PHYSICS B

You must take the entire B Exam as follows:

1st 90 minutes	Section I—Multiple Choice 70 Questions Percent of Total Grade—50
2nd 90 minutes	Section II—Free Response 6 Questions Percent of Total Grade—50

Each question in a section has equal weight. Battery-operated hand-held calculators and rulers or straightedges may be used in both sections. However, all calculator memories must be cleared of both programs and data and no peripheral devices such as magnetic cards or tapes will be permitted. Calculators may not be shared. A table of information that may be helpful is on the next page of this booklet.

This examination contains 70 multiple-choice questions. Therefore, please be careful to fill in only the ovals that are preceded by numbers 1 through 70 on your answer sheet.

General Instructions

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE INSTRUCTED TO DO SO.

INDICATE ALL YOUR ANSWERS TO QUESTIONS IN SECTION I ON THE SEPARATE ANSWER SHEET. No credit will be given for anything written in this examination booklet, but you may use the booklet for notes or scratchwork. 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.

Example:

Chicago is a

(A) state
(B) city
(C) country
(D) continent
(E) village

Sample Answer

Many candidates wonder whether or not to guess the answers to questions about which they are not certain. In this section of the examination, as a correction for haphazard guessing, one-fourth of the number of questions you answer incorrectly will be subtracted from the number of questions you answer correctly. It is improbable, therefore, that mere guessing will improve your score significantly; it may even lower your score, and it does take time. If, however, you are not sure of the correct answer but have some knowledge of the question and are able to eliminate one or more of the answer choices as wrong, your chance of getting the right answer is improved, and it may be to your advantage to answer such a question.

Use your time effectively, working as rapidly as you can without losing accuracy. Do not spend too much time on questions that are too difficult. Go on to other questions and come back to the difficult ones later if you have time. It is not expected that everyone will be able to answer all the multiple-choice questions.

TABLE OF INFORMATION

1 atomic mass unit,	$1\ \text{u} = 1.66 \times 10^{-27}$ kilogram
Rest mass of the proton,	$m_p = 1.67 \times 10^{-27}$ kilogram
Rest mass of the neutron,	$m_n = 1.67 \times 10^{-27}$ kilogram
Rest mass of the electron,	$m_e = 9.11 \times 10^{-31}$ kilogram
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19}$ coulomb
Avogadro's number,	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant,	$R = 8.32$ joules/(mole · K)
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ joule/K
Speed of light,	$c = 3.00 \times 10^{8}$ meters/second
Planck's constant,	$h = 6.63 \times 10^{-34}$ joule · second $= 4.14 \times 10^{-15}$ eV · second
	$hc = 1.99 \times 10^{-25}$ joule · meter $= 1.24 \times 10^{4}$ eV · angstrom
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}$ joule
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb^2/(newton · meter^2)
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ newtons · meter^2/coulomb^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Magnetic constant,	$k' = k/c^2 = \mu_0/4\pi = 10^{-7}$weber/(ampere · meter)
Acceleration due to gravity at the Earth's surface,	$g = 9.8$ meters/second^2
Universal gravitational constant,	$G = 6.67 \times 10^{-11}$ meter^3/(kilogram · second^2)
-1 atmosphere pressure,	$1\ \text{atm} = 1.0 \times 10^{5}$ newtons/meter^2 $= 1.0 \times 10^{5}$ pascals (Pa)
1 angstrom,	$1\ \text{Å} = 1 \times 10^{-10}$ meter
1 tesla,	$1\ \text{T} = 1$ weber/meter^2

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.

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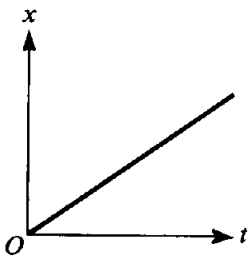
PHYSICS B

SECTION I

Time—90 minutes

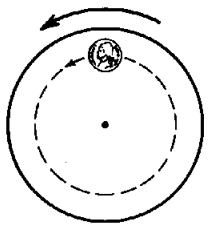
70 Questions

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.



1. The displacement x of an object moving along the x-axis is shown above as a function of time t. The acceleration of this object must be

   (A) zero
   (B) constant but not zero
   (C) increasing
   (D) decreasing
   (E) equal to g



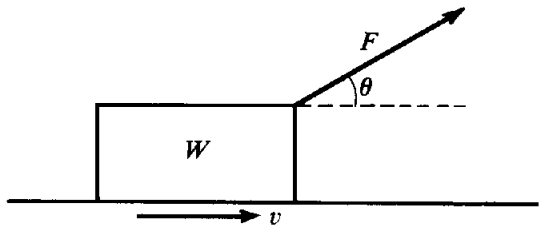
View from Above

2. The horizontal turntable shown above rotates at a constant rate. As viewed from above, a coin on the turntable moves counterclockwise in a circle as shown. Which of the following vectors best represents the direction of the frictional force exerted on the coin by the turntable when the coin is in the position shown?

   (A) ←
   (B) →
   (C) ↙
   (D) ↓
   (E) ↑

3. Which of the following quantities is a scalar that is always positive or zero?

   (A) Power
   (B) Work
   (C) Kinetic energy
   (D) Linear momentum
   (E) Angular momentum



4. A block of weight W is pulled along a horizontal surface at constant speed v by a force F, which acts at an angle of θ with the horizontal, as shown above. The normal force exerted on the block by the surface has magnitude

   (A) $W - F\cos\theta$
   (B) $W - F\sin\theta$
   (C) W
   (D) $W + F\sin\theta$
   (E) $W + F\cos\theta$

5. A 2-kilogram block rests at the edge of a platform that is 10 meters above level ground. The block is launched horizontally from the edge of the platform with an initial speed of 3 meters per second. Air resistance is negligible. The time it will take for the block to reach the ground is most nearly

   (A) 0.3 s
   (B) 1.0 s
   (C) 1.4 s
   (D) 2.0 s
   (E) 3.0 s

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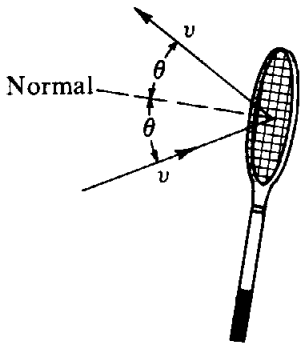
6. A horizontal force F is used to pull a 5-kilogram block across a floor at a constant speed of 3 meters per second. The frictional force between the block and the floor is 10 newtons. The work done by the force F in 1 minute is most nearly

(A) 0 J
(B) 30 J
(C) 600 J
(D) 1,350 J
(E) 1,800 J



7. A tennis ball of mass m rebounds from a racquet with the same speed v as it had initially, as shown above. The magnitude of the momentum change of the ball is

(A) 0
(B) mv
(C) $2mv$
(D) $2mv \sin \theta$
(E) $2mv \cos \theta$

8. The length of a simple pendulum with a period on Earth of one second is most nearly

(A) 0.12 m
(B) 0.25 m
(C) 0.50 m
(D) 1.0 m
(E) 10.0 m

9. A diver initially moving horizontally with speed v dives off the edge of a vertical cliff and lands in the water a distance d from the base of the cliff. How far from the base of the cliff would the diver have landed if the diver initially had been moving horizontally with speed $2v$?

