# AP® Physics B Exam

SECTION I: Multiple-Choice Questions

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO.**

**At a Glance**

**Total Time**
90 minutes
**Number of Questions**
70
**Percent of Total Grade**
50%
**Writing Instrument**
Pen required

### Instructions

Section I of this examination contains 70 multiple-choice questions. Fill in only the ovals for numbers 1 through 70 on your answer sheet.

CALCULATORS MAY NOT BE USED IN THIS PART OF THE EXAMINATION.

Indicate all of your answers to the multiple-choice questions on the answer sheet. No credit will be given for anything written in this exam booklet, but you may use the booklet for notes or scratch work. After you have decided which of the suggested answers is best, completely fill in the corresponding oval on the answer sheet. Give only one answer to each question. If you change an answer, be sure that the previous mark is erased completely. Here is a sample question and answer.

| Sample Question | Sample Answer |
|---|---|
| Chicago is a<br>(A) state<br>(B) city<br>(C) country<br>(D) continent<br>(E) village | Ⓐ ● Ⓒ Ⓓ Ⓔ |

Use your time effectively, working as quickly as you can without losing accuracy. Do not spend too much time on any one question. Go on to other questions and come back to the ones you have not answered if you have time. It is not expected that everyone will know the answers to all the multiple-choice questions.

### About Guessing

Many candidates wonder whether or not to guess the answers to questions about which they are not certain. Multiple choice scores are based on the number of questions answered correctly. Points are not deducted for incorrect answers, and no points are awarded for unanswered questions. Because points are not deducted for incorrect answers, you are encouraged to answer all multiple-choice questions. On any questions you do not know the answer to, you should eliminate as many choices as you can, and then select the best answer among the remaining choices.

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Advanced Placement Examination
PHYSICS B
SECTION I

TABLE OF INFORMATION FOR 2011

**CONSTANTS AND CONVERSION FACTORS**

| | |
|---|---|
| 1 unified atomic mass unit, | $1\ \text{u} = 1.66 \times 10^{-27}\ \text{kg}$ |
| | $= 931\ \text{MeV}/c^2$ |
| Proton mass, | $m_p = 1.67 \times 10^{-27}\ \text{kg}$ |
| Neutron mass, | $m_n = 1.67 \times 10^{-27}\ \text{kg}$ |
| Electron mass, | $m_e = 9.11 \times 10^{-31}\ \text{kg}$ |
| Electron charge magitude, | $e = 1.60 \times 10^{-19}\ \text{C}$ |
| Avogadro's number, | $N_0 = 6.02 \times 10^{23}\ \text{mol}^{-1}$ |
| Universal gas constant, | $R = 8.31\ \text{J}/(\text{mol}\cdot\text{K})$ |
| Boltzmann's constant, | $k_B = 1.38 \times 10^{-23}\ \text{J/K}$ |
| Speed of light, | $c = 3.00 \times 10^{8}\ \text{m/s}$ |
| Planck's constant, | $h = 6.63 \times 10^{-34}\ \text{J}\cdot\text{s}$ |
| | $= 4.14 \times 10^{-15}\ \text{eV}\cdot\text{s}$ |
| | $hc = 1.99 \times 10^{-25}\ \text{J}\cdot\text{m}$ |
| | $= 1.24 \times 10^{3}\ \text{eV}\cdot\text{nm}$ |
| Vacuum permittivity, | $\epsilon_0 = 8.85 \times 10^{-12}\ \text{C}^2/\text{N}\cdot\text{m}^2$ |
| Coulomb's law constant, | $k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}\ \text{N}\cdot\text{m}^2/\text{C}^2$ |
| Vacuum permeability, | $\mu_0 = 4\pi \times 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$ |
| Magnetic constant, | $k' = \mu_0/4\pi = 10^{-7}\ (\text{T}\cdot\text{m})/\text{A}$ |
| Universal gravitational constant, | $G = 6.67 \times 10^{-11}\ \text{m}^3/\text{kg}\cdot\text{s}^2$ |
| Acceleration due to gravity at Earth's surface, | $g = 9.8\ \text{m/s}^2$ |
| 1 atmosphere pressure, | $1\ \text{atm} = 1.0 \times 10^{5}\ \text{N/m}^2$ |
| | $= 1.0 \times 10^{5}\ \text{Pa}$ |
| 1 electron volt, | $1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$ |

**UNITS**

| Name | Symbol |
|---|---|
| meter | m |
| kilogram | kg |
| second | s |
| ampere | A |
| kelvin | K |
| mole | mol |
| hertz | Hz |
| newton | N |
| pascal | Pa |
| joule | J |
| watt | W |
| coulomb | C |
| volt | V |
| ohm | Ω |
| henry | H |
| farad | F |
| tesla | T |
| degree Celsius | °C |
| electron-volt | eV |

**PREFIXES**

| Factor | Prefix | Symbol |
|---|---|---|
| $10^9$ | giga | G |
| $10^6$ | mega | M |
| $10^3$ | kilo | k |
| $10^{-2}$ | centi | c |
| $10^{-3}$ | milli | m |
| $10^{-6}$ | micro | μ |
| $10^{-9}$ | nano | n |
| $10^{-12}$ | pico | p |

**VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES**

| $\theta$ | $\sin\theta$ | $\cos\theta$ | $\tan\theta$ |
|---|---|---|---|
| 0° | 0 | 1 | 0 |
| 30° | 1/2 | $\sqrt{3}/2$ | $\sqrt{3}/3$ |
| 37° | 3/5 | 4/5 | 3/4 |
| 45° | $\sqrt{2}/2$ | $\sqrt{2}/2$ | 1 |
| 53° | 4/5 | 3/5 | 4/3 |
| 60° | $\sqrt{3}/2$ | 1/2 | $\sqrt{3}$ |
| 90° | 1 | 0 | ∞ |

The following conventions are used in this examination.

I. Unless otherwise stated, the frame of reference of any problem is assumed to be inertial.
II. The direction of any electric current is the direction of flow of positive charge (conventional current).
III. For any isolated electric charge, the electric potential is defined as zero at an infinite distance from the charge.
IV. For mechanics and thermodynamics equations, *W* represents the work done on a system.

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**PHYSICS B**

**SECTION I**

**Directions:** Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case and then fill in the corresponding oval on the answer sheet.

**Note:** To simplify calculations, you may use $g = 10\ \text{m/s}^2$ in all problems.

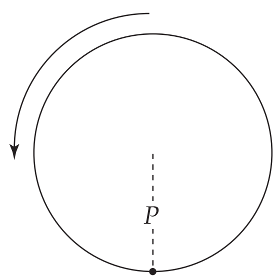
1. Which of the following must be true if the net force acting on an object is zero?

    I. The object is at rest
    II. The object has a constant velocity
    III. No forces act on the object

    (A) I only
    (B) II only
    (C) III only
    (D) Either I or III, but not II
    (E) None of these must be true

2. An elevator has a mass of 500 kg. It may safely carry an additional mass of 1000 kg and accelerate upward at $2\ \text{m/s}^2$. What is the tension in the cable under these maximum conditions?

