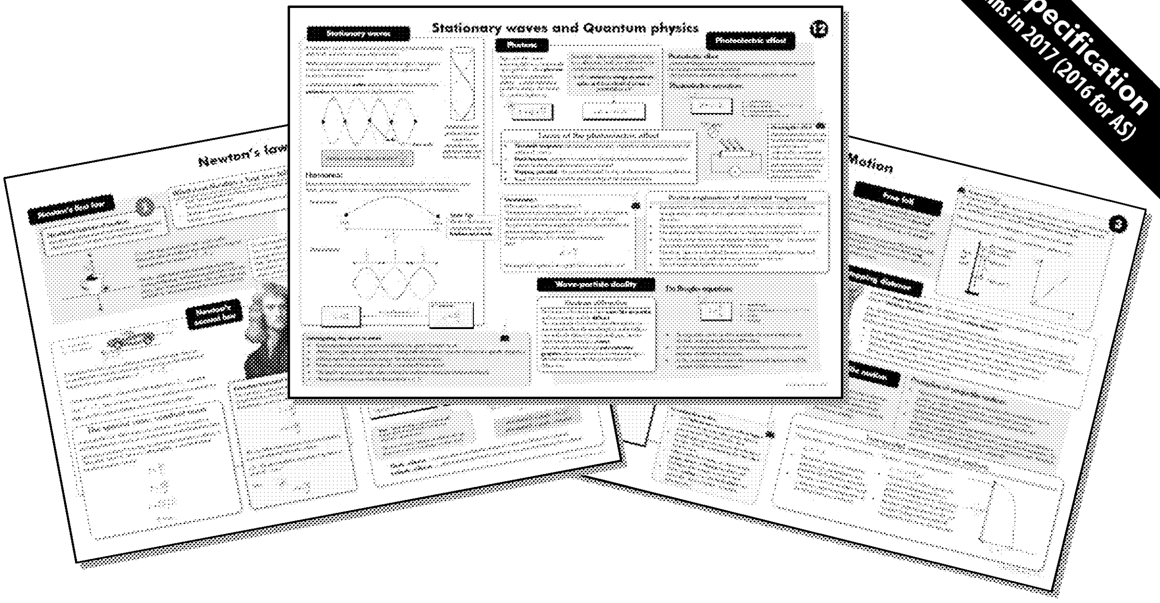
Physics AS / A Level Year 1 | OCR A | H156/H556

2015 specification
first exams in 2017 (2016 for AS)



Topic on a Page

For AS / A Level Year 1 OCR A Physics

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Contents

Teacher's Introduction

This Topic-on-a-page resource has been designed to help your students revise the key points of each topic and test their knowledge after you have taught each section of the **OCR A AS / A Level Year 1 Physics** specification. Each page is closely tied to the OCR A specification, ensuring all aspects of the course are covered. Activity pages are designed to be complementary to OCR A Topic Tests, so students won't be repeating the same questions.

There are four sections to this resource, each with its own features:

1. **Topic-on-a-page sheets**: these are the main pages which intend to clearly consolidate and recap all the key information from Year 1 of the OCR A Physics course.
2. **Activity pages**: these are identical to the Topic-on-a-page sheets, but contain a variety of tasks, from filling in missing words to performing calculations. The activity pages aim to ensure the student understands all the key knowledge required of them and gives them the opportunity to demonstrate how well they have remembered and understood the content of the course.
3. **Outline-only pages**: these are the Topic-on-a-page sheets, but with most of the content removed. Students can research the topics, e.g. for homework, and fill in as much information as they can.
4. **Mark scheme**: full answers for the activity pages.

The 'topic-on-a page', 'activity' and 'outline-only' sheets are designed to be A3 size, although they are still useable at A4 with no loss of detail. When photocopying activity pages on A3, we suggest photocopying the relevant worksheet on the reverse. If using at A4 size, we suggest photocopying each A3 'worksheet' (for writing answers) as a double-sided A4 page to avoid shrinking the space available for answers.

Each page presents information in a variety of ways, including:

- **Bold key words** – essential terminology in bold, allowing students to skim and revise main points quickly.
- **Bullet point processes** – complex processes and lists have been summarised into quick, easy-to-learn points.
- **Graphs** – sketch graphs illustrate complex points without providing unnecessary information.
- **Comparison tables** – a quick way of comparing key features of different structures, features or organisms.
- **Method and calculation boxes** – concisely state the equations used in required calculations.
- **Exam tips** – aid memorisation, revision and exam technique in areas where students typically struggle.

In addition, key practicals have been marked with a ⚗ and equations on the data sheet are marked with a DS.

We hope you find these pages useful during your teaching and your students' revision.

T Brown, December 2017

Units and measure

SI base units

SI (international system) base units:
A set of units of measure. They are defined as a fundamental set from which all other SI units can be derived.

Switching between units

Some units are equivalent. We switch between them by multiplying or dividing by the conversion factor. For example:

$$1\ \text{eV} = 1.60 \times 10^{-19}\ \text{J}$$
$$1\ \text{u} = 1.661 \times 10^{-27}\ \text{kg}$$
1 kWh = [illegible] J
1 ly = [illegible]

Example

a) Convert 13.2 eV to J.
b) Convert 49 J to eV.

a) To convert eV to J, multiply by 1.6×10^{-19}
$13.2 \times 1.6 \times 10^{-19} = 2.1 \times 10^{-18}$ J

b) To convert J to eV, divide by 1.6×10^{-19}
$\frac{49}{1.6 \times 10^{-19}} = 3.1 \times 10^{20}$ eV

A useful hint for remembering when to divide or multiply to convert units is to consider whether the number is getting bigger or smaller – 1 eV is a very small number of J, so the number needs to decrease as it's converted. 1 J is a lot of eV so the conversion should make the number bigger.

Derived units

Combining SI units can give the units for other quantities.

For example, velocity is measured in m s^{-1}, which uses both metres and secon[illegible]

Some derived units mi[illegible] a special name, such as Newton, N, which is equivalent to kg m s^{-2}.

Checking equations using un[illegible]

The units of an equation should [illegible] same [illegible] both sides – they should [illegible] This means we can [illegible] er a[illegible] equation is correct by [illegible] units.

Example

Gravitational potential energy is given by
$E = mgh$
The units of current, E, are [J] or [kg m^2 s^{-2}].
The units of the right-hand side of the equation, mgh, are:
[kg] × [m s^{-2}] × [m]
= [kg] × [m × m] × [s^{-2}]
= [kg m^2 s^{-2}] = [J]
The two sides of the equation have the same units, so the equation is homogenous!

Quantities and their SI base units

Physical quantity	Base unit	Symbol
Amount of substance	[illegible]	mol
Temperature	kelvin	K
Length	metre	m
[illegible]	second	s
Mass	kilogram	kg
Current	ampere	A

Estimation

Estimation:
A method of determining the value of a quantity without any given variables using educated guessing of the variables, usually to the power of 10

You will be expected to estimate quantities like those in the table. You will use them within equations to make educated estimates of the values of other physical quantities.

Table of estimates

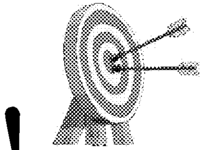
Physical quantity	Estimat
Mass of average man	60–
Speed of sound	300
Height of average man	1.6–
Mass of a car	10
Density of water	1000
Pressure of atmosphere	100

Prefixes

SI prefix:
A symbol that precedes a unit of measure to in
order of [illegible]

Prefixes and their orders of ma

Prefix	Prefix symbol	Or mag
tera	T	×
giga	G	×
mega	M	×
kilo	k	×
deci	d	×
centi	c	×
milli	m	×
micro	μ	×
nano	n	×
pico	p	×
femto	f	×



Uncertainties, vectors a

Errors and uncertainties

Don't confuse the terms!

Error:
The difference between the measured value and true value of measurement

Uncertainty:
The degree to which we can say a measurement is accurate. A measurement of 15.5 cm on a ruler would have an **absolute uncertainty** of ±0.1 cm.

Accuracy:
A measurement is accurate if its [illegible] close proximity to the ac[illegible] true [illegible]e.

Precision:
A meas[illegible] ecis[illegible] value is in [illegible]oxin[illegible] other repeated [illegible] of the same quantity.

Definitions of errors

Systematic error:
An error that causes the measurements to differ f[illegible] value by the same amount

Random error:
An error caused by unpredictable circumstances and resulting in measurements that differ from the true value by varying amounts

Percentage uncertainties: $\frac{\Delta a}{a} \times 100\ \%$

Sources of error

Systematic error:
- Imperfect calibration
- Imperfect methods of observation
- Interference of environment with method process

Random error:
- Mistakes made in inaccurate readings made by the experimenter
- Fluctuations in the reading on the instrument

Combining uncertainties

To combine errors:

$\varepsilon =$ absolute uncertainty
$\sigma =$ percentage uncertainty
$x, a, b, n =$ variables

Adding or subtracting variables

$$x = a + b$$
$$x = a - b$$

→ ***Add the absolute uncertainties***

$$\varepsilon_x = \varepsilon_a + \varepsilon_b$$

Multiplying or dividing variables

$$x = ab$$
$$x = \frac{a}{b}$$

→ ***Add the percentage uncertainties***

$$\sigma_x = \sigma_a + \sigma_b$$
$$\left(\sigma_x = \frac{\varepsilon_x}{x} \times 100\ \%\right)$$

Powers of variables

x [illegible]

→ ***Mu[illegible]ple [illegible]tage [illegible] the power***

$$\sigma_x = n\sigma_a$$

[illegible]ed[illegible] potential errors

Systematic error:
- Repeating experiment using a comparable apparatus to identify the source of error
- Accurate calibration of equipment
- Confirming experimental method against literature and sources

Random error:
- Taking averages over multiple measurements, not including anomalous results
- Repeating the experiment and averaging across all the measurements

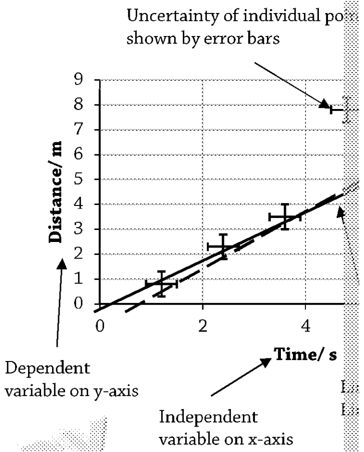
Scalars

Scalar: a physical q
simply using magnit

Vector: a physical q
both its magnitude A

Exam Tip!
You will be expected
vectors from measu

Uncertainties on



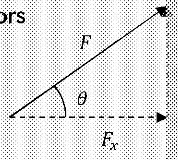
[illegible]entage uncertainty of gradien

$$\frac{|best\ gradient - worst\ gra}{best\ gradient}$$

Percentage uncertainty of y-interce

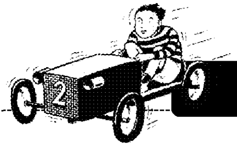
$$\frac{|best\ intercept - worst\ inte}{best\ intercept}$$

Resolving vectors



$F_x = F\cos\theta$
$F_y = F\sin\theta$

Motion



Motion along a straight line

$$s = vt$$

Displacement, s

↳ distance in a given direction

$$v = \frac{\Delta s}{\Delta t}$$

Velocity, v

↳ change of displacement per unit time

$$a = \frac{\Delta v}{\Delta t}$$

Acceleration, a

↳ change of velocit[illegible] per uni[illegible]ime

Instantaneous vs average

Instantaneous speed:
The speed at a particular point in time

Instantaneous v[illegible]
The velocity at a part[illegible]n time

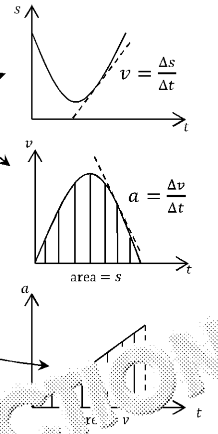
Instantaneous acceleration:
The acceleration at a particular point in time

A[illegible]:
[illegible]al distance travelled divided by the total [illegible] elapsed during the journey

Average velocity:
The total displacement travelled divided by the total time elapsed during the journey

Average acceleration:
The average velocity divided by the total time elapsed during the journey

- Velocity can be determined from the gradient of a displacement–time curve.
- Displacement can be determined from the area under a velocity–time curve.
- Acceleration can be determined from the gradient of the velocity–time curve.
- Velocity can be determined by the area under the acceleration–time curve.



Equations of motion

The following equations only hold if the object is travelling with uniform acceleration:

$$v = u + at$$

$$s = \frac{1}{2}$$ [illegible]

$$s = ut$$ [illegible]

$$v^2 = u^2 + 2as$$

Exam Tip!
If an object is falling, $a = g$

Investigating motion

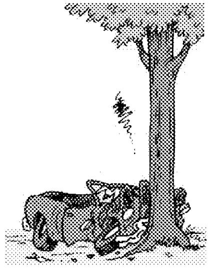
- Two **light gates** connected to a **data-logger** can measure the time taken for an object to pass from one light gate to the other.
- A single light gate can measure the velocity of an object directly by measuring the time taken for it to pass.
- Other methods of timing an object include **ticker timers** or **filming** the object and looking at time stamps, to reduce error.
- Using a **trolley** or an **air-track glider** can reduce the effect of friction on motion, reducing error.

