Electricity and Magnetism

Waves

Wave – a disturbance that travels through a medium in such a way that energy travels through the medium but matter does not.

All waves (sound waves, waves on a string, seismic waves, electromagnetic waves) have a vibrating object as their source.

the compression and expansion of air produced sound waves

a vibrating atom produces electromagnetic waves

shaking the end of a string produces a wave

Waves need:

1) source of disturbance

2) medium than can be disturbed (we will learn the electromagnetic waves don’t need a medium, they are special)

3) some physical connection through which adjacent portions of the medium influence each other.

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Two types of waves:

transverse waves - the medium is disturbed perpendicular to the direction of wave motion.

example: waves on guitar string

http://en.wikipedia.org/wiki/Transverse_wave

longitudinal waves – medium is disturbed parallel to the direction of wave motion.

example: sound waves

http://en.wikipedia.org/wiki/Longitudinal_wave

Water waves are a combination:

http://www.kettering.edu/~drussell/Demos/waves/wavemotion.html

Amplitude – (A)The maximum distance of the object of the object from the equilibrium position. In the absence of friction, the object oscillates between – A and + A.

period – (T) the time it takes for the object to move through one complete cycle.

For example if you pulled back a pendulum. The time it takes to swing to the other side and back.

frequency (f) the number of complete vibrations per unit time.

The reciprocal of the period. ($f = 1/T$)

Waves have alternating maxima and minima separated by nodes. At a **node** there is no displacement.

In a transverse wave there are crests and troughs.

In a longitudinal wave there are regions of high density and low density.

- **wavelength** – the distance between two successive points that behave identically.

  for example: adjacent maxima

  Wavelength is related to how much space a wave takes up.

$v = \Delta x/\Delta t$

The velocity of a wave can be found by the distance the wave travels divided by the time

In 1 period, the wave moves 1 wavelength.

$$v = \lambda/T = f\lambda$$

Speed of a wave

The velocity of a wave is determined by the wavelength and the frequency

velocity = wavelength * frequency

$v = \lambda f$

or v = wavelength/period

$v = \lambda/T$

Interference of waves

When two traveling waves meet, they pass through each other without changing. When they overlap, they add up.

This is a superposition principle. You just have to add up the displacements of the individual waves point by point.

see figure 8.8

When add up in phase (crest overlap with the other crest), they add up **constructively**. The resultant is larger in amplitude.

When waves are out of phase, they add up **destructively**. The resultant is diminished. It is possible for two waves to cancel each other out.

http://www.colorado.edu/physics/2000/applets/fourier.html

http://id.mind.net/~zona/mstm/physics/waves/interference/intrfrnc.html

Reflection

Reflection: When a wave encounters a change in medium the wave reflects, bounces back.

Examples: string tied to a pole, light hitting a mirror, ocean wave reaching the shore.

http://www.kettering.edu/~drussell/Demos/reflect/reflect.html

Refraction when a wave encounters a change in medium it also can get bet (refracted). This happens when the speed of the wave changes.

examples: ocean waves when the depth of the water changes.

light going from air to water. This is why a stick appears bent at the surface o the water

http://upload.wikimedia.org/wikipedia/commons/b/b9/Refraction-with-soda-straw.jpg

Waves are important because light is a wave.

Light travels as oscillations in electric and magnetic fields, an electromagnetic wave.

electricity – study of electric charges. The charges can be stationary, or they can be moving. When charges move there is a current.

Charges exert forces on each other.

like charges repel, opposite charge attract

The two types of charges are positive and negative (these are just names to show they are different)

The force between charges depends on the magnitude of the charges and the distance separating them.

This is similar to the gravitational attraction of gravity.

SI unit of charge is the Coulomb (C)

Positive charges are carried by protons. The protons are stuck in the nucleus of the atoms in material.

Negative charges are carried by electrons. The electrons orbit around the nucleus. It is easy for atoms to share or pass around electrons.

protons have charge of 1.6×10^{-19} C

electrons have charge of $- 1.6 \times 10^{-19}$ C

same magnitude of charge

Proton has mass of about 1836 x mass of electron

Objects typically are neutral. They have equal numbers of positive and negative charges.

Objects are charged when there is a net positive charge (lost electrons) or a net negative charge (gained electrons)

When a charge is built up, it is because electrons were transferred from one object to another.

How charges interact

The electric force is an example of a ‘field force’.

Suppose charges A and B interact. Charge A produces an electric field. The electric field exerts the force on Charge B.

Since similar charges repel, the electrons like to separate themselves from each other.

A spark is a current that lasts only a brief amount of time.