    (A) 4,900 N
    (B) 9,800 N
    (C) 11,700 N
    (D) 14,700 N
    (E) 17,700 N

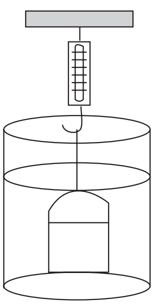



3. Here is the top view of a stopper tied to a string and spun in a horizontal circle. Which of the following would match with an object moving at point *P* in a counter-clockwise direction?

    (A) **v**↓ **a**↑ $\mathbf{F}_{net}$↑
    (B) **v**↓ **a**↓ $\mathbf{F}_{net}$↓
    (C) **v**→ **a**→ $\mathbf{F}_{net}$→
    (D) **v**→ **a**↓ $\mathbf{F}_{net}$↓
    (E) **v**→ **a**↑ $\mathbf{F}_{net}$↑

4. A ball is thrown with a velocity of 20 m/s at an angle of 30 degrees above the horizon. When the ball reaches its highest point, which of the following is true?

    (A) It has zero velocity.
    (B) It has zero acceleration.
    (C) It has minimum potential energy
    (D) It has minimum kinetic energy.
    (E) Two of the above



5. A 0.50 kg mass hangs from a spring scale. It is placed a container whose water level is initially at 1000 ml. The water level rises to 1200 ml when the mass is placed in the container as shown. What is the reading on the spring scale when the object is in the water?

    (A) 2.0 N
    (B) 3.0N
    (C) 5.0 N
    (D) 7.0 N
    (E) 12 N

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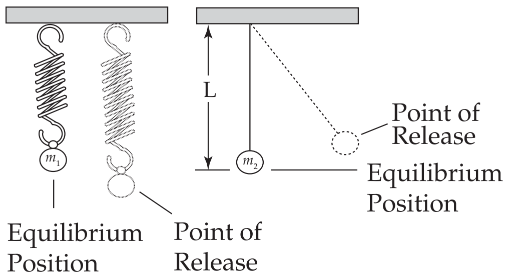
**Questions 6–7** refer to the following figure:




A mass on a spring and a simple pendulum undergo simple harmonic motion. There is no friction present as the mass on the spring, $m_1$, is displaced downward and released from rest or as the mass on the string, $m_2$, is displaced with a small sideways amplitude and released from rest.

6. Which of the following statements are true?

   I. Mechanical energy is constant.
   II. The momentum of the mass is constant.
   III. The period of the mass is constant.

   (A) I only
   (B) II only
   (C) III only
   (D) I and III, but not II
   (E) None of these must be true

7. If both masses have the same frequency of oscillation, what is the expression for the length of the string?

   (A) $\frac{m_1}{gk}$

   (B) $\frac{m_1 k}{g}$

   (C) $\frac{m_1 g}{k}$

   (D) $\frac{g}{m_1 k}$

   (E) $\frac{k}{m_1 g}$

8. A simple pendulum oscillates back and forth at a very small angle and undergoes simple harmonic motion with period $T$. The angle is halved, the mass hanging is reduced by a factor of three, and the length of the string is cut by a factor of four. What is the period of this new pendulum?

   (A) $4T$

   (B) $2T$

   (C) $T$

   (D) $\frac{1}{2}T$

   (E) $\frac{1}{4}T$

9. A frictionless cart of mass $2M$ moves at a velocity $V_0$. It collides and sticks to another frictionless cart of mass $M$ initially at rest. What is the final velocity of the two carts?

   (A) $V_0$

   (B) $\frac{V_0}{2}$

   (C) $\frac{3}{2}V_0$

   (D) $\frac{2}{3}V_0$

   (E) $\frac{1}{3}V_0$

10. A planet in a science fiction film is twice the radius of the earth and yet has only half the earth's mass. Gravity on that planet would be about

    (A) $\frac{1}{8}g$

    (B) $\frac{1}{4}g$

    (C) $1g$

    (D) $4g$

    (E) $8g$

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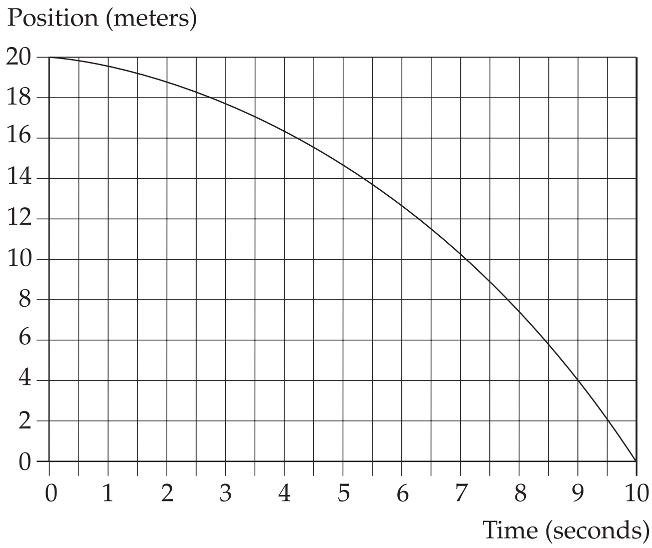


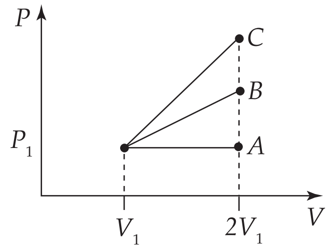

11. The instantaneous velocity at 9 seconds is closest to

(A) 4/9 m/s
(B) –4/9 m/s
(C) 7/4 m/s
(D) –7/4 m/s
(E) 2 m/s

12. A 100 g mass of Al has a specific heat of 0.27 cal/g°C. It is placed in an insulated container that contains 500 g of water which has a specific heat of 1 cal/g°C. They are allowed to come into thermal equilibrium. Consider the following statements:

I. The heat gained by the Al is equal to the heat lost by the water.
II. The temperature charge of the Al is equal to the temperature change of the water.
III. When in thermal equilibrium the two objects contain the same internal energy.

(A) I only
(B) II only
(C) III only
(D) Both I and II, but not III
(E) Both I and III, but not II




13. A cylinder with a piston on top contains an ideal gas at an initial pressure $P_1$, volume $V_1$, and Temperature $T_1$. The gas is allowed to expand to twice its original volume in three different ways as shown. The mechanical work done by the gas is

(A) greatest for path *A*
(B) greatest for path *B*
(C) greatest for path *C*
(D) equal for all paths
(E) can not be determined without knowing if isobaric, isothermal, or adiabatic

14. A charged particle moves through a magnetic field and experiences a force *F*. New particles are sent into the same magnetic field. If the new particles have twice the charge, twice the mass, and twice the velocity, the new force would be

(A) 4*F*

(B) 2*F*

(C) *F*

(D) $\frac{1}{2}F$

(E) $\frac{1}{4}F$

15. There is a negatively charged hollow sphere. Which of the following statements can be said of the sphere?

I. The electric field on the inside is zero.
II. For some distance $r > r_{sphere}$ you can consider the charge to be concentrated at the center to the sphere.
III. The electric field points inward toward the center of the sphere.

