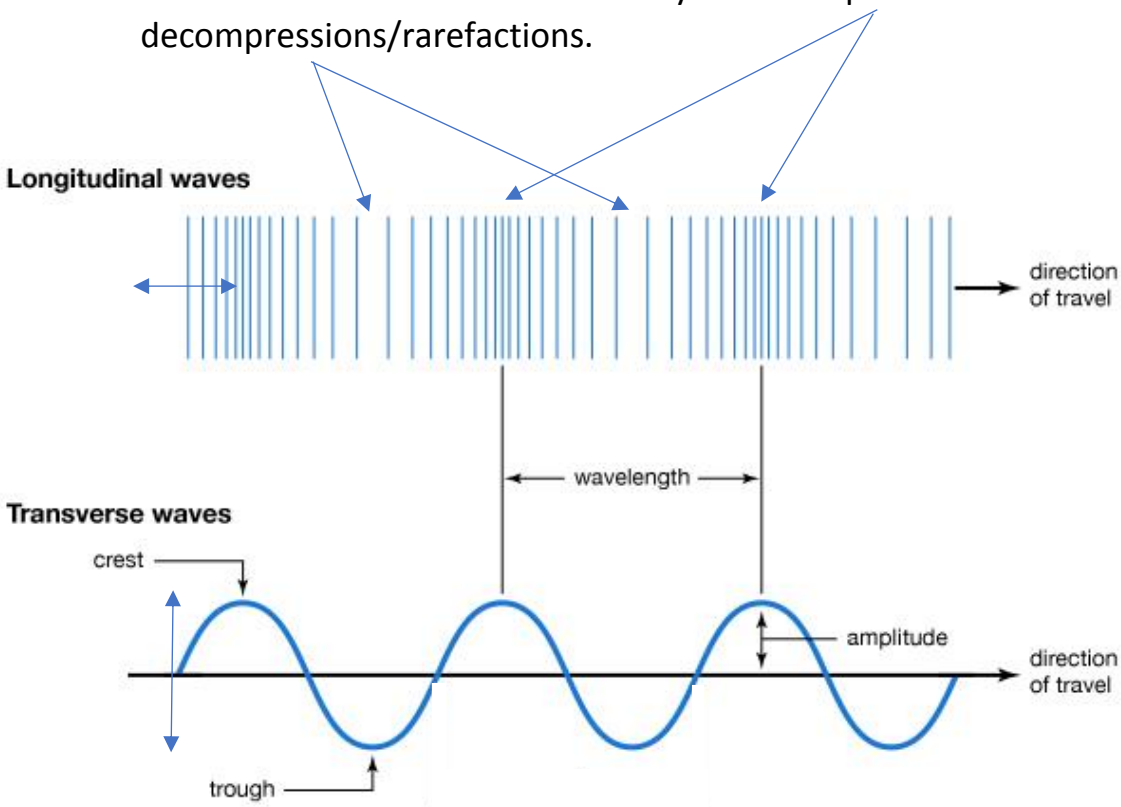
Topic 6 Waves

6.1.1 Transverse waves are produced by vibrations at right angle to the direction of travel of the wave. They have crests and troughs. Longitudinal waves are produced by vibrations parallel to the direction of travel of the wave. They have compressions and decompressions/rarefactions.



6.1.2 Wavelength = length of a wave, measured from crest to trough
Symbol λ or compression to rarefaction
Unit m

Amplitude = maximum displacement of a point on a wave
Symbol A (measured from the rest position or half the height)
Unit m

Frequency = the number of waves passing a point in 1 second
Symbol f
Unit Hertz, Hz

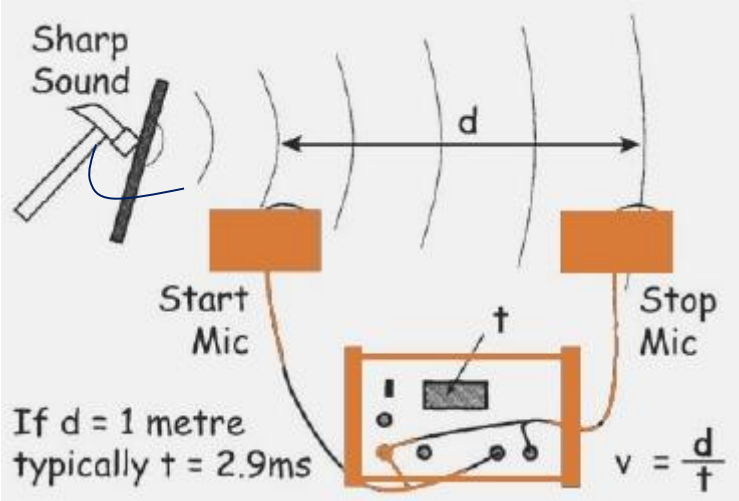
Period = the time for 1 wave to pass a point $T = \frac{1}{f}$
Symbol T
Unit s

