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## Physics C—Electricity and Magnetism Practice Exam 1— Multiple-Choice Questions

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### ANSWER SHEET

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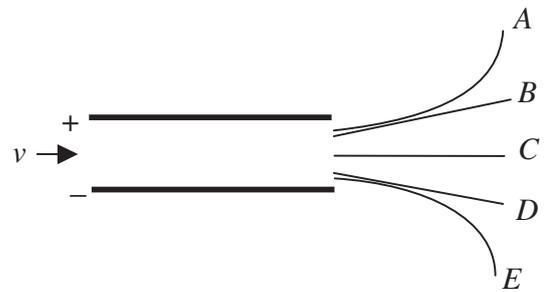
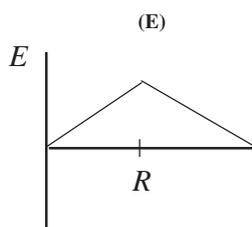
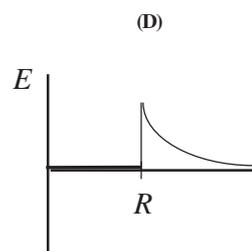
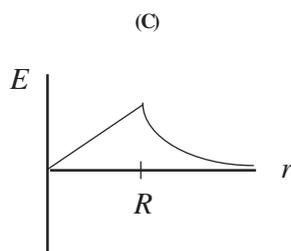
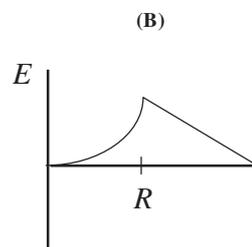
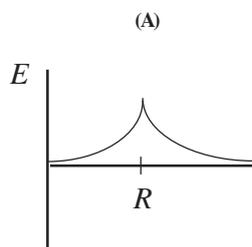
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## Physics C—Electricity and Magnetism Practice Exam 1— Multiple-Choice Questions

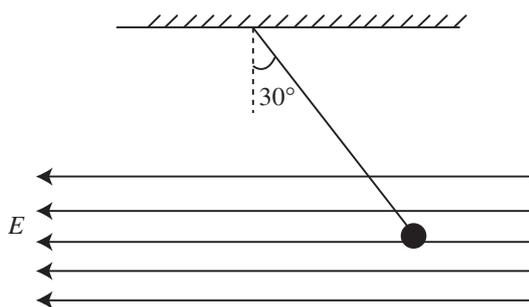
**Time:** 45 minutes. You may refer to the constants sheet and the equation sheet, both of which are found in the appendix. You may use a calculator.

- Experimenters  $A$  and  $B$  use test charges  $q_0$  and  $2q_0$ , respectively, to measure the electric field produced by two parallel plates.  $A$  finds a field that is
  - greater than the field found by  $B$
  - the same as the field found by  $B$
  - less than the field found by  $B$
  - either greater or less than the field found by  $B$ , depending on the accelerations of the test charges
  - either greater or less than the field found by  $B$ , depending on the masses of the test charges
- A solid conducting sphere has radius  $R$  and carries positive charge  $Q$ . Which of the following graphs represents the electric field  $E$  as a function of the distance  $r$  from the center of the sphere?



- An electron moving at constant velocity enters the region between two charged plates, as shown above. Which of the paths above correctly shows the electron's trajectory after leaving the region between the charged plates?
  - $A$
  - $B$
  - $C$
  - $D$
  - $E$
- Two isolated particles,  $A$  and  $B$ , are 4 m apart. Particle  $A$  has a net charge of  $2Q$ , and  $B$  has a net charge of  $Q$ . The ratio of the magnitude of the electric force on  $A$  to that on  $B$  is
  - 4:1
  - 2:1
  - 1:1
  - 1:2
  - 1:4

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5. A uniform electric field points to the left. A small metal ball charged to  $-2 \text{ mC}$  hangs at a  $30^\circ$  angle from a string of negligible mass, as shown above. The tension in the string is measured to be  $0.1 \text{ N}$ . What is the magnitude of the electric field? ( $\sin 30^\circ = 0.50$ ;  $\cos 30^\circ = 0.87$ ;  $\tan 30^\circ = 0.58$ .)
- (A)  $25 \text{ N/C}$   
 (B)  $50 \text{ N/C}$   
 (C)  $2,500 \text{ N/C}$   
 (D)  $5,000 \text{ N/C}$   
 (E)  $10,000 \text{ N/C}$