(A) I only
(B) II only
(C) III only
(D) I, II, and III
(E) Both I and III, but not II

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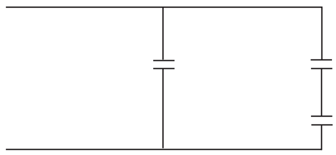
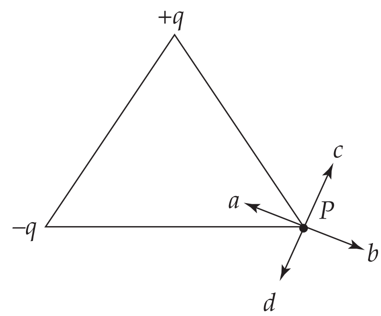


16. Each capacitor has a capacitance of C. What is the overall capacitance of the above circuit?
(A) 3C
(B) 3/2 C
(C) 2/3 C
(D) 1/3 C
(E) Cannot be determined with the voltage and charge

17. You have a wire of length $L$, radius $r$, and resistance $R$. You need to obtain half that resistance using the same material and changing only one factor. You could
(A) use half the length
(B) use twice the length
(C) use half the radius
(D) use twice the radius
(E) use twice the mass

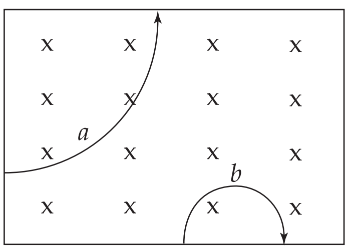
18. An electric motor has a label on it that reads: Input: 120V AC, 1.0 Amps, 60 Hz – Efficiency – 75%. At what constant speed can the motor lift up a 6 kg mass?
(A) 0.5 m/s
(B) 1.0 m/s
(C) 1.5 m/s
(D) 2.0 m/s
(E) 2.5 m/s

**Questions 19–20** refer to the following figure:




19. Two charges are placed as shown at the vertices of an equilateral triangle. What is the direction of the electric field at point $P$?
(A) $a$
(B) $b$
(C) $c$
(D) $d$
(E) the field cancels to zero at this point

20. If I placed a charge $+q$ at point $P$, the electric field at point $P$ would
(A) increase by 1/3
(B) increase by 1/2
(C) decrease by 1/3
(D) decrease by 1/2
(E) remain the same




21. A machine shoots either a proton, neutron, or electron into a magnetic field at various locations. The paths of two particles are shown above. Assume they are far enough apart so that they do not interact. What can you say about the paths that represent each particle?
(A) $a$ is the proton and $b$ is the electron.
(B) $b$ is the proton and $a$ is the electron.
(C) Either may be a neutron.
(D) You cannot make any conclusions without knowing the velocities.
(E) Two of the above are true.

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22. Heat is added to a cylindrical aluminum rod of radius r and length $\ell$. The coefficient of linear expansion for Al is $\alpha = 25 \times 10^{-6}$ 1/°C, The rod's temperature is increased from 10°C to 20°C. The length of the rod will now become

(A) $2\ell$

(B) $4\ell$

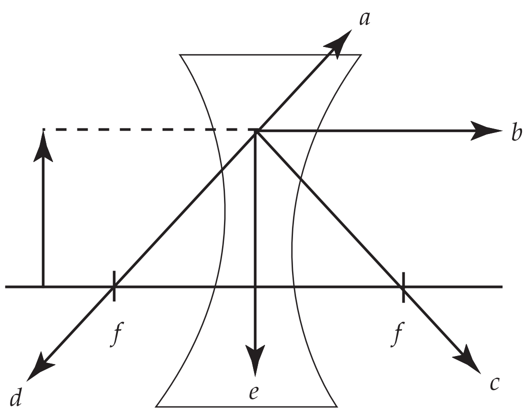
(C) $\ell^2$

(D) $\frac{1}{2}\ell$

(E) remain just about $\ell$

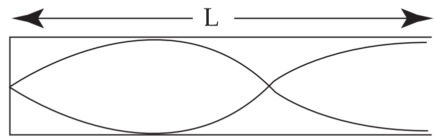
23. A rigid, solid container of constant volume holds an ideal gas of volume $V_1$ and temperature $T_1$ and pressure $P_1$. The temperature is increased in an isochoric process. Which of the following is NOT true?

(A) The average speed of the molecules increases.
(B) The pressure increases.
(C) The kinetic energy of the system increases.
(D) The volume increases.
(E) The number of collisions between molecules and the container increases.




24. A ray of light hits an object and travels parallel to the principal axis as shown by the dotted line. Which line shows the correct continuation of the ray after it hits the concave lens?

(A) *a*
(B) *b*
(C) *c*
(D) *d*
(E) *e*




25. A tube with one end closed and one end open resonates for a wave with wavelength $\lambda_a$ as shown. The next shorter wavelength at which resonance will occur is $\lambda_b$. The ratio of these two wavelengths $\frac{\lambda_a}{\lambda_b}$ is

(A) 1/4
(B) 1/3
(C) 3/5
(D) 5/3
(E) 3/1

26. Which of the following statements is true for a diverging lens?

I. It can only form virtual images.
II. The magnification is always less than 1.
III. It can form real images if the object is beyond the focal length and virtual images if the object is inside the focal length.

(A) I only
(B) II only
(C) III only
(D) II and III, only
(E) I and II only

27. Ultraviolet light has a wavelength of about $6 \times 10^{-8}$ m. What is the frequency of this light?

(A) $5 \times 10^{15}$ Hz
(B) 0.5 Hz
(C) 2 Hz
(D) 20 Hz
(E) $2 \times 10^{-16}$ Hz

28. Which of the following statements is true for both sound and light waves?

I. They can both be polarized.
II. They can both diffract.
III. They can both refract.

(A) I only
(B) II only
(C) III only
(D) I and II only
(E) II and III only

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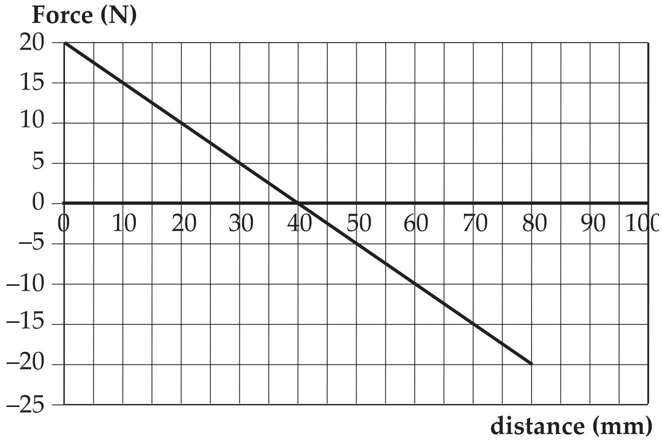
**Questions 29–30**

A spring stretches 4 cm when a 2.0 kg mass is hung from it. The mass is lifted up four cm and dropped. The following graph represents the net force acting on a spring as it falls 8 cm from top to bottom.




