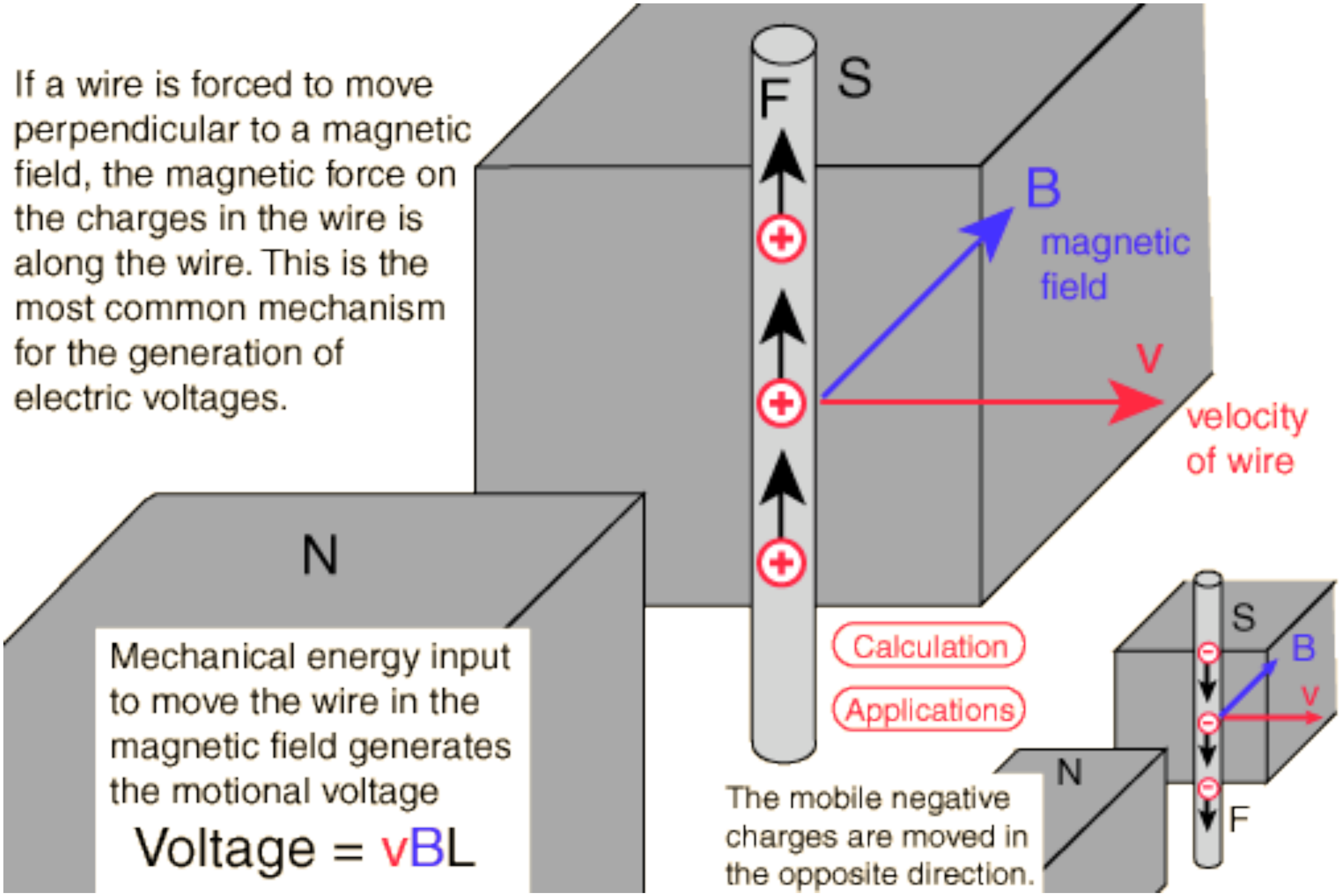
Lenz’s Law

Motional emf

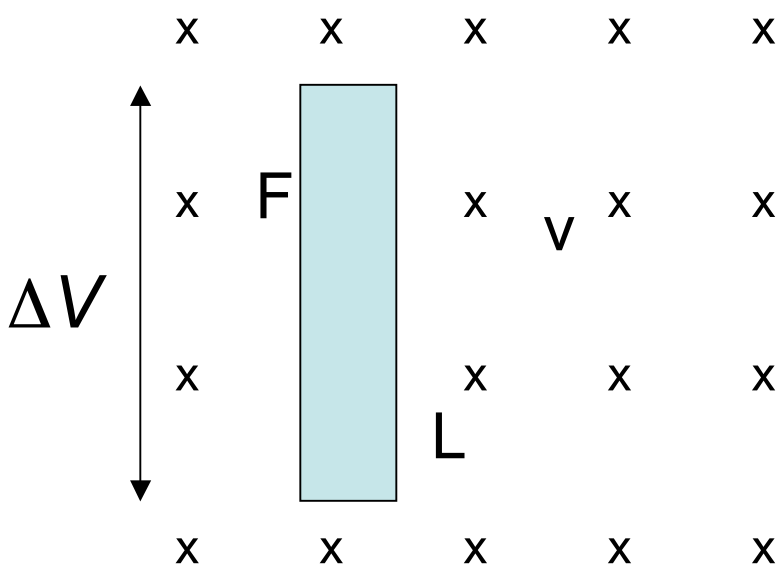
Lenz’s law

Applications of Faraday’s Law


If a wire is forced to move perpendicular to a magnetic field, the magnetic force on the charges in the wire is along the wire. This is the most common mechanism for the generation of electric voltages.
F
S
B
magnetic field
v
velocity of wire
N
Mechanical energy input to move the wire in the magnetic field generates the motional voltage
Voltage = vBL
Calculation
Applications
The mobile negative charges are moved in the opposite direction.
S
B
v
N
F