(A) d
(B) $\sqrt{2}d$
(C) $2d$
(D) $4d$
(E) It cannot be determined unless the height of the cliff is known.

10. Two bodies of masses 5 and 7 kilograms are initially at rest on a horizontal frictionless surface. A light spring is compressed between the bodies, which are held together by a thin thread. After the spring is released by burning through the thread, the 5-kilogram body has a speed of $\frac{1}{5}$ meter per second. The speed of the 7-kilogram body is

(A) $\frac{1}{12}$ m/s
(B) $\frac{1}{7}$ m/s
(C) $\frac{1}{\sqrt{35}}$ m/s
(D) $\frac{1}{5}$ m/s
(E) $\frac{7}{25}$ m/s

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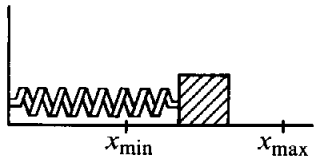
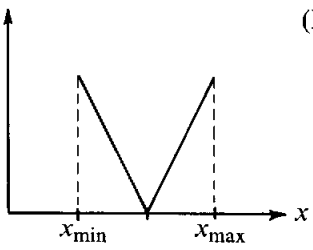
Questions 11-12

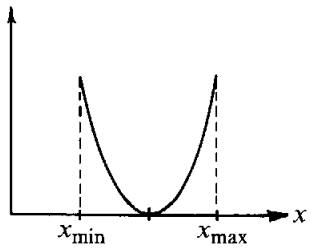


A block oscillates without friction on the end of a spring as shown above. The minimum and maximum lengths of the spring as it oscillates are, respectively, x_{min} and x_{max}. The graphs below can represent quantities associated with the oscillation as functions of the length x of the spring.

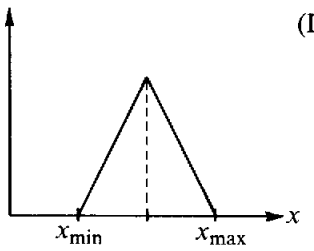
(A)



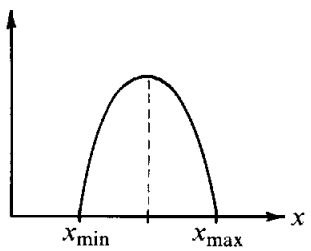
(B)



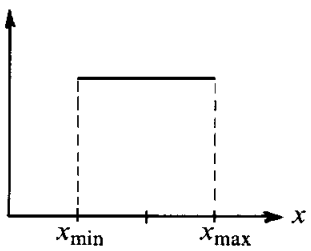
(C)



(D)



(E)



11. Which graph can represent the total mechanical energy of the block-spring system as a function of x?

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

12. Which graph can represent the kinetic energy of the block as a function of x?

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

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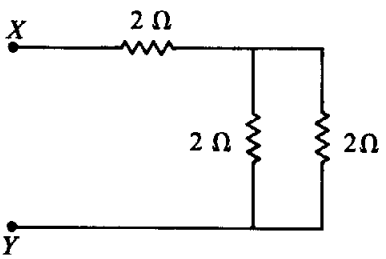
13. Mars has a mass $\frac{1}{10}$ that of Earth and a diameter $\frac{1}{2}$ that of Earth. The acceleration of a falling body near the surface of Mars is most nearly
    (A) $0.25\ m/s^2$
    (B) $0.5\ m/s^2$
    (C) $2\ m/s^2$
    (D) $4\ m/s^2$
    (E) $25\ m/s^2$

14. The capacitance of a parallel-plate capacitor can be increased by increasing which of the following?
    (A) The distance between the plates
    (B) The charge on each plate
    (C) The area of the plates
    (D) The potential difference across the plates
    (E) None of the above



15. The total equivalent resistance between points X and Y in the circuit shown above is
    (A) 3 Ω
    (B) 4 Ω
    (C) 5 Ω
    (D) 6 Ω
    (E) 7 Ω

16. An electron volt is a measure of
    (A) energy
    (B) electric field
    (C) electric potential due to one electron
    (D) force per unit electron charge
    (E) electric charge

Questions 17-18

An electron is accelerated from rest for a time of 10^{-9} second by a uniform electric field that exerts a force of 8.0×10^{-15} newton on the electron.

17. What is the magnitude of the electric field?
    (A) $8.0 \times 10^{-24}\ N/C$
    (B) $9.1 \times 10^{-22}\ N/C$
    (C) $8.0 \times 10^{-6}\ N/C$
    (D) $2.0 \times 10^{-5}\ N/C$
    (E) $5.0 \times 10^{4}\ N/C$

18. The speed of the electron after it has accelerated for the 10^{-9} second is most nearly
    (A) 10^1 m/s
    (B) 10^3 m/s
    (C) 10^5 m/s
    (D) 10^7 m/s
    (E) 10^9 m/s

19. An immersion heater of resistance R converts electrical energy into thermal energy that is transferred to the liquid in which the heater is immersed. If the current in the heater is I, the thermal energy transferred to the liquid in time t is
    (A) IRt
    (B) I^2Rt
    (C) IR^2t
    (D) IRt^2
    (E) $\frac{IR}{t}$

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20. A hollow metal sphere of radius R is positively charged. Of the following distances from the center of the sphere, which location will have the greatest electric field strength?

