PHYSICSBOWL 2017

March 29 – April 14, 2017

40 QUESTIONS – 45 MINUTES

The sponsors of the 2017 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 <u>two</u> divisions, each with <u>nineteen</u> 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 wanting a challenge.
- A school's team score in each division is the sum of the ***<u>five</u>*** highest student scores in that division.
- A school may compete in either or both divisions.

INSTRUCTIONS

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

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

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

Your *<u>School's CEEB code</u>* (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: *<u>45 minutes.</u>*

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

1. A scientist computes a speed as $\frac{12\ mm}{3\ \mu s}$. Which one of the following choices represents this same speed?

(A) $4\ \frac{km}{s}$ **(B)** $4\ \frac{nm}{s}$ **(C)** $4\ \frac{m}{s}$ **(D)** $4\ \frac{Gm}{s}$ **(E)** $4\ \frac{pm}{s}$

2. 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)** $160.0\ m$

3. Which one of the following choices is a vector quantity?

(A) average speed **(B)** kinetic energy **(C)** mass **(D)** time **(E)** acceleration

4. 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 ℃ **(D)** 100 °F **(E)** $0\ K$

5. 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) Huygens' Principle
(B) Kepler's First Law
(C) Hooke's Law
(D) Pascal's Principle
(E) Newton's First Law

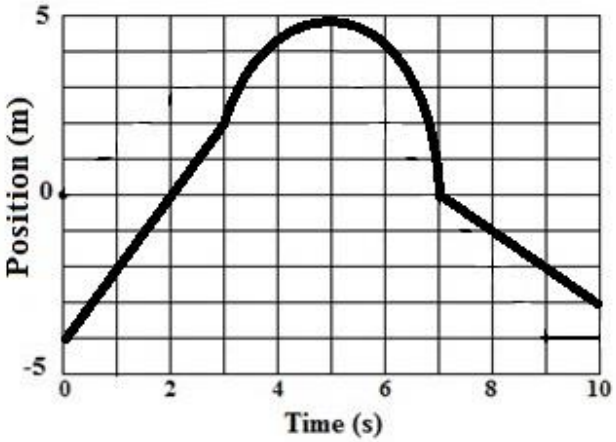
6. A mass connected to an ideal spring oscillates with a period T when it is released from rest at a position A from equilibrium. Which one of the following choices correctly identifies the period of oscillation for the mass connected to the same spring when it is released from rest at a position $2A$ from equilibrium?

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

7. A traveling sine wave of frequency 3.0 Hz is known to move at $6.0\frac{m}{s}$ 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)	

8. 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 $0\frac{m}{s^2}$? Time is represented as t.

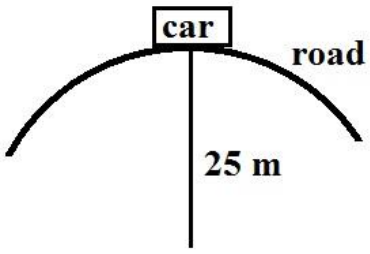


(A) only from $0\ s < t < 3\ s$
(B) only at $t = 5\ s$
(C) only from $7\ s < t < 10\ s$
(D) only from $0\ s < t < 3\ s$ and $7\ s < t < 10\ s$
(E) only from $0\ s < t < 3\ s$, $t = 5\ s$, and $7\ s < t < 10\ s$

9. A 4.00 kg object moves to the right with speed $5.00\frac{m}{s}$. A 5.00 kg object moves to the left with speed $3.00\frac{m}{s}$. After colliding, the 4.00 kg object moves to the left with speed $1.00\frac{m}{s}$. What is the speed of the 5.00 kg object after the collision?

(A) $1.00\frac{m}{s}$ **(B)** $1.80\frac{m}{s}$ **(C)** $3.00\frac{m}{s}$ **(D)** $4.11\frac{m}{s}$ **(E)** $7.80\frac{m}{s}$

10. A 2000 kg car moves over a hill at a constant speed of $12.0\frac{m}{s}$. At the very top of the hill, the shape of the road can be approximated as a circle with radius 25 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 kN **(B)** 8.5 kN **(C)** 11.5 kN **(D)** 20.0 kN **(E)** 31.5 kN

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

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.

11. What is the average speed of the block during the motion described?

(A) $7.00\frac{m}{s}$ **(B)** $3.74\frac{m}{s}$ **(C)** $3.65\frac{m}{s}$ **(D)** $2.65\frac{m}{s}$ **(E)** $2.58\frac{m}{s}$

12. Which one of the following choices best represents the magnitude of the block's acceleration during the motion described?