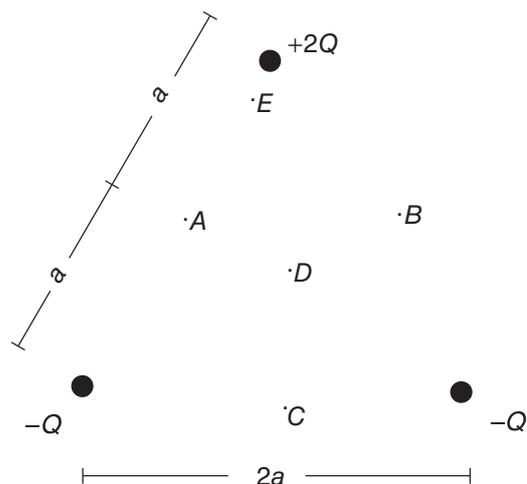
6. A thin semicircular conductor of radius  $R$  holds charge  $+Q$ . What is the magnitude and direction of the electric field at the center of the circle?

- (A)  $\frac{kQ}{R^2}$   $\uparrow$   
 (B)  $\frac{kQ}{R^2}$   $\downarrow$   
 (C)  $\frac{kQ}{\pi R^2}$   $\uparrow$   
 (D)  $\frac{kQ}{\pi R^2}$   $\downarrow$

(E) The electric field is zero at the center.

7. Above an infinitely large plane carrying charge density  $\sigma$ , the electric field points up and is equal to  $\sigma/2\epsilon_0$ . What is the magnitude and direction of the electric field below the plane?

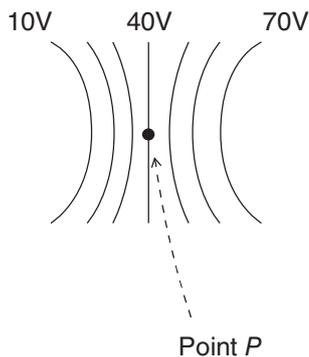
- (A)  $\sigma/2\epsilon_0$ , down  
 (B)  $\sigma/2\epsilon_0$ , up  
 (C)  $\sigma/\epsilon_0$ , down  
 (D)  $\sigma/\epsilon_0$ , up  
 (E) zero



8. Three charges are arranged in an equilateral triangle, as shown above. At which of these points is the electric potential smallest?

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

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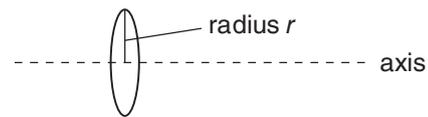


9. The diagram shows a set of equipotential surfaces. At point  $P$ , what is the direction of the electric field?
- (A) left  
 (B) right  
 (C) up the page  
 (D) down the page  
 (E) either left or right, which one cannot be determined

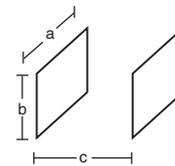
10. A metal sphere carries charge  $Q$ ; a nonconducting sphere of equal size carries the same charge  $Q$ , uniformly distributed throughout the sphere. These spheres are isolated from each other. Consider the electric field at the center of the spheres, within the spheres, and outside the spheres. Which of these electric fields will be the same for both spheres, and which will be different?

	Elsewhere	
At the Center	Within the Sphere	Outside the Sphere
(A) Same	Same	Same
(B) Same	Same	Different
(C) Same	Different	Same
(D) Different	Different	Same
(E) Different	Different	Different

11. Under what conditions is the net electric flux through a closed surface proportional to the enclosed charge?
- (A) under any conditions  
 (B) only when the enclosed charge is symmetrically distributed  
 (C) only when all nearby charges are symmetrically distributed  
 (D) only when there are no charges outside the surface  
 (E) only when enclosed charges can be considered to be point charges



12. A hollow metal ring of radius  $r$  carries charge  $q$ . Consider an axis straight through the center of the ring. At what point(s) along this axis is/are the electric field equal to zero?
- (A) only at the center of the ring  
 (B) only at the center of the ring, and a very long distance away  
 (C) only a very long distance away  
 (D) only at the center of the ring, a distance  $r$  away from the center, and a very long distance away  
 (E) everywhere along this axis



13. A parallel plate capacitor consists of identical rectangular plates of dimensions  $a \times b$ , separated by a distance  $c$ . To cut the capacitance of this capacitor in half, which of these quantities should be doubled?
- (A)  $a$   
 (B)  $b$   
 (C)  $c$   
 (D)  $ab$   
 (E)  $abc$
14. Two identical capacitors are hooked in parallel to an external circuit. Which of the following quantities must be the same for both capacitors?