Wave speed = $\frac{\text{distance travelled}}{\text{time taken}}$ $\frac{m}{s}$ = frequency x wavelength
Symbol v Hz m
Unit m/s

The speed of water waves can be determined via a ripple tank

see Practical Skills doc

The speed of sound can be determined using two microphones connected to a fast timer



Microphone 1 detects the sound and switches the timer on

Microphone 2 detects the sound a short time later and switches the timer off

We can measure the distance between the microphones with a ruler and divide by the time to get the speed

Practise what you have learned :-

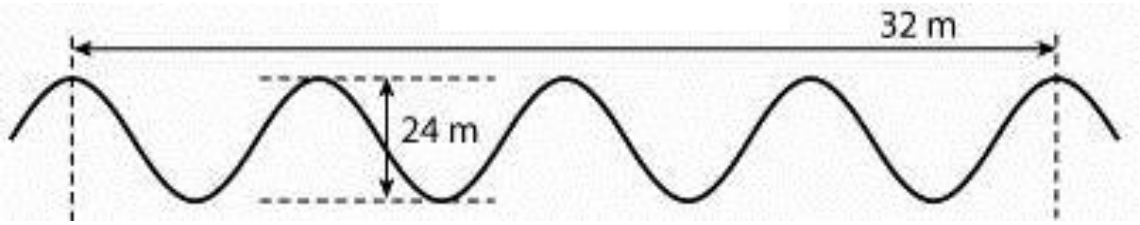
1. Light waves can travel through a vacuum.

   Are light waves transverse or longitudinal ?

2. Sound waves can't travel through a vacuum.

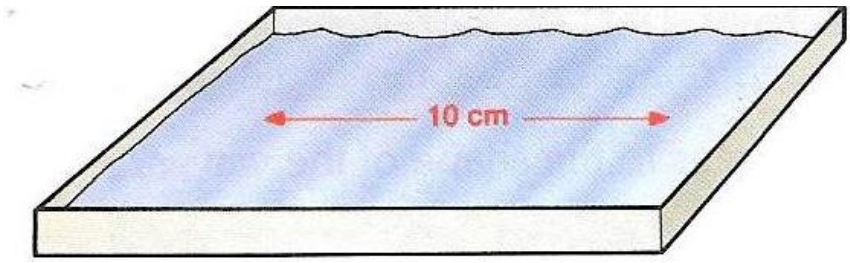
   Are sound waves transverse or longitudinal ?

3. Work out the wavelength and amplitude of the following wave



4. A girl notices that 270 water waves pass by her in one and a half minutes. Work out the frequency of the water waves.

5. Water waves were observed on a ripple tank as shown in the picture



(a) Work out the wavelength of the water waves

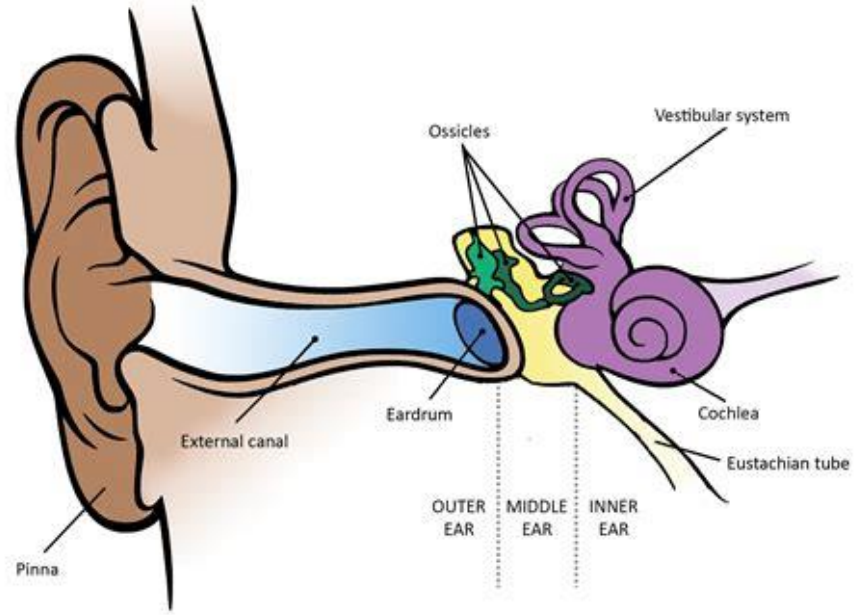
(b) If the frequency of the waves was 20Hz, work out their speed

6. In an experiment to determine the speed of sound, two microphones were placed 2m apart. The microphones switched a timer on and off when they detected the sound. The time for the sound to travel between the microphones was 5882 microseconds. Work out the speed of sound.

