Electromagnetic spectrum

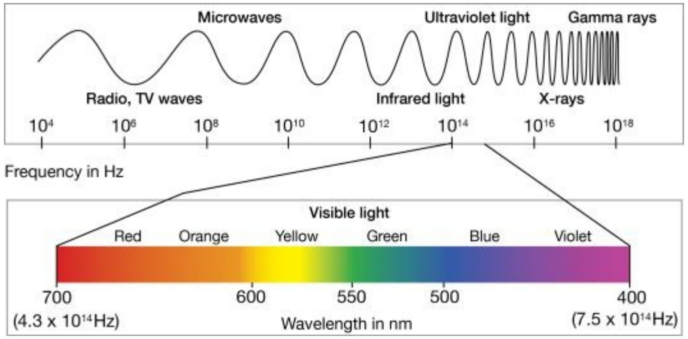
The big picture

Science explanations

• a family of radiations: ‘electromagnetic waves’ that behave similarly (reflection, refraction, dispersion, diffraction, interference, polarisation)

• differences: wavelength, frequency & photon energy;

ionising v non-ionising



How science works

• Practical applications of all parts of the spectrum

• Risks and benefits, health studies, making decisions

• Uncertainties in science

Main teaching challenges

The **electromagnetic spectrum** is

- mostly invisible
- an abstract idea

Students understand more when

- it is introduced carefully, by stages. **Start with visible light then extend through both UV & infrared.**
- it is made perceptible (concrete)
- connects with students' lives and interests

Prior learning

- sound (vibrations and waves)
- light
- source-journey-detector model of radiation

TASK:

How does the model apply to (1) sound? (2) light?

Source–journey–detector

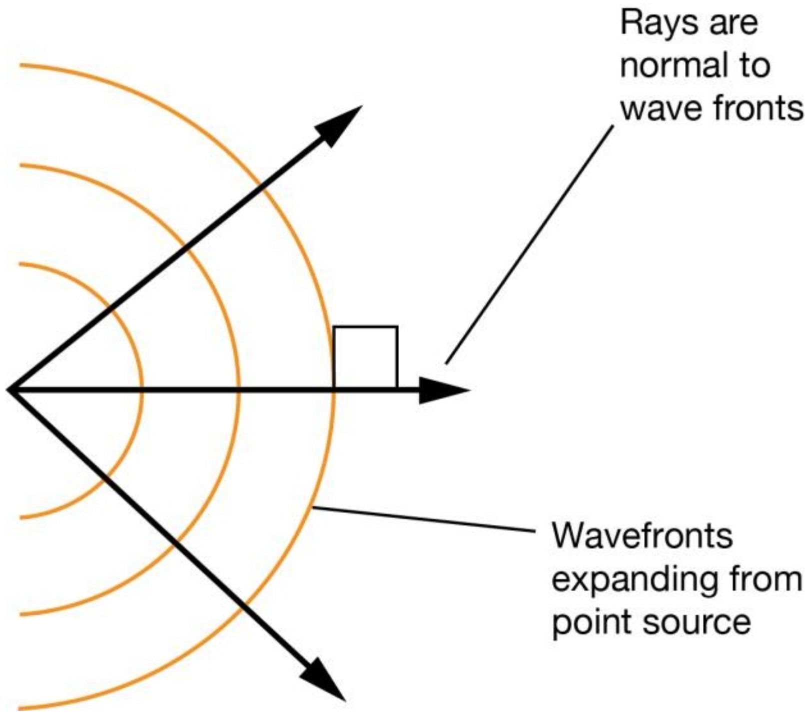
A useful model: makes the invisible more concrete.

Task: Name at least 1 source and 1 detector for each part of the full spectrum.

- gamma rays
- X-rays
- ultraviolet
- visible light
- infrared
- microwaves
- radio waves

Use sources & detectors, either as demonstration experiments, or as a circus of class experiments.