Sparks occur when there is so much charge on an object that for the electrons to get away from each other, the electrons must jump off the object.

Electric fields

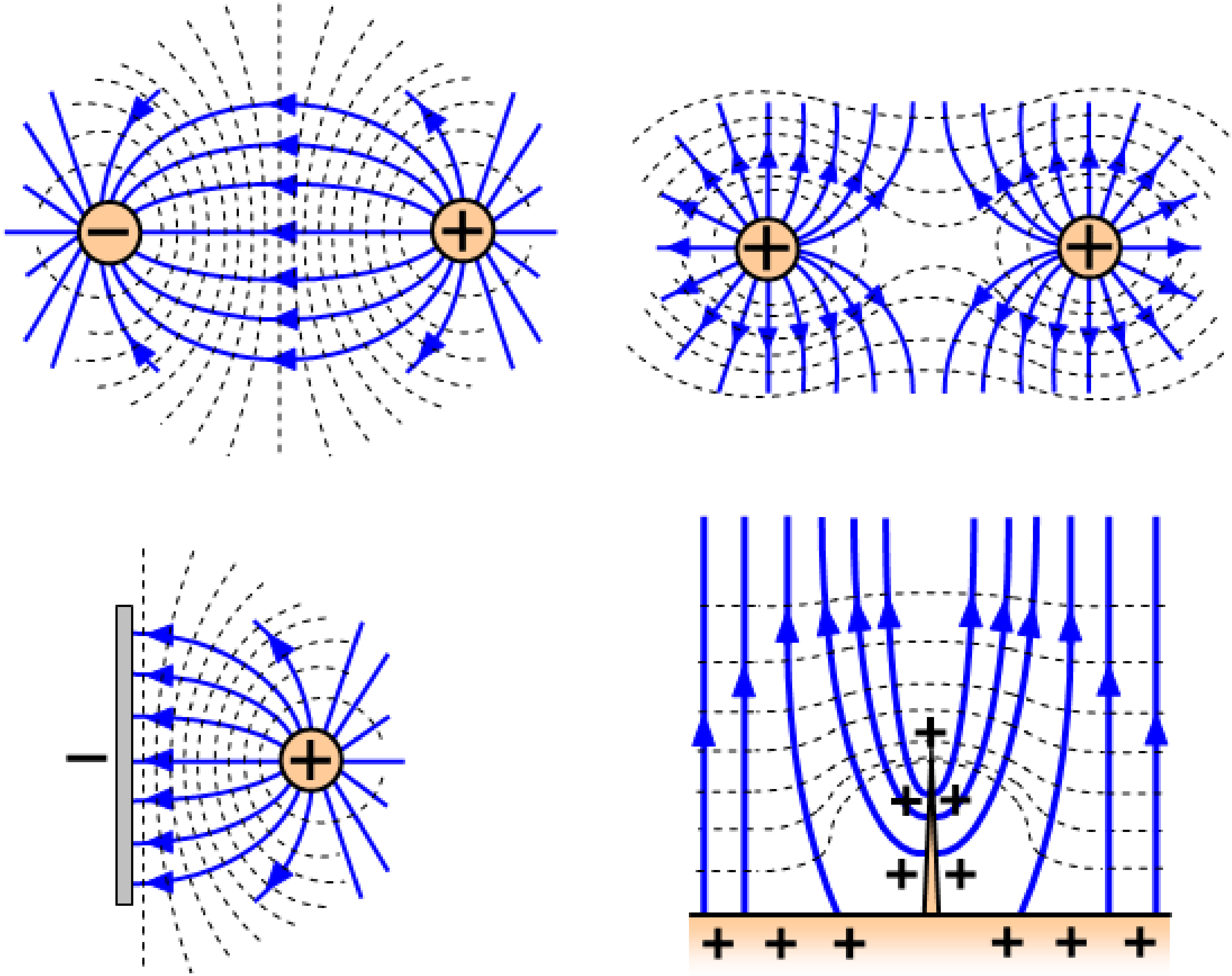
Electric fields are shown as field lines.

Field lines point away from positive charges.

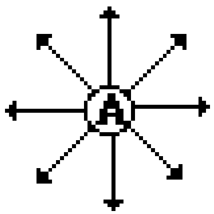
Field lines point towards negative charges.

Place a positive charge near a negative charge, the field lines will go from the positive charge to the negative charge.

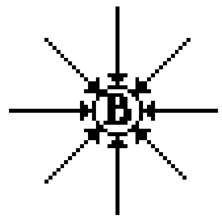
Electric field lines never intersect each other.



