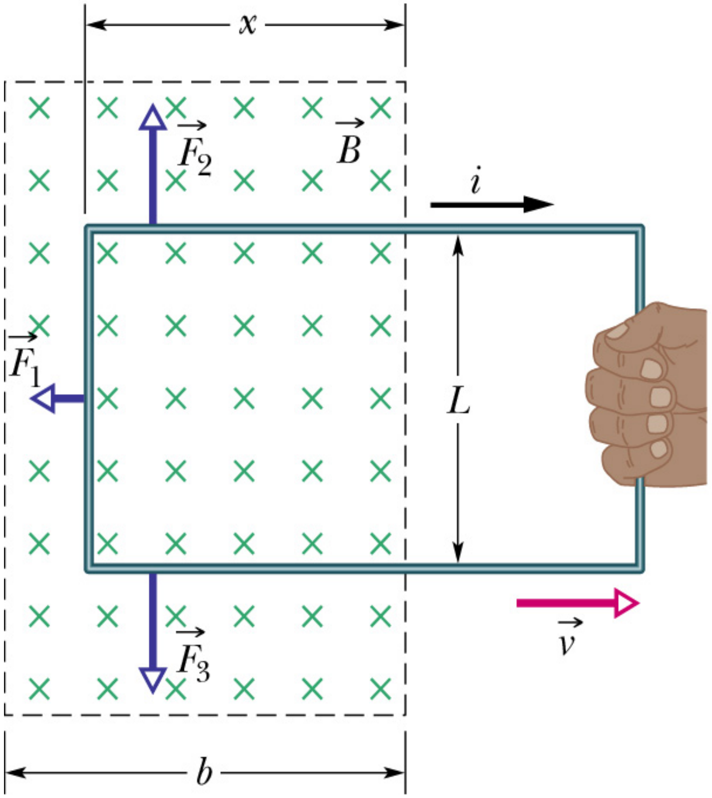
Loop + magnet

- If you pull a loop at a constant velocity, *v*, through a *B* field, you must apply a constant force, *F*
- As move loop to right, less area is in B field so magnetic flux decreases and current is induced in loop
- Magnetic flux when *B* is ⊥ and constant to area is