Motional emf

A voltage is produced by a conductor moving in a magnetic field



B into the page

Charges in the conductor experience a force upward

$$F = qvB$$

The work done in moving a charge from bottom to top

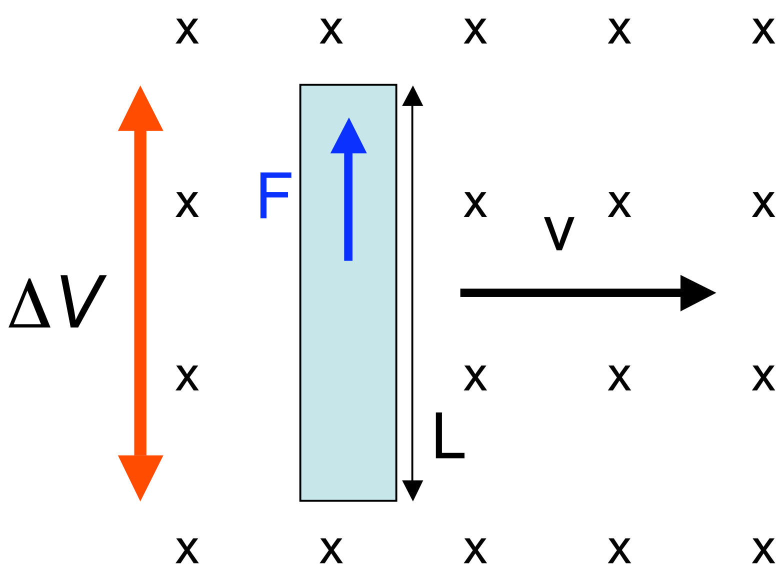
$$W = FL = qvBL$$

The potential difference is

$$\Delta V = \frac{W}{q} = vBL$$

Motional emf

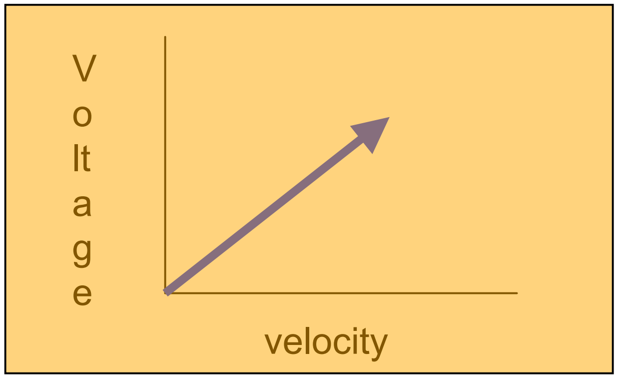
A voltage is produced by a conductor moving in a magnetic field



B into the page

Charges in the conductor experience a force upward

$$F = qvB$$



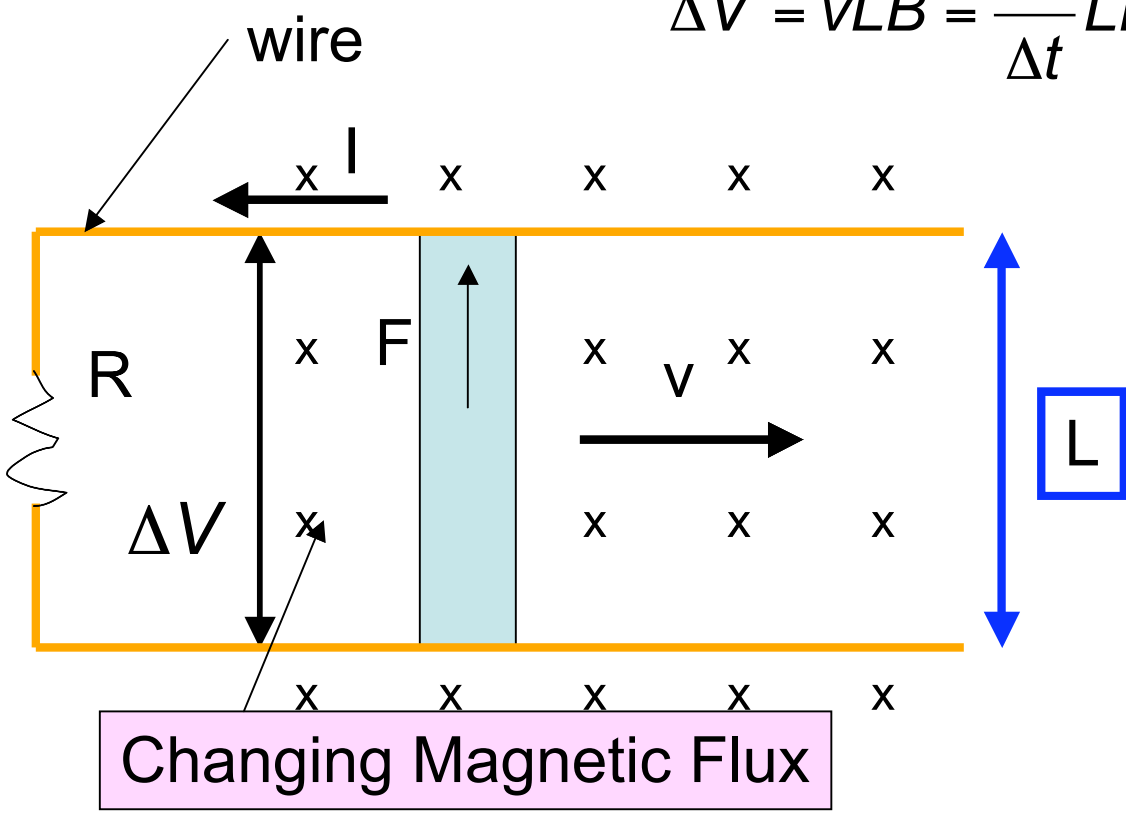
$$W = FL = qvBL$$

The potential difference is

$$\Delta V = \frac{W}{q} = vBL$$

The potential difference can drive a current through a circuit
The emf arises from changing flux due to changing area
according to Faraday's Law

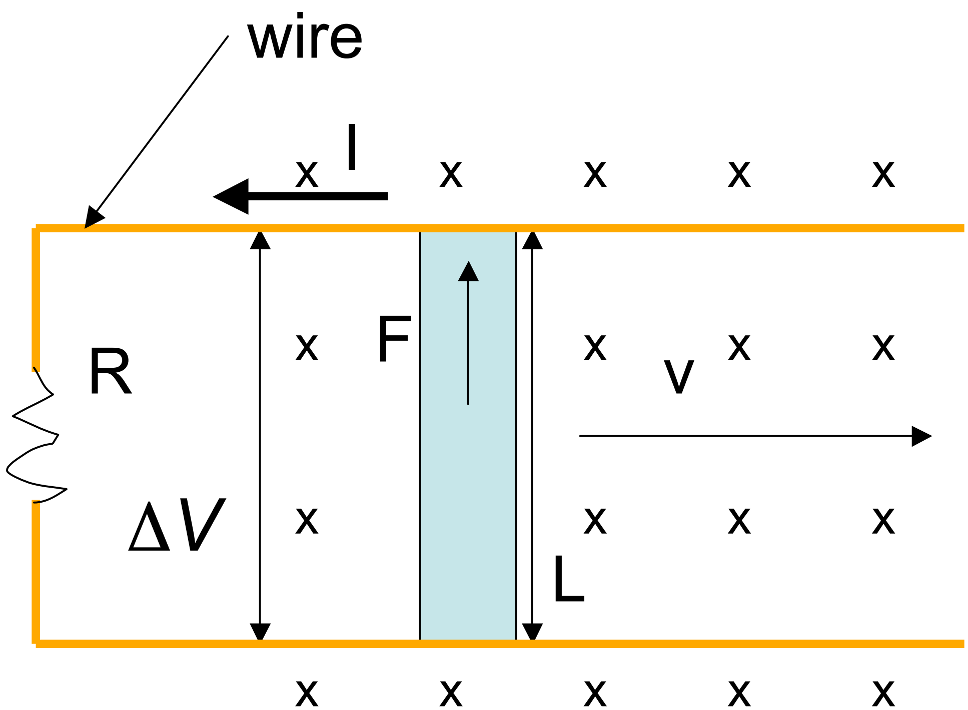
$$\Delta V = vLB = \frac{\Delta x}{\Delta t} LB = \frac{\Delta AB}{\Delta t} = \frac{\Delta \Phi_B}{\Delta t} = |\varepsilon|$$



$$I = \frac{|\varepsilon|}{R} = \frac{BLv}{R}$$

B into the page

18. R= 6.0 Ω and L=1.2 m and B=2.5 T. a) What speed should the bar be moving to generate a current of 0.50A in the resistor? b) How much power is dissipated in R? c) Where does the power come from?



