

Magnetic Induction

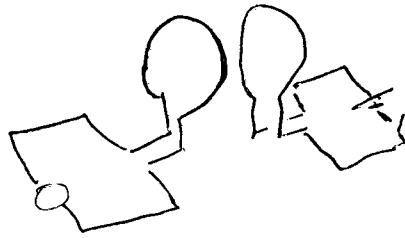
do demos

1830's Michael Faraday (England)
Joseph Henry (US)

⇒ do demo(s)

Induction - A changing magnetic field induces a changing electric field

⇒ induced EMF's, induced currents



(observe a current due to induced EMF)

No changing fields
Magneto statics

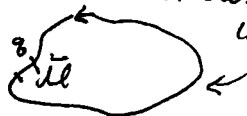
Kirchoff's rules

$$\sum V |_{\text{closed loop}} = 0$$

Also true in free space

$$\oint_C \vec{E} \cdot d\vec{l} = 0$$

line integral
(work to move charge about a closed loop)



With changing Magnetic field

$$\mathcal{E} = \oint \vec{E} \cdot d\vec{l} = - \frac{d\Phi_M}{dt}$$

Faraday's Law

True in wires/material
or
free space !!

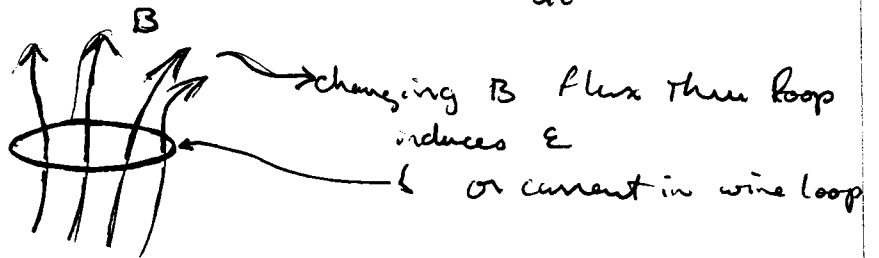
\mathcal{E} True only instantaneously!
unless $\frac{d\Phi_M}{dt}$ is constant

So, Think abt wire loop

$$\mathcal{E} = \oint \vec{B} \cdot d\vec{\ell} = -\frac{d\Phi_m}{dt}$$

Dirig geometry of loop

Dirig B magnitude or angle will cause Δ in Magnetic flux

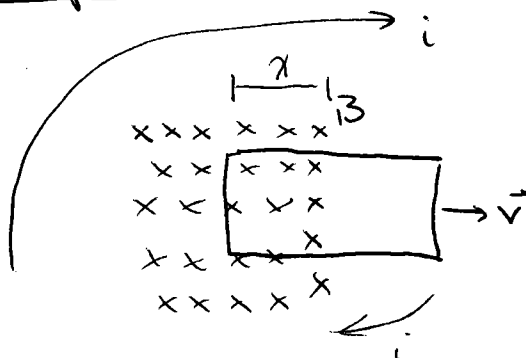


So we have induced \mathcal{E} ... current flows in loop
 \rightarrow induced current

What direction? \rightarrow NOTE the "-" in Faraday's law

Lenz's Law - An induced current in a closed conducting loop will appear in such a way direction that it opposes the change that produced it!

EXAMPLES



Explain induced i wants to \uparrow Φ_m - means it goes in what direction? wire arms!

$$\Phi_m = Blx$$

$$\mathcal{E} = -\frac{d\Phi_m}{dt} = -Bl \frac{dx}{dt} = -Blv$$

sets up a current $|i| = \frac{Blv}{R}$ - loop resistance
 Clockwise - why?

3 ways to look at -

① Φ_m being reduced
 induced i creates B that increased Φ_m

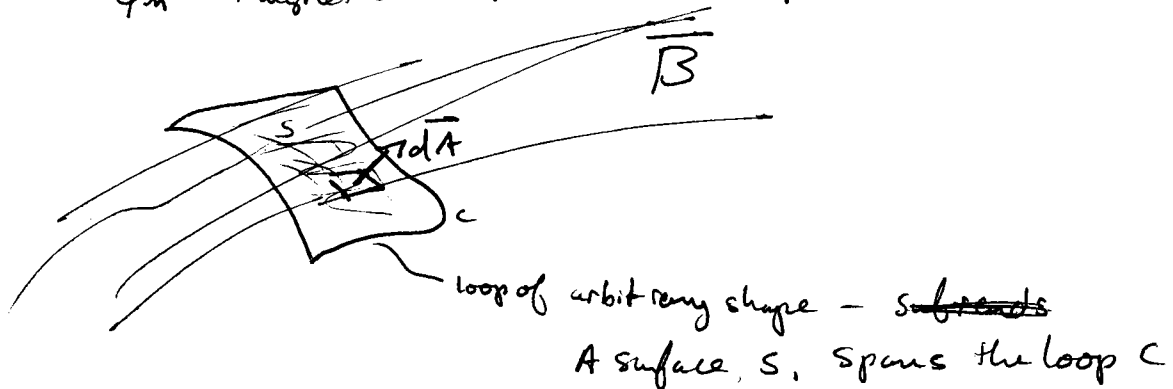


② Motional EMF
 \uparrow F
 \times B
 \rightarrow v
 \uparrow v of
 For "conductor y" due to v

