CollegeBoard

AP® Physics C: Electricity and Magnetism Practice Exam

From the 2014 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. Which of the following Gaussian surfaces would be the simplest to use to determine the electric field intensity near a long, straight, charged wire?

   (A) A cylinder whose axis coincides with the wire
   (B) A cylinder whose axis is perpendicular to the wire and passes through the wire
   (C) A sphere with the wire through its center
   (D) A cube with the wire passing through the centers of opposite faces
   (E) A cube with the wire along a diagonal

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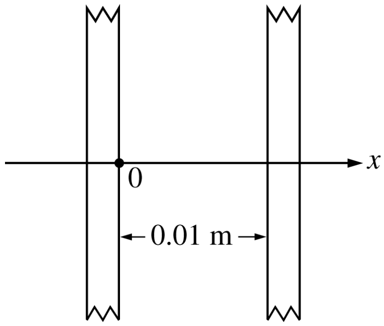
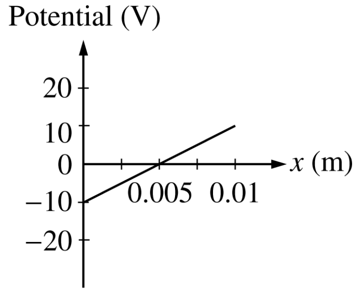
Questions 2-4





A uniform electric field exists between two parallel plates that are perpendicular to an x-axis and separated by 0.01 m, as shown above on the left. The graph above on the right shows the electric potential between the plates as a function of position x on the x-axis.

2. What is the electric potential energy of an object with a $1.0\ \mu C$ charge located at $x = 0.005$ m?

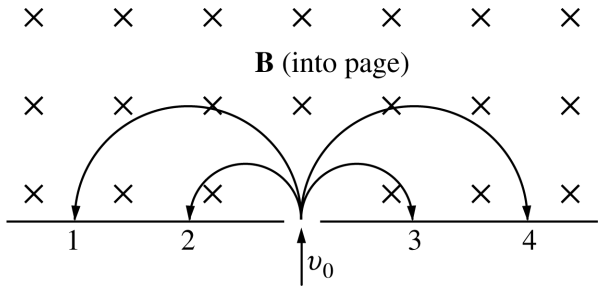
   (A) $-20\ \mu J$
   (B) $-10\ \mu J$
   (C) Zero
   (D) $10\ \mu J$
   (E) $20\ \mu J$

3. What is the magnitude of the electric field between the plates at $x = 0.005$ m?

   (A) Zero
   (B) 0.1 V/m
   (C) 0.2 V/m
   (D) 1000 V/m
   (E) 2000 V/m

4. What is the direction of the electric field between the plates at points on the x-axis?

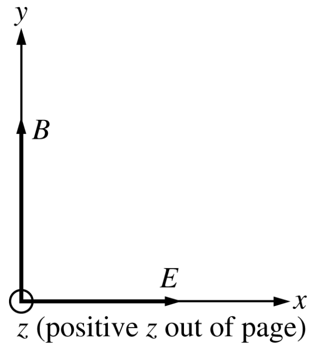
   (A) To the left at all points
   (B) To the right at all points
   (C) To the left for $x < 0.005$ m and to the right for $x > 0.005$ m
   (D) To the right for $x < 0.005$ m and to the left for $x > 0.005$ m
   (E) It is undefined because the field is zero at all points.



5. Two particles with the same speed v_0 enter a region of uniform magnetic field **B** directed into the page and are initially traveling perpendicular to **B**, as shown above. Particle Y has charge $-Q$ and mass M; particle Z has charge $+Q$ and mass $2M$. Which of the following pairs of paths shown is possible for the subsequent motion of the particles?

	Particle Y $-Q, M$	Particle Z $+Q, 2M$
(A)	1	4
(B)	2	4
(C)	3	1
(D)	4	1
(E)	4	2

Questions 6-7



A region contains a uniform electric field of strength E in the $+x$-direction and a uniform magnetic field of strength B in the $+y$-direction, relative to the axes shown above. A positively charged particle passes through these two fields in a straight line at a constant speed v.

