

**AAPT**  
PHYSICS EDUCATION

# PhysicsBowl

历年真题集 2007-2022



优易竞赛冲奖

UE Olympiad-Prep



优易国际教育  
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# Table of Contents

---

Constant Sheet

Equation Sheet

Answer Keys

PhysicsBowl 2007

PhysicsBowl 2008

PhysicsBowl 2009

PhysicsBowl 2010

PhysicsBowl 2011

PhysicsBowl 2012

PhysicsBowl 2013

PhysicsBowl 2014

PhysicsBowl 2015

PhysicsBowl 2016

PhysicsBowl 2017

PhysicsBowl 2018

PhysicsBowl 2019

PhysicsBowl 2021

PhysicsBowl 2022

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# Constant Sheet

You should use the following values in determining the answers on this test. If you use other values in calculating answers, you may obtain values that do not exactly match answer selections found on this test. You will then need to choose the answer on the test closest to your value.

acceleration due to gravity	$g$	$= 9.8 \text{ m/s}^2$
gravitational constant	$G$	$= 6.7 \times 10^{11} \text{ N} \cdot \text{m}^2/\text{kg}^2$
atomic mass unit	1u	$= 1.7 \times 10^{-27} \text{ kg} = 9.3 \times 10^2 \text{ MeV}/c^2$
electron volt	1 eV	$= 1.6 \times 10^{-19} \text{ J}$
rest mass of electron	$m_e$	$= 9.1 \times 10^{-31} \text{ kg}$
rest mass of proton	$m_p$	$= 1.7 \times 10^{-27} \text{ kg}$
elementary charge	$e$	$= 1.6 \times 10^{-19} \text{ C}$
Coulomb's constant	$k$	$= 9.0 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2$
permittivity constant	$\epsilon_0$	$= 8.9 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}^2$
permeability constant	$\mu_0$	$= 4\pi \times 10^{-7} \text{ T} \cdot \text{m}/\text{A}$
speed of sound in air (20 °C)	$v_s$	$= 340 \text{ m/s}$
speed of light in vacuum	$c$	$= 3.0 \times 10^8 \text{ m/s}$
Planck's Constant	$h$	$= 6.6 \times 10^{-34} \text{ J} \cdot \text{s} = 4.14 \times 10^{-15} \text{ eV} \cdot \text{s}$
Boltzmann Constant	$k_B$	$= 1.38 \times 10^{-23} \text{ J/K}$
Universal Gas Constant	$R$	$= 8.21 \times 10^{-2} \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}} = 8.31 \frac{\text{J}}{\text{mol} \cdot \text{K}}$
Avogadro's Number	$N_A$	$= 6.02 \times 10^{23} \text{ mol}^{-1}$
<b>Water Properties:</b>		
Latent Heat of Vaporization	$L_v$	$= 540 \text{ kcal/kg} = 2.3 \times 10^6 \text{ J/kg}$
Latent Heat of Fusion	$L_f$	$= 80 \text{ kcal/kg} = 3.3 \times 10^5 \text{ J/kg}$
Density	$\rho_w$	$= 1.0 \times 10^3 \text{ kg/m}^3$
Specific heat	$c_w$	$= 1.10 \text{ kcal/kg} \cdot \text{°C} = 4.2 \times 10^3 \text{ J/kg} \cdot \text{°C}$

# Equation Sheet

$$\Delta x = v_0 t + \frac{1}{2} a t^2$$

$$\Sigma \vec{F} = m\vec{a}$$

$$F_g = mg$$

$$v_t = r\omega$$

$$\Sigma \vec{\tau} = I\vec{\alpha}$$

$$W = Fd \cos \theta = F_{\parallel} d = F d_{\parallel}$$

$$\vec{F} = -k\vec{x}$$

$$\rho = \frac{m}{V}$$

$$P = \frac{F}{A}$$

$$Q = mc\Delta T$$

$$v = f\lambda$$

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

$$m = -\frac{d_i}{d_o}$$

$$V = \frac{kq}{r}$$

$$PE_e = \frac{kq_1 q_2}{r}$$

$$V = RI$$

$$B = \frac{\mu_0 I}{2\pi r}$$

$$E = \gamma m_0 c^2 = mc^2$$

$$v = v_0 + at$$

$$F_{fric} \leq \mu F_N$$

$$\vec{p} = m\vec{v}$$

$$a_t = r\alpha$$

$$KE = \frac{1}{2} m v^2$$

$$PE_s = \frac{1}{2} k x^2$$

$$T = 2\pi \sqrt{\frac{m}{k}}$$

$$F_{buoy} = \rho g V$$

$$PV = nRT = Nk_B T$$

$$Q = \pm mL$$

$$f_o = f_s \left( \frac{v_{snd} \pm v_{obs}}{v_{snd} \mp v_{src}} \right)$$

$$m\lambda = d \sin \theta$$

$$F_e = k \frac{q_1 q_2}{r^2}$$

$$V = \frac{W}{q}$$

$$Q = CV$$

$$P = IV$$

$$B = \mu_0 n I$$

$$E = hf$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$F_g = G \frac{m_1 m_2}{r^2}$$

$$a = \frac{v^2}{r}$$

$$\tau = RF \sin \theta = R_{\perp} F = RF_{\perp}$$

$$\Delta PE_g = mg\Delta y$$

$$P = \frac{W}{\Delta t}$$

$$T = 2\pi \sqrt{\frac{L}{g}}$$

$$P_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2$$

$$\Delta U = Q + W_{on\ system}$$

$$\Delta S = \frac{Q}{T}$$

$$n = \frac{c}{v}$$

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\Delta V = -Ed \cos \theta = -E_{\parallel} d = -Ed_{\parallel}$$

$$PE = \frac{1}{2} CV^2$$

$$F = qvB \sin \theta = qvB_{\perp}$$

$$F = ILB \sin \theta = ILB_{\perp}$$

$$p = \frac{h}{\lambda}$$

Moments of Inertia:

Solid disk or cylinder for a perpendicular axis through its center:  $I = \frac{1}{2} MR^2$

Thin rod about the center, perpendicular to rod:  $I = \frac{1}{12} MR^2$

Solid sphere about a diameter:  $\frac{2}{5} MR^2$

# Answer Keys

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2007-2022



2007 Answer keys	
Q1	D
Q2	D
Q3	A
Q4	E
Q5	C
Q6	C
Q7	A
Q8	B
Q9	E
Q10	B
Q11	D
Q12	E
Q13	A
Q14	C
Q15	D
Q16	C
Q17	A
Q18	E
Q19	D
Q20	B
Q21	A
Q22	D
Q23	C
Q24	C
Q25	D
Q26	B
Q27	B
Q28	A
Q29	C
Q30	E
Q31	B
Q32	B
Q33	C
Q34	A
Q35	D
Q36	E
Q37	B
Q38	E
Q39	A
Q40	C
Q41	D
Q42	E
Q43	B
Q44	E
Q45	E
Q46	A
Q47	C
Q48	D
Q49	C
Q50	A

2008 Answer Keys	
Q1	E
Q2	B
Q3	C
Q4	D
Q5	C
Q6	A
Q7	E
Q8	A
Q9	B
Q10	D
Q11	A
Q12	B
Q13	D
Q14	B
Q15	D
Q16	D
Q17	E
Q18	A
Q19	B
Q20	A
Q21	C
Q22	A
Q23	C
Q24	D
Q25	E
Q26	C
Q27	D
Q28	B
Q29	C
Q30	E
Q31	D
Q32	B
Q33	E
Q34	B
Q35	A
Q36	C
Q37	E
Q38	A
Q39	B
Q40	C
Q41	E
Q42	D
Q43	A
Q44	A
Q45	E
Q46	B
Q47	C
Q48	C
Q49	B
Q50	E

2009 Answer Keys	
Q1	D
Q2	B
Q3	A
Q4	C
Q5	D
Q6	D
Q7	B
Q8	C
Q9	A
Q10	E
Q11	B
Q12	D
Q13	E
Q14	B
Q15	C
Q16	A
Q17	D
Q18	E
Q19	B
Q20	C
Q21	C
Q22	D
Q23	C
Q24	B
Q25	E
Q26	D
Q27	C
Q28	E
Q29	B
Q30	A
Q31	A
Q32	E
Q33	A
Q34	E
Q35	A
Q36	D
Q37	A
Q38	B
Q39	D
Q40	C
Q41	E
Q42	D
Q43	B
Q44	C
Q45	A
Q46	D
Q47	E
Q48	B
Q49	C
Q50	D

2010 Answer Keys	
Q1	D
Q2	D
Q3	C
Q4	B
Q5	C
Q6	B
Q7	A
Q8	D
Q9	A
Q10	E
Q11	B
Q12	E
Q13	C
Q14	D
Q15	D
Q16	C
Q17	A
Q18	E
Q19	C
Q20	B
Q21	D
Q22	C
Q23	C
Q24	D
Q25	A
Q26	E
Q27	A
Q28	A
Q29	B
Q30	E
Q31	A
Q32	B
Q33	E
Q34	C
Q35	D
Q36	E
Q37	E
Q38	B
Q39	A
Q40	B
Q41	C
Q42	B
Q43	E
Q44	C
Q45	D
Q46	B
Q47	A
Q48	C
Q49	A
Q50	D

2011 Answer keys	
Q1	D
Q2	E
Q3	B
Q4	C
Q5	B
Q6	C
Q7	D
Q8	E
Q9	A
Q10	E
Q11	E
Q12	D
Q13	A
Q14	A
Q15	B
Q16	E
Q17	B
Q18	D
Q19	E
Q20	C
Q21	C
Q22	B
Q23	A
Q24	A
Q25	E
Q26	C
Q27	D
Q28	B
Q29	C
Q30	D
Q31	D
Q32	E
Q33	C
Q34	B
Q35	E
Q36	A
Q37	D
Q38	A
Q39	C
Q40	B
Q41	A
Q42	B
Q43	D
Q44	C
Q45	E
Q46	C
Q47	A
Q48	D
Q49	B
Q50	E

2012 Answer Keys	
Q1	B
Q2	C
Q3	B
Q4	D
Q5	C
Q6	E
Q7	A
Q8	D
Q9	D
Q10	E
Q11	B
Q12	D
Q13	C
Q14	B
Q15	A
Q16	B
Q17	C
Q18	A
Q19	D
Q20	E
Q21	A
Q22	B
Q23	A
Q24	C
Q25	D
Q26	E
Q27	D
Q28	E
Q29	E
Q30	B
Q31	A
Q32	C
Q33	E
Q34	C
Q35	A
Q36	D
Q37	B
Q38	E
Q39	A
Q40	D
Q41	C
Q42	A
Q43	B
Q44	D
Q45	C
Q46	D
Q47	C
Q48	E
Q49	A
Q50	B

2013 Answer Keys	
Q1	C
Q2	B
Q3	D
Q4	E
Q5	A
Q6	C
Q7	D
Q8	B
Q9	D
Q10	E
Q11	E
Q12	C
Q13	E
Q14	B
Q15	D
Q16	D
Q17	D
Q18	A
Q19	C
Q20	D
Q21	E
Q22	B
Q23	D
Q24	B
Q25	A
Q26	B
Q27	C
Q28	E
Q29	B
Q30	B
Q31	D
Q32	E
Q33	A
Q34	A
Q35	C
Q36	C
Q37	A
Q38	B
Q39	A
Q40	E
Q41	A
Q42	C
Q43	A
Q44	E
Q45	C
Q46	E
Q47	B
Q48	A
Q49	D
Q50	B

2014 Answer Keys	
Q1	B
Q2	D
Q3	D
Q4	A
Q5	C
Q6	E
Q7	C
Q8	E
Q9	A
Q10	D
Q11	C
Q12	C
Q13	B
Q14	E
Q15	D
Q16	D
Q17	A
Q18	B
Q19	E
Q20	C
Q21	C
Q22	D
Q23	B
Q24	D
Q25	E
Q26	B
Q27	A
Q28	B
Q29	A
Q30	C
Q31	C
Q32	E
Q33	B
Q34	A
Q35	E
Q36	A
Q37	D
Q38	A
Q39	E
Q40	B
Q41	D
Q42	C
Q43	D
Q44	E
Q45	B
Q46	A
Q47	D
Q48	E
Q49	C
Q50	B

2015 Answer keys	
Q1	B
Q2	C
Q3	A
Q4	B
Q5	E
Q6	D
Q7	A
Q8	E
Q9	C
Q10	E
Q11	B
Q12	D
Q13	C
Q14	D
Q15	E
Q16	A
Q17	D
Q18	C
Q19	B
Q20	C
Q21	B
Q22	A
Q23	A
Q24	C
Q25	E
Q26	A
Q27	D
Q28	B
Q29	E
Q30	B
Q31	D
Q32	D
Q33	C
Q34	A
Q35	E
Q36	B
Q37	A
Q38	D
Q39	E
Q40	C
Q41	A
Q42	C
Q43	B
Q44	E
Q45	B
Q46	E
Q47	C
Q48	B
Q49	A
Q50	D

2016 Answer Keys	
Q1	C
Q2	A
Q3	D
Q4	D
Q5	B
Q6	D
Q7	E
Q8	A
Q9	B
Q10	C
Q11	C
Q12	B
Q13	A
Q14	E
Q15	B
Q16	C
Q17	A
Q18	A
Q19	D
Q20	E
Q21	B
Q22	E
Q23	C
Q24	B
Q25	A
Q26	C
Q27	D
Q28	D
Q29	E
Q30	A
Q31	E
Q32	D
Q33	B
Q34	C
Q35	A
Q36	B
Q37	E
Q38	D
Q39	A
Q40	D
Q41	D
Q42	B
Q43	C
Q44	E
Q45	D
Q46	A
Q47	C
Q48	B
Q49	A
Q50	E

2017 Answer Keys	
Q1	A
Q2	D
Q3	E
Q4	A
Q5	E
Q6	C
Q7	B
Q8	D
Q9	B
Q10	B
Q11	C
Q12	D
Q13	B
Q14	D
Q15	C
Q16	D
Q17	C
Q18	E
Q19	B
Q20	D
Q21	E
Q22	E
Q23	E
Q24	D
Q25	B
Q26	A
Q27	C
Q28	A
Q29	E
Q30	A
Q31	A
Q32	C
Q33	A
Q34	C
Q35	B
Q36	E
Q37	B
Q38	A
Q39	A
Q40	D
Q41	C
Q42	C
Q43	E
Q44	B
Q45	A
Q46	D
Q47	D
Q48	C
Q49	B
Q50	B

2018 Answer Keys	
Q1	D
Q2	B
Q3	D
Q4	A
Q5	E
Q6	A
Q7	B
Q8	D
Q9	B
Q10	C
Q11	C
Q12	C
Q13	D
Q14	C
Q15	B
Q16	D
Q17	D
Q18	A
Q19	A
Q20	A
Q21	B
Q22	D
Q23	B
Q24	B
Q25	D
Q26	C
Q27	B
Q28	A
Q29	A
Q30	B
Q31	B
Q32	B
Q33	B
Q34	A
Q35	D
Q36	B
Q37	A
Q38	D
Q39	D
Q40	C
Q41	D
Q42	A
Q43	A
Q44	E
Q45	D
Q46	B
Q47	C
Q48	D
Q49	C
Q50	C

2019 Answer keys	
Q1	A
Q2	C
Q3	C
Q4	D
Q5	B
Q6	B or C
Q7	C
Q8	B
Q9	C
Q10	E
Q11	D
Q12	B
Q13	D
Q14	E
Q15	B
Q16	D
Q17	D
Q18	B
Q19	D
Q20	B
Q21	D
Q22	C
Q23	A
Q24	B
Q25	C
Q26	D
Q27	D
Q28	D
Q29	A
Q30	C
Q31	E
Q32	C
Q33	B
Q34	B
Q35	A
Q36	A
Q37	A
Q38	B
Q39	A
Q40	D
Q41	D
Q42	B
Q43	A
Q44	A
Q45	B
Q46	D
Q47	E
Q48	D
Q49	D
Q50	E

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

2022 Answer keys	
Q1	A
Q2	B
Q3	C
Q4	B
Q5	B
Q6	D
Q7	E
Q8	C
Q9	B
Q10	E
Q11	E
Q12	C
Q13	A
Q14	D
Q15	D
Q16	C
Q17	E
Q18	C
Q19	B
Q20	D
Q21	C
Q22	E
Q23	B
Q24	C
Q25	B
Q26	E
Q27	E
Q28	B
Q29	B
Q30	B
Q31	B
Q32	E
Q33	D
Q34	C
Q35	E
Q36	A
Q37	A
Q38	A
Q39	D
Q40	D
Q41	C
Q42	B
Q43	B
Q44	C
Q45	B
Q46	B
Q47	A
Q48	D
Q49	C
Q50	C

# PhysicsBowl 2007

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40 QUESTIONS – 45 MINUTES



Physics Bowl 2007

[Online Exam](#)

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微信扫码完成在线考试后，自动判分并呈现完整解析、错题录入错题本

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

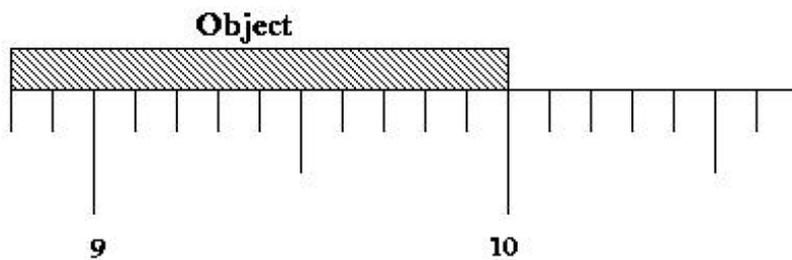
## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2007Q1]

A standard centimeter ruler is shown. Which recorded value is the most correct for the location of the shaded object's right end?



- (A) 10 cm
- (B) 10. cm
- (C) 10.0 cm
- (D) 10.00 cm
- (E) 10.0̄ cm

[PhysicsBowl, 2007Q2]

How thick is the average page of a physics textbook in micrometers?

- (A) 0.1
- (B) 1
- (C) 10
- (D) 100
- (E) 1000



[PhysicsBowl, 2007Q3]

Two automobiles are 150 kilometers apart and traveling toward each other. One automobile is moving at 60 km/h and the other is moving at 40 km/h. In how many hours will they meet?

- (A) 1.5
- (B) 1.75
- (C) 2.0
- (D) 2.5
- (E) 3.0

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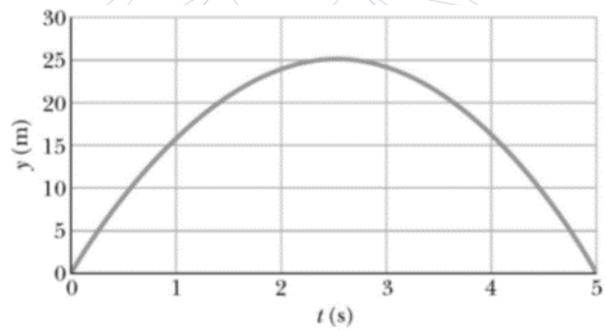
[PhysicsBowl, 2007Q4]

A particle moves on the  $x$ -axis. When the particle's acceleration is positive and increasing

- (A) its velocity must be positive.
- (B) its velocity must be negative.
- (C) it must be slowing down.
- (D) it must be speeding up.
- (E) none of the above must be true.

[PhysicsBowl, 2007Q5]

The position-time,  $y$  vs.  $t$ , graph for the motion of an object is shown. What would be a reasonable equation for the acceleration  $a$  that would account for this motion?



- (A)  $a = 0$
- (B)  $a = \text{positive constant}$
- (C)  $a = \text{negative constant}$
- (D)  $a = \text{positive constant times } t$
- (E)  $a = \text{negative constant times } t$



[PhysicsBowl, 2007Q6]

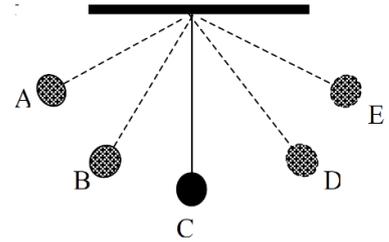
A 500-kg car is moving at 28 m/s. The driver sees a barrier ahead. If the car takes 95 meters to come to rest, what is the magnitude of the minimum average net force necessary to stop?

- (A) 47.5 N
- (B) 1400 N
- (C) 2060 N
- (D) 19600 N
- (E) 133000 N

[PhysicsBowl, 2007Q7]

A mass connected to a string swings back and forth as a pendulum with snapshots of the motion seen in the figure. Ignore the friction in the system. Which of the following statements about the pendulum-Earth system is correct?

- (A) The total mechanical energy in the system is constant.
- (B) The total mechanical energy in the system is maximum at  $B$ .
- (C) The potential energies at  $A$  and  $C$  are equal.
- (D) The kinetic energies at  $C$  and  $D$  are equal.
- (E) The kinetic energy at  $E$  equals the kinetic energy at  $C$ .



[PhysicsBowl, 2007Q8]

What does one obtain by dividing the distance of 12 Mm by the time of 4 Ts?

- (A) 3 nm/s
- (B) 3  $\mu\text{m/s}$
- (C) 3 mm/s
- (D) 3 km/s
- (E) 3 Gm/s

[PhysicsBowl, 2007Q9]

A block rests on an incline that makes the angle  $\phi$  with the horizontal. The block remains at rest as  $\phi$  is slowly increased. The magnitudes of the normal force and the static frictional force of the incline on the block

- (A) both increase
- (B) both decrease
- (C) both remain the same
- (D) increase and decrease, respectively
- (E) decrease and increase, respectively



[PhysicsBowl, 2007Q10]

Contact forces are examples of which of the fundamental forces?

- (A) Strong
- (B) Electromagnetic
- (C) Weak
- (D) Gravitational
- (E) None of these

[PhysicsBowl, 2007Q11]

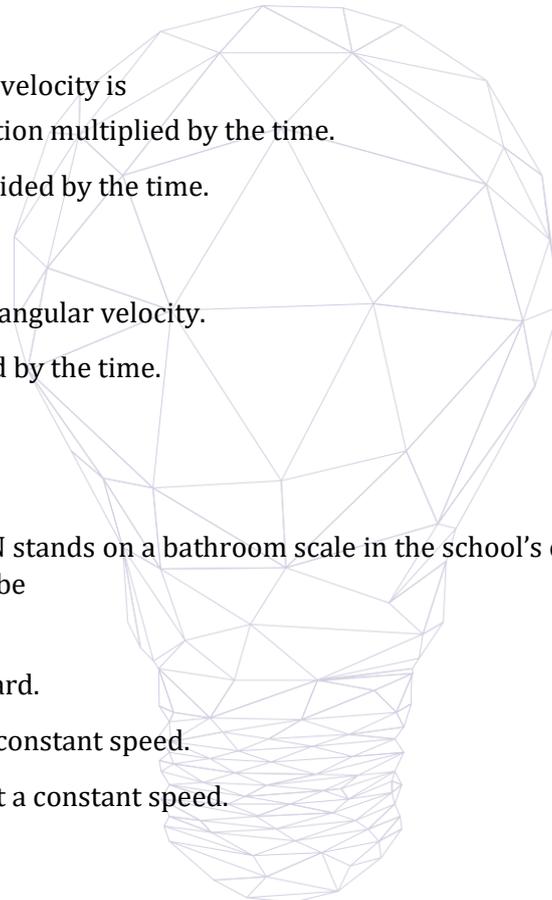
A cart is initially moving at 0.5 m/s along a track. The cart comes to rest after traveling 1 m. The experiment is repeated on the same track, but now the cart is initially moving at 1 m/s. How far does the cart travel before coming to rest?

- (A) 1 m
- (B) 2 m
- (C) 3 m
- (D) 4 m
- (E) 8 m

[PhysicsBowl, 2007Q12]

The definition of average velocity is

- (A) the average acceleration multiplied by the time.
- (B) distance traveled divided by the time.
- (C)  $\frac{1}{2}(v_f + v_0)$ .
- (D) radius multiplied by angular velocity.
- (E) displacement divided by the time.



[PhysicsBowl, 2007Q13]

A student weighing 500 N stands on a bathroom scale in the school's elevator. When the scale reads 520 N, the elevator must be

- (A) accelerating upward.
- (B) accelerating downward.
- (C) moving upward at a constant speed.
- (D) moving downward at a constant speed.
- (E) at rest.

[PhysicsBowl, 2007Q14]

An object moves to the East across a frictionless surface with constant speed. A person then applies a constant force to the North on the object. What is the resulting path that the object takes?

- (A) A straight line path partly Eastward, partly Northward
- (B) A straight line path totally to the North
- (C) A parabolic path opening toward the North
- (D) A parabolic path opening toward the East
- (E) An exponential path opening upward toward the North

**Questions 15 and 16 refer to this situation.**

Two identical mass objects are launched with the same speed from the same starting location. Object 1 is launched at an angle of  $30^\circ$  above the horizontal while Object 2 is launched at an angle of  $60^\circ$  above the horizontal. Ignore air resistance and consider the flight of each object from launch until it returns to the same launch height above the ground.

[PhysicsBowl, 2007Q15]

Which object returns to the starting height with the greatest speed?

- (A) Object 1 since it keeps a lower trajectory.
- (B) Object 2 since it is in the air for a longer time.
- (C) Object 2 since there is more work done on the object during flight
- (D) The speeds are the same.
- (E) It cannot be determined without more information.

[PhysicsBowl, 2007Q16]

Which object experiences the greatest change in the linear momentum?

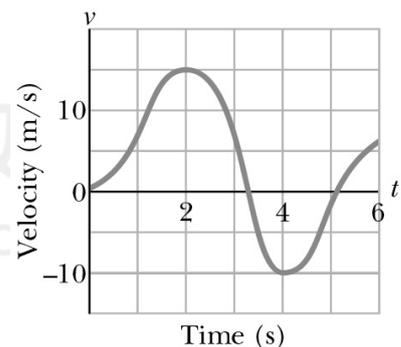
- (A) Object 1 since it has a higher final speed.
- (B) Object 2 since it has a higher final speed.
- (C) Object 2 since it is in the air for a longer time.
- (D) The change in momentum is the same for each.
- (E) It cannot be determined without more information.



[PhysicsBowl, 2007Q17]

A toy car moves along the  $x$ -axis according to the velocity versus time curve shown to the right. When does the car have zero acceleration?

- (A) at 2 and 4 seconds
- (B) at approximately 3.0 seconds
- (C) at approximately 3.3 and 5.1 seconds
- (D) the acceleration is always zero
- (E) at no time



[PhysicsBowl, 2007Q18]

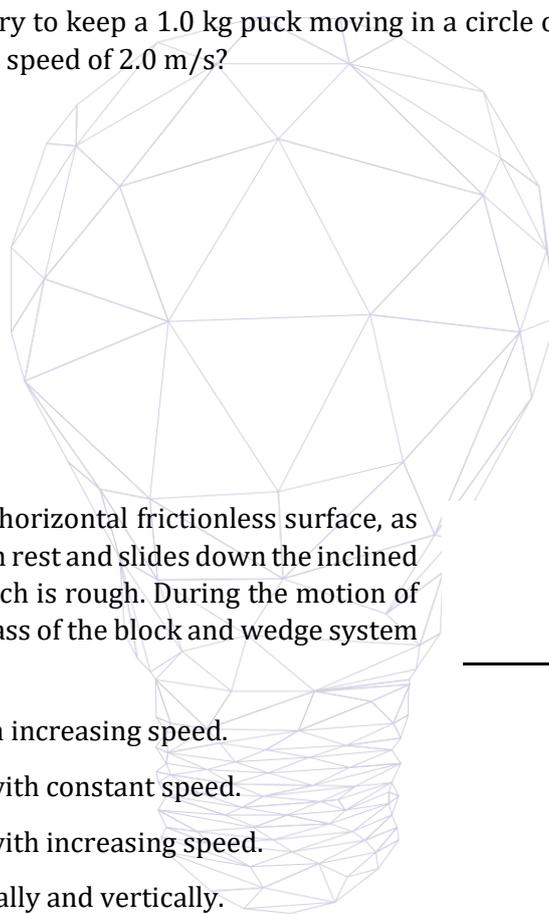
In which one of the following situations is the net force constantly zero on the object?

- (A) A mass attached to a string and swinging like a pendulum.
- (B) A stone falling freely in a gravitational field.
- (C) An astronaut floating in the International Space Station.
- (D) A snowboarder riding down a steep hill.
- (E) A skydiver who has reached terminal velocity.

[PhysicsBowl, 2007Q19]

What net force is necessary to keep a 1.0 kg puck moving in a circle of radius 0.5 m on a horizontal frictionless surface with a speed of 2.0 m/s?

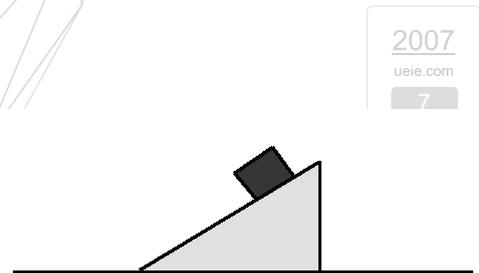
- (A) 0 N
- (B) 2.0 N
- (C) 4.0 N
- (D) 8.0 N
- (E) 16 N



[PhysicsBowl, 2007Q20]

A large wedge rests on a horizontal frictionless surface, as shown. A block starts from rest and slides down the inclined surface of the wedge, which is rough. During the motion of the block, the center of mass of the block and wedge system

- (A) does not move.
- (B) moves vertically with increasing speed.
- (C) moves horizontally with constant speed.
- (D) moves horizontally with increasing speed.
- (E) moves both horizontally and vertically.



## [PhysicsBowl, 2007Q21]

A box slides to the right across a horizontal floor. A person called Ted exerts a force  $T$  to the right on the box. A person called Mario exerts a force  $M$  to the left, which is half as large as the force  $T$ . Given that there is friction  $f$  and the box accelerates to the right, rank the sizes of these three forces exerted on the box.

- (A)  $f < M < T$
- (B)  $M < f < T$
- (C)  $M < T < f$
- (D)  $f = M < T$
- (E) It cannot be determined.

## [PhysicsBowl, 2007Q22]

A mass  $m$  is pulled outward until the string of length  $L$  to which it is attached makes a 90-degree angle with the vertical. The mass is released from rest and swings through a circular arc. What is the tension in the string when the mass swings through the bottom of the arc?

- (A) 0
- (B)  $mg$
- (C)  $2mg$
- (D)  $3mg$
- (E) It cannot be determined.

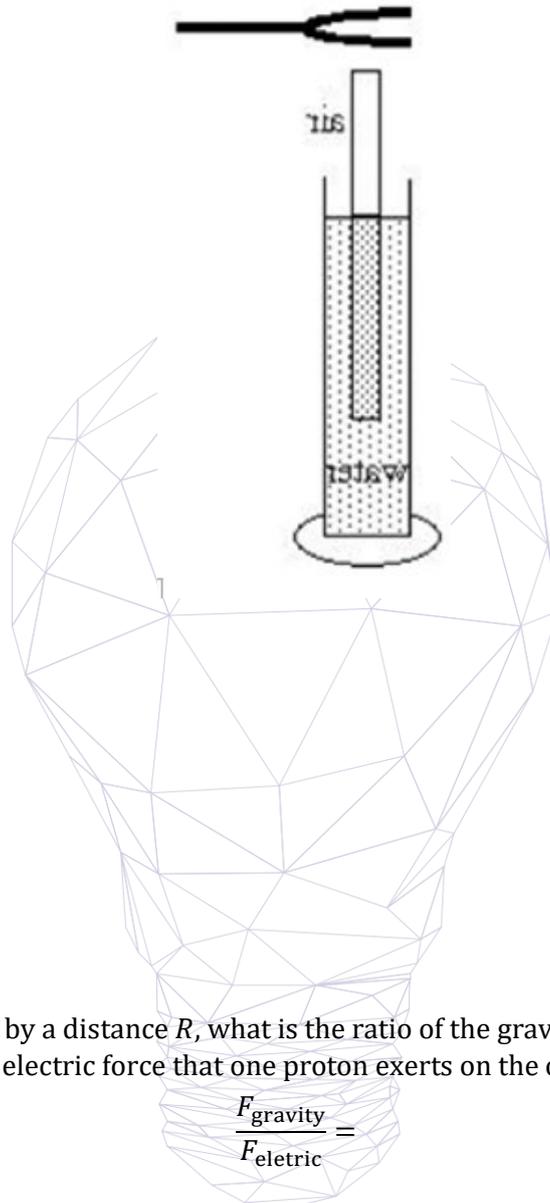
## [PhysicsBowl, 2007Q23]

The period of a mass-spring system undergoing simple harmonic oscillation is  $T$ . If the amplitude of the mass-spring system's motion is doubled, the period will be

- (A)  $\frac{1}{4}T$
- (B)  $\frac{1}{2}T$
- (C)  $T$
- (D)  $2T$
- (E)  $4T$

[PhysicsBowl, 2007Q24]

A resonance occurs with a tuning fork and an air column of size 39 cm. The next highest resonance occurs with an air column of 65 cm. What is the frequency of the tuning fork? Assume that the speed of sound is 343 m/s.



- (A) 329.8 Hz
- (B) 527.7 Hz
- (C) 659.6 Hz
- (D) 879.5 Hz
- (E) 1319 Hz



[PhysicsBowl, 2007Q25]

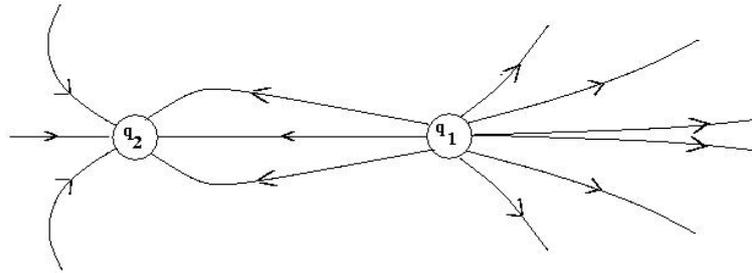
If two protons are spaced by a distance  $R$ , what is the ratio of the gravitational force that one proton exerts on the other to the electric force that one proton exerts on the other? That is,

$$\frac{F_{\text{gravity}}}{F_{\text{electric}}} =$$

- (A)  $\approx 10^{-8}$
- (B)  $\approx 10^{-16}$
- (C)  $\approx 10^{-20}$
- (D)  $\approx 10^{-36}$
- (E)  $\approx 10^{-43}$

[PhysicsBowl, 2007Q26]

For the diagram shown below, what is the ratio of the charges  $\frac{q_2}{q_1}$ , where the diagram shown has a representation of the field lines in the space near the charges.



- (A)  $-\frac{3}{2}$
- (B)  $-\frac{2}{3}$
- (C)  $\frac{2}{3}$
- (D)  $\frac{3}{2}$
- (E) 1

[PhysicsBowl, 2007Q27]

A junior Thomas Edison wants to make a brighter light bulb. He decides to modify the filament. How should the filament of a light bulb be modified in order to make the light bulb produce more light at a given voltage?

- (A) Increase the resistivity only.
- (B) Increase the diameter only.
- (C) Decrease the diameter only.
- (D) Decrease the diameter and increase the resistivity.
- (E) Increase the length only.

[PhysicsBowl, 2007Q28]

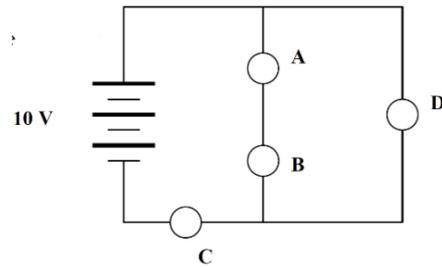
Which statement about a system of point charges that are fixed in space is necessarily true?

- (A) If the potential energy of the system is negative, net positive work by an external agent is required to take the charges in the system back to infinity.
- (B) If the potential energy of the system is positive, net positive work is required to bring any new charge not part of the system in from infinity to its final resting location.
- (C) If the potential energy of the system is zero, no negative charges are in the configuration.
- (D) If the potential energy of the system is negative, net positive work by an external agent was required to assemble the system of charges.
- (E) If the potential energy of the system is zero, then there is no electric force anywhere in space on any other charged particle not part of the system.

[PhysicsBowl, 2007Q29]

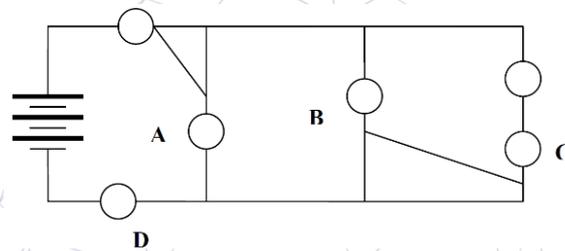
In the circuit diagram below, all of the bulbs are identical. Which bulb will be the brightest?

- (A) A
- (B) B
- (C) C
- (D) D
- (E) The bulbs all have the same brightness.



[PhysicsBowl, 2007Q30]

In the following circuit diagram, which one of the bulbs will not light?



- (A) A
- (B) B
- (C) C
- (D) D
- (E) They all light.



[PhysicsBowl, 2007Q31]

James Clerk Maxwell's great contribution to electromagnetic theory was his idea that

- (A) work is required to move a magnetic pole through a closed path surrounding a current.
- (B) a time-changing electric field acts as a current and produces a magnetic field.
- (C) the speed of light could be determined from simple electrostatic and magnetostatic experiments and finding the values of  $\mu_0$  and  $\epsilon_0$ .
- (D) the magnetic force on a moving charge particle is perpendicular to both its velocity and the magnetic field.
- (E) magnetism could be explained in terms of circulating currents in atoms.

[PhysicsBowl, 2007Q32]

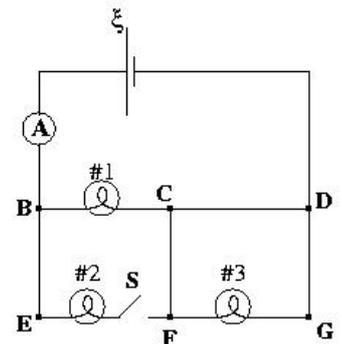
What does LASER stand for?

- (A) Light Amplification by Simulated Emission of Radiation.
- (B) Light Amplification by Stimulated Emission of Radiation.
- (C) Light Amplification by Simultaneous Emission of Radiation.
- (D) Light Amplification by Systematic Emission of Radiation.
- (E) Light Amplification by Serendipitous Emission of Radiation.

[PhysicsBowl, 2007Q33]

For the circuit shown, the ammeter reading is initially  $I$ . The switch in the circuit then is closed. Consequently:

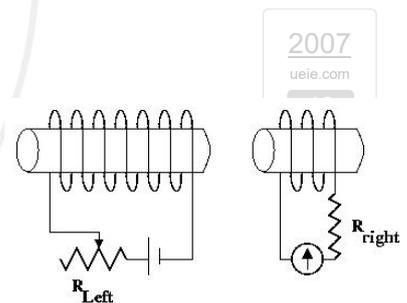
- (A) The ammeter reading decreases.
- (B) The potential difference between  $E$  and  $F$  increases.
- (C) The potential difference between  $E$  and  $F$  stays the same.
- (D) Bulb #3 lights up more brightly.
- (E) The power supplied by the battery decreases.



[PhysicsBowl, 2007Q34]

For the solenoids shown in the diagram (which are assumed to be close to each other), the resistance of the left-hand circuit is slowly increased. In which direction does the galvanometer needle in the righthand circuit move in response to this change?

- (A) The needle deflects to the left.
- (B) The needle deflects to the right.
- (C) The needle oscillates back and forth.
- (D) The needle rotates in counterclockwise circles.
- (E) The needle never moves.



[PhysicsBowl, 2007Q35]

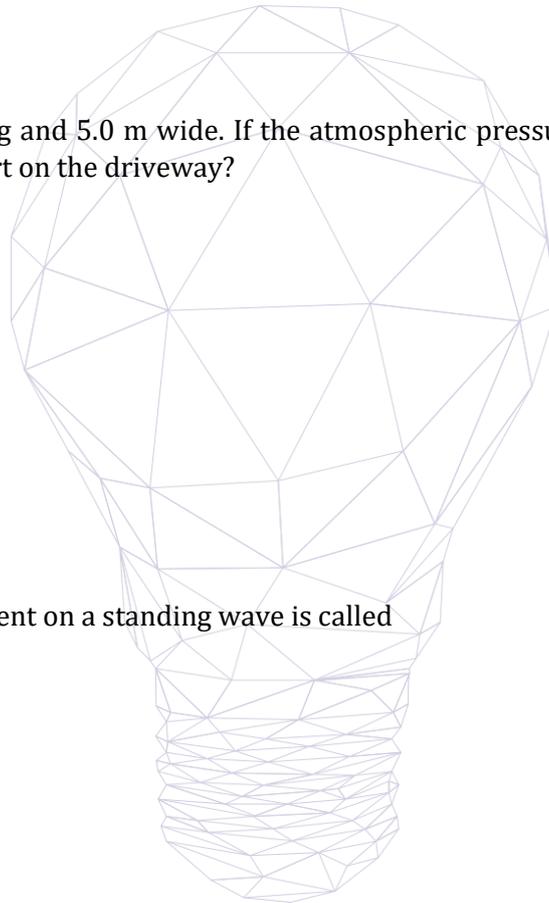
Two objects labeled  $K$  and  $L$  have equal mass but densities  $0.95D_0$  and  $D_0$ , respectively. Each of these objects floats after being thrown into a deep swimming pool. Which is true about the buoyant forces acting on these objects?

- (A) The buoyant force is greater on Object  $K$  since it has a lower density and displaces more water.
- (B) The buoyant force is greater on Object  $K$  since it has lower density and lower density objects always float “higher” in the fluid.
- (C) The buoyant force is greater on Object  $L$  since it is denser than  $K$  and therefore “heavier”.
- (D) The buoyant forces are equal on the objects since they have equal mass.
- (E) Without knowing the specific gravity of the objects, nothing can be determined.

[PhysicsBowl, 2007Q36]

A driveway is 22.0 m long and 5.0 m wide. If the atmospheric pressure is  $1.0 \times 10^5$  Pa, what force does the atmosphere exert on the driveway?

- (A)  $9.09 \times 10^{-8}$  N
- (B)  $1.1 \times 10^{-3}$  N
- (C) 909 N
- (D) 4545 N
- (E)  $1.1 \times 10^7$  N



[PhysicsBowl, 2007Q37]

A place of zero displacement on a standing wave is called

- (A) an antinode.
- (B) a node.
- (C) the amplitude.
- (D) the wavenumber.
- (E) the harmonic.

[PhysicsBowl, 2007Q38]

Absolute zero is best described as that temperature at which

- (A) water freezes at standard pressure.
- (B) water is at its triple point.
- (C) the molecules of a substance have a maximum kinetic energy.
- (D) the molecules of a substance have a maximum potential energy.
- (E) the molecules of a substance have minimum kinetic energy.

[PhysicsBowl, 2007Q39]

A mass of material exists in its solid form at its melting temperature  $10^\circ\text{C}$ . The following processes then occur to the material:

Process 1: An amount of thermal energy  $Q$  is added to the material and  $\frac{3}{4}$  of the material melts.

Process 2: An identical additional amount of thermal energy  $Q$  is added to the material and the material is now a liquid at  $50^\circ\text{C}$ .

What is the ratio of the latent heat of fusion to the specific heat of the liquid for this material?

- (A)  $80^\circ\text{C}$
- (B)  $60^\circ\text{C}$
- (C)  $40^\circ\text{C}$
- (D)  $20^\circ\text{C}$
- (E) More information is needed to answer this question.

[PhysicsBowl, 2007Q40]

Which is not true of an isochoric process on an enclosed ideal gas in which the pressure decreases?

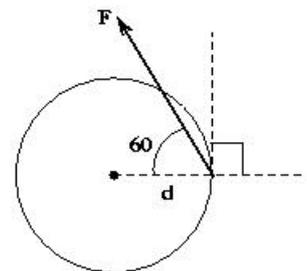
- (A) The work done is zero.
- (B) The internal energy of the gas decreases.
- (C) The heat is zero.
- (D) The rms speed of the gas molecules decreases.
- (E) The gas temperature decreases.



[PhysicsBowl, 2007Q41]

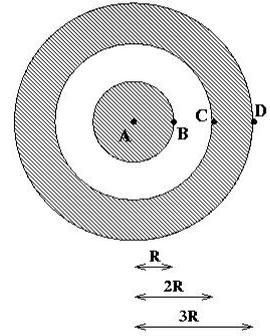
For the diagram shown, what is the magnitude of the torque from the applied force as measured from the center of the disk?

- (A)  $Fd \sin 30^\circ$
- (B)  $Fd \tan 30^\circ$
- (C)  $Fd \sin 90^\circ$
- (D)  $Fd \sin 120^\circ$
- (E)  $Fd \cos 120^\circ$



[PhysicsBowl, 2007Q42]

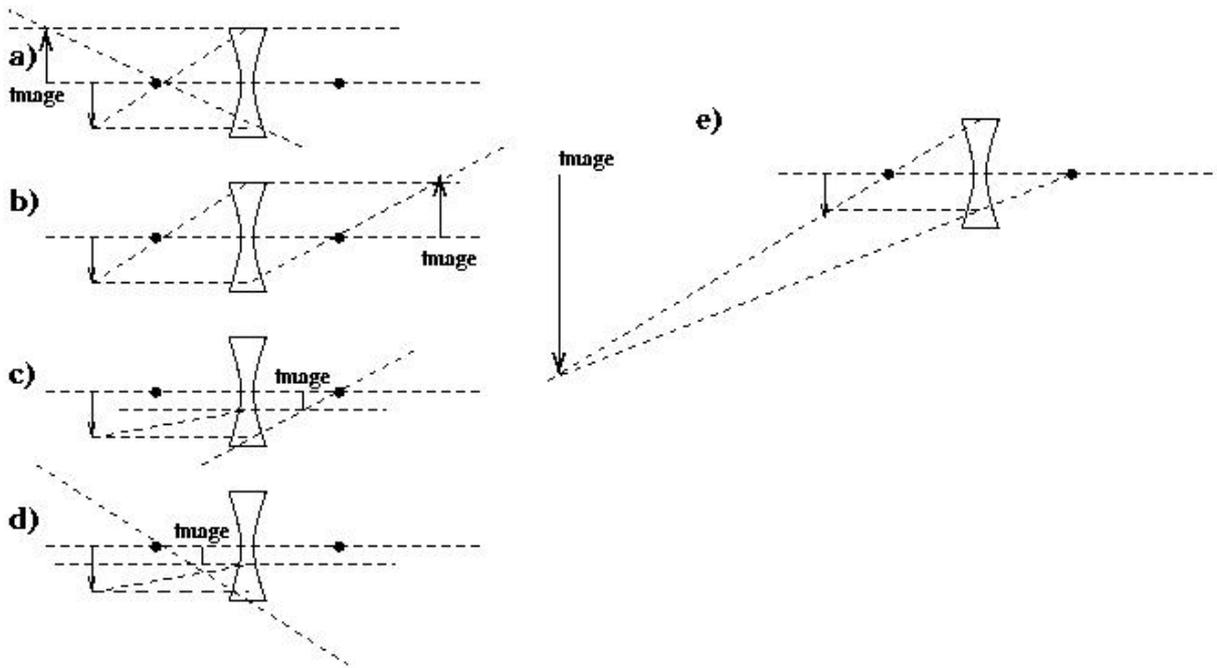
A solid spherical conductor has charge  $+Q$  and radius  $R$ . It is surrounded by a solid spherical shell with charge  $-Q$ , inner radius  $2R$ , and outer radius  $3R$ . Which of the following statements is true for the labeled points in the diagram? Assume these objects are isolated in space and that the electric potential is zero as the distance from the spheres approaches infinity. Point  $A$  is at the center of the inner sphere, Point  $B$  is located at  $r = R + \delta$ , Point  $D$  is located at  $r = 3R + \delta$  and Point  $C$  is located at  $r = 2R - \delta$  where  $\delta$  is an infinitesimal amount and all distances are from the center of the inner sphere.



- (A) The electric potential has a maximum magnitude at  $C$  and the electric field has a maximum magnitude at  $A$ .
- (B) The electric potential has a maximum magnitude at  $D$  and the electric field has a maximum magnitude at  $B$ .
- (C) The electric potential at  $A$  is zero and the electric field has a maximum magnitude at  $D$ .
- (D) The electric potential at  $A$  is zero and the electric field has a maximum magnitude at  $B$ .
- (E) Both the electric potential and electric field achieve a maximum magnitude at  $B$ .

[PhysicsBowl, 2007Q43]

Which of the following best represents the ray diagram construction for finding the image formed for the virtual object shown? The solid dots on either side of the lens locate the equal magnitude foci of the lens.



2007

[PhysicsBowl, 2007Q44]

A person vibrates the end of a string sending transverse waves down the string. If the person then doubles the rate at which he vibrates the string, the speed of the waves

- (A) doubles and the wavelength is unchanged
- (B) doubles and the wavelength doubled
- (C) doubles while the wavelength is halved
- (D) is unchanged while the wavelength is doubled
- (E) is unchanged while the wavelength is halved.

[PhysicsBowl, 2007Q45]

If the temperature of a material doubles on the Kelvin scale, by how much does the time-rate at which energy is radiated from the material change?

- (A) It is unchanged.
- (B) It is doubled.
- (C) It is 4 times greater.
- (D) It is 8 times greater.
- (E) It is 16 times greater.

[PhysicsBowl, 2007Q46]

An ideal gas undergoes a reversible isothermal expansion at  $T = 300$  K. The total change in entropy of the gas is  $2.5$  J/K. How much work was done by the environment on the gas during this process?

- (A)  $-750$  J
- (B)  $-120$  J
- (C)  $120$  J
- (D)  $750$  J
- (E) More information is required to answer this question.



[PhysicsBowl, 2007Q47]

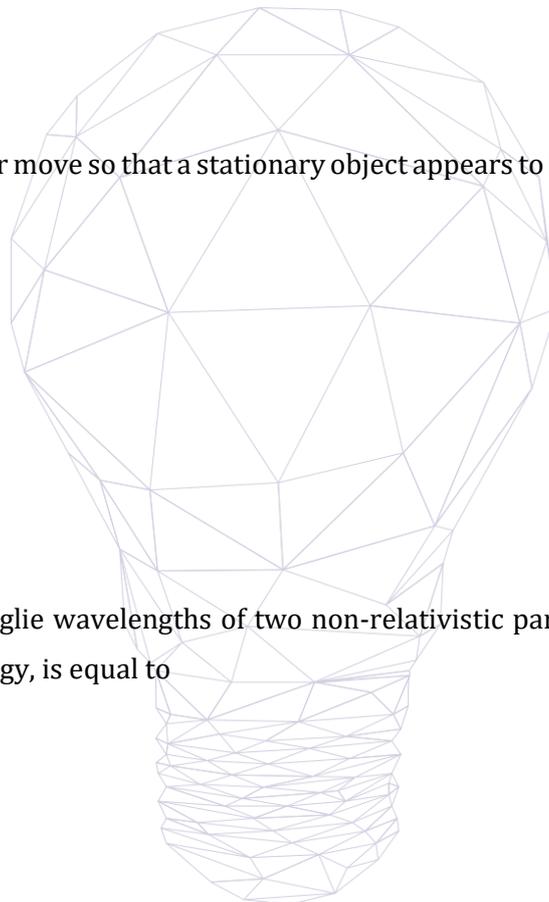
Two spaceships travel along paths that are at right angles to each other. Each ship travels at  $0.60c$  where  $c$  is the speed of light in a vacuum according to a stationary observer. If one of the ships turns on a green laser and aims it at a right angle to the direction of its travel, with what speed does the other speed record the speed of the green light?

- (A)  $0.40c$
- (B)  $0.85c$
- (C)  $1.00c$
- (D)  $1.17c$
- (E) More information is required about the direction that the light is traveling in order to answer the question.

[PhysicsBowl, 2007Q48]

How fast must an observer move so that a stationary object appears to be one-half of its proper length?

- (A)  $0.50c$
- (B)  $0.67c$
- (C)  $0.75c$
- (D)  $0.87c$
- (E)  $0.93c$



[PhysicsBowl, 2007Q49]

The ratio  $\frac{\lambda_1}{\lambda_2}$  of the de Broglie wavelengths of two non-relativistic particles with masses  $m_1$  and  $m_2$  and the same kinetic energy, is equal to

- (A)  $\frac{m_2}{m_1}$
- (B)  $\frac{m_1}{m_2}$
- (C)  $\sqrt{\frac{m_2}{m_1}}$
- (D)  $\sqrt{\frac{m_1}{m_2}}$
- (E) 1

## [PhysicsBowl, 2007Q50]

A gas undergoes radioactive decay with time constant  $\tau$ . A sample of 10000 particles is put into a container. After one time constant has passed, the experimenter places another 10000 particles into the original container. How much time passes from the addition of the particles until the container of gas reaches 10000 total particles again?

- (A)  $(0.405)\tau$
- (B)  $(0.500)\tau$
- (C)  $(0.693)\tau$
- (D)  $\tau$
- (E)  $2\tau$



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# PhysicsBowl 2008

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40 QUESTIONS – 45 MINUTES



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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2008Q1]

Of the following, which quantity is a vector?

- (A) Energy
- (B) Mass
- (C) Average speed
- (D) Temperature
- (E) Linear Momentum

[PhysicsBowl, 2008Q2]

In one year, there are approximately  $31.5 \times 10^6$  s. Which of the following representations using metric prefixes is equivalent to this value?

- (A) 31.5 ks
- (B) 31.5 Ms
- (C) 31.5 Gs
- (D) 31.5 ms
- (E) 31.5 ps

[PhysicsBowl, 2008Q3]

A dog starts from rest and runs in a straight line with a constant acceleration of  $2.5 \text{ m/s}^2$ . How much time does it take for the dog to run a distance of 10.0 m?

- (A) 8.0 s
- (B) 4.0 s
- (C) 2.8 s
- (D) 2.0 s
- (E) 1.4 s

[PhysicsBowl, 2008Q4]

One mole of an ideal gas has a temperature of  $100^\circ\text{C}$ . If this gas fills the  $10.0 \text{ m}^3$  volume of a closed container, what is the pressure of the gas?

- (A) 0.821 Pa
- (B) 3.06 Pa
- (C) 83.1 Pa
- (D) 310 Pa
- (E)  $1.84 \times 10^{24}$  Pa



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[PhysicsBowl, 2008Q5]

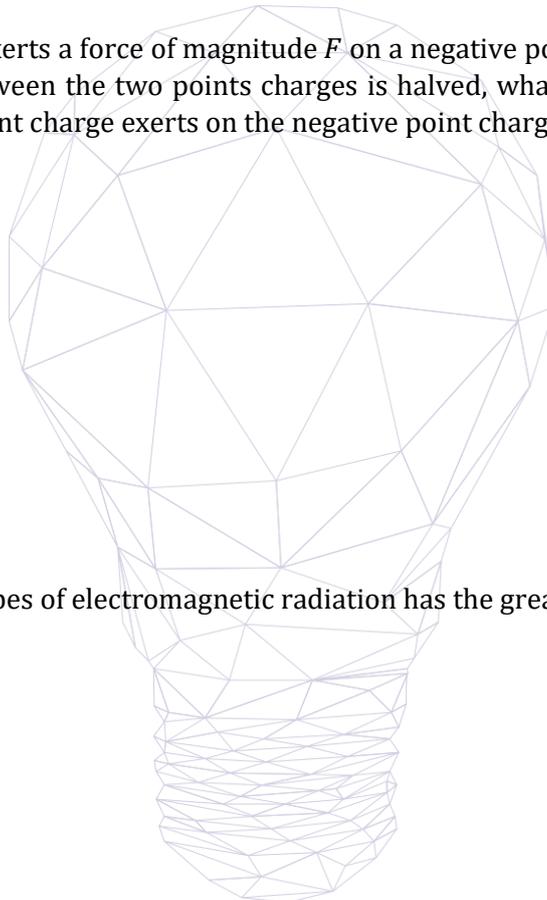
Approximately how much would it cost to keep a 100 W light bulb lit continuously for 1 year at a rate of \$0.10 /kW·hr?

- (A) \$1
- (B) \$10
- (C) \$100
- (D) \$1000
- (E) \$100000

[PhysicsBowl, 2008Q6]

A positive point charge exerts a force of magnitude  $F$  on a negative point charge placed a distance  $x$  away. If the distance between the two points charges is halved, what is the magnitude of the new force that the positive point charge exerts on the negative point charge?

- (A)  $4F$
- (B)  $2F$
- (C)  $F$
- (D)  $\frac{F}{2}$
- (E)  $\frac{F}{4}$



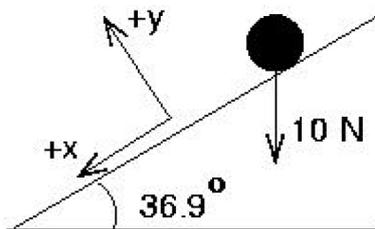
[PhysicsBowl, 2008Q7]

Which of the following types of electromagnetic radiation has the greatest energy per photon?

- (A) infrared
- (B) microwave
- (C) FM radio
- (D) AM radio
- (E) violet light

[PhysicsBowl, 2008Q8]

An object on an inclined plane has a gravitational force of magnitude 10 N acting on it from the Earth. Which of the following gives the correct components of this gravitational force for the coordinate axes shown in the figure? The  $y$ -axis is perpendicular to the incline's surface while the  $x$ -axis is parallel to the inclined surface.



	$x$ -component	$y$ -component
(A)	+6 N	-8 N
(B)	+8 N	-6 N
(C)	-6 N	+8 N
(D)	-8 N	+6 N
(E)	0 N	+10 N

[PhysicsBowl, 2008Q9]

When a beam of white light passes through a prism, the exiting light is seen as a spectrum of visible colors. This phenomenon is known as

- (A) diffraction
- (B) dispersion
- (C) interference
- (D) polarization
- (E) reflection



[PhysicsBowl, 2008Q10]

Which of the following could be a correct unit for pressure?

- (A)  $\text{kg}/\text{m}^2$
- (B)  $\text{kg}/\text{m}\cdot\text{s}$
- (C)  $\text{kg}/\text{s}^2$
- (D)  $\text{kg}/\text{m}\cdot\text{s}^2$
- (E)  $\text{m}\cdot\text{s}/\text{kg}$

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[PhysicsBowl, 2008Q11]

Which person has won a Nobel Prize in physics?

- (A) Marie Curie
- (B) Isaac Newton
- (C) Aristotle
- (D) Johannes Kepler
- (E) Stephen Hawking

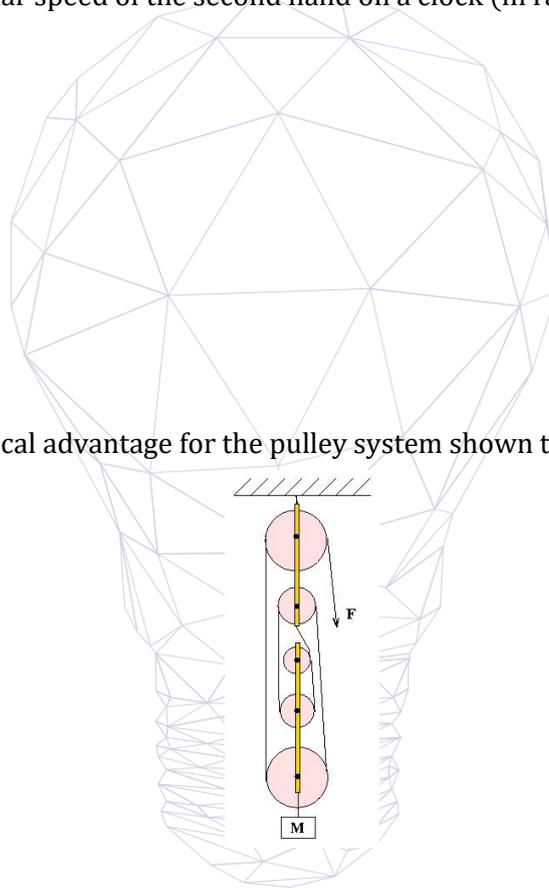
[PhysicsBowl, 2008Q12]

What is the average angular speed of the second hand on a clock (in rad/s)?

- (A) 6.28
- (B) 0.105
- (C) 0.0167
- (D)  $1.745 \times 10^{-3}$
- (E)  $2.778 \times 10^{-4}$

[PhysicsBowl, 2008Q13]

What is the ideal mechanical advantage for the pulley system shown to the right?



- (A)  $\frac{F}{Mg}$
- (B)  $\frac{Mg}{F}$
- (C) 3
- (D) 4
- (E) 5



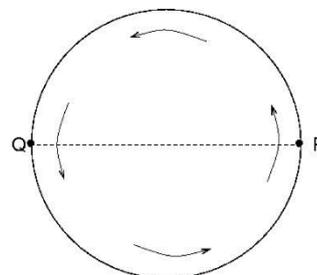
**Questions 14 and 15 refer to the following scenario:**

A particle continuously moves in a circular path at constant speed in a counterclockwise direction. Consider a time interval during which the particle moves along this circular path from point  $P$  to point  $Q$ . Point  $Q$  is exactly half-way around the circle from Point  $P$ .

[PhysicsBowl, 2008Q14]

What is the direction of the average velocity during this time interval?

- (A)  $\rightarrow$
- (B)  $\leftarrow$
- (C)  $\uparrow$
- (D)  $\downarrow$
- (E) The average velocity is zero.



[PhysicsBowl, 2008Q15]

What is the direction of the average acceleration during this time interval?

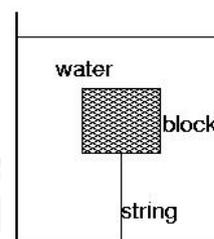
- (A)  $\rightarrow$
- (B)  $\leftarrow$
- (C)  $\uparrow$
- (D)  $\downarrow$
- (E) The average acceleration is zero.



[PhysicsBowl, 2008Q16]

A block is connected to a light string attached to the bottom of a large container of water. The tension in the string is 3.0 N. The gravitational force from the earth on the block is 5.0 N. What is the block's volume?

- (A)  $2.0 \times 10^{-4} \text{ m}^3$
- (B)  $3.0 \times 10^{-4} \text{ m}^3$
- (C)  $5.0 \times 10^{-4} \text{ m}^3$
- (D)  $8.0 \times 10^{-4} \text{ m}^3$
- (E)  $1.0 \times 10^{-3} \text{ m}^3$



[PhysicsBowl, 2008Q17]

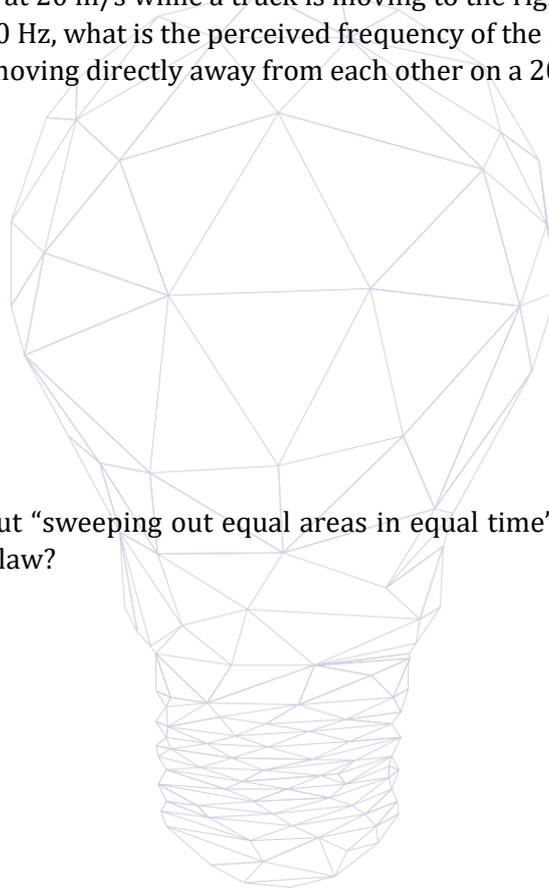
An ideal red pigment is mixed with an ideal blue pigment. After mixing, what color pigment results?

- (A) cyan
- (B) magenta
- (C) yellow
- (D) green
- (E) black

[PhysicsBowl, 2008Q18]

A car is moving to the left at 20 m/s while a truck is moving to the right at 25 m/s. If the truck emits a sound of frequency 5000 Hz, what is the perceived frequency of the sound by the driver of the car? Assume the vehicles are moving directly away from each other on a 20.0 °C day.

- (A) 4384 Hz
- (B) 4706 Hz
- (C) 4932 Hz
- (D) 5079 Hz
- (E) 5714 Hz



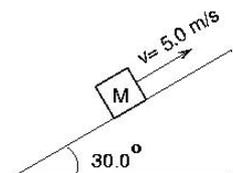
[PhysicsBowl, 2008Q19]

Kepler's Second Law about "sweeping out equal areas in equal time" can be derived most directly from which conservation law?

- (A) energy
- (B) angular momentum
- (C) linear momentum
- (D) mechanical energy
- (E) mass

[PhysicsBowl, 2008Q20]

A person pushes a block of mass  $M = 6.0$  kg with a constant speed of 5.0 m/s straight up a flat surface inclined 30.0° above the horizontal. The coefficient of kinetic friction between the block and the surface is  $\mu = 0.40$ . What is the net force acting on the block?



- (A) 0 N
- (B) 21 N
- (C) 30 N
- (D) 51 N
- (E) 76 N

[PhysicsBowl, 2008Q21]

Modern telescopes use mirrors, rather than lenses, to form images. One advantage of mirrors over lenses is that the images formed by mirrors are not affected by:

- (A) destructive interference
- (B) constructive interference
- (C) chromatic aberration
- (D) spherical aberration
- (E) atmospheric refraction

[PhysicsBowl, 2008Q22]

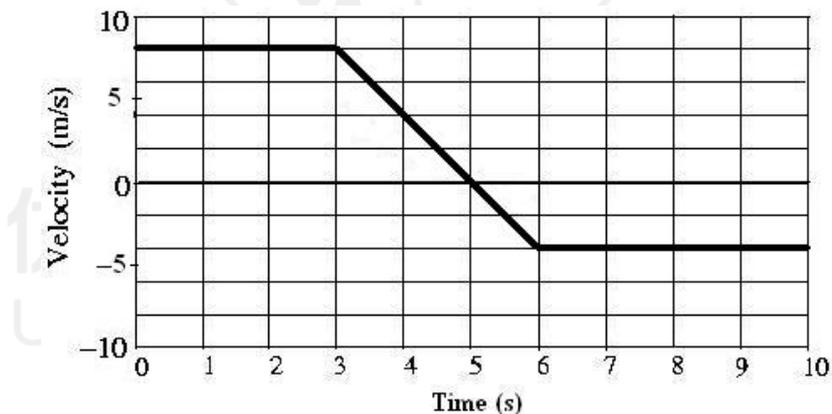
In a calorimeter, 20 grams of liquid water at  $100^{\circ}\text{C}$  is mixed with 50 grams of water vapor at  $100^{\circ}\text{C}$ . The system is allowed to come to equilibrium. Assuming that the calorimeter and the surroundings can be ignored, which of the following best describes the net energy exchange between the vapor and the liquid during the process of coming to equilibrium?

- (A) There is no net energy exchange.
- (B) Energy is transferred from the vapor to the liquid, vaporizing some of the liquid.
- (C) Energy is transferred from the vapor to the liquid, increasing the liquid's temperature.
- (D) Energy is transferred from the vapor to the liquid until all of the liquid vaporizes.
- (E) Energy is transferred from the liquid to the vapor, condensing some vapor.



Questions 23 and 24 refer to the following scenario:

The velocity vs. time graph for the motion of a car on a straight track is shown in the diagram. The thick line represents the velocity. Assume that the car starts at the origin  $x = 0$ .



[PhysicsBowl, 2008Q23]

At which time is the car the greatest distance from the origin?

- (A)  $t = 10$  s
- (B)  $t = 6$  s
- (C)  $t = 5$  s
- (D)  $t = 3$  s
- (E)  $t = 0$  s

[PhysicsBowl, 2008Q24]

What is the average speed of the car for the 10 second interval?

- (A) 1.20 m/s
- (B) 1.40 m/s
- (C) 3.30 m/s
- (D) 5.00 m/s
- (E) 5.40 m/s

[PhysicsBowl, 2008Q25]

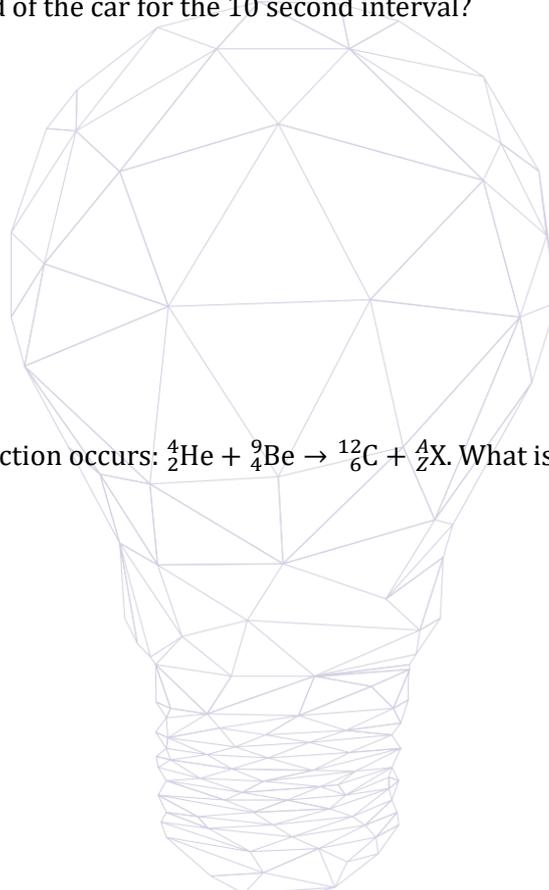
The following nuclear reaction occurs:  ${}^4_2\text{He} + {}^9_4\text{Be} \rightarrow {}^{12}_6\text{C} + {}^4_2\text{X}$ . What is  ${}^4_2\text{X}$ ?

- (A) a proton
- (B) an electron
- (C) a positron
- (D) an alpha particle
- (E) a neutron

[PhysicsBowl, 2008Q26]

If the principal quantum number of an electron is  $n = 4$ , how many possible values of the orbital magnetic quantum number  $m_l$  are there for this electron?

- (A) 3
- (B) 4
- (C) 7
- (D) 9
- (E) 16



[PhysicsBowl, 2008Q27]

A tube of length  $L_1$  is open at both ends. A second tube of length  $L_2$  is closed at one end and open at the other end. This second tube resonates at the same fundamental frequency as the first tube. What is the value of  $L_2$ ?