Picturing the journey



Photons, frequency, wavelength

speed of all electromagnetic waves, $c = f\lambda$

where f = frequency and λ = wavelength

$c = 3.0 \times 10^{8}\,\mathrm{m s^{-1}}$

… in ANY (inertial) frame of reference.

photon energy,

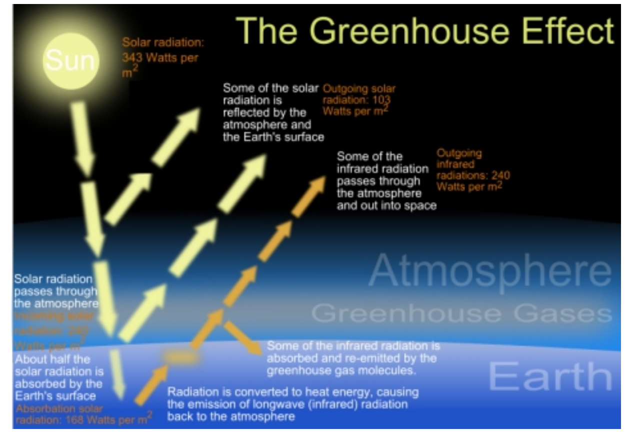
$$E = hf$$

Planck constant, $h = 6.63 \times 10^{-34}\,\mathrm{J \cdot s}$

Some contexts for teaching

Science in the news

e.g. global warming.
The greenhouse effect: a story about infrared radiation of different wavelengths



