Name____

Physics 111 Quiz #4, February 7, 2025

Please show all work, thoughts and/or reasoning to receive partial credit. The quiz is worth 10 points total, and all parts may not be of equal weight.

I affirm that I have carried out my academic endeavors with full academic honesty.

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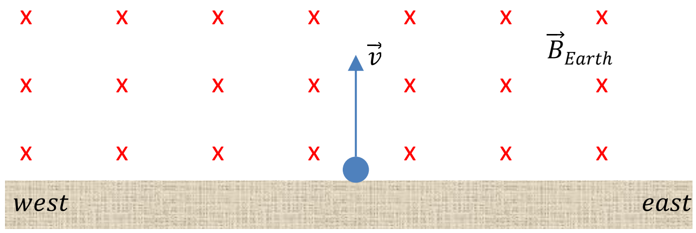
1. An electron is accelerated vertically upwards away from the Earth's surface and passes perpendicularly through the Earth's magnetic field ($B_{Earth} = 5.2 \times 10^{-5}T$) which points north with a speed $v = 7.2 \times 10^{6}\frac{m}{s}$ as shown below. Explain in detail in which direction the electrons move in the magnetic field?



Using the RHR where your fingers point along the direction of $\vec{B}$ (into the page), thumb along the direction of $\vec{v}$ (up the page), the palm/back of the right hand gives the magnetic force on a positive/negative charge respectively. Since these are electrons, the force is given by the back of the hand, and thus the magnetic force is to the east. The electron moves in a circle of radius R toward the east.

2. What is the radius of the electron's orbit?

$$F_B = qvB\sin\theta = evB\sin\theta = ma_c = m\frac{(v\sin\theta)^2}{R} \rightarrow R = \frac{mv\sin\theta}{eB}$$

$$R = \frac{9.11 \times 10^{-31}kg \times 7.2 \times 10^{6}\frac{m}{s} \times \sin 90}{1.6 \times 10^{-19}C \times 5.2 \times 10^{-5}T} = 0.79m$$

3. In the presence of the magnetic field, the electron experiences a magnetic force. Suppose that you wanted the electron to travel perpendicularly away from the surface of the Earth at a constant speed. To do this you decide to introduce an electric field. What magnitude and direction for this electric field would you need if the electron's velocity to remain constant? To earn full credit, in addition to calculating the magnitude of the electric field, you need to explain why the direction is as you state.

   By the RHR the magnetic force is to the east. Therefore, to keep the electron moving up away from the Earth, the electric force must point west. Since we have an electron and it feels a force in the direction opposite to the electric field, the electric field must point east.

   $$F_x:\ -F_B + F_E = 0 \rightarrow evB - eE = 0$$

   $$\rightarrow E = vB = 7.2 \times 10^6 \frac{m}{s} \times 5.2 \times 10^{-5} T = 374.4 \frac{N}{C}$$

4. Suppose that you turn off the electric field and that the electron does not leave the Earth's surface vertically, perpendicular to the magnetic field, but rather that the velocity of the electron is pointed into the plane of the paper in the direction of the magnetic field by an angle of $\theta = 40^0$ measured from the vertical. What is the radius and pitch of the electron's orbit?

   From the motion perpendicular to the magnetic field, we calculate the orbital period:

   $$v_\perp = v \sin\theta = \frac{2\pi R'}{T'} \rightarrow T' = \frac{2\pi R'}{v \sin\theta} = \frac{2\pi \times 0.60m}{7.2 \times 10^6 \frac{m}{s} \times \sin 50} = 6.9 \times 10^{-7} s$$

   where the radius of the electron's orbit is determined from the magnetic force.

   $$F_B = qvB\sin\theta = evB\sin\theta = ma_c = m\frac{(v\sin\theta)^2}{R} \rightarrow R' = \frac{mv\sin\theta}{eB}$$

   $$R' = \frac{9.11 \times 10^{-31} kg \times 7.2 \times 10^6 \frac{m}{s} \times \sin 50}{1.6 \times 10^{-19} C \times 5.2 \times 10^{-5} T} = 0.60m$$

   The pitch is determined from the motion parallel to the magnetic field:

   $$v_\parallel = v\cos\theta = \frac{L}{T'} \rightarrow L = vT'\cos\theta = 7.2 \times 10^6 \frac{m}{s} \times 6.9 \times 10^{-7} s \times \cos 50 = 3.2m$$

5. What is the period of the electron's orbit for the case in part 4?

   $$T' = \frac{2\pi R'}{v\sin\theta} = \frac{2\pi \times 0.60m}{7.2 \times 10^6 \frac{m}{s} \times \sin 50} = 6.9 \times 10^{-7} s$$