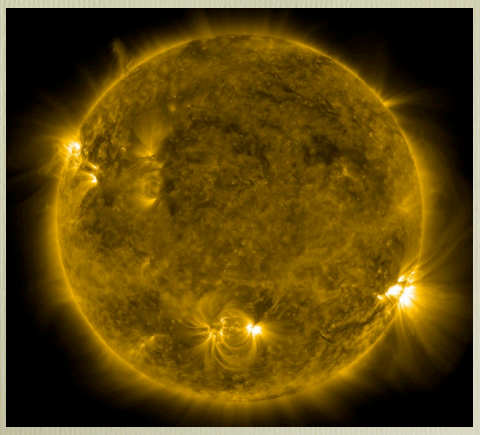
Fields and Waves

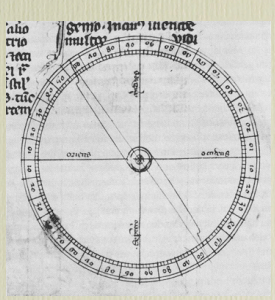


Sunspots

Magnets first observed as "lodestones": lumps of magnetic iron-ore (magnetite, or Fe_3O_4).

Can be suspended from a string and will point North. Used (?) by Vikings.

Letter on the Magnet by Petrus Peregrinus written in 1269.

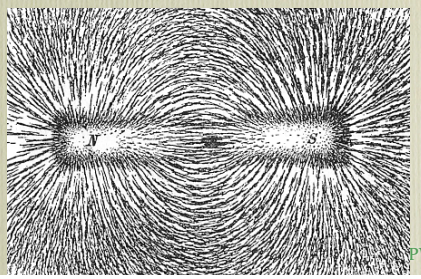


Wikisource

PW

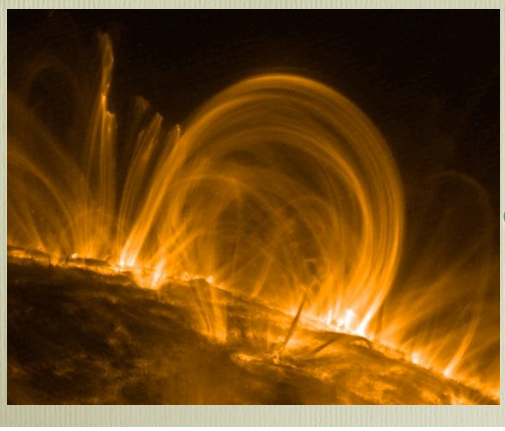
Basic Observations

- Some materials act as if they contain magnetic charges, or poles.
- Like poles (NN, SS) repel, unlike (NS,SN) attract
- Iron filings will map out “magnetic field”



PW/Wikipedi

Another way to see the field

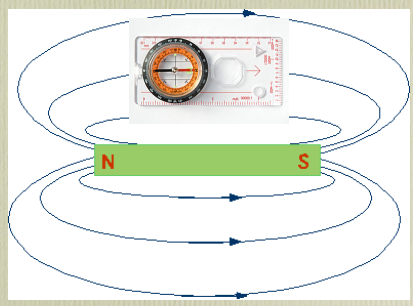


Coronal loop in sun (NASA)

Text

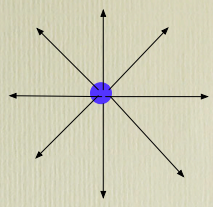
- Can map out magnetic field with a compass

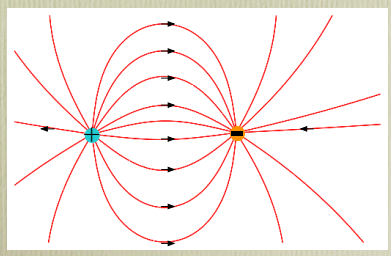
PW, Wikipedia



Note: (very important). Field has nothing to do with matter, can exist in vacuum

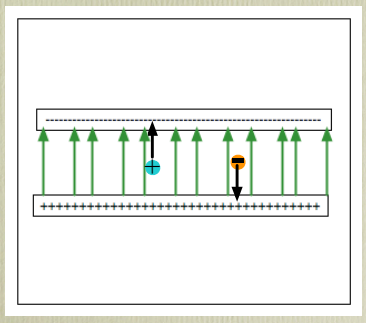
- To visualize electrical forces, it helps to think of electric **field**.
- e.g a point + charge
- note direction is given by the way a positive charge would move





or a positive and a negative charge

- Can make a constant field (like gravity near the earth) by arranging plates of charge.
- Lets us visualise how charges would move