Medical imaging

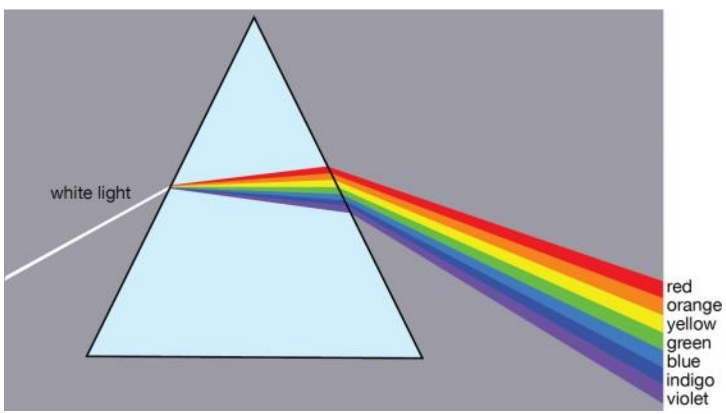
www.teachingmedicalphysics.org.uk/

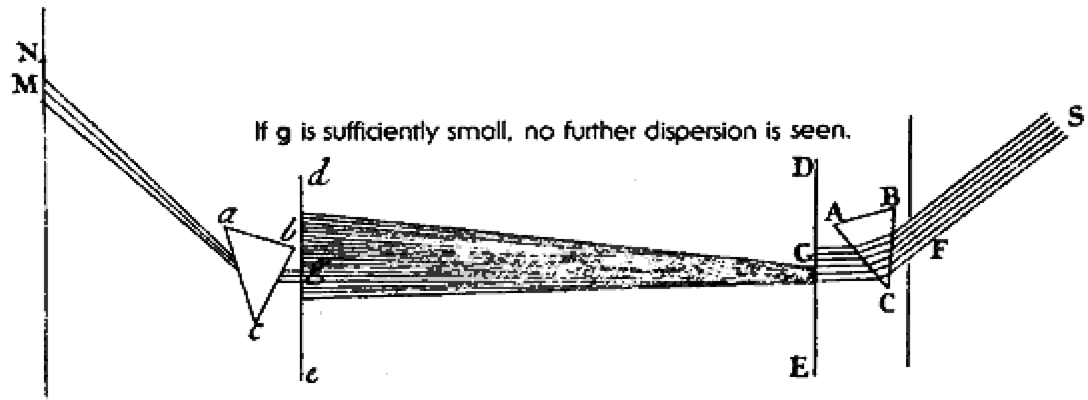
Modern astronomy

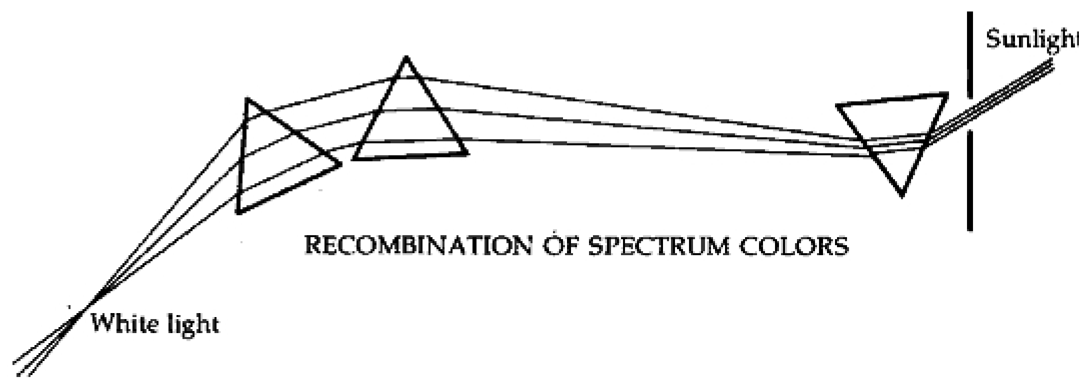
detecting emissions across the whole em spectrum Chromoscope

The visible spectrum

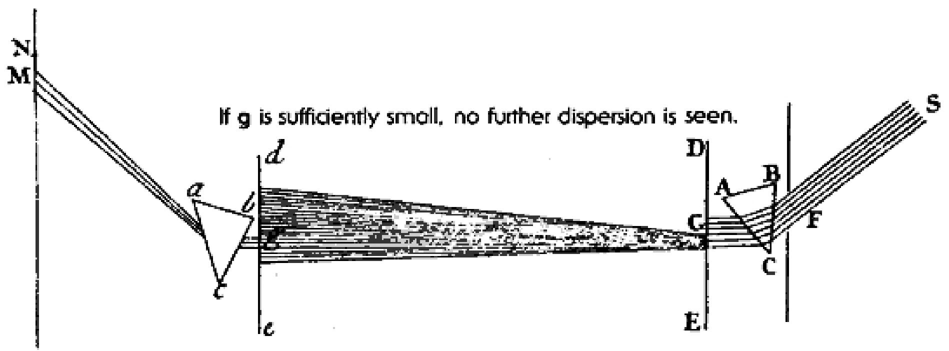
Light spectrum with a prism

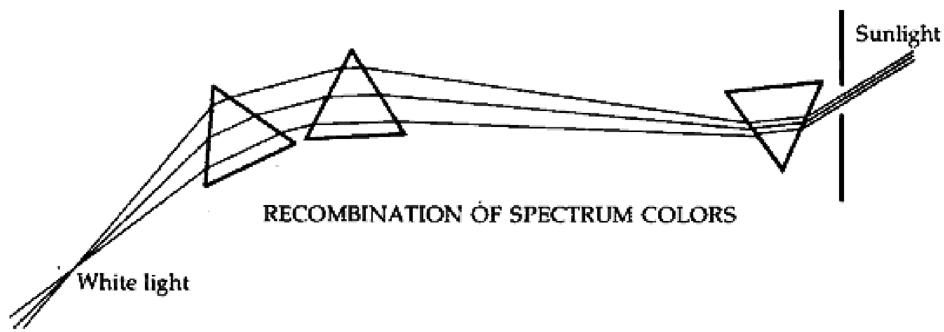






Newton’s prism experiments

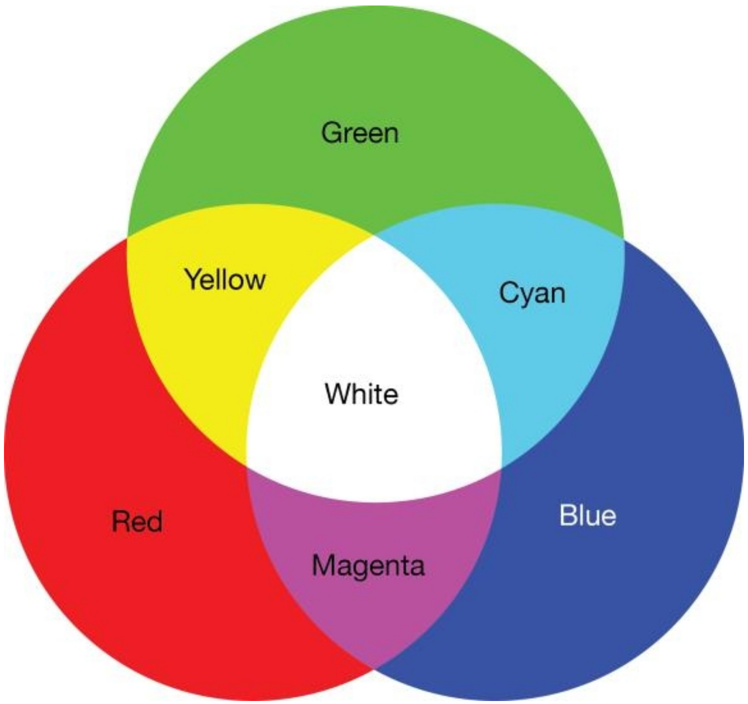




(light entering from the right)

