A Level Physics

Year 11-12 Transition Booklet 2025

TENACITY

Name ____________________________________

Tasks	Completed (tick)	Score/RAG Rating (for teacher to complete)
1.1 SI Units and their prefixes		
2.1 Constituents of the atom		
2.3.1 Particles and antiparticles		
3.1 Progressive waves		
3.2 Longitudinal and transverse waves		
Research Task 1		
Investigation Task 1		

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1.1 Use of SI units and their prefixes

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SI units

Scientists around the world use the same internationally agreed system of units. These are called SI (Système International) units. The system is built upon seven base units.

SI base units

Quantity	*Name of unit*	*Symbol*
length		
	kilogram	
		s
	ampere	
temperature		*K*
amount of substance		*mol*
luminous intensity	candela	*cd*

Note: the knowledge of the candela is not required for this course

(1) Complete the table above by doing some research.

Derived units

Quantities such as speed (*ms^{-1}*) and density (*kgm^{-3}*) which are not expressed in a single base unit are expressed in 'derived' units.

(2) Complete the table, below:

Quantity	*Symbol*	*Name of unit*	*Symbol for unit*	*Base units*
speed or velocity	v		ms^{-1}	ms^{-1}
acceleration	a		ms^{-2}	ms^{-2}
force	F			$kgms^{-2}$
energy	E			kgm^2s^{-2}
power	P		W	kgm^2s^{-3}
pressure	p		Pa	$kgm^{-1}s^{-2}$
frequency	f	hertz	Hz	s^{-1}
charge	Q	coulomb		As
potential difference	V	volt		$A^{-1}kgm^2s^{-3}$
resistance	R		Ω	$A^{-2}kgm^2s^{-3}$
capacitance	C	farad	F	$A^2kg^{-1}m^{-2}s^4$
magnetic flux	B	tesla	T	$A^{-1}kgs^{-2}$

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Prefixes

In Physics, we have to deal with quantities from the very large to the very small. A prefix is something that goes in front of a unit and acts as a multiplier. This sheet will give you practice at converting figures between prefixes.

(3) Complete the table, below:

Symbol	*Name*	*What it means*		*How to convert*	
P	peta	10^{15}	1000000000000000		↓ x1000
T		10^{12}	1000000000000	↑ ÷ 1000	↓ x1000
G		10^{9}	1000000000	↑ ÷ 1000	↓ x1000
M		10^{6}	1000000	↑ ÷ 1000	↓ x1000
k	kilo		1000	↑ ÷ 1000	↓ x1000
			1	↑ ÷ 1000	↓ x1000
m		10^{-3}	0.001	↑ ÷ 1000	↓ x1000
μ		10^{-6}	0.000001	↑ ÷ 1000	↓ x1000
n	nano		0.000000001	↑ ÷ 1000	↓ x1000
p	pico		0.000000000001	↑ ÷ 1000	↓ x1000
f	femto		0.000000000000001	↑ ÷ 1000	

(4) Convert the figures into the prefixes required.

s	*ms*	*μs*	*ns*	*ps*
134.6				
96.21				
0.773				

m	*km*	*mm*	*Mm*	*Gm*
12873				
0.295				
57.23				

kg	*Mg*	*mg*	*g*	*Gg*
94.76				
0.000765				
823.46				

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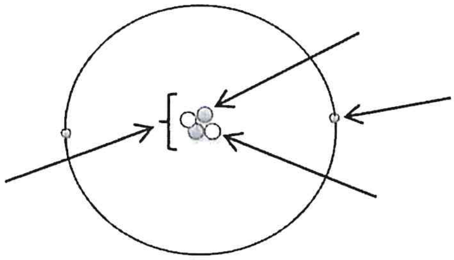
2.1 Constituents of the atom

The following diagram shows an atom of helium:



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(1) *Label the constituents of the atom, above.*

The atom shown is *helium-4* because it contains 4 nucleons (neutrons + protons) in the nucleus.

We label *helium-4* using the following notation:

$$^{4}_{2}He$$

The top number is called the 'nucleon number'. It is denoted by the symbol A.
(2) *What would this number be called in chemistry?*

The bottom number is called the 'proton number'.
(3) *Why do you think it is called this?*

(4) *What would this number be called in chemistry?*

The proton number is denoted by the symbol Z.

