9. A child pushes horizontally on a box of mass m which moves with constant speed v across a horizontal floor. The coefficient of friction between the box and the floor is μ. At what rate does the child do work on the box?

(A) μmgv
(B) mgv
(C) $v/\mu mg$
(D) $\mu mg/v$
(E) μmv^2

10. Quantum transitions that result in the characteristic sharp lines of the X-ray spectrum always involve

(A) the inner electron shells
(B) electron energy levels that have the same principal quantum number
(C) emission of beta particles from the nucleus
(D) neutrons within the nucleus
(E) protons within the nucleus

11. Which of the following experiments provided evidence that electrons exhibit wave properties?

I. Millikan oil-drop experiment
II. Davisson-Germer electron-diffraction experiment
III. J. J. Thomson's measurement of the charge-to-mass ratio of electrons

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

12. Quantities that are conserved in all nuclear reactions include which of the following?

I. Electric charge
II. Number of nuclei
III. Number of protons

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

13. Which of the following is true about the net force on an uncharged conducting sphere in a uniform electric field?

(A) It is zero.
(B) It is in the direction of the field.
(C) It is in the direction opposite to the field.
(D) It produces a torque on the sphere about the direction of the field.
(E) It causes the sphere to oscillate about an equilibrium position.

14. Two parallel conducting plates are connected to a constant voltage source. The magnitude of the electric field between the plates is 2,000 N/C. If the voltage is doubled and the distance between the plates is reduced to 1/5 the original distance, the magnitude of the new electric field is

(A) 800 N/C
(B) 1,600 N/C
(C) 2,400 N/C
(D) 5,000 N/C
(E) 20,000 N/C

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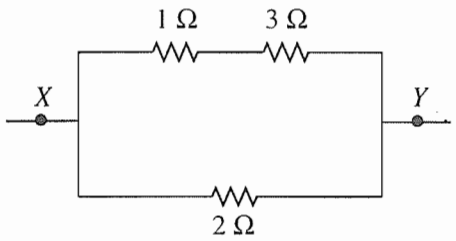
Questions 15-16 refer to the following diagram that shows part of a closed electrical circuit.



15. The electrical resistance of the part of the circuit shown between point X and point Y is

(A) $1\frac{1}{3}\ \Omega$

(B) $2\ \Omega$

(C) $2\frac{3}{4}\ \Omega$

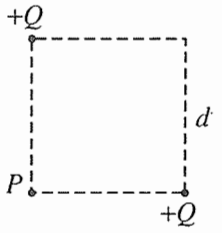
(D) $4\ \Omega$

(E) $6\ \Omega$

16. When there is a steady current in the circuit, the amount of charge passing a point per unit of time is

(A) the same everywhere in the circuit
(B) greater at point X than at point Y
(C) greater in the 1 Ω resistor than in the 2 Ω resistor
(D) greater in the 1 Ω resistor than in the 3 Ω resistor
(E) greater in the 2 Ω resistor than in the 3 Ω resistor

Questions 17-18



The figure above shows two particles, each with a charge of $+Q$, that are located at the opposite corners of a square of side d.

17. What is the direction of the net electric field at point P?

(A) ↖
(B) ↗
(C) ↙
(D) ↘
(E) ↓

18. What is the potential energy of a particle of charge $+q$ that is held at point P?

(A) Zero

(B) $\frac{\sqrt{2}}{4\pi\epsilon_0}\frac{qQ}{d}$

(C) $\frac{1}{4\pi\epsilon_0}\frac{qQ}{d}$

(D) $\frac{2}{4\pi\epsilon_0}\frac{qQ}{d}$

(E) $\frac{2\sqrt{2}}{4\pi\epsilon_0}\frac{qQ}{d}$

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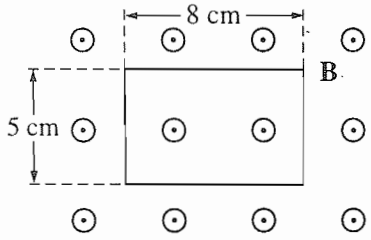
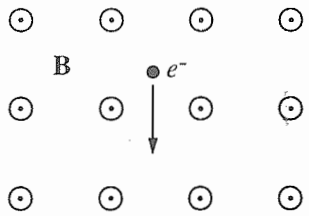


19. A rectangular wire loop is at rest in a uniform magnetic field **B** of magnitude 2 T that is directed out of the page. The loop measures 5 cm by 8 cm, and the plane of the loop is perpendicular to the field, as shown above. The total magnetic flux through the loop is

(A) zero
(B) 2×10^{-3} T·m^2
(C) 8×10^{-3} T·m^2
(D) 2×10^{-1} T·m^2
(E) 8×10^{-1} T·m^2

20. A certain coffeepot draws 4.0 A of current when it is operated on 120 V household lines. If electrical energy costs 10 cents per kilowatt-hour, how much does it cost to operate the coffeepot for 2 hours?

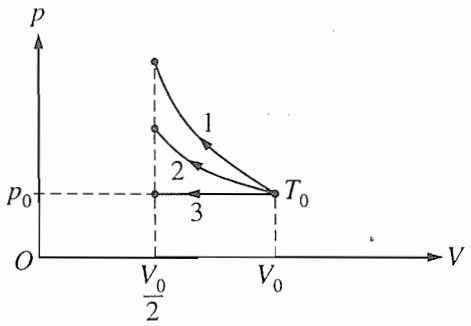
(A) 2.4 cents
(B) 4.8 cents
(C) 8.0 cents
(D) 9.6 cents
(E) 16 cents



21. An electron is in a uniform magnetic field **B** that is directed out of the plane of the page, as shown above. When the electron is moving in the plane of the page in the direction indicated by the arrow, the force on the electron is directed

(A) toward the right
(B) out of the page
(C) into the page
(D) toward the top of the page
(E) toward the bottom of the page

Questions 22-23



A certain quantity of an ideal gas initially at temperature T_0, pressure p_0, and volume V_0 is compressed to one-half its initial volume. As shown above, the process may be adiabatic (process 1), isothermal (process 2), or isobaric (process 3).

22. Which of the following is true of the mechanical work done on the gas?

(A) It is greatest for process 1.
(B) It is greatest for process 3.
(C) It is the same for processes 1 and 2 and less for process 3.
(D) It is the same for processes 2 and 3 and less for process 1.
(E) It is the same for all three processes.

23. Which of the following is true of the final temperature of this gas?

(A) It is greatest for process 1.
(B) It is greatest for process 2.
(C) It is greatest for process 3.
(D) It is the same for processes 1 and 2.
(E) It is the same for processes 1 and 3.