(A) 0 (center of the sphere)
(B) $3R/4$
(C) $5R/4$
(D) $2R$
(E) None of the above because the field is of constant strength

21. A square loop of copper wire is initially placed perpendicular to the lines of a constant magnetic field of 5×10^{-3} tesla. The area enclosed by the loop is 0.2 square meter. The loop is then turned through an angle of 90° so that the plane of the loop is parallel to the field lines. The turn takes 0.1 second. The average emf induced in the loop during the turn is

(A) 1.0×10^{-4} V
(B) 2.5×10^{-3} V
(C) 0.01 V
(D) 100 V
(E) 400 V

22. James Joule did much to establish the value of the

(A) universal gravitational constant
(B) speed of light
(C) mechanical equivalent of heat
(D) charge of an electron
(E) specific heat capacity of helium

23. An ideal gas in a closed container initially has volume V, pressure P, and Kelvin temperature T. If the temperature is changed to $3T$, which of the following pairs of pressure and volume values is possible?

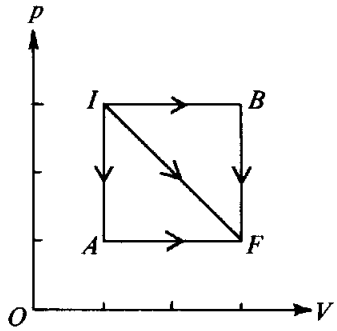
(A) $3P$ and V

(B) P and V

(C) P and $\frac{V}{3}$

(D) $\frac{P}{3}$ and V

(E) $3P$ and $3V$



24. If three identical samples of an ideal gas are taken from initial state I to final state F along the paths IAF, IF, and IBF as shown in the pV-diagram above, which of the following must be true?

(A) The work done by the gas is the same for all three paths.
(B) The heat absorbed by the gas is the same for all three paths.
(C) The change in internal energy of the gas is the same for all three paths.
(D) The expansion along path IF is adiabatic.
(E) The expansion along path IF is isothermal.

25. If the average kinetic energy of the molecules in an ideal gas at a temperature of 300 K is E, the average kinetic energy at a temperature of 600 K is

(A) $E/\sqrt{2}$
(B) E
(C) $\sqrt{2}\,E$
(D) $2\,E$
(E) $4\,E$

26. A metal rod of length L and cross-sectional area A connects two thermal reservoirs of temperatures T_1 and T_2. The amount of heat transferred through the rod per unit time is directly proportional to

(A) A and L
(B) A and $1/L$
(C) $1/A$ and L
(D) $1/A$ and $1/L$
(E) $\sqrt{A}$ and L^2

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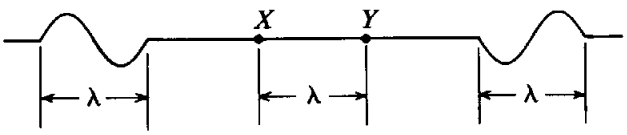
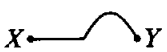
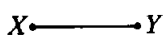
27. Which of the following is true of a single-slit diffraction pattern?

(A) It has equally spaced fringes of equal intensity.
(B) It has a relatively strong central maximum.
(C) It can be produced only if the slit width is less than one wavelength.
(D) It can be produced only if the slit width is exactly one wavelength.
(E) It can be produced only if the slit width is an integral number of wavelengths.

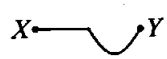


28. Two wave pulses, each of wavelength λ, are traveling toward each other along a rope as shown above. When both pulses are in the region between points X and Y, which are a distance λ apart, the shape of the rope will be which of the following?

(A) 

(B) 

(C) 

(D) 

(E) 

29. Which of the following CANNOT be accomplished by a single converging lens with spherical surfaces?

(A) Converting a spherical wave front into a plane wave front
(B) Converting a plane wave front into a spherical wave front
(C) Forming a virtual image of a real object
(D) Forming a real upright image of a real upright object
(E) Forming a real inverted image of a real upright object

30. A train whistle has a frequency of 100 hertz as heard by the engineer on the train. Assume that the velocity of sound in air is 330 meters per second. If the train is approaching a stationary listener on a windless day at a velocity of 30 meters per second, the whistle frequency that the listener hears is most nearly

(A) 90 Hz
(B) 110 Hz
(C) 120 Hz
(D) 240 Hz
(E) 300 Hz

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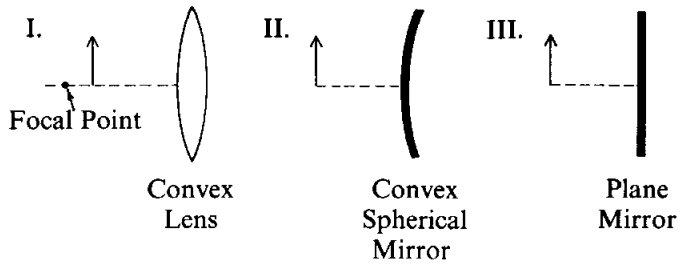
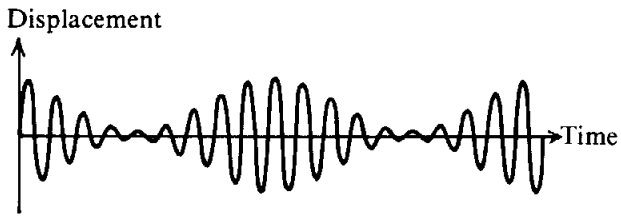
31. The image of the arrow is larger than the arrow itself in which of the following cases?



Convex Lens | Convex Spherical Mirror | Plane Mirror

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



32. Two sinusoidal functions of time are combined to obtain the result shown in the figure above. Which of the following can best be explained by using this figure?

(A) Beats
(B) Doppler effect
(C) Diffraction
(D) Polarization
(E) Simple harmonic motion

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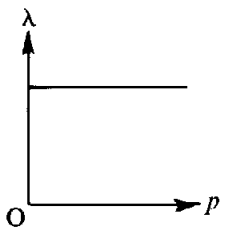
33. A postage stamp is placed 30 centimeters to the left of a converging lens of focal length 60 centimeters. Where is the image of the stamp located?

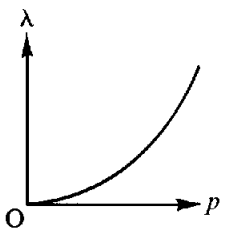
(A) 60 cm to the left of the lens
(B) 20 cm to the left of the lens
(C) 20 cm to the right of the lens
(D) 30 cm to the right of the lens
(E) 60 cm to the right of the lens

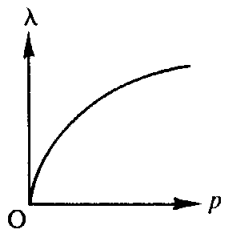
34. The nuclear reaction $X \rightarrow Y + Z$ occurs spontaneously. If M_X, M_Y, and M_Z are the masses of the three particles, which of the following relationships is true?