6. The velocity of the particle is in which direction?

(A) $+y$
(B) $+x$
(C) $-x$
(D) $+z$
(E) $-z$

7. The magnetic field strength B is equal to

(A) E

(B) Ev

(C) $\frac{E}{v}$

(D) $\frac{v}{E}$

(E) Ev^2

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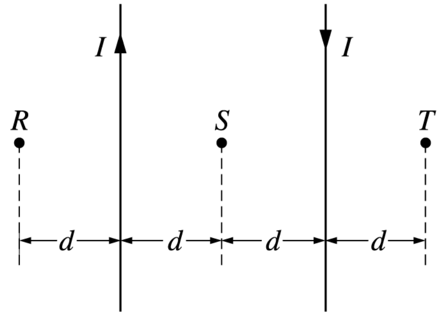
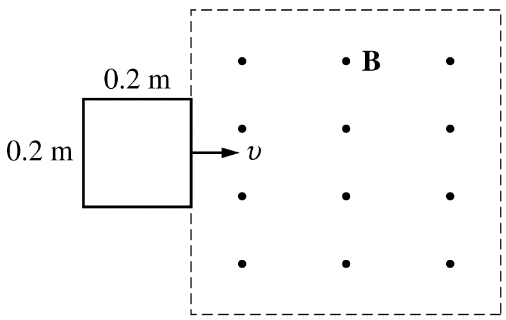
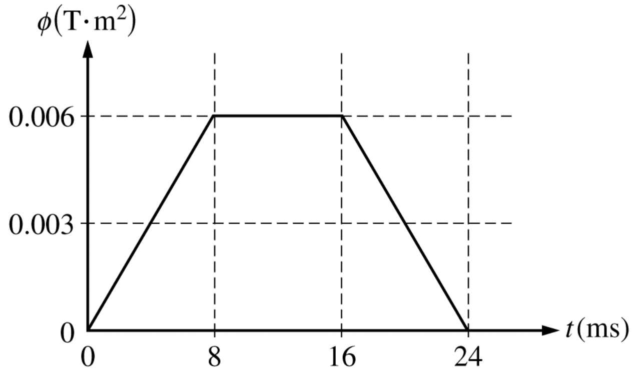


8. Two long, straight, parallel wires in the plane of the page carry equal currents I in opposite directions, as shown above. What are the directions of the resultant magnetic field **B**, if any, at each of the points R, S, and T ?

	$\underline{R}$	$\underline{S}$	$\underline{T}$
(A)	Out of the page	Into the page	Out of the page
(B)	Out of the page	None, **B** = 0	Out of the page
(C)	Out of the page	None, **B** = 0	Into the page
(D)	Into the page	None, **B** = 0	Out of the page
(E)	Into the page	Out of the page	Into the page

Questions 9-10





Note: Figure at left above not drawn to scale.

A square wire loop of side 0.2 m moves with a constant speed of $v = 25$ m/s through a region containing a magnetic field of strength $B = 0.15$ T, as shown above left. A graph of the magnetic flux ϕ through the loop as a function of time t is shown above right. Time $t = 0$ occurs when the right edge of the loop just begins to enter the field.

