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Photocopy Master Sheets

Years 9-10

Wave Energy

Disk filename = "12.Waves"

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Topics Available

Year 7-8 General Science

Disk Filename	Topic Name
01.Energy	Energy
02.Forces	Forces
03.Matter	Solids, Liquids & Gases
04.Mixtures	Separating Mixtures
05.Elements	Elements & Compounds
06.Cells	Living Cells
07.Life	Living Things
08.LifeSystems	Plant & Animal Systems
09.Astronomy	Astronomy
10.Earth	The Earth
11.Ecosystems	Ecosystems

Year 9-10 General Science

Disk Filename	Topic Name
12.Waves	Wave Energy (inc. Light)
13.Motion	Forces & Motion
14.Electricity	Electricity
15.Atoms	Atoms & Elements
16.Reactions	Compounds & Reactions
17.DNA	Cell Division & DNA
18.Evolution	Evolution of Life
19.Health	Health & Reproduction
20.Universe	The Universe
21.EarthScience	Earth Science
22.Resources	Resources & Technology

Year 11-12 Science Courses

Biology
Preliminary Core
Local Ecosystem
Patterns in Nature
Life on Earth
Evolution Aust. Biota
HSC Core
Maintain. a Balance
Blueprint of Life
Search for Better Health
Options
Communication
Genetics:Code Broken?

Chemistry
Preliminary Core
Chemical Earth
Metals
Water
Energy
HSC Core
Production of Materials
Acidic Environment
Chem.Monit.&Mngment
Options
Shipwrecks, Corrosion...
Industrial Chemistry

Earth & Envir. Science
Preliminary Core
Planet Earth...
Local Environment
Water Issues
Dynamic Earth
HSC Core
Tectonic Impacts
Environs thru Time
Caring for the Country
Option
Introduced Species

Physics
Preliminary Core
World Communicates
Electrical Energy...
Moving About
Cosmic Engine
HSC Core
Space
Motors & Generators
Ideas to Implementation
Options
Quanta to Quarks
Astrophysics

All Topics Available as PHOTOCOPY MASTERS and/or KCiC

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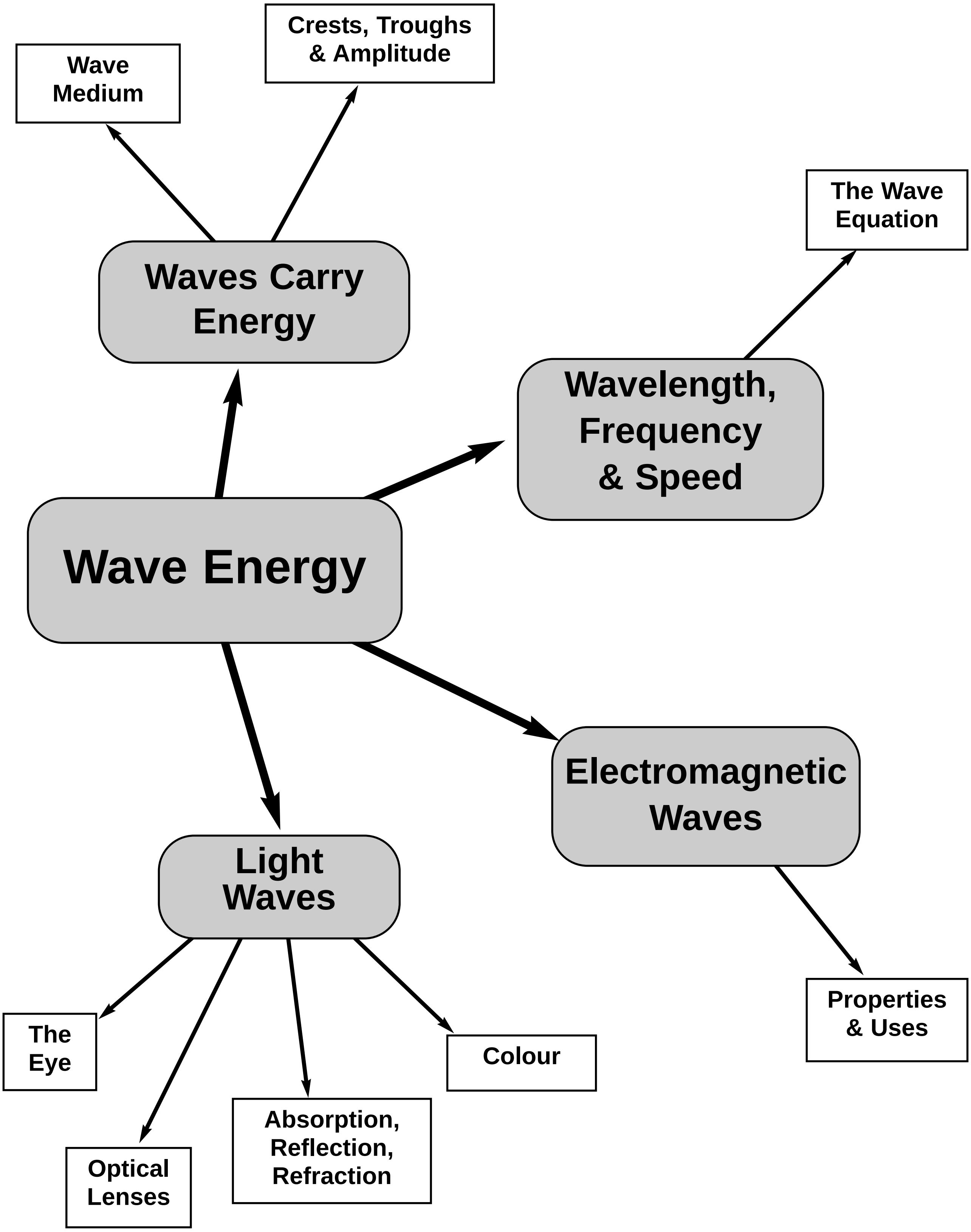
Black & White, A4 portrait-orientation
for clear, economical photocopying.

KCiC = Key Concepts in Colour
Full colour, formatted for on-screen study
and data projection. PDF + Powerpoint®

"Mind-Map" Outline of Topic

This topic belongs to Physics, the study of energy, force and motion.
In this topic you will study how energy moves in the form of waves, then go on to study one very important wave type... light.



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Make your own "Mind-Map" TITLE PAGE.
Cut out the boxes. Sort them into an appropriate lay-out on a page of your workbook, then glue them down. Add connecting arrows and colour in.

Wave Energy

The Wave Equation

Electromagnetic Waves

Waves Carry Energy

Wavelength, Frequency & Speed

Absorption, Reflection, Refraction

Light Waves

The Eye

Properties & Uses

Optical Lenses

Colour

Wave Medium

Crests, Troughs & Amplitude

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What is Energy? (Revision)

Energy is what causes things to change.

There are many different types of energy. Here are just a few:

Type of Energy	Changes Caused by this Energy
Kinetic (in moving objects)	Change in position because object is moving.
Potential (stored)	Only causes changes when released in another form.
Heat	Change in temperature. e.g. a stove causes food to get hot.
Light	Nerve changes in your eye which allow you to see things, or chemical changes in the film in a camera.
Sound	Vibrations in your ear which allow you to hear.
Electrical Energy	Can cause a light bulb to glow and produce light, or a stove element to get hot and produce heat.
Radio Waves	Can cause electrical vibrations in an antenna. This allows reception of mobile phone, radio & TV programs.

Waves Carry Energy

Many types of energy are carried as waves.
Waves carry energy from one place to another.
Only the energy moves... substances do NOT move from one place to another.
(A substance might vibrate as energy moves through, but it doesn't go anywhere.)

