St John Baptist De La Salle Catholic School, Addis Ababa

Grade 10 Physics Second Take-Home Examination
3rd Quarter

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Notes, and use of other aids is allowed. Read all directions carefully and write your answers in the space provided. To receive full credit, you must show all of your work. **Cheating or indications of cheating and similar answers will be punished accordingly**.

Information

- The Take-Home Exam is due on **Wednesday**, **April 27**.
- You should Work on it **individually** and consult me if you have any questions. As I have reiterated multiple times, cheating will have a serious consequence.
- For purposes of neatness and simplicity of grading, you should do the assignment on an **A-4 paper**.

Name:______________________________ Roll Number:______ Section:______

1. (2 points) A physicist performing a sensitive measurement wants to limit the magnetic force on a moving charge in her equipment to less than 4.00×10^{-12} N.

   (i) What is the greatest the charge can be if it moves at a maximum speed of 120.0 m/s in the Earth's field?

   (ii) Discuss whether it would be difficult to limit the charge to less than the value found in **(i)** by comparing it with typical static electricity and noting that static is often absent.

   Solution:

   (i)

This part is asking for the amount of charge.

$$F = Bqv$$

$$q = \frac{F}{Bv}$$

$$q = \frac{4.00 \times 10^{-12} N}{25 \times 10^{-6} T \times 120 m/s}$$

$$q = 1.33 \times 10^{-9} C$$

Why did we choose 25μT? Because the **B** is in the denominator and we want to find the maximum charge, we choose the least possible magnitude of the field which happens to be $25\mu T$

(ii)

Static charges usually range from 1μC and 1nC, thus with static electricity it would be a little difficult to limit the force. To see the scale, an electron moving near the speed of light in the Earth's magnetic field is 3.12×10^{-15}N.

Earth's magnetic field ranges from 25 *to* 65 μT *at its surface.*

2. (1 point) A cosmic ray electron moves at 7.50×10^6 **m/s** perpendicular to the Earth's magnetic field at an altitude where field strength is 1.00×10^{-5} **T**. What is the radius of the circular path the electron follows?

Solution:

$$Bqv = m\frac{v^2}{r}$$

$$Bq = m\frac{v}{r}$$

$$r = \frac{mv}{Bq}$$

$$r = \frac{9.11 \times 10^{-31} kg \times 7.5 \times 10^6 m/s}{1.0 \times 10^{-5} T \times 1.6 \times 10^{-19} C}$$

$$r = 4.27m$$

3. (2 points) Find the magnetic force(both the magnitude and direction) acting on a proton if its velocity is V=$3.6 \times 10^6 \hat{\boldsymbol{j}}$ m/s and it is in a magnetic field of B=$2\hat{\boldsymbol{i}} + 2\hat{\boldsymbol{j}} + 7\hat{\boldsymbol{k}}$T

Solution:

$$\mathbf{F} = \mathbf{qv} \times \mathbf{B}$$

First, we need to find $\mathbf{qV}$.

$$\mathbf{qV} = 1.6 \times 10^{-19} C \times (3.6 \times 10^{6} \hat{\boldsymbol{j}}) m/s$$

$$\mathbf{qv} = 5.76 \times 10^{-13} \hat{\boldsymbol{j}} \text{ Cm/s}$$

$$\mathbf{F} = 5.76 \times 10^{-13} \hat{\boldsymbol{j}} \text{ Cm/s} \times (2\hat{\boldsymbol{i}} + 2\hat{\boldsymbol{j}} + 7\hat{\boldsymbol{k}})$$

$$\mathbf{F} = -1.152 \times 10^{-12} \hat{\boldsymbol{k}} + 4.032 \times 10^{-12} \hat{\boldsymbol{i}} T$$

$$\mathbf{F} = (4.032 \times 10^{-12} \hat{\boldsymbol{i}} + -1.152 \times 10^{-12} \hat{\boldsymbol{k}}) N$$

To find the magnitude, we do the following;

$$\text{F} = \sqrt{(4.032 \times 10^{-12})^2 + (-1.152 \times 10^{-12} \hat{\boldsymbol{k}})^2} \text{N}$$

$$\text{F} = 4.193 \times 10^{-12} \text{N}$$

To find the direction of the force, we divide $\mathbf{F}$ by F.

