Review: Faraday's Law and Lenz's Law

- Michael Faraday (1791-1867) discovered that the amount of induced EMF depends on:
  - → The **rate of change of the magnetic field**
  - → The **angle between the magnetic field and the loop**
  - → The **area of the loop**
- All of these observations indicate that induced current is related to the **change in magnetic flux**, or $\Delta\Phi_B$ through the loop. We know from before that current is produced by an emf. So:

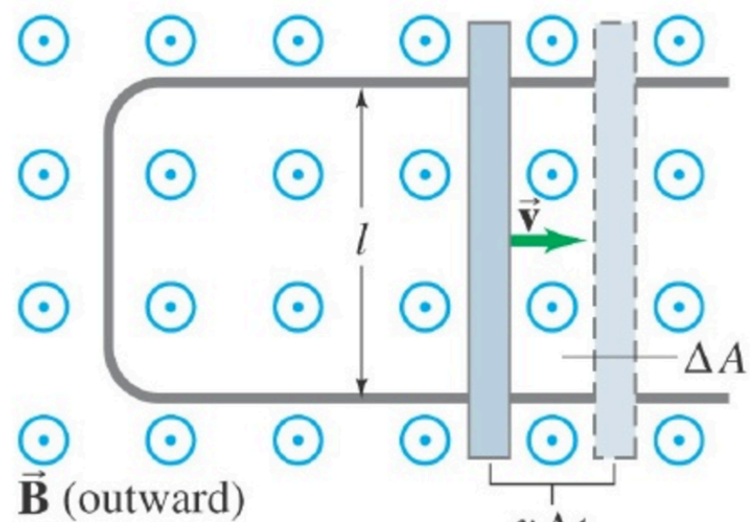
$$\varepsilon = -\frac{\Delta\Phi_B}{\Delta t}$$

If there is more than one loop, then we multiple the right side by "N" (the number of loops).

  - What does the negative sign mean?

Review: Induced EMF n moving conductors

- Another way to induce an emf is to move a conductor within a magnetic field.
- Moving the conductor creates a changing area of the loop, thus changing the magnetic flux and inducing an emf.
- An emf induced on a conductor moving in a magnetic field is sometimes called **motional emf**.



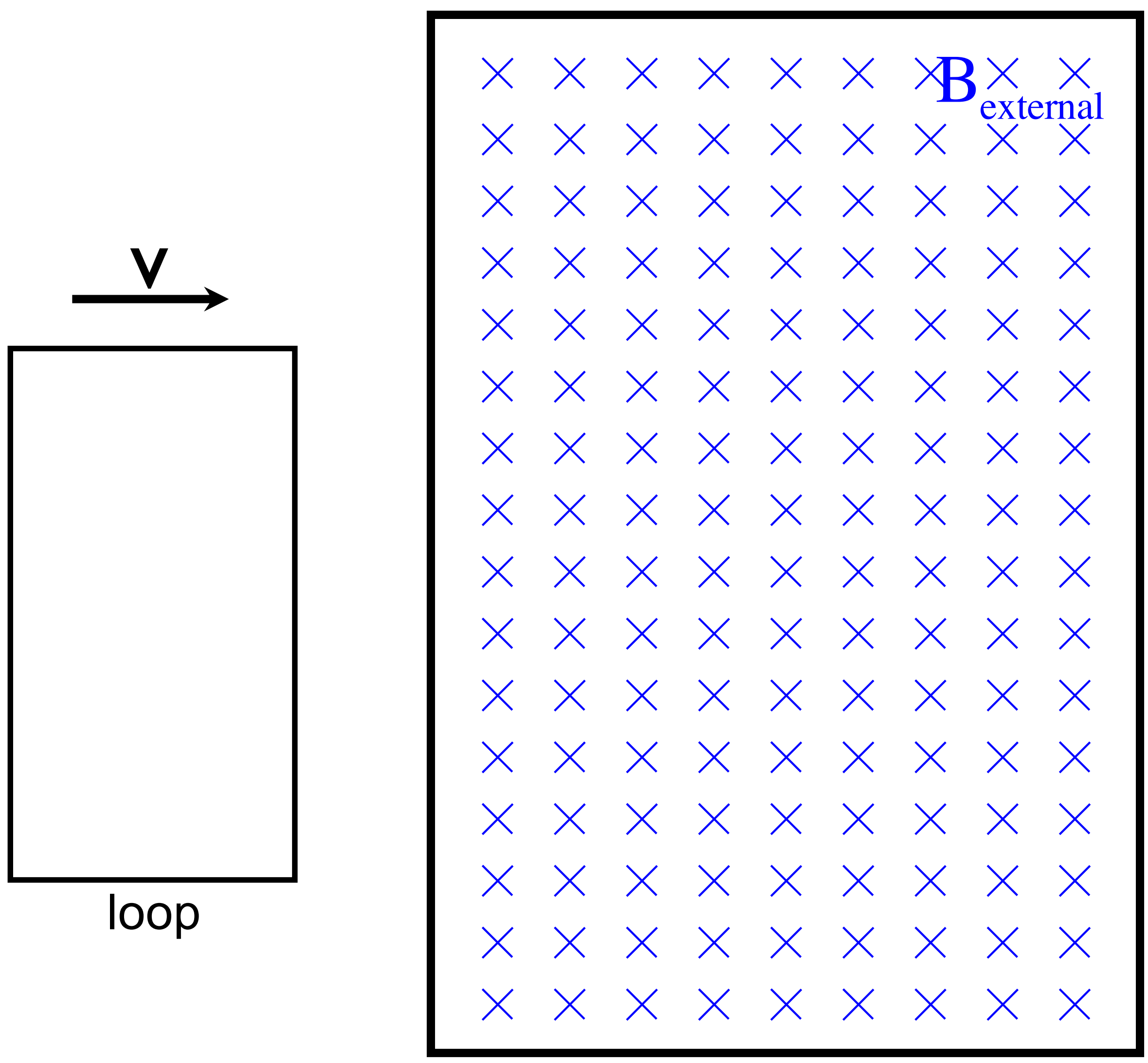
(a)

