PHYSICSBOWL 2013

April 3 – April 17, 2013

40 QUESTIONS – 45 MINUTES

The sponsors of the 2013 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 fourteen regions, each with two divisions.
  - *Division 01* is for students *taking physics for the first time* (even if that first course is AP Physics).
  - *Division 02* 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 *School's CEEB code* (given to you by your teacher)
- 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* (01 for first-year physics students, 02 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 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 01 students will answer only questions 1 – 40. Numbers 41 – 50 on the answer sheet should remain blank for all Division 01 students.

Division 02 students will answer only questions 11 – 50. Numbers 1 – 10 on the answer sheet should remain blank for all Division 02 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!

ATTENTION: **All Division 01 students, START HERE.**
All Division 02 students – skip the first 10 questions and begin on #11.

***** Treat $g = 10\ {}^{m}/_{s^2}$ for ALL questions #1 – #50.**

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

(A) 1×10^{-3} **(B)** 1×10^{-6} **(C)** 1×10^{-9} **(D)** 1×10^{-12} **(E)** 1×10^{-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.

2. With what speed does the object reach the ground?

(A) $31.3\frac{m}{s}$ **(B)** $25.0\frac{m}{s}$ **(C)** $12.5\frac{m}{s}$ **(D)** $10.0\frac{m}{s}$ **(E)** $2.50\frac{m}{s}$

3. 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)** $62.5\ m$

4. 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

5. 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

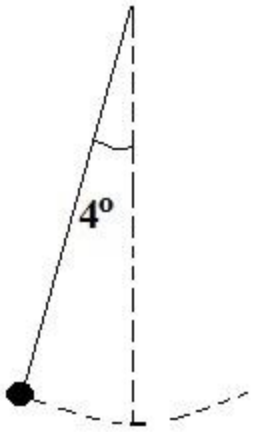
6. A $1.50\ m$-long string clamped at both ends is vibrating at its second harmonic. What is the wavelength associated with the string for this scenario?

(A) $3.00\ m$ **(B)** $2.25\ m$ **(C)** $1.50\ m$ **(D)** $1.00\ m$ **(E)** $0.75\ m$

7. 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) $4.17 \times 10^{-11} C$
(B) $8.33 \times 10^{-11} C$
(C) $1.67 \times 10^{-10} C$
(D) $9.13 \times 10^{-6} C$
(E) $1.29 \times 10^{-5} C$

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

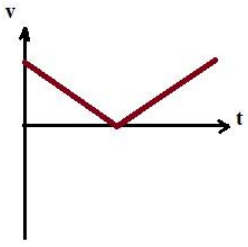


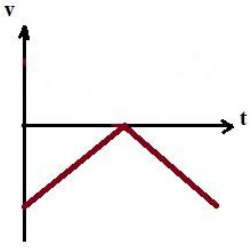
(A) Low Emission Dial
(B) Light Emitting Diode
(C) Light Energy Divider
(D) Lower Edge Disc
(E) Limiting Emission Diode

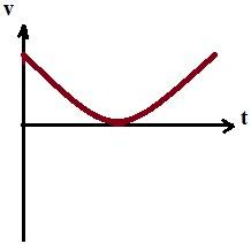
9. A simple pendulum oscillates with a period of 2.0 s. If the maximum oscillation of the pendulum is 4.0° from equilibrium, what is the length of the string for this pendulum?

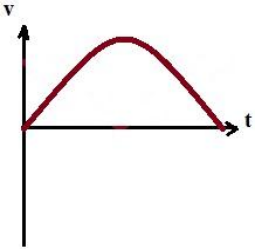
(A) 6.4 m **(B)** 3.2 m **(C)** 1.6 m **(D)** 1.0 m **(E)** 0.5 m

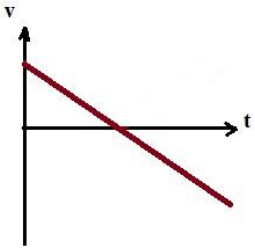
10. An object is thrown straight upward. The object remains in free fall until it returns to its initial launch point. Which one of the following graphs could represent the velocity of the object as a function of time during its flight?

(A)


(B)


(C)


(D)


(E)


ATTENTION: All Division 01 students, continue to question #40.
All Division 02 students, START HERE. Numbers 1 – 10 on your answer sheet should be blank. Your first answer should be for #11.