Combining colours of light

Additive principle



Note: Absorption of light by surfaces and filters involves <u>subtractive</u> principle (e.g. adding pigments)

Combining colours of light

SEP Activity 2

with light emitting diodes (LEDs) as light sources

Power source: 3V lithium batteries (disc-shaped)

Signalling with optical fibres

SEP Activity 3

Radiation model:

journey

source → detector

source: LED from previous experiment

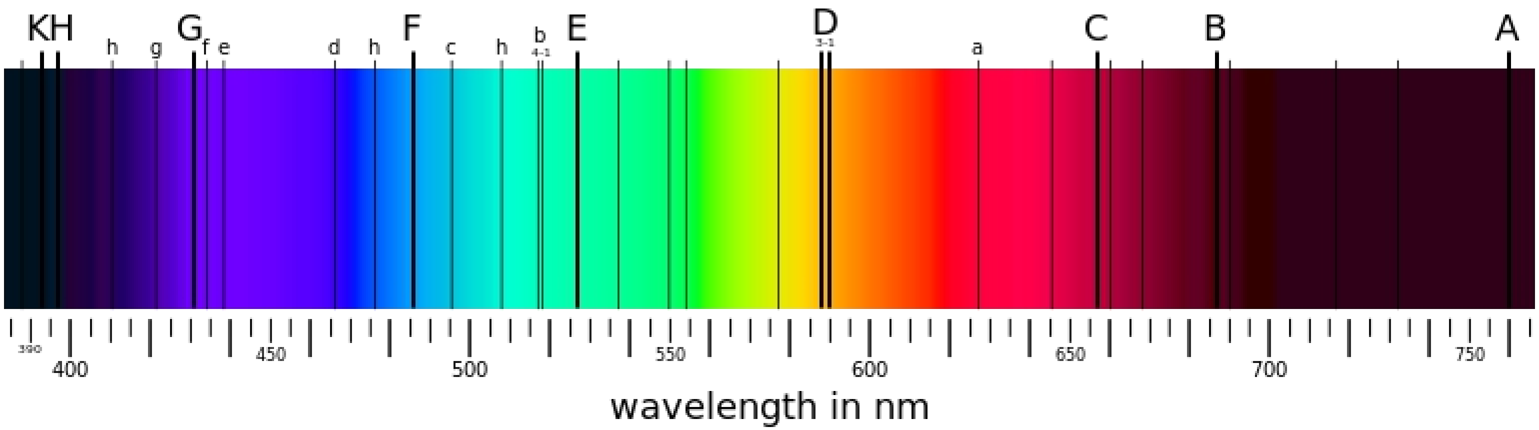
journey: through an optical fibre

detector: sheathed light dependent resistor (LDR) connected to a digital multimeter

Light sources

- Continuous spectra (temperature)
- Line spectra (emission and absorption)

the Sun: an absorption line spectrum



Light sources

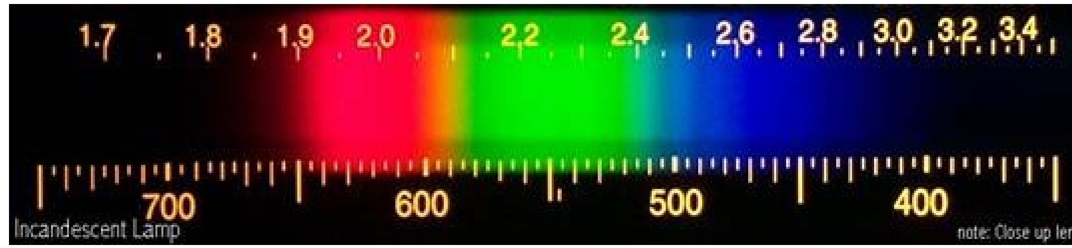
SEP Activity 1

Make a spectroscope.

