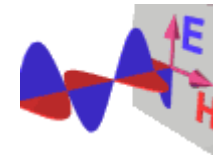
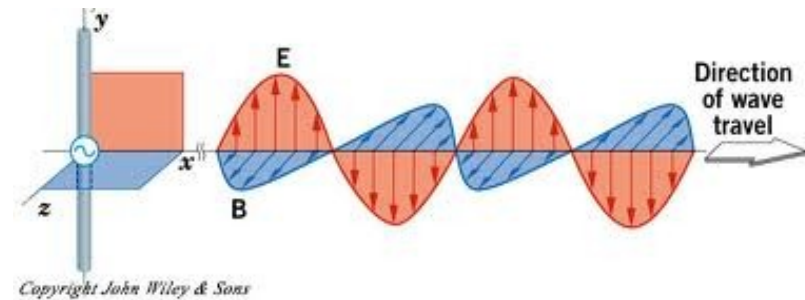


BIG IDEAS IN EM

1) electromagnetic wave

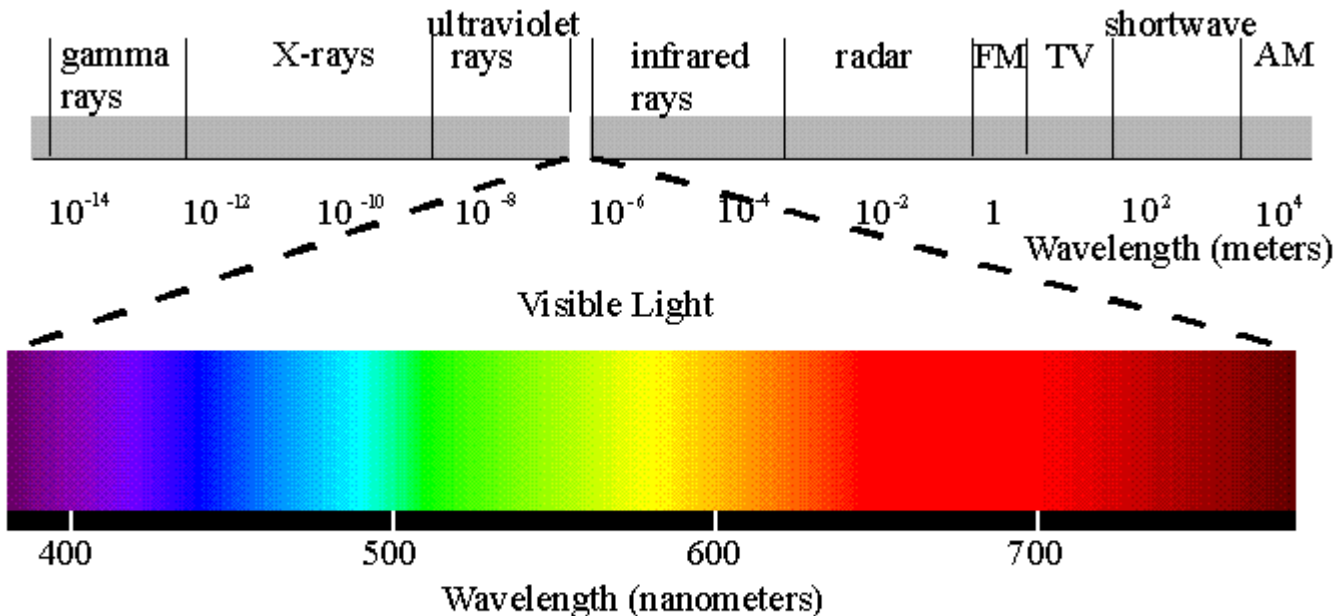
Such wave travels at the speed of light c . It does need a medium to propagate. It is made of a changing electric field E and of a changing magnetic field B . The fields are “shaking” As the wave propagates.

If you have AC current in an antenna it will create an E field That will induce a B field that will generate a E and so forth



<https://phet.colorado.edu/en/simulation/radio-waves>

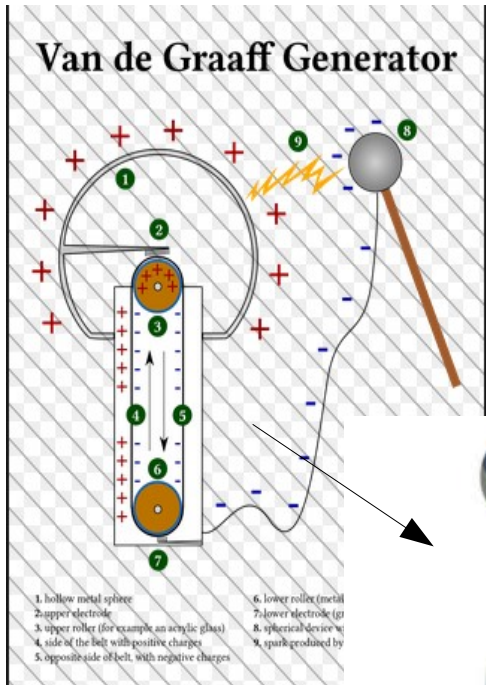
Electromagnetic spectrum



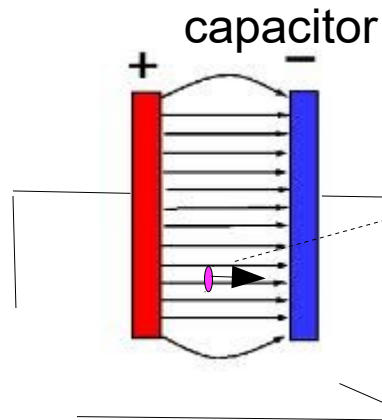
2) static electric field E produced by charges.

Voltage drop is to E what height is to mass.

A distribution of charge creates an electric field E in the space around it. A charge q in the electric field “feels” the field and speeds up. It is acted up by an electric force. $F_e = q E$. A positive charge moves from a high potential to a low potential = high voltage to low voltage.

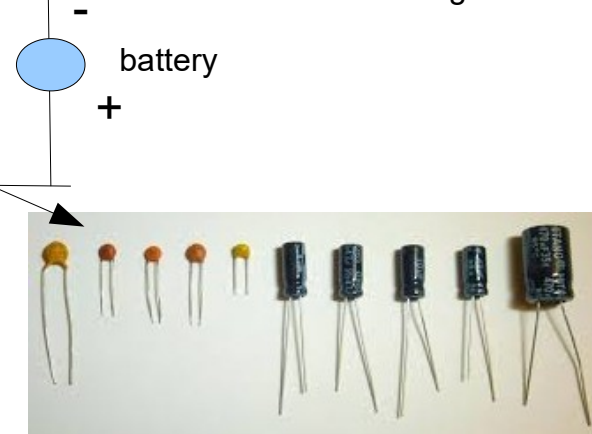


A charge placed inside
Will accelerate. Example: electrons in a cathode tube
Speed up from $-$ to $+$.



The electric field is a vector field.