B into the page

a) $$I = \frac{\varepsilon}{R} = \frac{BLv}{R}$$

$$v = \frac{IR}{BL} = \frac{0.5(6.0)}{2.5(1.2)}$$

$$v = 1.0 m/s$$

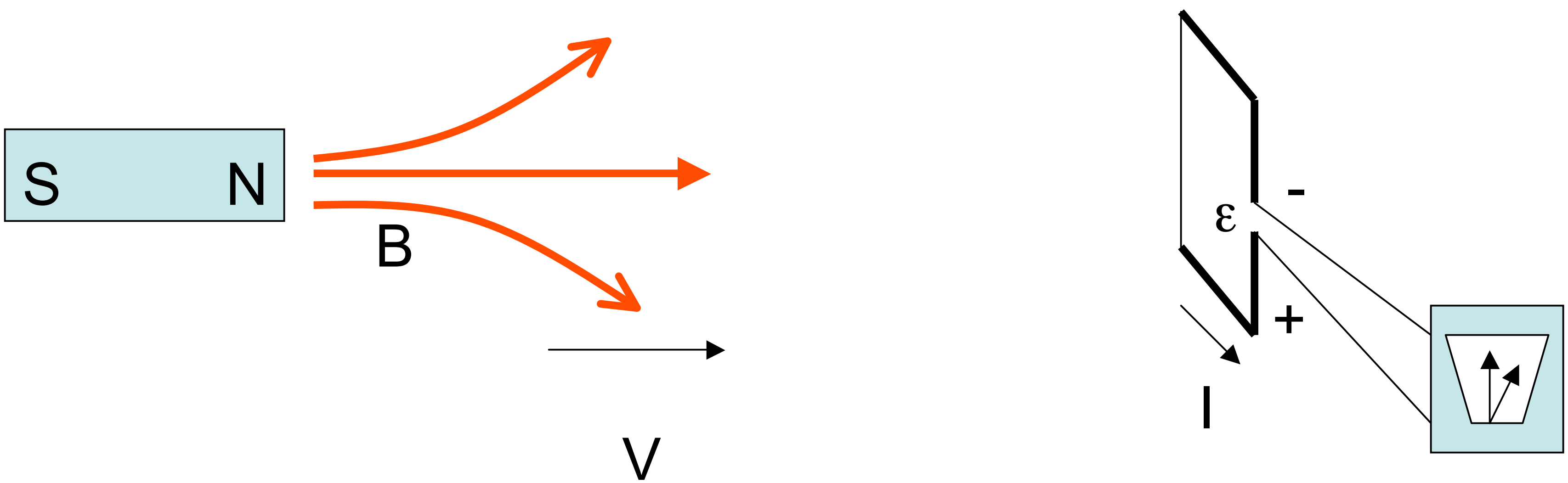
b) $$P = I^2R = (0.5)^2(6.0)$$

$$P = 1.5W$$

c) Work is done by the force moving the bar

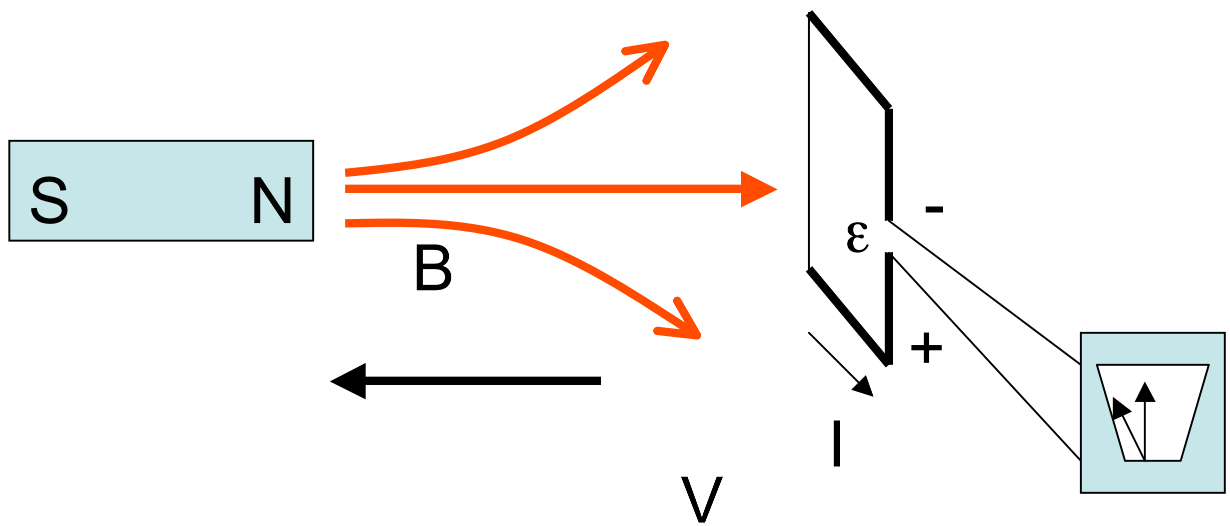
Lenz's Law
determines the direction of current flow.

[redacted]



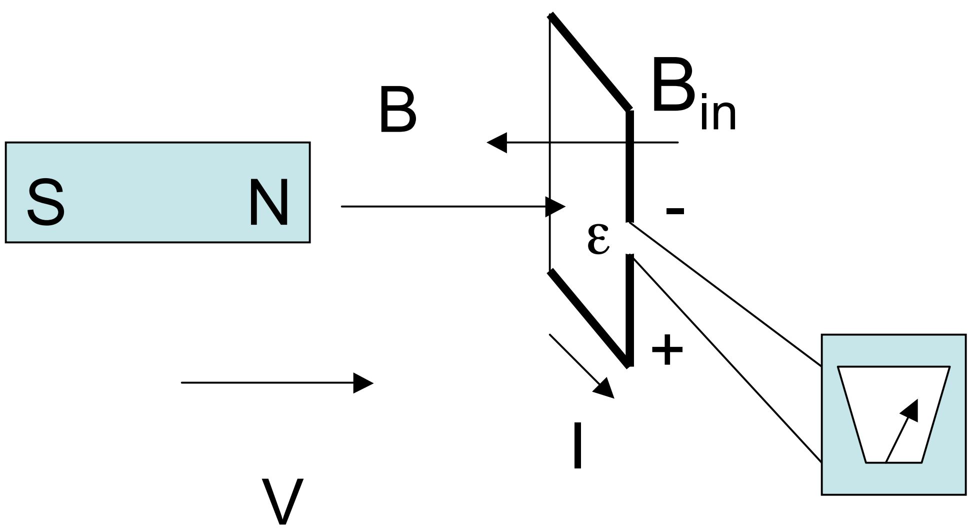
Lenz's Law
determines the direction of current flow.

