SCIENCE DEPARTMENT
BGS

Year 8

Physics Friend

Light and Sound

This booklet contains information to support your work in physics lessons. You must bring it with you to all physics lessons on the Light and Sound topic. Replacement booklets must be paid for at a cost of £1.

Name:

Form:

Science Teacher:

CONTENT

Keyword Words (find these words in the wordsearch below)

AMPLITUDE	BLUE	CYAN
DIFFUSE	DISPERSION	FREQUENCY
GREEN	INCIDENCE	LENS
MAGENTA	MEDIUM	PITCH
RED	REFLECTION	REFRACTION
RETINA	SOUND	SPECULAR
TRANSMISSION	VACUUM	VIBRATION
VOLUME	WAVE	WAVELENGTH
YELLOW		

A R E A I M C B I Z N S N V V

T Y A T M R E N L O D T O I O

N M D L X P C D I U R H I B L

E L O U U I L T I A E C T R U

G N N H D C C I N U E T C A M

A J O E D A E S T S M I E T E

M U N I R N M P U U K P L I Z

M C Z F S I U F S Y D E F O Q

E K E G S R F O E V N E E N V

C R Q S G I E L S S E Y R A B

Y U I Y D R L P V A C U U M N

A O D E R O J J S A N I T E R

N C X B W W A V E I S H E A V

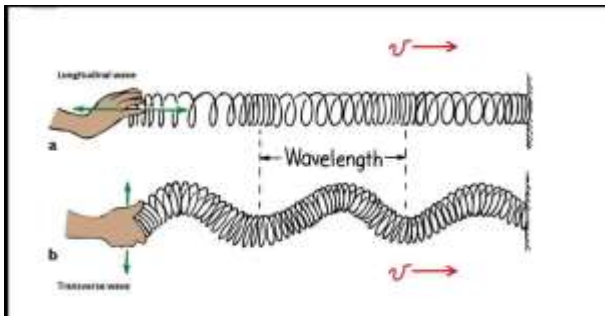
H T G N E L E V A W D R E S O

F R E Q U E N C Y A G K T M N

What are Waves?

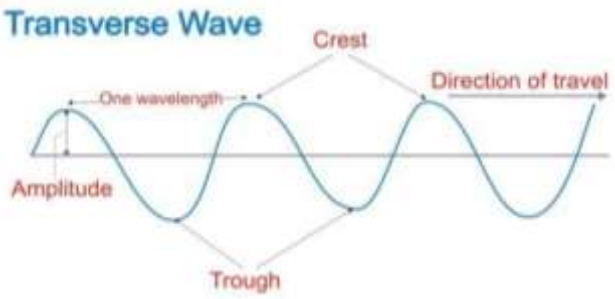
A wave is a disturbance that propagates through space transferring energy but not matter. There are different types of waves, e.g. water waves, sound waves, electromagnetic waves (such as visible light) and seismic waves (produced by earthquakes). Waves can be divided into two different groups:

- In a **TRANSVERSE** wave, the oscillation of the wave is perpendicular (at right angles) to the direction of energy transfer (the direction of travel of the wave)
- In a **LONGITUDINAL** wave, the oscillation of the wave is parallel to the direction of energy transfer.

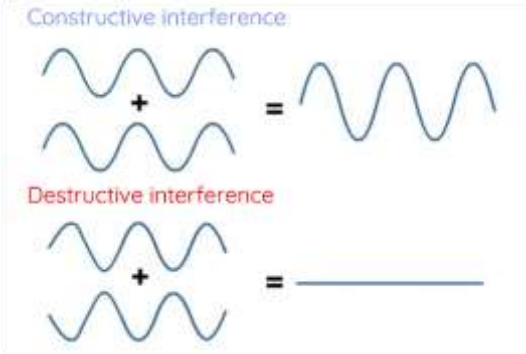


A wave has some important features that you must learn (shown below):

Wavelength – distance from one peak/trough to the next peak/trough (measured in metres, m)
Amplitude – distance from equilibrium position to a peak/trough
Frequency – number of waves passing a point each second (measured in Hertz, Hz)



When two waves of the same type meet, they can add together or cancel each other. This is called **superposition**. The two waves add together if a crest of one wave meets a crest of the other, while they will cancel each other if a crest from one wave is meeting a trough from the other.



