CollegeBoard

AP® Physics C: Electricity and Magnetism Practice Exam

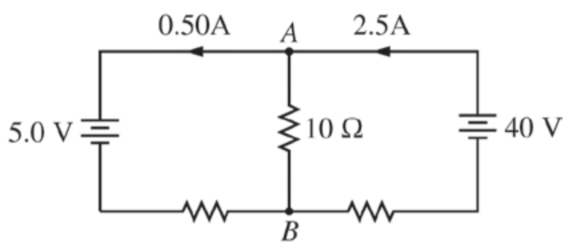
From the 2013 Administration

PHYSICS C: ELECTRICITY AND MAGNETISM
SECTION I
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 circle on the answer sheet.

1. A circuit contains a length of tungsten wire with resistance R. An increase in the resistance would result if which of the following could be decreased?

   (A) The resistivity of the tungsten
   (B) The cross-sectional area of the wire
   (C) The length of the wire
   (D) The temperature of the wire
   (E) The current in the wire

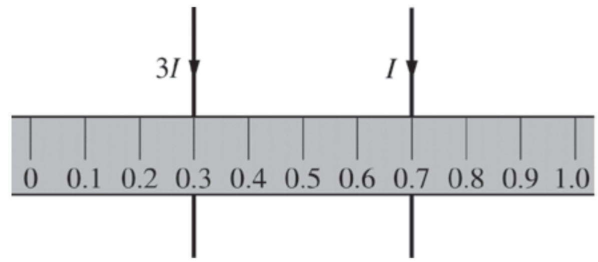


2. In the circuit shown above, a student has measured the currents that are given in the diagram, but does not know all the resistance values. The magnitude of the potential difference between points A and B is

   (A) 10 V
   (B) 20 V
   (C) 30 V
   (D) 35 V
   (E) 40 V

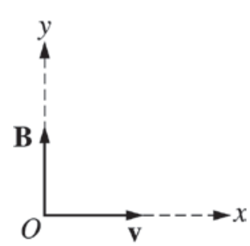
3. A 0.20 μF capacitor and a 0.10 μF capacitor are connected in parallel to a 6.0 V battery. The potential difference across the 0.20 μF capacitor is most nearly

   (A) 1.3 V
   (B) 2.0 V
   (C) 3.0 V
   (D) 4.0 V
   (E) 6.0 V



4. Two parallel, straight conductors carry currents $3I$ and I in the same direction, as shown in the figure above. A plastic meterstick is held against the wires so that they are positioned at the 0.3 m and 0.7 m mark, respectively. At what position on the meterstick is the magnetic field zero?

   (A) Nowhere on the meterstick
   (B) At the 0.1 m mark
   (C) At the 0.4 m mark
   (D) At the 0.6 m mark
   (E) At the 0.9 m mark



5. A positively charged particle moves with velocity **v** in the positive x-direction in a uniform magnetic field **B** directed in the positive y-direction, as shown above. The particle experiences a force in what direction?

   (A) Perpendicularly out of the plane of the page
   (B) Perpendicularly into the plane of the page
   (C) Positive x-direction
   (D) Negative x-direction
   (E) Positive y-direction

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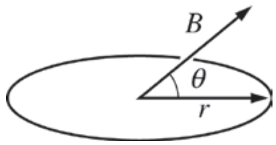


6. A circular loop of radius r is located in a uniform magnetic field of magnitude B directed at an angle θ to the plane of the loop, as shown above. What is the magnetic flux through the loop?

   (A) $\pi r^2 B \sin\theta$

   (B) $\pi r^2 B \cos\theta$

   (C) $\pi r^2 B$

   (D) $2\pi r B \cos\theta$

   (E) $2\pi r B$

7. A circular loop of wire of radius R is perpendicular to a magnetic field whose magnitude as a function of time t is given by the equation $B = bt^2 + ct$, where b and c are positive, nonzero constants. What is the magnitude of the emf induced in the loop as a function of time t?