***** Treat $g = 10\ {}^{m}/_{s^2}$ for ALL questions #1 – #50.**

11. 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.

12. 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

13. 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)** $2.00005\ m$

14. A small ball is thrown at an angle of 30.0° above the horizontal ground with a speed of $20.0\frac{m}{s}$. 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)** $20.0\ m$

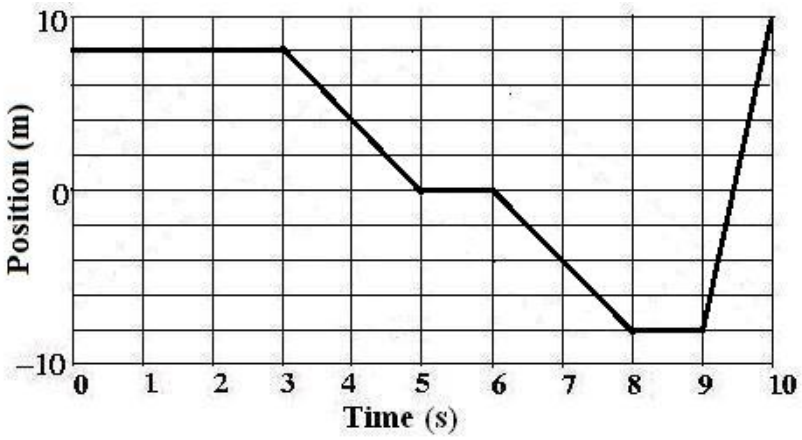
15. In a circuit, the flow of electrons in a horizontal wire produces a constant current of $3.20\ A$ for a time of $3.0\ hr$. Which one of the following choices best represents the number of electrons that pass through a vertical cross-section of the wire during this time?

(A) 9.60 **(B)** 6.00×10^{19} **(C)** 7.20×10^{22} **(D)** 2.16×10^{23} **(E)** 6.02×10^{23}

16. 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

17. 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)** $42\ m$

18. 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

19. 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

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

(A) 4.05×10^{18} **(B)** 4.10×10^{20} **(C)** 4.05×10^{21} **(D)** 4.10×10^{23} **(E)** 4.10×10^{26}

21. The following nuclear reaction occurs: ${}^{131}_{53}I \rightarrow {}^{131}_{54}Xe + {}^{A}_{Z}X$. What is ${}^{A}_{Z}X$?

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

22. 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)** $\frac{2}{5}R$

23. 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 $4.50\frac{rad}{s^2}$. What is the magnitude of the net force acting on the object after a time of $t = \frac{1}{3}s$ if the object remains at rest with respect to the disk?

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

24. 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.

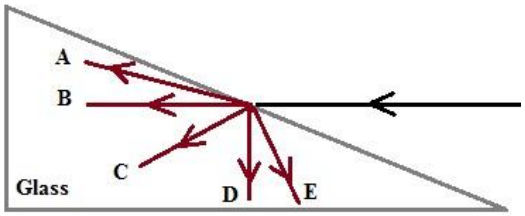
25. An ideal fluid completely fills a small horizontal tube that has a narrowing cross-sectional area as seen in the figure. Which one of the following choices best describes what has happened to the fluid's speed and its associated pressure in the narrower region as compared to the wider region?

(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.

26. 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 $^{m}/_{s^2}$ **(B)** 2.50 $^{m}/_{s^2}$ **(C)** 4.00 $^{m}/_{s^2}$ **(D)** 6.25 $^{m}/_{s^2}$ **(E)** 8.50 $^{m}/_{s^2}$

27. 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?

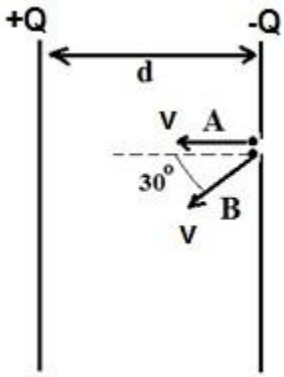


(A) A **(B)** B **(C)** C **(D)** D **(E)** E

28. 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_{obj} and the magnitude of the acceleration from gravity is g.