Free fall

[illegible] object's motion is entirely d
e[illegible]t of gravity, it is said to be in
An object in free fall accelerates d
acceleration of g. On Earth, $g =$

Objects dropped in a vacuum fall
fall. In an atmosphere, or any oth
drag forces act against the moti
object as it falls, slowing it down.

Stopping dist



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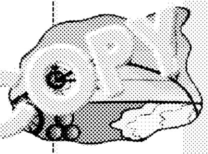
- At hig
- With
the ca

Projectile mo



Projectile:
A projectile is any objec
been propelled into the
force and has no means
propulsion, i.e. **it is onl**
upon by the force of g

Horizontal motion com

$$s_h = v_h t$$

- The faster an object is pr
horizontally, the further
travel in the horizontal d
- The time taken for an ob
a distance s will be indep
the initial horizontal vel

Forces in actio

Dynamics

Exerting a **net force** on an object causes the object to accelerate.

Force is measured in newtons, N, which is equivalent to kg m s^{-2}.

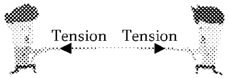
An object's **weight** is the force applied by an object due to gravity.

$$F = ma$$

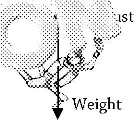
$$W = mg$$

Forces

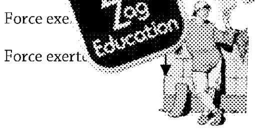
Tension:
The force experienced by pulling against an object.



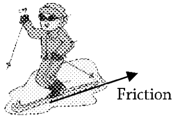
Upthrust:
A force that pushes up on an object in a fluid to the flui t d



Normal contact force:
The reaction force on ob ck o applied to it.



ion:
A force that opposes motion along a surface.



Free-body diagrams

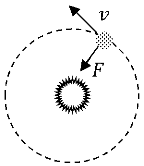
The forces acting on an object can be represented by free-body diagrams. In a free-body diagram, each force is represented by an arrow from the **centre of the object** in the **direction of the force**.

The **size of the arrow** is proportional to the **size of the force**.

Motion in one and two dimensions

An object will accelerate in the direction of an applied force. With no force exerted, the object will remain at the same velocity and travel in a straight line, or remain at rest.

If the force isn't parallel to the object's velocity, the path of the object will curve.

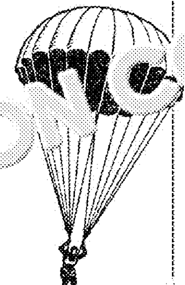


If Earth wasn't pulled towards the Sun it would move in a straight line. Instead, the gravitational attraction pulls Earth in a circle.

Non-uniform acceleration

Air resistance and terminal velocity

- An object travelling through a fluid, such as air, experiences a **dr force** acting against the direction of motion.
- As the object falls, it accelerates.
- As the velocity of an object increases for cting on the object.
- For a falling object, **ocit** eached when the **drag force is equal to th ce** and there is no more acceleration.



Exam Tip!

Objects with a larger surface area will experience a greater drag, as will less streamlined objects.

Investigating terminal velocity

To investigate terminal velocity, drop a **ball bearing** through a transparent **viscous fluid** such as glycerine or syrup. The ball bearing should reach terminal velocity quickly, and you'll be able to measure the time taken for the ball bearing to pass between **two marked points** using a **stopwatch**.
Repeat the experiment for different sizes and masses of ball bearing.
This can also be done with a **cone** dropped through air.

Moment of a force:

$$\text{ent} = Fx$$

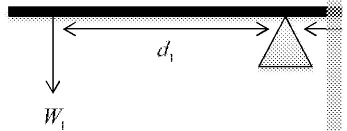
Torqu a cou

$$mom$$

F = force
x = distance from pivot
d = distance between forces

Principle of

For equilibrium:

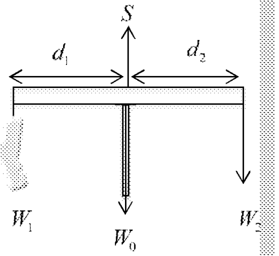


The sum of the clockwise moments = the

$$W_1 d_1 =$$

1. W_1 provides the anticlockwise mom
2. W_2 provides the clockwise moment

Suppor



$$S = W_0 + W_1 + W_2$$
$$W_1 d_1 = W_2 d_2$$

Density and pres

Density, ρ:

Density is a measure of how much mass is in a given volume.

Pressure, p:

Pressure is a measure of a force spread over an area.

Work, energy, power an

Work, energy and power

Energy: the capacity to do work

Power: the rate of doing work / the rate of energy transfer

Work done = energy transferred

In the case that the direction of action of the force is in line with the direction of displacement, i.e. cosθ = 1, W = Fx × (1)

Work done / energy transfer:

$$W = Fx\cos\theta$$

$$W = Fx$$

W = work done, in joules
F = force
x = distance
θ = angle between force and motion
P = power in watts
t = time in seconds
v = velocity in metres pe

Rate of en [illegible]:

$$P = Fv$$

Efficiency:

$$efficiency\ percentage = \frac{useful\ output\ power}{input\ power} \times 100\,\%$$

Derivations

Equations for kinetic and gravi[illegible] energy and power can all be derive[illegible] de[illegible]on of work done.

Kine[illegible]

[illegible]

$[F$ [illegible] $ma]$

$E_k = max$

$v^2 = u^2 + 2ax$

$[u = 0]$

$a = \frac{v^2}{2x}$

$E_k = m\frac{v^2}{2x}x$

$E_k = \frac{1}{2}m\,v^2$

[illegible]tational potential energy

$W = Fx = E_p$

$[F = mg, x = h]$

$E_p = mgh$

Power

$P = \frac{W}{t}$

$P = \frac{Fx}{t}$

$\frac{x}{t} = v$

$P = Fv$

Conservation of energy

Principle of conservation of energy:

For an isolated system, energy is conserved. Energy cannot be created or destroyed, only transferred into different forms.

Examples of different forms of energy:

- heat
- sound
- kinetic
- gravitational

Kinetic energy:

$$E_k = \frac{1}{2}mv^2$$

Potential energy:

$$E_p = mg\Delta h$$

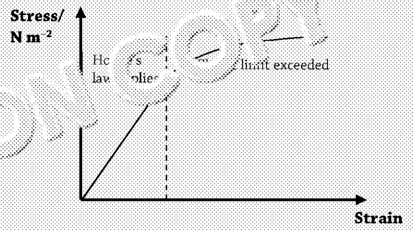
v = velocity
m = m[illegible]
[illegible]vit[illegible]
[illegible]g

Example of energy conservation:

1. As a ball is thrown upwards, the **kinetic energy** given to it by the throw is converted into **potential energy** and the ball slows down. All of the kinetic energy has been converted to potential energy at the **highest point** the ball reaches.
2. As the ball falls, potential energy is converted back into kinetic energy and the ball accelerates back towards the ground.
3. When the ball hits the ground, its kinetic energy is transferred to the ground and converted to heat and sound.

Young modulus

$$\text{Young modulus, } E = \frac{stress}{strain} = \frac{\sigma}{\varepsilon} = \frac{Fl}{Ax}$$



The Young modulus can be determined from the gradient of a stress–strain graph by comparing the equation for Young modulus (E):

$$\sigma = E\varepsilon$$

(tensile stress = Young modulus × tensile strain)

and the equation for the straight line up until the graph begins to curve:

$$y = mx + c$$

Hoo

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x =
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Newton's laws of m

Newton's first law

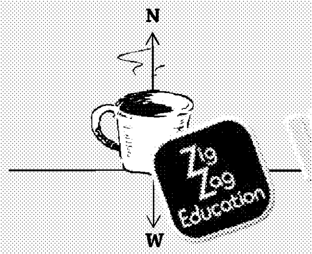
1

Newton's first law of motion:

An object will either stay at rest or move with constant velocity unless acted upon by an external net force.

What does Newton's first law tell us?

- A net force is needed to change an object's speed or direction (acceleration).
- An object at rest or travelling at constant velocity has no net force acting on it.



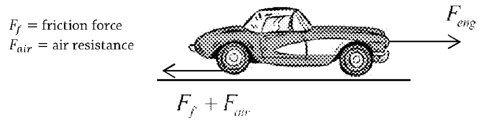
If a coffee mug is sitting at rest on a table, Newton's first law tells us that the forces acting on the mug must be balanced ($N = W$).

On the other hand, if we know that the forces acting on the mug are balanced, and there is no net force, then Newton's first law tells us that the mug is either at rest or moving with constant velocity.

Exam Tip!

You will expected to identify that if an object is at rest or moving with constant velocity, then the forces on that object are balanced – there is no resultant force.

Newton's second law



If we know that the car is accelerating towards the right, then we know that there must be a resultant force acting on the car directed towards the right and, therefore, $F_{eng} > F_f + F_{air}$.

On the other hand, if we know that the engine force F_{eng} is greater than $F_f + F_{air}$, then we know that there is a resultant force towards the right and the car must, therefore, be accelerating to the right.

The special case: constant mass

If we take the case where mass m is constant, then the equation detailing Newton's second law can be written in an alternative form.

Say a constant force, F, is acting on mass m that has initial velocity u. Then, after time t of the force being applied, the mass reaches its final velocity v, and we can say:

$$F = \frac{\Delta p}{\Delta t}$$

$$F = \frac{m\Delta v}{\Delta t}$$

$$F = \frac{m(v-u)}{t}$$

$$\boldsymbol{F = ma}$$

2

Newton's second law of motion:

The net force acting on an object is directly proportional to its rate of change of momentum and acts in the same direction.

$$F \propto \frac{\Delta p}{\Delta t}$$

$$F = k\frac{\Delta p}{\Delta t}$$

We can define the constant of proportionality k as 1 by defining the unit of force:

1 N = the force needed to accelerate 1 kg mass at a rate of 1 m s^{-2}

then,

$$F = \frac{\Delta p}{\Delta t}$$

DS

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Newton

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Current and pote

Charge

Electric current: the rate of flow of charge through a conductor

$I =$ current
$Q =$ total charge
$t =$ time

$$\Delta Q = I\Delta t$$

Charge is measured in **coulombs, C**

Net charge: the sum of charges in a body

$e =$ elementary charge $= 1.60 \times 10^{-19}$ C
$n =$ integer $= 0, 1, 2, 3, \ldots$

$$Q = \pm ne$$

Charge is **quantised**. This means that charge can [illegible] be f[illegible] a multiples [illegible]

For a proton, $Q = +1$
For an electron, $Q = -1$

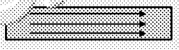
Moving charges

Electric current in metal: the flow of electrons

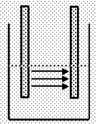
Conventional current: current from positive terminal to negative terminal

Electron flow: flow of electrons from negative terminal to positive terminal

Electric current in electrolyte: the flow of ions



Electrons carry charge through a metal.

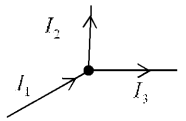


In an electrolyte, ions in the solution carry charge from one electrode to the other.

Kirchhoff's first law

Conservation of charge: Electric charge cannot be created or destroyed – total current is constant.

Kirchhoff's first law: The sum of the current into any point in an electrical circuit is equal to the sum of currents out of the point.



$$I_1 = I_2 + I_3$$

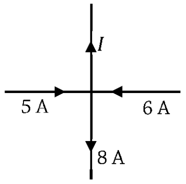
$$\sum I_{in} = \sum I_{out}$$

Example
Calculate I in the diagram to the right.

The current into a point equals the current out of a point:

$$I_{in} = I_{out}$$
$$5 + 6 = 8 + I$$
$$I = 11 - 8 = 3\text{ A}$$

(A negative value for I would indicate the current was flowing into the point.)



Mean drift velocity

Mean drift velocity: The average speed of charge carriers (e.g. electrons or ions) through a conductor. The greater the mean drift velocity, the greater the current.

$$I = Anev$$

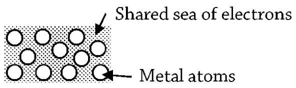
$A =$ cross-sectional area
$n =$ number density of charge carriers
$v =$ mean drift velocity

Conductors and insulators

Conductors:
For a conductor such as a metal, the charge carriers are electrons that are shared between atoms.

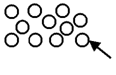
There are typically one o[illegible]e electrons per metal atom.

For a metal, $n = 10^{28}$ m^{-3} to 10^{29} m^{-3}.



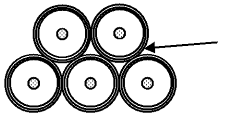
Insulators:
In an insulator, such as rubber, there are no charge carriers – all of the electrons are bound to atoms.

