

PHYSICSBOWL 2015

April 1 – April 17, 2015

40 QUESTIONS – 45 MINUTES

The sponsors of the 2015 PhysicsBowl, including the **American Association of Physics Teachers**, are providing some of the prizes to recognize outstanding high school physics students and their teachers through their performance on this year's contest.

- Schools compete in one of two divisions, each with nineteen regions.
 - *Division 1* is for students *taking physics for the first time* (even if that first course is AP Physics).
 - *Division 2* is for students taking a second (or more) course in physics or anyone wishing a challenge.
- A school's team score in each division is the sum of the five highest student scores in that division.
- A school may compete in either or both divisions.

INSTRUCTIONS

Answer sheet: Write and bubble-in the following **REQUIRED** information on your answer sheet:

- Your Name
- Your Teacher's AAPT Teacher code (given to you by your teacher – only **one** code per school!)
- Your Region (given to you by your teacher)
- Your Division (1 for first-year physics students, 2 for students in a second physics course)

If this information is not properly bubbled, **you will be disqualified** as your official score will be a zero.

Your School's CEEB code (given to you by your teacher), though not required, IS helpful in the event of a disqualification for identifying your school.

Your answer sheet will be machine graded. Be sure to use a #2 pencil, fill the bubbles completely, and make no stray marks on the answer sheet.

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!

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ATTENTION: All Division 1 students, **START HERE.**
 All Division 2 students – Begin on *question #11.*

*** Treat $g = 10.0 \text{ m/s}^2$ for ALL questions #1 – #50.

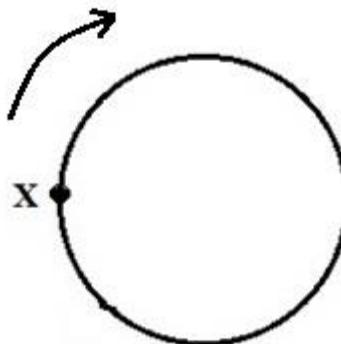
- Which one of the following choices correctly represents a length of 3.00 mm?
 - $3.00 \times 10^{-6} \text{ m}$
 - $3.00 \times 10^{-3} \text{ m}$
 - $3.00 \times 10^{-2} \text{ m}$
 - $3.00 \times 10^3 \text{ m}$
 - $3.00 \times 10^6 \text{ m}$
- A box uniformly slides 7.50 m to rest across a flat surface in a time of 12.0 s. What was the initial speed of the box when it started its slide?
 - $0.313 \frac{\text{m}}{\text{s}}$
 - $0.625 \frac{\text{m}}{\text{s}}$
 - $1.25 \frac{\text{m}}{\text{s}}$
 - $2.50 \frac{\text{m}}{\text{s}}$
 - $5.00 \frac{\text{m}}{\text{s}}$
- Which one of the following quantities is not a vector quantity?
 - Average speed
 - Average velocity
 - Linear momentum
 - Acceleration
 - Average force
- 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?
 - node
 - antinode
 - harmonic
 - overtone
 - amplitude
- 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?

	<i>Object moving upward</i>	<i>Object at peak of motion</i>	<i>Object moving downward</i>
(A)	Upward	Zero	Downward
(B)	Downward	Zero	Downward
(C)	Upward	Downward	Downward
(D)	Downward	Zero	Upward
(E)	Downward	Downward	Downward

- 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 $\frac{\text{m}}{\text{s}}$?
 - $533 \frac{\text{m}}{\text{s}}$
 - $45.0 \frac{\text{m}}{\text{s}}$
 - $20.0 \frac{\text{m}}{\text{s}}$
 - $8.9 \frac{\text{m}}{\text{s}}$
 - $0.75 \frac{\text{m}}{\text{s}}$

7. 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.



8. 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

9. 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 = $13.0 \frac{m}{s}$; constant acceleration = $1.5 \frac{m}{s^2}$

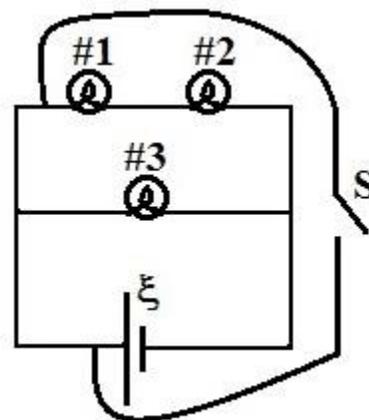
Car #2: position = 80.0 m; velocity = $9.30 \frac{m}{s}$; constant acceleration = $5.5 \frac{m}{s^2}$

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.