Examples of Energy Carried as Waves

Light & Sound Waves

When you see anything you are detecting light waves carrying energy to your eyes. Things that glow are emitting (giving out) light waves. Most things that you see are not emitting light, but reflecting it to your eyes.

When you hear anything, you are detecting sound waves.

In a lightning storm, the electrical discharge emits light waves... so you see the lightning flash. It also creates sound waves... so you hear the thunder. The sound waves travel more slowly that the light, so you hear the thunder after you see the lightning.

Water Waves

The energy of the wind blowing across the oceans creates water waves.

Water waves can carry the energy for thousands of kilometres across an ocean, until the waves "break" as they approach a coastline.

Before they break, the water doesn't actually go anywhere. The water moves up and down as huge amounts of energy flow past, but the water itself goes nowhere.

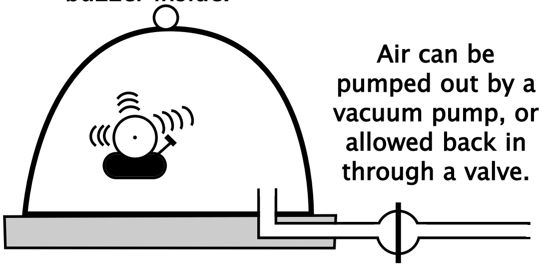
Once the wave breaks, the water itself surges forward. Now you can catch it, and now its energy batters the coast causing erosion and movement of sand.

Some Waves Need a "Medium"

Some waves can only travel through substances.
The substance vibrates as the wave energy passes through.
The substance is called the "medium" for the wave.
Without a medium, the wave cannot exist, and the energy cannot move.

Sound Needs a Medium

Your teacher might demonstrate this in class.



When the bell-jar is filled with air, you can clearly hear the bell ringing.

When most of the air is pumped out, you can barely hear it, but you can see that it is still ringing.

Sound cannot travel in a vacuum.
It must have a medium.
Sound waves not only travel in air, but can move through water or solids as well.

Water waves in the ocean need the water as a medium.
The shock waves of an earthquake need solid rock as their medium.

Some Waves Can Travel Through Vacuum

Not all waves need a medium to travel through.

Electromagnetic Waves

Light waves can (obviously) travel through empty space from the Sun to Earth.

Light does not need a medium to travel through.

Light can travel through some substances (such as air, water & glass), but it actually travels best through a vacuum.

Light is an electromagnetic (EM) wave. The energy is transmitted by the vibration of electric and magnetic fields.

There is a whole "family" of other EM waves which you will study later in this topic.

The Speed of Light

Light waves travel at the amazing speed of <u>300,000 kilometres per second</u>.

That's just over 3 seconds to travel 1 million km.

Light covers the distance from Sun to Earth (150,000,000km) in about 8 minutes. Our fastest space vehicles would take about 2 years to travel that far.

We have reason to believe that nothing can ever travel faster than the speed of light.

We should call it the "Speed of EM Waves" because all EM waves travel at this same speed.

Science Rejects Theories That Don't Work

To the scientists of the 18th and 19th centuries it seemed obvious that light waves must travel through something... there must be a "medium" for light waves. All other types of waves which had been studied (e.g. sound & water waves) needed a medium and could not travel in a vacuum.

The Theory of the Aether

The aether was thought to be a fluid which totally filled the Universe. It had no mass and did not interact with solid objects. For example, it had no effect on the planets moving through space.

The only property of the aether was that it allowed light waves to be propagated through space.

In the second half of the 19th century the existence of the whole family of electromagnetic (EM) waves was discovered. Light was just one type of a whole spectrum of EM waves travelling in the aether.

Scientists began experimenting to prove that the aether really existed.

The Michelson-Morley Experiment

This famous experiment in 1887 attempted to measure the interference patterns which theoretically should have occurred under certain conditions, as light travelled in the aether.

The expected interference patterns did not occur. The experiment was repeated many times, with greater precision each time. Same result... no aether effects.

Arguments went back-and-forth for 20 years, but it was finally settled by Albert Einstein in 1905. His Theory of Relativity gave a new way to think about light and how it travelled in space. There was no longer any need for an aether.

Soon, experiments to test Relativity gave clear, positive results and the aether was quietly forgotten. This is how Science works.

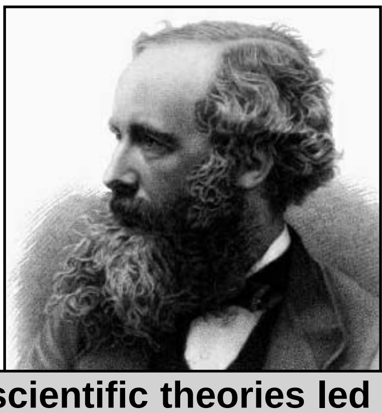
Scientific Developments Lead to New Technologies

In the mid-19th century, scientists were not quite sure what light was. Earlier theories that light was a stream of particles had been discounted, so it was generally agreed that light was a wave. But what kind?

James Clerk Maxwell **(Scottish, 1831-79)**
In 1864, Maxwell published his theory of Electromagnetic (EM) Waves.

He showed mathematically how a wave could be made of fluctuating electric and magnetic fields and how it would spread out at the speed of light.

His equations also suggested that there should be a whole spectrum of EM waves at other wavelengths and frequencies. The race was on to find them!



Radio Waves **were discovered and studied in 1880, and by 1895 the first radio communications began. By the 1930's the first pictures were transmitted by radio signal (television) and radar was being developed.**

In World War II, radar developed and extended into the *Microwave* band. From there we get modern communication networks (& microwave ovens).

In 1895, Wilhelm Rontgen discovered *X-Rays* and by the early 20th century they were used for medical imaging.

Maxwell's new scientific theories led directly to many new technologies which are vital in today's society.

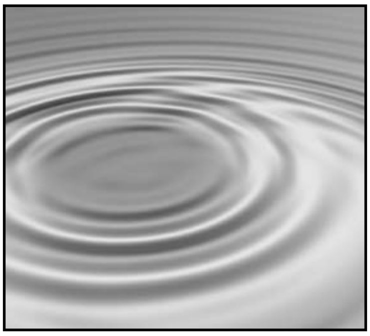
How Energy is Carried by a Wave

To understand how a wave carries energy it is best to start with something familiar, such as waves in water.

Water Waves

If you look at unbroken "swell" waves in water, you will see that they are made up of a series of <u>crests</u> and <u>troughs</u> which move across the surface.

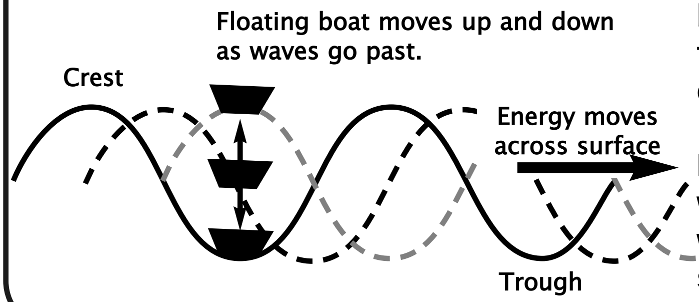
If you watch a boat as ocean swells go by, you will see that it simply moves up and down... it is not pushed along.



You cannot surf unbroken swells because the wave will not push you forward. You only float up and down on the crests and troughs.

Only the energy moves.

The water only oscillates up and down.

