PHYSICSBOWL – APRIL 1 – APRIL 15, 2010

40 QUESTIONS – 45 MINUTES

The sponsors of the 2010 PhysicsBowl, including the **American Association of Physics Teachers** and **Texas Instruments**, 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 15 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 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 ALL of this information is not properly bubbled, you will be disqualified from individual awards 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 will be required to answer only 40 questions. Answers should be marked on the answer sheet next to the number corresponding to the number of the question 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 these instructions 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!**

If your exam is a photocopy or previously opened, your school is in violation of US copyright law and the contest rules.

Do Not Open This Booklet Until You Are Told to Begin.

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

1. 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}

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

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

3. 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

4. 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) $v_3 < v_2 = v_1$

5. 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.

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

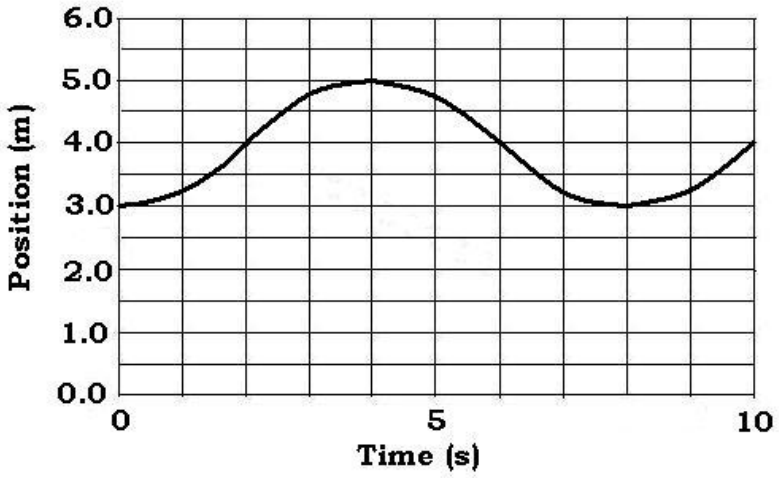
(A) "What goes up must come down."
(B) "For every action force, there is an equal but opposite reaction force."
(C) "An object at rest remains at rest."
(D) "The acceleration of an object is directly proportional to the force acting on the object but inversely proportional to the mass of the object."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

7. 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.



8. 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

9. 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

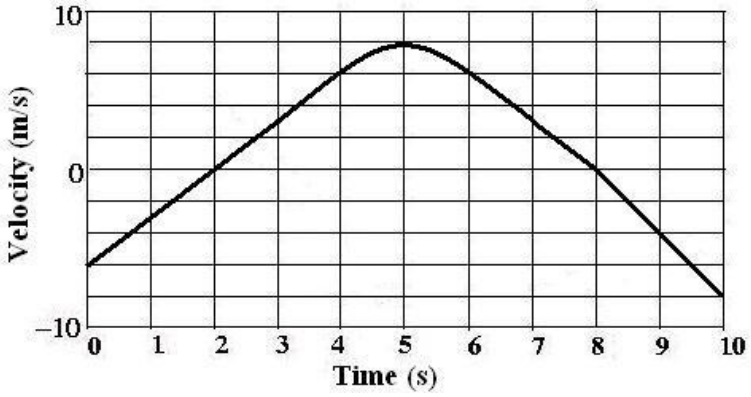
10. A particle travels at a constant speed around a circular path of radius R. If the particle makes one complete trip around the entire circle, what is the magnitude of the displacement for this trip?

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

<u>ATTENTION</u>: All Division 01 students, continue through question 40.

ATTENTION: All Division 02 students, START HERE. Numbers 1-10 on your answer sheet should be blank. Your first answer should be for #11.

11. 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 $0\ m/s^2$?



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

12. 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

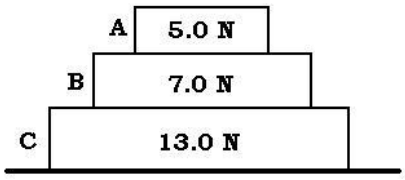
13. The Large Hadron Collider (LHC) is the largest particle accelerator in the world. To which of the following countries would you have to travel in order to visit the LHC?