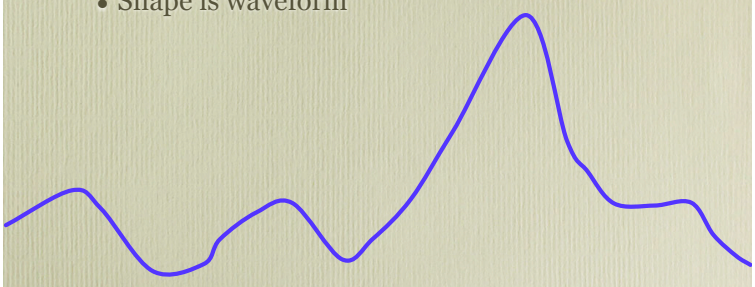
Waves

- Easiest to visualize are water waves or waves in string:
- One dimensional waves: e.g.
- Waves in slinky
- Waves in string
- Sound waves
- Light Waves

Text

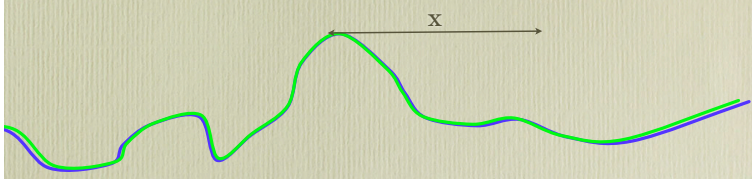
Waves can be any shape

- Shape is waveform



Text

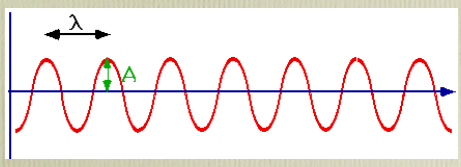
Most waves we are interested in move



- Speed (velocity) is distance that a peak moves in a second

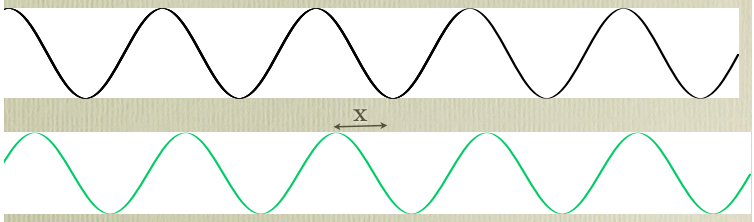
Mostly (for light anyway) we are interested in "periodic waves"

- Define wavelength λ = distance between peaks (or troughs: it doesn't matter)
- Amplitude is "height" of wave



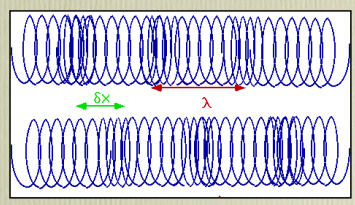
Again can define speed

- (need to be careful since it repeats)

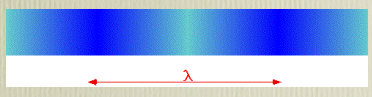


Longitudinal Waves

- i.e. particles move in direction of wave
- e.g. Slinky

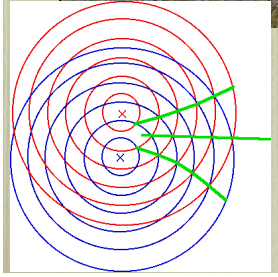


- Sound Waves
- Molecules move backwards and forwards to create regions of higher or lower density.
- Note sound travels through a solid in exactly the same way

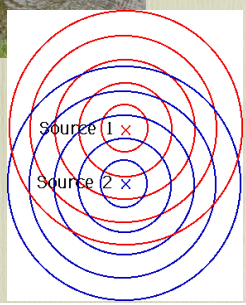


If we have two sources, waves will pass through each other

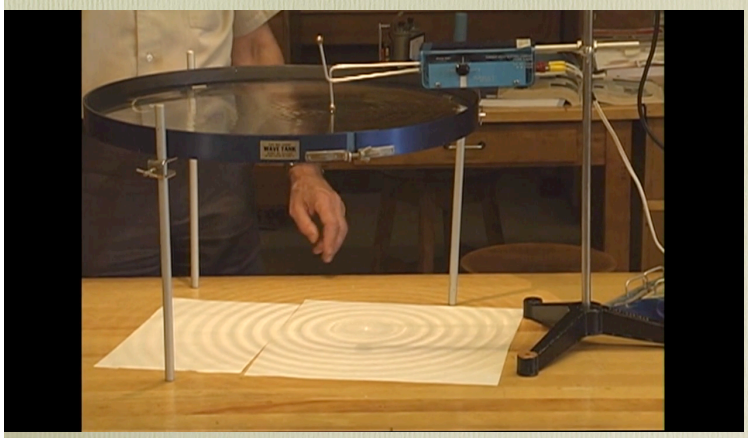
PW,



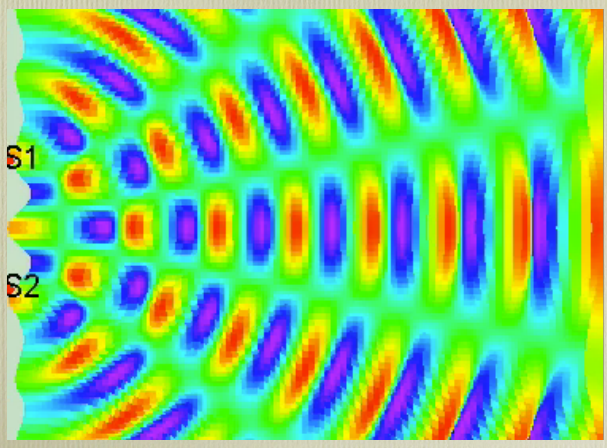
there are places where the crests add up



How do waves interact?