- I. the charge stored on the capacitor  
 II. the voltage across the capacitor  
 III. the capacitance of the capacitor
- (A) I only  
 (B) II only  
 (C) II and III only  
 (D) I and III only  
 (E) I, II, and III

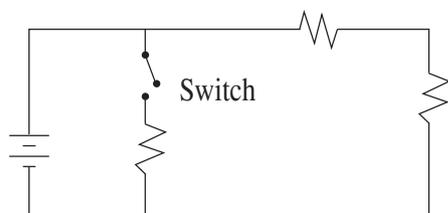
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15. A  $2\ \mu\text{F}$  capacitor is connected directly to a battery. When the capacitor is fully charged, it stores  $600\ \mu\text{C}$  of charge. An experimenter replaces the  $2\ \mu\text{F}$  capacitor with three  $18\ \mu\text{F}$  capacitors in series connected to the same battery. Once the capacitors are fully charged, what charge is stored on each capacitor?

(A)  $100\ \mu\text{C}$   
 (B)  $200\ \mu\text{C}$   
 (C)  $600\ \mu\text{C}$   
 (D)  $1200\ \mu\text{C}$   
 (E)  $1800\ \mu\text{C}$

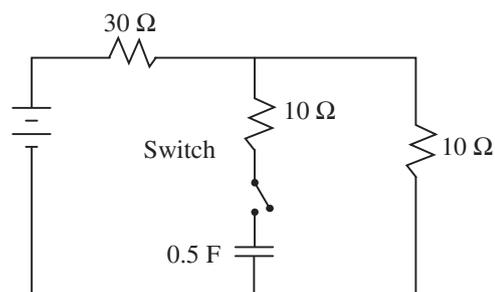
16. A spherical conductor carries a net charge. How is this charge distributed on the sphere?

(A) The charge is evenly distributed on the surface.  
 (B) The charge resides on the surface only; the distribution of charge on the surface depends on what other charged objects are near the sphere.  
 (C) The charge moves continually within the sphere.  
 (D) The charge is distributed uniformly throughout the sphere.  
 (E) The charge resides within the sphere; the distribution of charge within the sphere depends on what other charged objects are near the sphere.



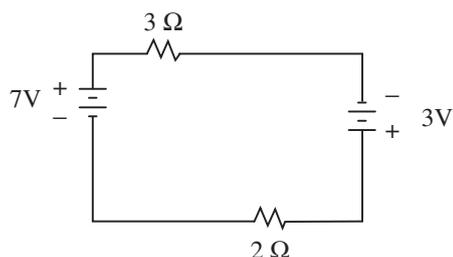
17. Three resistors are connected to a battery as shown in the diagram above. The switch is initially open. When the switch is closed, what happens to the total voltage, current, and resistance in the circuit?

	<u>Voltage</u>	<u>Current</u>	<u>Resistance</u>
(A)	increases	increases	increases
(B)	does not change	does not change	does not change
(C)	does not change	decreases	increases
(D)	does not change	increases	decreases
(E)	decreases	decreases	decreases



18. In the circuit shown above, the  $0.5\text{-F}$  capacitor is initially uncharged. The switch is closed at time  $t = 0$ . What is the time constant (the time for the capacitor to charge to 63% of its maximum charge) for the charging of this capacitor?

(A) 5 s  
 (B) 10 s  
 (C) 20 s  
 (D) 30 s  
 (E) 40 s



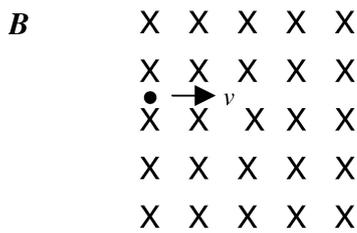
19. In the circuit shown above, what is the current through the  $3\ \Omega$  resistor?

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

20. A light bulb rated at  $100\ \text{W}$  is twice as bright as a bulb rated at  $50\ \text{W}$  when both are connected in parallel directly to a  $100\text{-V}$  source. Now imagine that these bulbs are instead connected in series with each other. Which is brighter, and by how much?