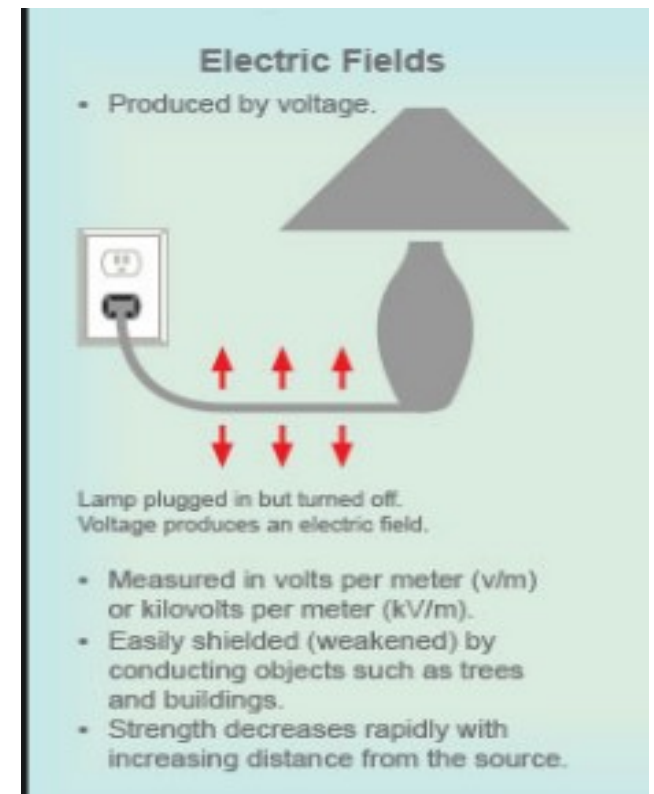
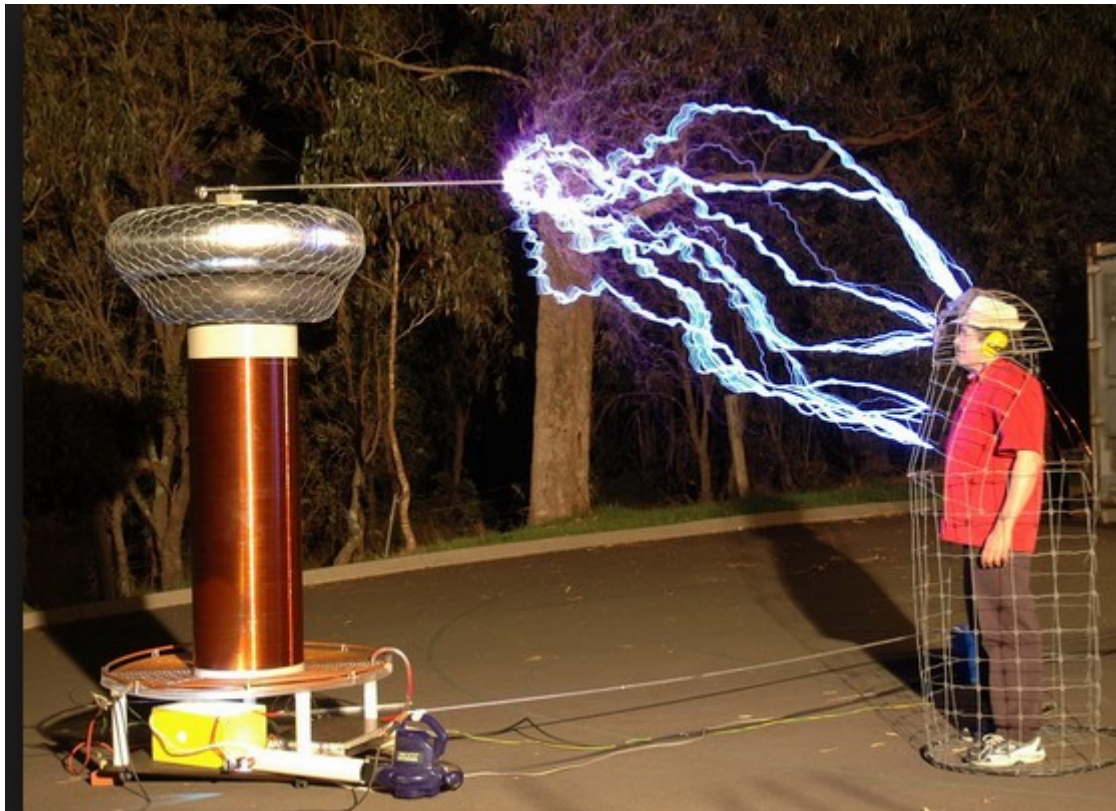
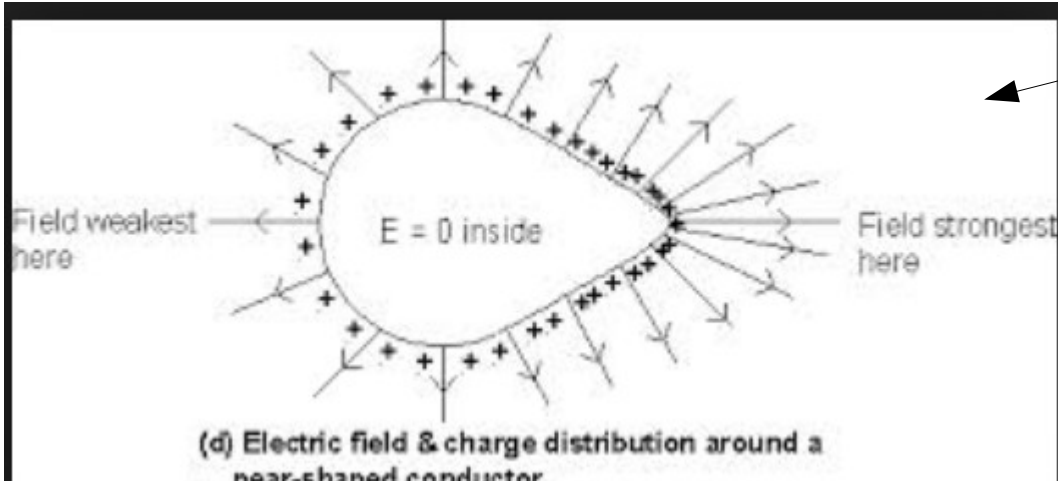
A positive charge placed
Inside an electric field will accelerate.
Like a mass in a gravitational field



