Physics 222

Midterm, Form: A

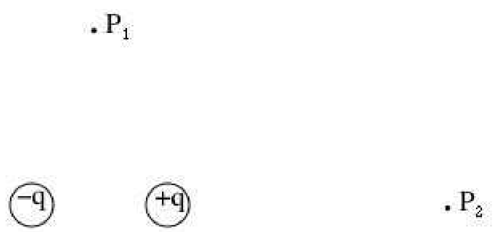
Name: ______________________

Date: ______________________

Here are some useful constants.

$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9$ Nm^2/C^2 $\quad$ $\frac{\mu_0}{4\pi} = 1 \times 10^{-7}$ tesla s/C $\quad$ $e = 1.6 \times 10^{-19} C$

Questions 1–5: A dipole consisting of two charged point-like particles with $|q| = 1$ μC, separated by a distance of 1×10^{-3} m is shown below.



The magnitude of the electric field at a distance r from a charged particle is

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2}$$

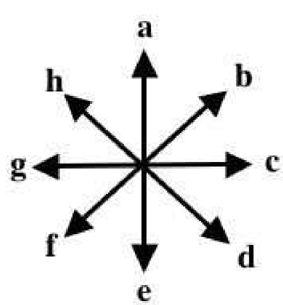
The magnitude of the electric field at a location on the axis of a dipole, far from the dipole at a distance r from the center of the dipole that is much greater than s, is

$$E = \frac{1}{4\pi\epsilon_0}\frac{2qs}{r^3}$$

The magnitude of the electric field at a location along a perpendicular bisector of a dipole, far from the dipole at a distance r from the center of the dipole, is

$$E = \frac{1}{4\pi\epsilon_0}\frac{qs}{r^3}$$

Use these arrows below to indicate directions of vectors.



1. What is the direction of the electric field at the point P_1?
   (a) a
   (b) b
   (c) c
   (d) d
   (e) e
   (f) f
   (g) g
   (h) h

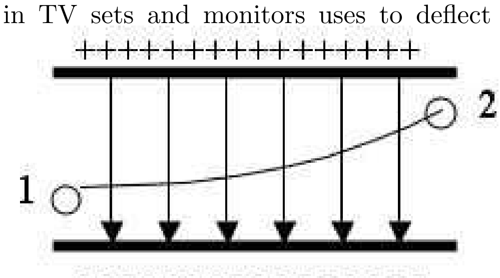
2. What is the direction of the electric field at the point P_2?
   (a) a
   (b) b
   (c) c
   (d) d
   (e) e
   (f) f
   (g) g
   (h) h

3. What is the direction of the dipole moment?
   (a) a
   (b) b
   (c) c
   (d) d
   (e) e
   (f) f
   (g) g
   (h) h

4. [7] What is the electric field at the midpoint of the dipole, at a point exactly in between the two particles?
   (a) 0
   (b) $< 3.6 \times 10^{10}, 0, 0 >$ N/C
   (c) $< -2000, 0, 0 >$ N/C
   (d) $< -8000, 0, 0 >$ N/C
   (e) correct answer not listed
   (f) $< -7.2 \times 10^{10}, 0, 0 >$ N/C

5. Suppose the electric field at point P_1 is $\vec{E}_1$ and suppose that the distance r from the dipole to P_1 is much greater than the width of the dipole s. If you double the distance r from the midpoint of the dipole to the point P_1, then the electric field at that point will be
   (a) $\vec{E}_1$
   (b) $\vec{E}_1/2$
   (c) $\vec{E}_1/4$
   (d) $\vec{E}_1/8$
   (e) $\vec{E}_1/16$

Questions 6–9: Oppositely charged parallel plates are arranged as shown below. An electron enters the region between the plates with a speed v. This is essentially what a CRT (cathode ray tube) in TV sets and monitors uses to deflect electrons.



In general, the potential difference between two locations in an electric field is

$$\Delta V = -\int_{P_1}^{P_2} \vec{E} \cdot d\vec{l}$$

The integral can be evaluated along any path because it gives the same results. In other words, the potential difference between two points only depends on the starting point and the finish point, and not the path in between.

