, 2021S1Q39]

Liquid X has density 0.80 g cm^{-3} and liquid Y has density 1.0 g cm^{-3}.

80 cm^3 of liquid X and 100 cm^3 of liquid Y are poured into a cylindrical container and allowed to settle. The two liquids do not mix or react.

The internal cross-sectional area of the container is 20 cm^2. The base of the container rests on a horizontal surface.

What is the pressure due to the liquids at a height of 4.0 cm above the interior of the base of the container?

(gravitational field strength=10 N kg^{-1})

(A) 10 Pa

(B) 40 Pa

(C) 42 Pa

(D) 50 Pa

(E) 100 Pa

(F) 400 Pa

(G) 420 Pa

(H) 500 Pa

[NSAA, 2021S1Q40]

A pulse of ultrasound travels from one end of a solid uniform rod of length L, starting at time $t = 0$.

The pulse is partially reflected by a crack in the rod and partially by the far end of the rod.

These two reflected pulses travel back along the rod, arriving at the end from which they started at times t_1 and t_2, where $t_2 > t_1$.

What is the distance between the crack and the **far end** of the rod?

(A) $\frac{t_1}{t_2}L$

(B) $\frac{t_2}{t_1}L$

(C) $\frac{t_1}{2t_2}L$

(D) $\frac{t_2}{2t_1}L$

(E) $\frac{(t_2-t_1)}{t_2}L$

(F) $\frac{(t_2-t_1)}{2t_2}L$

Part C

[NSAA, 2021S1Q41]

The following equations represent the reactions of four metals M, Q, R and T:

$$M(s) + HCl(aq) \rightarrow \text{no reaction}$$
$$R(s) + TSO_4(aq) \rightarrow RSO_4(aq) + T(s)$$
$$M(s) + QNO_3(aq) \rightarrow MNO_3(aq) + Q(s)$$
$$T(s) + 2HCl(aq) \rightarrow TCl_2(aq) + H_2(g)$$

Which option lists the order of reactivity of the four metals, from the most to the least reactive?

(A) M, Q, R, T

(B) M, R, T, Q

(C) Q, M, T, R

(D) Q, R, T, M

(E) R, M, T, Q

(F) R, T, M, Q

(G) T, M, R, Q

(H) T, R, Q, M

[NSAA, 2021S1Q42]

Consider the following three ions of calcium observed in mass spectrometry:

$$^{40}Ca^{2+} \qquad ^{42}Ca^{2+} \qquad ^{43}Ca^{+}$$

Which of the following statements is/are correct?

1 All three ions have the electron configuration 2, 8, 8.

2 $^{42}Ca^{2+}$ has more neutrons than $^{40}Ca^{2+}$.

3 $^{42}Ca^{2+}$ has more protons than $^{43}Ca^{+}$.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q43]

The relative isotopic abundances of a sample of magnesium are shown in the table.

isotope	percentage abundance
^{24}Mg	80
^{25}Mg	10
^{26}Mg	10

What is the relative atomic mass (A_r) of the magnesium?

(A) 24.0

(B) 24.3

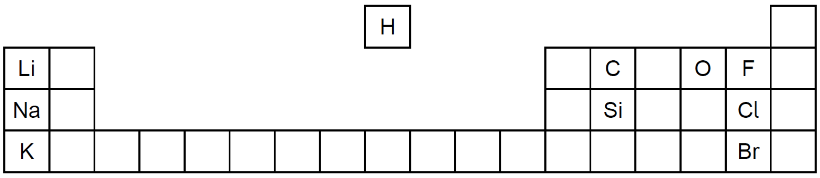
(C) 24.5

(D) 24.8

(E) 25.0

[NSAA, 2021S1Q44]

A portion of the Periodic Table is given:



Which one of these trends is correct?

(A) Boiling point: K > Na > Li

(B) Electrical conductivity: NaCl(l) > NaCl(s) > Na(s)

(C) Reactivity: $Br_2 > Cl_2 > F_2$

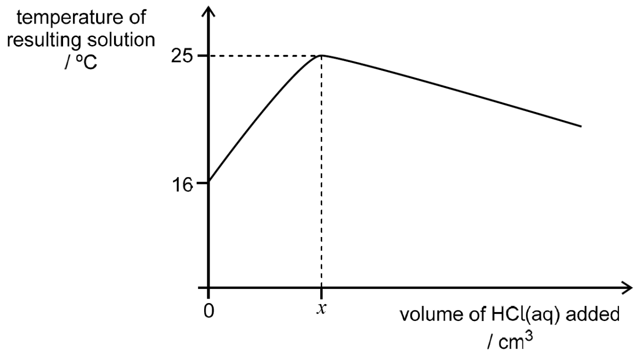
(D) Melting point: $SiO_2 > H_2O > Na_2O$

(E) Number of double bonds per molecule: $CO_2 > O_2 > H_2O$

[NSAA, 2021S1Q45]

1.0 mol dm^{-3} hydrochloric acid was slowly added from a burette into an insulated flask containing 50 cm^3 of aqueous sodium hydroxide. The flask was gently swirled and the temperature of the resulting solution measured continuously.

The two solutions had the same initial temperature and a graph was drawn of the temperature of the resulting solution against the volume of hydrochloric acid added.



Which of the following statements explains the shape of the graph?

(A) The reaction has reached a state of equilibrium.

(B) An endothermic reaction occurs after x cm^3 of hydrochloric acid is added.

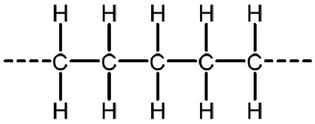
(C) The reaction rate decreases as the acid is used up.

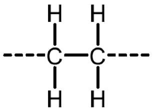
(D) The sodium hydroxide has been neutralised by x cm^3 hydrochloric acid.

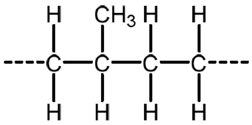
(E) The sodium hydroxide becomes a weaker base as the volume of the resulting solution increases.

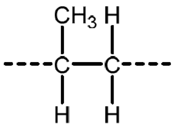
[NSAA, 2021S1Q46]

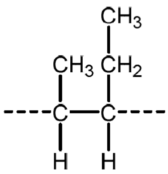
Which one of the following represents the repeating unit of poly(pent-2-ene)?

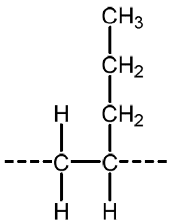
(A) 

(B) 

(C) 

(D) 

(E) 

(F) 

[NSAA, 2021S1Q47]

X is a gaseous element. X can react explosively with hydrogen to produce a single product.

When dissolved in water, this product forms an acidic aqueous solution Y. When aqueous silver nitrate is added to solution Y, a white precipitate forms.

Solution Y reacts with substance Z to form two products only. One of these products forms a white precipitate when aqueous sodium hydroxide is added to it.

Which of the following could be X and Z?

	X	*Z*
A	Br_2	$CaCO_3$
B	Br_2	CuO
C	Br_2	Mg
D	Cl_2	$CaCO_3$
E	Cl_2	CuO
F	Cl_2	Mg
G	O_2	$CaCO_3$
H	O_2	Mg

[NSAA, 2021S1Q48]

Some students were trying to assign oxidation numbers to each of the four sulfur atoms in the tetrathionate ion, $S_4O_6^{2-}$.

Which of the following lists gives the possible oxidation states of the four sulfur atoms present?

(A) 0, 0, +6, +6

(B) +3, +3, +3, +3

(C) 0, +2, +6, +6

(D) 0, 0, +5, +5

(E) – 2, – 2, +7, +7

[NSAA, 2021S1Q49]

The table shows the reagents in three organic reactions.

Which of the rows correctly show(s) the product(s) obtained from the specified reactants?

	reactants	*product(s)*
1	$CH_3CH{=}CH_2$ and HBr	1,2-dibromopropane (only)
2	C_2H_5COOH and CH_3OH, in the presence of an $H^+(aq)$ catalyst	methyl propanoate and water
3	C_2H_5OH and Na	sodium ethanoate and hydrogen

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q50]

Chlorine gas reacts with hot concentrated aqueous sodium hydroxide to form sodium chloride, sodium chlorate(V) and water.

The **unbalanced** ionic equation for this reaction is:

$$u\mathrm{Cl_2} + v\mathrm{OH^-} \rightarrow w\mathrm{Cl^-} + x\mathrm{ClO_3^-} + y\mathrm{H_2O}$$

What is the simplest ratio of $w : x$ in the balanced equation?

(A) 1 : 1

(B) 1 : 2

(C) 2 : 1

(D) 1 : 5

(E) 5 : 1

(F) 1 : 7

(G) 7 : 1

[NSAA, 2021S1Q51]

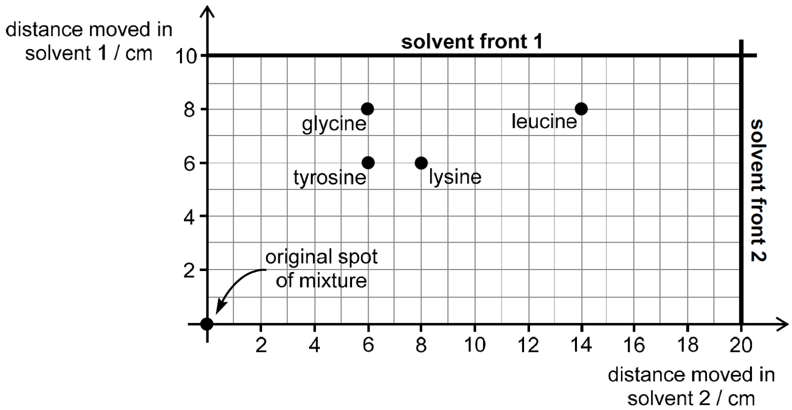
An experiment was carried out to separate the four amino acids present in a mixture of amino acids.

A spot of this mixture was placed on chromatography paper. The bottom of the paper was placed in solvent 1 and left until the solvent nearly reached the top of the paper.

The paper was then thoroughly dried and turned by 90°. The procedure was then repeated with solvent 2.

The amino acids were then identified with reference to known R_f values in the respective solvents.

The final positions of the amino acids on the chromatograph are shown on the following diagram.



Which of the following statements is correct?

(A) Leucine travels further relative to the solvent front in solvent 2 than in solvent 1.

(B) Lysine has a greater R_f value in solvent 1 than it has in solvent 2.

(C) Solvent 1 alone could be used to separate all four amino acids.

(D) Solvent 2 alone could be used to separate all four amino acids.

(E) The R_f value of tyrosine in solvent 1 is 0.6 and in solvent 2 is 0.7.

[NSAA, 2021S1Q52]

A reaction between copper and nitric acid produces a blue solution of copper(II) nitrate, water and substance X only.

Substance X does not contain copper or hydrogen.

The balanced equation for the reaction shows that 1 mole of copper reacts to produce 2 moles of water.

What is the identity of substance X?

(A) N_2

(B) NO

(C) NO_2

(D) NO_3

(E) N_2O_5

[NSAA, 2021S1Q53]

Ethanedioic acid, $(COOH)_2$, is a weak diprotic acid.

What is the minimum volume of a 2.50 mol dm^{-3} solution of ethanedioic acid required to neutralise 25.0 cm^3 of 2.00 mol dm^{-3} sodium hydroxide solution?

(A) 10.0 cm^3

(B) 12.5 cm^3

(C) 20.0 cm^3

(D) 25.0 cm^3

(E) 100 cm^3

[NSAA, 2021S1Q54]

Propene burns in air. For each mole of propene burned, 2000 kJ of heat is released.

2.10 g of propene is burned to heat a 1000 g sample of olive oil.

The olive oil has an initial temperature of 23.0 °C. It takes 2.00 J to heat one gram of olive oil by 1.0 °C.

Assume that all heat is transferred to the olive oil and none is lost to the surroundings.

What is the maximum temperature reached by the oil?

(M_r value: C_3H_6=42.0)

(A) 20.0 °C

(B) 43.0 °C

(C) 48.0 °C

(D) 50.0 °C

(E) 73.0 °C

(F) 100 °C

(G) 200 °C

(H) 223 °C

[NSAA, 2021S1Q55]

What is the calculated energy change for the following reaction using appropriate values from the data provided?

$$CH_4(g) + 2H_2O(g) \rightarrow CO_2(g) + 4H_2(g)$$

bond	*bond energy /kJ mol–1*
H–H	440
O–H	460
C–H	430
C–O	360
C=O	800
C≡O	1070

(A) $+200$ kJ mol^{-1}

(B) -200 kJ mol^{-1}

(C) $+720$ kJ mol^{-1}

(D) -720 kJ mol^{-1}

(E) $+1080$ kJ mol^{-1}

(F) -1080 kJ mol^{-1}

[NSAA, 2021S1Q56]

The balanced equation for an oxidation of ammonia is:

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

50.0 dm^3 of ammonia and 50.0 dm^3 of oxygen, both at 850 °C and 1 atmosphere pressure, are mixed and allowed to react to form the products shown in the equation. No other reactions occur.

What is the maximum total volume of gases (at 850 °C and 1 atmosphere pressure) after the reaction?

(Assume that all gases have the same volume at the given temperature and pressure.)

(A) 100 dm^3

(B) 110 dm^3

(C) 111 dm^3

(D) 125 dm^3

(E) 200 dm^3

[NSAA, 2021S1Q57]

The electrolysis of molten potassium chloride in an inert atmosphere produces potassium at the negative electrode and chlorine at the positive electrode.

The electrolysis of aqueous copper(II) sulfate solution deposits copper on the negative electrode.

The masses of potassium, chlorine and copper produced or deposited in these experiments were recorded.

Assume that the same number of electrons is transferred during the electrolysis of molten potassium chloride and aqueous copper(II) sulfate solution.

Which of the following gives the elements arranged in order of the mass produced/deposited during these electrolysis experiments, from lowest mass to highest mass?

(A_r values: Cl=35.5; K=39.0; Cu=63.5)

(A) chlorine, copper, potassium

(B) chlorine, potassium, copper

(C) copper, chlorine, potassium

(D) copper, potassium, chlorine

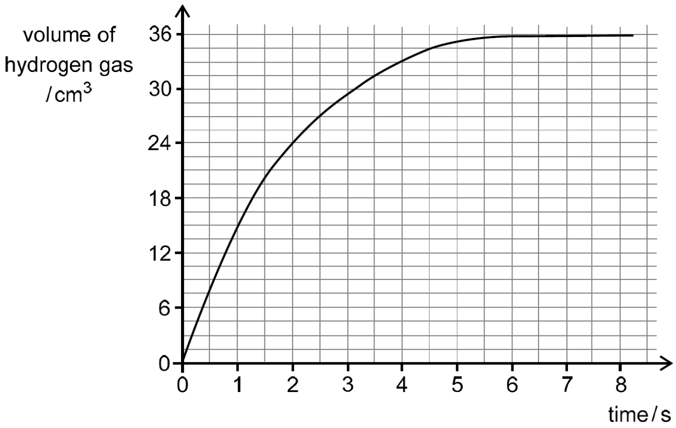
(E) potassium, chlorine, copper

(F) potassium, copper, chlorine

[NSAA, 2021S1Q58]

0.500 g of magnesium (an excess) was added to dilute hydrochloric acid.

The following graph shows the total volume of the gas released over time as the reaction progresses. All volumes were measured in cm^3 at room temperature and pressure.



What is the mass of magnesium remaining after two seconds?

(A_r value: Mg=24. Assume that the volume of one mole of gas at room temperature and pressure is 24.0 dm^3.)

(A) 0.024 g

(B) 0.036 g

(C) 0.048 g

(D) 0.452 g

(E) 0.464 g

(F) 0.476 g

[NSAA, 2021S1Q59]

A mixture of both sodium nitrate and barium bromide solids, with a combined mass of 6.36 g, was stirred into water and completely dissolved.

An excess of aqueous silver nitrate was added and a precipitate formed. The precipitate was filtered and dried. The mass of dry precipitate was 3.76 g.

What was the mass of sodium nitrate in the original mixture?

(M_r values: $NaNO_3$=85; $BaBr_2$=297; AgBr=188)

(A) 0.42 g

(B) 0.85 g

(C) 1.70 g

(D) 2.97 g

(E) 3.39 g

(F) 5.94 g

[NSAA, 2021S1Q60]

A spoonful of magnesium carbonate powder was added to excess hydrochloric acid in an open conical flask on an electronic balance.

$$MgCO_3(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + CO_2(g) + H_2O(l)$$

The mass of the flask and its contents was measured initially and at 1-minute intervals. The total mass of gas produced was then calculated.

The reaction stopped at 5 minutes.

Which row in the following table could represent the total mass of gas calculated after each measurement?

	1 minute	*2 minutes*	*3 minutes*	*4 minutes*	*5 minutes*
A	5 g	9 g	12 g	14 g	15 g
B	1 g	3 g	6 g	10 g	15 g
C	3 g	6 g	9 g	12 g	15 g
D	11 g	12 g	13 g	14 g	15 g
E	6 g	10 g	13 g	15 g	15 g

Part D

[NSAA, 2021S1Q61]

A selection pressure is a biological or physical factor in an environment that may result in evolution.

Which of the following situations result in selection pressures on one or more organisms?

1 clearing rainforests to grow palm oil plantations

2 introduction of a predator to islands with seabird colonies

3 long-term use of antibiotics in hospital wards

4 using an insecticide to kill the mosquitoes that spread malaria

(A) 1 and 2 only

(B) 1 and 4 only

(C) 2 and 3 only

(D) 1, 2 and 3 only

(E) 2, 3 and 4 only

(F) 1, 2, 3 and 4

[NSAA, 2021S1Q62]

A particular cell has the following features:

- a cell wall
- a cell membrane
- no mitochondria

Which of the following statements about this cell is correct?

(A) It may be an animal cell.

(B) It may have no nucleus.

(C) It may contain chloroplasts.

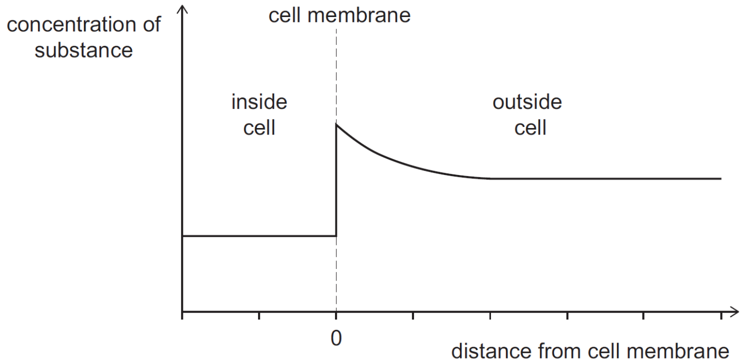
(D) It contains X and Y chromosomes.

(E) It is not able to respire.

[NSAA, 2021S1Q63]

A cell is studied. The graph shows the concentration of a substance at different distances from the cell membrane.

The concentrations shown are maintained over time.



Which of the following processes is/are responsible for maintaining the difference in the concentration of the substance across the membrane?

1 active transport

2 diffusion

3 osmosis

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

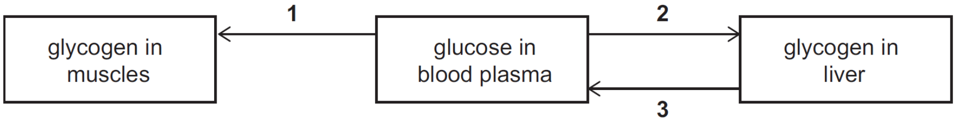
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3 only

[NSAA, 2021S1Q64]

The diagram shows some of the ways in which glucose can be added to or removed from blood plasma in humans.



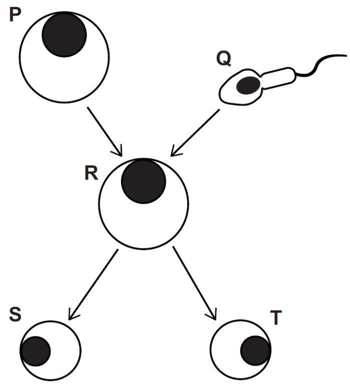
Which hormones stimulate the processes shown by the arrows?

	process 1	*process 2*	*process 3*
A	adrenaline	glucagon	insulin
B	adrenaline	adrenaline glucagon	glucagon
C	insulin	adrenaline	glucagon
D	insulin	insulin	adrenaline glucagon
E	glucagon	insulin	glucagon
F	glucagon	glucagon	insulin

[NSAA, 2021S1Q65]

The diagram shows two gametes, gamete P and gamete Q, fusing to form cell R in a healthy human. R divides to form two cells, S and T.

S and T grow into two separate individuals.



Which of the following statements is/are correct?

1. The number of double strands of DNA is the same in gamete P and cell T.
2. If gamete Q contains a Y chromosome, then both individuals that grow from cells S and T will be genetically male.
3. A mutation in the DNA in cell R before mitosis will always change the phenotype of cell S.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

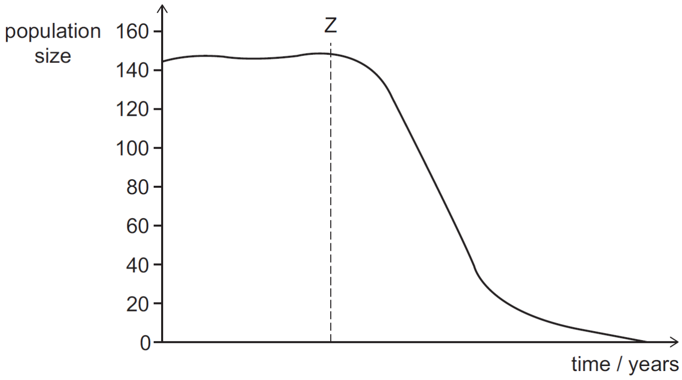
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q66]

The graph shows changes in population size (number of individuals) of a species of tortoise over the last century. These tortoises are only found on one small island in the Galapagos.



Which of the following could account for the change in population shown after time Z on the graph?

1 reduced rainfall

2 reduced availability of resources

3 failure to adapt to competition from an introduced species

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

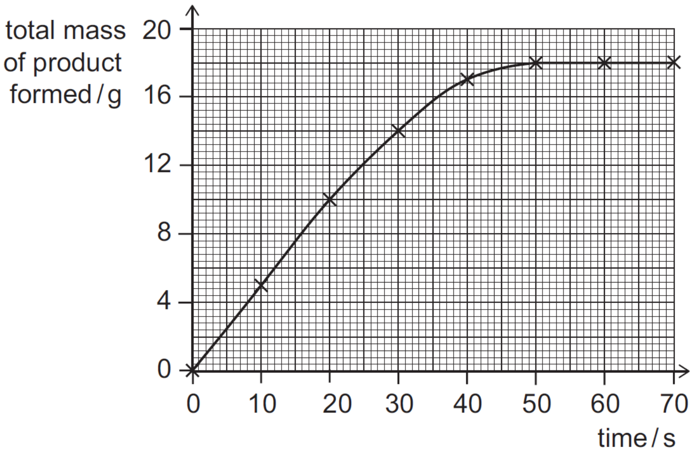
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q67]

An enzyme-catalysed reaction was studied and the mass of product formed was measured over time.

The results are shown in the graph.



Which of the following statements is/are correct?

1 The enzymes may have been used up in the reaction.

2 The initial rate of reaction is 120 g min^{-1}.

3 At high concentrations, the product formed may inhibit the enzymes.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q68]

A person ran on a treadmill for 360 seconds. Their rates of aerobic and anaerobic respiration were measured at the start and at the end of the time. The table shows the results.

	time=0 seconds	time=360 seconds
rate of aerobic respiration /arbitrary units	1.01	5.77
rate of anaerobic respiration /arbitrary units	0.01	3.67

Physiological changes occurred in the person during this time.

Which of the following statements is/are correct during the 360 seconds?

1 There was an increase in pH that caused a change in the shape of the respiratory enzyme's active sites.

2 Part of the increase in the rate of cellular respiration may have been due to a temperature increase in the muscles.

3 More carbon dioxide needed to be removed from the muscle cells.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q69]

Coat colour variation in a particular population of mice is only affected by one gene with two alleles, R and r. This gene is not on a sex chromosome.

Heterozygous mice have yellow fur. Embryos that are homozygous dominant do not survive.

A yellow male and a yellow female mouse were mated several times and a large number of offspring were produced. Some of the offspring were grey in colour and others were yellow.

Assuming that no new mutations have occurred, which of the following is correct?

(A) 25% of the live offspring will be grey in colour.

(B) All grey mice have a homozygous genotype for coat colour.

(C) Offspring with XY chromosomes are all heterozygous for coat colour.

(D) The live offspring of a cross between a yellow and a grey mouse will always be yellow.

(E) There is a 3 : 1 ratio of dominant to recessive alleles for this gene in the live offspring.

[NSAA, 2021S1Q70]

One strand of a section of DNA has the following sequence of bases:

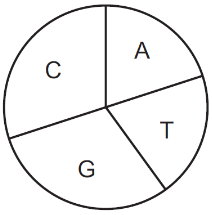
AATCGGTCTTGCGGCCAAGGCCCTT

The complementary strand is not shown.

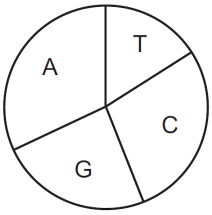
The charts show the proportions of the four bases A, C, G and T.

Which chart shows the correct proportions of bases for this section of double-stranded DNA?

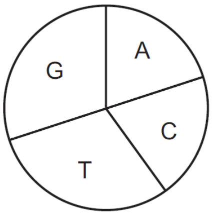
(Assume no mutations.)



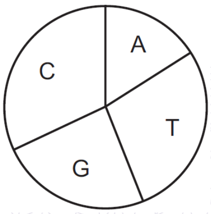
(A)



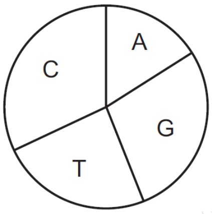
(B)



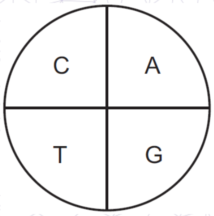
(C)



(D)



(E)

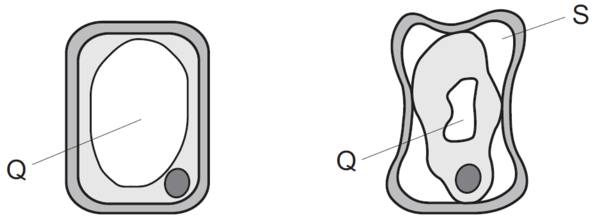


(F)

[NSAA, 2021S1Q71]

Two identical plant cells were removed from a leaf. One was placed in a concentrated sugar solution and the other was placed in distilled water, and both were left for 2 hours.

All other factors were kept constant during the experiment. The diagram shows the results, with regions of each cell labelled Q and S.



Which of the following statements is/are correct?

1 In the cell in distilled water, Q contains only distilled water.

2 In the cell in concentrated sugar solution, the number of solute particles in Q increased over the two hours.

3 S is a vacuum.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

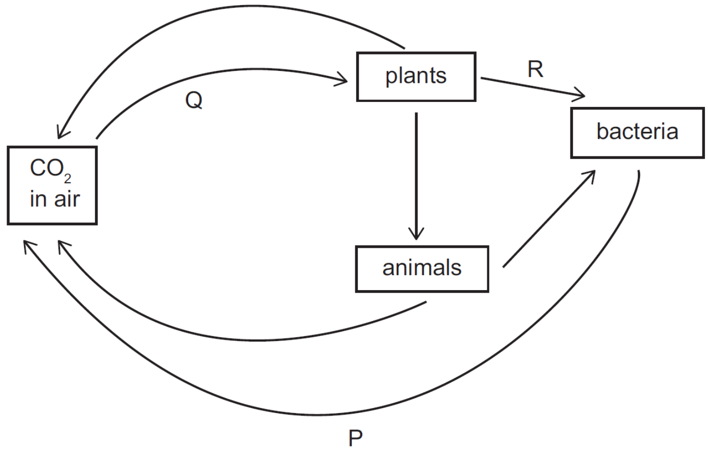
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q72]

The diagram shows some chemical processes involved in the carbon cycle. Three of these multi-stage processes are labelled P, Q and R.