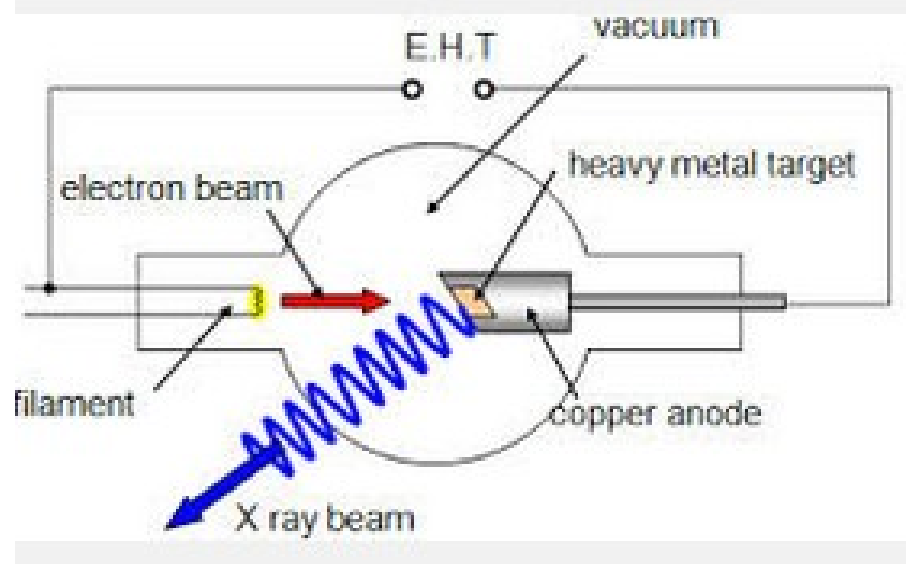
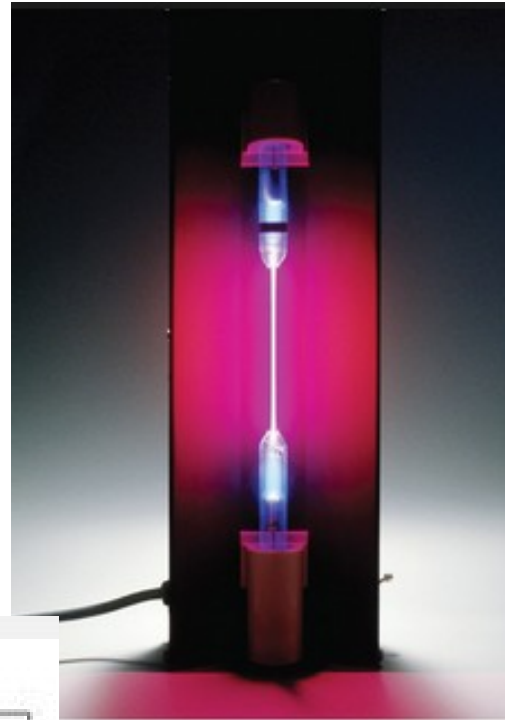
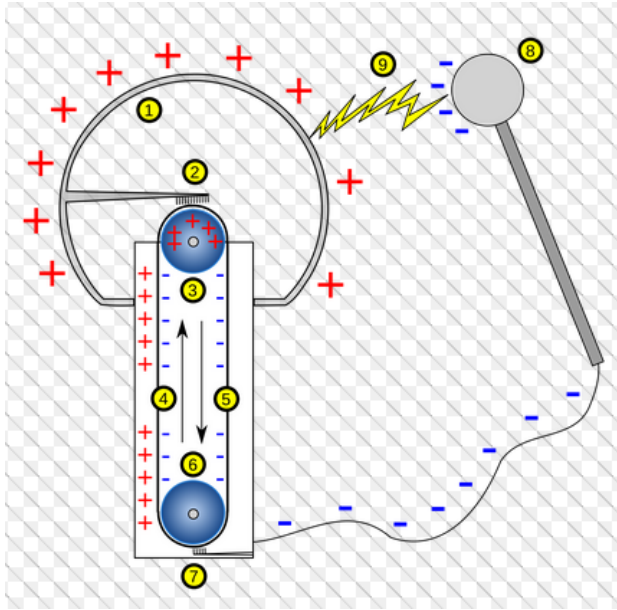
All appliances plugged in
Produce electric field