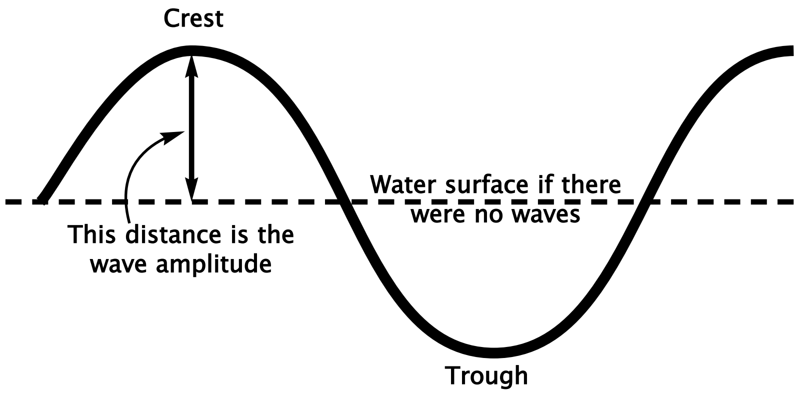


When the wave approaches shore it begins to "break". Now the water begins to tumble forward and you can catch it.

However, a broken wave is NOT a wave in the scientific sense.

Wave Amplitude

To a surfer, how <u>big</u> the surf waves are is a very important thing. In scientific terms, this is the <u>wave amplitude</u>.



Surfers tend to measure the height of a wave as the vertical distance from trough up to crest.

Notice that amplitude is measured from the "flat water surface" up to the crest.

Significance of Wave Amplitude

In a Sound Wave, the amplitude determines how <u>loud</u> the sound is... its volume.

When you turn up the volume, you are increasing the amplitude of the sound waves that you are hearing.

In a Light Wave, the amplitude determines the <u>brightness</u> of the light.

When you see 2 objects, but one is brighter than the other, the difference is the amplitude of the light waves which are entering your eye.

Worksheet 1
Waves Carry Energy

Student Name..

Fill in the blank spaces.

Waves carry a)......................... from one place to another.

Some waves require a substance, or b)............................., to travel through. As the wave moves, the particles in the substance c).............................., but they do not d)............................... An example is e)............................ waves which can travel in air, water or solids, but cannot travel through a f).............................

Other types of energy do not need a g)............................ to travel in. For example, h)........................... waves can travel through a vacuum. They also travel through substances such as air, i)...................... or ....

Light waves are just one type of a "family" of waves called j).................... - .... waves. All of these travel at a speed of k).............................. km/hour.

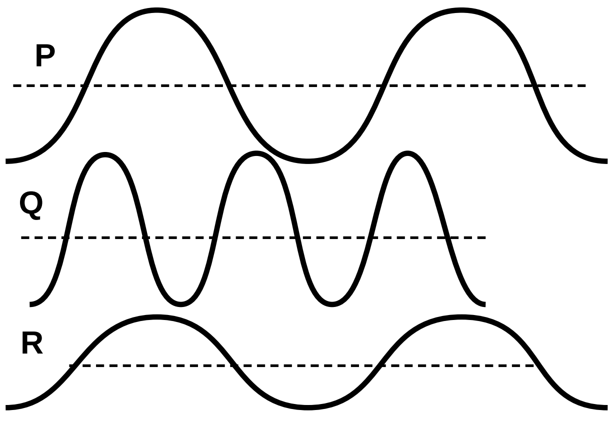
Waves of any kind have certain features in common. A wave moves as a series of l).................... (high points) and m)........................... (low points). In a water wave, the water itself simply moves n)............................ as the energy flows by.

The o)................................. of a wave is the distance from the "average" position to a crest or trough. In a sound wave this determines the p).......................... of the sound. With light waves this determines the q).................................. of the light.

Worksheet 2
Wave Characteristics

Student Name..

1.
The diagrams show 3 different waves drawn to the same scale.



a) On wave "P" label the position of a <u>crest</u> and a <u>trough</u>.
b) On wave Q draw an arrow to show the distance you would measure for the <u>amplitude</u> of the wave.
c) If these waves represent light waves, which one is the <u>least bright</u>?

2.
A cork is floating on a calm pond. Then someone drops a rock in the water so that a series of ripple waves move across the surface.
Describe the movement of the cork as the waves reach it and go past.

3.
An astronaut on the Moon watches as his partner hits a rock with a hammer. Explain why he can <u>see</u> it happen, but cannot <u>hear</u> the sound of it.

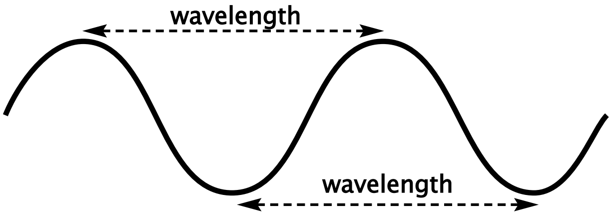
4.
Suggest how the astronaut can talk to his partner on the Moon.

Wavelength and Frequency

These 2 measurements are very important to describe different waves.

Wavelength (λ)

The wavelength is a measure of the distance from one wave crest to the next.



Wavelength can also be measured from one trough to the next.

The Greek letter "lambda" (λ) is often used as the symbol for wavelength.

Since wavelength is a distance, it can be measured in cm, metres, km, etc.

Some Actual Wavelengths

Some radio waves have a wavelength of several kilometres. Light waves have wavelengths less than $^{1}/_{1,000}$ of 1mm.

Ocean waves typically have wavelengths of between 20m to 100m. Ripples in a pond have wavelengths of a few cm.

Sound waves are typically a few cm in wavelength.

Frequency (f)

Frequency measures how many waves go past per second. Symbol "f" is used.

It is very difficult to visualise this with a diagram. Your teacher might demonstrate frequency with a slinky spring. (see below)

The unit of measurement is called the "hertz" (Hz) named after a great German scientist of the 19th century.

A frequency of 10Hz means that 10 complete waves are going past each second.

Some Actual Frequencies

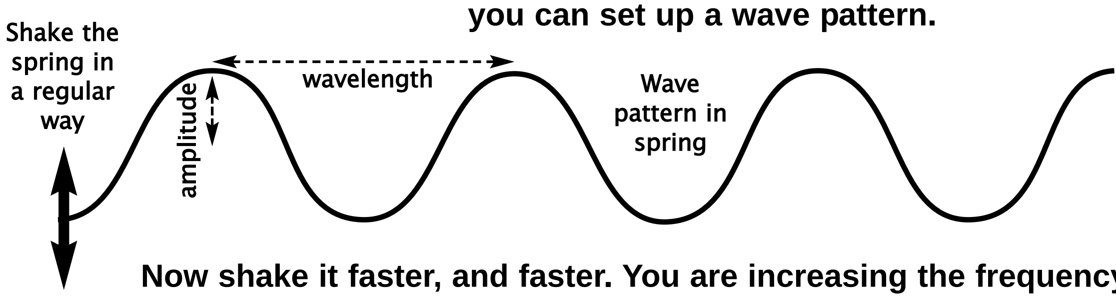
Ocean waves can have very low frequencies of only 0.1Hz, or less. This means that only $^{1}/_{10}$ of a wave passes in 1 second. Another way to think of this, is that it takes 10 seconds (or more) for one complete wave to go by.

Sound waves have frequencies of 100's and 1,000's of Hz.

