

NAME: \_\_\_\_\_

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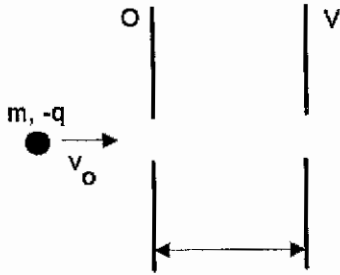
**General Instructions:** This test consists of two parts each worth 50% of the total. The first part consist of four conceptual questions while the second part consists of three problems. You are allowed one formula sheet for psychological support. Neatness and organization counts for 3% extra in total.

1. Two conducting spheres, one having twice the diameter of the other, are separated by a distance large compared to their diameters. The smaller sphere (1) initially has charge  $q$  and the larger sphere (2) is initially uncharged. If the spheres are connected by a long thin conducting wire:

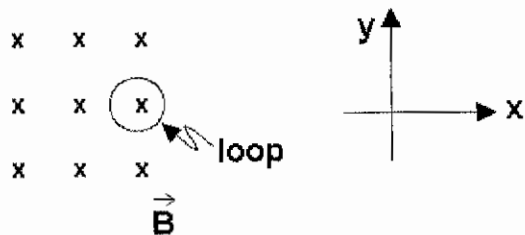


- (a) 1 and 2 have the same potential  
(b) 2 has twice the potential as 1  
(c) 2 has half the potential of 1  
(d) 2 has four times the potential as 1  
(e) 2 has one fourth the potential of 1  
(f) none of these
2. Refer to the previous problem. If the spheres are connected by a long thin conducting wire:
- (a) 1 and 2 have the same charge  
(b) 2 has twice the charge as 1  
(c) 2 has half the charge of 1  
(d) 2 has four times the charge as 1  
(e) 2 has one fourth the charge of 1  
(f) none of these
3. Two point charges,  $q_1$  and  $q_2$ , are placed a distance  $r$  apart. The electric field is zero at a point P between the charges, somewhere on the line segment connecting them. We conclude that:
- (a)  $q_1$  and  $q_2$  must have equal magnitudes and the same sign  
(b)  $q_1$  and  $q_2$  must have equal magnitudes and opposite signs  
(c) P must be midway between  $q_1$  and  $q_2$

- (d)  $q_1$  and  $q_2$  must have the same sign but may have different magnitudes  
 (e)  $q_1$  and  $q_2$  must have opposite signs and may have different magnitudes  
 (f) none of these
4. A particle (mass  $m$ , charge  $-q$ ) is projected with speed  $v_0$  into the region between two parallel plates as shown. The potential difference between the two plates is  $V$  and their separation is  $d$ . The change in kinetic energy of the particle before and after it has traversed this region is:

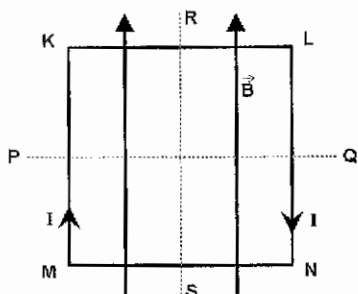


- (a)  $qV/d$   
 (b)  $2qV/mv_0^2$   
 (c)  $qV$   
 (d)  $qVd$   
 (e)  $mv_0^2/2$   
 (f) none of these
5. Let  $Q$  denote charge,  $V$  denote potential difference and  $U$  denote stored energy. Of these quantities, two capacitors  $C_1$  and  $C_2$  in series must have the same:
- (a)  $Q$  only  
 (b)  $V$  only  
 (c)  $U$  only  
 (d)  $Q$  and  $V$  only  
 (e)  $Q$  and  $U$  only  
 (f)  $V$  and  $U$  only  
 (g)  $Q$ ,  $V$ , and  $U$
6. A circular loop of wire is positioned half in and half out of a square region of uniform  $B$  field directed into the page, as shown. To induce a clockwise current in this loop: (Circle all that apply)
- (a) move it in  $+x$  direction  
 (b) move it in  $-x$  direction  
 (c) move it in  $+y$  direction  
 (d) move it in  $-y$  direction  
 (e) move it in  $+z$  direction  
 (f) move it in  $-z$  direction



