I. This question asks you to determine what happens to a charged particle that is accelerated through a potential difference and then enters a region with uniform magnetic field. **Show your work.**

A. A particle with charge $q$ and mass $m$ is accelerated from rest through a potential difference $V_1$. What is its velocity $v_1$ after it has been accelerated?

B. The charged particle then enters a region with a uniform magnetic field $B$ oriented perpendicular to its path. The field deflects the particle into a circular arc of radius $R_1$. What is the value of $R_1$, in terms of $q$, $m$, $B$ and $v_1$?

C. If the value of the accelerating potential was tripled, i.e., $V_2=3V_1$, what is the radius $R_2$ of the circular arc in terms of $R_1$?
II. The figure displays two long straight wires separated by a distance of $d$. The currents are $I_1$ to the right in the upper wire and $I_2$ to the left in the lower wire. The point $P$ is a distance $d/2$ below the lower wire.

A. Is the force between wire 1 and wire 2 attractive, repulsive or no force? (circle choice). Explain in words your choice.

B. What are the magnitude and direction of the magnetic field at point $P$ from wire 1? (show the direction on the figure with label $B_1$)

C. What are the magnitude and direction of the magnetic field at point $P$ from wire 2? (show the direction on the figure with label $B_2$)

D. What are the magnitude and direction of the net magnetic field at point $P$ from both wires? (show the direction on the figure with label $B_{\text{net}}$)

E. If $d=1.0$ m, $I_1=5.0$ A, and $I_2=10.$ A, what is the value of $B_{\text{net}}$? Correct answers have correct units and 2 significant figures.
III. Refer to the figure on the right. **Show your work.**

A. What is the magnitude of current in the upper branch?

B. What is the magnitude of current in the middle branch?

C. What is the magnitude of current in the lower branch?

D. What is the potential difference, \( V_{ab} \), of point \( a \) relative to point \( b \)?
IV. This problem explores how a current-carrying wire can be accelerated by a magnetic field. You will use the ideas of magnetic flux and the induced EMF due to change of flux through a loop.

A conducting rod is free to slide on two parallel rails with negligible friction. At the right end of the rails, a voltage source of strength $V$ in series with a resistor of resistance $R$ makes a closed circuit together with the rails and the rod. The rails and the rod are taken to be perfect conductors. The rails extend to infinity on the left. The arrangement is shown in the figure.

There is a uniform magnetic field of magnitude $B$, pervading all space, perpendicular to the plane of rod and rails. The rod is released from rest, and it is observed that it accelerates to the left.

A. In what direction does the magnetic field point? Explain in words your reasoning.

B. Assuming that the rails have no resistance, describe in words the motion of the rod.

C. What is the induced EMF? Express $\varepsilon$ in terms of the velocity, $v_r(t)$, the separation of the rails, $L$, and the magnetic field $B$.

D. What is the induced current $I$ in the rod? Express $I$ in terms of the velocity, $v_r(t)$ and other quantities.

E. What is the acceleration $a_r(t)$ of the rod? Express your answer as a function of $V$, $B$, the velocity of the rod $v_r(t)$, $L$, $R$ and the mass of the rod $m$.

F. At very long times, the acceleration goes to zero. When $a_r(t)=0$ what is the terminal velocity $v_r(t=\infty)$?