10. 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



ATTENTION: All Division 1 students, continue to question #40.
 All Division 2 students, START HERE. Numbers 1 – 10 on your answer sheet should be blank. Your first answer should be for #11.

*** Treat $g = 10.0 \text{ m/s}^2$ for ALL questions #1 – #50.

11. Two length measurements are made and recorded as $L_1 = 84.55 \text{ cm}$ and $L_2 = 33.55 \text{ cm}$. Two other length measurements are made and recorded as $L_3 = 1.750 \text{ cm}$ and $L_4 = 1.250 \text{ cm}$. 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?

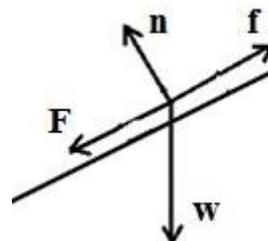
- (A) 115.100 cm (B) 115.10 cm (C) 115.1 cm (D) 115 cm (E) 120 cm

12. 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) $6.00 \text{ kg} \frac{\text{m}}{\text{s}}$ (B) $8.50 \text{ kg} \frac{\text{m}}{\text{s}}$ (C) $12.0 \text{ kg} \frac{\text{m}}{\text{s}}$ (D) $17.0 \text{ kg} \frac{\text{m}}{\text{s}}$ (E) $24.0 \text{ kg} \frac{\text{m}}{\text{s}}$

13. 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 $F = f$



14. 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) $5 \frac{\text{m}}{\text{s}^2}$ (B) $10 \frac{\text{m}}{\text{s}^2}$ (C) $15 \frac{\text{m}}{\text{s}^2}$ (D) $20 \frac{\text{m}}{\text{s}^2}$ (E) $40 \frac{\text{m}}{\text{s}^2}$

15. 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?

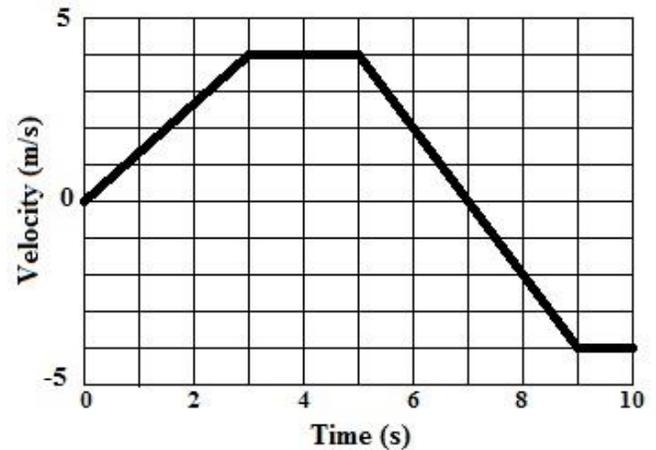
- (A) There is no Third Law pair force for this kind of situation.
 (B) The gravitational force acting on the skydiver by the Earth.
 (C) The force that molecules in the air exert on neighboring molecules in the air.
 (D) The force exerted on molecules in the air by the ground.
 (E) The force exerted on molecules in the air by the skydiver.

16. “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

17. 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 $5\text{ s} < t < 9\text{ s}$



18. 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 $340\frac{m}{s}$. 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

19. 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) $0.012\frac{kg}{m^3}$ (B) $0.12\frac{kg}{m^3}$ (C) $1.2\frac{kg}{m^3}$ (D) $120\frac{kg}{m^3}$ (E) $1.2 \times 10^4\frac{kg}{m^3}$

20. 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

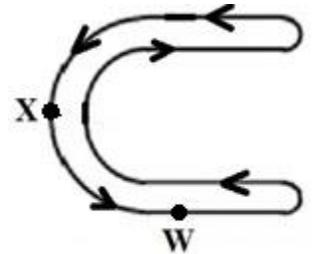
21. An object is launched from the ground at an angle of 60° above the horizontal with a speed of $20.0\frac{m}{s}$. What is the magnitude of the average velocity of the object from just after launch until it reaches its highest vertical position during flight?

- (A) $13.7\frac{m}{s}$ (B) $13.2\frac{m}{s}$ (C) $10.0\frac{m}{s}$ (D) $9.3\frac{m}{s}$ (E) $8.7\frac{m}{s}$

22. 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?

