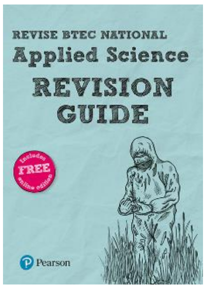
Tolworth Girls' Scho
& 6th Form

YEAR 12 TRANSITION PROGRAMME - INDEPENDENT STUDY TASK

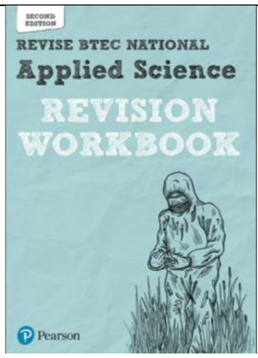
SUBJECT NAME : APPLIED SCIENCE BTEC

Activity	Main study Independent Study Task Activity Guidance Notes	Suggested supporting visits or readings.
Task 1	An introduction to nearly all of the topics studied during Unit 1 – Principles and Applications of Science is found below. Please read all of the pages in the document below on Biology, Chemistry and Physics. **Answer all 41 questions** from the bottom of these pages - that is only one question for each day of the summer holidays. Answer the questions on lined paper, making the page and question number clear next to each answer.	Please buy the following revision guide over the summer holidays in preparation for your first BTEC Applied Science lesson in September:  **Revision BTEC National Applied Science Revision Guide** **Publisher:** Pearson (August 2017) **ISBN:** 9781292150048 https://www.amazon.co.uk/National-Applied-Science-Revision-Guide/dp/1292150041/ref=sr_1_1?crid=1B30JF6C2NSB3&dchild=1&keywords=btec+applied+science+revision+guide&qid=1624351226&sprefix=btec+applied+scinec+re%2Caps%2C145&sr=8-1
Task 2	Fancy a book to read over the Summer holidays? Then look no further! Choose one of the following books to read over the summer and write a short synopsis on it (100-200 of your own words). **Biology** ▪ ***The Immortal Life of Henrietta Lacks*** by Rebecca Skloot. How one woman's cancer cells changed the medical world forever, and because a multi-million dollar industry. ▪ ***The Incredible Unlikeliness of Being*** by Alice Roberts. Alice Roberts combines embryology, genetics, anatomy, evolution and zoology to tell the incredible story of the human body ▪ ***Blood Work: A Tale of Medicine and Murder in the Scientific Revolution*** by Holly Tucker. The dramatic history of blood transfusions, from 17th century France onwards. There are many more ideas for Biology on this website: http://intobiology.org.uk/how-to-read-around-the-subject/	You might also be flicking through the TV channels on rainy days, so occasionally flick through the documentary channels and look for programmes that are related to Biology, Chemistry or Physics. Biology – cells, microscopy, specialised cells, blood vessels, atherosclerosis, muscles, nerves and brain chemicals (e.g. Parkinson's disease). https://www.bbc.co.uk/iplayer/episode/b03ccs7k/pain-pus-and-poison-the-search-for-modern-medicines-2-pus Chemistry – electronic structure, bonding, periodic table, chemical properties of elements. https://www.bbc.co.uk/iplayer/episode/b00q2mk5/chemistry-a-volatile-history-1-discovering-the-elements or https://hdclump.com/chemistry-a-volatile-history-episode-1-discovering-the-elements/ Physics – waves including endoscopy, optical fibres, musical instruments,

	Chemistry ▪ A Short History of Nearly Everything – Bill Bryson ▪ Uncle Tungsten – Oliver Sacks ▪ Molecules of Murder – John Emsley ▪ Stuff Matters – Mark Miodownik **Physics** • Hidden Figures – Margot Lee Shetterly • A Brief History of Time – Stephen Hawking • Human Universe – Brian Cox • Six Easy Pieces – Richard Feynman For all sciences there are some extremely interesting articles on the New Scientist website: https://www.newscientist.com/ BBC Science & Environment news can help keep you up to date with science news: https://www.bbc.co.uk/news/science_and_environment Some ideas for other good science websites can be found here: https://www.uk250.co.uk/science/	analogue & digital, EM waves, satellite communication, mobile phones, Bluetooth, infrared and Wi-Fi. https://www.bbc.co.uk/iplayer/episode/b08h9ctd/sound-waves-the-symphony-of-physics-series-1-2-using-sound Some documentary ideas: https://www.newscientist.com/article/2241718-the-10-best-documentaries-you-should-watch-right-now/ Some movie ideas: https://in.bookmyshow.com/buzz/blog/Movies/8-movies-scientist There are some fascinating TED Talks: https://www.ted.com/talks?topics%5B%5D=science Some ideas for scientists you could follow on Twitter: https://www.sciencemag.org/news/2014/09/top-50-science-stars-twitter Fed up of looking at a screen? Then how about listening to a podcast? There are lots of ideas here: https://www.bbcearth.com/blog/?article=the-best-nature-science-and-technology-podcasts
Task 3	If you find yourself at a loss for something to do this Summer then why don't you take a virtual tour of one of the many amazing science museums (or now they are reopen then visit them in person), ❖ Natural History Museum (https://www.nhm.ac.uk/visit/virtual-museum.html) ❖ Science Museum (https://www.sciencemuseum.org.uk/virtual-tour-science-museum) ❖ London Zoo (https://www.zsl.org/zsl-london-zoo/virtual-london-zoo) ❖ Some more suggestions can be found here: https://interestingengineering.com/11-science-and-tech-museums-you-can-tour-virtually	Many students have found the following workbook really useful: **Revision BTEC National Applied Science Revision Guide** **Publisher:** Pearson (May 2018) **ISBN:** 9781292258171 https://www.amazon.co.uk/National-Applied-Science-Revision-Workbook/dp/1292258179/ref=sr_1_2?crid=1B30JF6C2NSB3&dchild=1&keywords=btec+applied+science+revision+guide&qid=1624351503&sprefix=btec+applied+scinec+re%2Caps%2C145&sr=8-2