$$\Phi_B = BA = BLx$$

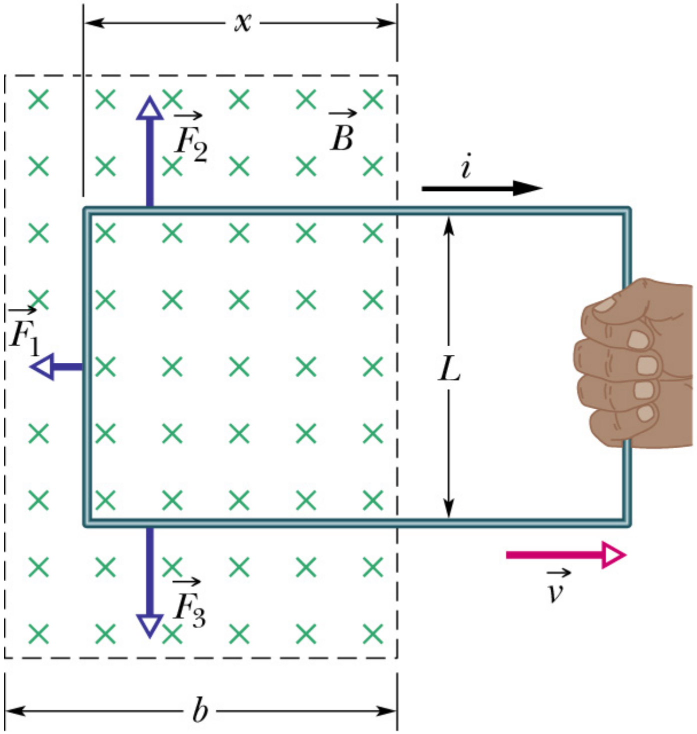
Loop + magnet

- Using Faraday's law

$$\mathrm{E} = \frac{d\Phi_B}{dt} = \frac{d}{dt} BLx = BL\frac{dx}{dt}$$

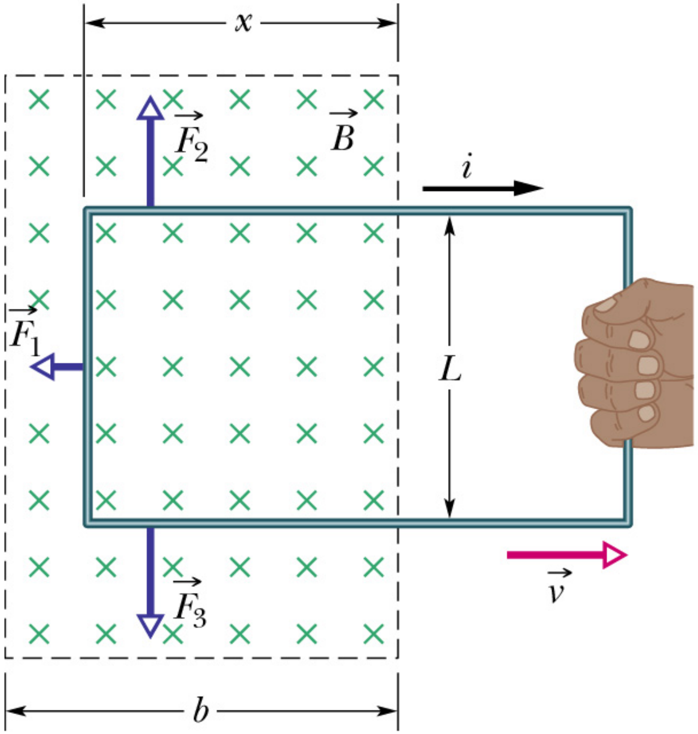
- Remember $v = dx/dt$ so

$$\boxed{\mathrm{E} = BLv}$$



- where L is the length of the loop and v is ⊥ to B field
- B is decreasing so B_i is in same direction (into page) and current is clockwise

Loop + magnet



- Since loop carries current through a *B* field there is a force given by

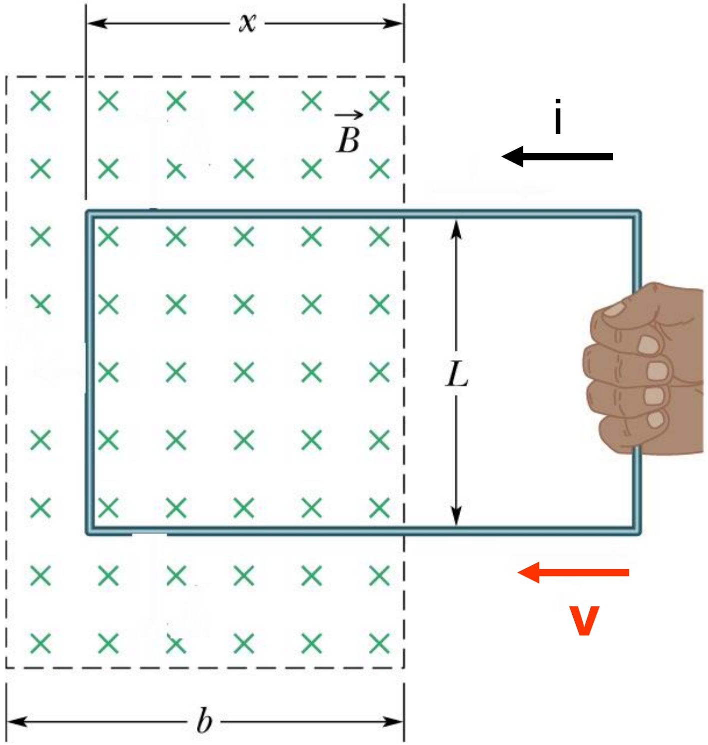
$$\vec{F}_B = i\vec{L} \times \vec{B}$$

- Use right-hand rule to find direction of F_B on segments of loop in *B* field
- Find forces, F2 and F3, cancel each other
- Force, F_1 opposes your force