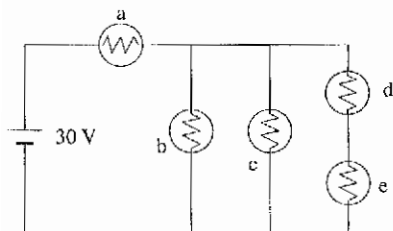
- (g) increase the strength of  $B$
- (h) decrease the strength of  $B$

7. A square loop of wire lies in the plane of the page and carries a current  $I$  as shown. There is a uniform magnetic field  $B$  parallel to the side  $MK$  as indicated. The loop will tend to rotate:



- (a) about  $PQ$  with  $KL$  coming out of the page
- (b) about  $PQ$  with  $KL$  going into the page
- (c) about  $RS$  with  $MK$  coming out of the page
- (d) about  $RS$  with  $MK$  going into the page
- (e) clockwise about an axis perpendicular to the page
- (f) counter-clockwise about an axis perpendicular to the page
- (g) the loop will not tend to rotate

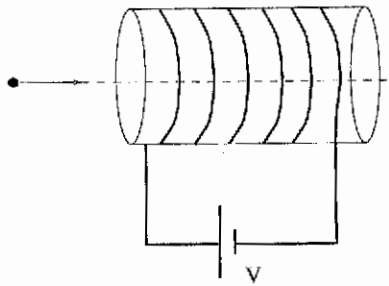
8. Five identical light bulbs are arranged in the following circuit.



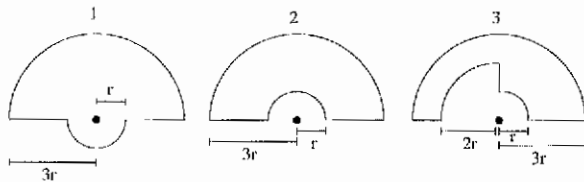
Arrange the bulbs in order from brightest to dimmest. In case of a tie, enclose the letters in parentheses.

Brightest:

:Dimmest



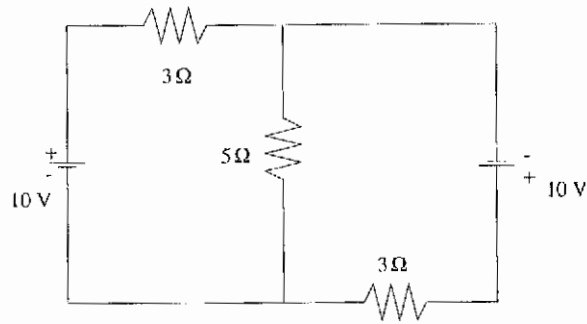
9. An electron is projected through a solenoid along the central axis. If the current ( $I$ ) as seen by the approaching electron is flowing clockwise around the solenoid, then the electron
- speeds up
  - slows down
  - is deflected to its right
  - is deflected to its left
  - is deflected up
  - is deflected down
  - is unaffected
10. The diagrams show three circuits consisting of concentric circular arcs, either half or quarter circles of radii  $r$ ,  $2r$ , or  $3r$ . All three circuits carry the same current. Rank the magnitudes of the magnetic fields at the centers.



- $B_1 < B_2 < B_3$
- $B_1 < B_3 < B_2$
- $B_2 < B_1 < B_3$
- $B_2 < B_3 < B_1$
- $B_3 < B_1 < B_2$
- $B_3 < B_2 < B_1$

**Part II Problems** (60 points) It would be prudent to use variables as much as possible and only substitute numbers in at the very end of each part. **SHOW YOUR WORK!**

- Find the currents (magnitude and direction) passing through the resistors in the following DC circuit.



