Physics 222

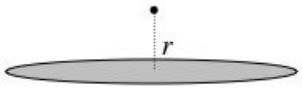
Midterm, Form: A

Name: _____

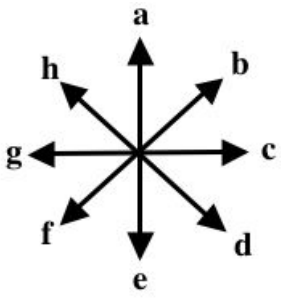
Date: _____

Electric Field

Questions 1–6: A circular area of a photocopier drum is uniformly positively charged with a net charge 1×10^{-6} C. A particle of toner at a very small distance r above the drum has a charge -2×10^{-10} C. Its distance from the drum is *much less* than the radius of the charged area of the drum.



Use the directions below to answer some of the questions.



1. What is the direction of the electric field due to the drum at the location of the toner particle?
   (a) a
   (b) b
   (c) c
   (d) d
   (e) e
   (f) f
   (g) g
   (h) h

2. What is the direction of the force on the toner particle?
   (a) a
   (b) b
   (c) c
   (d) d
   (e) e
   (f) f
   (g) g
   (h) h

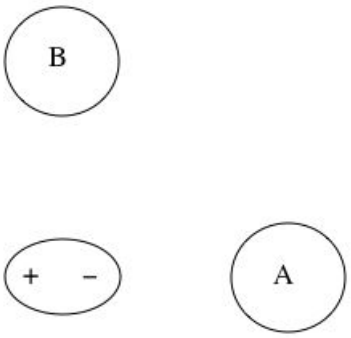
3. The force of the drum on the toner particle has a magnitude F. The force of the toner particle on the drum has a magnitude
   (a) less than F.
   (b) greater than F.
   (c) F.

4. Suppose the toner particle falls toward the drum. At a distance $r/2$, the force of the drum on the toner particle will be
   (a) $F/2$
   (b) $F/4$
   (c) $F/8$
   (d) $2F$
   (e) $4F$
   (f) $8F$
   (g) F, since E is constant near the drum.

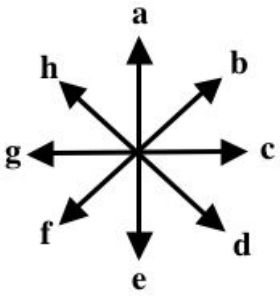
5. Suppose that the toner particle is removed and a neutral particle is placed at the initial location of the toner particle. The force of the charged drum on the neutral particle is
   (a) attractive.
   (b) repulsive.
   (c) zero.

Questions 6–10: A helium atom is neutral and has two protons (in the nucleus) and two electrons. On average, the atom is not polarized. However, because the electrons are moving, at a certain moment, it's possible that the electrons are on the same side of the atom. At this moment, the atom will temporarily be polarized. Its dipole moment, however, will be very small.

Suppose that at some instant, a helium atom is temporarily polarized, as shown in the image below. Points A and B mark the centers of nearby atoms and the dipole is the polarized helium atom.



Use the directions below to answer some of the questions.



6. What is the direction of the electric field at point A due to the dipole?
   (a) a
   (b) e
   (c) c
   (d) g
7. What is the direction of the electric field at point B due to the dipole?
   (a) a
   (b) e
   (c) c
   (d) g
8. How will atom A be polarized?
   (a) 
   (b) 
   (c) 
   (d) 
   (e) none of the above
9. How will atom B be polarized?
   (a) 
   (b) 
   (c) 
   (d) 
   (e) none of the above
10. What is the direction of the force of the dipole on atom A?
    (a) a
    (b) e
    (c) c
    (d) g
    (e) The force of the dipole on atom A is zero.

Section 2. Capacitor

Two metal discs of radius 20 cm are separated 1.0 mm. A battery is connected to the discs in order to maintain a potential difference of 1.5 volts across the discs at all times. Point A is 0.2 mm from the 1.5-volt disc.

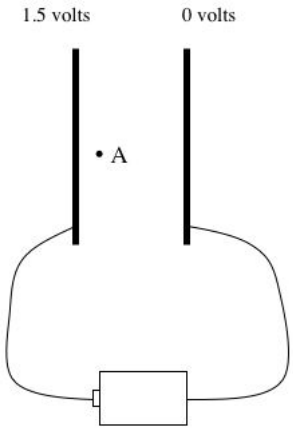


Figure 1:

11. Sketch the charge distribution on each disc.

12. What is the magnitude of the charge on each disc?

13. What is the potential at point A?

Suppose you insert a neutral thick metal disc of width 0.5 mm exactly in between the plates.

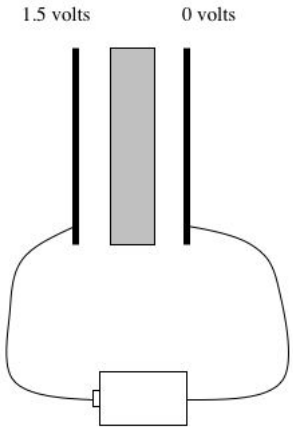


Figure 2:

14. Sketch the charge distribution on all metal discs.

15. What is the potential, V, at any point on the metal disc that is in between the plates?

16. What is the electric field in the gap between the outer disc (either one) and the middle disc?

17. What is the magnitude of the charge Q on an outer disc?

18. What is the electric field inside the middle metal disc due to the surface charge? Note: consider the net electric field inside the metal disc.

Section 3. Magnetic Fields

Questions 19–21: Current flows in a loop in the direction shown in the image below. If you are standing on the +x axis facing the loop, current flows clockwise.