**Net Force vs. Distance**

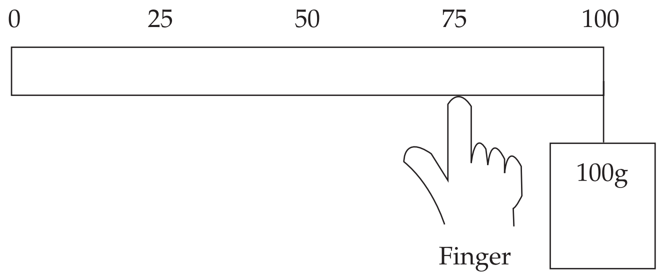
29. What is the net work done as the mass falls from 0 to 8 cm?
    (A) 160 J
    (B) 80 J
    (C) 20
    (D) 0 J
    (E) –5 J

30. What is the maximum velocity of the mass?
    (A) 0.2 m/s
    (B) 0.4
    (C) 0.8 m/s
    (D) 1.41 m/s
    (E) 4 m/s

31. A padded catcher's mitt slows down a 150 g ball from 20 m/s to rest in 0.01 seconds? What force does it exert on the ball?
    (A) 0.3 N
    (B) 33 N
    (C) 75 N
    (D) 133 N
    (E) 300 N

**Questions 32–33**

A 100 g mass is hung at the 100 cm mark of a uniform meter stick. You notice you can balance the meter stick on your finger if you place your finger at the 75 cm mark.




32. What is the torque the 100 g exerts on the meter stick taking the position of the finger to be the fulcrum?
    (A) 100 N·cm
    (B) 75 N·cm
    (C) 50 N·cm
    (D) 25 N·cm
    (E) 0 N·cm

33. What is the mass of the meter stick?
    (A) 200 g
    (B) 100 g
    (C) 75 g
    (D) 50 g
    (E) 25 g

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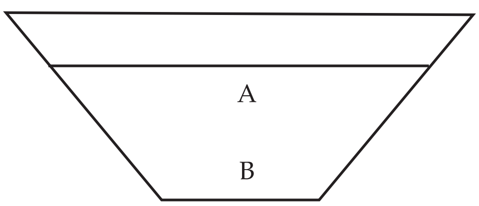
**Questions 34–35**

Photons are emitted only when incoming radiation of wavelengths less than $2 \times 10^{-6}$ m illuminates a metallic surface.

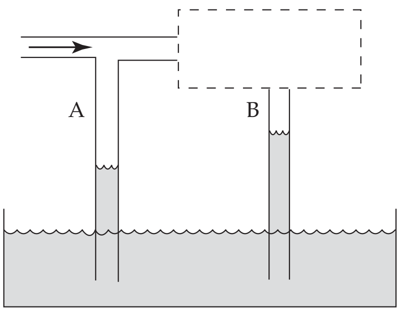
34. If you double the wavelength, the number of photons emitted will
    (A) increase by two
    (B) increase by four
    (C) decrease to one half
    (D) decrease to one fourth
    (E) drop to zero

35. The cutoff frequency is
    (A) $2.0 \times 10^{-6}$ Hz
    (B) $1.5 \times 10^{14}$ Hz
    (C) $6.7 \times 10^{-15}$ Hz
    (D) $4.0 \times 10^{12}$ Hz
    (E) 600 Hz

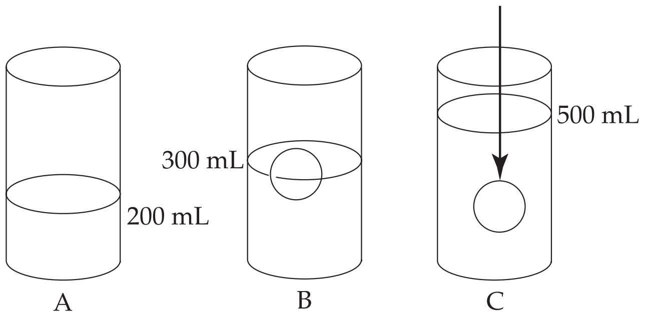
36. Which of the following is an isotope of Carbon $^{12}_{6}C$ with 7 neutrons in it?
    (A) $^{12}_{7}C$
    (B) $^{13}_{6}C$
    (C) $^{6}_{12}C$
    (D) $^{12}_{6}C$
    (E) $^{12}_{13}C$




37. A cup of water is shaped as shown. You can say
    (A) the pressure is greater at point A due to the greater horizontal area
    (B) the pressure is greater at point A due to the smaller depth below the surface
    (C) the pressure is greater at point B due to the smaller horizontal area
    (D) the pressure is greater at point B due to the greater depth below the surface
    (E) two of the above are correct




38. A tube with two T branches that have an open end is inserted in a liquid. However, the section of the tube above part B is hidden from view. The hidden section may be wider, more narrow, or the same width. Air is blown through the tube and the water levels rise as shown. You can say
    (A) the picture as drawn below is impossible—A and B must be at equal heights
    (B) the tube is more narrow and the air speed is greater above section B
    (C) the tube is more narrow and the air speed is less above section B
    (D) the tube is wider and the air speed is greater above section B
    (E) the tube is wider and the air speed is less above section B




39. You have a cylinder with water in it as shown above in picture A. In picture B you place a ball in that floats. In picture C you physically push the ball under the water to just below the surface. What is the density of the ball?
    (A) 0.33 g/mL
    (B) 3 g/mL
    (C) 2 g/mL
    (D) 0.5 g/mL
    (E) 0.6 g/mL

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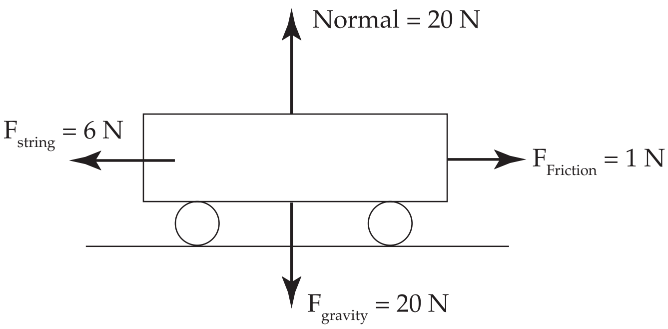
40. Two students on ice skates are initially at rest. Student G weighs 150 pounds. Student K weighs 200 pounds. When they push off against each other the ratio of the magnitudes of velocities of student G to student K, $\frac{v_G}{v_K}$ is

(A) 16/9
(B) 4/3
(C) 1/1
(D) 3/4
(E) 9/16




41. What is the acceleration of the cart shown?

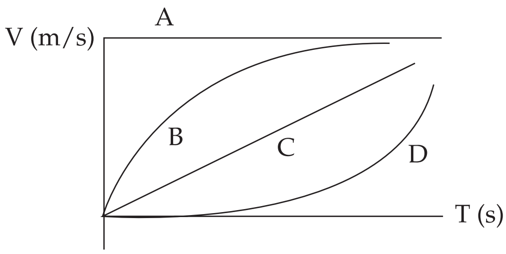
(A) 0 m/s/s
(B) 2.5 m/s/s
(C) 3 m/s/s
(D) 9.8 m/s/s
(E) 10 m/s/s

42. Knowing universal gravitation $F_G = \frac{Gm_1m_2}{r^2}$ and the circular motion equation $F_C = \frac{4\pi^2 m_1 r}{T^2}$ we can derive Kepler's third law for planets that travel in a basically circular orbit as

(A) $\frac{T^2}{r^3} = \frac{4\pi^2 G}{m_2}$
(B) $\frac{T^2}{r^3} = \frac{Gm_2}{4\pi^2}$
(C) $\frac{T^2}{r^3} = \frac{4\pi^2}{Gm_2}$
(D) $\frac{T^2}{r^3} = \frac{4\pi^2 m_2}{G}$
(E) $\frac{T^2}{r^3} = \frac{4Gm_2}{\pi^2}$

43. A mass hanging from a spring and a simple pendulum have the same period, T. They are placed in an elevator that accelerates upward at 10 m/s$^2$. What can you say about the each of the periods on the elevator?

