Chapter 25

Electromagnetic Induction

Motors & Generators

- A current-carrying wire placed in a magnetic field will experience a force.

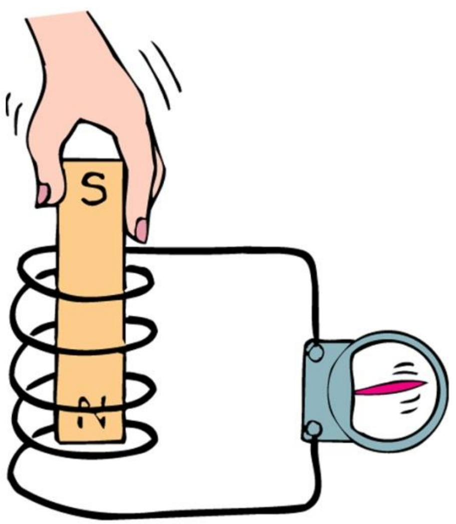
  This is the basis of an *electric motor*.

- Moving a conductor through a magnetic field can produce an electric current.

  This is the basic of an *electric generator*.

Electromagnetic Induction

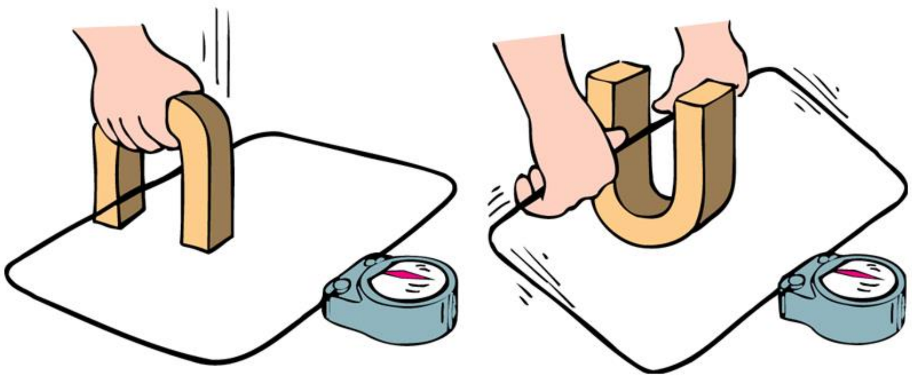
When a magnet is pushed into a coil of wire, a voltage is produced that sets the electrons in the coil into motion. In other words, current is produced.



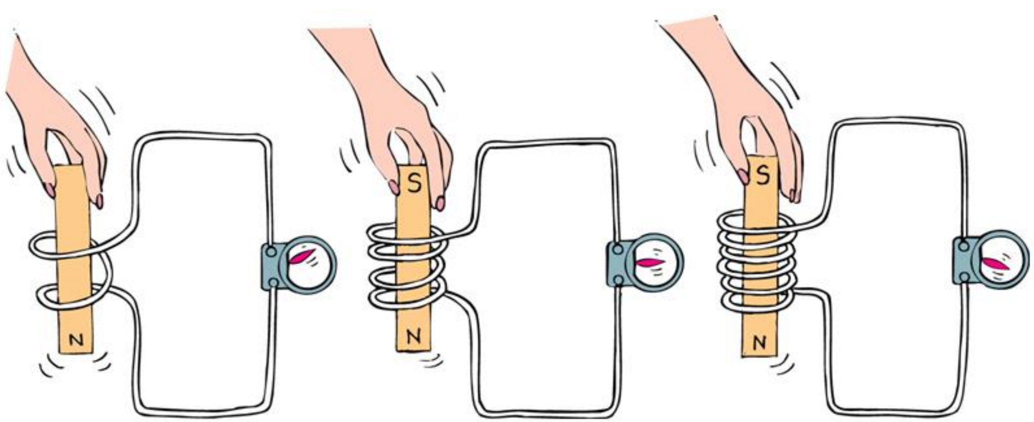
How much current depends on…

- Magnet strength
- Area of loop
- Number of loops
- Speed of the magnet

Electromagnetic Induction



Voltage is induced whether a magnet moves or the wire loop moves.



The voltage induced is directly proportional to the number of loops in the coil. (Twice the loops means twice the voltage.)