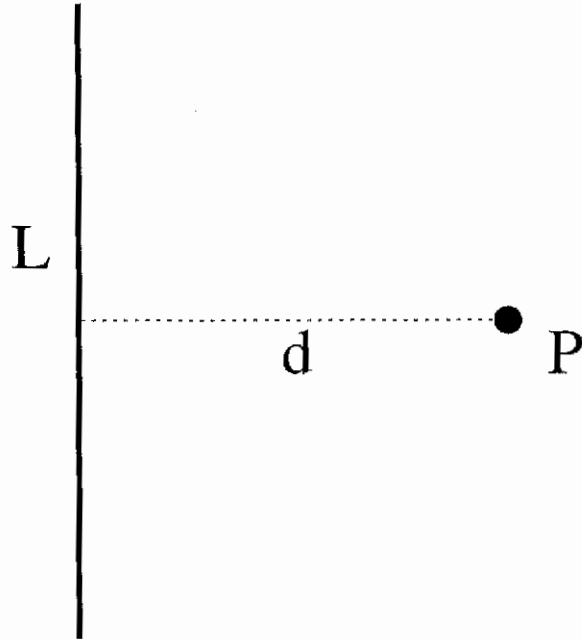
Resistor	Current	Direction
3 Ω (upper)		
5 Ω		
3 Ω (lower)		

2. A long straight wire of circular cross-section carries a uniformly distributed current of  $3.00\text{A}$  and has a radius of  $2.00\text{cm}$ . The amperian loop shown in the sketch at the right consist of two semi-circles, one of radius  $4\text{cm}$ , the other of radius  $2\text{cm}$ . The two semi circles are connected by straight segments as shown in the figure. For this amperian loop without using Ampere's Law, find (a)the magnetic field along both circular arcs, (b)the line integral of  $B$  along this arc 1 and arc 2 and (c)the net line integral of  $B$  along the two straight segments. (d)Find the line integral around the entire amperian loop and explain how your result agrees with Ampere's Law.

3. The figure below shows a conducting rod of length  $L$  being pulled along horizontal, frictionless, conducting rails at a constant velocity  $v$ . A uniform vertical magnetic field  $B$  fills the region in which the rod moves. (a) Find an expression for the induced  $EMF$  in terms of  $B$ ,  $l$ , and  $v$ . (b) In what direction will the induced current flow? (c) Find an expression for the current  $i$ . Assume the rails have zero resistance and the bar has a resistance of  $R$ . (d) If the external force is removed the velocity of the bar will decrease exponentially. Use Newtons second law to solve for  $v$  and prove this statement. (*Hint: Note that the force opposing the motion is just  $F = ilB$ , where  $i$  is obtained in part (c).*)

4. For the following problem, set up the required integral, but **DO NOT** attempt to evaluate it.

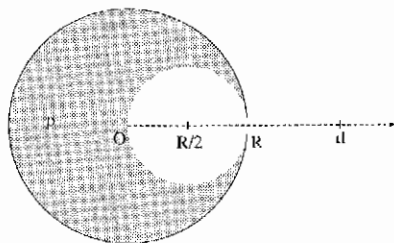
Find the electric potential at point P a distance  $d$  from the center of a wire with linear charge density  $\lambda$  and length  $L$ . Your answer should contain ONLY the dummy integration variable (such as "y") and the given quantities.



5. A series  $RLC$  circuit consists of an  $6.0 \omega$  resistor, a  $5.0 \mu F$  capacitor, and a  $40.0$  mH inductor. A variable frequency source of amplitude  $600V$  is applied across the combination. (a) Determine the power delivered to the circuit when the frequency is equal to one half the resonant frequency. (b) Determine the energy dissipated in the resistor  $R$  in one full cycle.

### Bonus Problem 10 pts.

6. A sphere of radius  $R$  is filled with a uniform volume charge density  $\rho$ . Then a spherical cavity of radius  $R/2$  is removed as shown in the figure.



- What is the magnitude of the electric field  $E$  at the center of the cavity (marked  $R/2$  in the figure)?
- What is the magnitude of the electric field  $E$  at a point outside the sphere, a distance  $d$  from the center (marked  $d$  in the figure)?
- What is the magnitude of the electric potential  $V$  at a point outside the sphere, a distance  $d$  from the center, with the convention that  $V(\infty)=0$ ?