The integral greatly simplifies for a uniform electric field to

$$\Delta V = -\vec{E} \cdot \Delta\vec{l} = -(E_x \Delta x + E_y \Delta y + E_z \Delta z)$$

The force on a charged particle at a certain location in an electric field is

$$\vec{F} = q\vec{E}$$

6. As the electron moves from point 1 to point 2, it
   (a) maintains a constant speed.
   (b) slows down.
   (c) speeds up.

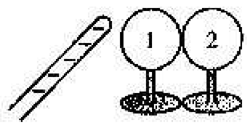
7. If the potential difference between the plates is 120 V and if they are separated by 0.05 m, what is the magnitude of the electric field between them?
   (a) 0.3 N/C
   (b) 4.8×10^4 N/C
   (c) 6 N/C
   (d) 2400 N/C

8. What is the magnitude of the force of the plates on an electron at any location between the plates?
   (a) 1.5×10^{22} N
   (b) 6 N
   (c) 1.6×10^{-18} N
   (d) 3.8×10^{-16} N

9. What is the direction of the force of the plates on an electron at any location between the plates?
   (a) always tangent to its path
   (b) always perpendicular to its path
   (c) upward toward the positive plate
   (d) downward toward the negative plate

10. A negatively charged sock is brought near a neutrally charged shirt. The sock and shirt will

    (a) repel.
    (b) attract.
    (c) not interact since charged objects and neutral objects do not interact electrically.

11. 

Two initially uncharged conductors, 1 and 2, are mounted on insulating stands and are in contact, as shown above. A negatively charged rod is brought near but does not touch them. With the rod held in place, conductor 2 is moved to the right by pushing its stand, so that the conductors are separated. Which of the following is now true of conductor 2?

    (a) It is uncharged
    (b) It is negatively charged.
    (c) It is positively charged.
    (d) It is charged, but its sign cannot be predicted.
    (e) It is at the same potential that it was before the charged rod was brought near.

12. For this type of material, any excess charged particles must be on the surface of the object.

    (a) insulator
    (b) conductor
    (c) both an insulator and a conductor
    (d) neither an insulator nor a conductor

13. For this type of material, electrons are not mobile; thus an external field causes atoms in the material to become polarized. Therefore, there can be a non-zero net electric field within the material.

    (a) insulator
    (b) conductor
    (c) both an insulator and a conductor
    (d) neither an insulator nor a conductor

14. For this type of material, valence electrons are mobile, and we think of them collectively as a "sea of electrons." In the presence of an electric field (due to external charged particles of course), this sea of electrons will distribute itself around the surface so that it produces an electric field everywhere inside the material that counteracts the applied electric field (due to external charged particles). The net electric field within the material is therefore zero.

    (a) insulator
    (b) conductor
    (c) both an insulator and a conductor
    (d) neither an insulator nor a conductor

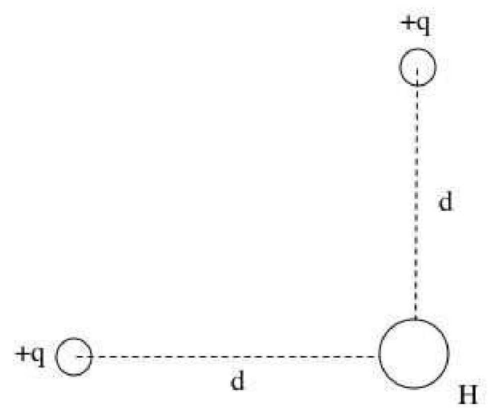
15. If this type of material is shaped like a sphere and has excess charged particles, the electric field due to the sphere at points outside the sphere is the same as if it were a charged point particle at its center.

    (a) insulator
    (b) conductor
    (c) both an insulator and a conductor
    (d) neither an insulator nor a conductor

16. Suppose a charged piece of Scotch tape has a net charge of $Q = -1 \times 10^{-7}$ C. How many excess electrons is this?

    (a) 1 electron
    (b) 1.6×10^{12} electrons
    (c) 1×10^{7} electrons
    (d) 6.02×10^{23} electrons
    (e) 6.25×10^{11} electrons

Questions 17–20: A hydrogen atom (neutrally charged of course) is near two charged particles as shown below.