(5) *Write the symbol notation for helium-3.*

(6) *How is it different to helium-4?*

We call *helium-3* and *helium-4* isotopes.

(7) Carbon-14 is a radioactive isotope ('radioisotope') of carbon. Write the symbol notation for carbon-14.

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(8)✏ *Complete the following table for the properties of the constituents of the atom:*

constituent	*charge*		*mass*	
	(coulombs)	*relative to the charge on a proton*	*(kg)*	*relative to the mass of a proton*
proton				
neutron				
electron				

Specific Charge

The word 'specific' in science indicates 'per unit mass'. So 'specific charge' is the charge per kilogram. If we want to work out the specific charge of a particle, we take its total charge (in coulombs) and divide it by its total mass (in kg).

$$specific\ charge = \frac{total\ charge\ (C)}{total\ mass\ (kg)}$$

(9)✏ *Looking at the formula, what is the unit for specific charge?*

Note that the neutral atom has zero charge and therefore zero specific charge.

(10)✏ *Why does the neutral atom have zero charge?*

(11)✏ *What is the specific charge of the following nuclei:*
1) *helium-3?*

2) *Carbon-12?*

2.3.1 Particles and antiparticles

The existence of antiparticles was proposed by the theoretical physicist Paul Dirac in 1928. He proposed that:

1) *for every particle, there exists a corresponding antiparticle.*
2) *If the particle has a charge, then the antiparticle has the opposite charge.*
3) *The antiparticle has the same rest mass as the particle.*

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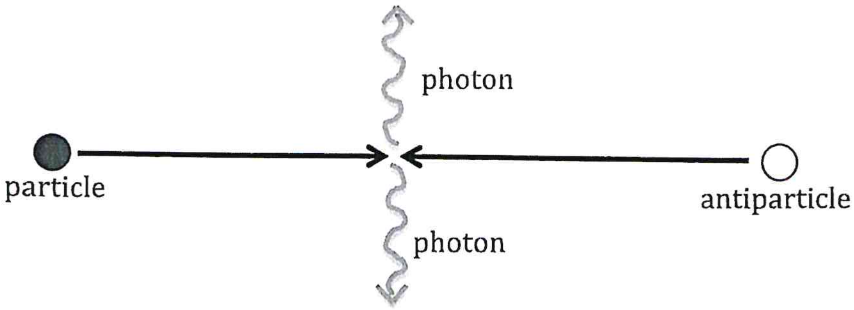
Annihilation

When an antiparticle meets its corresponding particle the two should annihilate, releasing energy as two photons.



The combined energy of these two photons should be equal to the total energy (kinetic energy + rest energy) of the particle and antiparticle. *(Note: the rest energy of a particle is the energy 'locked up' in its mass* m_o *and can be calculated using the relationship* $E=m_oc^2$*, where c is the speed of light =* $3 \times 10^8 ms^{-1}$*).*

(1) Using the relationship above, calculate the rest energy of an electron with a rest mass of $9.109 \times 10^{-31}kg$.

You should find this is a very small number when written in joules. This is often the case in calculations involving very small particles! For this reason, scientists often use another unit, called the electron-volt (*eV*) for small amounts of energy. ($1eV = 1.6 \times 10^{-19}J$)

Often the electron-volt is used with the prefix *k* (for kilo), *M* (for mega) or *G* (for giga). For example:
1000eV = 1keV
1000000eV = 1MeV
1000000000eV = 1GeV

(2) Write 150000eV in keV, in MeV and in GeV.

(3) How many joules is 150000eV?

If you look at the diagram for annihilation, 2 photons are produced, which travel in opposite directions (to conserve momentum). Both photons have the same energy. Therefore, their frequencies are the same.

Remember that the energy of a photon $E = hf$, where h is the Planck Constant ($=6.63 \times 10^{-34} m^2 kg s^{-1}$), and f is the frequency.