For an insulator, $n = 0$ m^{-3}.



Semiconductors:
In a semiconductor, such as silicon or compounds of gallium, electrons in high energy levels can easily absorb enough energy to become unbound from an atom, and can then move through the material.

For a semiconductor, $n = 10^{16}$ m^{-3} to 10^{25} m^{-3}.



Resistance and p

Resistance

Ohm's law: special case where $V \propto I$ if temperature (and therefore resistance) are kept constant

Ohmic conductor: a conductor that follows Ohm's law, so $V \propto I$

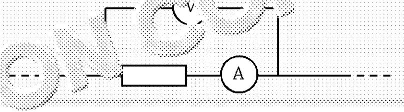
Non-ohmic conductor: a conductor that has a non-linear relationship between V and I and doesn't follow Ohm's law

$$\boxed{R = \frac{V}{I}}$$

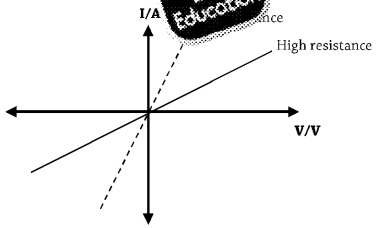
Current and potential difference are measured using ammeters and voltmeters, respectively.

Ammeters are placed in series with a component, while voltmeters are placed in parallel.

Ideal ammeters have zero resistance, while [illegible]eters have infinite resistance.

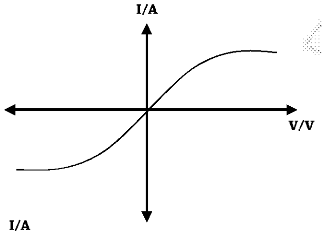


Current–voltage characterist

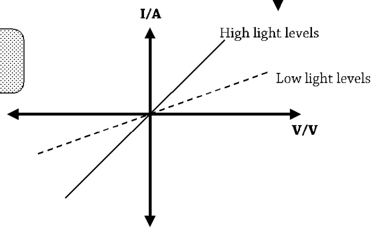


I–V graph for an **Ohmic conductor**, such as a **resistor**

graph for a **filament lamp**

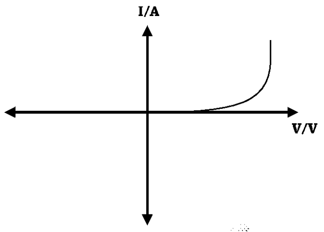


Explanation!
As the filament in the bulb carries higher amounts of current and heats up, the metal atoms vibrate and electrons cannot pass through the filament as easily. This increases the resistance of the filament.



I–V graph for a **light-dependent resistor (LDR)**

I–V graph for a **diode**



Diodes only cor[illegible]ity [illegible]r a certain threshol[illegible] Bel[illegible]s voltage, the c[illegible]ent [illegible]nnot [illegible]e potential difference [illegible]et u[illegible]n the diode.

Power

The power transferred by a component is given by:

$$\boxed{P = V [illegible]}$$

[illegible]ower
W = energy transferred
I = current
R = resistance

which can also be wr[illegible]

$$\boxed{P = I^2R} \quad \text{or} \quad \boxed{P = \frac{V^2}{R}}$$

The energy transferred by a component in a given time is equal to:

$$\boxed{W = VIt}$$

Kilowatt-hour

The kilowatt-hour (kW h) is a unit of energy that is used to describe energy usage.

1 kW h is the amount of energy used by an appliance using a power of 1 kW for one hour.

$$1\ \text{kW h} = 1 \times 1000 \times 60 \times 60 = 3.6 \times 10^6\ \text{J}$$

Ter

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Circuits, electromotive force and

Circuits

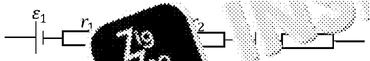
Kirchhoff's second law: In any electrical circuit, the sum of the electromotive force is equal to the sum of the potential differences in a closed loop:

$$\Sigma\varepsilon = \Sigma V \text{ around closed loop}$$

In DC circuits, charge and energy are also conserved.

Circuits with more than one power source

Series



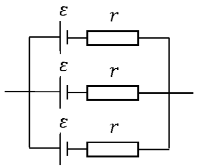
For power sources in series, the e.m.f. supplied to the circuit is:

$$\varepsilon_{total} = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 \ldots$$

The combined internal resistance of the power sources is:

$$r_{total} = r_1 + r_2 + r_3 \ldots$$

Parallel



For identical sources in parallel, the total e.m.f. supplied to the circuit is the same as the e.m.f. of one of the power sources.
The combined internal resistance of n power sources is:

$$\frac{1}{r_{total}} = \frac{n}{r}$$

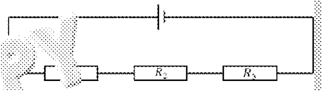
Series and parallel circuits

Series circuits:

$$R = R_1 + R_2 + \ldots$$

$$I = I_1 = I_2 = \ldots$$

$$V = V_1 + V_2 + \ldots$$



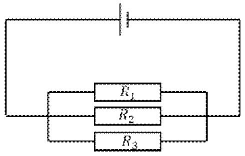
- Cells can be connected in series if a **higher voltage** needs to be supplied to the circuit.

Parallel circuits:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

$$I = I_1 + I_2 + \ldots$$

$$V = V_1 = V_2 = \ldots$$



- Cells can be connected in parallel to **increase the current** through the circuit.

Potential divider

A potential divider is the name of a circuit that can be used to alter the potential difference across an output when connected to a fixed input.

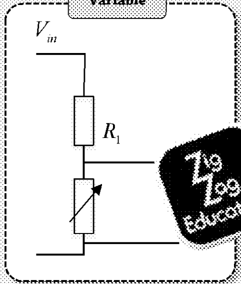
A variable component can be introduced to the circuit, which varies in resistance and, therefore, varies the voltage output of the circuit. In this case, the potential divider circuit can be used as a sensing circuit (e.g. to sense light levels or temperature).

[illegible] $R_1 +$ [illegible] $\times V_{in}$

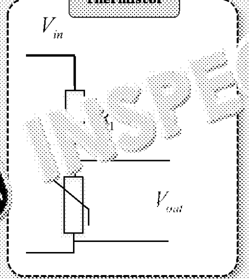
or

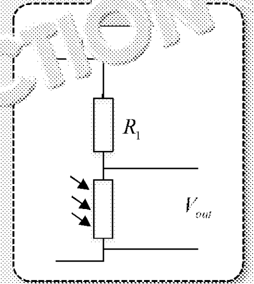
$$\frac{V_1}{V_2} = \frac{R_1}{R_2}$$

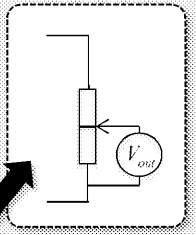
Variable



Thermistor







Investigating LDRs and thermistors
The change in resistance of **thermistors** and **LDRs** can be investigated by measuring V_{out} from a potential divider circuit as temperature or light levels are varied.

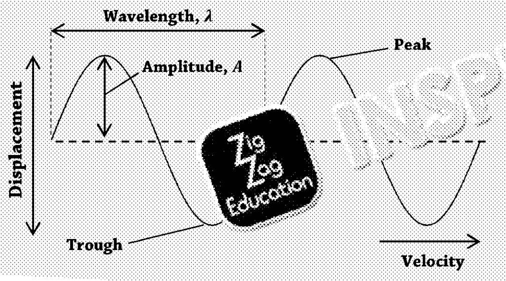
A **variable potential divider** or **potentiometer** is a potential divider with a sliding contact. In this case, the voltage output between two of the terminals can be varied by altering the sliding contact.

Exam Tip!
Remember, potential divider circuits are simply series circuits, so all the same rules f current, voltage and resistance relationshi in series apply.

Wave motion

Progressive waves

Progressive wave:
A wave that transfers energy from one point to another without transferring any matter. The particles in the matter oscillate but do not move along the wave.



Properties of a wave

- **Amplitude**: the maximum displacement from the equilibrium position
- **Frequency, f** : the number of complete waves passing a point per second
- **Wavelength, λ**: the minimum distance between two in-phase points on peaks/troughs
- **Phase difference**: the difference between the displacements of particles along a wave or on different waves
- **Period, T**: the time it takes for a single point of the wave to undergo one whole oscillation

Phase difference can be measured in radians, degrees or fractions of a cycle – one full wave = 2π radians or 360°

Wave equations:

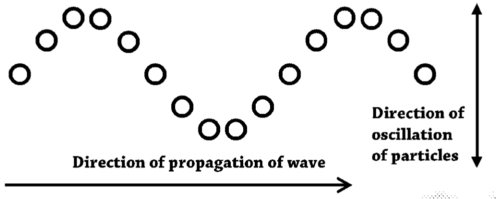
$$\text{velocity, } v = f\lambda$$

$$\text{frequency, } f = \frac{1}{T}$$

v = velocity
f = frequency
λ = wavelength
T = period

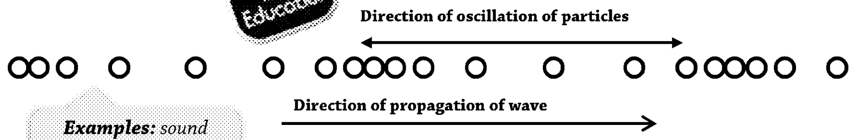
Transverse waves and longitudinal waves

Transverse wave:
a wave in which the medium's particles are displaced perpendicular to the direction of energy transfer



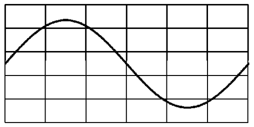
Examples: electromagnetic waves, w[illegible] standing waves on a string

Longitudinal wave:
a wave in which the medium's particles are displaced in the same direction as the energy transfer



Examples: sound waves, p waves from earthquakes

Oscilloscopes



An oscilloscope can be used to show a wave. One wavelength is shown here. **Displacement** is shown vertically and **time** is shown horizontally.

The **period** of the wave can be read off the oscilloscope as the time taken for a single oscillation, or the time it takes to return to the same displacement. Frequency then is $f = \frac{2\pi}{T}$.

The **amplitude** is the distance between the highest reading and the centre point of the wave.

Intensity

The **intensity** of a wave is the pow
which it transfers that power.

Intensity is defined in terms of the w

Intensity

When a wa
barrier it ca
through, it
direction of
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the incide

Diffracti
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A **ripple ta**
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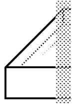
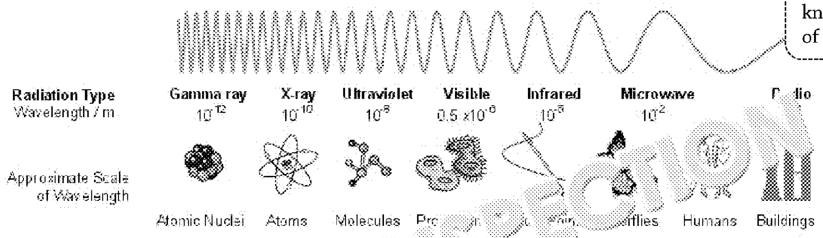


Electromagnetic spectrum

Refraction, diffraction and

Light is composed of electromagnetic waves. The different wavelengths of electromagnetic waves determine their properties.

All electromagnetic waves travel at $c = 3.00 \times 10^8$ m s^{-1} in a vacuum and are transverse.



Exam Tip!
You are expected to know these orders of magnitude.

Polarisation

Light consists of a number of transverse waves oscillating in several directions, so it can be polarised. There are a number of applications for **polarisers**.

- Polarising filters are used in sunglasses to reduce the amount of glare from unpolarised sunlight.
- Polarisation can be used in communication when radio waves are polarised and the aerial is aligned in the same direction as the plane of polarisation to receive the best signal.

Refraction of light

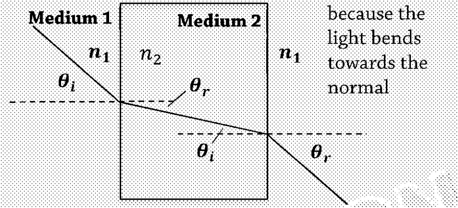
Exam Tip!
Note that you will be expected to recall that the refractive index of air is approximately 1.

When light enters a different medium, it changes speed.
The refractive index of a medium is the amount by which light slows in the medium compared to the speed of light in a vacuum.

Light bends due to the change in speed.

$$n = \frac{c}{v}$$

$$n \sin\theta = \text{constant}$$



Here, $n_2 > n_1$ because the light bends towards the normal

Total internal reflection

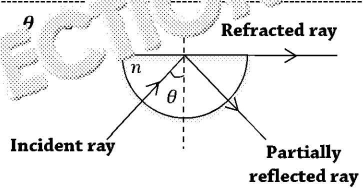
Total internal reflection refers to the situation where an incident light ray enters at angle of incidence greater than the critical angle, and the light doesn't pass through the boundary but reflects back into the material.