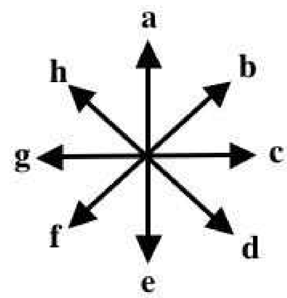


The magnitude of the force of a charged particle with charge q on a neutral atom is

$$F = (\frac{1}{4\pi\epsilon_0})^2(\frac{2\alpha q^2}{r^5})$$

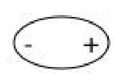
The force is due to the fact that the charged particles create an electric field at the location of the neutral atom. This electric field polarizes the atom, shifting its electron cloud such that the neutral atom acts like a dipole with a dipole moment $\vec{p}$. The induced dipole moment of the atom is directly proportional to the electric field at the location of the atom. The proportionality constant is called the polarizability α.

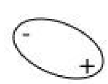
17. What is the direction of the net force on the hydrogen atom?

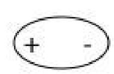


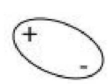
(a) a
(b) b
(c) c
(d) d
(e) e
(f) f
(g) g
(h) h

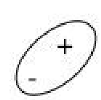
18. Which figure below is the most useful model for depicting the polarization of the hydrogen atom?

(a) 

(b) 

(c) 

(d) 

(e) 

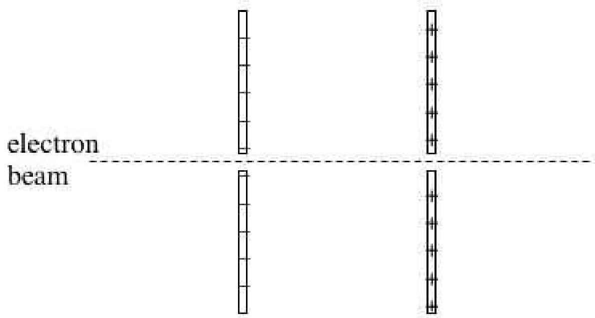
19. What is the direction of the induced dipole moment of the hydrogen atom?

    (a) a
    (b) b
    (c) c
    (d) d
    (e) e
    (f) f
    (g) g
    (h) h

20. The polarizability of hydrogen is about 7.4×10^{-41} Cm^2/V. The polarizability of carbon is about 20×10^{-41} Cm^2/V. If the magnitude of the force of a particle on the hydrogen atom is F, what would be the magnitude of the force of a particle on a carbon atom if it was at the same location as the hydrogen atom?

    (a) 0.37F
    (b) 0.14F
    (c) F
    (d) 2.7F
    (e) 7.3F

Questions 21–24: An electron beam is used in a cathode ray tube (CRT) to make the coating on a screen glow. The charge of an electron is -1.6×10^{-19} C, and its mass is about 9×10^{-31} kg. Suppose that electrons are accelerated by a region of uniform electric field. The electrons enter through a small hole in a capacitor plate and exit through a small hole in the other capacitor plate as shown in the figure below.



The potential energy of system with a charged particle of charge q at a location with potential V is

$$U = qV$$

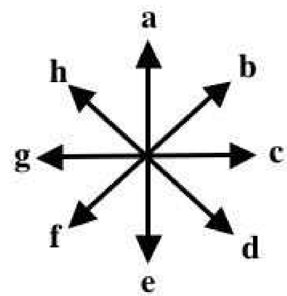
The kinetic energy of the electron is

$$K = \frac{1}{2}mv^2$$

The system is a closed system, thus the energy of the system is conserved (the energy principle!).

21. [7] If the speed of an electron entering the plate is 1×10^7 m/s what should be the potential difference ΔV across the plates in order for the speed of the electron to be $0.1c$ when exiting the plates? The constant c is the speed of light, 3×10^8 m/s.
    - (a) -2.53×10^5 volts
    - (b) -2230 volts
    - (c) 2.53×10^5 volts
    - (d) 2230 volts
    - (e) 2250 volts

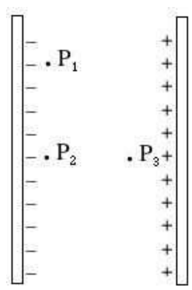
22. What is the direction of the electric field between the plates?