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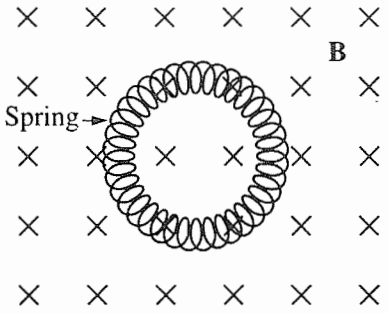

45. A metal spring has its ends attached so that it forms a circle. It is placed in a uniform magnetic field, as shown above. Which of the following will NOT cause a current to be induced in the spring?

(A) Changing the magnitude of the magnetic field
(B) Increasing the diameter of the circle by stretching the spring
(C) Rotating the spring about a diameter
(D) Moving the spring parallel to the magnetic field
(E) Moving the spring in and out of the magnetic field

Questions 46-47

A magnetic field of 0.1 T forces a proton beam of 1.5 mA to move in a circle of radius 0.1 m. The plane of the circle is perpendicular to the magnetic field.

46. Of the following, which is the best estimate of the work done by the magnetic field on the protons during one complete orbit of the circle?

(A) 0 J
(B) 10^{-22} J
(C) 10^{-5} J
(D) 10^{2} J
(E) 10^{20} J

47. Of the following, which is the best estimate of the speed of a proton in the beam as it moves in the circle?

(A) 10^{-2} m/s
(B) 10^{3} m/s
(C) 10^{6} m/s
(D) 10^{8} m/s
(E) 10^{15} m/s

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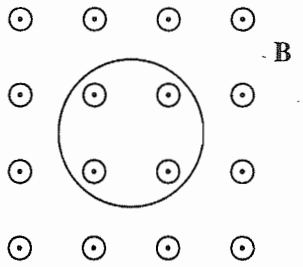
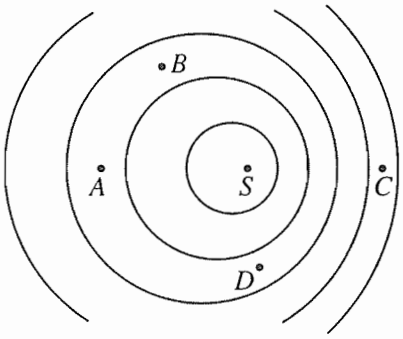


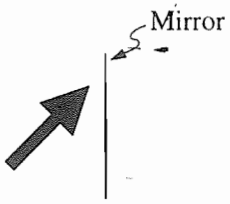
48. A single circular loop of wire in the plane of the page is perpendicular to a uniform magnetic field **B** directed out of the page, as shown above. If the magnitude of the magnetic field is decreasing, then the induced current in the wire is

(A) directed upward out of the paper
(B) directed downward into the paper
(C) clockwise around the loop
(D) counterclockwise around the loop
(E) zero (no current is induced)



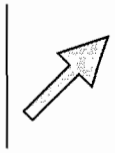
49. A small vibrating object on the surface of a ripple tank is the source of waves of frequency 20 Hz and speed 60 cm/s. If the source S is moving to the right, as shown above, with speed 20 cm/s, at which of the labeled points will the frequency measured by a stationary observer be greatest?

(A) *A*
(B) *B*
(C) *C*
(D) *D*
(E) It will be the same at all four points.

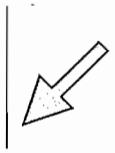


50. An object, slanted at an angle of 45°, is placed in front of a vertical plane mirror, as shown above. Which of the following shows the apparent position and orientation of the object's image?

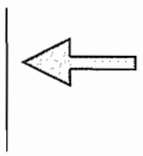
(A)



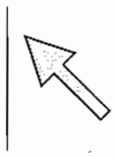
(B)



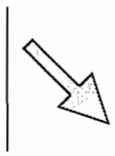
(C)



(D)



(E)



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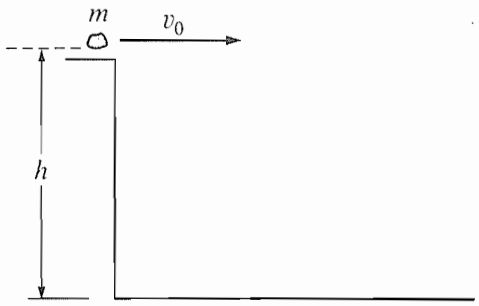
Questions 59-60



A rock of mass m is thrown horizontally off a building from a height h, as shown above. The speed of the rock as it leaves the thrower's hand at the edge of the building is v_0.

59. How much time does it take the rock to travel from the edge of the building to the ground?

(A) $\sqrt{hv_0}$
(B) h/v_0
(C) hv_0/g
(D) $2h/g$
(E) $\sqrt{2h/g}$

60. What is the kinetic energy of the rock just before it hits the ground?

(A) mgh
(B) $\frac{1}{2}mv_0^2$
(C) $\frac{1}{2}mv_0^2 - mgh$
(D) $\frac{1}{2}mv_0^2 + mgh$
(E) $mgh - \frac{1}{2}mv_0^2$

61. Which of the following statements is NOT a correct assumption of the classical model of an ideal gas?

(A) The molecules are in random motion.
(B) The volume of the molecules is negligible compared with the volume occupied by the gas.
(C) The molecules obey Newton's laws of motion.
(D) The collisions between molecules are inelastic.
(E) The only appreciable forces on the molecules are those that occur during collisions.

62. A sample of an ideal gas is in a tank of constant volume. The sample absorbs heat energy so that its temperature changes from 300 K to 600 K. If v_1 is the average speed of the gas molecules before the absorption of heat and v_2 is their average speed after the absorption of heat, what is the ratio v_2/v_1 ?

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

63. Two people of unequal mass are initially standing still on ice with negligible friction. They then simultaneously push each other horizontally. Afterward, which of the following is true?

(A) The kinetic energies of the two people are equal.
(B) The speeds of the two people are equal.
(C) The momenta of the two people are of equal magnitude.
(D) The center of mass of the two-person system moves in the direction of the less massive person.
(E) The less massive person has a smaller initial acceleration than the more massive person.

64. Two parallel conducting plates, separated by a distance d, are connected to a battery of emf $\mathcal{E}$. Which of the following is correct if the plate separation is doubled while the battery remains connected?

(A) The electric charge on the plates is doubled.
(B) The electric charge on the plates is halved.
(C) The potential difference between the plates is doubled.
(D) The potential difference between the plates is halved.
(E) The capacitance is unchanged.