Review Motional EMFs

Is there any flux through the loop as shown?

At what point will something begin to happen?

What would you expect to see as the loop enters the magnetic field area until it is fully within that area?



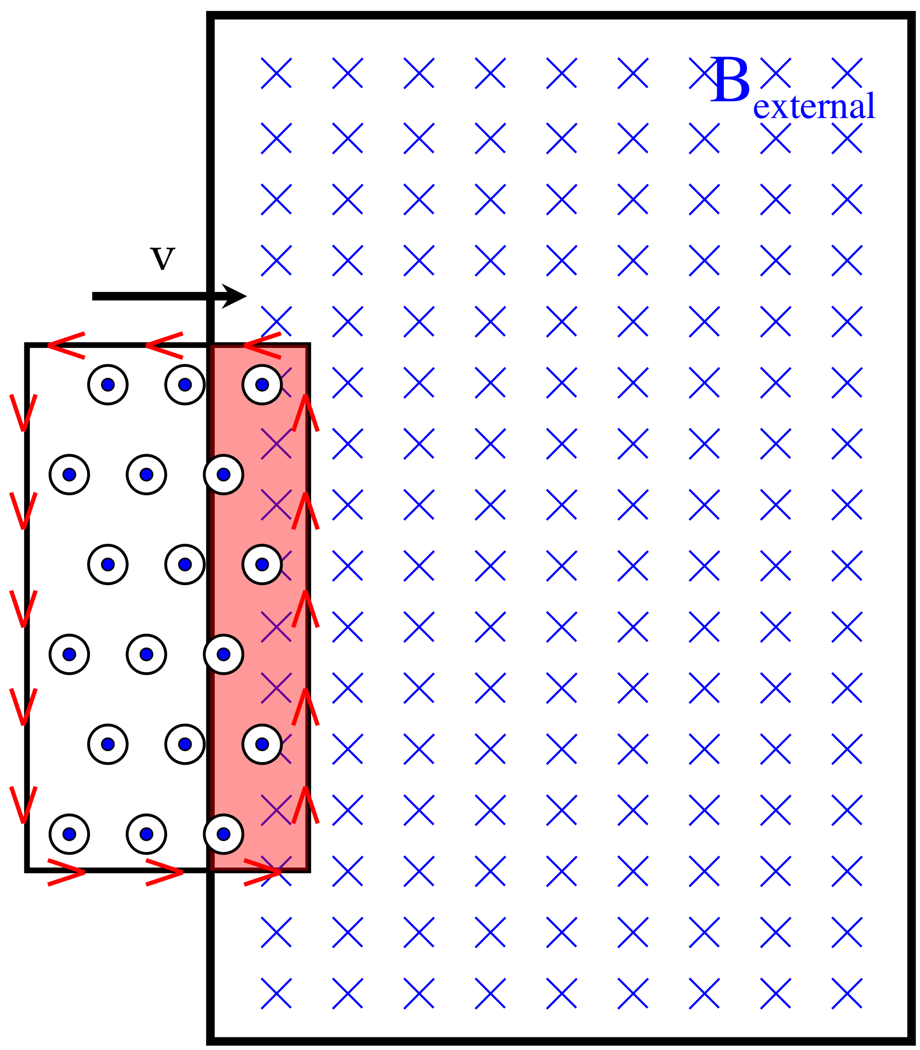
(Thanks to Mr. Fletcher for the following sequence of slides!)