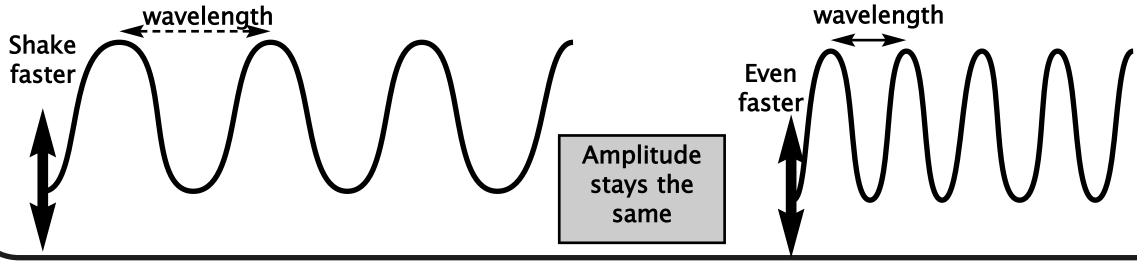
Light waves have frequencies measured in billions of Hz.

The Relationship of Wavelength & Frequency

If you shake one end of a "slinky spring" up and down, you can set up a wave pattern.



Now shake it faster, and faster. You are increasing the frequency. Notice that the wavelength gets less as frequency gets higher.



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Speed, Wavelength & Frequency

"Speed" means how fast something moves.
The speed of any wave depends on both its wavelength and frequency.

The Wave Equation

There is a simple, mathematical relationship between the wavelength, the frequency and the speed of any wave.

SPEED = WAVELENGTH x FREQUENCY

$$v = \lambda \times f$$

v = velocity (speed), measured in metres per second (m/s).

λ = wavelength, measured in metres (m). ("λ" is the Greek letter lambda)

f = frequency, measured in hertz (Hz).

Example Calculation

A series of water waves measure 80cm (0.80m) from crest to crest. Each second, 2.5 complete waves go past. What is the speed of the waves?

Solution

Wavelength = 0.80m. Frequency = 2.5Hz.

$v = \lambda \times f$
$= 0.80 \times 2.5$
$= 2.0$

The speed of the waves is 2.0 m/s.

Note: If you used λ = 80cm, the answer would be 200 cm/s. This is exactly the same, but in different units. You should try to use metres, and m/s whenever possible.

Worksheet 3
Using the Wave Equation

Student Name..

1. A sound wave with a frequency of 660Hz has a wavelength of 0.5m. What is the speed of the wave?

v = λ x f = ... x ....
= ....

The speed of the wave is .... m/s.

2. Another sound wave with a frequency of 3,300Hz has a wavelength of 10cm (0.1m). What is the speed of the wave?

v = λ x f = ... x ....
= ....

The speed of the wave is .... m/s.

3. A water wave has a wavelength of 50m. A complete wave takes 20sec. to go by, so its frequency is 0.05Hz. What is the speed of the wave?

v = λ x f = ... x ....
= ....

The speed of the wave is .... m/s.

4. A wave in a "slinky spring" measures 40cm (0.4m) from crest to crest. The spring is being shaken up and down 3 times per second. How fast does the wave travel?

5. A sound wave has a frequency 1,000Hz. It is travelling in air at a speed of 330 m/s. What is its wavelength?

6. Sound travels much faster in water than in air... 1,500 m/s. What wavelength would the 1,000Hz sound wave have in water?

Electromagnetic (EM) Waves

The EM waves are a "family" of waves which all travel at the "speed of light". They have many important properties and uses.

Type of Wave / Properties & Uses

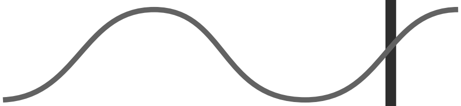
Long Wavelength, Low Frequency

Wavelength getting shorter

Frequency getting higher

Short Wavelength, High Frequency

Radio



Used for transmitting radio and TV programs & mobile phones.
Also, communication for planes, ships, military, etc.

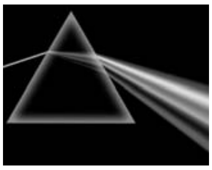
Microwaves

Microwaves of some frequencies can cause food to get hot. They are used in a microwave oven. Other frequencies are used in communications, radar and GPS.

Infra-Red

Infra-Red is heat radiation. Although we cannot see it, we can feel it on our skin.

Light



Light can be detected by our eyes, so to us it is the most important member of the EM family.

Photographic film and the light detectors in digital cameras are also sensitive to light radiation.

Ultra-Violet

Ultra-Violet (UV) rays are dangerous to living things. UV causes sunburn and can cause skin cancers. Luckily, most of the UV coming from the Sun is blocked by the ozone layer, high up in the atmosphere.

X-Rays

X-Rays are very penetrating and can go straight through many things. This is why they are used for medical imaging of bones, and for detecting weapons, etc in airline luggage. Excessive doses of X-rays can be very dangerous to people.

Gamma Rays

Gamma Rays are even more penetrating than X-rays. They are given off by radio-active substances. They can cause cancer, but can also kill cancer cells. They are used in "radiation" treatment of cancer patients.

Although we describe these as different types of wave, they actually form a continuous "spectrum". The only difference from one type to another is the frequency and wavelength.

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Worksheet 4
The Wave Equation
(More Difficult Problems)

These problems require the use of a scientific calculator. You must be familiar with its "exponential" function, and be able to work with "scientific notation" for very large, and very small numbers.

1.
A radio wave has a frequency of 50kHz (= 50,000 Hz) and wavelength of 6km.
a) Write the frequency value in "scientific (or standard) notation". ....
b) Convert the wavelength to metres, and write it in standard notation. ....
c) Use the Wave Equation to calculate the speed of the wave (in m/s).

$V = \lambda \times f$ = ... x.......................

= .... m/s
(answer in standard notation)

2.
A "short wave" radio signal has a wavelength of only 80 cm. (= 0.8 m). Its frequency is 3.75×10^8 Hz.
Calculate its speed.

Remember, ALL EM waves travel at 3.0×10^8 m/s (= 300,000 km/sec)

3.
Microwaves used in cooking have a frequency of 2.5×10^9 Hz.
What is their wavelength?

$V = \lambda \times f$, so $\lambda = V / f$

(answer in metres, and in cm)

Student Name...

4.
A typical infra-red wave has a wavelength of just $^1/_{100}$ mm (= 1×10^{-5} m).
What is the frequency of this wave?

$V = \lambda \times f$, so $f = V / \lambda$

Write the answer in standard notation, then again in normal decimal notation.

5.
A wave of visible light has a frequency of 6×10^{14} Hz.
Find the wavelength (in m).

6.
A wave of UV radiation has a wavelength of 5×10^{-9} m. Find its frequency.

7.
What is the frequency of an X-ray if its wavelength is 3×10^{-11} m?

8.
What is the wavelength of gamma radiation if its frequency is 5×10^{21} Hz?

Worksheet 5
EM Waves

Student Name...

Fill in the blank spaces.

All a)...................................... (EM) waves travel at the same speed: the "speed of light" which is b)...................... km/sec. They do not need a c)....................... and can travel through a vacuum.

The EM waves with the longest wavelength (and d)............................ frequency) are e)....................... waves. These are used to transmit signals for f)...................... and .... as well as mobile phones.

Microwaves have g)......................... wavelength and h)............................ frequency. They are also used in communication as well as i)...................

j)................................ is heat radiation. we cannot see it, but can feel it on our k)..........................

The next member of the EM "family" is l).......................... which is the only one that we can m)......................

n).. radiation can cause sunburn and skin cancer. Luckily, most of it is blocked by the o)................. layer of the atmosphere.

p)................. are used for medical imaging because they can q).................. .... many things including you.

r)................. rays are even more penetrating. They are given off by s)..................................... substances. These waves have the t).......................... wavelength and u).............................. frequency of all the EM waves.

Worksheet 6
EM Waves Questions

Student Name..

1.
Which 2 types of EM waves are used in a lot of our communications?

.... and ....