[illegible]



Lenz's Law

The polarity of the induced emf is such that it induces a current whose magnetic field opposes the change in magnetic flux through the loop. i.e. the current flows to maintain the original flux through the loop.



B increasing in loop

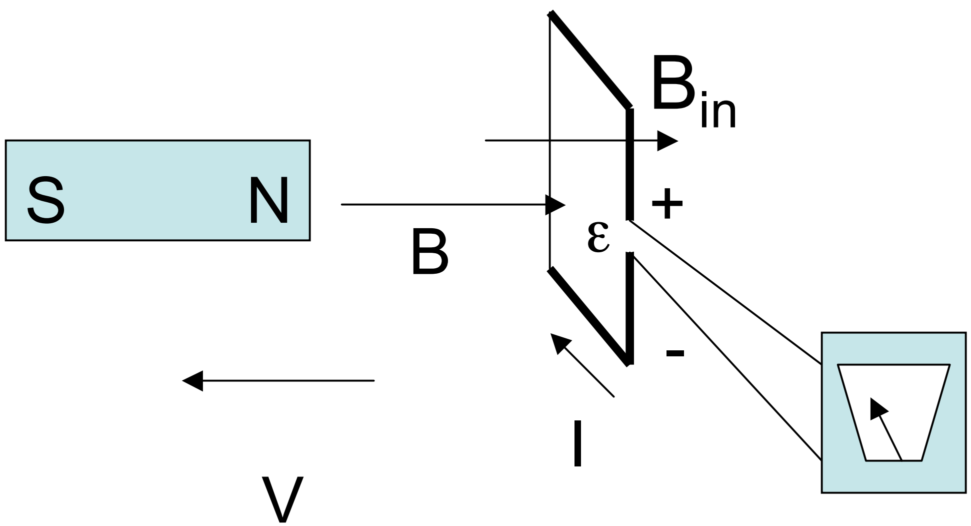
B_{in} acts to oppose the change in flux

Current direction that produces B_{in} is as shown (right hand rule)

Emf has the polarity shown. ε drives current in external circuit.

Now reverse the motion of the magnet

The current reverses direction



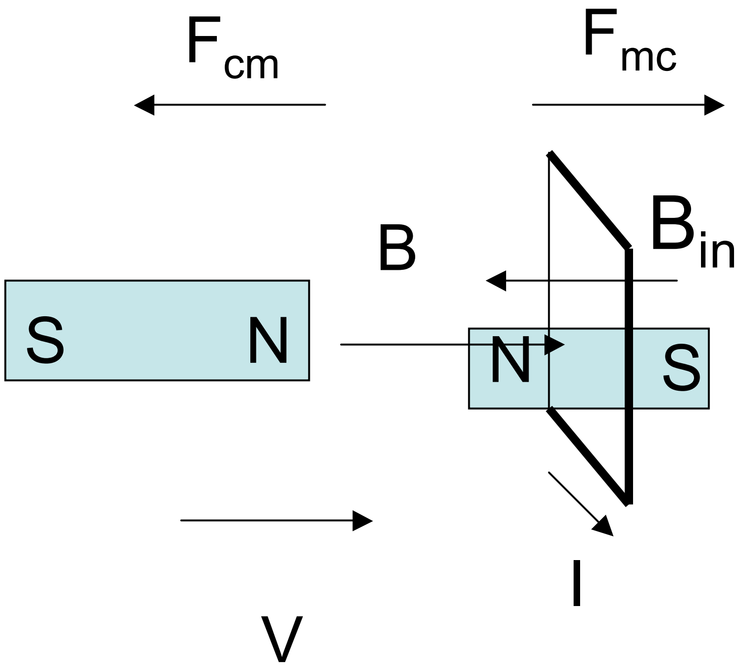
B decreasing in loop

B_{in} acts to oppose the change in flux

Current direction that produces Bin is as shown (right hand rule)

Emf has the polarity shown.

Lenz's Law and Reaction Forces



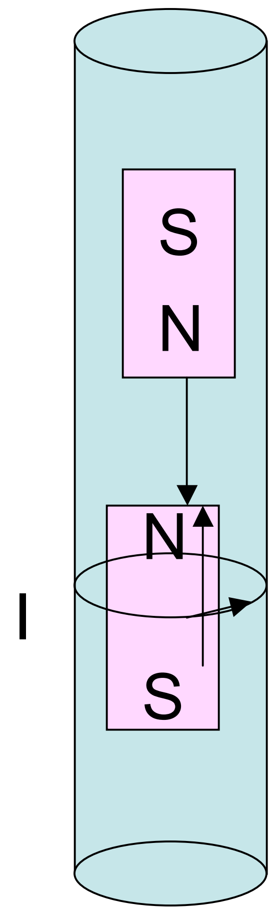
A force is exerted by the magnet on loop to produce the current

A force must be exerted by the current on the magnet to oppose the change

The current flowing in the direction shown induces a magnetic dipole in the current loop that creates a force in the opposite direction

Example. Eddy currents

A magnet is dropped down a cylindrical conductor. Currents are induced in the conductor to oppose the movement of the magnet