- (A)  $4L_1$
- (B)  $2L_1$
- (C)  $L_1$
- (D)  $\frac{1}{2}L_1$
- (E)  $\frac{1}{4}L_1$

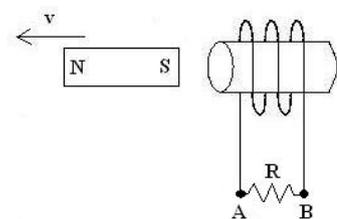
[PhysicsBowl, 2008Q28]

A diverging lens produces an image of a real object. This image is

- (A) virtual, larger than the object and upright.
- (B) virtual, smaller than the object and upright.
- (C) virtual, smaller than the object and inverted.
- (D) real, smaller than the object and inverted.
- (E) real, larger than the object and inverted.

[PhysicsBowl, 2008Q29]

A strong bar magnet is held very close to the opening of a solenoid as shown in the diagram. As the magnet is moved away from the solenoid at constant speed, what is the direction of conventional current through the resistor shown and what is the direction of the force on the magnet because of the induced current?



	Current through resistor	Force on Magnet
(A)	From A to B	To the left
(B)	From B to A	To the left
(C)	From A to B	To the right
(D)	From B to A	To the right
(E)	No current	To the right

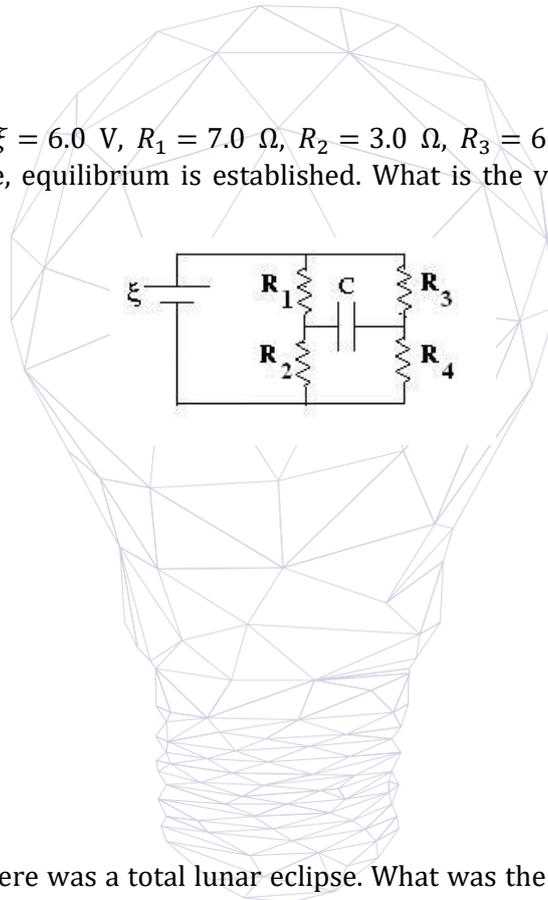
[PhysicsBowl, 2008Q30]

A light beam passes through the air and strikes the surface of a plastic block. Which pair of statements correctly describes the phase changes for the reflected wave and the transmitted wave?

	Reflected	Transmitted wave
(A)	90°	90°
(B)	No phase change	180°
(C)	No phase change	No phase change
(D)	180°	180°
(E)	180°	No phase change

[PhysicsBowl, 2008Q31]

For the circuit shown,  $\xi = 6.0 \text{ V}$ ,  $R_1 = 7.0 \text{ }\Omega$ ,  $R_2 = 3.0 \text{ }\Omega$ ,  $R_3 = 6.0 \text{ }\Omega$ , and  $R_4 = 12.0 \text{ }\Omega$ . After operating for a long time, equilibrium is established. What is the voltage across the capacitor at equilibrium?



- (A) 6.0 V
- (B) 4.2 V
- (C) 3.0 V
- (D) 2.2 V
- (E) 0.2 V



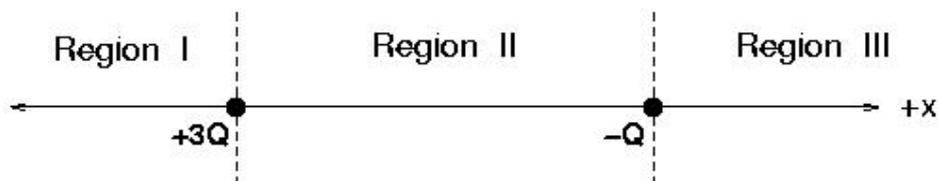
[PhysicsBowl, 2008Q32]

On February 20, 2008, there was a total lunar eclipse. What was the phase of the Moon during the eclipse?

- (A) New Moon
- (B) Full Moon
- (C) Dark Moon
- (D) Last Quarter
- (E) First Quarter

**Question 33 and 34 refer to the following scenario:**

Two point charges are fixed on the  $x$ -axis in otherwise empty space as shown below.



[PhysicsBowl, 2008Q33]

In which Region(s) is there a place on the  $x$ -axis (aside from infinity) at which the electric potential is equal to zero?

- (A) Only in Region II
- (B) Only in Region III
- (C) In both Regions I and II
- (D) In both Regions I and III
- (E) In both Regions II and III

[PhysicsBowl, 2008Q34]

In which Region(s) is there a place on the  $x$ -axis (aside from infinity) at which the electric field is equal to zero?

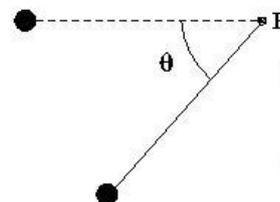
- (A) Only in Region II
- (B) Only in Region III
- (C) In both Regions I and II
- (D) In both Regions I and III
- (E) In both Regions II and III



[PhysicsBowl, 2008Q35]

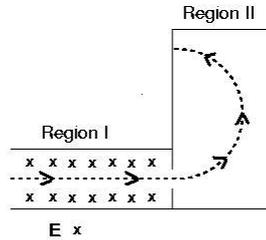
Astronauts on the Moon perform an experiment with a simple pendulum that is released from the horizontal position at rest. At the moment shown in the diagram with  $0^\circ < \theta < 90^\circ$ , the total acceleration of the mass may be directed in which of the following ways?

- (A) straight to the right
- (B) straight to the left
- (C) straight upward
- (D) straight downward
- (E) straight along the connecting string toward point  $P$  (the pivot)



[PhysicsBowl, 2008Q36]

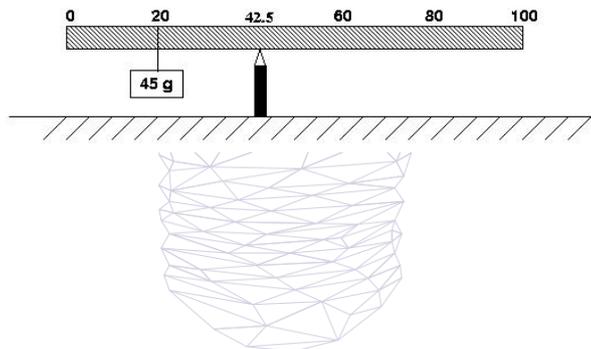
An electron moves in the plane of the page through two regions of space along the dotted-line trajectory shown in the figure. There is a uniform electric field in Region I directed into the plane of the page (as shown). There is no electric field in Region II. What is a necessary direction of the magnetic field in regions I and II? Ignore gravitational forces.



	Region I	Region II
(A)	Down the plane of the page	Up the plane of the page
(B)	Up the plane of the page	Into the plane of the page
(C)	Up the plane of the page	Out of the plane of the page
(D)	Down the plane of the page	Out of the plane of the page
(E)	Into the plane of the page	Up the plane of the page

[PhysicsBowl, 2008Q37]

A uniform meter stick has a 45.0 g mass placed at the 20 cm mark as shown in the figure. If a pivot is placed at the 42.5 cm mark and the meter stick remains horizontal in static equilibrium, what is the mass of the meter stick?



- (A) 18.0 g
- (B) 45.0 g
- (C) 72.0 g
- (D) 120.0 g
- (E) 135.0 g

2008

[PhysicsBowl, 2008Q38]

A 1200 kg satellite orbits Planet  $X$  in a circular orbit with a constant speed of  $5.00 \times 10^3$  m/s. The radius of orbit is  $7.50 \times 10^7$  m. What is the magnitude of the gravitational force exerted on the satellite by Planet  $X$ ?

- (A) 400 N
- (B) 200 N
- (C) 0.080 N
- (D) 0.0127 N
- (E) More information is required to answer this question.

[PhysicsBowl, 2008Q39]

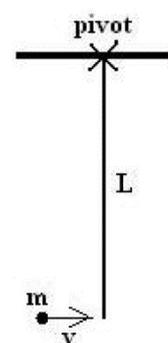
An ideal gas is enclosed in a container. The volume of the container is reduced to half the original volume at constant temperature. According to kinetic theory, what is the best explanation for the increase in pressure created by the gas?

- (A) The average speed of the gas particles decreases, but they hit the container walls more frequently.
- (B) The average speed of the gas particles is unchanged, but they hit the container walls more frequently.
- (C) The average speed of the gas particles increases as does the frequency with which they hit the container walls.
- (D) The average speed of the gas particles increases, overcoming the decreased frequency that they hit the container walls.
- (E) The internal energy of the gas increases.

[PhysicsBowl, 2008Q40]

A point particle of mass  $m$  collides with a thin rod pivoted at one end. The rod has mass  $M = 2m$ , length  $L$ , and moment of inertia  $I = \frac{1}{3}ML^2$ . The particle moves horizontally with speed  $V$  when it hits the bottom of the rod and sticks to it. What is the speed of the particle immediately after collision?

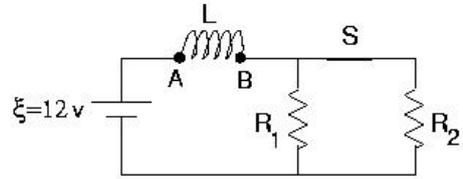
- (A)  $\frac{1}{3}V$
- (B)  $\frac{1}{\sqrt{3}}V$
- (C)  $\frac{3}{5}V$
- (D)  $\frac{3}{4}V$
- (E)  $\frac{\sqrt{3}}{2}V$



[PhysicsBowl, 2008Q41]

The circuit shown has been operating for a long time. The instant after the switch in the circuit labeled  $S$  is *opened*, what is the voltage across the inductor  $V_L$  and which labeled point ( $A$  or  $B$ ) of the inductor is at a higher potential? Take  $R_1 = 4.0 \Omega$ ,  $R_2 = 8.0 \Omega$ , and  $L = 2.5 \text{ H}$ .

- (A)  $V_L = 30 \text{ V}$ ; Points  $A$  and  $B$  are at equal potentials.
- (B)  $V_L = 12 \text{ V}$ ; Point  $A$  is at the higher potential.
- (C)  $V_L = 12 \text{ V}$ ; Point  $B$  is at the higher potential.
- (D)  $V_L = 6 \text{ V}$ ; Point  $A$  is at the higher potential.
- (E)  $V_L = 6 \text{ V}$ ; Point  $B$  is at the higher potential.



[PhysicsBowl, 2008Q42]

A parallel-plate capacitor is connected to a battery. Without disconnecting the capacitor, a student pulls the capacitor's plates apart so that the plate separation doubles. As a result of this action, what happens to the voltage across the capacitor and the energy stored by the capacitor?

- (A) the voltage doubles; the energy stays the same
- (B) the voltage halves; the energy doubles
- (C) the voltage doubles; the energy halves
- (D) the voltage stays the same; the energy halves
- (E) the voltage stays the same; the energy doubles

2008  
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15

[PhysicsBowl, 2008Q43]

Unpolarized light of intensity  $I_0$  enters a polarizer-analyzer system in which the angle between the transmission axes of the polarizer and analyzer is  $30^\circ$ . What is the intensity of the light leaving the analyzer?

- (A)  $\frac{3}{8} I_0$
- (B)  $\frac{1}{8} I_0$
- (C)  $\frac{3}{4} I_0$
- (D)  $\frac{1}{4} I_0$
- (E)  $\frac{1}{2} I_0$

[PhysicsBowl, 2008Q44]

A mole of a monatomic ideal gas has pressure  $P$ , volume  $V$ , and temperature  $T$ . Which of the following processes would result in the greatest amount of energy added to the gas from heat?

- (A) A process doubling the temperature at constant pressure.
- (B) An adiabatic free expansion doubling the volume.
- (C) A process doubling the pressure at constant volume.
- (D) An adiabatic expansion doubling the volume.
- (E) A process doubling the volume at constant temperature.

[PhysicsBowl, 2008Q45]

Electron #1 moves with speed  $0.30c$  where  $c$  is the speed of light. Electron #2 moves with speed  $0.60c$ . What is the ratio of the kinetic energy of electron #2 to electron #1?

- (A) 1.19
- (B) 1.32
- (C) 2.00
- (D) 4.00
- (E) 5.18

[PhysicsBowl, 2008Q46]

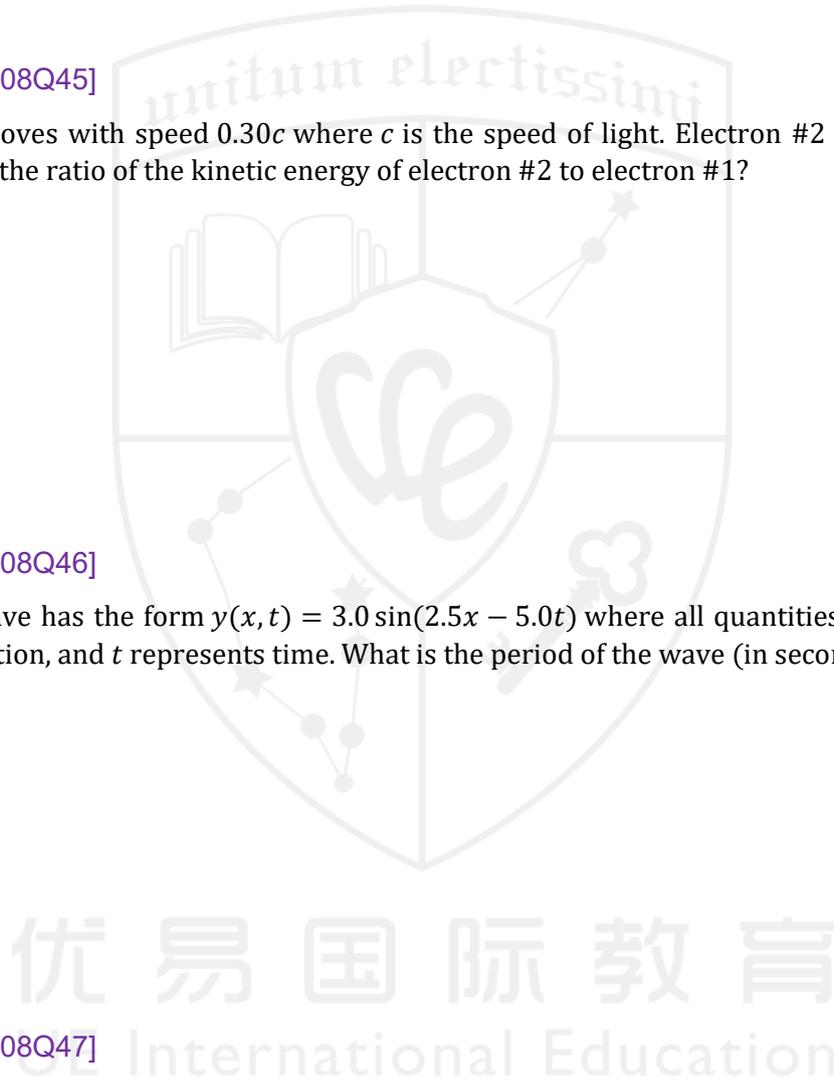
A traveling wave has the form  $y(x, t) = 3.0 \sin(2.5x - 5.0t)$  where all quantities given are in MKS units,  $x$  is position, and  $t$  represents time. What is the period of the wave (in seconds)?

- (A) 2.00
- (B) 1.26
- (C) 1.00
- (D) 0.63
- (E) 0.20

[PhysicsBowl, 2008Q47]

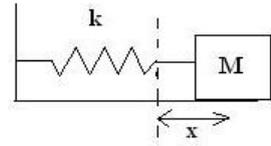
A radioactive sample decays with a half-life of 2.0 yr. Approximately how much time must pass so that only  $\frac{1}{3}$  of the original sample remains?

- (A) 6.0 yr
- (B) 3.4 yr
- (C) 3.2 yr
- (D) 3.0 yr
- (E) 2.8 yr



[PhysicsBowl, 2008Q48]

A block of mass  $M$  on a horizontal surface is connected to the end of a massless spring of spring constant  $k$ . The block is pulled a distance  $x$  from equilibrium and when released from rest, the block moves toward equilibrium. What minimum coefficient of kinetic friction between the surface and the block would prevent the block from returning to equilibrium with non-zero speed?



- (A)  $\frac{kx^2}{2Mg}$
- (B)  $\frac{kx}{Mg}$
- (C)  $\frac{kx}{2Mg}$
- (D)  $\frac{Mg}{2kx}$
- (E)  $\frac{k}{4Mgx}$

[PhysicsBowl, 2008Q49]

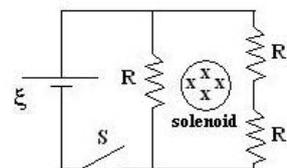
A circuit consists of a resistor, capacitor, and inductor connected in series to an AC source. As the source frequency increases, the current in the circuit decreases. Which statement about the circuit is **NOT** correct as the source frequency increases?

- (A) The impedance of the circuit increases.
- (B) The circuit is said to become more capacitive than inductive.
- (C) The phase angle for the circuit becomes more positive.
- (D) The inductive reactance increases.
- (E) The total power from the source decreases.



[PhysicsBowl, 2008Q50]

An infinitely long solenoid passes through the circuit as shown. The magnetic field of the solenoid, directed into the plane of the page, is weakening which produces a constant emf of magnitude  $\xi$  for a closed loop around the outside of the solenoid. Once equilibrium is established in this circuit, what is the voltage across the switch  $S$ ?



- (A) 0
- (B)  $\frac{1}{3}\xi$
- (C)  $\frac{2}{3}\xi$
- (D)  $\xi$
- (E)  $\frac{4}{3}\xi$

# PhysicsBowl 2009

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2009

[Online Exam](#)

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2009Q1]

Approximately how many seconds is it until the PhysicsBowl takes place in the year 2109?

- (A)  $10^2$
- (B)  $10^7$
- (C)  $10^8$
- (D)  $10^9$
- (E)  $10^{12}$

[PhysicsBowl, 2009Q2]

A room has a floor area of  $25 \text{ m}^2$ . What is this area written in  $\text{cm}^2$ ?

- (A) 25,000,000
- (B) 250,000
- (C) 2500
- (D) 0.25
- (E) 0.0025

[PhysicsBowl, 2009Q3]

Which one of the following quantities can have its unit expressed as  $\text{kg}\cdot\text{m}/\text{s}^2$ ?

- (A) Force
- (B) Power
- (C) Energy
- (D) Pressure
- (E) Linear Momentum

2009

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2

[PhysicsBowl, 2009Q4]

The length measurement  $L = 0.01230 \text{ cm}$  has how many significant digits?

- (A) 6
- (B) 5
- (C) 4
- (D) 3
- (E) 2

[PhysicsBowl, 2009Q5]

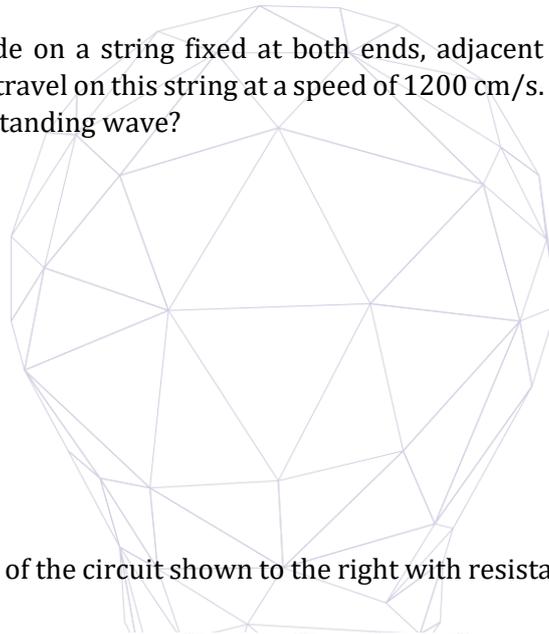
At an instant of time, a block of mass 0.50 kg has a position of 3.0 m, a speed of 4.0 m/s, and an acceleration of 1.0 m/s<sup>2</sup>. What is the block's kinetic energy (in Joules) at this instant?

- (A) 1.0
- (B) 1.5
- (C) 2.0
- (D) 4.0
- (E) 8.0

[PhysicsBowl, 2009Q6]

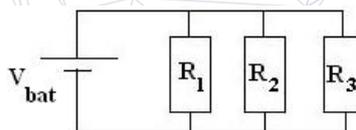
For a standing wave mode on a string fixed at both ends, adjacent antinodes are separated by a distance of 20 cm. Waves travel on this string at a speed of 1200 cm/s. At what frequency is the string vibrated to produce this standing wave?

- (A) 120 Hz
- (B) 60 Hz
- (C) 40 Hz
- (D) 30 Hz
- (E) 20 Hz



[PhysicsBowl, 2009Q7]

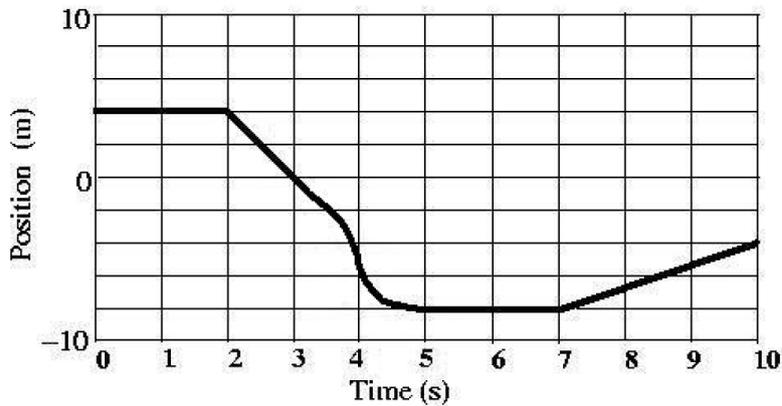
The equivalent resistance of the circuit shown to the right with resistances  $R_1 = 4.00 \Omega$ ,  $R_2 = 3.00 \Omega$  and  $R_3 = 2.00 \Omega$  is



- (A) 0.111  $\Omega$
- (B) 0.923  $\Omega$
- (C) 1.08  $\Omega$
- (D) 3.00  $\Omega$
- (E) 9.00  $\Omega$

[PhysicsBowl, 2009Q8]

Consider the motion of an object given by the position vs. time graph shown. For what time(s) is the speed of the object greatest?

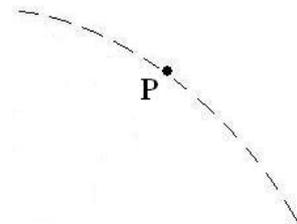


- (A) At all times from  $t = 0.0 \text{ s} \rightarrow t = 2.0 \text{ s}$
- (B) At time  $t = 3.0 \text{ s}$
- (C) At time  $t = 4.0 \text{ s}$
- (D) At all times from  $t = 5.0 \text{ s} \rightarrow t = 7.0 \text{ s}$
- (E) At time  $t = 8.5 \text{ s}$

[PhysicsBowl, 2009Q9]

The free fall trajectory of an object thrown horizontally from the top of a building is shown as the dashed line in the figure. Which sets of arrows best correspond to the directions of the velocity and of the acceleration for the object at the point labeled  $P$  on the trajectory?

- |     | velocity | acceleration |
|-----|----------|--------------|
| (A) | ↘        | ↓            |
| (B) | →        | ↓            |
| (C) | →        | ↖            |
| (D) | ↘        | ↙            |
| (E) | ↘        | ↘            |



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[PhysicsBowl, 2009Q10]

A car with mass  $M$  initially travels to the East with speed  $4V$ . A truck initially travels to the West with speed  $3V$ . After the vehicles collide, they move together to the West with common speed  $2V$ . What is the mass of the truck?

- (A)  $2M$
- (B)  $3M$
- (C)  $4M$
- (D)  $5M$
- (E)  $6M$

[PhysicsBowl, 2009Q11]

What is the orientation of the Earth, Sun and Moon during a total lunar eclipse?

- (A) The Sun is between the Earth and Moon.
- (B) The Earth is between the Sun and Moon.
- (C) The Moon is between the Sun and Earth.
- (D) The Earth, Moon and Sun make a right triangle.
- (E) The Earth is above the Sun and Moon.

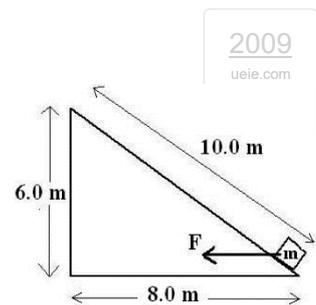
[PhysicsBowl, 2009Q12]

A 5.0 kg solid sphere is in free fall near the surface of the Earth. What is the magnitude of the gravitational force acting *on the Earth by the solid sphere*? The Earth's mass is  $5.98 \times 10^{24}$  kg.

- (A) 0 N
- (B) 5N
- (C) It is immeasurably small, but not zero.
- (D) 50 N
- (E)  $5.98 \times 10^{25}$  N

Questions 13 – 14 deal with the following information:

In the figure to the right, a box moves with speed 5.00 m/s at the bottom of a rough, fixed inclined plane. The box slides with constant acceleration to the top of the incline as it is being pushed directly to the left with a constant force of  $F = 240$  N. The box, of mass  $m = 20.0$  kg, has a speed of 2.50 m/s when it reaches the top of the incline.



[PhysicsBowl, 2009Q13]

What is the magnitude of the acceleration of the box as it slides the incline?

- (A)  $12.0 \text{ m/s}^2$
- (B)  $10.0 \text{ m/s}^2$
- (C)  $5.88 \text{ m/s}^2$
- (D)  $1.88 \text{ m/s}^2$
- (E)  $0.938 \text{ m/s}^2$

[PhysicsBowl, 2009Q14]

How much work is done by the applied force,  $F$ , to the box?

- (A) 2400 J
- (B) 1920 J
- (C) 1200 J
- (D) 988.5 J
- (E) -187.5 J

[PhysicsBowl, 2009Q15]

An ideal gas in a closed container of volume 6.0 L is at a temperature of 100 °C. If the pressure of the gas is 2.5 atm, how many moles of gas are in the container?

- (A) 0.0048
- (B) 0.018
- (C) 0.49
- (D) 1.83
- (E) 490

[PhysicsBowl, 2009Q16]

What condition *must* be met in order to use the rotational kinematics equation  $\Delta\theta = \omega_0 t + \frac{1}{2}\alpha t^2$ ?

- (A) The angular acceleration is constant.
- (B) The angular velocity is constant.
- (C) The linear acceleration is zero.
- (D) The angular acceleration is zero.
- (E) There is no restriction on the use of this equation.



[PhysicsBowl, 2009Q17]

A toy car moves 3.0 m to the North in one second. The car then moves at 9.0 m/s due South for two seconds. What is the average speed of the car for this three second trip?

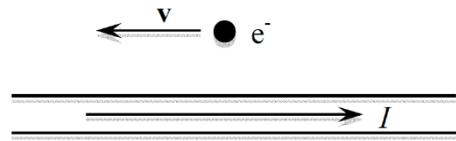
- (A) 4.0 m/s
- (B) 5.0 m/s
- (C) 6.0 m/s
- (D) 7.0 m/s
- (E) 12.0 m/s

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[PhysicsBowl, 2009Q18]

A wire has a conventional current  $I$  directed to the right. At the instant shown in the figure, an electron has a velocity directed to the left. The magnetic force on the electron at this instant is

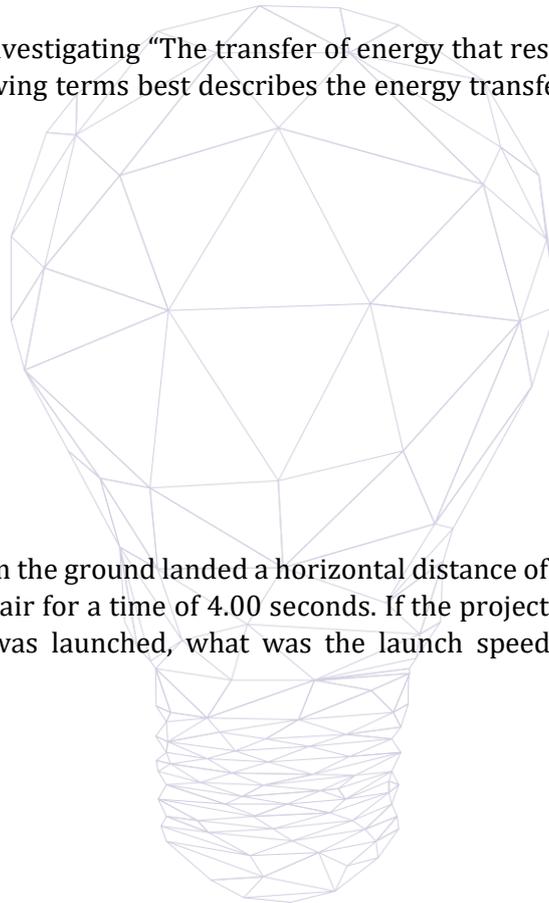
- (A) zero.
- (B) directed out of the plane of the page.
- (C) directed into the plane of the page.
- (D) directed toward the top of the page.
- (E) directed toward the bottom of the page.



[PhysicsBowl, 2009Q19]

A scientist claims to be investigating “The transfer of energy that results from the bulk motion of a fluid.” Which of the following terms best describes the energy transfer method that this scientist is studying?

- (A) radiation
- (B) convection
- (C) conduction
- (D) latent heat
- (E) specific heat



[PhysicsBowl, 2009Q20]

A projectile launched from the ground landed a horizontal distance of 120.0 m from its launch point. The projectile was in the air for a time of 4.00 seconds. If the projectile landed at the same vertical position from which it was launched, what was the launch speed of the projectile? Ignore air resistance.

- (A) 22.4 m/s
- (B) 30.0 m/s
- (C) 36.1 m/s
- (D) 42.4 m/s
- (E) 50.0 m/s

## [PhysicsBowl, 2009Q21]

A 20.0 kg box remains at rest on a horizontal surface while a person pushes directly to the right on the box with a force of 60 N. The coefficient of kinetic friction between the box and the surface is  $\mu_k = 0.20$ . The coefficient of static friction between the box and the surface is  $\mu_s = 0.60$ . What is the magnitude of the force of friction acting on the box during the push?

- (A) 200 N
- (B) 120 N
- (C) 60 N
- (D) 40 N
- (E) 0 N

## [PhysicsBowl, 2009Q22]

A point object is connected to the end of a long string of negligible mass and the system swings as a simple pendulum with period  $T$ . What is the period of the pendulum if the string is made to have one-quarter of its original length?

- (A)  $4T$
- (B)  $2T$
- (C)  $T$
- (D)  $T/2$
- (E)  $T/4$

## [PhysicsBowl, 2009Q23]

A person rubs a neutral comb through their hair and the comb becomes negatively charged. Which of the following is the best explanation for this phenomenon?

- (A) The hair gains protons from the comb.
- (B) The hair gains protons from the comb while giving electrons to the comb.
- (C) The hair loses electrons to the comb.
- (D) The comb loses protons to the person's hand holding the comb.
- (E) The comb loses protons to the person's hand while also gaining electrons from the hair.

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[PhysicsBowl, 2009Q24]

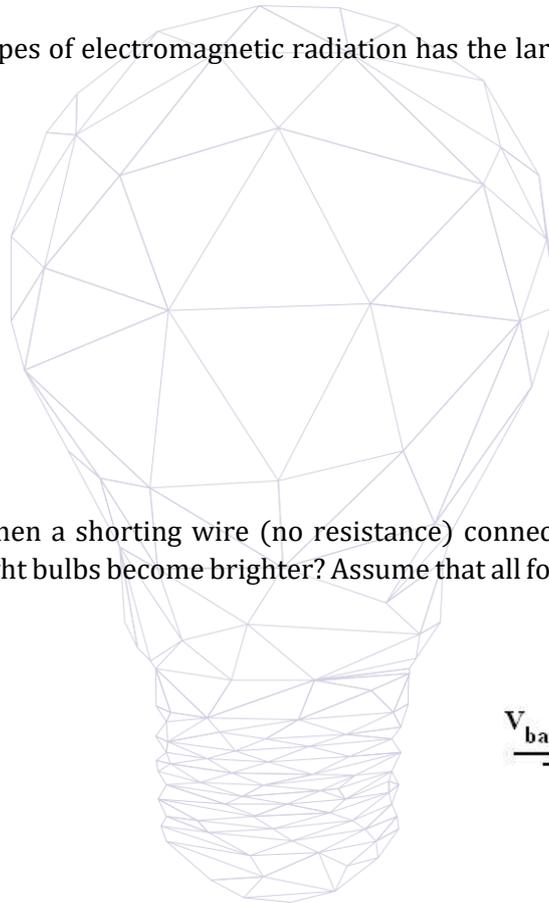
A point mass moves along a horizontal circular path of radius 8.0 m with a constant kinetic energy of 128 J. What is the magnitude of the net force acting on the mass as it moves?

- (A) 64 N
- (B) 32 N
- (C) 16 N
- (D) 8 N
- (E) 0 N

[PhysicsBowl, 2009Q25]

Which of the following types of electromagnetic radiation has the largest magnitude of momentum per photon?

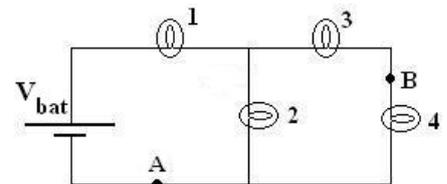
- (A) FM radio
- (B) Microwaves
- (C) Violet light
- (D) Infrared light
- (E) Gamma rays



[PhysicsBowl, 2009Q26]

For the circuit shown, when a shorting wire (no resistance) connects the points labeled *A* and *B*, which of the numbered light bulbs become brighter? Assume that all four bulbs are identical and have resistance *R*.

- (A) Bulb 1 only
- (B) Bulb 2 only
- (C) Bulb 3 only
- (D) Bulbs 1 and 3 only
- (E) Bulbs 1, 2 and 3



[PhysicsBowl, 2009Q27]

A proton moves straight up the plane of this page into a region that has a magnetic field directed to the right. If the particle is undeflected as it passes through this region, in what direction must there be a component of electric field? Ignore gravity.

- (A) To the left
- (B) Into the page
- (C) Out of the page
- (D) Down the page
- (E) To the right

[PhysicsBowl, 2009Q28]

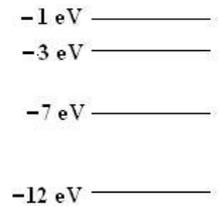
White light shines through ideal filters to produce cyan light. If an ideal pigment appears yellow in white light, what color does the pigment appear in the cyan light?

- (A) magenta
- (B) yellow
- (C) blue
- (D) red
- (E) green

[PhysicsBowl, 2009Q29]

The diagram to the right shows the lowest four energy levels for an electron in a hypothetical atom. The electron is excited to the  $-1$  eV level of the atom and transitions to the lowest energy state by emitting only two photons. Which of the following energies could not belong to either of the photons?

- (A) 2 eV
- (B) 4 eV
- (C) 5 eV
- (D) 6 eV
- (E) 9 eV



[PhysicsBowl, 2009Q30]

In terms of the seven fundamental SI units in the MKS system, the Ohm is written as

- (A)  $\frac{\text{kg}\cdot\text{m}^2}{\text{A}^2\cdot\text{s}^3}$
- (B)  $\frac{\text{kg}\cdot\text{m}^2\cdot\text{s}}{\text{C}^2}$
- (C)  $\frac{\text{kg}\cdot\text{m}}{\text{C}\cdot\text{s}}$
- (D)  $\frac{\text{kg}\cdot\text{m}^2}{\text{A}\cdot\text{s}^2}$
- (E)  $\frac{\text{kg}\cdot\text{s}^2}{\text{A}^2\cdot\text{m}^2}$

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[PhysicsBowl, 2009Q31]

A car moves to the right along a one-dimensional track for total time  $T$  in two parts.

- Part One: The car maintains constant non-zero speed  $V$  for the first  $\frac{3}{4}$  of the total time.
- Part Two: The car accelerates uniformly to rest during the last  $\frac{1}{4}$  of the total time.

What is the ratio of the distance traveled during Part One of the trip to the distance traveled during Part Two of the trip?

- (A) 6 : 1
- (B) 3 : 2
- (C) The values of  $V$  and  $T$  are required to answer the question.
- (D) 4 : 3
- (E) 8 : 3

[PhysicsBowl, 2009Q32]

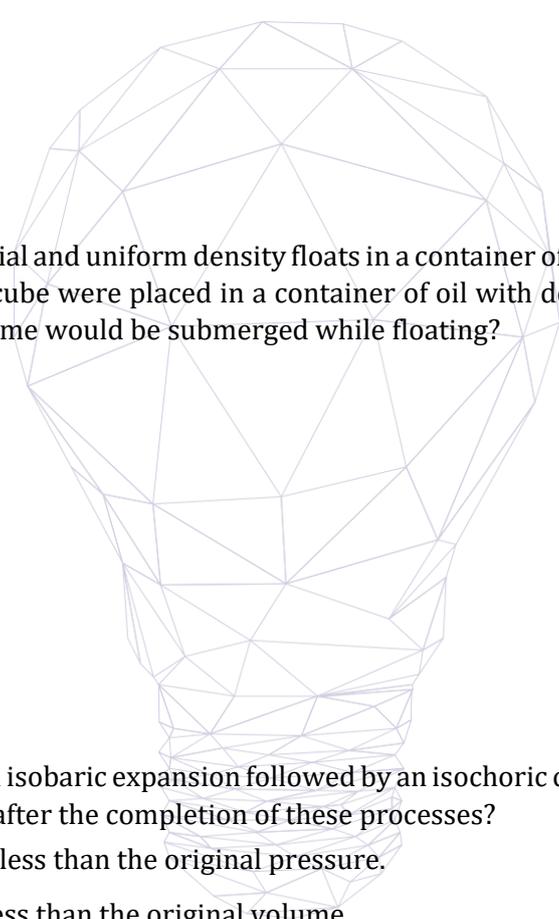
A cube of unknown material and uniform density floats in a container of water with 60% of its volume submerged. If this same cube were placed in a container of oil with density  $\rho_{\text{oil}} = 800 \text{ kg/m}^3$ , what portion of the cube's volume would be submerged while floating?

- (A) 33%
- (B) 50%
- (C) 58%
- (D) 67%
- (E) 75%

[PhysicsBowl, 2009Q33]

An ideal gas undergoes an isobaric expansion followed by an isochoric cooling. Which of the following statements *must* be true after the completion of these processes?

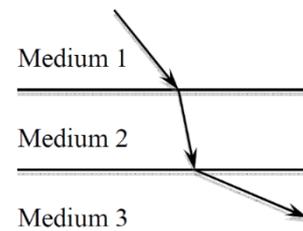
- (A) The final pressure is less than the original pressure.
- (B) The final volume is less than the original volume.
- (C) The final temperature is less than the original temperature.
- (D) The total quantity of heat,  $Q$ , associated with these processes is positive.
- (E) The internal energy of the gas is unchanged.



[PhysicsBowl, 2009Q34]

The diagram below shows the path taken by a monochromatic light ray traveling through three media. The symbols  $v_1$ ,  $\lambda_1$  and  $f_1$  represent the speed, wavelength, and frequency of the light in Medium 1, respectively. Which of the following relationships for the light in the three media is true?

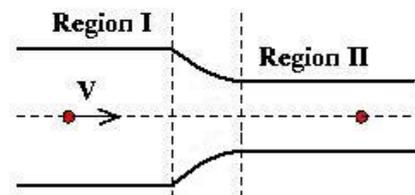
- (A)  $\lambda_1 < \lambda_3 < \lambda_2$
- (B)  $v_2 < v_3 < v_1$
- (C)  $f_2 < f_1 < f_3$
- (D)  $v_3 < v_1 < v_2$
- (E)  $\lambda_2 < \lambda_1 < \lambda_3$



[PhysicsBowl, 2009Q35]

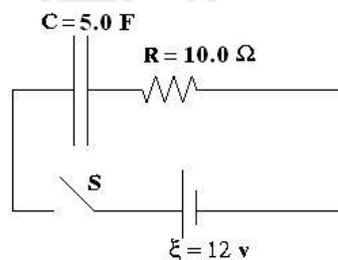
A piece of an ideal fluid is marked as it moves along a horizontal streamline through a pipe, as shown in the figure. In Region I, the speed of the fluid on the streamline is  $V$ . The cylindrical, horizontal pipe narrows so that the radius of the pipe in Region II is half of what it was in Region I. What is the speed of the marked fluid when it is in Region II?

- (A)  $4V$
- (B)  $V/2$
- (C)  $2V$
- (D)  $V/4$
- (E)  $V$



[PhysicsBowl, 2009Q36]

For the  $RC$  circuit shown, the resistance is  $R = 10.0 \Omega$ , the capacitance is  $C = 5.0 \text{ F}$  and the battery has voltage  $\xi = 12$  volts. The capacitor is initially uncharged when the switch  $S$  is closed at time  $t = 0$ . At some time later, the current in the circuit is  $0.50 \text{ A}$ . What is the magnitude of the voltage across the capacitor at that moment?

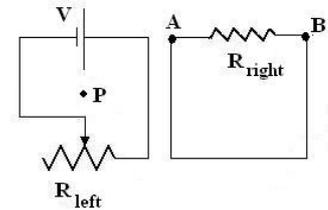


- (A) 0 volts
- (B) 5 volts
- (C) 6 volts
- (D) 7 volts
- (E) 12 volts

[PhysicsBowl, 2009Q37]

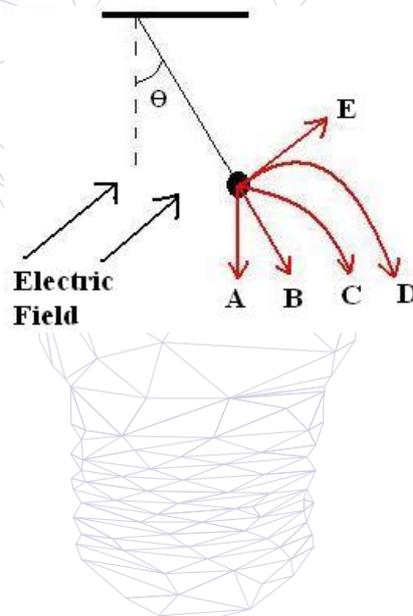
For the figure shown, the variable resistance in the circuit on the left is increased at a constant rate. What is the direction of the magnetic field at the point  $P$  at the center of the left-hand circuit and in what direction is the conventional current through the resistor in the right-hand circuit?

	Magnetic Field at $P$	Current through resistor
(A)	Into the page	From $B$ to $A$
(B)	Into the page	From $A$ to $B$
(C)	Out of the page	From $B$ to $A$
(D)	Out of the page	From $A$ to $B$
(E)	There is no field	There is no current



[PhysicsBowl, 2009Q38]

A small object of mass  $M$  and charge  $Q$  is connected to an insulating massless string in a vacuum on Earth. A uniform electric field exists throughout the region of the vacuum as indicated. The mass remains in static equilibrium at an angle of  $\theta$  with the vertical as shown in the figure. When the string is cut, which of the illustrated paths best indicates the trajectory of the mass?

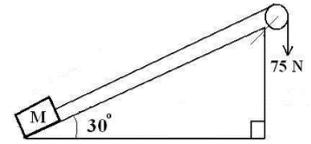


- (A) A
- (B) B
- (C) C
- (D) D
- (E) E



[PhysicsBowl, 2009Q39]

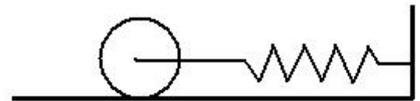
For the compound machine comprised of the inclined plane and pulley shown, a 75.0 N force is required to slide a box with mass  $M = 10.0$  kg up the incline at a constant speed. What is the efficiency of this compound machine?



- (A)  $\frac{1}{3}$
- (B)  $\frac{3}{8}$
- (C)  $\frac{1}{2}$
- (D)  $\frac{2}{3}$
- (E)  $\frac{3}{4}$

[PhysicsBowl, 2009Q40]

A uniform solid cylinder of mass  $M = 2.00$  kg and radius  $R = 10.0$  cm is connected about an axis through the center of the cylinder to a horizontal spring with spring constant 4.00 N/m. The cylinder is pulled back, stretching the spring 1.00 m from equilibrium. When released, the cylinder rolls without slipping. What is the speed of the center of the cylinder when it returns to equilibrium?

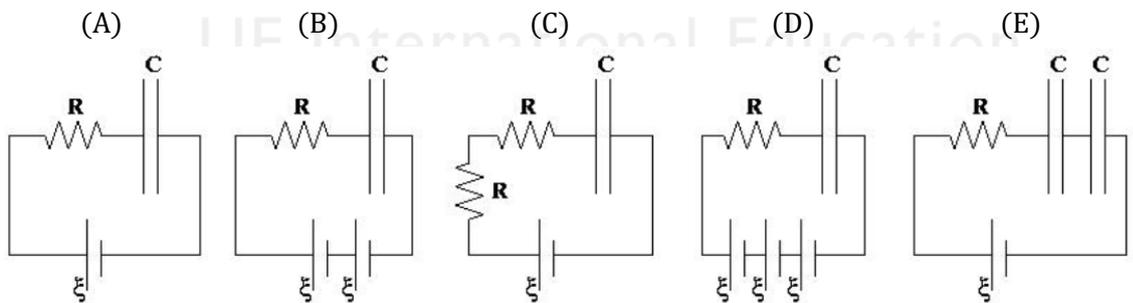


- (A) 0.577 m/s
- (B) 1.00 m/s
- (C) 1.15 m/s
- (D) 1.22 m/s
- (E) 1.41 m/s



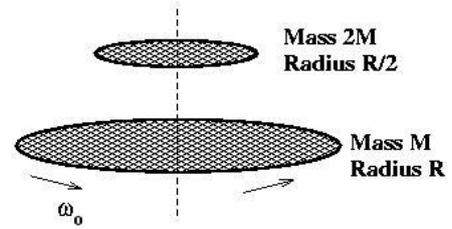
[PhysicsBowl, 2009Q41]

For the circuits shown below, which will take the least time to charge the capacitor(s) to 90% of the full charge? All batteries are ideal and identical with emf  $\xi$ , all resistors are identical with resistance  $R$ , and all capacitors are identical with capacitance  $C$  and are initially uncharged.



[PhysicsBowl, 2009Q42]

A uniform, solid disk with mass  $M$  and radius  $R$  is rotating on a fixed, frictionless platform with constant angular speed  $\omega_0$  about a fixed axis through its center. A second uniform solid disk of mass  $2M$  and radius  $\frac{R}{2}$  is placed from rest directly on top of the first disk so that the centers of the disks line up. When equilibrium is established, the disks are spinning at the same rate. What is the angular speed of the disks at equilibrium?



- (A)  $\frac{1}{4}\omega_0$
- (B)  $\frac{1}{3}\omega_0$
- (C)  $\frac{1}{2}\omega_0$
- (D)  $\frac{2}{3}\omega_0$
- (E)  $\sqrt{\frac{2}{3}}\omega_0$

[PhysicsBowl, 2009Q43]

A real object is located in front of a convex lens at a distance greater than the focal length of the lens. What type of image is formed and what is true of the image's size compared to that of the object?

	Type of Image	Size of Image
(A)	Real	Larger than object
(B)	Real	More information is needed
(C)	Virtual	Smaller than object
(D)	Virtual	Larger than object
(E)	More information is needed	More information is needed



[PhysicsBowl, 2009Q44]

In an ideal LC circuit, what is the time difference between all of the energy in the circuit being stored in the inductor and all of the energy being stored in the capacitor?

- (A) No time difference
- (B) One-eighth of a period of oscillation
- (C) One-quarter of a period of oscillation
- (D) One-half of a period of oscillation
- (E) After one full period of oscillation has passed

[PhysicsBowl, 2009Q45]

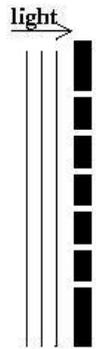
In neutron decay, the process is written as  $n \rightarrow p + e^- + \bar{\nu}$ , where  $\bar{\nu}$  is an antineutrino necessary to have conservation of momentum and energy. Who postulated the existence of neutrinos?

- (A) Pauli
- (B) Dirac
- (C) de Broglie
- (D) Heisenberg
- (E) Einstein

[PhysicsBowl, 2009Q46]

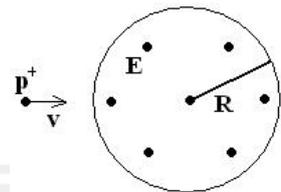
Monochromatic light is incident on a slide containing six infinitely thin, equally spaced slits as shown in the figure. The resulting interference pattern on a distant screen reveals a place of total destructive interference. Of the following, what must be the phase difference (in radians) between the electric fields from each of the adjacent slits for this location on the screen?

- (A) 0
- (B)  $\frac{\pi}{12}$
- (C)  $\frac{\pi}{6}$
- (D)  $\frac{\pi}{3}$
- (E)  $\frac{\pi}{2}$



[PhysicsBowl, 2009Q47]

A spatially uniform electric field is constrained within the circular region of radius  $R$  as shown. The field is directed out of the plane of the page and its strength is increasing uniformly in time. What is the direction of the force on the proton in the figure if the proton is moving to the right at the instant shown? Ignore gravity.



- (A) No Force
- (B) Up
- (C) Down
- (D) Out of the page
- (E) Into the page

**Questions 48 – 49 deal with the following information:**

An electromagnetic wave has an electric field given by the expression (in Cartesian coordinates):

$$\vec{E}(x, t) = 6.0 \cos(1.14 \times 10^7 x - 3.43 \times 10^{15} t) \hat{z}$$

[PhysicsBowl, 2009Q48]

What is the direction of the energy flow for the wave?

- (A)  $-x$
- (B)  $+x$
- (C)  $-y$
- (D)  $+y$
- (E)  $+z$

[PhysicsBowl, 2009Q49]

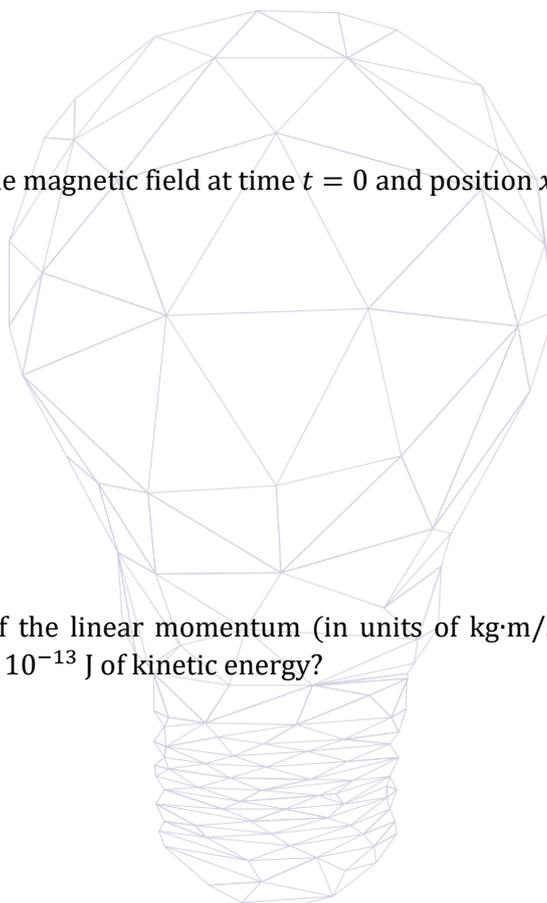
What is the direction of the magnetic field at time  $t = 0$  and position  $x = 0$ ?

- (A)  $-x$
- (B)  $+x$
- (C)  $-y$
- (D)  $+y$
- (E)  $+z$

[PhysicsBowl, 2009Q50]

What is the magnitude of the linear momentum (in units of kg·m/s) of an electron moving in a straight line if it has  $3.2 \times 10^{-13}$  J of kinetic energy?

- (A) 0
- (B)  $2.6 \times 10^{-22}$
- (C)  $7.6 \times 10^{-22}$
- (D)  $1.3 \times 10^{-21}$
- (E)  $1.9 \times 10^{-12}$



# PhysicsBowl 2010

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2007

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2010Q1]

The very first PhysicsBowl took place in 1985. Approximately how many seconds ago did students compete in this first contest?

- (A)  $10^2$
- (B)  $10^5$
- (C)  $10^7$
- (D)  $10^9$
- (E)  $10^{12}$

[PhysicsBowl, 2010Q2]

Which of the following is *NOT* a vector quantity?

- (A) Acceleration
- (B) Average Velocity
- (C) Linear Momentum
- (D) Potential Energy
- (E) Force

[PhysicsBowl, 2010Q3]

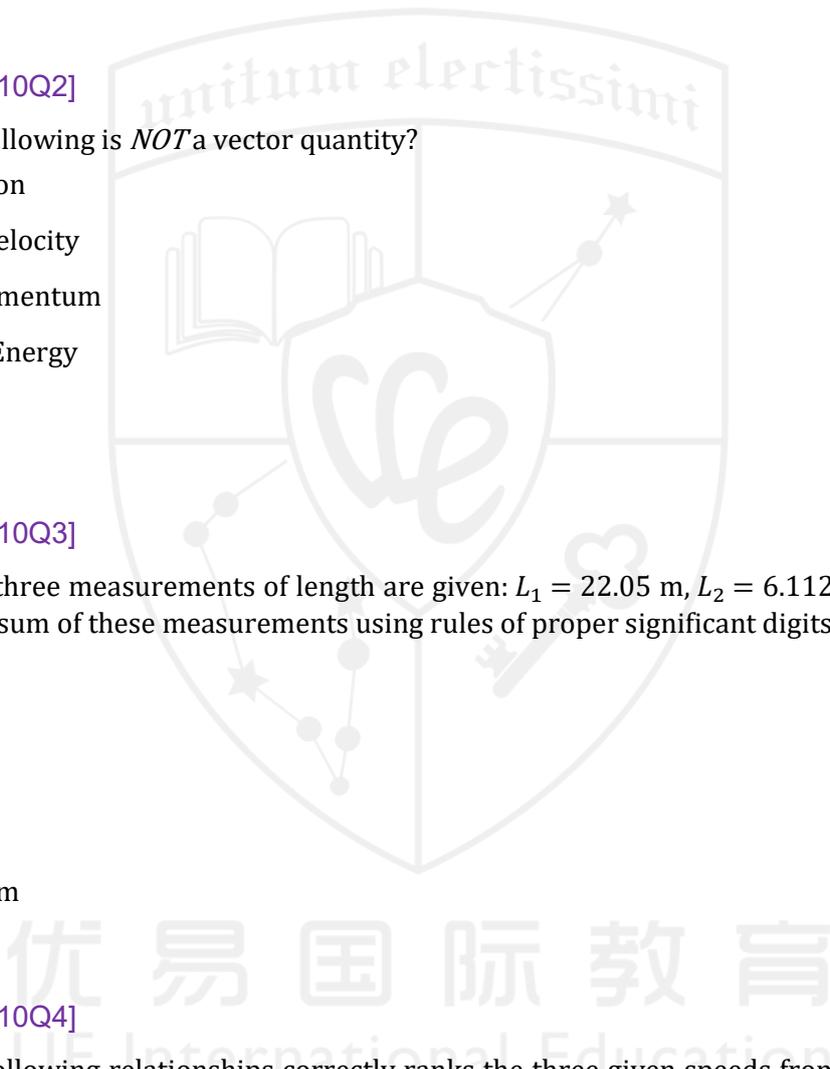
The following three measurements of length are given:  $L_1 = 22.05$  m,  $L_2 = 6.1123$  m and  $L_3 = 89.6$  m. What is the sum of these measurements using rules of proper significant digits?

- (A) 120 m
- (B) 118 m
- (C) 117.8 m
- (D) 117.76 m
- (E) 117.7623 m

[PhysicsBowl, 2010Q4]

Which of the following relationships correctly ranks the three given speeds from least to greatest? The speeds are given as  $v_1 = 1.25 \times 10^{-4}$  cm/ $\mu$ s,  $v_2 = 0.076$  Mm/week and  $v_3 = 9.50$  km/day.

- (A)  $v_1 < v_2 < v_3$
- (B)  $v_3 < v_2 < v_1$
- (C)  $v_2 < v_3 < v_1$
- (D)  $v_1 < v_3 < v_2$
- (E)  $v_3 < v_2 = v_1$



[PhysicsBowl, 2010Q5]

When computed with proper MKS units, the Universal Gas Constant divided by Boltzmann's constant is equal to

- (A) the speed of light.
- (B) Planck's constant.
- (C) Avogadro's number.
- (D) the permittivity of free space.
- (E) the Universal Gravitational constant.

[PhysicsBowl, 2010Q6]

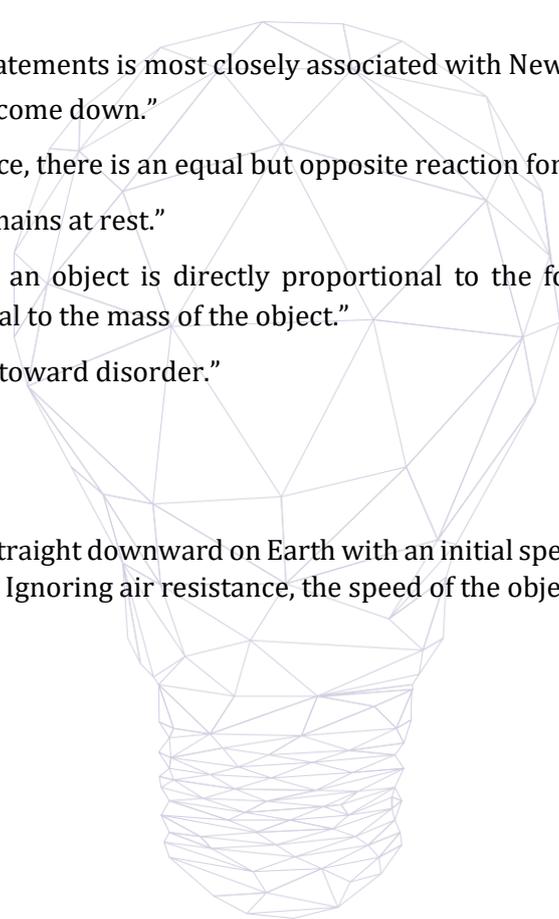
Which of the following statements is most closely associated with Newton's Third Law of Motion?

- (A) "What goes up must come down."
- (B) "For every action force, there is an equal but opposite reaction force."
- (C) "An object at rest remains at rest."
- (D) "The acceleration of an object is directly proportional to the force acting on the object but inversely proportional to the mass of the object."
- (E) "The Universe tends toward disorder."

[PhysicsBowl, 2010Q7]

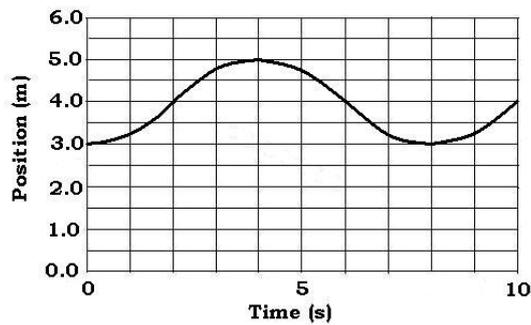
A small object is thrown straight downward on Earth with an initial speed of 12.0 m/s from a position 10.0 m above the ground. Ignoring air resistance, the speed of the object when it reaches the ground is

- (A) 18.4 m/s
- (B) 14.6 m/s
- (C) 14.0 m/s
- (D) 12.8 m/s
- (E) 12.0 m/s



The following information relates to Questions 8 and 9:

A mass is connected to the end of a spring and undergoes simple harmonic oscillation. The graph provided shows the position of the mass as measured from the floor as a function of time.



[PhysicsBowl, 2010Q8]

What is the period of the mass's oscillation (in units of seconds)?

- (A) 2.0
- (B) 4.0
- (C) 5.0
- (D) 8.0
- (E) 10.0

[PhysicsBowl, 2010Q9]

What is the amplitude of the mass's oscillation (in units of meters)?

- (A) 1.0
- (B) 2.0
- (C) 3.0
- (D) 4.0
- (E) 5.0

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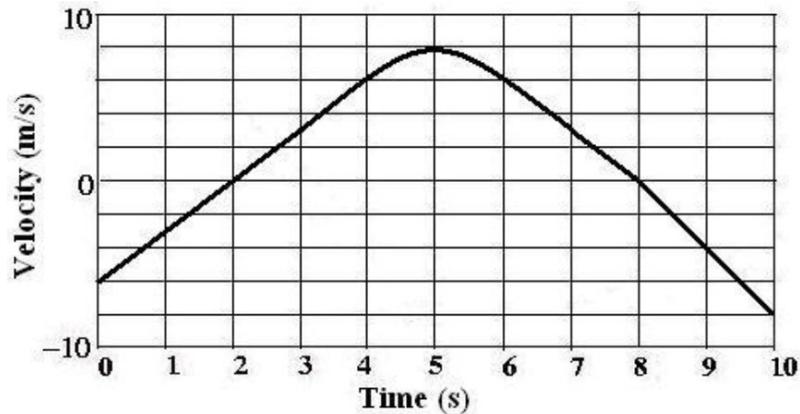
[PhysicsBowl, 2010Q10]

A particle travels at a constant speed around a circular path of radius  $R$ . If the particle makes one complete trip around the entire circle, what is the magnitude of the displacement for this trip?

- (A)  $\pi R$
- (B)  $2R$
- (C)  $2\pi R$
- (D)  $2\pi R^2$
- (E) 0

[PhysicsBowl, 2010Q11]

Consider the motion of an object given by the velocity vs. time graph shown. For which time(s) is the acceleration of the object equal to  $0 \text{ m/s}^2$ ?



- (A) Only at time  $t = 2.0 \text{ s}$
- (B) Only at time  $t = 5.0 \text{ s}$
- (C) Only at time  $t = 8.0 \text{ s}$
- (D) At times  $t = 2.0 \text{ s}$  and  $t = 5.0 \text{ s}$
- (E) At times  $t = 2.0 \text{ s}$ ,  $t = 5.0 \text{ s}$  and  $t = 8.0 \text{ s}$

[PhysicsBowl, 2010Q12]

A scientist sets up an experiment with a proton of charge  $+Q$  and mass  $M$  being placed near a helium nucleus (2 protons and 2 neutrons) of charge  $+2Q$  and mass  $4M$ . The objects are each released from rest and begin to move. From the scientist's point of view, which choice best describes the object that experiences the greatest magnitude of electric force from the other and which object experiences the greatest magnitude of acceleration? Ignore gravity.

	Largest magnitude of force	Largest magnitude of acceleration
(A)	The helium nucleus	The helium nucleus
(B)	The helium nucleus	The proton
(C)	The proton	The accelerations are equal
(D)	The forces are equal	The accelerations are equal
(E)	The forces are equal	The proton



[PhysicsBowl, 2010Q13]

The Large Hadron Collider (LHC) is the largest particle accelerator in the world. To which of the following countries would you have to travel in order to visit the LHC?

- (A) Germany
- (B) Italy
- (C) Switzerland
- (D) United States
- (E) Russia

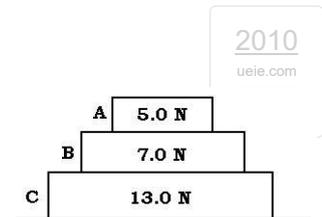
[PhysicsBowl, 2010Q14]

What temperature change on the Kelvin scale is equivalent to a 27 - degree change on the Celsius scale?

- (A) 300 K
- (B) 273 K
- (C) 246 K
- (D) 27 K
- (E) 9 K

[PhysicsBowl, 2010Q15]

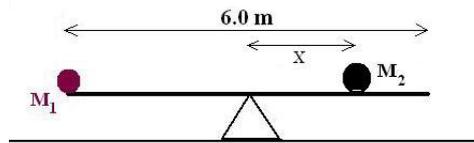
Three blocks, labeled *A*, *B* and *C*, remain at rest on a table. The magnitude of the gravitational force on each block is indicated on the figure. What is the magnitude of the contact force *on block C from block B*?



- (A) 1.0 N
- (B) 6.0 N
- (C) 7.0 N
- (D) 12.0 N
- (E) 13.0 N

[PhysicsBowl, 2010Q16]

A mass  $M_1 = 40$  kg is at the very edge of a 6.0 m long plank which is pivoted about its center of mass located directly at the center of its length. How far from the center of the plank should the mass  $M_2 = 80$  kg be placed so that the plank remains in static equilibrium in a horizontal position?

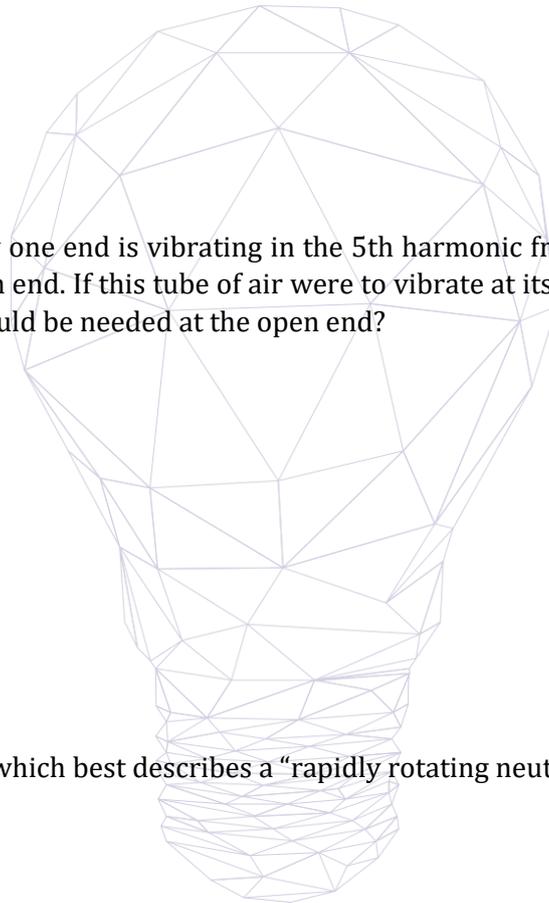


- (A) 0.50 m
- (B) 1.33 m
- (C) 1.50 m
- (D) 2.00 m
- (E) 3.00 m

[PhysicsBowl, 2010Q17]

A tube of air open at only one end is vibrating in the 5th harmonic from a tuning fork of frequency 120 Hz placed at the open end. If this tube of air were to vibrate at its fundamental frequency, what frequency tuning fork would be needed at the open end?

- (A) 24 Hz
- (B) 30 Hz
- (C) 40 Hz
- (D) 125 Hz
- (E) 600 Hz



[PhysicsBowl, 2010Q18]

Of the following choices, which best describes a “rapidly rotating neutron star emitting radiation”?

- (A) Supernova
- (B) Quasar
- (C) Nebula
- (D) White Dwarf
- (E) Pulsar

[PhysicsBowl, 2010Q19]

Which is the correct relationship for the speed ( $v$ ) of the following three electromagnetic waves in vacuum? The waves are: X-rays, UV rays, microwaves.

- (A)  $v_{\text{X-ray}} < v_{\text{microwaves}} < v_{\text{UV rays}}$
- (B)  $v_{\text{microwaves}} < v_{\text{UV rays}} < v_{\text{X-ray}}$
- (C)  $v_{\text{X-ray}} = v_{\text{microwaves}} = v_{\text{UV rays}}$
- (D)  $v_{\text{UV rays}} < v_{\text{microwaves}} < v_{\text{X-ray}}$
- (E)  $v_{\text{X-ray}} < v_{\text{UV rays}} < v_{\text{microwaves}}$

[PhysicsBowl, 2010Q20]

A sample of ideal gas is in a container at a temperature of 100 °C and a pressure of 2.50 atm. If the volume of the container is 25 L, approximately how many molecules of gas are in the container?

- (A)  $4.58 \times 10^{24}$
- (B)  $1.23 \times 10^{24}$
- (C)  $6.25 \times 10^{23}$
- (D)  $4.53 \times 10^{22}$
- (E)  $1.21 \times 10^{22}$

[PhysicsBowl, 2010Q21]

Which terminology is best associated with the amount of energy required to change the phase of a material per unit mass?

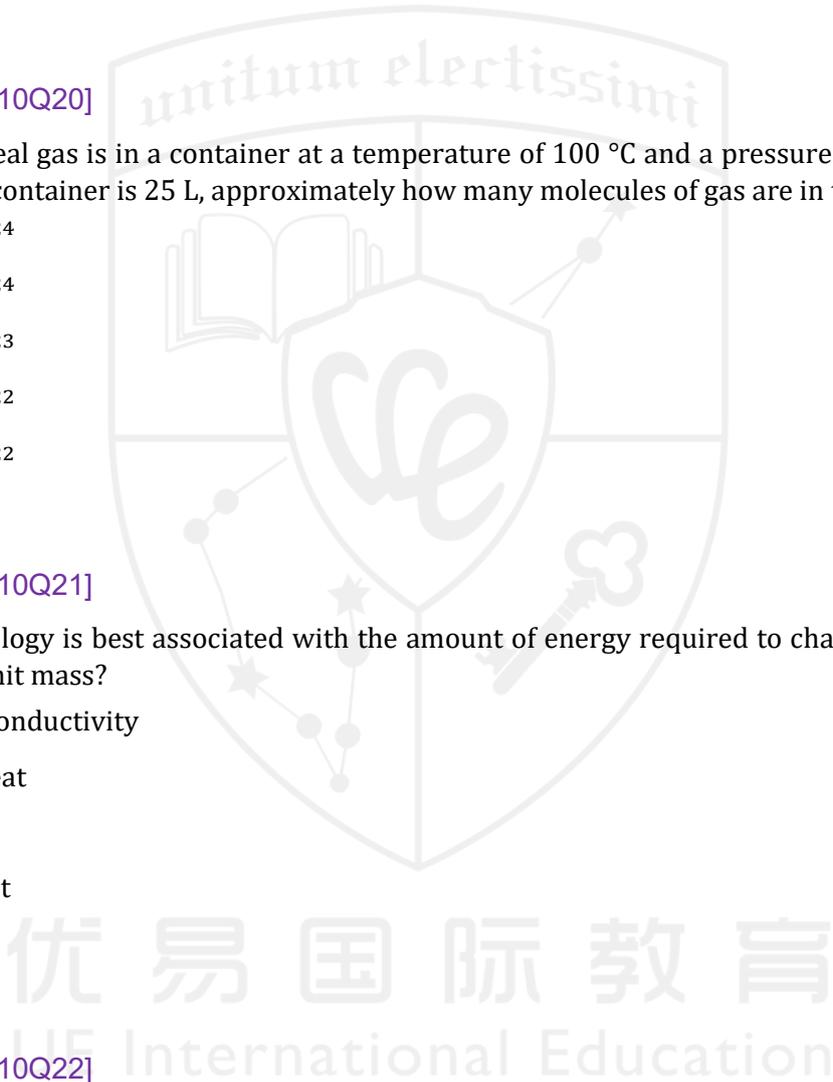
- (A) Thermal conductivity
- (B) Specific heat
- (C) Work
- (D) Latent heat
- (E) Entropy



[PhysicsBowl, 2010Q22]

A small and uniform 10.0 kg object floats at rest with 75% of the object submerged in a cubical tank containing 50.0 m<sup>3</sup> of water. What is the buoyant force acting on the object? Treat  $g = 10 \text{ m/s}^2$ .