   (A) $2\pi R\left(bt^2 + ct\right)$

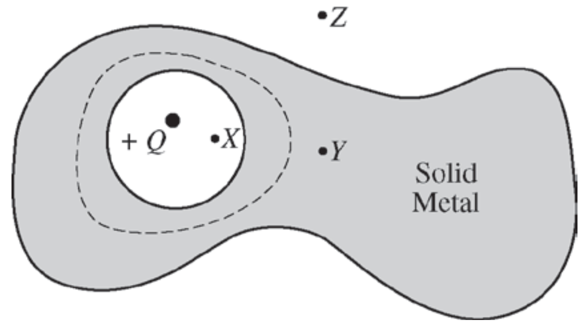
   (B) $2\pi R(2bt + c)$

   (C) $\pi R^2\left(bt^2 + ct\right)$

   (D) $\pi R^2(bt + c)$

   (E) $\pi R^2(2bt + c)$

Questions 8-10



A charge $+Q$ is inside a hollow region in an electrically neutral piece of solid metal, as shown above. The dashed line represents a Gaussian surface within the metal that completely encloses the hollow region.

8. At which of the three labeled points is the electric field equal to zero?

   (A) X only
   (B) Y only
   (C) X and Z only
   (D) Y and Z only
   (E) X, Y, and Z

9. What is the net electric flux through the Gaussian surface?

   (A) $-Q/\epsilon_0$
   (B) Zero
   (C) $+Q/\epsilon_0$
   (D) $+2Q/\epsilon_0$
   (E) It cannot be determined without knowing the exact shape of the Gaussian surface.

10. Which of the following correctly relates the electric potentials V at points X, Y, and Z?

    (A) $V_X < V_Y < V_Z$
    (B) $V_Y < V_X < V_Z$
    (C) $V_Y < V_Z < V_X$
    (D) $V_Z < V_X < V_Y$
    (E) $V_Z < V_Y < V_X$

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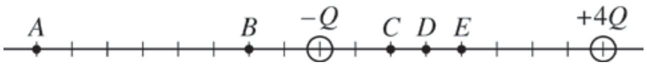
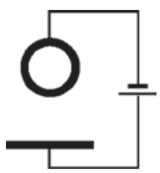


11. Two small spheres having charges $-Q$ and $+4Q$ are situated as shown above. The electric force on a small test charge will be zero if it is placed at point

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



12. A conducting plate and a conducting cylinder are connected to a battery, as shown above. Which of the following best represents the electric field between the two objects?

(A) 

(B) 

(C) 

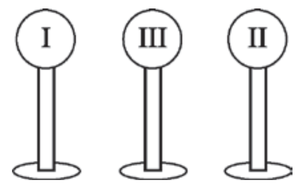
(D) 

(E) 

13. A uniform electric field exists in which of the following regions?

I. Around an infinite line of uniform linear charge density
II. On either side of an infinite thin sheet of uniform charge density
III. Between the spherical shells of a charged spherical capacitor

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



14. Three identical conducting spheres are mounted on insulating handles, as shown above. Spheres I and II have equal charges of $+Q$ and are separated by a fixed distance. They repel each other with an electrostatic force of magnitude F. Sphere III, initially uncharged, is first touched to sphere I, then to sphere II, and then removed. If the charge distribution on each sphere is assumed to always be spherical, the new magnitude of the electrostatic force between spheres I and II is

(A) zero
(B) $\frac{F}{16}$
(C) $\frac{F}{4}$
(D) $\frac{F}{2}$
(E) $\frac{3F}{8}$

15. Which of the following describes the electric field and electric potential inside a charged solid spherical conductor that is in electrostatic equilibrium?

	Field	Potential
(A)	Zero	Zero
(B)	Nonzero and uniform	Zero
(C)	Nonzero and uniform	Nonzero and uniform
(D)	Zero	Nonzero and uniform
(E)	Zero	Nonzero and nonuniform

16. A parallel-plate capacitor is connected to a battery until fully charged. If the battery remains connected while the separation between the plates is increased, which of the following remains constant?