6.1.4 Sound waves Physics only

Being longitudinal, sound waves can only travel through substances, not space

When a sound wave reaches an ear it causes the eardrum to vibrate



A human ear can hear frequencies from 20Hz up to 20kHz
Above 20kHz sounds are called ultrasounds
Below 20Hz sounds are called infrasounds

6.1.5 Waves for detection and exploration Physics only

The reflection of ultrasound at the boundary between two substances can be used to form images of unborn babies, to detect cracks in structures, to detect fish in oceans – processes which collectively are called SONAR
SOUND NAVIGATION AND RANGING

The basic principle is : send out an ultrasound, time how long it takes to reflect back then calculate how far away the object is using distance = speed x echo time/2

Seismic waves are produced by earthquakes
P waves (primary) are longitudinal, travel through solids and liquids
S waves (secondary) are transverse, travel only through solids
Detection of the waves by seismometers enables seismologists to work out the structure of the Earth

Practise what you have learned :-

1. The speed of sound in air at 35°C is 352m/s.
   Work out the frequencies of sounds, at that temperature, having the following wavelengths

   (a) 3.52m (b) 3.52mm (c) 352m

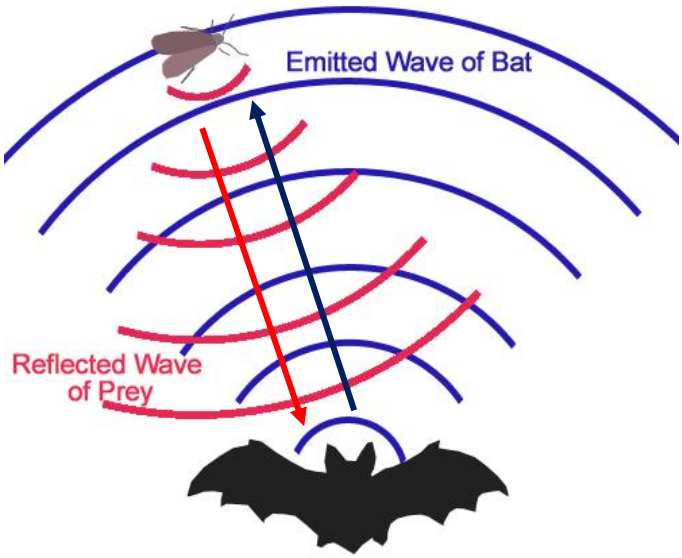
2. State whether the following sounds are audible, ultrasound or infrasound

   (a) 2kHz (b) 2Hz (c) 22000Hz

   Use your answers to question 1 to decide whether the following sounds are audible, ultrasound or infrasound

   (d) 3.52m (e) 352m (f) 3.52mm

3. A bat uses ultrasound to detect moths. Assume the speed of ultrasound is 352 m/s in this question.



   The bat sends out ultrasound waves which reflect back off their prey. The bat uses the time for the echo to return to calculate the distance to the moth and decides whether to pursue it.

   If the echo is detected after 0.5s, how far away is the moth ?

6.2.1 Electromagnetic waves

Are transverse, travel at the speed of light 3 x 10^8 m/s through space

There is a continuous spectrum of EM waves

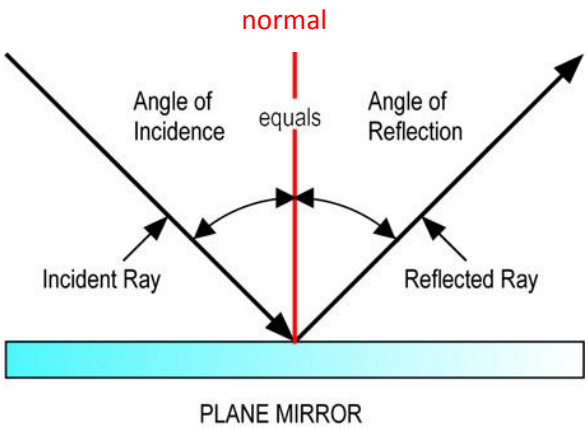
Radio	Micro	Infra red	Visible light	Ultraviolet	X	Gamma
> 1m	cm	mm to μm	10^{-7}m	10^{-8}m	< 10^8 m	

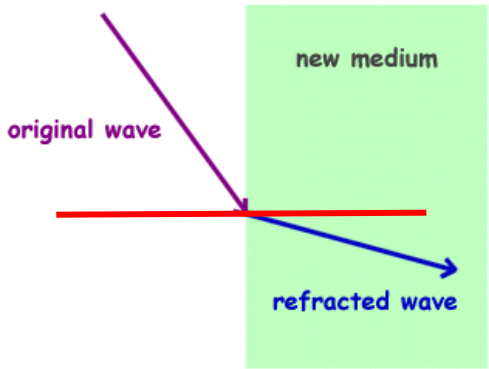
6.2.2 Properties of electromagnetic waves

Substances can absorb, reflect or transmit/refract EM waves

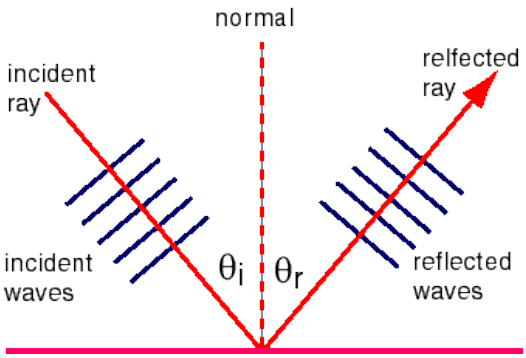
go in but don't come out — bounce off — pass through but change velocity