- (A) 500,000 N
- (B) 375,000 N
- (C) 100 N
- (D) 75 N
- (E) 25 N



[PhysicsBowl, 2010Q23]

A point object of mass  $M$  is connected to the end of a long string of negligible mass and the system swings as a simple pendulum with period  $T$ . The point object of mass  $M$  is now replaced with a point object of mass  $4M$ . When this new system swings as a simple pendulum, what is its period?

- (A)  $4T$
- (B)  $2T$
- (C)  $T$
- (D)  $T/2$
- (E)  $T/4$

[PhysicsBowl, 2010Q24]

By computing the area under the acceleration vs. time graph for a fixed time interval of an object's motion, what quantity has been determined for that object?

- (A) The average velocity during the time interval
- (B) The velocity at the end of the time interval
- (C) The average speed during the time interval
- (D) The change in velocity during the time interval
- (E) The velocity at the time midway through the time interval

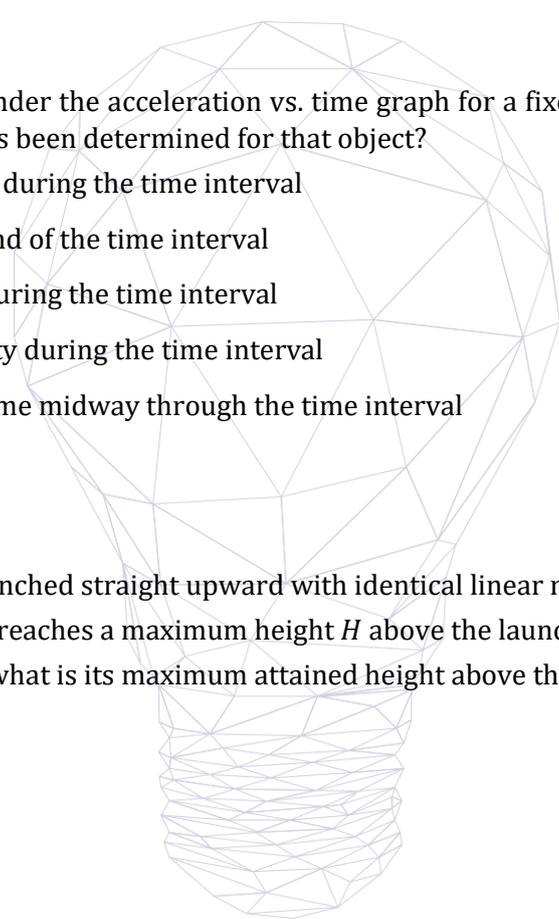
[PhysicsBowl, 2010Q25]

Two point objects are launched straight upward with identical linear momentum.

Object 1 has mass  $M$  and reaches a maximum height  $H$  above the launch point.

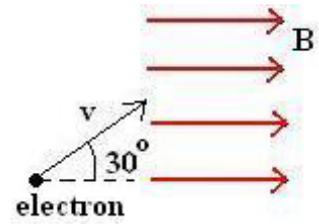
If object 2 has mass  $2M$ , what is its maximum attained height above the launch point in terms of  $H$ ?

- (A)  $H/4$
- (B)  $H/2$
- (C)  $H$
- (D)  $2H$
- (E)  $4H$



[PhysicsBowl, 2010Q26]

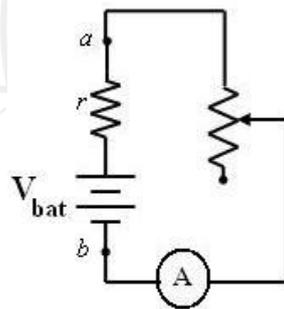
An electron moving in the plane of the page at an angle of  $30^\circ$  to the horizontal enters a region with a constant magnetic field directed horizontally in the plane of the page as shown. At the instant that the electron enters the magnetic field, which best describes the direction of the resulting magnetic force on the electron?



- (A) To the right
- (B) To the left
- (C) In a direction not listed here
- (D) Into the plane of the page
- (E) Out of the plane of the page

[PhysicsBowl, 2010Q27]

The circuit shown contains a battery (of emf  $V_{\text{bat}}$ ) with an internal resistance  $r$  connected to a rheostat (variable resistor). When the resistance of the rheostat is increased, which of the following statements is true?



- (A) The terminal voltage ( $V_a - V_b$ ) increases.
- (B) The current through the ammeter in the circuit increases.
- (C) The power associated with the internal resistance increases.
- (D) The potential difference across the rheostat decreases.
- (E) None of the above statements is true.

[PhysicsBowl, 2010Q28]

Which of the following *could* produce an enlarged but inverted image of a real object?

- (A) Place a converging lens at a distance greater than its focal length from the object.
- (B) Place a converging lens at a distance less than its focal length from the object.
- (C) Place a diverging lens at a distance less than the magnitude of its focal length from the object.
- (D) Place a diverging lens at a distance greater than the magnitude of its focal length from the object.
- (E) It is not possible to create the type of image desired.

[PhysicsBowl, 2010Q29]

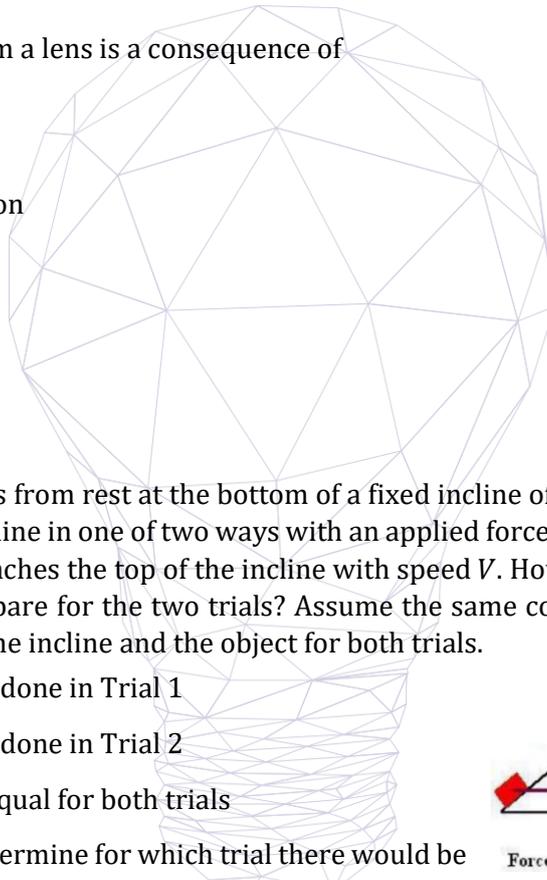
A ball initially at rest falls without air resistance from a height  $h$  above the ground. If the ball falls the first distance  $h/2$  in a time  $t$ , how much time is required to fall the remaining distance of  $h/2$ ?

- (A)  $0.25t$
- (B)  $0.41t$
- (C)  $0.50t$
- (D)  $0.71t$
- (E)  $1.00t$

[PhysicsBowl, 2010Q30]

Chromatic aberration from a lens is a consequence of

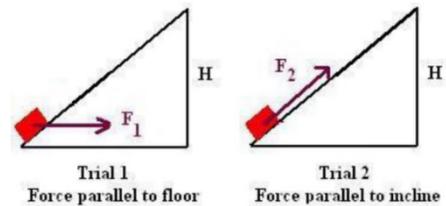
- (A) polarization
- (B) interference
- (C) total internal reflection
- (D) diffraction
- (E) dispersion



[PhysicsBowl, 2010Q31]

An object of mass  $M$  starts from rest at the bottom of a fixed incline of height  $H$ . A person decides to push the object up the incline in one of two ways with an applied force shown in the diagram. In each of the trials, the object reaches the top of the incline with speed  $V$ . How would the work done by the person on the block compare for the two trials? Assume the same constant non-zero coefficient of kinetic friction between the incline and the object for both trials.

- (A) More work would be done in Trial 1
- (B) More work would be done in Trial 2
- (C) The work would be equal for both trials
- (D) It is impossible to determine for which trial there would be more work done without knowing the value of the speed  $V$ .
- (E) It is impossible to determine for which trial there would be more work done without knowing the value of the coefficient of kinetic friction.



**Questions 32–33 deal with the following information:**

A rubber ball of mass 2.0 kg falling straight downward hits the ground with a speed of 0.90 m/s and then rebounds straight upward with a speed of 0.60 m/s. The collision time of the ball with the ground is  $t = 0.25$  s. Treat  $g = 10$  m/s<sup>2</sup> for this situation.

[PhysicsBowl, 2010Q32]

What is the magnitude of the average acceleration (in units of m/s<sup>2</sup>) of the ball while it is in contact with the ground?

- (A) 1.2
- (B) 6.0
- (C) 10.0
- (D) 13.0
- (E) 16.0

[PhysicsBowl, 2010Q33]

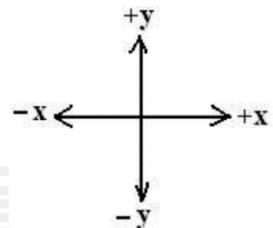
What is the magnitude of the average force (in units of Newtons) exerted by the ground on the ball while they are in contact?

- (A) 2.4
- (B) 12.0
- (C) 20.0
- (D) 26.0
- (E) 32.0

[PhysicsBowl, 2010Q34]

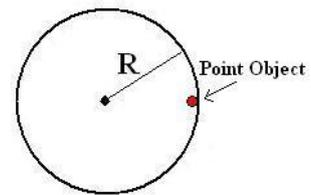
A 4.0 kg object in deep space moves at a constant velocity of 10 m/s along the  $+x$  axis. The object suddenly explodes into 2 equal mass pieces. Immediately after the explosion, one piece is now moving directly along the  $-y$  axis with a speed of 8.0 m/s. What was the size of the impulse (in proper MKS units) provided to this piece now moving along the  $-y$  axis from the explosion?

- (A) 12.8
- (B) 16.0
- (C) 25.6
- (D) 36.0
- (E) 43.1



[PhysicsBowl, 2010Q35]

A point object with mass  $M = 2.0$  kg is attached a distance  $R = 1.75$  m from the fixed center of a disk as shown in the figure. The disk starts rotating from rest with constant angular acceleration  $\alpha = 5.00$  rad/s<sup>2</sup> about an axis perpendicular to the plane of the page through the disk's center. After how much time  $T$  (in seconds) is the tangential component of the point object's acceleration equal in magnitude to the centripetal component of the point object's acceleration?

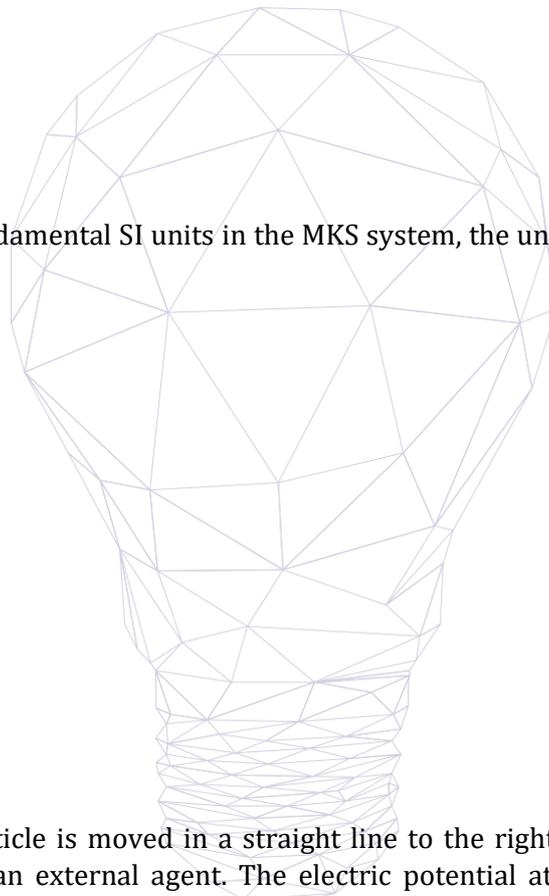


- (A) 0.769
- (B) 0.592
- (C) 0.500
- (D) 0.447
- (E) 0.350

[PhysicsBowl, 2010Q36]

In terms of the seven fundamental SI units in the MKS system, the unit for capacitance is written as which of the following?

- (A)  $\frac{A^2}{kg \cdot m^2}$
- (B)  $\frac{A \cdot s}{kg \cdot m^2}$
- (C)  $\frac{A \cdot s^2}{kg \cdot m}$
- (D)  $\frac{A^2 \cdot s^3}{kg \cdot m^2}$
- (E)  $\frac{A^2 \cdot s^4}{kg \cdot m^2}$



[PhysicsBowl, 2010Q37]

A positively charged particle is moved in a straight line to the right from position  $x = -4.0$  m to position  $x = -2.0$  m by an external agent. The electric potential at these positions in space are  $V_{(x=-4 \text{ m})} = -4$  volts and  $V_{(x=-2 \text{ m})} = -2.0$  volts. Which statement is true about the work done by the external agent moving the charge between these positions and the electric field component parallel to the direction of motion that the moving charged particle experiences? Assume the particle is moved at constant speed.

- (A) The external agent does no work since the speed was constant.
- (B) The external agent does negative work and the electric field is directed to the right.
- (C) The external agent does positive work and the electric field is directed to the right.
- (D) The external agent does negative work and the electric field is directed to the left.
- (E) The external agent does positive work and the electric field is directed to the left.

[PhysicsBowl, 2010Q38]

Two objects both move and uniformly accelerate to the right. At time  $t = 0$ , the objects are at the same initial position but

- Object 1 has initial speed twice that of Object 2
- Object 1 has one-half the acceleration of Object 2.

After some time  $T$ , the velocity of the two objects is the same.

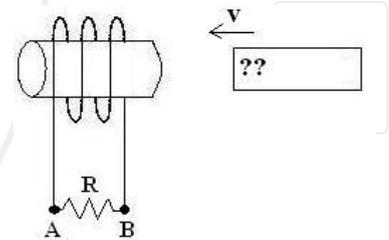
What is the ratio of the distance traveled in this time  $T$  by Object 2 to that traveled by Object 1?

- (A) 5 : 6
- (B) 4 : 5
- (C) 3 : 4
- (D) 2 : 3
- (E) 1 : 2

[PhysicsBowl, 2010Q39]

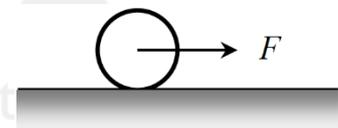
A strong bar magnet is held very close to the opening of a solenoid as shown in the diagram. As the magnet is moved to the left toward the solenoid, a conventional current through the resistor shown is directed from  $A$  to  $B$ . What is the direction of the force on the bar magnet because of the induced current in the solenoid and which magnetic pole does the “??” in the diagram represent?

	Force on magnet	Pole of magnet
(A)	To the right	North
(B)	To the left	North
(C)	To the right	South
(D)	To the left	South
(E)	There is no force	It can't be determined



[PhysicsBowl, 2010Q40]

A uniform, solid cylinder with a mass  $M$  and radius  $R$  is pulled by a horizontal force  $F$  acting through the center as shown. The cylinder rolls to the right without slipping. What is the magnitude of the force of friction between the cylinder and the ground?



- (A)  $\frac{1}{4}F$
- (B)  $\frac{1}{3}F$
- (C)  $\frac{1}{2}F$
- (D)  $\frac{2}{3}F$
- (E)  $\frac{3}{4}F$

[PhysicsBowl, 2010Q41]

Two spheres are heated to the same temperature and allowed to radiate energy to identical surroundings. The spheres have the same emissivity, but one sphere has twice the diameter of the other. If the smaller sphere radiates energy at a rate  $P$ , at what rate will the larger sphere radiate energy?

- (A)  $P$
- (B)  $2P$
- (C)  $4P$
- (D)  $8P$
- (E)  $16P$

[PhysicsBowl, 2010Q42]

A comet moves in an elliptical orbit around the sun. As the comet moves from aphelion (the point on the orbit farthest from the sun) to perihelion (the point on the orbit closest to the sun), which of the following results is true?

	Speed of the comet	Angular momentum of the comet/sun system	Gravitational potential energy of the comet/sun system
(A)	Increase	Increase	Decrease
(B)	Increase	Constant	Decrease
(C)	Decrease	Decrease	Increase
(D)	Increase	Increase	Constant
(E)	Constant	Constant	Constant

[PhysicsBowl, 2010Q43]

Two ions travel perpendicular to the same uniform magnetic field. The ions carry the same charge and have the same path radius in the magnetic field. Which of the following quantities must be the same for the two ions?

- (A) Mass
- (B) Speed
- (C) Charge-to-mass ratio
- (D) Kinetic energy
- (E) Magnitude of linear momentum

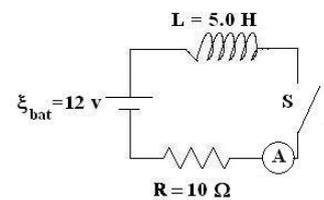
[PhysicsBowl, 2010Q44]

A radioactive sample of gas has a half-life of 100 seconds. If there are initially 10,000 of these gas molecules in a closed container, approximately how many of the molecules remain after a time of 250 seconds elapses?

- (A) 2500
- (B) 2190
- (C) 1770
- (D) 1560
- (E) 1250

[PhysicsBowl, 2010Q45]

For the ideal  $RL$  circuit shown, the resistance is  $R = 10.0 \Omega$ , the inductance is  $L = 5.0 \text{ H}$  and the battery has voltage volts  $\xi_{\text{bat}} = 12$  volts. Some time after the switch  $S$  in the circuit is closed, the ammeter in the circuit reads  $0.40 \text{ A}$ . At what rate is energy being stored by the inductor at this instant (in Watts)?

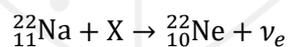


- (A) 0.40
- (B) 1.0
- (C) 2.0
- (D) 3.2
- (E) 4.8



[PhysicsBowl, 2010Q46]

For the following nuclear reaction, what is the unknown labeled by  $X$ ?

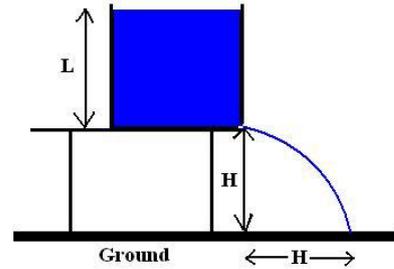


- (A) A proton
- (B) An electron
- (C) A neutron
- (D) An alpha particle
- (E) A positron

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[PhysicsBowl, 2010Q47]

An open cylindrical container with very large radius is at rest a distance  $H$  above the ground at the edge of a platform. A tiny hole develops at the bottom of the container and water from the container squirts out horizontally landing a distance  $H$  from the edge of the platform. For the water to land at this location, what is the depth of the water  $L$  in the container? The figure is not drawn to scale and air resistance is ignored.

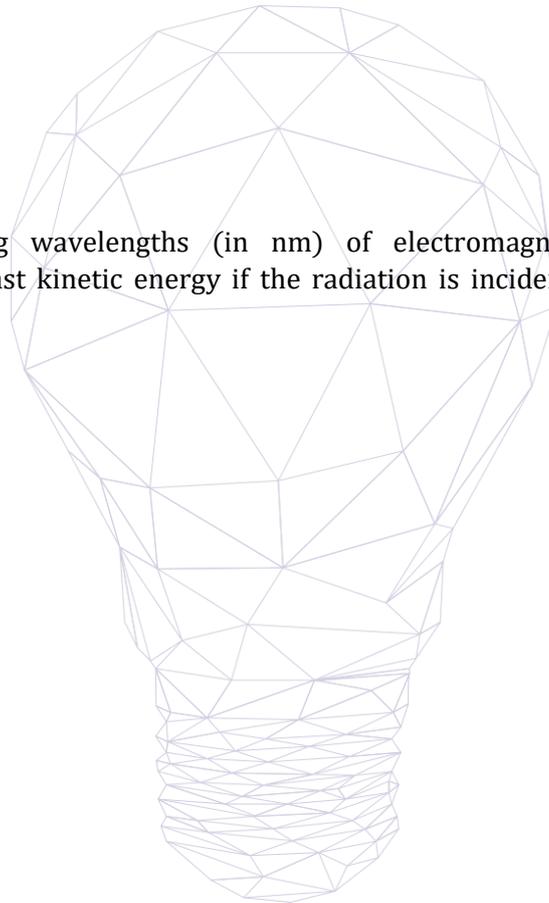


- (A)  $H/4$
- (B)  $H/\sqrt{2}$
- (C)  $H$
- (D)  $H\sqrt{2}$
- (E)  $2H$

[PhysicsBowl, 2010Q48]

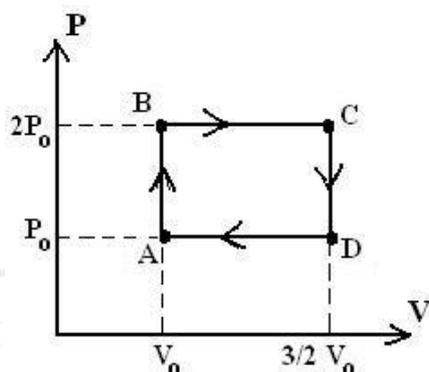
Which of the following wavelengths (in nm) of electromagnetic radiation will produce photoelectrons of the least kinetic energy if the radiation is incident on a material with a work function of 4.80 eV?

- (A) 992
- (B) 496
- (C) 248
- (D) 124
- (E) 62



[PhysicsBowl, 2010Q49]

A monatomic ideal gas is the working substance for an engine that undergoes the cyclic process ( $ABCD$ ) shown in the  $PV$  diagram. The processes are all isochoric or isobaric with pressures between  $P_0$  and  $2P_0$  and volumes between  $V_0$  and  $\frac{3}{2}V_0$ . What is the efficiency of this engine?



- (A)  $1/8$
- (B)  $1/5$
- (C)  $1/3$
- (D)  $2/3$
- (E)  $5/7$

[PhysicsBowl, 2010Q50]

An object of mass  $m$  is initially at rest. After this object is accelerated to a speed of  $2.40 \times 10^8$  m/s, it collides with and sticks to a second object of mass  $m$  at rest. Immediately after the collision, what is the common speed of the two masses?

- (A)  $2.25 \times 10^8$  m/s
- (B)  $1.80 \times 10^8$  m/s
- (C)  $1.66 \times 10^8$  m/s
- (D)  $1.50 \times 10^8$  m/s
- (E)  $1.20 \times 10^8$  m/s



# PhysicsBowl 2011

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2011

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2011Q1]

Which one of the following choices best represents the average mass of an adult human male?

- (A)  $1.0 \times 10^{-2}$  kg
- (B)  $1.0 \times 10^{-1}$  kg
- (C)  $1.0 \times 10^1$  kg
- (D)  $1.0 \times 10^2$  kg
- (E)  $1.0 \times 10^3$  kg

[PhysicsBowl, 2011Q2]

Albert Einstein's most famous equation is  $E = mc^2$ . The unit for the quantity represented by  $E$  can be written as which one of the following options?

- (A) seconds
- (B) newtons
- (C) kilograms
- (D) meters
- (E) joules

[PhysicsBowl, 2011Q3]

The distance of one thousand meters can be written as one kilometer. Which one of the following choices best represents a distance of one million meters?

- (A) one gigameter
- (B) one megameter
- (C) one micrometer
- (D) one nanometer
- (E) one terameter

[PhysicsBowl, 2011Q4]

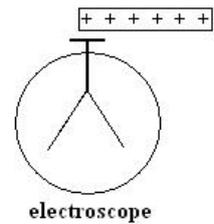
The following two measurements of length are recorded from an experiment:  $L_1 = 4.57 \times 10^3$  m and  $L_2 = 2.130 \times 10^2$  m. Using the rules of significant digits, what is the sum ( $L_1 + L_2$ ) of these measurements?

- (A)  $5 \times 10^3$  m
- (B)  $4.8 \times 10^3$  m
- (C)  $4.78 \times 10^3$  m
- (D)  $4.783 \times 10^3$  m
- (E)  $6.70 \times 10^3$  m



[PhysicsBowl, 2011Q5]

A positively charged rod is brought near a metal electroscope that is initially uncharged. As shown in the figure, the rod does not touch the electroscope. There is no charge transfer between the electroscope and rod, but the leaves of the electroscope move apart from each other when the rod is brought near the top of the electroscope. Which one of the following choices is the best explanation for this phenomenon?



- (A) Protons are repelled by the rod into the leaves of the electroscope.
- (B) Electrons are attracted out of the leaves of the electroscope toward the rod.
- (C) Protons are repelled into the leaves of the electroscope and electrons are attracted out of the leaves of the electroscope.
- (D) Positively charged electrons are repelled by the rod into the leaves of the electroscope.
- (E) Positively charged electrons are repelled into the leaves of the electroscope and regular electrons are attracted out of the leaves of the electroscope.

**Questions 6 – 7 deal with the following information:**

A ball of mass  $m = 0.100$  kg is launched straight upward so that it rises to a maximum height of 12.0 m above the launch point. Ignore air resistance.

[PhysicsBowl, 2011Q6]

When the ball reaches its maximum height, which one of the following choices best represents the magnitude of the net force acting on the ball?

- (A) 0 N
- (B) 0.100 N
- (C) 1.00 N
- (D) 10.0 N
- (E) 12.0 N



[PhysicsBowl, 2011Q7]

Approximately how much time does it take the ball to reach the maximum height from its launch?

- (A) 0.65 s
- (B) 1.10 s
- (C) 1.20 s
- (D) 1.55 s
- (E) 2.40 s

[PhysicsBowl, 2011Q8]

An object moves along a horizontal line with increasing speed. Which one of the following choices could represent the signs of the velocity and of the acceleration for the object to achieve this motion?

	Velocity	Acceleration
(A)	Zero	Zero
(B)	Positive	Zero
(C)	Positive	Negative
(D)	Negative	Positive
(E)	Negative	Negative

[PhysicsBowl, 2011Q9]

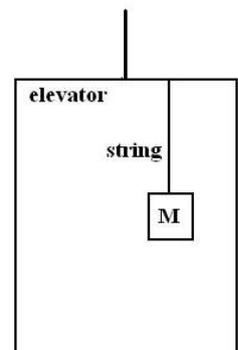
Which one of the following choices best represents the speed of  $60.0 \frac{\text{miles}}{\text{hr}}$  rewritten in units of  $\frac{\text{km}}{\text{day}}$ ?

- (A) 2300
- (B) 1440
- (C) 900
- (D) 4.00
- (E) 1.56

[PhysicsBowl, 2011Q10]

A string of negligible mass connects an object of mass  $M = 10 \text{ kg}$  to the ceiling of an elevator. The elevator experiences a constant downward speed of  $3.0 \text{ m/s}$ . Let  $T$  represent the magnitude of the force on the mass  $M$  by the string (tension),  $G$  represent the magnitude of the gravitational force by the Earth acting on the mass  $M$  hanging in the elevator, and  $F$  represent the magnitude of the net force acting on the mass  $M$ . Which one of the following choices describes the relationships between these forces?

- (A)  $F < T < G$
- (B)  $F = G = T$
- (C)  $F < G < T$
- (D)  $F = T < G$
- (E)  $F < T = G$



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[PhysicsBowl, 2011Q11]

The largest particle accelerator in the world is called the LHC. What does LHC stand for?

- (A) Large Hadron Conductor
- (B) Light Hadron Container
- (C) Light Hadron Collider
- (D) Large Hadron Container
- (E) Large Hadron Collider

[PhysicsBowl, 2011Q12]

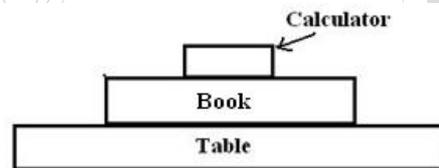
A 5.0 kg mass moves along the  $x$ -axis. At one instant of time, the mass has position 2.0 m, velocity 3.0 m/s and acceleration 4.0 m/s<sup>2</sup>. What is the net force acting on the mass at this instant of time?

- (A) 0 N
- (B) 10.0 N
- (C) 15.0 N
- (D) 20.0 N
- (E) 22.5 N

[PhysicsBowl, 2011Q13]

A physics book sits at rest on a table. On top of the book is a calculator, also at rest. Which one of the following choices is the Newton's Third Law pair force to the force that the table exerts on the book?

- (A) The contact force on the table by the book.
- (B) The gravitational force on the book by the Earth.
- (C) The gravitational force on the combination of the book and calculator by the Earth.
- (D) The contact force on the book by the calculator.
- (E) The contact force on the table by the ground supporting it.



## [PhysicsBowl, 2011Q14]

A car makes a trip in two parts:

Part 1: it travels a distance of 800 m at a constant speed of 4.0 m/s.

Part 2: it travels a distance of 1200 m at a constant speed of 20.0 m/s.

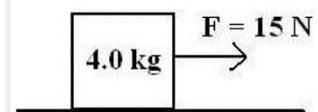
What is the average speed of the car for the entire two-part trip?

- (A) 7.7 m/s
- (B) 10.4 m/s
- (C) 12.0 m/s
- (D) 13.6 m/s
- (E) 17.3 m/s

## [PhysicsBowl, 2011Q15]

A 4.0 kg object is pushed to the right on a rough surface by a horizontal force of 15 N as shown. During the push, the object accelerates uniformly to the right at  $2.50 \text{ m/s}^2$ . What must be the magnitude of the force of friction also acting on the object during the push?

- (A) 0 N
- (B) 5 N
- (C) 10 N
- (D) 15 N
- (E) 25 N



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## [PhysicsBowl, 2011Q16]

Which one of the following is NOT a vector quantity?

- (A) Linear momentum
- (B) Electric field
- (C) Average velocity
- (D) Instantaneous acceleration
- (E) Kinetic energy

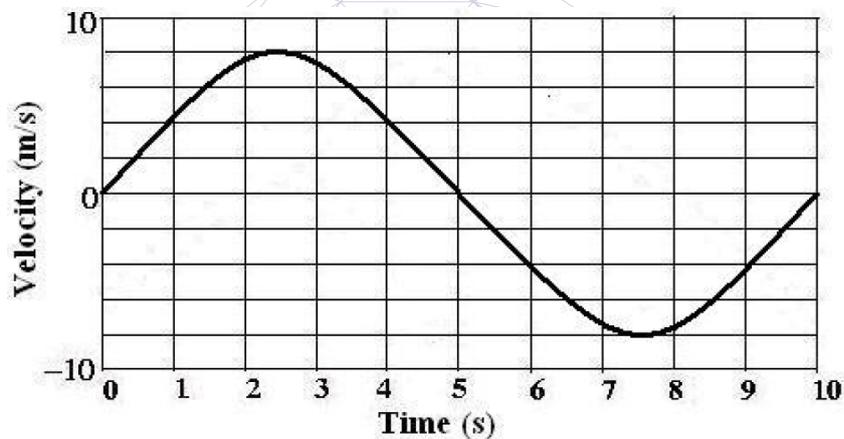
[PhysicsBowl, 2011Q17]

A new radio station broadcasts its signal with a wavelength of 3.40 m. At what frequency is this station broadcasting?

- (A)  $1.76 \times 10^8$  Hz
- (B)  $8.82 \times 10^7$  Hz
- (C) 100 Hz
- (D) 0.294 Hz
- (E)  $1.13 \times 10^{-8}$  Hz

**Questions 18 – 19 deal with the following information:**

The motion of an object moving along a straight line is given by the velocity vs. time graph shown.



[PhysicsBowl, 2011Q18]

Which one of the following choices best represents the average acceleration of the object during the time interval from  $t = 4.0$  s to  $t = 9.0$  s?

- (A)  $0.80 \text{ m/s}^2$
- (A)  $0 \text{ m/s}^2$
- (A)  $-0.80 \text{ m/s}^2$
- (A)  $-1.6 \text{ m/s}^2$
- (A)  $-3.2 \text{ m/s}^2$

[PhysicsBowl, 2011Q19]

Which one of the following choices best represents the instantaneous acceleration of the object at the time of  $t = 5.0$  s?

- (A)  $0 \text{ m/s}^2$
- (B)  $-1.6 \text{ m/s}^2$
- (C)  $-2.0 \text{ m/s}^2$
- (D)  $-3.2 \text{ m/s}^2$
- (E)  $-4.0 \text{ m/s}^2$

## [PhysicsBowl, 2011Q20]

The transistor is a solid piece of semiconducting material with many applications in electronics. The initial development of transistors and the Nobel Prize awarded for its invention occurred closest to which calendar year?

- (A) 1890
- (B) 1920
- (C) 1950
- (D) 1980
- (E) 2005

## [PhysicsBowl, 2011Q21]

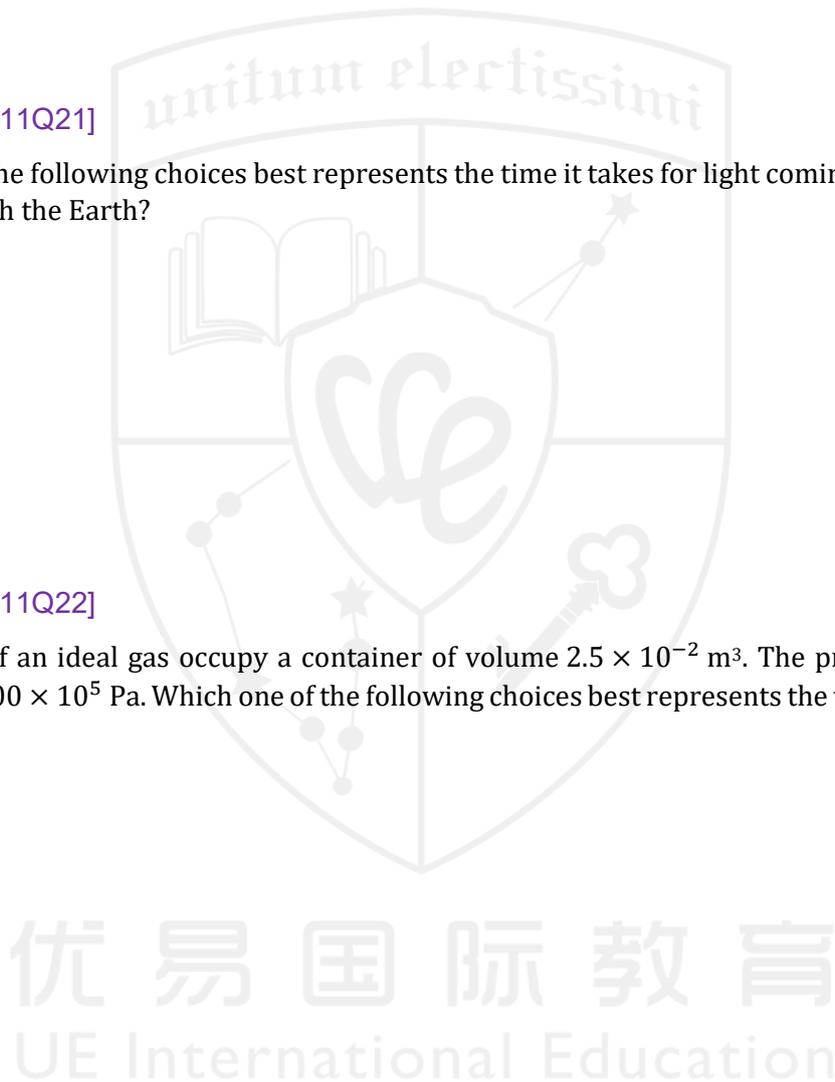
Which one of the following choices best represents the time it takes for light coming from the Moon's surface to reach the Earth?

- (A) 0.001 s
- (B) 0.10 s
- (C) 1.0 s
- (D) 10.0 s
- (E) 1 minute

## [PhysicsBowl, 2011Q22]

Three moles of an ideal gas occupy a container of volume  $2.5 \times 10^{-2} \text{ m}^3$ . The pressure inside this container is  $5.00 \times 10^5 \text{ Pa}$ . Which one of the following choices best represents the temperature of the gas?

- (A) 225 K
- (B) 500 K
- (C) 775 K
- (D) 1500 K
- (E) 50800 K

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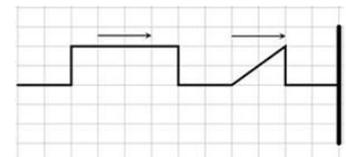
[PhysicsBowl, 2011Q23]

A string, clamped at both ends, has its tension fixed. A wave generator vibrates the string with a frequency  $f$  producing waves of wavelength  $\lambda$  which have speed  $v$ . The frequency of the wave generator now is doubled to  $2f$ . Which one of the following choices best describes the new values of the wavelength of waves produced and the speed of the waves on the string?

	Wavelength	Wave speed
(A)	$1/2 \lambda$	$v$
(B)	$1/2 \lambda$	$2v$
(C)	$\lambda$	$2v$
(D)	$\lambda$	$v$
(E)	$2\lambda$	$4v$

[PhysicsBowl, 2011Q24]

Two wave pulses travel to the right toward a rigid boundary as shown. After reflection of the triangular pulse, the pulses will interfere. Which one of the following pictures best represents the superposition of the pulses when the centers of the individual pulses coincide?



(A) (B) (C) (D) (E)



[PhysicsBowl, 2011Q25]

The product  $(3 \text{ Teslas}) \times (2 \text{ meters}) \times (4 \text{ meters/second})$  is equivalent to which one of the following?

- (A) 24 Amperes
- (B) 24 Coulombs
- (C) 24 Watts
- (D) 24 Ohms
- (E) 24 Volts

[PhysicsBowl, 2011Q26]

During the New Moon phase of the lunar cycle, approximately what percent of the Moon's surface receives light from the Sun?

- (A) 0%
- (B) 25.0%
- (C) 50.0%
- (D) 75.0%
- (E) 100%

[PhysicsBowl, 2011Q27]

The density of a solid cubic block is given as  $\rho = 0.750 \text{ g/cm}^3$ . This block is dropped into a large swimming pool filled with water. When equilibrium is established and all motion stops, which choice best describes the location of the block? The block is very small in comparison to the pool.

- (A) The block is resting at the bottom of the pool.
- (B) The block is completely submerged but stops 75% of the way to the bottom of the pool.
- (C) The block is completely submerged but stops 25% of the way to the bottom of the pool.
- (D) The block is floating with 75 % of its volume under the water's surface.
- (E) The block is floating with 25 % of its volume under the water's surface.

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[PhysicsBowl, 2011Q28]

A person throws an object of mass  $M$  straight upward with an initial non-zero speed  $v$ . The object rises to a maximum height  $H$  above the launch point. The person now throws an object of mass  $\frac{1}{2}M$  straight upward with initial speed  $2v$ . In terms of  $H$ , to what maximum height does the object of mass  $\frac{1}{2}M$  rise above the launch point? Ignore air resistance.

- (A)  $8H$
- (B)  $4H$
- (C)  $2H$
- (D)  $\sqrt{2}H$
- (E)  $H$

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[PhysicsBowl, 2011Q29]

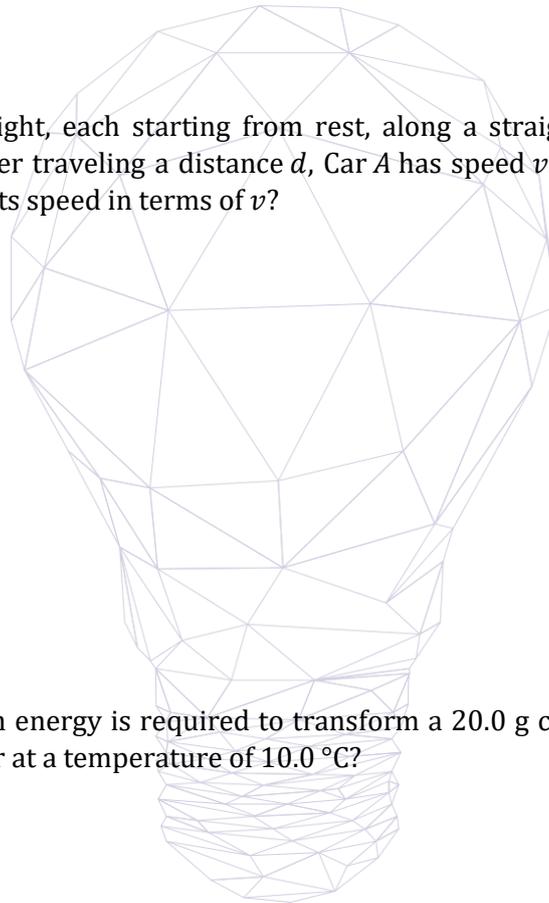
An electron moves with speed  $1.00 \times 10^3$  m/s as it enters a region of space that has only a uniform magnetic field. The electron is accelerated because of this field with a constant magnitude of  $8.00 \times 10^5$  m/s<sup>2</sup> for the entire time of  $1.00 \times 10^{-3}$  s that it is in the field. With what speed would the electron exit the field? Ignore gravity.

- (A)  $1.80 \times 10^3$  m/s
- (B)  $1.41 \times 10^3$  m/s
- (C)  $1.00 \times 10^3$  m/s
- (D)  $2.00 \times 10^2$  m/s
- (E) It depends on the initial angle of the electron's velocity with respect to the magnetic field.

[PhysicsBowl, 2011Q30]

Two cars travel to the right, each starting from rest, along a straight road. Car *A* has twice the acceleration of Car *B*. After traveling a distance *d*, Car *A* has speed *v*. When Car *B* has traveled the same distance *d*, what is its speed in terms of *v*?

- (A)  $\frac{1}{4}v$
- (B)  $\frac{1}{2}v$
- (C)  $\frac{\sqrt{3}}{2}v$
- (D)  $\frac{\sqrt{2}}{2}v$
- (E) *v*



[PhysicsBowl, 2011Q31]

Approximately how much energy is required to transform a 20.0 g cube of ice at a temperature of  $-10.0$  °C into liquid water at a temperature of  $10.0$  °C?

- (A) 840 J
- (B) 1300 J
- (C) 1700 J
- (D) 7900 J
- (E) 46,000 J

[PhysicsBowl, 2011Q32]

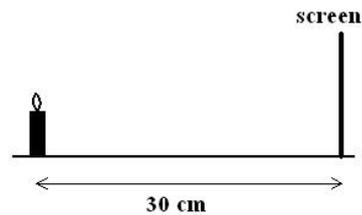
An ideal green pigment is mixed with an ideal red pigment. After mixing, which one of the following choices best represents the color of the pigment produced?

- (A) Blue
- (B) Cyan
- (C) Magenta
- (D) Yellow
- (E) Black

[PhysicsBowl, 2011Q33]

For the set-up shown of a candle and screen placed 30 cm apart, there are two locations at which a thin converging lens can be placed to produce a focused real image. One real image of the candle appears on the screen when the lens is located 12 cm from the candle. From this location, how does this lens now have to be moved in order to make the second real image of the candle appear on the screen?

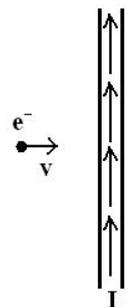
- (A) 3 cm toward the screen
- (B) 6 cm toward the candle
- (C) 6 cm toward the screen
- (D) 9 cm toward the candle
- (E) 9 cm toward the screen



[PhysicsBowl, 2011Q34]

A wire lies in the plane of the page with conventional current  $I$  shown. At the instant shown, what is the direction of the magnetic force on the electron that is moving directly to the right toward the wire?

- (A) Toward the bottom of the page
- (B) Toward the top of the page
- (C) Into the plane of the page
- (D) Out of the plane of the page
- (E) There is no force



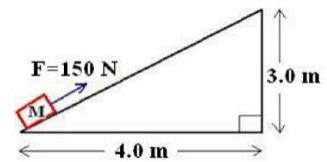
[PhysicsBowl, 2011Q35]

Mary rides her bicycle directed due South. She applies the brakes quickly bringing the bicycle to rest with the wheels rolling without slipping on the ground. Which one of the following choices best represents the direction of the angular acceleration of the bicycle's front wheel while it is slowing to rest from Mary's point of view?

- (A) Into the ground
- (B) North
- (C) South
- (D) East
- (E) West

[PhysicsBowl, 2011Q36]

For the inclined plane shown, a force of 150 N applied parallel to the incline's surface is needed to pull the object of mass  $M = 10.0$  kg along the entire length of the incline's surface at a constant speed. What is the actual mechanical advantage (AMA) for this scenario?

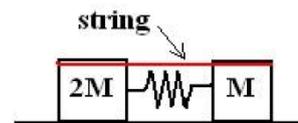


- (A)  $2/3$
- (B)  $3/2$
- (C)  $2/5$
- (D)  $3/5$
- (E)  $5/3$



[PhysicsBowl, 2011Q37]

Two blocks sit on a horizontal frictionless surface connected to an ideal spring. Initially everything is at rest and there is a string compressing the mass-spring system from equilibrium. At some time after the string is cut, the block of mass  $2M$  reaches its maximum kinetic energy  $K$ . What maximum kinetic energy does the block of mass  $M$  attain in terms of  $K$ ?

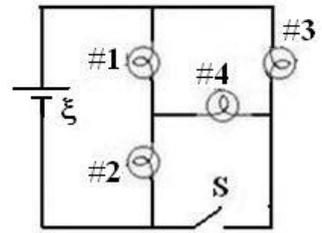


- (A)  $\frac{1}{4}K$
- (B)  $\frac{1}{2}K$
- (C)  $K$
- (D)  $2K$
- (E)  $4K$

[PhysicsBowl, 2011Q38]

For the circuit shown, the four light bulbs have identical resistance, all wires have zero resistance, and the battery is assumed to be ideal with emf  $\xi$ . When the switch,  $S$ , in the circuit is closed, a wire of zero resistance is added into the circuit. Which of the light bulbs will be dimmer after the switch is closed?

- (A) Only bulb #2
- (B) Only bulb #4
- (C) Only bulbs #1 and #4
- (D) Only bulbs #2 and #4
- (E) Only bulbs #1, #2 and #4



[PhysicsBowl, 2011Q39]

An object with mass  $M$  moves due East on a frictionless horizontal surface with a speed of  $V$ . A second object of mass  $\frac{1}{2}M$  has a speed of  $3V$ . The two objects collide and stick together. If the objects are moving due South after the collision, with what speed are they moving?

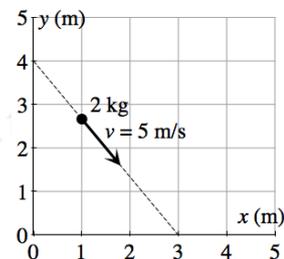
- (A)  $\frac{5}{3}V$
- (B)  $\frac{1}{3}V$
- (C)  $\frac{\sqrt{5}}{3}V$
- (D)  $\frac{4\sqrt{2}}{3}V$
- (E)  $\frac{\sqrt{33}}{3}V$

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14

[PhysicsBowl, 2011Q40]

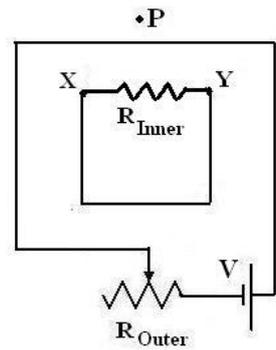
A 2.0 kg particle travels at a constant speed of 5.0 m/s along the line shown in the figure. What is the magnitude of the particle's angular momentum calculated from the origin?

- (A) 10 kg·m<sup>2</sup>/s
- (B) 24 kg·m<sup>2</sup>/s
- (C) 30 kg·m<sup>2</sup>/s
- (D) 32 kg·m<sup>2</sup>/s
- (E) 40 kg·m<sup>2</sup>/s



[PhysicsBowl, 2011Q41]

For the figure shown, the variable resistance of the outer circuit,  $R_{\text{Outer}}$ , is decreasing at a constant rate. While this is occurring, in which direction is the magnetic field associated with the outer circuit at the point  $P$  in the plane of the circuit and in which direction is the conventional current through the resistor  $R_{\text{Inner}}$  in the smaller interior circuit? The two circuits lie on a flat table.



	Magnetic Field at $P$	Current through $R_{\text{Inner}}$
(A)	Into the page	From $X$ to $Y$
(B)	Into the page	From $Y$ to $X$
(C)	Into the page	There is no current.
(D)	Out of the page	From $X$ to $Y$
(E)	Out of the page	From $Y$ to $X$

[PhysicsBowl, 2011Q42]

A parallel-plate capacitor of capacitance  $C$  has an insulating dielectric material of constant  $\kappa$  filling the entire region between its plates. This capacitor now is connected to a battery of voltage  $V$  and is fully charged before the battery is disconnected. The capacitor stores energy  $U$ .

Using insulating gloves, a person now removes the dielectric from the capacitor. After equilibrium is established following the removal of the dielectric, which one of the following choices best represents the energy stored by the capacitor in terms of  $U$ ?

- (A)  $\kappa^2 U$
- (B)  $\kappa U$
- (C)  $U$
- (D)  $U/\kappa$
- (E)  $U/\kappa^2$

[PhysicsBowl, 2011Q43]

A standing wave is created in an air-filled tube open at both ends when a tuning fork of frequency 552 Hz is placed near one of the open ends. A tuning fork of frequency 644 Hz produces the next highest harmonic for this tube. What is the length of the open tube? Assume room temperature.

- (A) 0.46 m
- (B) 0.92 m
- (C) 1.59 m
- (D) 1.85 m
- (E) 3.70 m

[PhysicsBowl, 2011Q44]

One mole of a monatomic ideal gas undergoes an isobaric expansion. In the process, the temperature of the gas increases from 300 K to 500 K. Which one of the following choices best represents the amount of work done by the gas on the surroundings?

- (A) 665 J
- (B) 1110 J
- (C) 1660 J
- (D) 2490 J
- (E) 4160 J

[PhysicsBowl, 2011Q45]

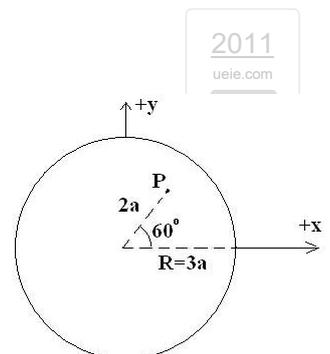
An object is placed in front of a thin converging lens resulting in a focused image forming on a screen. If the bottom half of the lens were covered with black paper, what happens to the image on the screen?

- (A) There is no change of any kind to the image.
- (B) Only the top half of the object is focused into an image on the screen.
- (C) Only the top half of the object is focused into an image on the screen and it now is half the size.
- (D) The image is fully formed, only it now is half as large.
- (E) The image is fully formed, only it is dimmer.

[PhysicsBowl, 2011Q46]

A hollow conducting sphere in static equilibrium is isolated in deep space with a net excess charge  $+Q$  on it. What is the electric potential (assuming  $V_{(r \rightarrow \infty)} = 0$ ) at the position labeled  $P$  shown in the interior of the figure? The sphere has radius  $R = 3a$  and the point of interest is at a location  $r = 2a$  from the center of the sphere at an angle of  $60^\circ$  with respect to the  $+x$ -axis.

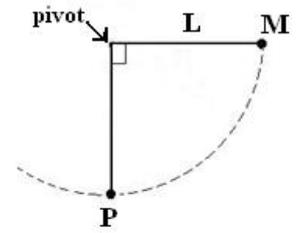
- (A) 0
- (B)  $\frac{kQ}{2a}$
- (C)  $\frac{kQ}{3a}$
- (D)  $\frac{kQ}{4a}$
- (E)  $\frac{\sqrt{3}kQ}{4a}$



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[PhysicsBowl, 2011Q47]

A simple pendulum of length  $L$  has a point mass  $M$  released from rest from the horizontal position shown. In the absence of air resistance and friction, the mass swings through the arc of a circle. Let  $T$  represent the magnitude of the force from the string on the mass (tension),  $G$  represent the magnitude of the gravitational force acting on the mass by the earth, and  $F$  represent the magnitude of the net force acting on the mass. Which one of the following choices describes the relationship among these forces when the mass swings at the bottom of the arc (point  $P$ )?

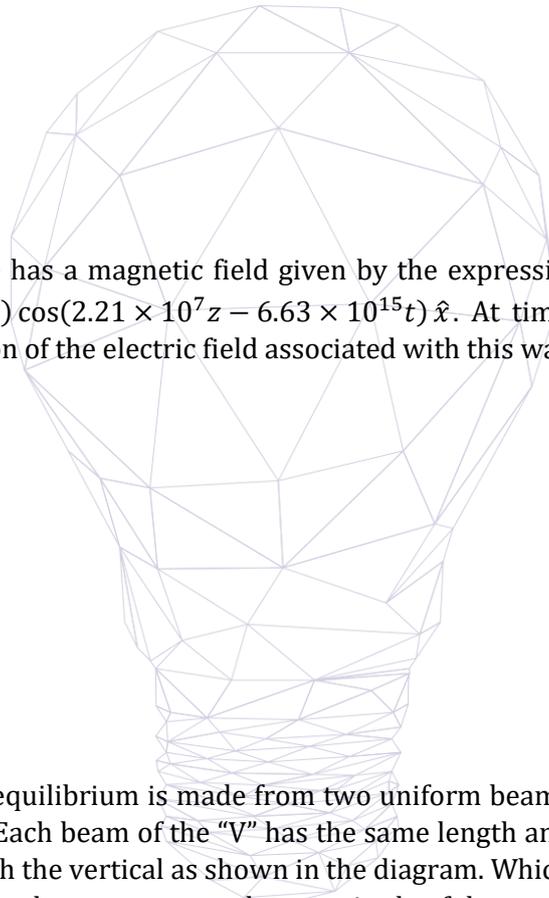


- (A)  $G < F < T$
- (B)  $F < G = T$
- (C)  $F < G < T$
- (D)  $T < F < G$
- (E)  $G = F < T$

[PhysicsBowl, 2011Q48]

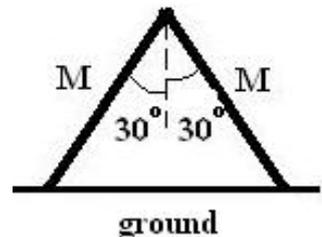
An electromagnetic wave has a magnetic field given by the expression (in Cartesian coordinates)  $\vec{B}(x, y, z, t) = (6.0 \times 10^{-6}) \cos(2.21 \times 10^7 z - 6.63 \times 10^{15} t) \hat{x}$ . At time  $t = 0$  and position  $x = y = z = 0$ , what is the direction of the electric field associated with this wave?

- (A)  $+x$
- (B)  $-x$
- (C)  $+y$
- (D)  $-y$
- (E)  $+z$



[PhysicsBowl, 2011Q49]

An inverted "V" in static equilibrium is made from two uniform beams each of mass  $M = 12$  kg. Each beam of the "V" has the same length and makes an angle of  $30^\circ$  with the vertical as shown in the diagram. Which one of the following choices best represents the magnitude of the static friction force acting on the left leg of the "V" from the level ground? The coefficient of static friction between each beam and the ground is  $\mu_s = 0.76$ .



- (A) 26.3 N
- (B) 34.6 N
- (C) 45.6 N
- (D) 69.3 N
- (E) 91.2 N

[PhysicsBowl, 2011Q50]

A person sets a one-meter long stick so that it makes a  $30^\circ$  angle with the  $x$ -axis. An observer in a space ship moving along the  $x$ -axis measures the angle of the stick to be  $60^\circ$  with the  $x$ -axis. With what speed is the space ship moving in terms of the speed of light,  $c$ ?

- (A)  $\frac{1}{2}c$
- (B)  $\frac{\sqrt{2}}{3}c$
- (C)  $\frac{3}{4}c$
- (D)  $\frac{2}{\sqrt{5}}c$
- (E)  $\frac{2\sqrt{2}}{3}c$



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# PhysicsBowl 2012

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2012

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

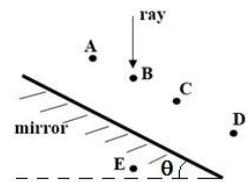
[PhysicsBowl, 2012Q1]

Which one of the following lengths is the largest?

- (A) one centimeter
- (B) one kilometer
- (C) one millimeter
- (D) one meter
- (E) one nanometer

[PhysicsBowl, 2012Q2]

A ray of light passes straight downward through the point labeled  $B$  in the diagram shown. The ray reaches a flat mirror placed at an angle  $\theta$  to the horizontal as shown. Which one of the locations labeled in the figure best represents the point through which the ray reflected from the mirror will pass?



- (A)  $A$
- (B)  $B$
- (C)  $C$
- (D)  $D$
- (E)  $E$



[PhysicsBowl, 2012Q3]

Which one of the following choices best represents the value of the speed of light using units of  $\frac{\text{miles}}{\text{week}}$ ?

- (A)  $5.90 \times 10^{12}$
- (B)  $1.13 \times 10^{11}$
- (C)  $1.61 \times 10^{10}$
- (D)  $6.75 \times 10^8$
- (E)  $1.13 \times 10^8$

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[PhysicsBowl, 2012Q4]

The wave speed is  $20.0 \text{ m/s}$  for waves traveling on a string tied at both ends. If sinusoidal waves with a frequency of  $2.00 \text{ Hz}$  are traveling on this string, which one of the following choices best represents the period of these waves?

- (A)  $40.0 \text{ s}$
- (B)  $10.0 \text{ s}$
- (C)  $3.16 \text{ s}$
- (D)  $0.50 \text{ s}$
- (E)  $0.10 \text{ s}$

[PhysicsBowl, 2012Q5]

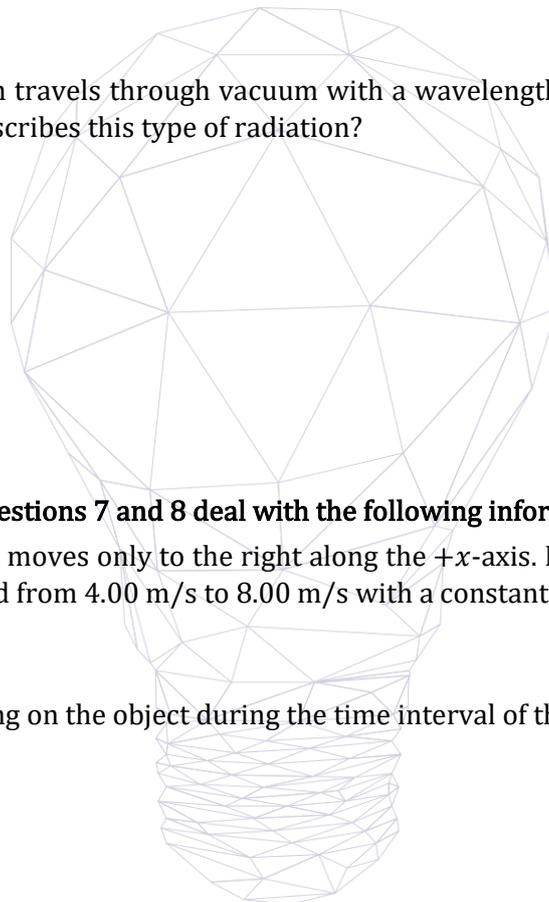
A solid rectangular box is measured to have length  $L = 13.34$  cm, width  $W = 8.45$  cm and height  $H = 3.36$  cm. Which one of the following choices best represents the volume of the box using proper significant digits?

- (A)  $4 \times 10^2 \text{ cm}^3$
- (B)  $3.8 \times 10^2 \text{ cm}^3$
- (C)  $3.79 \times 10^2 \text{ cm}^3$
- (D)  $3.787 \times 10^2 \text{ cm}^3$
- (E)  $3.7875 \times 10^2 \text{ cm}^3$

[PhysicsBowl, 2012Q6]

Electromagnetic radiation travels through vacuum with a wavelength of 400 nm. Which one of the following choices best describes this type of radiation?

- (A) X-rays
- (B) Radio Waves
- (C) Microwaves
- (D) Red Light
- (E) Violet Light



**Questions 7 and 8 deal with the following information:**

An object of mass 5.00 kg moves only to the right along the  $+x$ -axis. During some time interval, the object's speed is increased from 4.00 m/s to 8.00 m/s with a constant acceleration of 2.00 m/s<sup>2</sup>.

[PhysicsBowl, 2012Q7]

What is the net force acting on the object during the time interval of the acceleration?

- (A) 10.0 N
- (B) 20.0 N
- (C) 30.0 N
- (D) 40.0 N
- (E) The answer cannot be determined without more information about the forces involved.

[PhysicsBowl, 2012Q8]

Through what distance does the object move during the time interval of the acceleration?

- (A) 2.00 m
- (B) 4.00 m
- (C) 8.00 m
- (D) 12.0 m
- (E) 24.0 m

[PhysicsBowl, 2012Q9]

A constant current of 4.00 A through a light bulb results in a power of 24.0 W associated with the bulb. Which one of the following choices best represents the resistance of the light bulb?

- (A) 96.0  $\Omega$
- (B) 6.00  $\Omega$
- (C) 2.45  $\Omega$
- (D) 1.50  $\Omega$
- (E) 0.67  $\Omega$

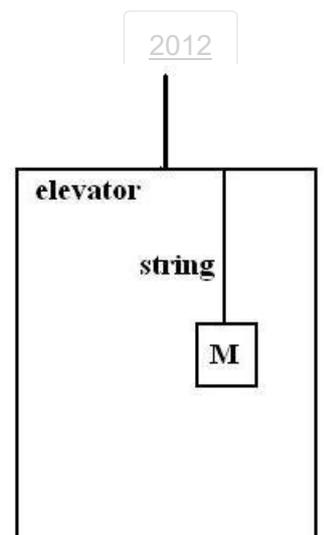
[PhysicsBowl, 2012Q10]

A string of negligible mass connects an object of mass  $M = 10$  kg to the ceiling of an elevator. The elevator experiences a constant downward acceleration of magnitude  $6.0$  m/s<sup>2</sup>.

Let  $T$  represent the magnitude of the force by the string (tension) acting on the mass  $M$ , let  $G$  represent the magnitude of the gravitational force by the Earth acting on the mass  $M$ , and let  $F$  represent the magnitude of the net force acting on the mass  $M$ .

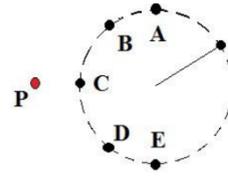
Which one of the following choices describes the relationships between these forces?

- (A)  $T = G = F$
- (B)  $F < G < T$
- (C)  $T = F < G$
- (D)  $F < T = G$
- (E)  $T < F < G$



[PhysicsBowl, 2012Q11]

A girl twirls a small mass connected to the end of a string counterclockwise in a horizontal circle above her head. The figure shows an outline of the mass's path viewed from above the twirling mass. If the girl needs the mass to pass through the point labeled *P* in the figure, at which lettered point on the path should she let go of the string?



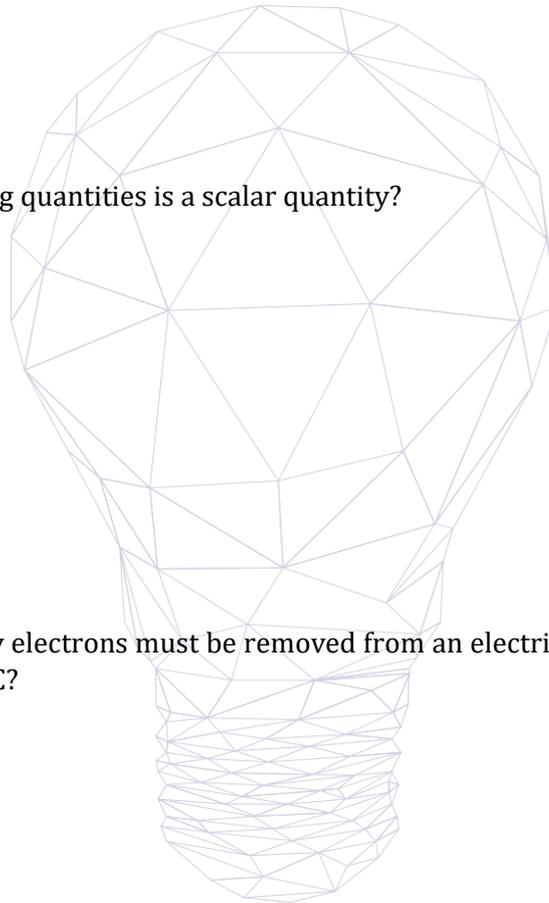
overhead view of the mass's circular path.

- (A) *A*
- (B) *B*
- (C) *C*
- (D) *D*
- (E) *E*

[PhysicsBowl, 2012Q12]

Which one of the following quantities is a scalar quantity?

- (A) Impulse
- (B) Linear Momentum
- (C) Acceleration
- (D) Speed
- (E) Displacement



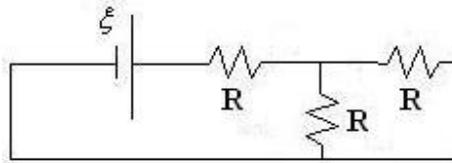
[PhysicsBowl, 2012Q13]

Approximately how many electrons must be removed from an electrically neutral object to give it a net charge of  $Q = +1.00 \text{ C}$ ?

- (A)  $1.60 \times 10^{-19}$
- (B) 1
- (C)  $6.25 \times 10^{18}$
- (D)  $6.02 \times 10^{23}$
- (E)  $1.10 \times 10^{30}$

[PhysicsBowl, 2012Q14]

For the circuit shown to the right, what is the equivalent resistance? Assume that all wires are ideal, the battery has no internal resistance, and all three resistors have identical resistance  $R$ .



- (A)  $3R$
- (B)  $\frac{3}{2}R$
- (C)  $\frac{2}{3}R$
- (D)  $\frac{1}{3}R$
- (E)  $R$

[PhysicsBowl, 2012Q15]

Which one of the following phases of the lunar cycle immediately follows “First Quarter”?

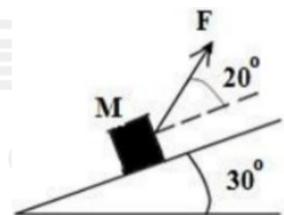
- (A) Waxing Gibbous
- (B) Waning Gibbous
- (C) Waxing Crescent
- (D) Waning Crescent
- (E) New Moon



[PhysicsBowl, 2012Q16]

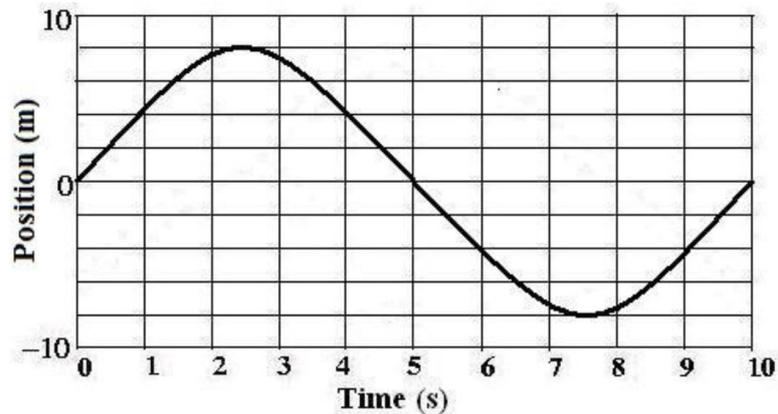
A constant force  $F = 50 \text{ N}$  (as shown in the figure) is applied for the 6.0 meter motion of the box upward along the incline. The mass of the block is  $M = 15 \text{ kg}$ . Which one of the following choices best represents the work done by the force  $F$  on the box for the motion?

- (A) 300 J
- (B) 282 J
- (C) 260 J
- (D) 193 J
- (E) 150 J



[PhysicsBowl, 2012Q17]

A mass moves according to the graph of position as a function of time shown below.



Which one of the following choices correctly represents the time instants or time interval for which the instantaneous velocity of the mass is considered always to be negative? Let  $t$  represent time.

- (A)  $t = 0.0 \text{ s}$ ,  $t = 5.0 \text{ s}$  and  $t = 10.0 \text{ s}$
- (B)  $0.0 \text{ s} < t < 2.5 \text{ s}$
- (C)  $2.5 \text{ s} < t < 7.5 \text{ s}$
- (D)  $5.0 \text{ s} < t < 10.0 \text{ s}$
- (E)  $2.5 \text{ s} < t < 10.0 \text{ s}$

[PhysicsBowl, 2012Q18]

A 1.00 kg object is released from rest near the surface of the Earth. The gravitational force acting on the 1.00 kg object by the Earth does 10.0 J of work on the object as it falls 1.00 m to the ground. Which one of the following choices best represents the amount of work done by the gravitational force acting on the Earth by the 1.00 kg object during the fall?

- (A) 0.0 J
- (B) -10.0 J
- (C) 10.0 J
- (D)  $-5.86 \times 10^{25} \text{ J}$
- (E)  $5.86 \times 10^{25} \text{ J}$

[PhysicsBowl, 2012Q19]

The magnitude of the linear momentum of a 4.00 kg point mass is changed from 6.00 kg·m/s to 14.0 kg·m/s in a time interval of 6.00 s. What is the change in the kinetic energy of the mass during this time interval?

- (A) 8.0 J
- (B) 10.0 J
- (C) 16.0 J
- (D) 20.0 J
- (E) 32.0 J



[PhysicsBowl, 2012Q20]

“Both the position and momentum of an electron cannot be known exactly at the same instant of time.” To whom is this concept attributed?

- (A) Pauli
- (B) de Broglie
- (C) Einstein
- (D) Dirac
- (E) Heisenberg

[PhysicsBowl, 2012Q21]

A child's balloon is filled with pure Xenon gas. This balloon then is released from rest two meters above the ground on Earth. Which one of the following choices best describes the response of the balloon?

- (A) The balloon immediately falls toward the ground.
- (B) The balloon floats gently in the air, finally reaching the ground after several minutes.
- (C) The balloon floats gently in the air, essentially hovering at the same height for at least a day.
- (D) The balloon very, very slowly and gently rises upward.
- (E) The balloon rapidly rises into the sky.

