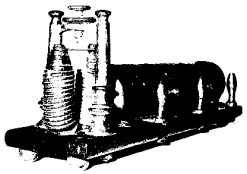
Magnetic Induction



Peter Watson

1. How can we levitate objects?
2. Can we get energy into objects without any physical contact?

Text

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

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
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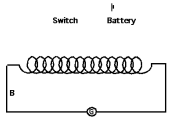
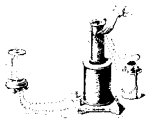
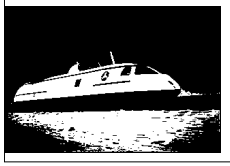


- Current in (A) produces mag. field in solenoid, so look for current in (B),
- He actually saw **no** effect for steady current in (A) but a momentary current in (B) when switch is opened or closed.
- i.e. **changing** mag. field ➠ electric current.
- A huge amount of technology depends on this simple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



•Mechanically powered flashlight

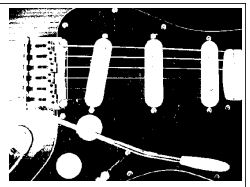


- Linear induction transport

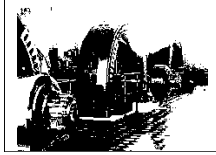
•Induction cookers

- Transformers

•electric guitar pickup



- generator

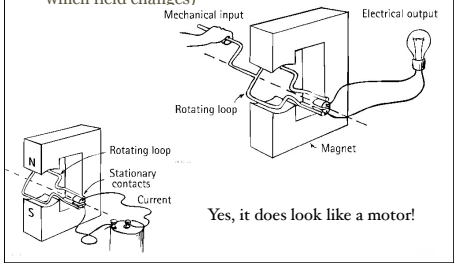


Generator

- 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)



Yes, it does look like a motor!

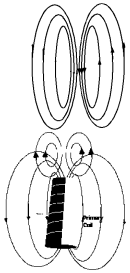
The "Jumping Ring" experiment

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

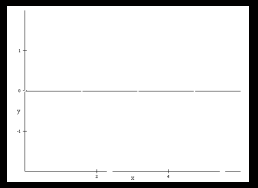
Lab Demo 12
Eddy Currents

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

Text

Must have changing magnetic field

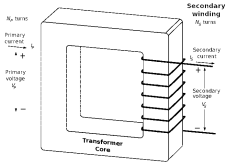
1. Changing current gives changing field



PW

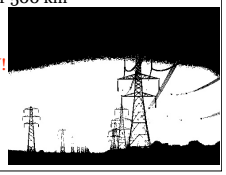
Transformer

- Two coils wrapped round iron loop
- Current in primary produces field in iron
- produces current in secondary
- Only works with A.C. (Why?)



Why?

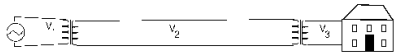
- Transmitting power loses energy
- Power lost = I^2R
- Power transmitted = IV
- So if we transmit 1 MW over 500 km
- at 110 V you lose 0.4MW
- at 850 kV you lose ~0.01 W!



- 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 ...

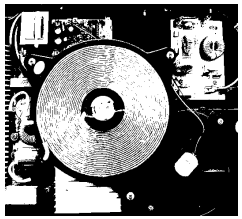
- We don't want 850000 V in our house
- So step up transformer at generator
- Step down at substation
-



- Note (ideally) power stays the same
- $P = I_p V_p = I_s V_s$
- so if V steps down, I steps up

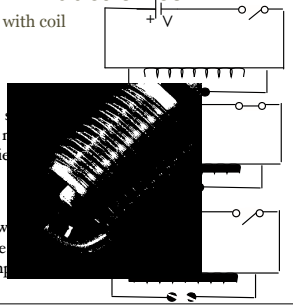
Induction Cooking

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



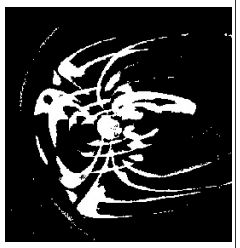
Induction coil

- Circuit with coil



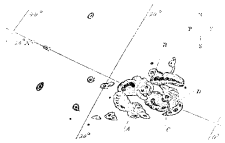
But not always good news!

- Solar storms produce huge currents in ionosphere
- Magnetic storm on earth
- Fluctuating field produces huge currents
- ~ 1 million amps!

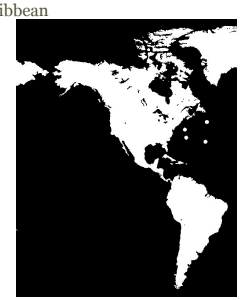


Carrington Event

- 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



- 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

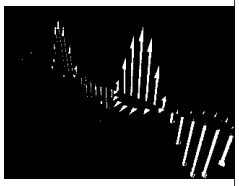
If it happened today .....

- 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