$$\vec{F}_{app} = -\vec{F}_1$$

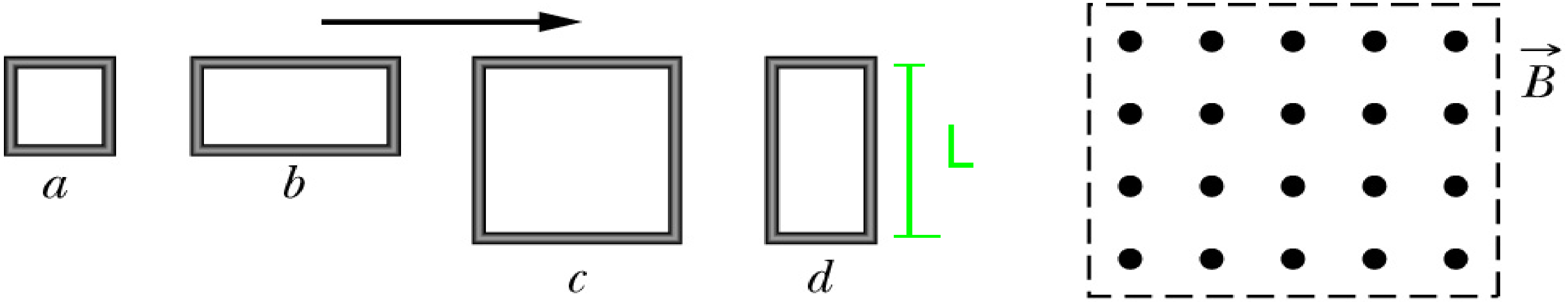
Loop + magnet

- What happens if we push the wire in?
- *B* is increasing so B_i is in the opposite direction (out of page), so the current is counter-clockwise.



Exercise

- Four wire loops with edge lengths of either L or 2L. All loops move through uniform *B* field at same velocity. Rank the four loops according to maximum magnitude of induced emf, greatest first.

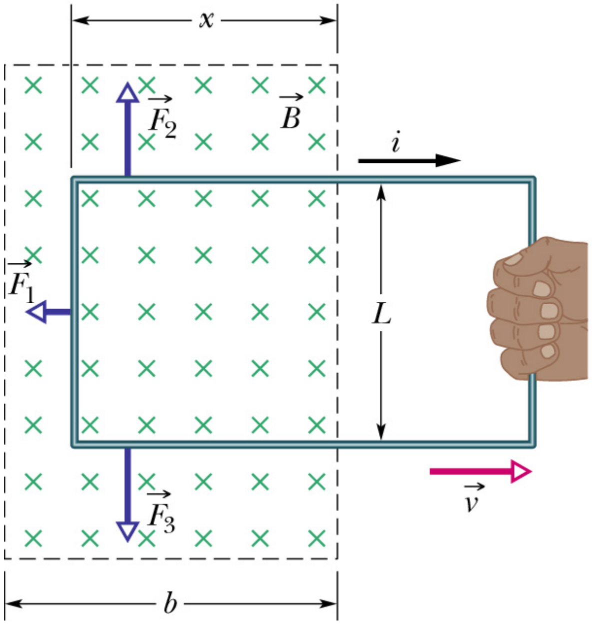


$$\mathcal{E} = BLv$$

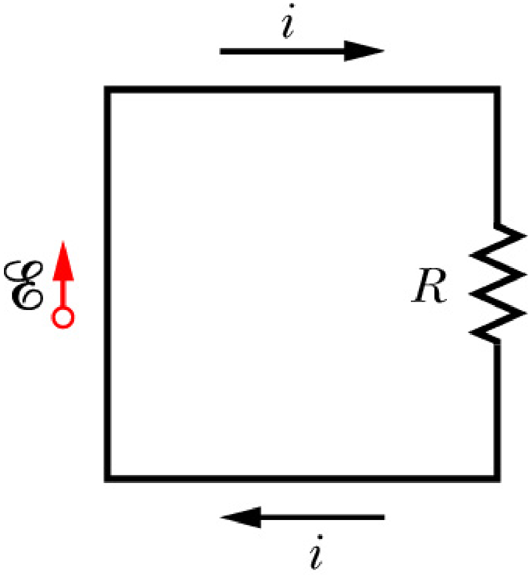
c & d tie, then
a & b tie

Loop + magnet

$$\mathcal{E} = BLv$$



- The circuit diagram is

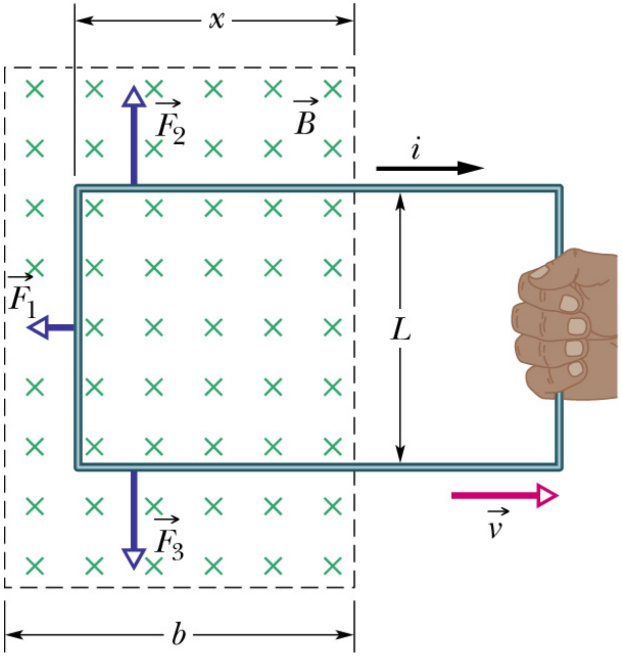


- With $\mathcal{E} = iR$
- Then $i = \dfrac{\mathcal{E}}{R} = \dfrac{BLv}{R}$
- And $\boxed{F_1 = iLB = \dfrac{B^2L^2v}{R}}$