In an electric field

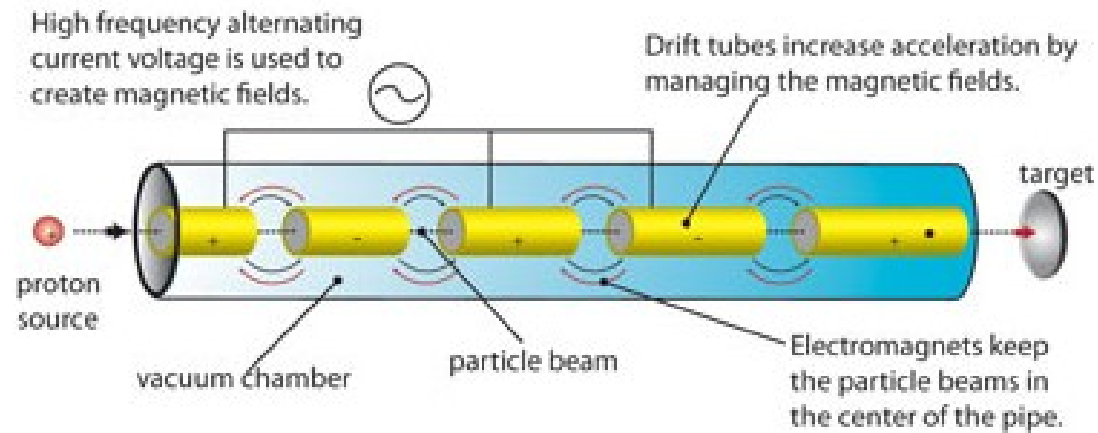
Could be you



Electric field between high voltage and ground = accelerates electrons



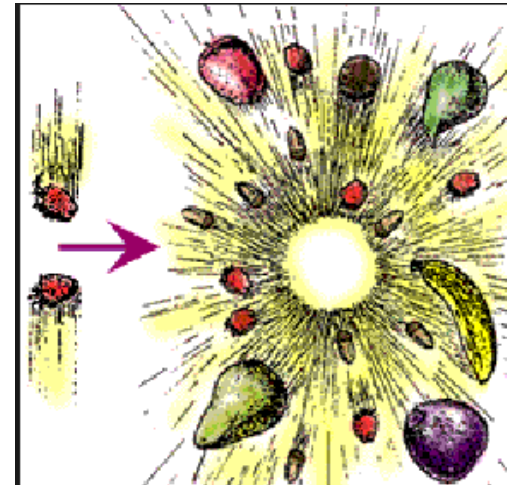
Linear Accelerator



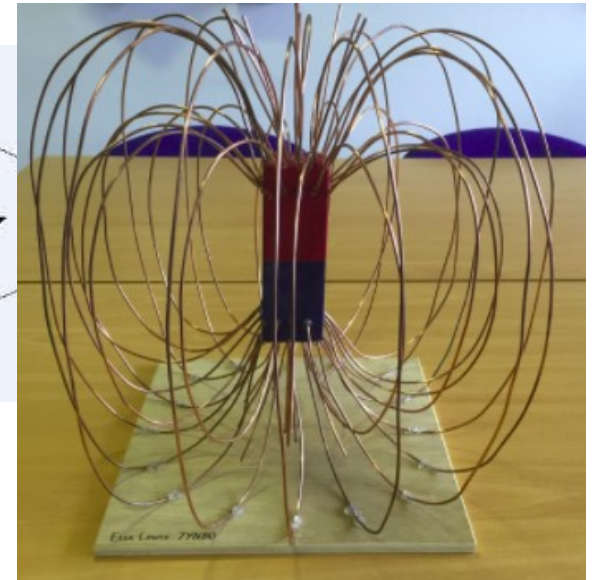
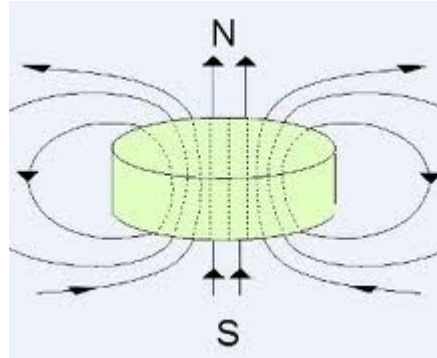
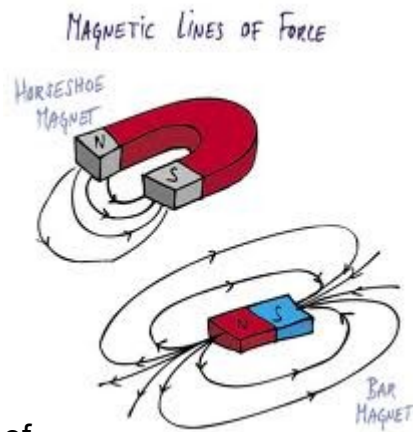
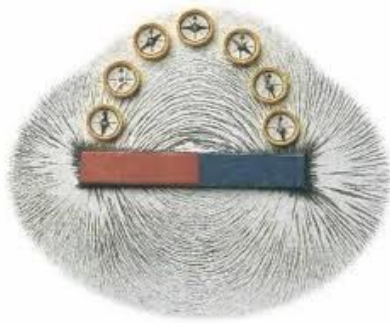
Watch movie about
accelerator

<http://atomic.lindahall.org/what-is-an-atom-smasher.html>

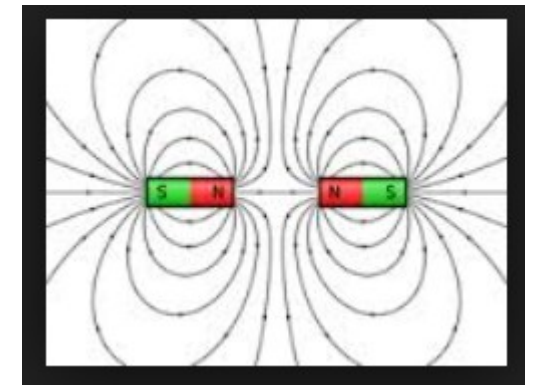
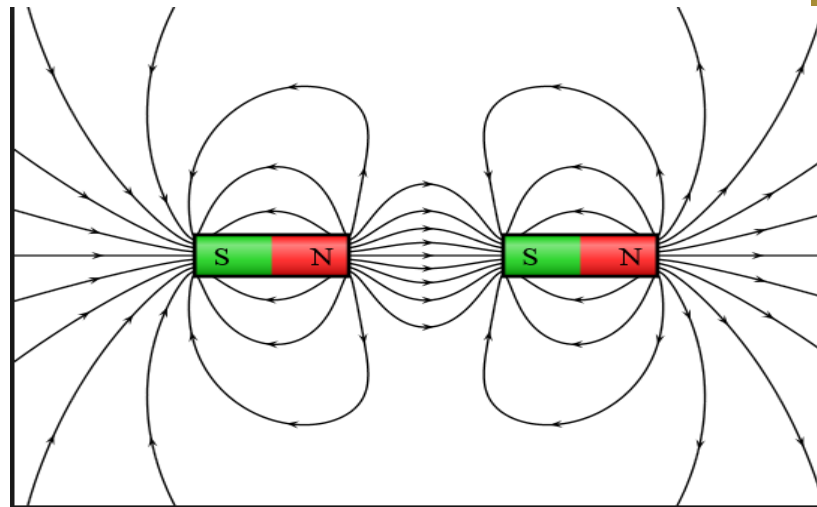
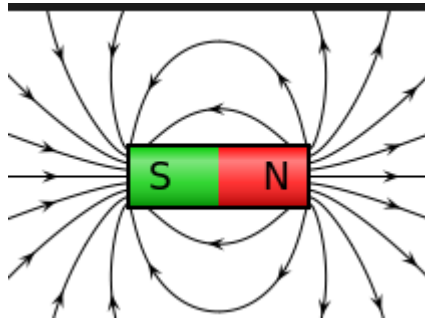
<http://www.triumf.ca/isotope-production>



2) static magnetic field

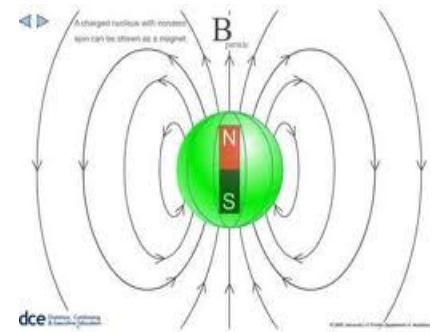
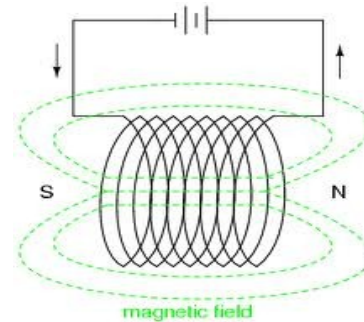
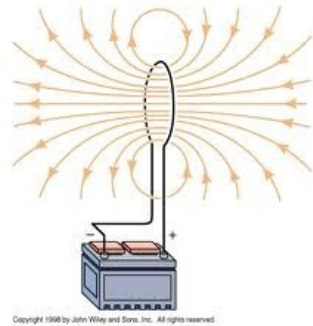
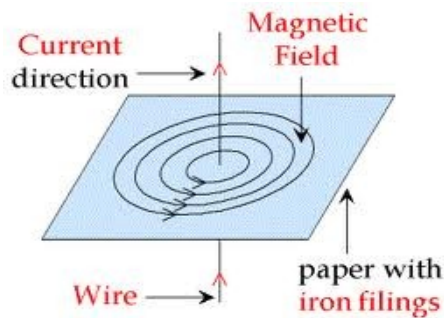


We can use iron filing
To map the field. The little pieces of
Iron get magnetized and behave like
Tiny compasses.

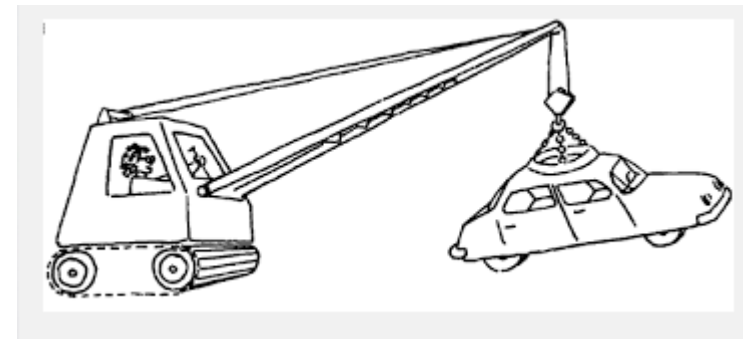
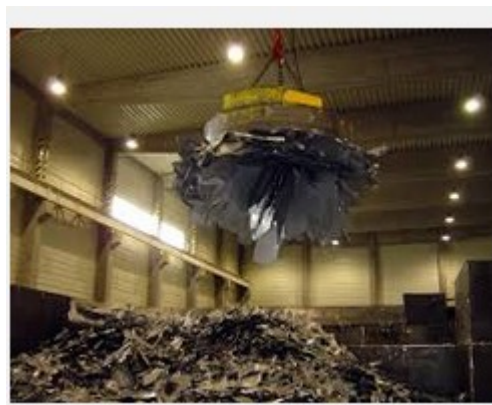


static magnetic field produced by current

Current in a wire produces a magnetic field in the space around. If the wire is coiled to form loops, the magnetic field is like the ones produced by a bar magnet. The coil becomes an electromagnet with a North and South poles!!