    - (a) a
    - (b) b
    - (c) c
    - (d) d
    - (e) e
    - (f) f
    - (g) g
    - (h) h

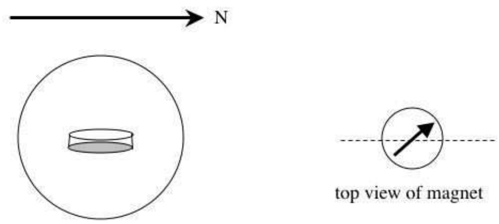
23. At which plate is the potential the greatest?
    - (a) the positive plate
    - (b) the negative plate
    - (c) neither, because the potential at the location of each plate is the same

24. At which of the points shown in the figure below is the magnitude of the *electric field* the greatest?



    - (a) P_1
    - (b) P_2
    - (c) P_3
    - (d) None of the above because the electric field is equal at all three points.

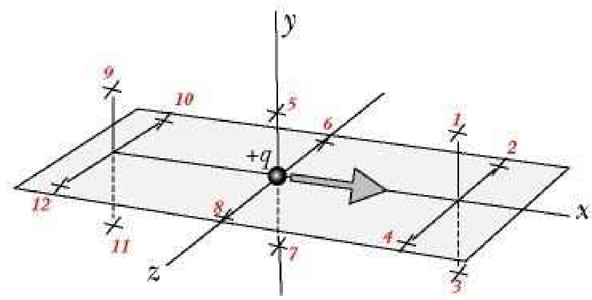
Questions 25–28: Current flows through a loop of wire that is connected to a battery. The plane of the loop is aligned with the north-south direction, and a compass is held at the center of the loop. (See the figure below.) The radius of the loop is 0.02 m, and the needle is deflected 30° from north as shown. The horizontal component of the earth's magnetic field is about 2×10^{-5} T at our latitude.



The magnetic field at locations along the z-axis of a loop of current-carrying wire is

$B_{loop} = \frac{\mu_0}{4\pi}\frac{2\pi R^2 I}{(z^2+R^2)^{3/2}}$

25. In what direction is current flowing around the loop?
    - (a) counterclockwise
    - (b) clockwise
    - (c) current is not flowing in the loop, so $I = 0$
26. What is the magnitude of the magnetic field at the center of the loop produced by the current in the wire?
    - (a) 0
    - (b) 2.9×10^{4} tesla
    - (c) 1.0×10^{-5} tesla
    - (d) 1.2×10^{-5} tesla
    - (e) 1.7×10^{-5} tesla
27. [7] What is the current in the wire?
    - (a) 0
    - (b) 0.32 ampere
    - (c) 0.38 ampere
    - (d) 0.54 ampere
    - (e) 9.2×10^{8} ampere
28. MRI (magnetic resonance imaging) machines use a large coil of wire to generate a large magnetic field within the coil. Suppose that the magnitude of the magnetic field at the center of a coil of radius R used in an MRI machine is B. If the MRI coil can be treated as a thin coil, what would be the magnitude of the magnetic field at a distance $2R$ from the center of the loop, along the +z axis?
    - (a) $B/2$
    - (b) $B/4$
    - (c) $B/8$
    - (d) $B/4^{3/2}$
    - (e) $B/5^{3/2}$
29. A positively charged particle moves with the velocity shown in the figure below. (*Matter & Interactions* Chabay and Sherwood)



What is the direction of the magnetic field at point 5?
- (a) +x
- (b) –x
- (c) +y
- (d) –y
- (e) +z
- (f) –z
- (g) none of the above

Answer Key for Exam A

1. (g)
2. (c)
3. (c)
4. (f)
5. (d)
6. (c)
7. (d)
8. (d)
9. (c)
10. (b)
11. (b)
12. (b)
13. (a)
14. (b)
15. (c)
16. (e)
17. (h)
18. (b)
19. (d)
20. (d)
21. (e)
22. (g)
23. (a)
24. (d)
25. (b)
26. (d)
27. (c)
28. (e)
29. (e)