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[PhysicsBowl, 2012Q22]

A girl swings a 4.0 kg mass with a constant speed of 3.24 m/s in a vertically-oriented circle of radius 0.75 m. What is the net force acting on the mass when it is at the lowest point of the circle?

- (A) 96N
- (B) 56 N
- (C) 40 N
- (D) 16 N
- (E) 0 N

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**The following two questions deal with the following information:**

A collision of two blocks takes place along a horizontal surface without friction.

A block with mass  $M_1 = 3.00$  kg initially moves to the left with speed  $V_1 = 5.00$  m/s when it hits a block with mass  $M_2 = 5.00$  kg initially moving to the right with speed  $V_2 = 2.00$  m/s.

After colliding, the block with mass  $M_1$  is moving to the right with speed 1.00 m/s.

[PhysicsBowl, 2012Q23]

Which of the blocks underwent a larger magnitude of acceleration during the collision?

- (A) The block with mass  $M_1$ .
- (B) The block with mass  $M_2$ .
- (C) The magnitude of the acceleration was the same for both blocks.
- (D) The answer depends on how much kinetic energy was transferred out of the two-block system.
- (E) More information about the time of the collision is required to answer the question.

[PhysicsBowl, 2012Q24]

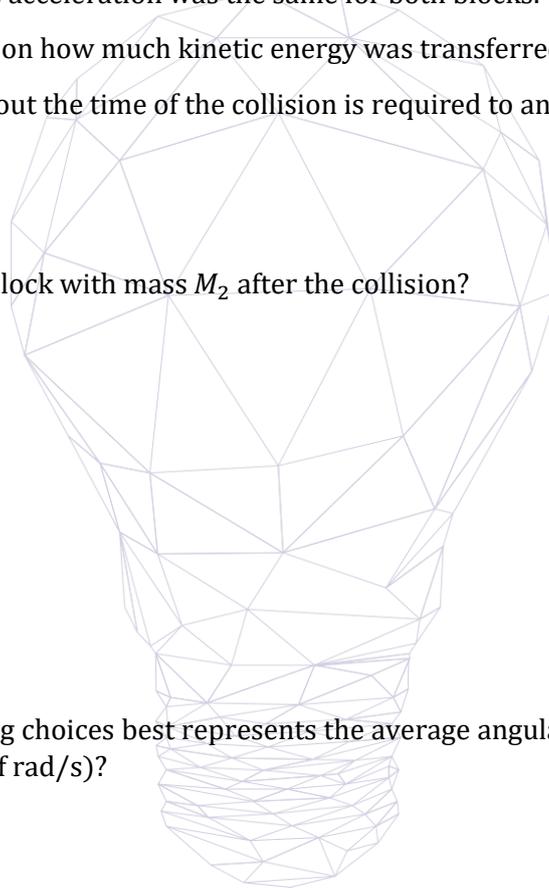
What is the speed of the block with mass  $M_2$  after the collision?

- (A) 0.40 m/s
- (B) 1.00 m/s
- (C) 1.60 m/s
- (D) 4.29 m/s
- (E) 4.40 m/s

[PhysicsBowl, 2012Q25]

Which one of the following choices best represents the average angular speed of the hour hand on a standard clock (in units of rad/s)?

- (A)  $5.24 \times 10^{-1}$
- (B)  $2.62 \times 10^{-1}$
- (C)  $1.75 \times 10^{-3}$
- (D)  $1.45 \times 10^{-4}$
- (E)  $7.27 \times 10^{-5}$



[PhysicsBowl, 2012Q26]

An object is thrown horizontally with speed 10.0 m/s from a height  $H$  above the ground. The object reaches the ground with a speed of 20.0 m/s. Which one of the following choices best represents the time of the object's flight to the ground? Ignore air resistance.

- (A) 1.00 s
- (B) 1.22 s
- (C) 1.41 s
- (D) 1.50 s
- (E) 1.73 s

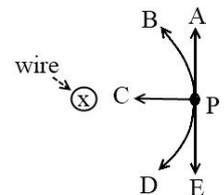
[PhysicsBowl, 2012Q27]

The pressure inside a container with two moles of an ideal gas is 0.75 atm. The temperature of the gas is 100 °C. The container maintains constant volume as the pressure is tripled. Which one of the following choices best represents the temperature of the gas after the pressure is tripled?

- (A) 33 °C
- (B) 300 °C
- (C) 573 °C
- (D) 846 °C
- (E) 1119 °C

[PhysicsBowl, 2012Q28]

A long straight wire has a conventional current directed into the plane of the page as shown in the figure. Which one of the arrows shown best indicates the direction of the magnetic field associated with this wire at the location labeled  $P$ ?



- (A)  $A$
- (B)  $B$
- (C)  $C$
- (D)  $D$
- (E)  $E$



[PhysicsBowl, 2012Q29]

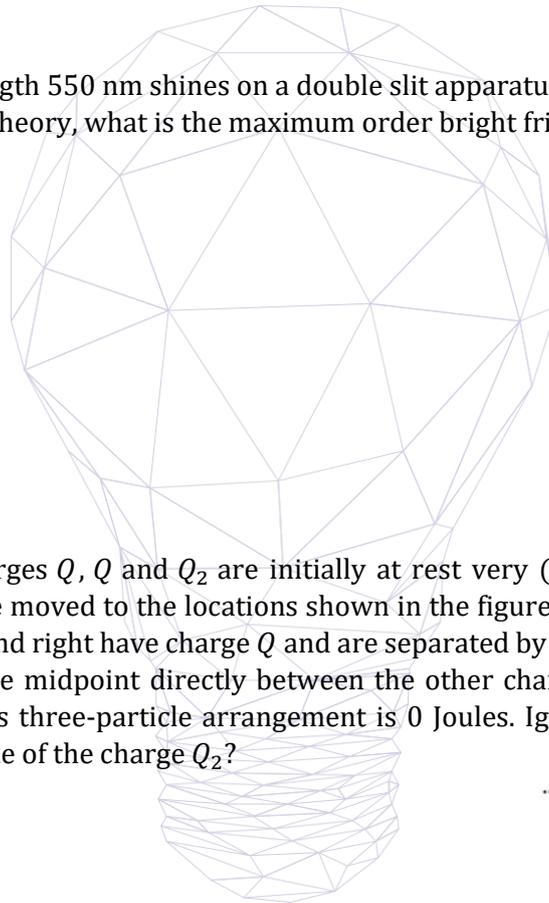
A vehicle completes one lap around a circular track at an average speed of 50 m/s and then completes a second lap at an average speed of  $V$ . The average speed of the vehicle for the completion of both laps was 80 m/s. What was the average speed  $V$  of the second lap?

- (A) 100 m/s
- (B) 110 m/s
- (C) 125 m/s
- (D) 150 m/s
- (E) 200 m/s

[PhysicsBowl, 2012Q30]

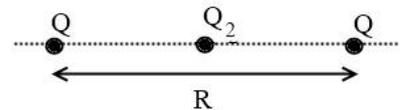
Coherent light of wavelength 550 nm shines on a double slit apparatus that has point slits spaced by a distance of 42.4  $\mu\text{m}$ . In theory, what is the maximum order bright fringe that can be viewed?

- (A) 1297
- (B) 77
- (C) 12
- (D) 8
- (E) 1



[PhysicsBowl, 2012Q31]

Three particles with charges  $Q$ ,  $Q$  and  $Q_2$  are initially at rest very (infinitely) far apart from one another. The particles are moved to the locations shown in the figure where they are fixed in place. The particles on the left and right have charge  $Q$  and are separated by a distance  $R$ . The particle with charge  $Q_2$  is located at the midpoint directly between the other charged particles. The total work required to configure this three-particle arrangement is 0 Joules. Ignore any self-energies for the particles. What is the value of the charge  $Q_2$ ?



- (A)  $-\frac{1}{4}Q$
- (B)  $-\frac{\sqrt{2}}{4}Q$
- (C)  $-\frac{1}{2}Q$
- (D)  $-\frac{1}{8}Q$
- (E) It is not possible to accomplish what is required.

[PhysicsBowl, 2012Q32]

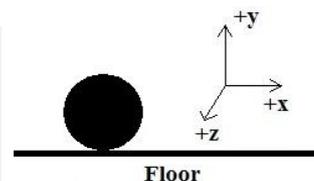
To whom was the first Nobel Prize in physics awarded?

- (A) Isaac Newton for his contributions to physics and calculus.
- (B) James Chadwick for the discovery of the neutron.
- (C) Wilhelm Röntgen for the discovery of X-rays.
- (D) Marie Curie for her work in radioactivity.
- (E) Albert Einstein for his explanation of the photoelectric effect and for the theories of relativity.

[PhysicsBowl, 2012Q33]

A solid, uniform sphere rolls without slipping on a floor along the  $+x$ -axis (to the right). The rotational kinetic energy associated with the sphere about an axis of rotation through its center of mass along the  $+z$ -axis (out of the plane of the page) is 20 Joules. What is the translational kinetic energy associated with the sphere?

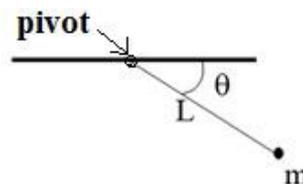
- (A) 8 J
- (B) 10 J
- (C) 20 J
- (D) 40 J
- (E) 50 J



[PhysicsBowl, 2012Q34]

A mass  $m$  attached to a light string of length  $L$  is located at an angle  $\theta$  below the horizontal as shown in the figure to the right. The mass then is released from rest. Calculated from an axis perpendicular to the plane of the page through the pivot, which one of the following choices represents the magnitude of the torque produced by the gravitational force acting on the mass at this instant?

- (A)  $mgL$
- (B)  $mgL \sin \theta$
- (C)  $mgL \cos \theta$
- (D)  $mgL(1 - \sin \theta)$
- (E)  $mgL(1 - \cos \theta)$



[PhysicsBowl, 2012Q35]

A student wants to set up an experiment with a thin convex lens of focal length  $f$  such that a thin real object produces a focused real image on a movable screen. At how many locations along the optical axis (principal axis) can the object be placed so that the distance between the object and the focused image on the screen is equal to  $3f$ ?

- (A) There is no location.
- (B) There is exactly one location.
- (C) There are exactly two locations.
- (D) There are exactly four locations.
- (E) There are an infinite number of locations.

[PhysicsBowl, 2012Q36]

A positive charge moves with constant velocity through a region of space containing both an electric field and a magnetic field. The electric field is directed out of the plane of the page. Ignoring any gravitational field, which one of the following choices represents possible directions of both the particle's velocity and the total magnetic field in the region of space?

	Velocity of particle	Magnetic Field
(A)	Toward the bottom of the page	Into the plane of the page
(B)	Into the plane of the page	Out of the plane of the page
(C)	To the left	Toward the bottom of the page
(D)	Toward the top of the page	To the right
(E)	Out of the plane of the page	Toward the top of the page



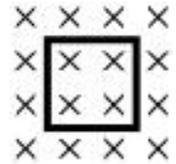
[PhysicsBowl, 2012Q37]

The cylindrical head of an aluminum nail has a diameter of 1.00 cm. For the top layer of atoms in the nail's head, which one of the following choices best represents the number of aluminum atoms in that layer?

- (A)  $10^{10}$
- (B)  $10^{15}$
- (C)  $10^{20}$
- (D)  $10^{25}$
- (E)  $10^{30}$

[PhysicsBowl, 2012Q38]

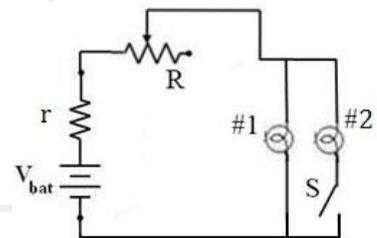
A square, conducting wire loop sits in a plane perpendicular to a spatially uniform magnetic field pointing into the plane of the page as shown. The magnetic field strength steadily increases with time. Which one of the following effects best describes the result of this field increase?



- (A) The entire loop moves up the plane of the page.
- (B) The loop rotates with the top edge of the loop initially moving out of the plane of the page and the bottom edge moving into the plane of the page.
- (C) The loop rotates with the top edge of the loop initially moving into the plane of the page and the bottom edge moving out of the plane of the page.
- (D) The legs of the loop attempt to increase the area enclosed by the loop.
- (E) The legs of the loop attempt to decrease the area enclosed by the loop.

[PhysicsBowl, 2012Q39]

For the circuit shown, all wires have no resistance, the battery has a constant internal resistance of  $r = 8.0 \Omega$  and the two light bulbs (#1 and #2) are identical, each with resistance  $R_{\text{bulb}}$ . The variable resistor is initially set to  $R = 26.0 \Omega$ . The switch  $S$  in the circuit now is closed. To what resistance must the variable resistor be set if bulb #1 is to have the same brightness after the switch is closed as it did with the switch open?



- (A)  $9.0 \Omega$
- (B)  $13.0 \Omega$
- (C)  $16.0 \Omega$
- (D)  $22.0 \Omega$
- (E) The answer can be computed only if the bulbs' resistance  $R_{\text{bulb}}$  is known.



[PhysicsBowl, 2012Q40]

Using the kinetic theory of gases, which one of the following choices best represents the rms (root mean square) speed of 58 grams of a monatomic ideal gas at a pressure of 3.0 atm in an enclosed container of volume 6.0 L?

- (A) 0.557 m/s
- (B) 9.71 m/s
- (C) 177 m/s
- (D) 307 m/s
- (E) 3150 m/s

**Questions 41 and 42 deal with the following information:**

A hypothetical radioactive substance Aaptinium decays via alpha-emission into Physicsbowlium. The decay constant for this alpha-emission is  $20 \text{ s}^{-1}$ .

[PhysicsBowl, 2012Q41]

Which one of the following statements correctly compares Physicsbowlium to Aaptinium?

- (A) Physicsbowlium has 4 fewer protons and 2 fewer neutrons than Aaptinium.
- (B) Physicsbowlium has 4 fewer neutrons and 2 fewer protons than Aaptinium.
- (C) Physicsbowlium has 2 fewer protons and 2 fewer neutrons than Aaptinium.
- (D) Physicsbowlium has 4 fewer protons than and the same number of neutrons as, Aaptinium.
- (E) Physicsbowlium has 2 fewer protons than and the same number of neutrons as, Aaptinium.

[PhysicsBowl, 2012Q42]

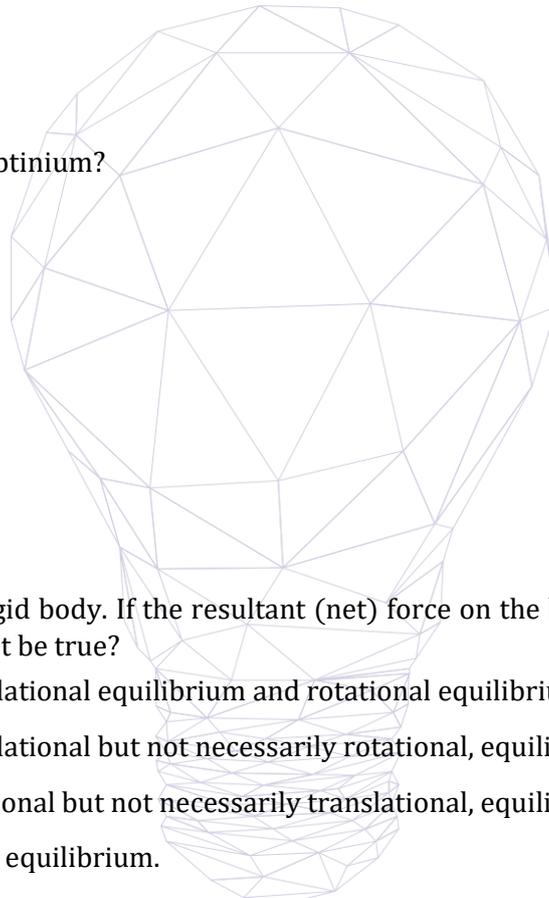
What is the half-life of Aaptinium?

- (A) 0.035 s
- (B) 0.050 s
- (C) 0.100 s
- (D) 0.297 s
- (E) 0.693 s

[PhysicsBowl, 2012Q43]

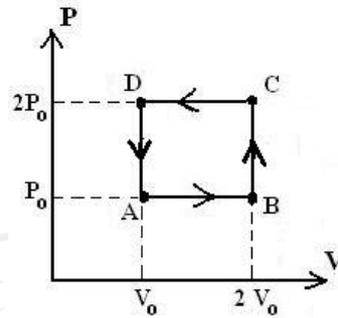
Several forces act on a rigid body. If the resultant (net) force on the body is zero, which one of the following statements must be true?

- (A) The object is in translational equilibrium and rotational equilibrium.
- (B) The object is in translational but not necessarily rotational, equilibrium.
- (C) The object is in rotational but not necessarily translational, equilibrium.
- (D) The object is in static equilibrium.
- (E) The object is in neither translational nor rotational equilibrium.



[PhysicsBowl, 2012Q44]

A monatomic ideal gas is the working substance for a refrigerator that undergoes the cyclic process ( $ABCD$ ) shown in the  $PV$  diagram. The processes are all isochoric or isobaric with pressures between  $P_0$  and  $2P_0$  and volumes between  $V_0$  and  $2V_0$ . What is the coefficient of performance for this refrigerator?



- (A)  $1/4$
- (B)  $1/3$
- (C)  $4/3$
- (D)  $11/2$
- (E)  $13/2$

[PhysicsBowl, 2012Q45]

A stationary atom of mass  $4.00 \times 10^{-26}$  kg spontaneously emits a photon of energy 10.0 eV. Which one of the following choices best represents the speed, in units of m/s, of the atom after emitting the photon?

2012

- (A)  $4.00 \times 10^7$
- (B)  $8.94 \times 10^3$
- (C)  $1.33 \times 10^{-1}$
- (D)  $1.58 \times 10^{-4}$
- (E)  $2.50 \times 10^{-8}$

[PhysicsBowl, 2012Q46]

There is a quantity called the Planck time,  $t_{\text{planck}}$ , which is computed in terms of constants as  $t_{\text{planck}}^2 = \frac{\hbar G}{c^n}$  where  $\hbar$  is Planck's constant divided by  $2\pi$ ,  $G$  is the Universal Gravitational Constant, and  $c$  is the speed of light. In order for this expression for time to be consistent, what is the numerical value of  $n$ , the power to which the speed of light is raised?

- (A) 2
- (B) 3
- (C) 4
- (D) 5
- (E) 6

[PhysicsBowl, 2012Q47]

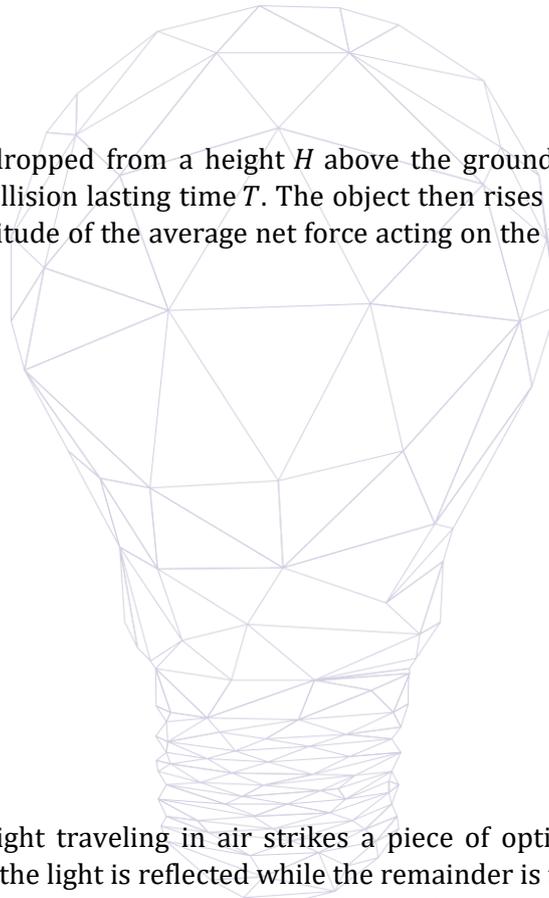
Water flows ideally through a cylindrically-shaped pipe. At the lower end, the pipe's cross-sectional area is  $30.0 \text{ cm}^2$  whereas in the upper portion, the pipe's cross-sectional area is  $10.0 \text{ cm}^2$  and fluid is moving at  $9.0 \text{ m/s}$ . Which one of the following choices best represents the difference in pressure between the lower section of the pipe and the upper section if the vertical distance between the centers of the pipe sections is  $2.0 \text{ m}$ ?

- (A)  $5.6 \text{ Pa}$
- (B)  $6.05 \text{ Pa}$
- (C)  $56 \text{ kPa}$
- (D)  $60.5 \text{ kPa}$
- (E)  $65 \text{ kPa}$

[PhysicsBowl, 2012Q48]

An object of mass  $M$  is dropped from a height  $H$  above the ground. The object bounces off of a horizontal surface in a collision lasting time  $T$ . The object then rises upward to a maximum height  $H/2$ . What was the magnitude of the average net force acting on the mass during the collision with the surface?

- (A)  $(2 - \sqrt{2}) \frac{M\sqrt{gH}}{T}$
- (B)  $(\frac{1}{\sqrt{2}} + 1) \frac{M\sqrt{gH}}{T}$
- (C)  $\sqrt{3} \frac{M\sqrt{gH}}{T}$
- (D)  $(2\sqrt{2} - 1) \frac{M\sqrt{gH}}{T}$
- (E)  $(\sqrt{2} + 1) \frac{M\sqrt{gH}}{T}$



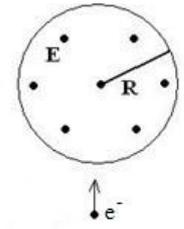
[PhysicsBowl, 2012Q49]

A beam of unpolarized light traveling in air strikes a piece of optically flat glass at an angle of incidence of  $58^\circ$ . Some of the light is reflected while the remainder is transmitted into the glass. The reflected beam is 100% polarized parallel to the surface of the glass. What is the index of refraction for the glass?

- (A) 1.60
- (B) 1.53
- (C) 1.47
- (D) 1.38
- (E) 1.18

[PhysicsBowl, 2012Q50]

A spatially uniform electric field is constrained within the circular region of radius  $R$  as shown. The field is directed out of the plane of the page and its strength is decreasing uniformly with time. Which one of the following choices best represents the direction of the Lorentz force on the electron at the instant shown in the figure when the electron is moving up the plane of the page? Ignore gravity.



- (A) No Force
- (B) Into the plane of the page
- (C) Out of the plane of the page
- (D) To the right
- (E) To the left



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# PhysicsBowl 2013

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2013

[Online Exam](#)

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

**The following 2 questions deal with the following information:**

A small object is released from rest and reaches the ground in a time of 2.50 s. Neglect air resistance.

[PhysicsBowl, 2013Q1]

Red light from a laser is noted to have a wavelength of 632.8 *nanometers*. Which one of the following choices best represents the meaning of the prefix *nano*?

- (A)  $1 \times 10^{-3}$
- (B)  $1 \times 10^{-6}$
- (C)  $1 \times 10^{-9}$
- (D)  $1 \times 10^{-12}$
- (E)  $1 \times 10^{-15}$

**Questions 2 – 3 deal with the following information:**

A small object is released from rest and reaches the ground in a time of 2.50 s. Neglect air resistance.

[PhysicsBowl, 2013Q2]

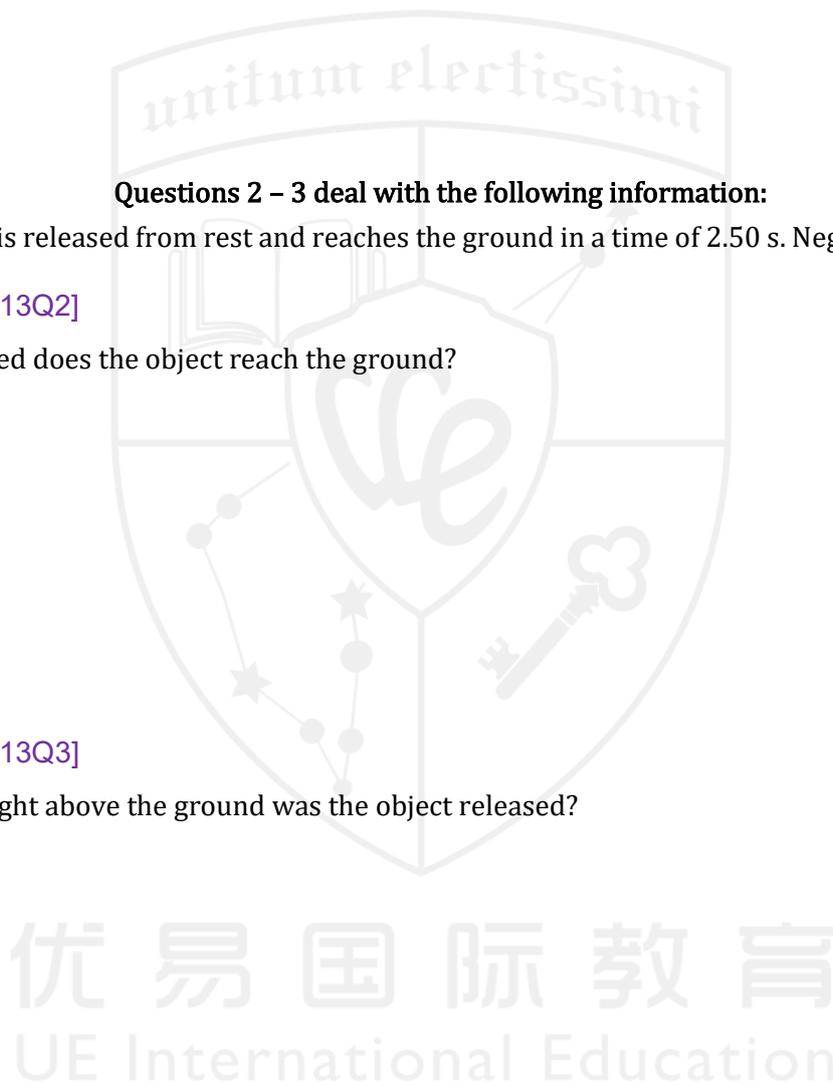
With what speed does the object reach the ground?

- (A) 31.3 m/s
- (B) 25.0 m/s
- (C) 12.5 m/s
- (D) 10.0 m/s
- (E) 2.50 m/s

[PhysicsBowl, 2013Q3]

From what height above the ground was the object released?

- (A) 6.25 m
- (B) 12.5 m
- (C) 25.0 m
- (D) 31.3
- (E) 62.5 m



[PhysicsBowl, 2013Q4]

A scientist calculated a quantity that was equal to one light-year. Which one of the following choices represents the type of quantity that the scientist calculated?

- (A) Time
- (B) Mass
- (C) Speed
- (D) Force
- (E) Distance

[PhysicsBowl, 2013Q5]

At an instant of time  $t$ , a point object of mass  $M$  moves with velocity  $\vec{V}$ , has acceleration  $\vec{A}$  and is at position  $(x, y)$ . In what direction must the linear momentum of the object be directed at this instant?

- (A) Along the direction of the velocity of the mass
- (B) Along the direction of the net force acting on the mass
- (C) Along the direction of the vector from the origin  $(0,0)$  to  $(x, y)$
- (D) Along the direction of the acceleration of the mass
- (E) Along the direction perpendicular to the object's acceleration

[PhysicsBowl, 2013Q6]

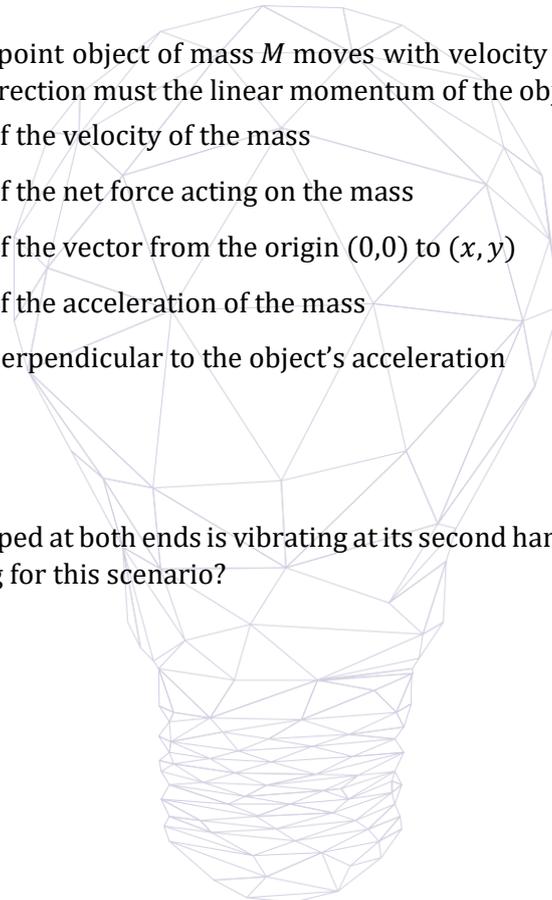
A 1.50 m-long string clamped at both ends is vibrating at its second harmonic. What is the wavelength associated with the string for this scenario?

- (A) 3.00 m
- (B) 2.25 m
- (C) 1.50 m
- (D) 1.00 m
- (E) 0.75 m

[PhysicsBowl, 2013Q7]

Two identical particles are fixed in place a distance of 0.50 m apart. The electric force that one particle exerts on the other has a magnitude of 3.00 N. Which one of the following choices best represents the magnitude of each particle's charge?

- (A)  $4.17 \times 10^{-11} \text{ C}$
- (B)  $8.33 \times 10^{-11} \text{ C}$
- (C)  $1.67 \times 10^{-10} \text{ C}$
- (D)  $9.13 \times 10^{-6} \text{ C}$
- (E)  $1.29 \times 10^{-5} \text{ C}$



[PhysicsBowl, 2013Q8]

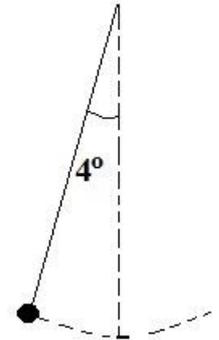
Some standard household lights are being replaced with LEDs. LED is the acronym for which one of the following choices?

- (A) Low Emission Dial
- (B) Light Emitting Diode
- (C) Light Energy Divider
- (D) Lower Edge Disc
- (E) Limiting Emission Diode

[PhysicsBowl, 2013Q9]

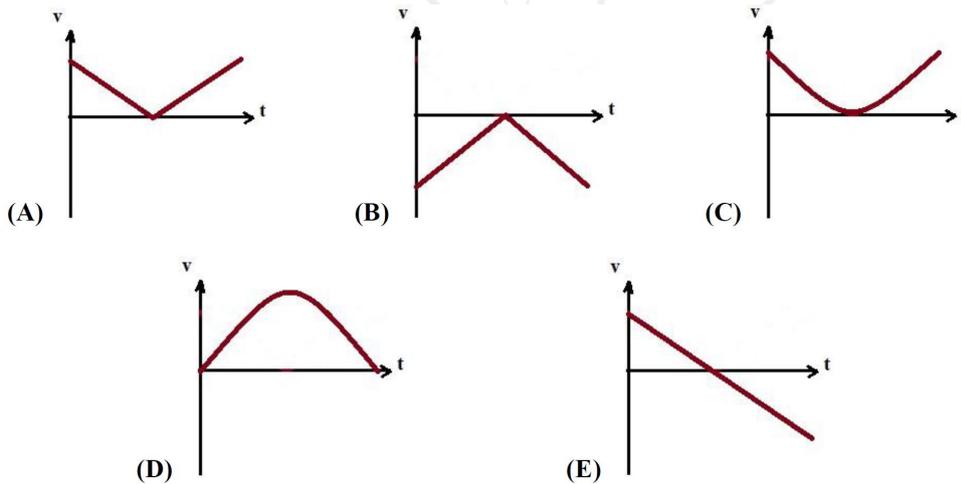
A simple pendulum oscillates with a period of 2.0 s. If the maximum oscillation of the pendulum is  $4.0^\circ$  from equilibrium, what is the length of the string for this pendulum?

- (A) 6.4 m
- (B) 3.2 m
- (C) 1.6 m
- (D) 1.0 m
- (E) 0.5 m



[PhysicsBowl, 2013Q10]

An object is thrown straight upward. The object remains in free fall until it returns to its initial launch point. Which one of the following graphs could represent the velocity of the object as a function of time during its flight?



[PhysicsBowl, 2013Q11]

There was great excitement in the physics community because of an announcement from the LHC during the summer of 2012. Which one of the following choices best represents the reason for the excitement?

- (A) The announcement that life was found on Mars.
- (B) The announcement that dark matter had been created and studied in the laboratory.
- (C) The announcement that the Hubble Telescope discovered a “spaceship-like” object near Alpha Centauri.
- (D) The announcement that the mass of a neutrino had been determined.
- (E) The announcement that there was experimental evidence of a particle consistent with a Higgs Boson.

[PhysicsBowl, 2013Q12]

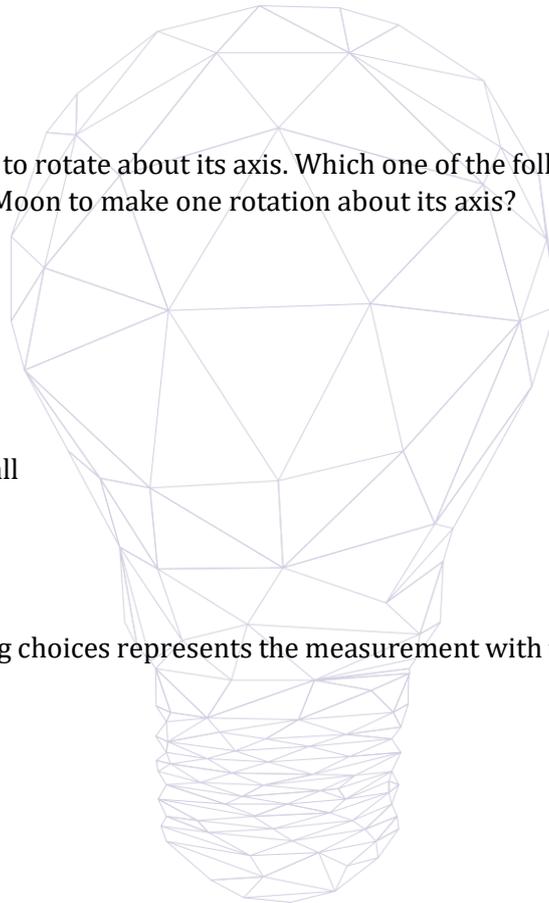
It takes the Earth one day to rotate about its axis. Which one of the following choices best represents the time that it takes the Moon to make one rotation about its axis?

- (A) One day
- (B) One week
- (C) One month
- (D) One year
- (E) It does not rotate at all

[PhysicsBowl, 2013Q13]

Which one of the following choices represents the measurement with the most number of significant digits?

- (A) 6.75 m
- (B)  $4.67 \times 10^9$  m
- (C) 0.000000012 m
- (D) 8100 m
- (E) 2.00005 m



## [PhysicsBowl, 2013Q14]

A small ball is thrown at an angle of  $30^\circ$  above the horizontal ground with a speed of 20.0 m/s. To what maximum height above the launch point does the ball rise during its motion? Ignore air resistance.

- (A) 2.5 m
- (B) 5.0 m
- (C) 10.0 m
- (D) 15.0 m
- (E) 20.0 m

## [PhysicsBowl, 2013Q15]

In a circuit, the flow of electrons in a horizontal wire produces a constant current of 3.20 A for a time of 3.0 hr. Which one of the following choices best represents the number of electrons that pass through a vertical cross-section of the wire during this time?

- (A) 9.60
- (B)  $6.00 \times 10^{19}$
- (C)  $7.20 \times 10^{22}$
- (D)  $2.16 \times 10^{23}$
- (E)  $6.02 \times 10^{23}$

## [PhysicsBowl, 2013Q16]

A block initially moving at 8.0 m/s accelerates uniformly to rest on a horizontal surface. The block travels a distance of 12.0 m during the slide. Which one of the following choices best represents the coefficient of kinetic friction between the surface and the block?

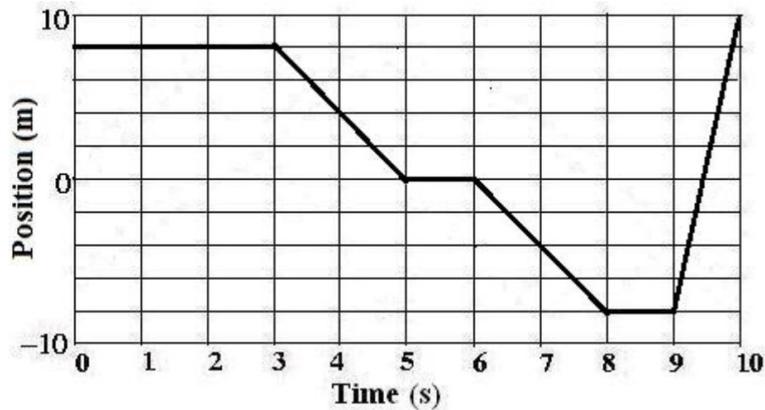
- (A) 1.20
- (B) 0.667
- (C) 0.533
- (D) 0.267
- (E) 0.133

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[PhysicsBowl, 2013Q17]

A position vs. time graph of a particle moving along a horizontal axis is shown. What is the total distance traveled by the particle from  $t = 0$  s to  $t = 10$  s?



- (A) 2 m
- (B) 18 m
- (C) 26 m
- (D) 34 m
- (E) 42 m

[PhysicsBowl, 2013Q18]

Which one of the following choices correctly identifies all of the listed situations for which there is a non-zero acceleration?

Situation I: A point object moves in a straight line with increasing speed.

Situation II: A point object moves in a circular path with constant speed.

Situation III: A point objects moves in a circular path with decreasing speed.

- (A) Situations I, II, & III
- (B) Only Situations I & III
- (C) Only Situations II & III
- (D) Only Situation III
- (E) Only Situation I



[PhysicsBowl, 2013Q19]

Which physicist won the Nobel Prize in physics partly for the explanation of the photoelectric effect?

- (A) Isaac Newton
- (B) Steven Hawking
- (C) Albert Einstein
- (D) Marie Curie
- (E) Neil deGrasse Tyson

[PhysicsBowl, 2013Q20]

A sample of ideal gas at a temperature of  $40.0\text{ }^{\circ}\text{C}$  is in a container of volume  $3.50 \times 10^{-2}\text{ m}^3$ . If the pressure of the gas is  $0.50\text{ atm}$ , how many molecules of the gas are in the container?

- (A)  $4.05 \times 10^{18}$
- (B)  $4.10 \times 10^{20}$
- (C)  $4.05 \times 10^{21}$
- (D)  $4.10 \times 10^{23}$
- (E)  $4.10 \times 10^{26}$

[PhysicsBowl, 2013Q21]

The following nuclear reaction occurs:  ${}_{53}^{131}\text{I} \rightarrow {}_{54}^{131}\text{Xe} + {}_Z^AX$ . What is  ${}_Z^AX$ ?

- (A) a neutron
- (B) a proton
- (C) a positron
- (D) an alpha particle
- (E) an electron

[PhysicsBowl, 2013Q22]

Four resistors, each of resistance  $R$ , are connected to a battery in the following way: "Two resistors are connected in series. This combination of two resistors is connected in parallel to a third resistor. This set of three resistors is connected in series to a fourth resistor." What is the equivalent resistance of this arrangement of four resistors?

- (A)  $\frac{5}{2}R$
- (B)  $\frac{5}{3}R$
- (C)  $\frac{4}{3}R$
- (D)  $\frac{3}{5}R$
- (E)  $\frac{2}{5}R$



[PhysicsBowl, 2013Q23]

A small object of mass 11.0 g is at rest 30.0 cm from a horizontal disk's center. The disk starts to rotate from rest about its center with a constant angular acceleration of  $4.50 \text{ rad/s}^2$ . What is the magnitude of the net force acting on the object after a time of  $t = \frac{1}{3} \text{ s}$  if the object remains at rest with respect to the disk?

- (A) 0 N
- (B)  $7.43 \times 10^{-3} \text{ N}$
- (C)  $1.49 \times 10^{-2} \text{ N}$
- (D)  $1.66 \times 10^{-2} \text{ N}$
- (E)  $2.23 \times 10^{-2} \text{ N}$

[PhysicsBowl, 2013Q24]

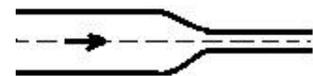
Which one of the following statements best describes Huygens's Principle?

- (A) An additional pressure is transmitted undiminished to all points in the fluid and to the walls of the container.
- (B) Each point on a wavefront acts as a source of secondary spherical wavelets (new waves).
- (C) For every action force, there is an equal but opposite reaction force.
- (D) It is impossible to have a process which has the sole result of transferring energy from a low temperature reservoir to a high temperature reservoir.
- (E) A time-changing magnetic field has an associated induced electric field.



[PhysicsBowl, 2013Q25]

An ideal fluid completely fills a small horizontal tube that has a narrowing cross-sectional area as seen in the figure. Which one of the following choices best describes what has happened to the fluid's speed and its associated pressure in the narrower region as compared to the wider region?



- (A) The fluid speed increased and the fluid pressure decreased.
- (B) The fluid speed increased and the fluid pressure increased.
- (C) The fluid speed increased and the fluid pressure remained the same.
- (D) The fluid speed decreased and the fluid pressure increases.
- (E) The fluid speed decreased and the fluid pressure decreases.

[PhysicsBowl, 2013Q26]

An object moving only to the right completes a 20.0 second trip in two stages, I and II. The average speed of the entire 20.0 second trip is 10.0 m/s.

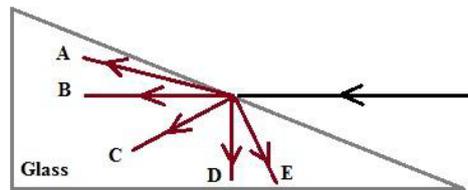
For stage I, the object moves with a constant velocity of 6.0 m/s for 12.0 seconds.

What constant acceleration must the object have during the 8.0 seconds of stage II?

- (A) 2.25 m/s<sup>2</sup>
- (B) 2.50 m/s<sup>2</sup>
- (C) 4.00 m/s<sup>2</sup>
- (D) 6.25 m/s<sup>2</sup>
- (E) 8.50 m/s<sup>2</sup>

[PhysicsBowl, 2013Q27]

Light of wavelength 600 nm is transmitted from air into a piece of glass. Which one of the labeled arrows best indicates the path of the light ray after it enters the glass?



- (A) A
- (B) B
- (C) C
- (D) D
- (E) E

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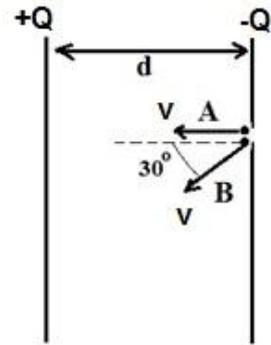
[PhysicsBowl, 2013Q28]

An object is in free fall close to the ground. A person intervenes and slows the object uniformly to rest. Which one of the following statements must be true about the magnitude of the acceleration of the object as it is being stopped by the person? The magnitude of the object's acceleration is  $a_{\text{obj}}$  and the magnitude of the acceleration from gravity is  $g$ .

- (A)  $a_{\text{obj}} = g$
- (B)  $a_{\text{obj}} > g$
- (C)  $a_{\text{obj}} < g$
- (D)  $a_{\text{obj}} \geq g$
- (E) None of the previous relations must be true.

[PhysicsBowl, 2013Q29]

Two electrons enter a region between charged capacitor plates with equal speed  $v$ . Electron  $A$  is directed horizontally to the left while electron  $B$  is directed at  $30^\circ$  below the horizontal. Each electron makes it to the left-hand plate. Which one of the following choices best compares the speeds of the charges ( $v_A, v_B$ ) upon arrival at the left plate? Consider only the electrons  $A$  and  $B$ 's interactions with the constant electric field between the plates, ignoring any relativistic effects.

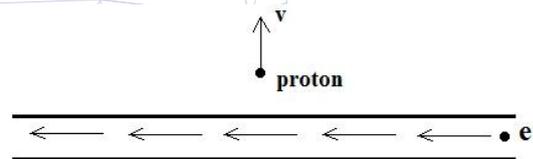


- (A)  $v_A > v_B$
- (B)  $v_A = v_B$
- (C)  $v_A < v_B$
- (D) The answer depends on the size of the plate separation,  $d$ .
- (E) The answer depends on the magnitude of the charge,  $Q$ , on each plate.

[PhysicsBowl, 2013Q30]

Electrons flow to the left in a wire as shown. For the proton moving toward the top of the page at the instant shown, what is the direction of the magnetic force on the proton?

- (A) To the left
- (B) To the right
- (C) Into the plane of the page
- (D) Out of the plane of the page
- (E) There is no force



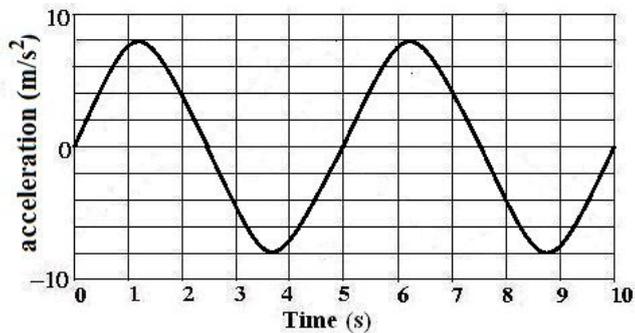
[PhysicsBowl, 2013Q31]

A monatomic ideal gas undergoes a reversible isothermal expansion in an enclosed container. Which one of the following quantities associated with the gas has a value of zero?

- (A) Heat
- (B) Entropy change
- (C) Work done
- (D) Internal energy change
- (E) Pressure change

[PhysicsBowl, 2013Q32]

An acceleration vs. time graph for an object moving along a line is shown. The object starts from rest at time  $t = 0$ . At what time(s) does the object attain a maximum displacement from its starting position?



- (A) At times  $t = 2.5$  s and  $t = 7.5$  s only
- (B) At times  $t = 5.0$  s and  $t = 10$  s only
- (C) At times  $t = 1.25$  s,  $t = 3.75$  s,  $t = 6.25$  s and  $t = 8.75$  s only
- (D) At times  $t = 2.5$  s,  $t = 5.0$  s,  $t = 7.5$  s and  $t = 10$  s only
- (E) At time  $t = 10$  s only

[PhysicsBowl, 2013Q33]

At the top of a high cliff, a small rock is dropped from rest. A ball is launched straight downward with an initial speed of 36.0 m/s at a time 2.10 s after the rock was dropped. When the ball has fallen 28.0 m further than the initially dropped rock, what is the speed of the ball relative to the rock?

2013

- (A) 15.0 m/s
- (B) 16.0 m/s
- (C) 20.0 m/s
- (D) 21.0 m/s
- (E) 36.0 m/s

[PhysicsBowl, 2013Q34]

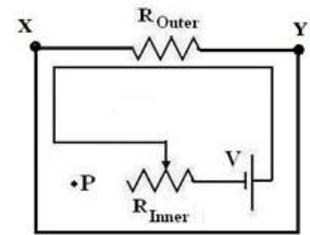
Which one of the following choices represents the base MKS units for sound intensity?

- (A)  $\frac{\text{kg}}{\text{s}^3}$
- (B)  $\frac{\text{m}}{\text{kg}\cdot\text{s}^3}$
- (C)  $\frac{\text{m}^2}{\text{kg}\cdot\text{s}^2}$
- (D)  $\frac{\text{kg}}{\text{m}\cdot\text{s}^2}$
- (E)  $\frac{\text{s}^2}{\text{m}\cdot\text{kg}}$

[PhysicsBowl, 2013Q35]

For the figure shown, the variable resistance of the inner circuit,  $R_{Inner}$ , is increasing at a constant rate. While this is occurring, in which direction is the magnetic field associated with the inner circuit at the point  $P$  in the plane of the circuit and in which direction is the flow of electrons through the resistor labeled  $R_{Outer}$ ?

	Magnetic Field at $P$	Electron flow through $R_{Outer}$
(A)	There is no field	There is no flow
(B)	Into the page	From $Y$ to $X$
(C)	Into the page	From $X$ to $Y$
(D)	Out of the page	From $Y$ to $X$
(E)	Out of the page	From $X$ to $Y$



[PhysicsBowl, 2013Q36]

The principal quantum number of an electron is  $n = 5$ . How many possible values of the orbital magnetic quantum number are there for this electron?

- (A) 25
- (B) 11
- (C) 9
- (D) 5
- (E) 4



[PhysicsBowl, 2013Q37]

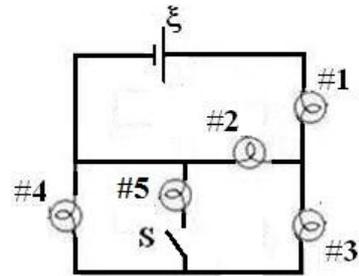
A real object in air is placed in front of a glass lens. The calculated image size is larger than the size of the original object. Which one of the following conclusions about the type of lens used and the type of image formed is correct?

	Type of Lens	Type of Image
(A)	Convex only	Could be virtual or real
(B)	Concave only	Will be virtual only
(C)	Either concave or convex	Will be virtual only
(D)	Convex only	Will be real only
(E)	Either concave or convex	Virtual for the concave lens; Real for the convex lens

[PhysicsBowl, 2013Q38]

Five identical light bulbs are connected into a circuit as shown. All wires are ideal with no resistance, and the ideal battery has emf  $\xi$ . When the switch  $S$  in the circuit is closed, aside from bulb #5, which of the other bulbs brighten?

- (A) Only Bulb #4
- (B) Only Bulbs #1 and #3
- (C) Only Bulbs #3 and #4
- (D) Only Bulbs #2, #3 and #4
- (E) Only Bulbs #1, #3 and #4



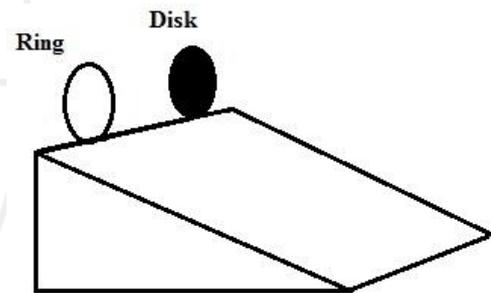
Questions 39-40 deal with the following information:

An ideal uniform solid disk and an ideal uniform ring each have mass  $M$  and radius  $R$ . Each object begins purely rolling without slipping down a rough inclined plane. The coefficients of friction for the disk and ring with the incline are  $\mu_{\text{disk}} > \mu_{\text{ring}}$ .

[PhysicsBowl, 2013Q39]

As each object rolls down the incline, which statement is correct about the force of friction from the incline on the objects?

- (A) The ring experiences a greater force of friction than the disk.
- (B) The disk experiences a greater force of friction than the ring.
- (C) The force of friction is equal and non-zero for both objects.
- (D) The force of friction is equal to zero for both objects.
- (E) Nothing can be concluded about the force of friction without more information.



[PhysicsBowl, 2013Q40]

As the objects roll, what is the ratio of the ring's angular acceleration to the disk's angular acceleration calculated about an axis perpendicular to the object's face and through its center of mass?

- (A) 1:2
- (B) 2:1
- (C)  $\mu_{\text{disk}}:\mu_{\text{ring}}$
- (D) 4:3
- (E) 3:4

[PhysicsBowl, 2013Q41]

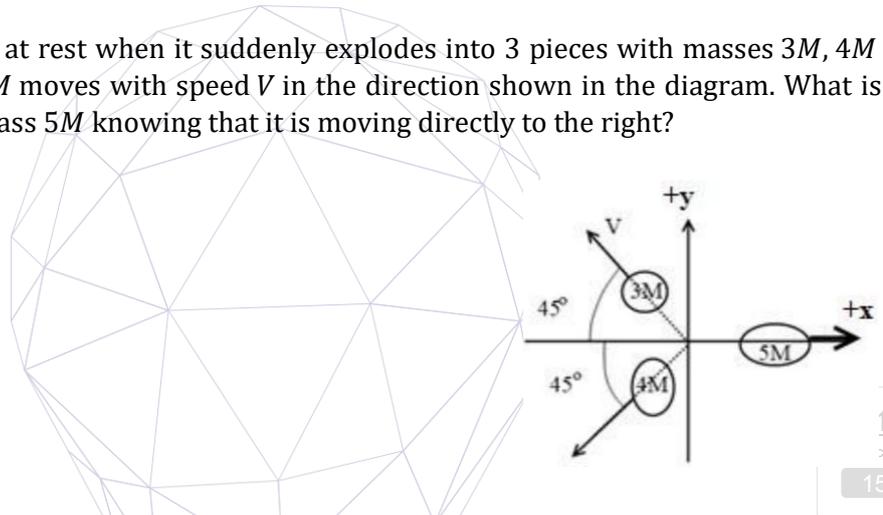
An engine operates between a low temperature of 273 °C and a high temperature of 546 °C. What is the maximum theoretical efficiency of this engine?

- (A) 1/3
- (B) 2/3
- (C) 1/4
- (D) 1/2
- (E) 3/4

[PhysicsBowl, 2013Q42]

An object of mass  $12M$  is at rest when it suddenly explodes into 3 pieces with masses  $3M$ ,  $4M$  and  $5M$ . The piece of mass  $3M$  moves with speed  $V$  in the direction shown in the diagram. What is the speed of the piece with mass  $5M$  knowing that it is moving directly to the right?

- (A)  $V$
- (B)  $\frac{3\sqrt{2}}{20}V$
- (C)  $\frac{3\sqrt{2}}{5}V$
- (D)  $\frac{3}{5\sqrt{2}}V$
- (E)  $\frac{7}{5\sqrt{2}}V$



[PhysicsBowl, 2013Q43]

A small 1.0 kg mass is launched from the top of a cliff with speed  $V$  at an angle of  $30^\circ$  above the horizontal. When the mass reaches the ground, its velocity is directed at  $45^\circ$  below the horizontal. Which one of the following choices is the magnitude of the total impulse that was imparted to the mass during its flight? Ignore air resistance.

- (A)  $\frac{1}{2}(\sqrt{3} + 1)V$
- (B)  $\sqrt{\frac{3(\sqrt{2}+1)}{2}}V$
- (C)  $\frac{1}{2}(\sqrt{3} - 1)V$
- (D)  $\frac{1}{2}\left(\sqrt{\frac{3}{2}} + 1\right)V$
- (E)  $\sqrt{\frac{3(\sqrt{2}+1)}{2(\sqrt{2}-1)}}V$

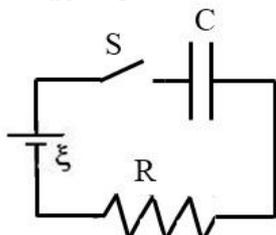
## [PhysicsBowl, 2013Q44]

Which one of the following terms/quantities is most closely associated with “the measure of the resistance of an object to length change under lengthwise tension or compression.”?

- (A) Bulk modulus
- (B) Plastic deformation
- (C) Shear modulus
- (D) Elastic limit
- (E) Young’s modulus

## [PhysicsBowl, 2013Q45]

The switch  $S$  in the  $RC$  circuit shown is closed at time  $t = 0$ . All circuit elements are ideal and  $R = 10.0 \Omega$ ,  $C = 2.20 \text{ F}$  and  $\xi = 12.0 \text{ V}$ . The capacitor is initially uncharged. How long after the switch is closed is the voltage across the capacitor three times as large as the voltage across the resistor?



- (A) 22.0 s
- (B) 24.2 s
- (C) 30.5 s
- (D) 36.0 s
- (E) 54.7 s

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## [PhysicsBowl, 2013Q46]

Which one of the following quarks was the last to be confirmed experimentally?

- (A) Charmed
- (B) Up
- (C) Strange
- (D) Down
- (E) Top

[PhysicsBowl, 2013Q47]

Which one of the following choices best represents the magnitude of the angular momentum of the Earth (expressed in base MKS units) associated with its rotation about its axis?

- (A)  $10^{38}$
- (B)  $10^{34}$
- (C)  $10^{30}$
- (D)  $10^{26}$
- (E)  $10^{22}$

[PhysicsBowl, 2013Q48]

Two identical samples of a monatomic ideal gas are to undergo reversible processes. Which one of the following choices is a correct statement about the heat associated with the processes?

Process 1: An isochoric pressure doubling

Process 2: An isobaric volume doubling

- (A) There is less heat associated with Process 1 than Process 2.
- (B) The heat is the same non-zero value for Processes 1 and 2.
- (C) There is more heat associated with Process 1 than Process 2.
- (D) The heat is zero for Processes 1 and 2.
- (E) More information is required to determine the relationship for the heats.



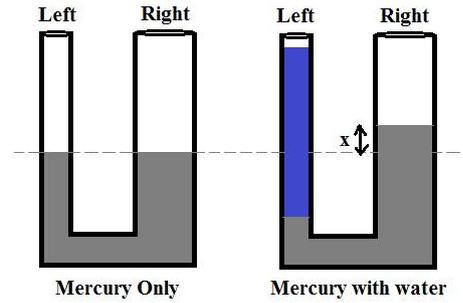
[PhysicsBowl, 2013Q49]

Two electrons move with the magnitude of their linear momentum having a ratio of 2 : 1. If the slower electron moves with a speed of  $1.20 \times 10^8$  m/s, what is the speed of the faster moving electron?

- (A)  $2.67 \times 10^8$  m/s
- (B)  $2.40 \times 10^8$  m/s
- (C)  $2.24 \times 10^8$  m/s
- (D)  $1.97 \times 10^8$  m/s
- (E)  $1.56 \times 10^8$  m/s

[PhysicsBowl, 2013Q50]

A U-tube is filled with mercury (density  $13.6 \text{ g/cm}^3$ ) as shown in the left-most figure. Water of mass 800 grams is added to the left-hand side of the tube. When equilibrium is re-established, the tube appears as shown in the right-most figure. The cross-sectional area of the left tube is  $6.50 \text{ cm}^2$  while the right tube has cross-sectional area  $15.0 \text{ cm}^2$ . Which one of the following choices best represents the height  $x$  above the original equilibrium that the mercury rises in the right tube? The drawings are not to scale.



- (A) 1.96 cm
- (B) 2.74 cm
- (C) 3.92 cm
- (D) 4.92 cm
- (E) 9.05 cm



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# PhysicsBowl 2014

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2014

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2014Q1]

An FM radio station sends a signal with a frequency of  $99.99 \times 10^6$  Hz. Which one of the following choices best represents this frequency expressed using metric prefixes?

- (A) 99.99 kHz
- (B) 99.99 MHz
- (C) 99.99 GHz
- (D) 99.99 THz
- (E) 99.99 nHz

[PhysicsBowl, 2014Q2]

In the laboratory, a student makes the following six measurements for the length of an object: 5.05 cm, 5.06 cm, 5.07 cm, 5.06 cm, 5.07 cm and 5.09 cm. Using the rules of significant digits, which one of the following choices correctly represents how she should express the average length of the object?

- (A) 5 cm
- (B) 5.06 cm
- (C) 5.06 $\bar{6}$  cm
- (D) 5.07 cm
- (E) 5.1 cm

[PhysicsBowl, 2014Q3]

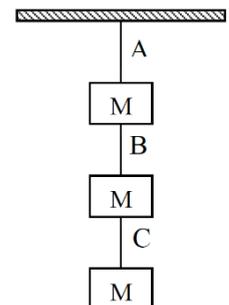
An object is dropped into free fall. Through how many meters does the object fall during the first 3.00 seconds of flight?

- (A) 10.0 m
- (B) 15.0 m
- (C) 30.0 m
- (D) 45.0 m
- (E) 90.0 m

[PhysicsBowl, 2014Q4]

Three equal masses are suspended from a classroom ceiling by a series of strings as shown in the figure. Which string has the greatest tension?

- (A) Only String *A*
- (B) Only String *B*
- (C) Only String *C*
- (D) Strings *A*, *B* and *C* have the same non-zero tension.
- (E) Strings *A*, *B* and *C* all have no tension.



[PhysicsBowl, 2014Q5]

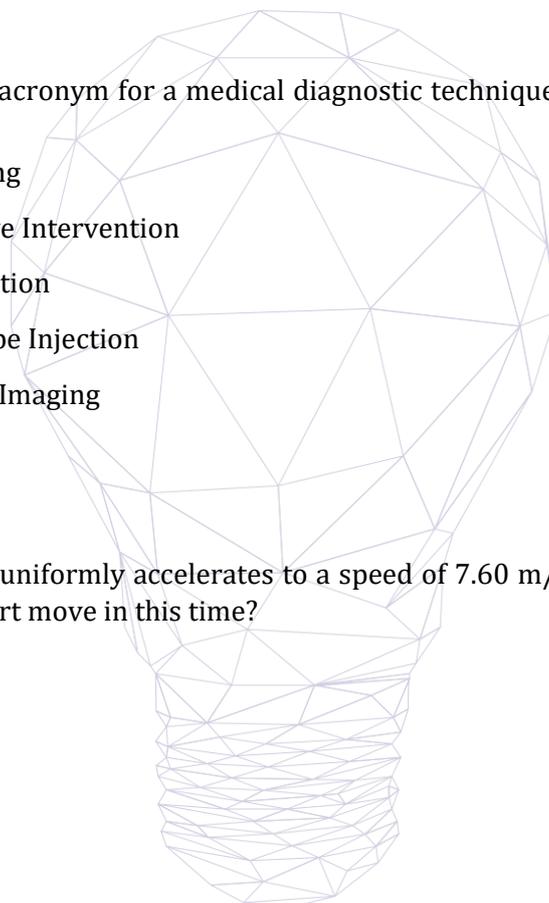
A simple pendulum consists of a massive bob connected to the end of a very light string. Which one of the following changes should be made in order to increase the period of the pendulum? Ignore air resistance.

- (A) Increase the mass of the bob
- (B) Decrease the mass of the bob
- (C) Increase the length of the string
- (D) Decrease the length of the string
- (E) Decrease the maximum angle of the pendulum's oscillation

[PhysicsBowl, 2014Q6]

MRI is a commonly used acronym for a medical diagnostic technique. MRI stands for which one of the following choices?

- (A) Medical Radio Imaging
- (B) Minimally Radioactive Intervention
- (C) Multiaxis Radar Injection
- (D) Magnetic Radioisotope Injection
- (E) Magnetic Resonance Imaging



[PhysicsBowl, 2014Q7]

Starting from rest, a cart uniformly accelerates to a speed of 7.60 m/s in a time of 3.00 s. Through what distance does the cart move in this time?

- (A) 5.7 m
- (B) 8.1 m
- (C) 11.4 m
- (D) 16.1 m
- (E) 22.8 m

[PhysicsBowl, 2014Q8]

A 2.50 kg mass connected to the end of an ideal spring oscillates in simple harmonic motion. The mass's position is described as a function of time by  $x(t) = 0.20 \cos(8.00t + 0.50)$  where all quantities are in base SI units. Which one of the following choices gives the numerical value of the oscillation's amplitude in base SI units?

- (A) 8.00
- (B) 4.00
- (C) 1.60
- (D) 0.50
- (E) 0.20

[PhysicsBowl, 2014Q9]

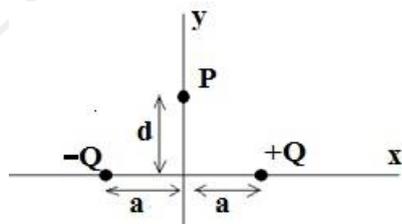
Which one of the following quantities is not a scalar quantity?

- (A) Force
- (B) Energy
- (C) Mass
- (D) Speed
- (E) Pressure

[PhysicsBowl, 2014Q10]

Two charges,  $-Q$  and  $+Q$ , are fixed in place on the  $x$ -axis, each a distance  $a$  from the origin as shown. At the point labeled  $P$ , a distance  $d$  along the  $y$ -axis from the origin, what is the direction of the electric field from the given charges?

- (A) Up the plane of the page
- (B) Down the plane of the page
- (C) To the right
- (D) To the left
- (E) There is no electric field.



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[PhysicsBowl, 2014Q11]

A crate gains 36.0 J of kinetic energy while its speed is increased from 2.00 m/s to 4.00 m/s. Which one of the following choices best represents the mass of the crate?

- (A) 36.0 kg
- (B) 18.0 kg
- (C) 6.0 kg
- (D) 3.0 kg
- (E) 1.5 kg

[PhysicsBowl, 2014Q12]

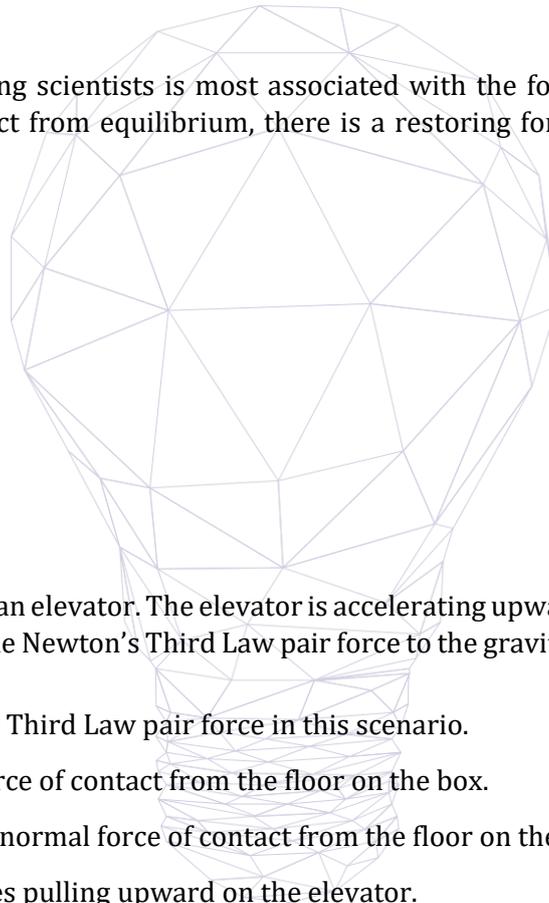
A box of mass 5.0 kg is being pushed to the right across a horizontal surface while a constant frictional force of 8.0 N acts on the box. At some instant of time, the box has a speed of 4.0 m/s and an acceleration of 3.0 m/s<sup>2</sup>. What is the magnitude of the net force acting on the box at this instant?

- (A) 7.0 N
- (B) 12.0 N
- (C) 15.0 N
- (D) 20.0 N
- (E) 23.0 N

[PhysicsBowl, 2014Q13]

Which one of the following scientists is most associated with the following statement: “For small displacements of an object from equilibrium, there is a restoring force that is proportional to the displacement.”?

- (A) Einstein
- (B) Hooke
- (C) Huygens
- (D) Kepler
- (E) Lenz



[PhysicsBowl, 2014Q14]

A box rests on the floor of an elevator. The elevator is accelerating upward. Which one of the following choices best represents the Newton’s Third Law pair force to the gravitational force acting on the box by the Earth?

- (A) There is no Newton’s Third Law pair force in this scenario.
- (B) The entire normal force of contact from the floor on the box.
- (C) Only a portion of the normal force of contact from the floor on the box.
- (D) The force of the cables pulling upward on the elevator.
- (E) The gravitational force acting on the Earth by the box.

[PhysicsBowl, 2014Q15]

Two objects,  $A$  and  $B$ , move in space and then collide.

Before collision: Object  $A$ , of mass  $5.0\text{ kg}$ , moves to the right with a speed of  $25.0\text{ m/s}$ .

Object  $B$ , of mass  $10.0\text{ kg}$ , moves to the left with a speed of  $20.0\text{ m/s}$ .

After collision: Object  $A$  moves to the left with a speed of  $25.0\text{ m/s}$ .

What is the velocity of object  $B$  after the collision?

- (A)  $30.0\text{ m/s}$  to the right
- (B)  $20.0\text{ m/s}$  to the right
- (C)  $20.0\text{ m/s}$  to the left
- (D)  $5.0\text{ m/s}$  to the right
- (E)  $5.0\text{ m/s}$  to the left

**Questions 16 & 17 refer to the following information:**

A toy car initially moves to the right at  $60.0\text{ cm/s}$ . Five seconds later, the car is moving at  $40.0\text{ cm/s}$  to the left. The total displacement of the car during this time is  $10.0\text{ cm}$  to the left of where it started.

[PhysicsBowl, 2014Q16]

Which one of the following choices best represents the magnitude of the average velocity of the car during the five second motion?

- (A)  $50.0\text{ cm/s}$
- (B)  $10.0\text{ cm/s}$
- (C)  $4.0\text{ cm/s}$
- (D)  $2.0\text{ cm/s}$
- (E)  $0.40\text{ cm/s}$



[PhysicsBowl, 2014Q17]

Which one of the following choices best represents the magnitude of the average acceleration of the car during the five second motion?

- (A)  $20.0\text{ cm/s}^2$
- (B)  $4.0\text{ cm/s}^2$
- (C)  $2.00\text{ cm/s}^2$
- (D)  $0.80\text{ cm/s}^2$
- (E)  $0.40\text{ cm/s}^2$

[PhysicsBowl, 2014Q18]

A rectangular block of wood has a mass of 17.8 g and dimensions of length: 3.00 cm, width: 4.00 cm and height: 2.00 cm. Which one of the following choices correctly gives the average density of the block?

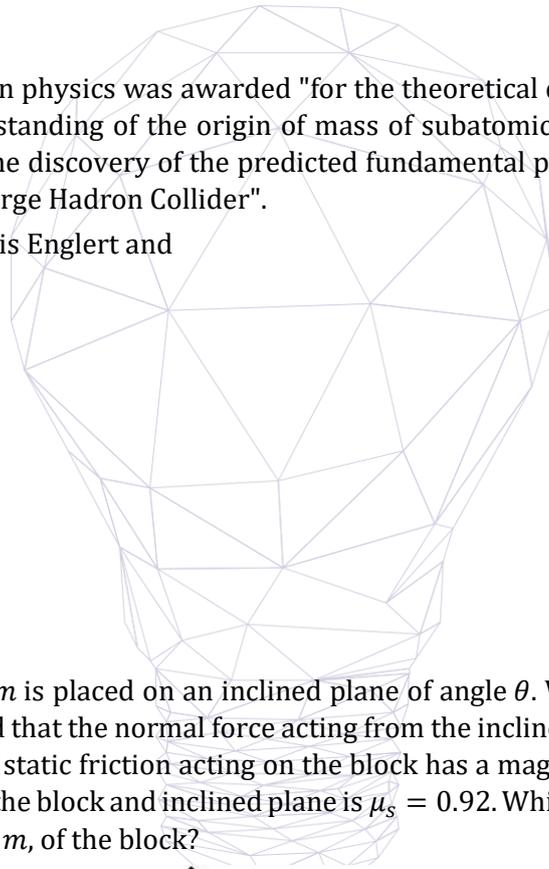
- (A)  $7.42 \times 10^5 \text{ kg/m}^3$
- (B)  $7.42 \times 10^2 \text{ kg/m}^3$
- (C)  $7.42 \text{ kg/m}^3$
- (D)  $7.42 \times 10^{-1} \text{ kg/m}^3$
- (E)  $7.42 \times 10^{-4} \text{ kg/m}^3$

[PhysicsBowl, 2014Q19]

In 2013, the Nobel Prize in physics was awarded "for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider".