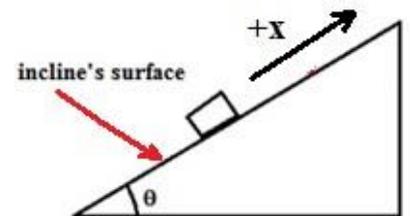
- (A) $v_2 = \frac{1}{\sqrt{2}}v_1$; $a_2 = \frac{1}{4}a_1$ (D) $v_2 = \frac{1}{2}v_1$; $a_2 = \frac{1}{2}a_1$
 (B) $v_2 = \frac{1}{2}v_1$; $a_2 = \frac{1}{4}a_1$ (E) $v_2 = v_1$; $a_2 = \frac{1}{2}a_1$
 (C) $v_2 = \frac{1}{\sqrt{2}}v_1$; $a_2 = \frac{1}{2}a_1$

23. 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

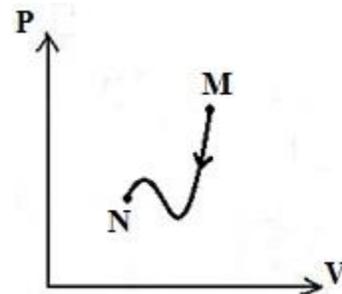
24. A mass on a frictionless incline has a gravitational force, a normal force from the incline, and a force applied by a person that all are equal in magnitude. The mass remains at rest and the incline makes an angle θ counterclockwise from the horizontal. Which one of the following choices best describes 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 θ 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.

25. 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, ΔU , 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?

	ΔU	Q	W
(A)	Positive	Negative	Positive
(B)	Negative	Positive	Negative
(C)	Negative	Negative	Negative
(D)	Positive	Positive	Negative
(E)	Negative	Negative	Positive

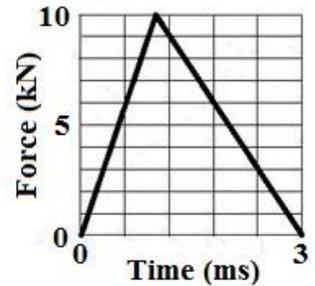


26. The position of a mass connected to a spring obeys $x(t) = A \cos(\omega t)$. What is the average speed of the mass for one full oscillation in terms of the mass's maximum speed during oscillation, v_{max} ?

- (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) $\frac{1}{2\pi\sqrt{2}} v_{max}$

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 $7.0 \frac{m}{s}$. Body 2 initially is at rest. A graph of the force exerted onto Body 2 from Body 1 during the collision is shown.



27. What is the mass of Body 2?

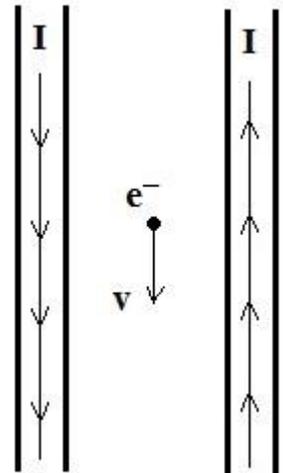
- (A) 2.81 kg (B) 3.50 kg (C) 4.59 kg (D) 5.53 kg (E) 7.50 kg

28. 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

29. 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



30. 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) $3.68 \times 10^3 \frac{kg}{m^3}$ (B) $2.72 \times 10^3 \frac{kg}{m^3}$ (C) $1.58 \times 10^3 \frac{kg}{m^3}$ (D) $9.20 \times 10^2 \frac{kg}{m^3}$ (E) $1.58 \times 10^2 \frac{kg}{m^3}$

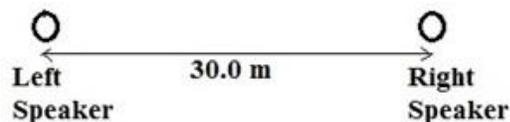
31. Approximately how many hydrogen atoms are there in the liquid water of Earth's oceans?

- (A) 10^{62} (B) 10^{57} (C) 10^{52} (D) 10^{47} (E) 10^{42}

32. 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?