Which of the following statements is/are correct?

1 P requires the presence of mitochondria.

2 Overall, Q releases heat.

3 R is sensitive to changes in pH and temperature.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q73]

Two different cells, cell L and cell M, were studied using a microscope and then drawn. The drawings are not shown.

Some of the data collected is shown in the table.

	cell L	*cell M*
actual maximum length of cell / μm	400	40
maximum length of cell in drawing / cm	2	1

Which of the following statements is/are correct?

1 Cell L has been magnified 50 times.

2 Cell M has been magnified 5 times as much as cell L.

3 Both cells could have a cell wall.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

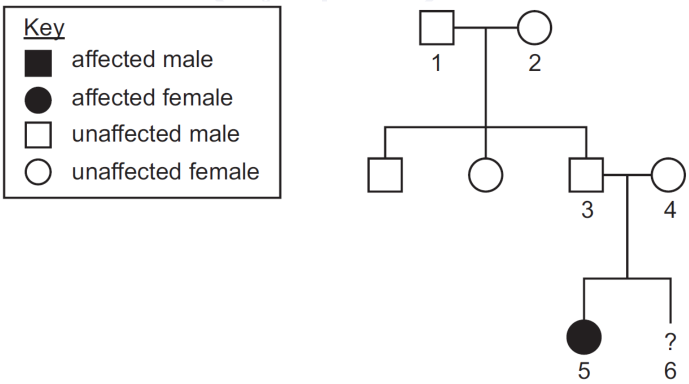
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q74]

The pedigree diagram shows the inheritance of a phenotypic feature caused by a recessive allele.



What is the probability that individual 6 is an unaffected male?

(A) 12.5%

(B) 25%

(C) 37.5%

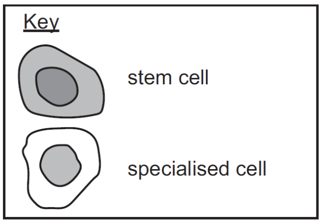
(D) 50%

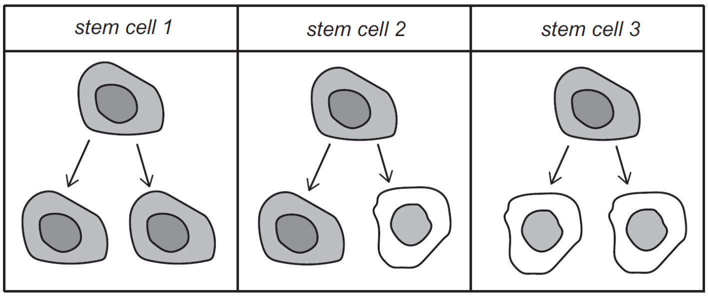
(E) 62.5%

(F) 75%

[NSAA, 2021S1Q75]

The diagrams show the daughter cells produced when three different stem cells divide.





Which of the following statements is correct?

(A) Only stem cell 1 shows division by mitosis.

(B) Some cancers result from divisions like that shown for stem cell 1.

(C) The total number of stem cells increases if they divide like stem cell 2.

(D) Stem cells in adults divide like stem cell 3.

(E) The total number of stem cells is maintained if they divide like stem cell 3.

[NSAA, 2021S1Q76]

A fungus feeds by releasing amylase onto starchy food. The soluble products of the breakdown of starch are absorbed by the fungus.

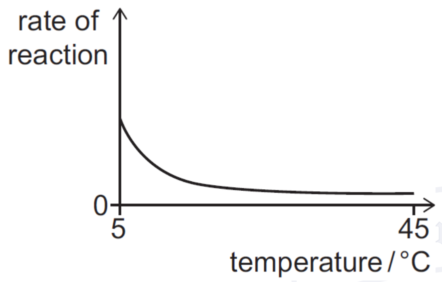
Test tubes were set up containing a mixture of starch solution and fungus. Each test tube was maintained at a different temperature between 5 °C and 45 °C.

Samples of the mixture were removed early in the experiments to determine the initial rates of this enzyme-catalysed reaction.

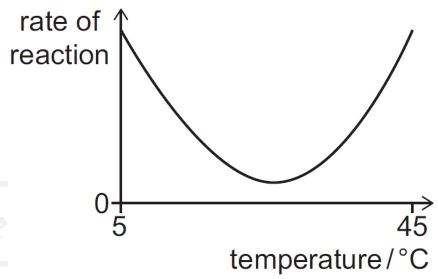
The results were plotted.

All of the other variables were kept constant.

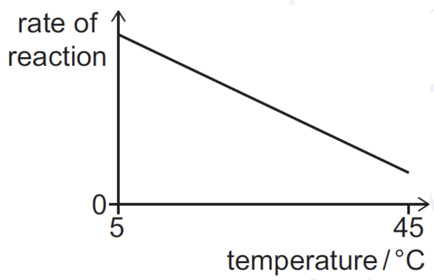
Which graph shows the expected results?



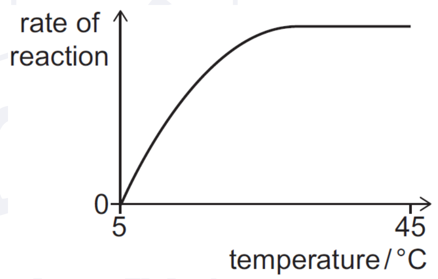
(A)



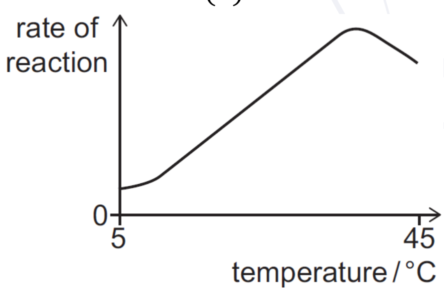
(B)



(C)



(D)



(E)

[NSAA, 2021S1Q77]

Red blood cells are produced by stem cells in the bone marrow.

A 1 mm^3 sample of blood from a healthy person was found to contain 4×10^6 red blood cells.

The person has a consistent average total blood volume of 0.006 m^3. Their total red blood cell count does not change and, on average, red blood cells have a lifespan of 100 days.

Which of the following statements is/are correct?

1 Red blood cells are phagocytic cells.

2 The average rate of production of red blood cells is 1×10^{10} cells per hour.

3 The stem cells that produce red blood cells do not have nuclei.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

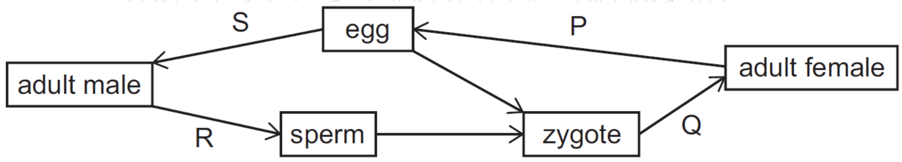
(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S1Q78]

The diagram shows the life cycle of one species of ant, in which males are haploid and females are diploid.



Which of the letters on the diagram represent(s) meiosis?

(A) P only

(B) Q only

(C) R only

(D) S only

(E) P and Q only

(F) P and R only

(G) P and S only

(H) Q and R only

[NSAA, 2021S1Q79]

A student compared the properties of different cells from one healthy human.

Which of the following statements is/are correct?

(Assume that no mutations occur.)

1 A cheek cell contains the same alleles as an embryonic stem cell.

2 A sperm cell contains the same genome as a cheek cell.

3 A white blood cell contains the same number of DNA bases as a mature red blood cell.

4 An embryonic stem cell produces all of the same proteins as a white blood cell.

(A) 1 only

(B) 2 only

(C) 3 only

(D) 4 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 4 only

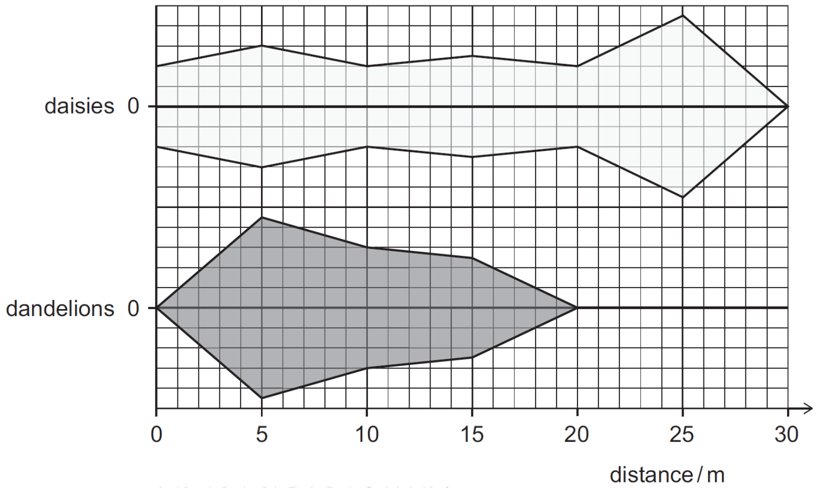
(H) 3 and 4 only

[NSAA, 2021S1Q80]

The kite diagram shows the distribution of dandelions and daisies along a transect in a field.

A quadrat with sides of 0.5 m was used to collect the data.

Each square on the vertical axis represents 1 plant. For example, in the quadrat centred at 5 m there were 6 daisies.



Which of the following statements about the data is/are correct?

1 Across the transect, the number of dandelions is proportional to the number of daisies.

2 Repeating the experiment along a different transect would result in an identical pattern.

3 The density of dandelions at 5 m is 36 plants per square metre.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

NSAA 2021 S2

NSAA 2021 S2

On-line Exam

Scan the QR code or click on the link to take an on-line exam.

Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 2 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

This paper contains **three** parts: **X**, **Y** and **Z**.

All candidates should complete only **one** part chosen from:

Part X	Physics
Part Y	Chemistry
Part Z	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt **all** 20 questions in your chosen part. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

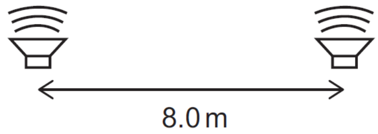
A Periodic Table is included.

Dictionaries and calculators are NOT permitted.

Part X

[NSAA, 2021S2Q1]

Two loudspeakers are positioned 8.0 m apart as shown.



The loudspeakers emit sound waves of the same single frequency. The wave emitted by one loudspeaker is 180° out of phase with the wave emitted by the other loudspeaker.

A point P is in front of the loudspeakers. P is 18.0 m from one loudspeaker and 24.0 m from the other loudspeaker. As a result of superposition of the two waves arriving at P, the amplitude of the sound at position P is a minimum.

The speed of the sound is 336 m s^{-1}.

What is the lowest possible frequency of the sound?

(A) 21 Hz

(B) 28 Hz

(C) 42 Hz

(D) 56 Hz

(E) 63 Hz

(F) 84 Hz

[NSAA, 2021S2Q2]

A block is at rest on a rough inclined plane.

The acute angle between the plane and the horizontal is greater than 45°.

The forces acting on the block are: friction (F), weight (W) and normal contact force (N).

How do the magnitudes of the three forces compare?

(A) $F < N < W$

(B) $F < W < N$

(C) $N < F < W$

(D) $N < W < F$

(E) $W < F < N$

(F) $W < N < F$

[NSAA, 2021S2Q3]

A dc power supply, a resistor of constant resistance 50 Ω and a piece of resistance wire are connected in series.

The length of the resistance wire is 20 m and its cross-sectional area is 0.10 mm^2. The wire is made from a material with resistivity 1.0×10^{-7} Ω m and the current in it is 200 mA.

What is the voltage across the terminals of the power supply?

(A) 4.0 V

(B) 6.0 V

(C) 9.9 V

(D) 10.0 V

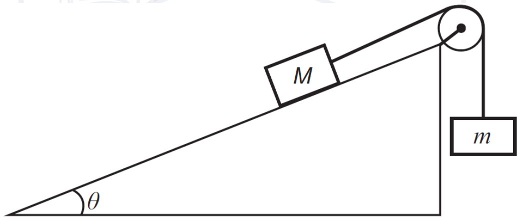
(E) 10.1 V

(F) 12.0 V

(G) 14.0 V

[NSAA, 2021S2Q4]

Two objects of mass M and m are connected by a rope over a pulley on an inclined plane as shown.



[diagram not to scale]

There is no friction between the plane and the object. The pulley is smooth, and the rope has negligible mass.

The angle θ of the plane to the horizontal is such that $\sin\theta = 0.80$ and $\cos\theta = 0.60$.

The object with mass M accelerates down the slope.

Which expression describes the full range of possible values of M compared with m?

(A) $M > \frac{3}{5}m$

(B) $M > \frac{4}{5}m$

(C) $M > m$

(D) $M > \frac{5}{4}m$

(E) $M > \frac{5}{3}m$

[NSAA, 2021S2Q5]

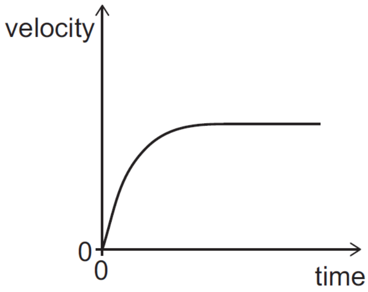
An object P falls vertically from rest through air and reaches terminal velocity.

An identical object Q is projected vertically upwards from the ground.

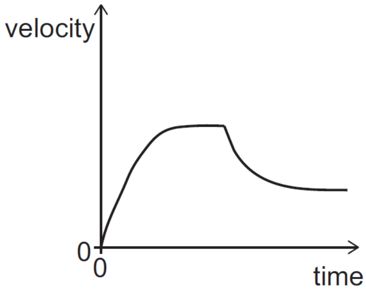
When Q reaches its maximum height, P collides with it. The two objects join together in such a way that there is no change to the area of cross section passing through the air.

The two combined objects then fall through the air as one object.

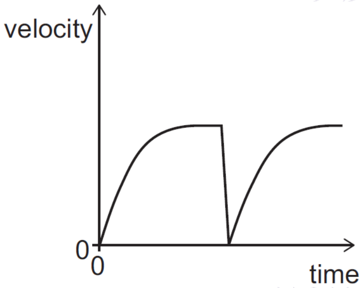
Which sketch graph shows the variation of velocity with time for object P before and after the collision?



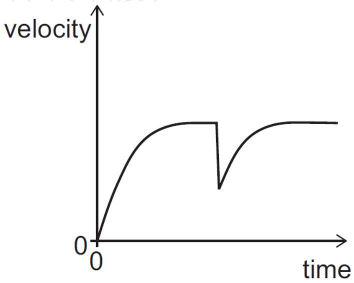
(A)



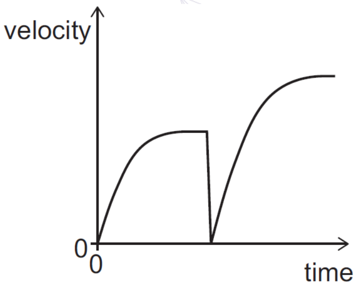
(B)



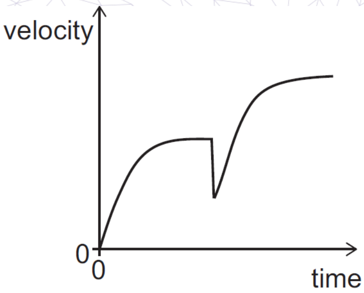
(C)



(D)



(E)



(F)

[NSAA, 2021S2Q6]

A lorry of mass m has an engine that develops a constant mechanical output power P.

The lorry is accelerated from rest by the engine in a horizontal straight line. The lorry experiences a total resistive force that is always proportional to the square of its speed.

The process is repeated for different values of P, and the maximum speed of the lorry is found to be proportional to P^n, where n is a constant.

What is the value of n?

(A) $\frac{1}{3}$

(B) $\frac{1}{2}$

(C) 1

(D) 2

(E) 3

[NSAA, 2021S2Q7]

A battery pack consists of 6 cells, each with an emf of 1.50 V and each with an internal resistance of 0.20 Ω.

The cells are arranged in two rows connected in parallel. Each row contains 3 cells connected in series.

The battery pack is connected to an external resistor of resistance 1.20 Ω.

What is the electrical power transferred in the external resistor?

(A) 2.7 W

(B) 3.6 W

(C) 7.5 W

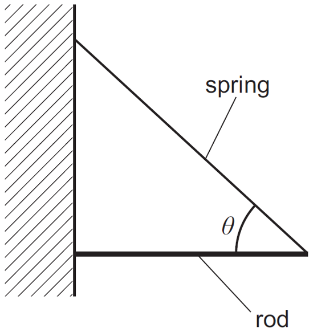
(D) 10.8 W

(E) 13.5 W

(F) 43.2 W

[NSAA, 2021S2Q8]

A light spring is used to support a uniform rod horizontally against a wall as shown. The angle between the spring and the rod is θ.



The spring constant of the spring is 20 N m^{-1} and the weight of the rod is 16 N.

The angle θ is such that $\cos\theta = \frac{3}{5}$ and $\sin\theta = \frac{4}{5}$.

How much energy is stored in the spring?

(A) 1.6 J

(B) 2.5 J

(C) 3.2 J

(D) 4.4 J

(E) 5.0 J

(F) 6.4 J

(G) 10 J

(H) 40 J

[NSAA, 2021S2Q9]

An object of mass 2.0 kg moves in a straight line under the action of a resultant force.

The displacement x of the object from its position at time $t = 0$ is given by

$$x = 4.0t^3$$

where x is in metres and t is in seconds.

At $t = 5.0$ s, what is the rate of change of momentum of the object?

(A) 6.7 kg m s^{-2}

(B) 66.7 kg m s^{-2}

(C) 120 kg m s^{-2}

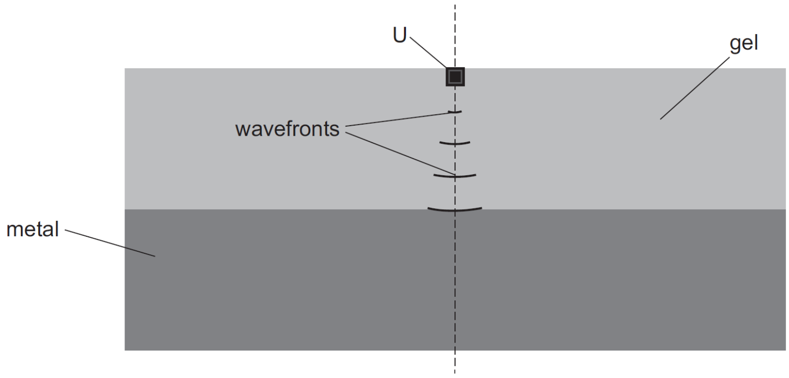
(D) 240 kg m s^{-2}

(E) 600 kg m s^{-2}

[NSAA, 2021S2Q10]

In an industrial process to test the purity of a metal, a narrow beam of ultrasound passes into block of the metal. The ultrasound generator U is immersed in a gel that is in contact with the metal. The ultrasound passes from the gel into the metal.

The arcs of circles shown in the gel are lines that represent the positions of the compressions (known as wavefronts) of the ultrasound wave that comes from U.



Ultrasound travels faster in the metal than in the gel.

The wavefronts in the metal are circular arcs with their centre at a point X that is on the dashed line.

Where on the dashed line is X?

(A) above U

(B) at U

(C) in the gel below U

(D) on the boundary between the gel and the metal

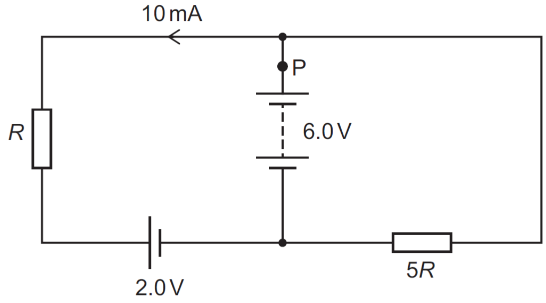
(E) in the metal

[NSAA, 2021S2Q11]

The diagram shows a circuit containing two power supplies with negligible internal resistance and two resistors with resistances R and $5R$.

The emfs of the power supplies and the magnitude and direction of the current in one part of the circuit are shown.

One point in the circuit is labelled P.



What is the magnitude of the current at P?

(A) 3.0 mA

(B) 7.0 mA

(C) 8.5 mA

(D) 11.5 mA

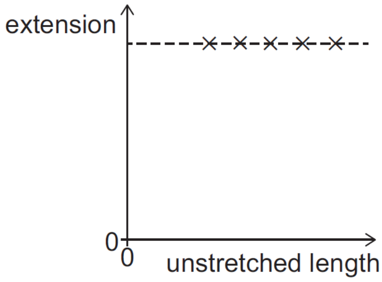
(E) 13 mA

(F) 25 mA

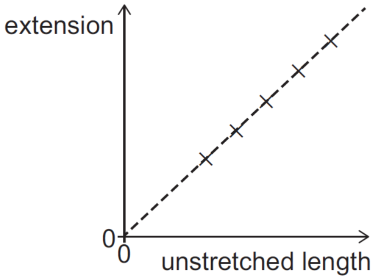
[NSAA, 2021S2Q12]

A selection of five wires made from the same metal have different unstretched lengths but equal masses. The wires are all subjected to the same small tension force and each wire extends within its limit of proportionality.

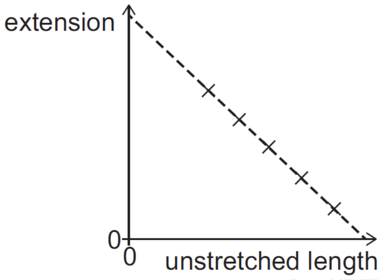
Which graph shows the relationship between the extension of the wires and the unstretched length of the wires?



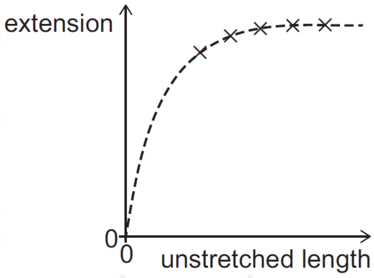
(A)



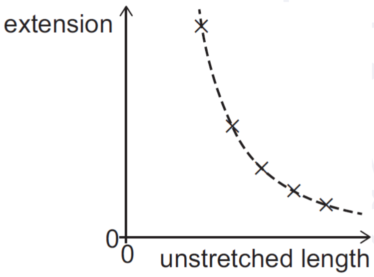
(B)



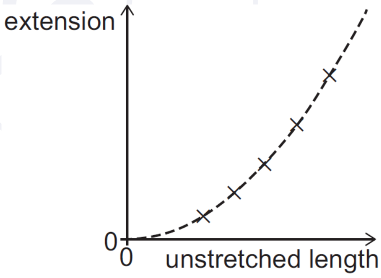
(C)



(D)



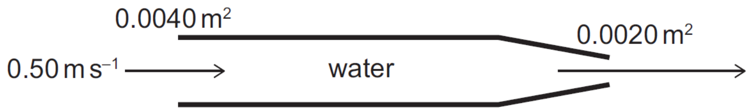
(E)



(F)

[NSAA, 2021S2Q13]

Water enters a horizontal pipe of cross-sectional area 0.0040 m^2 at constant speed 0.50 m s^{-1}. At the end of the pipe the cross-sectional area reduces to 0.0020 m^2 and the water leaves the pipe as shown. The density of water is 1000 kg m^{-3}.



How much power must be supplied to the water to maintain the flow in this section of the pipe? (Assume that the water is incompressible and that frictional forces can be neglected.)

(A) 0.25 W

(B) 0.50 W

(C) 0.75 W

(D) 1.0 W

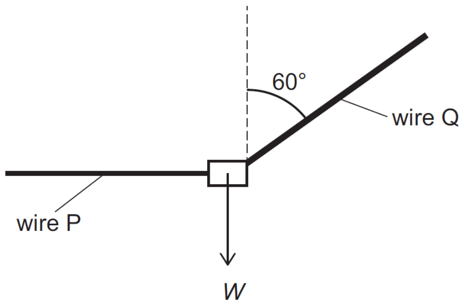
(E) 1.25 W

(F) 1.5 W

(G) 3.75 W

[NSAA, 2021S2Q14]

Two light wires P and Q support a load of weight W in equilibrium as shown. Wire P is horizontal and wire Q is at an angle of 60° to the vertical. The wires are made from the same material.



The radius of wire Q is twice the radius of wire P.

What is the ratio

$$\frac{\text{strain in wire P}}{\text{strain in wire Q}}?$$

(The wires do not exceed their limits of proportionality.)

(A) $\frac{\sqrt{3}}{8}$

(B) $\frac{\sqrt{3}}{4}$

(C) $\frac{\sqrt{3}}{2}$

(D) $\sqrt{3}$

(E) $2\sqrt{3}$

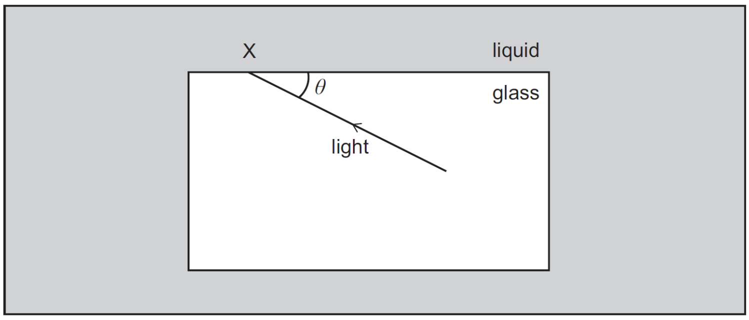
(F) $\frac{4}{\sqrt{3}}$

(G) $\frac{8}{\sqrt{3}}$

[NSAA, 2021S2Q15]

The speed of light in a block of glass is 2.0×10^8 m s^{-1}. The block of glass is immersed in a liquid of refractive index 1.2.

The diagram shows a ray of light travelling in the glass block striking the side of the block at the point labelled X. The acute angle between the ray and the side of the block is θ.



What is the full range of values of the acute angle θ for which light is refracted at X?

(The speed of light in a vacuum is 3.0×10^8 m s^{-1}.)

(A) $0° < \theta < \cos^{-1}\left(\frac{2}{3}\right)$

(B) $0° < \theta < \cos^{-1}\left(\frac{\sqrt{5}}{3}\right)$

(C) $0° < \theta < \cos^{-1}\left(\frac{3}{5}\right)$

(D) $0° < \theta < \cos^{-1}\left(\frac{4}{5}\right)$

(E) $\cos^{-1}\left(\frac{2}{3}\right) < \theta < 90°$

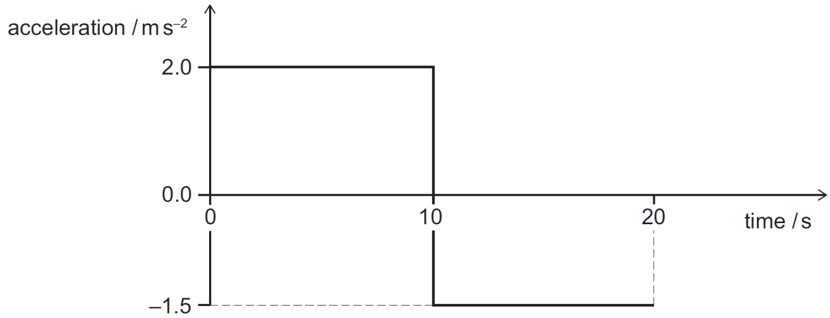
(F) $\cos^{-1}\left(\frac{\sqrt{5}}{3}\right) < \theta < 90°$

(G) $\cos^{-1}\left(\frac{3}{5}\right) < \theta < 90°$

(H) $\cos^{-1}\left(\frac{4}{5}\right) < \theta < 90°$

[NSAA, 2021S2Q16]

A car is at rest on a straight horizontal road. At time $t = 0$ s the car starts to move along the road. The graph shows how its acceleration varies from $t = 0$ s to $t = 20$ s.