Application: - electromagnet. A coil with an iron core inside behaves like a bar magnet. The Earth behaves like a bar magnet because of the ionized liquid in the outer core.

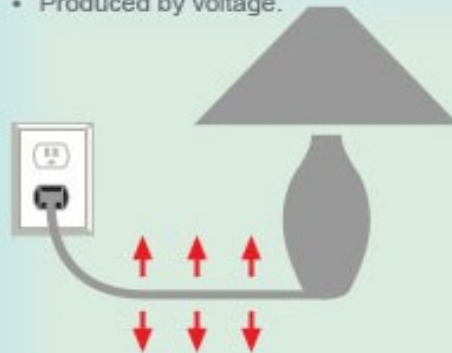


App solenoidOn

A Comparison of Electric and Magnetic Fields

Electric Fields

- Produced by voltage.

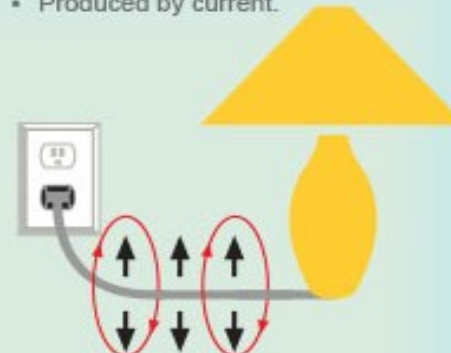


Lamp plugged in but turned off. Voltage produces an electric field.

- Measured in volts per meter (v/m) or kilovolts per meter (kV/m).
- Easily shielded (weakened) by conducting objects such as trees and buildings.
- Strength decreases rapidly with increasing distance from the source.

Magnetic Fields

- Produced by current.

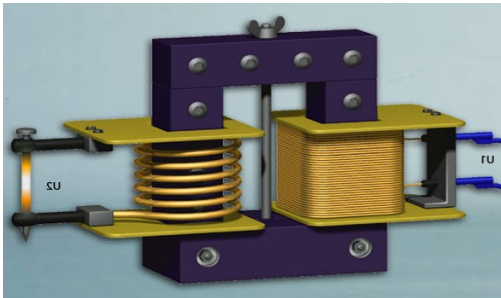
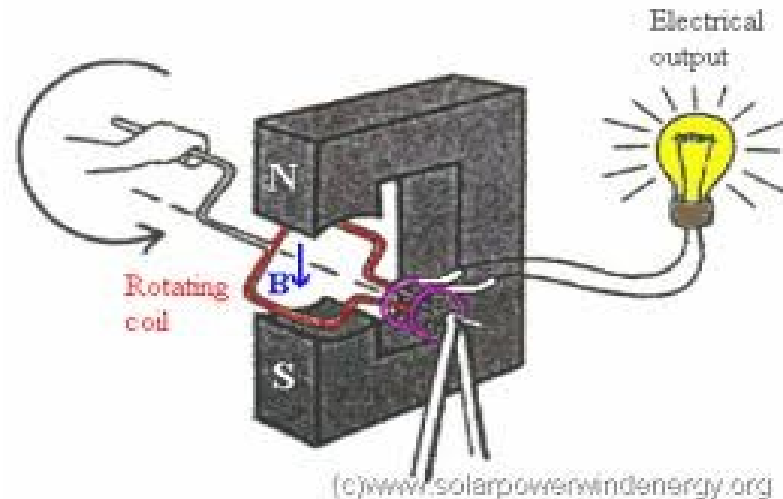
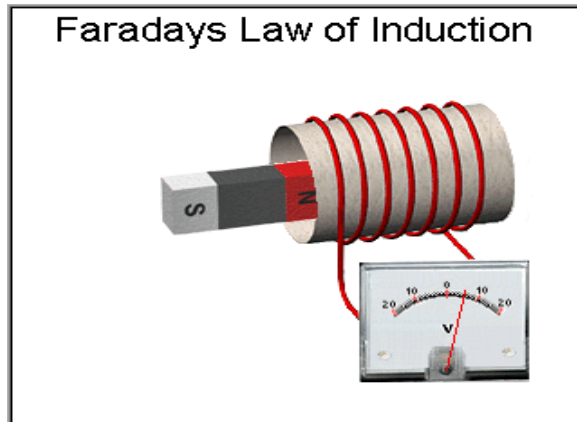


Lamp plugged in but turned on. Current now produces a magnetic field also.

- Measured in gauss (G) or tesla (T)
- Not easily shielded (weakened) by most material.
- Strength decreases rapidly with increasing distance from the source.

4) Faraday's law of induction

A changing magnetic field (moving a magnet in a coil or moving a coil around a magnet) induces an alternative current. This is how we produce electricity (AC).



application:transformer
Step up voltage or step down.

<https://www.youtube.com/watch?v=j6dx6R8YWjk>
demo

Transformer : alternative current (1A) in 1 coil (voltage 12V) creates a changing Magnetic field that, guided by the iron square, induces an alternative current In the second coil (more loops). The alternative current is less and the voltage Stepped up such as the energy is conserved : $u_1 I_1 = u_2 I_2$

$$U_1 = 12V$$

$$I_1 = 1A$$

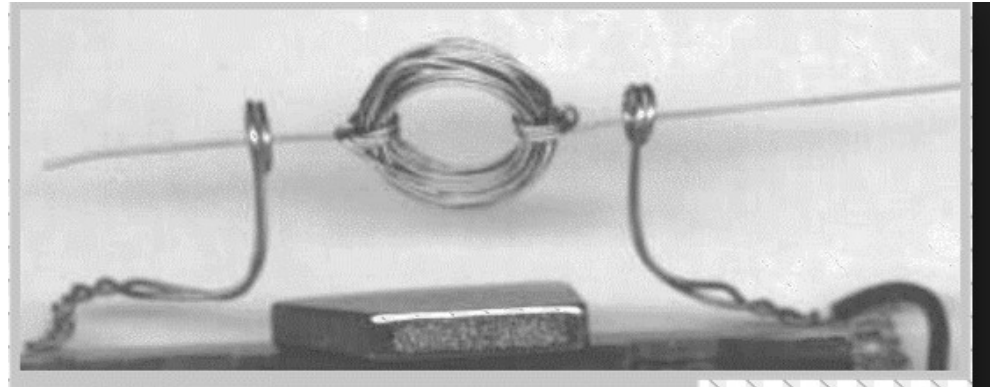
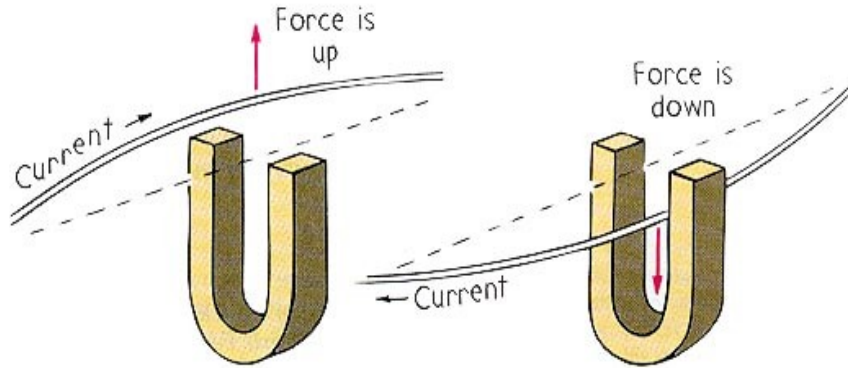
$$\text{Power} = 12W$$