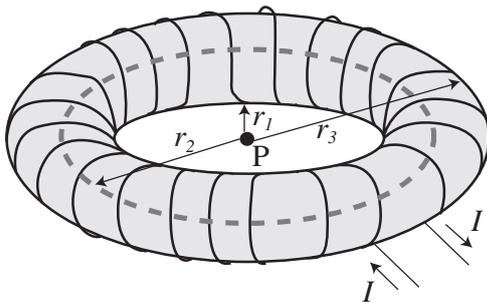
(A) The bulbs have the same brightness.  
 (B) The  $100\text{-W}$  bulb is twice as bright.  
 (C) The  $50\text{-W}$  bulb is twice as bright.  
 (D) The  $100\text{-W}$  bulb is four times as bright.  
 (E) The  $50\text{-W}$  bulb is four times as bright.

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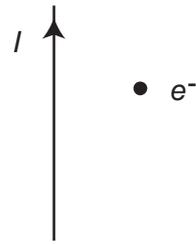
21. A uniform magnetic field  $B$  is directed into the page. An electron enters this field with initial velocity  $v$  to the right. Which of the following best describes the path of the electron while it is still within the magnetic field?

(A) It moves in a straight line.  
 (B) It bends upward in a parabolic path.  
 (C) It bends downward in a parabolic path.  
 (D) It bends upward in a circular path.  
 (E) It bends downward in a circular path.



22. Wire is wound around an insulated circular donut, as shown above. A current  $I$  flows in the wire in the direction indicated by the arrows. The inner, average, and outer radii of the donut are indicated by  $r_1$ ,  $r_2$ , and  $r_3$ , respectively. What is the magnitude and direction of the magnetic field at point  $P$ , the center of the donut?

(A) zero  
 (B)  $\frac{\mu_0 I}{2r_1}$   
 (C)  $\frac{\mu_0 I}{2r_2}$   
 (D)  $\frac{\mu_0 I}{2r_3}$   
 (E)  $\frac{\mu_0 I}{2\pi r_2}$



23. A wire carries a current toward the top of the page. An electron is located to the right of the wire, as shown above. In which direction should the electron be moving if it is to experience a magnetic force toward the wire?

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

24. Which of the following statements about electric and magnetic fields is FALSE:

(A) A charge moving along the direction of an electric field will experience a force, but a charge moving along the direction of a magnetic field will not experience a force.  
 (B) All charges experience a force in an electric field, but only moving charges can experience a force in a magnetic field.  
 (C) A positive charge moves in the direction of an electric field; a positive charge moves perpendicular to a magnetic field.  
 (D) All moving charges experience a force parallel to an electric field and perpendicular to a magnetic field.  
 (E) A negative charge experiences a force opposite the direction of an electric field; a negative charge experiences a force perpendicular to a magnetic field.

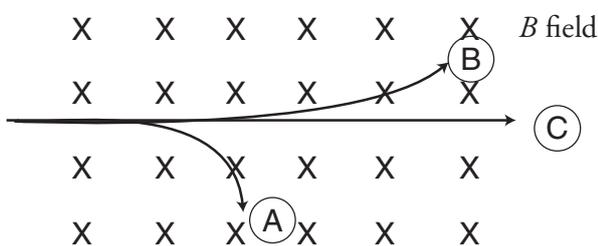
25. Which of these quantities decreases as the inverse square of distance for distances far from the objects producing the fields?

(A) the electric field produced by a finite-length charged rod  
 (B) the electric field produced by an infinitely long charged cylinder  
 (C) the electric field produced by an infinite plane of charge  
 (D) the magnetic field produced by an infinitely long, straight current-carrying wire  
 (E) the magnetic field produced by a wire curled around a torus

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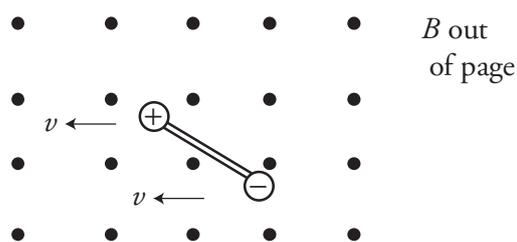
26. A proton enters a solenoid. Upon entry, the proton is moving in a straight line along the axis of the solenoid. Which of the following is a correct description of the proton's motion within the solenoid?