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

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

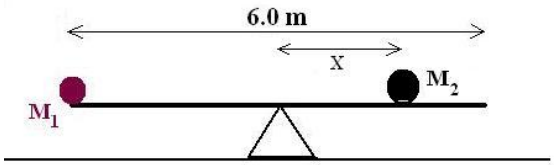
(A) $300\,K$ **(B)** $273\,K$ **(C)** $246\,K$ **(D)** $27\,K$ **(E)** $9\,K$

15. 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) $13.0\,N$

16. 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 (X) 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)** $3.00\,m$

17. 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

18. 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

19. 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) $v_{X\,ray} < v_{microwaves} < v_{UV\ rays}$
(B) $v_{microwaves} < v_{UV\ rays} < v_{X\,ray}$
(C) $v_{X\,ray} = v_{microwaves} = v_{UV\ rays}$
(D) $v_{UV\ rays} < v_{microwaves} < v_{X\,ray}$
(E) $v_{X\,ray} < v_{UV\ rays} < v_{microwaves}$

20. A sample of ideal gas is in a container at a temperature of $100\ ^{\circ}C$ 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) 4.58×10^{24} **(B)** 1.23×10^{24} **(C)** 6.25×10^{23} **(D)** 4.53×10^{22} **(E)** 1.21×10^{22}

21. 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

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

(A) 500000 N **(B)** 375000 N **(C)** 100 N **(D)** 75 N **(E)** 25 N

23. 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)** ${}^{T}/_{4}$

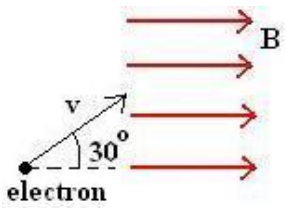
24. By computing the area under the acceleration vs. time graph for a fixed time interval of an object's motion, what quantity has been determined for that object?

(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

25. 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?

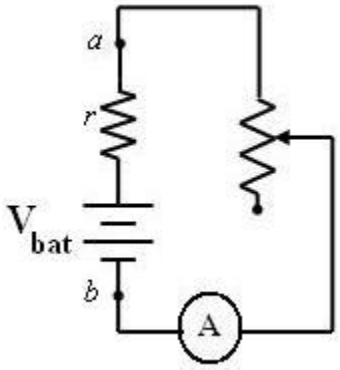
(A) ${}^{H}/_{4}$ **(B)** ${}^{H}/_{2}$ **(C)** H **(D)** $2H$ **(E)** $4H$

26. An electron moving in the plane of the page at an angle of 30° 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

27. The circuit shown contains a battery (of emf V_{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.

28. 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.

29. 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 $h/2$?

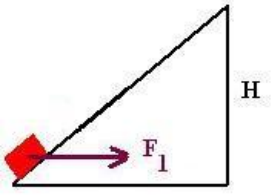
(A) $0.25t$ **(B)** $0.41t$ **(C)** $0.50t$ **(D)** $0.71t$ **(E)** $1.00t$

30. Chromatic aberration from a lens is a consequence of

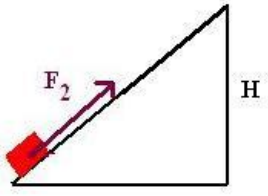
(A) polarization.
(B) interference.
(C) total internal reflection.
(D) diffraction.
(E) dispersion.

31. 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.



Trial 1
Force parallel to floor



Trial 2
Force parallel to incline

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 $g = 10\,{}^{m}\!/_{s^2}$ for this situation.

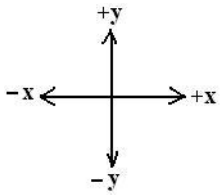
32. What is the magnitude of the average acceleration (in units of ${}^{m}\!/_{s^2}$) of the ball while it is in contact with the ground?

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

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

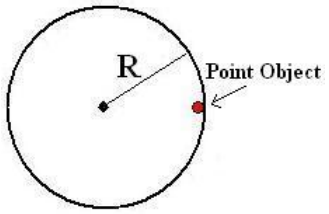
(A) 2.4 **(B)** 12.0 **(C)** 20.0 **(D)** 26.0 **(E)** 32.0

34. 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

35. 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 $\alpha = 5.00\,{}^{rad}\!/_{s^2}$ 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

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

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

37. 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 $V(x = -4\,m) = -4.0\,volts$ and $V(x = -2\,m) = -2.0\,volts$. 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.