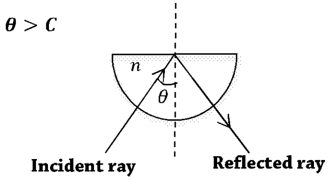
Conditions for total internal reflection:

1. The substance the light is travelling through has a **greater refractive index** than the other substance, i.e. $n_2 > n_1$
2. The angle of incidence is **greater** than the critical angle of the substance, i.e. $\theta > C$

$$\sin C = \frac{1}{n}$$

θ = incident angle
C = critical angle

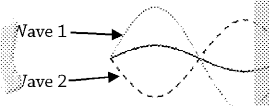




Investigating total internal reflection
Place a semicircular prism on a piece of paper. Shine a light onto the curved edge and mark the point where the light hits the straight edge. Change the angle the light makes with that point until no light passes through the straight edge. Mark the point light enters the block.

The angle between the incoming light and the normal is the critical angle.

Superposition:
When two waves meet they und
If the displacements of the wave
the waves add.



Investigating superposition

- To investigate superposition, two wa
- Two sound sources can be placed in
standing where waves cancel out or a
- Two microwave sources will heat up
- Shining light through two slits produ

Interference

Interference: The process of two coher
resultant wave either through cancellatio
The process of interference can occur wit
and other electromagnetic waves.

Coherent: Sources of waves are cohere
of the same frequency with constant phas

Path difference: The difference in the
two coherent wave sources to an interfere

Phase difference:
The amount that two waves are offset by

For constructive interference:

path difference = n

This corresponds to a phase difference of

For destructive interference:

path difference = (n

This corresponds to a phase difference of

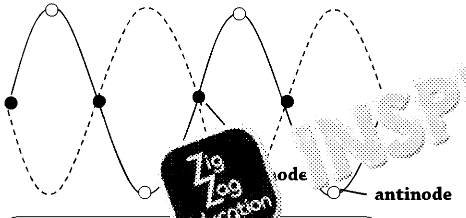
Stationary waves and qua

Stationary waves

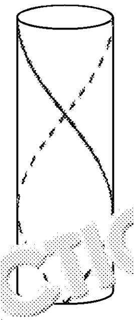
A stationary wave is a wave that is generated by a wave interfering with itself as it reflects along a fixed distance.

While progressive waves transfer energy across space and appear to move, there is no net transfer of energy or appearance of motion in a stationary wave.

A stationary wave has **nodes**, which show no displacement, and **antinodes**, where the greatest displacement occurs.



distance between adjacent nodes = $\frac{1}{2}\lambda$

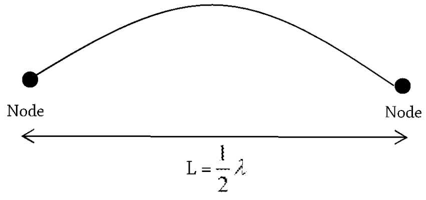


A stationary wave produced in an air column has antinodes at open ends of the tube, and nodes at closed ends.

Harmonics:

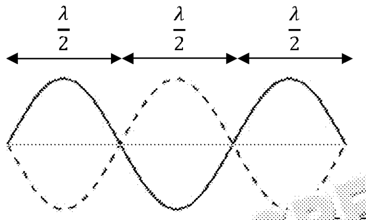
Many different stationary waves of different wavelengths can form in the same space, as long as the space can hold exactly a multiple of half-wavelengths.

First harmonic



Exam Tip!
The first harmonic is sometimes called the **fundamental mode**.

Third harmonic



$\lambda_1 = 2L$

first

n^{th} harmonic:

$\lambda_n = \frac{2L}{n}$

Investigating the speed of sound

- Stationary waves can be used to determine the speed of sound in air.
- Hitting an open glass cylinder with a tuning fork will create a wave of a specific frequency in the tube.
- Adding water to the cylinder changes the length of the space.
- When a stationary wave is produced, a sound will be produced.
- The height of air in the tube when a sound is produced is exactly a half-wavelength.
- The speed of sound can then be found from $v = f\lambda$.

Photons

Light acts like a wave; however, light is actually made up of particles called **photons**. A photon is a quantum of energy, or individual packet of energy. The energy of a photon is given by:

$$E = hf = \frac{hc}{\lambda}$$

Remember: when work on a subatomic level, y comfortable using the

1 eV = amount of en gains as it is accele potential

1 eV = 1.6

Terms of the photoele

- **Threshold frequency:** the minimum frequency r surface of a metal
- **Work function:** a property of materials that indica remove an electron from the surface of a metal
- **Stopping potential:** the potential needed to stop
- **$E_{k\,max}$:** the maximum possible kinetic energy of the

Determining *h*
LEDs can be used to find the value of h.

The energy of a photon is given by $E = hf$, so an LED mu minimum receive this amount of energy to give off light.

The potential difference supplied to the LED is varied unti minimum voltage required is found.

This is repeated for LEDs of different wavelengths.

Since

$$eV = \frac{hc}{\lambda}$$

we plot eV against $\frac{c}{\lambda}$ on a graph that has a gradient of

Wave–particle d

Electron diffracti

Electrons can be shown to have wave- and can even be made to **diffract**.

The wavelength of electrons and other smaller than the wavelength of visible only diffract through small gaps, such between atoms in a **crystal**.

Electron diffraction through **polycrys** allowed scientists to determine the spa atoms, as this changes the degree of di

Units and measurem

SI base units

1. Define the term 'SI base units'.

2. Fill in the empty boxes in the following table:

Physical quantity	Base unit
Amount of substance	
Temperature	
	metre
	second
Mass	
	ampere

3. Derive the following SI units from the SI base units:

a) Velocity

b) Power

c) Acceleration

d) Force

Estimation

6. Complete the following table of estimates:

Physical quantity	Estimated value
Mass of average man	
	300 m/s
Height of average man	
Mass of a car	1000 kg
	1000 kg m^{-3}
	100 000 Pa

7. A man lifts a 2 kg box from the floor to above his head.

Estimate the work done lifting the box.

Checking equations using units

4. Explain what is meant by a 'homogenous equation'.

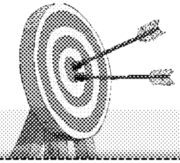
5. Check that the following equations are homogenous.

a) $\rho = \frac{m}{V}$

b) $v^2 = u^2 + 2as$

c) $P = VI$

Uncertainties, vectors an



Errors and uncertainties

1. Comment on some of the differences between systematic errors and random errors.

2. Explain the differences between an accurate measurement and a precise measurement.

4. Comment on potential methods to reduce:

a) systematic error

b) random error

3. State whether each of the following is an example of a systematic error or a random error:

a) unpredictable temperature fluctuations

b) uncalibrated oscilloscope

c) inaccurate experimental method

6. A physicist is carrying out an experiment on the electrical output of a circuit. The physicist measures 1.2 ± 0.2 A flowing through a 12 ± 1 V cell.

a) Calculate the percentage uncertainty in the measurement for current.

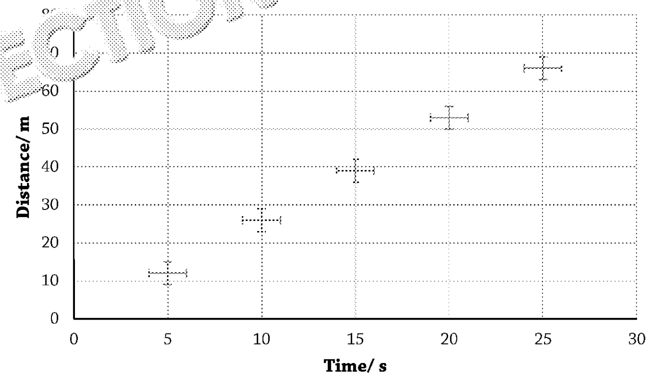
b) Calculate the percentage uncertainty in the power output of the cell.

5. A student measures the net force acting on a wire to be 10 ± 1 N in the upwards direction. The mass hanging on the wire is 1.2 ± 0.1 kg. The mass of the wire is negligible.

Calculate the acceleration of the mass upwards, including its uncertainty.

7. The graph below shows the data from an experiment.

Calculate the gradient of the graph including a percentage uncertainty.

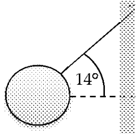


8. Explain the difference between

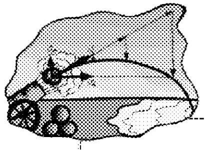
10. Two forces are acting at right an
initially acts in the upwards dire
30.0 N. Force 2 then acts (eastwa

Calculate the resultant force act
angle to the vertical.

11. A ball is projected into the air at



Calculate the velocity's horizon



Motion

Motion along a straight line

1. Define the following terms:

a) ‘displacement’

b) ‘average velocity’

c) ‘distance’

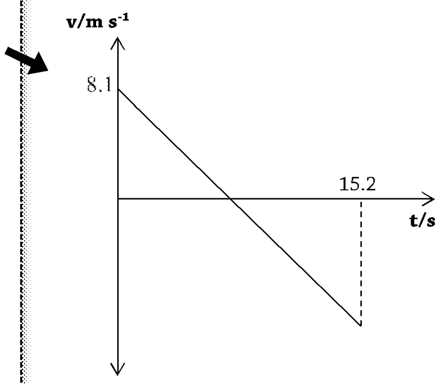
d) ‘average speed’

e) ‘instantaneous velocity’

f) ‘instantaneous speed’

g) ‘acceleration’

2. The velocity–time graph of a projectile thrown vertically upwards is shown on the right.

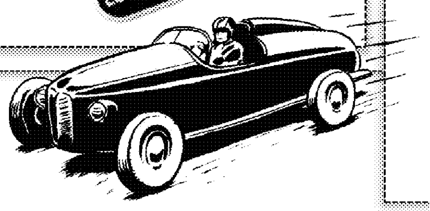


a) State the velocity of the projectile when the projectile is at maximum height.

b) Calculate the displacement of the projectile in 15.2 seconds.

c) Sketch the acceleration–time graph for the projectile over 15.2 seconds.

d) Explain how you could determine the acceleration from the velocity–time graph.



3. A car is travelling initially with a velocity of 2.20 ms^{-1}. The car accelerates uniformly, and eventually reaches the velocity of 12.2 ms^{-1} in [illegible]

a) Determine the acceleration of the car.

A second car is initially travelling with a velocity of 1.8 ms^{-1}. The car travels 13.2 metres with a constant acceleration of 1.3 ms^{-1}.

b) Calculate the final velocity of the car.

Fre

4. A ball is thrown up fro
initial velocity of 2.40
taken for the ball to h

Projectil

6. Explain how the verti
velocity of a projectile

8. A ball is projected hor
A second ball is dropp

Assume air resistance

a) Explain which bal

b) Determine the hei

c) Calculate how far

d) Explain what effe

Forces in action

Dynamics

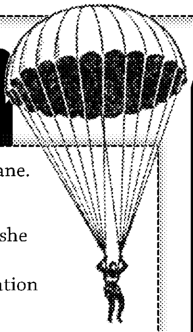
1. A 45.0 kg box is pushed along the ground with a force of 630 N. 110 N of friction acts on the box as it is pushed.

a) Calculate the weight of the box.

b) Calculate the acceleration of the box.

c) Draw a free [illegible] sh[illegible] the forces acting on the box.

Non-uniform acceleration

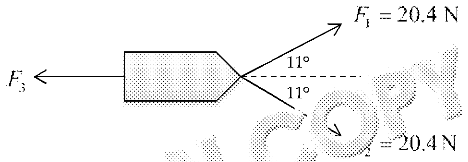


2. A skydiver jumps out a plane.

Explain the motion of the skydiver before and after she opens her parachute with reference to drag, acceleration and terminal velocity.

Coplanar forces

7. A tugboat is docked in the harbour. The tugboat sits in equilibrium.



a) [illegible] t[illegible] ho[illegible]al and vertical components of F_1.

b) Determine the value of F_3.

3. Define the followi

'moment of a force

'couple'

'moment of a coup

5. An ac
the b

Calcu

6. A lorr
comb
mass

Calcu

Work, energy, power and

Work, energy and power

1. Define the following terms:
  a) 'work'
  b) 'power'

2. A 10 kg box is pushed 7.60 m up an incline with a force of 142 N at an angle of 15.6° to the horizontal.
Calculate the work done in pushing the box up the inclined pla[illegible]

3. A heat engine uses 1.0[illegible] ava[illegible]
Calculate the percent[illegible] of [illegible]ngine.

Conservation of energy

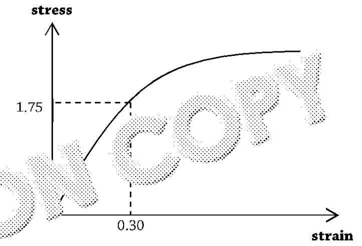
5. Define the principle of conservation of energy.

