Cambridge Ordinary Level Notes
Physics 5054

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Contents

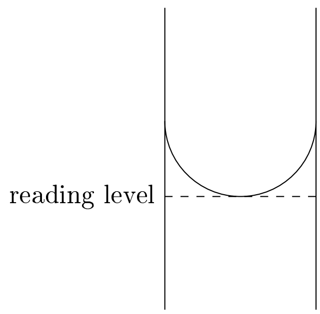

Figure 1: For colourless liquids.

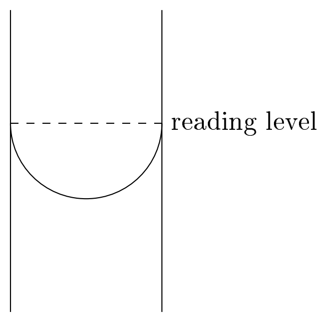

Figure 2: For coloured liquids.

1 Motion, forces and energy

1.1 Physical quantities and measurement techniques

1.1.1. *Describe how to measure a variety of lengths with appropriate precision using tapes, rulers and micrometers (including reading the scale on an analogue micrometer)*

Every ruler has a minimum length it can measure. Readings must be written rounded to that nearest reading. For a ruler calibrated to the nearest 0.1 mm, all readings should be written to the nearest 0.1 mm. To read micrometers, watch this video.

Understand that, given a set of equipment and something to measure, we must choose the equipment with maximum readings closest to the thing to measure.

1.1.2. *Describe how to use a measuring cylinder to measure the volume of a liquid and to determine the volume of a solid by displacement*

For colourless liquids, readings in a measuring cylinder must be taken from the lower meniscus, and for coloured liquids the upper meniscus should be used, see Figures 1 and 2.

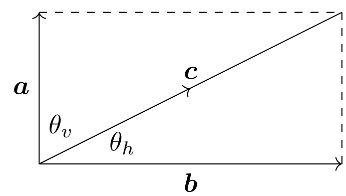

Figure 3: Vectors pointing outward.

1.1.3. *Describe how to measure a variety of time intervals using clocks and digital timers*

1.1.4. *Determine an average value for a small distance and for a short interval of time by measuring multiples (including the period of oscillation of a pendulum)*

For experiments involving oscillation, oscillations are counted, and total time for those oscillations is taken. The total time is divided by the number of oscillations, giving an average value for each oscillation, removing influence of inaccurate and anomalous experiment.

1.1.5. *Understand that a scalar quantity has magnitude (size) only and that a vector quantity has magnitude and direction*

1.1.6. *Know that the following quantities are scalars: distance, speed, time, mass, energy and temperature*

1.1.7. *Know that the following quantities are vectors: displacement, force, weight, velocity, acceleration, momentum, electric field strength and gravitational field strength*

1.1.8. *Determine, by calculation or graphically, the resultant of two vectors at right angles*

Mathematically, the resultant, $\boldsymbol{c}$, of two vectors, $\boldsymbol{a}$ and $\boldsymbol{b}$ has is given by:

$$\boldsymbol{c} = \sqrt{\boldsymbol{a}^2 + \boldsymbol{b}^2}$$

The angle with the horizontal, θ_h and that with the vertical θ_v can be found:

$$\tan\theta_v = \boldsymbol{b}/\boldsymbol{a}$$

$$\tan\theta_h = \boldsymbol{a}/\boldsymbol{b}$$

refer to Figure 3 and 4 for directionality.

1.2 Motion

1.2.1. *Define speed as distance travelled per unit time and define velocity as change in displacement per unit time*

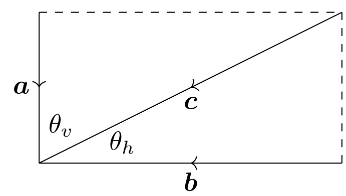

Figure 4: Vectors pointing inward.

Displacement is the distance of an object with respect to a certain point, called the origin. Essentially, displacement is the vector form of distance. Speed and velocity, $\boldsymbol{v}$ are the rates of change of distance and displacement, $\boldsymbol{s}$ with respect to time, t.

1.2.2. *Recall and use the equation*

$$\textit{(speed)} = \textit{(distance)}/\textit{(time)}$$

Mathematically,

$$\boldsymbol{v} = \boldsymbol{s}/t$$

1.2.3. *Recall and use the equation*

$$(\textit{average speed}) = (\textit{total distance})/(\textit{time taken})$$

1.2.4. *Define acceleration as change in velocity per unit time; recall and use the equation*

$$(\textit{acceleration}) = (\textit{change in velocity})/(\textit{time taken})$$

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

Symbolically,

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

where $\boldsymbol{v}$ is final and $\boldsymbol{u}$ is initial velocity.

1.2.5. *State what is meant by, and describe examples of, uniform acceleration and non-uniform acceleration*

When over a period of time, acceleration does not change, i.e., $\Delta \boldsymbol{a} = 0$, acceleration is said to be *uniform* or *constant*. When $\Delta \boldsymbol{a} \neq 0$, acceleration has changed, causing a *non-uniform* or *non-constant* acceleration.

1.2.6. *Know that a deceleration is a negative acceleration and use this in calculations*

A negative acceleration causes a decrease in velocity, and is called *deceleration*. A deceleration of x is the same as an acceleration of $-x$, and the opposite also applies.