Questions:

1. Explain the difference between a transverse wave and a longitudinal wave, giving one example of each.
2. Describe what is meant by the *amplitude* of a wave and explain how it relates to the energy of the wave.
3. A student watches ripples moving to the edge of a pond. They set a timer for 60 seconds and count 180 waves in this time. Calculate the frequency of the waves.

Sound Waves and Hearing

What are sound waves?

- Sound waves are produced by objects vibrating
- A sound wave travels through a medium (a solid, liquid or gas) due to the vibration of particles in the medium
- Sound waves must have a medium to travel through (they cannot pass through a vacuum)
- Sound waves are longitudinal waves

High/low pitch:

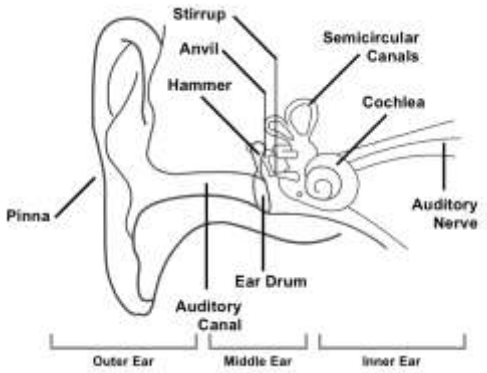
- The pitch of a sound is determined by the frequency of the sound wave (higher frequency = higher pitch)
- The volume of a sound is determined by the amplitude (higher amplitude = louder volume)
- The frequency range for human hearing is around 20Hz to 20,000Hz

The Ear and Hearing

- Humans are able to hear sounds with frequencies in the range 20 Hz to 20 kHz (approx.)
- The upper limit of this range varies from person to person and tends to get lower with age
- Sound that is above the range of human hearing is known as ultrasound
- Uses of ultrasound include SONAR and scanning of unborn babies

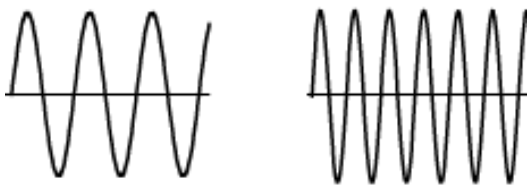
How the ear works:

- Sound is transmitted as sound waves from the environment. The sound waves are gathered by the outer ear and sent down the ear canal to the eardrum.
- The sound waves cause the eardrum to vibrate, which sets the three tiny bones in the middle ear into motion.
- The motion of the bones causes the fluid in the inner ear or cochlea to move.
- The movement of the inner ear fluid causes the hair cells in the cochlea to bend. The hair cells change the movement into electrical pluses.
- These electrical impulses are transmitted to the hearing (auditory) nerve and up to the brain, where they are interpreted as sound.



Questions:

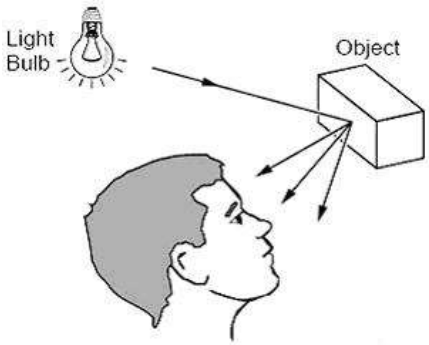
1. Describe the similarities and differences between the frequency and amplitude of the two waves below:



2. Explain why sound cannot travel through space
3. Explain how the human ear converts sound waves into signals that the brain can understand

Visible Light and Colour

- A **luminous object** is one which gives out its own light. We can see luminous objects because the light from them travels directly into our eyes. e.g. Sun, star, lightbulb etc
- A **non-luminous object** does not give out light. It can only be seen because light reflects from it and then enters our eyes (see diagram below).



Light waves are one part of a larger group of waves called electromagnetic (EM waves). The visible part of the EM spectrum that humans can see is only a small part. The coloured spectrum is continuous, where one colour merges seamlessly into the next.

Different colours of light correspond to light waves with different wavelengths. Red light has the longest wavelength that we can see, while violet light has the shortest. When we see white light, what our eyes are detecting is a mixture of all different colours (wavelengths) of light, which our brain interprets as white.