6. A 750 kg rollercoaster sits at the top of a big dip. The dip is 50.5 m high. Assume air resistance is negligible.
  a) State the energy transfer that occurs when the rollercoaster travels down into the bottom of the dip.
  b) Calculate the maximum possible velocity of the [illegible] bottom of the dip.

4. Derive from principles of work, equations for:
  a) the power transferred to an object travelling at velocity v by a force F
  b) the energy transferred to an object of mass m when accelerating it to a velocity v

Young's modulus

12. The following graph illustrates the relationship between stress and strain of a material:



Using the graph, determine the Young's modulus of the material.

7. a

b

9. A

Ca

10. Th

Ca

11. Th

De

A

B

C

Newton's laws of mo

Newton's first law

1. State Newton's first law.

2. State which of the following examples is a demonstration of Newton's first law:

a) a skydiver immediately after the diver jumps

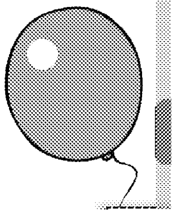
b) a box sitting at rest on the conveyor belt

c) a car braking rapidly to avoid a crash

3. A cyclist is travelling at a steady velocity of 8.9 m s^{-1}.

The driving force of the cyclist is 53 N.

State the magnitude of the drag force due to air resistance and frictional force acting on the cyclist.



9.

Newton's second law

4. a) State Newton's second law.

b) State the equation for Newton's second law.

5. State which of the following situations is an example of Newton's second law in practice:

a) a car uniformly accelerating from 0 to 60 seconds

b) a box pushed with a constant push force of 50 N, and experiencing an opposing frictional force of 2.4 N at the same time

c) a car sitting still in a traffic jam

6. Show that F = ma is a special case of Newton's second law.

7. A hot air balloon with a maximum number of passengers has a combined mass of [illegible] 10^3 kg. The balloon accelerates upwards at 1.2 m s^{-2}.

Assume air resistance is negligible.

a) Calculate the net force acting upon the balloon.

b) Sketch the forces acting on the balloon.

c) Calculate the force acting upwards.

10.

11.

12.

Current and potent

Charge

1. a) Define the term 'electric current'.

b) 34 C of charge flows through an electrical circuit in 500 seconds. Calculate the current in the circuit.

c) Determine the number of electrons passing through the circuit in 500 seconds.

Moving charges

2. Explain what is meant by the following phrases:

a) 'electric current in a metal'

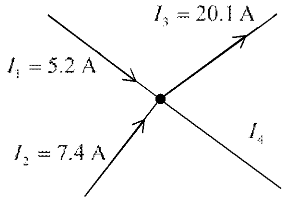
b) 'conventional current'

c) 'electron flow'

d) 'electric current in an electrolyte'

Kirchhoff's laws

3. Determine the magnitude and direction of I_4.



Mean drift velocity

4. What is the difference between conductors, insulators and semiconductors in terms of charge carriers?

5. A metal wire has a current of 10 mA running through it and has a cross-sectional area of 1 mm^2.

Estimate the mean drift velocity of electrons in the wire.

6.

7.

8.

9.

Resistance and pow

Resistance

1. A 15 Ω resistor is connected to a cell with terminal potential difference of 11.5 V.

a) Calculate the current in the circuit.

b) Determine the work done by electrons to overcome the terminal potential difference when 3.5 C of charge is flowing.

Current–voltage characteristics

2. Sketch the I–V graphs of the following electrical components:

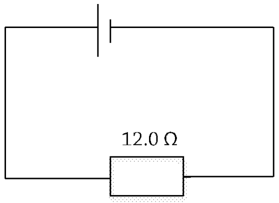
a) Thermistor

b) Semiconductor diode

c) Ohmic conductor

d) Filament lamp

3. 1.20 A is present in the following electrical circuit:



a) Calculate the potential difference across the resistor.

b) Determine the [illegible] resistor.

c) Calculate the work done by the charge carrier overcoming this resistance in 500 seconds.

Power

6. A kettle runs on a current of [illegible] A and a potential difference of 230 V. It takes the kettle [illegible] to boil. [illegible] 1 k[illegible] costs 10.6 p. Calculate the cost of boiling the kettle.

Circuits

Circuits

1. State Kirchhoff's second law.

5. Four 9.0 V batteries are placed in a circuit with a 19 Ω resistor.

Calculate the current through the resistor wh[illegible]

a) the batteries are placed in series with each other

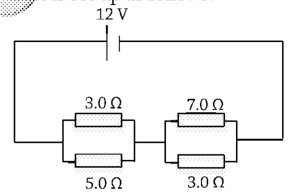
b) the batteries are placed in parallel with each other

Series and parallel circuits

2. Determine the total resistance of three 10 Ω resistors in series.

3. State the equation for the total resistance of resistors in parallel.

4. A circuit is set up as follows:



a) Calculate the total resistance of the circuit.

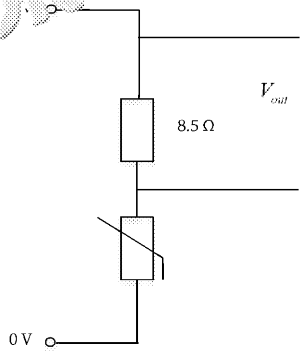
b) Calculate the total current following through the circuit.

c) State whether the same magnitude of current will be present through the 7 Ω and 5 Ω resistors. Give reasons for your answer.

Potential divider

6. A potential divider circuit is set up with a thermistor to act as a sensing circuit in a fridge to [illegible] cus[illegible]r when the fridge door has been left open too long and the temperature of the fridge is getting too high.

The voltage output is connected to an alarm, which rings when the voltage reaches a sufficiently high value.



a) Explain how the alarm rings as the temperatu[illegible]

At a certain temperature the resistance of the thermistor is measured to be 6.4 Ω.

b) Calculate the voltage output when the thermistor has resistance 6.4 Ω.

7.

8.

9.

Wave motion

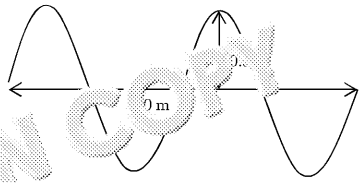
Progressive waves

1. Define the term 'progressive wave'.

2. Sketch a transverse and progressive wave, and indicate the following wave properties:

- amplitude
- displacement
- wavelength

3. The following wave is travelling at 1.4 m s^{-1}.



a) Determine the wavelength and amplitude of the wave.

b) Calculate the frequency of the wave.

c) How many waves are travelling past a fixed point in one second?

d) What is the period of the wave?

Transverse waves and longitudinal waves

4. a) Explain the difference between a longitudinal wave and a transverse wave.

b) Give an example of a longitudinal wave and of a transverse wave.

Intensity

5. a) A wave has an intensity of 83 W m^{-2}, which is incident over an area of 6.2 m^2.

Calculate the power transferred by the wave.

b) The amplitude of the wave halves.

Calculate the new intensity of the wave.

Polarisation

Polarisatic

a) Sketch a diagram of unpo

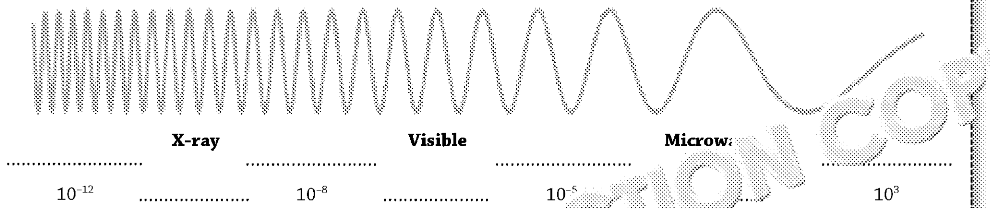
b) Sketch (a) after it has bee

c) Explain why polarisation
wave being transverse.

Refraction, diffraction and i

Electromagnetic spectrum

1. Complete the diagram to show the wavelengths (in metres) of the electromagnetic spectrum.



Refraction [illegible] t

2. Define the term 're

3. Given that $c_{air} = 2.997 \times 10^8$ m s^{-1}, show that the refractive index of air is approximately 1.

4. A light ray is travelling from air through the glass window of a high street shop. The light ray hits the shop window at an angle of 23.0°. The refractive index of the glass is 1.50.

a) Calculate the angle of refraction of the light ray in the glass.

b) Explain whether the light ray can undergo total internal reflection.

5. The shine of a diam[illegible]ct result of its high refractive index: $n_{diamond} = 2.42$. Determine the minimum angle required for total internal reflection within a diamond.

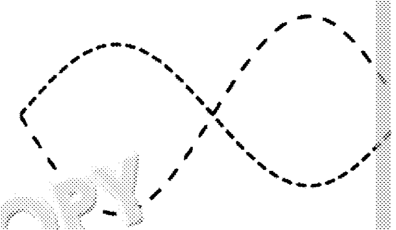
In

8. Define the following ter

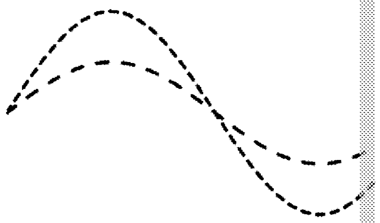
- 'interference'
- 'coherent'
- 'path difference'

9. Draw the resultant superposition of the w

a)



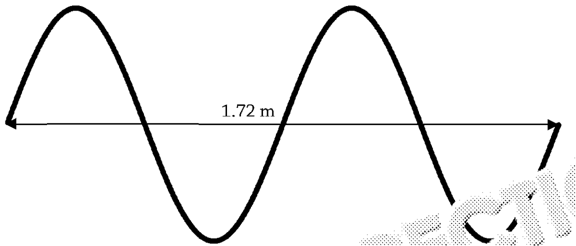
b)



Stationary waves and quan

Stationary waves

1. A stationary wave is displayed below.



Calculate the distance betw[illegible]any t[illegible]or[illegible]tionary wave.

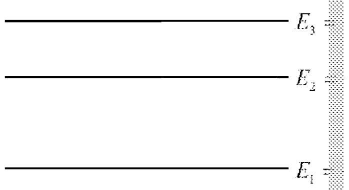
2. A stationary wave with wavelength 8 cm is produced on a string that is 20 cm long.
Draw the standing wave seen on the string.
Mark the nodes and antinodes.

Photons

3. Calculate the frequency of a photon of energy $E =$ [illegible] $^{-18}$ J

4. Calcula
of a pho
energy

5. The energy levels of a hydrogen atom are di



a) Determine the energy of the photon ca
to transition from energy level 2 to en

b) Determine whether the photon has bee
emitted.

Photoelectric effect

6. Explain what is meant by the 'photoelectric eff[illegible]'.

7. Light of 1.8×10^{15} Hz [illegible] the surface of zinc. The maximum kinetic energy of the en[illegible]ectrons is 5.05×10^{-19} J.

Determine the work function of zinc in electron volts.

8. [illegible] the following terms:

- 'threshold frequency'
- 'work function'
- 'stopping potential'
- $E_{k\,\max}$

Units and measure

SI base units

Quantities and their SI base units

Physical quantity	Base unit	Symbol
Amount of substance		
Temperature		
Length		
Mass		
Current		

Switching between units

Example

Estimation

Table of estimates

Physical quantity	Estimat
Mass of average man	
Speed of sound	
Height of average man	
Mass of a car	
Density of water	
Pressure of atmosphere	

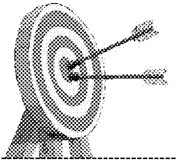
Prefixes

Prefixes and their orders of ma

Prefix	Prefix symbol	Ord mag
		×
		×
		×
		×
		×
		×
		×
		×
		×
		×

Derived units

Checking equations using units



Uncertainties, vectors an

Errors and uncertainties

Error:

Uncertainty:

Accuracy vs precision

Definitions of errors

[illegible] rtainties:

Combining uncertainties

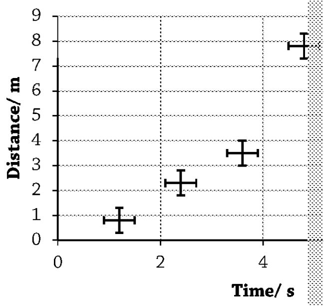
Sources of error

[illegible] rea [illegible] potential errors

Scalars

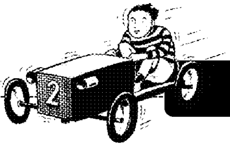
Exam Tip!
You will be expected
vectors from measu

Uncertainties on



Resolving vectors

Motion



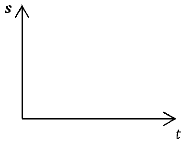
Motion along a straight line

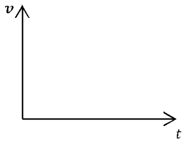
Displacement, s

Velocity, v

Acceleration, a

Instantaneous vs average





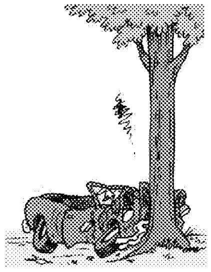
Equations of motion

Exam Tip!
If an object is falling, $a = g$

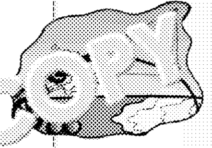
Investigating motion

Free fall

Stopping dista



Projectile mo



Forces in action

Dynamics

Forces

Tension:

Upthrust:

Normal contact force:

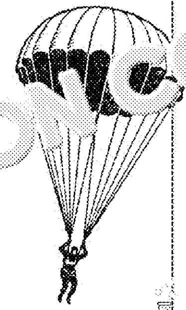
[illegible]ion:

Free-body diagrams

Motion in one and two dimensions

Non-uniform acceleration

Air resistance and terminal velocity



Exam Tip!
Objects with a larger surface area will experience a greater drag, as will less streamlined objects.