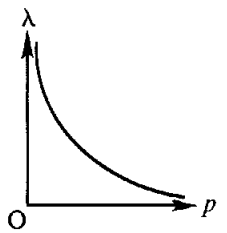
(A) $M_X < M_Y - M_Z$
(B) $M_X < M_Y + M_Z$
(C) $M_X > M_Y + M_Z$
(D) $M_X - M_Y < M_Z$
(E) $M_X - M_Z < M_Y$

35. Which of the following graphs best represents the de Broglie wavelength λ of a particle as a function of the linear momentum p of the particle?

(A)


(B)


(C)


(D)


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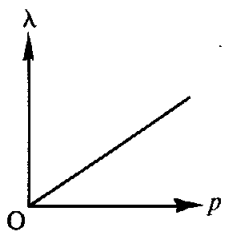

36. All of the following are properties of x-rays EXCEPT:

(A) They penetrate light materials.
(B) They ionize gases.
(C) They are deflected by magnetic fields.
(D) They discharge electrified bodies.
(E) They are diffracted by crystals.

37. Which of the following was one of Einstein's two basic postulates of special relativity?

(A) Clocks in a moving frame of reference appear to run slow.
(B) Mass and energy are related by $E = mc^2$.
(C) The speed of light is the same constant in all inertial frames of reference.
(D) No object can travel faster than the velocity of light.
(E) The mass of an object increases with increasing velocity.

38. The half-life of $^{234}_{90}\text{Th}$ is 24.1 days. If 4.0×10^{-5} kilogram of this isotope is present initially, what amount remains after 96.4 days?

(A) 2.0×10^{-5} kg
(B) 1.0×10^{-5} kg
(C) 5.0×10^{-6} kg
(D) 2.5×10^{-6} kg
(E) 1.2×10^{-6} kg

$$^{2}_{1}\text{H} + {}^{2}_{1}\text{H} \rightarrow {}^{3}_{1}\text{H} + {}^{1}_{1}\text{H} + 4\text{ MeV}$$

39. The equation above is an illustration of

(A) artificially produced radioactive decay
(B) naturally occurring radioactive decay
(C) nuclear disintegration
(D) nuclear fission
(E) nuclear fusion

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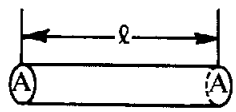
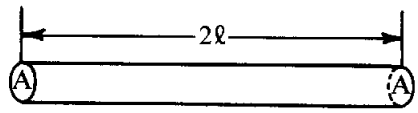
40. The five resistors shown below have the lengths and cross-sectional areas indicated and are made of material with the same resistivity. Which resistor has the least resistance?

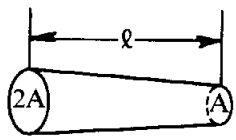
(A)



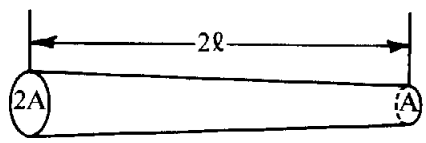
(B)



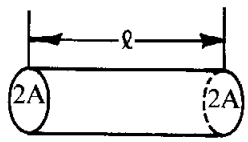
(C)

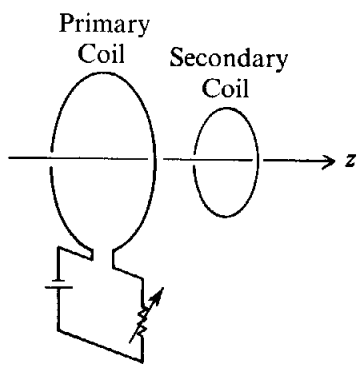


(D)



(E)





41. Two circular coils are situated perpendicular to the z-axis as shown above. There is a current in the primary coil. All of the following procedures will induce a current in the secondary coil EXCEPT

(A) rotating the secondary coil about the z-axis
(B) rotating the secondary coil about a diameter
(C) moving the secondary coil closer to the primary coil
(D) varying the current in the primary coil
(E) decreasing the cross-sectional area of the secondary coil

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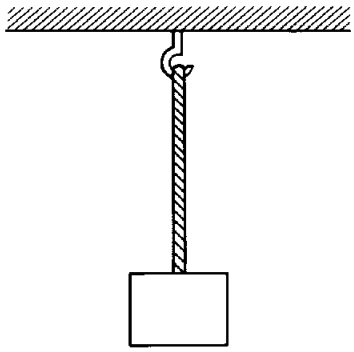
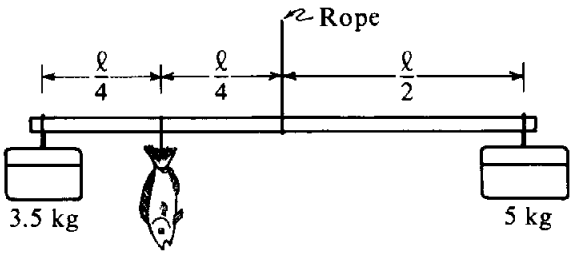


42. A uniform rope of weight 50 newtons hangs from a hook as shown above. A box of weight 100 newtons hangs from the rope. What is the tension in the rope?

(A) 50 N throughout the rope
(B) 75 N throughout the rope
(C) 100 N throughout the rope
(D) 150 N throughout the rope
(E) It varies from 100 N at the bottom of the rope to 150 N at the top.



43. To weigh a fish, a person hangs a tackle box of mass 3.5 kilograms and a cooler of mass 5 kilograms from the ends of a uniform rigid pole that is suspended by a rope attached to its center. The system balances when the fish hangs at a point $\frac{1}{4}$ of the rod's length from the tackle box. What is the mass of the fish?

(A) 1.5 kg
(B) 2 kg
(C) 3 kg
(D) 6 kg
(E) 6.5 kg

44. An object swings on the end of a cord as a simple pendulum with period T. Another object oscillates up and down on the end of a vertical spring, also with period T. If the masses of both objects are doubled, what are the new values for the periods?