Motional EMF

So what happens here?

--According to Faraday, as the flux changes (increasing in this case) as induced EMF is set up in the coil.

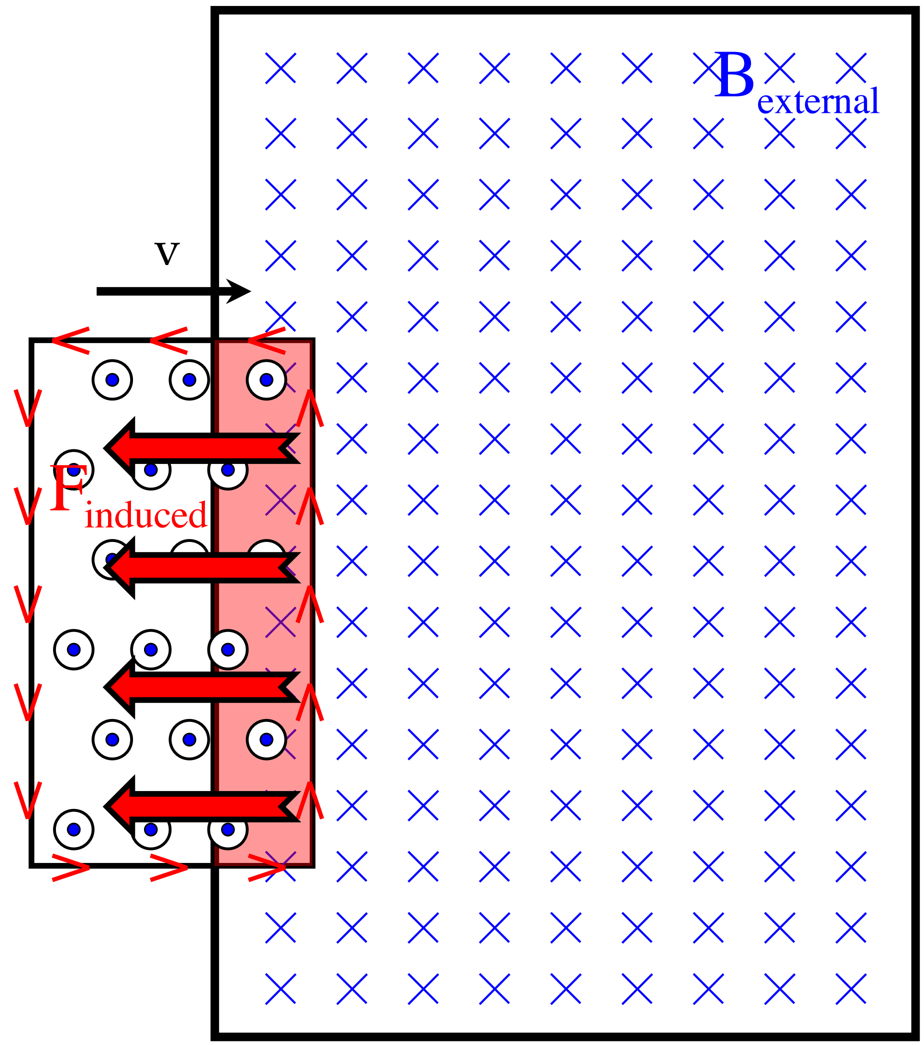
--The induced EMF sets up an induced current which, according to Lenz's Law, sets up a uniform induced B-field thru the coil opposite the direction of the external B-fld.