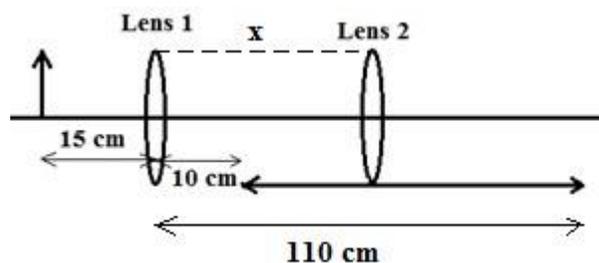
(A) 2.5 m/s^2 (B) 2.7 m/s^2 (C) 4.0 m/s^2 (D) 5.3 m/s^2 (E) 6.3 m/s^2

33. 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 $342 \frac{\text{m}}{\text{s}}$. 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

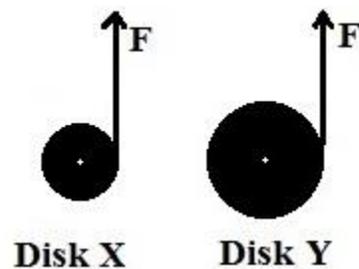
34. An upward-pointing object is placed 15.0 cm to the left of a lens system. The first lens is convex with focal length 10.0 cm . The second lens is convex with focal length 10 cm and its location from the first lens is varied from 10 cm away to 110 cm away. Which one of the following choices best represents the description of the final image formed as the second lens is moved from $x = 10 \text{ cm}$ to $x = 110 \text{ cm}$ from the first lens?



	$x = 10 \text{ cm away}$	→	→	→	→	→	→	→	$x = 110 \text{ cm away}$
(A)	Real & pointing downward								Real & pointing upward
(B)	Virtual & pointing downward								Real & pointing upward
(C)	Virtual & pointing upward								Real & pointing downward
(D)	Real & pointing upward								Real & pointing upward
(E)		Virtual & pointing downward							Real & pointing upward

35. 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) $L_X < L_Y$; $K_X = K_Y$



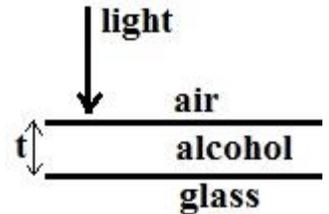
36. Rain falls vertically at 12.0 m/s with respect to a stationary observer. A car is moving at an angle of 40° below the horizontal with respect to the observer. A passenger sitting in the car notes that the rain makes an angle of 29.0° with the vertical. What is the car's speed with respect to the observer?

- (A) $2.29 \frac{m}{s}$ (B) $5.93 \frac{m}{s}$ (C) $9.03 \frac{m}{s}$ (D) $11.8 \frac{m}{s}$ (E) $16.2 \frac{m}{s}$

37. Which one of the following choices represents the base SI units of inductance?

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

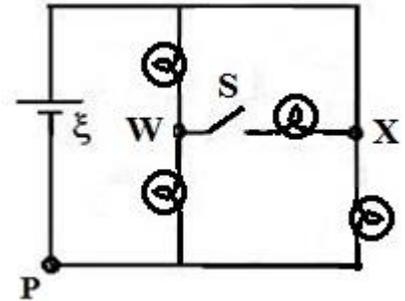
38. A thin film of alcohol ($n_{alcohol} = 1.35$) lies on a flat glass surface ($n_{glass} = 1.60$). When light of wavelength 540 nm is incident normal to the alcohol surface from air, the light is strongly reflected, but when light of wavelength 432 nm is incident normal to the surface from air, the 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

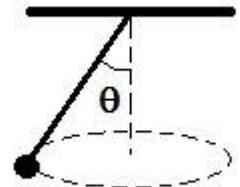
39. For the circuit shown, the four light bulbs have identical resistance, the battery is ideal and all wires have no resistance. After the switch, S , in the circuit is closed, which one of the following choices correctly describes what happens to the magnitude of the current at the point labeled P and to the magnitude of the potential difference from W to X ?

	<i>Current at P</i>	ΔV_{XW}
(A)	No change	Increases
(B)	Decreases	Increases
(C)	Increases	Increases
(D)	Decreases	Decreases
(E)	Increases	Decreases



40. 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 $4.0 \frac{m}{s}$. The string has a length of 2.50 m and forms an angle of θ 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



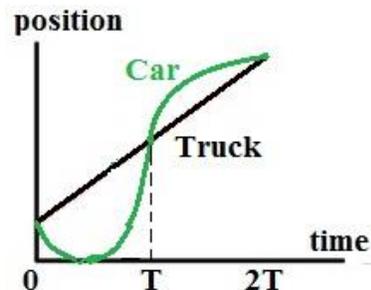
IMPORTANT: All Division 1 students STOP HERE. Your last answer should be for #40. Numbers 41-50 should remain blank for Division 1 students.

All Division 2 students continue to Questions 41 – 50.