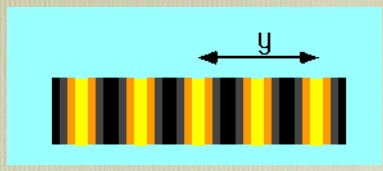


waves can add up or cancel out, like this



Wikisource

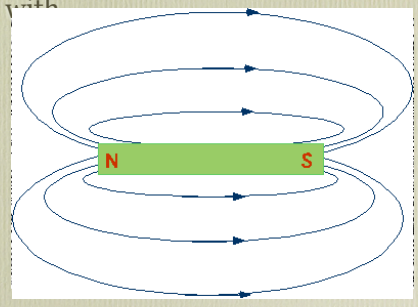
- When you do this for light, you get
- bright bands (adding up)
- dark bands (cancelling out)



Direct Demonstration that light is a wave (also lets you find λ)

So what is it a wave **in**?

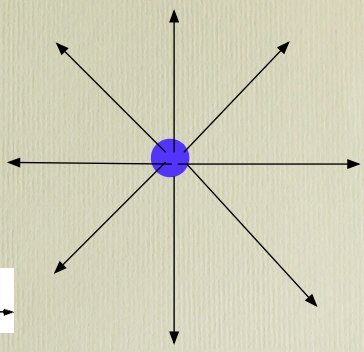
- Can map out magnetic field with iron filings



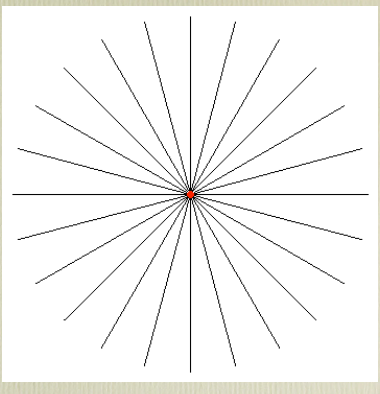
PW, Wikipedia

Charge (e.g. proton, electron) produces **electric** field

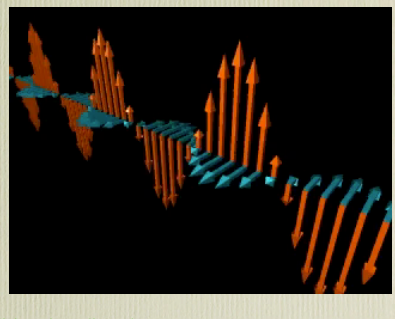
- Moving this charge changes field



- "kink" in lines of forces travels out at speed of light

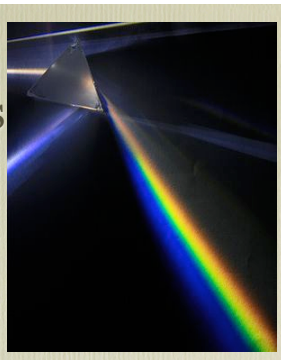


Faraday + Maxwell predict light from induced fields

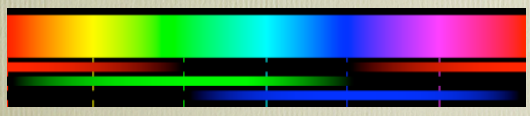


- magnetic field is at right angle to electric.
- which is why it is **Electromagnetic Radiation**

Prism splits light into its constituent colours

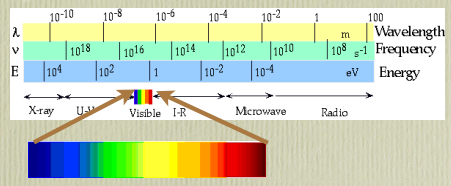


- Red (wavelength of 800 nanometres = 0.8 microns)
- Green ~520 nm
- Blue ~400 nm



Text

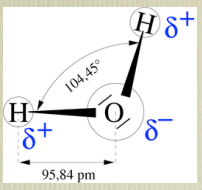
- Light is part of the whole electromagnetic spectrum



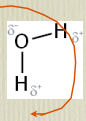
- All waves satisfy $f\lambda=c$
- (frequency ×wavelength = speed)

Matter and Waves Interact: e.g.

How does a microwave oven work?



1. Water molecule consists of charges
2. E.M wave "spins" molecule
3. transfer heat to surroundings



Why microwaves?

1. Visible & IR too strongly absorbed (that's how you grill meat!)
2. Need wavelengths short enough to fit inside oven
3. Fixed on 2.24 GHz (λ = 12.2 cm) produced by magnetron
4. heats water much more than fat or bone
5. microwaves are used for communication: e.g. GSM cell-phones use 900 MhZ & 1.8 GHz

Text