(A) Potential difference between the plates
(B) Capacitance
(C) Magnitude of the charge on each plate
(D) Stored electrostatic energy
(E) Electric field intensity in the region between the plates

17. Two long, straight wires are fixed parallel to one another a distance d_0 apart. The wires carry equal constant currents I_0 in the same direction. The attractive magnetic force per unit length between them is $f = F/L$. What is the force per unit length between the wires if their separation is $2d_0$ and each carries current $2I_0$?

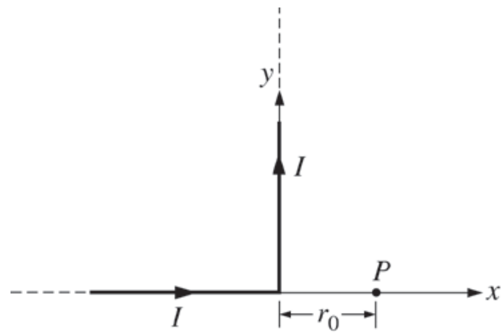
(A) $f/4$

(B) $f/2$

(C) f

(D) $3f/2$

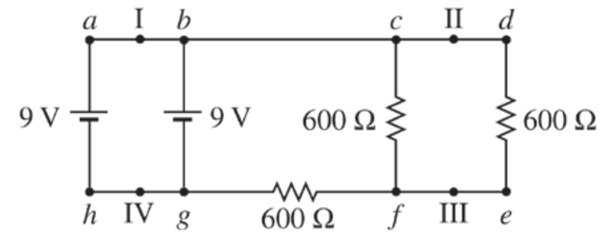
(E) $2f$



18. Suppose that the magnetic field due to a very long straight wire carrying current I has magnitude B_0 at a distance r_0 from the wire. If the wire is bent into a right angle and placed on the xy-axes as shown above, the magnitude of the magnetic field at point P on the x-axis at a distance of r_0 from the bend is most nearly

    (A) zero
    (B) $B_0/4$
    (C) $B_0/2$
    (D) B_0
    (E) $2B_0$

Questions 19-21



Two 9 V batteries and three identical 600 Ω resistors are connected in a circuit, as shown above. Neglect internal resistance in the batteries and consider all meters to be ideal.

19. A voltmeter would read 6 V if connected correctly between which two points in the circuit?

    (A) a and b
    (B) a and f
    (C) b and f
    (D) c and d
    (E) f and g

20. Ammeters are inserted at points I, II, III, and IV. At which of the other points would the ammeter register the same current as the ammeter at point IV ?

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

21. What is the total power dissipated in the three resistors?

    (A) 0.023 W
    (B) 0.045 W
    (C) 0.090 W
    (D) 0.36 W
    (E) 9.0 W

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22. A charge $+q$ is placed at the center of a cube. What is the flux of the electric field through one face of the cube?

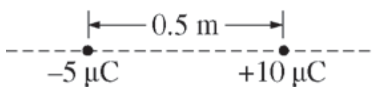
(A) 0

(B) $\dfrac{q}{\epsilon_0}$

(C) $\dfrac{q}{6\epsilon_0}$

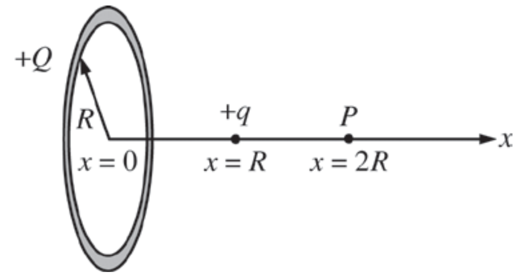
(D) $6\epsilon_0 q$

(E) The flux through one face cannot be determined from the information given.



23. A negative 5 μC charge is located 0.5 m from a positive 10 μC charge as shown above. At how many positions (excluding infinity) on a line passing through both charges is the electric potential equal to zero?

(A) 0
(B) 1
(C) 2
(D) 3
(E) 4



24. A thin ring of radius R has charge $+Q$ distributed uniformly around the ring. The center of the ring is at the origin of an x-axis perpendicular to the plane of the ring, as shown in the figure above. A point charge $+q$ on the x-axis at position $x = R$ is released from rest. What is its kinetic energy when it reaches position P at $x = 2R$ on the x-axis?