What is the displacement of the car from its starting position when $t = 20$ s?

(A) 5.0 m

(B) 25 m

(C) 35 m

(D) 175 m

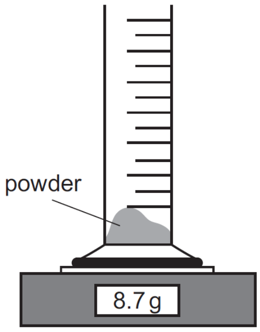
(E) 225 m

(F) 375 m

[NSAA, 2021S2Q17]

An empty measuring cylinder is placed on a balance, and the balance reading is then set to zero.

A mass of 8.7 g of a powder is poured into the measuring cylinder as shown in the diagram.



Liquid is poured into the cylinder to cover the powder completely. The powder does not dissolve. The reading on the measuring cylinder and the reading on the balance are recorded.

More liquid is added and a second pair of readings is recorded.

The table shows the two pairs of readings.

reading on measuring cylinder / cm^3	*reading on balance* /g
10.0	15.0
25.0	27.6

What is the density of the material from which the powder is made?

(A) 0.414 g cm^{-3}

(B) 1.16 g cm^{-3}

(C) 1.31 g cm^{-3}

(D) 1.45 g cm^{-3}

(E) 2.00 g cm^{-3}

(F) 2.50 g cm^{-3}

(G) 3.48 g cm^{-3}

(H) 6.00 g cm^{-3}

[NSAA, 2021S2Q18]

A stone of mass 100 g is fired horizontally from an 80 m high vertical cliff. The ground below the cliff is horizontal.

The kinetic energy of the stone when it hits the ground is 125 J.

What is the distance from the bottom of the cliff to the point where the stone hits the ground?

(gravitational field strength=10 N kg^{-1}; ignore air resistance and any effect of wind)

(A) 60 m

(B) 80 m

(C) 120 m

(D) 160 m

(E) 200 m

[NSAA, 2021S2Q19]

An electrical component is connected to a switch and a power supply which has a constant terminal potential difference V. The switch is initially open. At time $t = 0$ the switch is closed.

When the switch is closed, the current I in the component increases with time t as given by the equation

$$I = kt^2$$

where k is a positive constant.

When the current reaches a value I_F the component fails and the current falls instantly to zero.

How much electrical energy has been transferred to the component by the time it fails?

(All quantities are in standard SI units.)

(A) $\frac{Vk}{3}\left(\frac{I_F}{k}\right)^{\frac{3}{2}}$

(B) $Vk\left(\frac{I_F}{k}\right)^{\frac{3}{2}}$

(C) $3Vk\left(\frac{I_F}{k}\right)^{\frac{3}{2}}$

(D) $\frac{Vk}{3}\left(\frac{I_F}{k}\right)$

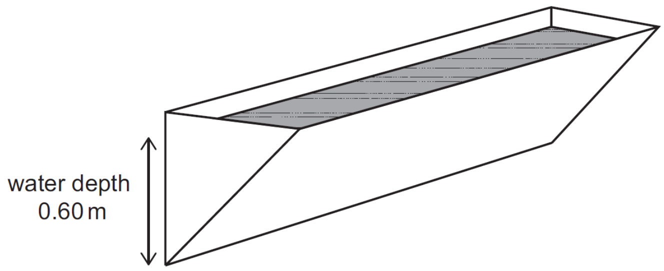
(E) $Vk\left(\frac{I_F}{k}\right)$

(F) $3Vk\left(\frac{I_F}{k}\right)$

[NSAA, 2021S2Q20]

A water trough has the shape of a prism, with a cross section that is a right-angled isosceles triangle.

One rectangular face and the two triangular ends of the trough are vertical, as shown.



[diagram not to scale]

The trough contains water of depth 0.60 m measured on the vertical rectangular face.

What is the force exerted by the water on one triangular end of the trough?

(density of water=1000 kg m^{-3}; gravitational field strength=10 N kg^{-1})

(A) 180 N

(B) 270 N

(C) 360 N

(D) 540 N

(E) 720 N

(F) 1080 N

(G) 6000 N

(H) 12 000 N

Part Y

[NSAA, 2021S2Q21]

A Group 1 metal hydrogencarbonate contains the HCO_3^- ion and decomposes at 200 °C.

When dilute hydrochloric acid is added to the residue from the thermal decomposition of this metal hydrogencarbonate, a gas is released that turns limewater cloudy. The residue also gives a yellow-orange colour in a flame test.

8.4 g of this metal hydrogencarbonate is heated to constant mass at 200 °C.

How much mass is lost in this reaction?

(A_r values: H=1; C=12; O=16; Li=7; Na=23; K=39)

(A) 2.2 g

(B) 2.6 g

(C) 3.1 g

(D) 4.0 g

(E) 4.4 g

(F) 5.3 g

(G) 6.2 g

[NSAA, 2021S2Q22]

Which of the following statements is correct for the bond angle (θ) in gaseous germanium(II) chloride, $GeCl_2$, molecules as predicted by the VSEPR model?

(A) $\theta = 90°$

(B) $90° < \theta < 120°$

(C) $\theta = 120°$

(D) $120° < \theta < 180°$

(E) $\theta = 180°$

[NSAA, 2021S2Q23]

Propanal can be reduced to propan-1-ol with hydrogen gas at high pressure and a platinum catalyst.

Radioactive propan-1-ol can be made if the hydrogen gas is replaced by pure tritium gas.

Tritium, ^{3}H, is the radioactive isotope of hydrogen.

All of the atoms other than ^{3}H in the radioactive propan-1-ol are the most abundant isotope for the element. The most abundant isotopes of carbon, hydrogen and oxygen are ^{12}C, ^{1}H and ^{16}O.

How many neutrons are there in one molecule of this radioactive propan-1-ol?

(A) 26

(B) 28

(C) 30

(D) 32

(E) 34

(F) 40

(G) 42

[NSAA, 2021S2Q24]

A sample of hydrated cobalt(II) sulfate, $CoSO_4 \cdot xH_2O$, with a mass of 5.62 g, was heated to convert the sample completely to 3.10 g of anhydrous cobalt(II) sulfate.

What is the value of x?

(A_r values: H=1.0; O=16.0; S=32.1; Co=58.9)

(A) 2

(B) 3

(C) 4

(D) 5

(E) 6

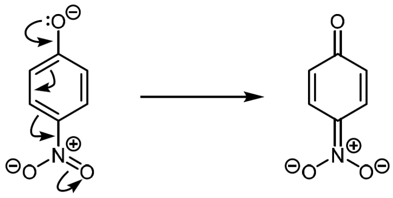
(F) 7

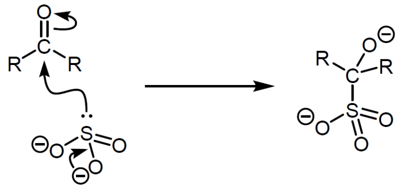
(G) 8

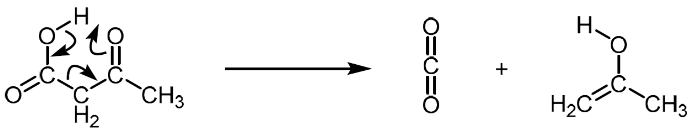
(H) 9

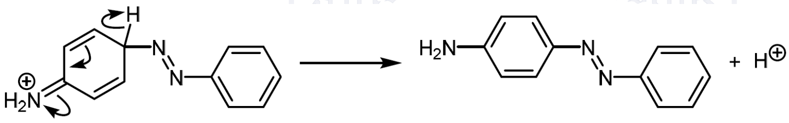
[NSAA, 2021S2Q25]

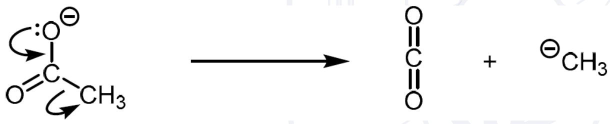
Which of the following does **not** give the species shown?

(A)


(B)


(C)


(D)


(E)


[NSAA, 2021S2Q26]

0.4 mol of a halogenoalkane reacted completely with hot, ethanolic potassium hydroxide to give 28 g of a single organic product X in 100% yield.

What percentage of all of the structural isomers with both the same functional group and molecular formula as X would show geometric (E/Z) isomerism?

(A_r values: H=1; C=12)

(A) 17%

(B) 20%

(C) 25%

(D) 33%

(E) 40%

(F) 50%

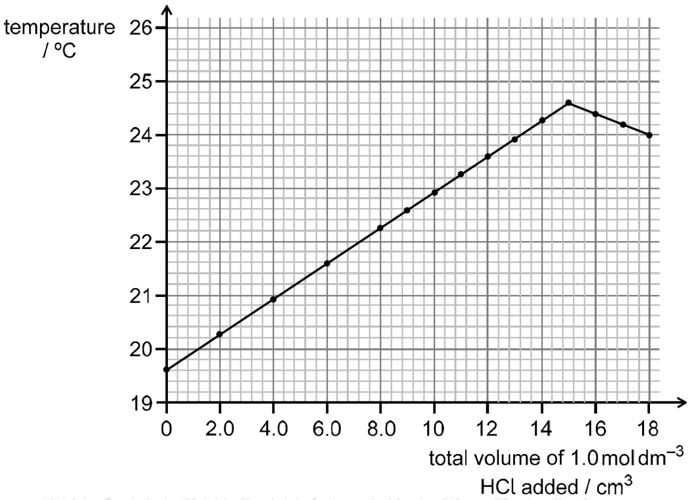
[NSAA, 2021S2Q27]

25.0 cm^3 of sodium hydroxide solution is placed in a polystyrene cup with a thermometer.

1.00 mol dm^{-3} hydrochloric acid is added from a burette to the stirred solution of sodium hydroxide.

Both solutions are at the same temperature before mixing.

The temperature is recorded each time a measured amount of hydrochloric acid is added, and the data is plotted on a graph.



Assuming that no heat is lost from the cup, what is the enthalpy change of reaction when one mole of aqueous sodium hydroxide is neutralised?

(Assume that all solutions have density 1.0 g cm^{-3} and specific heat capacity 4.2 J g^{-1} °C^{-1}.)

(A) – 56.0 kJ

(B) – 49.3 kJ

(C) – 35.0 kJ

(D) – 33.6 kJ

(E) – 21.0 kJ

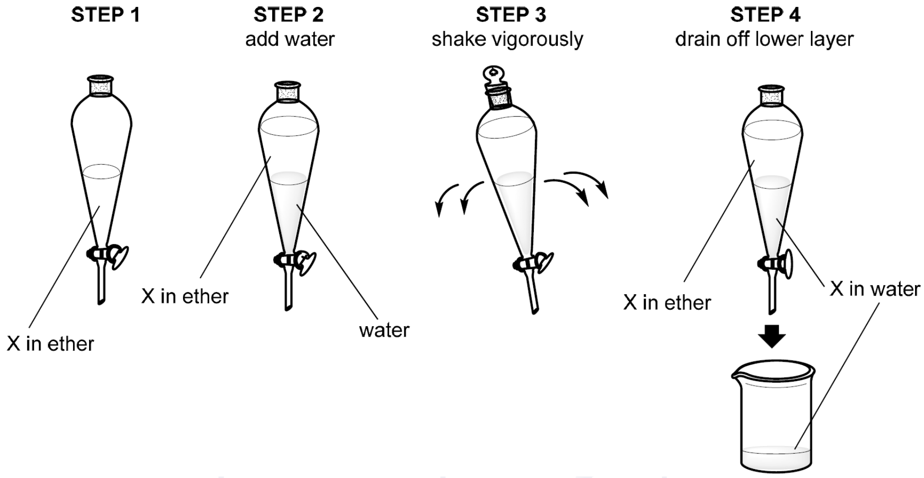
[NSAA, 2021S2Q28]

Consider the distribution of a solute X between two immiscible solvents: water and ether.

$$X(aq) \rightleftharpoons X(ether)$$

The equilibrium constant, K_c, is 0.15 at 25 °C.

50 cm³ of a solution of X in ether at 25 °C contains 21.5 g of X. 100 cm³ of water is added, shaken with the ether solution and allowed to reach equilibrium at 25 °C.



What is the maximum mass of X that can be transferred into the aqueous layer?

(A) 4.96 g

(B) 14.3 g

(C) 18.7 g

(D) 20.0 g

(E) 20.5 g

[NSAA, 2021S2Q29]

5.0 mol of 3-chloro-prop-1-ene (M_r=76.5) was reacted with excess sodium hydroxide to form a single product X in 80% yield.

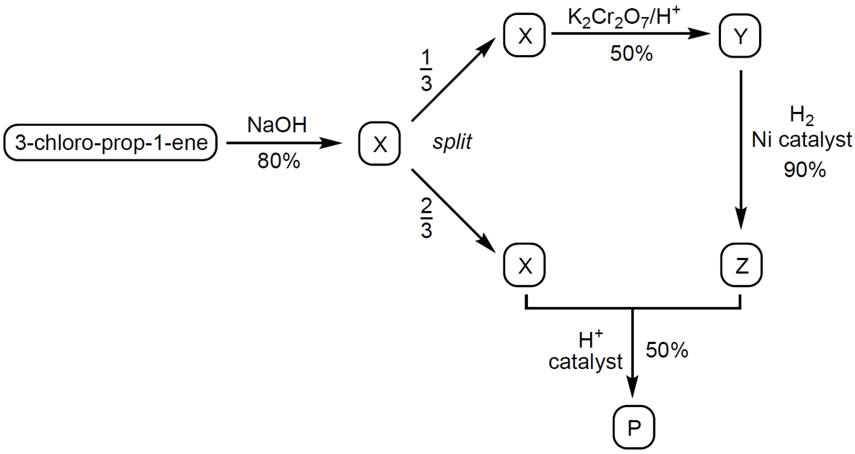
One third of compound X was heated with excess acidified potassium dichromate(VI) under reflux to form a single product Y in 50% yield.

All of compound Y was reacted with hydrogen gas at high temperature in the presence of nickel to form a single product Z in 90% yield.

The remaining quantity of compound X was reacted with all of compound Z in the presence of an acid catalyst to form product P in 50% yield.

What is the maximum mass of product P that could be produced from this synthesis?

(A_r values: H=1; C=12; O=16; Cl=35.5)



(A) 2.74 g

(B) 5.48 g

(C) 23.0 g

(D) 34.2 g

(E) 114 g

(F) 123 g

(G) 152 g

[NSAA, 2021S2Q30]

Iron(II) sulfate is used as a moss treatment on lawns and sports pitches. The recommended amount of iron is 2.5 kg per 10^4 m^2.

Analysis of a particular sports pitch showed it to contain 0.05 g of iron per m^2.

A pitch care company supplies three hydrated formulations:

- $FeSO_4{\cdot}7H_2O$ which contains 20% of iron by mass
- $FeSO_4{\cdot}4H_2O$ which contains 25% of iron by mass
- $FeSO_4{\cdot}H_2O$ which contains 33% of iron by mass

A 25 kg sack of one of the iron(II) sulfate formulations is to be used on the sports pitch but unfortunately it has lost its label. A small sample was heated to constant mass to form a white solid, and the mass of the sample decreased by more than 40% in this process.

The sports pitch is 90 m long and 60 m wide.

What mass of the iron(II) sulfate formulation (in kg) should be added to ensure that the iron content is at the recommended level?

(M_r values: $FeSO_4$=152; H_2O=18)

(A) 1.08 kg

(B) 1.35 kg

(C) 3.60 kg

(D) 4.32 kg

(E) 5.40 kg

(F) 6.75 kg

[NSAA, 2021S2Q31]

A compound contains potassium cations, and anions that contain only boron and fluorine. Each anion contains one boron atom.

0.630 g of this compound contains 0.195 g of potassium and 0.055 g of boron.

What is the shape of the anions in this compound?

(A_r values: B=11; F=19; K=39)

(A) linear

(B) bent (V-shaped)

(C) trigonal planar

(D) trigonal pyramidal

(E) tetrahedral

(F) square planar

[NSAA, 2021S2Q32]

The first ionisation energy of five elements is measured.

Which row matches the five elements to their first ionisation energy?

	first ionization energy /kJ mol^{-1}				
	557	736	1000	1060	1680
A	F	Mg	Al	P	S
B	F	P	S	Mg	Al
C	F	P	S	Al	Mg
D	Mg	Al	S	P	F
E	Mg	Al	P	S	F
F	Al	Mg	P	S	F
G	Al	Mg	S	P	F
H	S	P	Al	Mg	F

[NSAA, 2021S2Q33]

A yellow precipitate is formed when alkaline aqueous iodine reacts with alcohols that have the structure R-CH(OH)CH_3, where R is a carbon chain or H.

There are a number of structural isomers with the molecular formula $C_5H_{12}O$ that are alcohols.

Of these structural isomeric alcohols:

(i) how many will form a yellow precipitate when reacted with alkaline aqueous iodine;

(ii) how many, following mild oxidation and immediate distillation, will produce a silver mirror with Tollens' reagent?

	(i) *forms yellow precipitate*	(ii) *produces silver mirror*
A	1	1
B	2	3
C	2	4
D	2	7
E	3	3
F	3	4
G	3	7
H	4	4

[NSAA, 2021S2Q34]

The standard enthalpy change of formation of hydrogen iodide is +26 kJ mol^{-1}.

For the reaction of gaseous iodine with hydrogen

$$I_2(g) + H_2(g) \rightleftharpoons 2HI(g)$$

the enthalpy change of reaction can be calculated using bond enthalpy values.

The bond enthalpies are:

bond	*bond enthalpy* /kJ mol^{-1}
H–H	436
I–I	151
H–I	299

The sublimation of iodine is represented by: $I_2(s) \rightarrow I_2(g)$

Using the data provided, what is the enthalpy change for the sublimation of iodine?

(All data is given at room temperature and pressure.)

(A) −262 kJ mol^{-1}

(B) −236 kJ mol^{-1}

(C) −41 kJ mol^{-1}

(D) +37 kJ mol^{-1}

(E) +41 kJ mol^{-1}

(F) +63 kJ mol^{-1}

(G) +236 kJ mol^{-1}

[NSAA, 2021S2Q35]

Sodium hydrogencarbonate, $NaHCO_3$, and sodium carbonate are both used as antacids. They react with hydrochloric acid in the stomach to form the same products.

The contents of a person's stomach has a pH of 1.0, which is a concentration of 0.1 mol dm^{-3} HCl. The stomach contained 80 cm^3 of aqueous solution when the pH was measured.

Which of the following amounts of sodium hydrogencarbonate would bring the stomach contents into the normal range of pH 2.0-3.0?

(A_r values: H=1; C=12; O=16; Na=23)

(A) 0.0038 mol

(B) 0.0075 mol

(C) 0.0080 mol

(D) 0.016 mol

(E) 0.095 mol

[NSAA, 2021S2Q36]

X is a **di**carboxylic acid. When in aqueous solution, 2.36 g of X reacts with excess sodium carbonate to produce 480 cm^3 of carbon dioxide, measured at room temperature and pressure.

Assume that no gas dissolves in the water present.

Y is a liquid organic compound containing only one functional group. 1 mol of Y reacts exactly with 1 mol of sodium, giving off a gas that pops with a lighted splint. Aqueous Y does not change the colour of blue or red litmus papers.

When 50.0 cm^3 of gaseous Y is combusted in excess oxygen, 150 cm^3 of carbon dioxide and 200 cm3 of water vapour are the only products formed. All volumes are measured at the same temperature and pressure.

When heated in the presence of concentrated sulfuric acid, 1 mol of X reacts completely with 2 mol of Y to give 1 mol of organic product Z. Water is also produced in the reaction.

What is the relative molar mass of Z?

(A_r values: H=1; C=12; O=16. Assume that one mole of gas occupies 24 dm^3 at room temperature and pressure.)

(A) 101

(B) 160

(C) 166

(D) 170

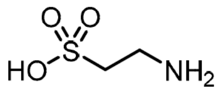
(E) 202

(F) 220

[NSAA, 2021S2Q37]

Cats are unable to synthesise the amino acid taurine in their bodies, so they must obtain it from their food. It is often added to cat food as an additive.

Taurine is a monoprotic acid with the following molecular structure:



M_r = 125

Dietary studies suggest that a cat should consume 10 mg of taurine per kilogram of body mass per day.

Brand X cat food contains taurine at a level of 0.008% by mass, but this level is too low for a cat to acquire a sufficient amount from a healthy amount of food.

Magnesium taurate is an ionic salt which liberates taurine in the body. 8 cm^3 of a 0.5 mol dm^{-3} aqueous solution of magnesium taurate was added to a 10 kg bag of brand X cat food and thoroughly mixed.

A particular cat bowl can hold a 50 g serving of cat food. A particular cat of mass 4000 g always eats a full serving.

What is the minimum number of bowls of cat food that this cat must eat to ensure that it has consumed its daily requirement of taurine?

(Assume that the addition of the solution does not significantly alter the total mass of the bag of cat food.)

(A) 2

(B) 3

(C) 4

(D) 5

(E) 6

(F) 7

(G) 8

[NSAA, 2021S2Q38]

Analysis of hydrocarbon P showed it to contain 0.60 g of carbon and 0.10 g of hydrogen, and to have a relative molecular mass of 70.

P reacts with hydrogen bromide to form a mixture of Q and R. However, the main product was Q.

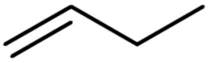
Q reacts with warm, aqueous sodium hydroxide to form S.

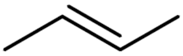
S reacts with warm, acidified potassium dichromate(VI) to form T. T does not produce a silver mirror with Tollens' reagent and does not produce bubbles when sodium carbonate is added.

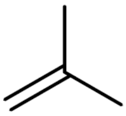
S undergoes dehydration on reaction with hot, concentrated sulfuric acid to form the original hydrocarbon P and a new compound U. Both P and U do not have stereoisomers.

What is the structure of compound U?

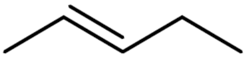
(A_r values: H=1; C=12)

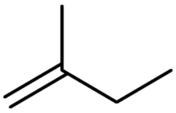
(A) 

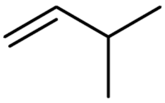
(B) 

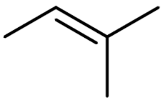
(C) 

(D) 

(E) 

(F) 

(G) 

(H) 

[NSAA, 2021S2Q39]

Lanthanum iodate(V), $La(IO_3)_3$, decomposes when heated to 600 °C to give a product that contains the ion Q.

An **unbalanced** ionic equation for the reaction is:

$$IO_3^- \rightarrow \text{ion Q} + I_2 + O_2$$

Ion Q contains only iodine in the +7 oxidation state and oxygen in the – 2 oxidation state.

The oxidation state of the lanthanum does not change in the reaction.

0.005 mol of $La(IO_3)_3$ is fully decomposed by heating. The iodine produced is titrated against a 0.4 mol dm^{-3} solution of sodium thiosulfate ($Na_2S_2O_3$). 30.0 cm^3 of the sodium thiosulfate solution is needed to reach the end-point. The equation for the reaction between iodine and sodium thiosulfate is:

$$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

What is the formula of the product that contains ion Q?

(A) $LaIO_5$

(B) $LaIO_6$

(C) $La(IO_4)_3$

(D) $La_3(IO_6)_5$

(E) $La_5(IO_4)_3$

(F) $La_5(IO_6)_3$

[NSAA, 2021S2Q40]

Consider the following chemical equation:

$$vQ + wP_4 + xH_2O \rightarrow yPH_4I + zH_3PO_4$$

where Q is a binary compound.

The molecules of Q are hexatomic and contain phosphorus in the +2 oxidation state.

Using the lowest integer values for all the coefficients v, w, x, y and z, what is the value of w when the equation is balanced?

(A) 1

(B) 2

(C) 13

(D) 16

(E) 24

(F) 26

Part Z

[NSAA, 2021S2Q41]

Cystic fibrosis and sickle cell anaemia are both recessive genetic conditions and the genes for these conditions are found on different non-sex chromosomes.

The following statements are true for one set of parents who have only one child:

- Both parents are heterozygous for cystic fibrosis.
- One parent is homozygous recessive for sickle cell anaemia.
- One parent is heterozygous for sickle cell anaemia.

What is the probability of this child having both conditions?

(A) 0.75

(B) 0.5

(C) 0.375

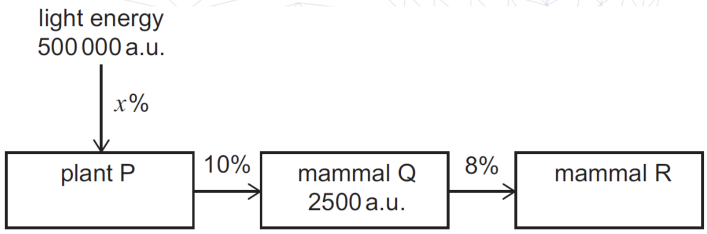
(D) 0.25

(E) 0.125

(F) 0.0625

[NSAA, 2021S2Q42]

The diagram shows a food chain. The numbers represent energy available and are in arbitrary units (a.u.), and the percentages represent efficiency of energy transfer.



The energy transfer between trophic levels is not 100% efficient.

Which row is correct for this food chain?

	efficiency of energy transfer x	*a reason for inefficiency of energy transfer from* Q *to* R
A	1%	energy lost as heat
B	1%	cellulose not digested
C	1%	some wavelengths of light not used
D	5%	energy lost as heat
E	5%	cellulose not digested
F	5%	some wavelengths of light not used

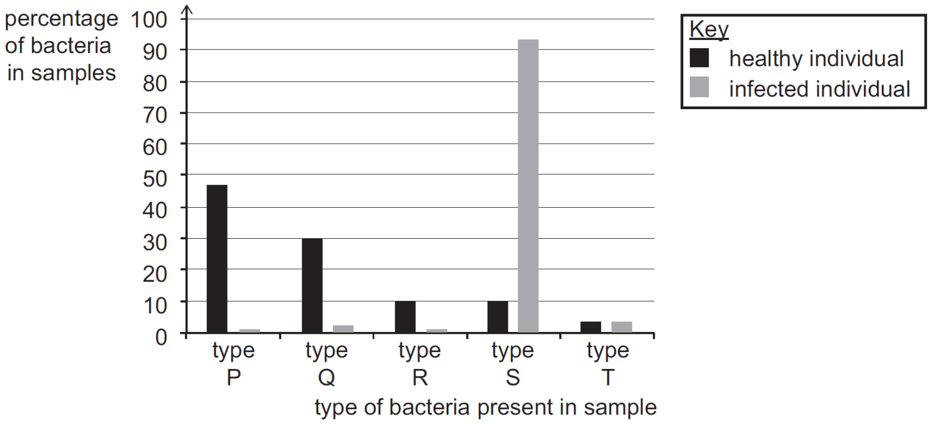
[NSAA, 2021S2Q43]

A number of patients in a hospital were infected with the same bacterial pathogen. The symptoms of this infection included pain in the abdomen, sickness and loss of appetite partly resulting from decreased production of acid in the stomach.

The bacteria present in their digestive systems were compared with those of healthy volunteers.