Questions:

1. **Using the diagram above, explain how the person is able to see the object.**

Colour

- Non-luminous objects appear the colour they do because of the colours (wavelengths) of light that they reflect
- A white object reflects all colours of light and absorbs none
- A red object, for example, reflects only red light and absorbs all other colours
- A black object absorbs all wavelengths of light and reflects none

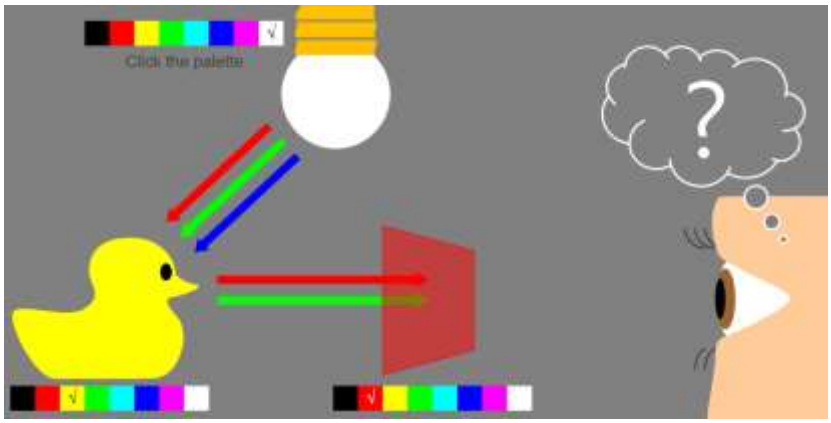
There is an almost 'perfect' black material that has been developed called 'Vantablack', which absorbs up to 99.96% of the light that falls on it. The material is made from an array of carbon nanotubes arranged perpendicular to its surface. When light strikes the material, instead of being reflected it enters the tubes, bouncing around inside and gradually being absorbed.

How do colour filters work? The answer is that the filter only allows light of one colour to pass through and absorbs all of the other colours. e.g. A blue filter allows the transmission of blue light, but not any other wavelength. Imagine looking at an object through a blue filter, the filter would only allow blue light into your eyes. If you then placed another filter (e.g. Red) between your eyes and the blue filter, the blue light would be absorbed by the red filter. Now the object you are looking at would 'appear' black.

Use this QR code to access a Javalab simulation on colour and filters:

Questions:

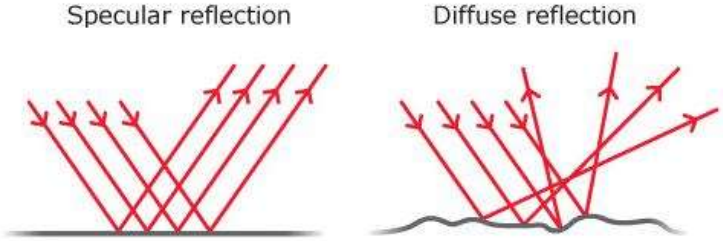
1. **Find a red object in your house. Explain why the object appears red.**
2. **Using the image below, what colour does the duck appear through the filter? Explain why it appears this colour.**



Reflection

Think about looking at a mirror and at a sheet of white paper. Both objects reflect all colours of light but you can see yourself clearly in a mirror, but not in paper. Why not? The answer is there are two types of reflection: **specular** and **diffuse**.

In a mirror, you see a clear image because the light undergoes **specular reflection**. Since the mirror is smooth, any light ray arriving in the same direction are reflected by the same angle. This means the light still travels in the same pattern as when it left the object so you can see a clear image. **Diffuse** reflection, on the other hand, happens when the surface is rough, such as on paper. This means the light rays are reflected at lots of different angles and loses its formation.



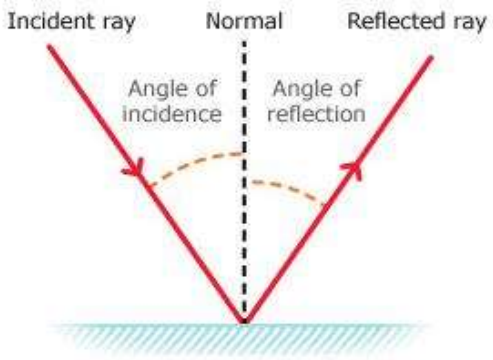
Remember that reflection doesn't just happen to light, it happens to all waves. Sound can also be reflected and this is what we call an echo.

The Law of Reflection

In science, when a theory has been seen to be true so many times it seems incredibly unlikely to ever fail, it becomes a law. That doesn't mean it will never be shown to be wrong, it just hasn't happened yet and scientists have trialled it a lot of times!