(A) $\dfrac{3}{10}\dfrac{kQq}{R}$

(B) $\dfrac{1}{2}\dfrac{kQq}{R}$

(C) $\dfrac{1}{\sqrt{3}}\dfrac{kQq}{R}$

(D) $\dfrac{kQq}{R}$

(E) $\dfrac{kQq}{R}\left(\dfrac{1}{\sqrt{2}} - \dfrac{1}{\sqrt{5}}\right)$

25. A parallel-plate capacitor is charged and the battery is removed. If a dielectric with dielectric constant $k > 1$ is then inserted in the capacitor, which of the following will decrease?

(A) The voltage across the capacitor
(B) The charge on one of the capacitor plates
(C) The distance between the capacitor plates
(D) The capacitance of the capacitor
(E) The resistance of the capacitor

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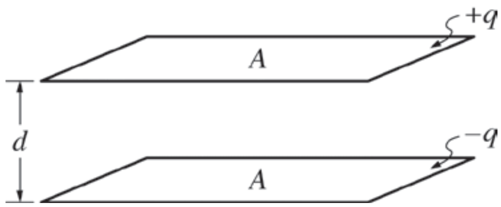


26. A parallel-plate capacitor of capacitance C consists of two plates of area A separated by distance d as shown above. The upper and lower plates are given a net charge of $+q$ and $-q$, respectively. What is the electric field between the plates?

(A) Zero

(B) $\dfrac{C}{2qd}$

(C) $\dfrac{C}{qd}$

(D) $\dfrac{2q}{Cd}$

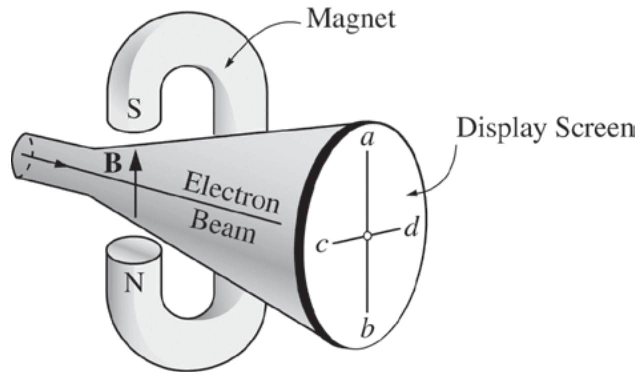
(E) $\dfrac{q}{Cd}$

27. Five air-filled parallel-plate capacitors have the plate areas and plate separations listed below, where A and d are constants. The capacitors are each connected to the same potential difference. Which capacitor stores the greatest amount of energy?

	Area	Separation
(A)	$2A$	$d/2$
(B)	$2A$	$2d$
(C)	A	d
(D)	$A/2$	$d/2$
(E)	$A/2$	$2d$

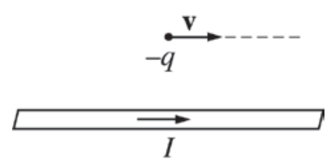
28. A compass needle is in a uniform magnetic field **B** with its north-seeking pole pointing in the direction of the field. The net magnetic force on the compass needle is

(A) in the direction of **B**
(B) in the direction of $-$**B**
(C) perpendicular to the plane determined by **B** and the needle
(D) in the same plane as **B** and the needle, but perpendicular to the needle
(E) zero



29. A horizontal electron beam in an oscilloscope is aimed at the center of the display screen, as shown in the diagram above. A C-shaped magnet is placed around the oscilloscope, producing a vertical magnetic field **B**, which is perpendicular to the beam. Which way, if any, will the beam be deflected by the magnetic field?

(A) Toward point a
(B) Toward point b
(C) Toward point c
(D) Toward point d
(E) The beam will not be deflected.



