Magnetic Induction

Peter Watson

A magnetic Induction machine c 1830.,© 2007, American Artifacts, Taneytown, Maryland.

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1. How can we levitate objects?

2. Can we get energy into objects without any physical contact?

- We have seen that
- moving charge ➡ mag. field
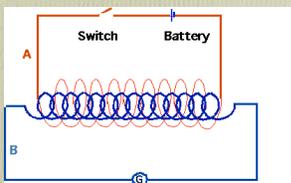- so mag. field ➡ moving charge?????????

Michael Faraday


This is what Faraday found

Faraday Experiment

- Two circuits:
- (A) has battery, switch and coil of wire
- (B) has second coil, wrapped round first and galvanometer (measures current
-

Switch   Battery

A

B

G

- Current in (A) produces mag. field in solenoid, so look for current in (B),
- He actually saw **no** effect for steady current in (A) but a momentary current in (B) when switch is opened or closed.
- i.e. **changing** mag. field ➡ electric current.
- A huge amount of technology depends on this simple observation
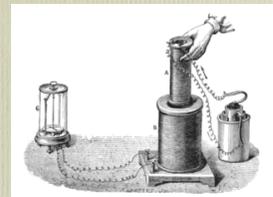
•Mechanically powered flashlight

• Linear induction transport

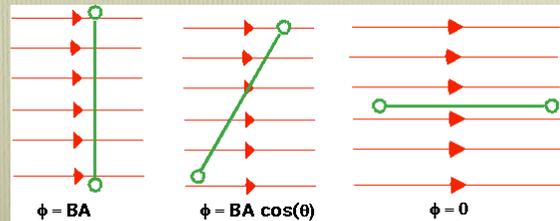•Induction cookers

• Transformers

•electric guitar pickup

• generator

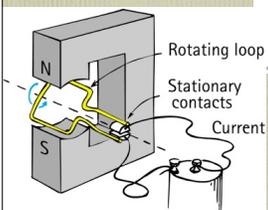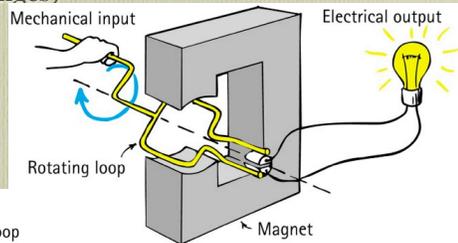# Generator

• Spin a coil in a magnetic field

• Magnetic field ("flux") through coil changes

• Voltage ~ rate of change of flux

$\phi = BA$ $\phi = BA\cos(\theta)$ $\phi = 0$

• Faraday's Law

• V = (number of turns) x (area) x (field) x (rate at which field changes)

Mechanical input

Electrical output

Rotating loop

Magnet

Rotating loop

Stationary contacts

Current

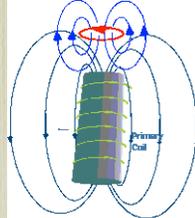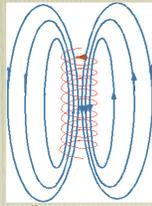Yes, it does look like a motor!

The "Jumping Ring" experiment

Jumping Ring Experiment

- Current in primary produces field in primary

  produces current in secondary (Faraday's Law)

- produces opposing mag. field (Lenz's Law)

- Opposing dipoles repel.

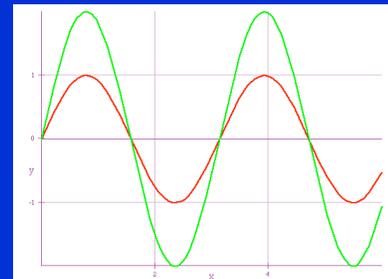## Eddy Currents and Magnetic Brakes

Lab Demo 12
Eddy Currents

1. Most Induction experiments only work with AC: why?

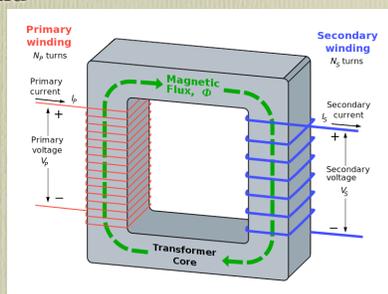## Must have changing magnetic field

1. Changing current gives changing field

Transformer

- Two coils wrapped round iron loop

- Current in primary produces field in iron

- produces current in secondary

- Only works with A.C. (Why?)

$$V_s = \frac{N_s}{N_p} V_p$$

Primary winding N_p turns

Secondary winding N_s turns

Primary current I_p

Magnetic Flux, Φ

Primary voltage V_p

Secondary current I_s

Secondary voltage V_s

Transformer Core

Why?

- Transmitting power loses energy

- Power lost = I²R

- Power transmitted = IV

- So if we transmit 1 MW over 500 km

- at 110 V you lose 0.4MW
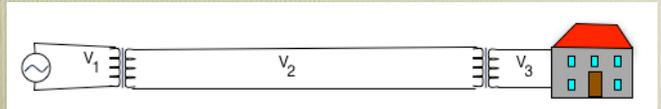
- at 850 kV you lose ~0.01 W!