$$U_2 = 24V$$

$$I_2 = 0.4A$$

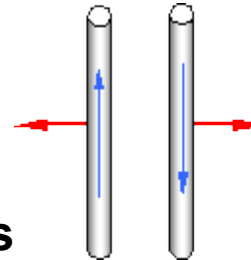
6) A moving charge feels a magnetic field. (seen above)

A magnetic field (from magnet or electromagnet) has no effect on a charge at rest. (electron, proton, ions ..). But a magnetic field applies a force on a moving charge if the charge move in a direction perpendicular to the magnetic field. The force produced is perpendicular to both the field and the velocity.

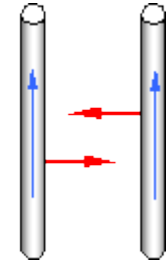


Electric motor

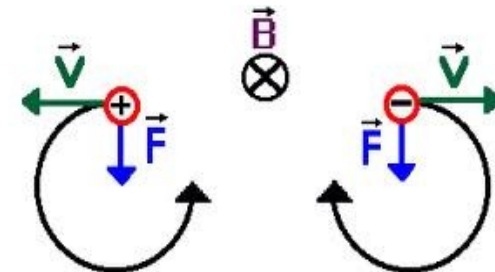
<https://www.youtube.com/watch?v=43AeuDvWc0k>



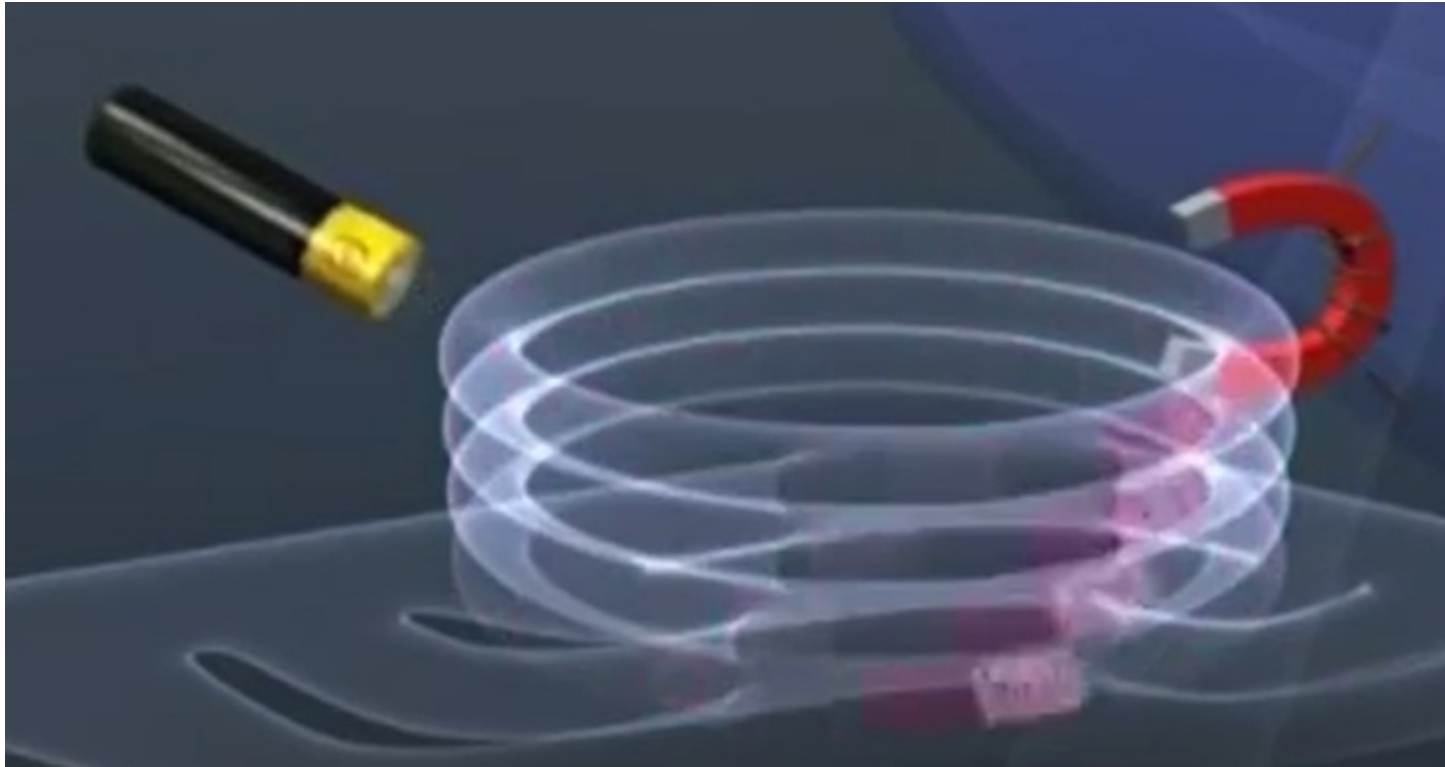
<https://www.youtube.com/watch?v=tUCtCYty-ns>



<https://www.youtube.com/watch?v=XU8nMKkzbT8>



<http://www.fnal.gov/pub/tevatron/tevatron-accelerator.html>



LHC uses both an electric field and a magnetic field.