30. A negative charge $-q$ is moving with a velocity **v** to the right, parallel to a wire that is carrying a current I to the right, as shown above. The direction of the force on the charge due to the magnetic field produced by the wire is

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

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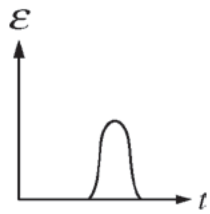
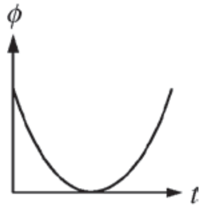
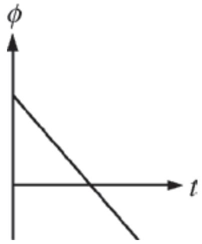
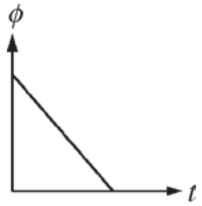
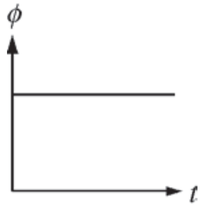


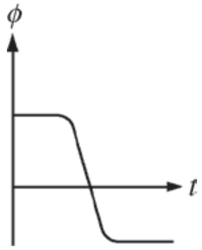
31. The graph above shows an emf $\mathcal{E}$ induced in a loop of wire as a function of time t. Which of the following graphs best corresponds to the magnetic flux passing through the loop of wire as a function of time t ?

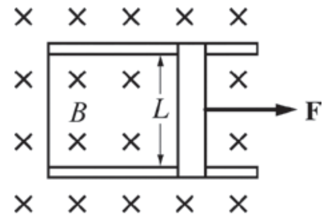
(A) 

(B) 

(C) 

(D) 

(E) 



Top View

32. A metal rod of length L that can slide on horizontal frictionless metal rails is moved through a uniform magnetic field of magnitude B that is perpendicular to the rails, as shown in the figure above. The other ends of the rails are connected by a wire to form a circuit of resistance R. An external force of magnitude F is applied to the rod so that the rod maintains a constant speed υ. What is the power supplied by the force?

(A) $\dfrac{B^2L^2\upsilon}{R}$

(B) $\dfrac{B^2L^2\upsilon}{R^2}$

(C) $\dfrac{B^2L\upsilon^2}{R}$

(D) $\dfrac{B^2L^2\upsilon^2}{R}$

(E) $\dfrac{B^2L\upsilon^3}{R}$

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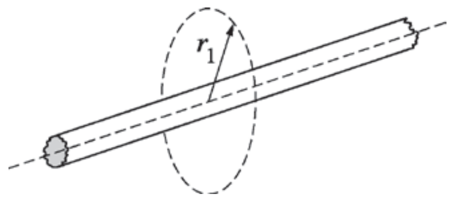


33. An electric field is produced by the very long, uniformly charged rod shown above. If the strength of the electric field is E_1 at a distance r_1 from the axis of the rod, at what distance from the axis is the field strength $\frac{E_1}{10}$?

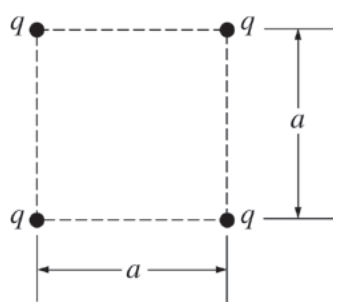
(A) $\frac{r_1}{100}$

(B) $\frac{r_1}{10}$

(C) $\sqrt{10}\, r_1$

(D) $10\, r_1$

(E) $100\, r_1$



34. Four identical point charges q are fixed at the corners of a square with sides of length a, as shown above. The potential at the center of the square due to these charges is

(A) zero

(B) $\frac{1}{4\pi\epsilon_0}\frac{q}{\sqrt{2}a}$

(C) $\frac{1}{4\pi\epsilon_0}\frac{q}{a}$

(D) $\frac{1}{4\pi\epsilon_0}\frac{4q}{a}$

(E) $\frac{1}{4\pi\epsilon_0}\frac{4\sqrt{2}q}{a}$

35. A total charge Q is uniformly distributed throughout a spherical volume of radius a. Which of the following is a dimensionally correct expression for the potential difference between the center of the sphere and its surface?