9. What is the magnitude of the induced emf in the wire loop at $t = 4$ ms?

(A) 0 V
(B) 0.50 V
(C) 0.75 V
(D) 3.0 V
(E) 6.0 V

10. What is the total width of the magnetic field through which the loop moves?

(A) 0.1 m
(B) 0.2 m
(C) 0.4 m
(D) 0.6 m
(E) 0.8 m

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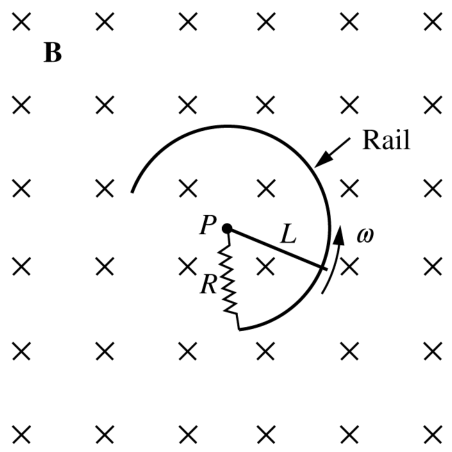
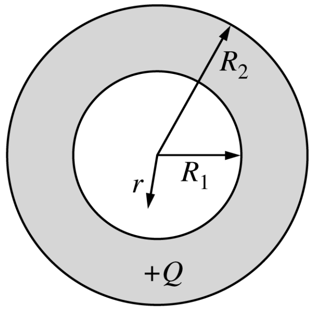


11. A conducting rod of length L is pivoted at point P. The other end slides with negligible friction on a conducting rail in the shape of a circular arc. The plane of the rail and rod is perpendicular to a uniform magnetic field of magnitude B directed into the page, as shown in the figure above. The rod rotates counterclockwise at constant angular velocity ω. Assume that all the resistance of the circuit is contained in the resistor R. Which of the following describes the induced current in the view shown?

(A) It is counterclockwise and constant.
(B) It is counterclockwise and increasing.
(C) It is clockwise and constant.
(D) It is clockwise and increasing.
(E) It is oscillating.

Questions 12-13



A charge $+Q$ is uniformly distributed throughout a nonconducting spherical shell of inner radius R_1 and outer radius R_2, as shown above. The electric field is determined at a distance r from the center of the spherical shell.

12. The electric field for $r < R_1$ is

(A) zero

(B) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{R_1^2}$

(C) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{R_2^2}$

(D) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{(R_2 - R_1)^2}$

(E) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{R_2^2 - R_1^2}$

13. The electric field for $r > R_2$ is

(A) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{R_1^2}$

(B) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{R_2^2}$

(C) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{r^2}$

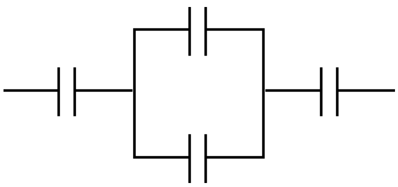
(D) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{r^2 - R_2^2}$

(E) $\dfrac{1}{4\pi\epsilon_0}\dfrac{Q}{R_2^2 - R_1^2}$

GO ON TO THE NEXT PAGE.

14. The maximum charge a capacitor can store on one plate is limited by which of the following?

(A) How much charge can physically fit on the conducting plates
(B) The maximum time rate of change of the charge on the other plate
(C) The nonzero energy needed to remove an electron from the conducting plates
(D) The finite value of the capacitance
(E) The electrical discharge when the electric field between the plates becomes too great

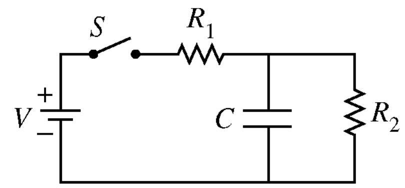


15. The four capacitors in the combination illustrated above each have capacitance C. If all the capacitors are then filled with a dielectric having dielectric constant 2, what is the new total capacitance of the combination?

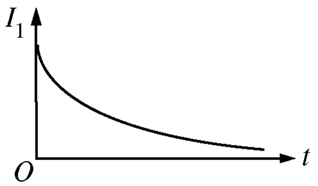
(A) $(2/5)C$
(B) $(4/5)C$
(C) $(5/4)C$
(D) $(5/2)C$
(E) $5C$

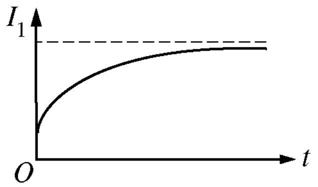
16. Circuit P consists of three identical capacitors connected in parallel with a battery. Circuit S consists of the same three capacitors connected in series with the same battery. When the capacitors are fully charged, what is the ratio of the total energy stored in circuit P to the total energy stored in circuit S ?