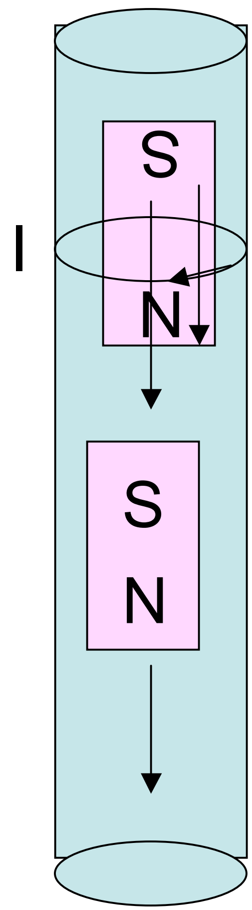
B increasing

B_{in} Induced magnetic field

creates magnetic dipole that opposes the movement of magnet

Example. Eddy currents

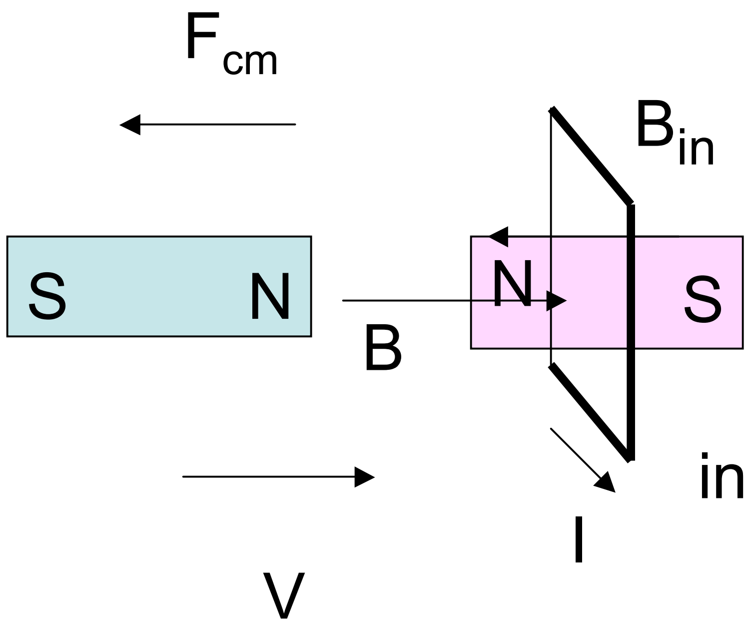
What about the region behind the magnet?



B_{in} creates magnetic dipole that opposes the movement of magnet

B decreasing

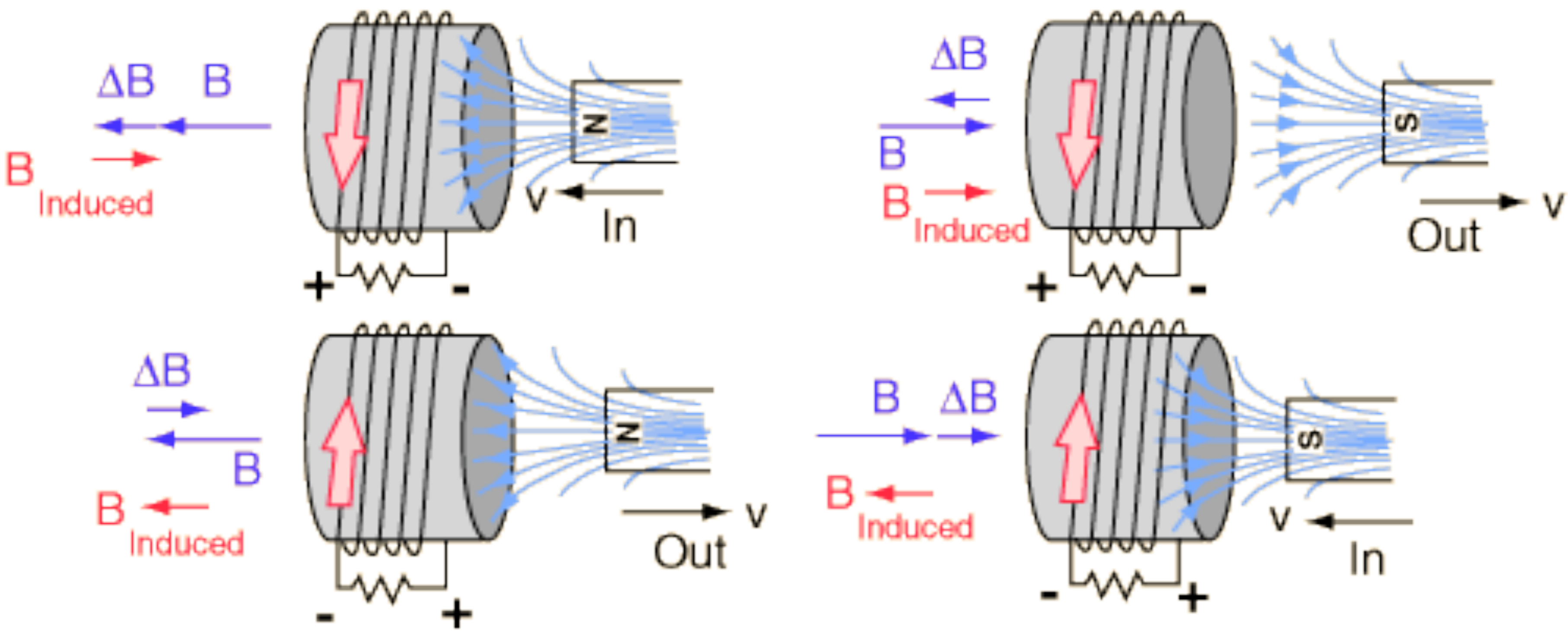
Work



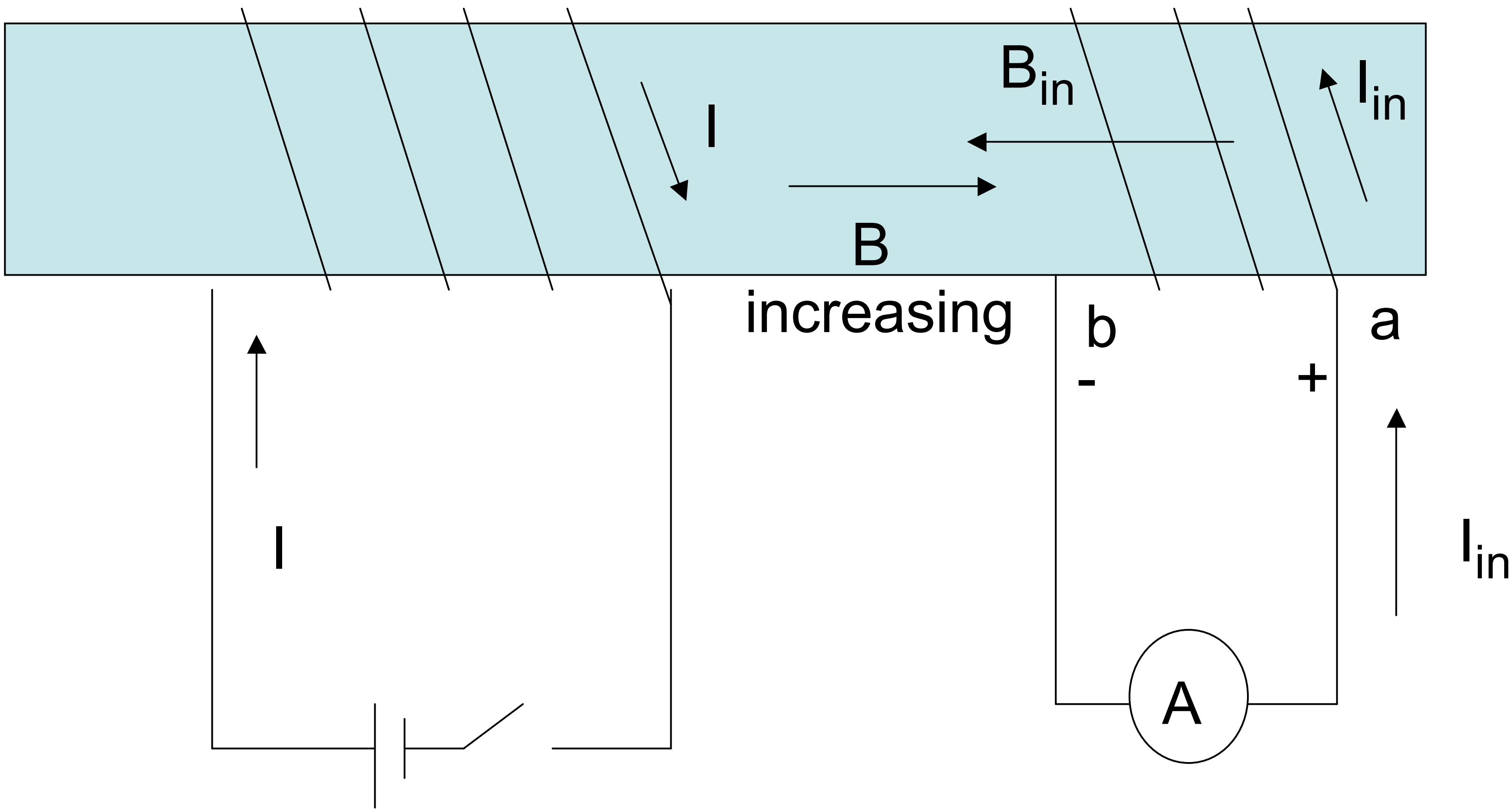
Work done against the reaction force by the force moving the magnet drives the current flow.

