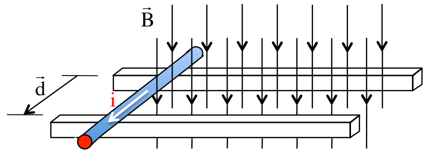
Problem 29.37

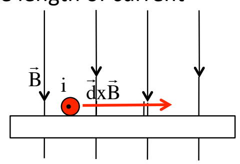
This is fun!



The current in the current-carrying wire interacts with the magnetic field as:

$$\vec{F} = i\vec{d}x\vec{B}$$

where i is the magnitude of the current, $\vec{d}$ is a vector whose direction is the direction of current and whose magnitude is equal to the length of current--carrying wire in the B-field (see sketch), and $\vec{B}$ is the magnetic field.

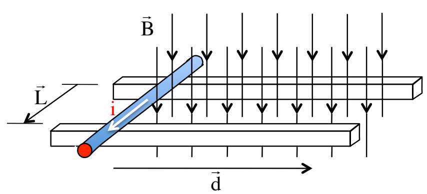


Looking at the set-up from the side, you can see how the cross-product produces a force that will motivate the cylinder to the right.

The magnitude of that force will be:

$$F = idB\sin 90^\circ$$

Here's the fun part.



The magnetic force will do work on the rod, and the energy imparted will go into increasing both the rolling kinetic energy and the translational kinetic energy of the cylinder. As this is a fairly involved conservation of energy expression, I've laid it out on the next page.

$$\sum KE_1 + \sum U_1 + \sum W_{ext} = \sum KE_2 + \sum U_2$$

$$0 + 0 + W_{Bfld} = \left[\left(\frac{1}{2}\right)mv^2 + \left(\frac{1}{2}\right)I\omega^2\right] + 0$$

$$\Rightarrow \vec{F}_{Bfld} \bullet \vec{L} = \left(\frac{1}{2}\right)mv^2 + \left(\frac{1}{2}\right)\left(\frac{1}{2}mR^2\right)\left(\frac{v}{R}\right)^2$$

$$\Rightarrow (idB)L\ \cos 0^\circ = \left(\frac{1}{2}\right)m\left(v^2 + \frac{v^2}{2}\right)$$

$$\Rightarrow v = \left(\frac{4}{3m}\right)(idB)L$$

$$\Rightarrow v = \left(\frac{4}{3(.72\text{ kg})}\right)(48\text{ A})(.12\text{ m})(.24\text{ T})(.45\text{ m})$$

$$= 1.07\text{ m/s}$$