If you have aspirations of studying nursing or midwifery you might find these places or their websites interesting:

- Anaesthesia Heritage Centre
- British Dental Association Museum
- Florence Nightingale Museum
- Museum at St Bartholomew's Hospital
- The Old Operating Theatre and Herb Garret
- Wellcome Collection
- Hunterian Museum (Royal College of Surgeons)



Please complete the set tasks and submit to your subject teacher on the first lesson in September. If you are unable to print the completed work, please email it to one of the BTEC Science teachers:
Mr Dowthwaite joe.dowthwaite@tolworthgirlsschool.co.uk

Places to go for help:

1. The specification for BTEC Level 3 Applied Science: https://qualifications.pearson.com/content/dam/pdf/BTEC-Nationals/Applied-Science/2016/specification-and-sample-assessments/9781446938164_BTECNat_AppSci_ExtCert_Spec.pdf
2. Unit 1 and Unit 3 past papers: https://qualifications.pearson.com/en/qualifications/btec-nationals/applied-science-2016.coursematerials.html#filterQuery=category:Pearson-UK:Category%2FExternal-assessments&filterQuery=category:Pearson-UK:Unit%2FUnit-1&filterQuery=category:Pearson-UK:Unit%2FUnit-3
3. BTEC Textbook Unit 1 Chapter: https://www.pearsonschoolsandfecolleges.co.uk/asset-library/pdf/Secondary/BTEC-Nationals/Applied-Science-2016/BTECNationalinAppliedScienceUnit01Sampleredactedwebready.pdf

Eukaryotic and Prokaryotic Cells

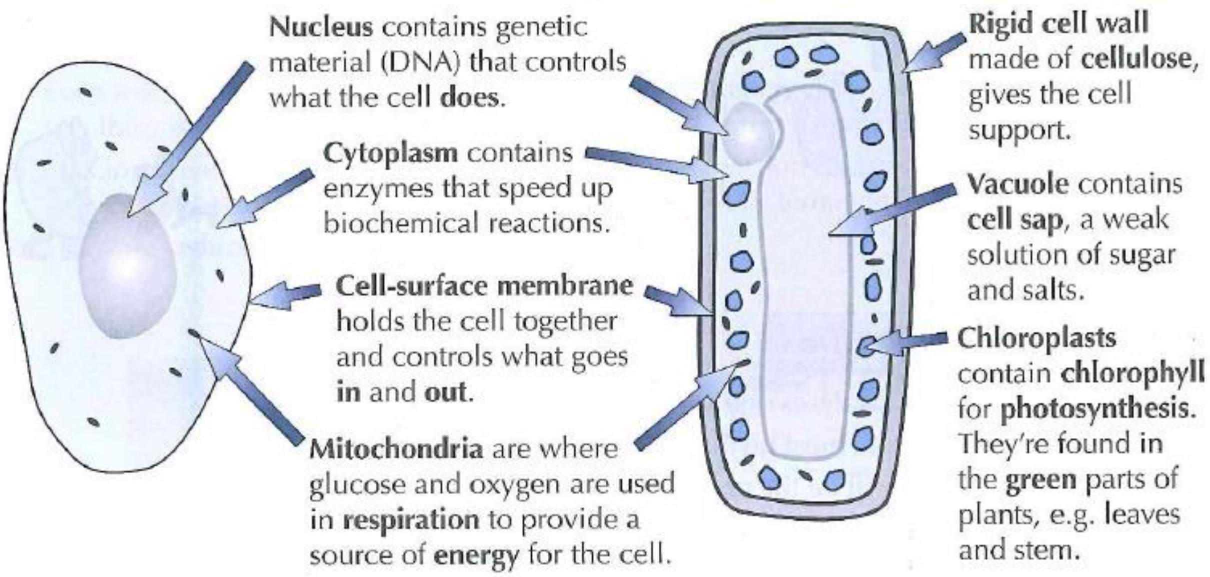
Organisms can be Prokaryotes or Eukaryotes