	Pendulum	Mass on Spring
(A)	$T/\sqrt{2}$	$\sqrt{2}\,T$
(B)	T	$\sqrt{2}\,T$
(C)	T	T
(D)	$\sqrt{2}\,T$	T
(E)	$\sqrt{2}\,T$	$T/\sqrt{2}$

45. A proton collides with a nucleus of ${}^{14}_{7}\mathrm{N}$. If this collision produces a nucleus of ${}^{11}_{6}\mathrm{C}$ and one other particle, that particle is

(A) a proton
(B) a neutron
(C) a deuteron
(D) an α particle
(E) a β particle

46. The scattering of alpha particles by a thin gold foil was measured by Geiger and Marsden. The Rutherford model of the atom was proposed in order to explain why

(A) more particles were scattered through angles greater than 90° than were scattered through angles less than 90°
(B) the fraction of particles scattered through large angles was too large to be explained by previous models of the atom
(C) no particles passed through the foil undeflected
(D) the most common scattering angle was about 90°
(E) the most common scattering angle was about 180°

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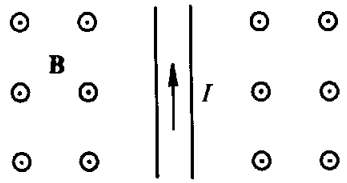


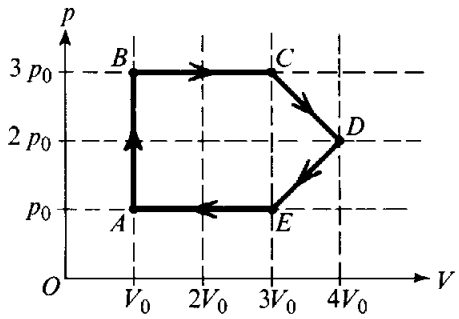
47. A wire in the plane of the page carries a current I directed toward the top of the page, as shown above. If the wire is located in a uniform magnetic field **B** directed out of the page, the force on the wire resulting from the magnetic field is

(A) directed into the page
(B) directed out of the page
(C) directed to the right
(D) directed to the left
(E) zero

48. Which of the following is always a characteristic of an adiabatic process?

(A) The temperature does not change ($\triangle T = 0$).
(B) The pressure does not change ($\triangle P = 0$).
(C) The internal energy does not change ($\triangle U = 0$).
(D) No heat flows into or out of the system ($Q = 0$).
(E) No work is done on or by the system ($W = 0$).

Questions 49-50



An ideal gas undergoes a cyclic process as shown on the graph above of pressure p *versus* volume V.

49. During which process is no work done on or by the gas?

(A) AB
(B) BC
(C) CD
(D) DE
(E) EA *

50. At which point is the gas at its highest temperature?

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

* In the actual examination, option (E) was erroneously printed as EF, instead of EA. Because this was an incorrect option anyway, the question was scored as it stood.

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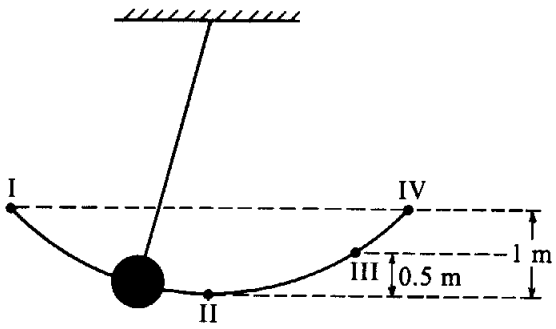
Questions 51-52



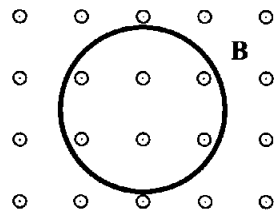
A ball swings freely back and forth in an arc from point I to point IV, as shown above. Point II is the lowest point in the path, III is located 0.5 meter above II, and IV is 1 meter above II. Air resistance is negligible.

51. If the potential energy is zero at point II, where will the kinetic and potential energies of the ball be equal?

(A) At point II
(B) At some point between II and III
(C) At point III
(D) At some point between III and IV
(E) At point IV

52. The speed of the ball at point II is most nearly

(A) 3.0 m/s
(B) 4.5 m/s
(C) 9.8 m/s
(D) 14 m/s
(E) 20 m/s



53. A magnetic field **B** that is decreasing with time is directed out of the page and passes through a loop of wire in the plane of the page, as shown above. Which of the following is true of the induced current in the wire loop?

(A) It is counterclockwise in direction.
(B) It is clockwise in direction.
(C) It is directed into the page.
(D) It is directed out of the page.
(E) It is zero in magnitude.

54. Two isolated charges, $+q$ and $-2q$, are 2 centimeters apart. If F is the magnitude of the force acting on charge $-2q$, what are the magnitude and direction of the force acting on charge $+q$?

	Magnitude	Direction
(A)	$\frac{1}{2}F$	Toward charge $-2q$
(B)	$\frac{1}{2}F$	Away from charge $-2q$
(C)	F	Toward charge $-2q$
(D)	F	Away from charge $-2q$
(E)	$2F$	Toward charge $-2q$

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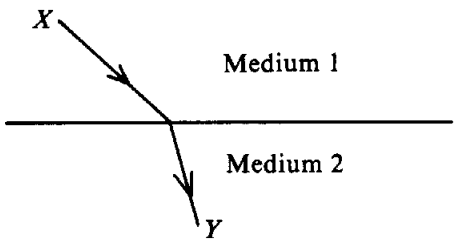
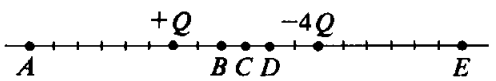


55. Light leaves a source at X and travels to Y along the path shown above. Which of the following statements is correct?

(A) The index of refraction is the same for the two media.
(B) Light travels faster in medium 2 than in medium 1.
(C) Snell's law breaks down at the interface.
(D) Light would arrive at Y in less time by taking a straight line path from X to Y than it does taking the path shown above.
(E) Light leaving a source at Y and traveling to X would follow the same path shown above, but in reverse.