- (A) The proton will be bent in a parabolic path.
- (B) The proton will be bent in a circular path.
- (C) The proton will continue in its straight path at constant velocity.
- (D) The proton will continue in its straight path and slow down.
- (E) The proton will continue in its straight path and speed up.



27. A uniform magnetic field points into the page. Three subatomic particles are shot into the field from the left-hand side of the page. All have the same initial speed and direction. These particles take paths A, B, and C, as labeled in the diagram above. Which of the following is a possible identity for each particle?

- | <u>A</u>       | <u>B</u>   | <u>C</u> |
|----------------|------------|----------|
| (A) antiproton | proton     | electron |
| (B) antiproton | positron   | neutron  |
| (C) proton     | electron   | neutron  |
| (D) positron   | antiproton | neutron  |
| (E) electron   | proton     | neutron  |

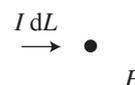


28. The electric dipole shown above consists of equal-magnitude charges and has an initial leftward velocity  $v$  in a uniform magnetic field pointing out of the page, as shown above. The dipole experiences

- (A) a clockwise net torque, and a net force to the left
- (B) a counterclockwise net torque, and a net force to the left
- (C) no net torque, and a net force to the left
- (D) a counterclockwise net torque, and no net force
- (E) a clockwise net torque, and no net force

29. A beam of electrons has speed  $10^7$  m/s. It is desired to use the magnetic field of the Earth,  $5 \times 10^{-5}$  T, to bend the electron beam into a circle. What will be the radius of this circle?

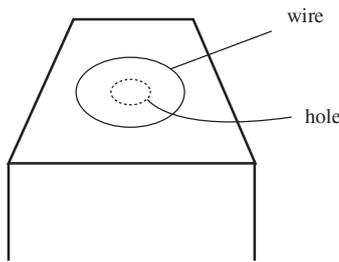
- (A) 1 nm
- (B) 1  $\mu$ m
- (C) 1 mm
- (D) 1 m
- (E) 1 km



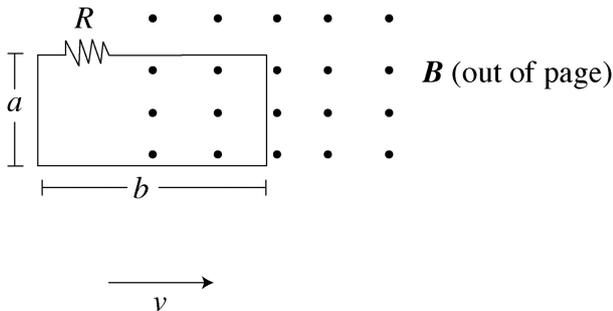
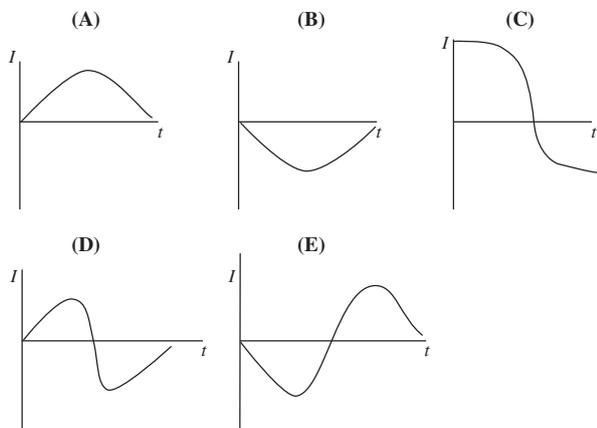
30. A very small element of wire of length  $dL$  carries a current  $I$ . What is the direction of the magnetic field produced by this current element at point  $P$ , shown above?

- (A) to the right
- (B) toward the top of the page
- (C) into the page
- (D) out of the page
- (E) there is no magnetic field produced at point  $P$  by this element.

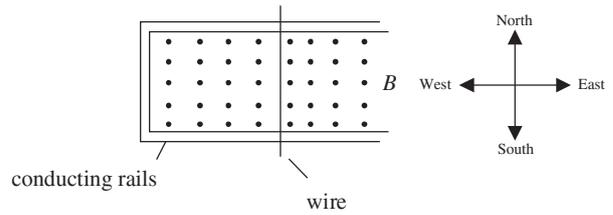
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31. A loop of wire surrounds a hole in a table, as shown above. A bar magnet is dropped, north end down, from far above the table through the hole. Let the positive direction of current be defined as counterclockwise as viewed from above. Which of the following graphs best represents the induced current  $I$  in the loop?