ATTENTION: All Division 1 students, **STOP HERE**.
All Division 2 students, continue to question #50.

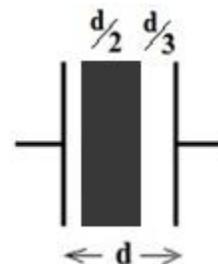
Questions 41 – 42 deal with the following information:

A car and a truck are moving on a horizontal track. The position vs. time graph for the two vehicles is shown.



41. 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.
42. 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 $T < t < 2T$.
43. 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 $24.0 \text{ kg} \frac{\text{m}}{\text{s}}$. The object is moving in the x-y plane. What is the y-component of the object's linear momentum?
- (A) $8.00 \text{ kg} \frac{\text{m}}{\text{s}}$ (B) $15.0 \text{ kg} \frac{\text{m}}{\text{s}}$ (C) $26.0 \text{ kg} \frac{\text{m}}{\text{s}}$ (D) $32.0 \text{ kg} \frac{\text{m}}{\text{s}}$ (E) $97.0 \text{ kg} \frac{\text{m}}{\text{s}}$
44. 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

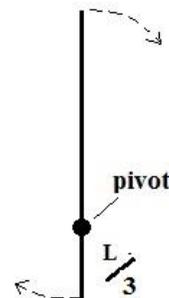
45. A $6.00 \mu\text{F}$ parallel-plate capacitor is disconnected from a 12 volt battery after being fully charged. A person now carefully inserts a dielectric material of constant $\kappa = 2$ so that it fills one-half of the space between the plates as shown. How much work was done by the person while inserting the dielectric?



- (A) $-81 \mu\text{J}$ (B) $-108 \mu\text{J}$ (C) $-144 \mu\text{J}$ (D) $-216 \mu\text{J}$ (E) $-288 \mu\text{J}$

46. A uniform rod of mass M and length L is fixed to rotate about a frictionless pivot located $L/3$ 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) $\frac{1}{4}g$

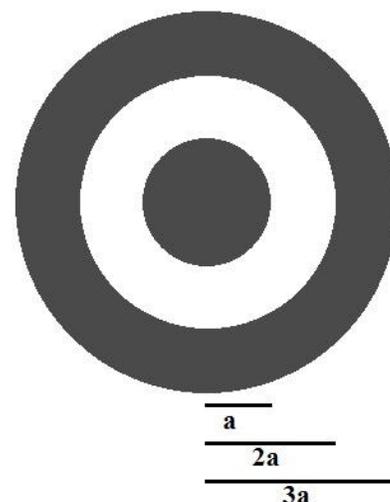


47. One mole of a diatomic ideal gas undergoes a reversible adiabatic process. The pressure and volume initially are given as $P = 2.0 \text{ atm}$ and $V = 30 L$. If the volume is halved during the adiabatic process, how much work was done on the gas sample by the surroundings?

- (A) 6790 J (B) 5530 J (C) 4850 J (D) 4200 J (E) 3040 J

48. 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 $V_{3a} = kQ/3a$. If the electric potential V_a at $r = a$ is 0 volts, what is the charge on the inner spherical shell, Q_{in} ?

- (A) $Q_{in} = -3/2 Q$
 (B) $Q_{in} = -2/3 Q$
 (C) $Q_{in} = -1/3 Q$
 (D) $Q_{in} = -2Q$
 (E) $Q_{in} = -1/2 Q$

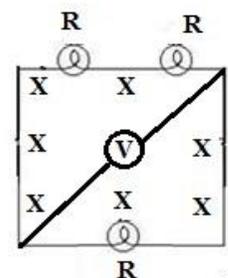


49. The kinetic energy associated with an electron is twice its rest energy. At what speed is the electron traveling?

- (A) $2.83 \times 10^8 \frac{m}{s}$ (B) $2.67 \times 10^8 \frac{m}{s}$ (C) $2.60 \times 10^8 \frac{m}{s}$ (D) $2.25 \times 10^8 \frac{m}{s}$ (E) $2.12 \times 10^8 \frac{m}{s}$

50. A magnetic field directed into the plane of the page is decreasing in time. A constant emf ξ 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) 0ξ (B) $\frac{1}{2} \xi$ (C) $\frac{1}{3} \xi$ (D) $\frac{1}{6} \xi$ (E) $\frac{2}{3} \xi$



IMPORTANT: All Division 2 students STOP HERE. Your last answer should be for #50.