PHY222, Spring 2005

Quiz 3 — Chapters 16–17, Form: A

Name: ____________________

Date: ____________________

Electric Potential

Questions 1–2: Suppose that the magnitude of the electric field in some region of space varies linearly as a function of y-position but always points in the $+x$ direction so that the electric field at a location $\vec{r}$ is

$$\vec{E} = < 2y, 0, 0 > \tag{1}$$

The potential difference between two points in this field is given by

$$\Delta V = -\int_i^f \vec{E} \cdot \vec{dl} \tag{2}$$

where $\vec{dl} = < dx, dy, dz >$ is a tiny displacement along a path from point i to point f.

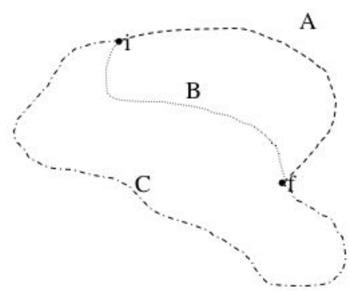

Figure 1:

1. Along which path shown in Fig. 1 is the potential difference the greatest?
   - (a) A
   - (b) B
   - (c) C
   - (d) None of the above because the potential difference between two points is path independent.
2. If you substitute the electric field into the dot product of equation 2 to calculate the potential difference, what equation results?
   - (a) $\Delta V = -\int_i^f 2y dx$
   - (b) $\Delta V = -\int_i^f 2y dy$
   - (c) $\Delta V = -\int_i^f 2y dz$
   - (d) $\Delta V = -\int_i^f 2y dx + 2y dy$

Capacitor

Questions 3–8: Capacitor plates with charges $+Q$ and $-Q$ are shown in the figure below. The electric potential at the positively charged plate is 8 volts, and the electric potential at the negatively charged plate is 0 volts.

The picture is not drawn to scale because the capacitor's plates are discs with radius 20 cm, yet their separation is only 1 mm. Points C and D are halfway between the plates, and point E is three-fourths of the separation from the positive plate.

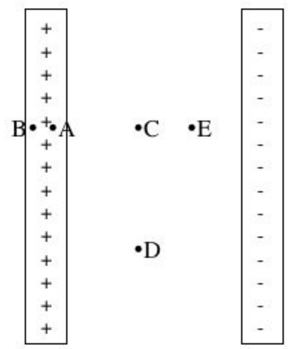

Figure 2:

3. What is the direction of the electric field everywhere between the plates?
   (a) to the left
   (b) to the right
   (c) upward
   (d) downward
   (e) None of the above because the electric field is zero everywhere between the plates.
4. Rank the magnitude of the net electric field at each point.
   (a) $(C = D = E) > (A = B = 0)$
   (b) $(A = B) > (C = D) > E$
   (c) $(C = D) > E > (A = B)$
   (d) $(B > A > (C = D) > E)$
   (e) $A = B = C = D = E$
5. Rank the electric potential V at each point.
   (a) $(B > A > (C = D) > E)$
   (b) $A = B = C = D = E$
   (c) $(C = D) > E > (A = B)$
   (d) $(A = B) > (C = D) > E$
   (e) $(C = D = E) > (A = B = 0)$
6. What is the electric potential at point E?
   (a) 8 volts
   (b) 6 volts
   (c) 4 volts
   (d) 2 volts
   (e) 0 volts
7. What is the electric field between the plates?
   (a) 8000 N/C
   (b) 40 N/C
   (c) 4000 N/C
   (d) It can't be determined because the charge on each plate is not given.

8. If you separate the plates so that they are 2 mm apart, but otherwise do not change the charge on each plate, then
   (a) the electric field between the plates decreases by a factor of 1/2.
   (b) the potential difference across the plates increases by a factor of 2.
   (c) both the electric field between the plates and the potential difference across the plates decrease by 1/2.
   (d) the electric field between the plates and the potential difference across the plates remain the same.

Questions 9–10: Ok, so let's make a slight modification to the situation. Let's take the same capacitor plates, but this time we will connect them to an 8-volt battery. The battery will charge the plates to a charge of $+Q$ and $-Q$ just the same as before. However, in this situation, the battery will maintain a constant potential difference across the plates, regardless of the plate separation or what is between the plates.