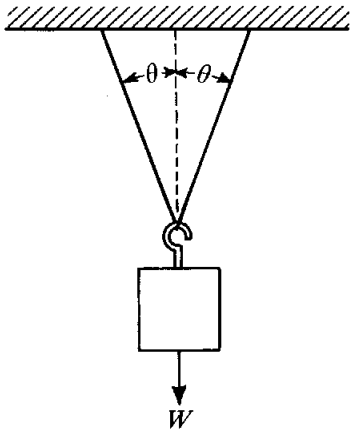
56. A nucleus of tritium contains 2 neutrons and 1 proton. If the nucleus undergoes beta decay, emitting an electron, the nucleus is transmuted into

(A) the nucleus of an isotope of helium
(B) the nucleus of an isotope of lithium
(C) an alpha particle
(D) a triton
(E) a deuteron



57. Charges $+Q$ and $-4Q$ are situated as shown above. The net electric field is zero nearest which point?

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



58. When an object of weight W is suspended from the center of a massless string as shown above, the tension at any point in the string is

(A) $2W \cos \theta$

(B) $\frac{W \cos \theta}{2}$

(C) $W \cos \theta$

(D) $\frac{W}{2 \cos \theta}$

(E) $\frac{W}{\cos \theta}$

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59. A positive charge of 10^{-6} coulomb is placed on an insulated solid conducting sphere. Which of the following is true?

(A) The charge resides uniformly throughout the sphere.
(B) The electric field inside the sphere is constant in magnitude, but not zero.
(C) The electric field in the region surrounding the sphere increases with increasing distance from the sphere.
(D) An insulated metal object acquires a net positive charge when brought near to, but not in contact with, the sphere.
(E) When a second conducting sphere is connected by a conducting wire to the first sphere, charge is transferred until the electric potentials of the two spheres are equal.

60. An object weighing 4 newtons swings on the end of a string as a simple pendulum. At the bottom of the swing, the tension in the string is 6 newtons. What is the magnitude of the centripetal acceleration of the object at the bottom of the swing?

(A) 0
(B) $\frac{1}{2}g$
(C) g
(D) $\frac{3}{2}g$
(E) $\frac{5}{2}g$

61. A satellite of mass M moves in a circular orbit of radius R at a constant speed v. Which of the following must be true?

I. The net force on the satellite is equal to $\frac{Mv^2}{R}$ and is directed toward the center of the orbit.
II. The net work done on the satellite by gravity in one revolution is zero.
III. The angular momentum of the satellite is a constant.

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

62. A truck traveled 400 meters north in 80 seconds, and then it traveled 300 meters east in 70 seconds. The magnitude of the average velocity of the truck was most nearly

(A) 1.2 m/s
(B) 3.3 m/s
(C) 4.6 m/s
(D) 6.6 m/s
(E) 9.3 m/s

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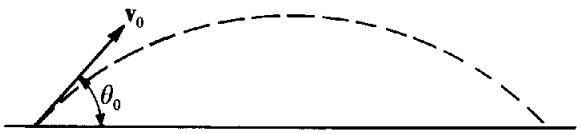
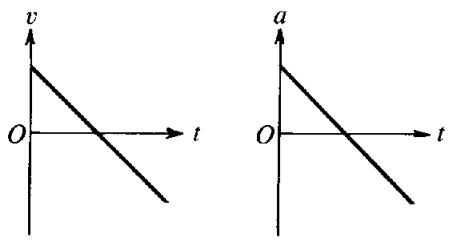
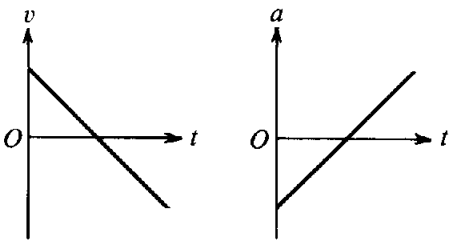
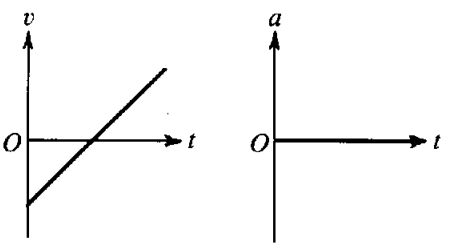
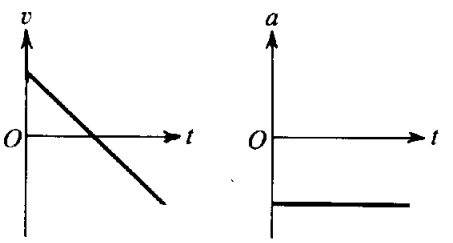


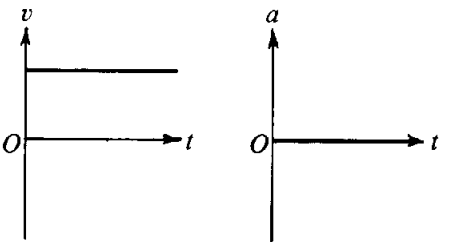
63. A projectile is fired with initial velocity v_0 at an angle θ_0 with the horizontal and follows the trajectory shown above. Which of the following pairs of graphs best represents the vertical components of the velocity and acceleration, v and a, respectively, of the projectile as functions of time t?

(A)


(B)


(C)


(D)


(E)


64. Which of the following statements is true of a beta particle?

(A) Its speed in a vacuum is 3×10^8 m/s.
(B) It has a charge equal and opposite to that of an alpha particle.
(C) It is more penetrating than a gamma ray of the same energy.
(D) It has a mass of about 1,840 times that of a proton.
(E) It can exhibit wave properties.

65. A space traveler is moving relative to the Earth at 2.4×10^8 meters per second (0.8 c), as measured in the Earth's frame of reference. In one year as measured in the Earth's frame of reference, the space traveler will do which of the following?

(A) Travel 0.6 light-year and age 0.6 year.
(B) Travel 0.8 light-year and age 0.6 year.
(C) Travel 0.8 light-year and age 1 year.
(D) Travel 0.8 light-year and age 1.67 years.
(E) Travel 1 light-year and age 1 year.

GO ON TO THE NEXT PAGE

Questions 66-67

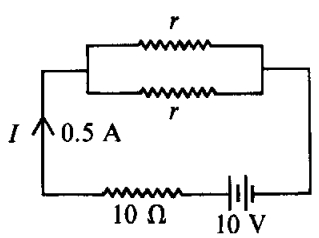
An electron and a positron, each of mass 9.1×10^{-31} kilogram, are in the same general vicinity and have very small initial speeds. They then annihilate each other, producing two photons.