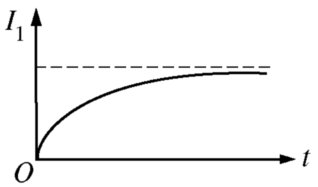
(A) 9
(B) 3
(C) 1
(D) $1/3$
(E) $1/9$

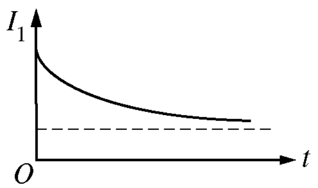


17. Capacitor C and resistors R_1 and R_2 are connected to a battery as illustrated above. The capacitor is initially uncharged. The battery supplies constant voltage V after the switch S is closed at time $t = 0$. Which of the following graphs best represents the current I_1 through the resistor R_1 as a function of t ?

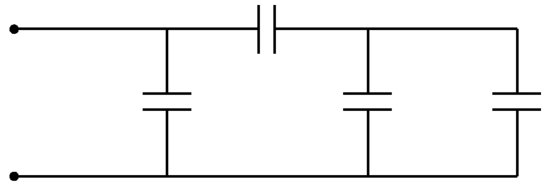
(A)


(B)


(C)


(D)


(E)

18. Four identical capacitors of capacitance C are connected as illustrated above. What is their equivalent capacitance?

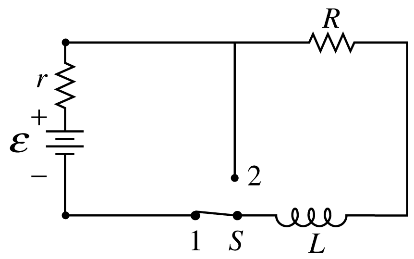
(A) $3C/5$

(B) $4C/3$

(C) $5C/3$

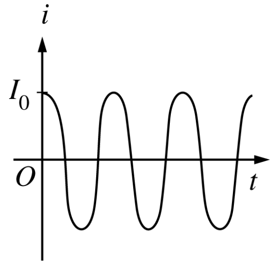
(D) $3C$

(E) $4C$

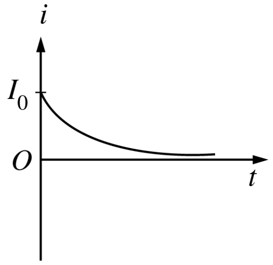


19. The circuit shown above consists of a battery of emf $\mathcal{E}$ and internal resistance r, a resistor R, an inductor L, and a switch S, initially in position 1. After the current i in the inductor reaches its maximum value I_0, S is switched instantaneously from position 1 to position 2 at time $t = 0$. Subsequent variation of i with t is best represented by which of the following graphs?

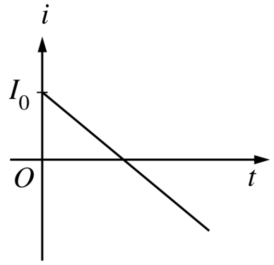
(A)



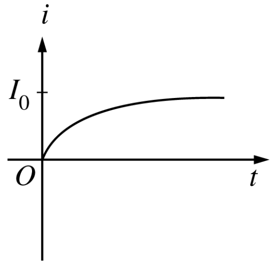
(B)



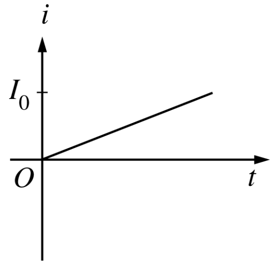
(C)



(D)



(E)



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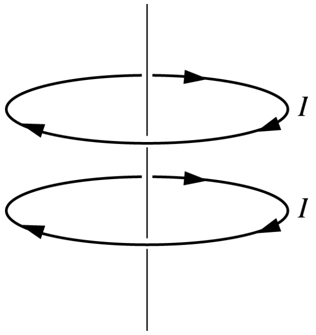

20. Two conducting loops that are centered on the same axis carry equal currents I in the same direction as shown in the diagram above. If the current in the upper loop suddenly decreases to zero, what happens to the current in the lower loop according to Lenz's law?