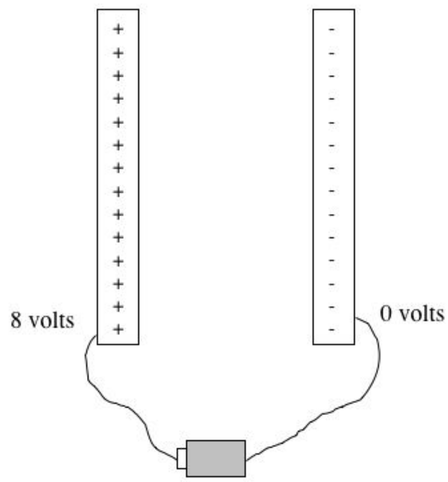

Figure 3:

9. If you separate the plates so that they are 2 mm apart, then
   (a) the electric field between the plates decreases by a factor of 1/2.
   (b) the charge on each plate decreases by a factor of 1/2.
   (c) both the electric field between the plates and the charge on each plate decrease by 1/2.
   (d) the electric field between the plates and the charge on each plate remain the same.

10. Suppose you insert an insulator with a dielectric constant K and thickness 1 mm in between the plates that are separated 1 mm. On the picture above, sketch the insulator and sketch what happens to the insulator (does it become charged, polarized, or what?). Sketch the electric field due to the capacitor plates, the electric field due to the insulator, and the net electric field. Note that the potential difference remains 8 volts and the plate separation remains 1 mm.
    As a result of the insulator between the plates,
    (a) the net electric field between the plates increases.
    (b) the charge on each plate increases.
    (c) both the net electric field between the plates and the charge on each plate increases.

Section 3. Biot-Savart Law

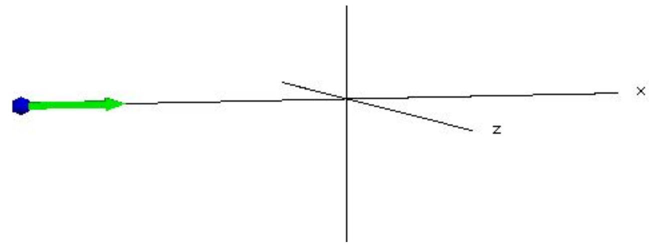

Figure 4:

Questions 11–12: An electron is moving in the direction shown below.

11. On the image above, sketch the magnetic field at a point on the +y axis, the -y axis, the +x axis, the -x axis, the +z axis, and the -z axis. If the magnetic field at any of these points is zero, say so.
12. If the electron has a speed of 3×10^7 m/s when it is at the origin, what is the magnetic field at the location $\vec{r} = < 0, 1 \times 10^{-8}, 0 >$ m?

Questions 13–14: You bend a wire into a loop and connect the ends of the wire to a battery, as shown below.

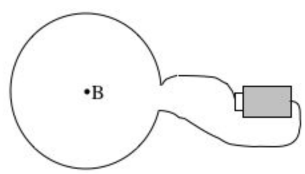

Figure 5:

13. In what "direction" does current flow around the wire?

14. What is the direction of the magnetic field at the center of the wire?

Section 4. Measuring magnetic fields

A coil of radius 2 cm and 20 turns is aligned such that its magnetic moment is perpendicular to the earth's magnetic field. When the coil is connected to a battery, a compass, located 20 cm from the center of the coil, deflects 30 ° as shown in the figure below.

Because the compass is sufficiently far from the coil, treat the coil as a magnetic dipole with a $1/r^3$ magnetic field far from the coil.

Figure 6:

15. What is the magnetic field due to the current in the coil?

16. In what "direction" (or sense) is current flowing in the wire? Be very clear by using drawings and/or language to describe it.

17. What is the current in the coil?

18. What is the magnitude of the magnetic moment $|\vec{\mu}|$ of the coil? Also, sketch this vector.

Answer Key for Exam A

Electric Potential

1. (d)
2. (a)

Capacitor

3. (b)
4. (a)
5. (d)
6. (d)
7. (a)
8. (b)
9. (c)
10. (b)

Section 3. Biot-Savart Law

11. $\vec{B}$ on the x axis is zero. $\vec{B}$ on the $+y$ axis is in the $-z$ direction. $\vec{B}$ on the $-y$ axis is in the $+z$ direction. $\vec{B}$ on the $+z$ axis is in the $+y$ direction. $\vec{B}$ on the $-z$ axis is in the $-y$ direction.

12. $B = 1 \times 10^{-7} qv/r^2$ since $\vec{v}$ and $\hat{r}$ are perpendicular.
    $B = 0.0048$ tesla

13. counterclockwise

14. $+z$ direction (or out of the page)

Section 4. Measuring magnetic fields

15. $B_{coil} = B_{earth} tan(30) = 1.2 \times 10^{-5}$ tesla

16. From this side view, current is flowing in at the top and out at the bottom.

17. $B_{axis} = 1 \times 10^{-7} 2IAN/r^3$ where N is the number of turns and A is the area of the coil. The distance from the center of the coil to the compass is r.

    As a result, $I = 18.4$ amps

18. $\mu = IA = 0.0231$ amp m^2