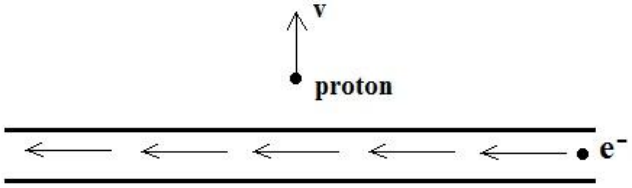
(A) $a_{obj} = g$
(B) $a_{obj} > g$
(C) $a_{obj} < g$
(D) $a_{obj} \geq g$
(E) None of the previous relations must be true.

29. 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° 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.

30. 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?

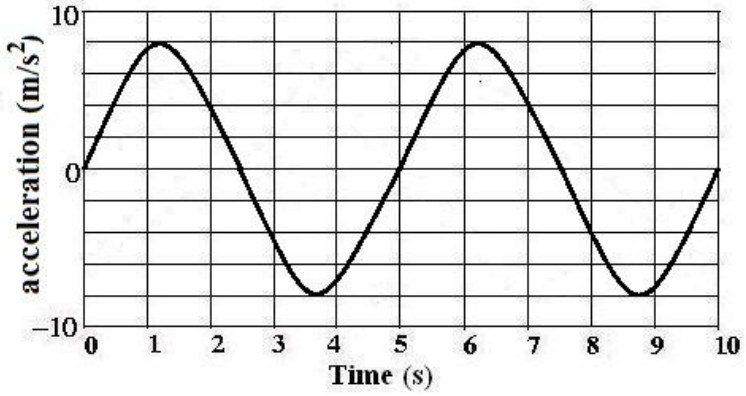


(A) To the left
(B) To the right
(C) Into the plane of the page
(D) Out of the plane of the page
(E) There is no force

31. 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

32. An acceleration vs. time graph for an object moving along a line is shown. The object starts from rest at time $t = 0\ s$. 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

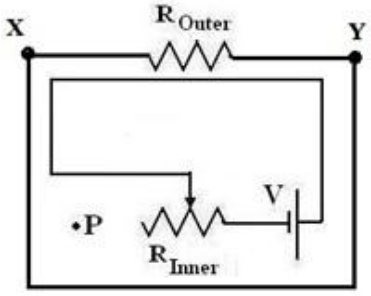
33. At the top of a high cliff, a small rock is dropped from rest. A ball is launched straight downward with an initial speed of $36.0\frac{m}{s}$ at a time $2.10\ s$ after the rock was dropped. When the ball has fallen $28.0\ m$ further than the initially dropped rock, what is the speed of the ball relative to the rock?

(A) $15.0\frac{m}{s}$ **(B)** $16.0\frac{m}{s}$ **(C)** $20.0\frac{m}{s}$ **(D)** $21.0\frac{m}{s}$ **(E)** $36.0\frac{m}{s}$

34. Which one of the following choices represents the base MKS units for sound intensity?

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

35. 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

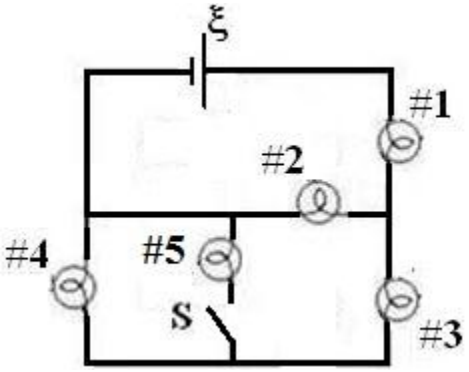
36. The principal quantum number of an electron is $n = 5$. How many possible values of the orbital magnetic quantum number m_l are there for this electron?

(A) 25 **(B)** 11 **(C)** 9 **(D)** 5 **(E)** 4

37. 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

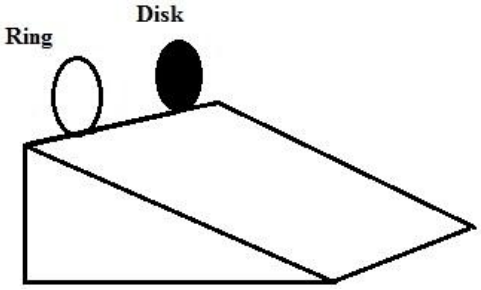
38. Five identical light bulbs are connected into a circuit as shown. All wires are ideal with no resistance, and the ideal battery has emf ξ. When the switch S in the circuit is closed, aside from bulb #5, which of the other bulbs brighten?