Samples were taken from each person and examined in order to identify the type of bacteria present and their relative proportions.

The results of the study are shown in the chart.



Which of the following statements could be correct?

1 Type S and type T feed on different biological molecules.

2 The DNA sequence of bacterial genes was used to classify the bacteria.

3 Type P, type Q and type R reduce in number because they require an alkaline environment.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

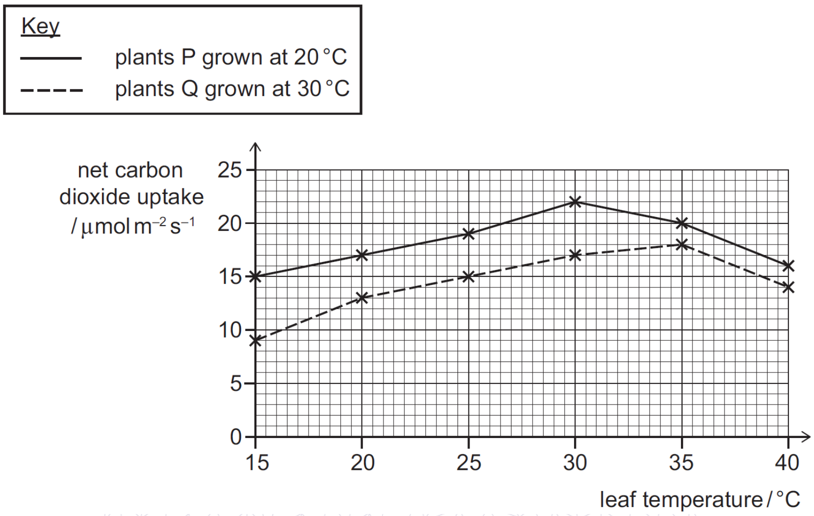
(H) 1, 2 and 3

[NSAA, 2021S2Q44]

A scientist studied one species of plant and grew some at 20 °C (plants P) and some at 30 °C (plants Q). All other variables were kept constant.

The scientist then placed plants from each group into six separate temperature-controlled cabinets, each at a different temperature. The plants were left for 15 minutes to adjust to their new temperature. The scientist then measured the rate of net carbon dioxide uptake by the leaves on the plants. All other variables were kept constant.

The results are shown in the graph.



Which of the following statements is/are correct?

1 At 35 °C, a 200 cm^2 leaf of plant P would take up 1.44×10^7 μmol of carbon dioxide in one hour.

2 Assuming that their respiration rates are the same, the rate of oxygen production in a leaf from plant P at 20 °C will be approximately equal to that in a leaf of the same size from plant Q at 30 °C.

3 The optimum temperature for maximum rate of photosynthesis in plant P must be 30 °C.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

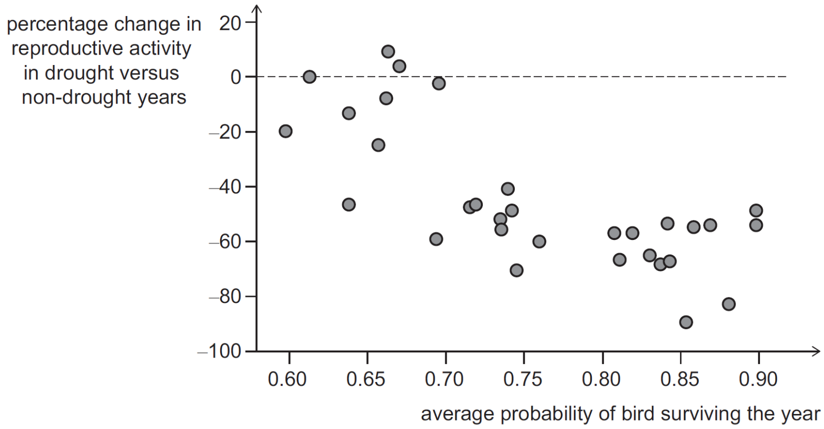
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S2Q45]

A group of scientists studied the effect of droughts on the reproduction rate and lifespan of different species of birds.

The graph shows their results. Each data point refers to a different species.



Which of these statements is/are correct?

1. The overall trend for this data shows that birds with shorter life expectancies tended to change their reproduction rates less in drought years.
2. Some birds were found to reproduce more in drought years than in non-drought years.
3. These birds were being studied for the effect of a biotic factor on their population size.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S2Q46]

The average volume of a mammalian mitochondrion is 0.5 μm^3. The density of the enzymes within the mitochondria is 450 mg of enzymes per mm^3 of mitochondrial volume.

What is the mass, in mg, of enzyme inside an average mammalian mitochondrion, and how would a decrease in enzyme density within all mitochondria inside a cell change the rate of anaerobic respiration in the cell as a whole?

(Assume that the overall metabolic rate of the cell remains constant.)

	mass of enzyme inside an average mammalian mitochondrion /mg	*change in the rate of anaerobic respiration in the cell as a whole that may occur if the enzyme density decreases*
A	2.25×10^{-7}	decreases
B	2.25×10^{-7}	increases
C	2.25×10^{-3}	decreases
D	2.25×10^{-3}	increases
E	2.25×10^{-1}	decreases
F	2.25×10^{-1}	increases
G	2.25×10^{2}	decreases
H	2.25×10^{2}	increases

[NSAA, 2021S2Q47]

At a certain time, the percentage of oxygen carried in the blood entering the right atrium is 40% of its maximum capacity.

At this time, a section of a human pulmonary artery is 5 cm long and has a lumen diameter of 2.8 mm.

Another artery in the human body is the renal artery.

What is the volume of blood in this pulmonary artery section, and the oxygen level in the blood in the renal artery, at this time?

	volume of blood in the lumen of this pulmonary artery section / mm^3	*percentage of oxygen carried in the blood in the renal artery*
A	$5 \times (0.14)^2 \times \pi$	less than 40%
B	$50 \times (1.4)^2 \times \pi$	less than 40%
C	$2.8 \times (25)^2 \times \pi$	less than 40%
D	$5 \times (0.14)^2 \times \pi$	40%
E	$50 \times (1.4)^2 \times \pi$	40%
F	$5 \times (0.14)^2 \times \pi$	greater than 40%
G	$50 \times (1.4)^2 \times \pi$	greater than 40%
H	$2.8 \times (25)^2 \times \pi$	greater than 40%

[NSAA, 2021S2Q48]

A 1 cm^3 sample of blood was taken from an infected patient. This sample was added to saline solution to make a total volume of 50 cm^3.

This diluted sample was then viewed using a haemocytometer, a special microscope slide that allows the number of blood cells in a known volume to be counted. The volume analysed using the haemocytometer was 1.0×10^{-4} cm^3.

The type and number of cells counted is shown.

cell type	*number of cells*
mature red blood cell	12
white blood cell	4
bacterial cell	5

Using this data only, how many cells with nuclei were present in the 1 cm^3 sample from the patient?

(A) 4.0×10^4

(B) 9.0×10^4

(C) 1.6×10^5

(D) 2.0×10^6

(E) 4.5×10^6

(F) 6.0×10^6

(G) 8.0×10^6

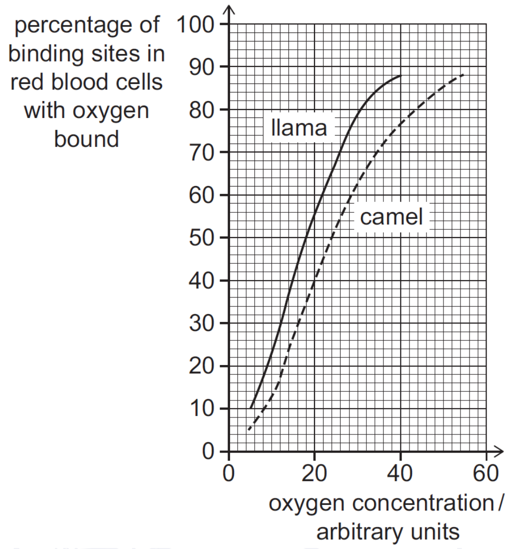
(H) 1.05×0^7

[NSAA, 2021S2Q49]

The oxygen saturation of red blood cells is the percentage of haemoglobin binding sites in red blood cells with oxygen bound to them.

Camels and llamas have evolved from the same ancestor. Camels live at low altitude and llamas live at high altitude.

The graph shows the effect of oxygen concentration on the oxygen saturation of red blood cells in camels and llamas.



Which of the following statements is/are correct?

1 The difference in oxygen binding properties of the red blood cells of camels and llamas is an example of different phenotypes.

2 The different oxygen binding properties evolved because of mutations caused by different oxygen concentrations.

3 50% oxygen saturation of llama red blood cells occurs at $\frac{3}{4}$ of the oxygen concentration required for 50% oxygen saturation of camel red blood cells.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S2Q50]

Water in a particular plant moves from a high water potential to a low (more negative) water potential. Water potential is measured in MPa.

Which row correctly describes the most direct pathway for water movement into, through, and out of this plant?

	Water potential in soil /MPa	*Water potential in plant root* /MPa	*tissue in plant for water transport*	*water potential in leaf* /MPa	*water potential in atmosphere* /MPa	*a mechanism for water leaving the leaf*
A	−75	−1.5	xylem	−0.1	−0.033	diffusion
B	−0.033	−0.1	xylem	−1.5	−75	diffusion
C	−0.033	−0.1	phloem	−1.5	−75	diffusion
D	−75	−1.5	phloem	−0.1	−0.033	osmosis
E	−1.5	−75	phloem	−0.033	−0.1	osmosis
F	−0.033	−0.1	xylem	−1.5	−75	osmosis

[NSAA, 2021S2Q51]

On a cool spring day (day 1), a healthy human produces 1500 cm^3 of urine.

The concentration of urea in the urine was measured as 2.00 g per 100 cm^3.

On a similar day (day 2), the same person plays a game of hockey and produces 20% less urine. However, the mass of urea excreted in the urine remains the same.

The volume of urine produced is affected by the movement of water in the nephron.

Which row shows the urea concentration in the urine, in g dm^{-3}, on day 1 and day 2, and the explanation for the change in urine volume?

	urea concentration /g dm^{-3}		*explanation for change in urine volume*	
	day 1	*day 2*	*change in ADH (vasopressin)*	*change in water movement in the nephron*
A	20.0	16.7	decrease	decrease in secretion of water
B	20.0	16.7	increase	increase in reabsorption of water
C	20.0	25.0	decrease	decrease in secretion of water
D	20.0	25.0	increase	increase in reabsorption of water
E	30.0	25.0	decrease	decrease in secretion of water
F	30.0	25.0	increase	increase in reabsorption of water
G	30.0	36.0	decrease	decrease in secretion of water
H	30.0	36.0	increase	increase in reabsorption of water

[NSAA, 2021S2Q52]

A scientist conducts an experiment to study a single-celled organism in a growth tube.

The organism divides once every 50 minutes using binary fission. Binary fission produces the same number of daughter cells per division as a cell dividing by mitosis.

The scientist starts with 150 cells. The experiment is left for 300 minutes.

The average volume of every cell is 5 μm^3.

To ensure there are sufficient nutrients available for the cells, the final volume of cells within the tube must not be more than 1% of the total volume of material inside the tube.

What is the minimum volume of nutrient solution required inside the growth tube at the start of the experiment?

(Assume that all the cells are alive and capable of dividing.)

(A) 4.8×10^{-3} mm^3

(B) 9.5×10^{-3} mm^3

(C) 3.1×10^{-1} mm^3

(D) 4.8×10^{-1} mm^3

(E) 9.5×10^{-1} mm^3

(F) 9.5×10^{2} mm^3

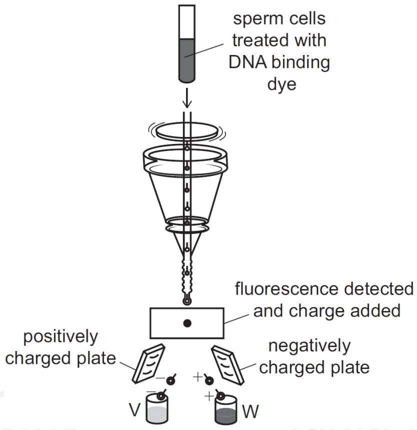
(G) 4.8×10^{3} mm^3

(H) 3.1×10^{5} mm^3

[NSAA, 2021S2Q53]

Sex determination in cows is identical to that in humans. To maximise productivity, dairy farmers want their cows to have female calves only.

Sperm cells can be sorted using their DNA content. This method is used to ensure the sex of calves born to dairy cows following artificial insemination. The method used is described below:



- The sperm cells are treated with a DNA binding dye.
- The greater the DNA content, the brighter the binding dye fluoresces.
- The brighter sperm cells are given a positive charge and the remaining sperm cells are given a negative charge.
- The charged sperm cells pass through a pair of charged plates and are attracted to the plate with the opposite charge.
- The sperm cells are collected in beakers below the plates.

Assume that all the separated sperm cells are alive and capable of fertilisation, no mutations have occurred, and the method of separation is 100% efficient.

Which of the following statements is/are correct?

1 Sperm cells in beaker V have fewer chromosomes.

2 For maximum productivity, dairy farmers should only use positively charged sperm cells.

3 The chance of obtaining a female calf using sperm cells from beaker W will be double that of using unseparated sperm cells.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S2Q54]

In a sample of four healthy human cells, three rounds of division occur. After the three divisions, there are a total of 1472 chromosomes present in the sample.

The diploid number in human cells is 46.

Which of the following statements about this sample is/are correct?

1 The cells could all be fertilised eggs that divided by mitosis only.

2 The cell divisions could be two rounds of mitosis and then one round of complete meiosis.

3 If a single mutation occurred in one allele just before the second division in one cell, then the final percentage of the cells with this mutation would be 12.5%.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S2Q55]

Samples of solution removed from different positions inside a nephron are analysed.

The rate of flow of the solution through the nephron is measured at each position where the samples are taken.

The rate of flow is the volume of solution passing a particular point per unit time.

In the Bowman's capsule, the concentration of sodium ions is the same as in the blood. The rate of flow is 100 arbitrary units.

At the collecting duct, the concentration of sodium ions is twice that in the blood. The rate of flow is 1 arbitrary unit.

Which row in the table is correct?

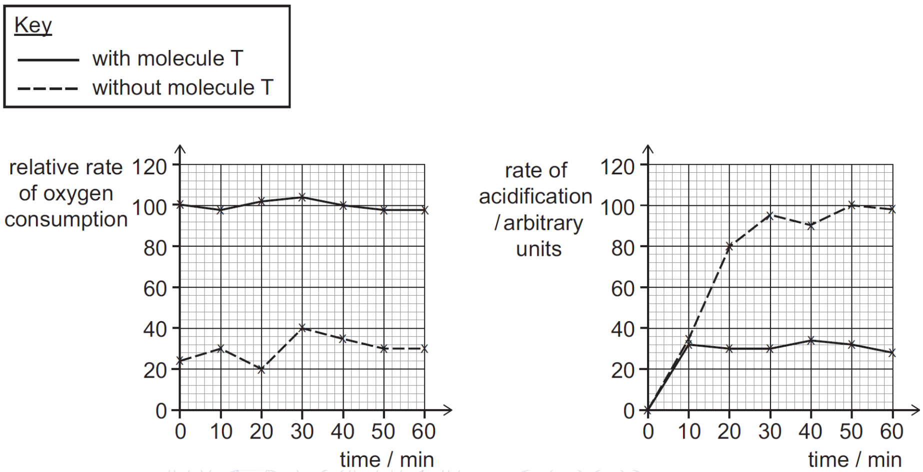
	percentage sodium ions reabsorbed in the nephron	*a process by which sodium ions can be reabsorbed from the nephron*
A	2%	active transport
B	2%	diffusion
C	50%	osmosis
D	50%	diffusion
E	98%	active transport
F	98%	osmosis

[NSAA, 2021S2Q56]

Mutations can occur in the genes coding for some of the enzymes that catalyse respiration reactions. This can result in mitochondria that do not function correctly.

Scientists studying this tested a molecule, T, for its ability to restore the function to these mitochondria in human cells.

The graphs show the rate of oxygen consumption, measured relative to the percentage of healthy mitochondria, and the rate of acidification of the cellular environment, over time.



Which of the following statements is/are correct?

1. Molecule T could reduce the rate of lactic acid production in the cells.
2. Between 20 and 30 minutes, the oxygen consumption rate without molecule T increases by 50%.
3. The concentration gradient for oxygen between the cell cytoplasm and the mitochondria is steeper with molecule T compared to without molecule T.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

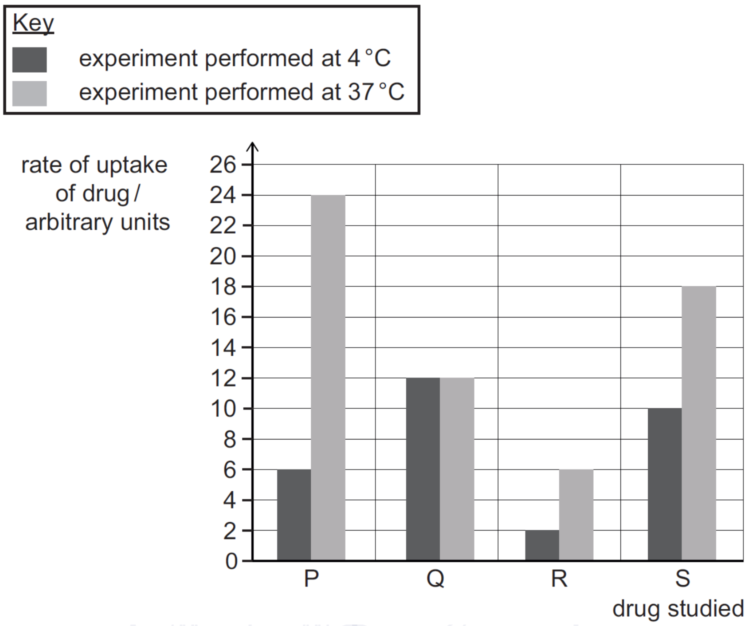
(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S2Q57]

Scientists studied the processes by which drugs cross the cell membrane and enter cells.

The rate of uptake of four drugs, P, Q, R and S, was studied at 4 °C and at 37 °C. The results are shown in the chart. All other variables were kept constant.



Which of the following conclusions can be drawn from the results?

1 The percentage increase in rate of uptake of R from 4 °C to 37 °C is 2.5 times more than the percentage increase in the rate of uptake of S.

2 The concentration of Q must be the same inside and outside the cell.

3 P must be transported across the cell membrane using active transport only.

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2021S2Q58]

Commercial varieties of tomato are produced from wild varieties of tomato.

The genetic diversity of tomatoes can be measured and expressed as a number.

A population of wild varieties of tomato was found to have a genetic diversity of 0.30.

The table shows the genetic diversity of a population of commercial tomatoes grown at different times.

year	*genetic diversity*
pre-1960	0.10
1960	0.05
1980	0.20
2000	0.30

Which of the following statements about these tomatoes could be correct?

1 Selective breeding of tomatoes occurred before 1960.

2 The addition of genetic material, enabling the tomatoes to produce memory cells so that they are resistant to diseases, increased the genetic diversity from 1960 onwards.

3 The average rate of increase in genetic diversity per day between 1960 and 2000 is approximately $\frac{25}{1460\,000}$.

4 The increase in genetic diversity was 50% greater during the 1960 to 1980 period than the 1980 to 2000 period.

(A) 1 and 2 only

(B) 1 and 3 only

(C) 1 and 4 only

(D) 2 and 3 only

(E) 2 and 4 only

(F) 1, 2 and 3 only

(G) 1, 3 and 4 only

(H) 2, 3 and 4 only

[NSAA, 2021S2Q59]

A mathematical test can be used to determine whether there is a statistically significant difference between the expected and the observed number of individuals with each phenotype in a population.

The value required for this test is calculated using the following expression:

$$\frac{(\text{observed} - \text{expected})^2}{\text{expected}} + \cdots + \frac{(\text{observed} - \text{expected})^2}{\text{expected}}$$

where each term uses the observed number of individuals and expected number of individuals with each phenotype in turn.

In a monohybrid cross between two individuals that showed the same phenotype, 160 offspring were produced. 36 of these offspring showed a different phenotype to both parents for the same characteristic.

The characteristic is controlled by a single gene with one dominant allele and one recessive allele.

Which of the following expressions calculates the value required for the mathematical test for this cross?

(Assume no mutations and that no genotype results in the death of individuals.)

(A) $\frac{4}{120} + \frac{4}{40}$

(B) $\frac{4}{124} + \frac{4}{36}$

(C) $\frac{16}{120} + \frac{16}{40}$

(D) $\frac{16}{124} + \frac{16}{36}$

(E) $\frac{32}{160}$

(F) $\frac{44}{124} + \frac{44}{36}$

(G) $\left(\frac{44^2}{80}\right) + \left(\frac{44^2}{80}\right)$

(H) $\left(\frac{44^2}{124}\right) + \left(\frac{44^2}{36}\right)$

[NSAA, 2021S2Q60]

An investigation was carried out to discover the evolutionary relationships between three different species of mammal, a human, a monkey and a hedgehog, as shown in the flow diagram:

Stage 1		Stage 2		Stage 3
Some human blood was injected into a rabbit. The rabbit's white blood cells produced antibodies that reacted with the human blood.	→	Some of the rabbit's blood was removed and divided into three samples.	→	One sample of rabbit blood was mixed with human blood. The second sample was mixed with monkey blood and the third sample was mixed with hedgehog blood. The amount of precipitate formed for each mixture of blood was measured.

When an antigen binds to an antibody, a precipitate is formed, which is measured in stage 3.

Some of the results for stage 3 are shown in the table.

P and Q each represent one of the non-human mammals.

species of mammal	*amount of precipitate formed* /arbitrary units
P	58
Q	17

Which row is correct for this investigation?

	biological molecules that form antibodies in stage 1	*the amount of precipitate formed for the sample with human blood in stage 3* /arbitrary units	*species Q*
A	amino acids	greater than 58	monkey
B	amino acids	greater than 58	hedgehog
C	amino acids	less than 17	monkey
D	amino acids	less than 17	hedgehog
E	nucleotides	greater than 58	monkey
F	nucleotides	greater than 58	hedgehog
G	nucleotides	less than 17	monkey
H	nucleotides	less than 17	hedgehog

NSAA 2022 S1

NSAA 2022 S1
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 60 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **four** parts: **A**, **B**, **C** and **D**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **one** further part chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **two** parts. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators are NOT permitted.

Part A

[NSAA, 2022S1Q1]

Which one of the following is a simplification of

$$y\left(\frac{3x^{\frac{1}{2}}z}{y^3}\right)^2$$

(A) $\frac{3xz^2}{y^4}$

(B) $\frac{3xz^2}{y^5}$

(C) $\frac{9x^{\frac{1}{2}}z^2}{y^5}$

(D) $\frac{9xz^2}{y^4}$

(E) $\frac{9xz^2}{y^5}$

(F) $\frac{9x^{\frac{5}{2}}z^2}{y^5}$

[NSAA, 2022S1Q2]

Triangle PQR has a right angle at Q.

The point T lies on QR such that $QT = \frac{1}{4}QR$.

$$PT = 6 \text{ cm}$$
$$PR = 12 \text{ cm}$$

What is the length of QT, in cm?

(A) 2

(B) $2\sqrt{3}$

(C) $\frac{3}{2}\sqrt{2}$

(D) $\frac{6}{5}\sqrt{5}$

(E) $\frac{2}{7}\sqrt{21}$

[NSAA, 2022S1Q3]

Find the complete set of values of x that satisfy the inequality

$$\frac{3}{4}(5-x)-\frac{1}{2}(6-x)-x<0$$

(A) $x<\frac{1}{3}$

(B) $x>\frac{1}{3}$

(C) $x<\frac{3}{5}$

(D) $x>\frac{3}{5}$

(E) $x<\frac{3}{4}$

(F) $x>\frac{3}{4}$

(G) $x<\frac{3}{2}$

(H) $x>\frac{3}{2}$

[NSAA, 2022S1Q4]

I have two fair dice, X and Y, each of which has six sides.

The faces on X are labelled 1, 1, 2, 3, 4, 5.

The faces on Y are labelled 2, 3, 4, 5, 6, 6.

I roll the dice together and calculate my total score by adding the number rolled on X to the number rolled on Y.

What is the probability that my total score is greater than 9?

(A) $\frac{1}{4}$

(B) $\frac{1}{6}$

(C) $\frac{1}{9}$

(D) $\frac{5}{12}$

(E) $\frac{5}{36}$

[NSAA, 2022S1Q5]

Rob keeps a record of what he earns each day.

On Monday, he earned 50% less than he earned on Sunday.

On Tuesday, he earned 20% more than he earned on Monday.

On Wednesday, he earned 30% less than he earned on Tuesday.

On Wednesday, he earned £84.

How much did Rob earn on Sunday?

(A) £15.12

(B) £35.28

(C) £117.60

(D) £200

(E) £210

(F) £300

(G) £1200

[NSAA, 2022S1Q6]

The nth term of a sequence T is $(n-3)^2$, where n is a positive integer.

The nth term of another sequence V is $3n+p$, where p is a constant and n is a positive integer.

The 10th term in T is equal to twice the 5th term in V.

What is the 4th term in V?

(A) -16

(B) 4

(C) 16.5

(D) 21.5

(E) 31

(F) 46

(G) 95

[NSAA, 2022S1Q7]

Which one of the following is a simplification of

$$\frac{5x^2-17x-12}{25x^2-9} \div \frac{x^2+x-12}{x^2-x-6}$$

(A) $\frac{(x-4)(x+2)}{(x-3)(x+4)}$

(B) $\frac{(x-3)(x+2)}{(5x-3)(x+3)}$

(C) $\frac{(x-4)(x+2)}{(5x-3)(x+4)}$

(D) $\frac{(x-4)(x-3)}{(5x-3)(x-6)}$

(E) $\frac{(x+2)}{(5x+3)}$

(F) $\frac{(x+4)(x-6)}{(5x+3)(x+2)}$

(G) $\frac{(x-3)(x+2)}{(5x+3)(x+3)}$

[NSAA, 2022S1Q8]

S is a list of six numbers:

$$1, 2, x, x+1, x+1, 15 \quad \text{where } 2 \leq x \leq 14$$

The mean of S is one more than the median of S.

What is the value of x?

(A) $2\frac{2}{3}$

(B) $3\frac{2}{3}$

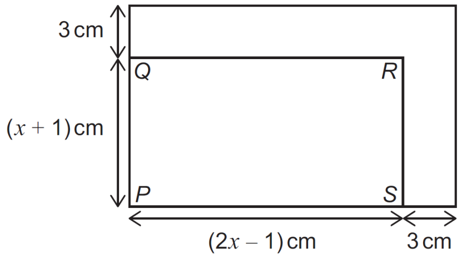
(C) $4\frac{2}{3}$

(D) $5\frac{2}{3}$

(E) $6\frac{2}{3}$

[NSAA, 2022S1Q9]

A rectangle $PQRS$ has length $(2x - 1)$ cm and width $(x + 1)$ cm as shown on the diagram.
A larger rectangle is made by adding 3 cm to both the length and the width of $PQRS$, as shown.
The larger rectangle has an area of 360 cm^2.



[diagram not to scale]

What is the ratio of PQ to PS?

(A) $1 : 2$

(B) $4 : 7$

(C) $5 : 8$

(D) $7 : 11$

(E) $10 : 17$

(F) $17 : 31$

[NSAA, 2022S1Q10]

t is inversely proportional to the square of w.
t and w are positive numbers.
$t = 36$ when $w = 2 \times 10^{-2}$.
What is the value of w when $t = 100$?