1) **Prokaryotic** (pronounced like this: pro-carry-ot-ick) organisms are prokaryotic cells (i.e. they're **single-celled** organisms) and **eukaryotic** (you-carry-ot-ick) organisms are made up of eukaryotic cells.
2) Both types of cells contain **organelles**. Organelles are parts of cells — each one has a **specific function**.

Eukaryotic cells are **complex** and include all **animal** and **plant** cells.
Prokaryotic cells are **smaller** and **simpler**, e.g. **bacteria**.

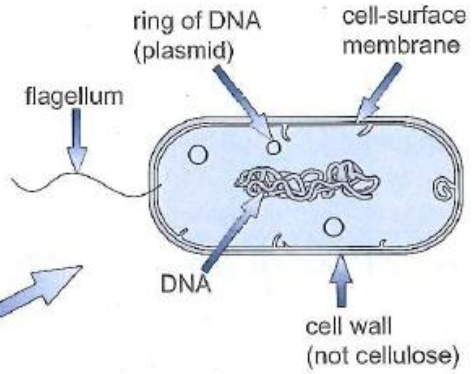
4 organelles **animal** and **plant** cells have in **common**:

3 extras that **only plant cells** have:



Bacterial Cells are Prokaryotic

1) Prokaryotes like bacteria are roughly a **tenth the size** of eukaryotic cells.
2) Prokaryotic cells **don't contain** a nucleus, mitochondria or chloroplasts.
3) As they **don't** have a nucleus, their **DNA floats freely** in the **cytoplasm**. Some prokaryotes also have **rings of DNA** called **plasmids**.
4) Some prokaryotes have a **flagellum** which **rotates** and allows the cell to **move**.
5) The diagram shows a bacterial cell as seen under an **electron microscope** (see next page).



Bacterial cheerleaders — they never stop swirling their flagella...

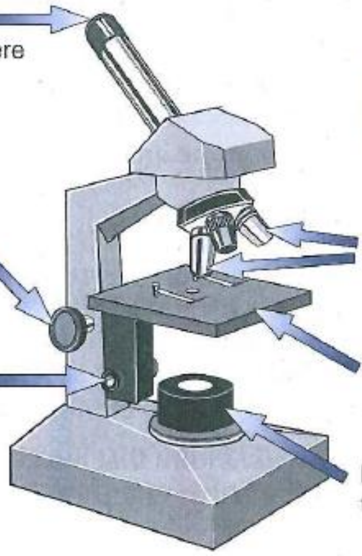
1) Give an example of a prokaryotic cell.
2) Name four organelles that plant and animals cells both have.
3) What is the function of mitochondria?

Microscopes

*You Can **See Cell Structure** with a **Light Microscope***

A **light microscope** can magnify up to 1500 times and allows you to see individual animal and plant cells along with the organelles inside them.

1) If the cells have been **stained** you can see the dark-coloured **nucleus** surrounded by lighter-coloured **cytoplasm.**
2) Tiny **mitochondria** and the black line of the **cell membrane** are also visible.
3) In plant cells, the **cell wall**, **chloroplasts** and the **vacuole** can be seen.



A light microscope can also be called an **optical** microscope.

Electron Microscopes** have a **Greater Magnification

1) The detailed **ultrastructure** of cells was revealed in the 1950s when the **electron microscope** was invented.
2) An electron microscope can **magnify** objects more than 500 000 times and, more importantly, it allows **greater detail** to be seen than a light microscope. For example, it allows you to see the detailed **structures inside organelles** such as mitochondria and chloroplasts.
3) The image that's recorded is called an **electron micrograph**.

I put a slide on the stage and then slid straight off the edge...

1) Name three things visible with a light microscope in both animal and plant cells.
2) Which type of microscope must be used to show the detailed ultrastructure of a cell?
3) What is the image recorded by an electron microscope called?