Investigating terminal velocity

Moment of a force:

Torqu
a cou

Principle of

Support

Density and pres

Density, ρ:

Pressure, p:

Work, energy, power and

Work, energy and power

Work done / energy transfer:

Rate of energy [illegible]r:

Efficiency:

Derivations

Kinetic energy

Gravitational potential energy

Power

Conservation of energy

Young modulus

Hoo

Elas

En
sp

Determining

Newton's laws of mo

Newton's first law

①

What does Newton's first law tell us?

New

Exam Tip!

You will expected to identify that if an object is at rest or moving with constant velocity, then the forces on that object are balanced – there is no resultant force.

Newton's second law

②

The special case: constant mass

Current and poten

Charge

Electric current:

Net charge:

Moving charges

Kirchhoff's first law

Example

Mean drift velocity

Conductors [illegible]

Conductors:

[illegible]

Semiconductors:

Resistance and pow

Resistance

Measuring current and potential difference

Current–voltage characterist

Power

Kilowatt-hour

Ter

Circuits, electromotive force and i

Circuits

Series and parallel circuits

Circuits with more than one power source

Potential divider

Variable

Thermistor

Investigating LDRs and thermistors

Exam Tip!
Remember, potential divider circuits are simply series circuits, so all the same rules f current, voltage and resistance relationshi in series apply.

Wave motion

Progressive waves

Properties of a wave

Wave equations:

Transverse waves and longitudinal waves

Oscilloscopes

Intensity

Refraction, diffraction and i

Electromagnetic spectrum

Exam Tip!
You are expected to know the orders of magnitude for the electromagnetic spectrum.

Polarisers

Refraction of light

Exam Tip!
Note that you will be expected to recall that the refractive index of air is approximately 1.

Total internal reflection

Investigating total internal reflection

Superposition:

Investigating superposition

Interference

Stationary waves and quan

Stationary waves

Harmonics:

Exam Tip!
The first harmonic is sometimes called the **fundamental mode**.

Investigating the speed of sound

Photons

Terms of the photoelec

Determining *h*

Wave–particle du

Electron diffractio

Mark Scheme

1. Units and measurements

1. The SI base units are a set of fundamental units from which all other SI units can be derived.

2.

Physical quantity	Base unit
Amount of substance	mole
Temperature	kelvin
Length	metre
Time	second
Mass	kilogram
Current	ampere

3. a) v [illegible]

$v = \frac{\mathrm{m}}{\mathrm{s}}$

$v = \mathrm{m\ s^{-1}}$

b) $P = \frac{E}{t}$

$P = \frac{J}{s}$

$P = \frac{\mathrm{kg\ m^2\ s^{-2}}}{\mathrm{s}}$

$P = \mathrm{kg\ m^2\ s^{-3}}$

c) $a = \frac{v}{t}$

$a = \frac{\frac{d}{t}}{t}$

$a = \frac{d}{t^2}$

$a = \frac{\mathrm{m}}{\mathrm{s}^2}$

$a = \mathrm{m\ s^{-2}}$

d) $F = ma$

$F = m\frac{v}{t}$

$F = m\frac{d}{t^2}$

$F = \mathrm{kg}\frac{\mathrm{m}}{\mathrm{s}^2}$

F [illegible] s^{-}

4. An equation with the same units on both sides.

5. a) $\rho = \frac{m}{V}$

Units $\rho =$

Units $\frac{m}{V} =$

Units $\frac{m}{V} =$

Units $\frac{m}{V} =$

b) $v^2 = u^2 +$

Units $v^2 =$

Units $v^2 =$

Units $u^2 +$

Units $u^2 +$

Units $u^2 +$

c) $P = VI$

Units $P =$

Units $P =$

Units $VI =$

Units $VI =$

Units $VI =$

Units VI =

(In SI unit

6.

Physical qu
Mass of avera
Speed of s
Height of aver
Mass of a
Density of
Air press

7. $W = F \times d$

$W = mg \times h$

$h = height\ of\ a$

$m = mass\ of\ bo$

$W = (2 \times 10) \times 2$

$W = 40\ \mathrm{J}$

8. Independent va column, depend the second colu All data should significant figur Units should be

9. Each axis requir Independent va dependent varia y-axis. Data poi Axis marks shou Line of best fit s

2. Uncertainties, vectors and scalars

1. Systematic errors are errors which cause the measurements to deviate from the true value by a set amount in one direction, whereas random errors cause the measurement values to randomly deviate from the true value. Additionally, systematic errors are errors which can be predicted, whereas random errors are due to unpredictable fluctuations causing the readings to alter during investigation.

2. A measurement is accurate if its value is in close proximity to the true (accepted) value, whereas a precise measurement is a measurement that is in close proximity to other repeated measurements

3. a) random
   b) systematic
   c) sy

4. a)
   - Regular calibration of equipment
   - Regular inspection of instruments / repeat the measurement with the same type of apparatus to ensure obtaining comparable results
   - Ensuring accurate experimental method is used
   - Good record keeping of measurement readings / care taken when reading measurements

   b)
   - Take repeated measurements and find the mean
   - Use specifically chosen equipment / experimental method to reduce random fluctuations in surroundings (e.g. equipment that is less affected by temperature changes in surroundings)

5. $a=\frac{F}{m}$

$a=\frac{10}{1.2}$

$a=8.3 \text{ m s}^{-2}$

$\frac{\Delta F}{F}=\frac{1}{10}$

$\frac{\Delta F}{F}=0.1$

$\frac{\Delta m}{m}=\frac{0.1}{1.2}$

$\frac{\Delta m}{m}=0.1$

$\frac{\Delta a}{a}=\frac{\Delta F}{F}+\frac{\Delta m}{m}$

$\frac{\Delta a}{a}=0.1+0.1$

$\frac{\Delta a}{a}=0.2$

$\Delta a=0.2\times 8.3$

$\Delta a=\pm 1.7$

$a=8.3\pm 1.7$ m

6. a) % *uncerta*

   % *uncerta*

   % *uncerta*

   b) % *uncerta*

   % *uncerta*

   % *uncerta*

   % *uncerta*

7. Worst gradient =

Uncertainty =

Uncertainty =

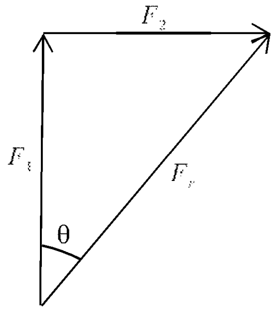
Gradient = 2.7

8. A scalar is a phy
defined by its m
defined by its m

9.

Scalar
Mass
Energy
Tempera
Distanc
Speed

10.



$a^2 + b^2 = c^2$

$F_1^2 + F_2^2 = F_r^2$

$(30.0)^2 + (10.4)^2 = 1008.16$ N

$F_r^2 = 1008.16$ N

$F_r = 31.8$ N

$\tan\theta =$

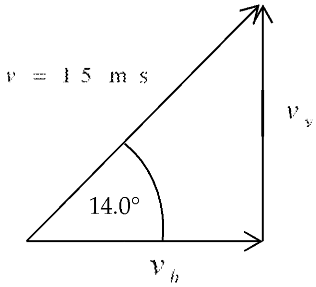
$\tan\theta = \dfrac{10.4}{30}$

$\tan\theta = 0.35$

$\theta = \tan^{-1}(0.35)$

$\theta = 19.1°$

11.



$v_h = v\cos\theta$

$v_h = 15.0 \times \cos 14°$

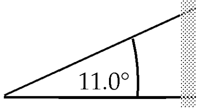
$v_h = 14.6$ m s^{-1}

$v_v = v\sin\theta$

$v_v = 15.0 \times \sin 14.0°$

$v_v = 3.62$ m s^{-1}

12.



$W_{per} = W\cos\theta$

$W_{per} = 78.0 \times \text{co}$

$W_{per} = 76.6$ N

$W_{par} = W\sin\theta$

$W_{par} = 78.0 \times \text{si}$

$W_{par} = 14.9$ N

3. Motion

1. a) The distance in a given direction

   b) The total displacement travelled in the total time elapsed for the journey

   c) The separation between two points in space

   d) The total distance travelled in the total time elapsed during the journey

   e) The velocity at an instance of time

   f) The speed at an instance of time

   g) Rate of change of velocity

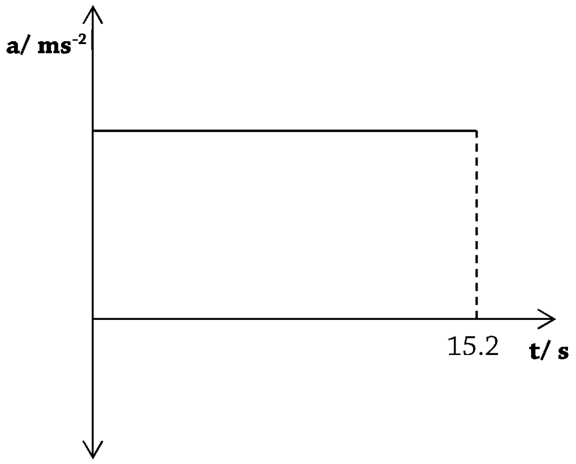
2. a) 0 m s^{-1}

   b) *displacement* = [illegible] *velocity time graph*

   $$displacement = 2\times\left(\frac{1}{2}\times 8.1\times\left(\frac{15.2}{2}\right)\right)$$

   $$displacement = 61.6 \text{ m}$$

   c)



   d) From the gradient of the velocity–time graph

3. a)

   $$a = \frac{v-u}{t}$$

   $$a = \frac{12.2-2.2}{10.5}$$

   $$a = 0.952 \text{ m s}^{-2}$$

   b)

   $$v^2 = u^2 + 2as$$

   $$v = \sqrt{u^2 + 2as}$$

   v [illegible] ^{2} [illegible] 13.2

   v [illegible] s^{-1}

4. Height reached

   $$v^2 = u^2 + 2as$$

   $$\frac{v^2 - u^2}{2a} = s$$

   $$s_{up} = \frac{0 - 2.4^2}{2 \times -9.81} =$$

   $s_{total} = 8.5 + 0.$

   Time falling

   $$s = ut + \frac{1}{2}at^2$$

   $$ut = 0$$

   $t = \sqrt{\frac{2s}{g}} = \sqrt{\frac{2 \times}{9.}}$

   Time to top of p

   $$v = u + at$$

   $$u = 0$$

   $t = \frac{u}{g} = \frac{2.4}{9.81} = 0.$

   $t_{total} = 1.34 +$

5. a) Car 3, 7 m

   b) Weight of c
   brakes, poo

6. The horizontal c
   velocity remains
   it is not affected
   vertical compon
   throughout the
   upon by accelera

7. The horizontal a
   projectile are ind

8. a) They both

   b)

   $$s = \frac{1}{2}gt^2$$

   $s = \frac{1}{2}\times 9.8$

   $$s = 177 \text{ m}$$

   c)

   $$d = vt$$

   $d = 5.5\times 6$

   $$d = 33 \text{ m}$$

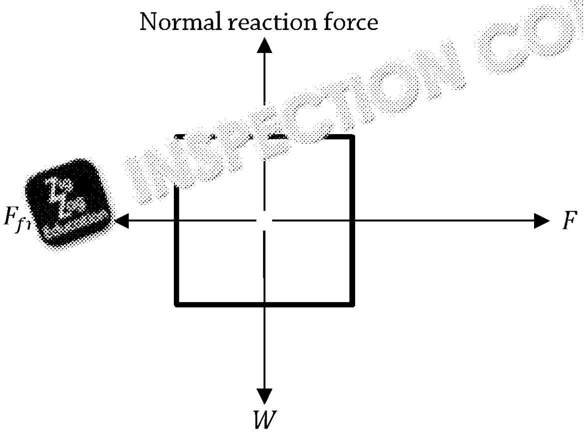
   d) It would ha
   The range
   of the proj

4. Forces in motion

1. a) $W = mg$
   $W = 45.0 \times 9.81$
   $W = 441\ \text{N}$

   b) $F = ma$
   $a = \frac{F}{m}$
   $a = \frac{630 - 110}{45.0}$
   $a = 11.6\ \text{m s}^{-2}$

   c)



2.
- The skydiver will accelerate towards the ground and as the velocity of the skydiver increases the drag force acting on the skydiver will also increase. The skydiver will continue accelerating towards the ground until the skydiver opens her parachute.
- Once the skydiver opens the parachute, the drag force acting will dramatically increase, and eventually the drag force (acting upwards) will equal the weight of the skydiver (acting downwards). When this occurs, the skydiver will have reached terminal velocity.
- The skydiver will then travel towards the ground at a constant velocity.