Motional EMF

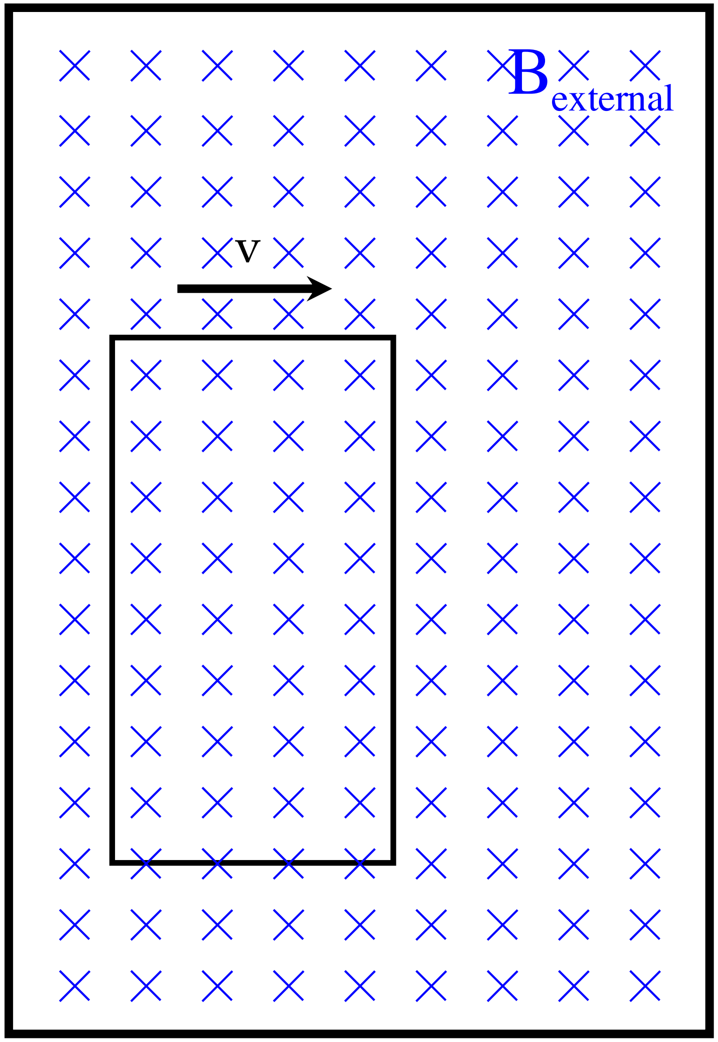
--the induced current will interact with *external* B-fld ($F_{ind} = I_{ind}\vec{L}x\vec{B}_{ext}$) producing a force on coil that FIGHTS the coil's incursion into the region.

--continuing the motion's constant speed, the flux continues to increase at a constant rate, the induced EMF stays constant, the current stays constant as does the induced force opposing motion.