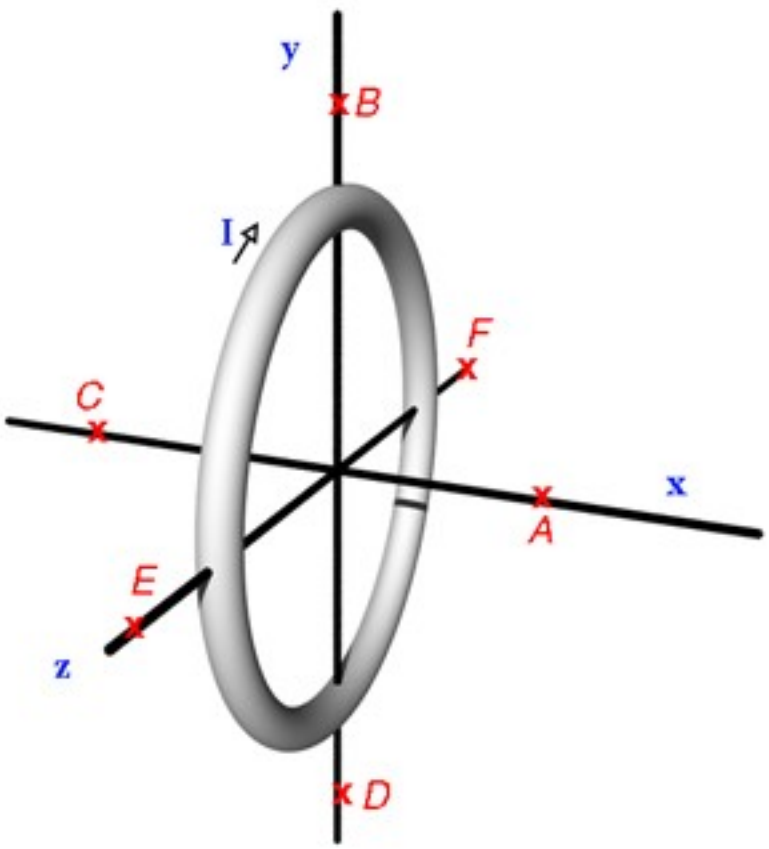


Figure 3:

The battery and wire connected to the loop are not shown.

19. On the figure above, sketch the magnetic field at points A, B, C, D, E, and F due to the current in the loop.

20. Sketch the magnetic dipole moment (vector) of the loop.

21. Suppose that you want to replace the ring with a dipole magnet, like the one you used in lab. Sketch where you would place the magnet and label the N and S poles of the magnet.

Questions 22–23: You place a compass along the axis of a magnetic dipole at a distance of 50 cm from the magnet, oriented as shown in the figure below.

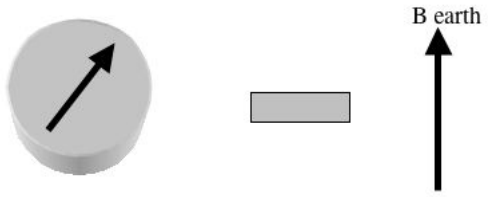


Figure 4:

22. If the compass needle is deflected 30 ° from north, what is the magnitude of the magnetic dipole moment of the magnet?

23. Sketch the magnetic dipole moment vector of the magnet and label the magnet's N and S poles.

Answer Key for Exam A

Electric Field

1. (a)
2. (e)
3. (c)
4. (g)
5. (a)

6. (d)
7. (c)
8.
9.
10. (d)

Section 2. Capacitor

11. 1.5 volt plate is positively charged; 0 volt plate is negatively charged.

12. $\Delta V = -E_x \Delta x$
    $E_x = 1.5volt/0.001m = 1500$ N/C
    $E = Q/(A\epsilon_0$
    $Q = 1.7 \times 10^{-9}$ C

13. $\Delta V = -E_x \Delta x$
    $V_A - 0 = 1500(0.0008m) = 1.2volt$

14. Left plate is positively charged; right plate is negatively charged; left side of center plate is negatively charged; right side of center plate is positively charged.

15. Because the center plate is at the same potential everywhere, then they only potential difference is across the left gap and the right gap. The potential changes linearly with x across the gap, and the potential difference across the whole thing is 1.5 volts. Since each gap has the same width, then the potential difference across each gap is 1.5/2=0.75 volts. Thus, the potential at the center plate is 0.75 volts.

16. $\Delta V = -E_x \Delta x$
    $E_x = 0.75/0.00025m = 3000$ N/C

17. $E = Q/A/\epsilon_0$
    $Q = 3.4 \times 10^{-9}$ C

18. $\vec{E}_{net} = \vec{E}_{surface} + \vec{E}_{capacitor} = 0$
    $\vec{E}_{surface} = -\vec{E}_{capacitor}$
    $E_{x_{surface}} = -3000$ N/C

Section 3. Magnetic Fields

19. at A, $\vec{B}$ is in –x direction
    at B, $\vec{B}$ is in +x direction
    at C, $\vec{B}$ is in –x direction
    at D, $\vec{B}$ is in +x direction
    at E, $\vec{B}$ is in +x direction
    at F, $\vec{B}$ is in +x direction

20. The magnetic dipole moment is in the –x direction.

21. At the center of the coil, aligned with the axis of the coil, the N side on the -x axis and the S side on the +x axis.

22. $\vec{B}_{magnet} = B_{earth} tan(30) = 1.15 \times 10^{-5}$ T
    $B_{dipole} = \mu_0/4\pi 2\mu/r^3$
    $\mu = 7.22$ amp m^2

23. The magnetic dipole moment is to the right; the S pole is on the left and N pole is on the right.