Two electrons, labeled A and B are accelerated to different velocities and are sent into a region containing a constant, uniform magnetic field of magnitude 1.5 T but with unknown direction. The electrons' initial velocities are in the +x direction, and they enter the magnetic field region at the origin. Within the region of the field, they follow curved paths confined to the x-y plane (z = 0) then emerge at different locations on the y axis: electron A emerges at y = a, and electron B emerges at y = b, where b > a as shown.

1. [7 pts.] What is the direction of the uniform magnetic field in the region x > 0? Explain how you know this.

2. [13 pts.] What is the ratio of the electrons' velocities: \( \frac{v_A}{v_B} \)? Give this ratio in terms of the values \( a \) and \( b \).

\[ R = \frac{mv}{q_1B} \]

\[ \frac{v_A}{v_B} = \frac{1q_1B(a/2)}{1q_1B(b/2)} = \frac{a}{b} \]

Values of \( 1q, m, B \) are the same for both electrons!

A square loop with sides \( d = 0.2 \text{ m} \) carries a current \( I \) and pivots without friction about the z-axis. A uniform magnetic field, \( B = 2.4 \text{ T} \), points in the +x direction, and the loop initially makes an angle \( \theta = 70^\circ \) with the x-z plane.

1. [7 pts.] What is the direction of the torque on the loop? Explain how you know this.

2. [13 pts.] The magnitude of the torque on the loop is measured to be \( \tau = 1.2 \text{ N} \cdot \text{m} \). What is the magnitude of the current \( I \) in the loop?

\[ \tau = \mu \times B \Rightarrow \tau \text{ is obtained from magnetic moment } (\mu) \]

\( \mu \text{ is perpendicular to the loop itself and direction is given by RHR.} \)

\[ \tau \text{ is INTO the Page!} \]

\[ \tau = \mu \cdot B \cdot \sin \phi = \mu I d^2 \cdot B \cdot \sin (\theta + 90^\circ) \Rightarrow I = \frac{\tau}{d^2 \cdot B \cdot \sin (\theta + 90^\circ)} \]

\[ I = 36.5 \text{A} \]
A rectangular loop of wire has a width of $a = 12$ cm and a height of $b = 24$ cm. It lies in the same plane as an infinite wire that carries a current $I = 5.00$ A. The left edge of the wire is a distance $a$ from the infinite wire, as shown. Assume that the rectangular loop also carries a current of $I$ that flows in the direction shown by the arrows.

1. **[13 pts.]** What is the magnitude of the magnetic force on the rectangular loop? 
2. **[7 pts.]** With the currents directed as shown, what is the direction of the force on the rectangular loop? Explain how you know.

B. A solid, infinitely long, conducting rod has a radius $a = 15$ cm and lies along the $z$ axis. It carries a current $I = 30$ A in the $+z$ direction. The current is uniformly distributed across the rod. It is surrounded, at a distance $b = 30$ cm by a thin coaxial conducting shell that carries a current of the same magnitude, but directed in the $-z$ direction.

1. **[13 pts.]** What is the magnitude of the magnetic field at a distance of 10 cm from the origin?
2. **[7 pts.]** What is the direction of the magnetic field at the point $(x = 0, y = 10$ cm)? Explain how you know.
SHOW ALL WORK!

A rectangular wire loop of unknown length \( L \), width \( w \), and a resistance of \( R = 3 \, \Omega \) is pulled out of a constant, uniform magnetic field with velocity \( v \). The magnetic field is of unknown magnitude \( B \), points into the plane of the paper, and is confined to the rectangular region as shown. Work must be done on the loop at the rate of 12 J/s \((F \cdot v = 12 \, J/s)\) to move it through the magnetic field.

1. [7 pts.] What is the direction of the current running through the loop? Explain how you know.

2. [13 pts.] What is the magnitude of the current running through the loop?

\[
\begin{align*}
1. \quad &\text{clockwise} + 3 \text{pts.} \\
5. \quad &\text{explanation: explanation of Lenz's law; I in direction to} \\
&\text{oppose } \Delta \mathbf{B} \text{; \( \mathbf{E}_B = q \, \mathbf{v} \times \mathbf{B} \), careful to distinguish } \mathbf{F}_B \text{ on} \\
&\text{charge } q \text{ and applied external force } \mathbf{F}. + 4 \text{ pts.} \\
2. \quad &P = IV = I^2R \\
&\sqrt{\frac{P}{R}} = \left| I \right| \Rightarrow \sqrt{\frac{12 \, J/s}{3 \, \Omega}} = 2 \, A \\
&\text{\( \alpha \): } F = I \omega B \Rightarrow \frac{F}{\omega B} = I \\
\text{and } I = \frac{E}{R} = \frac{IR}{R} \Rightarrow B = \frac{IR}{\omega v} \Rightarrow -7 \text{ pt for arithmetic error} \\
\text{now } I = \frac{F}{\omega \left( \frac{IR}{\omega v} \right)} = \frac{F v}{IR} \Rightarrow I^2 = \frac{F v}{R} \\
&\text{\( \implies I = \sqrt{\frac{12 \, J/s}{3 \, \Omega}} = 2 \, A. \) } \\
\end{align*}
\]