(A) It also decreases to zero.
(B) It decreases, but not to zero.
(C) It does not change.
(D) It increases.
(E) Its direction is reversed.

Questions 21-22

A meter that registers 0.20 mA at full scale has an internal resistance of 500 Ω.

21. To use this meter as an ammeter with a range of 0 to 1 A, one should connect an additional resistance of approximately

(A) 0.10 Ω in parallel with the meter
(B) 0.10 Ω in series with the meter
(C) 500 Ω in series with the meter
(D) 4,500 Ω in series with the meter
(E) 5,000 Ω in parallel with the meter

22. To use this meter as a voltmeter with a range of 0 to 1 V, one should connect an additional resistance of approximately

(A) 0.10 Ω in parallel with the meter
(B) 0.10 Ω in series with the meter
(C) 500 Ω in series with the meter
(D) 4,500 Ω in series with the meter
(E) 5,000 Ω in parallel with the meter

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23. Copper wire A has twice the length and half the diameter of copper wire B, but carries the same current I. If P is the rate at which energy is dissipated in wire B, what is the rate at which energy is dissipated in wire A?

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

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

(C) P

(D) $4P$

(E) $8P$

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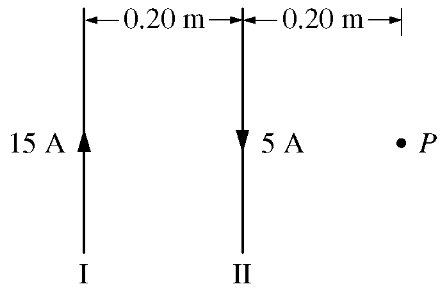
Questions 24-25



Two parallel wires that lie in the plane of the page, as shown above, are a distance of 0.20 m apart. Wire I carries a current of 15 A toward the top of the page, and wire II carries a current of 5 A toward the bottom of the page.

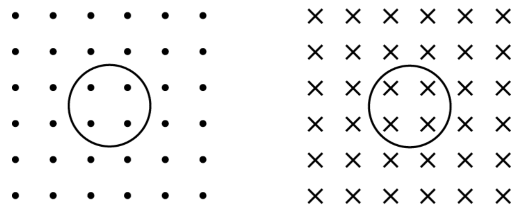
24. What is the magnitude of the net magnetic field at point P, located 0.20 m to the right of wire II ?

(A) 0.5 μT
(B) 1.0 μT
(C) 2.5 μT
(D) 5.0 μT
(E) 7.5 μT

25. What is the magnitude of the force per meter that wire I exerts on wire II ?

(A) 25 μN/m
(B) 50 μN/m
(C) 75 μN/m
(D) 100 μN/m
(E) 150 μN/m

Questions 26-27



B = 1.5 T (out of page)   **B** = 1.5 T (into page)

A circular conducting ring of area 0.20 m^2 lies in the plane of the page inside a spatially uniform magnetic field that is perpendicular to the page. The field changes smoothly from 1.5 T directed out of the page, as shown above on the left, to 1.5 T directed into the page, as shown above on the right. The change takes place at a constant rate during a total time interval of 0.6 s.

26. What is the magnitude of the average emf induced during the 0.6 s time interval?

(A) 0 V
(B) 0.5 V
(C) 1.0 V
(D) 1.5 V
(E) 2.0 V

27. When viewed as shown in the figure, what is the direction of the induced current during the first and second halves of the 0.6 s time interval?