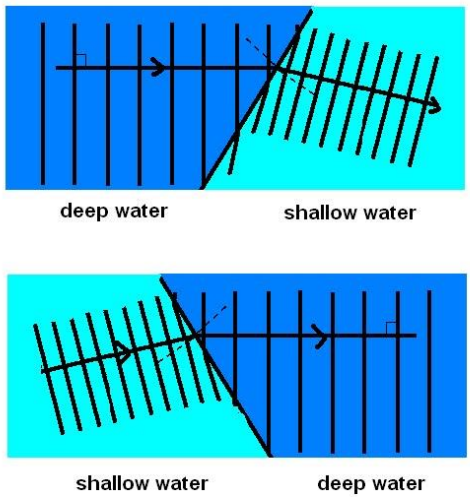
Ray diagrams show the direction in which waves travel





HIGHER A WAVEFRONT DIAGRAM SHOWS WHAT THE WAVES DO





same speed, f and λ

Change of speed and λ. Same f

Experiment to see which colour is the best emitter of infra red waves (heat waves)

See Practical skills doc

Experiment to see which colour is the best absorber of infra red waves

See Practical skills doc

Dull black surfaces are the best emitters and absorbers of infra red waves

6.2.3 Dangers of electromagnetic waves

Radio waves are harmless

Microwaves can raise body temperature because they are absorbed by water, producing heat

Infra red waves can burn you

Light waves can blind you

Ultraviolet, X and Gamma waves have enough energy that they can ionise atoms in your cells, mutating genes leading to cancer.

6.2.4 Uses for electromagnetic waves

Radio waves are used for communication eg radio and television and RADAR
RADIO DETECTION AND RANGING

Microwaves are used for satellite communications and, because they are absorbed by water to produce heat, cooking food

Infra red waves are used for heating our homes, cooking food and thermal imaging

Visible light is used for sight and optical fibre communications

Ultraviolet waves are used for security marking (eg bank notes) and tanning (sunbeds)

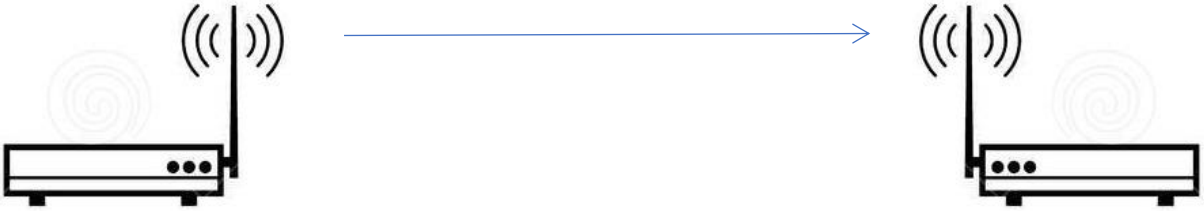
X rays are used for medical imaging broken bones and teeth

Gamma waves are used for medical diagnosis (medical tracers) and treatment of cancer

Test yourself on what you have learned :-

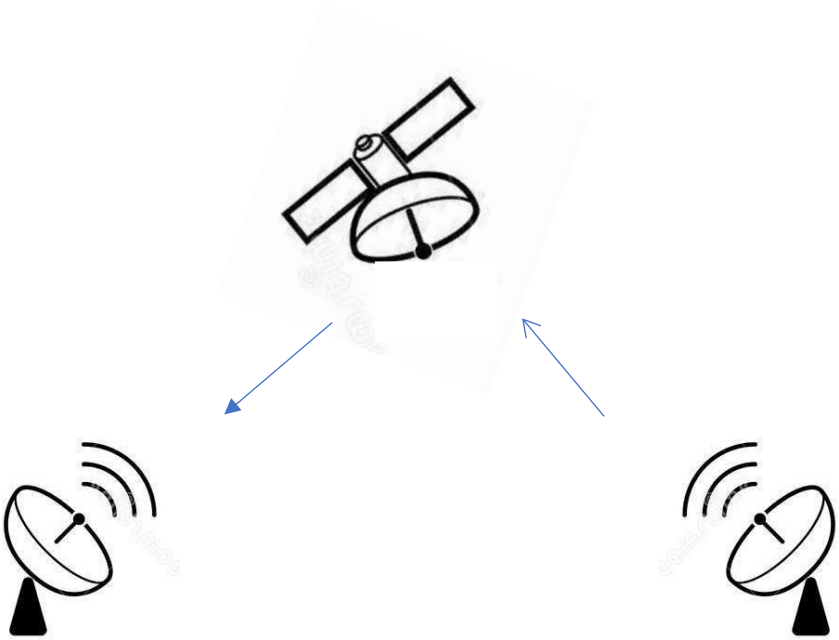
1. State the electromagnetic wave evident in the picture and, either what it is being used for or what the danger is