(A) 1.2×10^{-4}

(B) 1.2×10^{-2}

(C) 1.44×10^{-6}

(D) 1.44×10^{-3}

(E) $\frac{10}{3} \times 10^{-4}$

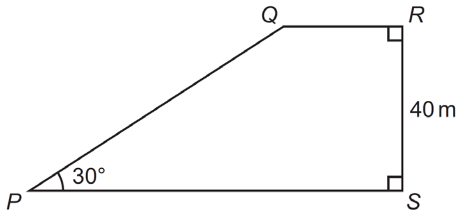
(F) $\frac{10}{3} \times 10^{-2}$

(G) 7.2×10^{-6}

(H) 7.2×10^{-3}

[NSAA, 2022S1Q11]

$PQRS$ is a trapezium as shown.



[diagram not to scale]

$\tan RSQ = \frac{5}{8}$

What is the length of PS, in metres?

(A) 45

(B) 65

(C) 80

(D) 120

(E) $25 + \frac{40\sqrt{3}}{3}$

(F) $40 + \frac{64\sqrt{3}}{3}$

(G) $25 + 40\sqrt{3}$

(H) $64 + 40\sqrt{3}$

[NSAA, 2022S1Q12]

A cyclist rides along a track to the top of a hill then immediately turns around and descends along the same track to her starting point.

She takes 40 minutes at an average speed of 12 km h^{-1} to reach the top.

Her average speed for the whole journey is 15 km h^{-1}.

What is the average speed of her descent?

(A) 16 km h^{-1}

(B) 18 km h^{-1}

(C) 20 km h^{-1}

(D) 24 km h^{-1}

(E) 30 km h^{-1}

[NSAA, 2022S1Q13]

A solid cylinder has radius r cm and height h cm.
A cube has side length $3r$ cm.
The total surface area of the cylinder is equal to four times the total surface area of the cube.
Which of the following is an expression for h in terms of r?

(A) $\left(\frac{18}{\pi} - 2\right)r$

(B) $\left(\frac{18}{\pi} - 1\right)r$

(C) $\frac{27r}{\pi}$

(D) $\left(\frac{27}{\pi} - 1\right)r$

(E) $\left(\frac{27}{4\pi} - 1\right)r$

(F) $\frac{108r}{\pi}$

(G) $\left(\frac{108}{\pi} - 1\right)r$

(H) $\left(\frac{108}{\pi} - \frac{1}{2}\right)r$

[NSAA, 2022S1Q14]

Consider the equation $2x^2 + 4x + c = 0$, where c is a constant.
The positive difference between the roots of this equation is $\sqrt{10}$.
What is the value of c?

(A) -5

(B) -4.5

(C) -3

(D) -0.5

(E) 0.75

(F) 8

[NSAA, 2022S1Q15]

The variables x and y are related by the equation:

$$x = 5 - \frac{2y^3 + 1}{1 - 2y^3}$$

Which of the following is a rearrangement to make y the subject?

(A) $y = \sqrt[3]{\frac{x-4}{8x-48}}$

(B) $y = \sqrt[3]{\frac{x-6}{8x-32}}$

(C) $y = \sqrt[3]{\frac{x-2}{x-6}}$

(D) $y = \sqrt[3]{\frac{x-3}{x-4}}$

(E) $y = \sqrt[3]{\frac{x-4}{2x-12}}$

(F) $y = \sqrt[3]{\frac{x-6}{2x-8}}$

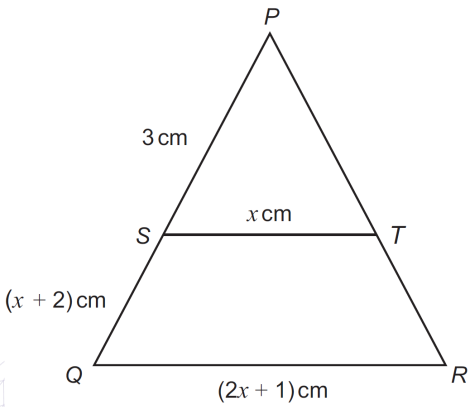
[NSAA, 2022S1Q16]

PQR is a triangle as shown.

S and T are points on the sides PQ and PR.

ST is parallel to QR.

$PS = 3$ cm
$ST = x$ cm
$QS = (x + 2)$ cm
$QR = (2x + 1)$ cm



[diagram not to scale]

What is the length, in cm, of QR?

(A) $2 + \sqrt{5}$

(B) $2 + \sqrt{13}$

(C) $5 + 2\sqrt{7}$

(D) $5 + 2\sqrt{11}$

(E) 7

(F) 9

[NSAA, 2022S1Q17]

Three different numbers are chosen at random from $\sqrt{1}, \sqrt{2}, \sqrt{3}, \sqrt{4}, \sqrt{5}$.

What is the probability that the three numbers form the three sides of a right-angled triangle?

(A) $\frac{1}{15}$

(B) $\frac{1}{10}$

(C) $\frac{3}{10}$

(D) $\frac{1}{3}$

(E) $\frac{2}{5}$

(F) $\frac{2}{3}$

(G) $\frac{4}{5}$

[NSAA, 2022S1Q18]

P, Q and R are regular polygons.

Q has three times as many sides as P.

An interior angle of Q is $10°$ larger than an interior angle of P.

R has twice as many sides as Q.

How much larger is an interior angle of R than an interior angle of Q, in degrees?

(A) $2\frac{1}{2}$

(B) 5

(C) $6\frac{2}{3}$

(D) $7\frac{1}{2}$

(E) 10

(F) 15

(G) $16\frac{2}{3}$

[NSAA, 2022S1Q19]

The point $(-1, 5)$ is translated to the point $(3, 2)$ by two successive translations.

The first translation is by the vector $\begin{pmatrix} 3p \\ -4p \end{pmatrix}$.

The second translation is by the vector $\begin{pmatrix} q \\ -2q \end{pmatrix}$.

What is the value of $p + q$?

(A) -14

(B) -7

(C) -5

(D) -1

(E) 1

(F) 5

(G) 7

(H) 14

[NSAA, 2022S1Q20]

Consider the graphs of the form

$$y = x^2 + 2ax + a$$

What is the complete range of values of a for which the minimum point of the graph lies above the x-axis?

(A) There are no values of a

(B) $a < 0$

(C) $0 < a < 1$

(D) $-1 < a < 1$

(E) $a < -1$ or $a > 1$

(F) $a < 0$ or $a > 1$

(G) a can take any value

Part B

[NSAA, 2022S1Q21]

There is a constant current in a conducting wire. A charge of 20 C passes through the wire in 1.5 minutes.

An 18 cm straight section of this wire lies in a uniform magnetic field. This section of wire is perpendicular to the direction of the field. The magnetic field strength is 0.15 T.

What is the magnitude of the magnetic force on this section of wire?

(A) 0.0060 N

(B) 0.36 N

(C) 0.60 N

(D) 0.81 N

(E) 36 N

(F) 49 N

(G) 81 N

(H) 4900 N

[NSAA, 2022S1Q22]

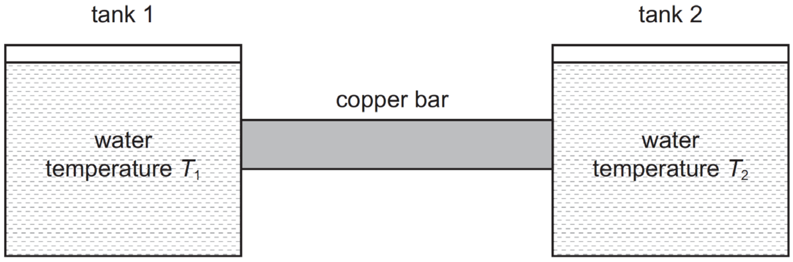
A rider on a rollercoaster moves very quickly towards a solid wall. While moving, the rider shouts, and hears an echo of the shout from the wall. The echo is quieter than the original shout.

How do the amplitude and frequency of the echo heard by the rider compare to the amplitude and frequency of the original shout?

	amplitude	*frequency*
(A)	lower	lower
(B)	lower	unchanged
(C)	lower	higher
(D)	unchanged	lower
(E)	unchanged	higher
(F)	higher	lower
(G)	higher	unchanged
(H)	higher	higher

[NSAA, 2022S1Q23]

The diagram shows a system consisting of two large copper tanks of water connected to each other by a solid cylindrical copper bar.



The temperature of the water in tank 1 is T_1. The water in tank 2 is at a higher temperature T_2.

The following four statements list changes that can be made, independently, to the system.

At all times $T_1 < T_2$.

1 increase temperature T_1

2 increase temperature T_2

3 increase the length of the copper bar

4 increase the diameter of the copper bar

Which two changes each independently result in an increase in the rate of conduction of thermal energy along the copper bar?

(A) 1 and 2

(B) 1 and 3

(C) 1 and 4

(D) 2 and 3

(E) 2 and 4

(F) 3 and 4

[NSAA, 2022S1Q24]

Two identical resistors are connected in parallel to a 6.0 V battery. The two resistors dissipate a total power of 0.15 W.

One of these resistors is removed from the circuit and connected to a 12 V battery.

How much charge passes through this resistor in 6.0 minutes?

(A) 0.025 C

(B) 0.050 C

(C) 0.15 C

(D) 0.30 C

(E) 0.75 C

(F) 1.5 C

(G) 9.0 C

(H) 18 C

[NSAA, 2022S1Q25]

A small piece of space debris of mass 0.10 g strikes the International Space Station at a relative speed of 15 000 m s^{-1}.

The piece of debris comes to rest relative to the space station in a time of 0.010 s.

What is the average force exerted on the space station by the piece of debris during this time?

(A) 0.0010 N

(B) 1.0 N

(C) 1.5 N

(D) 100 N

(E) 150 N

(F) 1500 N

[NSAA, 2022S1Q26]

A block of mass 6.0 kg is pushed along a rough horizontal surface by a constant force of 8.0 N. The block accelerates uniformly from rest. After 4.0 s its velocity is 2.0 m s^{-1}.

How much work is done against resistive forces during this 4.0 s?

(A) 12 J

(B) 20 J

(C) 24 J

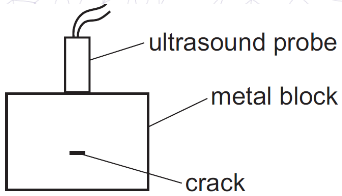
(D) 32 J

(E) 40 J

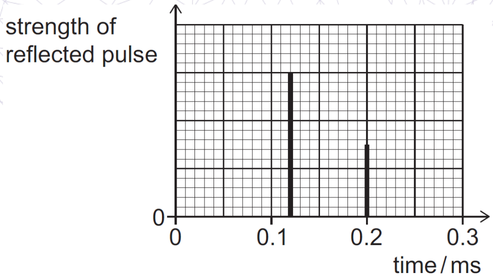
(F) 64 J

[NSAA, 2022S1Q27]

Ultrasound is used to find a crack inside a cuboid block of metal. An ultrasound probe is held in contact with the top surface of the metal block and perpendicular to the surface. A short pulse of ultrasound is sent into the metal block at time $t = 0$ ms and reflects from both the crack and the bottom surface of the metal block.



The times between the emission of the ultrasound pulse and the return of the reflections to the probe, and the strengths of the reflected pulses, are measured. The results are shown on the graph.



The speed of ultrasound in the metal is 5000 m s^{-1}.

What is the distance between the **bottom surface** of the metal block and the crack?

(A) 0.2 m

(B) 0.3 m

(C) 0.4 m

(D) 0.5 m

(E) 0.6 m

(F) 1.0 m

[NSAA, 2022S1Q28]

Power is supplied to an electric motor at 0.800 kW.

The motor has an efficiency of 60% and is switched on for half an hour.

How much energy is **wasted** during this time?

(A) 0.160 J

(B) 0.240 J

(C) 160 J

(D) 240 J

(E) 576 J

(F) 864 J

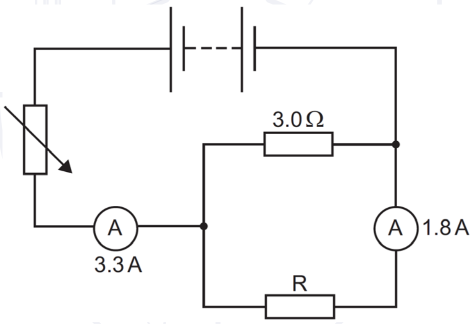
(G) 576, 000 J

(H) 864, 000 J

[NSAA, 2022S1Q29]

The diagram shows a circuit that includes two ammeters and a resistor R.

The readings on the ammeters are shown.



What is the resistance of resistor R?

(A) 0.40 Ω

(B) 2.5 Ω

(C) 3.0 Ω

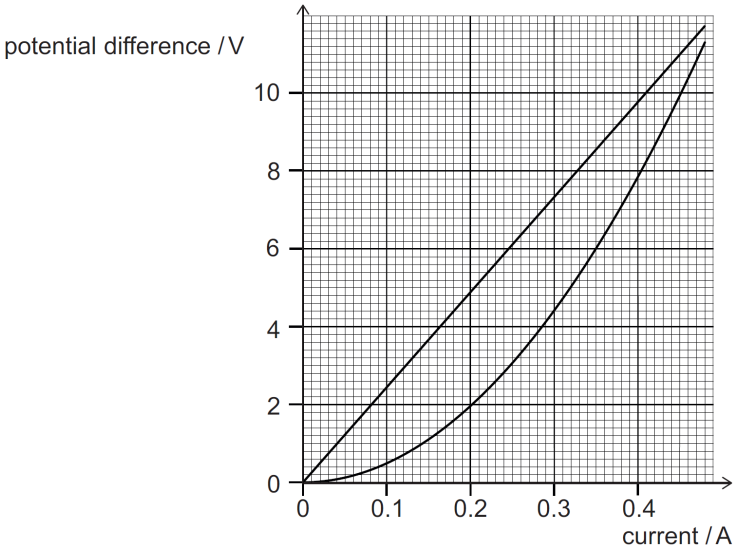
(D) 3.6 Ω

(E) 5.5 Ω

(F) 8.5 Ω

[NSAA, 2022S1Q30]

The graph shows potential difference plotted against current for a filament lamp and a resistor.



The lamp and the resistor are connected in parallel with each other to a 6.0 V power supply and the current in the lamp, I, is recorded.

In a second circuit, the lamp and the resistor are now connected in series with each other to the same power supply, and the current in the resistor is 0.18 A. The potential difference across the lamp, V, is recorded.

What are the values of I in the first circuit and V in the second circuit?

	I / A	V / V
(A)	0.25	1.6
(B)	0.25	3.0
(C)	0.25	4.4
(D)	0.35	1.6
(E)	0.35	3.0
(F)	0.35	4.4

[NSAA, 2022S1Q31]

A child is bouncing a ball of mass 0.16 kg vertically up and down on a bat. Each time the ball hits the bat the duration of the contact is 0.20 s. The speed of the ball immediately before hitting the bat and immediately after it loses contact with the bat is 4.0 m s^{-1}.

What is the average contact force between the bat and the ball during each collision?

(gravitational field strength = 10 N kg^{-1})

(A) 1.6 N

(B) 3.2 N

(C) 4.8 N

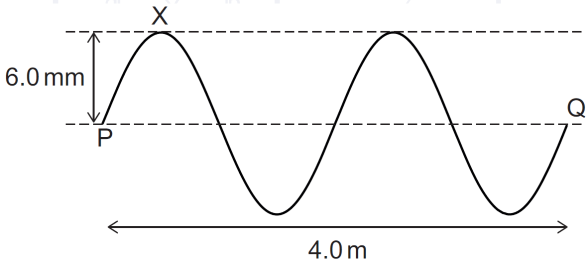
(D) 6.4 N

(E) 8.0 N

[NSAA, 2022S1Q32]

A transverse wave on a string has a speed of 500 m s^{-1}.

The horizontal distance between two points P and Q on the wave is 4.0 m, as shown in the diagram.



At time t = 0 ms, point X on the string is at its maximum displacement of 6.0 mm above equilibrium.

What is the displacement of point X at time t = 7.0 ms?

(A) 6.0 mm above equilibrium

(B) between 0 mm and 6.0 mm above equilibrium

(C) 0 mm

(D) between 0 mm and 6.0 mm below equilibrium

(E) 6.0 mm below equilibrium

[NSAA, 2022S1Q33]

A neutral atom Q of a particular element contains a total of 20 particles (protons, neutrons and electrons).

The table shows information about the number of particles and relative charges of four atoms or ions W, X, Y and Z.

atom or ion	*number of particles*	*relative charge of atom or ion*
W	21	0
X	21	−1
Y	20	+1
Z	22	0

Which of these atoms or ions could be of a different isotope to Q but of the same element as Q?

(A) W only

(B) X only

(C) Z only

(D) X and Z only

(E) W and Y only

(F) W, X and Y only

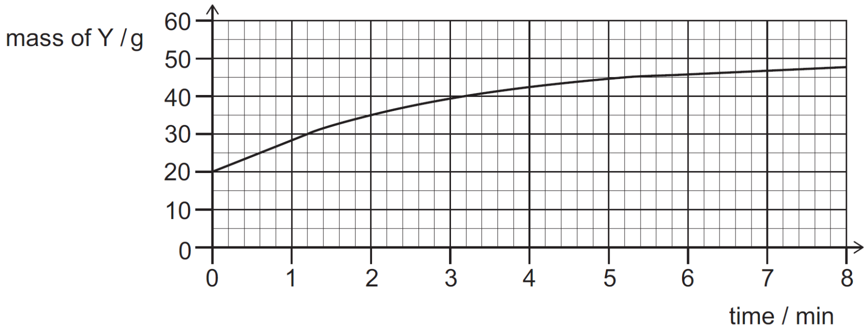
(G) W, Y and Z only

(H) X, Y and Z only

[NSAA, 2022S1Q34]

Radioactive isotope X undergoes a single beta (β^-) decay to form the stable isotope Y.

A sample consists only of X and Y. The graph shows how the mass of Y present in the sample varies with time. After a long time, the mass of Y in the sample becomes a constant 50 g.



What is the half-life of X?

(A) 0.6 minutes

(B) 1.2 minutes

(C) 2.0 minutes

(D) 3.2 minutes

(E) 4.0 minutes

(F) 5.2 minutes

[NSAA, 2022S1Q35]

A piece of metal of mass 50 g is at thermal equilibrium in a hot liquid at temperature T.

The metal is removed from the liquid and immediately placed in 100 g of water that is at 20 °C. The water is stirred and reaches a final temperature of 26 °C.

material	*specific heat capacity* / J kg^{-1} °C^{-1}
hot liquid	2000
metal	350
water	4200

What is the temperature T of the hot liquid?

(Assume that heat transfers to or from the surroundings are negligible.)

(A) 38 °C

(B) 51 °C

(C) 150 °C

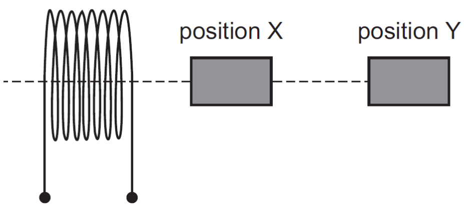
(D) 170 °C

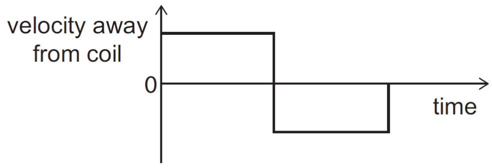
(E) 480 °C

[NSAA, 2022S1Q36]

A bar magnet is placed at position X close to one end of a coil and on the axis of the coil as shown.

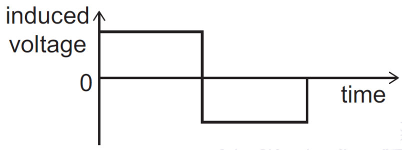
The graph shows how the velocity of the magnet varies as it is then moved rapidly to position Y and back to position X.

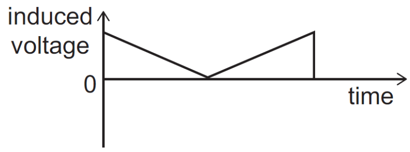


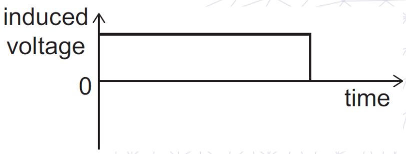


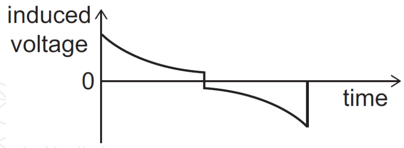
The magnetic field of the bar magnet still affects the coil when the magnet is at position Y.

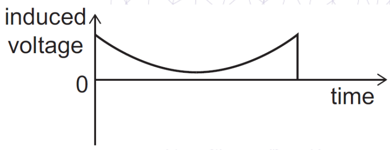
Which graph represents how the induced voltage in the coil changes as the magnet moves?

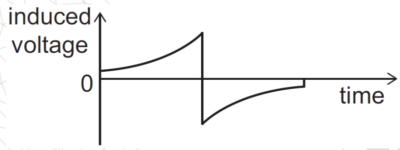
(A)


(B)


(C)


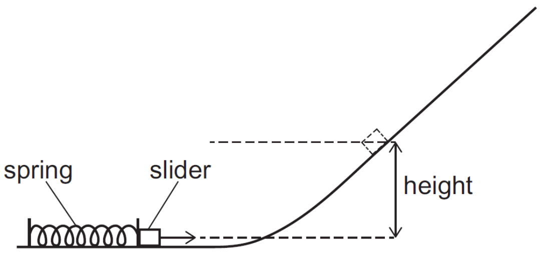
(D)


(E)


(F)


[NSAA, 2022S1Q37]

A small slider of mass 30 g is at rest near the bottom of a frictionless slope and in contact with a light uncompressed spring as shown.



[diagram not to scale]

The spring is compressed by 5.0 cm and the slider remains in contact with it.

The spring is released and causes the slider to rise up the slope to a maximum vertical height of 20 cm.

The slider is replaced with one of mass 20 g.

The spring is now compressed by 15 cm, and the new slider remains in contact with it.

To what maximum vertical height does this new slider rise after it is released?

(the spring obeys Hooke's law; assume that air resistance is negligible)

(A) 40 cm

(B) 60 cm

(C) 90 cm

(D) 120 cm

(E) 180 cm

(F) 270 cm

[NSAA, 2022S1Q38]

A tall, smooth cylinder contains air at atmospheric pressure of 1.00×10^5 Pa. The density of the air in the cylinder is 1.20 kg m^{-3}.

A heavy piston is now placed in the top of the cylinder and allowed to fall slowly downwards, compressing the air until the piston rests in equilibrium.

The mass of the piston is 50.0 kg and its cross-sectional area is 0.0200 m^2.

What is the density of the air in the cylinder when the piston rests in equilibrium?

(gravitational field strength = 10 N kg^{-1}; assume that the air behaves as an ideal gas and that the temperature remains constant)

(A) 0.960 kg m^{-3}

(B) 1.20 kg m^{-3}

(C) 1.25 kg m^{-3}

(D) 1.28 kg m^{-3}

(E) 1.50 kg m^{-3}

(F) 4.80 kg m^{-3}

[NSAA, 2022S1Q39]

There are two types of earthquake waves, called P-waves and S-waves.

When an earthquake occurs, both types of wave are produced at the same time and follow the same path.

The P-waves travel outwards from the source at 5.0 km s^{-1} and the S-waves travel out at 3.0 km s^{-1}.

A seismic monitoring station detects the P-waves 30 s before the S-waves.

How far have the waves travelled from the source of the earthquake to reach the seismic monitoring station?

(A) 60 km

(B) 90 km

(C) 135 km

(D) 150 km

(E) 225 km

[NSAA, 2022S1Q40]

A solid cuboid has a mass of 32 kg and a density of 4.0 g cm^{-3}.

Faces 1, 2 and 3 of the cuboid have different areas.

When the cuboid rests on one of these faces on a flat horizontal surface, the pressure on the surface due to the cuboid is 1.6 N cm^{-2}.

When it rests on another of these faces, the pressure on the surface due to the cuboid is 0.80 N cm^{-2}.

What is the pressure on the surface due to the cuboid when it rests on the third of these faces?

(gravitational field strength = 10 N kg^{-1})

(A) 0.40 N cm^{-2}

(B) 1.2 N cm^{-2}

(C) 3.2 N cm^{-2}

(D) 6.4 N cm^{-2}

(E) 8.0 N cm^{-2}

NSAA 2022 S2

NSAA 2022 S2
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 2 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

This paper contains **three** parts: **X**, **Y** and **Z**.

All candidates should complete only **one** part chosen from:

Part X	Physics
Part Y	Chemistry
Part Z	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt **all** 20 questions in your chosen part. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

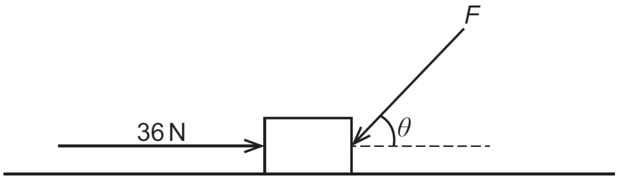
A Periodic Table is included.

Dictionaries and calculators are NOT permitted.

Part X

[NSAA, 2022S2Q1]

The diagram shows an object of mass 2.4 kg on a smooth horizontal surface.



A force F acts on the object at an acute angle θ to the horizontal, where $\tan\theta = \frac{4}{3}$.

A force of 36 N acts on the object towards the right.

The object is in equilibrium.

What is the magnitude of the normal contact force exerted on the object by the surface?

(gravitational field strength = 10 N kg^{-1})

(A) 24 N

(B) 27 N

(C) 48 N

(D) 51 N

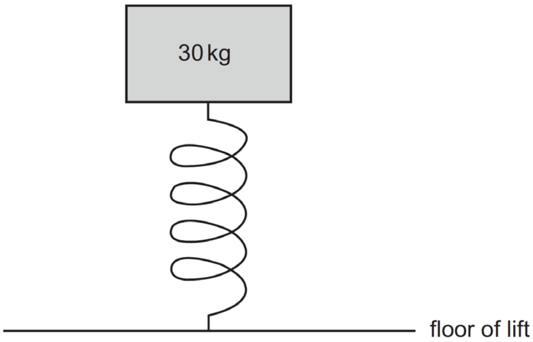
(E) 72 N

(F) 75 N

[NSAA, 2022S2Q2]

The length of a spring when no force acts on it is L. The spring constant of the spring is 3.0×10^3 N m^{-1}.

The spring is on the floor of an accelerating lift (elevator), and the spring supports a 30 kg mass.



The lift is accelerating downwards at 2.0 m s^{-2}.

What is the difference between L and the length of the spring when the lift is accelerating downwards?

(gravitational field strength = 10 N kg^{-1}; the spring obeys Hooke's law)

(A) 0 cm

(B) 2.0 cm

(C) 8.0 cm

(D) 10 cm

(E) 12 cm

[NSAA, 2022S2Q3]

Electrical energy is transmitted at high voltage to a remote farm using an overhead power cable. Each of the two wires in the cable has a resistance of 2.5 Ω. The step-down transformer in the farm has a voltage ratio of 5.0. The transformer is ideal and 100% efficient. It supplies a power of 40 kW to a resistive load at the farm at a voltage of 250 V.

What is the rate at which electrical energy is transferred to thermal energy in the overhead cable?

(A) 1.28 kW

(B) 2.56 kW

(C) 5.12 kW

(D) 32 kW

(E) 64 kW

(F) 128 kW

[NSAA, 2022S2Q4]

A wave is passing through a medium.

A particle of the medium has zero displacement from its equilibrium position at 0.12 s intervals, and at no other times.

The wavelength of the wave is greater than 10.0 m.

Two points are 5.0 m apart along the direction of travel of the wave.