The energy of the annihilation is shared between the two photons. Therefore:

the energy of one photon = ½ x energy of annihilation

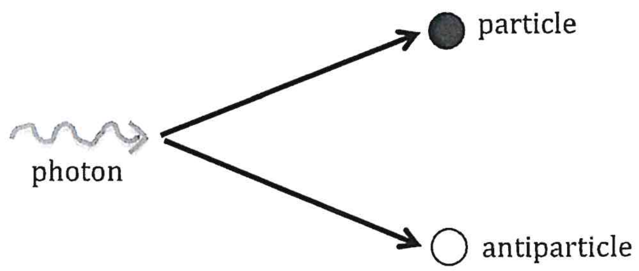
If the particles collide with negligible kinetic energy (i.e. not moving very fast), the energy of annihilation is just the rest energy of the two particles. In this case:

$$energy\ of\ one\ photon = rest\ energy\ of\ one\ particle$$
$$hf = m_o c^2$$

(4) This is actually the <u>minimum energy</u> that a photon produced during annihilation will have. Why?

Pair production

We have seen that a particle and antiparticle can produce electromagnetic radiation (annihilation). The opposite can also occur where a photon can produce a particle and antiparticle. This is called pair production.



In this situation, the photon energy is converted into the rest energy of the two particles (essentially, giving them mass) and any extra energy goes into the kinetic energy of the two particles. The minimum energy required (i.e. just to create the mass of the particle and antiparticle) is given by:

$$photon\ energy = 2 \times rest\ energy\ of\ the\ particle$$
$$hf = 2m_o c^2$$

(5) What is the minimum energy of the photon required to produce a proton-antiproton pair? (rest mass of proton = 1.67×10^{-27}kg)

(6) What is the minimum frequency of the photon required to produce a proton-antiproton pair?

3.1 Progressive waves

Progressive waves are waves which carry energy from one place to another. Waves which travel in a medium cause the particles in the medium to be displaced from their equilibrium position. Particles can either be displaced parallel to the direction the wave is progressing or at right angles. These are called longitudinal and transverse waves, respectively.

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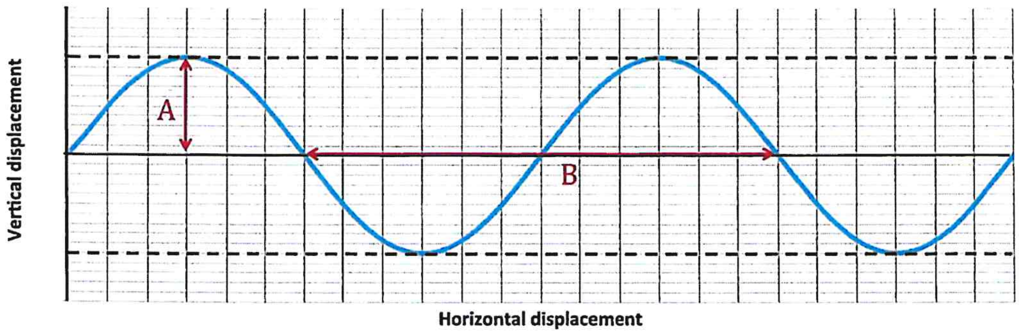
Let us consider a transverse wave:



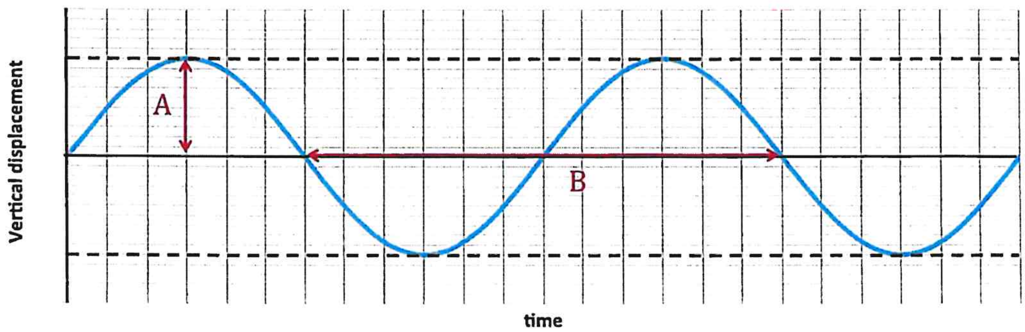
We can see a 'snapshot' of the wave at a certain time. The vertical displacement is shown for particles at different horizontal positions.

(1) What do arrows A and B represent?

(2) What units could B be measured in?

(3) What is the equilibrium position on this graph – label it.