(A) $3.43\frac{m}{s^2}$ **(B)** $2.40\frac{m}{s^2}$ **(C)** $1.20\frac{m}{s^2}$ **(D)** $0.329\frac{m}{s^2}$ **(E)** $0.232\frac{m}{s^2}$

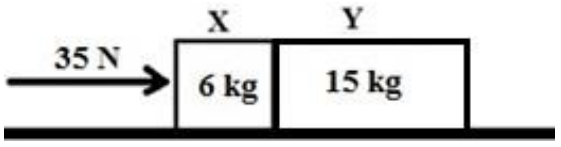
13. According to currently accepted theory, dark matter makes up approximately what percent of the Universe?

(A) 5 % **(B)** 25 % **(C)** 50 % **(D)** 80 % **(E)** 99 %

14. 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

15. 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

16. 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

17. 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

18. 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) $1.40\frac{rad}{s}$ **(B)** $6.60\frac{rad}{s}$ **(C)** $8.80\frac{rad}{s}$ **(D)** $13.2\frac{rad}{s}$ **(E)** $17.6\frac{rad}{s}$

19. An ideal gas at a temperature of 100 ℃ 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)** $1.88 \times 10^8\ Pa$

20. 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

21. 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.

22. A large swimming pool is filled with a liquid having a density of $5.00 \times 10^2\ \frac{kg}{m^3}$. 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.

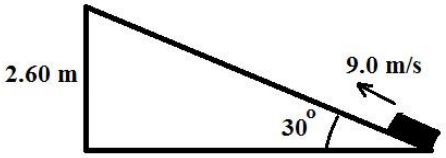
23. A 1500 kg car and a 6000 kg truck have a perfectly inelastic collision on a street. Which one of the following choices correctly identifies the object(s) that lose kinetic energy from the impact?

(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.

24. What condition must be met for the angular momentum of a system to be constant?

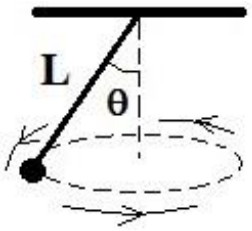
(A) The mechanical energy is constant.
(B) There is no net external force acting on the system.
(C) The system is in static equilibrium.
(D) There is no net external torque acting on the system.
(E) Only the gravitational force is acting on the system.

25. A box slides with uniform acceleration up an incline. The box has an initial speed of $9.0\frac{m}{s}$ and rises vertically $2.60\ m$ before coming to rest. If the angle of the incline is 30°, what is the coefficient of kinetic friction between the box and the incline?



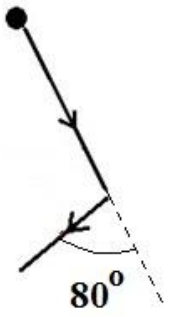
(A) 0.298 **(B)** 0.322 **(C)** 0.372 **(D)** 0.483 **(E)** 0.557

26. A 4.00 kg mass is in uniform circular motion as shown in the figure. The string to which the mass is attached has a length of $L = 3.00\ m$ and forms an angle of $\theta = 50.0^{\circ}$ with the vertical. What is the speed of the mass?



(A) $5.23\frac{m}{s}$ **(B)** $5.54\frac{m}{s}$ **(C)** $5.98\frac{m}{s}$ **(D)** $6.62\frac{m}{s}$ **(E)** $6.90\frac{m}{s}$

27. A 2.0 kg mass moves at $10.0\frac{m}{s}$ when it has a collision in space. The mass's speed was unchanged, but the direction of its velocity was altered by 80°. If the collision lasted $0.25\ s$, what was the magnitude of the average force exerted on the mass?



(A) $0\ N$ **(B)** $54.7\ N$ **(C)** $102.8\ N$ **(D)** $122.5\ N$ **(E)** $150.3\ N$

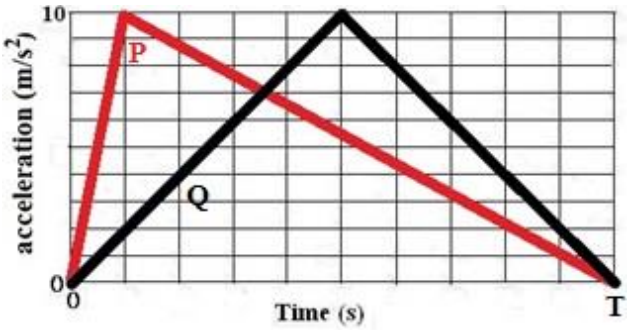
28. A shipment of parts is labeled in units of "ohm·second." Which one of the following choices represents an equivalent unit?