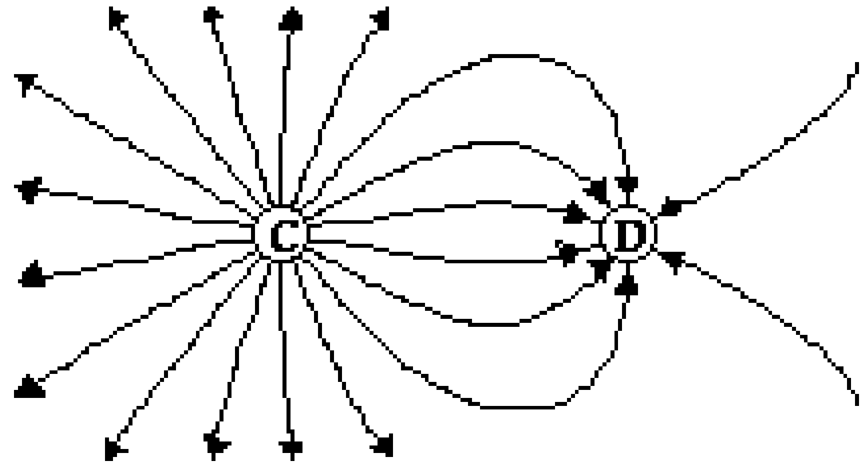
(resourcefulphysics.org)