Now consider the same wave, where vertical displacement is plotted against time. In this case we are considering the motion of a particle at a fixed position as the wave passes:



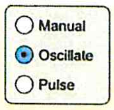
(4) What do arrows A and B represent?

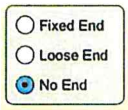
(5) The frequency of the waves is the number of waves that pass a fixed point in one second. How could we find the frequency from the displacement-time graph?

(6) What units is frequency measured in?

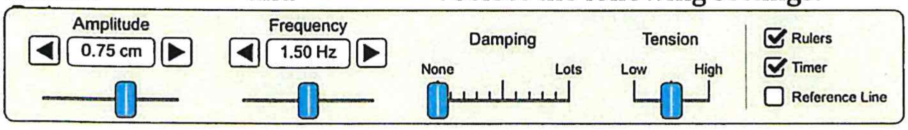
PhET simulation

Open the following sim: https://tinyurl.com/mtwczmj

Choose 

and 

. Select the following settings:



(7) Look at one of the green particles. What do you notice about the motion compared to the direction of wave travel? Is this a transverse or longitudinal wave?

(8) Pause the animation and record the wavelength of the wave.

(9) Now use the timer to time 10 complete waves passing a certain point (e.g. out the window).

(10) If 10 waves pass in the time you have measured and each wave has the length you have measured, what is the wave speed?

The wave equation relates wave speed (v), frequency (f) and wavelength (λ):

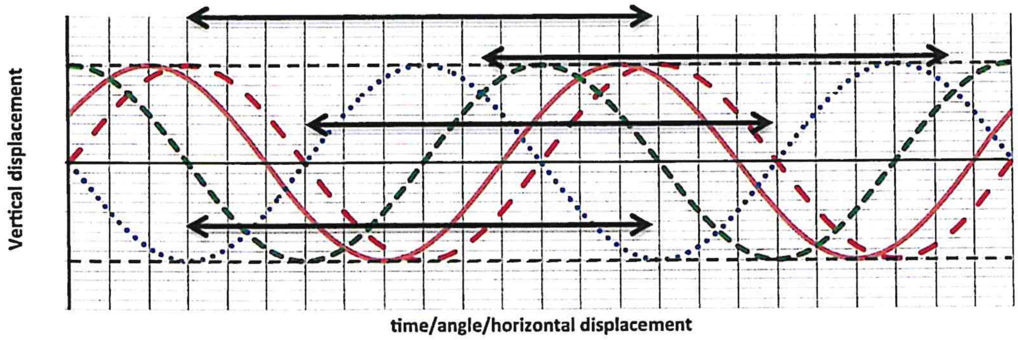
$$v = f\lambda$$

(11) Use your values above to see if this equation works for your measurements.

Phase difference

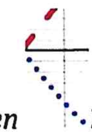
If we look at the two graphs at the top of this worksheet, we see that they are identical, apart from the x-axis label. We often find it useful to talk about waves in terms of cycles. A cycle is the portion of a wave between two wave crests or between two wave troughs, or indeed between any two identical points on the wave graph.

Consider the waves below:



All the arrows indicate a wave cycle. For time on the x-axis, one whole wave cycle represents the period of a wave. For displacement on the x-axis, one whole cycle represents the wavelength. For the sinusoidal function, one whole cycle represents 360°.

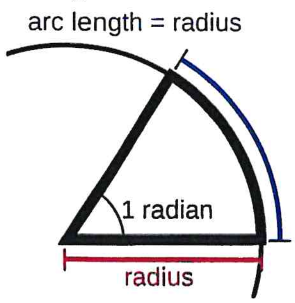
If we think about cycles in terms of angles, we can describe the relationship between waves. For example, comparing the two waves , we can see that the large-dash wave is 30° ahead of the solid line wave. We say there is a phase difference of 30°.

(12) What is the phase difference between *?*

(13) What is the phase difference between *?*

Phase difference in radians

Phase differences are often expressed in radians. A radian is a dimensionless unit of angle and relates arc length to the radius of the circle:



For example, it the angle is 1 radian, then the arc length = radius, as shown in the diagram.

We find that there are 3.142 radians (or pi radians) in 180°.

So, to convert from degrees to radians:

$$angle\ in\ radians = \frac{angle\ in\ degrees}{180} \times \pi$$

(14)✏ Convert your phase differences (above) into radians.