The phase difference between the particles at the two points at the same instant is $\frac{\pi}{3}$ radians.

What is the speed of the wave?

(A) 1.8 m s^{-1}

(B) 3.6 m s^{-1}

(C) 7.2 m s^{-1}

(D) 62.5 m s^{-1}

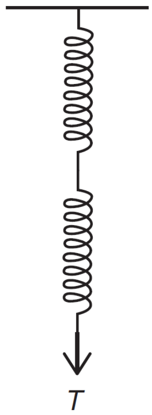
(E) 125 m s^{-1}

(F) 250 m s^{-1}

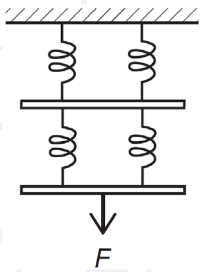
[NSAA, 2022S2Q5]

Three light springs, P, Q and R, are identical.

Springs P and Q are connected in series as shown. A downwards force T is applied to the lower end.



Spring R is cut into four equal lengths, and the four pieces arranged symmetrically as shown. The two connecting bars have negligible mass. A downwards force F is applied to the centre of the lower bar.



The total extensions of the two systems are equal. The springs obey Hooke's law.

Which expression gives T in terms of F?

(A) $\frac{F}{16}$

(B) $\frac{F}{8}$

(C) $\frac{F}{4}$

(D) $\frac{F}{2}$

(E) $2F$

(F) $4F$

(G) $8F$

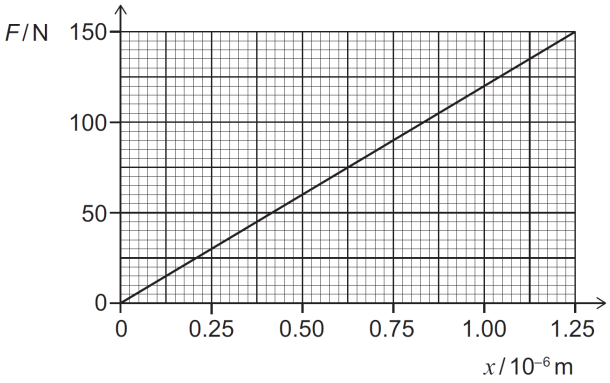
(H) $16F$

[NSAA, 2022S2Q6]

A nylon cube resting on a horizontal surface has a volume of 64 cm^3.

A force F is applied vertically downwards on the top face of the cube so that it compresses the height by x.

The graph shows the variation of F with x.



What is the Young modulus of the nylon?

(Assume that changes in horizontal cross-sectional area are negligible.)

(A) 7.7×10^3 Pa

(B) 4.8×10^6 Pa

(C) 9.6×10^6 Pa

(D) 1.2×10^8 Pa

(E) 1.5×10^9 Pa

(F) 3.0×10^9 Pa

(G) 1.9×10^{12} Pa

[NSAA, 2022S2Q7]

Five lampposts alongside a straight road are positioned at uniform intervals of 60 m.

A motorbike travelling at a constant velocity passes the first lamppost at time $t = 0$ s. It passes the fifth lamppost at $t = 20$ s.

A car travelling in the same direction as the motorbike is accelerating at 6.0 m s^{-2}. At time $t = 0$ s the car passes the first lamppost at a velocity of 3.0 m s^{-1}.

At what time t does the car overtake the motorbike?

(A) 1.5 s

(B) 2.0 s

(C) 2.5 s

(D) 3.0 s

(E) 3.5 s

(F) 4.0 s

(G) 5.0 s

[NSAA, 2022S2Q8]

An electrical appliance has an input power P which is a function of time t during the first 10 seconds after it is switched on.

This function is

$$P = 3t^2 + 4t$$

where P is in watts and t is in seconds.

The appliance is switched on at time $t = 0$.

The appliance has a constant efficiency of 90%.

What is the energy **wasted** by the appliance during the period $t = 2.0$ s to $t = 3.0$ s after it is switched on?

(A) 0.60 J

(B) 0.70 J

(C) 1.9 J

(D) 2.9 J

(E) 4.5 J

(F) 17 J

(G) 26 J

(H) 41 J

[NSAA, 2022S2Q9]

A solid cylinder is made of transparent glass of refractive index $\frac{2}{\sqrt{3}}$. It is surrounded by air.

A ray of light travelling in air hits the cylinder at the centre of one circular face at a non-zero angle θ to the normal, and refracts as it enters the cylinder.

The ray then strikes the curved surface of the cylinder at an angle of incidence equal to the critical angle.

What is the value of θ?

(A) $\sin^{-1}\frac{\sqrt{3}}{4}$

(B) $\sin^{-1}\frac{1}{\sqrt{3}}$

(C) $\sin^{-1}\frac{2}{\sqrt{6}}$

(D) $\sin^{-1}\frac{\sqrt{3}}{2}$

(E) $\sin^{-1} 1$

[NSAA, 2022S2Q10]

An object of mass 20 kg is acted on by a force that varies in magnitude during the time interval $t = 0$ s to $t = 1.0$ s.

The force causes the object's displacement x to change with time t according to the relationship

$$x = -t^3 - 3t^2 + 4$$

where x is in metres and t is in seconds.

What is the magnitude of the impulse on the object over this time interval?

(A) 2.8 kg m s^{-1}

(B) 9.0 kg m s^{-1}

(C) 55 kg m s^{-1}

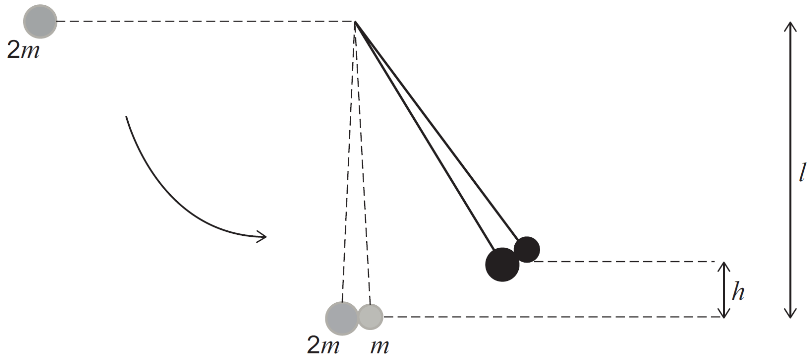
(D) 80 kg m s^{-1}

(E) 100 kg m s^{-1}

(F) 180 kg m s^{-1}

[NSAA, 2022S2Q11]

Two small hard spheres of mass m and $2m$ are suspended side by side from light vertical strings of length l. The more massive sphere is raised so that its string is horizontal, and then released. It swings through 90° and strikes the smaller sphere. The two spheres stick together, and rise to a maximum height h as shown in the diagram.



[diagram not to scale]

Which expression gives the height h in terms of l?

(Assume that air resistance is negligible.)

(A) $\frac{4l}{27}$

(B) $\frac{8l}{27}$

(C) $\frac{4l}{9}$

(D) $\frac{2l}{3}$

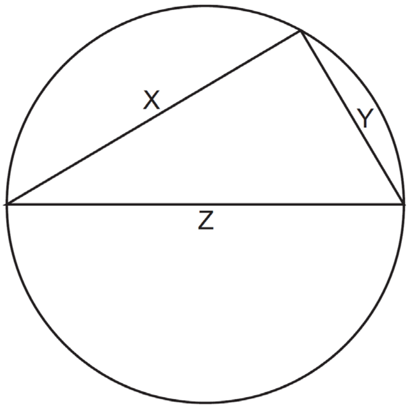
(E) $\frac{8l}{9}$

(F) l

(G) $2l$

[NSAA, 2022S2Q12]

Three resistance wires X, Y and Z, made from the same metal, are connected to each other and to a circular plastic ring as shown.



[diagram not to scale]

Wires X and Y each have twice the diameter of wire Z.

Wire X is 12 cm long. Wire Z is 15 cm long and is connected across a diameter of the ring.

A power supply is connected to the two corners of the triangle that lie on the diameter.

What is the value of the ratio

$$\frac{\text{current in } X}{\text{current in } Z}?$$

(A) $\frac{1}{5}$

(B) $\frac{7}{20}$

(C) $\frac{7}{10}$

(D) $\frac{5}{7}$

(E) $\frac{7}{5}$

(F) $\frac{10}{7}$

(G) $\frac{20}{7}$

(H) 5

[NSAA, 2022S2Q13]

A light rope has cross-sectional area 6.0×10^{-8} m^2 and unstretched length 0.24 m.

The rope is fixed horizontally between two supports that are 0.24 m apart.

When a 1.0 kg mass is suspended from the middle of the rope, the vertical displacement of the middle of the rope from its original position is 0.050 m.

The rope obeys Hooke's law. Assume that changes in cross-sectional area are negligible.

What is the Young modulus of the material from which the rope is made?

(gravitational field strength = 10 N kg^{-1})

(A) 5.2×10^8 N m^{-2}

(B) 8.0×10^8 N m^{-2}

(C) 1.0×10^9 N m^{-2}

(D) 1.3×10^9 N m^{-2}

(E) 2.0×10^9 N m^{-2}

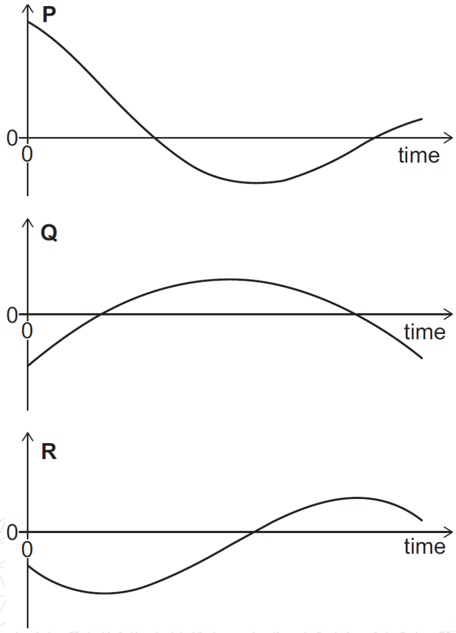
(F) 2.6×10^9 N m^{-2}

(G) 5.2×10^9 N m^{-2}

[NSAA, 2022S2Q14]

The three graphs show the displacement, velocity and acceleration against time for an object moving in a straight line.

The time axis is shown to the same scale on all three graphs.



Which graph represents which quantity?

	graph P	graph Q	graph R
(A)	acceleration	displacement	velocity
(B)	acceleration	velocity	displacement
(C)	displacement	acceleration	velocity
(D)	displacement	velocity	acceleration
(E)	velocity	acceleration	displacement
(F)	velocity	displacement	acceleration

[NSAA, 2022S2Q15]

A system of light springs that does not obey Hooke's law has an unstretched length of 2.0 m. The extension x of the system is related to the force F applied to it by

$$F = px^2$$

where p is a constant.

A force of 2400 N increases the length of the system to 2.2 m.

How much work is done in increasing the length of the system from 3.0 m to 4.0 m?

(A) 1.2 kJ

(B) 60 kJ

(C) 70 kJ

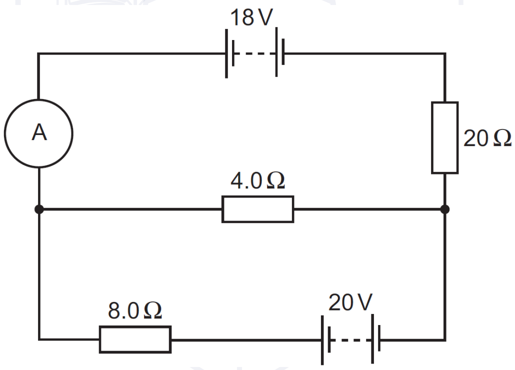
(D) 120 kJ

(E) 140 kJ

(F) 740 kJ

[NSAA, 2022S2Q16]

The diagram shows a circuit that includes two batteries, each with negligible internal resistance.



What is the reading on the ammeter?

(A) 0.0029 A

(B) 0.0071 A

(C) 0.063 A

(D) 0.083 A

(E) 0.50 A

(F) 0.65 A

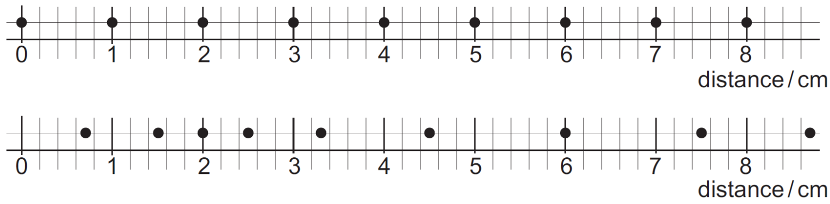
(G) 1.2 A

(H) 2.0 A

[NSAA, 2022S2Q17]

The upper diagram shows the equilibrium positions of nine equally spaced particles in a medium.

The lower diagram shows the positions of the same nine particles when a longitudinal wave is travelling through the medium. The wave is shown at time $t = 0$, travelling to the right.

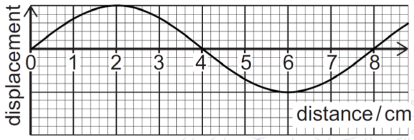


The frequency of the wave is 0.5 Hz.

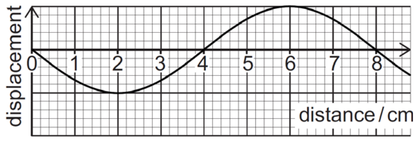
Which graph represents the displacements of the particles at a later time $t = 0.5$ s?

(On the graphs, positive displacement values represent particle displacements to the right.)

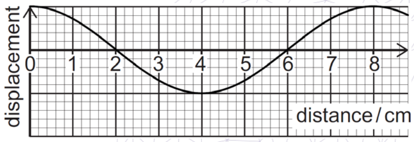
(A)



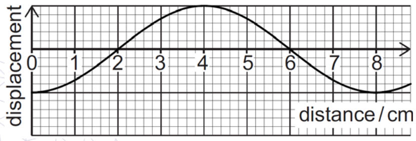
(B)



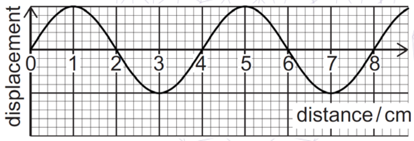
(C)



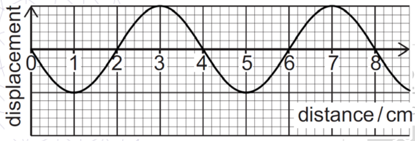
(D)



(E)



(F)



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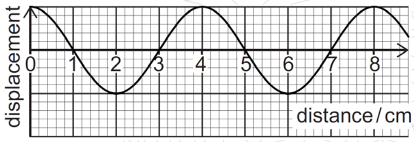

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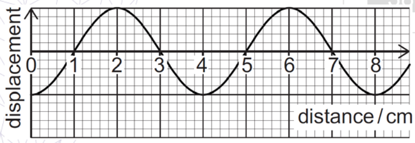


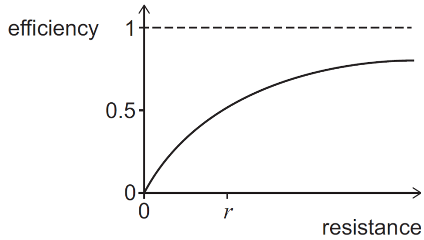
[NSAA, 2022S2Q18]

A power supply with constant emf and internal resistance r is connected to an external resistor. The efficiency of the system is defined as

$$\text{efficiency} = \frac{\text{power dissipated by external resistor}}{\text{total power supplied by cell}}$$

Which graph shows how the efficiency varies with the resistance of the external resistor?

(A)



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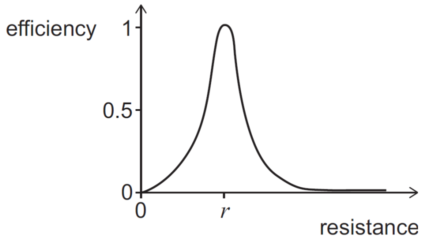

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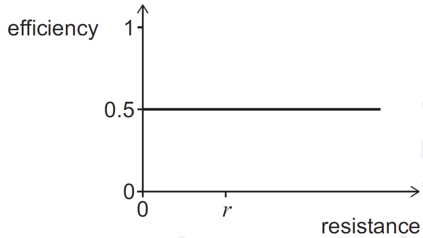

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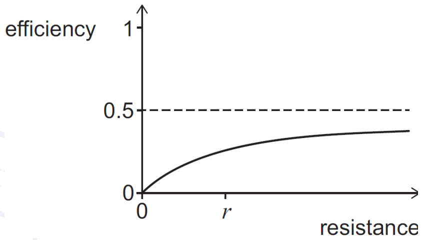

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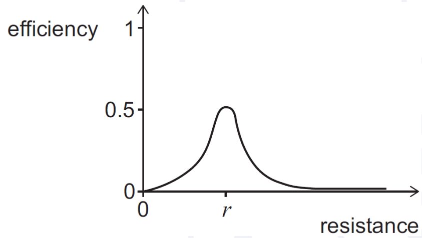

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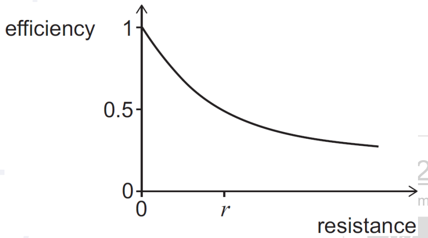


[NSAA, 2022S2Q19]

A 10 kg projectile is launched from ground level at an angle of 60° above the horizontal, with an initial speed of 12 m s^{-1}. The horizontal component of its velocity is to the right.

At the point during its flight when the vertical component of its velocity is zero, the projectile splits into two pieces, P and Q, each of mass 5 kg.

Immediately after the projectile splits, piece P has velocity 14 m s^{-1} to the right.

What is the speed of piece Q immediately before it hits the ground?

(Assume that air resistance is negligible, and that the ground is horizontal.)

(A) 2 m s^{-1}

(B) $\sqrt{31}$ m s^{-1}

(C) $6\sqrt{3}$ m s^{-1}

(D) $4\sqrt{7}$ m s^{-1}

(E) $2\sqrt{43}$ m s^{-1}

(F) $4\sqrt{13}$ m s^{-1}

(G) $4\sqrt{19}$ m s^{-1}

(H) $2\sqrt{127}$ m s^{-1}

[NSAA, 2022S2Q20]

The density ρ of a sphere varies from its centre to its surface according to the equation

$$\rho = \rho_0\left(1 - \frac{x}{2R}\right)$$

where x is the distance from its centre, R is its radius and ρ_0 is the density at its centre.

What is the mass of the sphere?

(the surface area of a sphere of radius x is equal to $4\pi x^2$)

(A) $\frac{2\pi R^3\rho_0}{3}$

(B) $\frac{5\pi R^3\rho_0}{6}$

(C) $\frac{8\pi R^3\rho_0}{9}$

(D) $\pi R^3\rho_0$

(E) $\frac{29\pi R^3\rho_0}{24}$

(F) $\frac{19\pi R^3\rho_0}{15}$

(G) $\frac{4\pi R^3\rho_0}{3}$

(H) $2\pi R^3\rho_0$

NSAA 2023 S1

NSAA 2023 S1
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 1 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

At the end of 60 minutes, your supervisor will collect this question paper and answer sheet before giving out Section 2.

This paper contains **four** parts: **A**, **B**, **C** and **D**.

All candidates should complete **Part A** Mathematics.

All candidates should then complete **one** further part chosen from:

Part B	Physics
Part C	Chemistry
Part D	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt all of the questions in your **two** parts. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

Dictionaries and calculators are NOT permitted.

Part A

[NSAA, 2023S1Q1]

The surface area of a solid sphere of radius R is equal to the total surface area of 10 solid closed cylinders of radius r and height $4r$.

Which of the following is an expression for R in terms of r ?

(The surface area of a sphere of radius R is $4\pi R^2$.)

(A) $R = 5r$

(B) $R = 12r$

(C) $R = 2\sqrt{5}r$

(D) $R = \frac{1}{2}\sqrt{10}r$

(E) $R = \sqrt{10}r$

(F) $R = \frac{3}{2}\sqrt{10}r$

(G) $R = \sqrt{15}r$

[NSAA, 2023S1Q2]

Which of the following statements is/are correct?

1 $\frac{47}{93} \div \frac{33}{71} = \frac{71}{93} \div \frac{33}{47}$

2 53% of $84 = 84\%$ of 53

3 $\left(2\sqrt{3}\right)^2 = \left(3\sqrt{2}\right)^2$

(A) none of them

(B) 1 only

(C) 2 only

(D) 3 only

(E) 1 and 2 only

(F) 1 and 3 only

(G) 2 and 3 only

(H) 1, 2 and 3

[NSAA, 2023S1Q3]

Which of the following is a correct rearrangement of

$$y = p - \frac{q - r}{s - x}$$

to make x the subject?

(A) $x = s - \frac{q-r}{p+y}$

(B) $x = \frac{q-r}{p+y} - s$

(C) $x = s - \frac{q-r}{p-y}$

(D) $x = \frac{q-r}{p-y} - s$

(E) $x = s - \frac{q-r}{y-p}$

(F) $x = \frac{q-r}{y-p} - s$

[NSAA, 2023S1Q4]

Six numbers in increasing order are:

$$2, x, x, y, 23.5, 27.5$$

The mean of the six numbers is 12.

The median of the six numbers is 7.25.

What is the mode of the six numbers?

(A) 4.5

(B) 4.75

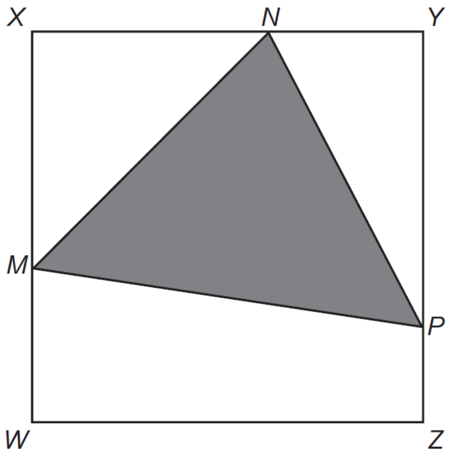
(C) 5

(D) 9.625

(E) 10

(F) 11.75

[NSAA, 2023S1Q5]



[diagram not to scale]

$WXYZ$ is a square of side length 1.

$WM : MX = 1 : 2$

$XN : NY = 3 : 1$

$YP : PZ = 4 : 1$

What is the area of triangle MNP?

(A) $\frac{1}{3}$

(B) $\frac{2}{5}$

(C) $\frac{9}{20}$

(D) $\frac{1}{30}$

(E) $\frac{19}{60}$

(F) $\frac{23}{60}$

[NSAA, 2023S1Q6]

Which of the following is a simplification of

$$\frac{4x-8}{x^2+4x-12} \div \frac{x-6}{x^3-36x}$$

(A) $\frac{1}{4}$

(B) $\frac{1}{4x}$

(C) 4

(D) $4x$

(E) $\frac{4x(x+6)}{(x-6)}$

(F) $\frac{4x(x-6)}{(x+6)}$

(G) $\frac{4}{x(x+6)^2}$

(H) $\frac{4}{x(x-6)^2}$

[NSAA, 2023S1Q7]

Given that

$$\frac{27^{2(x-2)}}{9^{(2x-3)}} = (81)^{\frac{3}{2}}$$

what is the value of x?

(A) 0

(B) 2.5

(C) 3

(D) 6

(E) 7.5

(F) 9

(G) 10.5

(H) 12

[NSAA, 2023S1Q8]

The solutions of the equation $3x^2 - 6x - 2 = 0$ are p and q, where $p > q$.

What is the value of $3p + 2q$?

(A) $-10 - \frac{2}{3}\sqrt{15}$

(B) $-10 - \frac{2}{3}\sqrt{3}$

(C) $-5 - \frac{1}{3}\sqrt{15}$

(D) $-5 - \frac{1}{3}\sqrt{3}$

(E) $5 + \frac{1}{3}\sqrt{15}$

(F) $5 + \frac{1}{3}\sqrt{3}$

(G) $10 + \frac{2}{3}\sqrt{15}$

(H) $10 + \frac{2}{3}\sqrt{3}$

[NSAA, 2023S1Q9]

Last year, the salary of the coach of a football club was 80% of the salary of the star player.

At the start of the new year, the coach received a 15% increase in salary and the star player received a 38% increase in salary.

What percentage of the star player's new salary is the coach's new salary?

(A) 46%

(B) 57%

(C) $61\frac{3}{5}\%$

(D) $66\frac{2}{3}\%$

(E) 77%

(F) $83\frac{1}{3}\%$

[NSAA, 2023S1Q10]

Two of the angles of a triangle are 90° and θ, where

$$\tan\ \theta = \sqrt{2}$$

The length of the hypotenuse of the triangle is $3\sqrt{6}$ cm.

What is the area of the triangle, in cm^2?

(A) $\frac{9\sqrt{2}}{2}$

(B) $9\sqrt{2}$

(C) $9\sqrt{3}$

(D) $9\sqrt{6}$

(E) $18\sqrt{2}$

(F) $18\sqrt{3}$

(G) $18\sqrt{6}$

[NSAA, 2023S1Q11]

An athlete's training session consists of several complete repetitions of a three-part programme:

1. Walk 100 m at an average speed of 6 km h^{-1}
2. Jog 200 m at an average speed of 10 km h^{-1}
3. Run 100 m at an average speed of 20 km h^{-1}

What is the athlete's average speed for the complete training session, in km h^{-1}?

(A) 7.2

(B) 9.6

(C) 11.5

(D) 12

(E) 14.4

[NSAA, 2023S1Q12]

The line joining the points with coordinates $(q, 2-q)$ and $(2q+2, q-4)$ is perpendicular to the line with equation $3x - 4y + 5 = 0$

What is the value of q?

(A) $-\frac{2}{5}$

(B) $-\frac{1}{6}$

(C) 1

(D) $\frac{18}{11}$

(E) $\frac{16}{7}$

(F) $\frac{5}{2}$

(G) 6

[NSAA, 2023S1Q13]

Two objects X and Y are similar.

The surface area of object Y is double the surface area of object X.

The volume of object Y is $7\sqrt{2}$ cm³ more than the volume of object X.

What is the volume of object X, in cm³?

(A) $14 - 7\sqrt{2}$

(B) $14 + 7\sqrt{2}$

(C) $\frac{42-7\sqrt{2}}{17}$

(D) $\frac{42+7\sqrt{2}}{17}$

(E) $\frac{7\sqrt{2}}{3}$

(F) $7\sqrt{2}$

(G) $4 - \sqrt{2}$

(H) $4 + \sqrt{2}$

[NSAA, 2023S1Q14]

x, y and z are positive variables.
y is inversely proportional to the square of x.
When $y = 20$, $x = 3$
z is directly proportional to x.
When $z = 1.2$, $x = 6$
What is z when $y = 80$?

(A) 0.0225

(B) 0.03

(C) 0.15

(D) 0.3

(E) 0.36

(F) 0.6

(G) 1.2

[NSAA, 2023S1Q15]

The equation

$$\left(\frac{a \times 10^4 + 2a \times 10^3}{3 \times 10^{-1}}\right)^2 = 8 \times 10^9$$

has two solutions for a.
What is the positive difference between these two solutions?

(A) 0

(B) $2\sqrt{5}$

(C) $4\sqrt{5}$

(D) $20\sqrt{5}$

(E) $40\sqrt{5}$

(F) $200\sqrt{5}$

[NSAA, 2023S1Q16]

For any real number x, the function $V(x)$ is defined as:

$$V(x) = 10^{x^2+6x+7}$$

What is the smallest value of $V(x)$?