2.
Originally, the science of Astronomy was done with light waves... by eye and telescope. Today, modern astronomers use ALL the types of EM waves.
What feature of all EM waves make them useful for studying outer space?

3. At what speed do all EM waves travel?

4.
"Night-vision" cameras use infra-red detectors to allow photograhs of people in pitch dark conditions.
Explain why a person (or other animal) can be "seen" by the camera.

5. a)
Some EM waves are quite dangerous to people. Name the three most dangerous.

.... and .... and ....

b) Are these the high, or low frequency members of the EM "family"?

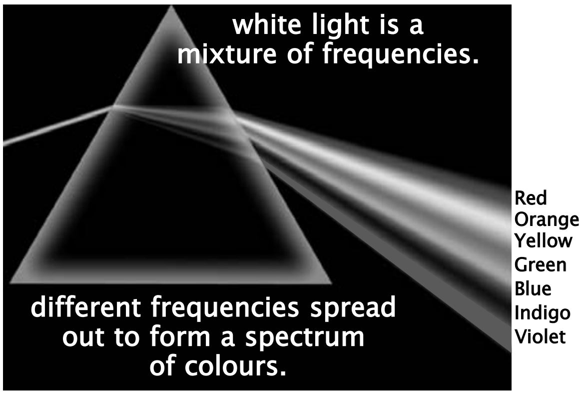
Light Waves & Colour

Visible light is just a very narrow section of the entire "spectrum" of EM waves.
Light includes a range of frequencies and wavelengths.
We see the different frequency light waves as different colours.

Colours of the Rainbow

What we call "white light" is really a mixture of different light waves of different frequency.

If white light (e.g. a beam of sunlight) is passed through a glass prism, the different frequencies are separated to reveal the "spectrum" of white light.



Are Colours Real?

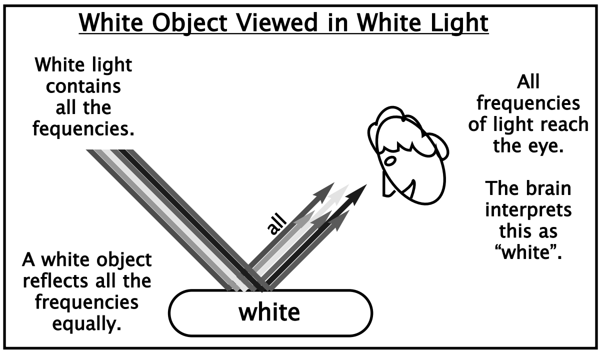
Each frequency of light is detected separately in our eye and different signals are sent to the brain.

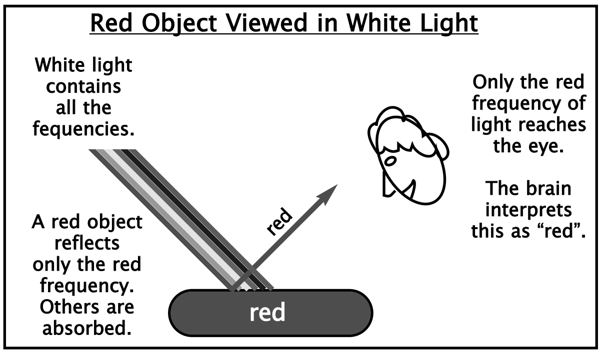
It is in the brain that colours are "seen". Colour really exists only as the way your brain interprets the information from the eye regarding the different frequencies of light.

The light waves themselves are not coloured. They are different wavelengths and are vibrating at different rates (different frequencies).

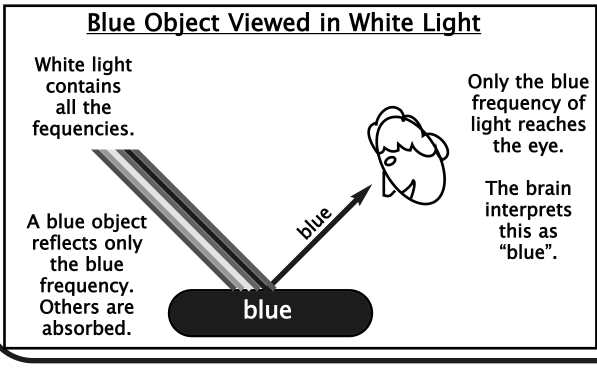
Why Things Look Coloured

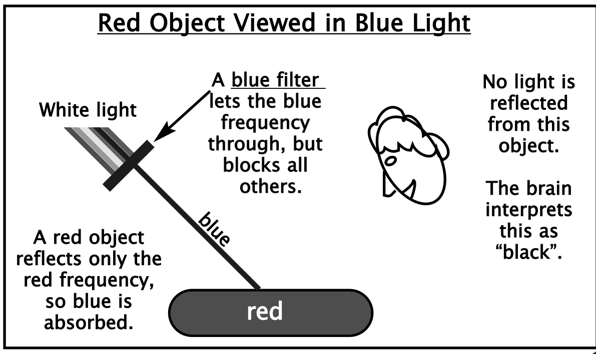
So why does one thing appear red, and another looks blue?
It is all about which frequencies of light bounce off the objects we look at.





You may be able to experiment with these situations using a "ray-box" lamp, coloured filters and coloured objects, in a darkened room.





Absorption, Reflection & Refraction

When a light wave strikes any substance, any of 3 things can happen.

Absorption

The energy of the wave can be absorbed by the substance.

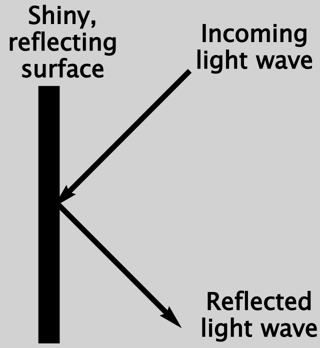
<u>Where does the energy go</u>? It causes some of the particles in the substance to vibrate, so it has become <u>heat</u> energy.

Even substances which are <u>transparent</u>, like glass or water, absorb some light. In perfectly clear water, light can only penetrate about 50m. By 100m down in the ocean it is totally dark.

Reflection

This means to bounce off.

Light always reflects at the same angle at which it hits the reflecting surface.

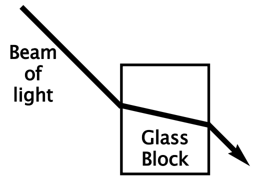


More about reflection below.

Refraction

This occurs when the light penetrates into a <u>transparent</u> substance, such as glass or water.

The light waves changes their speed and can <u>change direction</u>.



Refraction will be covered in more detail later in this topic.

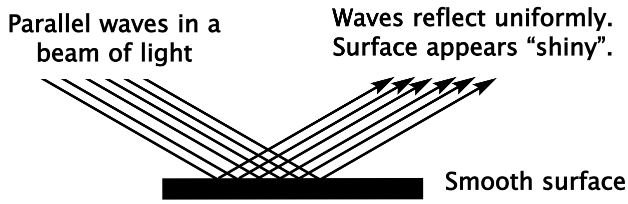
Reflection of Light

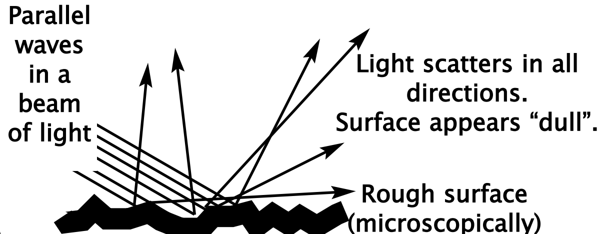
All waves can reflect, or bounce off things. The reflection of <u>sound waves</u> causes <u>echoes</u>. Reflection of <u>radio</u> or <u>microwaves</u> allows <u>radar</u> to work. Reflection of light allows us to see things.