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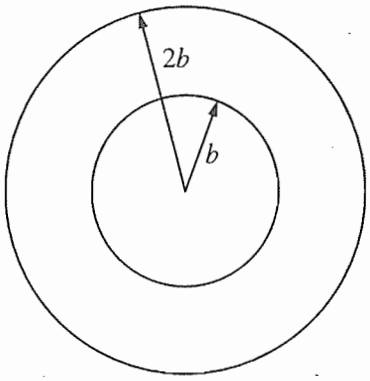
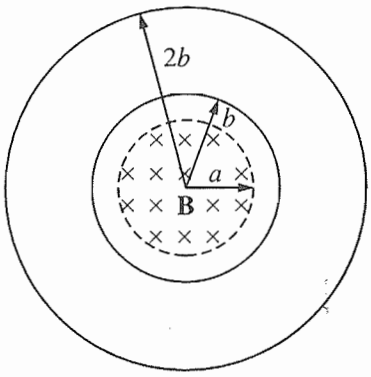
Questions 65-66



Two concentric circular loops of radii b and $2b$, made of the same type of wire, lie in the plane of the page, as shown above.

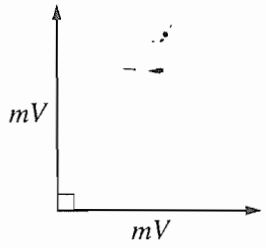
65. The total resistance of the wire loop of radius b is R. What is the resistance of the wire loop of radius $2b$?

(A) $R/4$
(B) $R/2$
(C) R
(D) $2R$
(E) $4R$



66. A uniform magnetic field **B** that is perpendicular to the plane of the page now passes through the loops, as shown above. The field is confined to a region of radius a, where $a < b$, and is changing at a constant rate. The induced emf in the wire loop of radius b is $\mathcal{E}$. What is the induced emf in the wire loop of radius $2b$?

(A) Zero
(B) $\mathcal{E}/2$
(C) $\mathcal{E}$
(D) $2\mathcal{E}$
(E) $4\mathcal{E}$



67. A stationary object explodes, breaking into three pieces of masses m, m, and $3m$. The two pieces of mass m move off at right angles to each other with the same magnitude of momentum mV, as shown in the diagram above. What are the magnitude and direction of the velocity of the piece having mass $3m$?

	Magnitude	Direction
(A)	$\frac{V}{\sqrt{3}}$	↗
(B)	$\frac{V}{\sqrt{3}}$	↙
(C)	$\frac{\sqrt{2}\,V}{3}$	↗
(D)	$\frac{\sqrt{2}\,V}{3}$	↙
(E)	$\sqrt{2}\,V$	↙

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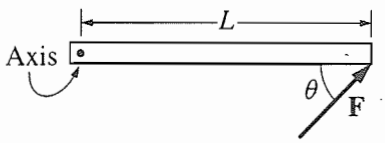


View from Above

68. A rod on a horizontal tabletop is pivoted at one end and is free to rotate without friction about a vertical axis, as shown above. A force **F** is applied at the other end, at an angle θ to the rod. If **F** were to be applied perpendicular to the rod, at what distance from the axis should it be applied in order to produce the same torque?

(A) $L \sin \theta$
(B) $L \cos \theta$
(C) L
(D) $L \tan \theta$
(E) $\sqrt{2}\, L$

69. Which of the following imposes a limit on the number of electrons in an energy state of an atom?

(A) The Heisenberg uncertainty principle
(B) The Pauli exclusion principle
(C) The Bohr model of the hydrogen atom
(D) The theory of relativity
(E) The law of conservation of energy

70. A 4 μF capacitor is charged to a potential difference of 100 V. The electrical energy stored in the capacitor is

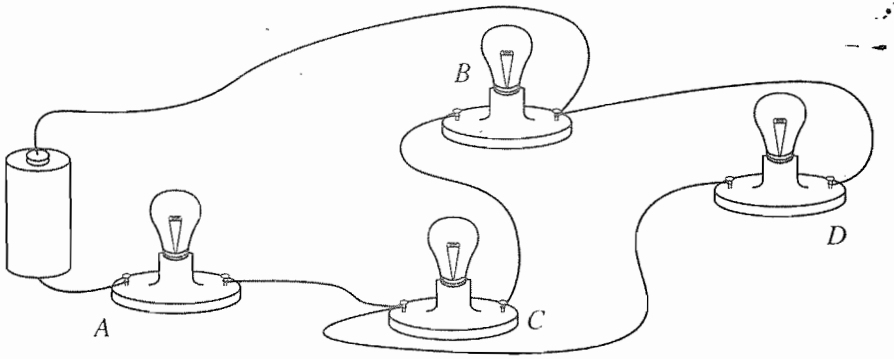
(A) 2×10^{-10} J
(B) 2×10^{-8} J
(C) 2×10^{-6} J
(D) 2×10^{-4} J
(E) 2×10^{-2} J

STOP

END OF SECTION I

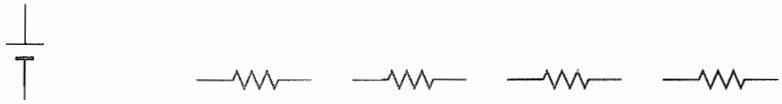
IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON THIS SECTION.

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



4. (10 points)
In the circuit shown above, A, B, C, and D are identical lightbulbs. Assume that the battery maintains a constant potential difference between its terminals (i.e., the internal resistance of the battery is assumed to be negligible) and the resistance of each lightbulb remains constant.

(a) Draw a diagram of the circuit in the box below, using the following symbols to represent the components in your diagram. Label the resistors A, B, C, and D to refer to the corresponding lightbulbs.



Battery Resistors

Draw your diagram in this box only.

GO ON TO THE NEXT PAGE

(b) List the bulbs in order of their brightnesses, from brightest to least bright. If any two or more bulbs have the same brightness, state which ones. Justify your answer.

(c) Bulb D is then removed from its socket.

i. Describe the change in the brightness, if any, of bulb A when bulb D is removed from its socket. Justify your answer.

ii. Describe the change in the brightness, if any, of bulb B when bulb D is removed from its socket. Justify your answer.

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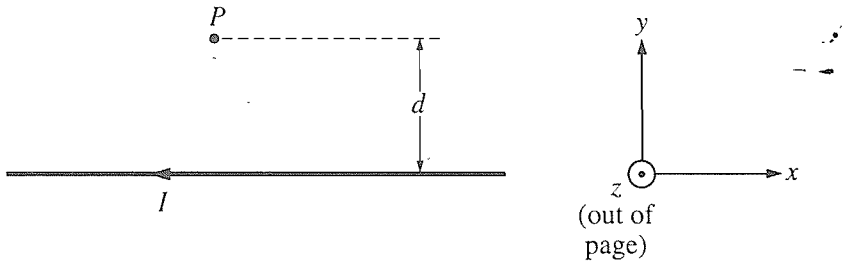

Figure 1

8. (10 points)
The long, straight wire shown in Figure 1 above is in the plane of the page and carries a current I. Point P is also in the plane of the page and is a perpendicular distance d from the wire. Gravitational effects are negligible.