Magnetic field deflect ions and electrons (electricity)

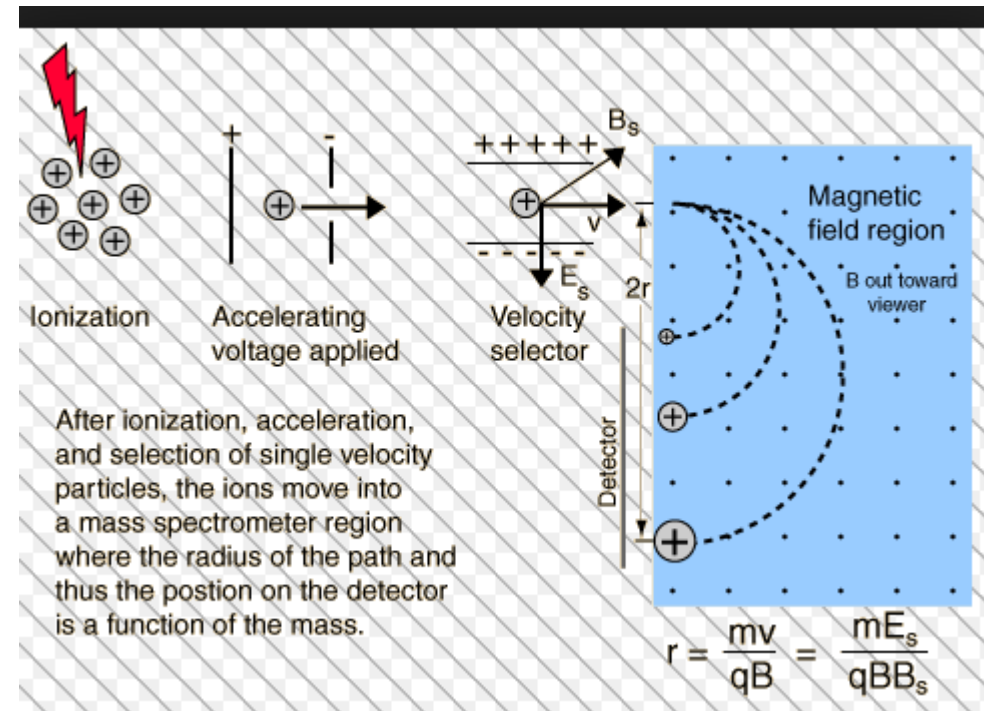
Application: mass spectrometer =

find the mass of ions –

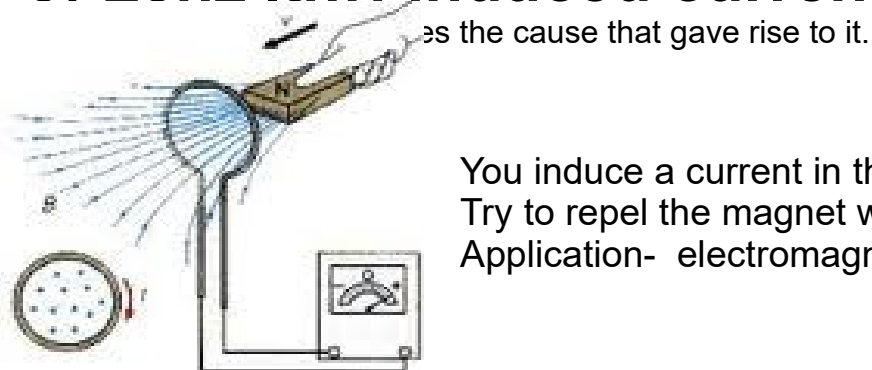
You can sort ionized molecules according to their masses.

More mass = more inertia = large radius (can't make a sharp turn).

See movie about cyclotron and
Cathode ray tube



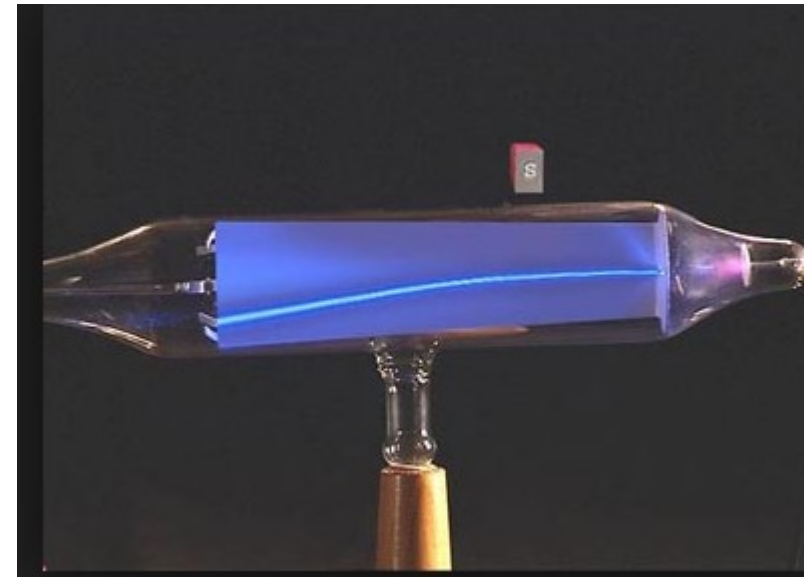
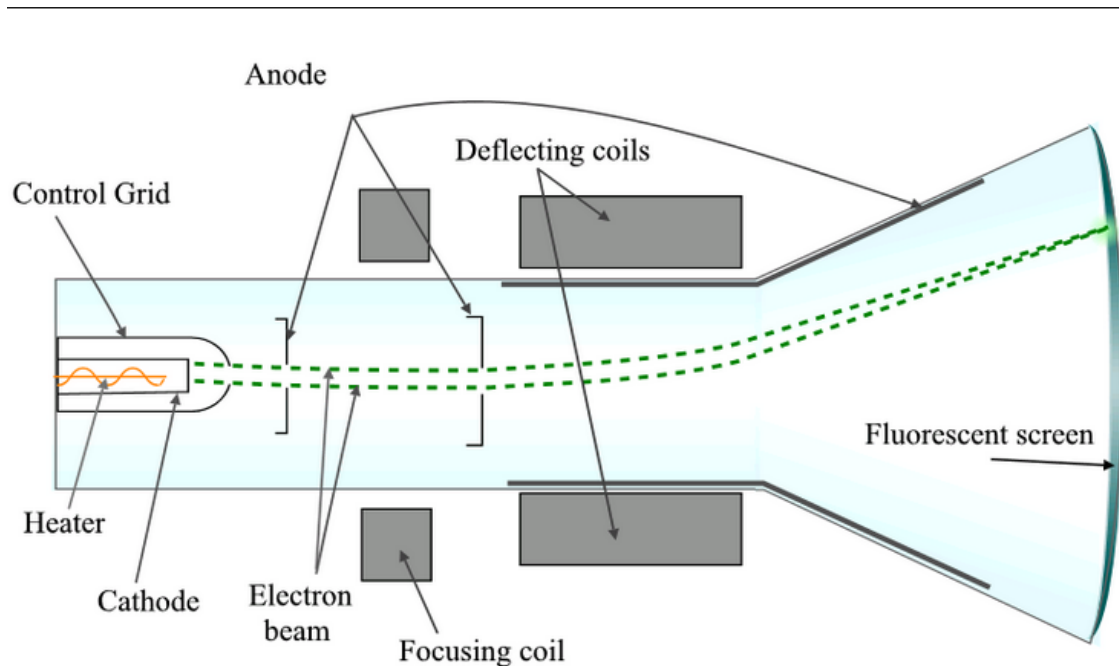
5) Lenz law: induced current