(A) henry **(B)** farad **(C)** joule **(D)** volt **(E)** weber

29. 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

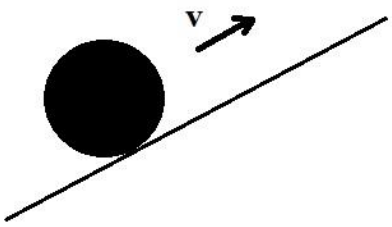
30. Two cars, P and Q, each start from rest at the origin and will move along the x-axis. The acceleration vs. time graph for each car is shown. Which one of the following choices correctly identifies the relationship for both the speeds (v_P and v_Q) and the positions (x_P and x_Q) of the cars at time 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)	$v_P = v_Q$	$x_P < x_Q$

31. 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

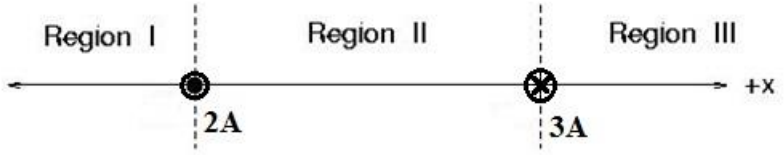


32. A projectile is launched at an angle of 40° above the horizontal with a speed of $30\,\frac{m}{s}$. How much time passes before the position of the projectile makes an angle of 20° above the horizontal from the original launch point?

(A) 3.02 s **(B)** 2.38 s **(C)** 2.18 s **(D)** 1.93 s **(E)** 1.64 s

33. Two long wires are fixed in space so that the conventional current in the left wire ($2\ A$) comes out of the plane of the page and the conventional current in the right wire ($3\ A$) 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?

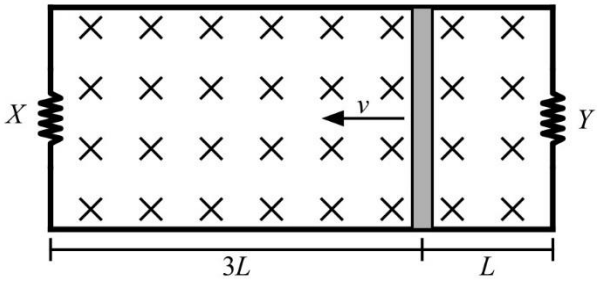
(A) Only in Region I
(B) In both Regions I and II
(C) Only in Region II
(D) In both Regions I and III
(E) In both Regions II and III



34. 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)** $31.2\ kg$

35. 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	$I_X > I_Y$

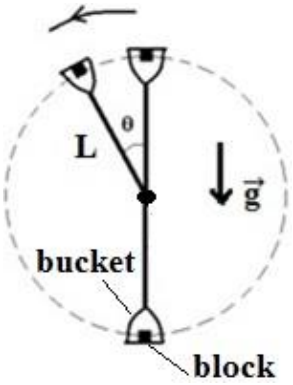
36. A scientist performs an experiment in which she determines the shortest length of a gas column needed to create resonance for a vibrating tuning fork over a tube closed at one end. She plots the gas column length against the inverse of the frequency for a set of tuning forks and finds that she has 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)** $4m$

37. 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}

38. 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.

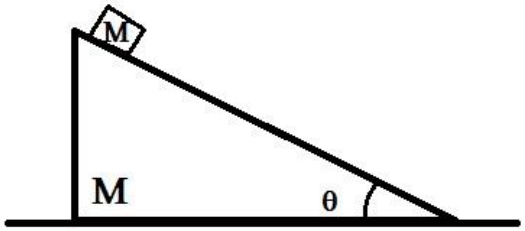


(A) 8.0 N **(B)** 10.0 N **(C)** 15.4 N **(D)** 18.7 N **(E)** 37.3 N

39. 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)** $\frac{2}{3}v$

40. 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 θ 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) $Mg\ (2 - \sin\theta)$

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

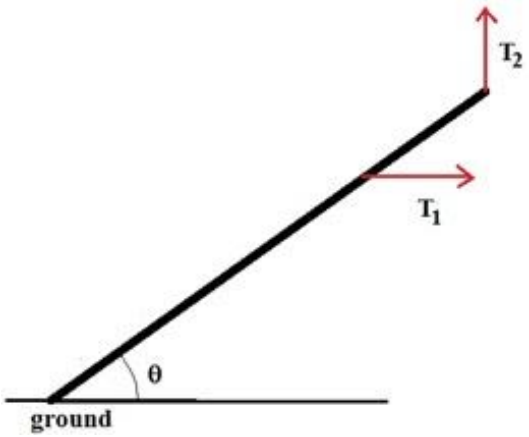
All Division 2 students continue to Questions 41 – 50.