Faraday's Law

Voltage induced is directly proportional to:

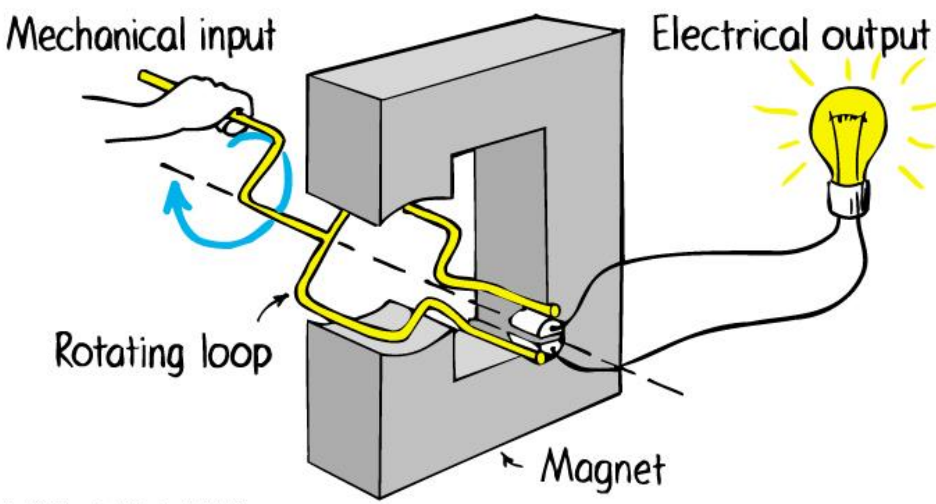
- # of loops, *N*
- Cross-sectional area, *A* of each loop
- Rate at which the magnetic field, **B**, changes in those loops, $\Delta B/\Delta t$.

This is known as Faraday's law of induction:

$$V \propto NA \frac{\Delta B}{\Delta t}$$

Generators

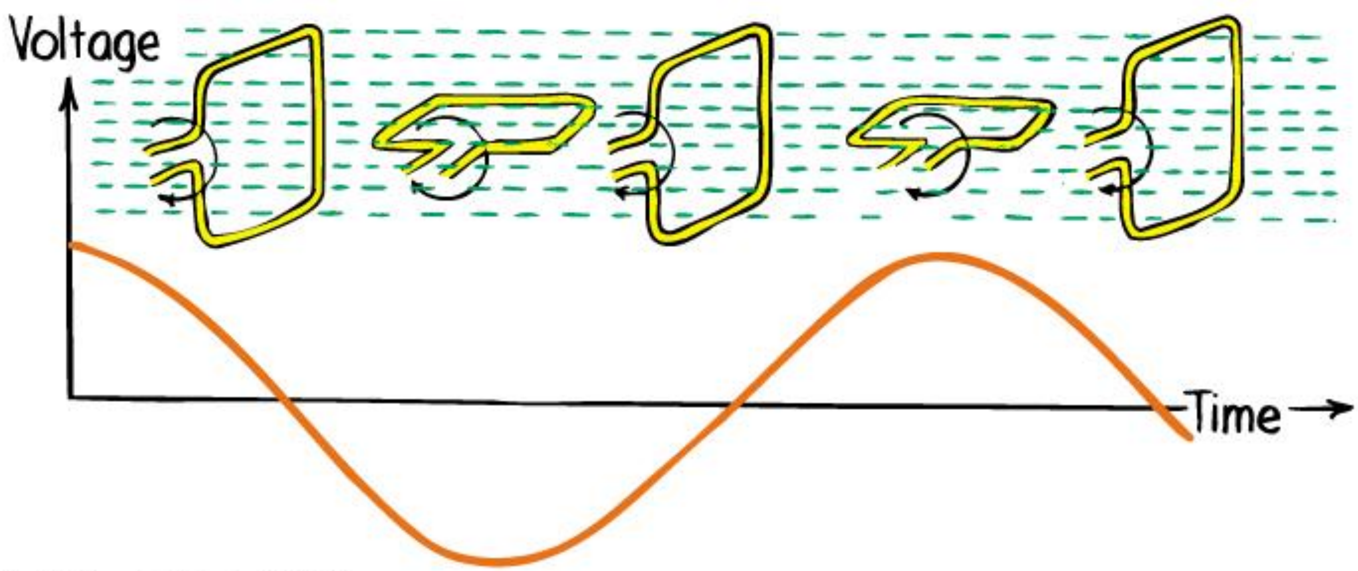
A generator is a device that converts mechanical energy to electrical energy. To accomplish this, move a conductor through a non-uniform magnetic field to create a voltage.