Loop + magnet

- Energy is conserved - so where does the work you do moving the loop in and out go?

- The current flowing through the resistance produces heat at the rate



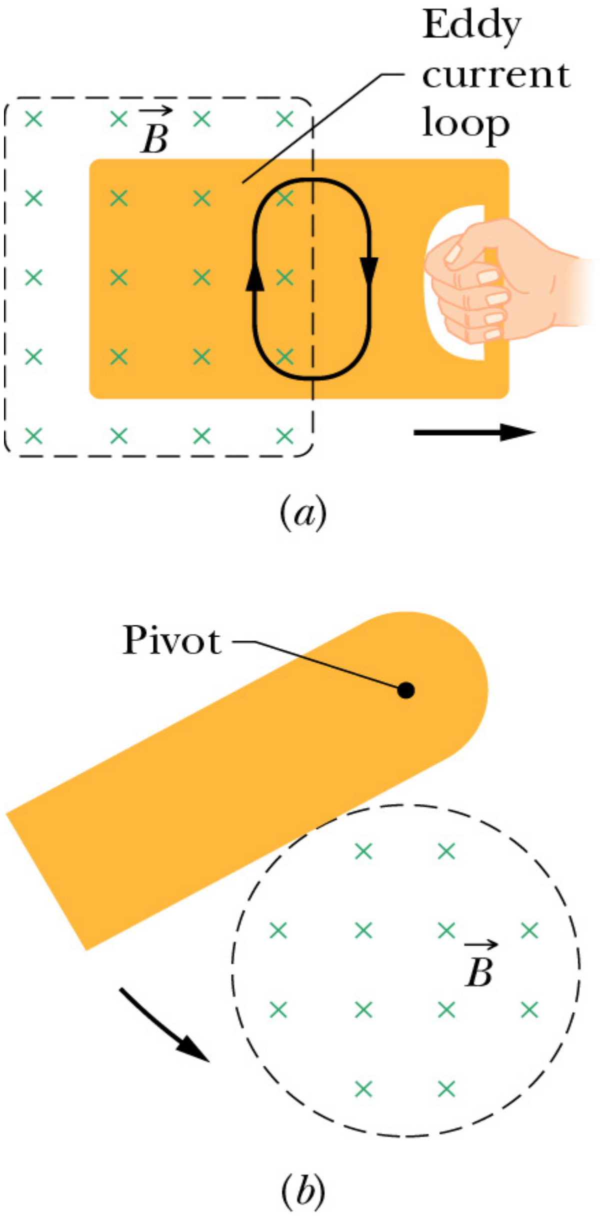
$$\boxed{P = i^2 R = \frac{B^2 L^2 v^2}{R}}$$

since

$$i = \frac{BLv}{R}$$

Eddy currents

- Instead of a loop of wire, what happens when a bulk piece of metal moves through a *B* field?
- Free electrons in metal move in circles as if caught in a whirlpool called eddy currents
- A metal plate swinging through a *B* field will generate eddy currents