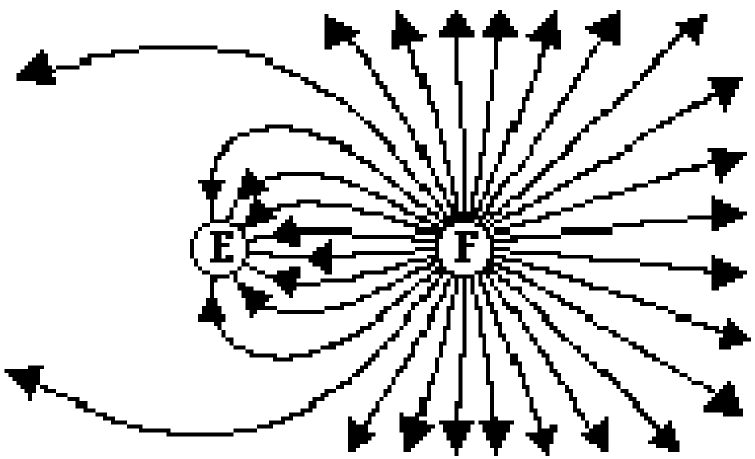
A: + or -



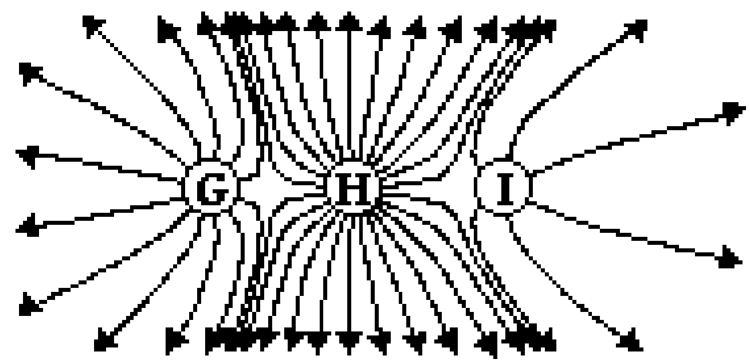
B: + or -



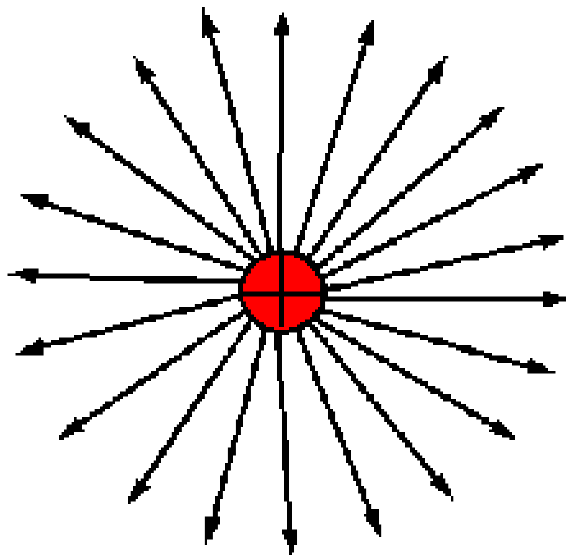
C: + or - D: + or -



E: + or - F: + or -



G: + or - H: + or - I: + or -



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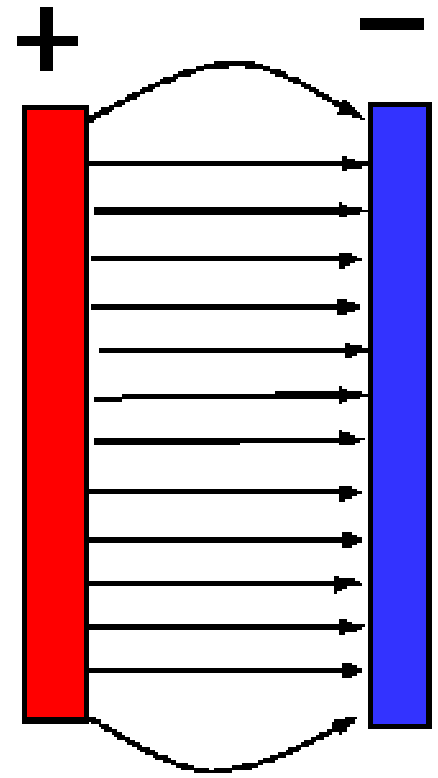

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Magnetism

Electricity depends on charges.

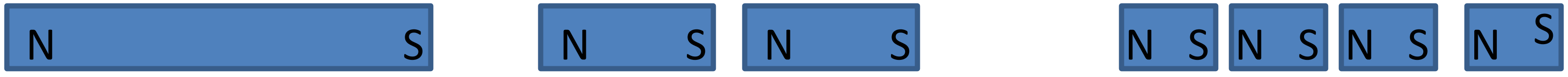
Magnetism depends on ‘poles’. (North and South)

An object can have only one type of charge. For example only positive charges.

Objects ***<u>cannot</u>*** have only one type of magnetic pole.

Magnetic monopoles do not exist.

If you cut a magnet into two pieces, you will have two magnets each with a north and south pole. We can repeat this over and over again.



Magnets will exert forces on each other via magnetic fields.

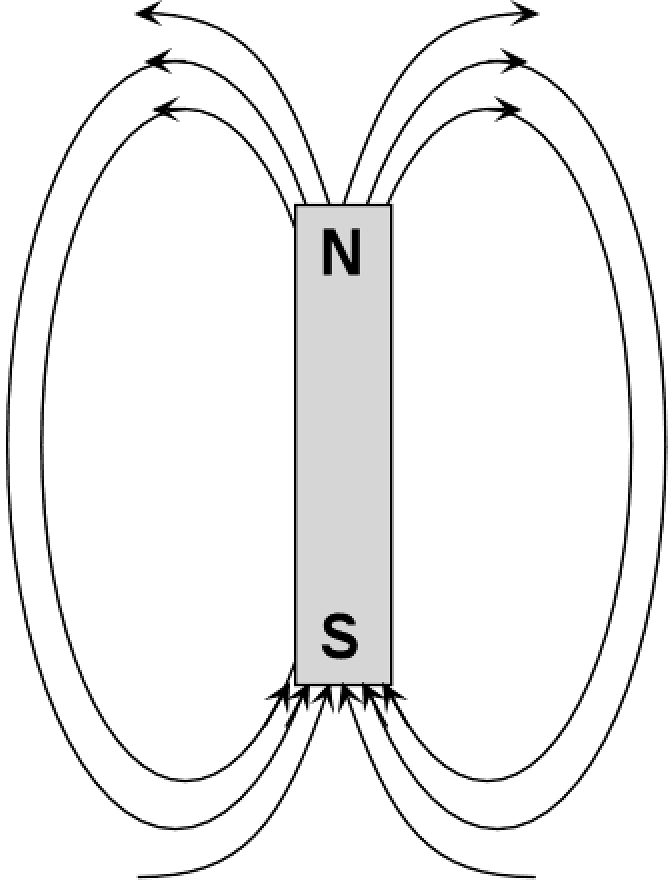
Place two magnets near each other. Magnet 1 has a magnetic field. Magnet 2 will align itself with the magnetic field from magnet 1.

Magnet 2 want to align itself with the magnetic field lines of the magnetic field from magnet 1.

Magnetic field lines

Magnetic field lines go from the north pole of the magnet to the south pole. Then they follow the magnet back to the north pole.