(a) With reference to the coordinate system in Figure 1, what is the direction of the magnetic field at point P due to the current in the wire?

A particle of mass m and positive charge q is initially moving parallel to the wire with a speed v_0 when it is at point P, as shown in Figure 2 below.

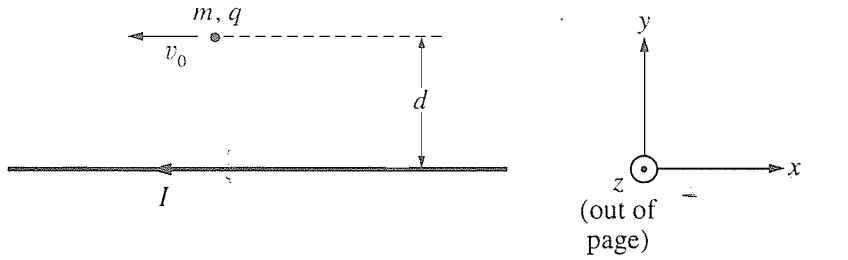

Figure 2

(b) With reference to the coordinate system in Figure 2, what is the direction of the magnetic force acting on the particle at point P ?

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(c) Determine the magnitude of the magnetic force acting on the particle at point P in terms of the given quantities and fundamental constants.

(d) An electric field is applied that causes the net force on the particle to be zero at point P.

i. With reference to the coordinate system in Figure 2, what is the direction of the electric field at point P that could accomplish this?

ii. Determine the magnitude of the electric field in terms of the given quantities and fundamental constants.

End of Examination

Chapter III Answers to the 1998 AP Physics B Examination

- Section I: Multiple Choice
  - Blank Answer Sheet
- Section II: Free Response

Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions and the percentage of AP candidates who answered each question correctly. A copy of the blank answer sheet appears on the following pages.

Answer Key and Percent Answering Correctly

Item No.	Correct Answer	Percent Correct	Item No.	Correct Answer	Percent Correct	Item No.	Correct Answer	Percent Correct
1	B	77%	25	B	41%	48	D	39%
2	C	76%	26	B	33%	49	C	72%
3	E	70%	27	E	51%	50	D	78%
4	C	59%	28	D	43%	51	D	19%
5	C	50%	29	B	84%	52	B	45%
6	E	22%	30	D	48%	53	C	59%
7	A	71%	31	A	77%	54	B	14%
8	D	82%	32	B	84%	55	B	19%
9	A	47%	33	D	32%	56	D	38%
10	A	9%	34	B	42%	57	C	39%
11	B	59%	35	A	18%	58	C	45%
12	A	17%	36	A	79%	59	E	66%
13	A	51%	37	A	49%	60	D	30%
14	E	53%	38	D	15%	61	D	53%
15	A	66%	39	E	69%	62	C	16%
16	E	37%	40	B	23%	63	C	56%
17	C	68%	41	A	74%	64	B	24%
18	D	17%	42	E	53%	65	D	37%
19	C	32%	43	B	62%	66	C	9%
20	D	48%	44	C	53%	67	D	45%
21	A	72%	45	D	45%	68	A	50%
22	A	53%	46	A	23%	69	B	34%
23	A	59%	47	C	17%	70	E	27%
24	C	75%						

PHYSICS C

SECTION I, ELECTRICITY AND MAGNETISM

Time—45 minutes

35 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.

36. A resistor R and a capacitor C are connected in series to a battery of terminal voltage V_0. Which of the following equations relating the current I in the circuit and the charge Q on the capacitor describes this circuit?

(A) $V_0 + QC - I^2R = 0$

(B) $V_0 - \frac{Q}{C} - IR = 0$

(C) $V_0^2 - \frac{1}{2}\frac{Q^2}{C} - I^2R = 0$

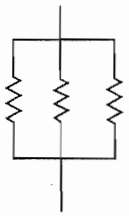
(D) $V_0 - C\frac{dQ}{dt} - I^2R = 0$

(E) $\frac{Q}{C} - IR = 0$

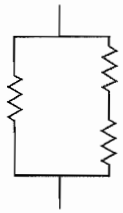
37. Which of the following combinations of 4 Ω resistors would dissipate 24 W when connected to a 12 V battery?

(A)

(B)

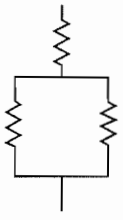


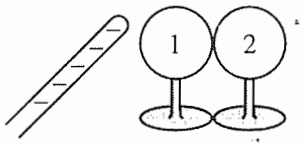
(C)



(D)

(E)





38. Two initially uncharged conductors, 1 and 2, are mounted on insulating stands and are in contact, as shown above. A negatively charged rod is brought near but does not touch them. With the rod held in place, conductor 2 is moved to the right by pushing its stand, so that the conductors are separated. Which of the following is now true of conductor 2 ?

(A) It is uncharged.
(B) It is positively charged.
(C) It is negatively charged.
(D) It is charged, but its sign cannot be predicted.
(E) It is at the same potential that it was before the charged rod was brought near.

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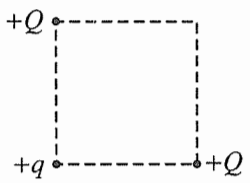
Questions 39-40



As shown above, two particles, each of charge $+Q$, are fixed at opposite corners of a square that lies in the plane of the page. A positive test charge $+q$ is placed at a third corner.

39. What is the direction of the force on the test charge due to the two other charges?

(A) 

(B)

(C) 

(D)

(E) 

40. If F is the magnitude of the force on the test charge due to only one of the other charges, what is the magnitude of the net force acting on the test charge due to both of these charges?

(A) Zero

(B) $F/\sqrt{2}$

(C) F

(D) $\sqrt{2}\,F$

(E) $2\,F$

41. Gauss's law provides a convenient way to calculate the electric field outside and near each of the following isolated charged conductors EXCEPT a

(A) large plate
(B) sphere
(C) cube
(D) long, solid rod
(E) long, hollow cylinder

42. A wire of resistance R dissipates power P when a current I passes through it. The wire is replaced by another wire with resistance $3R$. The power dissipated by the new wire when the same current passes through it is

(A) $\frac{P}{9}$

(B) $\frac{P}{3}$

(C) P

(D) $3P$

(E) $6P$

GO ON TO THE NEXT PAGE

Questions 43-44

A narrow beam of protons produces a current of 1.6×10^{-3} A. There are 10^9 protons in each meter along the beam.