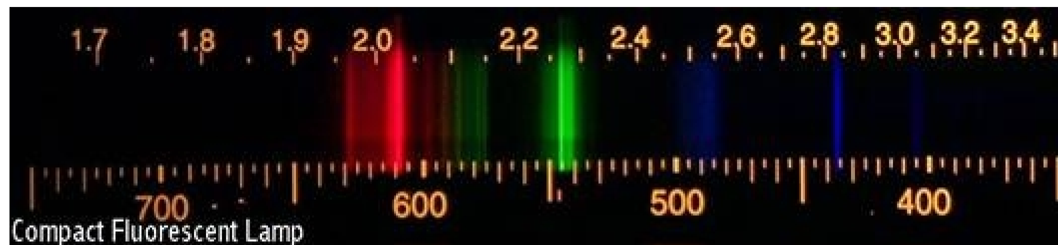
Use your spectroscope to compare light sources.

What you see

Filament lamp



Fluorescent lamp



- 700 nm
- 700 nanometres

- 400 nm
- 400 nanometres

Photo credit http://home.comcast.net/~mcculloch-brown/astro/spectrostar.html

Beyond the visible

Detecting infrared

Radiation model: **source** —**journey**→ **detector**

source: non-luminous objects (warm, cool)

Classic experiments: various surfaces with IR thermometer as detector; TV etc ‘remote’ with mobile phone camera as detector; radiant heater with hand as detector (Al foil, one side blackened)

SEP Activity 4

detector: infrared photo-transistor connected to a digital multimeter

Signalling with infrared

SEP Activity 5

Use terminal blocks to make

- transmitter (source) – infrared LED in series with a 82 Ω resistor, powered by 2 AA batteries
- receiver (detector) – photo-transistor in series with an LED, powered by 2 AA batteries

Allow an air gap of 5-6 cm (journey)

Also: Try detecting the infrared signal emitted by a TV remote control when you press one of its buttons.

Detecting ultraviolet

Radiation model: source —journey→ detector

Classic experiments: UV lamp illuminating detectors such as fluorescent rocks, white fabrics with and without ‘optical brighteners’, fluorescent nail polish

SEP Activity 7

source: sunlight

detector 1: phosphorescent film

detector 2: UV-sensitive beads

journey: detect direct sunlight, or sunlight that has passed through a windowpane; filtering effect of sunscreens & sunglasses

Detecting microwaves

Radiation model: source —journey→ detector

Classic experiment: microwave source & detector with accessories

SEP Activity 6

source: mobile phone (phone a friend?)

detector: phone flasher

journey: Place various materials between the source and detector (e.g. conductive mesh, paper, dry muslin, wet muslin).

Mobile phones

Precautionary principle:

UK government recommends children under 8 years avoid using mobile phones.

How would you *know* if there were health risks associated with using mobiles?

Health studies: sample size & matching populations.

Possible student activity:

Use Ofcom's Sitefinder database to find out about local mobile network base stations. Compare exposure levels with information from the Health Protection Agency.

Detecting radio waves

Radiation model: **source** —**journey**→ **detector**

source: SEP short-circuit kit, SEP 'noisy motor', AM broadcast

detector: simple AM radio

Detecting gamma rays

Radiation model: **source** —**journey**→ **detector**

Classic experiment

source: radioactive Co-60 or Ra-226

detector: GM tube with audible output plus ratemeter or counter

Properties of em waves

Diffraction

Diffraction: waves passing through a narrow opening spread as they emerge on the other side. **Ripple tank demonstration.**

Diffraction grating

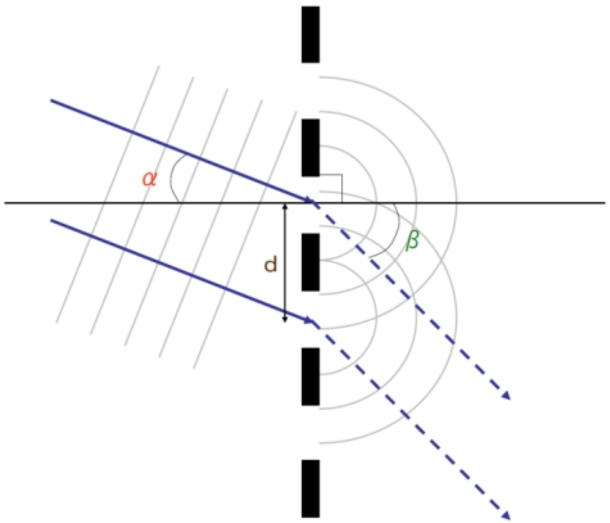
Diffraction grating: a surface with many fine grooves in it, which act as parallel openings.