(A) They both increase.
(B) They both decrease.
(C) They both remain the same.
(D) The period of the mass on the spring remains the same but the period of the pendulum decreases.
(E) The period of the pendulum remains the same but the period of the mass on the spring decreases.




44. In deep space a rocket ship starts off at rest. It fires off its engines, using up fuel. The thruster exerts a constant force, but the mass decreases as it fires gas backwards. Which line would best represent the velocity of the rocket?

(A) A
(B) B
(C) C
(D) D
(E) Cannot be determined

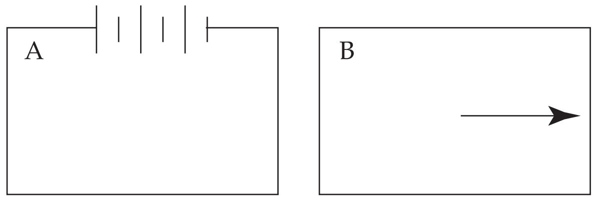
**GO ON TO THE NEXT PAGE.**

**Questions 45–46**


Two large flat parallel plates are separated by a distance of $d$. The lower plate is at a potential of $V_1$ with respect to the ground. The upper plate is at a potential of $V_2$ with respect to the ground.

45. How much work is done moving a charge $q$ and mass $m$ from the lower plate to the upper plates?
    (A) $W = q(V_2 - V_1)d$
    (B) $W = q(V_2 - V_1)$
    (C) $W = (V_2 - V_1)d$
    (D) $W = mq(V_2 - V_1)d$
    (E) $W = \frac{(V_2 - V_1)d}{q}$

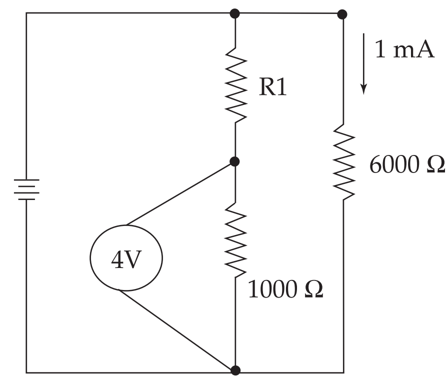
46. The particle on the top plate is now released from rest. The velocity it has as it strikes the bottom plate is given by
    (A) $\sqrt{\frac{2m(V_2 - V_1)d}{q}}$
    (B) $\sqrt{\frac{(V_2 - V_1)}{2qmd}}$
    (C) $\sqrt{\frac{2q(V_2 - V_1)d}{m}}$
    (D) $\sqrt{\frac{2mq}{(V_2 - V_1)d}}$
    (E) $\sqrt{2qm(V_2 - V_1)d}$




47. Two loops of conducting wire are near each other as shown. Loop A has a battery attached as indicated. Loop B is now pulled away from loop A. What can we say about the direction of the current in each loop as loop B is pulled away as shown?

| | Loop A | Loop B |
|---|---|---|
| (A) | clockwise | clockwise |
| (B) | clockwise | counterclockwise |
| (C) | counterclockwise | clockwise |
| (D) | counterclockwise | counterclockwise |
| (E) | counterclockwise | none present |

**Questions 48–49** refer to the following circuit diagram.

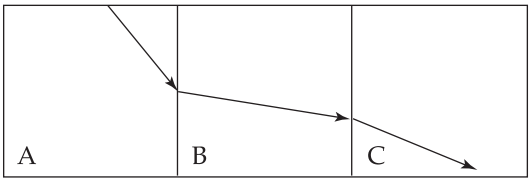



48. What is the voltage across R1?
    (A) 2 V
    (B) 4 V
    (C) 6 V
    (D) 8 V
    (E) 12 V

**GO ON TO THE NEXT PAGE.**

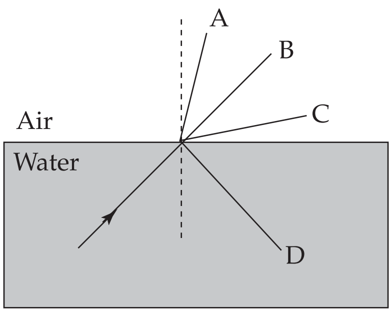
49. What is the current coming out of the battery?

(A) 1 mA
(B) 2 mA
(C) 3 mA
(D) 4 mA
(E) 5 mA




50. A ray of light travels though three different regions (mediums) as shown. List the three regions in order of increasing index of refraction.

(A) ABC
(B) CBA
(C) ACB
(D) BCA
(E) CAB




51. A beam of light goes from water to air. Depending on the actual angle that the light strikes the surface, which of the following are possible outcomes?

(A) A only
(B) B only
(C) C only
(D) A or D
(E) C or D

52. An alarm whose frequency is 400 Hz is dropped out of a third-floor window. The student who drops it measures the frequency with a very sensitive oscilloscope. The measured frequency

(A) appears higher than 400 Hz and the frequency increases as it falls
(B) appears higher than 400 Hz and the frequency decreases as it falls
(C) appears lower than 400 Hz and the frequency decreases as it falls
(D) appears lower than 400 Hz and the frequency increases as it falls
(E) remains constant throughout the fall

53. When a light wave in air hits a thin film ($n_{film} > n_{air}$), part of the wave is transmitted into the film and part is reflected. At the bottom of the thin film part of the wave is transmitted into air and part is reflected back up. What can you say about the reflected wave's phase at the top layer and bottom layers?

(A) Only the top reflection is inverted.
(B) Only the bottom reflection is inverted.
(C) Neither reflection is inverted.
(D) Both reflections are inverted.
(E) Only the transmitted waves are inverted.

54. An object is placed 10 cm in front of a diverging mirror. What is the focal length of the mirror if image appears 2 cm behind the mirror?

(A) –3/5 cm
(B) –5/3 cm
(C) –2/5 cm
(D) –5/2 cm
(E) –1/12 cm

55. Which of the following statements are true?

I. The focal length of a lens depends on the material the lens is made out of.
II. The focal length of the lens depends on the light intensity.
III. The focal length of the lens depends on the shape of the lens.