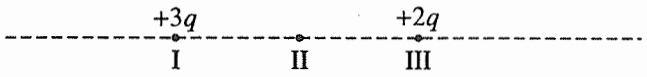
43. Of the following, which is the best estimate of the average speed of the protons in the beam?

(A) 10^{-15} m/s
(B) 10^{-12} m/s
(C) 10^{-7} m/s
(D) 10^{7} m/s
(E) 10^{12} m/s

44. Which of the following describes the lines of magnetic field in the vicinity of the beam due to the beam's current?

(A) Concentric circles around the beam
(B) Parallel to the beam
(C) Radial and toward the beam
(D) Radial and away from the beam
(E) There is no magnetic field.

Questions 45-46 refer to two charges located on the line shown in the figure below, in which the charge at point I is $+3q$ and the charge at point III is $+2q$. Point II is halfway between points I and III.



45. Other than at infinity, the electric field strength is zero at a point on the line in which of the following ranges?

(A) To the left of I
(B) Between I and II
(C) Between II and III
(D) To the right of III
(E) None; the field is zero only at infinity.

46. The electric potential is negative at some points on the line in which of the following ranges?

(A) To the left of I
(B) Between I and II
(C) Between II and III
(D) To the right of III
(E) None; this potential is never negative.

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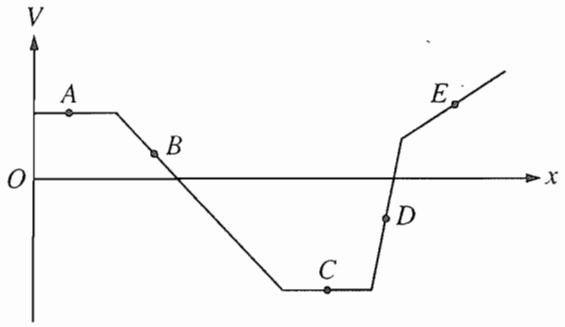
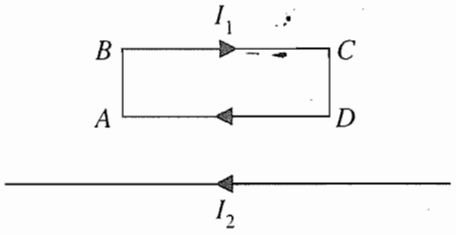


47. The graph above shows the electric potential V in a region of space as a function of position along the x-axis. At which point would a charged particle experience the force of greatest magnitude?

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

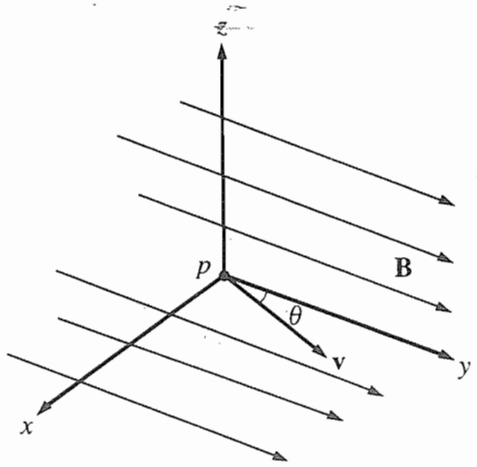
48. The work that must be done by an external agent to move a point charge of 2 mC from the origin to a point 3 m away is 5 J. What is the potential difference between the two points?

(A) 4×10^{-4} V
(B) 10^{-2} V
(C) 2.5×10^{3} V
(D) 2×10^{6} V
(E) 6×10^{6} V



49. A rigid, rectangular wire loop $ABCD$ carrying current I_1 lies in the plane of the page above a very long wire carrying current I_2, as shown above. The net force on the loop is

(A) toward the wire
(B) away from the wire
(C) toward the left
(D) toward the right
(E) zero



50. A uniform magnetic field $\mathbf{B}$ is parallel to the xy-plane and in the $+y$-direction, as shown above. A proton p initially moves with velocity $\mathbf{v}$ in the xy-plane at an angle θ to the magnetic field and the y-axis. The proton will subsequently follow what kind of path?

(A) A straight-line path in the direction of $\mathbf{v}$
(B) A circular path in the xy-plane
(C) A circular path in the yz-plane
(D) A helical path with its axis parallel to the y-axis
(E) A helical path with its axis parallel to the z-axis

GO ON TO THE NEXT PAGE

51. A parallel-plate capacitor has charge $+Q$ on one plate and charge $-Q$ on the other. The plates, each of area A, are a distance d apart and are separated by a vacuum. A single proton of charge $+e$, released from rest at the surface of the positively charged plate, will arrive at the other plate with kinetic energy proportional to

(A) $\frac{edQ}{A}$

(B) $\frac{Q^2}{eAd}$

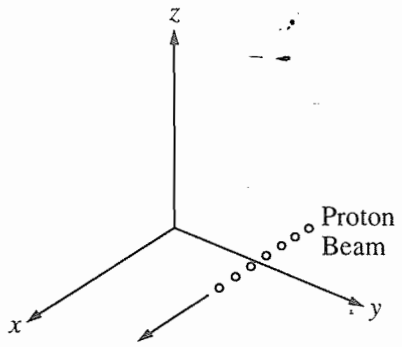
(C) $\frac{AeQ}{d}$

(D) $\frac{Q}{ed}$

(E) $\frac{eQ^2}{Ad}$

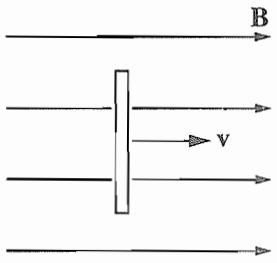
52. In which of the following cases does there exist a nonzero magnetic field that can be conveniently determined by using Ampere's law?

(A) Outside a point charge that is at rest
(B) Inside a stationary cylinder carrying a uniformly distributed charge
(C) Inside a very long current-carrying solenoid
(D) At the center of a current-carrying loop of wire
(E) Outside a square current-carrying loop of wire



53. A beam of protons moves parallel to the x-axis in the positive x-direction, as shown above, through a region of crossed electric and magnetic fields balanced for zero deflection of the beam. If the magnetic field is pointed in the positive y-direction, in what direction must the electric field be pointed?

(A) Positive y-direction
(B) Positive z-direction
(C) Negative x-direction
(D) Negative y-direction
(E) Negative z-direction



54. A vertical length of copper wire moves to the right with a steady velocity $\mathbf{v}$ in the direction of a constant horizontal magnetic field $\mathbf{B}$, as shown above. Which of the following describes the induced charges on the ends of the wire?