Thus, we get:

$$\frac{\mathbf{F}}{\text{F}} = \frac{(4.032 \times 10^{-12} \hat{\boldsymbol{i}} + -1.152 \times 10^{-12} \hat{\boldsymbol{k}}) \text{N}}{4.193 \times 10^{-12} \text{N}}$$

$$\frac{\mathbf{F}}{\text{F}} = 0.9616 \hat{\boldsymbol{i}} + 0.2747 \hat{\boldsymbol{k}}$$

4. (1 point) When a loop of wire is placed into a magnetic field, a voltage is generated. This voltage is called the Hall voltage, the idea is that the voltage is a result of an equilibrium between the electric force and magnetic force. Give an expression of the Hall voltage in terms of current, magnetic field, electron density, charge and area of the conductor.

Solution:

$$F_b = F_e$$

$$Bqv = qE$$

$$E = Bv$$

The Hall voltage, ΔV_H, is thus given by:

$$\Delta V_H = Ed$$

$$\Delta V_H = Bvd$$

To express the speed in terms of the current, we can use the following expression.

$$I = nAe^{-}v$$
$$v = \frac{I}{nAe^{-}}$$

Thus, we put the following expression in the above equation.

$$\Delta V_H = B\frac{I}{nAe^{-}}d$$
$$\Delta V_H = \frac{BId}{nAe^{-}}$$

5. (2 points) What is the force and torque on a square-shaped 6A current carrying loop of conducting wire that has an area of 0.0025m^2 and surrounded by a permanent magnet with a field strength of B = 2×10^{-2}T that is tilted at 37^0 to the loop? **Solution:**

(i)

Since the area of the loop is $0.0025m^2$, we can find the length of the square.

$$l = \sqrt{A}$$
$$l = \sqrt{0.0025m^2}$$
$$l = 0.05m$$

The force on a current carrying loop is given by:

$$F = BILsin\theta$$
$$F = 2 \times 10^{-2}T \times 6A \times 0.5m \times \sin 37^0$$
$$F = 0.078N$$

The force that we found now is just the one acting on one of the loops. However, the **total force on the loop is 0** since the forces cancel one another.

The torque is just the force multiplied the distance from the axis.
The distance from the axis(**r**) as we have seen in class in half the width of the loop.

$$r = \frac{l}{2}$$
$$r = 0.025m$$
$$\tau = Fr$$
$$\tau = 0.078N \times 0.025m$$
$$\tau = 1.95 \times 10^{-3}Nm$$

This is the torque just on one loop and the total torque on coil is:

$$\tau = 3.9 \times 10^{-3}Nm$$

6. (2 points) Find the charge to mass ratio of a charge moving if it is moving at a speed of V = 2.0×10^3 m/s in a magnetic field of 0.08G and it has the same trajectory as an electron in the same magnetic field.

   (i) Does the sign of the charge affect its trajectory?

Solution:

(i)

We know that the trajectory of the electron is similar to the trajectory of this unknown particle. That means, the radius of the path is the same in both cases(since the trajectories are *similar*) We know that

$$Bqv = m\frac{v^2}{r}$$

$$r = \frac{mv}{Bq}$$

We know the mass of an electron and its charge, thus it's easy to compute the trajectory carved out by it.

$$r = \frac{9.11 \times 10^{-31}kg \times 2.0 \times 10^3 m/s}{0.08 \times 10^{-4}T \times 1.6 \times 10^{-19}C}$$

$$r = 1.4235 \times 10^{-3}m$$

Now that we have found the trajectory of an electron thrown into the same field with the same speed, we can use that as the radius of the unknown charge because it has been stated that their trajectories are similar.

$$Bqv = m\frac{v^2}{r}$$

Since we have been asked to find the charge to mass ratio of the unknown charge,

$$\frac{q}{m} = \frac{v}{Br}$$

$$\frac{q}{m} = \frac{2 \times 10^3 m/s}{0.08 \times 10^{-4}T \times 1.4235 \times 10^{-3}m}$$

$$\frac{q}{m} = 1.7563 \times 10^{11}C/kg$$

Interestingly, an electron also has the same charge to mass ratio as our unknown particle.

(ii)

No. The sign of the charge only affects the direction of the trajectory not whether the trajectories are similar or not. Thus, our unknown particle here could be an electron or may very well be a positively charged ”electron”.