(A) I only
(B) II only
(C) III only
(D) I, II, and III
(E) Both I and III, but not II

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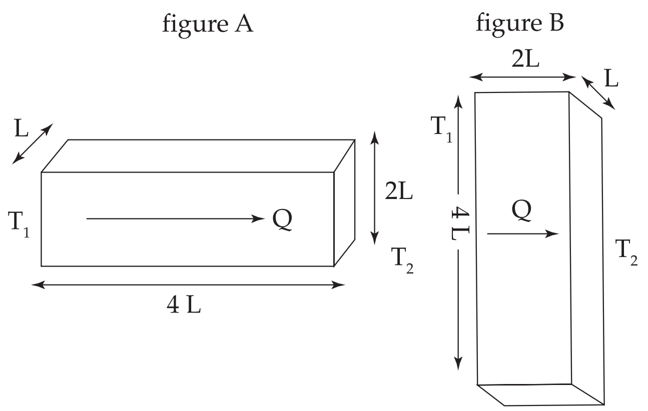



56. Heat flows through a block of iron as shown in figure A at a rate of H. The temperatures on each side of the block are $T_1$ and $T_2$ respectively. If the block is rotated 90º as shown in figure B, the rate at which heat is transferred is now

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

57. The maximum efficiency of a heat engine which operates between a temperature of 27ºC and 227ºC is

(A) 12%
(B) 20%
(C) 40%
(D) 60%
(E) 75%

**Questions 58–59**

Uranium-238 decays into thorium-234 and an alpha particle as illustrated below.

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$$

58. What is the ratio of neutrons in thorium to the number of neutrons in uranium $\frac{n_{Th}}{n_U}$?

(A) 234/238
(B) 90/92
(C) 144/146
(D) 1/1
(E) 324/330

59. Which of the following statements are true for the above reaction?

I. Charge is conserved.
II. The number of nucleons is conserved.
III. Mass–energy is conserved.

(A) I only
(B) II only
(C) III only
(D) Both II and III, but not I
(E) I, II, and III must be true

60. A generator can provide 2000 W of power for 30 seconds before it shuts off. How high can it lift a 50 kg mass in this time?

(A) 12 m
(B) 33 m
(C) 120 m
(D) 330 m
(E) 660 m

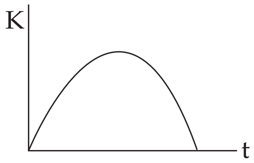
**GO ON TO THE NEXT PAGE.**

61. A projectile is launched with an initial velocity of $v_x = 5$ m/s and $v_{yi} = 20$ m/s. Which of the following is true about the projectile at the top of the motion?

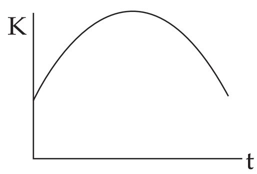
| | $v_x$ (m/s) | $v_y$(m/s) | a (m/s$^2$) |
|---|---|---|---|
| (A) | 0 | 0 | 0 |
| (B) | 0 | 20 | –10 |
| (C) | 5 | 0 | 0 |
| (D) | 5 | 20 | –10 |
| (E) | 5 | 0 | –10 |

62. The kinetic energy of the projectile launched at an angle is best represented by

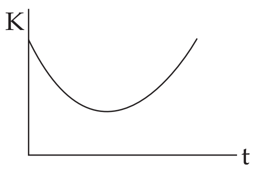
(A)



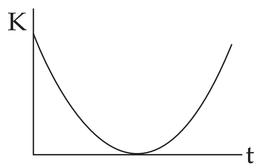

(B)



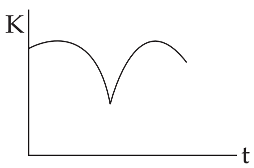

(C)




(D)

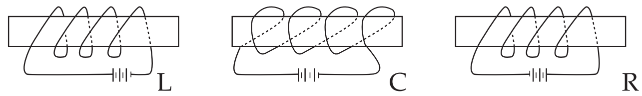



(E)




63. A small cart of mass M is initially at rest. It collides elastically with a large cart of mass 4M and velocity $v$. The large cart loses half its kinetic energy to the little cart. The little cart now has a velocity of

(A) $1.41v$
(B) $v$
(C) $2v$
(D) $4v$
(E) $8v$




64. Three solenoids are arranged next to each other as shown above. What can we say about the solenoids interactions?

(A) L and C attract; C and R repel.
(B) L and C attract; C and R attract.
(C) L and C repel; C and R repel.
(D) L and C repel; C and R attract.
(E) L and R repel; L and C attract.

65. A particle of mass $M$ and charge $q$ and velocity $v$ is directed toward a uniform electric field of strength $E$ and travels a distance $d$. How far does the particle travel if the original velocity is doubled and the mass is cut in half?

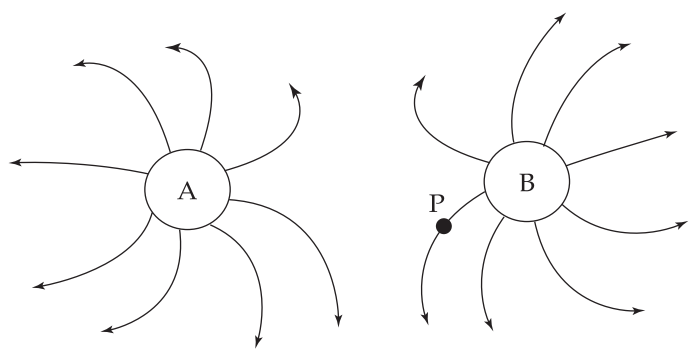
(A) $4d$

(B) $2d$

(C) $d$

(D) $\frac{1}{2}d$

(E) $\frac{1}{4}d$




66. The diagram above shows the electric field lines around a region of space due to two charges A and B. Which of the following statements is true?

(A) The field is uniform.
(B) Charge A is positive and charge B is negative.
(C) Both charges are negative.
(D) A positive charge starting at rest from point P would move toward B.
(E) The equipotential lines are perpendicular to the field lines.

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Section I

**Questions 67–68**

A stopper of mass M is tied to a string of length R and swings around horizontally in uniform circular motion with a velocity of $v$ when acted on by a force of F.

67. What is the period of the stopper?

(A) $\sqrt{\dfrac{4\pi^2 MR}{F}}$

(B) $\sqrt{\dfrac{MR}{4\pi^2 F}}$

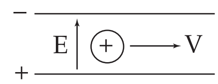
(C) $\sqrt{\dfrac{4\pi^2}{FMR}}$

(D) $\sqrt{\dfrac{4\pi^2 R}{MF}}$

(E) $\sqrt{\dfrac{MR}{4\pi^2 F}}$

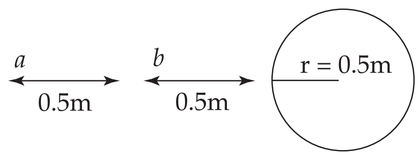
68. What is the power developed by the force?

(A) FR
(B) FV
(C) FV/R
(D) $mv^2$
(E) 0




69. A particle travels through a uniform electric field E = 5 N/C as shown. What is the size and direction of the magnetic field needed to have a 0.2 C charge with mass 0.005 kg pass through undeflected at a velocity of 4 m/s?