(a)



(b)

Dish on a satellite in the sky



Dishes on the ground

(c)

(d)

(e)

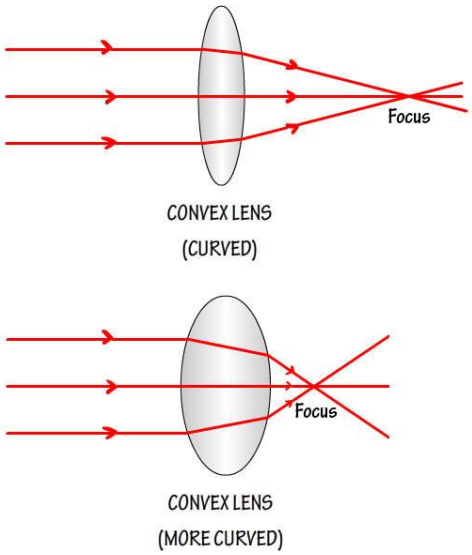
2. A radio wave used to broadcast radio 4 has a wavelength of 1500m
   Work out its frequency

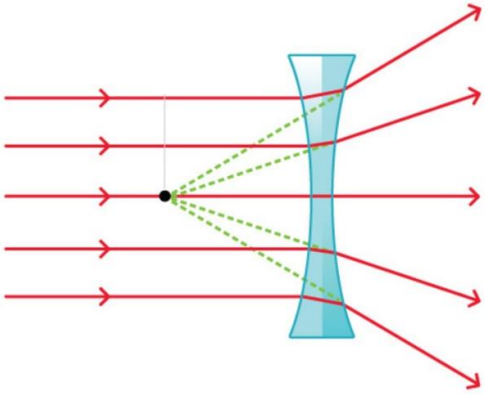
3. Write a list of electromagnetic waves in order of frequency, highest frequency first

4. Explain why ultraviolet, X and gamma waves are more dangerous than the other electromagnetic waves

6.2.5 Lenses Physics only

are curved pieces of plastic or glass which refract light
can be convex (converging) or concave (diverging)





In ray diagrams the lenses will be represented by

The distance of the focal point from the centre of the lens is called the focal length

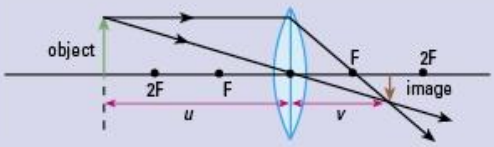
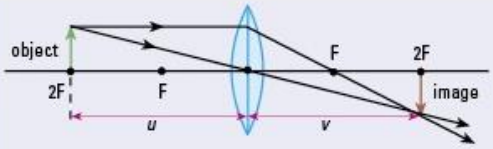
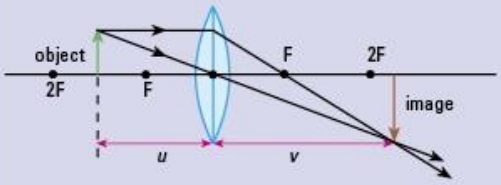
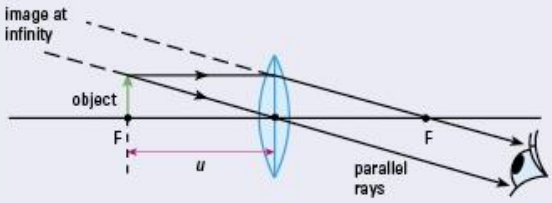
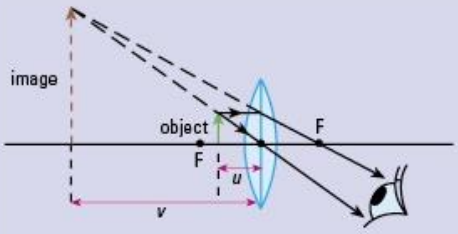
Lenses can be used to form images (see next page) of different sizes

A real image is one that can be formed on a screen
A virtual image is one that can't form on a screen
(you have to look into the lens to see it)

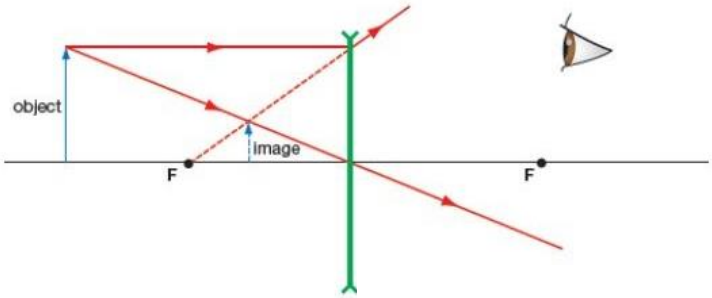
$$\text{Magnification} = \frac{\text{image size}}{\text{object size}}$$

Images formed by lenses

A light ray traveling parallel to the principle axis refracts through the focal point
A light ray traveling through the centre of a lens passes straight through