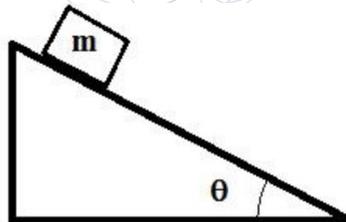
The winners were François Englert and

- (A) Stephen Hawking
- (B) Edward Witten
- (C) Edwin Hubble
- (D) Brian Greene
- (E) Peter Higgs



[PhysicsBowl, 2014Q20]

A uniform block of mass  $m$  is placed on an inclined plane of angle  $\theta$ . When released, the block does not move. It is determined that the normal force acting from the incline on the block has a magnitude of 62 N while the force of static friction acting on the block has a magnitude of 38 N. The coefficient of static friction between the block and inclined plane is  $\mu_s = 0.92$ . Which one of the following choices best represents the mass,  $m$ , of the block?



- (A) 2.4 kg
- (B) 6.2 kg
- (C) 7.3 kg
- (D) 8.4 kg
- (E) 10.0 kg

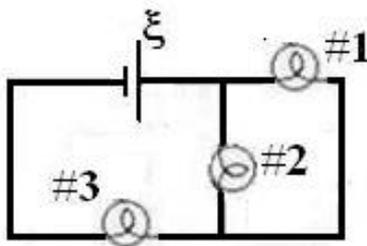
[PhysicsBowl, 2014Q21]

A tuning fork placed over a 57 cm column of air closed only at its bottom end produces a standing wave in the 3rd harmonic. The speed of sound in air is 342 m/s. What is the frequency of the tuning fork?

- (A) 150 Hz
- (B) 300 Hz
- (C) 450 Hz
- (D) 600 Hz
- (E) 900 Hz

[PhysicsBowl, 2014Q22]

For the circuit shown, all three light bulbs have the same resistance. The battery and wires have no resistance. What is the proper ranking of the bulbs' brightness?

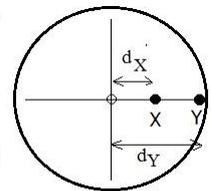


- (A) Bulb 1 = Bulb 2 = Bulb 3
- (B) Bulb 3 < Bulb 2 = Bulb 1
- (C) Bulb 2 < Bulb 1 < Bulb 3
- (D) Bulb 1 = Bulb 2 < Bulb 3
- (E) Bulb 1 = Bulb 3 < Bulb 2



[PhysicsBowl, 2014Q23]

Two small identical coins (labeled  $X$  and  $Y$ ) are at rest on a horizontal disk rotating at a constant rate about an axis perpendicular to the plane of the disk and through its center. The distance of the coins from the center of disk is related by  $d_X = \frac{1}{2}d_Y$ . Which one of the following choices correctly identifies the relationship between  $f_X$  and  $f_Y$ , the frictional force on coin  $X$  and on coin  $Y$ , respectively?

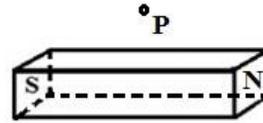


- (A)  $f_X = \frac{1}{4}f_Y$
- (B)  $f_X = \frac{1}{2}f_Y$
- (C)  $f_X = f_Y$
- (D)  $f_X = 2f_Y$
- (E)  $f_X = 4f_Y$

[PhysicsBowl, 2014Q24]

For the bar magnet shown in the figure, which choice best describes the direction of the magnetic field at the point  $P$  located directly above the center of the magnet?

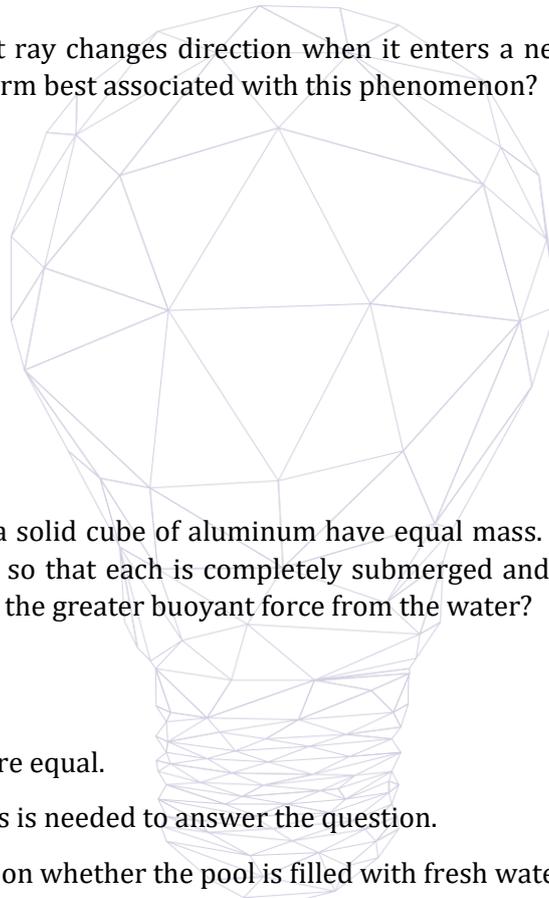
- (A) Up the plane of the page
- (B) To the right
- (C) Down the plane of the page
- (D) To the left
- (E) Out of the plane of the page



[PhysicsBowl, 2014Q25]

It is observed that a light ray changes direction when it enters a new material. Which one of the following choices is the term best associated with this phenomenon?

- (A) Doppler Effect
- (B) Interference
- (C) Polarization
- (D) Diffraction
- (E) Refraction



[PhysicsBowl, 2014Q26]

A solid cube of iron and a solid cube of aluminum have equal mass. The cubes are placed into the same large pool of water so that each is completely submerged and resting on the pool's bottom. Which object experiences the greater buoyant force from the water?

- (A) The iron cube.
- (B) The aluminum cube.
- (C) The buoyant forces are equal.
- (D) The mass of the cubes is needed to answer the question.
- (E) The answer depends on whether the pool is filled with fresh water or salt water.

[PhysicsBowl, 2014Q27]

Two spherical, non-rotating planets,  $X$  and  $Y$ , have the same uniform density  $\rho$ . Planet  $X$  has twice the radius of Planet  $Y$ . Let  $g_x$  and  $g_y$  represent the accelerations due to gravity at the surfaces of Planet  $X$  and Planet  $Y$ , respectively. What is the ratio of  $g_x : g_y$ ?

- (A) 2 : 1
- (B) 1 : 2
- (C) 1 : 1
- (D) 4 : 1
- (E) 1 : 4

## [PhysicsBowl, 2014Q28]

A waterproof speaker placed at the bottom of a swimming pool emits a sound wave that travels toward the surface of the water. In the water, the sound wave has a frequency  $f_{\text{water}}$ , wavelength  $\lambda_{\text{water}}$  and wave speed  $v_{\text{water}}$ . When the sound wave enters the air it has a frequency  $f_{\text{air}}$ , wavelength  $\lambda_{\text{air}}$  and wave speed  $v_{\text{air}}$ . Which one of the following relationships correctly compares the frequencies, wavelengths and wave speeds of the waves in the air and water?

- (A)  $f_{\text{water}} = f_{\text{air}}; \lambda_{\text{water}} = \lambda_{\text{air}}; v_{\text{water}} = v_{\text{air}}$
- (B)  $f_{\text{water}} = f_{\text{air}}; \lambda_{\text{water}} > \lambda_{\text{air}}; v_{\text{water}} > v_{\text{air}}$
- (C)  $f_{\text{water}} < f_{\text{air}}; \lambda_{\text{water}} > \lambda_{\text{air}}; v_{\text{water}} = v_{\text{air}}$
- (D)  $f_{\text{water}} < f_{\text{air}}; \lambda_{\text{water}} = \lambda_{\text{air}}; v_{\text{water}} < v_{\text{air}}$
- (E)  $f_{\text{water}} = f_{\text{air}}; \lambda_{\text{water}} < \lambda_{\text{air}}; v_{\text{water}} > v_{\text{air}}$

## [PhysicsBowl, 2014Q29]

An electron with charge  $-e$  and mass  $m$  travels at a speed  $v$  in a plane perpendicular to a magnetic field of magnitude  $B$ . The electron follows a circular path of radius  $R$ . In a time  $t$ , the electron travels halfway around the circle. What is the amount of work done by the magnetic force on the electron in this time?

- (A) zero
- (B)  $-\pi evBR$
- (C)  $\pi evBR$
- (D)  $-2evBR$
- (E)  $-\frac{\pi mv}{eB}$

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10

## [PhysicsBowl, 2014Q30]

Considering only the Moon-Earth system (ignore any influence of the Sun), which one of the following best expresses the magnitude of the Moon's acceleration about the Earth?

- (A)  $3 \times 10^{-1} \text{ m/s}^2$
- (B)  $3 \times 10^{-2} \text{ m/s}^2$
- (C)  $3 \times 10^{-3} \text{ m/s}^2$
- (D)  $3 \times 10^{-4} \text{ m/s}^2$
- (E)  $3 \times 10^{-5} \text{ m/s}^2$

[PhysicsBowl, 2014Q31]

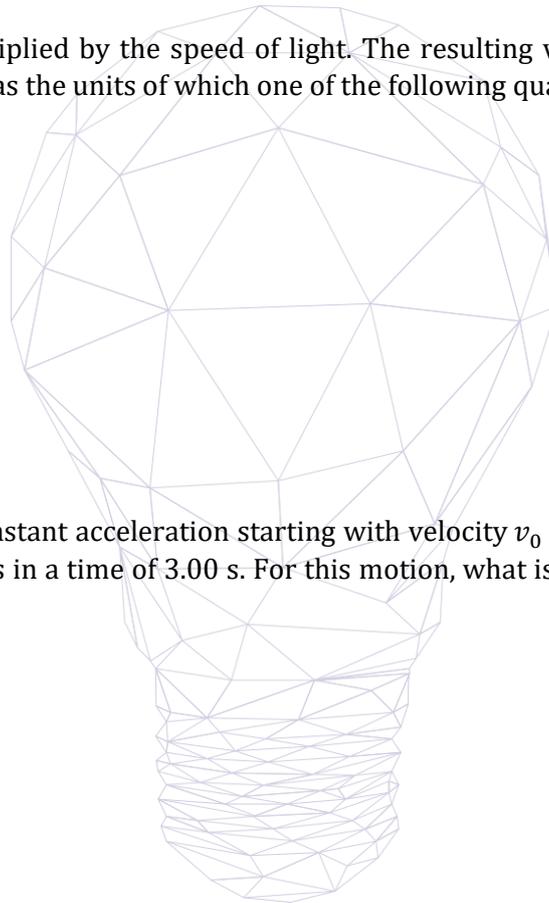
A toy crane exerts an upward force and delivers a useful power output of 0.10 W to raise a block vertically at a constant speed. At what constant speed will this crane raise a 0.20 kg block?

- (A) 0.01 m/s
- (B) 0.02 m/s
- (C) 0.05 m/s
- (D) 0.20 m/s
- (E) 0.50 m/s

[PhysicsBowl, 2014Q32]

Planck's constant is multiplied by the speed of light. The resulting value then is divided by three meters. This final value has the units of which one of the following quantities?

- (A) Force
- (B) Linear Momentum
- (C) Speed
- (D) Frequency
- (E) Energy



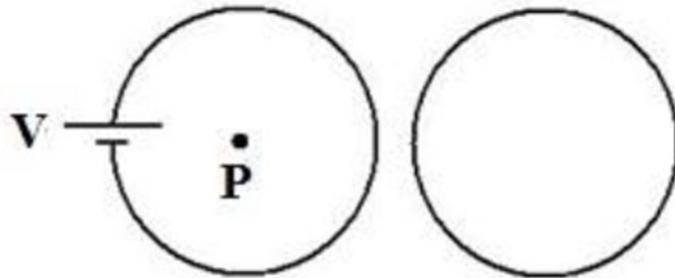
[PhysicsBowl, 2014Q33]

An object moves with constant acceleration starting with velocity  $v_0 = 5.00$  m/s and ending with a velocity of  $v = -1.00$  m/s in a time of 3.00 s. For this motion, what is the average speed associated with the object?

- (A) 2.00 m/s
- (B) 2.17 m/s
- (C) 2.50 m/s
- (D) 2.83 m/s
- (E) 3.00 m/s

[PhysicsBowl, 2014Q34]

Two circular loops of resistive wire are placed next to each other as in the figure. The circular loop on the left is connected to a constant voltage source  $V$ . The resistance of this loop is increasing linearly with time. As the resistance is changing, what is the direction of the magnetic field at point  $P$  (the center of the left-hand loop) and what is the orientation of the conventional current in the right-hand loop (as viewed in the figure from above)?



	Magnetic Field Direction	Current Orientation
(A)	Into the plane of the page	Counterclockwise
(B)	Into the plane of the page	Clockwise
(C)	Out of the plane of the page	Counterclockwise
(D)	Out of the plane of the page	Clockwise
(E)	There is no field	There is no current

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[PhysicsBowl, 2014Q35]

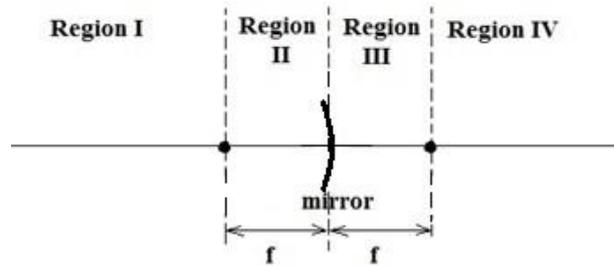
There are several statements presented below that attempt to describe physical phenomena. Which one of the following statements is correct?

- (A) The coefficient of friction is a value always less than or equal to one, but greater than or equal to zero.
- (B) For horizontal surfaces, the normal force acting on an object always cancels the gravitational force.
- (C) An ideal gas's temperature must change if both work is done and energy is exchanged as heat with it.
- (D) Increasing the spacing between slits in the Young's double slit experiment results in an increase in the spacing between the dark regions on a distant viewing screen.
- (E) In electrostatic equilibrium, an electric field is perpendicular to the surface of a charged conductor.

[PhysicsBowl, 2014Q36]

A concave mirror with focal length  $f$  is shown in the figure. A real object now is placed to the left of the mirror. In theory, which one of the following choices best describes everywhere that it is impossible for an image to form from the mirror?

- (A) Region II only.
- (B) Regions II and III only.
- (C) Regions III and IV only
- (D) Regions II and IV only
- (E) Regions I, II and IV only



[PhysicsBowl, 2014Q37]

A new element is discovered and named PhysicsBowlum (atomic symbol *Phys*). Its entry onto the standard periodic table of elements appears as in the figure (with Helium shown as well). Given a sample of *Phys* which acts as a perfect monatomic ideal gas, what is the root-mean-square speed of the atoms of the gas if the sample is at 20 °C?

- (A) 1.04 m/s
- (B) 4.00 m/s
- (C) 33.0 m/s
- (D) 126 m/s
- (E) 191 m/s

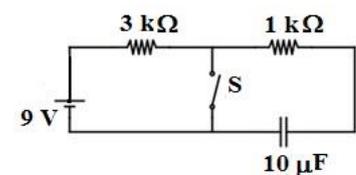
2 <i>He</i> 4.003	200 <i>Phys</i> 458.7
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[PhysicsBowl, 2014Q38]

In the circuit shown, the switch  $S$  has been left open for a very long time. All circuits elements are considered to be ideal. Which one of the following statements best describes the behavior of the current through the switch  $S$  once it is closed?

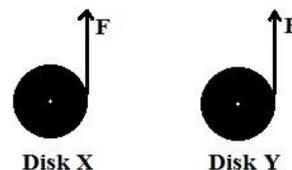
- (A) The current initially is 12 mA and decreases to a steady 3 mA.
- (B) The current initially is 3 mA and increases to a steady 12 mA.
- (C) The current initially is 9 mA and decreases to a steady 3 mA.
- (D) The current initially is 6 mA and decreases to a steady 3 mA.
- (E) The current is a steady 3 mA.



[PhysicsBowl, 2014Q39]

Two uniform disks,  $X$  and  $Y$ , have masses  $m_X < m_Y$ , equal radii and equal initial non-zero kinetic energies. Each disk rotates counterclockwise in the plane of the page about a fixed frictionless axis through its center. As shown in the figure, a force  $F$  is applied tangent to each disk at its right edge for the same amount of time. After the forces are applied, let  $L$  represent the magnitude of the angular momentum about the center of a disk and  $K$  represent the kinetic energy of a disk. Which one of the following choices correctly compares these quantities for disk  $X$  and disk  $Y$ ?

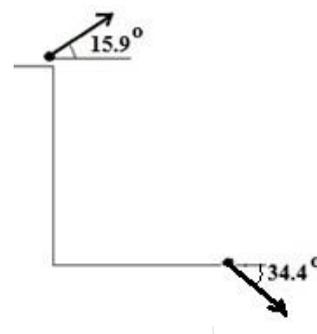
- (A)  $L_X > L_Y; K_X < K_Y$
- (B)  $L_X > L_Y; K_X > K_Y$
- (C)  $L_X = L_Y; K_X = K_Y$
- (D)  $L_X < L_Y; K_X < K_Y$
- (E)  $L_X < L_Y; K_X > K_Y$



[PhysicsBowl, 2014Q40]

A small 1.35 kg mass is launched from the top of a cliff at an angle of  $15.9^\circ$  above the horizontal. When the mass reaches the ground 4.33 seconds later, its velocity is directed at  $34.4^\circ$  below the horizontal. What is the speed of the mass when it reaches the ground? Ignore air resistance.

- (A) 60.7 m/s
- (B) 54.1 m/s
- (C) 46.4 m/s
- (D) 43.3 m/s
- (E) 38.8 m/s



[PhysicsBowl, 2014Q41]

“No two electrons in an atom can have an identical set of the four quantum numbers.” is a statement most closely associated with which one of the following scientists?

- (A) Albert Einstein
- (B) Enrico Fermi
- (C) Sheldon Cooper
- (D) Wolfgang Pauli
- (E) Isaac Newton

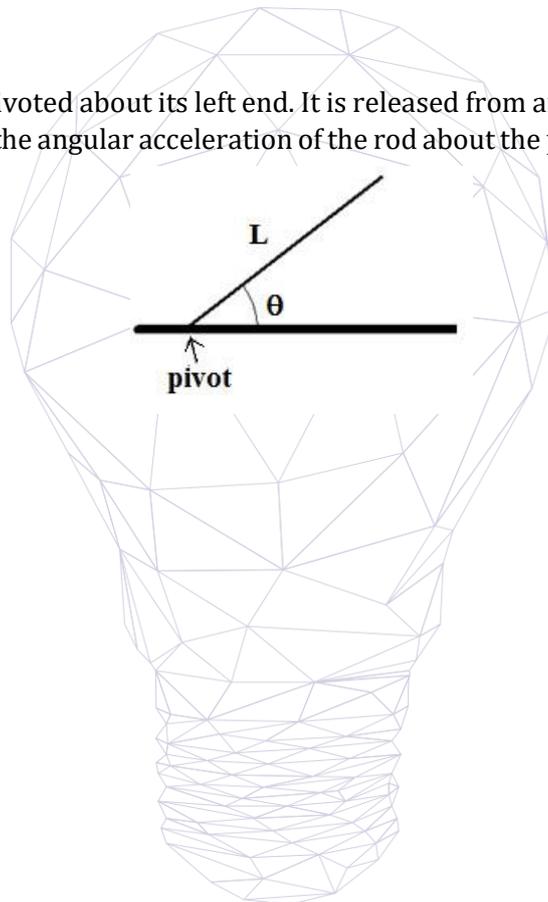
[PhysicsBowl, 2014Q42]

Plane-polarized light with intensity  $I$  is incident on a single polarizing sheet. If the intensity of the light become  $\frac{1}{4}I$  after passing through the polarizer, what is the angle between the transmission axis of the polarizer and the polarization plane of the incident light?

- (A)  $75^\circ$
- (B)  $67.5^\circ$
- (C)  $60^\circ$
- (D)  $30^\circ$
- (E)  $22.5^\circ$

[PhysicsBowl, 2014Q43]

A long rod of length  $L$  is pivoted about its left end. It is released from an angle  $\theta$  above the horizontal. What is the magnitude of the angular acceleration of the rod about the pivot when the rod is released?

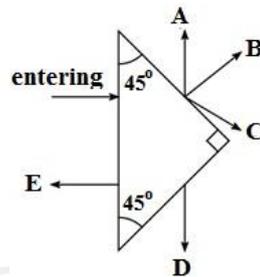


- (A)  $\frac{6g}{L} \cos \theta$
- (B)  $\frac{6g}{L} \sin \theta$
- (C)  $\frac{3g}{2L} \sin \theta$
- (D)  $\frac{3g}{2L} \cos \theta$
- (E)  $\frac{3g}{L} \sin \theta$



[PhysicsBowl, 2014Q44]

A ray of monochromatic light enters the right-triangular glass as shown. The glass has an index of refraction of 2.00 and it is surrounded by air. Which one of the lettered rays shows the path of the light after it exits the glass?



- (A) A
- (B) B
- (C) C
- (D) D
- (E) E

[PhysicsBowl, 2014Q45]

A long thin rod of mass  $M$  and length  $L$  is pivoted at one end so that it swings as a pendulum. The rod is set into simple harmonic oscillation and has a period of motion  $T$ . A second thin rod with mass  $2M$  and length  $2L$  also is pivoted at one end to swing as a pendulum. When this second rod is set into simple harmonic oscillation, what is its period?

- (A)  $2T$
- (B)  $\sqrt{2}T$
- (C)  $T$
- (D)  $\frac{1}{\sqrt{2}}T$
- (E)  $\frac{1}{2}T$

[PhysicsBowl, 2014Q46]

A monatomic, ideal gas undergoes an isobaric process. During the process, the gas performs 80 joules of work on the surroundings. Which one of the following statements best describes the heat exchange during this process?

- (A) 200 joules of energy was added to the gas.
- (B) 200 joules of energy was removed from the gas.
- (C) 80 joules of energy was added to the gas.
- (D) 80 joules of energy was removed from the gas.
- (E) It cannot be determined without knowing the change in temperature for the gas.

[PhysicsBowl, 2014Q47]

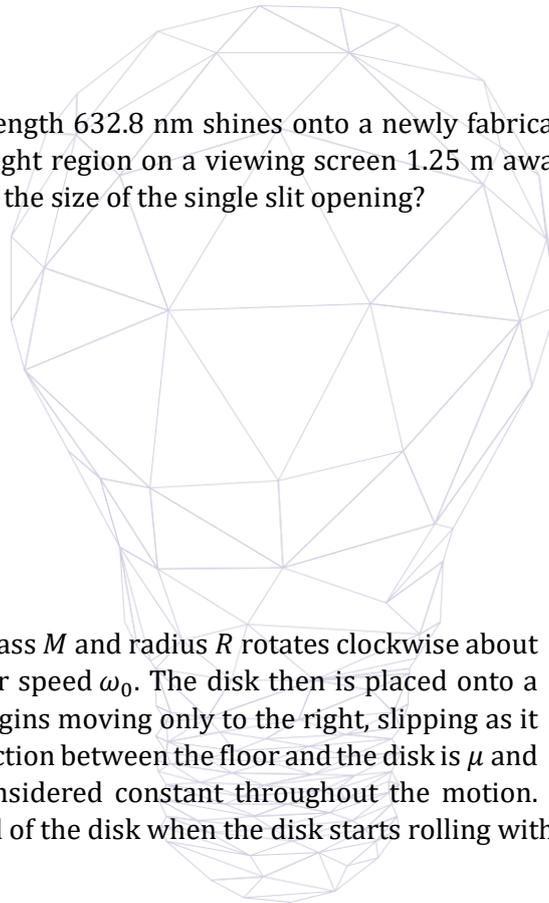
An air-filled parallel-plate capacitor of capacitance  $C$  is fully charged after being connected to a battery of voltage  $V$ . The battery then is disconnected and an insulating dielectric slab of constant  $\kappa$  is inserted between the capacitor's plates, fully filling the region. What is the voltage between the plates once equilibrium is established with the dielectric in place?

- (A)  $\kappa^2 V$
- (B)  $\kappa V$
- (C)  $V$
- (D)  $V/\kappa$
- (E)  $V/\kappa^2$

[PhysicsBowl, 2014Q48]

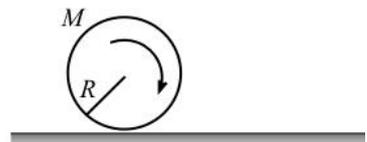
A laser beam with wavelength 632.8 nm shines onto a newly fabricated single slit. As a result, the width of the principal bright region on a viewing screen 1.25 m away is 1.00 m. Which one of the following best represents the size of the single slit opening?

- (A) 0.79  $\mu\text{m}$
- (B) 0.85  $\mu\text{m}$
- (C) 1.01  $\mu\text{m}$
- (D) 1.58  $\mu\text{m}$
- (E) 1.70  $\mu\text{m}$



[PhysicsBowl, 2014Q49]

A solid, uniform disk of mass  $M$  and radius  $R$  rotates clockwise about its center with an angular speed  $\omega_0$ . The disk then is placed onto a horizontal surface and begins moving only to the right, slipping as it rolls. The coefficient of friction between the floor and the disk is  $\mu$  and the frictional force is considered constant throughout the motion. What is the angular speed of the disk when the disk starts rolling without slipping?



- (A)  $\frac{\mu}{2} \omega_0$
- (B)  $\frac{1}{2} \omega_0$
- (C)  $\frac{1}{3} \omega_0$
- (D)  $\frac{2\mu}{3} \omega_0$
- (E)  $\frac{3}{5} \omega_0$

## [PhysicsBowl, 2014Q50]

Two clocks,  $A$  and  $B$ , are synchronized on Earth. Clock  $A$  is placed onto a space ship that leaves Earth in a straight line with a speed of  $2.40 \times 10^8$  m/s. On Earth, a scientist with clock  $B$  has her telescope fixed directly on clock  $A$ . If each clock started at  $t=0$  s, what time does the scientist observe on clock  $A$  when clock  $B$  reads  $t=90$  s? Assume the time of acceleration for the ship leaving the Earth was negligible.

- (A) 24 s
- (B) 30 s
- (C) 50 s
- (D) 54 s
- (E) 72 s



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40 QUESTIONS – 45 MINUTES



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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2015Q1]

Which one of the following choices correctly represents a length of 3.00 mm?

- (A)  $3.00 \times 10^{-6}$  m
- (B)  $3.00 \times 10^{-3}$  m
- (C)  $3.00 \times 10^{-2}$  m
- (D)  $3.00 \times 10^3$  m
- (E)  $3.00 \times 10^6$  m

[PhysicsBowl, 2015Q2]

A box uniformly slides 7.50 m to rest across a flat surface in a time of 12.0 s. What was the initial speed of the box when it started its slide?

- (A) 0.313 m/s
- (B) 0.625 m/s
- (C) 1.25 m/s
- (D) 2.50 m/s
- (E) 5.00 m/s

[PhysicsBowl, 2015Q3]

Which one of the following quantities is not a vector quantity?

- (A) Average speed
- (B) Average velocity
- (C) Linear momentum
- (D) Acceleration
- (E) Average force



[PhysicsBowl, 2015Q4]

A standing wave on a string is produced. Which one of the following choices best describes the location on the string at which maximum constructive interference occurs?

- (A) node
- (B) antinode
- (C) harmonic
- (D) overtone
- (E) amplitude

[PhysicsBowl, 2015Q5]

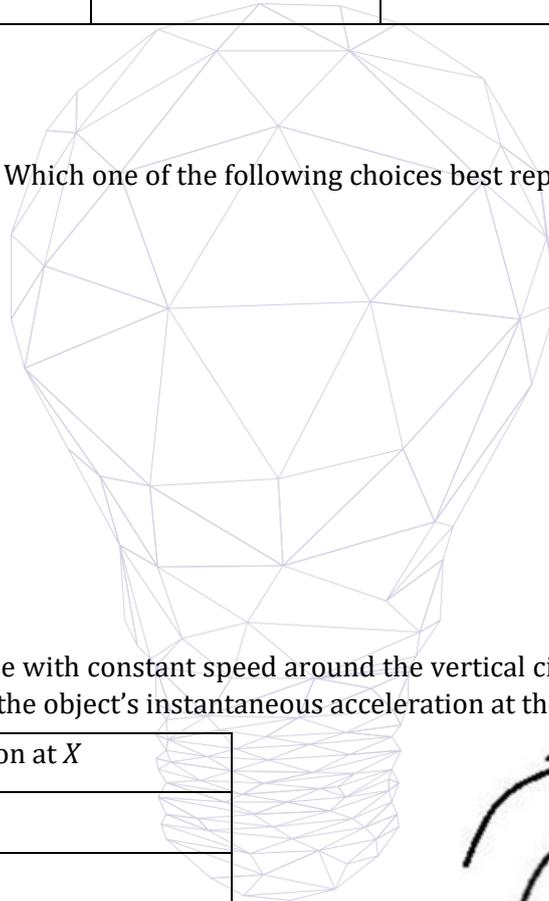
An object initially is moving upward while in free fall. Which one of the following choices best represents the direction of the object's acceleration during its flight?

	Object moving upward	Object at peak of motion	Object moving downward
(A)	Upward	Zero	Downward
(B)	Downward	Zero	Downward
(C)	Upward	Downward	Downward
(D)	Downward	Zero	Upward
(E)	Downward	Downward	Downward

[PhysicsBowl, 2015Q6]

A car travels at  $20.0 \frac{\text{miles}}{\text{hr}}$ . Which one of the following choices best represents the speed of the car in SI units of m/s?

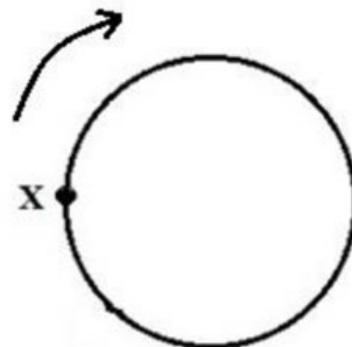
- (A) 533 m/s
- (B) 45.0 m/s
- (C) 20.0 m/s
- (D) 8.9 m/s
- (E) 0.75 m/s



[PhysicsBowl, 2015Q7]

An object moves clockwise with constant speed around the vertical circle shown. Which arrow best indicates the direction of the object's instantaneous acceleration at the point labeled X?

	Acceleration at X
(A)	→
(B)	↓
(C)	←
(D)	↘
(E)	There is no acceleration.



[PhysicsBowl, 2015Q8]

A negatively charged balloon remains at rest when placed on a vertical wall. Which one of the following terms is most closely associated with the electrical phenomenon allowing the balloon to remain on the wall?

- (A) Radiation
- (B) Grounding
- (C) Reduction
- (D) Current
- (E) Polarization

[PhysicsBowl, 2015Q9]

Two cars are moving to the right on a horizontal track, each with constant acceleration. At an instant of time, the information about the cars is shown:

Car #1: position= 125.0 m; velocity= 13.0 m/s; constant acceleration= 1.5 m/s<sup>2</sup>

Car #2: position= 80.0 m; velocity= 9.30 m/s; constant acceleration= 5.5 m/s<sup>2</sup>

During the next 1.0 s of motion, which one of the following choices best represents what happens to the distance between the cars?

- (A) It decreases during the entire 1.0 second of motion.
- (B) It increases during the entire 1.0 second of motion.
- (C) It initially increases and then decreases resulting in a greater distance between the cars after 1.0 second.
- (D) It initially increases and then decreases resulting in a smaller distance between the cars after 1.0 second.
- (E) It initially increases and then decreases resulting in the same distance between the cars after 1.0 second.

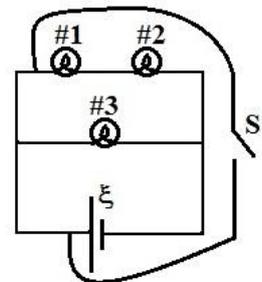
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[PhysicsBowl, 2015Q10]

For the circuit shown, the three light bulbs have identical resistance  $R$ , the battery is ideal, and all wires have no resistance. Which one of the following choices correctly identifies the light bulbs that either become dimmer or go out completely when the switch,  $S$ , in the circuit is closed?

- (A) All 3 bulbs
- (B) Bulbs #1 and #2 only
- (C) Bulb #3 only
- (D) Bulb #1 only
- (E) None of the bulbs



[PhysicsBowl, 2015Q11]

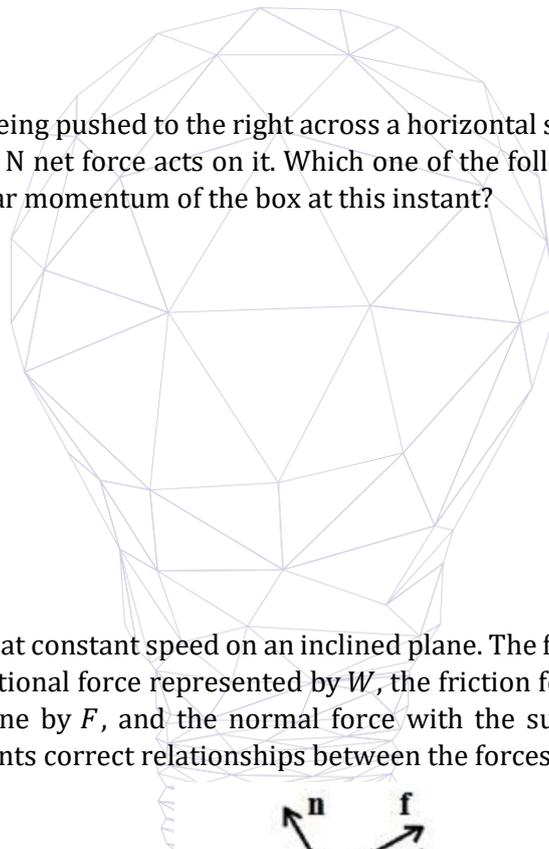
Two length measurements are made and recorded as  $L_1 = 84.55$  cm and  $L_2 = 33.55$  cm. Two other length measurements are made and recorded as  $L_3 = 1.750$  cm and  $L_4 = 1.250$  cm. These measurements are used to compute the quantity  $(L_1 + L_2) - (L_3 + L_4)$  using the rules of significant figures. Which one of the following choices best represents the correct result to this calculation?

- (A) 115.100 cm
- (B) 115.10 cm
- (C) 115.1 cm
- (D) 115 cm
- (E) 120 cm

[PhysicsBowl, 2015Q12]

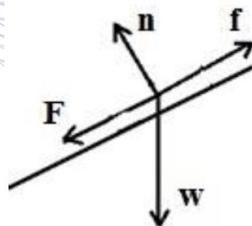
A box of mass 12.0 kg is being pushed to the right across a horizontal surface. When the box has 12.0 J of kinetic energy, a 12.0 N net force acts on it. Which one of the following choices best represents the magnitude of the linear momentum of the box at this instant?

- (A) 6.00 kg·m/s
- (B) 8.50 kg·m/s
- (C) 12.0 kg·m/s
- (D) 17.0 kg·m/s
- (E) 24.0 kg·m/s



[PhysicsBowl, 2015Q13]

An object is being pushed at constant speed on an inclined plane. The free body diagram of the object is shown with the gravitational force represented by  $W$ , the friction force by  $f$ , the applied external push parallel to the incline by  $F$ , and the normal force with the surface by  $n$ . Which one of the following choices represents correct relationships between the forces?



- (A)  $n > W$  and  $F < f$
- (B)  $n < W$  and  $F = f$
- (C)  $n < W$  and  $F < f$
- (D)  $n = W$  and  $F > f$
- (E)  $n = W$  and  $F = f$

[PhysicsBowl, 2015Q14]

A particle has a position,  $x$ , as a function of time,  $t$ , given as  $x(t) = -15 - 25t + 10t^2$ . Which one of the following choices represents the magnitude of the particle's acceleration? All quantities are expressed in base SI units.

- (A) 5 m/s<sup>2</sup>
- (B) 10 m/s<sup>2</sup>
- (C) 15 m/s<sup>2</sup>
- (D) 20 m/s<sup>2</sup>
- (E) 40 m/s<sup>2</sup>

[PhysicsBowl, 2015Q15]

A skydiver falls downward through the air with constant speed. Which one of the following choices correctly describes the Newton's Third Law pair force to the air resistance acting on the skydiver during the fall?

- (A) There is no Third Law pair force for this kind of situation.
- (B) The gravitational force acting on the skydiver by the Earth.
- (C) The force that molecules in the air exert on neighboring molecules in the air.
- (D) The force exerted on molecules in the air by the ground.
- (E) The force exerted on molecules in the air by the skydiver.

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6

[PhysicsBowl, 2015Q16]

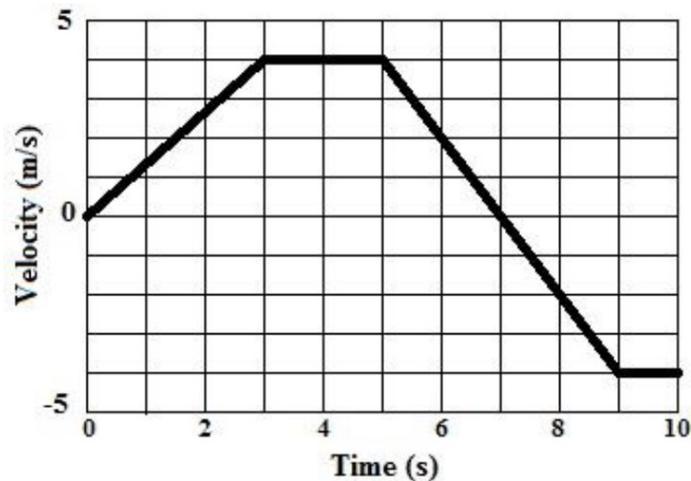
"Particles of matter also have associated wavelengths and can behave as waves." To which scientist is this concept attributed?

- (A) de Broglie
- (B) Pauli
- (C) Fermi
- (D) Heisenberg
- (E) Rydberg

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[PhysicsBowl, 2015Q17]

An object starts at the origin and its velocity along a line vs. time is graphed. Which one of the following choices best gives the proper interval(s) of time for which the object is moving away from the origin?



- (A) Only for times  $0 \text{ s} < t < 3 \text{ s}$
- (B) Only for times  $0 \text{ s} < t < 5 \text{ s}$
- (C) Only for times  $3 \text{ s} < t < 5 \text{ s}$
- (D) Only for times  $0 \text{ s} < t < 7 \text{ s}$
- (E) For times  $0 \text{ s} < t < 3 \text{ s}$  and  $5 \text{ s} < t < 9 \text{ s}$



[PhysicsBowl, 2015Q18]

A 680 Hz tuning fork is placed over a tube open at both ends that is filled with air. As a result, a standing wave in the 3rd harmonic is produced. The speed of sound in air is 340 m/s. What is the length of the tube?

- (A) 0.38 m
- (B) 0.67 m
- (C) 0.75 m
- (D) 1.33 m
- (E) 1.50 m

[PhysicsBowl, 2015Q19]

Ten moles of helium gas are enclosed in a container at a pressure of 1.00 atm and at a temperature of 400 K. Which one of the following choices best represents the density of this gas sample?

- (A)  $0.012 \text{ kg/m}^3$
- (B)  $0.12 \text{ kg/m}^3$
- (C)  $1.2 \text{ kg/m}^3$
- (D)  $120 \text{ kg/m}^3$
- (E)  $1.2 \times 10^4 \text{ kg/m}^3$

[PhysicsBowl, 2015Q20]

Which one of the following choices best represents the work for which the 2014 Nobel Prize in Physics was awarded?

- (A) Landing the Rosetta Philae Lander on the surface of Comet 67P/Churyumov-Gerasimenko
- (B) The detection of dark matter
- (C) The invention of the blue LED
- (D) The creation of a tractor beam using sound
- (E) The detection of neutrinos from the Sun which agreed with theory

[PhysicsBowl, 2015Q21]

An object is launched from the ground at an angle of  $60^\circ$  above the horizontal with a speed of 20.0 m/s. What is the magnitude of the average velocity of the object from just after launch until it reaches its highest vertical position during flight?

- (A) 13.7 m/s
- (B) 13.2 m/s
- (C) 10.0 m/s
- (D) 9.3 m/s
- (E) 8.7 m/s

[PhysicsBowl, 2015Q22]

Satellite 1 makes a circular orbit around the Earth with a radius  $r_1 = R$ .

Satellite 2 makes a circular orbit around the Earth with a radius  $r_2 = 2R$ .

We let  $v$  represent the speed of a satellite and  $a$  represent the magnitude of a satellite's acceleration. Which one of the following choices gives the correct relation between the speeds and accelerations of the satellites?

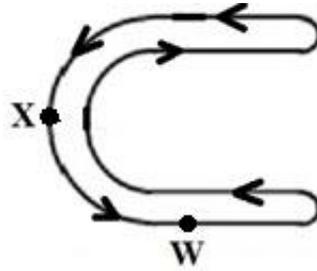
- (A)  $v_2 = \frac{1}{\sqrt{2}}v_1$ ,  $a_2 = \frac{1}{4}a_1$
- (B)  $v_2 = \frac{1}{2}v_1$ ,  $a_2 = \frac{1}{4}a_1$
- (C)  $v_2 = \frac{1}{\sqrt{2}}v_1$ ,  $a_2 = \frac{1}{2}a_1$
- (D)  $v_2 = \frac{1}{2}v_1$ ,  $a_2 = \frac{1}{2}a_1$
- (E)  $v_2 = v_1$ ,  $a_2 = \frac{1}{2}a_1$

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8

[PhysicsBowl, 2015Q23]

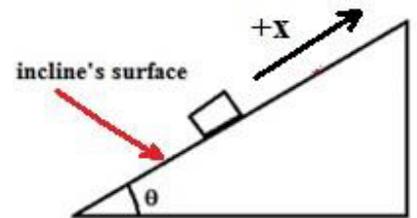
A car moves with constant speed around a horseshoe-shaped path as shown with the arrows in the figure. Which one of the following choices best describes the direction of the average acceleration of the car in traveling from  $W$  to  $X$ ?



- (A) ↙
- (B) ↖
- (C) ↗
- (D) ↘
- (E) There is no average acceleration

[PhysicsBowl, 2015Q24]

A mass on a frictionless incline has a gravitational force, a normal force from the incline, and a force applied by a person that all are equal in magnitude. The mass remains at rest and the incline makes an angle  $\theta$  counterclockwise from the horizontal. Which one of the following choices best describes the orientation of the applied force by the person? The  $+x$ -axis is directed upward, parallel to the incline's surface as shown in the figure.

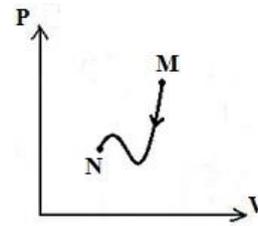


- (A) The applied force is oriented directly along the  $+x$  axis.
- (B) The applied force is oriented at an angle  $\theta$  clockwise from the  $+x$  axis.
- (C) The applied force is oriented at an angle  $90^\circ - \theta$  clockwise from the  $+x$  axis.
- (D) The applied force is oriented at an angle  $90^\circ - \theta$  counterclockwise from the  $+x$  axis.
- (E) This is a completely impossible situation that never can be realized physically.

## [PhysicsBowl, 2015Q25]

A gas undergoes the unusual process  $M \rightarrow N$  in the pressure vs. volume graph shown. Which one of the following choices properly represents the signs of the internal energy change of the gas,  $\Delta U$ , the total energy transferred as heat to the gas,  $Q$ , and the total work done on the gas by the surroundings,  $W$ , for this process?

	$\Delta U$	$Q$	$W$
(A)	Positive	Negative	Positive
(B)	Negative	Positive	Negative
(C)	Negative	Negative	Negative
(D)	Positive	Positive	Negative
(E)	Negative	Negative	Positive



## [PhysicsBowl, 2015Q26]

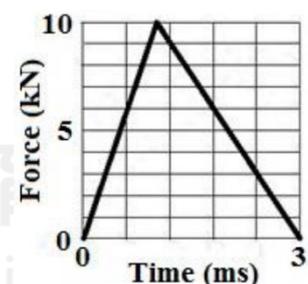
The position of a mass connected to a spring obeys  $x(t) = A \cos(\omega t)$ . What is the average speed of the mass for one full oscillation in terms of the mass's maximum speed during oscillation,  $v_{\max}$ ?

- (A)  $\frac{2}{\pi} v_{\max}$
- (B)  $\frac{1}{\sqrt{2}} v_{\max}$
- (C)  $\frac{1}{2} v_{\max}$
- (D)  $\frac{\sqrt{2}}{\pi} v_{\max}$
- (E)  $\frac{1}{2\pi\sqrt{2}} v_{\max}$

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Questions 27–28 deal with the following information:

On a frictionless horizontal surface, two bodies make a head-on collision and stick together. Body 1 has a mass of 3.50 kg and initially moves to the right with speed 7.0 m/s. Body 2 initially is at rest. A graph of the force exerted onto Body 2 from Body 1 during the collision is shown.



## [PhysicsBowl, 2015Q27]

What is the mass of Body 2?

- (A) 2.81 kg
- (B) 3.50 kg
- (C) 4.59 kg
- (D) 5.53 kg
- (E) 7.50 kg

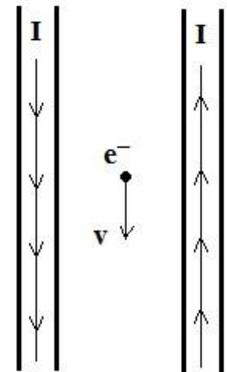
[PhysicsBowl, 2015Q28]

How much kinetic energy was transformed to other kinds of energy from the collision?

- (A) 67.1 J
- (B) 52.6 J
- (C) 42.9 J
- (D) 38.2 J
- (E) 30.0 J

[PhysicsBowl, 2015Q29]

An electron moves at constant non-zero velocity directly between two long straight wires. The conventional current in each wire has the same magnitude, but the currents are in opposite directions as shown in the figure. Ignoring gravity, which choice best reflects the direction of the magnetic field and the direction of the electric field that exist at the location of the electron? Any electric field in the region originates from an unseen external source.



	Electric Field	Magnetic Field
(A)	No Field	No Field
(B)	To the left	Into the plane of the page
(C)	To the right	Into the plane of the page
(D)	To the left	Out of the plane of the page
(E)	To the right	Out of the plane of the page



[PhysicsBowl, 2015Q30]

A spring scale reads 2.50 N when a small solid mass hangs from it in air. The spring scale reads 1.58 N when the mass at the end of the spring is completely submerged in a container of water. Which one of the following choices best represents the density of the solid mass?

- (A)  $3.68 \times 10^3 \text{ kg/m}^3$
- (B)  $2.72 \times 10^3 \text{ kg/m}^3$
- (C)  $1.58 \times 10^3 \text{ kg/m}^3$
- (D)  $9.20 \times 10^2 \text{ kg/m}^3$
- (E)  $1.58 \times 10^2 \text{ kg/m}^3$

## [PhysicsBowl, 2015Q31]

Approximately how many hydrogen atoms are there in the liquid water of Earth's oceans?

- (A)  $10^{62}$
- (B)  $10^{57}$
- (C)  $10^{52}$
- (D)  $10^{47}$
- (E)  $10^{42}$

## [PhysicsBowl, 2015Q32]

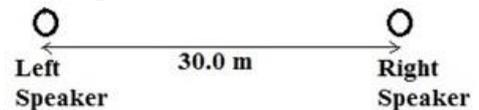
An object moving along a line completes a 20.0 second trip with an average speed of 10.0 m/s in two stages. During stage 1, the object moves with a constant velocity of 6.0 m/s to the right for 12.0 seconds. What constant magnitude acceleration directed to the left must the object have during the 8.0 seconds of stage 2?

- (A)  $2.5 \text{ m/s}^2$
- (B)  $2.7 \text{ m/s}^2$
- (C)  $4.0 \text{ m/s}^2$
- (D)  $5.3 \text{ m/s}^2$
- (E)  $6.3 \text{ m/s}^2$

## [PhysicsBowl, 2015Q33]

Two spherical speakers separated by 30.0 m each emit a constant frequency signal of 57.0 Hz in phase with each other. The speed of sound is 342 m/s. How many locations of complete destructive interference of the incoming signals are there on the line between the speakers?

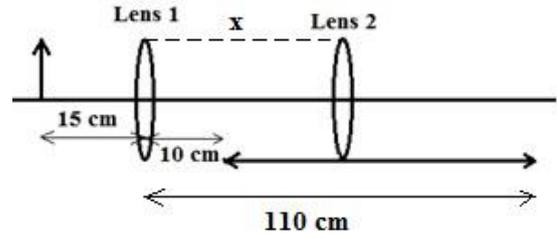
- (A) 12
- (B) 11
- (C) 10
- (D) 9
- (E) 6



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[PhysicsBowl, 2015Q34]

An upward-pointing object is placed 15 cm to the left of a lens system. The first lens is convex with focal length 10 cm. The second lens is convex with focal length 10 cm and its location from the first lens is varied from 10 cm away to 110 cm away. Which one of the following choices best represents the description of the final image formed as the second lens is moved from  $x = 10$  cm to  $x = 110$  cm from the first lens?



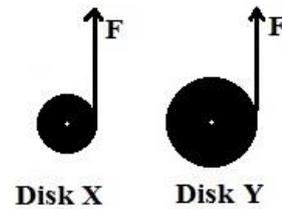
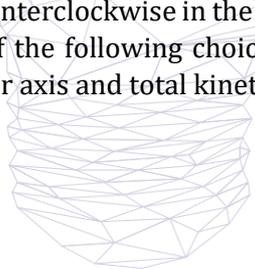
	$x = 10$ cm away $\rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow \rightarrow x = 110$ cm away		
(A)	Real & pointing downward	Virtual & pointing downward	Real & pointing upward
(B)	Virtual & pointing downward	Virtual & pointing upward	Real & pointing upward
(C)	Virtual & pointing upward	Virtual & pointing downward	Real & pointing downward
(D)	Real & pointing upward	Virtual & pointing downward	Real & pointing upward
(E)	Virtual & pointing downward		Real & pointing upward



[PhysicsBowl, 2015Q35]

Two uniform disks,  $X$  and  $Y$ , have equal masses,  $M$ , but different radii such that  $r_X < r_Y$ . Both disks initially are at rest. A force  $F$  is applied tangent to each disk at its right edge for the same amount of time. As a result, each disk rotates counterclockwise in the plane of the page about a fixed frictionless axis through its center. Which one of the following choices correctly compares the magnitudes of angular momentum  $L$  about the center axis and total kinetic energy  $K$  of disk  $X$  and disk  $Y$ ?

- (A)  $L_X < L_Y; K_X < K_Y$
- (B)  $L_X < L_Y; K_X > K_Y$
- (C)  $L_X = L_Y; K_X = K_Y$
- (D)  $L_X = L_Y; K_X < K_Y$
- (E)  $L_X < L_Y; K_X = K_Y$



[PhysicsBowl, 2015Q36]

Rain falls vertically at 12.0 m/s with respect to a stationary observer. A car is moving at an angle of  $40^\circ$  below the horizontal with respect to the observer. A passenger sitting in the car notes that the rain makes an angle of  $29.0^\circ$  with the vertical. What is the car's speed with respect to the observer?

- (A) 2.29 m/s
- (B) 5.93 m/s
- (C) 9.03 m/s
- (D) 11.8 m/s
- (E) 16.2 m/s

[PhysicsBowl, 2015Q37]

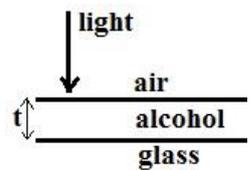
Which one of the following choices represents the base SI units of inductance?

- (A)  $\frac{\text{kgm}^2}{\text{A}^2\text{s}^2}$
- (B)  $\frac{\text{kgm}^2}{\text{As}}$
- (C)  $\frac{\text{kgm}}{\text{A}^2\text{s}^2}$
- (D)  $\frac{\text{kgm}^2}{\text{A}^2\text{s}^3}$
- (E)  $\frac{\text{kgm}}{\text{A}^2\text{s}^3}$

[PhysicsBowl, 2015Q38]

A thin film of alcohol ( $n_{\text{alcohol}} = 1.35$ ) lies on a flat glass surface ( $n_{\text{glass}} = 1.60$ ). When light of wavelength 540 nm is incident normal to the alcohol surface from air, the light is strongly reflected, but when light of wavelength 432 nm is incident normal to the surface from air, the reflected light is minimized. Which one of the following choices could represent the thickness,  $t$ , of the alcohol film?

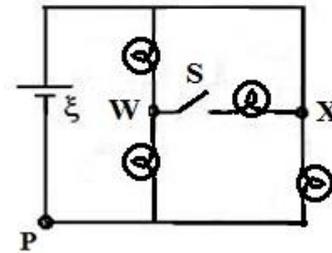
- (A) 216 nm
- (B) 320 nm
- (C) 324 nm
- (D) 400 nm
- (E) 486 nm



[PhysicsBowl, 2015Q39]

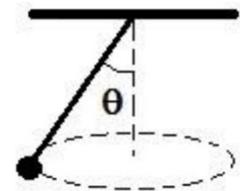
For the circuit shown, the four light bulbs have identical resistance, the battery is ideal and all wires have no resistance. After the switch,  $S$ , in the circuit is closed, which one of the following choices correctly describes what happens to the magnitude of the current at the point labeled  $P$  and to the magnitude of the potential difference from  $W$  to  $X$ ?

	Current at $P$	$\Delta V_{XW}$
(A)	No change	Increases
(B)	Decreases	Increases
(C)	Increases	Increases
(D)	Decreases	Decreases
(E)	Increases	Decreases



[PhysicsBowl, 2015Q40]

A 2.0 kg mass is connected to the end of string and moves about the string's fixed end in a conical motion with a constant speed of 4.0 m/s. The string has a length of 2.50 m and forms an angle of  $\theta$  with the vertical. What is the tension in the string?

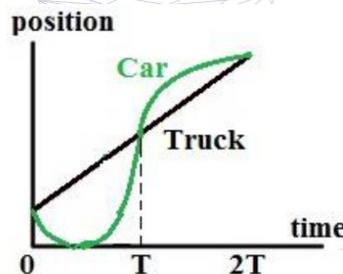


- (A) 20.0 N
- (B) 23.7 N
- (C) 27.4 N
- (D) 29.8 N
- (E) 32.5 N



Questions 41 – 42 deal with the following information:

A car and a truck are moving on a horizontal track. The position vs. time graph for the two vehicles is shown.



[PhysicsBowl, 2015Q41]

For the entire time shown in the graph, which one of the following choices correctly describes the relationship between the average speed of the truck to that of the car?

- (A) The truck's average speed is less than the average speed of the car.
- (B) The truck's average speed is the same as the average speed of the car.
- (C) The truck's average speed is greater than the average speed of the car.
- (D) The truck's average speed is positive while the car's average speed is negative but of the same magnitude.
- (E) A relationship cannot be determined without more information.

[PhysicsBowl, 2015Q42]

Which one of the following choices best describes the instants of time,  $t$ , at which the car and truck travel with the same speed?

- (A) Only at times  $t = 0$ ,  $t = T$  and  $t = 2T$ .
- (B) At one instant during the interval  $0 < t < T$  and at one instant during the interval  $T < t < 2T$ .
- (C) At two instants during the interval  $0 < t < T$  and at one instant during the interval  $T < t < 2T$ .
- (D) At one instant during the interval  $0 < t < T$  and at two instants during the interval  $T < t < 2T$ .
- (E) At two instants during the interval  $0 < t < T$  and at two instants during the interval  $T < t < 2T$ .



[PhysicsBowl, 2015Q43]

An object of mass 4.0 kg has a total kinetic energy of 100.0 J and an  $x$ -component of linear momentum equal to 24.0 kg·m/s. The object is moving in the  $x$ - $y$  plane. What is the  $y$ -component of the object's linear momentum?

- (A) 8.00 kg·m/s
- (B) 15.0 kg·m/s
- (C) 26.0 kg·m/s
- (D) 32.0 kg·m/s
- (E) 97.0 kg·m/s

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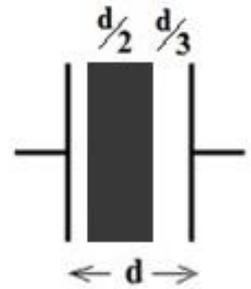
[PhysicsBowl, 2015Q44]

Which one of the following choices is most associated with the following statement: "When the pressure of a gas is held constant, the volume of the gas is directly proportional to the temperature."?

- (A) Newton's Law
- (B) Boyle's Law
- (C) Avogadro's Law
- (D) Graham's Law
- (E) Charles's Law

[PhysicsBowl, 2015Q45]

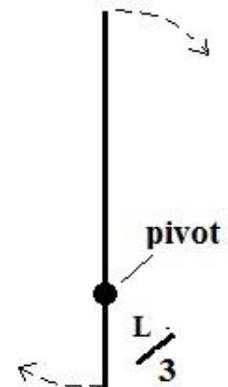
A  $6.00 \mu\text{F}$  parallel-plate capacitor is disconnected from a 12 volt battery after being fully charged. A person now carefully inserts a dielectric material of constant  $\kappa = 2$  so that it fills one-half of the space between the plates as shown. How much work was done by the person while inserting the dielectric?



- (A)  $-81 \mu\text{J}$
- (B)  $-108 \text{Mj}$
- (C)  $-144 \mu\text{J}$
- (D)  $-216 \mu\text{J}$
- (E)  $-288 \mu\text{J}$

[PhysicsBowl, 2015Q46]

A uniform rod of mass  $M$  and length  $L$  is fixed to rotate about a frictionless pivot located  $\frac{L}{3}$  from one end. The rod is released from rest incrementally away from being perfectly vertical, resulting in the rod rotating clockwise about the pivot. When the rod is horizontal, what is the magnitude of the tangential acceleration of its center of mass?



- (A)  $\frac{1}{6}g$
- (B)  $\frac{1}{2}g$
- (C)  $\frac{4}{3}g$
- (D)  $\frac{2}{3}g$
- (E)  $\frac{1}{4}g$

[PhysicsBowl, 2015Q47]

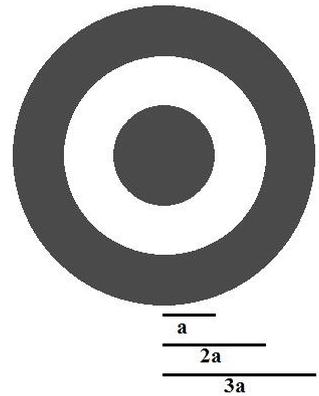
One mole of a diatomic ideal gas undergoes a reversible adiabatic process. The pressure and volume initially are given as  $P = 2.0 \text{ atm}$  and  $V = 30 \text{ L}$ . If the volume is halved during the adiabatic process, how much work was done on the gas sample by the surroundings?

- (A) 6790 J
- (B) 5530 J
- (C) 4850 J
- (D) 4200 J
- (E) 3040 J

[PhysicsBowl, 2015Q48]

Two concentric charged conducting shells are in free space. The outer shell has inner radius  $2a$  and outer radius  $3a$ . The inner shell has radius  $a$ . It is known that the electric potential at  $r = 3a$  is  $V_{3a} = \frac{kQ}{3a}$ . If the electric potential  $V_a$  at  $r = a$  is 0 volts, what is the charge on the inner spherical shell,  $Q_{\text{in}}$ ?

- (A)  $Q_{\text{in}} = -\frac{3}{2}Q$
- (B)  $Q_{\text{in}} = -\frac{2}{3}Q$
- (C)  $Q_{\text{in}} = -\frac{1}{3}Q$
- (D)  $Q_{\text{in}} = -2Q$
- (E)  $Q_{\text{in}} = -\frac{1}{2}Q$



[PhysicsBowl, 2015Q49]

The kinetic energy associated with an electron is twice its rest energy. At what speed is the electron traveling?

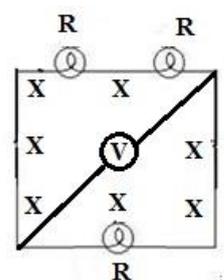
- (A)  $2.83 \times 10^8$  m/s
- (B)  $2.67 \times 10^8$  m/s
- (C)  $2.60 \times 10^8$  m/s
- (D)  $2.25 \times 10^8$  m/s
- (E)  $2.12 \times 10^8$  m/s



[PhysicsBowl, 2015Q50]

A magnetic field directed into the plane of the page is decreasing in time. A constant emf  $\xi$  is produced for the square loop enclosing the field in the figure. The square loop has three identical light bulbs of resistance  $R$  in it and an ideal voltmeter connected to the corners through the center of the loop. What is the magnitude of the voltmeter's reading?

- (A)  $0\xi$
- (B)  $\frac{1}{2}\xi$
- (C)  $\frac{1}{3}\xi$
- (D)  $\frac{1}{6}\xi$
- (E)  $\frac{2}{3}\xi$



# PhysicsBowl 2016

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2016

[Online Exam](#)

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

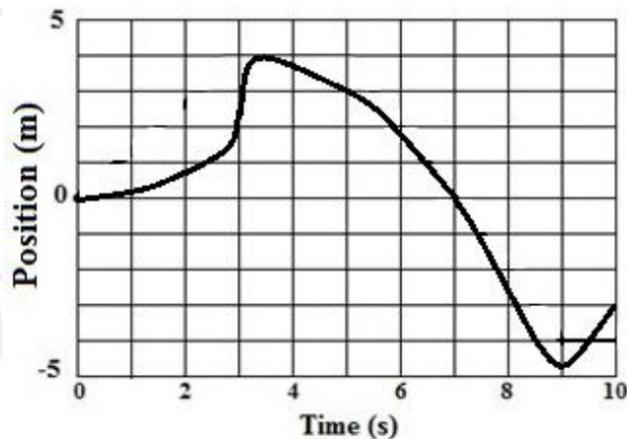
[PhysicsBowl, 2016Q1]

Which one of the following choices represents the smallest amount of time?

- (A) 1 day
- (B) 1 minute
- (C) 1 second
- (D) 1 week
- (E) 1 year

[PhysicsBowl, 2016Q2]

The position vs. time graph of an object moving on a horizontal line is shown. At what time(s) is the object moving with its greatest speed?



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2

- (A) At time  $t = 3.0$  s only
- (B) At time  $t = 3.5$  s only
- (C) At times  $t = 3.5$  s and  $t = 9.0$  s
- (D) At time  $t = 7.0$  s only
- (E) At time  $t = 9.0$  s only

[PhysicsBowl, 2016Q3]

A car accelerates uniformly from 0 km/hr to 60 km/hr in 4.50 s. Which one of the following choices best represents the acceleration of the car?

- (A)  $13.3 \text{ m/s}^2$
- (B)  $9.8 \text{ m/s}^2$
- (C)  $4.8 \text{ m/s}^2$
- (D)  $3.7 \text{ m/s}^2$
- (E)  $0.37 \text{ m/s}^2$

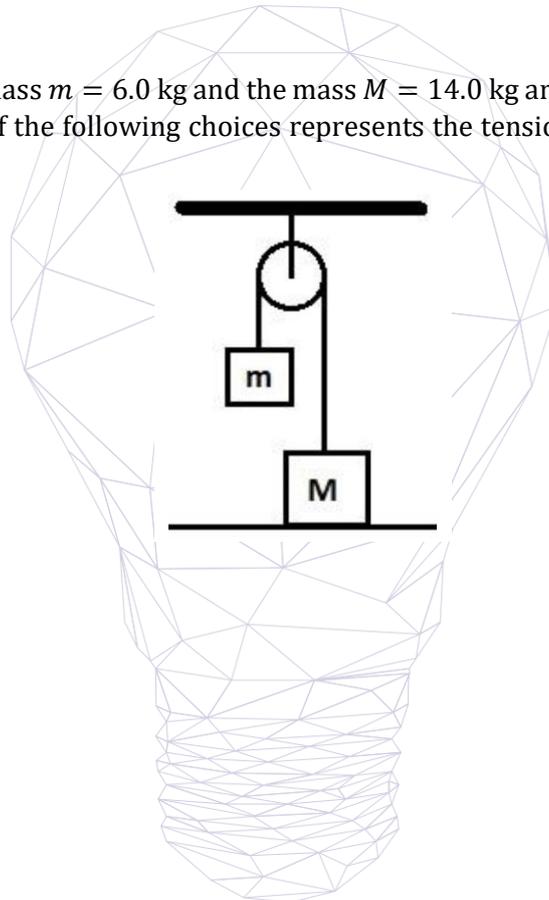
[PhysicsBowl, 2016Q4]

The following four length measurements are recorded:  $5.4 \times 10^{-1}$  m,  $5.4 \times 10^0$  m,  $5.40 \times 10^1$  m and  $5.400 \times 10^2$  m. Which one of the following choices best represents the sum of these values using the rules of significant digits?

- (A)  $6 \times 10^2$  m
- (B)  $6.0 \times 10^2$  m
- (C)  $6.00 \times 10^2$  m
- (D)  $5.999 \times 10^2$  m
- (E)  $5.9994 \times 10^2$  m

[PhysicsBowl, 2016Q5]

In the figure shown, the mass  $m = 6.0$  kg and the mass  $M = 14.0$  kg are stationary. The mass  $M$  rests on the floor. Which one of the following choices represents the tension in the string connecting the masses?



- (A) 40 N
- (B) 60 N
- (C) 80 N
- (D) 140 N
- (E) 200 N

[PhysicsBowl, 2016Q6]

An object, thrown straight downward with a speed of 20.0 m/s, takes 2.00 s to reach the ground below. From what height above the ground was the object thrown? Ignore air resistance.

- (A) 20.0 m
- (B) 40.0 m
- (C) 50.0 m
- (D) 60.0 m
- (E) 80.0 m

[PhysicsBowl, 2016Q7]

Three cylindrical resistors are made of the same material. The length and radius of each resistor is:

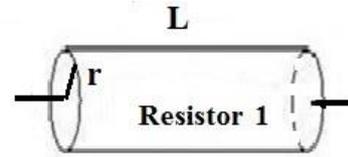
Resistor 1: Length  $L$ , radius  $r$

Resistor 2: Length  $L/2$ , radius  $r/2$

Resistor 3: Length  $L/4$ , radius  $r/2$

Which one of the following choices correctly ranks the resistance of these resistors ( $R_1, R_2, R_3$ )?

- (A)  $R_1 = R_2 < R_3$
- (B)  $R_2 < R_1 < R_3$
- (C)  $R_3 < R_2 < R_1$
- (D)  $R_1 < R_2 = R_3$
- (E)  $R_1 = R_3 < R_2$



[PhysicsBowl, 2016Q8]

In the history of physics, the names Nicolaus Copernicus, Galileo Galilei, James Clerk Maxwell and Isaac Newton are very recognizable. Which one of the following choices correctly orders these names chronologically by the approximate dates of each person's scientific work (ending with the most recent)?

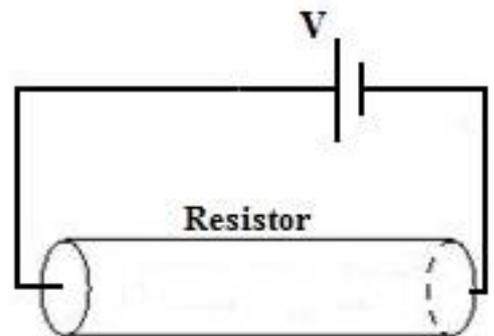
- (A) Copernicus → Galileo → Newton → Maxwell
- (B) Copernicus → Galileo → Maxwell → Newton
- (C) Galileo → Copernicus → Newton → Maxwell
- (D) Galileo → Newton → Copernicus → Maxwell
- (E) Newton → Copernicus → Maxwell → Galileo



[PhysicsBowl, 2016Q9]

In the circuit shown, an electric current exists in the metal resistor connected to the battery. Which one of the following choices best describes the direction of electron flow through the resistor and the direction of the electric field through the interior of the resistor?

	Direction of electron flow in resistor	Direction of electron field in resistor
(A)	→	→
(B)	←	→
(C)	→	←
(D)	←	←
(E)	→	There is no electric field.



[PhysicsBowl, 2016Q10]

A person wishes to accelerate an object upward uniformly. Which one of the following choices must be true of the force,  $F$ , provided by the person onto the object?  $W$  represents the magnitude of the gravitational force acting on the object. Ignore any effects of the air or of the Earth's rotation.

- (A)  $F = W$
- (B)  $F \geq W$
- (C)  $F > W$
- (D)  $F \geq 2W$
- (E)  $F > 2W$

Questions 11 – 12 deal with the following information:

A 12.0 N net force directed to the right is exerted on a 3.0 kg block for 5.0 s. The block was initially at rest and slides on a horizontal surface.

[PhysicsBowl, 2016Q11]

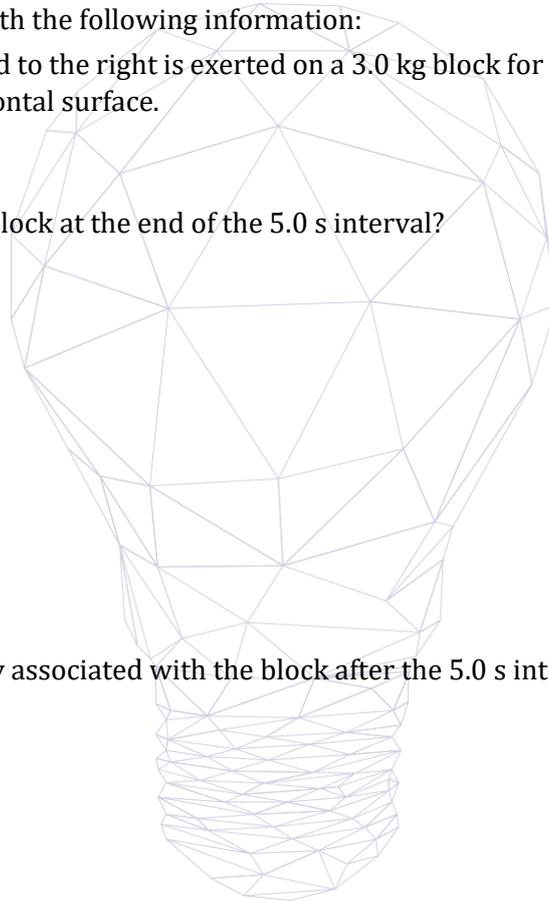
What is the speed of the block at the end of the 5.0 s interval?