	First Half	Second Half
(A)	Clockwise	Clockwise
(B)	Clockwise	Counterclockwise
(C)	Counterclockwise	Clockwise
(D)	Counterclockwise	Counterclockwise
(E)	Undefined, since the current is zero	Undefined, since the current is zero

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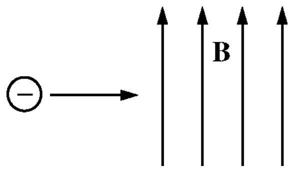
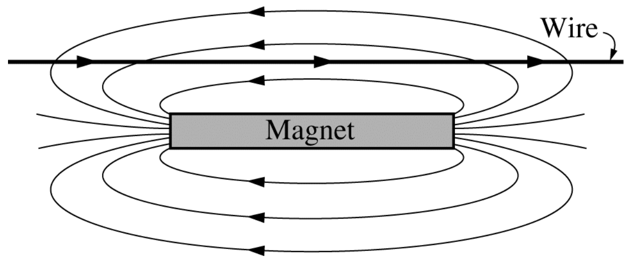


28. An electron moving to the right with constant velocity enters a region with a uniform magnetic field **B** directed toward the top of the page, as shown above. In what direction will the electron initially be deflected?

    (A) Toward the top of the page
    (B) Toward the bottom of the page
    (C) Into the page
    (D) Out of the page
    (E) Toward the left



29. A wire is placed parallel to a bar magnet, as shown above, and carries current to the right. Several magnetic field lines outside the bar magnet are shown. Which of the following correctly describes the net magnetic force and torque on the wire?

	Net Force	Torque
(A)	Toward the top of the page	Zero
(B)	Toward the bottom of the page	Zero
(C)	Toward the right	Nonzero
(D)	Zero	Zero
(E)	Zero	Nonzero

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30. Two identical spheres are 10.0 cm apart and carry equal charges that create a force of 4.00×10^{-8} N on each. Their diameters are much smaller than their separation distance. First one sphere is completely discharged. The spheres are then moved together until they touch, and finally they are moved to 5.00 cm apart. The new force between the spheres is

(A) 16.0×10^{-8} N
(B) 8.00×10^{-8} N
(C) 4.00×10^{-8} N
(D) 2.00×10^{-8} N
(E) 1.00×10^{-8} N

31. A positively charged particle is at the origin of an x-axis. The potential difference between the points on the axis at $x = 1.0$ m and $x = 2.0$ m due to the particle is 0.90 V. The value of the charge is most nearly

(A) 1.0×10^{-10} C
(B) 1.3×10^{-10} C
(C) 2.0×10^{-10} C
(D) 3.0×10^{-10} C
(E) 4.0×10^{-10} C

32. If the charge on a parallel-plate capacitor is decreased from 6 pC to 2 pC and the plate separation is increased from 1 mm to 3 mm, the energy stored in the capacitor will change from U_0 to

(A) $U_0/4$
(B) $U_0/3$
(C) $3U_0$
(D) $8U_0$
(E) $27U_0$

33. A solid metal sphere is in equilibrium and has a net charge Q placed on it. If the sphere is heated so that it expands uniformly without affecting the amount of charge and so that it is still in equilibrium, which of the following will be unaffected by the expansion?

I. The surface charge density
II. The electric potential inside the sphere
III. The electric field inside the sphere

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

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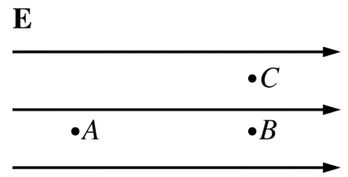
34. A conducting spherical shell S has a charge Q distributed over its surface. The total electric flux through any imaginary concentric spherical shell of radius r that encloses S is

(A) inversely proportional to r
(B) inversely proportional to r^2
(C) directly proportional to r
(D) directly proportional to r^2
(E) independent of r



35. The diagram above shows a uniform horizontal electric field and three points that lie in the field. Which of the following is true of the electric potential at the points shown?

I. It is lower at point A than at point B.
II. It is lower at point A than at point C.
III. It is the same at points A and B.
IV. It is the same at points B and C.

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

GO ON TO THE NEXT PAGE.

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.