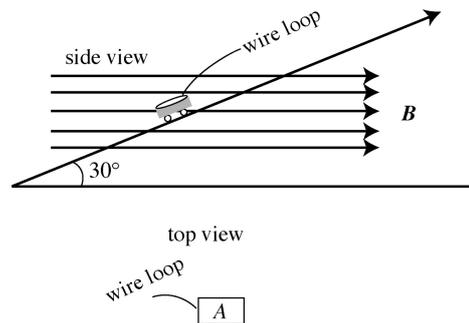


32. A rectangular loop of wire has dimensions  $a \times b$  and includes a resistor  $R$ . This loop is pulled with speed  $v$  from a region of no magnetic field into a uniform magnetic field  $B$  pointing through the loop, as shown above. What is the magnitude and direction of the current through the resistor?
- (A)  $Bav/R$ , left-to-right  
 (B)  $Bbv/R$ , left-to-right  
 (C)  $Bav/R$ , right-to-left  
 (D)  $Bbv/R$ , right-to-left  
 (E)  $Bba/R$ , right-to-left



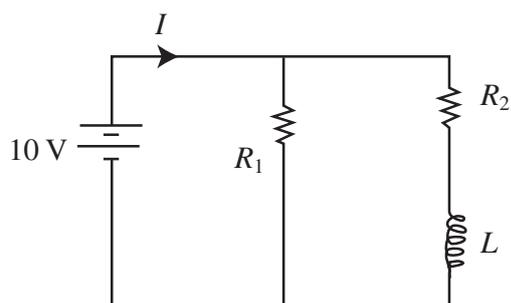
33. A conducting wire sits on smooth metal rails, as shown above. A variable magnetic field points out of the page. The strength of this magnetic field is increased linearly from zero. Immediately after the field starts to increase, what will be the direction of the current in the wire and the direction of the wire's motion?

	Current in the Wire	Motion of the Wire
(A)	north	no motion
(B)	north	east
(C)	north	west
(D)	south	west
(E)	south	east



34. A uniform magnetic field  $B$  points parallel to the ground. A toy car is sliding down a frictionless plane inclined at  $30^\circ$ . A loop of wire of resistance  $R$  and cross-sectional area  $A$  lies in the flat plane of the car's body, as shown above. What is the magnetic flux through the wire loop?
- (A) zero  
 (B)  $BA \cos 30^\circ$   
 (C)  $BA \cos 60^\circ$   
 (D)  $BA$   
 (E)  $(BA \cos 60^\circ)/R$

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35. If the two equal resistors  $R_1$  and  $R_2$  are connected in parallel to a 10-V battery with no other circuit components, the current provided by the battery is  $I$ . In the circuit shown above, an inductor of inductance  $L$  is included in series with  $R_2$ . What is the current through  $R_2$  after the circuit has been connected for a long time?

- (A) zero
- (B)  $(1/4) I$
- (C)  $(1/2) I$
- (D)  $I$
- (E)  $I \frac{R_1 + R_2}{LR_2}$

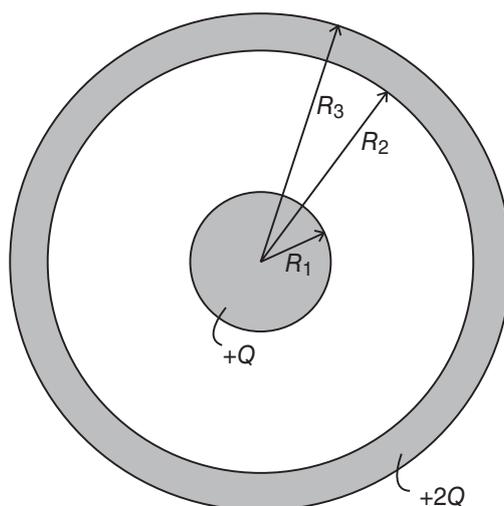
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**Physics C—Electricity and Magnetism Practice Exam 1—  
Free-Response Questions**

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**Time:** 45 minutes. You may refer to the constants sheet and the equation sheet, both of which are found in the appendix. You may use a calculator.