The law of reflection states that, for any reflection:

"The angle of incidence is equal to the angle of reflection"



For example, if the angle of incidence (the angle between the incident ray and the normal) was 30°, the angle of reflection (between reflected ray and normal) would also be 30°. You will test this law in lessons with your teacher.

Questions:

1. What is the difference between specular and diffuse reflection? Give an example of a surface for each.
2. Why can you see your reflection clearly in a mirror but not on a piece of white paper, even though both reflect light?
3. According to the law of reflection, what is the angle of reflection if the angle of incidence is 45°?

Refraction

Key terms:

A transparent substance is one that we can see through, e.g. clear glass, plastic, water

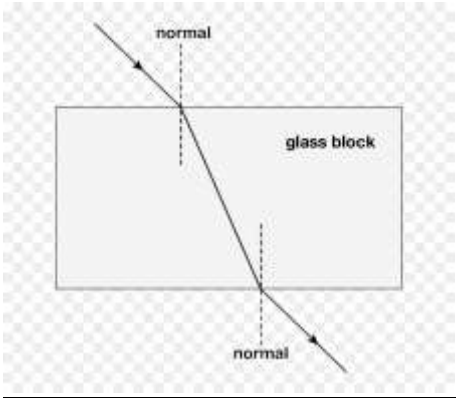
A translucent substance allows light to pass through it, but we cannot see a clear image through it, e.g. frosted glass, tracing paper

An opaque substance does not allow light to pass through it and we cannot therefore see anything through it, e.g. metals, brick, wood

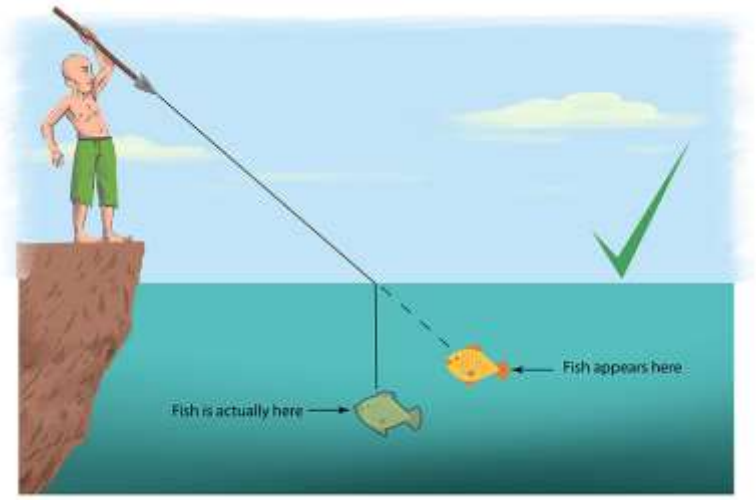
Refraction occurs when a wave crosses the boundary between two materials of different densities. This is most easily observed with visible light (as you saw in the class practical). When light passes into a medium which is more dense, it slows down and changes direction. When the light passes into a medium which is less dense, it will speed up and change direction again:

As a ray enters a more dense substance (where its speed is lower), the ray of light bends (refracts) towards the normal. This angle of refraction is therefore smaller than the angle of incidence.

As a ray enters a less dense substance, the ray of light refracts away from the normal. This angle of refraction is therefore larger than the angle of incidence.



In the image below, the person 'appears' to see the fish in the higher position. In reality, the fish is actually in the lower position. The refraction of light at the boundary between water and air tricks our brains.

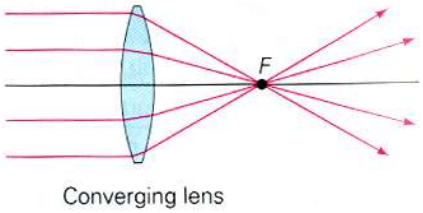


Questions:

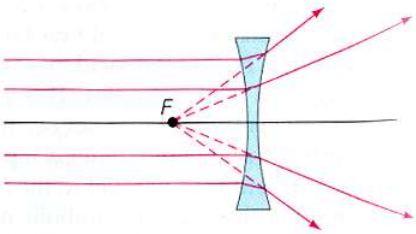
1. What is the difference between a transparent, translucent, and opaque substance? Give an example of each.
2. What happens to a ray of light when it enters a more dense material, like from air into glass?
3. A light ray passes from water (more dense) into air (less dense). What happens to the speed and direction of the ray?