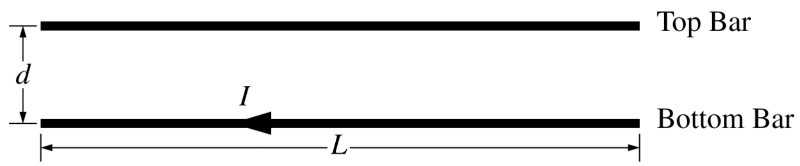
DO NOT TURN TO ANY OTHER TEST MATERIALS.

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**

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.

Two metal bars of length L are held a vertical distance d apart $(L >> d)$, as shown in the figure above. Each wire carries a current I, and the wires repel each other. The current is to the left in the bottom metal bar.

(a) In the figure above, draw an arrow indicating the direction of the current in the top bar.

(b) In the figure above, use appropriate symbols to indicate the direction of the magnetic field both above and below the bottom bar due to its current I.

(c) Derive an expression for the magnetic force acting on the top bar in terms of I, L, d, and fundamental constants, as appropriate.

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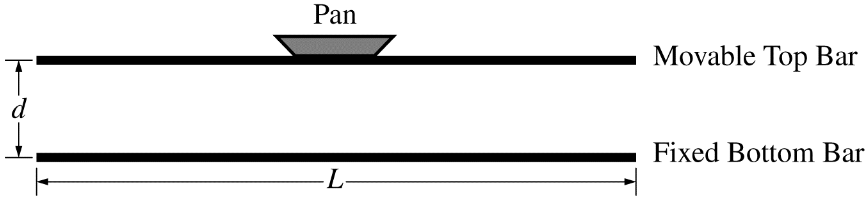
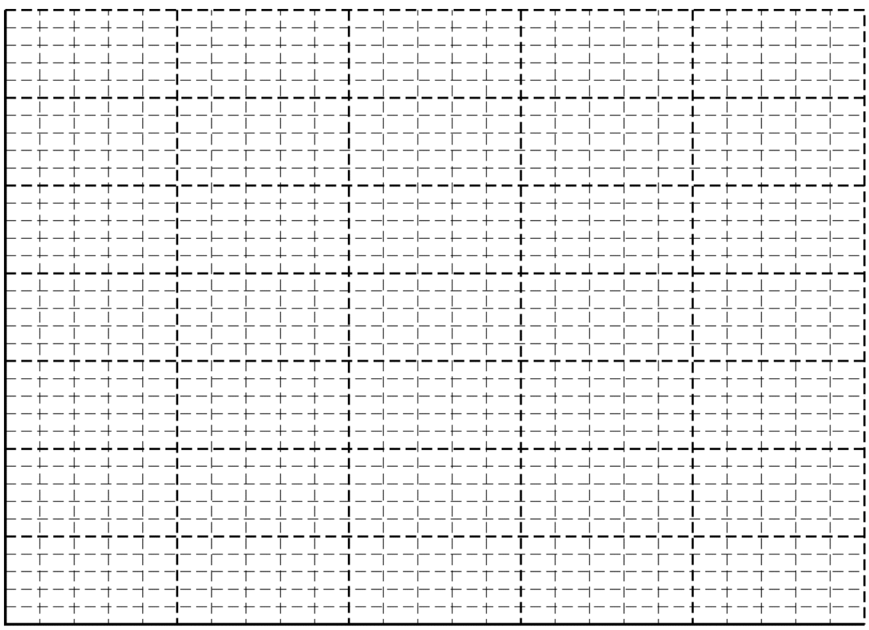
The bars are now used in an experiment, as shown in the figure below. The bottom bar is fixed in place. The top bar is suspended from springs (that are not shown), is free to move up and down, and has a pan attached to it for adding small weights. The top bar is originally horizontal and balanced in the equilibrium position as shown. No current is flowing in the bars. Both bars are part of the same closed circuit (the remainder of the circuit is not shown) and connected to a variable power supply. A small object is placed in the pan on the top bar, forcing it down until it comes close to the bottom bar. The current is turned on and increased until it pushes the top bar back to its original equilibrium position. The process is repeated several times with different objects of known mass, and the current is measured with an ammeter each time. The resulting data are given in the table below.