Shiny & Dull

Surfaces that are very smooth (at the microscopic level) cause parallel beams of light to bounce off uniformly. This appears "shiny".

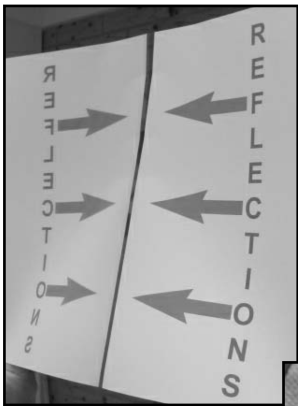
Surfaces that are rougher cause light waves to bounce off in all directions and scatter everywhere. Since only part of the light comes to your eye, the surface appears non-shiny, or dull.





Mirrors

Mirrors are the ultimate in shiny. Their surface is so smooth that light reflects off almost perfectly.



If the mirror is flat (a "plane mirror") it forms a perfect, back-to-front reflected image.

Curved mirrors can <u>magnify</u> the image, or make it smaller.

If the curve of the mirror is more complicated it can form distorted, "crazy" images.

Worksheet 7
Colour

Student Name..

1. List (in order) the colours of the "spectrum" of white light.

..............., ..., ..., ...

................, ... and ....

2. What colour do we see if all the frequencies of visible light enter our eye?

3. a) Describe what happens to the various frequencies when white light falls on a "green" object.

b) Which frequency(-ies) reach our eye?

c) What colour do we see the object to be?

4. Many fish are "silver" in colour because they are very shiny, and reflect all frequencies very well. Many fish are not silver, but red when viewed in air.

In the ocean, below a depth of about 10 metres, only blue & violet light penetrates. (All the red, orange, etc is absorbed by the water.)
a) At this depth, what colour does a "silver" fish appear to be?
Explain.

b) What colour would a "red" fish appear to be?

c) Explain how being bright red (in air) might help a fish hide at 10m depth.

Worksheet 8
Colour & Reflection

Student Name..

Fill in the blank spaces.

Our brains interpret the different a)............................... of light waves as different b)........................... A mixture of all the colours is seen as c) "................".

If "white" light falls on an object that reflects the yellow frequency, but absorbs all others, we would see it as d).............................. If we looked at the same object under blue light (in a darkened room) it would appear e).................. because all the f)................ light falling on it is being g)....................

When light strikes any substance, there are 3 things that can happen:

it can be h)............................ by the substance, or i)............................. off the surface, or it can penetrate into the substance and be j).............................

When it is absorbed, the energy makes the particles k).......................... more, so it has become l).................... energy.

If it reflects, it will bounce off at the same m)...................... as which it hit. Flat surfaces which reflect all the waves uniformly appear to be n).................... If the surface is rough at a microscopic level, the light waves bounce off in o)......................................, and are scattered. This appears p) "................".

Refraction of Light

Refraction can occur to all waves, but is especially important with light. Refraction occurs when waves enter a new medium, such as light passing from air into glass or water.

Examples of Light Refraction

Just look at this spoon standing in a cup of tea. It seems to be broken at the water surface. In fact, the spoon is not broken, and is perfectly straight.

We see the top of the spoon by light rays that travel through air to our eyes.

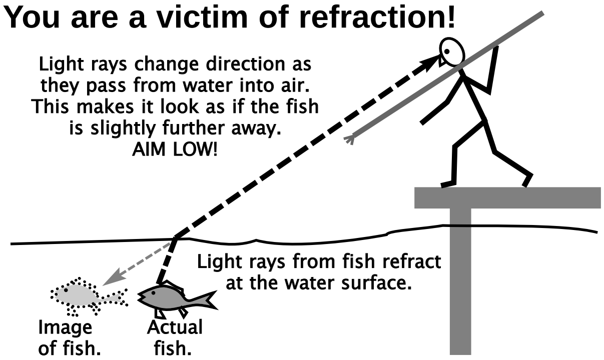
However, light from the bottom of the spoon travels through water, then glass, then air to our eyes.

As light rays travel from one "medium" into the next, they change direction slightly; they are <u>refracted</u>.

Refraction causes the image of the bottom of the spoon to be offset from the image of the top of it... it looks broken.

Imagine spear-fishing from above the water surface. You look down into the clear water, and there is dinner. You throw the spear with perfect accuracy... and you miss!

You are a victim of refraction!



You see the fish because of light reflecting from it, to your eyes. However, as the light waves passed from water into air, they were refracted and changed direction slightly.

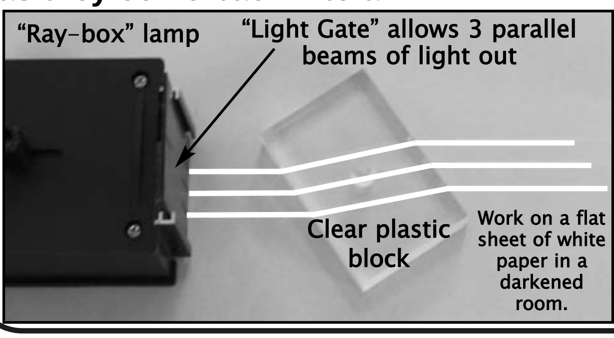
This caused the image of the fish to be moved a bit. Your spear hit a false image.

Experiments with Refraction

You can easily investigate refraction of light with a "ray-box kit".

The photograph shows a typical experimental investigation.

You can see that the light beams change direction as they enter the block of clear plastic, and again (opposite direction) as they come back into air.



<u>Things To Investigate</u>

- **Rotate the plastic block so the light beams strike it at different angles. Do the beams <u>always</u> change direction?**
- **Try different shapes of plastic blocks. (curved, triangular, etc)**
- **Look for evidence that when the beam hits the surface:**
  - **some light <u>reflects</u> off it.**
  - **some enters and is <u>refracted</u>.**
  - **some is <u>absorbed</u> by the plastic.**

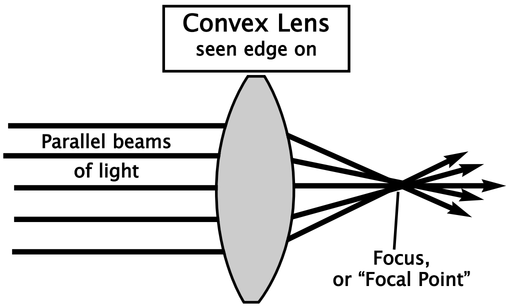
Optical Lenses ("Optical" = to do with seeing things)

We use many optical devices to help us see things better.
Spectacles and contact lenses correct people's vision. Microscopes magnify tiny objects, while telescopes make distant objects look closer. Cameras and projectors focus images onto film or onto a screen for viewing.
All of these rely on curved lenses which refract light in special ways.

Convex Lenses

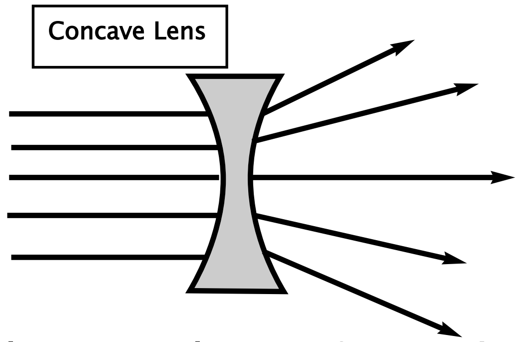
If you look through a convex lens at close-up things (e.g. the writing on a page) you will quickly find out that a convex lens is a "magnifying glass".

Using a ray-box kit, you can see what a convex lens does to parallel beams of light, by refraction.