3. **Moment of a force:** The moment of a force about a point is defined as the product of the force and the perpendicular distance from the line of action of the force to the point.

   Couple: A pair of equal and opposite parallel forces acting on an object along different lines.

   Moment of a couple: The moment of a couple is defined as the product of the force and the perpendicular distance between the lines of action of the forces.

4. $moment = F \times d$
   $moment = 30 \times 0.2$
   $moment = 6\ \text{N m}$

5. $W_1 d_1 = W_2 d_2$
   $d_2 = \frac{W_1 d_1}{W_2}$
   $d_2 = \frac{660 \times 1.60}{750}$
   $d_2 = 1.41\ \text{m}$

6. $S_1 D = W d_2$
   $S_1 = \frac{W d_2}{D}$
   $S_1 = \frac{7.9 \times 10^7 \times}{6 \times 1}$
   $S_1 = 4.2 \times 10^9$

7. a) *Horizontal:*
   $F_{1h} = F_1\ \text{c}$
   $F_{1h} = 20.4$
   $F_{1h} = 20.0$

   Vertical:
   $F_{1v} = F_1\ \text{si}$
   $F_{1v} = 20.4$
   $F_{1v} = 3.89$

   b) $F_3 = F_{1h} +$
   $F_3 = 20.4$
   $F_3 = 40.1$

5. Work, energy, power and materials

1. a) Moving an object with a force in the direction of the force

   b) The rate of doing work / the rate of energy transfer

2. $W = F\cos\theta d$

   $W = 142\times\cos 15.6\times 7.6$

   $W = 1040$ J

3. $efficiency = \dfrac{output}{input}\times 100\ \%$

   $efficiency = \dfrac{1.02\times10^{6}}{5.6\times10^{6}}\times 100\ \%$

   $efficiency = 18.2\%$

4. a) P

   $P = \quad\ \ \ \ _{t}$

   $\frac{x}{t} = v$

   $P = Fv$

   b) $W = Fx = E_k$

   $[F = ma]$

   $E_k = max$

   $v^2 = u^2 + 2ax$

   $[u = 0]$

   $a = \frac{v^2}{2x}$

   $E_k = m\frac{v^2}{2x}x$

   $E_k = \frac{1}{2}m\,v^2$

5. For an isolated system, energy is conserved. Energy cannot be created or destroyed, only transferred into different forms.

6. a) Gravitational potential energy to kinetic energy

   b) $mgh = \dfrac{1}{2}mv^2$

   $gh = \dfrac{1}{2}v^2$

   $v = \sqrt{2gh}$

   $v = \sqrt{2\times9.81\times50.5}$

   $v = 31.5$ m s^{-1}

7. a) Th applied is directly proportional to the extension of the material unless the elastic limit has been reached.

   b) $F = k\Delta L$

   $F = 2.9\times\left(5\times10^{-2}\right)$

   $F = 0.1$ N

8. a) The point
   return to i
   removed

   b) The force

   c) The extens

9. $\rho = \dfrac{m}{v}$

   $\rho = \dfrac{0.10}{(5.2\times10^{-6}}$

   $\rho = 1890$ kg m

10. $E = \dfrac{1}{2}F\Delta L$

    $E = \dfrac{1}{2}\times 45\times 0.0$

    $E = 1.1$ J

11. A = limit of pro
    B = Ultimate te
    C = Breaking po

12. E = gradient of s

    $E = \dfrac{1.75}{0.3}$

    $E = 5.83$ N m^{-2}

6. Newton's laws of motion

1. An object will either stay at rest or move with constant velocity unless acted upon by an external resultant force.

2. a) No

   b) Yes

   c) No

3. Since the cyclist is traveling at a constant velocity, the forces acting on the cyclist must be balanced. Therefore, the combination of frictional force and drag force must be equal to the driving force [illegible] 3

4. a) The net force acting on an object is directly proportional to the rate of change of momentum and is in the same direction.

   b) $F = \frac{\text{[illegible]}}{\Delta t} = \left(\frac{\Delta mv}{\Delta t}\right)$

5. a) Yes

   b) Yes

   c) No

6. Newton's second law states:

$$F = \frac{\Delta(mv)}{t}$$

Therefore, when the mass is constant it can be rewritten as

$$F = \frac{m\Delta v}{\Delta t}$$

$$F = \frac{m(v-u)}{t}$$

$$a = \frac{v-u}{t}$$

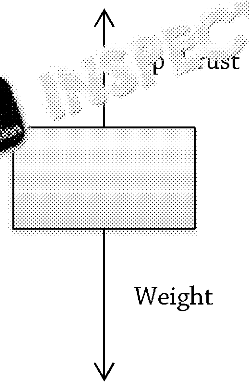
$$F = ma$$

7. a) $F = ma$

   $F = 3.5\times 10^3 \times 1.2$

   $F = 4.2\times 10^3$ N

   b)



   c) $F_{net} = Upth$

   $Upthrust =$

   $Upthrust =$

   $Upthrust =$

8. If object A exert
exert an equal b

9. When the air is
third law states
will exert a force
balloon, and the
force back on th
a resultant force
the balloon will
to the escaping

10. $p = mv$

$p = 930\times 7.2$

$p = 6696$

$p = 6700$ kg m

11. a) $m_1u_1 + m_2$

   890×10.6

   $9434 = 25$

   $830v_2 = 9$

   $830v_2 = 6$

   $v_2 = 8.26$

   b) $E_{kbefore} = \frac{1}{2}$

   $E_{kbefore} = \frac{1}{2}$

   $E_{kbefore} = 5$

   $E_{kafter} = \frac{1}{2}$

   $E_{kafter} = \frac{1}{2}$

   $E_{kafter} = 3.2$

   $E_{kbefore} \neq E$

   Therefore

12. a) $Impulse =$

   $Impulse =$

   $Impulse =$

   b) $Impulse =$

   $Impulse =$

   $v = \frac{Impuls}{m}$

   $v = \frac{2.6}{45\times 10}$

   $v = 58$ m s

7. Current and potential

1. a) The rate of flow of electric charge

   b) $I = \dfrac{\Delta Q}{\Delta t}$

   $I = \dfrac{34}{500}$

   $I = 0.068$ A

   c) $n = \dfrac{Q}{q}$

   $n = \dfrac{34}{1.6 \times 10^{-19}}$

   $n = 2.1 \times 10^{20}$

2. a) **Electric current in metals:** the flow of electrons

   b) **Conventional current:** current from positive terminal to negative terminal

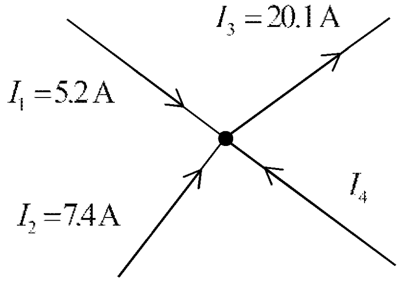
   c) **Electron flow:** flow of electrons from negative to positive terminal

   d) **Electric current in electrolyte:** the flow of ions

3. $I_4 = I_3 - (I_1 + 1_2)$

   $I_4 = 20.1 - (7.4 + 5.2)$

   $I_4 = 7.5$ A



4. Conductors have free electrons that are shared between atoms. Typically, $n = 10^{28}$ m^{-3} to 10^{29} m^{-3}. Electrons in insulators are tightly bound to atoms and cannot move between atoms. $n = 0$. Semiconductors have electrons that are typically bound to atoms but can be freed from atoms by absorbing energy. $n = 10^{15}$ m^{-3} to 10^{18} m^{-3}

5. $I = Anev$

   $v = \frac{I}{Ane}$

   $I \sim 10^{-2}$ $A \sim 10^{-6}$ $n \sim 10^{28}$ $e \sim 10^{-19}$

   $v \sim \frac{10^{-2}}{10^{-6} \times 10^{28} \times 10^{-19}}$

   $v \sim 10^{-5}$ m s^{-1}

6.

Component
Cell
Lamp
Voltmeter
Ammeter
Resistor
Diode
Thermistor
LDR (light-dependent resistor)
Variable resistor

7. **Potential diffe**
carriers across e
electromotive
carriers in the p

8. $W = VQ$

   $V = \frac{W}{Q}$

   $V = \frac{96.5}{37}$

   $V = 2.6$ V

9. Answer

   $eV = \frac{1}{2}mv^2$

   $v = \sqrt{\frac{2eV}{m}}$

   $v = \sqrt{\frac{2 \times 1.60 \times 1}{9.1}}$

   $v = 1.25 \times 10^8$

8. Resistance and power

1. a) $I = \frac{V}{R}$

$I = \frac{11.5}{15}$

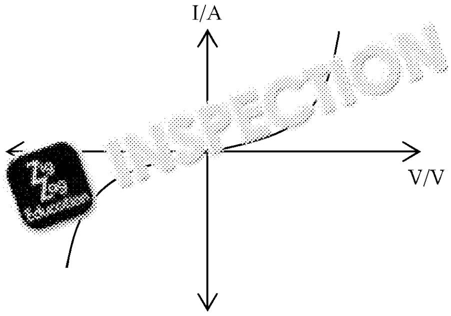
$I = 0.77$ A

b) $W = VQ$

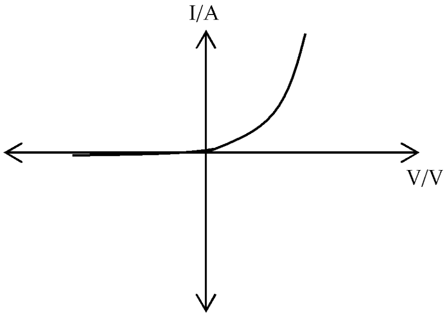
$W = 11.5 \times 3.5$

40 J

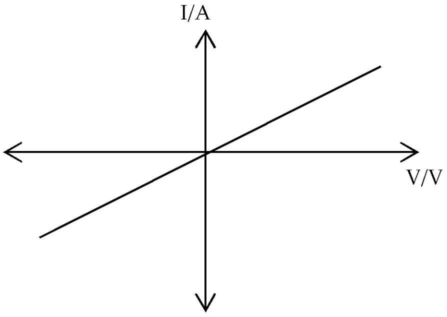
2. a)



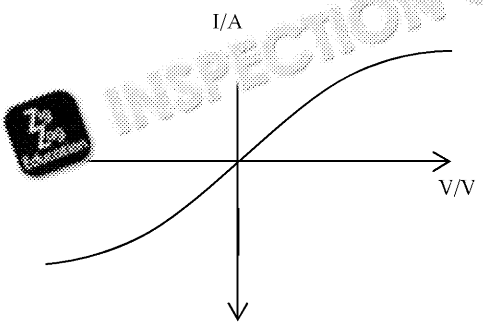
b)



c)



d)



3. a) $V = IR$

$V = 1.2 \times 1$

$V = 14.4$

b) $P = IV$

$P = 1.2 \times 1$

$P = 17.28$

$P = 17.3$ W

c) $E = Pt$

$E = 17.28$

$E = 8640$

4. a) $\rho = \frac{RA}{L}$

$\rho = \frac{6.7 \times 2}{79}$

$\rho = 1.8 \times 1$

b) If the leng
resistance

5. a) i) As th
vibra
the c

ii) A the
comp
negat
mean
the re
decre

6. $E = IVt$

$E = 12.0 \times 23$

$E = 317\,400$ J

$E = \frac{317\,400}{1000 \times 60 \times 6}$

cost $= 0.08817$

cost $= 0.935$ p

9. Circuits

1. In any electrical circuit, the sum of the electromotive force is equal to the sum of the potential differences in a closed loop. ($\Sigma\varepsilon = \Sigma V$ *around closed loop*)

2. $R_T = R_1 + R_2 + R_3$
   $R_T = 10 + 10 + 10$
   $R_T = 30\ \Omega$

3. $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots$

4. a) $\frac{1}{R_T} = \frac{1}{3} + \frac{1}{5}$
   $\frac{1}{R_T} = \frac{8}{15}$
   R [illegible] Ω
   $\frac{1}{R_T} = \frac{1}{7} + \frac{1}{3}$
   $\frac{1}{R_T} = \frac{10}{21}$
   $R_T = 2.1\ \Omega$

   $R_T = 1.9 + 2.1$
   $R_T = 4.0\ \Omega$

   b) $I = \frac{V}{R}$
   $I = \frac{12}{4}$
   $I = 3.0$ A

   c) No, as the current splits across parallel branches ($I_T = I_1 + I_2 + \ldots$) and the branches have different resistance, more current goes through the 5Ω.