(A) $\left(\frac{1}{8\pi\epsilon_0}\right)Q$

(B) $\left(\frac{1}{8\pi\epsilon_0}\right)Qa^2$

(C) $\left(\frac{1}{8\pi\epsilon_0}\right)Qa$

(D) $\left(\frac{1}{8\pi\epsilon_0}\right)\frac{Q}{a}$

(E) $\left(\frac{1}{8\pi\epsilon_0}\right)\frac{Q}{a^2}$

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S T O P

END OF ELECTRICITY AND MAGNETISM SECTION I

IF YOU FINISH BEFORE TIME IS CALLED,
YOU MAY CHECK YOUR WORK ON ELECTRICITY AND MAGNETISM SECTION I ONLY.

DO NOT TURN TO ANY OTHER TEST MATERIALS.

MAKE SURE YOU HAVE DONE THE FOLLOWING.

- **PLACED YOUR AP NUMBER LABEL ON YOUR ANSWER SHEET**
- **WRITTEN AND GRIDDED YOUR AP NUMBER CORRECTLY ON YOUR ANSWER SHEET**
- **TAKEN THE AP EXAM LABEL FROM THE FRONT OF THIS BOOKLET AND PLACED IT ON YOUR ANSWER SHEET**

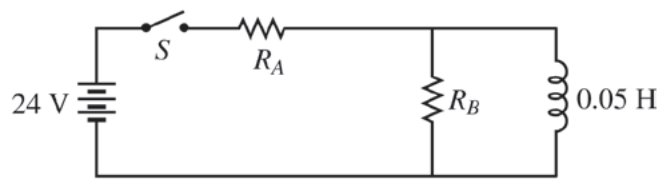
PHYSICS C: ELECTRICITY AND MAGNETISM

SECTION II

Time—45 minutes

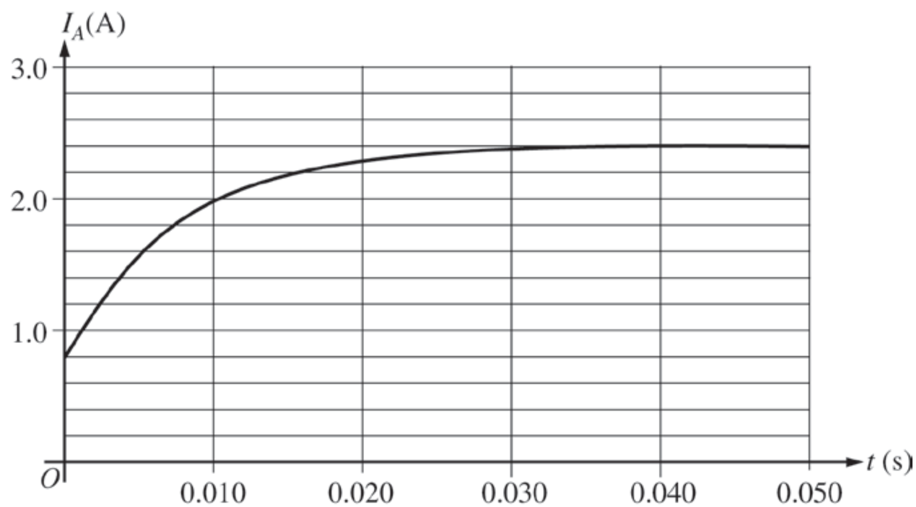
3 Questions

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.



E&M. 1.

Students are given the circuit above in their lab, but they do not know the values of the two resistances R_A and R_B. The battery has a terminal voltage of 24 V and the inductor has an inductance of 0.05 H. Assume the internal resistance of both the battery and the inductor to be negligible. The switch S is closed at time $t = 0$. In order to determine the values of the resistances R_A and R_B, the students measure the current as a function of time through the resistance R_A. The graph of their results is below.



(a) On the circuit diagram above, insert an ammeter to measure the current through R_A.

(b) Use the data taken by the students to calculate the value of R_A.