ATTENTION: All Division 1 students – <u>STOP HERE</u>.
All Division 2 students – continue to question #50.

41. Pure red light shines through a diffraction grating of $1200\,\frac{lines}{cm}$ 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?

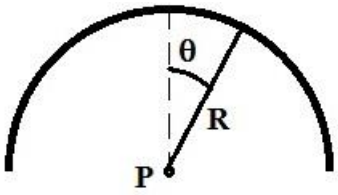
(A) $0.02\ m$ **(B)** $0.10\ m$ **(C)** $1.0\ m$ **(D)** $2.0\ m$ **(E)** $4.0\ m$

42. 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 θ in the figure?



(A) 18.4°
(B) 21.8°
(C) 33.7°
(D) 36.9°
(E) 45.0°

43. A semi-circle has radius R, total charge Q, and a charge per unit length given as $\lambda = \lambda_0 \cos\theta$ with θ defined in the figure and λ_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)** $\frac{k_e\lambda_0\,\pi}{2R}$

44. 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)** $1.70\ s$

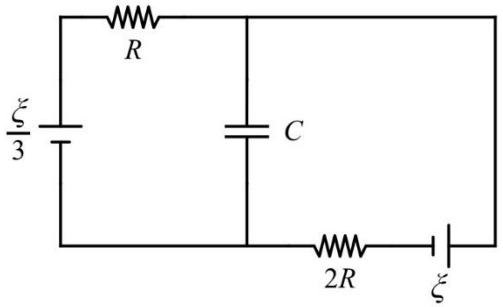
45. Which one of the following magnifications cannot be produced using a single converging lens?

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

46. 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?

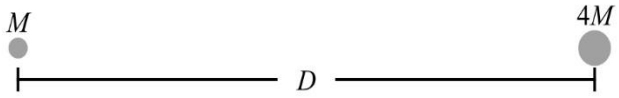
(A) There is a net movement of electrons from sphere *Y* to sphere *X* until the electric field just outside the surface of each sphere has the same magnitude.
(B) There is a net movement of electrons from sphere *Y* to sphere *X* until the electric potential just outside the surface of each sphere has 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.

47. 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)** $\frac{2}{3}\xi$

48. 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?

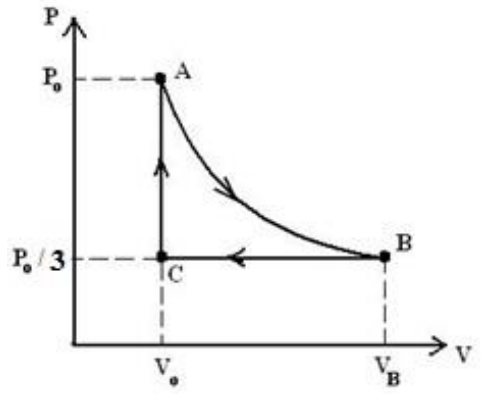


(A) $\frac{\pi^2 D^3}{5GT^2}$ **(B)** $\frac{4\pi^2 D^3}{5GT^2}$ **(C)** $\frac{4\pi^2 D^3}{GT^2}$ **(D)** $\frac{16\pi^2 D^3}{5GT^2}$ **(E)** $\frac{25\pi^2 D^3}{4GT^2}$

49. Two identical particles travel to the right. The particle traveling at $2.40 \times 10^8 \frac{m}{s}$ collides with and sticks to the other particle traveling at $1.80 \times 10^8 \frac{m}{s}$. Which one of the following choices best represents the speed of the resulting object after collision?

(A) $2.20 \times 10^8 \frac{m}{s}$ **(B)** $2.14 \times 10^8 \frac{m}{s}$ **(C)** $2.10 \times 10^8 \frac{m}{s}$ **(D)** $2.06 \times 10^8 \frac{m}{s}$ **(E)** $2.00 \times 10^8 \frac{m}{s}$

50. 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

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