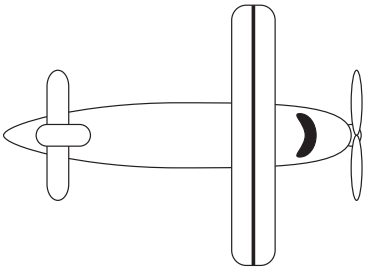
Quiz on Magnetic Fields and Forces Solutions

1. Using the diagram below, indicate the direction of the magnetic force on the electrons in the antenna. Find the magnitude of this force. Justify your answer.



An arrow should be drawn down. The northward component of the magnetic field does not produce any force as it is parallel to the velocity of the electrons. The downward component of the magnetic force produces a force pointing east, by the right hand rule, noting that the electrons are negatively charged.

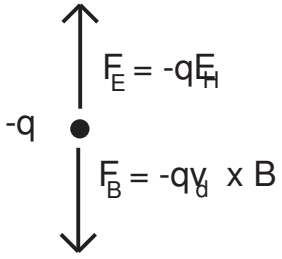
The magnitude of the force is

$$F_B = |q\mathbf{v} \times \mathbf{B}| = qvB\sin\theta = \left(1.602\times10^{-19}\right)(95)\left(6.5\times10^{-5}\right)\sin 56.3° = 8.23\times10^{-22}\,N$$

2. The electrons in the antenna will quickly reach equilibrium, and cease to accelerate Explain why this happens and draw a free body diagram of an electron in the antenna labeling all forces.

As electrons move to the East end of the antenna, an electric field will develop pointing east, which will counteract the magnetic force by pushing the electrons west. As the antenna is a conductor, this field will be constant.

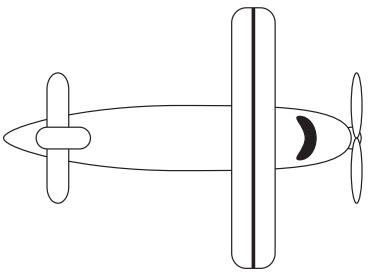
Eventually, $F_E = F_B$, so that the electrons in the wire will reach equilibrium.



3. Determine the magnitude of the electric field generated in the antenna.

$$F_E = F_B$$
$$qE = F_B$$
$$E = \frac{F_B}{q} = \frac{\left(8.23\times10^{-22}\right)}{\left(1.602\times10^{-19}\right)} = 5.14\ mN/C$$

4. Determine the potential difference between the ends of the antenna. Label which end of the antenna is at a higher potential on the figure below:



$$V = Ed = (0.00514)(20) = 103\,mV$$

The potential will be higher at the West end (top of picture) as the field points down to the East.

5. What would happen to the potential difference if the plane began to gain altitude? What would happen if the plane began to lose altitude? Justify your answer.

If the plane began to gain altitude, the velocity vector would gain an upward component, and if the plane maintained the same speed, the magnetic force would increase, as there is a greater angle between the velocity vector and the magnetic field vector. This would increase the voltage.

If the plane began to lose altitude, the velocity vector would begin to point down, and so the angle between the field and the velocity would decrease, decreasing the magnetic force. This would decrease the voltage, assuming that the plane maintained the same speed.