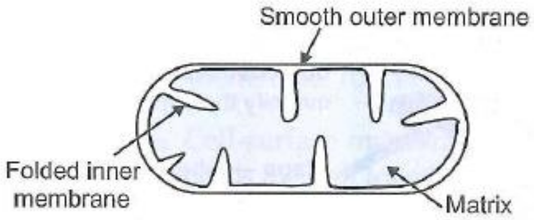
Functions of the Nucleus, Mitochondria and Cell Wall

Nucleus

1) The **nucleus** is the control centre of the cell.
2) It contains **DNA** (deoxyribonucleic acid): the coded information needed for **making proteins**.
3) During **cell division** the chromosomes carrying the long DNA molecules coil up, becoming shorter and thicker and visible with a light microscope.
4) Electron micrographs show that there's a **double membrane** around the nucleus.

Mitochondria

Mitochondria are about the size of bacteria, so they can be seen with a light microscope, but you need an electron microscope to see any of the detail.
Each mitochondrion has a **smooth outer membrane** and a **folded inner membrane**:



A **mitochondrion**

Their job is to capture the energy in glucose in a form that the cell can use.
To do this **aerobic respiration** takes place inside the mitochondria.

Word equation: GLUCOSE + OXYGEN → CARBON DIOXIDE + WATER + (ENERGY)

The energy released by respiration ends up in molecules of **ATP** (adenosine triphosphate).
ATP is used in the cell to provide the energy for **muscle contraction, active transport** (called active uptake in some text books) and **building large molecules** from small ones, as well as many other processes.

Cell Wall — Plants

1) The plant cell wall is relatively rigid and provides **support** for the cell.
2) It mainly consists of bundles of long, straight **cellulose molecules**.
3) The cellulose molecules lay side by side to form **microfibrils**.

*Doctor, doctor my DNA is getting shorter and thicker...**

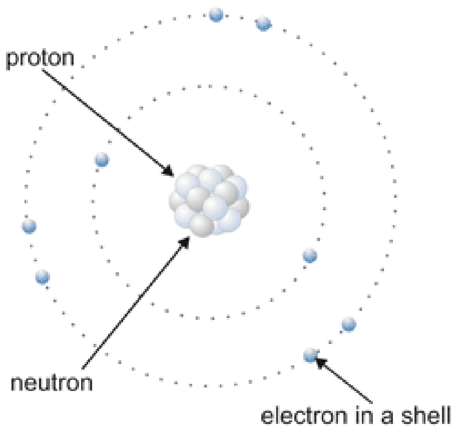
1) Which organelle acts as the control centre of the cell?
2) In which organelle does aerobic respiration occur?
3) Describe the membranes of a mitochondrion.
4) What is the word equation for aerobic respiration?
5) Name the molecule used to provide energy for processes in the cell.
6) Name the molecule that is found in bundles in plant cell walls.

...that's the least of your worries — you're going to divide soon.

Atomic Structure

What Are *Atoms* Like?

1) Atoms are made up of **three** types of **subatomic particle**: **protons**, **neutrons** and **electrons**.
2) In the **centre** of all atoms is a **nucleus** containing **neutrons** and **protons**.
3) Almost all of the **mass** of the atom is contained in the **nucleus** which has an overall **positive** charge. The positive charge arises because each of the **protons** in the nucleus have a **+1** charge.
4) The **neutrons** in the nucleus have a very similar **mass** to the protons but they are **uncharged**.
5) **Electrons** are much **smaller** and **lighter** than either the neutrons or protons. They have a **negative charge** (**–1**) and **orbit** the nucleus in **shells** (or energy levels).



6) There's an **attraction** between the **protons** in the nucleus and the **electrons** in the shells.
7) The nucleus is **tiny** compared with the total volume occupied by the whole atom.
8) The **volume** occupied by the **shells** of the electrons determines the **size** of the atom.

Here's a round up of the **properties** of the subatomic particles:

Particle	Relative Mass	Relative Charge
Proton	1	+1
Neutron	1	0
Electron	$\frac{1}{2000}$	–1

What is the *Charge* on an Atom?

The overall charge on an atom is **zero**.

This is because each **+1** charge from a **proton** in the nucleus is **cancelled out** by a **–1** charge from an **electron**.

If an atom **loses** or **gains** electrons it becomes **charged**. These charged particles are called **ions**.

EXAMPLE: How many electrons has an Al^{3+} ion lost or gained?

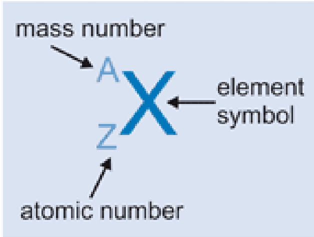
The Al^{3+} ion has a charge of **+3**, so there must be **3 more protons** than **electrons**.
Ions are formed when **electrons** are lost or gained, so Al^{3+} must have **lost 3 electrons**.

Neutrons are the perfect criminals — they never get charged...

1) Which subatomic particles are found in the nucleus?
2) What is the charge on an ion formed when an atom loses two electrons?
3) What is the charge on an ion formed when an atom gains two electrons?