Motional EMF

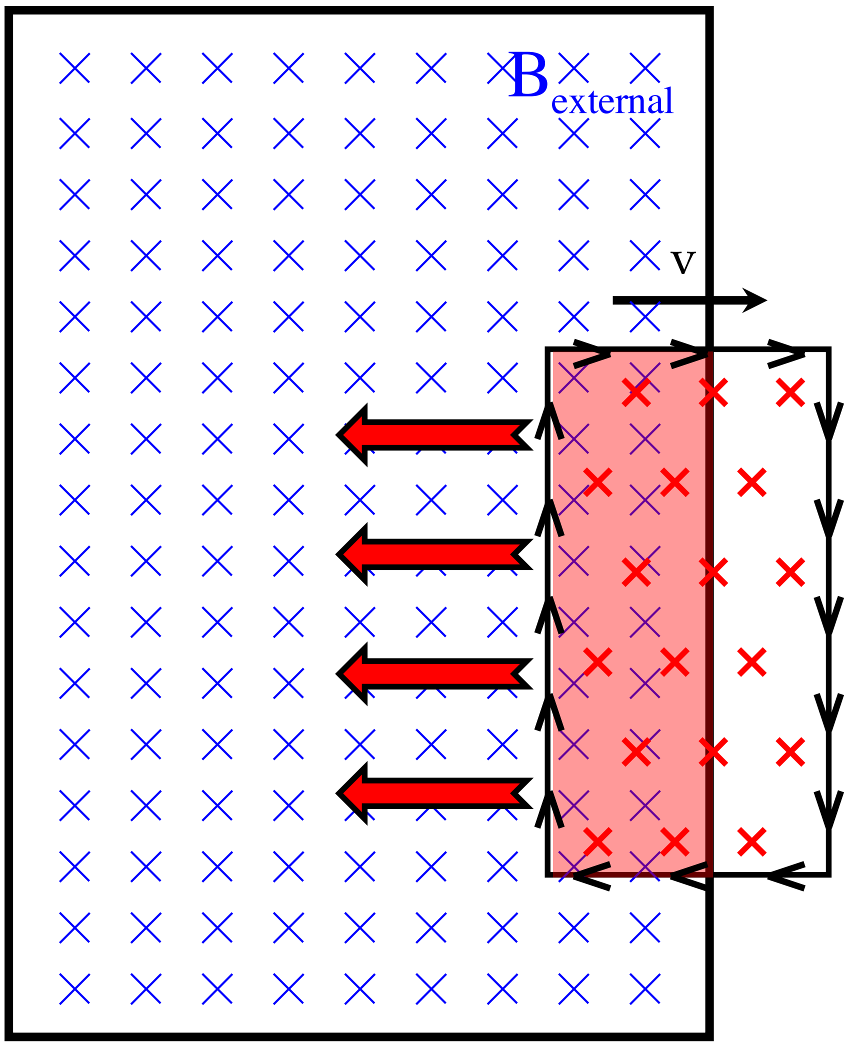
--once completely in the external B-fld, there is no longer a changing magnetic flux so the induced EMF ceases as does the induced current.



Motional EMF

When the coil emerges:

--Now Φ_B decreases thru the coil so the induced B-fld must ADD to the external field to oppose the change. That is produces a current that is CLOCKWISE, which produces an interactive force with the EXTERNAL B-fld that FIGHTS the coil leaving the field.



Review Motional EMF

- Bottom line: Any coil that moves into or out of an external magnetic field will feel a magnetic force that fights the motion.

  - That is, if the coil is pushed *into* the magnetic field, the force produced by the interaction of the induced current in the coil with the external field will make it harder to do this.
  - If the coil is pulled *out of* the magnetic field, the force produced by the interaction of the induced current in the coil and the external magnetic field will make it harder to do this.

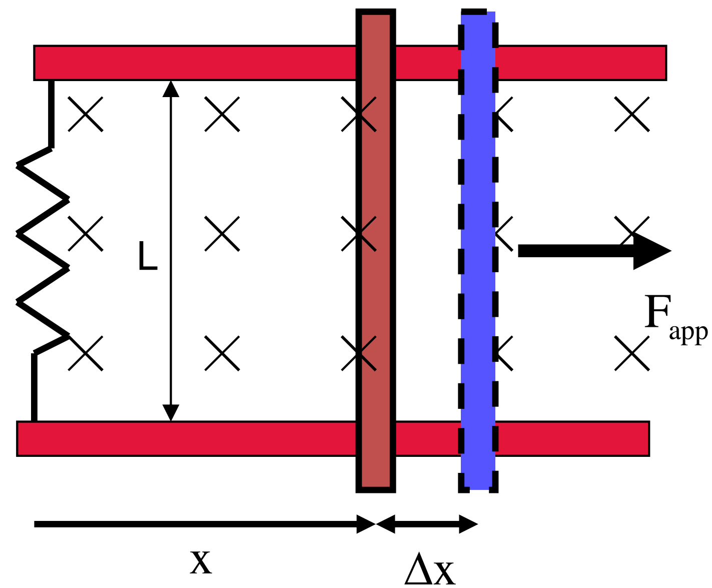
- IN ALL CASES, the interaction of the induced current with the external magnetic field will produce a force on the coil that FIGHTS THE CHANGE.

Review Problem 20.30

At what speed should the bar move to produce a current of .5 amps in the resistor if:

R = 6 Ω, L=1.2 m and

B = 2.5 Teslas into the page.