	Top End	Bottom End
(A)	Positive	Negative
(B)	Negative	Positive
(C)	Negative	Zero
(D)	Zero	Negative
(E)	Zero	Zero

GO ON TO THE NEXT PAGE

55. Suppose that an electron (charge $-e$) could orbit a proton (charge $+e$) in a circular orbit of constant radius R. Assuming that the proton is stationary and only electrostatic forces act on the particles, which of the following represents the kinetic energy of the two-particle system?

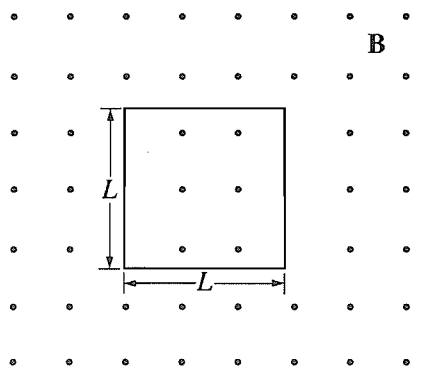
(A) $\frac{1}{4\pi\epsilon_0}\frac{e}{R}$

(B) $\frac{1}{8\pi\epsilon_0}\frac{e^2}{R}$

(C) $-\frac{1}{8\pi\epsilon_0}\frac{e^2}{R}$

(D) $\frac{1}{4\pi\epsilon_0}\frac{e^2}{R^2}$

(E) $-\frac{1}{4\pi\epsilon_0}\frac{e^2}{R^2}$



56. A square wire loop with side L and resistance R is held at rest in a uniform magnetic field of magnitude B directed out of the page, as shown above. The field decreases with time t according to the equation $B = a - bt$, where a and b are positive constants. The current I induced in the loop is

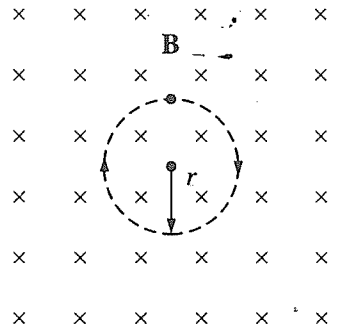
(A) zero

(B) aL^2/R, clockwise

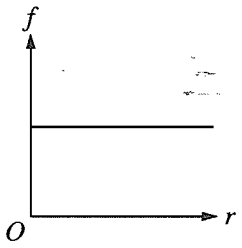
(C) aL^2/R, counterclockwise

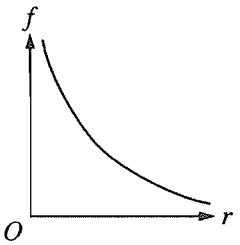
(D) bL^2/R, clockwise

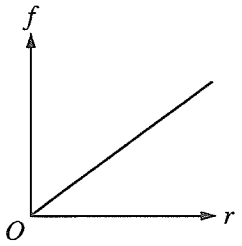
(E) bL^2/R, counterclockwise

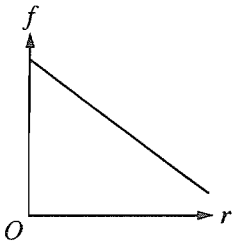


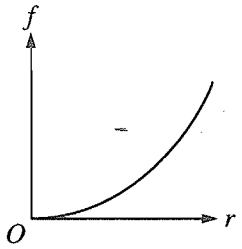
57. A negatively charged particle in a uniform magnetic field **B** moves in a circular path of radius r, as shown above. Which of the following graphs best depicts how the frequency of revolution f of the particle depends on the radius r ?

(A)


(B)


(C)


(D)


(E)


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58. If the only force acting on an electron is due to a uniform electric field, the electron moves with constant

(A) acceleration in a direction opposite to that of the field
(B) acceleration in the direction of the field
(C) acceleration in a direction perpendicular to that of the field
(D) speed in a direction opposite to that of the field
(E) speed in the direction of the field

Questions 59-60

In a region of space, a spherically symmetric electric potential is given as a function of r, the distance from the origin, by the equation $V(r) = kr^2$, where k is a positive constant.

59. What is the magnitude of the electric field at a point a distance r_0 from the origin?

(A) Zero
(B) kr_0
(C) $2kr_0$
(D) kr_0^2
(E) $\frac{2}{3}kr_0^3$

60. What is the direction of the electric field at a point a distance r_0 from the origin and the direction of the force on an electron placed at this point?

	Electric Field	Force on Electron
(A)	Toward origin	Toward origin
(B)	Toward origin	Away from origin
(C)	Away from origin	Toward origin
(D)	Away from origin	Away from origin
(E)	Undefined, since the field is zero	Undefined, since the force is zero

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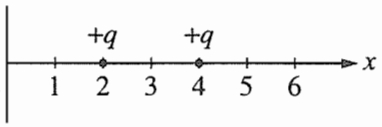
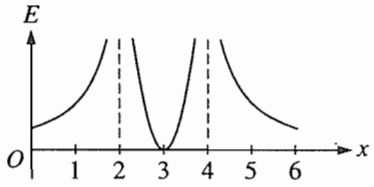
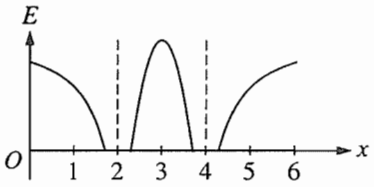


61. Two charged particles, each with a charge of $+q$, are located along the x-axis at $x = 2$ and $x = 4$, as shown above. Which of the following shows the graph of the magnitude of the electric field along the x-axis from the origin to $x = 6$?

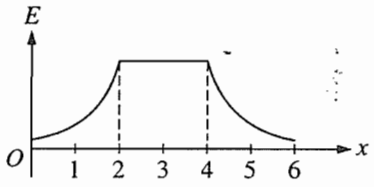
(A)



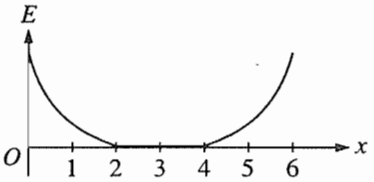
(B)



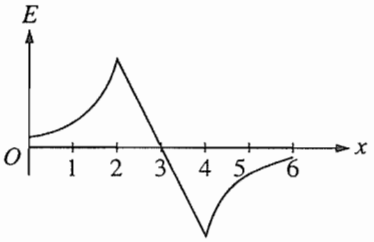
(C)



(D)



(E)



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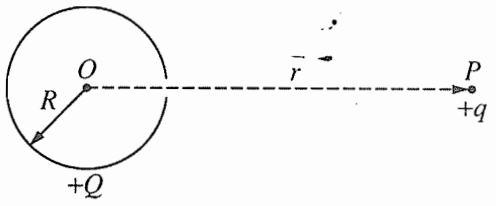
62. A positive electric charge is moved at a constant speed between two locations in an electric field, with no work done by or against the field at any time during the motion. This situation can occur only if the

(A) charge is moved in the direction of the field
(B) charge is moved opposite to the direction of the field
(C) charge is moved perpendicular to an equipotential line
(D) charge is moved along an equipotential line
(E) electric field is uniform



63. The nonconducting hollow sphere of radius R shown above carries a large charge $+Q$, which is uniformly distributed on its surface. There is a small hole in the sphere. A small charge $+q$ is initially located at point P, a distance r from the center of the sphere. If $k = 1/4\pi\epsilon_0$, what is the work that must be done by an external agent in moving the charge $+q$ from P through the hole to the center O of the sphere?