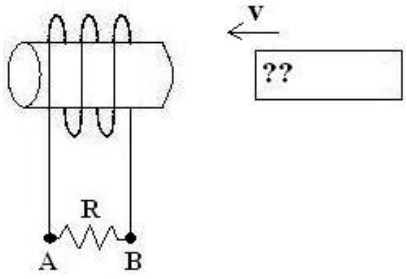
38. Two objects both move and uniformly accelerate to the right.
At time $t = 0$, the objects are at the same initial position but
- Object 1 has initial speed twice that of Object 2
- Object 1 has one-half the acceleration of Object 2.

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?

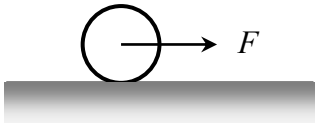
(A) 5:6 **(B)** 4:5 **(C)** 3:4 **(D)** 2:3 **(E)** 1:2

39. 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



40. 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)** $\frac{3}{4}F$

IMPORTANT: All Division 01 students STOP HERE. Your last answer should be number 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. 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)** 2 *P* **(C)** 4 *P* **(D)** 8 *P* **(E)** 16 P

42. 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)	Increases	Increases	Decreases
(B)	Increases	Constant	Decreases
(C)	Decreases	Decreases	Increases
(D)	Increases	Increases	Constant
(E)	Constant	Constant	Constant

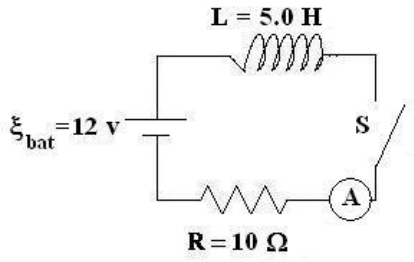
43. Two ions travel perpendicular to the same uniform magnetic field. The ions carry the same charge and have the same path radius in the magnetic field. Which of the following quantities must be the same for the two ions?

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

44. 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

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



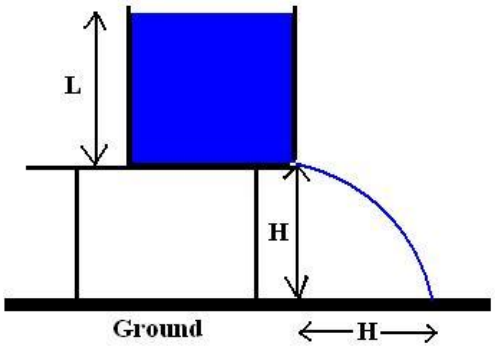
(A) 0.40 **(B)** 1.0 **(C)** 2.0 **(D)** 3.2 **(E)** 4.8

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

$$^{22}_{11}Na + X \rightarrow {}^{22}_{10}Ne + \nu_e$$

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

47. 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

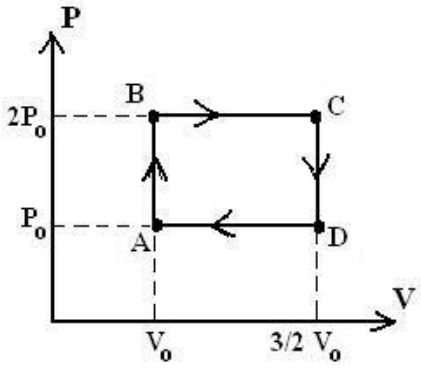
(D) $H\sqrt{2}$

(E) $2H$

48. 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

49. A monatomic ideal gas is the working substance for an engine that undergoes the cyclic process (ABCDA) 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)** $5/7$

50. An object of mass *m* is initially at rest. After this object is accelerated to a speed of $2.40\times10^8\,\frac{m}{s}$, 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) $2.25\times10^8\,\frac{m}{s}$ **(B)** $1.80\times10^8\,\frac{m}{s}$ **(C)** $1.66\times10^8\,\frac{m}{s}$ **(D)** $1.50\times10^8\,\frac{m}{s}$ **(E)** $1.20\times10^8\,\frac{m}{s}$

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