(c) Use the data taken by the students to calculate the value of R_B.

(d) Calculate the initial rate of change of current in the inductor.

(e) In reality, both the battery and the inductor have nonnegligible internal resistance. Would the true value of R_A be greater than or less than the value you obtained in part (b)?

_____ Greater than ______ Less than

Justify your answer.

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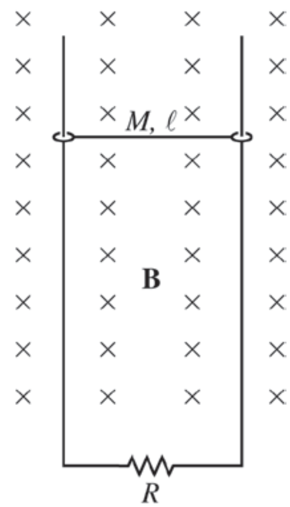


E&M. 2.

A bar of mass M and length ℓ is connected to two long vertical frictionless rails. The bar and the rails have negligible resistance. They are placed in a uniform magnetic field of strength B directed into the page as shown above. The bottoms of the rails are connected by a resistor of resistance R. The bar is released from rest in the position shown. Express all algebraic answers in terms of the given quantities and fundamental constants.

(a) Indicate on the diagram the direction of the current in the resistor.

At a particular time T, the bar is falling with speed v_1 but has not yet reached the bottom of the magnetic field.

(b) Calculate the power dissipated as heat in the resistor at time T.

(c) Calculate the magnitude of the magnetic force on the bar at time T and state its direction.

At some time before leaving the magnetic field, the bar reaches a terminal velocity.

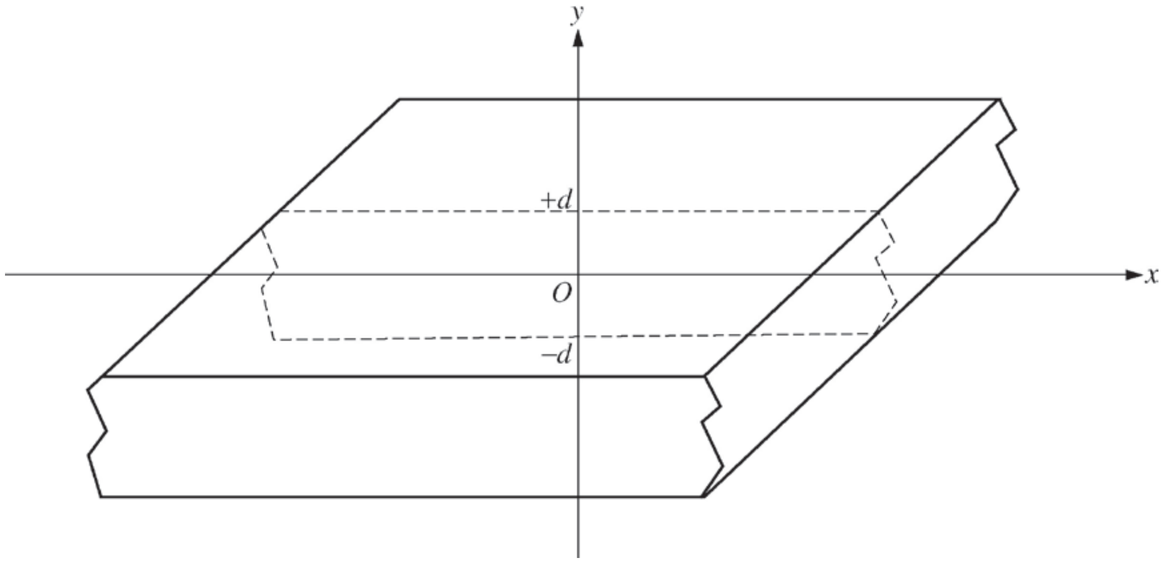
(d) Determine this terminal velocity.

(e) Write, but do NOT solve, the differential equation for the velocity of the falling bar while it is in the magnetic field.