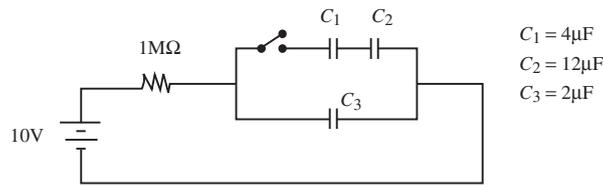
**E&M 1**

A metal sphere of radius  $R_1$  carries charge  $+Q$ . A concentric spherical metal shell, of inner radius  $R_2$  and outer radius  $R_3$ , carries charge  $+2Q$ .

- (a) Let  $r$  represent the distance from the center of the spheres. Calculate the electric field as a function of  $r$  in each of the following four regions:
1. between  $r = 0$  and  $r = R_1$
  2. between  $r = R_1$  and  $r = R_2$
  3. between  $r = R_2$  and  $r = R_3$
  4. between  $r = R_3$  and  $r = 0$
- (b) How much charge is on each surface of the outer spherical shell? Justify your answer.
- (c) Determine the electric potential of the outer spherical shell.
- (d) Determine the electric potential of the inner metal sphere.

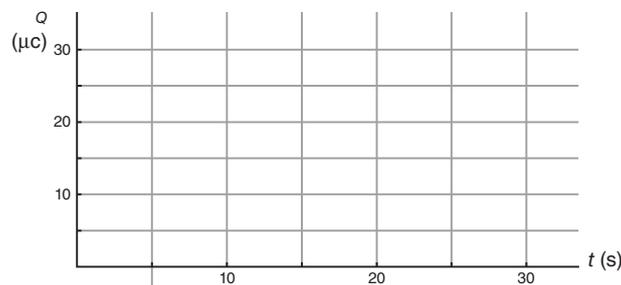
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**E&M 2**



A  $1\text{ M}\Omega$  resistor is connected to the network of capacitors shown above. The circuit is hooked to a 10-V battery. The capacitors are initially uncharged. The battery is connected, and the switch is closed at time  $t = 0$ .

- (a) Determine the equivalent capacitance of  $C_1$ ,  $C_2$ , and  $C_3$ .
- (b) Determine the charge on and voltage across each capacitor after a long time has elapsed.
- (c) On the axes below, sketch the total charge on  $C_3$  as a function of time.

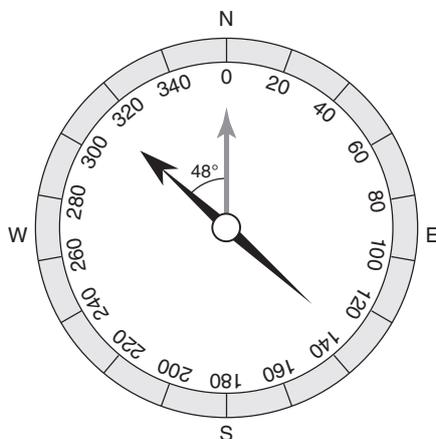


- (d) After the capacitors have been fully charged, the switch is opened, disconnecting  $C_1$  and  $C_2$  from the circuit. What happens to the voltage across and charge on  $C_3$ ? Justify your answer.

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**E&M 3**

In the laboratory, far from the influence of other magnetic fields, the Earth's magnetic field has a value of  $5.00 \times 10^{-5}$  T. A compass in this lab reads due north when pointing along the direction of Earth's magnetic field.



A long, straight current-carrying wire is brought close to the compass, deflecting the compass to the position shown above,  $48^\circ$  west of north.

- Describe one possible orientation of the wire and the current it carries that would produce the deflection shown.
- Calculate the magnitude  $B_{\text{wire}}$  of the magnetic field produced by the wire that would cause the deflection shown.
- The distance  $d$  from the wire to the compass is varied, while the current in the wire is kept constant; a graph of  $B_{\text{wire}}$  vs.  $d$  is produced. On the axes below, sketch the shape of this graph.



- It is desired to adjust this plot so that the graph becomes a straight line. The vertical axis is to remain  $B_{\text{wire}}$ , the magnetic field produced by the wire. How could the quantity graphed on the horizontal axis be adjusted to produce a straight-line graph? Justify your answer.
- The current carried by the wire is 500 mA. Determine the slope of the line on the graph suggested in part (d).

**STOP. End of Physics C—Electricity and Magnetism Practice Exam 1—Free-Response Questions**