- (A) 12 m/s
- (B) 15 m/s
- (C) 20 m/s
- (D) 36 m/s
- (E) 60 m/s

[PhysicsBowl, 2016Q12]

What is the kinetic energy associated with the block after the 5.0 s interval?

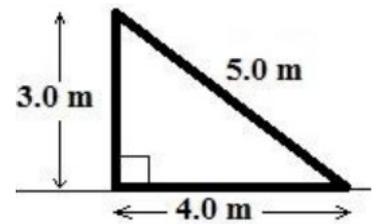
- (A) 180 J
- (B) 600 J
- (C) 800 J
- (D) 1200 J
- (E) 1600 J



[PhysicsBowl, 2016Q13]

For the inclined plane shown, which one of the following choices best represents the value of the incline's ideal mechanical advantage?

- (A) 1.67
- (B) 1.33
- (C) 1.25
- (D) 0.80
- (E) 0.75



[PhysicsBowl, 2016Q14]

A scientist obtains an answer that has units equivalent to those from computing the square root of the ratio of the Universal Gravitational constant to Coulomb's constant. Which one of the following choices has these same units?

- (A) energy divided by time
- (B) length divided by time
- (C) mass divided by energy
- (D) electric field strength divided by magnetic field strength
- (E) charge divided by mass



[PhysicsBowl, 2016Q15]

A radio station broadcasts its signal at a frequency of 100.0 MHz. What is the wavelength of the station's signal?

- (A) 3.00 km
- (B) 3.00 m
- (C) 3.00 mm
- (D) 0.33 m
- (E) 0.33 km

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[PhysicsBowl, 2016Q16]

A uniform stick is fixed to rotate about an axis through its center. The stick starts from rest and rotates through an angle of  $90^\circ$  in a time of 1.0 s. If the angular acceleration of the stick is constant, what is the angular speed of the stick about its rotation axis after one full revolution?

- (A)  $4\pi$  rad/s
- (B)  $2\sqrt{2}\pi$  rad/s
- (C)  $2\pi$  rad/s
- (D)  $\sqrt{2}\pi$  rad/s
- (E)  $\pi$  rad/s

[PhysicsBowl, 2016Q17]

“All planets in the solar system follow elliptical orbits with the Sun located at one focus of the ellipse.” This statement is best summarized by which one of the following choices?

- (A) Kepler’s First Law
- (B) Kepler’s Second Law
- (C) Newton’s Universal Law of Gravitation
- (D) Einstein’s Law of Gravity
- (E) Schwarzschild’s Law of Orbits

[PhysicsBowl, 2016Q18]

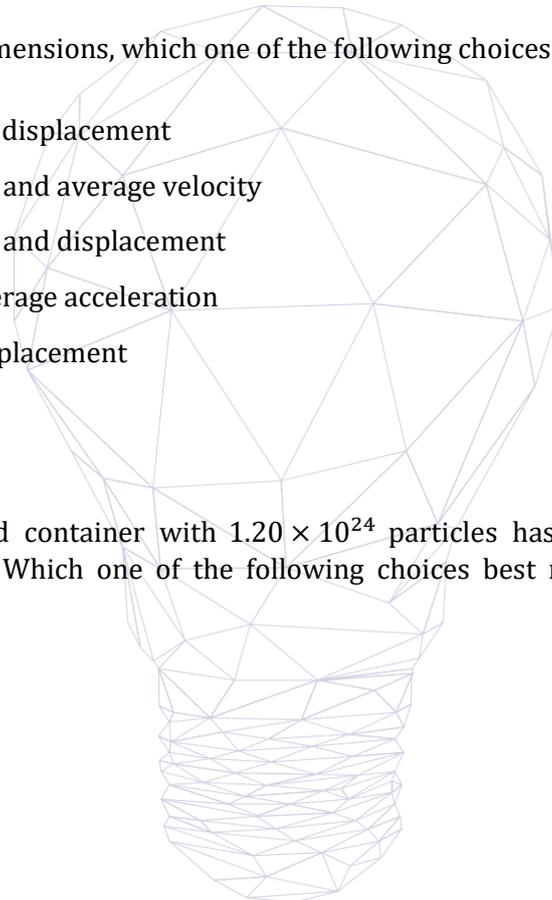
For any motion in two dimensions, which one of the following choices identifies quantities that must have the same direction?

- (A) average velocity and displacement
- (B) average acceleration and average velocity
- (C) average acceleration and displacement
- (D) final velocity and average acceleration
- (E) final velocity and displacement

[PhysicsBowl, 2016Q19]

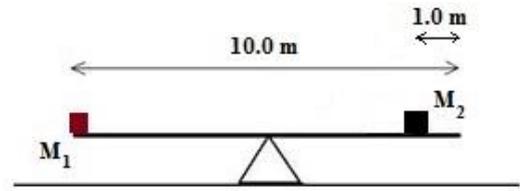
An ideal gas in a sealed container with  $1.20 \times 10^{24}$  particles has a pressure of 1.0 atm at a temperature of 27.0 °C. Which one of the following choices best represents the volume of the container?

- (A) 450 m<sup>3</sup>
- (B) 4.5 m<sup>3</sup>
- (C) 0.49 m<sup>3</sup>
- (D) 0.049 m<sup>3</sup>
- (E) 0.00049 m<sup>3</sup>



## [PhysicsBowl, 2016Q20]

A uniform 10.0 m long plank is pivoted about its center of gravity. A mass  $M_1$  then is placed at the left edge of the plank and a second mass  $M_2$  is placed 1.0 m from the right end. This system is in static equilibrium (shown). If each mass now is moved 2.0 m closer to the center of the plank, which one of the following choices best describes the subsequent motion of the plank?



- (A) The plank remains in static equilibrium.
- (B) The plank rotates at constant angular speed until the right side reaches the ground.
- (C) The plank rotates at constant angular speed until the left side reaches the ground.
- (D) The plank angularly accelerates until the right side reaches the ground.
- (E) The plank angularly accelerates until the left side reaches the ground.

## [PhysicsBowl, 2016Q21]

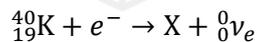
At 1.94 s after launch, a projectile in free fall achieved its minimum speed during flight. If that minimum speed was 15.0 m/s, what was the projectile's initial angle of launch from the horizontal?

- (A) 82.6°
- (B) 52.3°
- (C) 50.6°
- (D) 39.4°
- (E) 37.7°

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## [PhysicsBowl, 2016Q22]

For the following nuclear reaction, which one of the following choices correctly identifies the quantity labeled  $X$ ?



- (A)  ${}_{19}^{40}\text{K}$
- (B)  ${}_{18}^{40}\text{K}$
- (C)  ${}_{18}^{39}\text{Ar}$
- (D)  ${}_{19}^{39}\text{K}$
- (E)  ${}_{18}^{40}\text{Ar}$

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[PhysicsBowl, 2016Q23]

At a party, two spherical balloons are expanded to have the same radius. Balloon #1 is filled with helium gas while balloon #2 is filled with xenon gas. Which one of the following statements about the buoyant forces on the balloons is correct?

- (A) The buoyant force is greater for the helium balloon.
- (B) The buoyant force is greater for the xenon balloon.
- (C) The buoyant force is the same for each balloon.
- (D) The balloon experiencing the greater buoyant force cannot be determined without knowing the radius.
- (E) The balloon experiencing the greater buoyant force cannot be determined without knowing the atmospheric pressure at the time.

[PhysicsBowl, 2016Q24]

A proton moves with constant non-zero velocity in a region of space that has a uniform magnetic field directed into the plane of the page. The proton moves directly up the plane of the page. What is the direction of the electric field in this region of space? Ignore gravity.

- (A) To the left
- (B) To the right
- (C) Down the plane of the page
- (D) Up the plane of the page
- (E) There is no electric field necessary



[PhysicsBowl, 2016Q25]

The plates of a large parallel-plate capacitor are separated by a distance of 0.05 m. The potential difference between the plates is 24.0 V. A charge released from rest between the plates experiences an electric force of 1.00 N. What is the magnitude of the charge released between the plates?

- (A) 2.08 mC
- (B) 4.17 mC
- (C) 8.33 mC
- (D) 16.6 mC
- (E) 33.3 mC

[PhysicsBowl, 2016Q26]

A 10.0 kg mass moves to the right at 8.00 m/s. A 5.0 kg mass moves to the left at 7.00 m/s. With what speed does the center of mass of this two-mass system move?

- (A) 7.67 m/s
- (B) 7.50 m/s
- (C) 3.00 m/s
- (D) 2.00 m/s
- (E) 0.50 m/s

[PhysicsBowl, 2016Q27]

A tuning fork of frequency  $f$  is placed over a long tube closed at one end producing the third lowest frequency standing wave for the tube. What frequency tuning fork would be needed to produce the fourth lowest frequency standing wave?

- (A)  $\frac{4}{3}f$
- (B)  $\frac{5}{3}f$
- (C)  $\frac{6}{5}f$
- (D)  $\frac{7}{5}f$
- (E)  $\frac{5}{4}f$



[PhysicsBowl, 2016Q28]

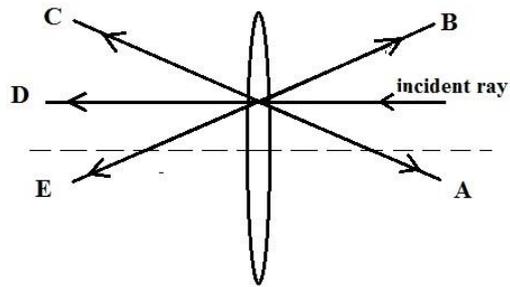
Recent excitement in the physics community came from the February, 2016 announcement from LIGO that

- (A) alien life had been discovered on a distant planet.
- (B) dark matter had been discovered.
- (C) there was proof of dark energy's existence.
- (D) gravitational waves had been detected.
- (E) objects had been observed to travel faster than the speed of light.

[PhysicsBowl, 2016Q29]

A ray of light is incident onto a thin glass lens as shown. Which one of the following arrows best indicates the path of the refracted ray?

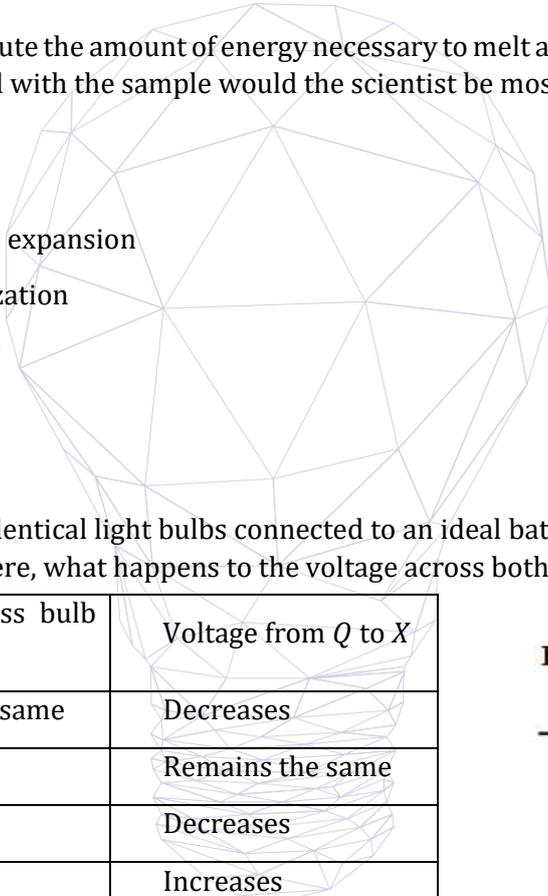
- (A) A
- (B) B
- (C) C
- (D) D
- (E) E



[PhysicsBowl, 2016Q30]

A scientist wishes to compute the amount of energy necessary to melt a known mass of a solid sample. Which quantity associated with the sample would the scientist be most interested in knowing?

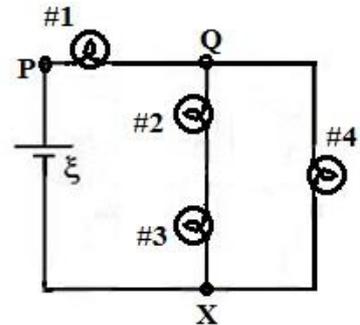
- (A) Latent heat of fusion
- (B) Specific heat
- (C) Coefficient of thermal expansion
- (D) Latent heat of vaporization
- (E) Thermal conductivity



[PhysicsBowl, 2016Q31]

The circuit shown has 4 identical light bulbs connected to an ideal battery. If bulb #2 were removed leaving an open circuit there, what happens to the voltage across both bulb #1 and from Q to X?

	Voltage across bulb #1	Voltage from Q to X
(A)	Remains the same	Decreases
(B)	Decreases	Remains the same
(C)	Increases	Decreases
(D)	Increases	Increases
(E)	Decreases	Increases



[PhysicsBowl, 2016Q32]

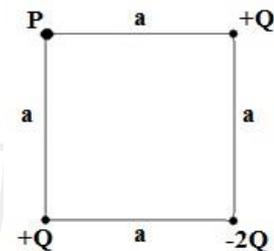
A mass connected to a string forms a simple pendulum. The mass is released from rest and undergoes simple harmonic motion. Which one of the following choices correctly ranks the magnitude of the tension in the string ( $T$ ), the gravitational force on the mass ( $W$ ), and the net force acting on the mass ( $F$ ) when the mass swings through its lowest point?

- (A)  $F < W = T$
- (B)  $W < T < F$
- (C)  $W < F = T$
- (D)  $F < W < T$
- (E) More information is required to answer the question.

[PhysicsBowl, 2016Q33]

Given the configuration of three charges,  $+Q$ ,  $+Q$  and  $-2Q$ , which one of the following choices best represents the direction of the electric field at the point  $P$  and the sign of the electric potential at  $P$  from these charges?

	Field Direction at $P$	Sign of Electric Potential at $P$
(A)	↘	Positive
(B)	↖	Positive
(C)	↙	Negative
(D)	↗	Negative
(E)	Zero	Zero

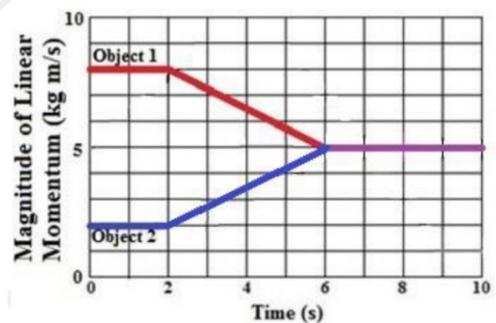


116  
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12

[PhysicsBowl, 2016Q34]

The graph shows the magnitude of the linear momentum of two solid objects colliding on the  $x$ -axis. Which one of the following statements must be true based on the information provided?

- (A) The objects remain stuck together after the collision.
- (B) Object 2 experiences the greater force from the collision.
- (C) Object 2 cannot have more mass than object 1.
- (D) The kinetic energy loss was maximized with no external forces present in the two-object system.
- (E) The kinetic energy of the two-object system is the same both before and after the collision.



[PhysicsBowl, 2016Q35]

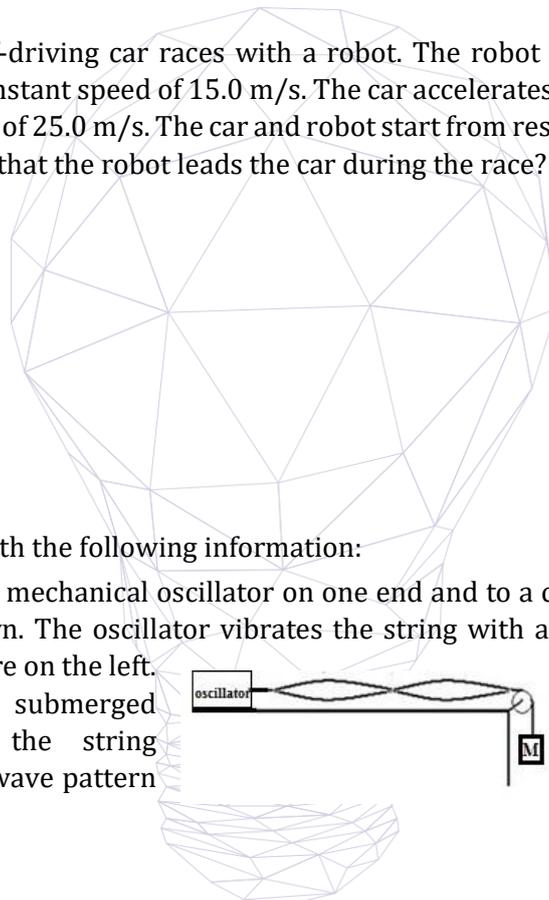
Which one of the following choices best describes what it means for an object to be iridescent?

- (A) The color of the object appears to change with a change in the angle of view.
- (B) The object appears to have two images formed from it because of differences in index of refraction.
- (C) The color of the object appears to be different based on its temperature.
- (D) The object remains illuminated after turning off all surrounding light sources.
- (E) The object is alive and producing light biochemically.

[PhysicsBowl, 2016Q36]

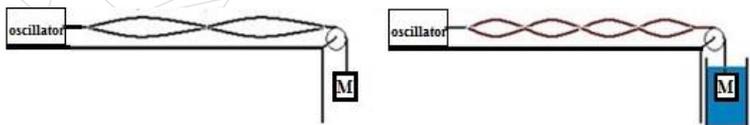
On a straight road, a self-driving car races with a robot. The robot accelerates at  $8.50 \text{ m/s}^2$  until reaching its maximum constant speed of  $15.0 \text{ m/s}$ . The car accelerates at  $5.60 \text{ m/s}^2$  until reaching its maximum constant speed of  $25.0 \text{ m/s}$ . The car and robot start from rest from the same location. What is the maximum distance that the robot leads the car during the race?

- (A) 3.3 m
- (B) 6.9 m
- (C) 10.2 m
- (D) 13.2 m
- (E) 17.3 m



Questions 37 – 38 deal with the following information:

A string is connected to a mechanical oscillator on one end and to a cube-shaped mass,  $M = 8.0 \text{ kg}$ , at the other end as shown. The oscillator vibrates the string with a frequency of  $f$  producing the standing wave in the figure on the left. When the mass is submerged completely in water, the string vibrates in the standing wave pattern shown on the right.



[PhysicsBowl, 2016Q37]

What is the value of the ratio for the tension when the mass is submerged in water to the tension when the mass is hanging in air?

- (A) 4
- (B) 2
- (C)  $\frac{1}{\sqrt{2}}$
- (D)  $\frac{1}{2}$
- (E)  $\frac{1}{4}$

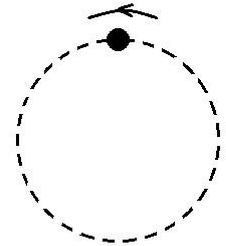
[PhysicsBowl, 2016Q38]

What is the length of one side of the cube of mass  $M$ ?

- (A) 0.006 m
- (B) 0.091 m
- (C) 0.126 m
- (D) 0.182 m
- (E) 0.200 m

Questions 39 and 40 deal with the following information:

An object moves in a circle, starting at the top, with initial speed 17.0 m/s. The object's speed increases uniformly until it has moved counterclockwise through an angle of  $55^\circ$ . The average acceleration for this motion is  $9.8 \text{ m/s}^2$  directed straight downward.



[PhysicsBowl, 2016Q39]

What is the final speed of the object?

- (A) 29.6 m/s
- (B) 26.8 m/s
- (C) 20.8 m/s
- (D) 18.4 m/s
- (E) 17.1 m/s

[PhysicsBowl, 2016Q40]

What is the time for this motion?

- (A) 15.4 s
- (B) 18.0 s
- (C) 2.26 s
- (D) 2.48 s
- (E) 2.93 s



[PhysicsBowl, 2016Q41]

A small object is launched  $30^\circ$  above the horizontal from a height of 10.0 m above the ground. If the initial speed of the object is 15.0 m/s, at what angle below the horizontal is the object moving when it reaches the ground? Ignore air resistance.

- (A)  $36.1^\circ$
- (B)  $39.1^\circ$
- (C)  $43.3^\circ$
- (D)  $50.9^\circ$
- (E)  $68.5^\circ$

[PhysicsBowl, 2016Q42]

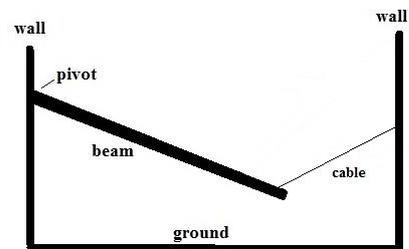
An object (which points upward) is placed 21.0 cm from a converging lens of focal length 18.0 cm. Which one of the following choices is true about the image formed by the lens?

- (A) The image is larger than the object, virtual and points upward.
- (B) The image is larger than the object, real and points downward.
- (C) The image is smaller than the object, virtual and points upward.
- (D) The image is smaller than the object, real and points upward.
- (E) The image is smaller than the object, real and points downward.

[PhysicsBowl, 2016Q43]

A uniform beam connected to a wall at the hinge is in static equilibrium as shown. The cable connected to the beam is massless. What are the directions of the horizontal and vertical components of force acting at the pivot on the beam?

	Horizontal component	Vertical component
(A)	To the right	Upward
(B)	To the right	Downward
(C)	To the left	Upward
(D)	To the left	Downward
(E)	It cannot be determined	It cannot be determined



## [PhysicsBowl, 2016Q44]

A proton moves in a circular orbit in a uniform magnetic field,  $B$ . A helium nucleus moves in a circular orbit in the same magnetic field. If each particle experiences the same magnitude magnetic force during its motion, what is the ratio of the speed of the helium to the speed of the proton?

- (A) 4 : 1
- (B) 1 : 4
- (C) 1 : 1
- (D) 2 : 1
- (E) 1 : 2

## [PhysicsBowl, 2016Q45]

Light of wavelength 250 nm shines onto a metallic surface. It is known that the electrons ejected from the surface range in speed as  $0 \leq v \leq 4.85 \times 10^5$  m/s. What is the work function of the surface?

- (A) 4.97 eV
- (B) 1.60 eV
- (C) 3.63 eV
- (D) 4.30 eV
- (E) 1.34 eV

## [PhysicsBowl, 2016Q46]

Two spherical, non-rotating planets,  $X$  and  $Y$ , have the same uniform density  $\rho$ . Planet  $X$  has twice the radius of Planet  $Y$ . Let  $v_X$  and  $v_Y$  represent the escape speed at the surfaces of Planet  $X$  and Planet  $Y$ , respectively. What is the ratio of  $v_X : v_Y$ ?

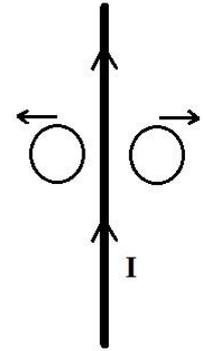
- (A) 2 : 1
- (B) 1 : 2
- (C) 1 : 1
- (D) 4 : 1
- (E) 1 : 4

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[PhysicsBowl, 2016Q47]

Two small loops of wire are located close to a wire with conventional current directed up the page. A scientist then moves the loops away from the current as shown. What is the orientation of the conventional current in each loop while this occurs?



	Left loop	Right loop
(A)	Clockwise	Clockwise
(B)	Clockwise	Counterclockwise
(C)	Counterclockwise	Clockwise
(D)	Counterclockwise	Counterclockwise
(E)	No current	No current

[PhysicsBowl, 2016Q48]

From a given state of  $P$ ,  $V$  and  $T$  for an ideal gas, which one of the following reversible processes has the most heat associated with it?

- (A) Isothermal expansion doubling the volume
- (B) Isobaric expansion doubling the volume
- (C) Isovolumic pressure doubling
- (D) Adiabatic expansion doubling the volume
- (E) Isobaric compression halving the volume



[PhysicsBowl, 2016Q49]

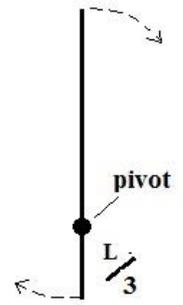
John is at rest on a platform that he measures to be 500 m long on the  $x$ -axis. He then sees a spaceship moving along the  $x$ -axis with a speed of  $1.80 \times 10^8$  m/s as it crosses the length of the platform. Sitting in her chair, the spaceship's pilot measures the time it takes her to cross the platform. What type of time interval does she measure and what value does she obtain?

	Type of time interval	Time
(A)	Proper time	$2.22 \mu\text{s}$
(B)	Improper time	$2.22 \mu\text{s}$
(C)	Proper time	$2.78 \mu\text{s}$
(D)	Improper time	$2.78 \mu\text{s}$
(E)	Neither proper nor improper	$3.48 \mu\text{s}$

[PhysicsBowl, 2016Q50]

A uniform stick of mass  $M$  and length  $L$  is fixed to rotate about a frictionless pivot located  $\frac{L}{3}$  from one end. The stick is released from rest incrementally away from being perfectly vertical, resulting in the stick rotating clockwise about its pivot. When the stick is horizontal, what is the tangential speed of the center of mass about the pivot?

- (A)  $\frac{1}{\sqrt{15}}\sqrt{gL}$
- (B)  $\sqrt{\frac{3}{10}}\sqrt{gL}$
- (C)  $\frac{1}{\sqrt{10}}\sqrt{gL}$
- (D)  $\frac{3}{\sqrt{20}}\sqrt{gL}$
- (E)  $\frac{1}{\sqrt{12}}\sqrt{gL}$



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# PhysicsBowl 2017

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2017

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2017Q1]

A scientist computes a speed as  $\frac{12 \text{ mm}}{3 \mu\text{s}}$ . Which one of the following choices represents this same speed?

- (A) 4 km/s
- (B) 4 nm/s
- (C) 4 m/s
- (D) 4 Gm/s
- (E) 4 pm/s

[PhysicsBowl, 2017Q2]

A small object is released from rest and falls freely for 4.00 s until reaching the ground. What was the height above the ground from which the object was released?

- (A) 10.0 m
- (B) 20.0 m
- (C) 40.0 m
- (D) 80.0 m
- (E) 160.0 m

[PhysicsBowl, 2017Q3]

Which one of the following choices is a vector quantity?

- (A) average speed
- (B) kinetic energy
- (C) mass
- (D) time
- (E) acceleration

[PhysicsBowl, 2017Q4]

At which one of the following temperatures does water undergo a phase change into a solid at a pressure of 1.0 atm?

- (A) 273 K
- (B) 0 °F
- (C) 32 °C
- (D) 100 °F
- (E) 0 K



[PhysicsBowl, 2017Q5]

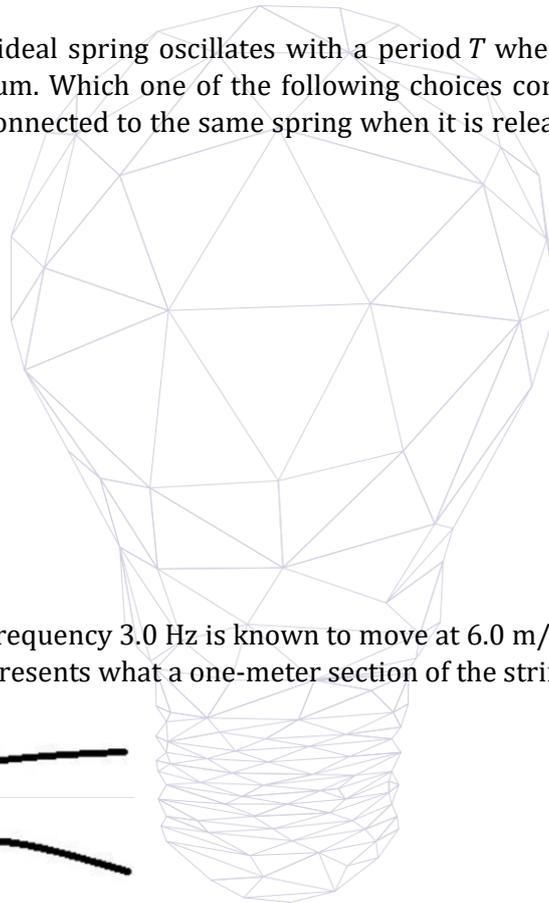
Which one of the following choices is most closely associated with the following observation about an isolated object: "The linear momentum of the object is constant."?

- (A) Huygen's Principle
- (B) Kepler's First Law
- (C) Hooke's Law
- (D) Pascal's Principle
- (E) Newton's First Law

[PhysicsBowl, 2017Q6]

A mass connected to an ideal spring oscillates with a period  $T$  when it is released from rest at a position  $A$  from equilibrium. Which one of the following choices correctly identifies the period of oscillation for the mass connected to the same spring when it is released from rest at a position  $2A$  from equilibrium?

- (A)  $\frac{1}{4}T$
- (B)  $\frac{1}{2}T$
- (C)  $T$
- (D)  $2T$
- (E)  $4T$



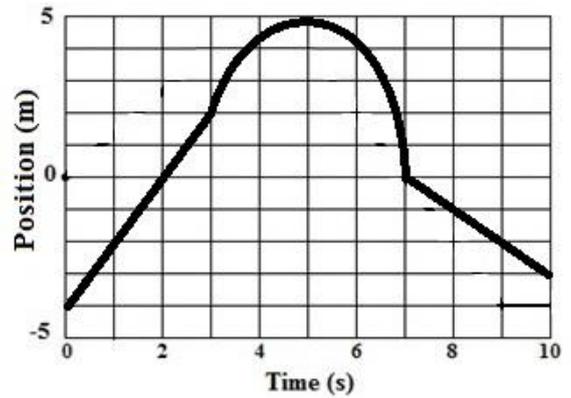
[PhysicsBowl, 2017Q7]

A traveling sine wave of frequency 3.0 Hz is known to move at 6.0 m/s on a string. Which one of the following figures best represents what a one-meter section of the string could look like at an instant of time?

- (A)
- (B)
- (C)
- (D)
- (E)

[PhysicsBowl, 2017Q8]

A mass moves along the  $x$  - axis following the position vs. time graph provided. During what time interval(s) does the mass have an acceleration of  $0 \text{ m/s}^2$ ? Time is represented as  $t$ .



- (A) only from  $0 \text{ s} < t < 3 \text{ s}$
- (B) only at  $t = 5 \text{ s}$
- (C) only from  $7 \text{ s} < t < 10 \text{ s}$
- (D) only from  $0 \text{ s} < t < 3 \text{ s}$  and  $7 \text{ s} < t < 10 \text{ s}$
- (E) only from  $0 \text{ s} < t < 3 \text{ s}$ ,  $t = 5 \text{ s}$  and  $7 \text{ s} < t < 10 \text{ s}$

[PhysicsBowl, 2017Q9]

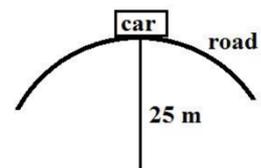
A  $4.00 \text{ kg}$  object moves to the right with speed  $5.00 \text{ m/s}$ . A  $5.00 \text{ kg}$  object moves to the left with speed  $3.00 \text{ m/s}$ . After colliding, the  $4.00 \text{ kg}$  object moves to the left with speed  $1.00 \text{ m/s}$ . What is the speed of the  $5.00 \text{ kg}$  object after the collision?

- (A)  $1.00 \text{ m/s}$
- (B)  $1.80 \text{ m/s}$
- (C)  $3.00 \text{ m/s}$
- (D)  $4.11 \text{ m/s}$
- (E)  $7.80 \text{ m/s}$



[PhysicsBowl, 2017Q10]

A  $2000 \text{ kg}$  car moves over a hill at a constant speed of  $12.0 \text{ m/s}$ . At the very top of the hill, the shape of the road can be approximated as a circle with radius  $25 \text{ m}$ , as indicated in the figure. Which one of the following choices best represents the magnitude of the upward force exerted by the road on the car?



- (A)  $0 \text{ kN}$
- (B)  $8.5 \text{ kN}$
- (C)  $11.5 \text{ kN}$
- (D)  $20.0 \text{ kN}$
- (E)  $31.5 \text{ kN}$

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**Questions 11 – 12 refer to the following information:**

A 5.00 kg block slides with uniform acceleration on a horizontal surface for 5.00 s. The block's kinetic energy strictly decreases from 50.0 J to 20.0 J in this time.

[PhysicsBowl, 2017Q11]

What is the average speed of the block during the motion described?

- (A) 7.00 m/s
- (B) 3.74 m/s
- (C) 3.65 m/s
- (D) 2.65 m/s
- (E) 2.58 m/s

[PhysicsBowl, 2017Q12]

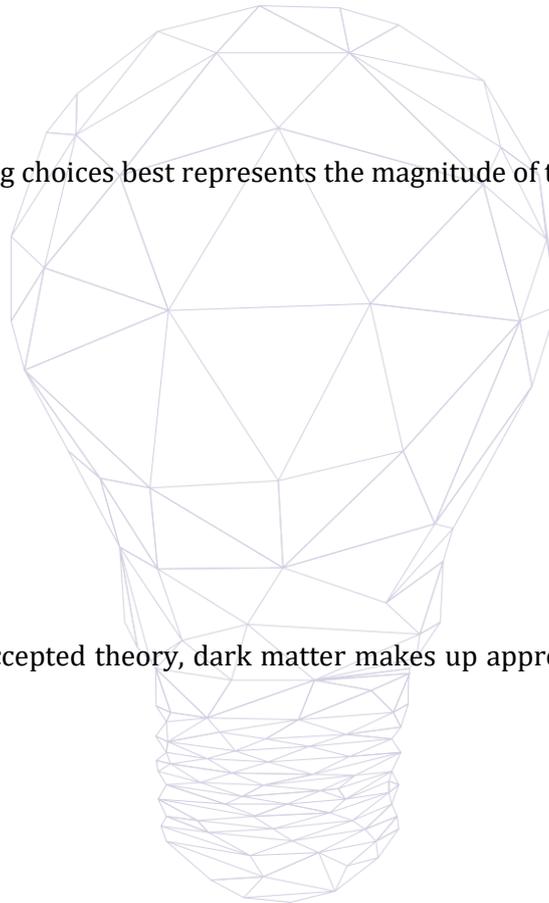
Which one of the following choices best represents the magnitude of the block's acceleration during the motion described?

- (A) 3.43 m/s<sup>2</sup>
- (B) 2.40 m/s<sup>2</sup>
- (C) 1.20 m/s<sup>2</sup>
- (D) 0.329 m/s<sup>2</sup>
- (E) 0.232 m/s<sup>2</sup>

[PhysicsBowl, 2017Q13]

According to currently accepted theory, dark matter makes up approximately what percent of the Universe?

- (A) 5%
- (B) 25%
- (C) 50%
- (D) 80%
- (E) 99%



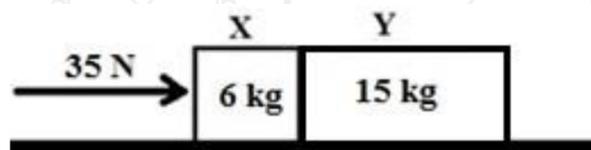
[PhysicsBowl, 2017Q14]

A block is suspended in the air at the end of a string held by a person. The person pulls on the string uniformly accelerating the block upward for a short time. During this time, which one of the following choices correctly identifies the Newton's Third Law pair force to the force of the string on the block?

- (A) the gravitational force from the Earth on the block
- (B) the force from the string on the person
- (C) the force from the person on the string
- (D) the force from the block on the string
- (E) the force from the person on the block

[PhysicsBowl, 2017Q15]

Two blocks  $X$  and  $Y$  are in contact on a frictionless horizontal surface. A constant 35 N force is applied to the right onto block  $X$ . What is the magnitude of the force that block  $Y$  exerts onto block  $X$ ?



- (A) 35 N
- (B) 28 N
- (C) 25 N
- (D) 14 N
- (E) 10 N

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6

[PhysicsBowl, 2017Q16]

Which one of the following choices best represents the type of electromagnetic wave associated with a frequency of  $10^{18}$  Hz?

- (A) AM radio
- (B) microwaves
- (C) ultraviolet light
- (D) X rays
- (E) red light

[PhysicsBowl, 2017Q17]

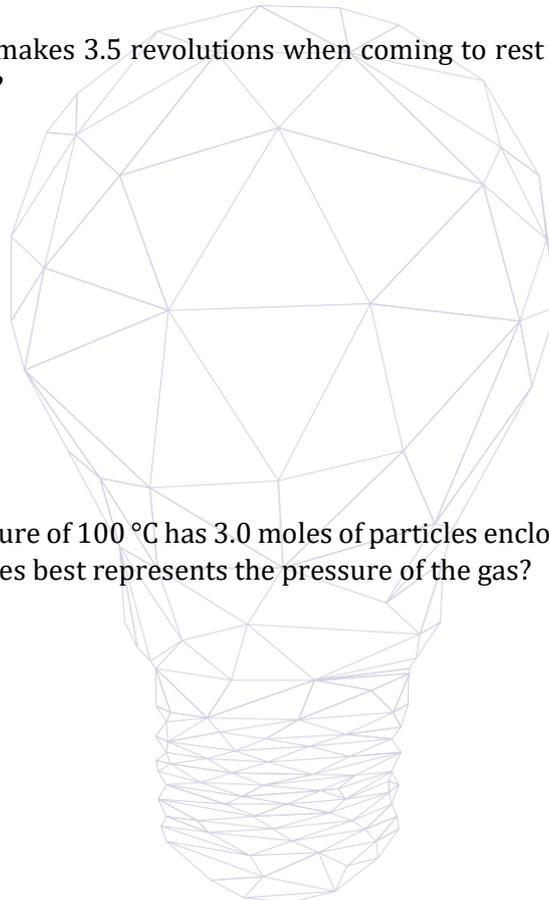
The following lengths are added together:  $L_1 = 8.36 \times 10^1$  m,  $L_2 = 9.20 \times 10^2$  m,  $L_3 = 1.39 \times 10^{-1}$  m and  $L_4 = 2.1 \times 10^0$  m. How many significant digits are in the resulting sum?

- (A) 2
- (B) 3
- (C) 4
- (D) 5
- (E) 7

[PhysicsBowl, 2017Q18]

A disk of radius 75.0 cm makes 3.5 revolutions when coming to rest in 2.50 s. What was the initial angular speed of the disk?

- (A) 1.40 rad/s
- (B) 6.60 rad/s
- (C) 8.80 rad/s
- (D) 13.2 rad/s
- (E) 17.6 rad/s



[PhysicsBowl, 2017Q19]

An ideal gas at a temperature of 100 °C has 3.0 moles of particles enclosed in a 5.0 L container. Which one of the following choices best represents the pressure of the gas?

- (A)  $4.99 \times 10^5$  Pa
- (B)  $1.86 \times 10^6$  Pa
- (C)  $5.02 \times 10^6$  Pa
- (D)  $5.05 \times 10^7$  Pa
- (E)  $1.88 \times 10^8$  Pa

[PhysicsBowl, 2017Q20]

An object appears green when ideal cyan light shines on it. If ideal yellow light were to shine on the object, which one of the following choices identifies the color(s) that the object could appear?

- (A) only red
- (B) only yellow
- (C) only green or black
- (D) only yellow or green
- (E) only yellow, green, or red

## [PhysicsBowl, 2017Q21]

The change in linear momentum of an object is always in the same direction as the

- (A) velocity of the object.
- (B) displacement of the object.
- (C) average speed of the object.
- (D) average velocity of the object.
- (E) average acceleration of the object.

## [PhysicsBowl, 2017Q22]

A large swimming pool is filled with a liquid having a density of  $5.00 \times 10^2 \text{ kg/m}^3$ . A person wants to see what happens if she jumps into the deep end of the pool (3.0 meters deep). Which one of the following choices correctly identifies what will happen to the person? Assume that the person does not try to move their arms or legs until discovering what happens after equilibrium is established.

- (A) The person will float with much more than 50% of their body's volume above the liquid's surface.
- (B) The person will float with approximately 50% of their body's volume above the liquid's surface.
- (C) The person will float with much less than 50% of their body's volume above the liquid's surface.
- (D) The person will sink but remain off the bottom of the pool.
- (E) The person will sink to the pool's bottom.

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8

## [PhysicsBowl, 2017Q23]

A 1,500 kg car and a 6,000 kg truck have a perfectly inelastic collision on a street. Which one of the following choices correctly identifies the object(s) that lose kinetic energy from the impact?

- (A) Neither object loses kinetic energy.
- (B) Only the car loses kinetic energy.
- (C) Only the truck loses kinetic energy.
- (D) Both the car and truck lose kinetic energy.
- (E) The answer cannot be determined without more information.

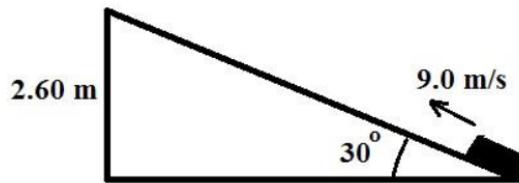
## [PhysicsBowl, 2017Q24]

What condition must be met for the angular momentum of a system to be constant?

- (A) The mechanical energy is constant.
- (B) There is no net external force acting on the system.
- (C) The system is in static equilibrium.
- (D) There is no net external torque acting on the system.
- (E) Only the gravitational force is acting on the system.

[PhysicsBowl, 2017Q25]

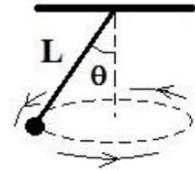
A box slides with uniform acceleration up an incline. The box has an initial speed of  $9.0 \text{ m/s}$  and rises vertically  $2.60 \text{ m}$  before coming to rest. If the angle of the incline is  $30^\circ$ , what is the coefficient of kinetic friction between the box and the incline?



- (A) 0.298
- (B) 0.322
- (C) 0.372
- (D) 0.483
- (E) 0.557

[PhysicsBowl, 2017Q26]

A  $4.00 \text{ kg}$  mass is in uniform circular motion as shown in the figure. The string to which the mass is attached has a length of  $L = 3.00 \text{ m}$  and forms an angle of  $\theta = 50.0^\circ$  with the vertical. What is the speed of the mass?



- (A)  $5.23 \text{ m/s}$
- (B)  $5.54 \text{ m/s}$
- (C)  $5.98 \text{ m/s}$
- (D)  $6.62 \text{ m/s}$
- (E)  $6.90 \text{ m/s}$



[PhysicsBowl, 2017Q27]

A  $2.0 \text{ kg}$  mass moves at  $10.0 \text{ m/s}$  when it has a collision in space. The mass's speed was unchanged, but the direction of its velocity was altered by  $80^\circ$ . If the collision lasted  $0.25 \text{ s}$ , what was the magnitude of the average force exerted on the mass?



- (A)  $0 \text{ N}$
- (B)  $54.7 \text{ N}$
- (C)  $102.8 \text{ N}$
- (D)  $122.5 \text{ N}$
- (E)  $150.3 \text{ N}$

[PhysicsBowl, 2017Q28]

A shipment of parts is labeled in units of “ohm·second.” Which one of the following choices represents an equivalent unit?

- (A) henry
- (B) farad
- (C) joule
- (D) volt
- (E) weber

[PhysicsBowl, 2017Q29]

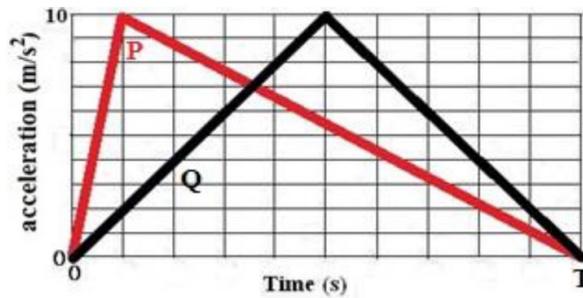
Two lightbulbs ( $X$  and  $Y$ ) are connected in series to a battery. Bulb  $X$  is brighter than bulb  $Y$ . Assume all circuit elements are ideal. If bulbs  $X$  and  $Y$  are connected in parallel with each other to the same battery, which one of the following choices best represents what is observed?

	Bulb $X$	Bulb $Y$	Comparison
(A)	Brightens	Brightens	Bulb $X$ remains brighter than bulb $Y$
(B)	Brightens	No change	Bulb $X$ remains brighter than bulb $Y$
(C)	Dims	Brightens	Bulb $X$ remains brighter than bulb $Y$
(D)	Dims	Brightens	Bulb $Y$ now is brighter than bulb $X$
(E)	Brightens	Brightens	Bulb $Y$ now is brighter than bulb $X$



[PhysicsBowl, 2017Q30]

Two cars,  $P$  and  $Q$ , each start from rest at the origin and will move along the  $x$ -axis. The acceleration vs. time graph for each car is shown. Which one of the following choices correctly identifies the relationship for both the speeds ( $v_P$  and  $v_Q$ ) and the positions ( $x_P$  and  $x_Q$ ) of the cars at time  $T$ ?

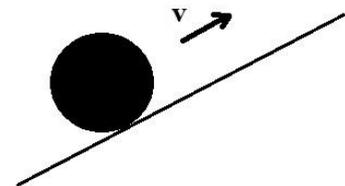


	speeds	positions
(A)	$v_P = v_Q$	$x_P > x_Q$
(B)	$v_P > v_Q$	$x_P > x_Q$
(C)	$v_P = v_Q$	$x_P = x_Q$
(D)	$v_P < v_Q$	$x_P < x_Q$
(E)	$v_P = v_Q$	$x_P < x_Q$



[PhysicsBowl, 2017Q31]

A solid cylinder rolls without slipping on a rough inclined plane. Which one of the following choices best represents the type and direction of friction (if any) acting on the cylinder as it rolls up the incline?



- (A) Static friction directed up the incline
- (B) Kinetic friction directed up the incline
- (C) There is no friction
- (D) Kinetic friction directed down the incline
- (E) Static friction directed down the incline

[PhysicsBowl, 2017Q32]

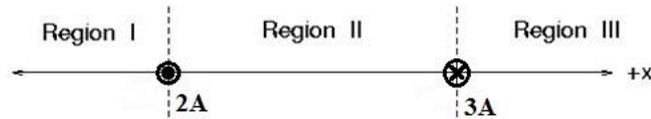
A projectile is launched at an angle of  $40^\circ$  above the horizontal with a speed of 30 m/s. How much time passes before the position of the projectile makes an angle of  $20^\circ$  above the horizontal from the original launch point?

- (A) 3.02 s
- (B) 2.38 s
- (C) 2.18 s
- (D) 1.93 s
- (E) 1.64 s

[PhysicsBowl, 2017Q33]

Two long wires are fixed in space so that the conventional current in the left wire (2A) comes out of the plane of the page and the conventional current in the right wire (3A) goes into the plane of the page. In which Region(s) is there a place on the  $x$ -axis (aside from infinity) at which the magnetic field is equal to zero from these currents?

- (A) Only in Region I
- (B) In both Regions I and II
- (C) Only in Region II
- (D) In both Regions I and III
- (E) In both Regions II and III



[PhysicsBowl, 2017Q34]

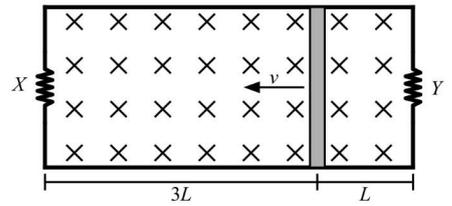
A 9.20 m long uniform plank rests on a frictionless ice pond. A 52 kg box rests on the plank's left end while a 71 kg person stands at the plank's right end. After the person walks to the left on the plank and stands at the same location as the box, the plank has slid 3.84 m to the right relative to the pond's shore. Which one of the following choices best represents the mass of the plank?



- (A) 123 kg
- (B) 61.5 kg
- (C) 47.1 kg
- (D) 36.5 kg
- (E) 31.2 kg

[PhysicsBowl, 2017Q35]

A metal bar is moving to the left across a set of frictionless conducting rails as seen in the figure. Throughout the region between the rails, there is a uniform magnetic field directed into the plane of the page. The resistors labeled  $X$  and  $Y$  are identical. Which one of the following choices correctly indicates the direction of the conventional current in the resistors and the relation between the magnitude of the currents through each resistor at the instant shown?



	Current through $X$	Current through $Y$	Relation between Currents ( $I_X, I_Y$ )
(A)	Up the plane of the page	Up the plane of the page	$I_X > I_Y$
(B)	Up the plane of the page	Up the plane of the page	$I_X = I_Y$
(C)	Up the plane of the page	Down the plane of the page	$I_X > I_Y$
(D)	Down the plane of the page	Down the plane of the page	$I_X = I_Y$
(E)	Down the plane of the page	Down the plane of the page	$I_X > I_Y$



[PhysicsBowl, 2017Q36]

A scientist performs an experiment in which she determines the shortest length of a gas column needed to create resonance for a vibrating tuning fork over a tube closed at one end. She plots the gas column length against the inverse of the frequency for a set of tuning forks and finds that she has a straight line fit through the data. Representing the slope of the line as  $m$ , which one of the following choices correctly identifies the speed of waves through the gas in the experiment?

- (A)  $\frac{1}{4}m$
- (B)  $m$
- (C)  $2m$
- (D)  $\frac{4}{3}m$
- (E)  $4m$

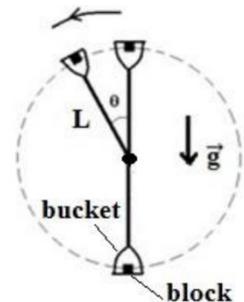
[PhysicsBowl, 2017Q37]

Which one of the following choices best approximates the magnitude of the Earth's angular momentum (expressed in base MKS units) associated with its orbit around the Sun?

- (A)  $10^{36}$
- (B)  $10^{40}$
- (C)  $10^{44}$
- (D)  $10^{48}$
- (E)  $10^{52}$

[PhysicsBowl, 2017Q38]

A small 2.0 kg block rests at the bottom of a bucket. The bucket is spun in a vertical circle of radius  $L$  by a rope. When the bucket reaches the highest point in its motion, it moves just fast enough for the block to remain in place in the bucket. When the bucket is at an angle  $\theta = 30^\circ$  from the vertical, as seen in the figure, what is the magnitude of the normal force (perpendicular to the surface) provided by the bucket onto the block? Note that the direction of the gravitational field is indicated in the diagram by  $\vec{g}$  and that the block does not touch any sides of the bucket aside from the bottom of it.



- (A) 8.0 N
- (B) 10.0 N
- (C) 15.4 N
- (D) 18.7 N
- (E) 37.3 N



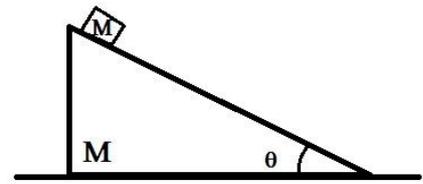
[PhysicsBowl, 2017Q39]

A point wave source travels along the  $x$ -axis at constant speed  $v_s$ . Stationary observers on the  $x$ -axis measure the wavelength of the waves that they receive. The ratio of the wavelength measured at a location behind the source to the wavelength measured at a location in front of the source is 1.50. If the wave speed is  $v$ , what is the source speed  $v_s$ ?

- (A)  $\frac{1}{5}v$
- (B)  $\frac{1}{4}v$
- (C)  $\frac{1}{3}v$
- (D)  $\frac{1}{2}v$
- (E)  $\frac{2}{3}v$

[PhysicsBowl, 2017Q40]

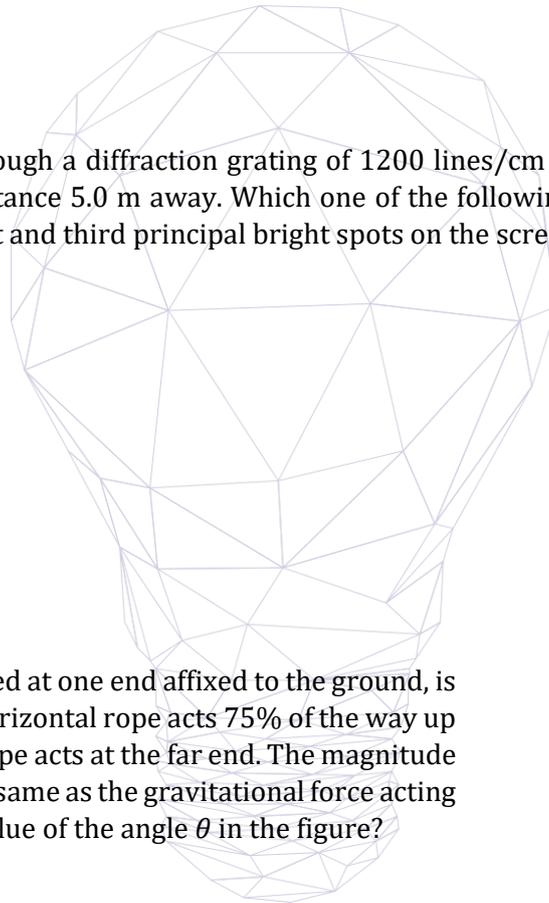
A small object of mass  $M$  is released from rest at the top of a frictionless incline. The incline has a mass  $M$  and makes an angle  $\theta$  with the horizontal. The incline remains at rest on a table as the small object slides. During the slide, what is the magnitude of the normal force from the table on the incline?



- (A)  $2Mg(1 - \tan \theta)$
- (B)  $2Mg(1 - \sin \theta)$
- (C)  $2Mg$
- (D)  $Mg(2 - \sin^2 \theta)$
- (E)  $Mg(2 - \sin \theta)$

[PhysicsBowl, 2017Q41]

Pure red light shines through a diffraction grating of 1200 lines/cm and produces an interference pattern on a screen a distance 5.0 m away. Which one of the following choices best represents the distance between the first and third principal bright spots on the screen?

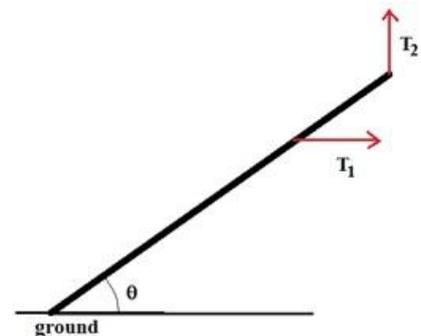


- (A) 0.02 m
- (B) 0.10 m
- (C) 1.0 m
- (D) 2.0 m
- (E) 4.0 m



[PhysicsBowl, 2017Q42]

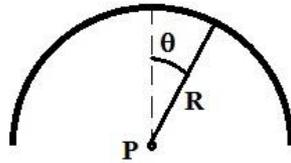
A long uniform rod, pivoted at one end affixed to the ground, is in static equilibrium. A horizontal rope acts 75% of the way up the rod while a vertical rope acts at the far end. The magnitude of each rope's force is the same as the gravitational force acting on the rod. What is the value of the angle  $\theta$  in the figure?



- (A)  $18.4^\circ$
- (B)  $21.8^\circ$
- (C)  $33.7^\circ$
- (D)  $36.9^\circ$
- (E)  $45.0^\circ$

[PhysicsBowl, 2017Q43]

A semi-circle has radius  $R$ , total charge  $Q$ , and a charge per unit length given as  $\lambda = \lambda_0 \cos \theta$  with  $\theta$  defined in the figure and  $\lambda_0$  a positive constant. Which one of the following choices gives the electric field strength at the point labeled  $P$ ?



- (A) 0
- (B)  $\frac{2k_e\lambda_0}{R^2}$
- (C)  $\frac{k_eQ\lambda_0}{R}$
- (D)  $\frac{2k_eQ\lambda_0}{\pi R^2}$
- (E)  $\frac{k_e\lambda_0\pi}{2R}$

[PhysicsBowl, 2017Q44]

A ball is launched vertically upward. The vertical position of the ball 0.70 s after release is the same as its vertical position 4.10 s after its release. At what time is the object first at a vertical position that is one-half of the maximum height it obtains during its flight?

- (A) 0.35 s
- (B) 0.70 s
- (C) 0.85 s
- (D) 1.20 s
- (E) 1.70 s



[PhysicsBowl, 2017Q45]

Which one of the following magnifications cannot be produced using a single converging lens?

- (A)  $\frac{1}{2}$
- (B) 2
- (C)  $-\frac{1}{2}$
- (D) -1
- (E) -2

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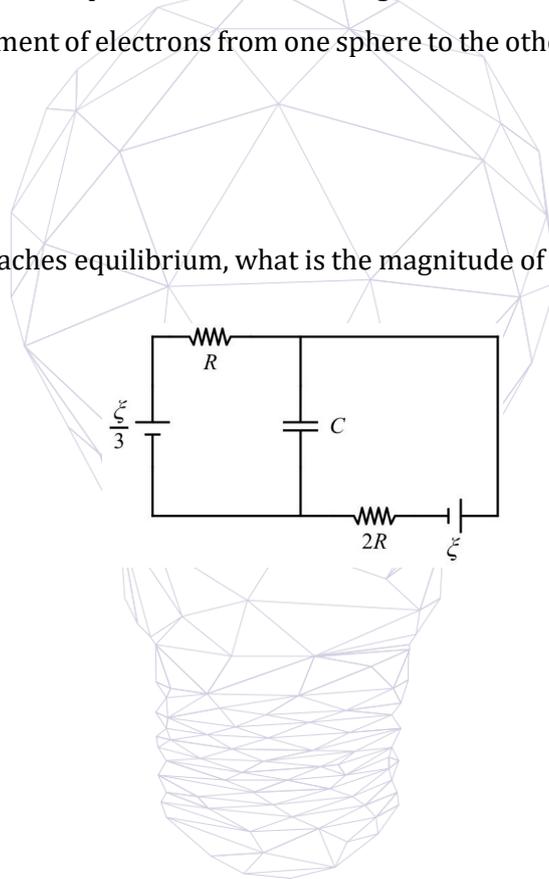
[PhysicsBowl, 2017Q46]

Two copper spheres,  $X$  and  $Y$ , with different radii ( $R_X > R_Y$ ) and equal excess charge  $+Q$ , are placed apart from each other. A scientist using insulating gloves connects the spheres with a copper wire. Which one of the following choices best describes what happens after the connection is made?

- (A) There is a net movement of electrons from sphere  $Y$  to sphere  $X$  until the electric field just outside the surface of each sphere has the same magnitude.
- (B) There is a net movement of electrons from sphere  $Y$  to sphere  $X$  until the electric potential just outside the surface of each sphere has the same magnitude.
- (C) There is a net movement of electrons from sphere  $X$  to sphere  $Y$  until the electric field just outside the surface of each sphere has the same magnitude.
- (D) There is a net movement of electrons from sphere  $X$  to sphere  $Y$  until the electric potential just outside the surface of each sphere has the same magnitude.
- (E) There is no net movement of electrons from one sphere to the other because the spheres already have equal charge.

[PhysicsBowl, 2017Q47]

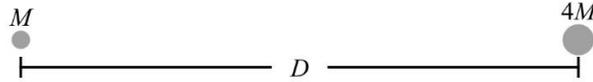
Once the circuit shown reaches equilibrium, what is the magnitude of the potential difference across the capacitor?



- (A)  $0\xi$
- (B)  $\frac{1}{9}\xi$
- (C)  $\frac{2}{9}\xi$
- (D)  $\frac{5}{9}\xi$
- (E)  $\frac{2}{3}\xi$

[PhysicsBowl, 2017Q48]

In the binary star system shown, the two stars follow circular orbits about the system's center of mass. The stars are separated by a distance  $D$  that is large compared to their size and are subject only to their mutual gravitational attraction. The orbital period of the star of mass  $M$  is  $T$ . Which one of the following choices represents the total mass of the binary star system?



- (A)  $\frac{\pi^2 D^3}{5GT^2}$
- (B)  $\frac{4\pi^2 D^3}{5GT^2}$
- (C)  $\frac{4\pi^2 D^3}{GT^2}$
- (D)  $\frac{16\pi^2 D^3}{5GT^2}$
- (E)  $\frac{25\pi^2 D^3}{4GT^2}$

[PhysicsBowl, 2017Q49]

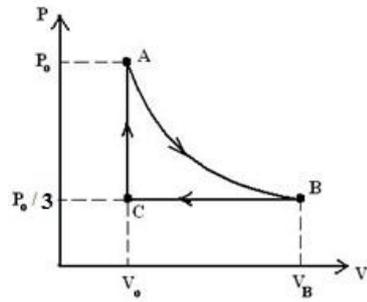
Two identical particles travel to the right. The particle traveling at  $2.40 \times 10^8$  m/s collides with and sticks to the other particle traveling at  $1.80 \times 10^8$  m/s. Which one of the following choices best represents the speed of the resulting object after collision?

- (A)  $2.20 \times 10^8$  m/s
- (B)  $2.14 \times 10^8$  m/s
- (C)  $2.10 \times 10^8$  m/s
- (D)  $2.06 \times 10^8$  m/s
- (E)  $2.00 \times 10^8$  m/s

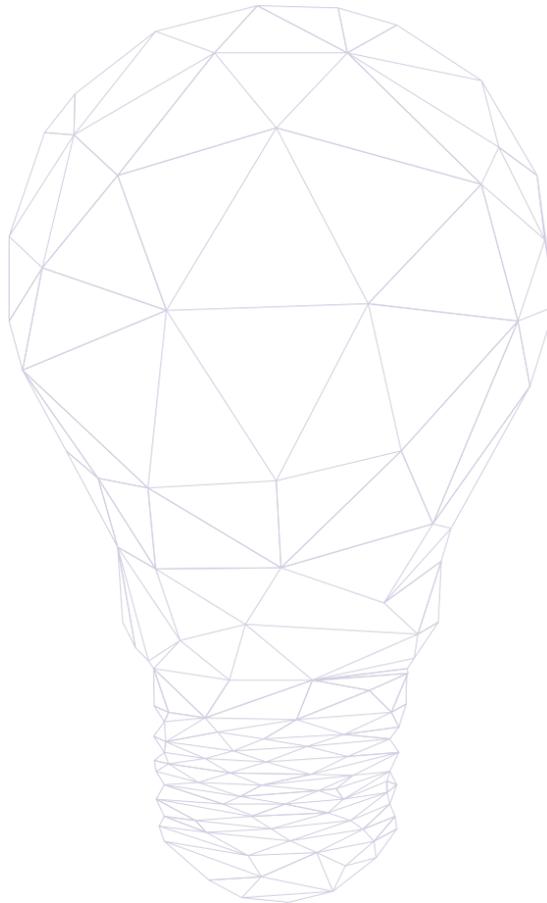


[PhysicsBowl, 2017Q50]

A monatomic ideal gas undergoes the reversible cyclic process ( $ABCA$ ) shown in the  $PV$  diagram. Process  $A \rightarrow B$  is adiabatic. What is the efficiency of this engine?



- (A) 0.15
- (B) 0.22
- (C) 0.33
- (D) 0.47
- (E) 0.67



# PhysicsBowl 2018

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2018

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2018Q1]

A quick Google search reveals that your phone operates at a frequency of  $850 \times 10^6$  Hz. Which of the following choices best represents this frequency using metric prefixes?

- (A) 850  $\mu$ Hz
- (B) 850 mHz
- (C) 850 kHz
- (D) 850 MHz
- (E) 850 GHz

[PhysicsBowl, 2018Q2]

A standard metal electroscope is positively charged. A person that is grounded (neutral charge) then touches the top portion of the electroscope with their finger. Which one of the following choices most correctly explains what happens when the finger touches the electroscope?

- (A) The leaves of the electroscope come back together because excess protons conduct to the finger from the electroscope.
- (B) The leaves of the electroscope come back together because electrons conduct to the electroscope from the finger.
- (C) The leaves remain where they are as nothing occurs.
- (D) The leaves of the electroscope move apart as electrons conduct from the electroscope to the finger.
- (E) The leaves of the electroscope move apart as protons conduct from the finger to the electroscope.

[PhysicsBowl, 2018Q3]

Which of the following is *NOT* a vector quantity?

- (A) Acceleration
- (B) Average velocity
- (C) Linear momentum
- (D) Potential energy
- (E) Force



[PhysicsBowl, 2018Q4]

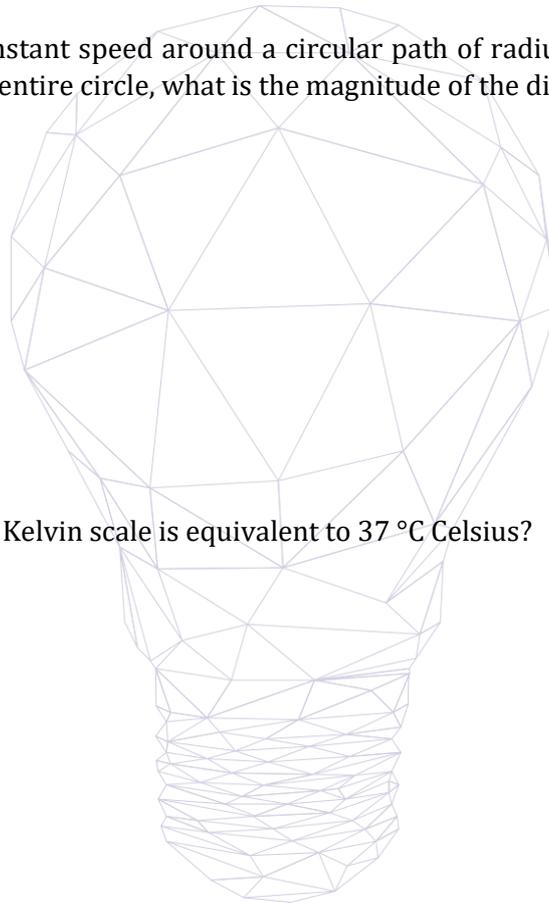
A ball is thrown vertically downward with an initial speed of 12.0 m/s from a height of 10.0 m above the ground. Ignoring air resistance, what is the speed of the ball when it reaches the ground?

- (A) 18.5 m/s
- (B) 14.6 m/s
- (C) 14.0 m/s
- (D) 12.8 m/s
- (E) 12.0 m/s

[PhysicsBowl, 2018Q5]

A particle travels at a constant speed around a circular path of radius  $R$ . If the particle makes one complete trip around the entire circle, what is the magnitude of the displacement for this trip?

- (A)  $\pi R$
- (B)  $2R$
- (C)  $2\pi R$
- (D)  $4R$
- (E) 0



[PhysicsBowl, 2018Q6]

What temperature on the Kelvin scale is equivalent to 37 °C Celsius?

- (A) 310 K
- (B) 283 K
- (C) 256 K
- (D) 37 K
- (E) 19 K

[PhysicsBowl, 2018Q7]

What is the percent uncertainty in the measurement  $2.54 \pm 0.16$  cm?

- (A) 2.9%
- (B) 6.3%
- (C) 8.7%
- (D) 12.6%
- (E) 14%

[PhysicsBowl, 2018Q8]

An Olympic bobsled needs to negotiate a 100 m radius turn at 35 m/s without skidding. What minimum banking angle of the turn is needed for this to happen? (Ignore friction.)

- (A)  $21^\circ$
- (B)  $31^\circ$
- (C)  $41^\circ$
- (D)  $51^\circ$
- (E)  $61^\circ$

[PhysicsBowl, 2018Q9]

The mean diameter of the Earth is  $12.76 \times 10^3$  km. What is the surface area of the Earth in  $\text{m}^2$ ?

- (A)  $4.01 \times 10^7$
- (B)  $5.12 \times 10^{14}$
- (C)  $1.09 \times 10^{21}$
- (D)  $1.68 \times 10^9$
- (E)  $2.05 \times 10^{15}$

[PhysicsBowl, 2018Q10]

A 2.0 m long organ pipe which is open at both ends resonates at its fundamental frequency. Neglecting any end effects, what wavelength is formed by this pipe in this mode of vibration?

- (A) 1 meter
- (B) 2 meters
- (C) 4 meters
- (D) 6 meters
- (E) 8 meters

[PhysicsBowl, 2018Q11]

In a classroom demonstration, a teacher discussing the air in the room as an ideal gas slides a solid barrier of negligible thickness into place, cutting the room into two equal-sized volumes. What is the air pressure for the portion of the room in which the teacher is standing, assuming the original pressure in the whole room was  $P$ ? Treat the room as a sealed container.

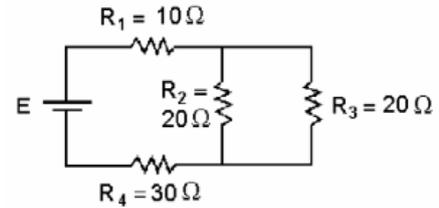
- (A)  $\frac{1}{4}P$
- (B)  $\frac{1}{2}P$
- (C)  $P$
- (D)  $2P$
- (E)  $4P$

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[PhysicsBowl, 2018Q12]

What is the equivalent resistance in the circuit that is shown at right?

- (A)  $55 \Omega$
- (B)  $80 \Omega$
- (C)  $50 \Omega$
- (D)  $45 \Omega$
- (E)  $75 \Omega$



[PhysicsBowl, 2018Q13]

An X-ray photon collides with a free electron, and the photon is scattered. During the collision:

- (A) there is conservation of momentum but not energy
- (B) there is conservation of neither momentum nor energy
- (C) there is conservation of energy but not momentum
- (D) there is conservation of both momentum and energy
- (E) impossible to predict if momentum and energy are conserved without additional information

[PhysicsBowl, 2018Q14]

Three identical wood blocks are raced across three different flat surfaces, with the faces of the blocks on the surfaces. Each block is pulled horizontally with the same force  $F$  from one edge by a light string attached to the block. Block 1 is pulled on a frictionless surface. Block 2 is pulled on a surface with a nonzero kinetic friction coefficient, and a zero static friction coefficient. Block 3 is pulled on a surface with a nonzero static friction coefficient, and the same kinetic coefficient as for Block 2, where  $\mu_k < \mu_s$ . If each block starts from rest and is pulled until traveling the same fixed horizontal distance, which of the following choices correctly ranks the times ( $t_1, t_2, t_3$ ) it takes for each block to traverse the distance?

- (A)  $t_1 < t_2 < t_3$
- (B)  $t_1 = t_2 = t_3$
- (C)  $t_1 < t_2 = t_3$
- (D)  $t_3 < t_2 < t_1$
- (E)  $t_2 < t_3 < t_1$

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[PhysicsBowl, 2018Q15]

A sample of ideal gas is in a container at a temperature of  $100\text{ }^{\circ}\text{C}$  and a pressure of  $2.5\text{ atm}$ . If the volume of the container is  $0.025\text{ m}^3$ , approximately how many molecules of gas are in the container?

- (A)  $4.58 \times 10^{24}$
- (B)  $1.23 \times 10^{24}$
- (C)  $6.25 \times 10^{23}$
- (D)  $4.53 \times 10^{22}$
- (E)  $1.21 \times 10^{22}$

[PhysicsBowl, 2018Q16]

Determining the area under an object's acceleration vs. time graph for a fixed time interval will calculate

- (A) the object's average velocity during the time interval
- (B) the object's velocity at the end of the time interval
- (C) the object's average speed during the time interval
- (D) the object's change in velocity during the time interval
- (E) the object's velocity at the time midway through the time interval

[PhysicsBowl, 2018Q17]

A thick-walled metal pipe of length  $20.0\text{ cm}$  has an inside diameter of  $2.00\text{ cm}$  and an outside diameter of  $2.40\text{ cm}$ . What is the total surface area of the pipe, including the inside, outside, and ends, in  $\text{cm}^2$ ?