Object distance (u)	Ray diagram	Type of image	Image distance (v)	Uses
$u > 2f$		- inverted - real - diminished	$f < v < 2f$ - opposite side of the lens	- camera - eye
$u = 2f$		- inverted - real - same size	$v = 2f$ - opposite side of the lens	- photocopier making same-sized copy
$f < u < 2f$		- inverted - real - magnified	$v > 2f$ - opposite side of the lens	- projector - photograph enlarger
$u = f$		- upright - virtual - magnified	- image at infinity - same side of the lens	- to produce a parallel beam of light, e.g. a spotlight
$u < f$		- upright - virtual - magnified	- image is behind the object - same side of the lens	- magnifying glass

All images formed by diverging lenses are virtual and smaller

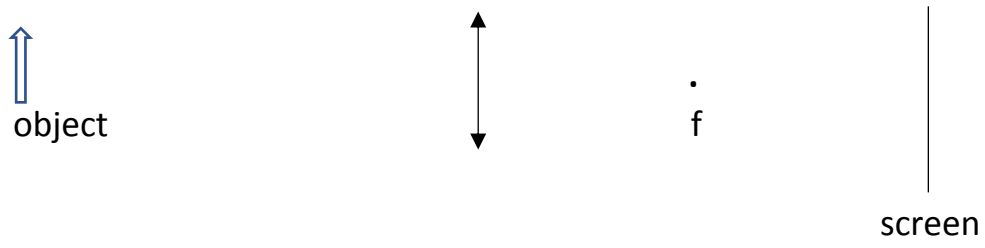


Practise what you have learned :-

1. How does the thickness of a lens affect the amount of refraction through it ?
   The thicker the lens the the refraction
   (insert the word more or less)

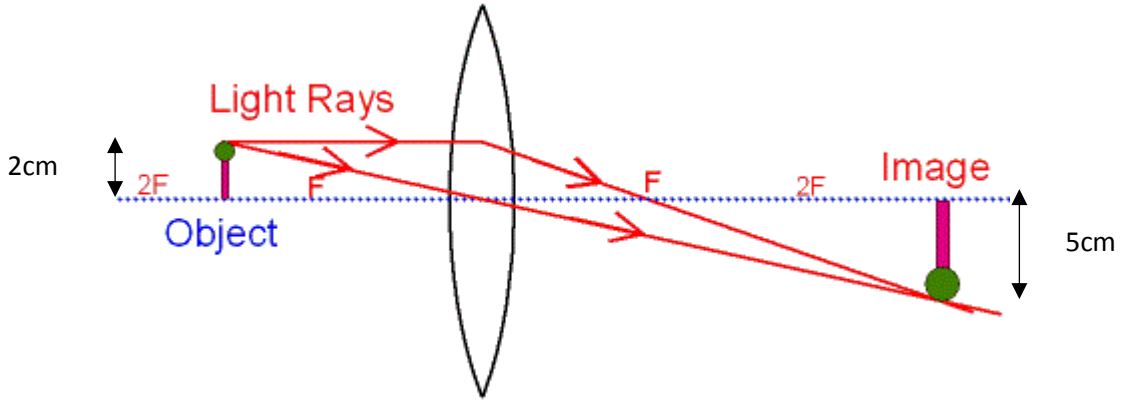
2. A lens forms a real image.
   What type of lens must it be ?

3. The picture shows the arrangement of a lens, object and screen
   f indicates the focal point of the lens



(a) Indicate on the picture what is meant by the focal length of the lens
(b) Underline words in the list below that could be used to describe the image that would be formed on the screen
REAL VIRTUAL MAGNIFIED SAME SIZE SMALLER UPSIDE DOWN UPRIGHT

4. The next picture shows a lens forming an image

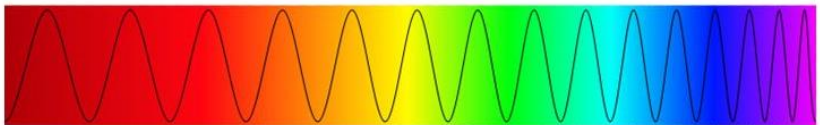


Write a description of the image formed by this lens, including the magnification it produces

6.2.6 Visible light and colour Physics only

Visible light is one of seven categories of electromagnetic wave having a wavelength between 7×10^{-7}m (or 700×10^{-9}m, 700nm) and 4×10^{-7}m.
Light from luminous sources such as the Sun and light bulbs is white but it is made up of 7 different colours