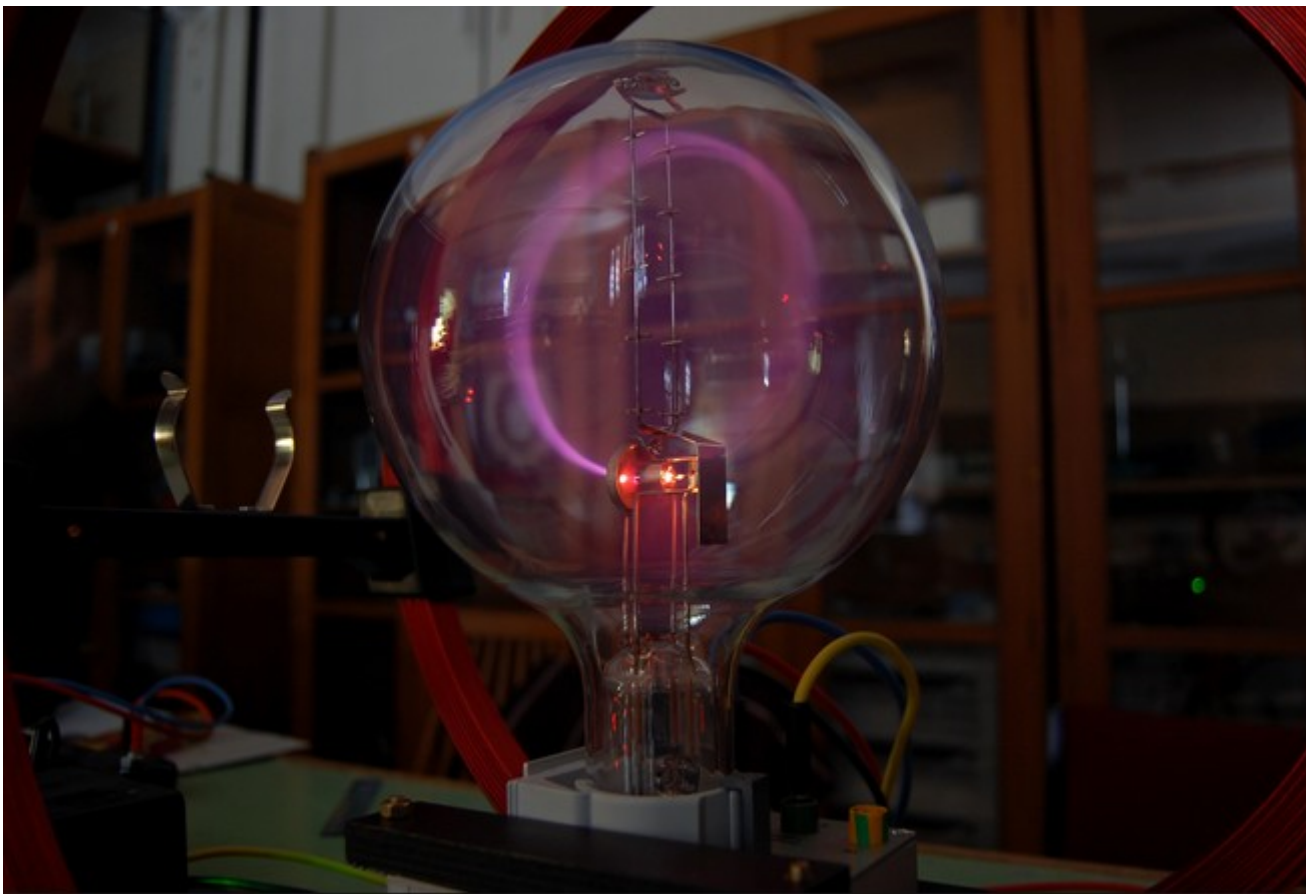
You induce a current in the loop. The induced current creates a magnetic field that Try to repel the magnet when it is going in and attract it when the magnet is going out.
Application- electromagnetic brakes – see experiment.

<https://www.youtube.com/watch?v=sPLawCXvKmg>

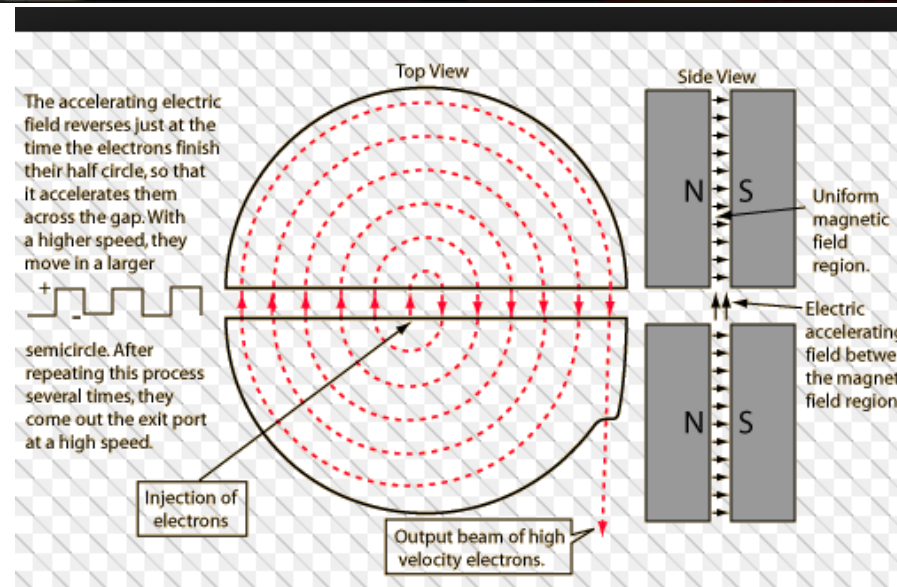
<https://www.youtube.com/watch?v=38XPT9sWlso>



The electric field between the cathode and the anode speeds up the Electrons. The magnetic field deflects the electrons.
(idea behind TV screen or oscilloscope)



cyclotron



Used for proton
Therapy and to make
radioisotopes

8) equations of Maxwell = unification of magnetism and electricity

AND GOD SAID,"

$$\nabla \times \bar{E} = -\mu \frac{\partial \bar{H}}{\partial \tau} \longrightarrow \text{Faraday's law of induction. A changing magnetic field (H) induces an electric Field (E) or alternative current.}$$

$$\nabla \times \bar{H} = \mathbf{J}_c + \epsilon \frac{\partial \bar{E}}{\partial \tau} \longrightarrow \text{Ampere's law completed by Maxwell. A direct current (J) creates a magnetic field. A changing electric field. creates a changing magnetic field. Even in space, in Absence of wire. That's what makes light. Auto generating E and B.}$$

$$\nabla \cdot \bar{D} = \rho_v \longrightarrow \text{Gauss's law. A distribution of charge creates an electric field in space. The lines Don't make close loop. The lines diverge from a source and converge to a sink (Van Graaf)}$$

$$\nabla \cdot \bar{B} = 0 \longrightarrow \text{Magnetic field make loop. They leave the north pole and come back into the south pole Back into the North. You can't single out a pole . You can single out a charge.}$$

LET THERE BE
LIGHT."

Playing with the equations, Maxwell found the speed of light C (3 10⁸ m/s).

When we compute the electric field, and the electric force between charges, we include a parameter $K_e = 9 \cdot 10^9$
For example: electric field from a point charge $E = K_e q / d^2$

When we compute the magnetic field we include a parameter $K_m = 10^{-7}$
magnetic field produced by a wire $B = K_m 2I/d$
if you compute the ratio K_e/K_m amazingly you get
9 10¹⁶ (m/s)² which is the square of the speed of light !!!!