Atomic Number, Mass Number and Isotopes

Atomic *and* ***Mass*** *Numbers*



1) If you look at an element in the periodic table, you'll see it's given **two numbers**. These are the **atomic number** and the **mass number**.
2) The **atomic number** of an element is given the symbol **Z**. It's sometimes called the **proton number** as it represents the number of **protons** in the nucleus of the element.
3) For **neutral** atoms the number of **protons equals** the number of **electrons**, but you need to take care when considering ions as the number of electrons changes when an ion forms from an atom.
4) The **mass number** of an atom is given the symbol **A**. It represents the **total** number of **neutrons** and **protons** in the nucleus.
5) **Subtracting Z** from **A** allows you to calculate the number of **neutrons** in the nucleus.

EXAMPLE: Use the periodic table to complete the following information about sodium.

Element	Symbol	Z	A	No. Protons	No. Neutrons	No. Electrons
Sodium			23			

The periodic table tells you that the **symbol** for sodium is **Na** and **Z** is **11**.

The number of **protons** in sodium is the same as the **atomic number**, which is **11**.

You work out the number of **neutrons** by **subtracting** Z from A: 23 – 11 = **12**.

The number of **electrons** is the **same** as the number of protons, which is **11**.

Isotopes

1) Atoms of the same **element** always have the same number of **protons**, so they'll always have the same **atomic number**, but their **mass numbers** can **vary** slightly.
2) Atoms of the same **element** with different **mass numbers** are called **isotopes**.
3) Isotopes have the same number of **protons** but different numbers of **neutrons** in their nuclei.

EXAMPLE: Copper has an atomic number of 29. Its two main isotopes have mass numbers of 63 and 65. How many neutrons does each of the isotopes have?

The ^{63}Cu isotope has 63 – 29 = **34 neutrons**.

The ^{65}Cu isotope has 65 – 29 = **36 neutrons**.

Finding the number of neutrons — it's as easy as knowing your A – Z...

1) Use the periodic table to work out how many neutrons are in a neutral phosphorus atom.
2) In terms of the numbers of subatomic particles, state two similarities and one difference between two isotopes of the same element.
3) Three neutral isotopes of carbon have mass numbers 12, 13 and 14. State the numbers of protons, neutrons and electrons in each.

Relative Atomic Mass

*Calculating the **Relative Atomic Mass***

1) The average mass of an element is called its **relative atomic mass**, or A_r.
2) When you look up the **relative atomic mass** of an element on a **detailed** copy of the periodic table, you'll see that it isn't always a **whole number**. This is because the value given is the **average** mass number of two or more **isotopes**.
3) The **value** of the relative atomic mass is further complicated by the fact that some isotopes are **more abundant** than others. It's a **weighted average** of all the element's different isotopes.
4) You can use the **relative abundances** and **relative isotopic masses** (the mass number of a single, specific isotope) of each isotope to work out the **relative atomic mass** of an element.
5) Relative abundances of isotopes are often given as **percentages**. To work out the **relative atomic mass** of an element, all you need to do is multiply **each isotopic mass** by its **relative abundance**, add all the values together and divide by **100**.

EXAMPLE: What is the relative atomic mass of chlorine given that 75% of atoms have an atomic mass of 35 and 25% of atoms have an atomic mass of 37?

Average mass = (abundance of $^{35}Cl \times 35$ + abundance of $^{37}Cl \times 37) \div 100$

$= [(75 \times 35) + (25 \times 37)] \div 100$

$= (2625 + 925) \div 100$

$= 3550 \div 100$

= **35.5** (You can check your answer against a periodic table to see if it's right.)

*Calculating the **Relative Formula Mass***

If you **add up** the relative atomic masses of all the atoms in a chemical formula, you get the **relative formula mass**, or M_r, of that compound.

(If the compound is molecular, you might hear the term relative molecular mass used instead, but it means pretty much the same.)

EXAMPLE: Calculate the relative formula mass of $CaCl_2$.

Ca has an atomic mass of 40.1 and Cl has an atomic mass of 35.5.

$M_r = (1 \times 40.1) + (2 \times 35.5)$

= **111**

Together, my brother and I weigh 143 kg — it's our relative mass...

1) Find the relative atomic mass of lithium if its composition is 8% ^{6}Li and 92% ^{7}Li.
2) Find the relative atomic mass of carbon if its composition is 99% ^{12}C and 1% ^{13}C.
3) Find the relative atomic mass of silver if its composition is 52% ^{107}Ag and 48% ^{109}Ag.
4) Find the relative formula mass of sodium fluoride, NaF.
5) Find the relative formula mass of chloromethane, CH_3Cl.

