I. A current-carrying wire is placed between the poles of an electromagnet. The direction of the magnetic field $\vec{B}$ produced by the magnet is shown in the figure. Invent a rule that relates the directions of the magnetic force $\vec{F}_m$, the directions of the magnetic field $\vec{B}$, and the directions of the current in the wire $I$.

a. Come up with a rule that relates the directions of $\vec{F}_m$, $\vec{B}$, and $I$.

b. Think of the current as a flow of electrons with velocity $\vec{v}$. Can you relate the force an electron feels to the magnetic field and the velocity? Hint: What is the difference between conventional current and the flow of electrons?

II. The figures below each show the current in a wire $I$, the magnetic force $\vec{F}_B$, and the magnetic field $\vec{B}$. For each situation depicted in the table, find the direction of the unknown physical quantity and draw it on the figure. Explain in words your reasoning for each situation.
III. Magnetic forces and torques on a small current loop

A. A small current loop is placed in a uniform magnetic field which is directed to the right of the page. On top is shown the loop and the field; below is shown the current loop in a cross-sectional view.

1. On the two sides of the loop labeled A and B, draw and label a vector that represents the direction of the (external) magnetic field.

2. On the two sides of the loop labeled A and B, draw and label a vector to show the magnetic force exerted by the external field on the current at that side of the loop. Explain in words why you made the choices you did.

3. What is the net effect of the magnetic forces exerted on the loop?

4. Draw and label a vector to show the torque exerted by the field on the current at that side of the loop. Explain in words why you made the choices you did.
5. Suppose that the loop were to rotate until oriented as shown. Now, what is the net effect of the magnetic forces exerted on the loop?

6. Draw and label a vector to show the magnetic torque exerted by the external field on the current at that side of the loop.

7. Is there an orientation for which the loop remains at rest? Draw the loop below showing the directions of the current and the orientation of the loop (like the drawings above). Explain in words why you chose the orientation you did.

IV. Application of magnetic torques

A rigid wire in the shape of a rectangular loop of Area A is shown edge-on in the illustrations below. The loop resides in a uniform external magnetic field directed to the right.

1. In each of the figures below, draw a vector to show the torque the loop experiences in the uniform magnetic field.
2. What are the magnitudes of the torques exerted on the wires of the loop shown in the figures? Express the torque in terms of $I$, $B$, and $A$.

   a. Configuration i

   b. Configuration ii

   c. Configuration iii.

3. What would happen if the loop was allowed to freely rotate about an axis indicated by the arrow?

4. What is the magnetic potential energy of loops labeled i-iii? Express the potential energy in terms of $I$, $B$, and $A$.

   a. Configuration i

   b. Configuration ii

   c. Configuration iii.
5. If \( I = 1.0 \, \text{A} \), \( B = 3.0 \, \text{T} \), \( A = 0.5 \, \text{m}^2 \), what is the magnitude of the torque in figures i-iii? Correct answers have correct units.

a. Configuration i

b. Configuration ii

c. Configuration iii.

6. If \( I = 1.0 \, \text{A} \), \( B = 3.0 \, \text{T} \), \( A = 0.5 \, \text{m}^2 \), what is the potential energy in figures i-iii? Correct answers have correct units.

a. Configuration i

b. Configuration ii

c. Configuration iii.