(A) Zero

(B) $\frac{kqQ}{r}$

(C) $\frac{kqQ}{R}$

(D) $\frac{kq(Q-q)}{r}$

(E) $kqQ\left(\frac{1}{R}-\frac{1}{r}\right)$

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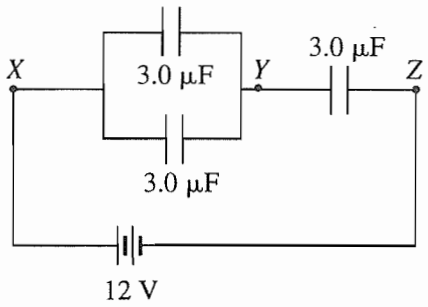
Questions 64-65



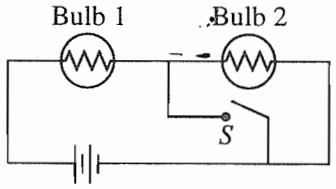
Three identical capacitors, each of capacitance 3.0 μF, are connected in a circuit with a 12 V battery as shown above.

64. The equivalent capacitance between points X and Z is

(A) 1.0 μF
(B) 2.0 μF
(C) 4.5 μF
(D) 6.0 μF
(E) 9.0 μF

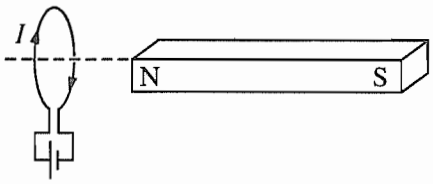
65. The potential difference between points Y and Z is

(A) zero
(B) 3 V
(C) 4 V
(D) 8 V
(E) 9 V



66. The circuit in the figure above contains two identical lightbulbs in series with a battery. At first both bulbs glow with equal brightness. When switch S is closed, which of the following occurs to the bulbs?

	Bulb 1	Bulb 2
(A)	Goes out	Gets brighter
(B)	Gets brighter	Goes out
(C)	Gets brighter	Gets slightly dimmer
(D)	Gets slightly dimmer	Gets brighter
(E)	Nothing	Goes out



67. A bar magnet and a wire loop carrying current I are arranged as shown above. In which direction, if any, is the force on the current loop due to the magnet?

(A) Toward the magnet
(B) Away from the magnet
(C) Toward the top of the page
(D) Toward the bottom of the page
(E) There is no force on the current loop.

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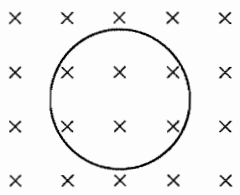
B (into page)



68. A wire loop of area A is placed in a time-varying but spatially uniform magnetic field that is perpendicular to the plane of the loop, as shown above. The induced emf in the loop is given by $\mathcal{E} = bAt^{1/2}$, where b is a constant. The time-varying magnetic field could be given by

(A) $\frac{1}{2} bAt^{-1/2}$

(B) $\frac{1}{2} bt^{-1/2}$

(C) $\frac{1}{2} bt^{1/2}$

(D) $\frac{2}{3} bAt^{3/2}$

(E) $\frac{2}{3} bt^{3/2}$

Questions 69-70

A capacitor is constructed of two identical conducting plates parallel to each other and separated by a distance d. The capacitor is charged to a potential difference of V_0 by a battery, which is then disconnected.

69. If any edge effects are negligible, what is the magnitude of the electric field between the plates?

(A) $V_0 d$

(B) V_0/d

(C) d/V_0

(D) V_0/d^2

(E) V_0^2/d

70. A sheet of insulating plastic material is inserted between the plates without otherwise disturbing the system. What effect does this have on the capacitance?

(A) It causes the capacitance to increase.
(B) It causes the capacitance to decrease.
(C) None; the capacitance does not change.
(D) Nothing can be said about the effect without knowing the dielectric constant of the plastic.
(E) Nothing can be said about the effect without knowing the thickness of the sheet.

STOP

END OF SECTION I, ELECTRICITY AND MAGNETISM

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.

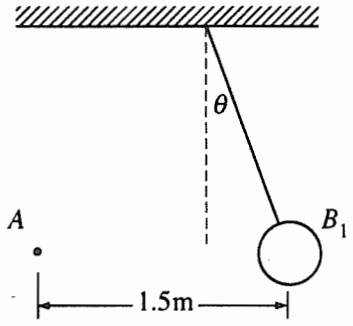
PHYSICS C

SECTION II, ELECTRICITY AND MAGNETISM

Time—45 minutes

3 Questions

Directions: Answer all three questions. The suggested time is about 15 minutes for answering each of the questions, which are worth 15 points each. The parts within a question may not have equal weight. Show all your work in this booklet in the spaces provided after each part, NOT in the green insert.



Note: Figure not drawn to scale.

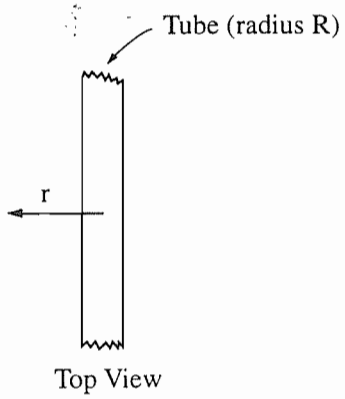
E & M. 1. The small sphere A in the diagram above has a charge of 120 μC. The large sphere B_1 is a thin shell of nonconducting material with a net charge that is uniformly distributed over its surface. Sphere B_1 has a mass of 0.025 kg, a radius of 0.05 m, and is suspended from an uncharged, nonconducting thread. Sphere B_1 is in equilibrium when the thread makes an angle $\theta = 20°$ with the vertical. The centers of the spheres are at the same vertical height and are a horizontal distance of 1.5 m apart, as shown.

(a) Calculate the charge on sphere B_1.