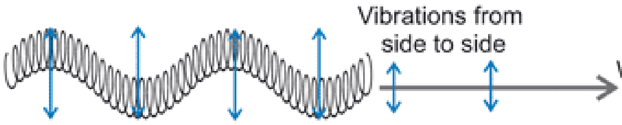
Waves

Waves Transfer **Energy** Without Transferring **Matter**

1) Waves are **oscillations** that transfer energy — like water waves or electromagnetic waves.
2) Waves carry **energy** from one place to another **without** transferring **matter**.

Transverse Waves Vibrate at **90°** to the Direction of Travel

Transverse waves have **vibrations** at **90°** to the direction of **energy transfer** and **travel**.
E.g. **electromagnetic** waves (like light) or shaking a Slinky® spring from side to side.

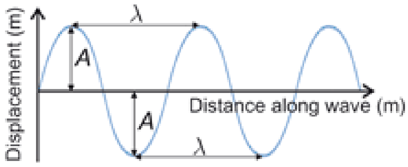


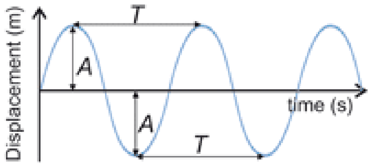
Longitudinal Waves Vibrate **Along** the Direction of Travel

Longitudinal waves vibrate in the **same direction** as the direction of **energy transfer** and **travel**.
They are made of alternate **compressions** and **rarefactions** of the medium.
E.g. sound waves or pushing on the end of a Slinky® spring.

You Can Show Wave Motion on a **Graph**

A **displacement-distance** graph shows **how far** each part of the wave is **displaced** from its **equilibrium position** for different distances along the wave.





You can also consider **just one point** on a wave and plot how its **displacement** changes with **time**. This is a **displacement-time** graph.

Displacement = how far a point on the wave has moved from its equilibrium position
Amplitude (*A*) = the largest possible displacement from the equilibrium position
Wavelength (λ) = the length of one wave cycle, from crest to crest or trough to trough
Period (*T*) = the time taken for a whole cycle (vibration) to complete, or to pass a given point

Transverse waves are terrible singers — they always skip the chorus...

1) Sketch a graph of displacement against distance for five full wavelengths of a wave with amplitude 0.01 metres and wavelength 0.02 metres.
2) Sketch a graph of displacement against time for three complete oscillations of one part of a wave of amplitude 0.05 metres and time period 0.8 seconds.

Frequency and the Wave Equation

Frequency is the Number of Oscillations per Second

If a wave has a **time period** of 0.2 seconds, it takes 0.2 seconds for a point on the wave to complete **one full oscillation**. So in one second the point will complete **5 full oscillations**.

The number of oscillations that one point on a wave completes every second is called the **frequency** of the wave. It has the symbol f and is measured in **hertz** (Hz).

So a wave with a time period of 0.2 seconds has a **frequency** of 5 hertz.

The equation for frequency is:

$$\text{Frequency} = \frac{1}{\text{time period}} \quad \text{or} \quad f = \frac{1}{T}$$

EXAMPLE: A wave has a frequency of 350 Hz. What is the period of oscillation of one point on that wave?

$T = \frac{1}{f} = \frac{1}{350} = 0.002857... =$ **0.0029 s (to 2 s.f.)**

The Wave Equation Relates Speed, Frequency and Wavelength

For a wave of **frequency** f (in hertz), **wavelength** λ (in metres) and **wave speed** v (in metres per second) the wave equation is:

$$\text{speed} = \text{frequency} \times \text{wavelength} \quad \text{or} \quad v = f \times \lambda$$

EXAMPLE: Sound is a longitudinal wave. If a sound with a frequency of 250 Hz has a wavelength of 1.32 metres in air, what is the speed of sound in air?

$v = f \times \lambda = 250 \times 1.32 =$ **330 ms^{-1}**

EXAMPLE: All electromagnetic waves travel at 3.0×10^8 ms^{-1} in a vacuum. If a radio wave has a wavelength of 1.5 km in a vacuum, what is its frequency?

$v = f \times \lambda$, so $f = \frac{v}{\lambda} = \frac{3.0 \times 10^8}{1.5 \times 10^3} =$ **200 000 Hz** (or 200 kHz)

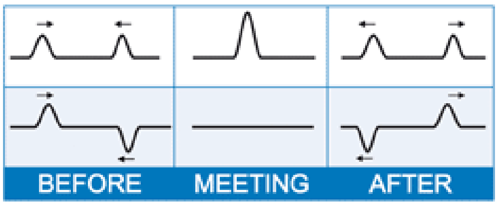
Wave equation: lift arm + oscillate hand = pleasant non-vocal greeting...