(f) A second identical resistor is placed in parallel with the first. Is the terminal velocity reached by the bar in this case greater than, less than, or equal to that in part (d)?

_______Greater than _______Less than _______Equal to

Justify your answer.



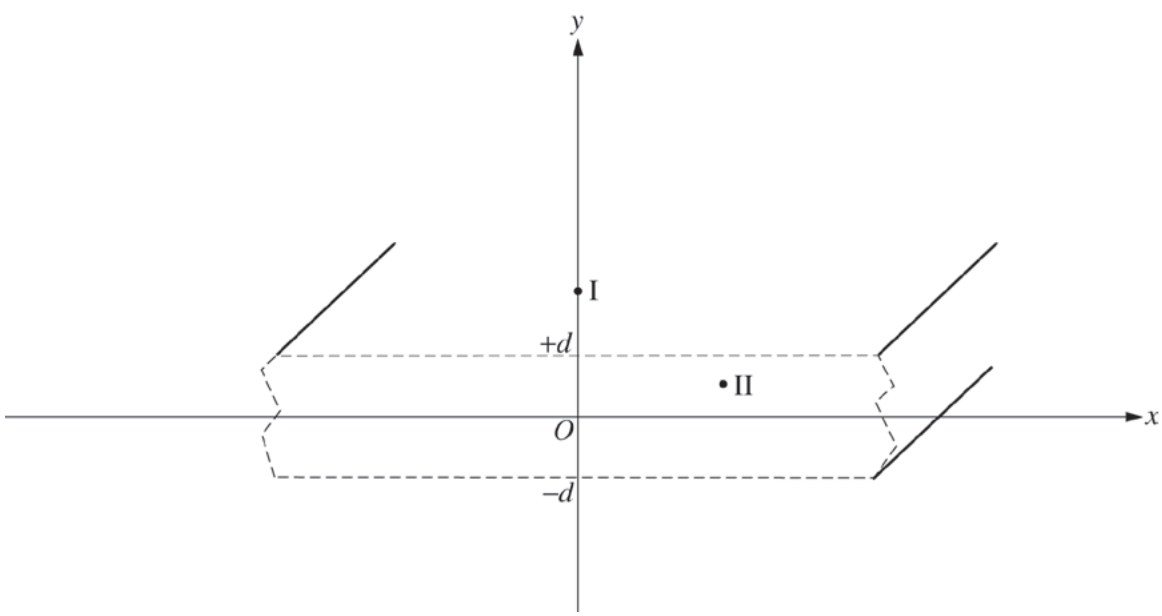
E&M. 3.

A nonconducting slab of infinite length and width and thickness $2d$ is positioned on a coordinate system as shown above. The slab is charged, and the charge per unit volume ρ is given by the expression $\rho(y) = C|y|$, where $-d \leq y \leq +d$ and C is a positive constant.

(a) On the diagram below, do the following.

i. Indicate with vectors the direction of the electric field at point I $(y > d)$ and point II $(0 < y < d)$.

ii. Draw a Gaussian surface that could be used to calculate the magnitude of the electric field at point I.



(b) Using Gauss's law, derive expressions in terms of the given quantities and fundamental constants for the magnitude of the electric field E at the following points.

i. Point I $(y > d)$

ii. Point II $(0 < y < d)$

(c) Calculate the potential difference between the origin and point I .

THIS PAGE MAY BE USED FOR SCRATCH WORK.

STOP

END OF EXAM

THE FOLLOWING INSTRUCTIONS APPLY TO THE COVERS OF THE SECTION II BOOKLET.

- **MAKE SURE YOU HAVE COMPLETED THE IDENTIFICATION INFORMATION AS REQUESTED ON THE FRONT AND BACK COVERS OF THE SECTION II BOOKLET.**
- **CHECK TO SEE THAT YOUR AP NUMBER LABEL APPEARS IN THE BOX(ES) ON THE COVER(S).**
- **MAKE SURE YOU HAVE USED THE SAME SET OF AP NUMBER LABELS ON ALL AP EXAMS YOU HAVE TAKEN THIS YEAR.**