66. What is the approximate energy of each emerging photon?

(A) 0.51 MeV
(B) 2.0 MeV
(C) 4.0 MeV
(D) 6.6 MeV
(E) It cannot be determined unless the frequency of the photon is known.

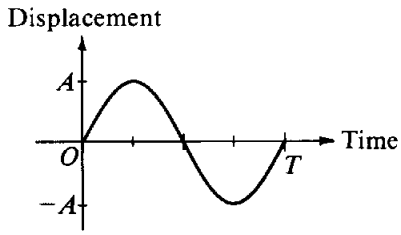
67. What is the angle between the paths of the emerging photons?

(A) 0°
(B) 30°
(C) 45°
(D) 90°
(E) 180°



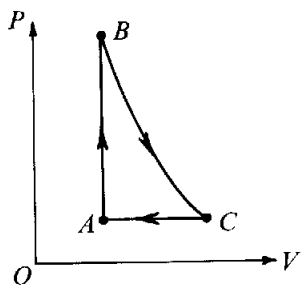
68. In the circuit shown above, the value of r for which the current I is 0.5 ampere is

(A) 0 Ω
(B) 1 Ω
(C) 5 Ω
(D) 10 Ω
(E) 20 Ω



69. An object is attached to a spring and oscillates with amplitude A and period T, as represented on the graph above. The nature of the velocity v and acceleration a of the object at time $T/4$ is best represented by which of the following?

(A) $v > 0$, $a > 0$
(B) $v > 0$, $a < 0$
(C) $v > 0$, $a = 0$
(D) $v = 0$, $a < 0$
(E) $v = 0$, $a = 0$



70. Gas in a chamber passes through the cycle $ABCA$ as shown in the diagram above. In the process AB, 12 joules of heat is added to the gas. In the process BC, no heat is exchanged with the gas. For the complete cycle $ABCA$, the work done by the gas is 8 joules. How much heat is added to or removed from the gas during process CA ?

(A) 20 J is removed.
(B) 4 J is removed.
(C) 4 J is added.
(D) 20 J is added.
(E) No heat is added to or removed from the gas.

END OF SECTION I

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS SECTION.

DO NOT GO ON TO SECTION II UNTIL YOU ARE TOLD TO DO SO.

PHYSICS B
SECTION II
Free-Response Questions
Time—90 minutes
6 required questions of equal weight
Percent of total grade—50

General Instructions

When you are told to begin, carefully tear out the green insert, and start work. The questions in the green insert are duplicates of those in this booklet. A table of information that may be helpful is on the next page of this booklet.

Show your work. You are to write your answer to each question in the pink booklet. Several additional answer pages follow each question. Be sure to write CLEARLY and LEGIBILY. If you make an error, you may save time by crossing it out rather than trying to erase it.

TABLE OF INFORMATION

1 atomic mass unit,	$1\ \text{u} = 1.66 \times 10^{-27}$ kilogram
Rest mass of the proton,	$m_p = 1.67 \times 10^{-27}$ kilogram
Rest mass of the neutron,	$m_n = 1.67 \times 10^{-27}$ kilogram
Rest mass of the electron,	$m_e = 9.11 \times 10^{-31}$ kilogram
Magnitude of the electron charge,	$e = 1.60 \times 10^{-19}$ coulomb
Avogadro's number,	$N_0 = 6.02 \times 10^{23}$ per mole
Universal gas constant,	$R = 8.32$ joules/(mole · K)
Boltzmann's constant,	$k_B = 1.38 \times 10^{-23}$ joule/K
Speed of light,	$c = 3.00 \times 10^{8}$ meters/second
Planck's constant,	$h = 6.63 \times 10^{-34}$ joule · second $= 4.14 \times 10^{-15}$ eV · second
	$hc = 1.99 \times 10^{-25}$ joule · meter $= 1.24 \times 10^{4}$ eV · angstrom
1 electron volt,	$1\ \text{eV} = 1.60 \times 10^{-19}$ joule
Vacuum permittivity,	$\epsilon_0 = 8.85 \times 10^{-12}$ coulomb^2/(newton · meter^2)
Coulomb's law constant,	$k = 1/4\pi\epsilon_0 = 9.0 \times 10^{9}$ newtons · meter^2/coulomb^2
Vacuum permeability,	$\mu_0 = 4\pi \times 10^{-7}$ weber/(ampere · meter)
Magnetic constant,	$k' = k/c^2 = \mu_0/4\pi = 10^{-7}$weber/(ampere · meter)
Acceleration due to gravity at the Earth's surface,	$g = 9.8$ meters/second^2
Universal gravitational constant,	$G = 6.67 \times 10^{-11}$ meter^3/(kilogram · second^2)
1 atmosphere pressure,	$1\ \text{atm} = 1.0 \times 10^{5}$ newtons/meter^2 $= 1.0 \times 10^{5}$ pascals (Pa)
1 angstrom,	$1\ \text{Å} = 1 \times 10^{-10}$ meter
1 tesla,	1 T = 1 weber/meter^2

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.

PHYSICS B

SECTION II

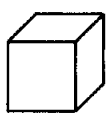
Time—90 minutes

6 Questions

ANSWER ALL OF THE QUESTIONS. EACH OF THE SIX QUESTIONS HAS EQUAL WEIGHT, BUT THE PARTS WITHIN A QUESTION MAY NOT HAVE EQUAL WEIGHT. SHOW YOUR WORK. CREDIT FOR YOUR ANSWERS DEPENDS ON THE QUALITY OF YOUR EXPLANATIONS.

1. A helicopter holding a 70-kilogram package suspended from a rope 5.0 meters long accelerates upward at a rate of 5.2 m/s^2. Neglect air resistance on the package.

   (a) On the diagram below, draw and label all of the forces acting on the package.

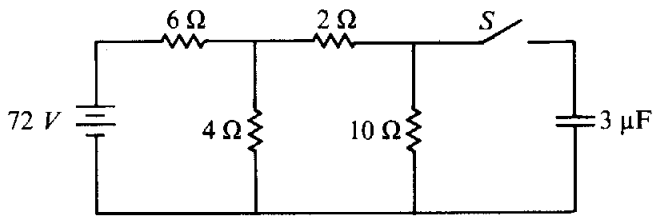


   (b) Determine the tension in the rope.

   (c) When the upward velocity of the helicopter is 30 meters per second, the rope is cut and the helicopter continues to accelerate upward at 5.2 m/s^2. Determine the distance between the helicopter and the package 2.0 seconds after the rope is cut.