Concave Lenses

(They go in, in the middle, like a cave)
Using a ray-box kit, you can see that a concave lens does NOT refract light to a focus, but spreads the beams apart.



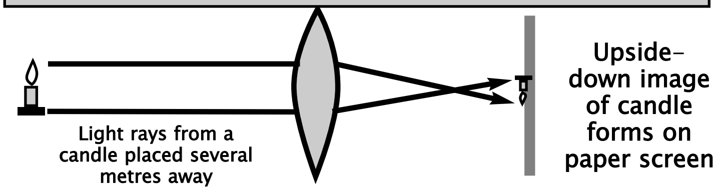
Only a convex lens can focus an image onto a screen or film, so they are the main lenses in cameras, projectors, etc.

Focusing an Image With a Convex Lens

You might try this activity.

Try again with a concave lens... it will not work.
Images can only be focused on a screen by convex lenses.

In a darkened room, hold a convex lens in front of a paper "screen". Move lens or paper back-and-forth to focus the image of a distant, lit candle onto the "screen".



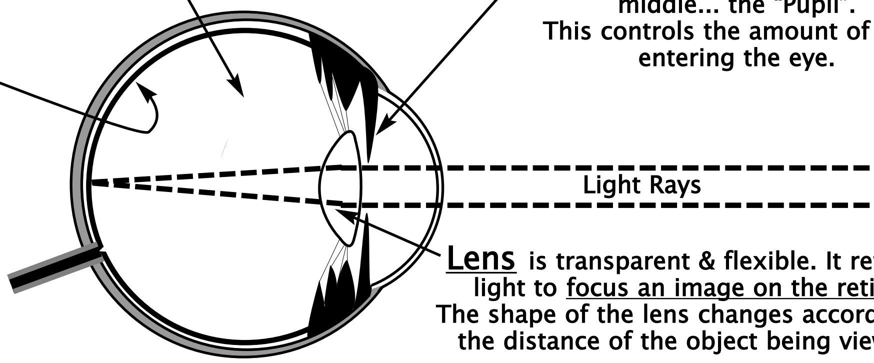
How the Eye Works

Our eyes are optical devices. Inside the eye a convex lens focuses an image on light sensitive cells in the retina. From there, nerve messages are sent to the brain.

The eyeball is filled with a clear jelly-liquid. This keeps the eye's shape, and lets light through.

Iris is the "colour" of the eye. It is a ring of muscle which can open or close the hole in the middle... the "Pupil". This controls the amount of light entering the eye.

Retina is sensitive to light, and sends off nerve messages.



Optic Nerve Carries nerve signals from Retina to brain.

Lens is transparent & flexible. It refracts light to focus an image on the retina. The shape of the lens changes according to the distance of the object being viewed.

Worksheet 9
Refraction & Lenses

Student Name..

Fill in the blank spaces.

Refraction occurs when a wave enters a new a)..........................., such as when light goes from air into b)......................

Refraction can cause waves to c).. slightly. This can cause the image of things to be d)........................ slightly, when viewed through glass or e)......................

A f)......................... lens is made of curved glass which is thicker in the middle. It refracts rays of light so that they all meet at a g)...................... point. This type of lens can h)............................ an image onto a screen, as in a projector.

This type of lens can also act as a i) ".................................... glass" to make things look bigger. That's why they are used in j).......................... to make small things appear larger, and in k)............................ to make distant objects look closer.

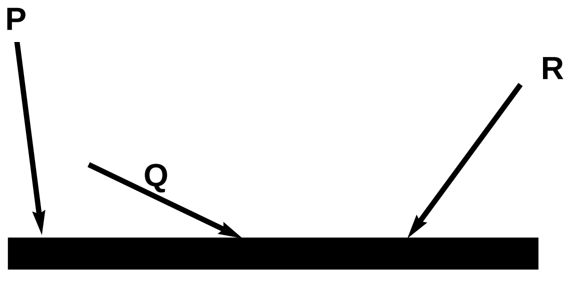
A l)............................ lens is curved the opposite way so it is m).......................... in the middle. This type will not n).................. light rays and cannot project an image.

The eye is an o)........................... device containing a p)......................... lens. The lens focuses light onto light-sensitive cells in the q)............................ This sends r)................... messages to the s)..........................., where we actually "see" things.

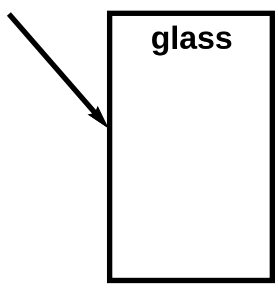
Worksheet 10
Reflection & Refraction

Student Name..

1. The diagram shows a flat mirror. P,Q&R are 3 light rays striking the mirror. Use a ruler to sketch the path of each reflected ray.



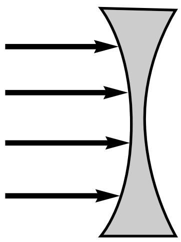
2. **This diagram shows a beam of light striking a block of glass. As it hits the glass some of the beam reflects and some refracts. Sketch and label clearly the 2 parts of the beam.**



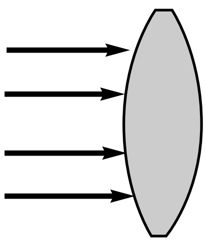
3. In the situation shown in Q2, <u>what else</u> may have happened to some of the light in the beam?

4. Complete these diagrams to show the path of the light rays that pass through these 2 lenses.

Also <u>name</u> the type of lens in each case.



....



.... lens

Topic Test
Wave Energy

Student Name.. Score =   /22

Answer all questions in the spaces provided.

1. (5 marks)
True of False? **T or F**

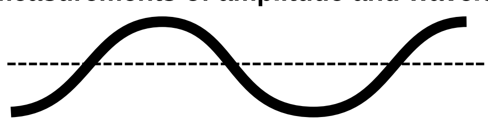
a) Light and sound waves can both travel through a vacuum. ......
b) The water only moves up & down as a water wave passes. ......
c) Amplitude is measured from trough up to crest. ......
d) The highest frequency EM waves are radio waves. ......
e) A red object viewed in red light would appear red. ......

2. (4 marks)
Fill in the blank spaces.

The wavelength of a wave is the distance a)..
The frequency is a measure of how many b)... per sec.
The unit of frequency is the c)..................
For any type of wave, if the wavelength gets shorter, the frequency gets d)..........................

3. (3 marks)
Small water waves in a lake have a wavelength of 1.5m. Their frequency is 0.5Hz. What is their speed?
Shown full working, and units for answer.

4. (2 marks)
Mark clearly on this wave diagram the measurements of amplitude and wavelength.



5. (5 marks)
Match each description to an item from the list. To answer, write the letter (A,B,C, etc) of the list item beside the description.

Description matches with **List Item**

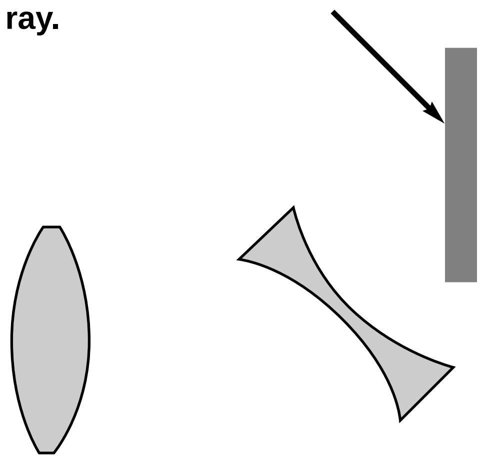
a) The substance that a wave travels through. ....
b) Shortest wavelength EM wave. ....
c) What lenses do to light rays. ....
d) EM wave used to cook. ....
e) Lens that can focus light. ....