Where we have a phase difference between two waves of π (180°), we say that waves are 'in antiphase'. Where we have zero phase difference, we say waves are 'in phase'.

(15)✏ What two waves above are in antiphase? How do you think they would combine together?

3.2 Longitudinal and transverse waves

As discussed in 3.1, progressive waves transfer energy from one place to another. This means that the direction of wave travel is the direction the energy is moved. Oscillations that facilitate this movement of energy are either parallel to this direction (longitudinal waves) or at right angles to this direction (transverse waves).

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It is best to observe some animations of longitudinal and transverse waves: http://www.acs.psu.edu/drussell/Demos/waves/wavemotion.html

Sound waves and seismic-P waves are examples of longitudinal waves. They are often described as compressional waves as particles in the medium are squeezed together (compressed) and stretched apart (called rarefaction), as the wave passes.

Water waves, seismic-S waves and electromagnetic waves are examples of transverse waves. Electromagnetic waves do not require a medium in which to travel. In electromagnetic waves the oscillations are in the magnetic and electric fields which are not only at right angles to the direction of wave travel, but at right angles to each other: http://www.walter-fendt.de/html5/phen/electromagneticwave_en.htm

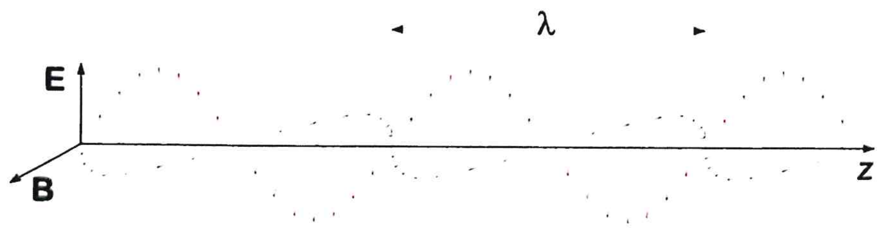
All electromagnetic waves travel at the same speed (the speed of light) in a vacuum.

(1) What is the speed of light in a vacuum?

(2) What happens to electromagnetic waves when they enter a material?

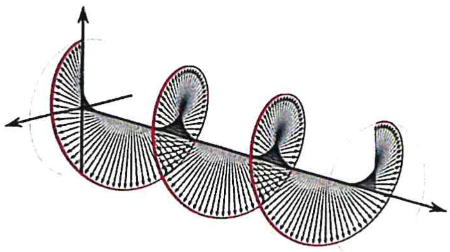
Polarisation

The following diagram shows an electromagnetic wave that is plane-polarised:



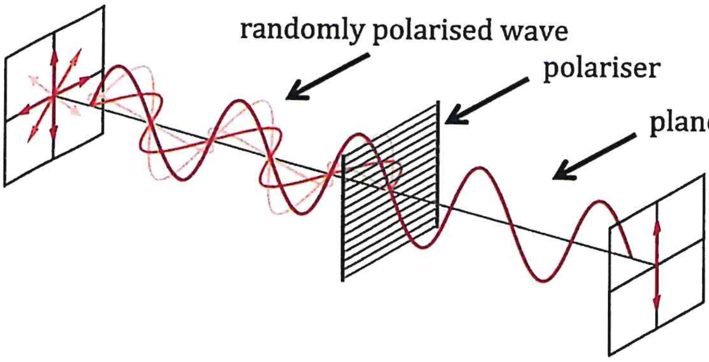
The electric field (E) is oscillating in the vertical plane and the magnetic field (B) is oscillating in the horizontal plane. Plane-polarised means that either E and B are oscillating in one plane only. Only transverse waves can be polarised.

The following diagram shows a circularly polarised wave:



In this case only the electric field orientation is shown.

In the following diagram, randomly polarised electromagnetic (EM) waves are passed through a polariser, which only lets through a certain component, producing plane-polarised light. The transmitted plane polarised wave has a lower intensity than the randomly orientated wave.



The situation above can be studied using a microwaves and a metal grille for a polarizer. When the electric field (shown in red) oscillates in the direction of the metal grille, an oscillating current is produced in the grille which stops transmission of the wave. If the grille is at right angles to the electric field, no current is produced in the grille and the waves is transmitted (as shown).