(A) 0.001

(B) 0.01

(C) 0.1

(D) 1

(E) 10

(F) 100

(G) 1000

[NSAA, 2023S1Q17]

X and Y are the end-points of a line segment.

Point P has coordinates $(-8,5)$.

P lies on the line segment XY such that $XP : PY$ is $1 : 2$ and $\overrightarrow{XP} = \begin{pmatrix} 4 \\ -3 \end{pmatrix}$.

A point Q is such that $\overrightarrow{QY} = \begin{pmatrix} 7 \\ 6 \end{pmatrix}$.

What are the coordinates of point Q?

(A) $(7,5)$

(B) $(3,8)$

(C) $(1,-12)$

(D) $(-3,-10)$

(E) $(-7,-7)$

(F) $(-11,-4)$

[NSAA, 2023S1Q18]

The 2nd term of a linear (arithmetic) sequence is equal to twice the 8th term.

The 5th term is $\frac{9}{4}$

What is the 20th term of the sequence?

(A) -9

(B) $-\frac{7}{4}$

(C) $-\frac{3}{2}$

(D) 6

(E) $\frac{31}{4}$

(F) $\frac{27}{2}$

[NSAA, 2023S1Q19]

Find the maximum value of

$$2^{\sin x} \times 3^{-\sin x}$$

where $0^\circ \leq x \leq 360^\circ$.

(A) $\frac{2}{3}$

(B) 1

(C) $\frac{3}{2}$

(D) 2

(E) 3

(F) 6

[NSAA, 2023S1Q20]

Two bags contain counters which are identical except for colour.

The first bag contains 3 blue and 2 yellow counters.

The second bag contains x red, 1 blue and 2 yellow counters.

A counter is picked at random from the first bag and placed in the second bag.

A counter is then picked at random from the second bag. The probability that this counter is yellow is 0.2. What is the probability that this counter is red?

(A) $\frac{1}{4}$

(B) $\frac{3}{11}$

(C) $\frac{3}{10}$

(D) $\frac{1}{3}$

(E) $\frac{2}{3}$

(F) $\frac{7}{10}$

(G) $\frac{8}{11}$

(H) $\frac{3}{4}$

PART B

[NSAA, 2023S1Q21]

An object has mass m and weight W on the Moon. The Moon has no atmosphere.

The object is released from rest at height h above the surface of the Moon.

Which expression gives the speed of the object as it reaches the surface?

(A) $\frac{Wh}{m}$

(B) $\frac{2Wh}{m}$

(C) $\frac{2mh}{W}$

(D) $2mWh$

(E) $\sqrt{2mWh}$

(F) $\sqrt{\frac{Wh}{m}}$

(G) $\sqrt{\frac{2Wh}{m}}$

(H) $\sqrt{\frac{2mh}{W}}$

[NSAA, 2023S1Q22]

A spaceship of mass 10000 kg is moving at 2.0 m s^{-1} relative to a space station.

The spaceship is captured by a robotic arm attached to the space station and brought to rest by a force of 1000 N.

How far will the spaceship move in its initial direction relative to the space station while the force is being applied?

(Assume that the acceleration of the space station is negligible.)

(A) 0.050 m

(B) 0.10 m

(C) 0.20 m

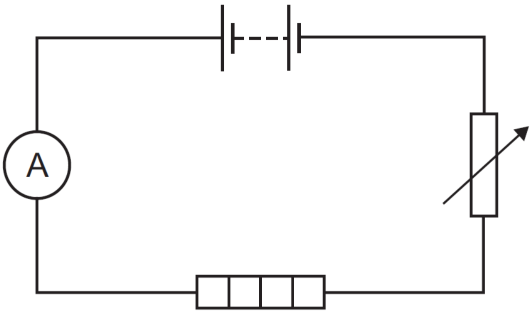
(D) 5.0 m

(E) 10 m

(F) 20 m

[NSAA, 2023S1Q23]

A heater is connected in series with a dc power supply, a variable resistor and an ammeter in the circuit shown.



The variable resistor is adjusted until the reading on the ammeter is 0.50 A and the resistance of the heater is 8.0 Ω.

How much energy is converted to thermal energy in 5.0 minutes?

(A) 10 J

(B) 40 J

(C) 160 J

(D) 600 J

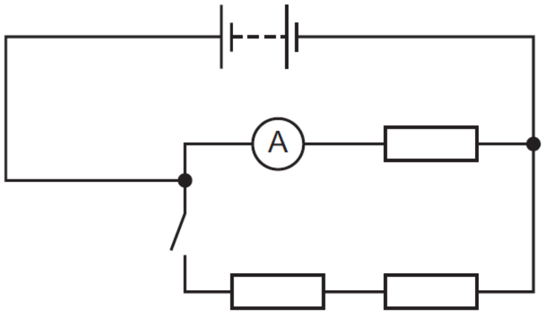
(E) 2400 J

(F) 9600 J

[NSAA, 2023S1Q24]

A circuit is set up as shown. All three resistors are identical.

When the switch is open, the reading on the ammeter is 1.0 A and the power transferred from the battery is 1.0 W.



The switch is now closed.

What is the new reading on the ammeter and what is the new power transferred from the battery?

	ammeter reading / A	power transferred / W
(A)	0.67	0.67
(B)	0.67	1.3
(C)	0.67	1.5
(D)	0.67	2.0
(E)	1.0	1.0
(F)	1.0	1.5
(G)	1.0	2.0
(H)	1.0	3.0

[NSAA, 2023S1Q25]

A car travels for a total time of 20 s. For the first t seconds its speed is 5.0 m s^{-1} and for the remainder of the journey its speed is 10 m s^{-1}.

The average speed for the whole journey is 8.5 m s^{-1}.

What is the value of t?

(A) 3.0

(B) 6.0

(C) 10

(D) 17

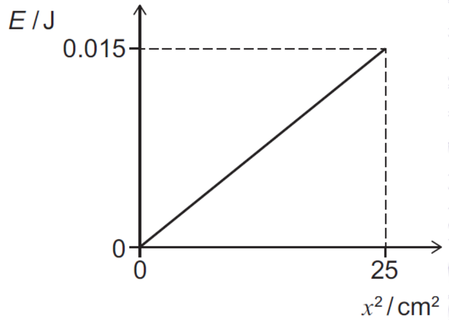
(E) $\frac{20}{3}$

(F) $\frac{40}{3}$

[NSAA, 2023S1Q26]

A spring is initially unstretched. A force F is used to stretch the spring. The extension x and the energy E stored in the stretched spring are measured for different values of F.

The graph shows how the energy E, in J, varies with the extension squared, x^2, in cm^2.



What is the magnitude of F when the spring stores 0.015 J of energy?

(A) 0.30 N

(B) 0.60 N

(C) 1.2 N

(D) 1.5 N

(E) 2.4 N

(F) 3.0 N

(G) 30 N

(H) 60 N

[NSAA, 2023S1Q27]

The nuclide symbol for helium-3 is ^3_2He.

A nuclide of element X has double the nuclear charge and four times the mass of helium-3.

This nuclide of X decays by a single beta (β^-)emission to form a nuclide of element Z.

What is the nuclide symbol for this nuclide of Z?

(A) ^8_2Z

(B) ^8_4Z

(C) $^{12}_4Z$

(D) ^8_5Z

(E) $^{12}_5Z$

(F) $^{16}_5Z$

(G) ^7_8Z

(H) $^{16}_8Z$

[NSAA, 2023S1Q28]

A solid, cylindrical metal bar has a uniform cross-sectional area of 12 cm^2 and a volume of 180 cm^3.

The bar rests on a horizontal surface on one of its circular faces.

The pressure on the surface due to the bar is 0.45 N cm^{-2}.

What is the density of the metal, in g cm^{-3}?

(gravitational field strength = 10 N kg^{-1})

(A) 2.5 g cm^{-3}

(B) 3.0 g cm^{-3}

(C) 3.75 g cm^{-3}

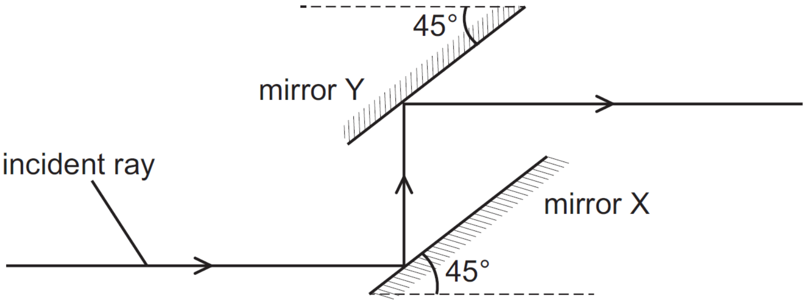
(D) 7.5 g cm^{-3}

(E) 15 g cm^{-3}

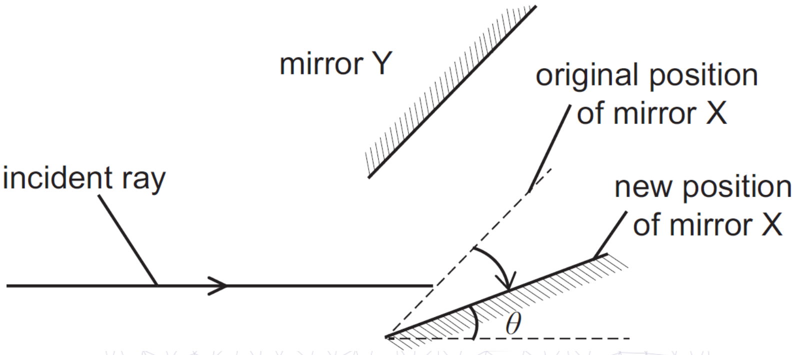
(F) 33 g cm^{-3}

[NSAA, 2023S1Q29]

A ray of light is directed horizontally towards two long, plane mirrors X and Y which are both at 45° to the horizontal. After two reflections the ray is travelling horizontally again.



Mirror X is now rotated clockwise through less than 45°. After this rotation, mirror X makes an angle θ with the horizontal, where $\theta < 45°$. The direction of the incident ray is unchanged.



In what direction and through what angle should mirror Y be rotated in order for the ray to be still horizontal and travelling to the right after reflecting from mirror Y?

(A) clockwise through an angle θ

(B) anticlockwise through an angle θ

(C) clockwise through an angle 2θ

(D) anticlockwise through an angle 2θ

(E) clockwise through an angle $45° - \theta$

(F) anticlockwise through an angle $45° - \theta$

[NSAA, 2023S1Q30]

Two samples of pure radioactive isotopes X and Y decay with half-lives of 2 days and 3 days, respectively.

Both X and Y decay in a single step into different stable isotopes.

Initially the number of atoms of X is twice the number of atoms of Y.

After how many days are the expected numbers of atoms of X and Y equal to each other?

(A) The expected numbers of atoms of X and Y are never equal.

(B) 2 days

(C) 3 days

(D) 4 days

(E) 6 days

(F) 12 days

[NSAA, 2023S1Q31]

Two stones are held at rest at the same height at the top of a cliff.

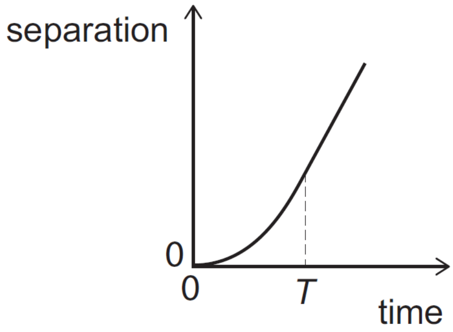
One stone is released and falls freely under gravity.

A time T later, the other stone is released and falls freely under gravity.

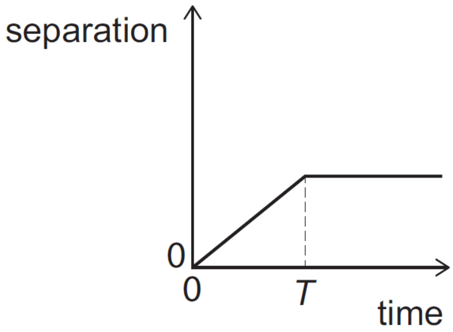
Which graph shows how the vertical distance separating the stones varies with time, from the moment the first stone is released and before the first stone lands?

(Assume that air resistance is negligible.)

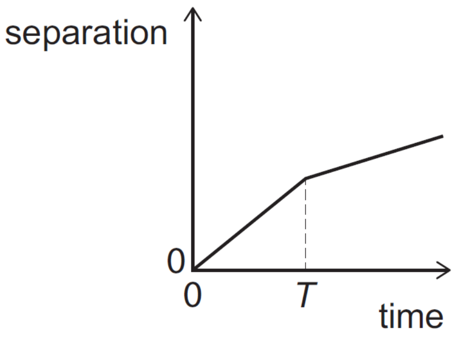
(A)



(B)



(C)



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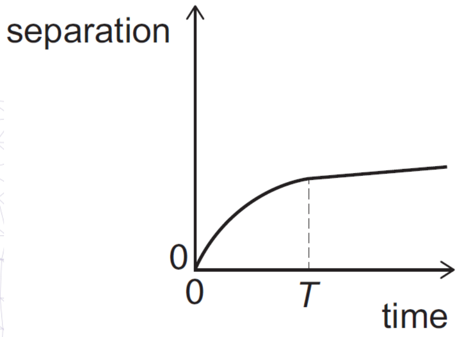

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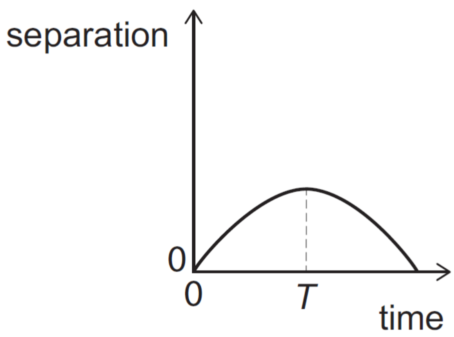
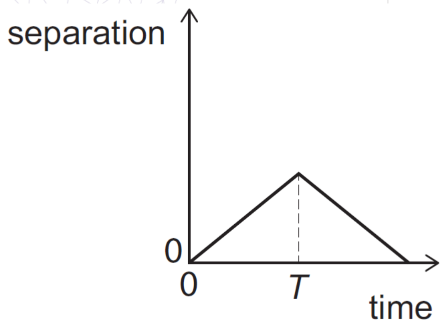
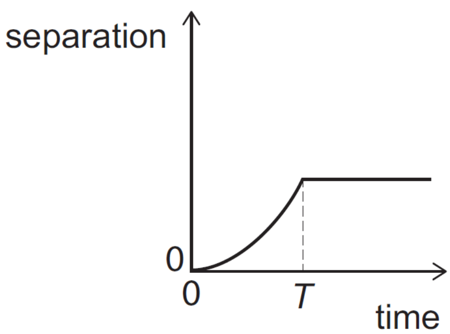


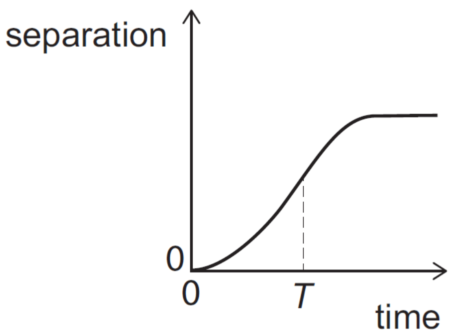
(F)



(G)



(H)



[NSAA, 2023S1Q32]

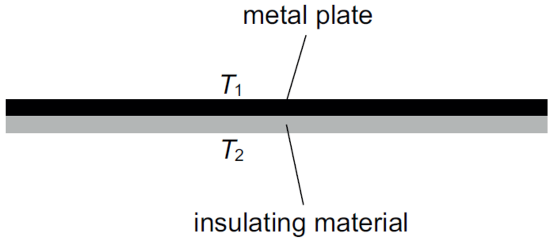
A large, flat, metal plate is coated on one side with a layer of thermally insulating material of the same thickness a as the metal plate.

The uninsulated top surface of the metal plate is maintained at a constant temperature T_1.

The bottom surface of the insulating material is maintained at a constant, lower temperature T_2.

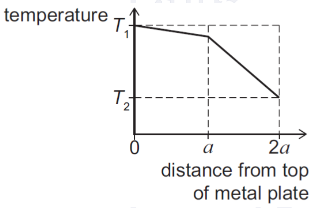
The system is in equilibrium.

The diagram shows this arrangement.

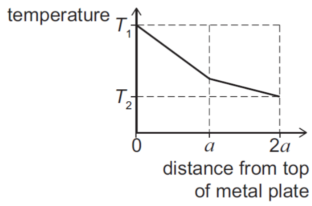


Which graph could show how the temperature varies with distance from the top surface of the metal plate to the bottom surface of the insulating material?

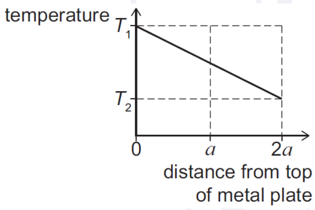
(A)



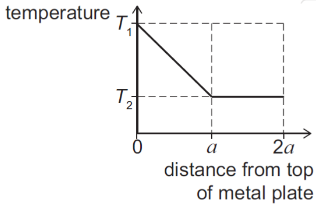
(B)



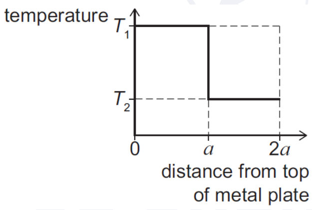
(C)



(D)



(E)



[NSAA, 2023S1Q33]

The mixture reaches thermal equilibrium.

What is its equilibrium temperature, T?

(specific latent heat of fusion of ice = 330 J g^{-1}

specific heat capacity of liquid water = 4.2 J g^{-1} $°C^{-1}$

assume that there is no heat transfer between the mixture and its surroundings)

(A) $T < 0$ °C

(B) $T = 0$ °C

(C) 0 °C $< T <$ 20 °C

(D) $T = 20$ °C

(E) 20 °C $< T <$ 30 °C

(F) $T = 30$ °C

(G) $T > 30$ °C

[NSAA, 2023S1Q34]

The voltage output of a power station is stepped up using a transformer before the power is transmitted to a distant town. The primary coil of this transformer has 300 turns and the secondary coil has 1500 turns.

In the town, a step-down transformer reduces the voltage supplied by the transmission cables to 33000 V for distribution within the town. The step-down transformer supplies a current of 1500 A.

The current in the transmission cables is 450 A and both transformers are ideal and 100% efficient.

What is the voltage output of the power station?

(Assume that the resistance of the transmission cables is negligible.)

(A) 1980 V

(B) 6600 V

(C) 22000 V

(D) 110000 V

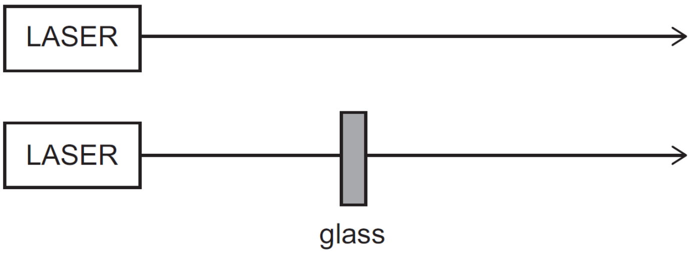
(E) 550000 V

[NSAA, 2023S1Q35]

A physicist introduces a thin piece of glass into the path of a laser beam in order to delay the beam. The light of the laser beam has a single wavelength L in air.

While the beam is inside the glass it completes 10 more complete oscillations compared to the same beam passing through the same thickness of air.

The speed of light in air is c and the speed of light in glass is $\frac{2}{3}c$



What is the thickness of the glass?

(A) $6.7L$

(B) $10L$

(C) $13L$

(D) $15L$

(E) $20L$

(F) $30L$

[NSAA, 2023S1Q36]

A transverse wave with an amplitude of 3.0 cm travels along a stretched string. The wave has a frequency of 12 Hz and a wavelength of 0.25 m.

What is the average speed of a particle in the string as the string oscillates during a time of 2.0 s?

(A) 36 cm s^{-1}

(B) 72 cm s^{-1}

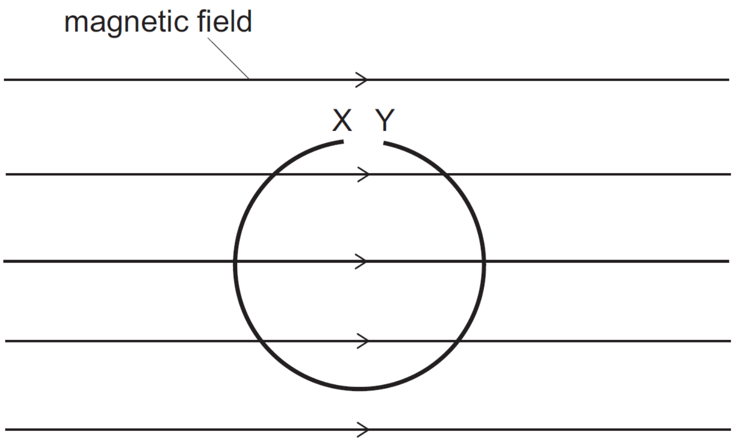
(C) 125 cm s^{-1}

(D) 144 cm s^{-1}

(E) 300 cm s^{-1}

[NSAA, 2023S1Q37]

A copper ring, with a small gap XY, rests in a uniform horizontal magnetic field. The ring lies in the plane of the page and the direction of the magnetic field is horizontal from left to right, as shown in the diagram.



A voltage is now applied across XY, such that X is connected to the positive terminal of the power supply and Y is connected to the negative terminal.

Which statement describes the motion of the ring immediately after the voltage is applied?

(Assume that the mechanism supporting the ring allows the ring to move freely and allows the voltage to be applied continuously.)

(A) The ring moves towards the bottom of the page.

(B) The ring moves towards the top of the page.

(C) The ring moves towards the left of the page.

(D) The ring moves towards the right of the page.

(E) The ring rotates about an axis perpendicular to the plane of the page in a clockwise direction.

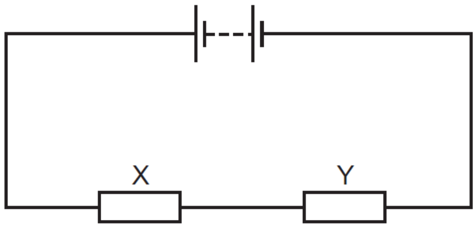
(F) The ring rotates about an axis perpendicular to the plane of the page in an anti-clockwise direction.

(G) The ring rotates about an axis that is in the plane of the page and parallel to the field.

(H) The ring rotates about an axis that is in the plane of the page and perpendicular to the field.

[NSAA, 2023S1Q38]

A battery and two resistors X and Y are connected in series.



The power transferred by the battery is 6 W.

The resistance of X is 10 Ω.

The voltage across Y is 4 V.

What is the current in the circuit?

(A) $\frac{2}{5}$ A

(B) $\frac{3}{5}$ A

(C) $\frac{3}{4}$ A

(D) 1 A

(E) $\sqrt{\frac{3}{10}}$ A

(F) $\sqrt{\frac{3}{5}}$ A

[NSAA, 2023S1Q39]

A cubic block of wood of side length L floats in water with the top face of the block horizontal and above the surface.

The block is displaced downwards by a small distance $\frac{L}{10}$ without becoming fully submerged, and then released.

The density of the wood is 0.80 g cm^{-3} and the density of water is 1.0 g cm^{-3}.

What is the initial acceleration of the block after it is released?

(gravitational field strength = 10 N kg^{-1})

(A) 0.80 m s^{-2}

(B) 1.0 m s^{-2}

(C) 1.25 m s^{-2}

(D) 1.80 m s^{-2}

(E) 8.0 m s^{-2}

(F) 11.0 m s^{-2}

[NSAA, 2023S1Q40]

A diver at the bottom of a lake of depth d fills a syringe with an ideal gas and seals the nozzle. The piston remains free to move. The volume of the gas in the syringe at the bottom of the lake is 90 cm^3.

As the diver returns to the surface, the temperature of the gas does not change. At the surface of the lake the gas in the syringe is at atmospheric pressure and the volume of the gas is 720 cm^3.

What is the volume of the gas in the syringe at a depth $\frac{d}{2}$?

(A) 160 cm^3

(B) 180 cm^3

(C) 206 cm^3

(D) 225 cm^3

(E) 288 cm^3

(F) 315 cm^3

(G) 360 cm^3

(H) 405 cm^3

NSAA 2023 S2

NSAA 2023 S2
On-line Exam

Scan the QR code or click on the link to take an on-line exam.
Full solutions can be accessed after submission.

TIME ALLOWED: 60 MINUTES

This paper is Section 2 of 2.

A separate answer sheet is provided for this paper. Please check you have one. You also require a soft pencil and an eraser.

Please complete the answer sheet with your candidate number, centre number, date of birth, and name.

This paper contains **three** parts: **X**, **Y** and **Z**.

All candidates should complete only **one** part chosen from:

Part X	Physics
Part Y	Chemistry
Part Z	Biology

Each part has 20 multiple-choice questions. There are no penalties for incorrect responses, only marks for correct answers, so you should attempt **all** 20 questions in your chosen part. Each question is worth one mark.

For each question, choose the **one** option you consider correct and record your choice on the separate answer sheet. If you make a mistake, erase thoroughly and try again.

You **must** complete the answer sheet within the time limit.

You can use the question paper for rough working, but **no extra paper** is allowed. Only your responses on the answer sheet will be marked.

A Periodic Table is included.

Dictionaries and calculators are NOT permitted.

Part X

[NSAA, 2023S2Q1]

A block of weight W slides down a rough plane at a constant speed.

The plane is at an angle of 30° to the horizontal.

The block is now pulled by a force of $3W$ acting parallel to and up the plane. The block has constant acceleration.

Which expression gives the acceleration of the block?

(gravitational field strength $= g$)

(A) $2g$

(B) $\frac{5}{2}g$

(C) $3g$

(D) $(3-\sqrt{3})g$

(E) $\left(3-\frac{1}{\sqrt{3}}\right)g$

(F) $\left(3-\frac{\sqrt{3}}{2}\right)g$

(G) $\left(3-\frac{2}{\sqrt{3}}\right)g$

[NSAA, 2023S2Q2]

The speed v of an object moving in a straight line is related to time t by the equation

$$v = kt^2$$

where k is a constant.

At $t = 10$ s the speed of the object is 48 m s^{-1} and the resultant force on the object is 24 N.

What is the mass of the object?

(A) 0.15 kg

(B) 0.40 kg

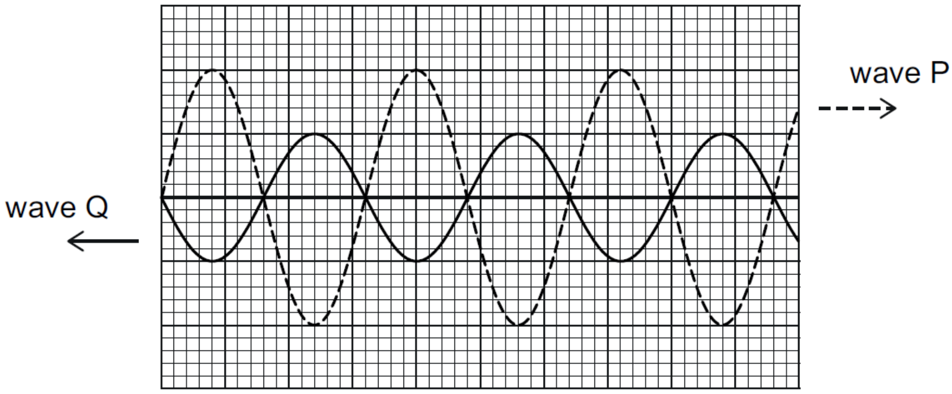
(C) 1.2 kg

(D) 2.5 kg

(E) 6.7 kg

[NSAA, 2023S2Q3]

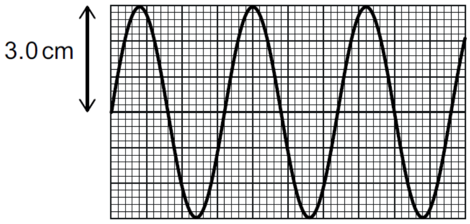
Two waves P and Q, which superpose, are shown in the diagram in a particular region at time $t = 0$.