Lenses

Light refracts as it passes from air into a lens (usually glass). There are two types of lenses, converging (convex) and diverging (concave):



Converging lens

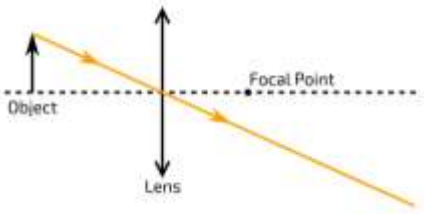


Diverging lens

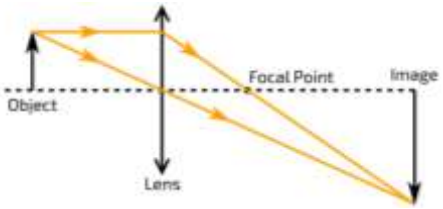
With a converging lens, light converges (meets) at the principal focus (F). With a diverging lens, the light diverges (spreads out) 'appearing' to have originated from the principal focus (left of the lens in the diagram).

How to complete a ray diagram:
We use ray diagrams to work out the 'nature' of the image formed by a lens. The 'nature' of an image, is whether it is upright or inverted and whether it is magnified or diminished (compared to the object)

1. Draw a straight line from the top of the object straight through the centre of the lens (this line does not refract)



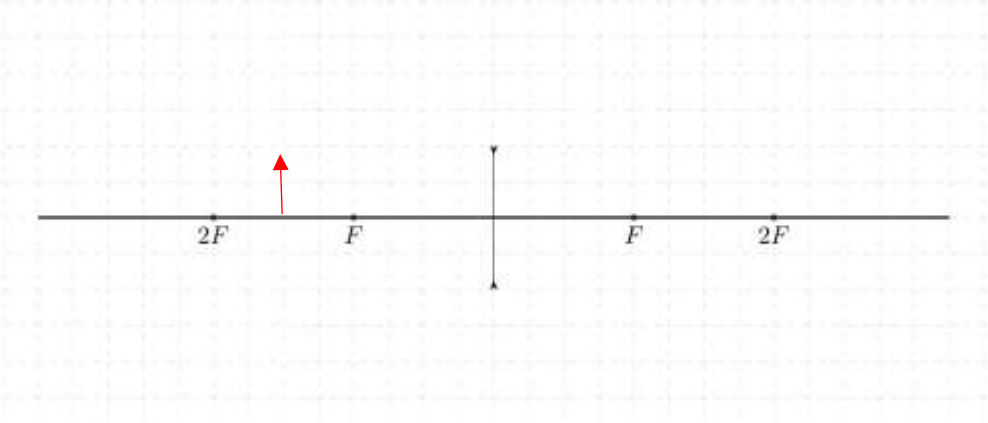
2. Now, draw a straight line from the top of the object that runs parallel to the axis of the template. When that ray reaches the lens, it must refract and pass through the focal point, F.



3. Where these two lines cross tells where the top of the image is formed. An image formed below the axis is an inverted image (upside down). We can also compare the image size to the object size and state whether it is magnified or diminished. (in the diagram above, the image is magnified and inverted compared to the object).

Questions:

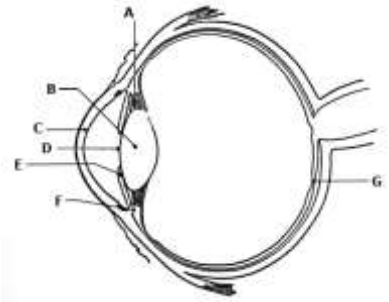
1. Using the instructions given in the notes, complete the ray diagram below:



2. For the diagram above, state the 'nature' of the image.

The Eye

The eye is the sensory organ in the body that detects light. Light enters through the clear cornea which protects the eye from dirt and microbes. The light passes through the pupil and is refracted by the lens. This refraction causes the light rays to meet at the retina and form an image. This causes impulses to be sent via the optic nerve to the brain to be interpreted.



Questions:

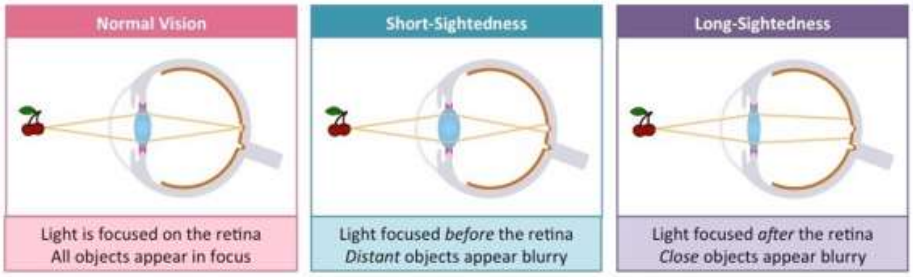
Match up the label and function to the name of the part of the eye.