induced magnetic dipole

4 cases:


ΔB
B
B
Induced
N
v
In
+
-
ΔB
B
B
Induced
S
Out
v
+
-
ΔB
B
B
Induced
N
Out
v
-
+
B
ΔB
B
Induced
S
v
In
-
+

Two coils are connected by an iron core. Is the emf from a to b positive or negative when the switch is closed?



current flows from b to a

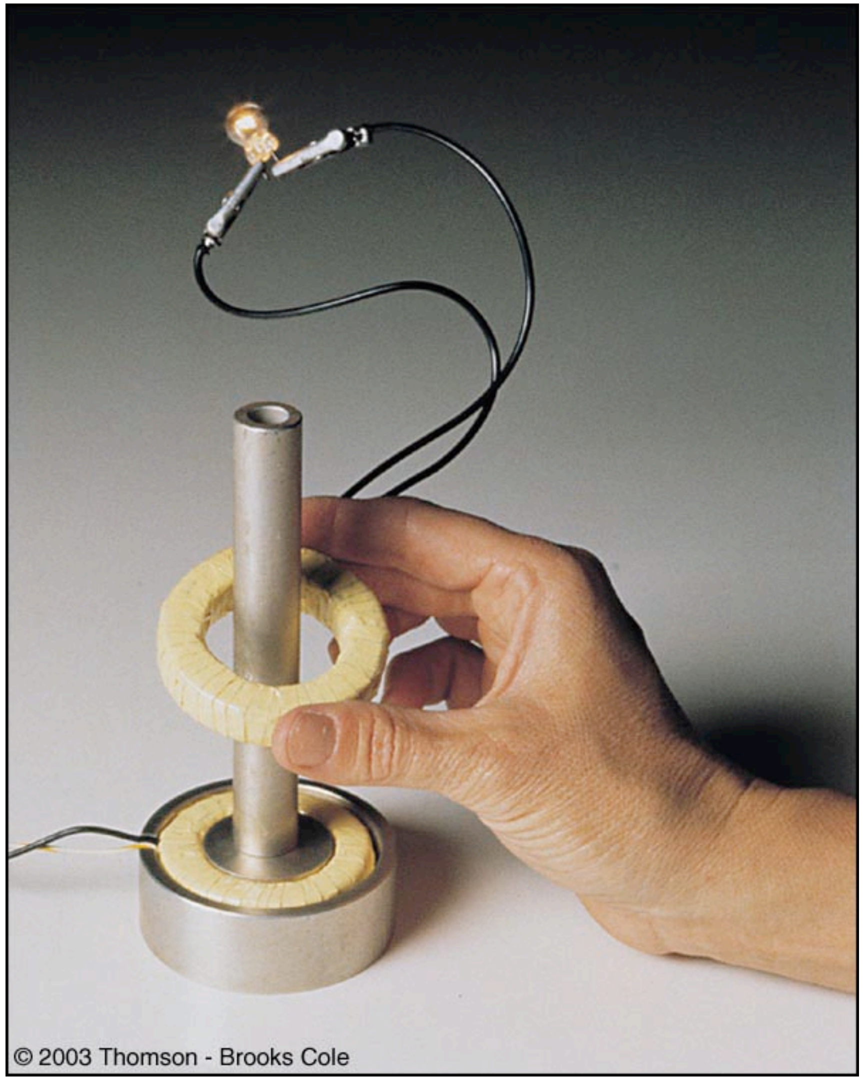
I_{ab} is negative therefore ε_{ab} is negative