③ \leftarrow F
 \times B
 \rightarrow i
 F produced by current works to slow down \vec{v}

what is Φ_M

$\Phi_M \equiv$ Magnetic Flux thru the loop

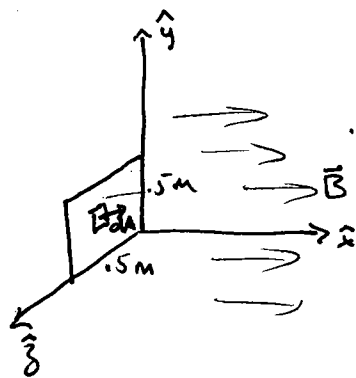


$$\int_S \vec{B} \cdot d\vec{A} = \Phi_M$$

Think of this exactly as you thought of $\int E \cdot dA$ for Gauss's Law

But surface is NOT closed
and use E instead of B

Simple example of Magnetic Flux calculation



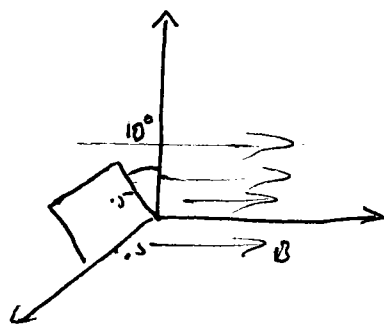
.5 m square loop in y-z plane

\vec{B} uniform - 2 T est A in \hat{x} direction

$$\vec{B} \cdot d\vec{A} = B dA$$

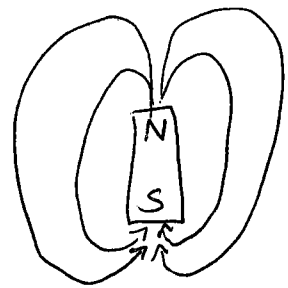
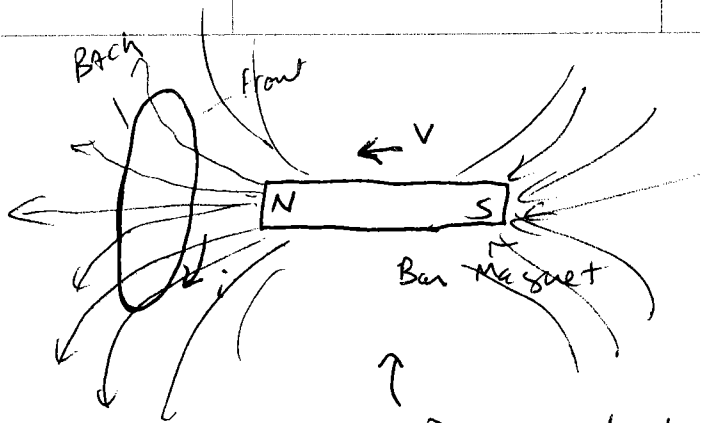
$$\int \vec{B} \cdot d\vec{A} = |B| \int dA = BA = 2T (.5m)^2 = .5 T \cdot m^2$$

same problem:
except loop now rotated



$$d\vec{A} \cdot \vec{B} = |B| |dA| \cos \theta$$

$$\int \vec{B} \cdot d\vec{A} = |B| \cos \theta \int dA = (\cos 10^\circ) .5 T \cdot m^2$$



Bar magnet looks like a dipole for electrostatics

Φ_m increases

B due, induced i decreases B

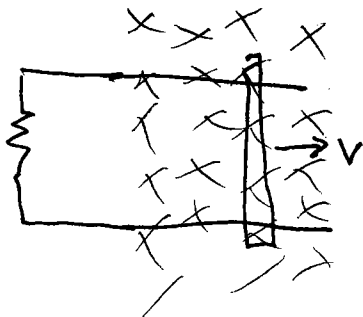
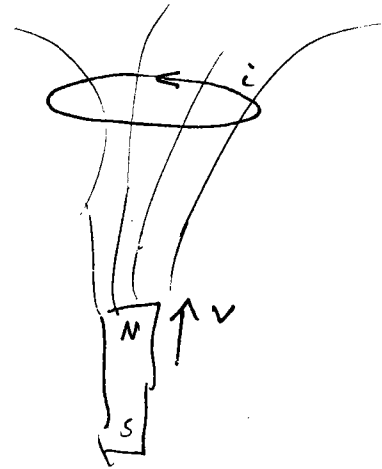
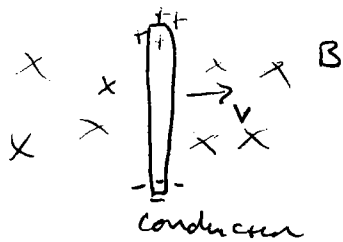
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Note:

Motional EMF

vs.

EMF induced by changing B field



Sometimes Both - can think of either way (not both added)

$$\mathcal{E} = IR$$

400 SERIES MILLER SQUARE
 400 SERIES LASER SQUARE
 400 SERIES RELEASE SQUARE
 400 SERIES THERMOCOPIED SQUARE
 400 SERIES UNIFORM SQUARE
 400 SERIES UNIFORM WHITE SQUARE
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