(A) 20 T out of the page
(B) 20 T into the page
(C) 1.2 T out of the page
(D) 1.2 T into the page
(E) 0.8 T out of the page




70. A hollow metal sphere carries a charge of 3 C. How does the magnitude of the field at point *a* compare to point *b*?

(A) $E_a = 1/4\ E_b$
(B) $E_a = 4/9\ E_b$
(C) $E_a = 9/4\ E_b$
(D) $E_a = 4/1\ E_b$
(E) $E_a = 3/2\ E_b$

**END OF SECTION I**

**PHYSICS B**

SECTION II

Free-Response Questions

Time—90 minutes

6 required questions. Questions 1–4 are worth 15 points each. Questions 5–6 are worth 10 points each.

Percent of total grade—50

General Instructions

Use a separate piece of paper to answer these questions.

Show your work. Be sure to write CLEARLY and LEGIBLY. If you make an error, you may save time by crossing it out rather than trying to erase it.

**GO ON TO THE NEXT PAGE.**

## ADVANCED PLACEMENT PHYSICS B EQUATIONS FOR 2011

### NEWTONIAN MECHANICS

$v = v_0 + at$

$x = x_0 + v_0 t + \frac{1}{2}at^2$

$v^2 = v_0^2 + 2a(x - x_0)$

$\Sigma \mathbf{F} = \mathbf{F}_{net} = m\mathbf{a}$

$F_{fric} \le \mu N$

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

$\tau = rF \sin\theta$

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

$\mathbf{J} = \mathbf{F}\Delta t = \Delta\mathbf{p}$

$K = \frac{1}{2}mv^2$

$\Delta U_g = mgh$

$W = F\Delta r \cos\theta$

$P_{avg} = \frac{W}{\Delta t}$

$P = Fv\cos\theta$

$\mathbf{F}_s = -k\mathbf{x}$

$U_s = \frac{1}{2}kx^2$

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

$T_p = 2\pi\sqrt{\frac{\ell}{g}}$

$T = \frac{1}{f}$

$F_G = -\frac{Gm_1m_2}{r^2}$

$U_G = -\frac{Gm_1m_2}{r}$

$a$ = acceleration
$F$ = force
$f$ = frequency
$h$ = height
$J$ = impulse
$K$ = kinetic energy
$k$ = spring constant
$\ell$ = length
$m$ = mass
$N$ = normal force
$P$ = power
$p$ = momentum
$r$ = radius or distance
$T$ = period
$t$ = time
$U$ = potential energy
$v$ = velocity or speed
$W$ = work done on a system
$x$ = position
$\mu$ = coefficient of friction
$\theta$ = angle
$\tau$ = torque

### ELECTRICITY AND MAGNETISM

$F = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r^2}$

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

$U_E = qV = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$

$E_{avg} = -\frac{V}{d}$

$V = \frac{1}{4\pi\epsilon_0}\sum_i \frac{q_i}{r_i}$

$C = \frac{Q}{V}$

$C = \frac{\epsilon_0 A}{d}$

$U_c = \frac{1}{2}QV = \frac{1}{2}CV^2$

$I_{avg} = \frac{\Delta Q}{\Delta t}$

$R = \frac{\rho\ell}{A}$

$V = IR$

$P = IV$

$C_p = \sum_i C_i$

$\frac{1}{C_s} = \sum_i \frac{1}{C_i}$

$R_s = \sum_i R_i$

$\frac{1}{R_p} = \sum_i \frac{1}{R_i}$

$F_B = qvB\sin\theta$

$F_B = BI\ell\sin\theta$

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

$\phi_m = BA\cos\theta$

$\mathcal{E}_{avg} = -\frac{\Delta\phi_m}{\Delta t}$

$\mathcal{E} = B\ell v$

$A$ = area
$B$ = magnetic field
$C$ = capacitance
$d$ = distance
$E$ = electric field
$\mathcal{E}$ = emf
$F$ = force
$I$ = current
$\ell$ = length
$P$ = power
$Q$ = charge
$q$ = point charge
$R$ = resistance
$r$ = distance
$t$ = time
$U$ = potential (stored) energy
$V$ = electric potential or potential difference
$v$ = velocity or speed
$\rho$ = resistivity
$\theta$ = angle
$\phi_m$ = magnetic flux

GO ON TO THE NEXT PAGE.

## ADVANCED PLACEMENT PHYSICS EQUATIONS FOR 2011

### FLUID MECHANICS AND THERMAL PHYSICS

$P = P_0 + \rho g h$

$F_{buoy} = \rho V g$

$A_1 v_1 = A_2 v_2$

$P + \rho g y + \frac{1}{2}\rho v^2 = \text{const.}$

$\Delta \ell = \alpha \ell_0 \Delta T$

$H = \frac{kA\,\Delta T}{L}$

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

$PV = nRT = Nk_B T$

$K_{avg} = \frac{3}{2}k_B T$

$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3k_B T}{\mu}}$

$W = -P\Delta V$

$\Delta U = Q + W$

$e = \left|\frac{W}{Q_H}\right|$

$e_c = \frac{T_H - T_C}{T_H}$

$A$ = area
$e$ = efficiency
$F$ = force
$h$ = depth
$H$ = rate of heat transfer
$k$ = thermal conductivity
$K_{avg}$ = average molecular kinetic energy
$\ell$ = length
$L$ = thickness
$M$ = molar mass
$n$ = number of moles
$N$ = number of molecules
$P$ = pressure
$Q$ = heat transferred to a system
$T$ = temperature
$U$ = internal energy
$V$ = volume
$v$ = velocity or speed
$v_{rms}$ = root-mean-square velocity
$W$ = work done on a system
$y$ = height
$\alpha$ = coefficient of linear expansion
$\mu$ = mass of molecule
$\rho$ = density

### ATOMIC AND NUCLEAR PHYSICS

$E = hf = pc$

$K_{\max} = hf - \phi$

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

$\Delta E = (\Delta m)c^2$

$E$ = energy
$f$ = frequency
$K$ = kinetic energy
$m$ = mass
$p$ = momentum
$\lambda$ = wavelength
$\phi$ = work function

### WAVES AND OPTICS

$v = f\lambda$

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

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

$\sin\theta_c = \frac{n_2}{n_1}$

$\frac{1}{s_i} + \frac{1}{s_0} = \frac{1}{f}$

$M = \frac{h_i}{h_0} = -\frac{s_i}{s_0}$

$f = \frac{R}{2}$

$d\sin\theta = m\lambda$

$x_m \sim \frac{m\lambda L}{d}$

$d$ = separation
$f$ = frequency or focal length
$h$ = height
$L$ = distance
$M$ = magnification
$m$ = an integer
$n$ = index of refraction
$R$ = radius of curvature
$s$ = distance
$v$ = speed
$x$ = position
$\lambda$ = wavelength
$\theta$ = angle