GO ON TO THE NEXT PAGE

(b) Suppose that sphere B_1 is replaced by a second suspended sphere B_2 that has the same mass, radius, and charge, but that is conducting. Equilibrium is again established when sphere A is 1.5 m from sphere B_2 and their centers are at the same vertical height. State whether the equilibrium angle θ_2 will be less than, equal to, or greater than 20°. Justify your answer.

The sphere B_2 is now replaced by a very long, horizontal, nonconducting tube, as shown in the top view below. The tube is hollow with thin walls of radius $R = 0.20$ m and a uniform positive charge per unit length of $\lambda = +0.10\ \mu C/m$.



Top View

(c) Use Gauss's law to show that the electric field at a perpendicular distance r from the tube is given by the expression $E = \frac{1.8 \times 10^3}{r}$ N/C, where $r > R$ and r is in meters.

GO ON TO THE NEXT PAGE

(d) The small sphere A with charge 120 μC is now brought into the vicinity of the tube and is held at a distance of $r = 1.5$ m from the center of the tube. Calculate the repulsive force that the tube exerts on the sphere.

(e) Calculate the work done against the electrostatic repulsion to move sphere A toward the tube from a distance $r = 1.5$ m to a distance $r = 0.3$ m from the tube.

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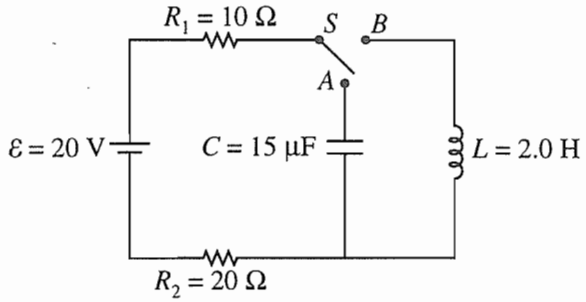

E & M. 2. In the circuit shown above, the switch S is initially in the open position shown, and the capacitor is uncharged. A voltmeter (not shown) is used to measure the correct potential difference across resistor R_1.

(a) On the circuit diagram above, draw the voltmeter with the proper connections for correctly measuring the potential difference across resistor R_1.

(b) At time $t = 0$, the switch is moved to position A. Determine the voltmeter reading for the time immediately after $t = 0$.

(c) After a long time, a measurement of potential difference across R_1 is again taken. Determine for this later time each of the following.

i. The voltmeter reading

ii. The charge on the capacitor

GO ON TO THE NEXT PAGE

(d) At a still later time $t = T$, the switch S is moved to position B. Determine the voltmeter reading for the time immediately after $t = T$.

(e) A long time after $t = T$, the current in R_1 reaches a constant final value I_f.

i. Determine I_f.

ii. Determine the final energy stored in the inductor.

(f) Write, but do not solve, a differential equation for the current in resistor R_1 as a function of time t after the switch is moved to position B.

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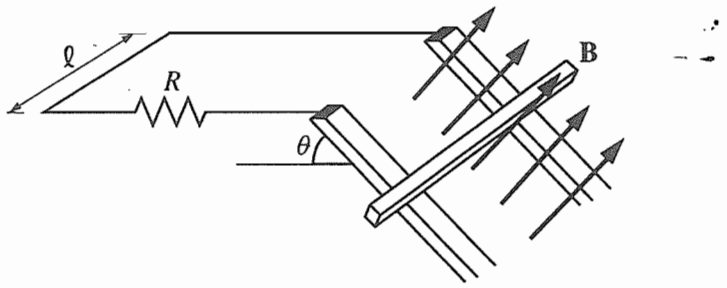

E & M. 3. A conducting bar of mass m is placed on two long conducting rails a distance ℓ apart. The rails are inclined at an angle θ with respect to the horizontal, as shown above, and the bar is able to slide on the rails with negligible friction. The bar and rails are in a uniform and constant magnetic field of magnitude B oriented perpendicular to the incline. A resistor of resistance R connects the upper ends of the rails and completes the circuit as shown. The bar is released from rest at the top of the incline. Express your answers to parts (a) through (d) in terms of m, ℓ, θ, B, R, and g.

(a) Determine the current in the circuit when the bar has reached a constant final speed.

(b) Determine the constant final speed of the bar.

GO ON TO THE NEXT PAGE

(c) Determine the rate at which energy is being dissipated in the circuit when the bar has reached its constant final speed.

(d) Express the speed of the bar as a function of time t from the time it is released at $t = 0$.

(e) Suppose that the experiment is performed again, this time with a second identical resistor connecting the rails at the bottom of the incline. Will this affect the final speed attained by the bar, and if so, how? Justify your answer.

STOP

END OF SECTION II, ELECTRICITY AND MAGNETISM

IF YOU FINISH BEFORE TIME IS CALLED, YOU MAY CHECK YOUR WORK ON SECTION II, ELECTRICITY AND MAGNETISM, ONLY. DO NOT TURN TO ANY OTHER TEST MATERIALS.

Chapter V Answers to the 1998 AP Physics C Examination

- Section I: Multiple Choice
  - Blank Answer Sheet
- Section II: Free Response

Section I: Multiple Choice

Listed below are the correct answers to the multiple-choice questions and the percentage of AP candidates who answered each question correctly.

Answer Key and Percent Answering Correctly

Mechanics			Electricity & Magnetism		
Item No.	Correct Answer	Percent Correct	Item No.	Correct Answer	Percent Correct
1	B	82%	36	B	74%
2	E	82%	37	E	65%
3	D	78%	38	C	77%
4	B	67%	39	E	93%
5	C	69%	40	D	79%
6	A	56%	41	C	56%
7	A	56%	42	D	75%
8	D	45%	43	D	29%
9	D	18%	44	A	75%
10	A	53%	45	C	80%
11	E	45%	46	E	61%
12	C	68%	47	D	34%
13	C	81%	48	C	45%
14	B	61%	49	A	49%
15	A	42%	50	D	33%
16	C	54%	51	A	28%
17	A	50%	52	C	45%
18	B	82%	53	E	50%
19	A	35%	54	E	63%
20	B	18%	55	B	26%
21	D	89%	56	E	50%
22	E	42%	57	A	19%
*23	—	—	58	A	53%
24	A	67%	59	C	50%
25	B	56%	60	B	24%
26	C	63%	61	A	74%
27	D	46%	62	D	64%
28	C	59%	63	E	39%
29	E	29%	64	B	71%
30	B	71%	65	D	27%
31	E	48%	66	B	46%
32	E	65%	67	A	24%
33	B	36%	68	E	30%
34	A	37%	69	B	62%
35	D	58%	70	A	61%

*This question was not counted when the exam was scored.