Magnetic field lines form closed loops.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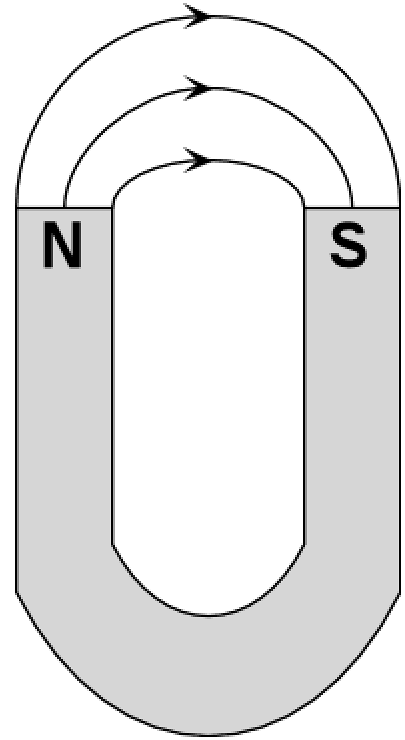
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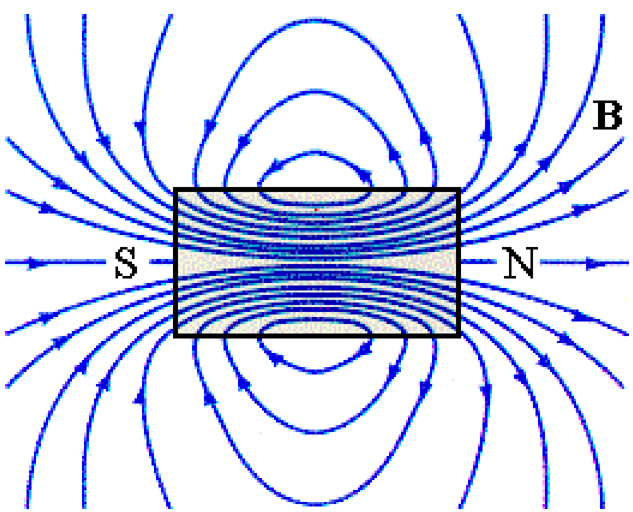
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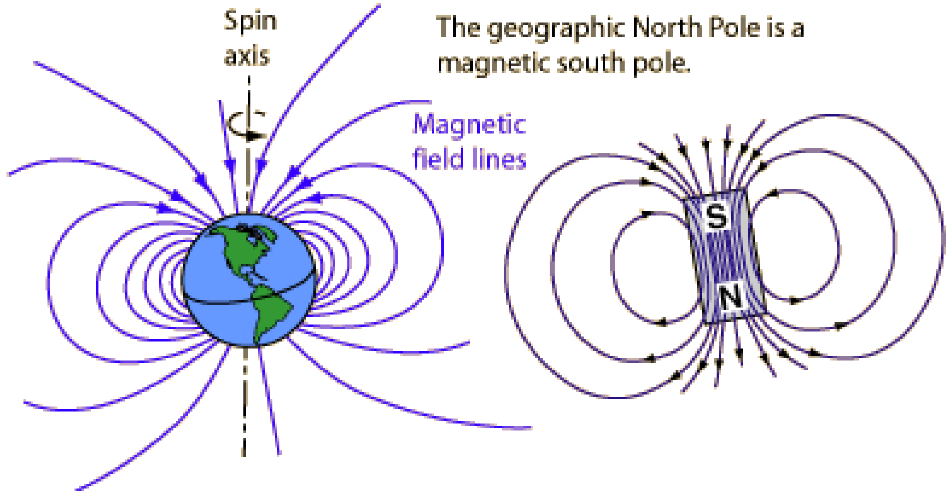
Earth's Magnetic Field

Due to the rotation of the Earth and the iron core inside it, the Earth has a magnetic field. The field is similar to that of a bar magnet.



The north pole of a compass needle is a magnetic north pole. It is attracted to the geographic North Pole, which is a magnetic south pole (opposite magnetic poles attract).

If your compass is made of a needle tie to a string, the needle want to follow the field lines.

Not only will the needle move in the horizontal plane, it is free to point in different vertical directions.

At different latitudes, the needle will have different dip angles.

At the magnetic south pole the needle will point straight down.

At the magnetic north pole the needle will point straight up.

- Also the magnetic poles are not aligned perfectly with the geographic poles.
- The magnetic south pole is somewhere in northern Canada.
- So a compass points towards the magnetic south pole instead of the geographic north pole.

Because of this if you hold a compass in New York and another in California, the direction of the needles will be different.

There is evidence that sometimes, for unknown reasons that the magnetic field of the Earth reverses itself.

When certain magnetic rocks harden, they will align themselves with the magnetic field of the Earth.

Sample show that rocks of different ages are aligned in different directions.

http://science.nasa.gov/headlines/y2003/29dec_magneticfield.htm

Magnetic force

Magnetic field exert forces only on moving charges.

Also the charge cannot be moving parallel or anti-parallel to the magnetic field.

There has to be some angle in between the direction of motion and the field.