1) A radio wave has a frequency of 6.25×10^5 Hz.
   What is the time period of the radio wave?
2) A sound wave has a time period of 0.0012 s. Find the frequency of the sound.
3) A wave along a spring has a frequency of 3.5 Hz and a wavelength of 1.4 m.
   What is the speed of the wave?
4) A wave has time period 7.1 s and is moving at speed 180 ms^{-1}.
   a) What is the frequency of the wave?
   b) What is the wavelength of the wave?

Superposition of Waves

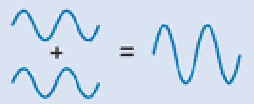
Superposition *Happens When* ***Two*** *Waves* ***Meet***

1) If two waves meet (e.g. waves on a rope travelling in opposite directions), their displacements will briefly **combine**.
2) They become **one single wave**, with a **displacement** equal to the displacement of each individual wave **added together**.
3) This is called **superposition**.
4) If two **crests** meet, the **heights** of the waves are **added together** and the crest height **increases**. This is called **constructive interference** because the **amplitude** of the superposed waves is **larger** than the amplitude of the individual waves.
5) If the **crest** of one wave meets the **trough** of another wave, you **subtract** the trough **depth** from the crest **height**. So if the crest height is **the same** as the trough depth they'll **cancel out**. This is called **destructive interference** because the **amplitude** of the superposed waves is **smaller** than that of the individual waves.
6) After combining, the waves then carry on **as they were** before.



If Waves are ***In Phase*** *they* ***Interfere Constructively***

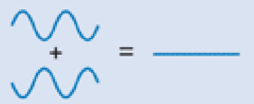
1) Two waves travelling in the **same direction** are **in phase** with each other when the **peaks** of one wave **exactly line up** with the **peaks** of the **other**, and the **troughs** of one wave **exactly line up** with the **troughs** of the **other**.
2) If these waves are **superposed**, they **interfere constructively**. The **combined amplitude** of the final wave is equal to the **sum** of the individual waves.



In phase, constructive interference

If Waves are ***Out of Phase*** *they* ***Interfere Destructively***

1) Two waves are **exactly out of phase** if the **peaks** of one wave line up with the **troughs** of the other (and vice versa).
2) If these waves are **superposed**, they **interfere destructively**. If the individual waves had the same amplitude originally, they will **cancel each other out**.



Out of phase, destructive interference

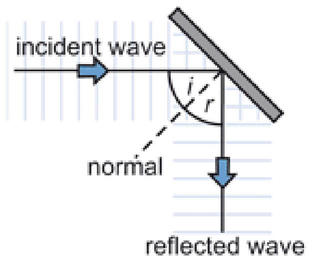
Constructive interference — getting woken up early by noisy builders...

1) What is meant by:
   a) superposition?
   b) constructive interference?
   c) destructive interference?
2) A wave with an amplitude of 0.67 mm is superposed with an identical wave with the same amplitude. The waves are in phase. What is the amplitude of the superposed wave?
3) Two waves, both of amplitude 19.1 m, are exactly out of phase. What is the amplitude of the single wave formed when they superpose?
4) A wave with an amplitude of 35 cm is in phase with a 41 cm amplitude wave. The waves meet and constructive interference occurs. What is the amplitude of the combined wave?

Reflection and Diffraction

*Waves can be **Reflected***

1) When a wave hits a **boundary** between one medium and another, some (or nearly all) of the wave is **reflected back**.

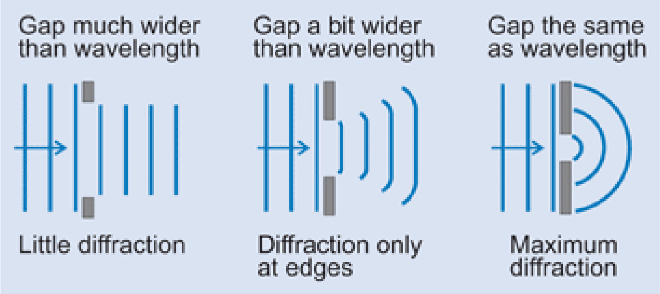


2) The angle of the **incident** (incoming) wave is called the **angle of incidence**, and the angle of the **reflected** wave is called the **angle of reflection.**
3) The angles of incidence and reflection are both **measured from the normal** — an imaginary line running **perpendicular** to the **boundary**.
4) The **law of reflection** says that:

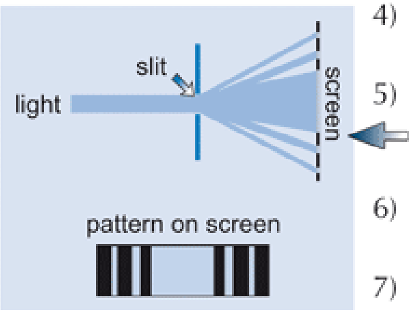
angle of incidence (*i*) = angle of reflection (*r*)

Diffraction** — Waves **Spreading Out

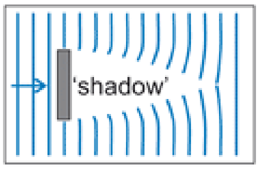
1) Waves **spread out** ('**diffract**') at the edges when they pass through a **gap** or **pass an object**.
2) The **amount** of diffraction depends on the **size** of the gap relative to the **wavelength** of the wave. The **narrower the gap**, or the **longer the wavelength**, the more the wave spreads out.