5. a) $\varepsilon = \varepsilon_1 + \varepsilon_2 + \varepsilon_3 + \varepsilon_4$
   $\varepsilon = 4 \times 9.0 = 36$ V
   $V = IR$
   $I = \frac{V}{R}$
   $I = \frac{36}{[illegible]}$
   I [illegible]

   b) $\varepsilon = \varepsilon_1 = \varepsilon_2 = \varepsilon_3 = \varepsilon_4$
   $\varepsilon = 9.0$
   $V = IR$
   $I = \frac{V}{R}$
   $I = \frac{9.0}{19}$
   $I = 0.47$ A

6. a) As the tem
   the thermi
   does the p
   thermistor
   across the
   difference
   until high e

   b) $V_{out} = \frac{8.}{8.5+}$
   $V_{out} = 6.8$ V

7. a) **Terminal**
   difference a

   b) **Electrom**
   energy give
   charge – th
   there is no

   c) **Internal**
   source tha
   passes thro
   between te

8. a) $\varepsilon = IR + Ir$
   $r = \frac{\varepsilon - IR}{I}$
   $r = \frac{24-(1}{}$
   $r = 1.2\ \Omega$

   b) $V = IR$
   $V = 1.9 \times 1$
   $V = 22$ V

   c) When ther
   be done by
   through th
   as some en
   therefore,
   e.m.f. is su
   some volts

   Therefore,
   supplied to
   e.m.f. of th

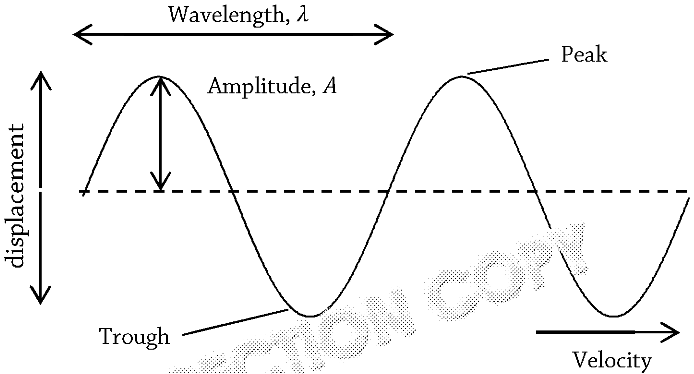
9. Comparing $V = -$
   $c = 15$
   $c = e.m.f$
   $e.m.f = 15$ V

   $m = -r$
   $m = \frac{5-15}{3.2-0}$
   $m = -3.1$
   $r = 3.1\ \Omega$

10. Wave motion

1. A wave that transfers energy from one point to another without transferring any m oscillate but do not move along the wave.

2.



3. a) $A = 0.5$ m

λ [illegible]

$\lambda = 2.5$ m

b) $f = \frac{c}{\lambda}$

$f = \frac{1.4}{2.5}$

$f = 0.56$ Hz

c) 0.56 waves

d) $T = \frac{1}{f}$

$T = \frac{1}{0.56}$

$T = 1.8$ s

4. a) A transverse wave's particles oscillate perpendicular to the direction of energy longitudinal wave oscillate in the same direction as energy transfer.

b) Longitudinal: sound, P-waves from earthquakes
Transverse: electromagnetic, waves on a string

5. a) $I = \frac{P}{A}$

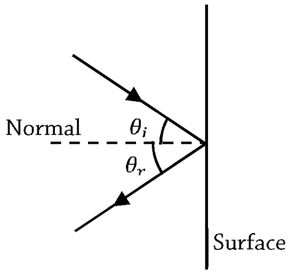
$P = IA$

$P = 83 \times 6.2$

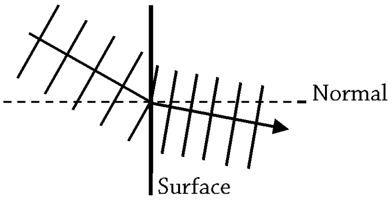
$P = 515$ W

b) Intensity ∝ (amplitude)^2
Amplitude decreases by factor ½
Intensity decreases by factor ½^2 = ¼
$\frac{83}{4} = 20.8$ W m^{-2}

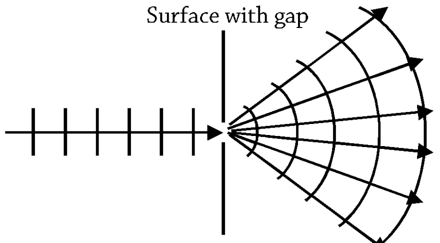
6. a)



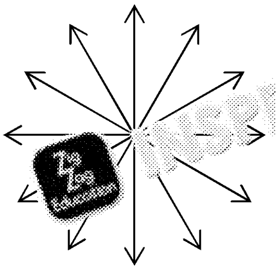
b)



c)



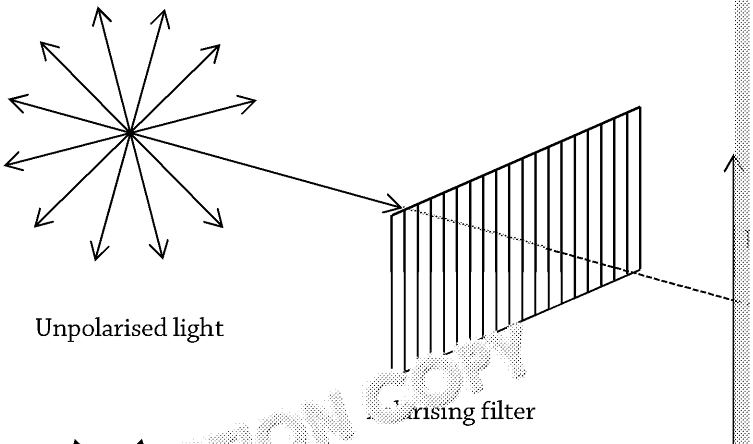
7. a)



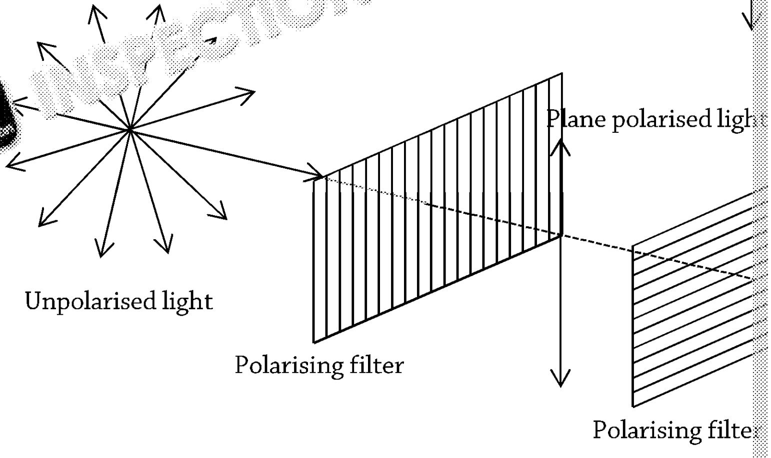
b)

c) A longitudinal wave cannot be plane polarised as it already only oscillates in o
be plane polarised, it must be a transverse wave (a wave that oscillates in mult

8. a)

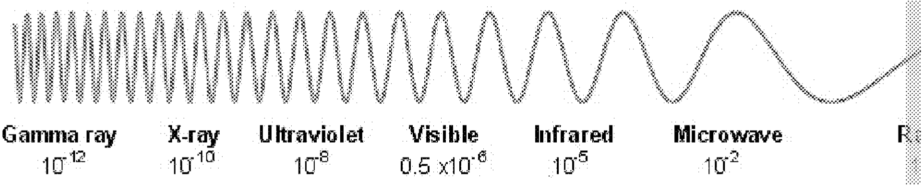


b)



11. Refraction, diffraction and interference

1.



2. Refraction refers to the process of light rays changing speed and direction as they pass between the interface of the boundary of two mediums.

3. $n = \frac{c_2}{c_1}$

Given that $c \approx c_{air}$

$n = \frac{c}{c_{air}}$

4. a) $n_1 \sin\theta_1 = n_2 \sin\theta_2$

$1 \times \sin 23 = 1.5 \times \sin\theta_2$

$\sin\theta_2 = \frac{\sin 23}{1.5}$

$\sin\theta_2 = 0.26$

$\theta_2 = \sin^{-1}(0.26)$

$\theta_2 = 15°$

b) No, because the light ray is moving from a lower refractive index to a higher refractive index, which contradicts the condition that for total internal reflection to occur, the light has to be travelling from higher refractive index to lower.

5. $\sin\theta_c = \frac{n_2}{n_1}$

$\sin\theta_c = \frac{n_{air}}{n_{diamond}}$

$\theta_c = \sin^{-1}(\frac{n_{air}}{n_{diamond}})$

$\theta_c = \sin^{-1}(\frac{1}{2.42})$

$\theta_c = 24.4°$

6. **Interference**: The p[illegible] two coherent waves creating [illegible] either through cancellation or rein[illegible]
Coherence: Sources of waves are coherent if they emit waves of the same frequency with constant phase difference.
Path difference: The difference in the distances between two coherent wave sources.

7. A single light so
sources of light u
source hits the d
the slits, causing
and interfere co
destructively, if
destructive inter
regions of light r

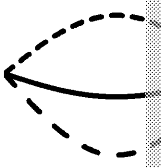
8. $w = \frac{\lambda D}{s}$

$s = \frac{\lambda D}{w}$

$s = \frac{(330 \times 10^{-9})}{(1.5 \times 10}$

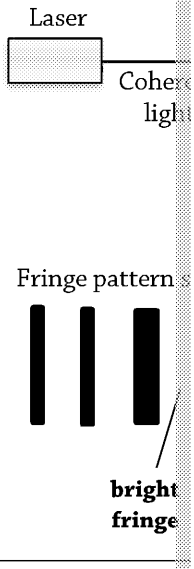
$s = 2.9 \times 10^{-4}$ m

9. a)



b)

10.



12. Stationary wave and quantum mechanics

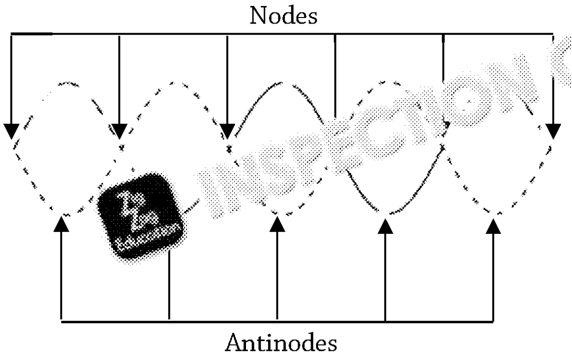
1. $d = \frac{1}{2}\lambda$

   $d = \frac{1}{2}\left(\frac{1}{2} \times 1.72\right)$

   $d = 0.43$ m

2. $\frac{20}{8} = 2.5$ wavelengths

   i.e. 5th harmonic



3. $E = hf$

   $f = \frac{E}{h}$

   $f = \frac{2.8 \times 10^{-18}}{6.63 \times 10^{-34}}$

   $f = 4.22 \times 10^{15}$ Hz

4. Calculate the wavelength of a photon with an energy of 38 eV.

   $E = \frac{hc}{\lambda}$

   $\lambda = \frac{hc}{E}$

   $E = 38 \text{ eV} = 38 \times 1.60 \times 10^{-19} = 6.08 \times 10^{-18}$ J

   $\lambda = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{6.08 \times 10^{-18}}$

   $\lambda = 3.27 \times 10^{-8}$ m (= 32.7 nm)

5. a) $E_3 - E_2 = -1.5 - (-3.4)$ eV

   $E_3 - E_2 = 1.9$ eV

   b) Since the electron has moved from lower energy level to a higher energy level, the electron has gained energy and, therefore, must have absorbed a photon (and its energy).

6. The photoelectric effect is a term for the process of electron emission from the surface of a metal due to light with a frequency above the threshold frequency incident on its surface.

7. $E_{k\,\max} = hf - \phi$

   $\phi = hf - E_{k\,\max}$

   $\phi = 6.63 \times 10^{-34}$

   $\phi = 6.88 \times 10^{-19}$

   $\phi = \frac{6.88 \times 10^{-19}}{1.6 \times 10^{-19}}$

   $\phi = 4.3$ eV

- **Threshol**
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  the metal
- **Stopping**
  to stop an
- **$E_{k\,max}$**: the
  of the pho

9. While light is hi
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   as waves.

10. - The proces
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      round a ba
    - The photo
      that electr
      properties

11 a) $\lambda = \frac{h}{mv}$

   $\lambda = \frac{}{(9.11}$

   $\lambda = 2.9 \times 1$

   b) The wavele

   c) The amoun