Electromagnetic Induction

Alternating induced voltage

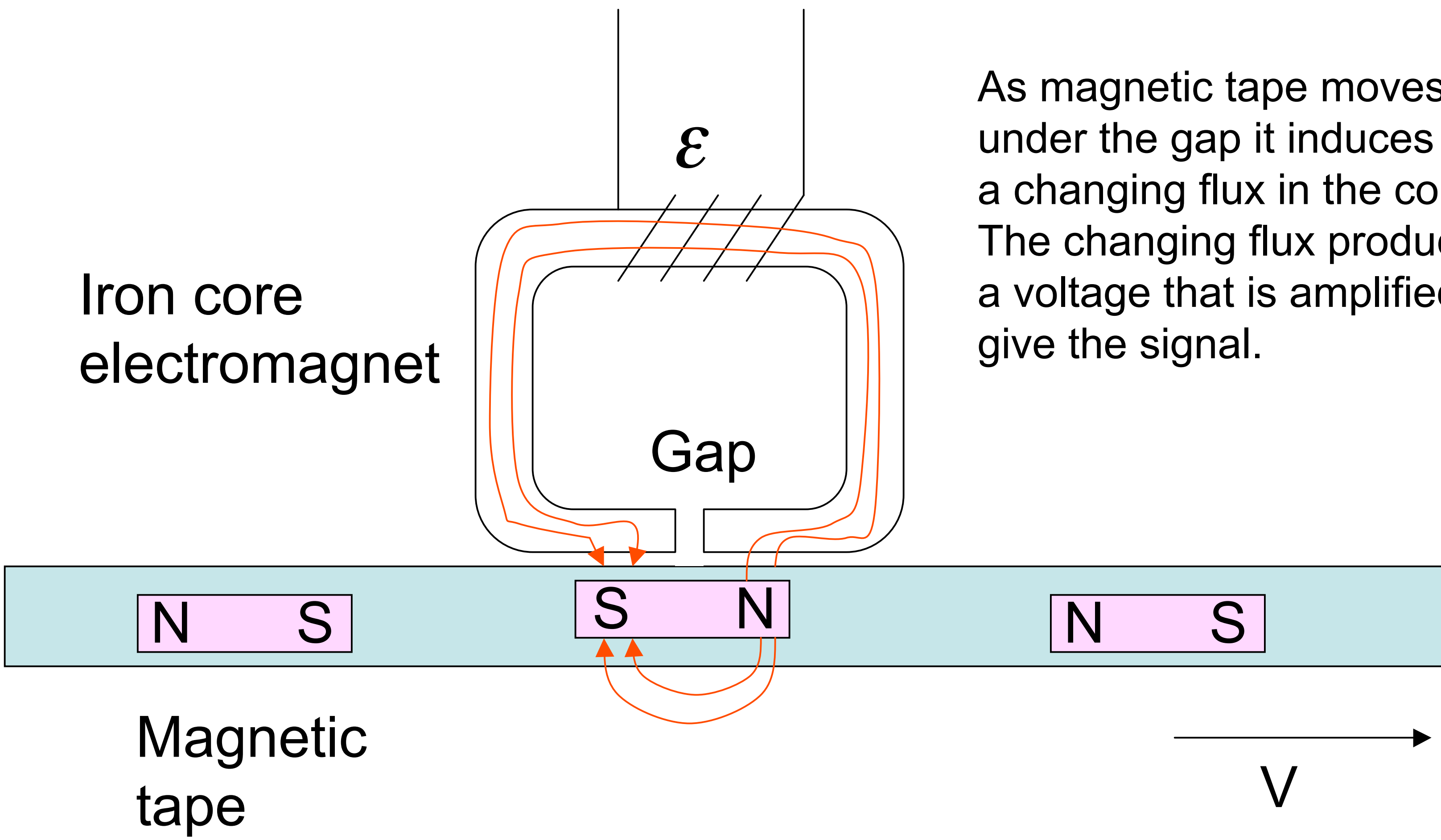
Alternating magnetic field

Alternating current (varies with time)



Energy transfer through space

Application of Faraday's Law
Generation of voltage by a tape recorder



As magnetic tape moves under the gap it induces a changing flux in the coil. The changing flux produces a voltage that is amplified to give the signal.

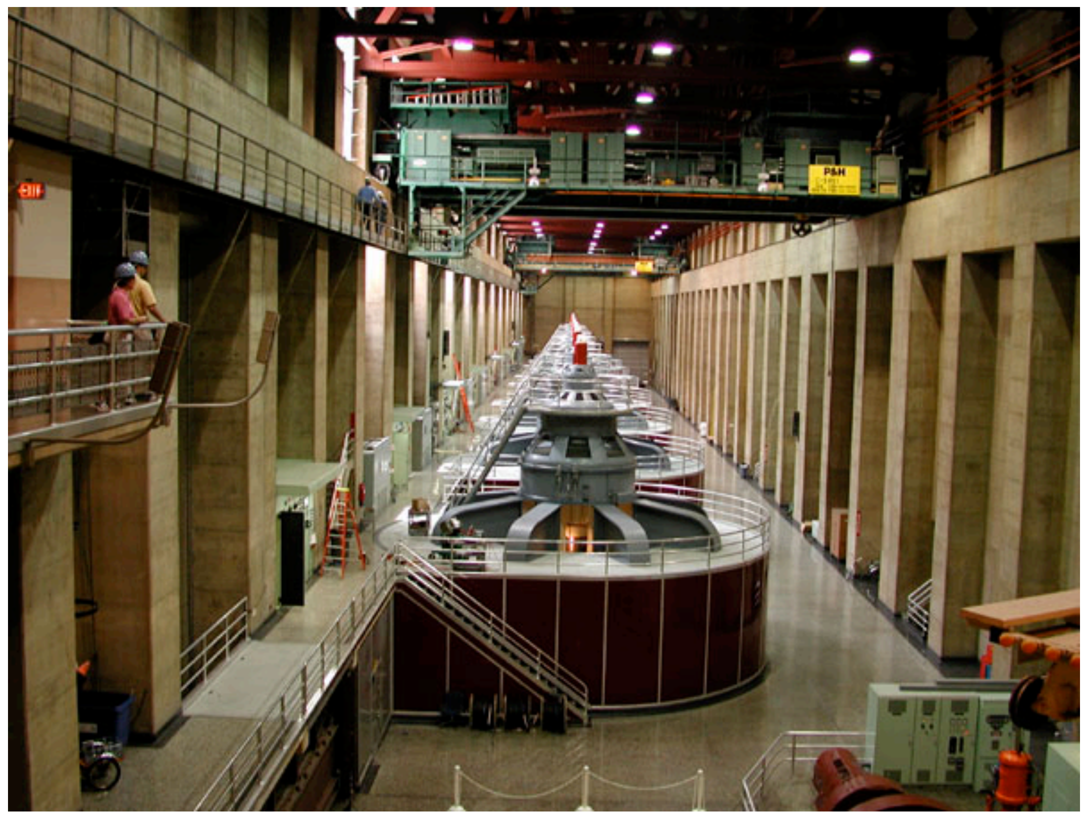
20.3 Electrical Generator

Electrical Generators

Self-induction

Hoover Dam

Electrical generators



Electrical Generator

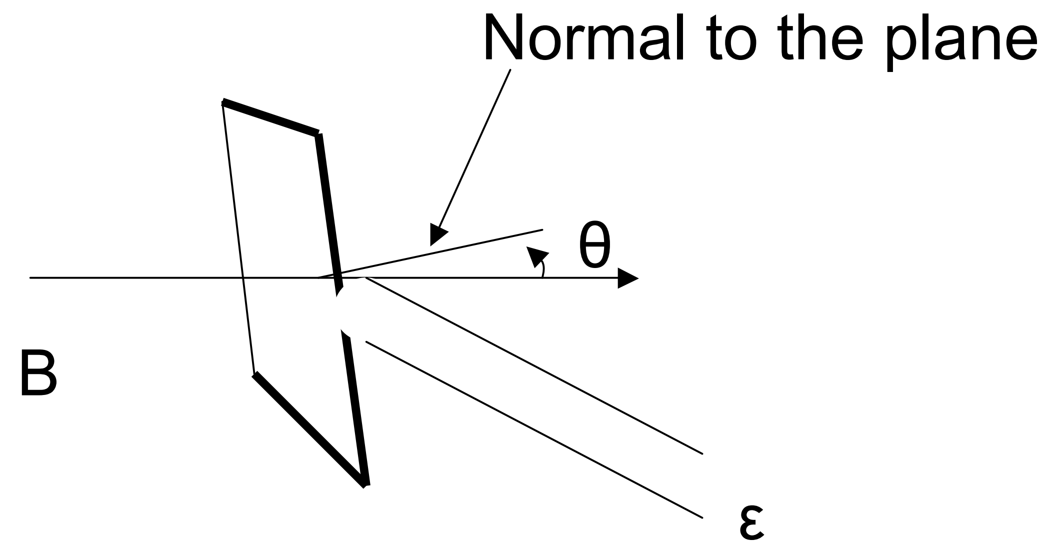
Uses mechanical work to generate electrical current

Changing flux through a rotating coil produces emf
Faraday’s Law

Alternating current is produced

Direct current can be produced using a commutator.

