3. Motional EMF and Lenz's Law

(a) Magnitude of the Induced EMF

The motional EMF is $\mathcal{E} = BLv$.

$$\mathcal{E} = (1.2\,\mathrm{T})(0.10\,\mathrm{m})(5.0\,\mathrm{m/s}) = \mathbf{0.60}\,\mathrm{V}$$

(b) Direction of the Induced EMF

By the right-hand rule for Lorentz force, $\vec{F} = q(\vec{v} \times \vec{B})$, positive charges are pushed to the bottom of the rod. The direction of the EMF is **down** the rod.

(c) Magnitude of the Current

By Ohm's Law, $I = \mathcal{E}/R$.

$$I = \frac{0.60\,\text{V}}{0.40\,\Omega} = \mathbf{1.5}\,\text{A}$$

(d) Direction of the Current

The current flows from high to low potential, resulting in a **clockwise** current in the loop.

(e) Rate of Thermal Energy Generation

The power dissipated is $P = I^2R$.

$$P_{\text{thermal}} = (1.5\,\text{A})^2(0.40\,\Omega) = \mathbf{0.90}\,\text{W}$$

(f) External Force Needed

To maintain constant velocity, an external force must balance the magnetic drag force $\vec{F}_m = I(\vec{L} \times \vec{B})$. This force is directed to the right, so the external force must be to the left with magnitude:

$$F_{\text{ext}} = ILB = (1.5\,\text{A})(0.10\,\text{m})(1.2\,\text{T}) = \mathbf{0.18}\,\text{N}$$

(g) Rate of Work Done by This Force

The rate of work is power, $P_{\text{ext}} = F_{\text{ext}}v$.

$$P_{\text{ext}} = (0.18\,\text{N})(5.0\,\text{m/s}) = \mathbf{0.90}\,\text{W}$$