Spectrum from a diffraction grating

Wavefronts diffracted by grooves of the grating

• superposition produces an interference pattern.

• pattern width depends on wavelength (colour).



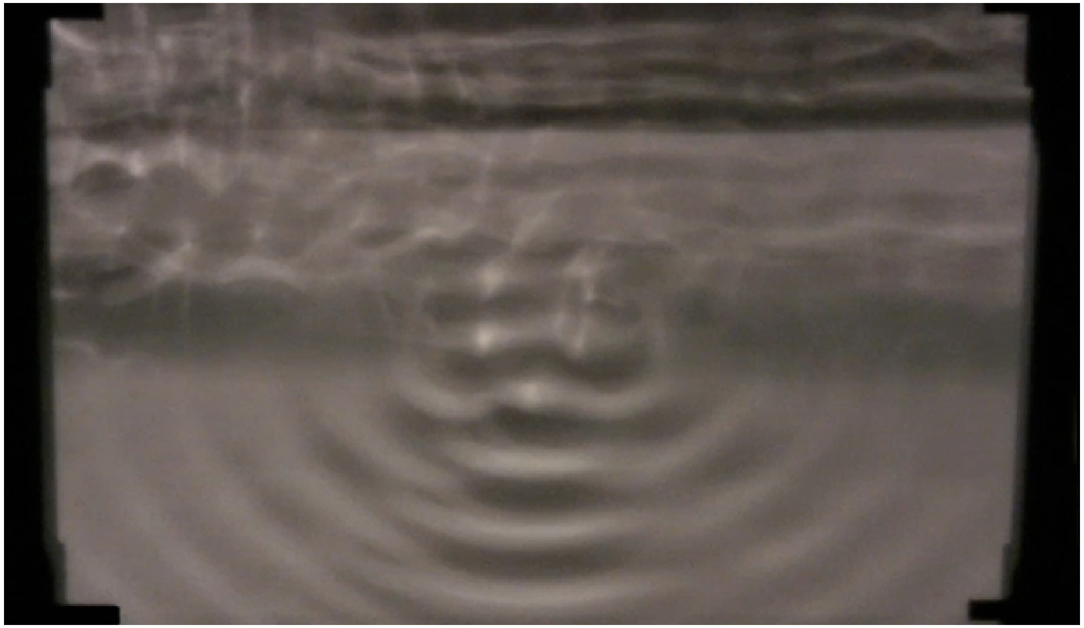
Diffraction at a single slit

View a strong light source through narrow gap between two fingers.

See the parallel black lines? – a diffraction pattern.

diffraction

in a ripple tank



SEP diffraction grids

SEP Activity 8

Holding the grid close to your eye, view a point source of visible light with grid of

- horizontal lines
- zigzag lines

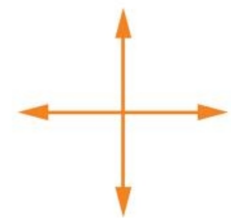
Polarisation of light

em waves: transverse electric & magnetic oscillations, produced by vibrating charges

A **polarising filter** absorbs components of electric field oscillations in one plane (and transmits components of the oscillations in the perpendicular plane).

A light wave is known to vibrate in a multitude of directions...

... in general, a light wave can be thought to vibrate in a vertical plane and in a horizontal plane.



Relationship between long-chain molecule orientation and the orientation of the polarization axis

When molecules in the filter are aligned vertically, the polarization axis is horizontal.

When molecules in the filter are aligned horizontally, the polarization axis is vertical.

Support, references

talkphysics.org

SPT 11-14 *Light & sound*

Gatsby SEP booklets … free @ National STEM Centre e.library

Radiation and communication

Seeing beyond the visible

Light and matter

Practical resources available from Mindsets

David Sang (ed, 2011) *Teaching secondary physics* ASE / Hodder