Hewitt, *Conceptual Physics*, Ninth Edition.

Generators cont'd

As the loop is rotated, the area through which the magnetic field penetrates the loop is continuously changing: increasing, then decreasing, then increasing again, and so on. In this case, an AC voltage is induced.



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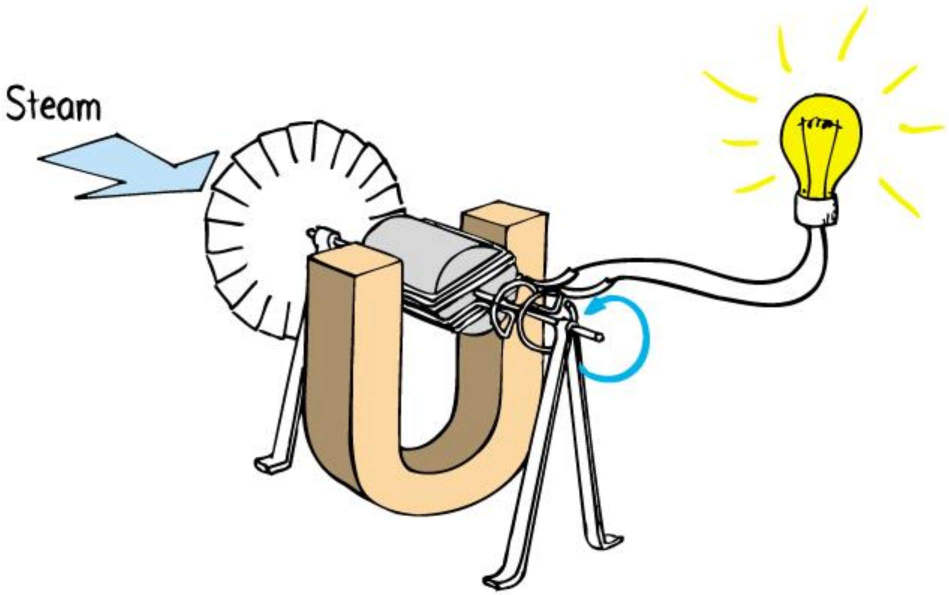
To Generate Electricity…

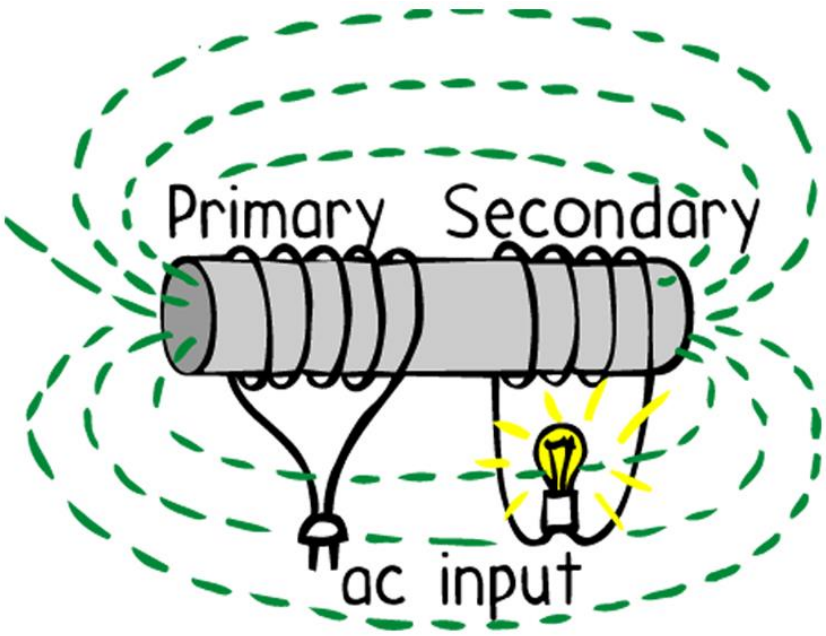
...you simply need some means of spinning the coil inside the magnetic field (or spinning a magnet inside of a coil. A turbine attaches to the coil (or magnet) can be spun by…



- Burn coaling or fissioning uranium , to boil water, to create steam;
- Water spilling over a dam;
- Wind;
- A superhero that stand there all day and turns the crank him/herself.