### GEOMETRY AND TRIGONOMETRY

Rectangle
$A = bh$

Triangle
$A = \frac{1}{2}bh$

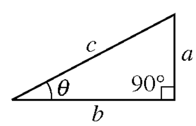
Circle
$A = \pi r^2$
$C = 2\pi r$

Parallelepiped
$V = \ell wh$

Cylinder
$V = \pi r^2 \ell$
$S = 2\pi r\ell + 2\pi r^2$

Sphere
$V = \frac{4}{3}\pi r^3$
$S = 4\pi r^2$

Right Triangle
$a^2 + b^2 = c^2$
$\sin\theta = \frac{a}{c}$
$\cos\theta = \frac{b}{c}$
$\tan\theta = \frac{a}{b}$




$A$ = area
$C$ = circumference
$V$ = volume
$S$ = surface area
$b$ = base
$h$ = height
$\ell$ = length
$w$ = width
$r$ = radius

**GO ON TO THE NEXT PAGE.**

**PHYSICS B**

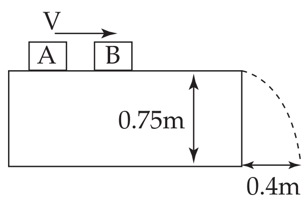
SECTION II

Time—90 minutes

6 Questions

**Directions:** Answer all six questions. The suggested time is 17 minutes for answering each of questions 1–4, and about 11 minutes for answering each of questions 5–6. The parts within a question may not have equal weight.

1. (15 points)




Block A has a mass of 0.5 kg and is sliding to the right across a frictionless table at 1.5 m/s. It collides with block B of unknown mass which is initially at rest and sticks to it. Together the two blocks slide off the table and hit the floor 0.25 meters from the end of the table. The table is 0.75 meters high.

(a) What was the speed of the blocks when they left the table?

(b) What is the mass of the block B?

(c) How much kinetic energy was lost in this collision?

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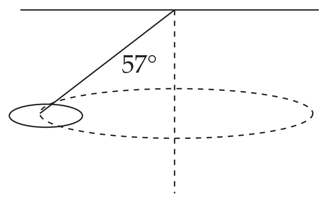


2. (15 points)

A conical pendulum is hanging from a string that is 2.2 meters long. It makes a horizontal circle. The mass of the ball at the end of the string is 0.5 kg.

(a) Below, make a free-body diagram for the ball at the point shown in the above illustration. Label each force with an appropriate letter.

(b) Write out Newton's second law in both the X and Y direction in terms used in your above free-body diagram.

(c) Calculate the centripetal acceleration from your free-body diagram.

(d) What is the radius of the circle that the ball is traveling in?

(e) What is the speed of the ball?

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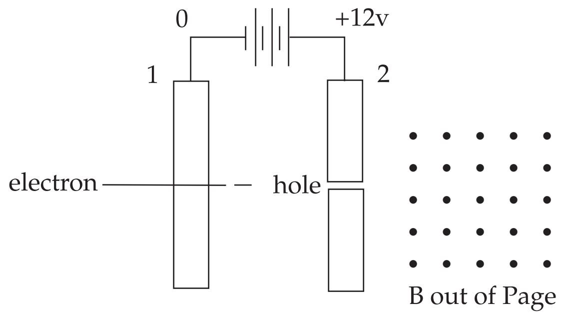



3. (15 points)

Two tests are run. In both trials you may ignore the effect of gravity.

**Test 1**: There are two large parallel plates separated by a distance $d$ = 0.5 m with a potential difference of 0.12 V across them. There is a uniform magnetic field B pointing perpendicularly out of the paper of strength 0.002T starting to the right of plate 2. An electron is released from rest at plate 1 as shown above. It passes through a hole in plate 2 and enters the magnetic field and only experiences forces due to the magnetic field.

**Test 2:** The same set-up is run with the following two exceptions.

The battery is switched so that plate 1 becomes positive and plate 2 becomes negative.

A proton is used instead of an electron.

(a) Compare the force acting on each charge.

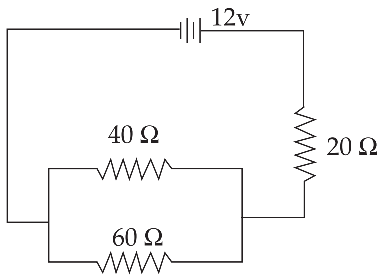
(b) Compare the speed of the proton as it emerges from the whole to the speed of the electron as it emerges from the hole.

(c) The charges will curve around once they are in the magnetic field. Make a sketch of each path. How far away will the two charges be when they strike the plate?

(d) Compare the time it takes for the electron to return to the plate to the time it takes the proton to return to the plate.

**GO ON TO THE NEXT PAGE.**

4. (15 points)




The circuit shown is built and all three resisters are placed in 1000 mL of water initially at a temperature of 10ºC in an insulated container for 15 minutes. The specific heat of water is 1 cal/gºC and there are 4.186 J for every cal.

(a) What is the equivalent resistance of the circuit?

(b) What is the power?

(c) What is the energy transferred in the 15 minutes?

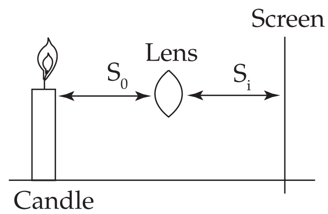
(d) What is the temperature change of the water?

**GO ON TO THE NEXT PAGE.**

5. (10 points)

A student has a convex lens of unknown focal length. He lights a candle in a darkened room and uses the lens and moves a screen until he forms a sharp image and records the distance from the candle to the lens and the distance from the lens to the screen. Above is a sketch of his set-up and his data.

| $s_o$ (cm) | $s_i$ (cm) |
|---|---|
| 15 | 61.5 |
| 20 | 29.8 |
| 30 | 19.3 |
| 40 | 18.0 |
| 50 | 15.6 |
| 60 | 15.3 |
| 70 | 14.7 |
| 80 | 13.9 |
| 90 | 13.7 |
| 100 | 13.7 |
| 110 | 13.4 |
| 120 | 13.2 |

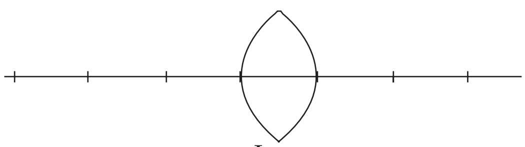



(a) What type of image is formed and what orientation is it?

(b) Where is the image formed if the candle is placed 6 cm from the lens?

(c) Use ray tracing to make a sketch when the object is 6 cm from the lens.

(d) What effect would it have if a lens with the same focal length was used but with only half the diameter?




6. (10 points)

A laser whose wavelength is $\lambda_a = 4.7 \times 10^{-7}$ meter shines through a diffraction grating. The light hits a screen L = 2 m away and the third order maximum is detected 0.42 m on either side of the central maximum.

(a) What is the separation between slits?

(b) What is the path difference from the diffraction grating to the third maximum measured in meters?

(c) A new laser whose wavelength is $\lambda_b = 6.3 \times 10^{-7}$ meter shines though the slits and both its third maximums are labeled. What is the distance from the third order maximum using $\lambda_a$ and the closest third maximum using $\lambda_b$?

**STOP**

**END OF EXAM**