List Items Not all will be used. Some may be used more than once.

A. refraction
B. medium
C. concave
D. gamma rays
E. convex
F. microwave

6. (3 marks)
This diagram shows a ray of light striking a flat mirror at a 45° angle. There are 2 lenses nearby, exactly as shown.

Use a ruler to construct the path taken by the light ray.



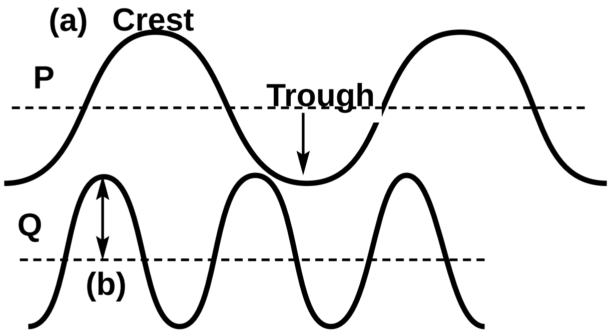
Answer Section

Worksheet 1

a) energy b) medium
c) oscillate / move up & down
d) go anywhere e) sound
f) vacuum g) medium
h) light i) glass or water
j) electromagnetic k) 300,000 km/hr
l) crests m) troughs
n) up & down o) amplitude
p) volume q) brightness

Worksheet 2

1.



(c) wave R (smallest amplitude)
2. The cork moves up and down only.
3. Light waves can travel through a vacuum, but sound waves cannot. (No air on the Moon... vacuum.)
4. By radio, which is an EM wave and can travel through a vacuum.

Worksheet 3

1. $v = \lambda \times f = 0.5 \times 660 = 330$ m/s

2. $v = \lambda \times f = 0.1 \times 3{,}300 = 330$ m/s

3. $v = \lambda \times f = 50 \times 0.05 = 2.5$ m/s

4. $v = \lambda \times f = 0.4 \times 3 = 1.2$ m/s

5. $v = \lambda \times f$
so $\lambda = V/f = 330/1{,}000 = 0.33$ m

6. $v = \lambda \times f$
so $\lambda = V/f = 1{,}500/1{,}000 = 1.5$ m

Worksheet 4

1. a) $50{,}000 = 5\text{x}10^4$ Hz
b) 6 km = 6,000 m = $6\text{x}10^3$ m
c) $v = \lambda \times f = 6\text{x}10^3 \times 5\text{x}10^4$
$= 3\text{x}10^8$ m/s

2. $v = \lambda \times f = 0.8 \times 3.75\text{x}10^8$
$= 3\text{x}10^8$ m/s

3. $V = \lambda \times f$,
so $\lambda = V / f = 3\text{x}10^8 / 2.5\text{x}10^9$
$= 0.12$ m (= 12 cm)

4. $V = \lambda \times f$,
so $f = V / \lambda = 3\text{x}10^8 / 1\text{x}10^{-5}$
$= 3\text{x}10^{13}$ Hz
= 30,000,000,000,000 Hz

5. $V = \lambda \times f$,
so $\lambda = V / f = 3\text{x}10^8 / 6\text{x}10^{14}$
$= 5\text{x}10^{-7}$ m

6. $V = \lambda \times f$,
so $f = V / \lambda = 3\text{x}10^8 / 5\text{x}10^{-9}$
$= 6\text{x}10^{16}$ Hz

7. $V = \lambda \times f$,
so $f = V / \lambda = 3\text{x}10^8 / 3\text{x}10^{-11}$
$= 1\text{x}10^{19}$ Hz

8. $V = \lambda \times f$,
so $\lambda = V / f = 3\text{x}10^8 / 5\text{x}10^{21}$
$= 6\text{x}10^{-14}$ m

Worksheet 5

a) electromagnetic b) 300,000 km/s
c) medium d) lowest
e) radio f) radio & TV
g) shorter h) higher
i) cooking or GPS or radar
j) Infra-red k) skin
l) light m) see
n) Ultra-violet o) ozone
p) X-rays q) penetrate through
r) Gamma s) radio-active
t) shortest u) highest

Worksheet 6

1. radio & microwaves
2. They can all travel through the vacuum of space, carrying information about the Universe.
3. Speed of light = $3x10^8$m/s =300,000km/s
4. Our body heat gives off infra-red waves which are detected by the camera.
5. a) UV & X-ray & gamma rays
b) high frequency

Worksheet 7

1. radio, microwaves, infra-red, light, ultra-violet, X-ray, gamma
2. white
3. a) The green light frequency is reflected, but all others are absorbed.
b) Green frequency only.
c) Green.
4. a) Silver fish would appear to be blue/violet because those are the only frequencies of light in the water. They will reflect off the fish to our eyes.
b) Black.
The fish appears red at the surface because only red frequency reflects off it. Blue & violet frequencies would be absorbed.
c) Looking black, it could hide in any shadow (under weed or a rock) and not be seen.

Worksheet 8

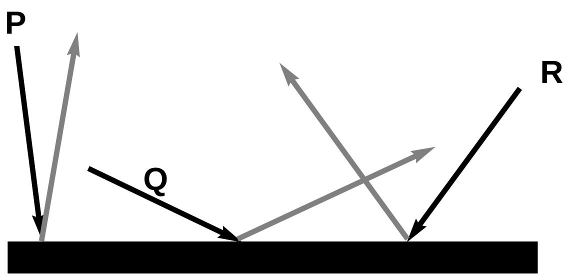
a) frequencies	b) colours
c) white	d) yellow
e) black	f) yellow
g) absorbed.	h) absorbed
i) reflected	j) refracted
k) vibrate	l) heat
m) angle	n) shiny
o) all directions	p) dull

Worksheet 9

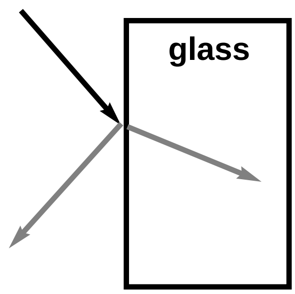
a) medium	b) glass / water
c) change direction	
d) offset / shifted	e) water
f) convex	g) focal
h) project	i) magnifying
j) microscopes	k) telescopes
l) concave	m) thinner
n) focus	o) optical
p) convex	q) retina
r) nerve	s) brain

Worksheet 10

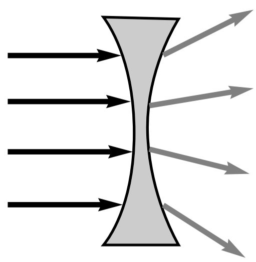
1.



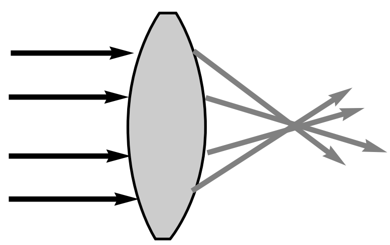
2.



3. Some was absorbed.
4.



Concave



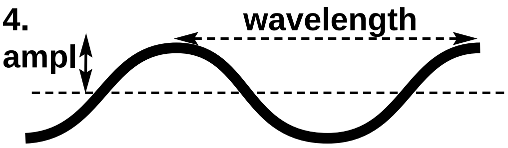
Convex

Topic Test

1. a) F b) T c) F d) F e) T

2.a) from crest to crest
b) waves go by per sec.
or, vibrations occur per sec.
c) hertz (Hz)
d) higher

3. $V = \lambda \times f = 1.5 \times 0.5 = 0.75$ m/s

4.


5. a) B b) D c) A
d) F e) E

6.