3) A **narrow gap** is one about the same size as the **wavelength** of the wave. So whether a gap counts as narrow or not depends on the wave.



4) If light is shone at a **narrow slit** about the **same width** as the **wavelength** of the light, the light **diffracts**.
5) The diffracted light forms a **diffraction pattern** of **bright** and **dark fringes**. This pattern is caused by **constructive** and **destructive interference** of light waves (see p.34).
6) You get diffraction around the edges of **obstacles** too.
7) The **shadow** is where the wave is **blocked**. The **wider** the obstacle compared to the **wavelength**, the **less diffraction** it causes, so the **longer** the shadow.



Mind the gap between the train and the platform — you might diffract...

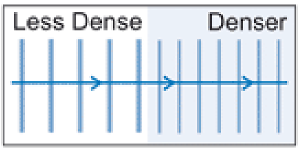
1) What is the law of reflection?
2) Sketch a diagram of a light wave being reflected at an angle by a mirror. Label the incident and reflected waves, the normal, the angle of incidence and the angle of reflection.
3) A water wave travels through a gap about as wide as its wavelength. The gap is made slightly larger. How will the amount of diffraction change?
4) What happens when light is shone at a slit about the same size as its wavelength?

Refraction

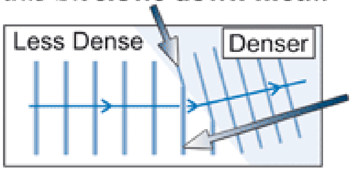
*Waves can be **Refracted***

1) Reflection isn't all that happens when a wave meets a boundary. Usually, some of it is **refracted** too — it passes through the boundary and **changes direction**.
2) Waves travel at **different speeds** in **different media**.
   E.g. — electromagnetic waves, like light, usually travel slower in denser media.

If a wave hits a boundary 'face on', it **slows down** without changing direction.



But if the wave hits at an angle, this bit **slows down first**...



...while this bit carries on at the same speed until it meets the boundary. The wave **changes direction**.

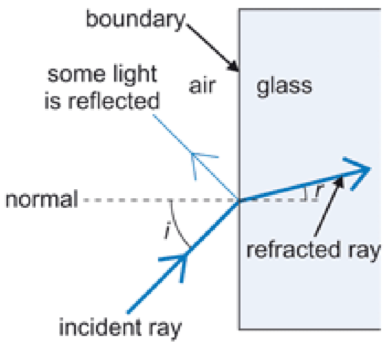
When an electromagnetic wave enters a **denser** medium, it bends **towards** the normal.
When one enters a **less dense** medium, it bends **away** from the normal.

*The **Refractive Index** is a **Ratio of Speeds***

The **refractive index** of a medium, n, is the **ratio** of the speed of light in a **vacuum** to the speed of light in **that medium**. **Every** transparent material has a refractive index and different materials have **different refractive indices**.

*You can **Calculate** the Refractive Index using **Snell's Law***

When an **incident ray** travelling in **air** meets a boundary with **another material**, the **angle of refraction** of the ray, r, depends on the **refractive index** of the material and the **angle of incidence**, i.



This is called **Snell's Law**.

refractive index (n) = $\frac{\sin i}{\sin r}$

EXAMPLE: The angle of incidence of a beam of light on a glass block is 65°. The angle of refraction is 35°. What is the refractive index of the block?

$$n = \frac{\sin i}{\sin r} = \frac{\sin 65}{\sin 35} = 1.580... = \mathbf{1.6}$$

You can **rearrange** Snell's Law to find an angle of refraction or incidence, e.g. $r = \sin^{-1}\left(\frac{\sin i}{n}\right)$.

This page has a high refractive index — it's really slowed me down...

1) A wave hits a boundary between two media head on. Describe what happens to the wave.
2) A wave hits a boundary between two media at an angle. Describe what happens to the wave.
3) A light wave travelling in air hits a transparent material at an angle of 72° to the normal to the boundary. The angle of refraction is 39°. What is the refractive index of the material?
4) A light wave hits the surface of the water in a pond at 23° to the normal. The refractive index of the pond water is 1.3. What is the angle of refraction?