Transformers

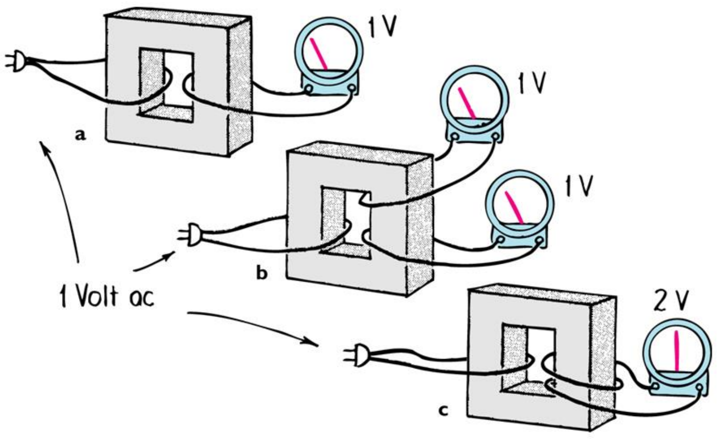
- The electrical analog to a mechanical lever.
- Trade voltage for current & vice sersa.



- They’re more than meets the eye! (But they’re not robots in disguise).

Transformers (cont'd)

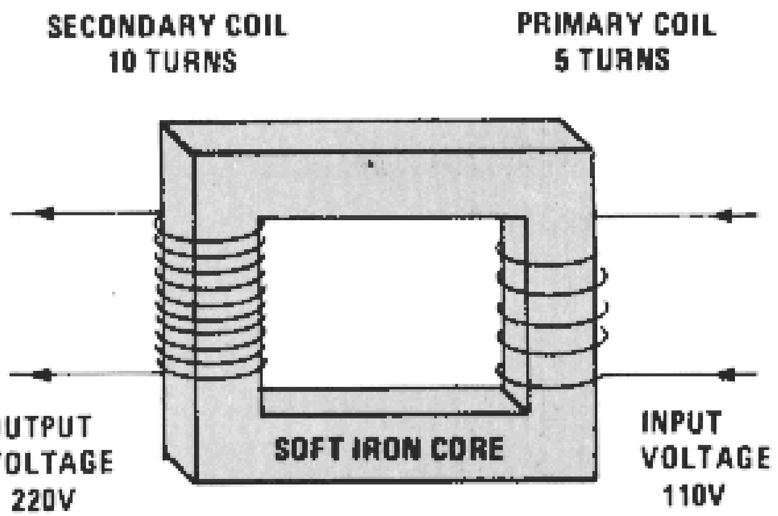
$$\frac{V_{prim}}{N_{prim}} = \frac{V_{sec}}{N_{sec}}$$



For example:

If there are twice as many loops in the Secondary as the Primary, the output voltage will be double that of the input voltage.

This is a "step-up" transformer.



Transformers (cont'd)

Of course you can't get something for nothing, so if you gain something, you have to give up something.

Ideally, $Power_{prim} = Power_{sec}$ and $Power = VI$.

So, if $\frac{V_{prim}}{N_{prim}} = \frac{V_{sec}}{N_{sec}}$, then $I_{prim}N_{prim} = I_{sec}N_{sec}$.

If voltage is increased (as with a step-up transformer) by some factor, then the current must decrease by that same factor. For the previous example, if the output voltage is double the input voltage, then the output current must be half that of the input current.

Field Induction

Michael Faraday (1831):

An electric field is induced in any region of space in which a magnetic field is changing. In other words, changing magnetic field produce electric fields.

James Clerk Maxwell (1860):

A magnetic field is induced in any region of space in which an electric field is changing. In other words, changing electric field produce magnetic fields.

Maxwell discovered that light is just electromagnetic waves in the frequency rang to which our eyes are sensitive!