Flux through a rotating loop in a B field



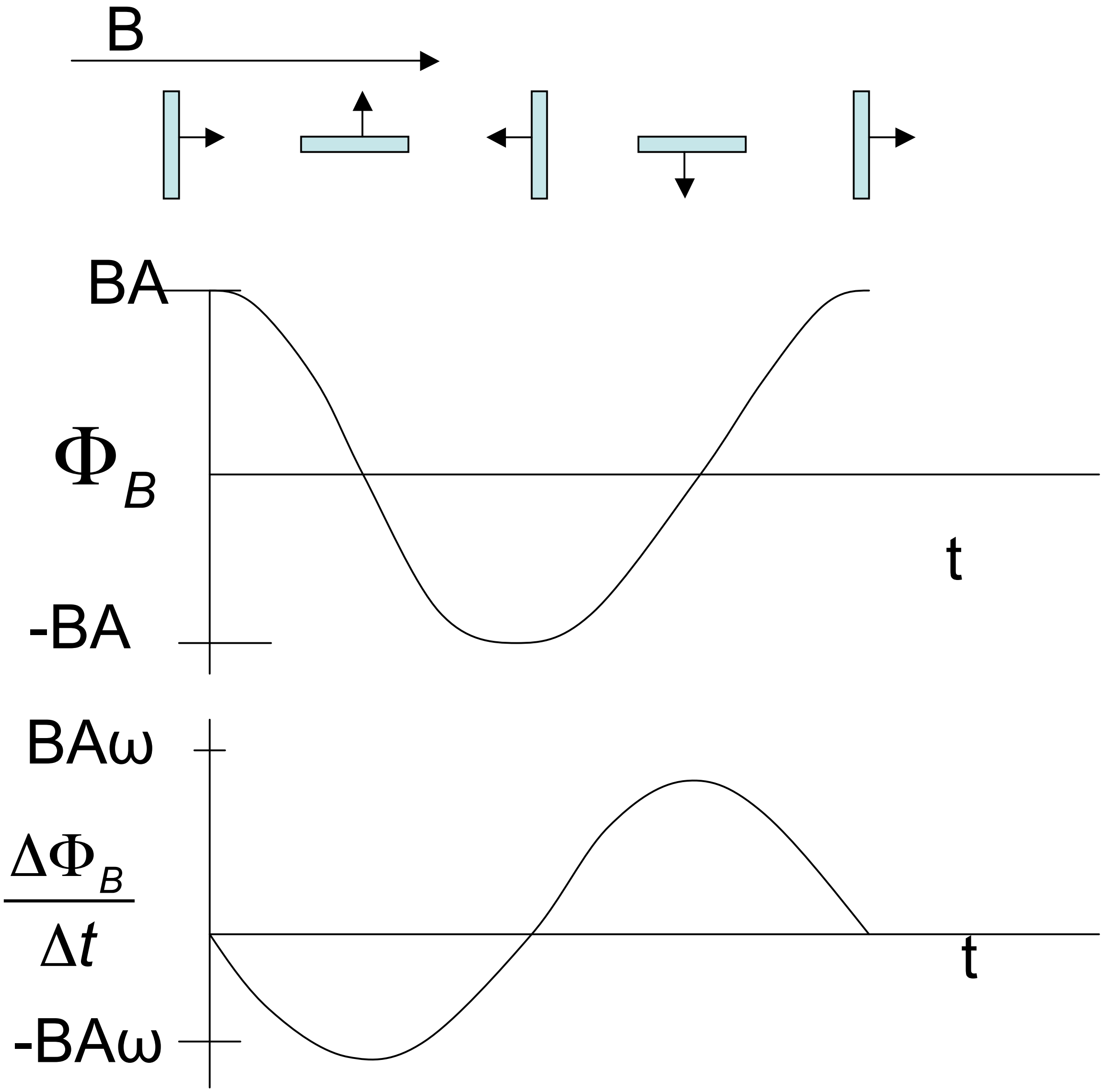
The flux through the loop

$$\Phi_B = BA\cos\theta$$

$$\theta = \omega t$$

ω = angular velocity (radians/s)

Relation between Φ_B and $\dfrac{\Delta\Phi_B}{\Delta t}$



$$\Phi_B = BA\cos\omega t$$

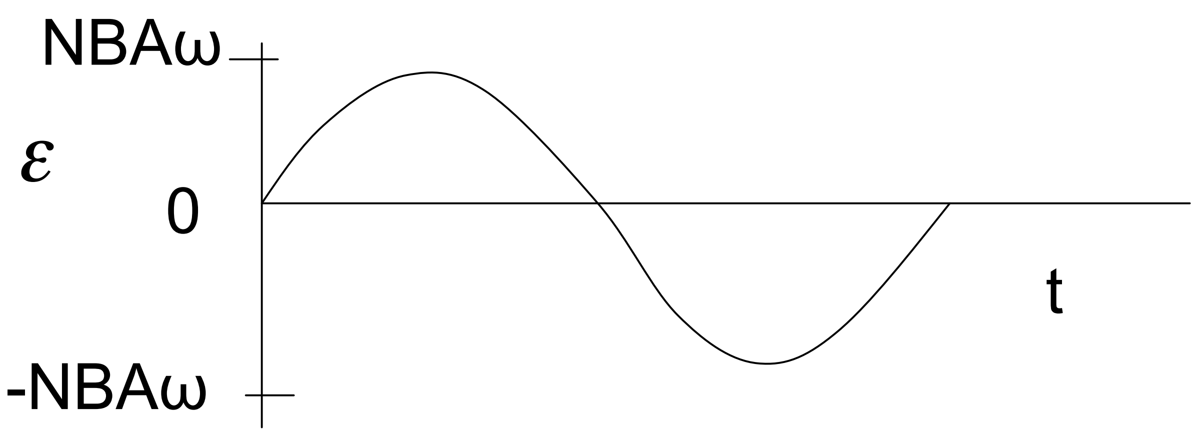
$$\frac{\Delta\Phi_B}{\Delta t} = -BA\omega\sin\omega t$$

proportional to ω

The emf generated by a loop of N turns rotating at constant angular velocity ω is

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

$$\varepsilon = NBA\omega \sin \omega t$$



35. In a model ac generator, a 500 turn rectangular coil 8.0 cmx 20 cm rotates at 120 rev/min in a uniform magnetic field of 0.60 T. a) What is the maximum emf induced in the coil?

$$\varepsilon = NBA\omega \sin \omega t$$

The maximum value of ε

$$\varepsilon_{\max} = NBA\omega$$

$$\varepsilon_{\max} = (500)(0.6)(0.08x0.2)\frac{(120x2\pi)}{60} = 60V$$