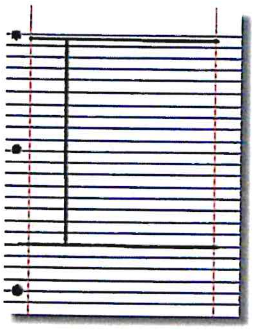
(3) When two polarisers are angled at 90° to each other, this is a situation known as 'crossed polarisers'. What do you think happens in this situation?

(4) Do some research and find 3 uses of polarisers.

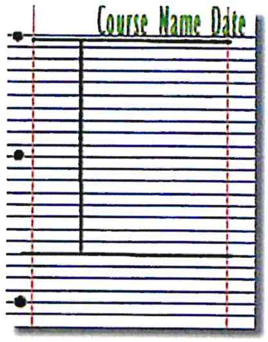
Research Task 1

Research, reading and note making are essential skills for A level Physics study. For the following task you are going to produce 'Cornell Notes' to summarise your reading.

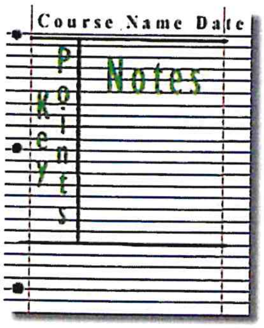
1. Divide your page into three sections like this



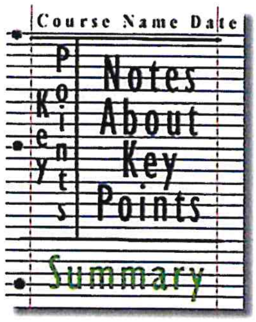
2. Write the name, date and topic at the top of the page



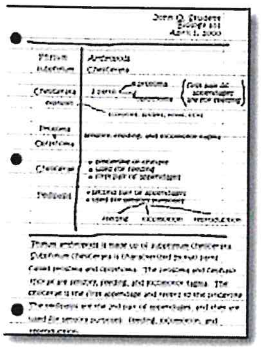
3. Use the large box to make notes. Leave a space between separate idea. Abbreviate where possible.



4. Review and identify the key points in the left hand box



5. Write a summary of the main ideas in the bottom space



Images taken from http://coe.jmu.edu/learningtoolbox/cornellnotes.html

Research Task 1 (cont)

Physics provides daily online-only news and commentary about a selection of papers from the APS journal collection. The website is aimed at the reader who wants to keep up with highlights of physics research with explanations that don't rely on jargon and technical detail.

For each of the following topics, you are going to use the resources to produce one page of Cornell style notes.

Use the links or scan the QR code to take you to the resources.

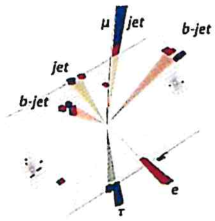
APS physics

Physics

Topic 1: **Sizing up the top quarks interaction with the Higgs**

Available at: https://physics.aps.org/articles/v11/56

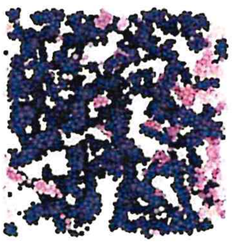
A proton collision experiment at CERN provides a new handle on the Higgs boson's interaction with the heaviest of the quarks.



Topic 2: **Why soft solids get softer**

Available at: https://physics.aps.org/articles/v11/50

Soft materials like gels and creams exhibit fatigue resulting from the stretching of their constituent fibres, according to experiments and simulations.



Topic 3: **Listening for the cosmic hum of black holes**

Available at: https://physics.aps.org/articles/v11/36

A new analysis technique would allow the gravitational-wave "background" from distant black hole mergers to be detected in days instead of years.

Investigation Task

This task is to get you to think about how you would use standard lab equipment to design and plan a practical investigation.

Below is an investigation question, first you need to think about how you might investigate and come up with 3 or 4 ideas. How will it work? How will you present the data?

Once you have one that works draw a labelled diagram and write out a plan on how this investigation would be carried out. – this is a similar process to that with the required practicals.

Investigation Question: How can the potential difference output of a wind turbine greatest.

As well as standard lab equipment you have a strong fan attached to a variable resistor to make the air speed change. You also have a model wind turbine with detachable blades (8 in total) that can be made difference lengths and can rotate once fixed to the turbine.