GO ON TO THE NEXT PAGE

2. A ball thrown vertically downward strikes a horizontal surface with a speed of 15 meters per second. It then bounces, and reaches a maximum height of 5 meters. Neglect air resistance on the ball.
   (a) What is the speed of the ball immediately after it rebounds from the surface?
   (b) What fraction of the ball's initial kinetic energy is apparently lost during the bounce?
   (c) If the specific heat of the ball is 1,800 J/kg °C, and if all of the lost energy is absorbed by the molecules of the ball, by how much does the temperature of the ball increase?



3. The circuit shown above includes a switch S, which can be closed to connect the 3-microfarad capacitor in parallel with the 10-ohm resistor or opened to disconnect the capacitor from the circuit.

Case I. Switch S is open. The capacitor is not connected. Under these conditions determine:

(a) the current in the battery
(b) the current in the 10-ohm resistor
(c) the potential difference across the 10-ohm resistor

Case II. Switch S is closed. The capacitor is connected. After some time, the currents reach constant values. Under these conditions determine:

(d) the charge on the capacitor
(e) the energy stored in the capacitor

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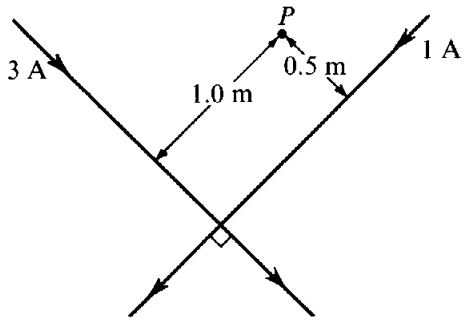

4. The magnitude of the magnetic field in teslas at a distance d from a long straight wire carrying a current I is given by the relation $B = 2 \times 10^{-7} I/d$. The two long straight wires shown above are perpendicular, insulated from each other, and small enough so that they may be considered to be in the same plane. The wires are not free to move. Point P, in the same plane as the wires, is 0.5 meter from the wire carrying a current of 1 ampere and is 1.0 meter from the wire carrying a current of 3 amperes.

   (a) What is the direction of the net magnetic field at P due to the currents?

   (b) Determine the magnitude of the net magnetic field at P due to the currents.

   A charged particle at point P that is instantaneously moving with a velocity of 10^6 meters per second toward the top of the page experiences a force of 10^{-7} newtons to the left due to the two currents.

   (c) State whether the charge on the particle is positive or negative.

   (d) Determine the magnitude of the charge on the particle.

   (e) Determine the magnitude and direction of an electric field also at point P that would make the net force on this moving charge equal to zero.

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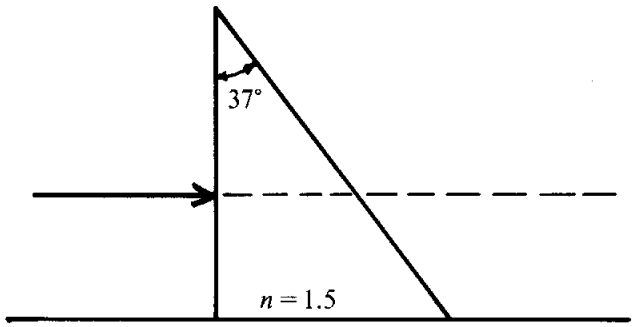

Figure I

5. The triangular prism shown in Figure I above has index of refraction 1.5 and angles of 37°, 53°, and 90°. The shortest side of the prism is set on a horizontal table. A beam of light, initially horizontal, is incident on the prism from the left.

   (a) On Figure I above, sketch the path of the beam as it passes through and emerges from the prism.

   (b) Determine the angle with respect to the horizontal (angle of deviation) of the beam as it emerges from the prism.

   (c) The prism is replaced by a new prism of the same shape, which is set in the same position. The beam experiences total internal reflection at the right surface of this prism. What is the minimum possible index of refraction of this prism?

The new prism having the index of refraction found in part (c) is then completely submerged in water (index of refraction = 1.33) as shown in Figure II below. A horizontal beam of light is again incident from the left.

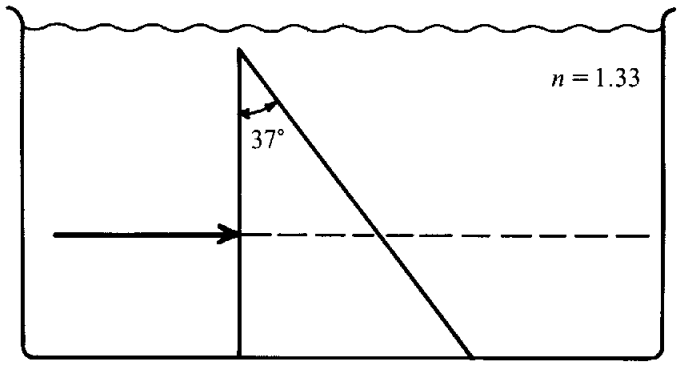

Figure II

   (d) On Figure II, sketch the path of the beam as it passes through and emerges from the prism.

   (e) Determine the angle with respect to the horizontal (angle of deviation) of the beam as it emerges from the prism.

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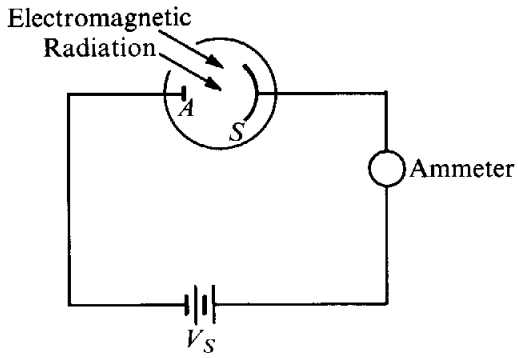

6. Electromagnetic radiation is incident on the surface S of a material as shown above. Photoelectrons are emitted from the surface S only for radiation of wavelength 5,000 angstroms or less. It is found that for a certain ultraviolet wavelength, which is unknown, a potential V_S of 3 volts is necessary to stop the photoelectrons from reaching the anode A, thus eliminating the photoelectric current.

   (a) Determine the frequency of the 5,000 Å radiation.

   (b) Determine the work function for the material.

   (c) Determine the energy of the photons associated with the unknown wavelength.

   (d) Determine the unknown wavelength.

END OF EXAMINATION