# Q2

If the light bulb is unscrewed, then the circuit is disconnected. Therefore, no current can flow. Now, moving the rod will cause electrons to separate from the protons in the rod, but no current will be induced because the circuit is broken. Therefore, no opposing force will be created and so once the rod is moving on that frictionless wire surface, no force will be needed to keep it at a constant velocity.
The part of the metal that is in the magnetic field contains charges moving with a velocity \( v \). Those charges experience a force \( \uparrow \) if positive and a force \( \downarrow \) if negative. This separates the charges and creates an emf. The emf in turn creates a current \( \uparrow \) through the metal. The charges in the piece of the plate that is outside the magnetic field feel no force but this piece of the metal provides a path for current to make a closed loop and for the moving charges to return to where they came from. The moving charges in the current \( I \) formed on the metal in the magnetic field also experience a force \( \downarrow \) directed to the left, which slows the moving slab down.

So, \( x \times \mathbf{q} \rightarrow \uparrow \mathbf{B} \) feel a force \( \uparrow \)

\[
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\]

and then \( x \times \mathbf{v} \) with velocity \( \uparrow \) feel a force \( \downarrow \)
The current in the bar experiences a force due to the magnetic field, causing it to move to the right. But now the bar is moving and that creates an emf that produces a current in the bar that is opposite to the one from the battery. That current feels a force from the magnetic field pointing to the left, which in turn slows the rod down. The rod will eventually reach an equilibrium where the force from the induced emf and from the battery emf balance and the velocity of the rod will be constant.

If a solenoid is connected to an ac source, then the magnetic field through the coil will be varying, like this...
(4) cont'd

Putting a copper ring (which is a conductor) inside the solenoid like so:

![Diagram of copper ring inside solenoid]

will heat up the copper ring because the changing magnetic field pointing parallel to the axis of the solenoid changes the flux through the area of the ring and in turn an alternating current flows in the copper. Since the copper has some resistance, energy is dissipated in the form of heat in the ring.

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The motional emf created by a conductor moving perpendicular to a magnetic field is:

\[ \mathcal{E} = vBL \]

where \( v \) = velocity of the conductor, \( B \) = the magnetic field and \( L \) = the length of the conductor.

So, for this problem,

\[ \text{emf} = (7.6 \times 10^2 \text{ m/s}) (5.1 \times 10^{-5} \text{ T}) (2 \times 10^{-3} \text{ m}) \]

\[ = 7.752 \times 10^{-3} \text{ V} \]
Through a loop of area \( A \),
\[
\Phi = \text{Flux} = B A \cos \theta
\]
where \( B \) is the magnetic field and \( \theta \) is the angle between the normal to the loop and the magnetic field. \( \Delta \Phi = \text{change in flux} = \Phi_f - \Phi_i \)
where \( f \Rightarrow \text{Final} \) and \( i \Rightarrow \text{initial} \).

Initially, the area of the loop is:

\[
A = L_1 \times L_2 + \frac{1}{2} \pi r^2 \quad \text{and} \quad \phi = 0^\circ
\]

\[
\Phi_i = B (L_1 \times L_2 + \frac{1}{2} \pi r^2)
\]

Finally, after one half a rotation, the area of the loop is:

\[
A = (L_1 \times L_2) - \frac{1}{2} \pi r^2 \quad \text{and} \quad \phi \text{ still} = 0^\circ
\]
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Consider

so the final flux

\[ \Phi_f = [(L_1L_2) - \frac{1}{2}\pi r^2]B \]

Then \[ \Delta \Phi = B(L_1L_2 - \frac{1}{2}\pi r^2) - B(L_1L_2 + \frac{1}{2}\pi r^2) \]

\[ = -B\pi r^2 \quad \text{(independent of } L_1 \text{ and } L_2) \]

\[ = -(-75T)(\pi)(0.2m)^2 \]

\[ = -9.4 \times 10^{-2} \text{ Wb} \]

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In order to find the induced current, we need to find the induced emf due to the change in flux over time,

\[ \mathcal{E} = -\frac{\Delta \Phi}{\Delta t} \]

where \( \Delta t \) is the change in time and \( \Delta \Phi = BDA \)

\( \phi = 0^\circ \) at all times so \( \cos 0^\circ = 1 \)

Initially,

Finally, \( \Delta A = \text{shaded region} \)
The shaded region is a fraction of the total area of the circle \( \pi R^2 \). The fraction is determined by how much of a cycle the rod turns (a cycle = once around) in the time \( \Delta t \).

\[
f = \frac{\text{cycles}}{\text{sec}} = \frac{\omega}{\frac{2\pi}{5}}\text{ rad/s}
\]

where \( \omega = 15 \text{ rad/s} \) in this problem.

Then in time \( \Delta t \), the rod moves

\[
\frac{\omega \Delta t}{2\pi} \text{ Fraction of a cycle.}
\]

So,

\[
\Delta A = \frac{\omega \Delta t (\pi r^2)}{2\pi}
\]

Then

\[
\Delta \phi = \frac{B\omega \Delta t (\pi r^2)}{2\pi}
\]

and

\[
\Delta \phi = \frac{-B\omega \pi r^2}{2\pi} \frac{\Delta t}{\Delta t} = \frac{-B\omega r^2}{2} \quad \text{(the negative sign implies the direction of the current)}
\]

The current then through the resistor:

\[
I = \frac{\Delta \phi}{R} = \frac{B\omega r^2}{2R} = \frac{(3.8 \times 10^{-2} T)(15 \text{ rad/s})(0.5 \text{ m})}{2} = 2.38 \times 10^{-3} \text{ A}
\]

Counter clockwise.
The emf induced in a rotating planar coil is \( E = NBA\omega\sin\omega t \) where \( N \) is the number of loops, \( A \) is the area of each loop, \( B \) is the magnetic field and \( \omega \) is the angular velocity of the spinning loop.

So, \( \omega = 2\pi f \)

\[ E = NBA(2\pi f) \sin((2\pi f)t) = E_0 \sin((2\pi f)t) \quad \text{where} \quad E_0 = \text{max} \text{ Emf} \]

So \( E_0 = NBA(2\pi f) \)

Solving for \( B \):
\[ B = \frac{E_0}{2\pi fNA} = \frac{5500V}{2\pi (60Hz)(150)(.8\text{m}^2)} \]

\[ B = 1144 \text{ T} \]

Since \( 1 \text{ gauss} = 10^{-4} \text{ T} \)

\[ (.144 \text{ T}) \left( \frac{1 \text{ gauss}}{10^{-4} \text{ T}} \right) = 1.1 \times 10^3 \text{ gauss} \]
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Two coils parallel with a common axis:

\[ E_{\text{secondary}} = -N \frac{\Delta I_{\text{primary}}}{\Delta t} \]

If \( M \), the mutual inductance, goes up by a factor of 3, so does the induced emf in the secondary coil.

New emf = \( 3(0.4 \text{ V}) = 1.2 \text{ V} \)

#10  1st, in order to figure out which pairs of wires belong together, measure the resistance across different pairs. If it is infinite, the wires do not belong together (they are from 2 separate coils). If the resistance is really small, (practically 0) then the wires belong to the same coil. After figuring that out, you
(4) cond.

you can then apply an ac current to one pair and measure the induced emf in the other pair by measuring the terminal voltage with a voltmeter. That value would be \( V_1 \). Then, switching leads and measuring \( V_2 \), you could find the ratio of \( \frac{V_1}{V_2} - \frac{N_1}{N_2} \) giving you the ratio of the turns on the two coils.