- Why?

- Think back to the water analogy: if you have a hydraulic system

- Better to transmit a little water at very high pressure than a lot of water at low pressure

But ...

- We don't want 850000 V in our house

- So step up transformer at generator
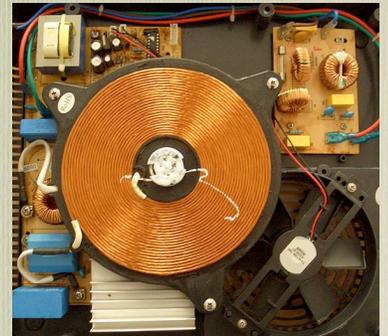
- Step down at substation

- $$V_s = \frac{N_s}{N_p} V_p$$

- Note (ideally) power stays the same

- $P = I_p V_p = I_s V_s$
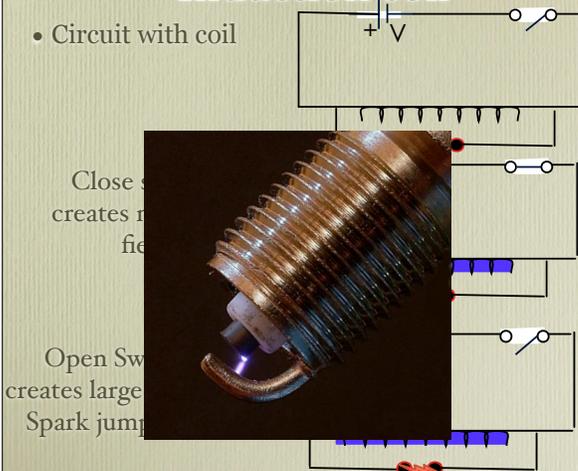
- so if V steps down, I steps up

Induction Cooking

- Very efficient, since only pan is heated
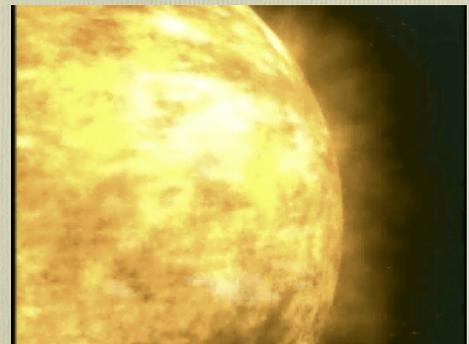
- Expensive, since need special pans

Induction coil

- Circuit with coil
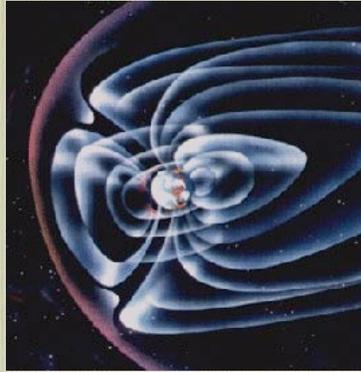
Close s
creates r
fie

Open Sw
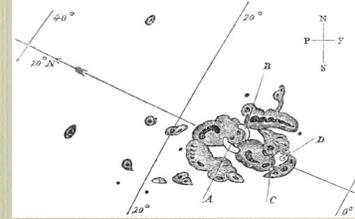creates large
Spark jump

But not always good news!

- Solar storms produce huge currents in ionosphere

- Magnetic storm on earth

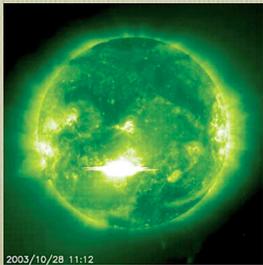- Fluctuating field produces huge currents

- ~ 1 million amps!

Carrington Event

- Biggest solar storm in (recorded) history

- 28th August-2nd Sept 1859

- Blew out telegraph linkages all over Europe & US

- Aurora seen in Caribbean

- From Sciam

2003/10/28 11:12

- March 1989

- Quebec blackout: 9 hours,

- communications down everywhere

- aurora in Texas (thought to be first-strike in nuclear war.

- Probably 1/10th of strength of Carrington event

- Hydro Quebec spend B$4.3 to improve protection

If it happened today …..

- Nightmare scenario:

- **surge protectors don't trip fast enough, all power transformers in North America melt.**

- **Lead time for construction is 3 years…**

- Hopefully:

- 12 hours warning of storm would allow power lines to be isolated

- surge protectors would burn out but could be replaced …

- but communication satellites would probably fail

Maxwell

- Faraday's law says

- Changing magnetic field ⇒induced electric field

- Maxwell's equations

- Changing electric field ⇒induced magnetic field

- magnetic field is at right angle to electric.

- which is why it is **Electromagnetic Radiation**
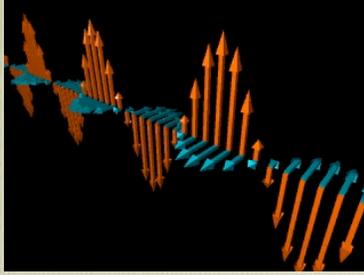
Hence Faraday + Maxwell predict light from induced fields