Additional questions:

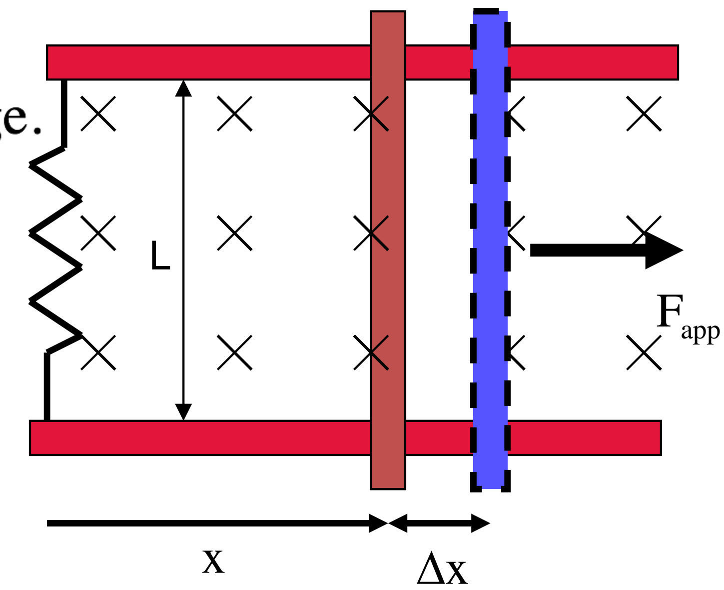
a.) In what direction will the induced flow?

b.) How fast will the bar be moving to effect the situation outlined above?

c.) If you want the bar to move with a constant velocity, how large a force would you have to apply to the bar to make that happen?

$R = 6\ \Omega$, L=1.2 m and

$B = 2.5$ Teslas into the page.



a.) Magnetic flux is increasing, external B into page, which implies induced B out of page and so induced current is counterclockwise.

b.)

$$\varepsilon_{induced} = -N\frac{\Delta\phi_B}{\Delta t}$$

$$= -(1)\ B\cos 0^\circ \frac{\Delta(A)}{\Delta t}$$

$$= -\ B\frac{(A_{final} - A_{initial})}{\Delta t}$$

$$= -\ B\frac{(L(x+\Delta x) - Lx)}{\Delta t}$$

$$= -\ B\,L\frac{\Delta x}{\Delta t}$$

$$= -\ B\,L\,v$$

$$= -\ 3\ v$$

$$\varepsilon_{induced} = i\,R$$

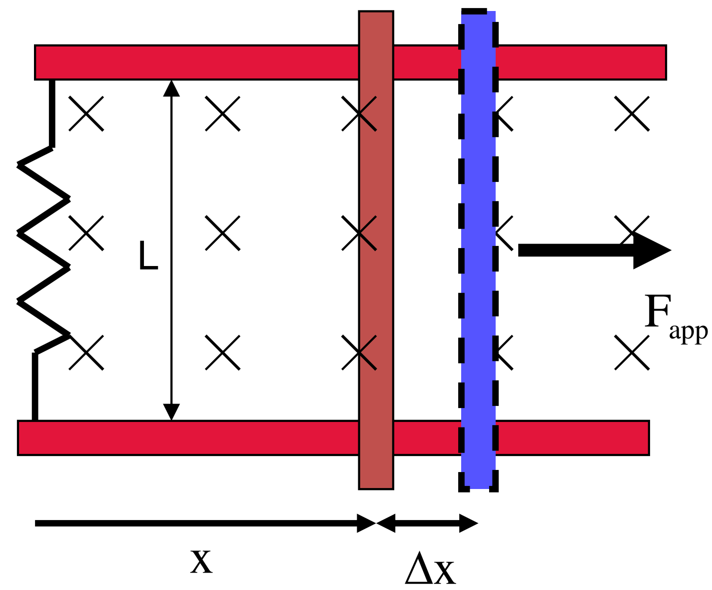
$$\Rightarrow\ 3\ v = (.5\ A)(6\ \Omega)$$

$$\Rightarrow\ v = 1\ m/s$$

Additional questions:

a.) In what direction will the induced flow?

According to Lenz's Law: the external B field is into the page; the magnetic flux is increasing, so the induced B field must be out of the page; this will be produced by a current flowing counterclockwise.



c.) If you want the bar to move with a constant velocity, how large a force and in what direction would you have to apply to the bar to make that happen?

The induced current will interact with the external magnetic field as governed by:

$$F = i\,L \times B$$

$$= (.5 \text{ amps})(1.2 \text{ m})(2.5 \text{ tesla})$$

$$= 1.5 \text{ newtons}$$

The cross product, the force on the strip due to the current in the B-field moving through the strip will be to the left, therefore you will have to pull to the right.