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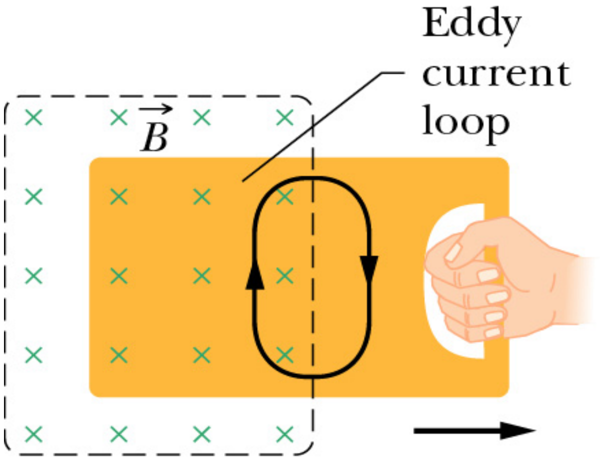
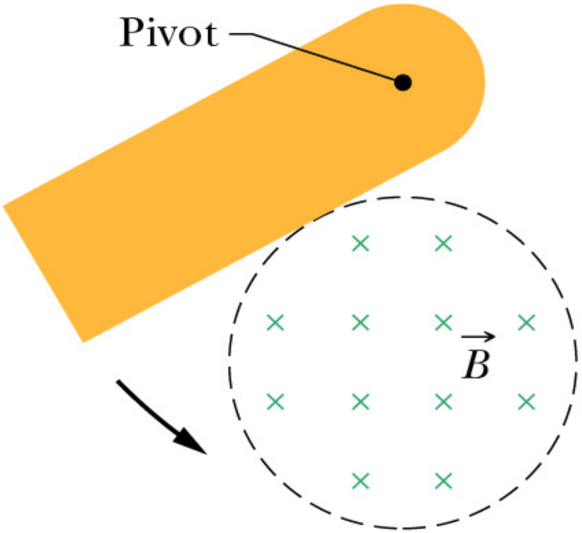


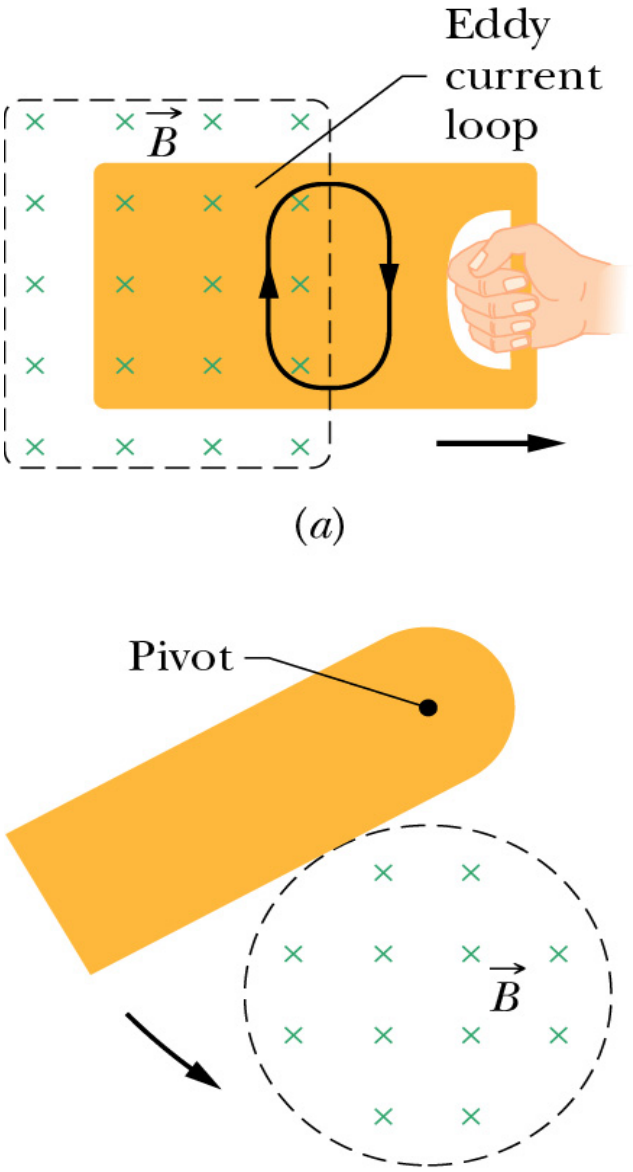
(a)



(b)

Eddy currents

- Eddy currents will oppose the change that caused them – Lenz’s law
- Induced eddy currents will always produce a retarding force when plate enters or leaves *B* field causing the plate to come to rest
- Cutting slots in metal plate will greatly reduce the eddy currents



(*a*)

(*b*)

Eddy currents

- Induction and eddy currents are used for braking systems on some subways and rapid transit cars
- Moving vehicle has electromagnet (e.g. solenoid) which is positioned near steel rails
- Current in electromagnet generates B field
- Relative motion of B field to rails induces eddy currents in rails
- Eddy currents produce a drag force on the moving vehicle
- Eddy currents decrease steadily as car slows giving a smooth stop

Eddy currents

- Eddy currents often undesirable since they dissipate energy in form of heat
- Moving conducting parts often laminated
  - Build up several thin layers separated by nonconducting material
  - Layered structure confines eddy currents to individual layers
- Used in transformers and motors to minimize eddy currents and improve efficiency