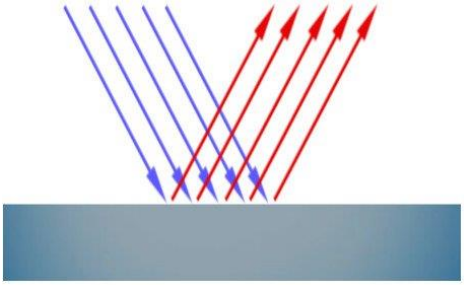
Visible light



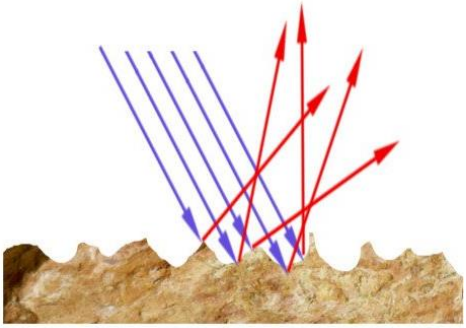
700 nm **400 nm**

Red orange yellow green cyan blue violet

If we see colour it is either due to reflection or refraction
and transmission or absorption



Reflection from a smooth surface
is called specular reflection
Angle of incidence = Angle of reflection

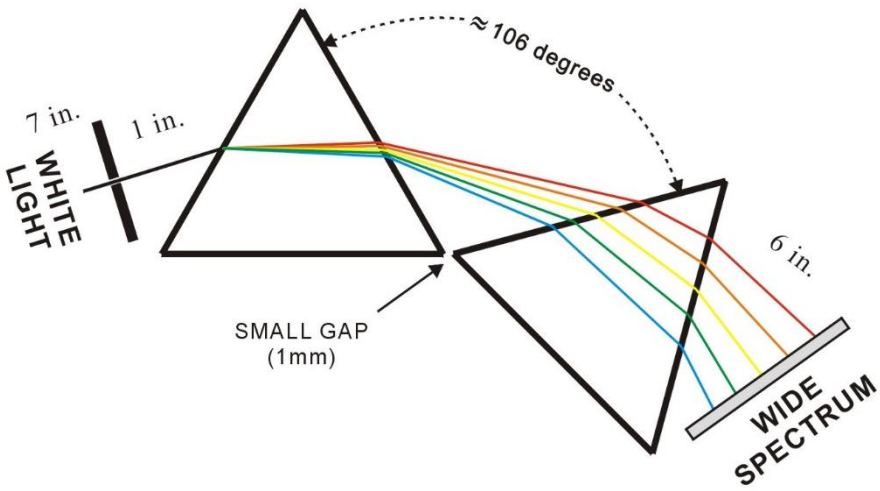


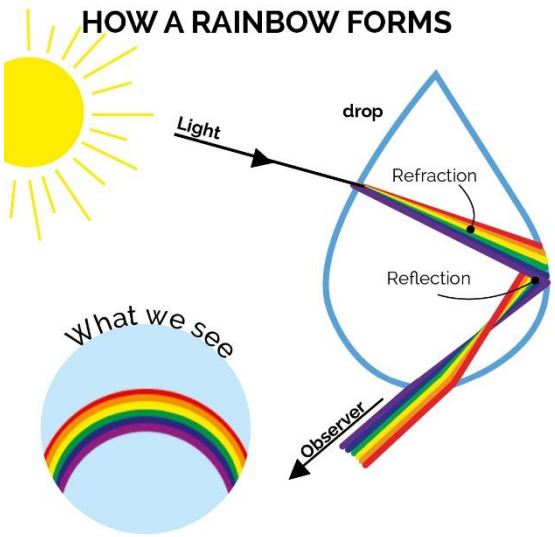
Reflection from a rough surface
is called diffuse reflection

Smooth Water Surface

Wavy Water Surface

Colour due to refraction

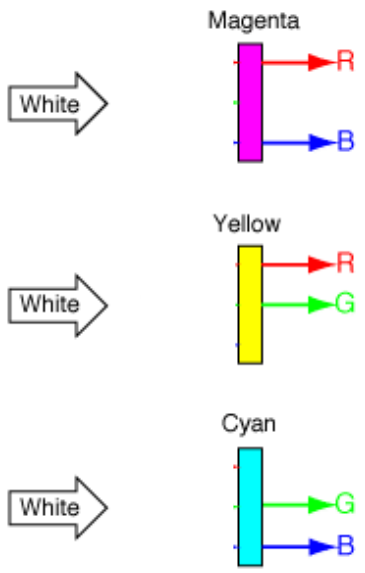




Filters are coloured pieces of plastic which transmit some colours and absorb others

Red, Green and Blue are considered to be the primary colours of light
A red filter will transmit just red light through it and absorb all the other colours
A green filter will do likewise with green light and a blue filter with blue

Yellow, Magenta and Cyan are considered to be the secondary colours of light
The following happens if we use filters of those colours



The colour of an opaque object depends on the light that it reflects to our eyes
A red object reflects red light (and a little orange)
A green object reflects green light (and a little yellow and blue)

The colours next to green in the visible light spectrum

So a red object viewed through a green filter would look black because it is reflecting red light but the filter absorbs that colour and nothing is transmitted

If green light is shone on a red object then the object will look black because it absorbs the green light and reflects nothing