Weight of Object in Pan (N)	Current (A)	Current^2 (A^2)
1.00×10^{-4}	5.3	27.9
2.00×10^{-4}	7.6	58.4
3.00×10^{-4}	9.6	91.4
4.00×10^{-4}	11.3	128
5.00×10^{-4}	12.5	157

(d) Plot the current squared as a function of the weight of the objects on the grid below. Clearly scale and label all axes and include units as appropriate.



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(e) Draw a straight line that best represents the data points and write the equation of the line.

(f) The length of the bars L is 10.2 cm. The center-to-center distance d between the bars is 6.24 mm. Using the equation of the line determined in part (e), calculate a numerical value for the vacuum permeability μ_0.

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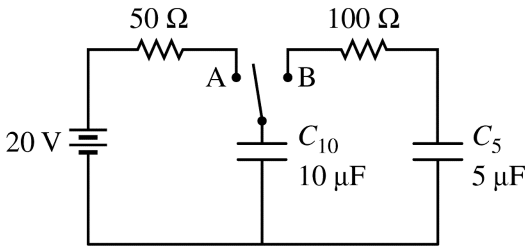


E&M 2.

In the circuit above, the two capacitors are initially uncharged and the switch is initially open. At time $t = 0$ the switch is moved to position A.

(a) Calculate the current in each of the two resistors immediately after the switch is moved to position A.

i. Current in the $50\ \Omega$ resistor

ii. Current in the $100\ \Omega$ resistor

(b)

i. Determine the amount of charge stored on the bottom plate of the $10\ \mu F$ capacitor a long time after the switch is moved to position A.

ii. Indicate the sign of the charge on the bottom plate of the $10\ \mu F$ capacitor.

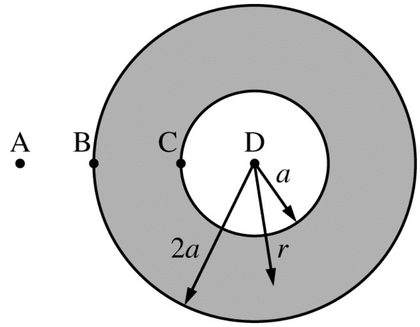
____ Positive   ____ Negative

Some time later, the switch is moved to position B.

(c) On the axes below, sketch a graph of the current I in the $100\ \Omega$ resistor as a function of time t after the switch is moved to position B. Explicitly label any intercepts, asymptotes, maxima, or minima with numerical values or algebraic expressions, as appropriate.

(d) Calculate the amount of charge on each capacitor a long time after the switch has been moved to position B.

(e) Calculate the total energy dissipated in the $100\ \Omega$ resistor after the switch is moved to position B.



E&M 3.

A spherical insulating shell of radius $2a$ has a hollow cavity of radius a, as shown in the figure above. The charge density in the shell for $a < r < 2a$ varies according to the expression $\rho = br^2$, where b is a positive constant and r is the distance from the center of the shell. Express all algebraic answers to the following in terms of a, b, r, and fundamental constants, as appropriate.

(a) Derive an expression for the total charge on the shell.

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(b) Using Gauss's law, derive an expression for the magnitude of the electric field in each of the following regions.

i. $r > 2a$

ii. $r < a$

(c) Derive an expression for the electric potential at the outer surface of the shell, where $r = 2a$. Assume the potential to be zero at $r = \infty$.

(d) Consider the four points A, B, C, and D labeled in the diagram. Rank the four points from highest to lowest based on the electric potential at each point (highest = 1). If two points have the same electric potential, give them the same ranking.

____ A ____ B ____ C ____ D

Justify your rankings.

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 <u>AND</u> 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 <u>ALL</u> AP EXAMS YOU HAVE TAKEN THIS YEAR.**