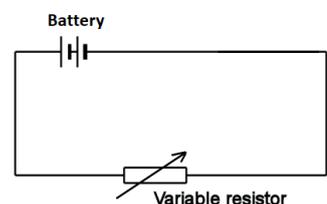
- (A) 276
- (B) 277
- (C) 278
- (D) 279
- (E) 282



[PhysicsBowl, 2018Q18]

The circuit shown contains a battery with an internal resistance,  $r$  connected to a variable resistor. When the resistance of the variable resistor is increased, which of the following statements is true?

- (A) The terminal voltage increases.
- (B) The current through the variable resistor in the circuit increases.
- (C) The power dissipated by the internal resistance increases.
- (D) The potential difference across the variable resistor decreases.
- (E) None of the above statements are true.



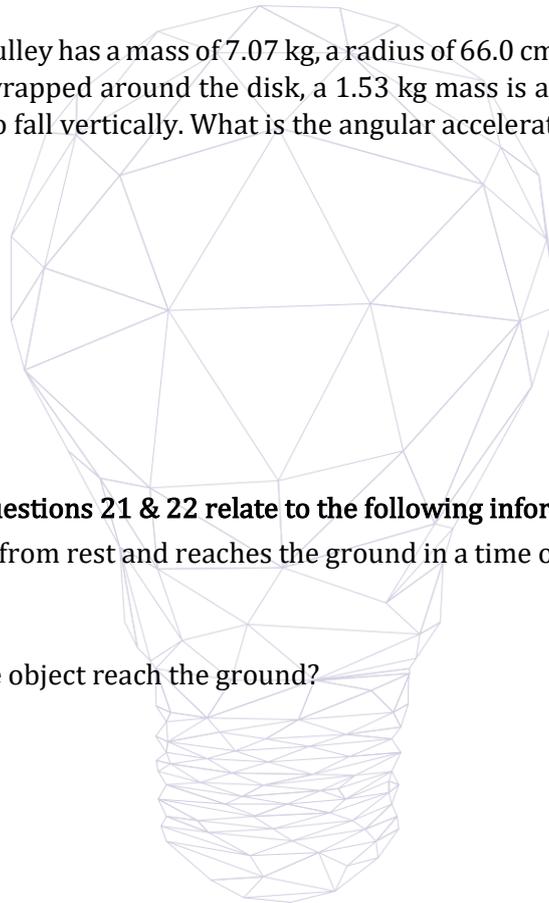
[PhysicsBowl, 2018Q19]

- Which of the following *could* produce an enlarged but inverted image of a real object?
- (A) A converging lens placed at a distance greater than its focal length from the object.
  - (B) A converging lens placed at a distance less than its focal length from the object.
  - (C) A diverging lens placed at a distance less than the magnitude of its focal length from the object.
  - (D) A diverging lens placed at a distance greater than the magnitude of its focal length from the object.
  - (E) It is not possible to create the type of image desired.

[PhysicsBowl, 2018Q20]

A frictionless, solid disk pulley has a mass of 7.07 kg, a radius of 66.0 cm, and is free to rotate vertically about an axle. A rope is wrapped around the disk, a 1.53 kg mass is attached to the end of the rope, and the mass is allowed to fall vertically. What is the angular acceleration of the pulley?

- (A) 4.58 rad/s<sup>2</sup>
- (B) 7.98 rad/s<sup>2</sup>
- (C) 9.87 rad/s<sup>2</sup>
- (D) 2.25 rad/s<sup>2</sup>
- (E) zero



**Questions 21 & 22 relate to the following information**

A small object is released from rest and reaches the ground in a time of 2.50 s. Neglect air resistance.

[PhysicsBowl, 2018Q21]

With what speed does the object reach the ground?

- (A) 31.3 m/s
- (B) 25.0 m/s
- (C) 12.5 m/s
- (D) 10.0 m/s
- (E) 2.50 m/s

[PhysicsBowl, 2018Q22]

From what height above the ground was the object released?

- (A) 6.25 m
- (B) 12.5 m
- (C) 25.0 m
- (D) 31.3 m
- (E) 62.5 m

[PhysicsBowl, 2018Q23]

Induced electric currents due to changing magnetic flux can be explained using which one of the following laws?

- (A) Gauss's Law
- (B) Faraday's Law
- (C) Ohm's Law
- (D) Ampere's Law
- (E) Volta's Law

[PhysicsBowl, 2018Q24]

A small ball is thrown at an angle of  $30.0^\circ$  above the horizontal ground with a speed of 20.0 m/s. What is the maximum height above the launch point to which the ball rises? Ignore air resistance.

- (A) 2.5 m
- (B) 5.0 m
- (C) 10.0 m
- (D) 15.0 m
- (E) 20.0 m

[PhysicsBowl, 2018Q25]

In a circuit, the flow of electrons in a horizontal wire produces a constant current of 3.20 A for a time of 3.0 hours. Which of the following choices best represents the number of electrons that pass through a vertical cross-section of wire during this time?

- (A) 9.6
- (B)  $6.00 \times 10^{19}$
- (C)  $7.20 \times 10^{22}$
- (D)  $2.16 \times 10^{23}$
- (E)  $6.02 \times 10^{23}$



[PhysicsBowl, 2018Q26]

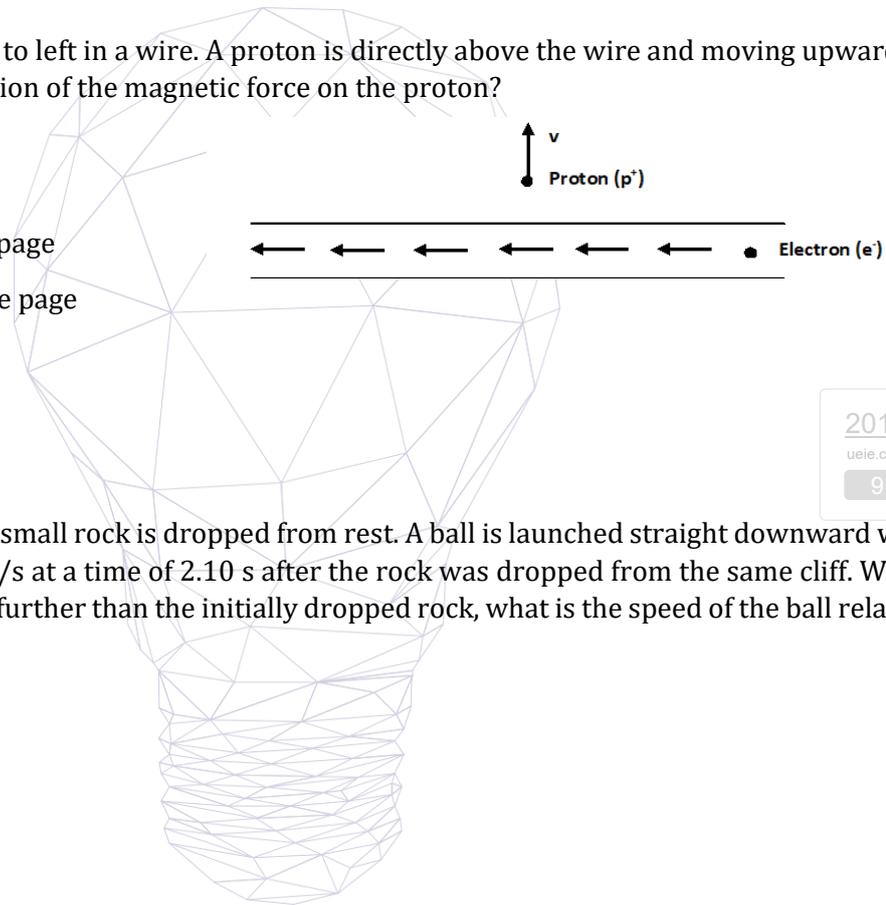
A simple pendulum consists of a mass  $M$  attached to a string of length  $L$  of negligible mass. For this system, when undergoing small oscillations

- (A) the frequency is proportional to the amplitude.
- (B) the period is proportional to the amplitude.
- (C) the frequency is independent of the mass  $M$ .
- (D) the frequency is independent of the length  $L$ .
- (E) the frequency is inversely proportional to the length  $L$ .

[PhysicsBowl, 2018Q27]

Electrons flow from right to left in a wire. A proton is directly above the wire and moving upward as shown. What is the direction of the magnetic force on the proton?

- (A) to the left
- (B) to the right
- (C) into the plane of the page
- (D) out of the plane of the page
- (E) toward the wire



[PhysicsBowl, 2018Q28]

At the top of a high cliff, a small rock is dropped from rest. A ball is launched straight downward with an initial speed of 36.0 m/s at a time of 2.10 s after the rock was dropped from the same cliff. When the ball has fallen 28.0 m further than the initially dropped rock, what is the speed of the ball relative to the rock?

- (A) 15.0 m/s
- (B) 16.0 m/s
- (C) 20.0 m/s
- (D) 21.0m/s
- (E) 36.0m/s

[PhysicsBowl, 2018Q29]

An object that is 8.60 cm tall is placed in front of a convex mirror. The resulting image is 7.60 cm tall, and 14.2 cm from the mirror. What is the focal length of the mirror?

- (A) -122 cm
- (B) -105 cm
- (C) 14.0 cm
- (D) -16.9 cm
- (E) -4.2 cm

[PhysicsBowl, 2018Q30]

A radian per second is a unit of:

- (A) angular displacement
- (B) angular velocity
- (C) angular acceleration
- (D) angular momentum
- (E) rotational kinetic energy

[PhysicsBowl, 2018Q31]

A standing transverse wave is formed on a tightly stretched string. The distance between a node and an adjacent antinode is:

- (A)  $1/8$  wavelength
- (B)  $1/4$  wavelength
- (C)  $1/2$  wavelength
- (D) 1 wavelength
- (E) unable to be determined without more information.

[PhysicsBowl, 2018Q32]

For a negative point charge, the electric field vectors:

- (A) circle the charge
- (B) point radially in toward the charge
- (C) point radially away from the charge
- (D) pass directly through the charge
- (E) cross at infinity

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[PhysicsBowl, 2018Q33]

A torque of 150 Newton-meters causes the driveshaft of a car to rotate at 450 radians per second. How much power is produced by this torque?

- (A) 53,300 W
- (B) 67,500 W
- (C) 70,000 W
- (D) 72,500 W
- (E) 75,000 W

[PhysicsBowl, 2018Q34]

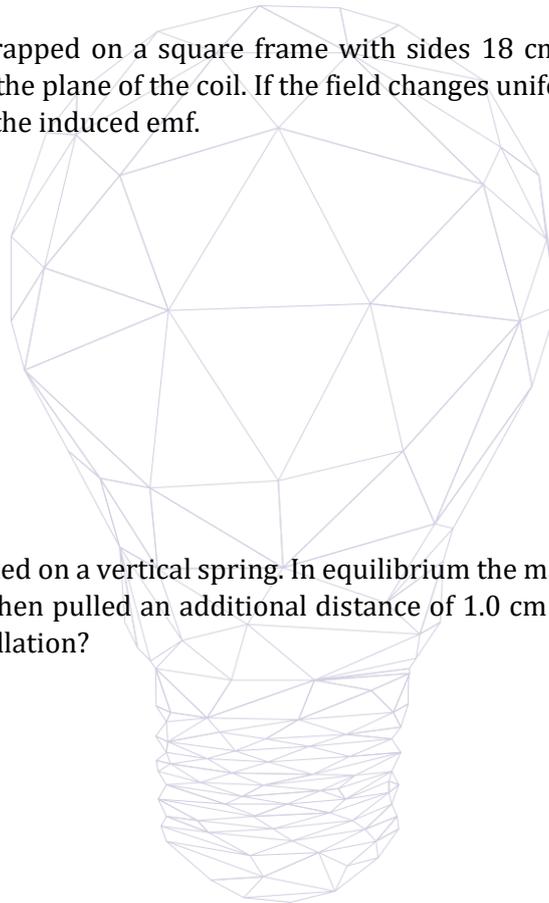
For the hydrogen atom, which series describes electron transitions to the  $N = 1$  orbit, the lowest energy electron orbit?

- (A) Lyman series
- (B) Balmer series
- (C) Paschen series
- (D) Curie series
- (E) Bohr series

[PhysicsBowl, 2018Q35]

200 turns of wire are wrapped on a square frame with sides 18 cm. A uniform magnetic field is applied perpendicular to the plane of the coil. If the field changes uniformly from 0.50 T to 0 in 8.0 s, find the average value of the induced emf.

- (A) 2.05 V
- (B) 4.05 V
- (C) 0.205 V
- (D) 0.405 V
- (E) 0.605 V



[PhysicsBowl, 2018Q36]

A 0.30 kg mass is suspended on a vertical spring. In equilibrium the mass stretches the spring 2.0 cm downward. The mass is then pulled an additional distance of 1.0 cm down and released from rest. What is the period of oscillation?

- (A) 0.14 s
- (B) 0.28 s
- (C) 0.024 s
- (D) 0.046 s
- (E) 0.064 s

## [PhysicsBowl, 2018Q37]

An electron is traveling due north and has a speed of  $4.0 \times 10^5$  m/s. It enters a region where the Earth's magnetic field has the magnitude  $5.0 \times 10^{-5}$  T to the north and directed downward at  $45^\circ$  below the horizontal. What is the magnitude of the force acting on the electron?

- (A)  $2.3 \times 10^{-18}$  N
- (B)  $3.2 \times 10^{-18}$  N
- (C)  $4.2 \times 10^{-18}$  N
- (D)  $2.5 \times 10^{-19}$  N
- (E)  $3.23 \times 10^{-19}$  N

## [PhysicsBowl, 2018Q38]

Why does the sky appear to be more blue when looking directly overhead than it does when looking toward the horizon?

- (A) The atmosphere is denser at higher altitude than it is at the Earth's surface.
- (B) The temperature of the upper atmosphere is higher than it is at the Earth's surface.
- (C) There are fewer clouds directly overhead than near the horizon.
- (D) The sunlight travels over a longer path at the horizon, resulting in more scattering.
- (E) The sunlight entering the atmosphere from directly above undergoes greater refraction and dispersion.



## [PhysicsBowl, 2018Q39]

A mass that is in simple harmonic motion obeys the following position versus time equation:  $y = (0.50 \text{ m}) \sin\left(\frac{\pi}{2t}\right)$  where  $t$  is in seconds. What is the period of vibration of this mass?

- (A) 1.0 s
- (B) 2.0 s
- (C) 3.0 s
- (D) 4.0 s
- (E) 5.0 s

[PhysicsBowl, 2018Q40]

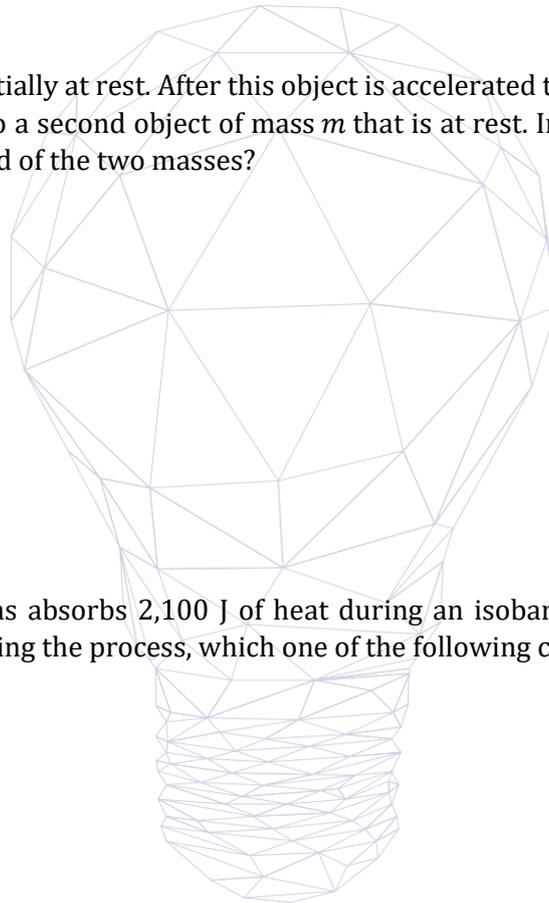
Which of the following wavelengths (in nm) of electromagnetic radiation will produce photoelectrons of the least kinetic energy if the radiation is incident on a material with a work function of 4.80 eV?

- (A) 992
- (B) 496
- (C) 248
- (D) 124
- (E) 62

[PhysicsBowl, 2018Q41]

An object of mass  $m$  is initially at rest. After this object is accelerated to a speed of  $2.40 \times 10^8$  m/s, it collides with and sticks to a second object of mass  $m$  that is at rest. Immediately after the collision, what is the common speed of the two masses?

- (A)  $2.25 \times 10^8$  m/s
- (B)  $1.80 \times 10^8$  m/s
- (C)  $1.66 \times 10^8$  m/s
- (D)  $1.50 \times 10^8$  m/s
- (E)  $1.20 \times 10^8$  m/s



[PhysicsBowl, 2018Q42]

Two moles of an ideal gas absorbs 2,100 J of heat during an isobaric process. If the gas changes temperature by 36 °C during the process, which one of the following choices could identify the gas?

- (A) Carbon monoxide
- (B) Water vapor
- (C) Ammonia
- (D) Helium
- (E) Hydrogen sulfide

[PhysicsBowl, 2018Q43]

In August of 2017, the gravitational waves from the collision and merger of two neutron stars were detected. After their collision, several forms of electromagnetic radiation were subsequently detected. What was the first type of electromagnetic radiation detected after the gravitational waves were detected?

- (A) Gamma rays
- (B) Visible light
- (C) Radio waves
- (D) X-rays
- (E) Microwaves

[PhysicsBowl, 2018Q44]

Which of the following terms/quantities is most closely associated with “the measure of resistance of an object to length change under lengthwise tension or compression”?

- (A) Bulk modulus
- (B) Plastic deformation
- (C) Shear modulus
- (D) Elastic limit
- (E) Young’s modulus

[PhysicsBowl, 2018Q45]

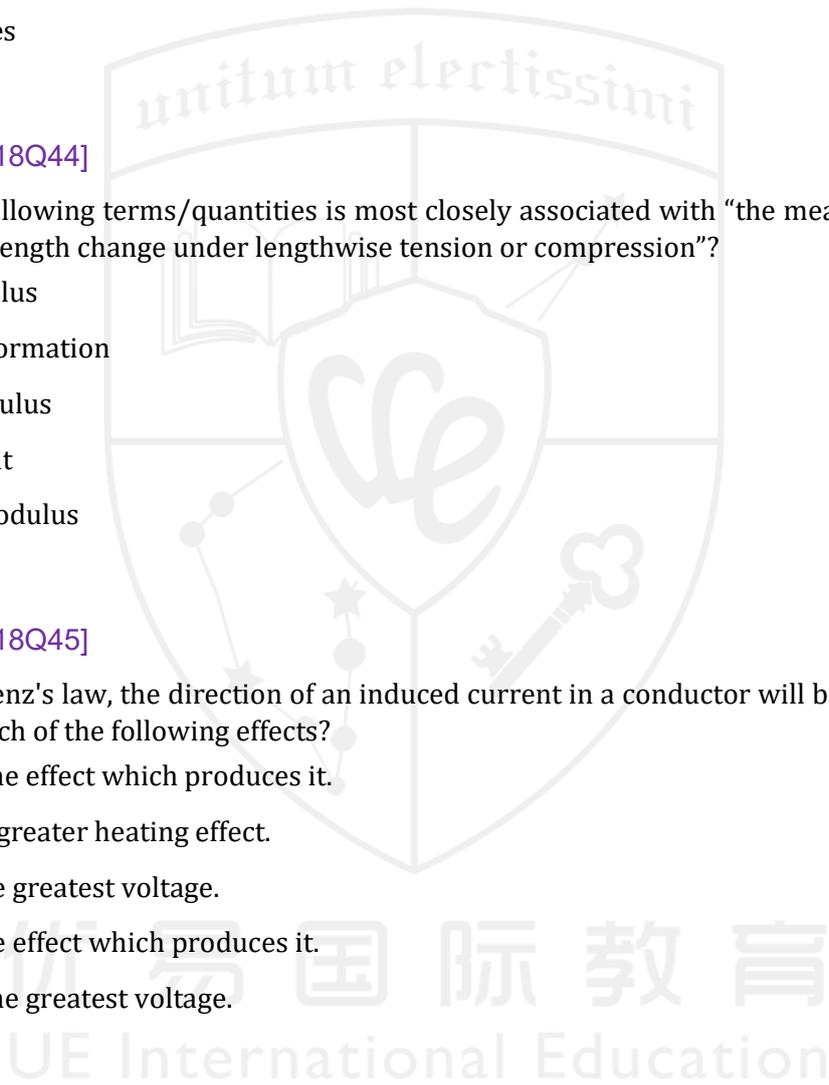
According to Lenz's law, the direction of an induced current in a conductor will be that which tends to produce which of the following effects?

- (A) Enhance the effect which produces it.
- (B) Produce a greater heating effect.
- (C) Oppose the greatest voltage.
- (D) Oppose the effect which produces it.
- (E) Enhance the greatest voltage.

[PhysicsBowl, 2018Q46]

When an ideal gas is taken through an isochoric process,

- (A)  $\Delta U = 0$
- (B)  $W = 0$
- (C)  $Q = 0$
- (D)  $\Delta U = W$
- (E) none of the above



[PhysicsBowl, 2018Q47]

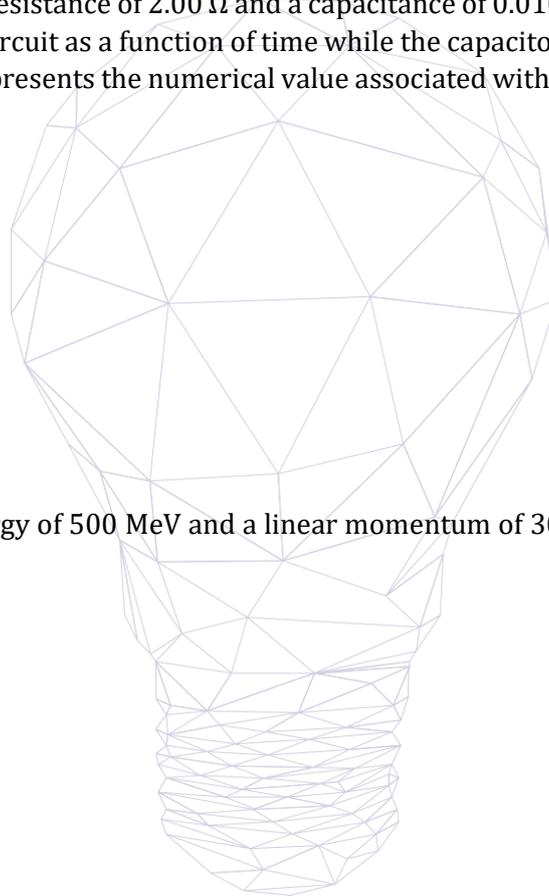
The existence of the neutrino was proposed to explain

- (A) alpha decay
- (B) gamma emission
- (C) beta decay
- (D) fission
- (E) fusion

[PhysicsBowl, 2018Q48]

A series  $RC$  circuit has a resistance of  $2.00\ \Omega$  and a capacitance of  $0.010\ \text{F}$ . A student plots the natural log of the current in the circuit as a function of time while the capacitor is charging. Which one of the following choices best represents the numerical value associated with the slope of the resulting line?

- (A) 0.02
- (B)  $-0.02$
- (C) 50
- (D)  $-50$
- (E) 0.5



[PhysicsBowl, 2018Q49]

A particle has a total energy of  $500\ \text{MeV}$  and a linear momentum of  $300\ \text{MeV}/c$ . What is the mass of the particle?

- (A)  $800\ \text{MeV}/c^2$
- (B)  $583\ \text{MeV}/c^2$
- (C)  $400\ \text{MeV}/c^2$
- (D)  $267\ \text{MeV}/c^2$
- (E)  $200\ \text{MeV}/c^2$

[PhysicsBowl, 2018Q50]

Two spheres are heated to the same temperature and allowed to radiate energy to identical surroundings. The spheres have the same emissivity, but one sphere has twice the diameter of the other. If the smaller sphere radiates energy at a rate  $P$ , at what rate will the larger sphere radiate energy?

- (A)  $P$
- (B)  $2P$
- (C)  $4P$
- (D)  $8P$
- (E)  $16P$



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# PhysicsBowl 2019

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2019

[Online Exam](#)

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the question number on the test.

**Division 1 students will answer only questions 1 – 40.** Numbers 41 – 100 on the answer sheet should remain blank for all Division 1 students.

**Division 2 students will answer only questions 11 – 50.** Numbers 1 – 10 and 51 – 100 on the answer sheet should remain blank for all Division 2 students.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

**Good Luck!**

[PhysicsBowl, 2019Q1]

Select the smallest value from the choices below

- (A)  $15 \times 10^{-3}$
- (B)  $0.15 \times 10^0$
- (C)  $0.00015 \times 10^3$
- (D)  $150 \times 10^{-3}$
- (E)  $0.00000015 \times 10^6$

[PhysicsBowl, 2019Q2]

Related to the historical development of understanding gravity, which is the proper chronological order for the work of these three scientists, from earliest to latest?

- (A) Cavendish, Galileo, Newton
- (B) Galileo, Cavendish, Newton
- (C) Galileo, Newton, Cavendish
- (D) Newton, Galileo, Cavendish
- (E) Newton, Cavendish, Galileo

[PhysicsBowl, 2019Q3]

An isolated solid metal sphere with a radius  $R$  is given a positive charge  $Q$ . The electric potential at the surface of the sphere is  $V$ . What is the electric potential at a distance of  $0.5R$  from the center of the sphere?

- (A) zero
- (B)  $0.5V$
- (C)  $V$
- (D)  $2V$
- (E)  $4V$



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[PhysicsBowl, 2019Q4]

Consider a situation where the acceleration of an object is always directed perpendicular to its velocity. This means that

- (A) the object is increasing speed.
- (B) the object is decreasing speed.
- (C) the object is not moving.
- (D) the object is turning.
- (E) this situation would not be physically possible.

[PhysicsBowl, 2019Q5]

The acceleration due to gravity on the Moon is less than the acceleration due to gravity on the Earth. Which of the following is true about the mass and weight of an astronaut on the Moon's surface, compared to Earth?

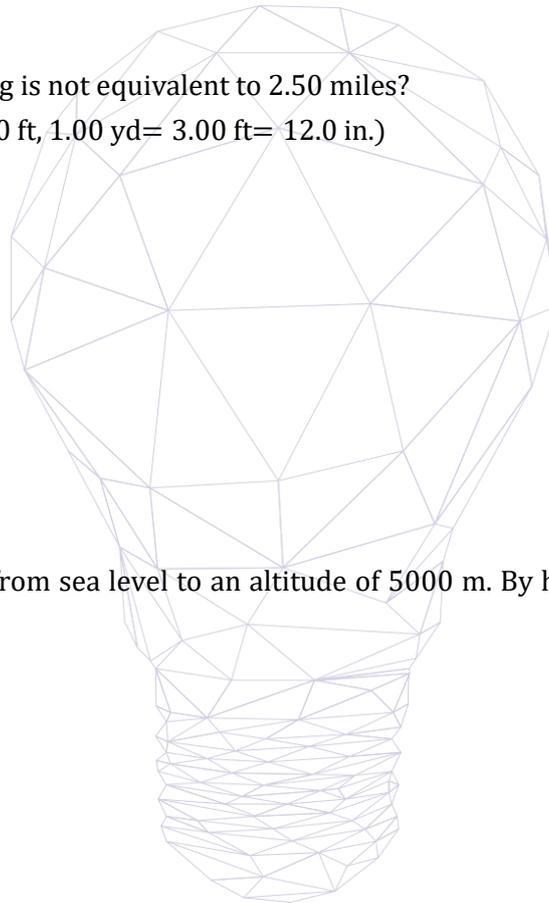
- (A) Mass is less, weight is the same.
- (B) Mass is the same, weight is less.
- (C) Both mass and weight are less.
- (D) Both mass and weight are the same.
- (E) Mass is more, weight is less

[PhysicsBowl, 2019Q6]

Which one of the following is not equivalent to 2.50 miles?

(1.00 mi= 1.61 km= 5280 ft, 1.00 yd= 3.00 ft= 12.0 in.)

- (A)  $1.32 \times 10^4$  ft
- (B)  $1.58 \times 10^5$  in
- (C)  $4.02 \times 10^3$  km
- (D)  $4.40 \times 10^3$  yd
- (E)  $4.02 \times 10^5$  cm



[PhysicsBowl, 2019Q7]

A 100 kg person travels from sea level to an altitude of 5000 m. By how many Newtons does their weight change?

- (A) 0.8 N
- (B) 1.2 N
- (C) 1.6 N
- (D) 2.0 N
- (E) 2.4 N

## [PhysicsBowl, 2019Q8]

A candle, a converging lens and a white screen are placed in a line with the lens between the candle and the screen. A distance of 72 cm separates the candle and screen. As the lens is moved to all points between the candle and the screen, only one focused image of the candle can be made on the screen. What is the focal length of the converging lens?

- (A) 12 cm
- (B) 18 cm
- (C) 24 cm
- (D) 36 cm
- (E) It cannot be determined without knowing the location of the lens when the focused image is produced.

## [PhysicsBowl, 2019Q9]

Standby power (sometimes called vampire power) is the power used by a device that is off but plugged in and in a standby mode. Regulations typically limit this power to 1 Watt. If electricity costs \$0.10 per kilowatt hour, then to the nearest order of magnitude, and assuming 1 Watt, how much does it cost to leave a device in standby mode for one year?

- (A) \$0.01
- (B) \$0.10
- (C) \$1.00
- (D) \$10.00
- (E) \$100.00

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## [PhysicsBowl, 2019Q10]

A student generates a transverse periodic wave on a string. The wave travels away from the student at a constant speed  $v$ . Which of the following changes by itself will increase the speed at which the wave travels away from the student?

- (A) The student could use the same string but increase the frequency at which they generate the wave.
- (B) The student could use the same string but increase the wavelength of the waves they generate.
- (C) The student could use the same string but increase the amplitude of the waves they generate.
- (D) The student could use a string with the same length and tension, but greater linear density
- (E) The student could use the same string, but placed under greater tension.

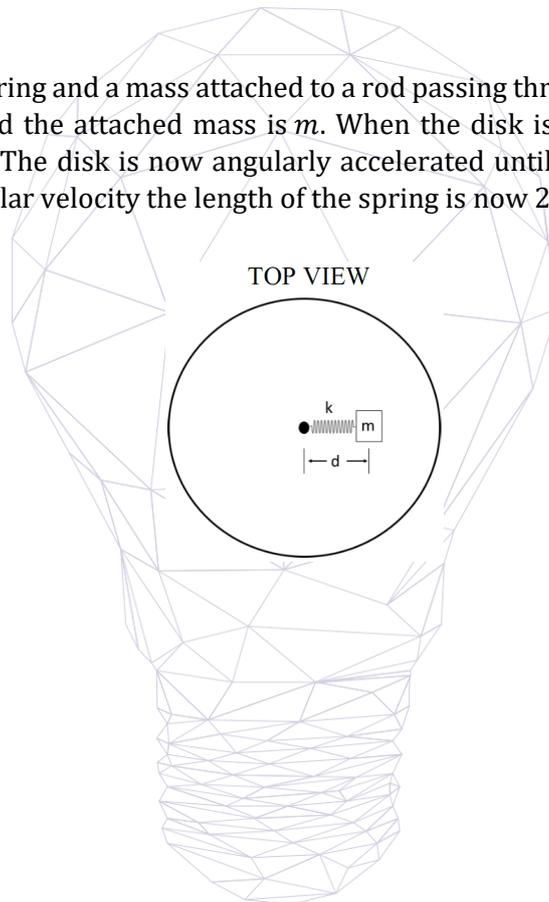
[PhysicsBowl, 2019Q11]

You throw a ball at angle  $\theta$  and measure its horizontal range,  $R$ . You now throw the same ball again at the same angle, but with twice the original speed. Its horizontal range, compared to your first throw (in both cases, the ball lands at the same height from which it was thrown) would be

- (A)  $1.4R$
- (B)  $0.5R$
- (C)  $2R$
- (D)  $4R$
- (E) the same

[PhysicsBowl, 2019Q12]

A horizontal disk has a spring and a mass attached to a rod passing through its center. The spring has a spring constant of  $k$  and the attached mass is  $m$ . When the disk is not rotating, the equilibrium length of the spring is  $d$ . The disk is now angularly accelerated until it reaches a constant angular velocity of  $\omega$ . At this angular velocity the length of the spring is now  $2d$ . What is the angular velocity of the disk?



- (A)  $\sqrt{\frac{k}{d}}$
- (B)  $\sqrt{\frac{k}{2m}}$
- (C)  $\sqrt{\frac{2k}{m}}$
- (D)  $\sqrt{\frac{2d}{k}}$
- (E)  $\sqrt{\frac{d}{2k}}$

[PhysicsBowl, 2019Q13]

You measure that 4000 kcal of heat conducts through a window in your house in one hour when the house is kept at 20 °C. The window is a 4.0 m<sup>2</sup> pane of 0.30 cm thick glass ( $k=2.0 \times 10^{-4}$  kcal/s·m·°C). What is the outside temperature?

- (A) 4 °C
- (B) 8 °C
- (C) 13 °C
- (D) 16 °C
- (E) 18 °C

[PhysicsBowl, 2019Q14]

The red glow in the neon tube of an advertising sign is a result of

- (A) fluorescence
- (B) incandescence
- (C) iridescence
- (D) coherence
- (E) de-excitation

[PhysicsBowl, 2019Q15]

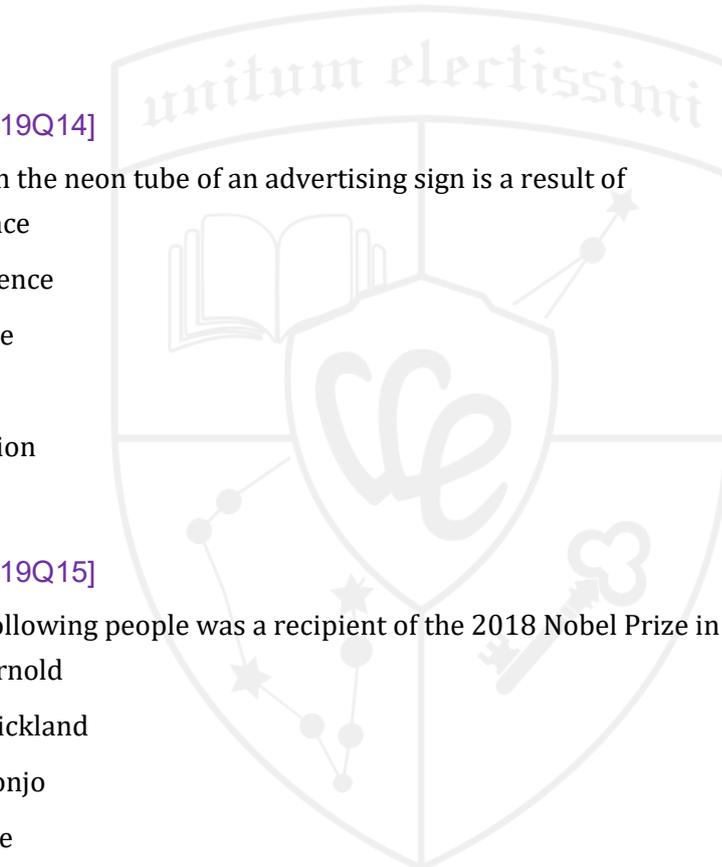
Which of the following people was a recipient of the 2018 Nobel Prize in Physics?

- (A) Frances Arnold
- (B) Donna Strickland
- (C) Tasuku Honjo
- (D) Kip Thorne
- (E) Joachim Frank

[PhysicsBowl, 2019Q16]

Water flows out of a horizontal drainpipe at the rate of 120 kg per minute. Its initial vertical velocity is zero and it falls 3.20 m to the ground. What is the average force it exerts when it hits the ground?

- (A) 6.0 N
- (B) 10.0 N
- (C) 12.0 N
- (D) 16.0 N
- (E) 20.0 N



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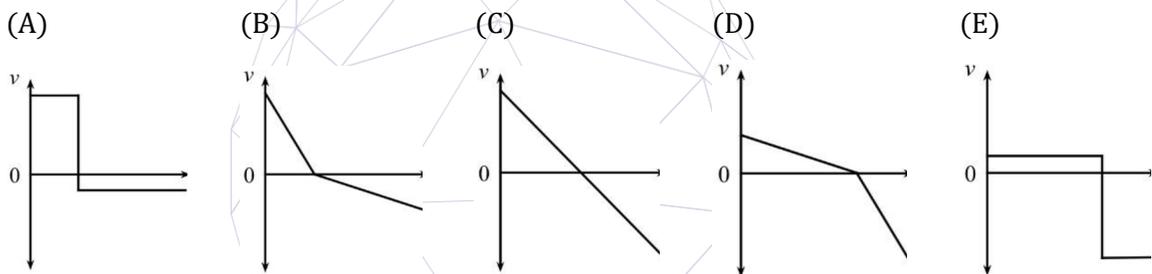
[PhysicsBowl, 2019Q17]

A sphere has a radius of  $1.96 \pm 0.01$  m. What is the approximate uncertainty in its volume?

- (A)  $31.5 \pm 0.2$  m<sup>3</sup>
- (B)  $31.5 \pm 0.3$  m<sup>3</sup>
- (C)  $31.5 \pm 0.4$  m<sup>3</sup>
- (D)  $31.5 \pm 0.5$  m<sup>3</sup>
- (E)  $31.5 \pm 0.6$  m<sup>3</sup>

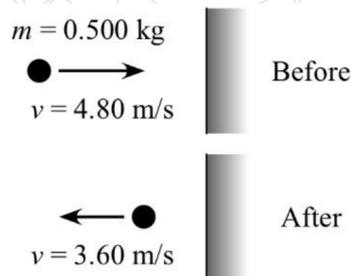
[PhysicsBowl, 2019Q18]

A block slides up and back down a rough incline. Which of the following graphs could represent the velocity of the block as a function of time? All graphs use the same scale and uphill as the positive direction.



[PhysicsBowl, 2019Q19]

A ball with a mass of 0.500 kg traveling at 4.80 m/s strikes a wall and rebounds in the opposite direction at 3.60 m/s. What is the magnitude of the impulse that acted on the ball during the collision with the wall?



- (A) 0.600 N·s
- (B) 1.20 N·s
- (C) 2.70 N·s
- (D) 4.20 N·s
- (E) 16.8 N·s

[PhysicsBowl, 2019Q20]

A string, fixed at both ends, vibrates at a frequency of 12 Hz with a standing transverse wave pattern containing 3 loops (antinodes). What frequency is needed if the standing wave pattern is to contain 4 loops (antinodes)?

- (A) 12 Hz
- (B) 16 Hz
- (C) 36 Hz
- (D) 48 Hz
- (E) 60 Hz

[PhysicsBowl, 2019Q21]

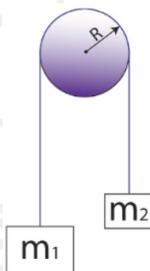
Let  $M$  represent the magnification of an image. For which of the following arrangements of an object and an optical device would  $-1 < M < 0$ ?

- (A) The object is placed less than one focal length in front of a converging mirror.
- (B) The object is placed between one focal length and two focal lengths in front of a diverging mirror.
- (C) The object is placed less than one focal length in front of a diverging lens.
- (D) The object is placed more than two focal lengths in front of a converging lens.
- (E) The object is placed between one focal length and two focal lengths in front of a plane mirror.



[PhysicsBowl, 2019Q22]

An Atwood machine is shown in the diagram at the right with  $m_1 = 0.60$  kg and  $m_2 = 0.40$  kg. What is the magnitude of the acceleration of  $m_2$ ? Ignore friction and the mass of the pulley.



- (A)  $4.2 \text{ m/s}^2$
- (B)  $3.3 \text{ m/s}^2$
- (C)  $2.0 \text{ m/s}^2$
- (D)  $5.0 \text{ m/s}^2$
- (E)  $1.0 \text{ m/s}^2$

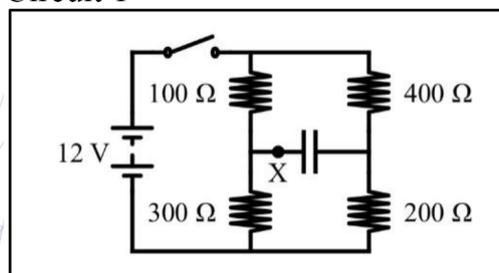
[PhysicsBowl, 2019Q23]

A 30.0-N block falls straight down from a height of 10.0 m, and strikes the ground with a velocity of 7.00 m/s. What average force of air friction acts on it as it falls?

- (A) 22.65-N
- (B) 45.45-N
- (C) 75.0-N
- (D) 205.6-N
- (E) 293-N

Questions 24 & 25 refer to Circuit 1.

Circuit 1



[PhysicsBowl, 2019Q24]

The capacitor is initially uncharged. Which of the following choices best represents the current at Point X immediately after the switch is closed?

- (A) Zero
- (B) 24 mA directed to the right
- (C) 36 mA directed to the left
- (D) 48 mA directed to the left
- (E) 72 mA directed to the right

[PhysicsBowl, 2019Q25]

If the capacitor has a capacitance of 15  $\mu\text{F}$  and is uncharged prior to closing the switch, what is the steady-state charge on the capacitor?

- (A) 3  $\mu\text{C}$
- (B) 45  $\mu\text{C}$
- (C) 75  $\mu\text{C}$
- (D) 90  $\mu\text{C}$
- (E) 120  $\mu\text{C}$



[PhysicsBowl, 2019Q26]

A 15.0-mW laser emits a beam that is 2.00 mm in diameter. What is the intensity of this beam?

- (A)  $1.19 \times 10^3 \text{ W/m}^2$
- (B)  $1.19 \times 10^4 \text{ W/m}^2$
- (C)  $3.59 \times 10^4 \text{ W/m}^2$
- (D)  $4.77 \times 10^4 \text{ W/m}^2$
- (E)  $2.98 \times 10^5 \text{ W/m}^2$

[PhysicsBowl, 2019Q27]

The unit that is used to measure magnetic flux is:

- (A) Coulomb (C)
- (B) Farad (F)
- (C) Tesla (T)
- (D) Weber (Wb)
- (E) Henry (H)

[PhysicsBowl, 2019Q28]

A curve on a racetrack has a radius of 80 m and is banked at  $45^\circ$ . Suppose that the road surface on the curve somehow became frictionless (perhaps caused by an ice storm or an oil spill) and a car needs to navigate this curve. What is the safe speed with which to take the curve without either sliding up or down the bank of the curve?

- (A) 9 m/s
- (B) 14 m/s
- (C) 21 m/s
- (D) 28 m/s
- (E) 33 m/s

[PhysicsBowl, 2019Q29]

A convex lens has a focal length of 50 mm. How far from the lens must an object be placed if it is to form a virtual image magnified in size by a factor of three?

- (A) 33 mm
- (B) 38 mm
- (C) 43 mm
- (D) 48 mm
- (E) 53 mm

[PhysicsBowl, 2019Q30]

Consider the bicycle wheel shown at the right to be a ring with a 60 cm diameter and a mass of 1.5 kg. Attached to the wheel is a gear with a radius of 4.0 cm and negligible mass. A force of 20 N is applied tangentially to the gear for 4.0 s. Starting from rest, what linear speed does the wheel achieve, assuming it rolls without slipping?



- (A) 3.0 m/s
- (B) 5.9 m/s
- (C) 7.1 m/s
- (D) 16.4 m/s
- (E) 24 m/s

[PhysicsBowl, 2019Q31]

The intensity level is measured to be 60 dB at a distance of 15 m from a speaker. What is the intensity level at a point 2.0 m from the speaker? Assume that the speaker radiates equally in all directions.

- (A) 55.7 dB
- (B) 57.5 dB
- (C) 67.0 dB
- (D) 75.5 dB
- (E) 77.5 dB



[PhysicsBowl, 2019Q32]

A pine wood block is floating in a small pool. There is a second pine wood block that sits on top of the first and does not touch the water. If the top block is taken off and placed in the water, how does the new water level in the pool compare to the original water level?

- (A) Rises
- (B) Lowers
- (C) Does not change
- (D) It depends upon the size of the blocks
- (E) It depends upon the amount of water in the pool.

[PhysicsBowl, 2019Q33]

Two cars are being tested on a track. *Car 1* accelerates from rest on this straight track at  $a_1 = 3.0 \text{ m/s}^2$ . Two seconds later, *Car 2* accelerates from rest at  $a_2 = 12.0 \text{ m/s}^2$ . How much time after *Car 1* starts will *Car 2* pass *Car 1*?

- (A) 3.0 s
- (B) 4.0 s
- (C) 5.0 s
- (D) 6.0 s
- (E) 7.0 s

[PhysicsBowl, 2019Q34]

The table at right lists the finish times for the 2008 Men's Olympic 100 m butterfly swim final in Beijing. From the data, what is the best estimate of the distance the 2nd place finisher, Cavic, was behind the 1st place finisher, Phelps?

100 m Men's Butterfly Swim		
1	Michael Phelps	50.58 s
2	Milorad Cavic	50.59 s
3	Andrew Lauterstein	51.12 s
4	Ian Crocker	51.13 s
5	Jason Dunford	51.47 s
6	Takuro Fujii	51.50 s
7	Andrii Serdinov	51.59 s
8	Ryan Pini	51.86 s

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- (A) 0.2 cm
- (B) 2.0 cm
- (C) 5.0 cm
- (D) 10 cm
- (E) 20 cm

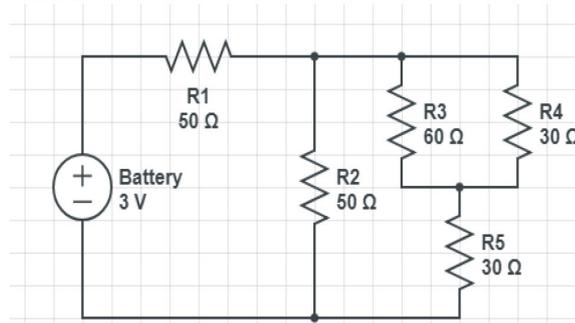
[PhysicsBowl, 2019Q35]

In a mixture of hydrogen, oxygen, and nitrogen gases at room temperature, the molecules having the greatest average speed are those of

- (A) Hydrogen
- (B) Oxygen
- (C) Nitrogen
- (D) All have the same speed
- (E) It depends upon the composition of the mixture

Questions 36 & 37 refer to Circuit 2. The battery is assumed ideal with an emf of 3.0 V

Circuit 2



[PhysicsBowl, 2019Q36]

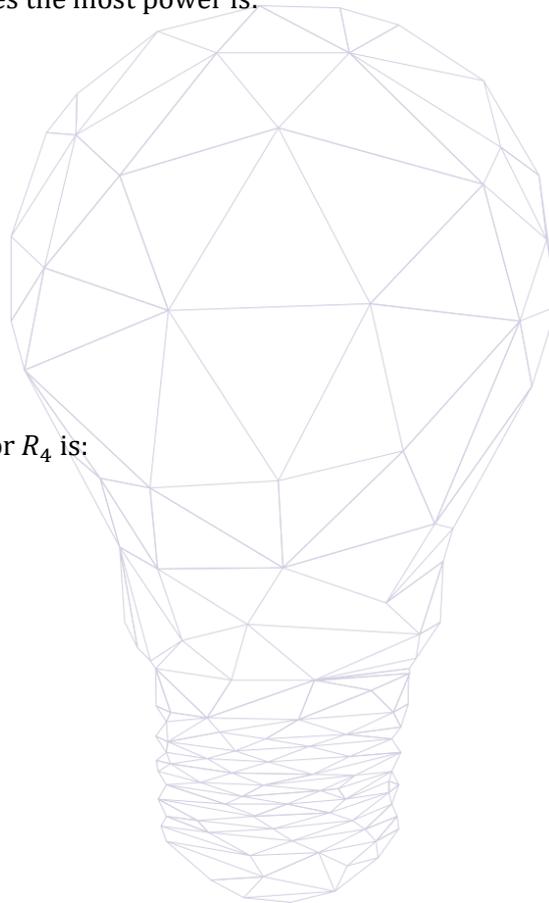
The resistor that dissipates the most power is:

- (A)  $R_1$
- (B)  $R_2$
- (C)  $R_3$
- (D)  $R_4$
- (E)  $R_5$

[PhysicsBowl, 2019Q37]

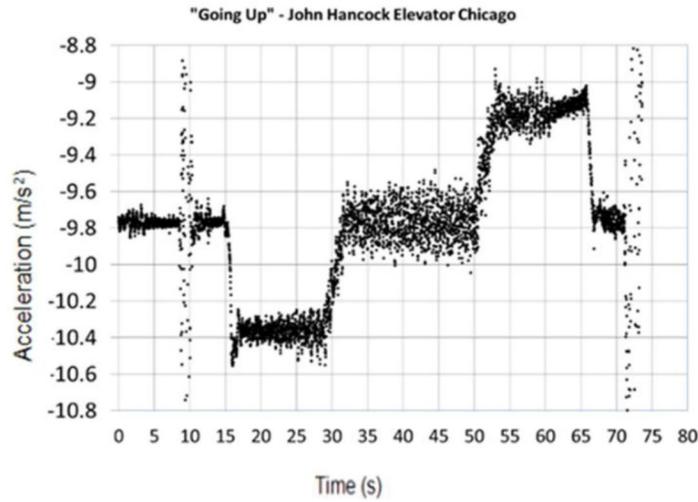
The voltage across resistor  $R_4$  is:

- (A) 0.4 V
- (B) 0.6 V
- (C) 1.2 V
- (D) 1.5 V
- (E) 3.0 V



[PhysicsBowl, 2019Q38]

Shown here is accelerometer data for an elevator ride in a skyscraper in Chicago. The spikes at roughly 10 s and 72 s are caused by the handling of the accelerometer which rested on the floor of the elevator and occurred before the elevator started moving up, and after it reached the top, respectively. What is the best estimate for the peak vertical speed for this elevator

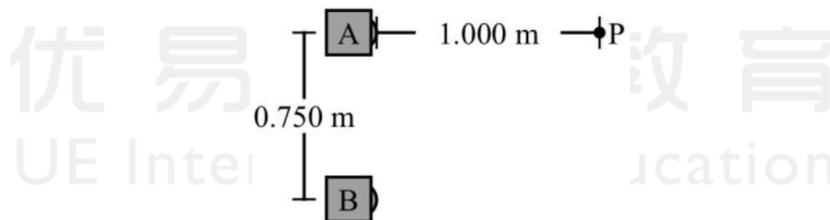


- (A) 4 m/s
- (B) 8 m/s
- (C) 12 m/s
- (D) 16 m/s
- (E) 20 m/s



[PhysicsBowl, 2019Q39]

The picture shows two speakers, *A* and *B*, which emit the same 680-Hz tones in phase. Point *P* is located 1.000 m directly in front of *Speaker A*. A sound sensor at Point *P* records a minimum sound intensity. *Speaker B* is slowly moved away from *Speaker A* along the line joining them. How far must *Speaker B* be moved further from *Speaker A* until the sound sensor at Point *P* first records a maximum sound intensity?



- (A) 0.368 m
- (B) 0.438 m
- (C) 0.500 m
- (D) 0.686 m
- (E) 0.982 m

[PhysicsBowl, 2019Q40]

The bulb of a mercury thermometer has a volume of  $0.100 \text{ cm}^3$  at  $10 \text{ }^\circ\text{C}$  and contains  $0.100 \text{ cm}^3$  of mercury. The capillary tube above the bulb has a cross-sectional area of  $0.012 \text{ mm}^2$ . The volume thermal expansion coefficient of mercury is  $1.8 \times 10^{-4} \text{ (}^\circ\text{C)}^{-1}$ . How much will the mercury rise when the temperature rises by  $30 \text{ }^\circ\text{C}$  (the expansion of the glass is negligible)?

- (A) 0.045 mm
- (B) 0.45 mm
- (C) 4.5 mm
- (D) 45 mm
- (E) 45 cm

[PhysicsBowl, 2019Q41]

To monitor the breathing of a hospital patient, a thin belt is wrapped around a patient's chest and back. The belt is a 200 turn coil of conducting wire. When the patient inhales, the area of the coil increases by  $39.0 \text{ cm}^2$ . The magnitude of the Earth's magnetic field is  $50.0 \text{ } \mu\text{T}$  and makes an angle of  $28.0^\circ$  to the plane of the coil. Assuming the patient takes  $1.80 \text{ s}$  to inhale, how much emf is induced in the coil?

- (A)  $1.91 \times 10^{-5} \text{ V}$
- (B)  $9.57 \times 10^{-8} \text{ V}$
- (C)  $9.57 \times 10^{-4} \text{ V}$
- (D)  $1.02 \times 10^{-5} \text{ V}$
- (E)  $3.44 \times 10^{-5} \text{ V}$



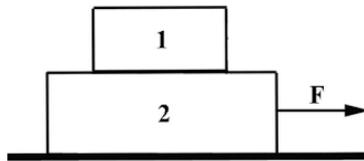
[PhysicsBowl, 2019Q42]

Three identical samples of a monatomic ideal gas are taken from a temperature  $T$  to a temperature  $2T$ . Sample  $A$  undergoes an adiabatic process. Sample  $B$  undergoes an isobaric process and Sample  $C$  undergoes an isochoric process. Which of the following correctly ranks the heats added to the samples during the three processes?

- (A)  $Q_A < Q_B < Q_C$
- (B)  $Q_A < Q_C < Q_B$
- (C)  $Q_B < Q_A < Q_C$
- (D)  $Q_C < Q_A < Q_B$
- (E)  $Q_C < Q_B < Q_A$

[PhysicsBowl, 2019Q43]

Two boxes are stacked on a table as shown at right. The mass of box 1 is  $m$  and the mass of box 2 is  $3m$ . The surface between box 2 and the table is smooth and the surface between the two boxes is rough. When a force,  $F$ , is applied, box 1 does not slide on box 2. What is the minimum coefficient of static friction between the boxes?



- (A)  $\frac{F}{4mg}$
- (B)  $\frac{F}{3mg}$
- (C)  $\frac{F}{2mg}$
- (D)  $\frac{F}{mg}$
- (E)  $\frac{2mg}{F}$

[PhysicsBowl, 2019Q44]

Consider a traveling wave on a string of length  $L$ , mass  $M$  and tension  $T$ . A standing wave is set up. Which of the following is true?

- (A) The wave velocity depends on  $M, L, T$ .
- (B) The wavelength of the wave is proportional to the frequency.
- (C) The velocity of a given particle in the string is equal to the wave velocity.
- (D) The wavelength is proportional to  $T$ .
- (E) The frequency depends upon  $L$ .



[PhysicsBowl, 2019Q45]

A heat engine is operating between  $40^\circ\text{C}$  and  $380^\circ\text{C}$  and has an efficiency that is 60 % of a Carnot engine that is operating between the same temperatures. If the engine absorbs heat at a rate of 60 kW, at what rate does it exhaust heat?

- (A) 36 kW
- (B) 41 kW
- (C) 48 kW
- (D) 57 kW
- (E) 60 Kw

[PhysicsBowl, 2019Q46]

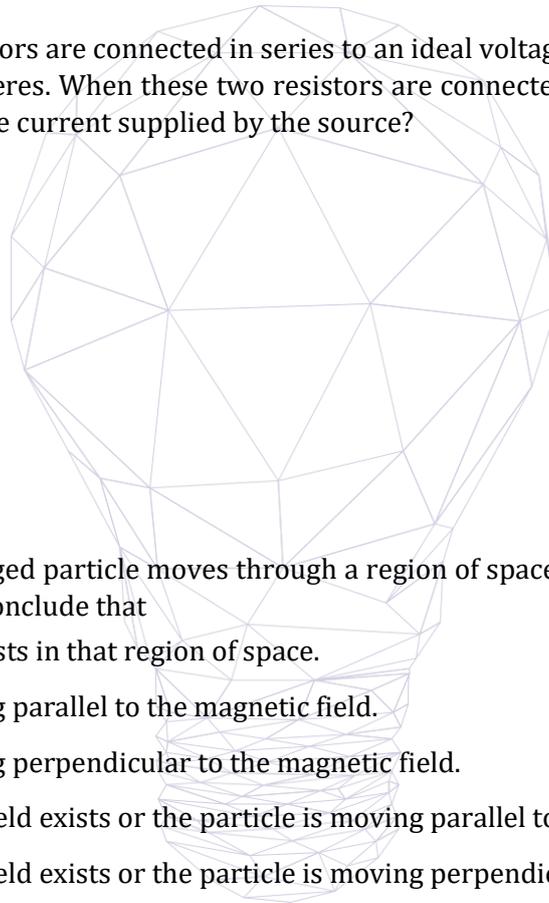
In physics experiments located deep underground, the two types of cosmic rays that most commonly reach the experimental apparatus are:

- (A) alpha particles and neutrons
- (B) protons and electrons
- (C) iron nuclei and carbon nuclei
- (D) muons and neutrinos
- (E) positrons and electrons

[PhysicsBowl, 2019Q47]

When two identical resistors are connected in series to an ideal voltage source, the current supplied by the source is 2.0 Amperes. When these two resistors are connected in parallel to the same ideal voltage source, what is the current supplied by the source?

- (A) 0.5 Ampere
- (B) 1.0 Ampere
- (C) 2.8 Amperes
- (D) 4.0 Amperes
- (E) 8.0 Amperes



[PhysicsBowl, 2019Q48]

It is observed that a charged particle moves through a region of space and experiences no magnetic force. From this we can conclude that

- (A) no magnetic field exists in that region of space.
- (B) the particle is moving parallel to the magnetic field.
- (C) the particle is moving perpendicular to the magnetic field.
- (D) either no magnetic field exists or the particle is moving parallel to the magnetic field.
- (E) either no magnetic field exists or the particle is moving perpendicular to the magnetic field.

[PhysicsBowl, 2019Q49]

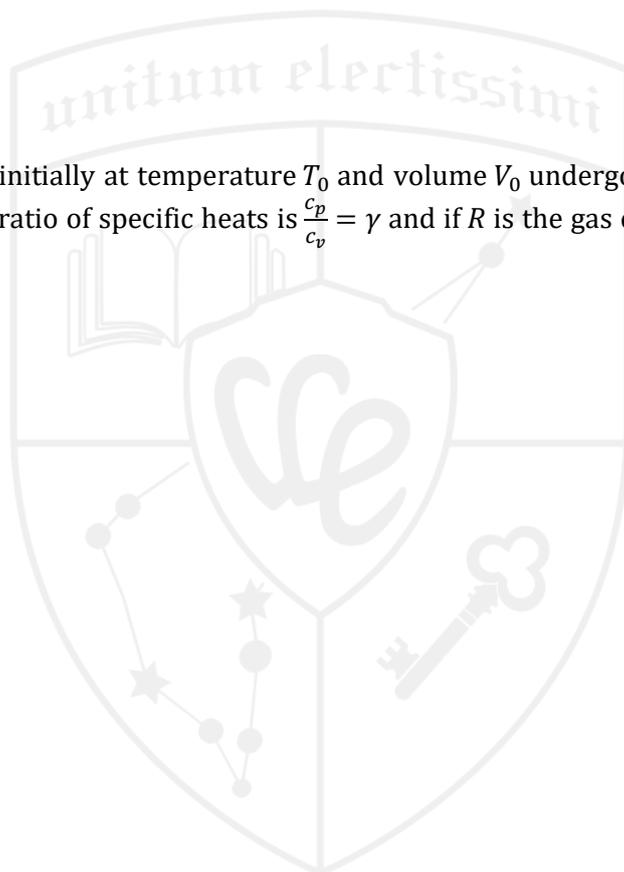
A lump of clay whose rest mass is 4.0 kg is traveling at three-fifths of the speed of light when it collides head-on with an identical lump going in the opposite direction at the same speed. If the two lumps stick together and no energy is radiated away, what is the mass of the composite lump?

- (A) 4.0 kg
- (B) 6.4 kg
- (C) 8.0 kg
- (D) 10.0 kg
- (E) 13.3 kg

[PhysicsBowl, 2019Q50]

One mole of ideal gas initially at temperature  $T_0$  and volume  $V_0$  undergoes a reversible isothermal expansion to  $V_1$ . If the ratio of specific heats is  $\frac{c_p}{c_v} = \gamma$  and if  $R$  is the gas constant, the work done by the

- (A) zero
- (B)  $RT_0 \left(\frac{V_1}{V_0}\right)^\gamma$
- (C)  $RT_0 \left(\frac{V_1}{V_0} - 1\right)$
- (D)  $c_v T_0 \left[1 - \left(\frac{V_0}{V_1}\right)^{\gamma-1}\right]$
- (E)  $RT_0 \ln\left(\frac{V_1}{V_0}\right)$



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# PhysicsBowl 2021

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2021

[Online Exam](#)

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions.

**Division 1 students will answer only questions 1 – 40.** Do not answer questions 41 – 50.

**Division 2 students will answer only questions 11 – 50.** Do not answer questions 1 – 10.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

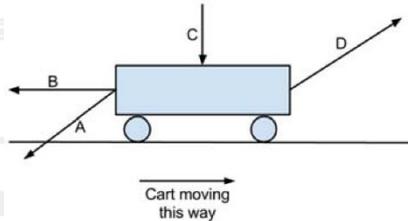
[PhysicsBowl, 2021Q1]

The Joule (J) is a derived unit of energy in the International System of Units. It is equal to which of the following

- (A)  $\text{kg} \left( \frac{\text{m}}{\text{s}} \right)$
- (B)  $\text{kg} \left( \frac{\text{m}}{\text{s}^2} \right)$
- (C)  $\text{kg} \left( \frac{\text{m}^2}{\text{s}} \right)$
- (D)  $\text{kg} \left( \frac{\text{m}^2}{\text{s}^2} \right)$
- (E)  $\text{kg} \left( \frac{\text{m}^2}{\text{s}^3} \right)$

[PhysicsBowl, 2021Q2]

A force,  $F$ , could be applied to a cart in a variety of directions as shown at right. Which of the applications of  $F$  would result in no work being done?



- (A) A
- (B) B
- (C) C
- (D) D
- (E) All of them result in work being done.



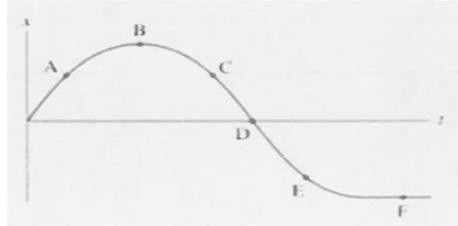
[PhysicsBowl, 2021Q3]

A brick is moving at a speed of 3 m/s and a pebble is moving at a speed of 5 m/s. If both objects have the same kinetic energy, what is the ratio of the brick's mass to the pebble's mass?

- (A) 25 : 9
- (B) 5 : 3
- (C) 4 : 1
- (D) 3 : 1
- (E)  $\sqrt{5} : \sqrt{3}$

[PhysicsBowl, 2021Q4]

The figure to the right shows the position-time graph of an object traveling in a straight line, starting out moving to the right (the positive  $x$ -direction). At which points is the object moving to the left?

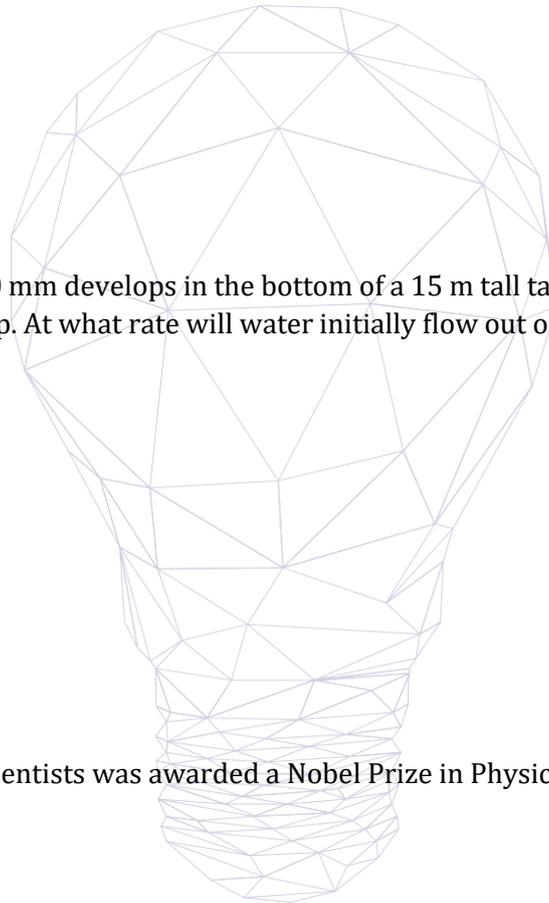


- (A) B and F
- (B) E and F
- (C) A, B and C
- (D) C, D and E
- (E) None of the above

[PhysicsBowl, 2021Q5]

A hole with a radius of 1.0 mm develops in the bottom of a 15 m tall tank filled to the top with water. The tank is open at the top. At what rate will water initially flow out of the hole?

- (A)  $5.4 \times 10^{-3} \text{ m}^3/\text{s}$
- (B)  $5.4 \times 10^{-4} \text{ m}^3/\text{s}$
- (C)  $5.4 \times 10^{-5} \text{ m}^3/\text{s}$
- (D)  $5.4 \times 10^{-6} \text{ m}^3/\text{s}$
- (E)  $5.4 \times 10^{-7} \text{ m}^3/\text{s}$



[PhysicsBowl, 2021Q6]

Which of the following scientists was awarded a Nobel Prize in Physics in 1956 and again in 1972?

- (A) John Bardeen
- (B) Enrico Fermi
- (C) Murray Gell-Mann
- (D) Hans Bethe
- (E) Wolfgang Pauli

## [PhysicsBowl, 2021Q7]

Two cranes are used to lift loads vertically at constant speed from the ground to the top of a building. Crane 1 lifts an 8000-N load a height of 40 m in a time of 20 minutes. Crane 2 lifts a 6,400-N load a height of 50 m in a time of 16 minutes. Which statement below correctly compares the mechanical power output of each crane?

- (A) The cranes have the same power because they perform the same amount of work.
- (B) The cranes have the same power because the ratio of force exerted to time is the same.
- (C) Crane 1 has a greater power because it exerts more force to lift the load.
- (D) Crane 1 has a greater power because it raises the load over a longer time.
- (E) Crane 2 has a greater power because it performs the same amount of work in less time.

## [PhysicsBowl, 2021Q8]

An ice skater is rotating with her arms extended. When she pulls in her arms, her rate of rotation increases. No external torques act on the skater. Which of the following statements is true?

- (A) Her moment of inertia increased.
- (B) Her kinetic energy is conserved.
- (C) Her angular momentum decreased.
- (D) She does work when pulling in her arms.
- (E) Her angular momentum increased.

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## [PhysicsBowl, 2021Q9]

A rock that has a mass of 12 kg is sliding on a rough, horizontal surface. It has 24 J of kinetic energy and the friction force on it is a constant 0.50 N. What distance will it slide before coming to rest?

- (A) 2.0 m
- (B) 12 m
- (C) 24 m
- (D) 36 m
- (E) 48 m

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## [PhysicsBowl, 2021Q10]

The average density of blood is  $1.06 \times 10^3 \text{ kg/m}^3$ . Imagine that you donate a pint of blood during a local blood drive. What mass of blood, in grams, have you donated? (1 pt =  $\frac{1}{2}$  L, 1 L = 1000 cm<sup>3</sup>.)

- (A) 530 g
- (B) 0.530 g
- (C) 5300 g
- (D)  $5.30 \times 10^5$  g
- (E) 53.0 g

[PhysicsBowl, 2021Q11]

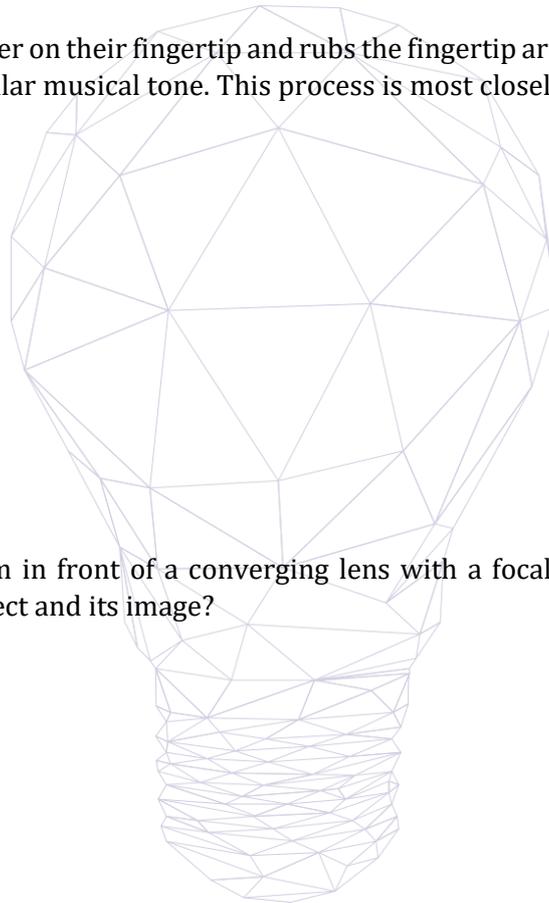
An object of mass  $m$  initially at rest experiences a uniform, non-zero acceleration. Which of the following statements is correct?

- (A) The object's displacement is directly proportional to its time of travel.
- (B) The object's velocity is directly proportional to its time of travel.
- (C) The object's acceleration is directly proportional to its time of travel.
- (D) The object's kinetic energy is directly proportional to its time of travel.
- (E) The net force acting on the object is directly proportional to its time of travel.

[PhysicsBowl, 2021Q12]

A person places some water on their fingertip and rubs the fingertip around the top surface of a water glass to produce a particular musical tone. This process is most closely associated with which of the following phenomena?

- (A) Diffraction
- (B) Dispersion
- (C) Doppler effect
- (D) Refraction
- (E) Resonance



[PhysicsBowl, 2021Q13]

An object is placed 20 cm in front of a converging lens with a focal length of 30 cm. What is the distance between the object and its image?

- (A) 8 cm
- (B) 32 cm
- (C) 40 cm
- (D) 60 cm
- (E) 80 cm

[PhysicsBowl, 2021Q14]

A person standing 5.0 m from a barking dog measures the sound intensity level to be 65 dB. What would be the intensity level at that same distance if two identical dogs very close to each other are barking?