(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 $\mu_{disk} > \mu_{ring}$.



39. 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.

40. 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)** μ_{disk}: μ_{ring} **(D)** 4: 3 **(E)** 3: 4

IMPORTANT: All Division 01 students <u>STOP HERE</u>. Your last answer should be for #40.
Numbers 41-50 should remain blank for Division 01 students.

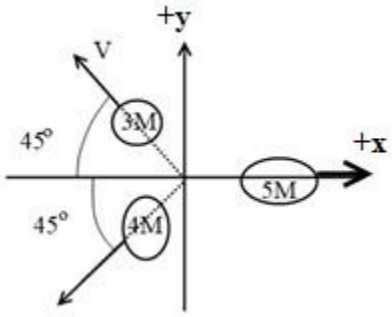
All Division 02 students continue to Questions 41 – 50.

ATTENTION: All Division 01 students, STOP HERE.
All Division 02 students, continue to question #50.

41. An engine operates between a low temperature of 273 ℃ and a high temperature of 546 ℃. What is the maximum theoretical efficiency of this engine?

(A) $^1/_3$ **(B)** $^2/_3$ **(C)** $^1/_4$ **(D)** $^1/_2$ **(E)** $^3/_4$

42. 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)** $\frac{7}{5\sqrt{2}}V$

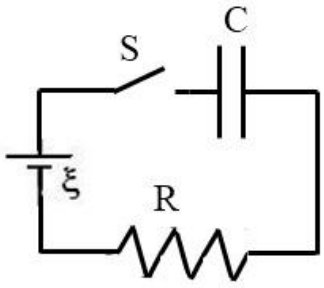
43. A small 1.0 kg mass is launched from the top of a cliff with speed V at an angle of 30° above the horizontal. When the mass reaches the ground, its velocity is directed at 45° below the horizontal. Which one of the following choices is the magnitude of the total impulse that was imparted to the mass during its flight? Ignore air resistance.

(A) $\frac{1}{2}\left(\sqrt{3}+1\right)V$ **(B)** $\sqrt{\frac{3}{2}\frac{(\sqrt{2}+1)}{2}}\,V$ **(C)** $\frac{1}{2}\left(\sqrt{3}-1\right)V$ **(D)** $\frac{1}{2}\left(\sqrt{\frac{3}{2}}+1\right)V$ **(E)** $\sqrt{\frac{3}{2}\frac{(\sqrt{2}+1)}{(\sqrt{2}-1)}}\,V$

44. 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

45. The switch S in the RC circuit shown is closed at time $t = 0$. All circuit elements are ideal and $R = 10.0\ \Omega$, $C = 2.20\ F$ and $\xi = 12.0\ V$. 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

46. Which one of the following quarks was the last to be confirmed experimentally?

(A) Charmed **(B)** Up **(C)** Strange **(D)** Down **(E)** Top

47. 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}

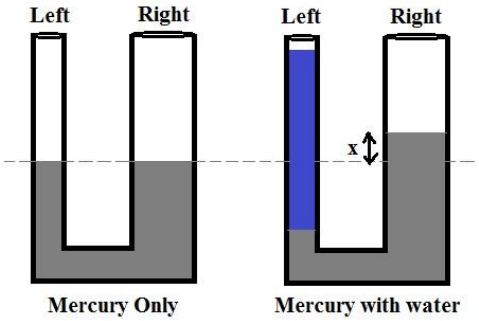
48. Two identical samples of a monatomic ideal gas are to undergo reversible processes. Which one of the following choices is a correct statement about the heat associated with the processes?
Process 1: An isochoric pressure doubling
Process 2: An isobaric volume doubling

(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.

49. 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 $1.20 \times 10^8 \frac{m}{s}$, what is the speed of the faster moving electron?

(A) $2.67 \times 10^8 \frac{m}{s}$ **(B)** $2.40 \times 10^8 \frac{m}{s}$ **(C)** $2.24 \times 10^8 \frac{m}{s}$ **(D)** $1.97 \times 10^8 \frac{m}{s}$ **(E)** $1.56 \times 10^8 \frac{m}{s}$

50. A U-tube is filled with mercury (density 13.6 $^{g}/_{cm^3}$) 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 cm^2 while the right tube has cross-sectional area 15.0 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

IMPORTANT: All Division 02 students STOP HERE. Your last answer should be for #50.