Practise what you have learned :-

1. Write a list of the 7 colours of visible light in order of frequency, highest first

2. Work out the frequency of a blue light having a wavelength of 500nm

3. Describe the difference between an image formed by specular reflection and an image formed by diffuse reflection

4. What is it about the actions of red, green and blue filters that suggest those three colours are primary colours ?

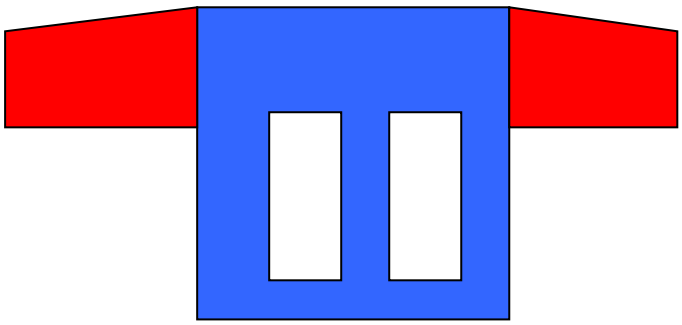
5. What is it about the actions of magenta and green filters that suggest those colours are secondary colours ?

6. White light is shone through a yellow filter. What **three** colours would be transmitted through it ?

7. The picture shows a snowman

Explain why the snowman is white, the carrot is orange and the hat is blue

8. The picture shows a football shirt as it appears in white light



Describe the appearance of the shirt if only red light shines on it

And if only green light shines on it

If you looked at the shirt through a blue filter, what would you see ?

6.3 Infra red radiation (heat waves)

Electromagnet waves mm to μm

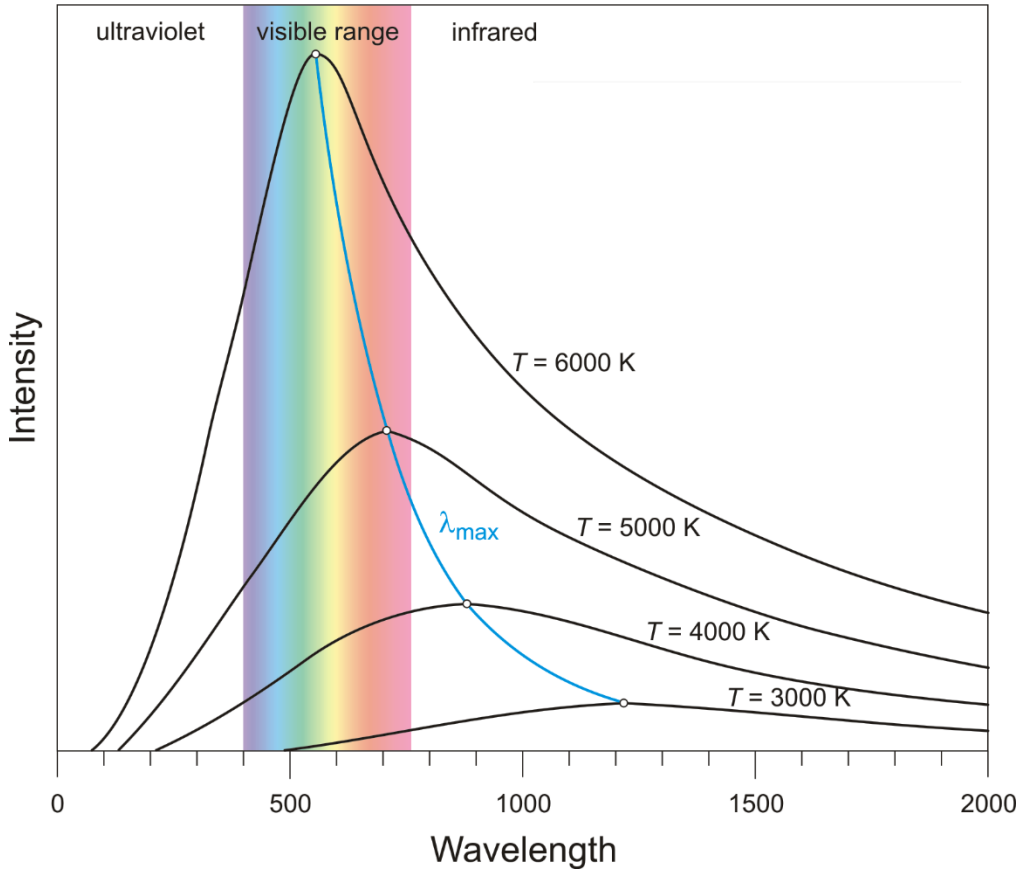
See set practical : absorption and emission of infra red waves

Dull, black surfaces are the best emitters and absorbers of infra red waves

HIGHER

The emission of electromagnetic waves depends on the temperature of an object

Hot objects emit obviously emit more radiation (the intensity is higher) and the frequency is higher (wavelength lower)



So an object at 3000 Kelvin emits relatively low intensity, infra red radiation

An object at 6000K (eg the surface of the Sun) emits higher intensity, visible light

The temperature of the Earth depends on how much radiation it absorbs from the Sun and how much it reflects and re-radiates back into space. Having a temperature of approximately 300K, the radiation it radiates into space is much lower intensity, infra red radiation.