- (A) 34 dB
- (B) 65 dB
- (C) 68 dB
- (D) 130 dB
- (E) 136 dB

[PhysicsBowl, 2021Q15]

In the Millikan oil-drop experiment the UPWARD force on a stationary oil drop is due to the:

- (A) gravitational and electric fields
- (B) gravitational field and the charge on the drop
- (C) electric field only
- (D) electric field and the charge on the drop
- (E) charge on the drop only

[PhysicsBowl, 2021Q16]

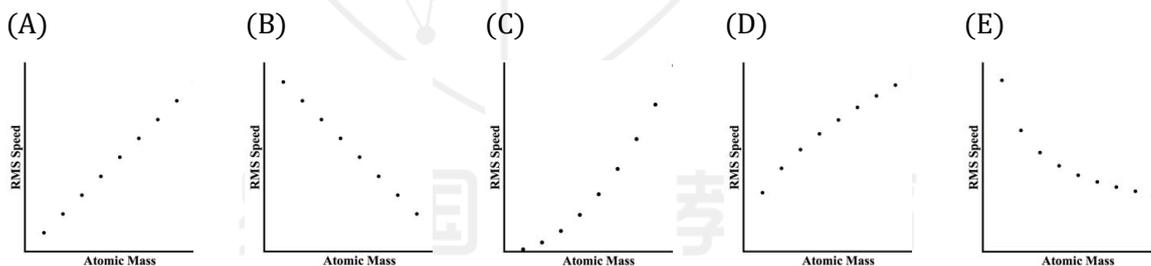
A uniform wooden block is a rectangular prism with dimensions of  $10\text{ cm} \times 6\text{ cm} \times 2\text{ cm}$ . The block will be placed on a level table in one of three possible orientations with a side parallel to the tabletop. Let  $P_L$  equal the largest possible pressure the block can exert on the table and  $P_S$  equal the smallest possible pressure the block can exert on the table. What is the ratio  $\frac{P_L}{P_S}$ ?

- (A)  $\frac{5}{3}$
- (B) 3
- (C) 5
- (D) 9
- (E) 25



[PhysicsBowl, 2021Q17]

Several samples of different ideal gases all have the same temperature. Which of the following graphs could show the relationship between the atomic mass of the gas and the rms speed of the gas atoms?



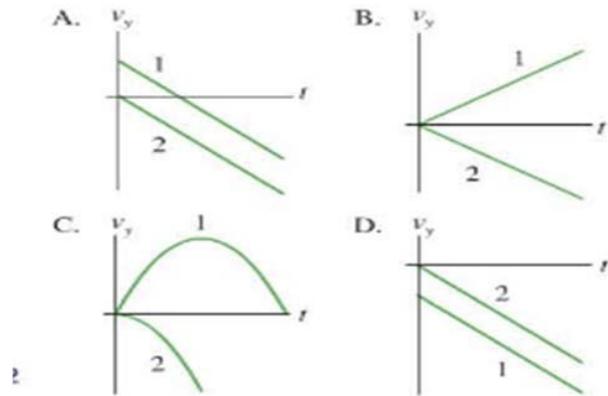
[PhysicsBowl, 2021Q18]

Two separate simple pendulums are swinging back and forth. It is found that pendulum A has twice the frequency of pendulum B. Which statement could account for this difference?

- (A) Pendulum B is twice as long as pendulum A.
- (B) Pendulum B was released before pendulum A.
- (C) Pendulum B is twice as massive as pendulum A.
- (D) The length of pendulum B is four times the length of pendulum A.
- (E) The mass of pendulum B is four times the mass of pendulum A.

[PhysicsBowl, 2021Q19]

At  $t = 0$ , Ball 1 is rolling up a ramp and Ball 2 is released from the top of the same ramp. The balls don't collide. Which velocity vs. time graph at right best represents the motion of the two balls?



- (A) A
- (B) B
- (C) C
- (D) D
- (E) Both A & D

[PhysicsBowl, 2021Q20]

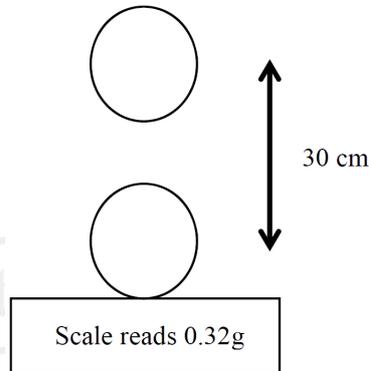
A simple and correct way to comprehend satellites orbiting Earth is to view them as

- (A) balanced between gravitational and centripetal forces.
- (B) beyond the main pull of Earth's gravity.
- (C) in mechanical equilibrium with a net force of zero.
- (D) having sufficient tangential velocities to fall around rather than into Earth.
- (E) all of the above.



[PhysicsBowl, 2021Q21]

Two balloons are charged identically and uniformly by rubbing them with wool. One is placed on a scale which is then tared. No charge is transferred to the scale. The other is then placed above it separated by 30 cm. The scale reads 0.32 grams. What is the closest estimate for the charge on each balloon?



- (A) 200 C
- (B) 200 mC
- (C) 200  $\mu$ C
- (D) 200 nC
- (E) 200 pC

[PhysicsBowl, 2021Q22]

A fighter jet pilot is capable of tolerating an upward force that is equivalent to seven times their weight. This pilot is traveling at a speed of 250 m/s while pulling out of a vertical dive. What is the minimum radius of curvature of the plane's dive path?

- (A) 4.25 m
- (B) 3.64 m
- (C) 1042 m
- (D) 893 m
- (E) 450 m



[PhysicsBowl, 2021Q23]

The mass of Mars is  $6.40 \times 10^{23}$  kg. Its radius is 3395 km. What is the mean density of Mars in  $\text{kg}/\text{m}^3$ ?

- (A)  $9.76 \times 10^2$
- (B)  $1.95 \times 10^3$
- (C)  $3.90 \times 10^3$
- (D)  $7.81 \times 10^3$
- (E)  $7.94 \times 10^4$

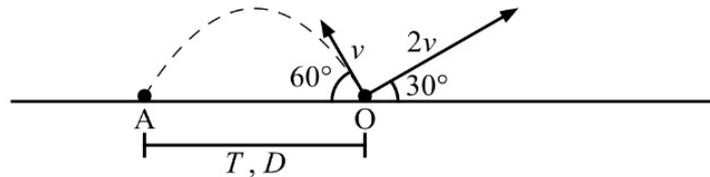
[PhysicsBowl, 2021Q24]

In a panic, you squeeze the brake handle on your bicycle, lock up the rear wheel, and skid a certain distance on a straight, level path before stopping. If you had been traveling twice as fast, what distance would you have skidded, under the same conditions?

- (A) You would have skidded 4 times farther.
- (B) You would have skidded twice as far.
- (C) You would have skidded 1.4 times farther.
- (D) You would have skidded 8 times farther.
- (E) It is impossible to tell from the information given.

**Questions 25 & 26 refer to the following information:**

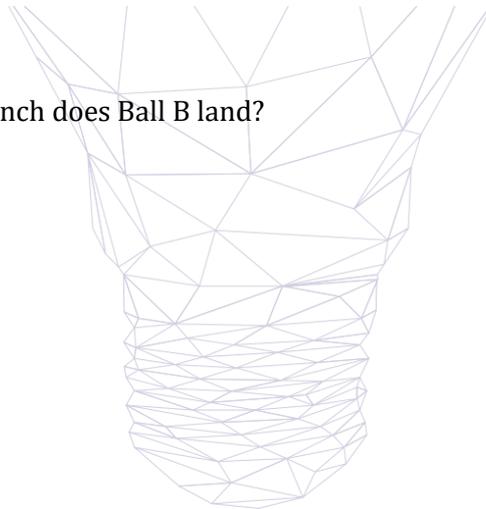
Two balls, A and B, are launched simultaneously from the origin (O) on a level surface at the respective angles of  $60^\circ$  and  $30^\circ$  shown in the picture. Ball A has a launch speed  $v$  while Ball B has a launch speed  $2v$ . Ball A lands  $T$  seconds after launch at a horizontal distance  $D$  from the origin.



[PhysicsBowl, 2021Q25]

How many seconds after launch does Ball B land?

- (A)  $0.50T$
- (B)  $0.87T$
- (C)  $1.15T$
- (D)  $1.73T$
- (E)  $2.00T$



[PhysicsBowl, 2021Q26]

What horizontal distance separates the landing points of Ball A and Ball B?

- (A)  $2D$
- (B)  $3D$
- (C)  $4D$
- (D)  $5D$
- (E)  $6D$

[PhysicsBowl, 2021Q27]

You are given three 6-ohm resistors. Neglecting the resistance of any connecting wires, which of the following resistances CANNOT be made using one or more of these resistors?

- (A) 2 ohms
- (B) 3 ohms
- (C) 9 ohms
- (D) 12 ohms
- (E) 15 ohms

[PhysicsBowl, 2021Q28]

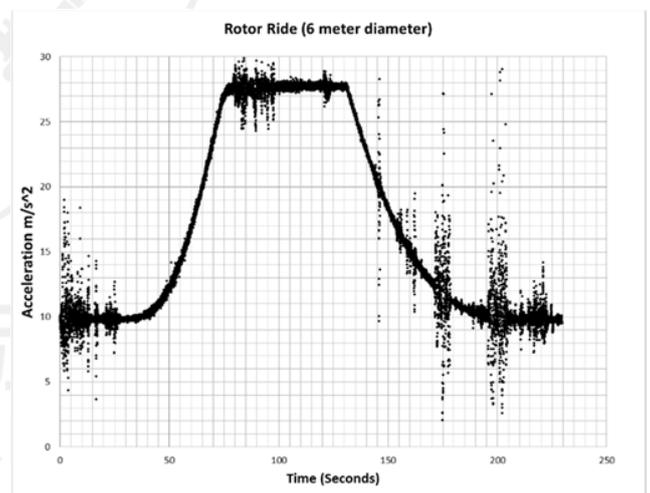
Electric energy can be generated in many ways, two of which are with nuclear plants using nuclear fission reactions, or coal fired plants utilizing chemical reactions. Energy density for a fuel has units of Joules/kilogram. What is the approximate ratio of nuclear versus chemical energy density?

- (A) 1
- (B)  $10^3$
- (C)  $10^6$
- (D)  $10^9$
- (E)  $10^{12}$

[PhysicsBowl, 2021Q29]

An amusement park ride called “The Rotor” has people standing in a vertical cylinder, in this case 6 m in diameter, which rotates and presses them against the wall with sufficient force that the floor can then drop without them sliding down the wall. Shown here is the magnitude of accelerometer data from a device carried in a pocket by a rider. Assuming the high plateau averages  $27.7 \text{ m/s}^2$ , what is the peak centripetal acceleration? (Consider the spikes noise caused by movement of the rider.)

- (A) 0
- (B)  $10 \text{ m/s}^2$
- (C)  $20 \text{ m/s}^2$
- (D)  $26 \text{ m/s}^2$
- (E)  $28 \text{ m/s}^2$



[PhysicsBowl, 2021Q30]

You drop a rock off a bridge into the river below and hear the splash 2.5 s later. How far above the river is the bridge?

- (A) 25 m
- (B) 27 m
- (C) 29 m
- (D) 31 m
- (E) 33 m

[PhysicsBowl, 2021Q31]

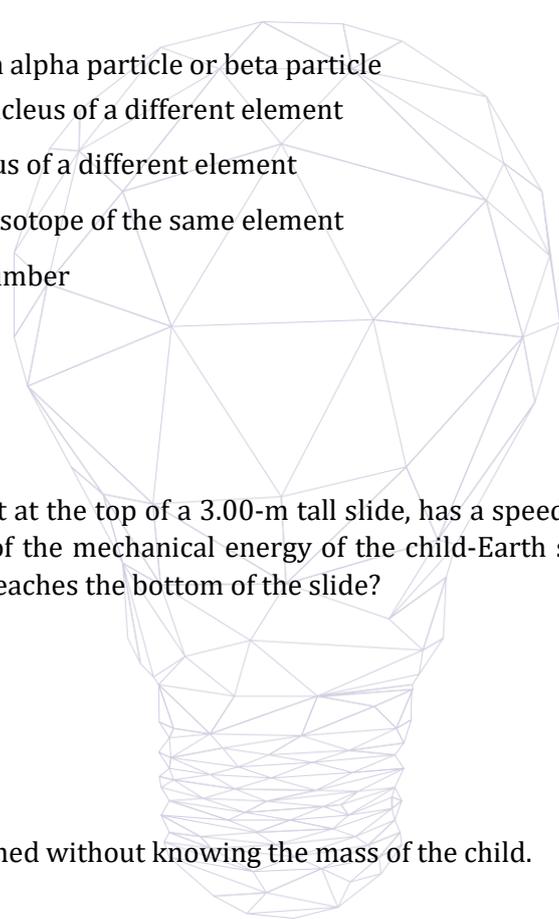
Any nucleus that emits an alpha particle or beta particle

- (A) always becomes a nucleus of a different element
- (B) may become a nucleus of a different element
- (C) becomes a different isotope of the same element
- (D) increases its mass number
- (E) increases its mass

[PhysicsBowl, 2021Q32]

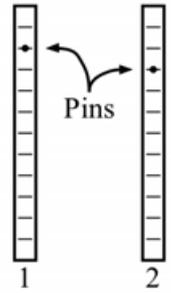
A child, starting from rest at the top of a 3.00-m tall slide, has a speed of 2.52 m/s at the bottom of the slide. What percent of the mechanical energy of the child-Earth system at the top of the slide remains when the child reaches the bottom of the slide?

- (A) 8.4%
- (B) 10.6%
- (C) 32.5%
- (D) 46.0%
- (E) It cannot be determined without knowing the mass of the child.



[PhysicsBowl, 2021Q33]

Two identical uniform sticks have small holes drilled in them. The sticks are marked with equally spaced lines as shown. Each stick is suspended from a pin through the hole and is free to rotate about the pin. Both sticks are displaced a small angle from the vertical and released. What is the ratio of the period of pendulum one to the period of pendulum two?



- (A) 1 : 1
- (B) 2 : 3
- (C) 4 : 3
- (D) 10 : 9
- (E) 16 : 9

[PhysicsBowl, 2021Q34]

A projectile will be launched from a 2.00-m tall platform and must hit a target at a horizontal distance of 25.0 m away on an identical 2.00-m tall platform. What is the slowest speed at which the projectile can be launched?

- (A) 10.2 m/s
- (B) 12.5 m/s
- (C) 15.8 m/s
- (D) 17.7 m/s
- (E) 21.0 m/s



[PhysicsBowl, 2021Q35]

A motorcycle has a total mass of 150 kg. Each wheel has a mass of 10 kg and a radius of 30 cm. As the motorcycle is moving, what is the ratio of the rotational kinetic energy of the wheels to the total translational kinetic energy of the motorcycle? Assume the wheels are uniform disks and roll without slipping.

- (A) 0.033 : 1
- (B) 0.067 : 1
- (C) 0.33 : 1
- (D) 0.67 : 1
- (E) 3.3 : 1

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[PhysicsBowl, 2021Q36]

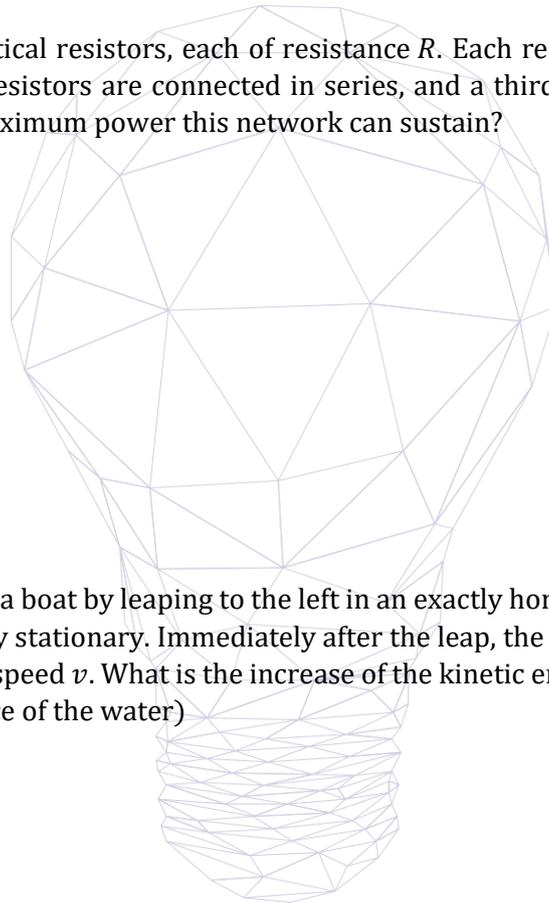
A spring loaded projectile launcher launches a plastic ball horizontally with a speed of 4.0 m/s. If the spring were compressed twice as far, the ball's launch speed would be

- (A) 1.0 m/s
- (B) 2.0 m/s
- (C) 4.0 m/s
- (D) 8.0 m/s
- (E) 16 m/s

[PhysicsBowl, 2021Q37]

You are given three identical resistors, each of resistance  $R$ . Each resistor can sustain a maximum power of  $P$ . Two of the resistors are connected in series, and a third is connected in parallel with these two. What is the maximum power this network can sustain?

- (A)  $\frac{2P}{3}$
- (B)  $\frac{3P}{2}$
- (C)  $2P$
- (D)  $3P$
- (E)  $6P$



[PhysicsBowl, 2021Q38]

A man of mass  $m$ , gets off a boat by leaping to the left in an exactly horizontal direction. Both the man and the boat were initially stationary. Immediately after the leap, the boat of mass  $M$ , is observed to be moving to the right at speed  $v$ . What is the increase of the kinetic energy in the man-boat system? (Neglect the resistive force of the water)

- (A)  $\frac{1}{2}Mv^2$
- (B)  $\frac{1}{2}mv^2$
- (C)  $\frac{1}{2}(M + m)v^2$
- (D)  $\frac{1}{2}\left(M + \frac{M^2}{m}\right)v^2$
- (E)  $\frac{1}{2}\frac{Mm}{(M+m)}v^2$

[PhysicsBowl, 2021Q39]

A monatomic ideal gas undergoes an adiabatic expansion. Which of the following statements is true about the gas?

- (A) The final temperature of the gas is less than the initial temperature of the gas.
- (B) Heat enters the gas from the surroundings during the process.
- (C) The final pressure of the gas is greater than the initial pressure of the gas.
- (D) Work is done on the gas from the surroundings during the process.
- (E) The internal energy of the gas remains unchanged during the process.

[PhysicsBowl, 2021Q40]

What temperature exists inside a solar collector (effective collection area of  $15 \text{ m}^2$ ) on a bright sunny day when the outside temperature is  $+20 \text{ }^\circ\text{C}$ ? Assume that the collector is thermally insulated, that the Sun radiates the collector with a power per unit area of  $600 \text{ W/m}^2$ , and that the collector acts as a perfect blackbody.

- (A)  $73 \text{ }^\circ\text{C}$
- (B)  $93 \text{ }^\circ\text{C}$
- (C)  $107 \text{ }^\circ\text{C}$
- (D)  $131 \text{ }^\circ\text{C}$
- (E)  $154 \text{ }^\circ\text{C}$

[PhysicsBowl, 2021Q41]

A P-type semiconductor is doped to produce one of the following. What will it produce:

- (A) both holes and electrons
- (B) positive electrons
- (C) negative electrons
- (D) holes
- (E) positive protons

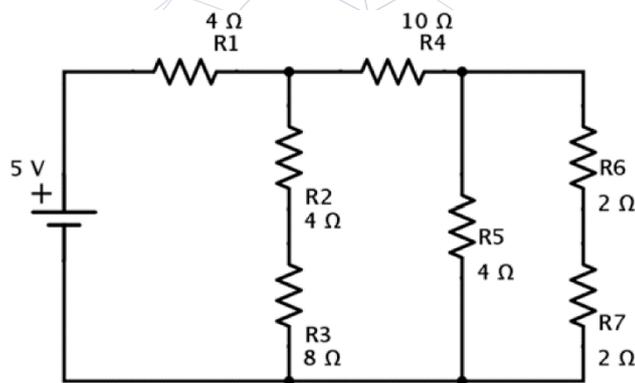
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[PhysicsBowl, 2021Q42]

A radioactive sample of gas has a half-life of 100 seconds. If there are initially 10000 of these gas molecules in a closed container, approximately how many of the molecules remain after a time of 250 seconds elapses?

- (A) 2500
- (B) 2190
- (C) 1770
- (D) 1560
- (E) 1250

Questions 43 & 44 refer to the circuit shown below



[PhysicsBowl, 2021Q43]

What is the voltage drop across  $R_5$ ?

- (A) 0.250 V
- (B) 0.500 V
- (C) 1.00 V
- (D) 2.00 V
- (E) 3.00 V

[PhysicsBowl, 2021Q44]

What is the current in  $R_3$ ?

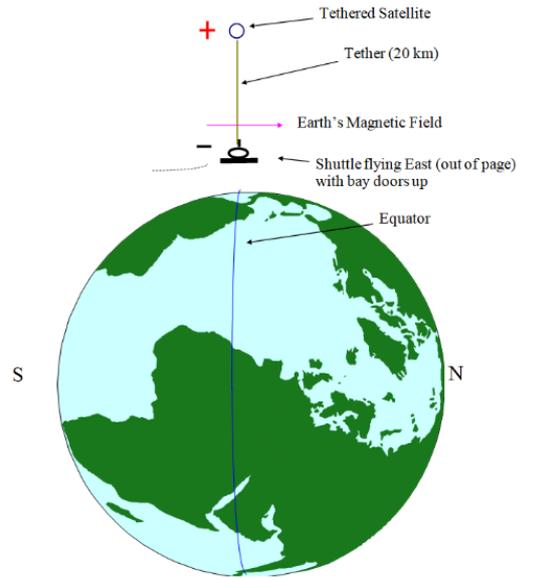
- (A) 0.125 A
- (B) 0.250 A
- (C) 0.500 A
- (D) 0.750 A
- (E) 1.00 A



[PhysicsBowl, 2021Q45]

In the 1990s, the space shuttle flew two separate tethered satellite experiments. One purpose was to generate power via the induced voltage in a 20 km long tether moving perpendicular to the Earth's 0.5 Gauss magnetic field lines at roughly 8 km/s. What is the theoretical voltage across the tether to the nearest order of magnitude?

- (A) 10 Volts
- (B) 100 Volts
- (C) 1,000 Volts
- (D) 10,000 Volts
- (E) 100,000 Volts



[PhysicsBowl, 2021Q46]

An engine absorbs heat at a temperature of 727 °C and exhausts heat at a temperature of 527°C. If the engine operates at maximum possible efficiency, for 2000 J of heat input, the amount of work the engine performs is most nearly

- (A) 400 J
- (B) 1450 J
- (C) 1600 J
- (D) 2000 J
- (E) 2760 J



[PhysicsBowl, 2021Q47]

In an ideal LC circuit, what is the time difference between all of the energy in the circuit being stored in the inductor and all of the energy being stored in the capacitor?

- (A) No time difference
- (B) One-eighth of a period of oscillation
- (C) One-quarter of a period of oscillation
- (D) One-half of a period of oscillation
- (E) After one full period of oscillation has passed

[PhysicsBowl, 2021Q48]

Two identical metal spheres are hung from a common point by 30-cm long, nonconducting threads of negligible mass. The spheres each have a mass of 0.20 g and are given identical charges. It is found that due to the electrostatic repulsion force, the angle between the threads is  $20^\circ$ . How much charge was placed on each sphere?

- (A) 11 nC
- (B) 16 nC
- (C) 21 nC
- (D) 26 nC
- (E) 31 nC

[PhysicsBowl, 2021Q49]

A collimated laser beam emerging from a commercial He-Ne laser has a diameter of 1.0 mm. Two convex lenses are used to convert this beam to a well-collimated beam with 10.0 mm diameter. The first lens has a focal length of 1.5 cm and is to be mounted at the output of the laser. What is the focal length,  $f$ , of the second lens and how far from the first lens should it be placed?

	$f$ (cm)	Distance (cm)
(A)	4.5	6
(B)	10	10
(C)	10	11.5
(D)	15	15
(E)	15	16.5



[PhysicsBowl, 2021Q50]

A free electron (rest mass:  $m_e = 0.5 \frac{MeV}{c^2}$ ) has a total energy of 1.5 MeV. Its momentum,  $p$ , in terms of  $\frac{MeV}{c}$  is about

- (A) 0.86
- (B) 1.0
- (C) 1.4
- (D) 1.5
- (E) 2.0

# PhysicsBowl 2022

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40 QUESTIONS – 45 MINUTES



PhysicsBowl 2022

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## Questions

The test is composed of 50 questions; however, students answer only 40 questions.

**Division 1 students will answer only questions 1 – 40.** Do not answer questions 41 – 50.

**Division 2 students will answer only questions 11 – 50.** Do not answer questions 1 – 10.

## Calculator

A hand-held calculator may be used. Any memory must be cleared of data and programs. Calculators may not be shared.

## Formulas and constants

Only the formulas and constants provided with the contest may be used.

## Time limit

45 minutes.

## Score

Your score is equal to the number of correct answers (no deduction for incorrect answers). If there are tie scores, the entries will be compared from the end of the test forward until the tie is resolved. Thus, the answers to the last few questions may be important in determining the winner and you should consider them carefully.

## Good Luck!

[PhysicsBowl, 2022Q1]

A 20,000 kg truck is traveling at 25 km/hr. At what speed does a 1000 kg car need to travel to have the same kinetic energy as the truck?

- (A) 112 km/hr
- (B) 132 km/hr
- (C) 102 km/hr
- (D) 79.0 km/hr
- (E) 89.0 km/hr

[PhysicsBowl, 2022Q2]

Who was the *last* person to walk on the Moon?

- (A) Buzz Aldrin
- (B) Eugene Cernan
- (C) Neil Armstrong
- (D) Sally Ride
- (E) Gus Grissom

[PhysicsBowl, 2022Q3]

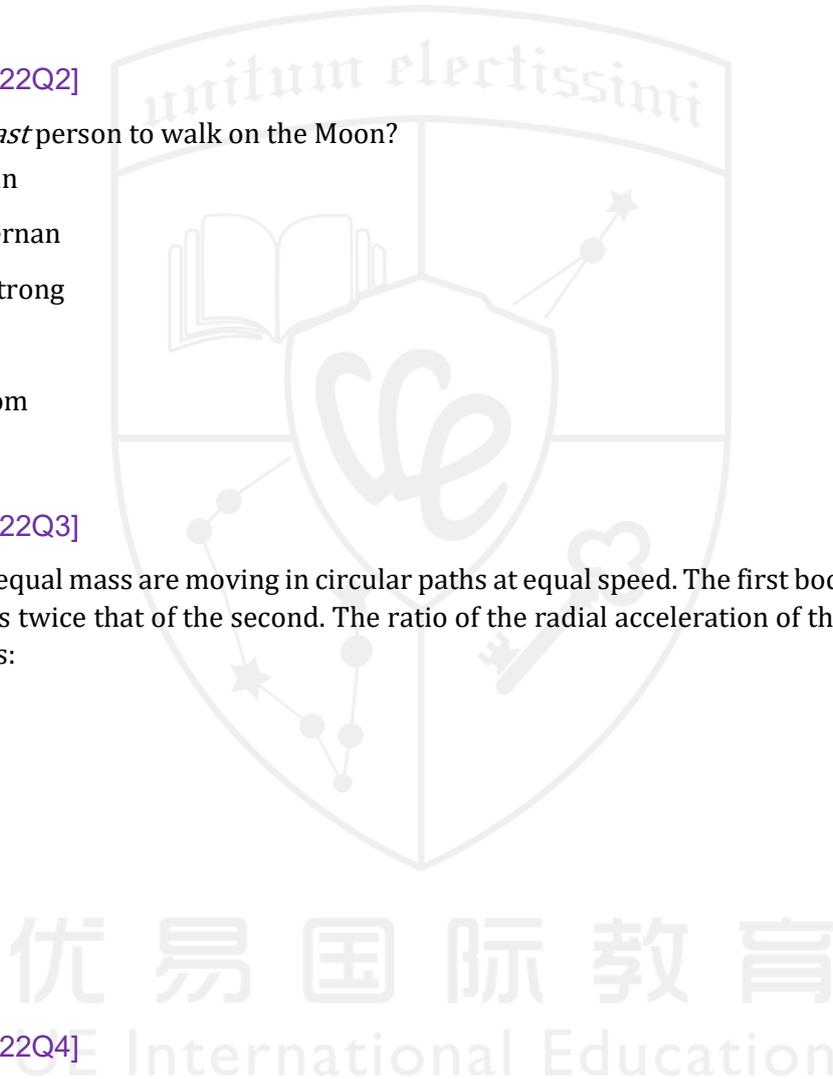
Two bodies of equal mass are moving in circular paths at equal speed. The first body moves in a circle whose radius is twice that of the second. The ratio of the radial acceleration of the first body to that of the second is:

- (A) 1 to 4
- (B) 1 to 3
- (C) 1 to 2
- (D) 1 to 1
- (E) 1 to 0.5

[PhysicsBowl, 2022Q4]

A bullet with a mass of 5.0 g is fired horizontally into a 2.0 kg wooden block which is resting on a horizontal table. The bullet stops in the block and the block and bullet combination move 2.0 m. The coefficient of kinetic friction between the block and surface of the table is 0.2. Find the initial speed of the bullet.

- (A) 1123 m/s
- (B) 1134 m/s
- (C) 1132 m/s
- (D) 113.2 m/s
- (E) 113.4 m/s



[PhysicsBowl, 2022Q5]

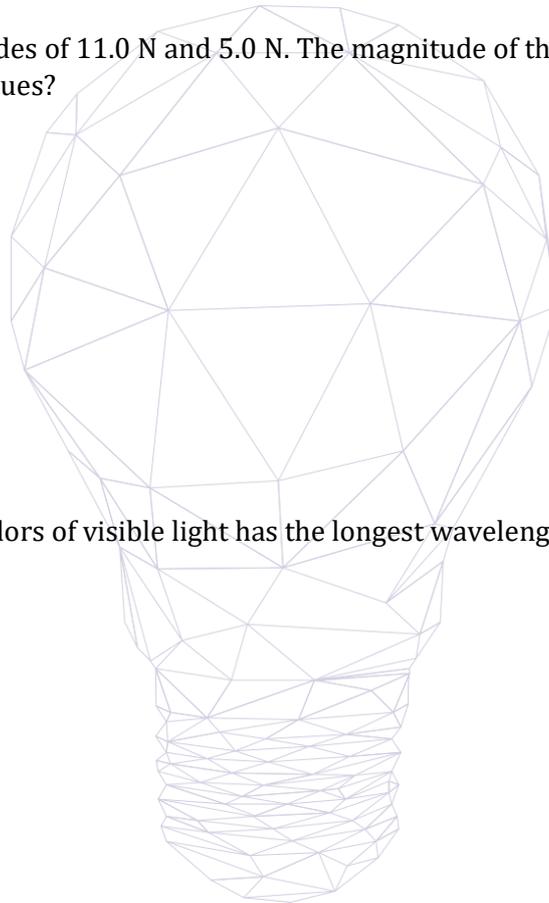
A car is moving along a straight horizontal road at a speed of 20 m/s. The brakes are applied and a constant force of 5000 N brings the car to a stop in 10 s. What is the mass of the car?

- (A) 1250 kg
- (B) 2500 kg
- (C) 5000 kg
- (D) 7500 kg
- (E) 10,000 kg

[PhysicsBowl, 2022Q6]

Two forces have magnitudes of 11.0 N and 5.0 N. The magnitude of their sum could NOT be equal to which of the following values?

- (A) 16.0 N
- (B) 9.0 N
- (C) 7.0 N
- (D) 5.0 N
- (E) 6.0 N



[PhysicsBowl, 2022Q7]

Which of the following colors of visible light has the longest wavelength?

- (A) Violet
- (B) Yellow
- (C) Blue
- (D) Green
- (E) Red

[PhysicsBowl, 2022Q8]

An increase in the translational motion of the molecules of a gas confined in a steel tank will be observed in one of the following ways. It will produce an increase in:

- (A) the temperature of the gas only.
- (B) the pressure of the gas only.
- (C) both the temperature and pressure of the gas.
- (D) the temperature of the gas and a decrease in its pressure.
- (E) the volume of the gas.

[PhysicsBowl, 2022Q9]

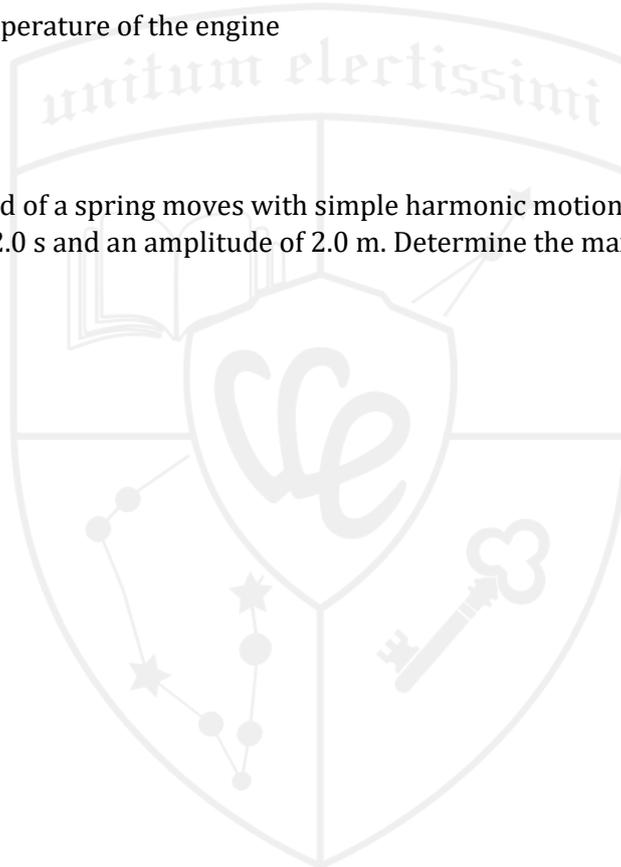
When descending mountain roads, large trucks pulling a heavy load can burn up the brakes. Once the brakes are no longer useful, the driver may need to guide the truck up a “runaway truck lane” on the side of the road. The runaway truck lane is directed uphill and often has a thick layer of sand or gravel or both on the surface. Which of the following is **one** of the reasons the truck will stop?

- (A) An increase in kinetic energy
- (B) A decrease in potential energy
- (C) A decrease in fuel
- (D) A transfer of energy to the gravel on the track of the runaway truck lane
- (E) The change in temperature of the engine

[PhysicsBowl, 2022Q10]

A 4.0 kg mass at the end of a spring moves with simple harmonic motion on a horizontal frictionless table with a period of 2.0 s and an amplitude of 2.0 m. Determine the maximum force exerted on the spring.

- (A) 25.1 N
- (B) 158 N
- (C) 39.5 N
- (D) 63.0 N
- (E) 79.0 N



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**The following information is to be used for Questions 11 & 12:**

The James Webb Space Telescope was launched on December 25, 2021, and arrived at its destination, LaGrange Point 2, on January 24, 2022. This point is approximately 1,500,000 km from the Earth and it is where the telescope will orbit the sun.

[PhysicsBowl, 2022Q11]

What was James Webb's former occupation?

- (A) Astronomer
- (B) Telescope designer/engineer
- (C) Silicon Valley entrepreneur and financier of the telescope project
- (D) Space shuttle astronaut/pilot
- (E) NASA Administrator

[PhysicsBowl, 2022Q12]

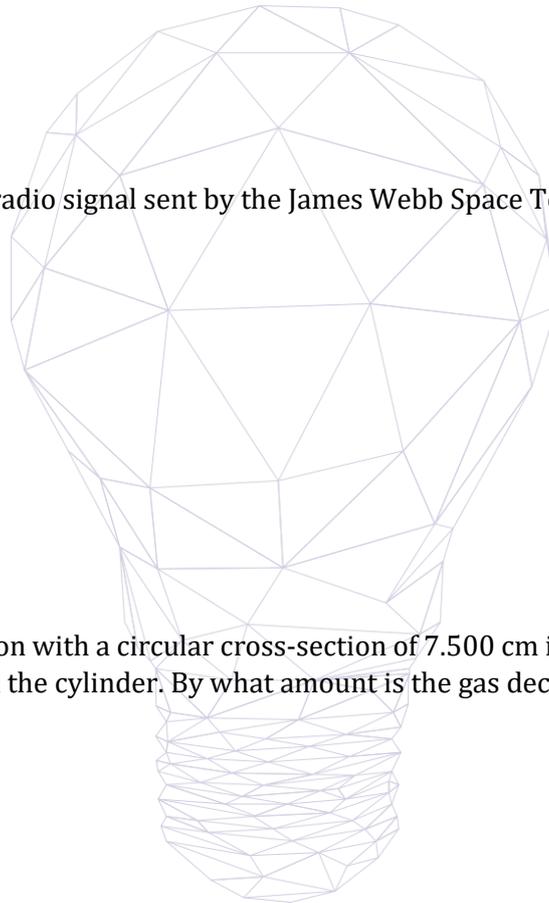
How long will it take the radio signal sent by the James Webb Space Telescope to reach the Earth?

- (A) 0.005 s
- (B) 0.05 s
- (C) 5 s
- (D) 50 s
- (E) 5000 s

[PhysicsBowl, 2022Q13]

A car engine moves a piston with a circular cross-section of 7.500 cm in diameter a distance of 3.250 cm to compress the gas in the cylinder. By what amount is the gas decreased in volume?

- (A) 143.6 cm<sup>3</sup>
- (B) 153.6 cm<sup>3</sup>
- (C) 662.7 cm<sup>3</sup>
- (D) 682.7 cm<sup>3</sup>
- (E) 88.36 cm<sup>3</sup>



[PhysicsBowl, 2022Q14]

A fisherman watches a dolphin leap out of the water at an angle of  $35^\circ$  above the horizontal. The horizontal component of the dolphin's velocity is 7.7 m/s. Find the magnitude of the vertical component of the velocity.

- (A) 4.4 m/s
- (B) 6.3 m/s
- (C) 11 m/s
- (D) 5.4 m/s
- (E) 3.2 m/s

[PhysicsBowl, 2022Q15]

Two simple pendula are 60 cm and 63 cm in length. They hang vertically, one in front of the other. If they are set in motion simultaneously, find the time taken for one to gain a complete cycle of oscillation on the other.

- (A) 15.4 s
- (B) 15.7 s
- (C) 31.5 s
- (D) 62.4 s
- (E) 79.7 s

[PhysicsBowl, 2022Q16]

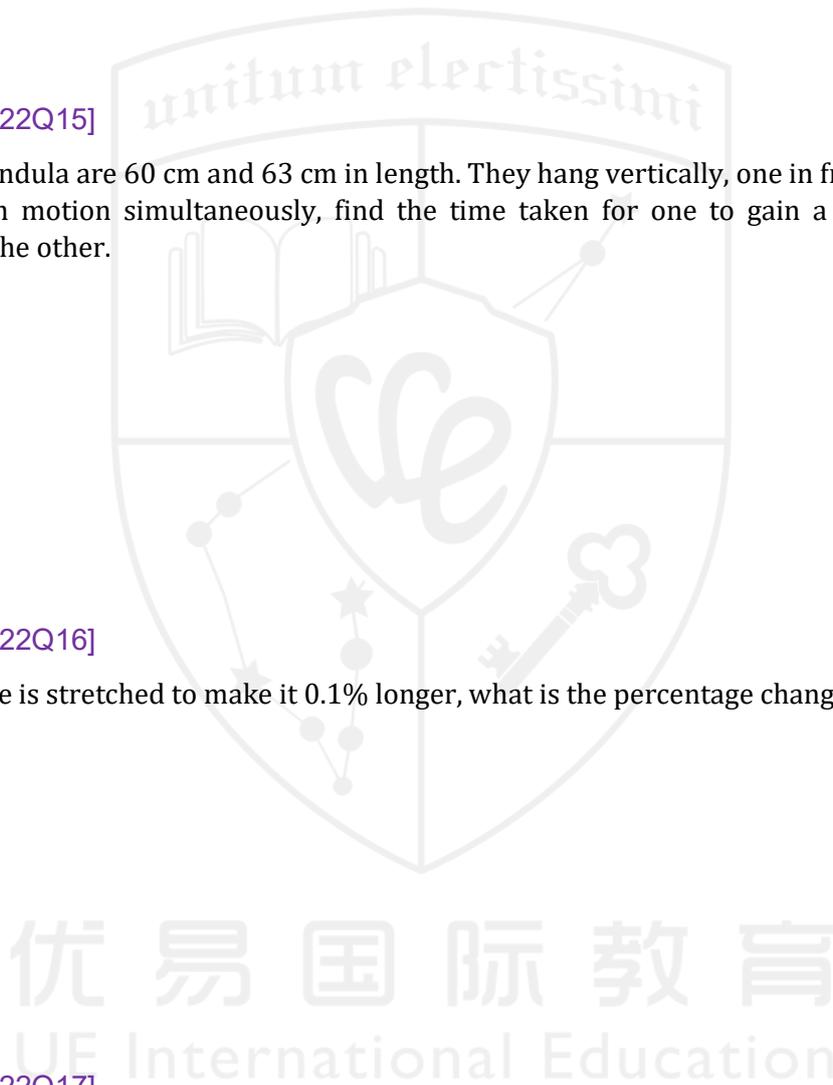
If a copper wire is stretched to make it 0.1% longer, what is the percentage change in its resistance?

- (A) 0.01%
- (B) 0.1%
- (C) 0.2%
- (D) 0.4%
- (E) 0.5%

[PhysicsBowl, 2022Q17]

A block of wood initially at rest slides down an inclined plane. Neglecting friction, the kinetic energy of the block at the bottom of the plane is:

- (A) all converted into heat.
- (B) less than its kinetic energy at the top of the plane.
- (C) dependent on the materials of which the block is made.
- (D) dependent on the materials of which the inclined plane is made.
- (E) equal to its potential energy (with respect to the bottom of the plane) when it was at the top of the plane.



[PhysicsBowl, 2022Q18]

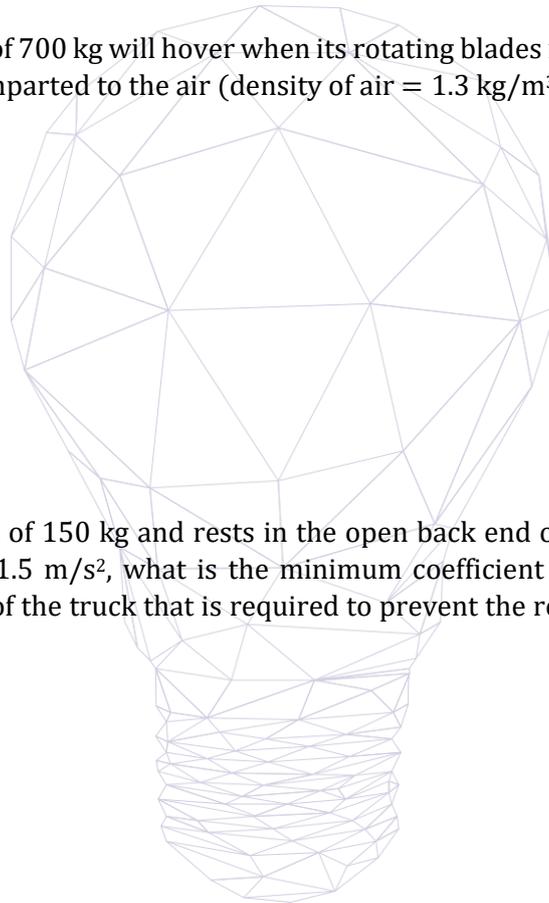
In the last one second of a free fall, an apple traveled three-fourths of its total path. From what height did the apple fall?

- (A) 10 m
- (B) 15 m
- (C) 20 m
- (D) 25 m
- (E) 30 m

[PhysicsBowl, 2022Q19]

A helicopter with a mass of 700 kg will hover when its rotating blades move through an area of  $50\text{m}^2$ . Find the average speed imparted to the air (density of air =  $1.3\text{ kg/m}^3$ )

- (A) 7.66 m/s
- (B) 10.4 m/s
- (C) 16.5 m/s
- (D) 38.0 m/s
- (E) 44.1 m/s



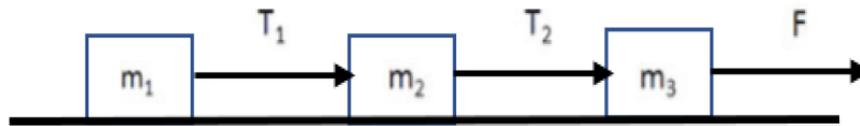
[PhysicsBowl, 2022Q20]

A refrigerator has a mass of 150 kg and rests in the open back end of a delivery truck. If the truck accelerates from rest at  $1.5\text{ m/s}^2$ , what is the minimum coefficient of static friction between the refrigerator and the bed of the truck that is required to prevent the refrigerator from sliding off the back of the truck?

- (A) 0.08
- (B) 0.10
- (C) 0.12
- (D) 0.15
- (E) 0.18

[PhysicsBowl, 2022Q21]

Three blocks ( $m_1 = 1 \text{ kg}$ ,  $m_2 = 2 \text{ kg}$ ,  $m_3 = 3 \text{ kg}$ ) connected by cords are pulled by a constant force,  $F$ , of 18 N on a frictionless horizontal table.  $T_2$  is the tension in the rope between  $m_2$  and  $m_3$ . What is  $T_2$ ?



- (A) 3 N
- (B) 6 N
- (C) 9 N
- (D) 12 N
- (E) 15 N

[PhysicsBowl, 2022Q22]

An object starting from rest moves on a circular path with a radius 40 cm and a constant tangential acceleration of  $10 \text{ cm/s}^2$ . How much time is needed after the motion begins for the centripetal acceleration of the object to be equal to the tangential acceleration?

- (A) 0.2 s
- (B) 1.0 s
- (C) 1.2 s
- (D) 1.8 s
- (E) 2.0 s



[PhysicsBowl, 2022Q23]

The distance between the electron and the proton in the hydrogen atom is about  $0.53 \times 10^{-10} \text{ m}$ . By what factor is the electrical force between the electron and proton stronger than the gravitational force between them?

- (A)  $1.3 \times 10^{39}$
- (B)  $2.3 \times 10^{39}$
- (C)  $3.3 \times 10^{39}$
- (D)  $4.3 \times 10^{39}$
- (E)  $5.3 \times 10^{39}$

[PhysicsBowl, 2022Q24]

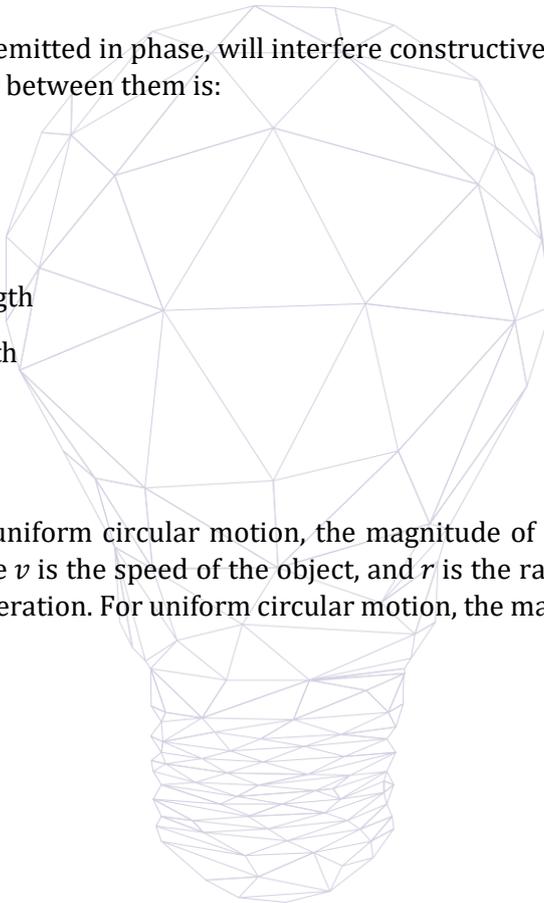
A 3.00 kg bucket of water is raised with an upward acceleration of  $2.20 \text{ m/s}^2$  from a well by means of an attached rope. What is the tension in the rope?

- (A) 30.2 N
- (B) 33.3 N
- (C) 36.6 N
- (D) 39.0 N
- (E) 43.2 N

[PhysicsBowl, 2022Q25]

Two light waves, initially emitted in phase, will interfere constructively with maximum amplitude if the path-length difference between them is:

- (A) 1.5 wavelengths
- (B) one wavelength
- (C) one-half wavelength
- (D) one-quarter wavelength
- (E) one-eighth wavelength



[PhysicsBowl, 2022Q26]

For an object moving in uniform circular motion, the magnitude of the centripetal acceleration is given by  $a_c = v^2/r$ , where  $v$  is the speed of the object, and  $r$  is the radius of the circle. The “jerk” is the rate of change of acceleration. For uniform circular motion, the magnitude of the jerk is given by:

- (A) zero
- (B)  $v^2/r$
- (C)  $v^2r$
- (D)  $v^3/r$
- (E)  $v^3/r^2$

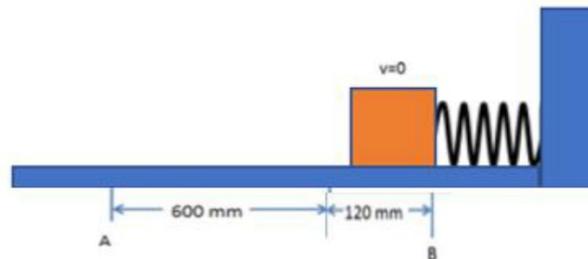
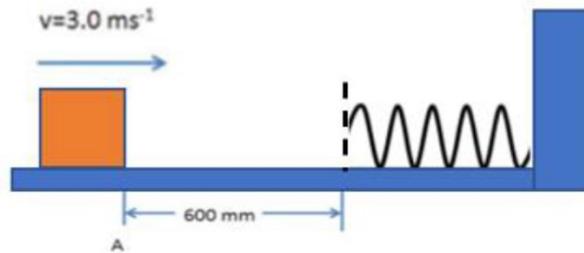
[PhysicsBowl, 2022Q27]

A machine gun fires 100 g bullets at a speed of 1000 m/s. The person holding the machine gun in their hands can exert an average force of 150 N against the gun. If the gun is to remain stationary, what is the maximum number of bullets that can be fired per minute?

- (A) 10
- (B) 15
- (C) 30
- (D) 60
- (E) 90

[PhysicsBowl, 2022Q28]

A spring with spring constant  $k = 20 \text{ kN/m}$ , is used to stop a  $50 \text{ kg}$  box that is sliding on a horizontal surface. The spring is initially in its equilibrium state. At position  $A$ , shown in the top diagram, the box has a speed of  $3.0 \text{ m/s}$ . The compression of the spring when the box is instantaneously at rest (position  $B$  in the bottom diagram) is  $120 \text{ mm}$ . Determine the coefficient of kinetic friction between the box and the surface.



- (A) 0.125
- (B) 0.230
- (C) 0.245
- (D) 0.280
- (E) 0.315

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[PhysicsBowl, 2022Q29]

A cyclist, using a power meter while on a training ride, checks and sees that she is doing work at the rate of  $500 \text{ W}$ . How much average force does her foot exert on the pedals when she is traveling at  $8.0 \text{ m/s}$ ?

- (A) 31 N
- (B) 63 N
- (C) 80 N
- (D) 320 N
- (E) 710 N

[PhysicsBowl, 2022Q30]

A ticker tape timer is operating at 60 Hz. It was used to analyze the motion of a battery-powered car. The following displacements were measured for five intervals on the ticker tape.

	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5
Displacement	0.055 m	0.065 m	0.055 m	0.070 m	0.060 m

What is the average speed of the car?

- (A) 0.612 m/s
- (B) 3.66 m/s
- (C) 0.366 m/s
- (D) 0.947 m/s
- (E) 6.32 m/s

[PhysicsBowl, 2022Q31]

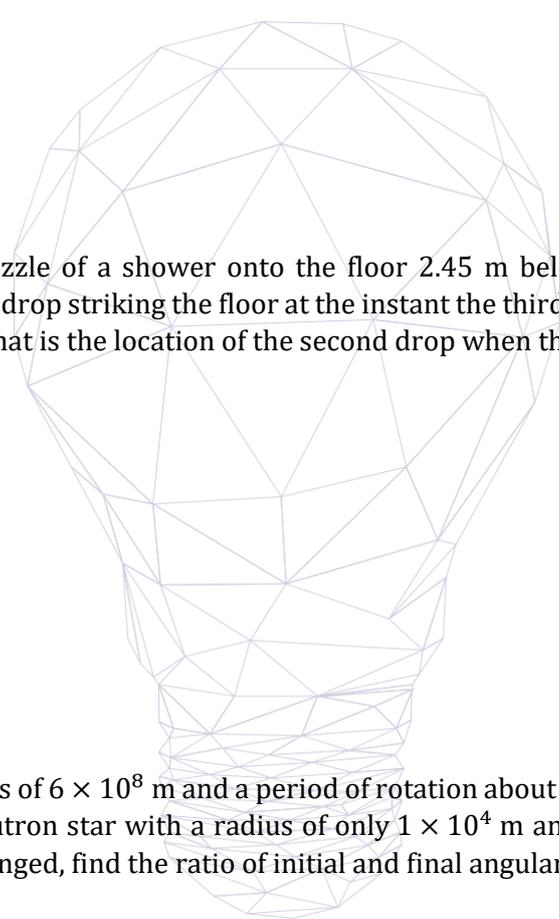
Water drips from the nozzle of a shower onto the floor 2.45 m below. The drops fall at regular intervals of time, the first drop striking the floor at the instant the third drop begins to fall. Measured from the shower head, what is the location of the second drop when the first drop strikes the floor.

- (A) 0.313 m
- (B) 0.613 m
- (C) 0.938 m
- (D) 1.25 m
- (E) 1.563 m

[PhysicsBowl, 2022Q32]

A star initially has a radius of  $6 \times 10^8$  m and a period of rotation about its axis of 30 days. Eventually, it collapses to form a neutron star with a radius of only  $1 \times 10^4$  m and a period of 0.1 s. Assuming that the mass has not changed, find the ratio of initial and final angular momentum of the star.

- (A) 15.92
- (B) 214.6
- (C) 103.1
- (D) 442.1
- (E) 138.9



[PhysicsBowl, 2022Q33]

For ordinary conversation, a sound level meter reads 60 dB. What is the intensity of this sound wave?

- (A)  $6.0 \times 10^{-6} \text{ W/m}^2$
- (B)  $1.0 \times 10^{-4} \text{ W/m}^2$
- (C)  $6.0 \times 10^{-4} \text{ W/m}^2$
- (D)  $1.0 \times 10^{-6} \text{ W/m}^2$
- (E)  $1.0 \times 10^{-8} \text{ W/m}^2$

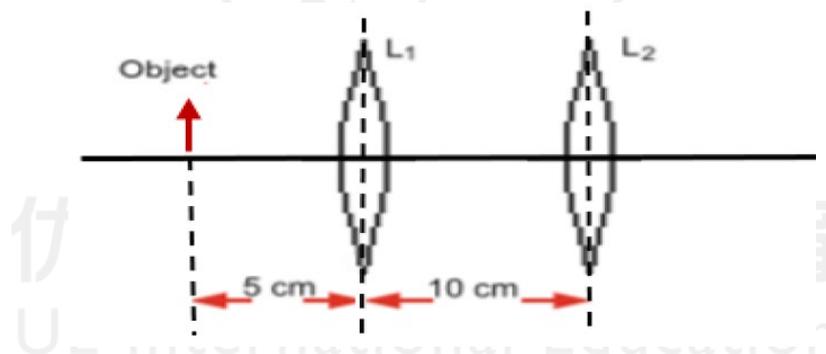
[PhysicsBowl, 2022Q34]

A tiny ball with a mass of 0.6 g carries a charge of magnitude  $8 \mu\text{C}$ . It is suspended by a thread in a downward directed electric field of intensity 300 N/C. What is the tension in the thread if the charge on the ball is positive?

- (A)  $2.40 \times 10^{-3} \text{ N}$
- (B)  $6.00 \times 10^{-3} \text{ N}$
- (C)  $8.40 \times 10^{-3} \text{ N}$
- (D)  $6.00 \times 10^{-2} \text{ N}$
- (E)  $6.24 \times 10^{-3} \text{ N}$

[PhysicsBowl, 2022Q35]

A combination of two thin convex lenses is placed as shown at right. An object is placed 5 cm in front of  $L_1$  which has a focal length of 10 cm.  $L_2$  is 10 cm behind  $L_1$  and has a focal length of 12 cm. How far from  $L_2$  is the final image for this lens combination?



- (A) 8 cm
- (B) 15 cm
- (C) 22 cm
- (D) 24 cm
- (E) 30 cm



[PhysicsBowl, 2022Q36]

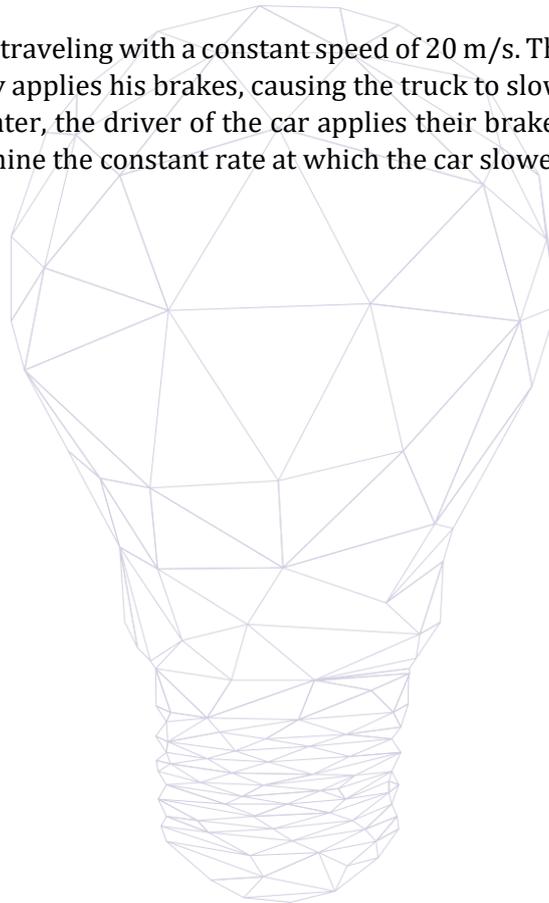
A thick glass plate has parallel sides. A beam of white light is incident on one side at an angle between  $0^\circ$  and  $90^\circ$  with the normal. Which color emerges from the other side first?

- (A) All of them
- (B) red
- (C) green
- (D) violet
- (E) None of them

[PhysicsBowl, 2022Q37]

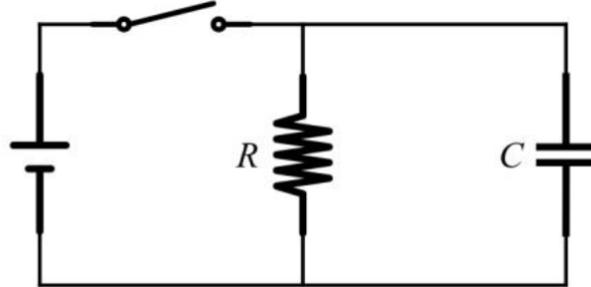
A car and a truck are both traveling with a constant speed of 20 m/s. The car is 10 m behind the truck. The truck driver suddenly applies his brakes, causing the truck to slow to a stop at the constant rate of  $2 \text{ m/s}^2$ . Two seconds later, the driver of the car applies their brakes and just manages to avoid a rear-end collision. Determine the constant rate at which the car slowed.

- (A)  $3.33 \text{ m/s}^2$
- (B)  $4.33 \text{ m/s}^2$
- (C)  $1.33 \text{ m/s}^2$
- (D)  $3.03 \text{ m/s}^2$
- (E)  $3.93 \text{ m/s}^2$



[PhysicsBowl, 2022Q38]

In the circuit shown below, the voltage source, switch, capacitor and connecting wires have no resistance. Let  $\Delta V_R$  and  $\Delta V_C$  represent the potential differences across the resistor and the capacitor, respectively. The capacitor is initially uncharged. Which of the following choices correctly compares these potential differences immediately after the switch is closed and after the circuit has reached steady state.



	Switch Closed	Steady State
(A)	$\Delta V_R = \Delta V_C$	$\Delta V_R = \Delta V_C$
(B)	$\Delta V_R > \Delta V_C$	$\Delta V_R = \Delta V_C$
(C)	$\Delta V_R = \Delta V_C$	$\Delta V_R < \Delta V_C$
(D)	$\Delta V_R > \Delta V_C$	$\Delta V_R < \Delta V_C$
(E)	$\Delta V_R < \Delta V_C$	$\Delta V_R > \Delta V_C$

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14

[PhysicsBowl, 2022Q39]

A radioactive carbon-14 nucleus decays into a beta particle, an antineutrino, and a nitrogen-14 nucleus. In a particular decay, the beta particle has momentum,  $p$ , and the nitrogen nucleus has momentum of magnitude  $4p/3$  at an angle of  $90^\circ$  to  $p$ . At what angle (with respect to the beta particle) do you expect the antineutrino to be emitted?

- (A)  $52^\circ$
- (B)  $37^\circ$
- (C)  $90^\circ$
- (D)  $127^\circ$
- (E)  $33^\circ$

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[PhysicsBowl, 2022Q40]

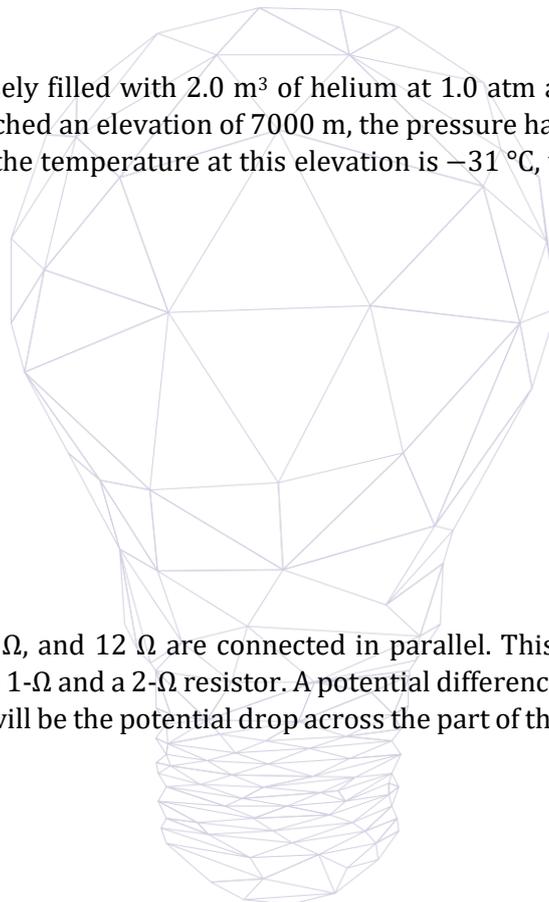
An Olympic ice skater in Beijing spins at  $4\pi$  rad/s with her arms extended. If her moment of inertia with arms folded is 80% of that with arms extended, what is her angular velocity when she folds her arms?

- (A)  $\pi$  rad/s
- (B)  $2\pi$  rad/s
- (C)  $3\pi$  rad/s
- (D)  $5\pi$  rad/s
- (E)  $6\pi$  rad/s

[PhysicsBowl, 2022Q41]

A weather balloon is loosely filled with  $2.0 \text{ m}^3$  of helium at 1.0 atm and  $27^\circ\text{C}$ . The balloon is then released. When it has reached an elevation of 7000 m, the pressure has dropped to 0.41 atm and the balloon has expanded. If the temperature at this elevation is  $-31^\circ\text{C}$ , what is the new volume of the balloon?

- (A)  $2.7 \text{ m}^3$
- (B)  $3.2 \text{ m}^3$
- (C)  $3.9 \text{ m}^3$
- (D)  $4.6 \text{ m}^3$
- (E)  $5.1 \text{ m}^3$



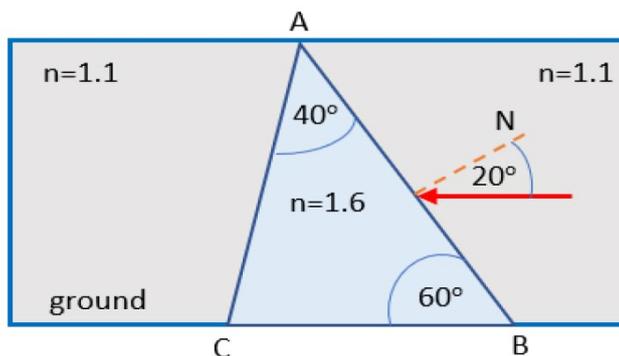
[PhysicsBowl, 2022Q42]

Three resistors of  $4 \Omega$ ,  $6 \Omega$ , and  $12 \Omega$  are connected in parallel. This parallel arrangement is then connected in series with a  $1\text{-}\Omega$  and a  $2\text{-}\Omega$  resistor. A potential difference of 120 V is applied across the ends of the circuit. What will be the potential drop across the part of the circuit connected in parallel?

- (A) 12 V
- (B) 48 V
- (C) 24 V
- (D) 36 V
- (E) 72 V

[PhysicsBowl, 2022Q43]

A triangular glass prism ( $n = 1.6$ ) is immersed in a liquid ( $n = 1.1$ ) as shown. A laser light is incident as shown on face  $AB$  making an angle of  $20^\circ$  with the normal ( $N$ ). Calculate the angle that the ray emerging from  $AC$  makes with the ground when it leaves  $AC$  and strikes the ground.



- (A)  $28.1^\circ$
- (B)  $30.3^\circ$
- (C)  $33.8^\circ$
- (D)  $36.1^\circ$
- (E)  $18.9^\circ$

[PhysicsBowl, 2022Q44]

How long would it take  $4.0 \times 10^{20}$  nuclei to decay to  $1.0 \times 10^{19}$  atoms if their half-life was 14.7 years?

- (A) 29.4 years
- (B) 58.8 years
- (C) 78.2 years
- (D) 147 years
- (E) 161 years



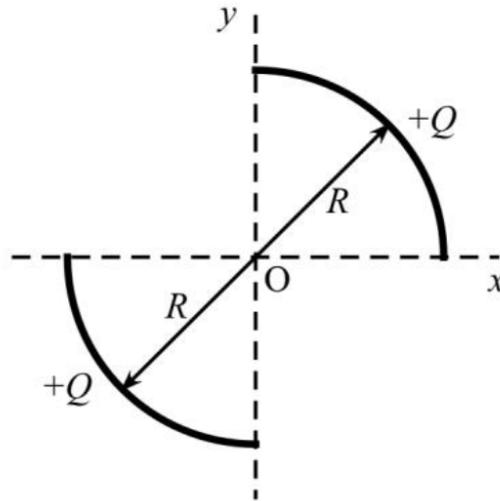
[PhysicsBowl, 2022Q45]

An electric field of 1500 V/m and a magnetic field act on an electron moving with a speed of 3000 m/s. If the resultant force is to be zero, what should be the strength of the magnetic field?

- (A) 0.35 T
- (B) 0.50 T
- (C) 0.72 T
- (D) 0.81 T
- (E) 0.96 T

[PhysicsBowl, 2022Q46]

Each of the two curved rods shown in the picture form one-quarter of a circle with a radius  $R$ . Both rods carry a uniformly distributed electric charge  $+Q$ . Which of the following choices correctly expresses the net electric field and net electric potential at the origin? Assume  $V \rightarrow 0$  as  $r \rightarrow \infty$ .



	Electric Field	Electric Potential
(A)	zero	zero
(B)	zero	$\frac{2kQ}{R}$
(C)	$\frac{2kQ}{R^2}$	zero
(D)	$\frac{\sqrt{2kQ}}{R^2}$	$\frac{2kQ}{R}$
(E)	$\frac{2kQ}{R^2}$	$\frac{2kQ}{R}$



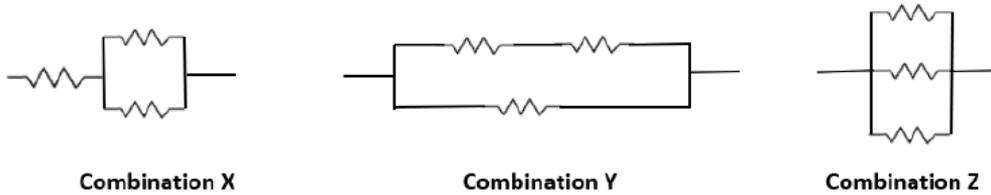
[PhysicsBowl, 2022Q47]

A shipping box in a warehouse has a mass of 2.00 kg and slides down an inclined plane that makes an angle of  $30^\circ$  with the horizontal. The coefficient of kinetic friction between the box and the plane surface is 0.866. How much force (parallel to the incline) should be applied to the box so that it moves down the plane at constant speed?

- (A) 5.00 N
- (B) 6.50 N
- (C) 3.80 N
- (D) 4.60 N
- (E) 11.0 N

[PhysicsBowl, 2022Q48]

The diagram below shows combinations X, Y and Z of three identical resistors. What is the correct order of the **total** resistance of the combinations going from **lowest** resistance to **highest** resistance?



- (A) Y, X, Z
- (B) Z, X, Y
- (C) X, Y, Z
- (D) Z, Y, X
- (E) Y, Z, X

[PhysicsBowl, 2022Q49]

If the Earth suddenly stopped in its orbit and the orbit is assumed to be circular, how much time would elapse before it falls into the Sun?

- (A) 147 minutes
- (B) 1.22 days
- (C) 64.5 days
- (D) 228 days
- (E) 2.34 years



[PhysicsBowl, 2022Q50]

An ideal gas system, with an initial volume of  $1.0 \text{ m}^3$  at standard temperature and pressure, undergoes the following three-stage cycle: Stage 1 – an isothermal expansion to twice its original volume. Stage 2 – a process by which its volume remains constant, its pressure returns to its original value and  $104 \text{ J}$  of heat is added to the system. Stage 3 – an isobaric compression to its original volume, with  $3 \times 10^4 \text{ J}$  of heat being removed from the system. Calculate the work done on the system during Stage 3.

- (A)  $-7.005 \times 10^4 \text{ J}$
- (B)  $-1.013 \times 10^4 \text{ J}$
- (C)  $-1.013 \times 10^5 \text{ J}$
- (D)  $-7.050 \times 10^5 \text{ J}$
- (E)  $-2.030 \times 10^5 \text{ J}$