A	Holds the lens in place
B	Refracts light to form an image on the retina
C	Transparent window that allows light into the eye
D	A hole to allow light into the lens.
E	Controls the size of the pupil for varying light intensity.
F	Contracts and relaxes to change the shape of the lens.
G	Contains rods and cones to convert light into nerve impulses.

Iris
Retina
Lens
Cornea
Pupil
Suspensory ligaments
Ciliary muscles

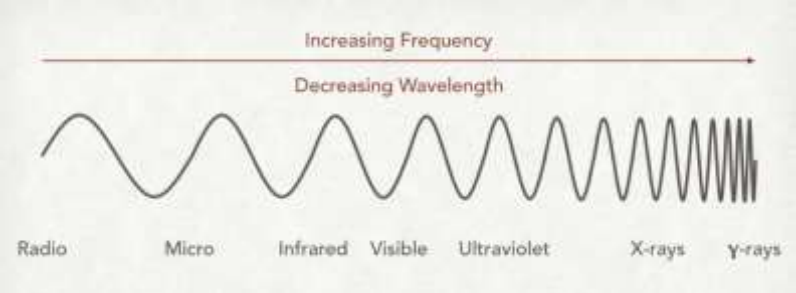
Interesting facts about the eye:

- The image formed on the retina is actually upside down! Your brain has to correct this.
- There are two types of light sensitive cells: rods and cones. Rods are very sensitive while cones are the ones that allow you to see colours. Dogs don't have as many cones so they cannot see colours as well as humans.
- Eagles have five times as many cones in the fovea as humans giving them a much higher visual acuity (detail). This is how they can spot mice from so high up in the air.
- The military use red torches instead of white because they don't affect your night vision as much.
- In dim light, you will find that you see in 'black and white'. This is because the rods are more sensitive to low levels of light than the cones, which detect colour.
- If something is in the 'corner of your eye', it is difficult to tell what colour it is. This is because the cone cells, which detect colour, are located in the middle of the retina and not around the edge.



Electromagnetic Waves

Electromagnetic waves are waves that can propagate through empty space (vacuum). EM waves (also referred to as EM radiation) form a continuous spectrum of waves with different wavelengths and frequencies. All EM waves travel at the same speed (300,000,000 m/s, the 'speed of light') through a vacuum. The spectrum is made up of 7 different types of wave, as shown below:



- In order to learn the order of the electromagnetic spectrum, we can use a mnemonic, e.g. Robot Monkeys Invent Very Unusual Xbox Games.

The seven parts of the EM spectrum have many uses:

Type of Wave	**Uses**	**Dangers**
Radio Waves	Communication; Radio and TV Signals	None
Microwaves	Heating food; Satellite communications; Mobile phones	Internal heating of body tissue
Infra Red	Remote controls; heating food (grills); Optical fibres	Can burn skin
Visible Light	Seeing; Photography; LASERs; Optical fibres	Can cause damage to eyes
Ultra Violet	Security markings on banknotes; Forensic science	Sunburn; Skin cancer; Eye damage
X Rays	Medical imaging; Airport security	Cancer and cell mutation
Gamma Rays	Cancer treatment; Sterilising surgical equipment	Cancer and cell mutation

Questions:

1. Which part of the EM spectrum is the most dangerous? Explain your answer.
2. Which part of the spectrum can humans detect?

Revision

1. Draw two waves in your book. One with a high frequency and one with a low frequency.
2. Now draw two waves, they have the same frequency but one is loud and one is quiet. Label these two waves, one with large amplitude and one with a low amplitude
3. Draw a picture of a wave and label the wavelength, amplitude, peaks and troughs.
4. State which travels faster, light or sound.
5. Through which material does sound travel fastest, air or concrete? Explain why.
6. Draw an accurate (with pencil and ruler) ray of light reflecting from a mirror. State the 'law of reflection' and use it to help with the drawing
7. Explain what the following parts of the eye do: lens, retina and iris
8. Explain how a coloured filter works and why things look a particular colour when viewed through the filter
9. Explain why a red object would look red when white light hits it