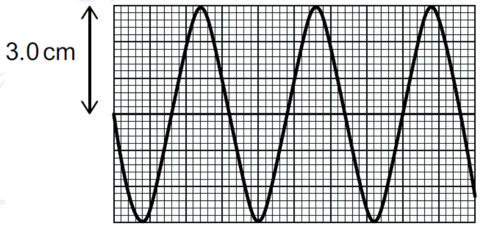
Both waves have period T and are moving in the directions shown by the arrows. Wave P has amplitude 2.0 cm and wave Q has amplitude 1.0 cm.

Which diagram represents the resultant wave formed in the same region by waves P and Q at time $t = \frac{T}{2}$?

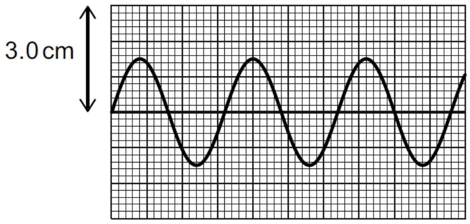
(A)



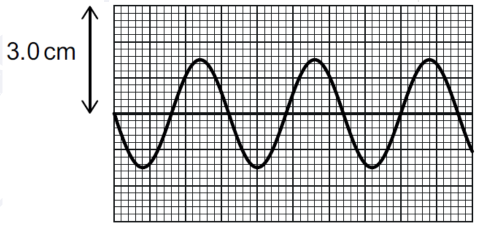
(B)



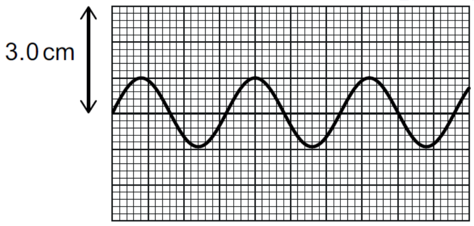
(C)



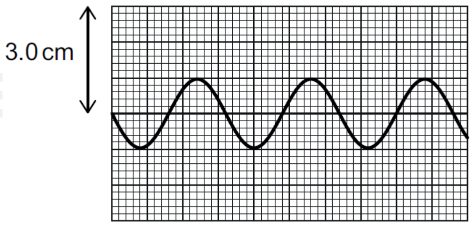
(D)



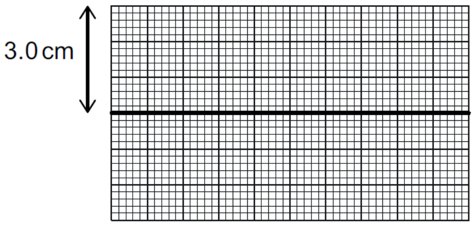
(E)



(F)

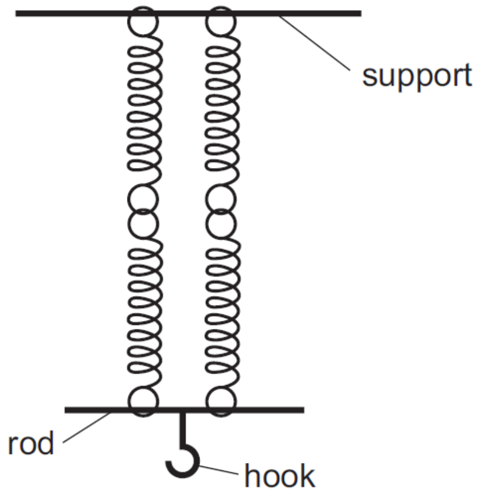


(G)



[NSAA, 2023S2Q4]

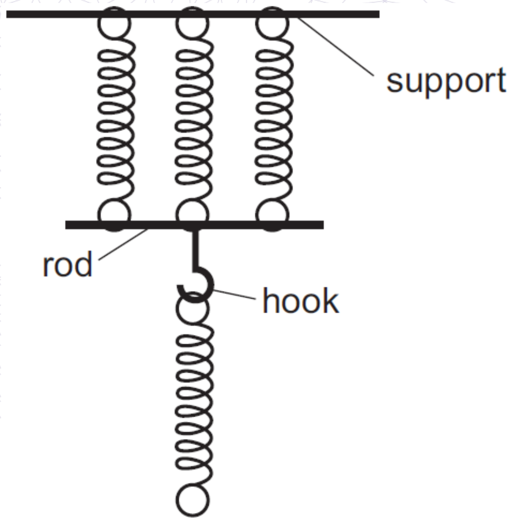
Four identical springs are arranged as shown and suspended from a support.



The mass of the springs, rod and hook are negligible.

A load of weight 8.4 N is attached to the hook at the lower end of the springs and this causes a total extension of the system of 24 mm.

The arrangement is then changed to:



The load of 8.4 N is attached to the bottom of the lower spring.

What is the total extension of the system at equilibrium in the second arrangement?

(The springs obey Hooke's law.)

(A) 3 mm

(B) 12 mm

(C) 16 mm

(D) 24 mm

(E) 32 mm

(F) 48 mm

(G) 64 mm

[NSAA, 2023S2Q5]

A student and a child are standing on trolleys X and Y, respectively, which are close to each other but not touching. The trolleys are initially stationary on a straight, horizontal frictionless track. The student is initially holding a ball of mass 5.0 kg.

The total mass of the student, the ball and trolley X is 80 kg.

The total mass of the child and trolley Y is 20 kg.

The student on trolley X throws the ball to the child on trolley Y. The ball travels at a horizontal speed of 12 m s^{-1} relative to the ground. The child then catches the ball.

What is the speed of separation of the trolleys after the child has caught the ball?

(Assume that air resistance is negligible.)

(A) 1.6 m s^{-1}

(B) 2.4 m s^{-1}

(C) 3.2 m s^{-1}

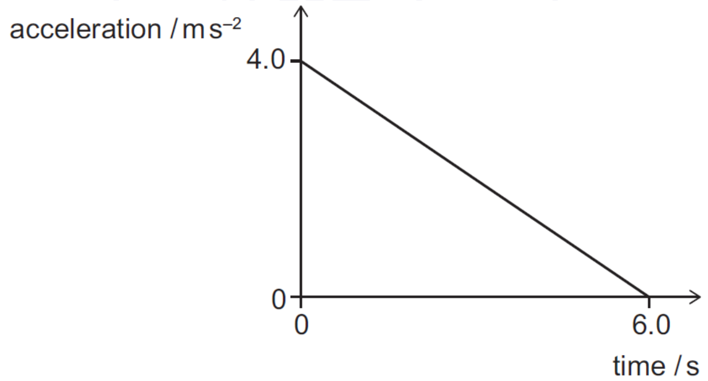
(D) 3.8 m s^{-1}

(E) 24 m s^{-1}

[NSAA, 2023S2Q6]

The variation of the acceleration with time of an object moving in a straight line is shown on the graph.

At time = 0 s the velocity of the object is 8.0 m s^{-1}.



What is the maximum velocity of the object between time = 0 s and time = 6 s?

(A) 5.0 m s^{-1}

(B) 8.0 m s^{-1}

(C) 12 m s^{-1}

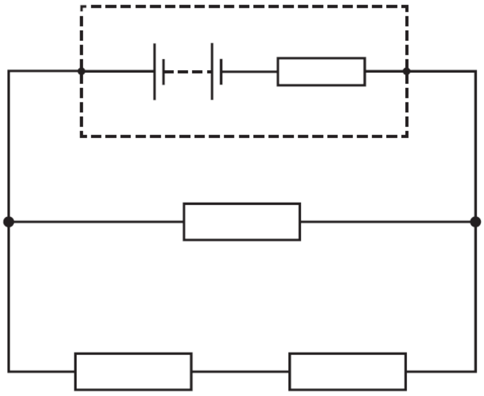
(D) 20 m s^{-1}

(E) 32 m s^{-1}

(F) 44 m s^{-1}

[NSAA, 2023S2Q7]

The diagram shows a circuit that includes a battery with an emf of 18 V and internal resistance r.



The three identical resistors in the external circuit each have resistance R.

The terminal potential difference across the battery is 16 V.

Which expression gives R in terms of r?

(A) $R = \frac{10r}{3}$

(B) $R = \frac{16r}{3}$

(C) $R = 6r$

(D) $R = 12r$

(E) $R = \frac{27r}{2}$

(F) $R = 24r$

(G) $R = \frac{51r}{2}$

[NSAA, 2023S2Q8]

Three identical bar magnets, each of mass m, and two identical trolleys, X and Y, also each of mass m, are arranged with the bar magnets fixed to the trolleys as shown. The trolleys are held at rest a short distance apart on a smooth horizontal track.

The trolleys are released at the same time. They move towards each other and collide.

Find the value of the ratio

$$\frac{\text{kinetic energy of } X \text{ immediately before collision}}{\text{kinetic energy of } Y \text{ immediately before collision}}.$$

(A) $\frac{4}{9}$

(B) $\frac{1}{2}$

(C) $\frac{2}{3}$

(D) 1

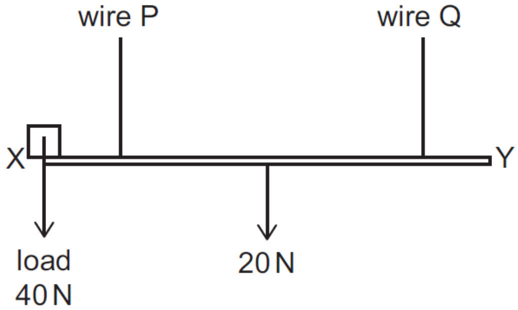
(E) $\frac{3}{2}$

(F) 2

(G) $\frac{9}{4}$

[NSAA, 2023S2Q9]

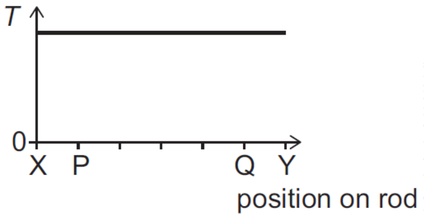
A uniform rod XY of length 3.0 m has a weight of 20 N. The rod is supported by two light wires, P and Q, as shown. P and Q are attached 0.50 m from ends X and Y, respectively.



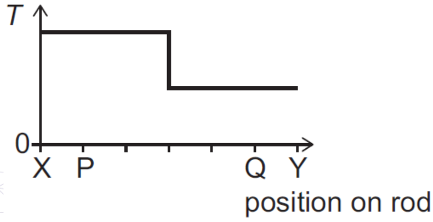
A 40 N load is moved from end X to end Y. The rod remains horizontal at all times.

Which graph shows the variation of the tension T in wire P with the position of the load as it is moved along the rod?

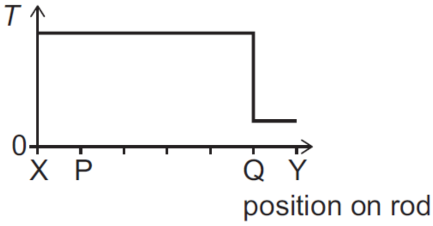
(A)



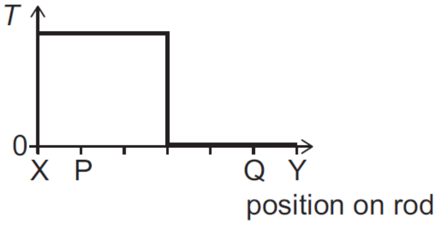
(B)



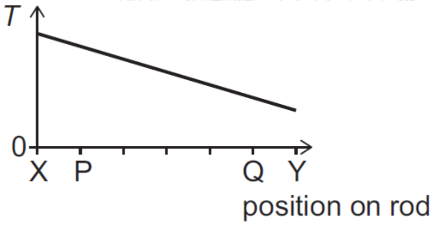
(C)



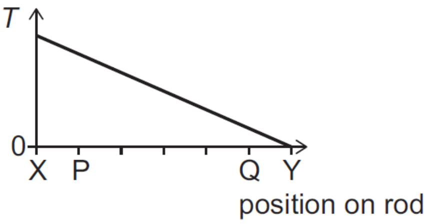
(D)



(E)

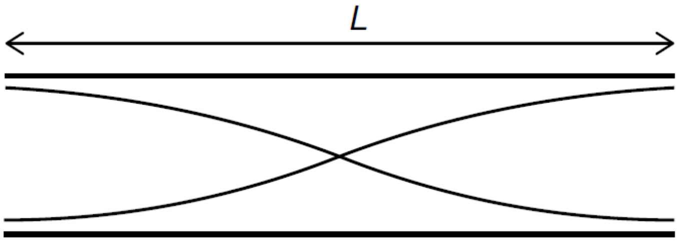


(F)



[NSAA, 2023S2Q10]

A pipe of length L open at both ends contains a stationary sound wave with 1 node, as shown in the diagram.



The frequency of the stationary wave in this pipe is $4f$.

A second pipe is open at one end and closed at the other end. A stationary sound wave in this pipe contains one more node than the stationary wave shown in the diagram.

The frequency of the stationary wave in the second pipe is f.

The speed of sound is the same in both pipes.

What is the length of the second pipe?

(A) $4L$

(B) $6L$

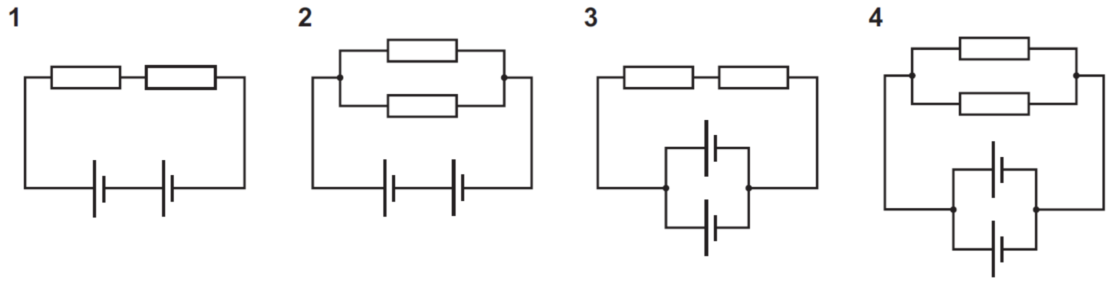
(C) $8L$

(D) $10L$

(E) $12L$

[NSAA, 2023S2Q11]

The resistors in the following four circuits are identical.



The cells are identical and have no internal resistance. Each cell can supply the same total amount of energy at a constant voltage before becoming exhausted.

t_1, t_2, t_3 and t_4 are the lengths of time after which the cells in circuits 1, 2, 3 and 4, respectively, become exhausted.

Which comparison of t_1, t_2, t_3 and t_4 is correct?

(A) $t_1 = t_2 < t_3 = t_4$

(B) $t_1 = t_3 < t_2 = t_4$

(C) $t_2 < t_1 = t_4 < t_3$

(D) $t_2 = t_4 < t_1 = t_3$

(E) $t_3 < t_1 = t_4 < t_2$

(F) $t_3 = t_4 < t_1 = t_2$

[NSAA, 2023S2Q12]

A particle of mass m is accelerated from rest by a resultant force of varying magnitude that acts in a constant direction. The kinetic energy E of the particle increases with time t according to the equation

$$E = kt$$

where k is a constant.

Which expression gives the resultant force on the particle at time T?

(A) k

(B) $2mk$

(C) $\sqrt{2mkT}$

(D) $\sqrt{\frac{mk}{2T}}$

(E) $\sqrt{\frac{mk}{8T}}$

(F) $\sqrt{\frac{2mk}{T}}$

(G) $\sqrt{\frac{k}{2mT}}$

[NSAA, 2023S2Q13]

A light horizontal wire of cross-sectional area A is fixed at two points a distance $2L$ apart. The initial tension in the wire is zero.

An object of weight W is fixed directly to the centre of the wire. The wire stretches so that the object rests in equilibrium at a vertical distance of $\frac{3L}{4}$ below the original position of the wire.

What is the Young modulus of the wire?

(Assume that the wire does not exceed its limit of proportionality.)

(A) $\frac{2W}{A}$

(B) $\frac{4W}{A}$

(C) $\frac{5W}{2A}$

(D) $\frac{2W}{3A}$

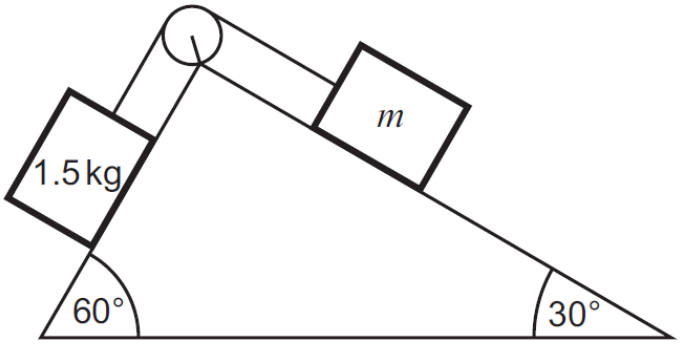
(E) $\frac{10W}{3A}$

(F) $\frac{20W}{3A}$

(G) $\frac{5W}{6A}$

[NSAA, 2023S2Q14]

A triangular ramp with angles to the horizontal of 60° and 30° is placed with its largest face horizontal. A block of mass 1.5 kg and a block of mass m are joined by a light, inextensible string and placed on the ramp as shown.



The string passes over a light, frictionless pulley.

The maximum force of friction between the block of mass 1.5 kg and the surface of the ramp is 3.5 N.

The maximum force of friction between the block of mass m and the surface of the ramp is 5.0 N.

What is the maximum value of m that allows the blocks to remain stationary on the surfaces? (gravitational field strength = 10 N kg^{-1})

(A) 1.5 kg

(B) 1.65 kg

(C) 2.35 kg

(D) $\left(\frac{16\sqrt{3}}{15}\right)$ kg

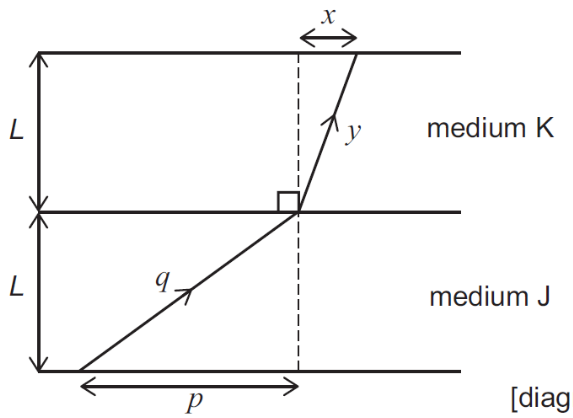
(E) $\left(0.60\sqrt{3}\right)$ kg

(F) $\left(0.30 + 1.5\sqrt{3}\right)$ kg

(G) $\left(1.7 + 1.5\sqrt{3}\right)$ kg

[NSAA, 2023S2Q15]

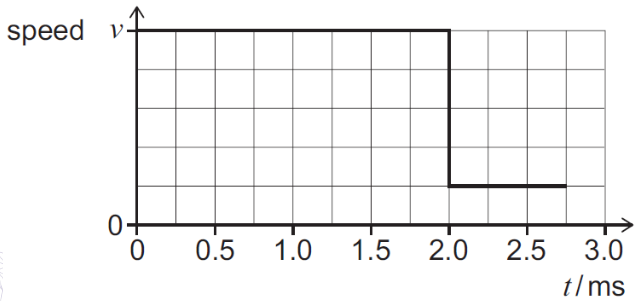
A sound wave travels through medium J, reaches a boundary, and then travels through medium K as shown. The thickness of each medium is L.



The wave travels a distance q in medium J and a distance y in medium K.

The horizontal distance travelled in medium J is p. The horizontal distance travelled in medium K is x.

The wave travels at speed v in medium J. The graph shows how the speed of the wave varies with time t as it travels distances q and y, and that the wave leaves medium K at $t = 2.75$ ms.



What is the value of $\frac{x}{p}$?

(A) $\frac{3}{200}$

(B) $\frac{3}{40}$

(C) $\frac{8}{75}$

(D) $\frac{3}{8}$

(E) $\frac{8}{15}$

(F) $\frac{8}{3}$

(G) $\frac{200}{3}$

[NSAA, 2023S2Q16]

The drag force F acting on a sphere of radius r falling at constant speed v though air is given by

$$F = krv$$

where k is a constant.

For a sphere of uniform density and mass m falling at a constant speed, the drag force heats the surrounding air at a constant rate P.

Another sphere of the same material but with mass $8m$ falls through the air at a different constant speed.

What is the rate at which the drag force on the heavier sphere heats the surrounding air?

(A) $2P$

(B) $4P$

(C) $8P$

(D) $16P$

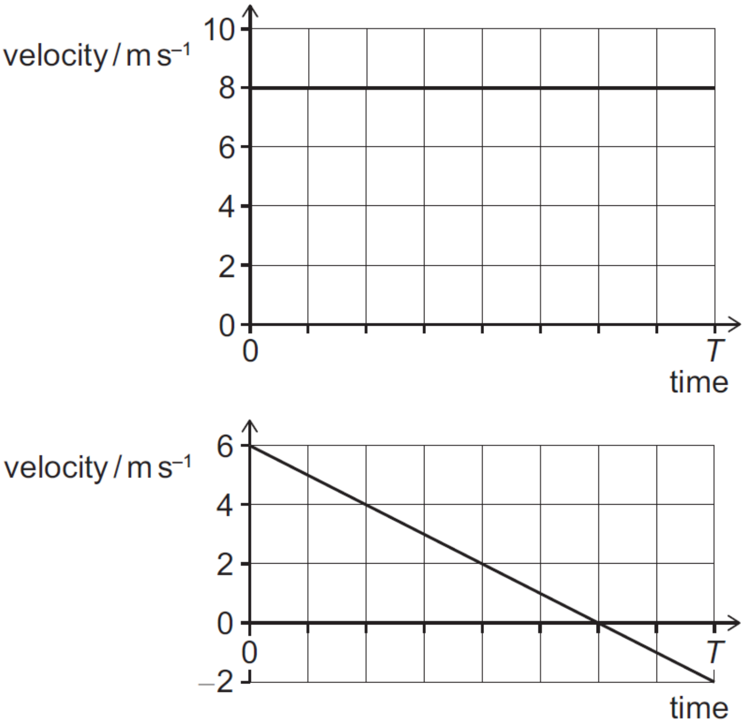
(E) $32P$

(F) $64P$

[NSAA, 2023S2Q17]

A projectile is launched from an inclined plane.

The graphs show the variation of the horizontal and vertical components of the velocity of the projectile with time from when it is launched until it hits the plane at time T.



What is the angle of the plane to the horizontal?

(gravitational field strength = $10\ \text{N kg}^{-1}$)

(A) $\tan^{-1}\frac{1}{32}$

(B) $\tan^{-1}\frac{1}{8}$

(C) $\tan^{-1}\frac{1}{4}$

(D) $\tan^{-1}\frac{5}{16}$

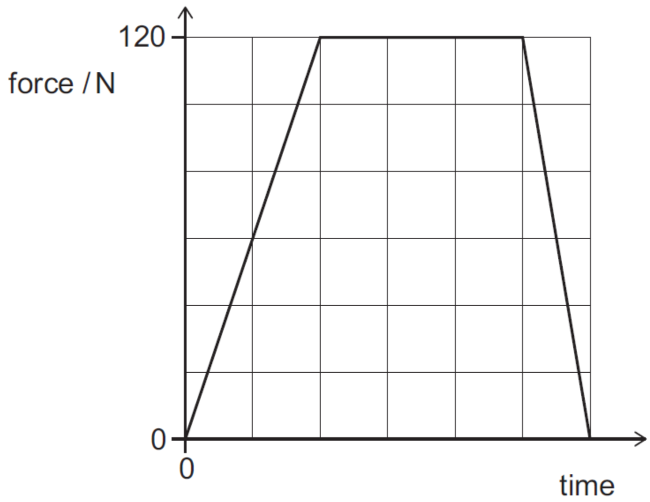
(E) $\tan^{-1}\frac{1}{3}$

(F) $\tan^{-1}\frac{4}{3}$

[NSAA, 2023S2Q18]

A tennis ball of mass 0.060 kg travels horizontally and strikes a vertical wall at 30 m s^{-1}. It leaves the wall in the opposite direction at 20 m s^{-1}.

The graph shows how the resultant horizontal force acting on the ball varies with time during this collision.



What is the duration of the collision?

(A) $\frac{1}{200}$ s

(B) $\frac{1}{150}$ s

(C) $\frac{1}{100}$ s

(D) $\frac{1}{40}$ s

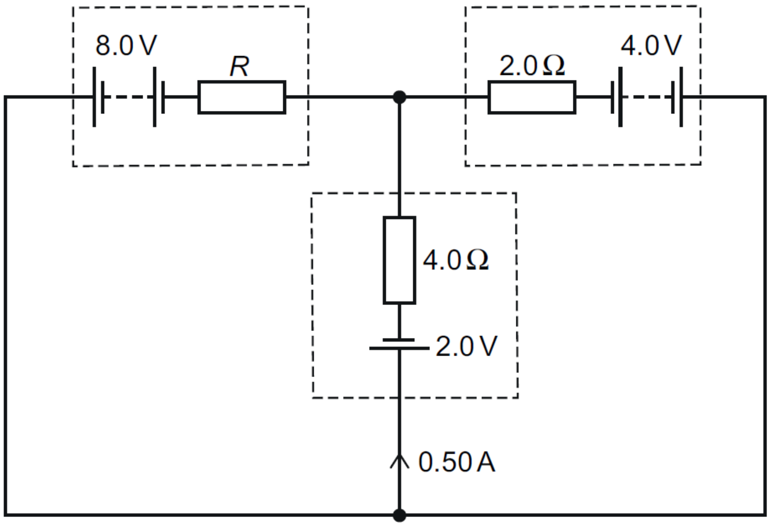
(E) $\frac{1}{30}$ s

(F) $\frac{1}{20}$ s

[NSAA, 2023S2Q19]

A battery with an emf of 8.0 V and internal resistance R and another battery with an emf of 4.0 V and internal resistance 2.0 Ω are connected to a cell with an emf of 2.0 V and internal resistance 4.0 Ω in the circuit shown.

The current in the 2.0 V cell is 0.50 A in the direction shown in the diagram.



What is the resistance R?

(A) 1.6 Ω

(B) 2.7 Ω

(C) 3.2 Ω

(D) 8.0 Ω

(E) 16 Ω

[NSAA, 2023S2Q20]

A model for how the resistivity ρ of damp soil varies with depth x from the surface is given by

$$\rho = \rho_0\left(1 - \frac{kx^2}{h^2}\right)$$

where h is the maximum depth, and k and ρ_0 are other constants.

What is the resistance of a vertical column of damp soil of cross-sectional area A and depth h?

(A) $\frac{\rho_0 h}{A}$

(B) $\frac{\rho_0 h}{A}(1-k)$

(C) $\frac{\rho_0 h}{2A}(2-k)$

(D) $\frac{\rho_0 h}{A}(1-3k)$

(E) $\frac{\rho_0 h}{A}\left(1-\frac{k}{3}\right)$

(F) $\frac{\rho_0}{A}\left(1-\frac{kh}{3}\right)$

(G) $\frac{\rho_0 h^2}{A}\left(\frac{1}{2}-\frac{k}{4}\right)$

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