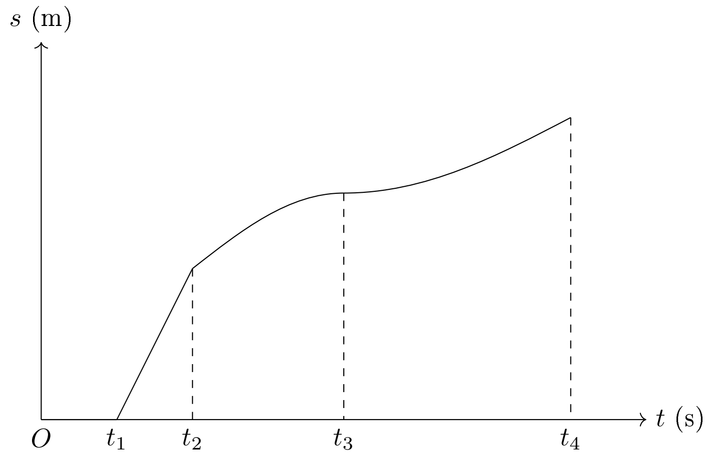

Figure 5: Distance-time graph.

1.2.7. *Sketch, plot and interpret distance–time and speed–time graphs*

The motion of objects can be investigated by their data, which is made more convenient by the use of graphical representations of the data. The distance covered by the object and the velocity or speed of the object can be plotted against time.

1.2.8. *Determine from the shape of a distance–time graph when an object is:*

(a) at rest

(b) moving with constant speed

(c) accelerating

(d) decelerating

For a distance time graph, understand that the gradient of the curve gives speed of the object being observed. This is further discussed in Section 1.2.11 onwards.

Observe Figure 5.

For $0 \leq t \leq t_1$, the distance travelled by the object being observed is not changing. This simply means it is not moving, is stationary and at rest.

For $t_1 \leq t \leq t_2$, the distance travelled by the object is increasing. The nature of the increase is to be observed. For this interval, the line is straight. This means the gradient is constant, and for a distance-time curve the gradient is the object's speed. Hence, for $t_1 \leq t \leq t_2$, the object travels with constant, uniform speed.

For $t_2 \leq t \leq t_3$, the distance travelled increases still, but the nature of the increase is different. If we were to image a tangent along the graph in the interval, we would see that the steepness of the tangent decreases as the tangent

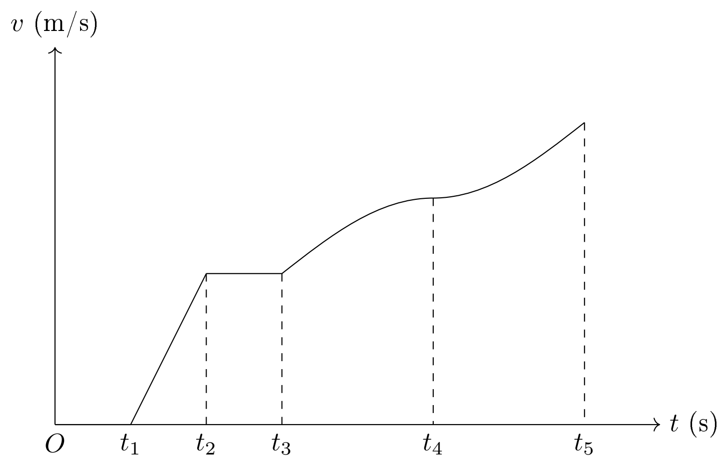

Figure 6: Speed-time graph

travel rightward, i.e., as time increases. Hence, here, the object travels with a decreasing speed.

For $t_3 \leq t \leq t_4$, we use the same approach as the previous interval. However, here we will notice the tangent increasing in gradient. Therefore, here, the object travels with increasing speed.

1.2.9. *Determine from the shape of a speed–time graph when an object is:*

(a) at rest

(b) moving with constant speed

(c) moving with constant acceleration

(d) moving with changing acceleration

Understand that, for a speed-time graph, the gradient of the curve gives acceleration of the observed object and the area under it gives the distance travelled by the object. This matter is further discussed in Section 1.2.11 onwards.

Observe Figure 6, consider that an object's speed has been plotted against time.

For $0 \leq t \leq t_1$, notice that the graph is at the vertical coordinate of 0. That means speed for this time is zero, and the object is not moving, i.e., is at rest.

For $t_1 \leq t \leq t_2$, the speed of the object has increased. The graph for this interval is straight, meaning the speed has increased at a constant rate. The rate of change of velocity is acceleration, and hence, the object has accelerated uniformly for this time interval.

For $t_2 \leq t \leq t_3$, the speed of the object does not change, but it has a non-zero value. This means the object now travels at a uniform speed.

For $t_3 \leq t \leq t_4$, the speed of the object increases. The nature of the increase is to be investigated. Observing the tangent as t increases, we see its slope decreases, therefore, here, the object travels with decreasing acceleration.

For $t_4 \leq t \leq t_5$, the speed of the object increases still. Observing the tangent to the curve, we see its slope increases, hence, here the object travels with increasing acceleration.

1.2.10. *State that the acceleration of free fall g for an object near to the surface of the Earth is approximately constant and is approximately 9.8 m/s*^{2}

For an object near the surface of the Earth, it is attracted by the Earth. This force of attraction is said to be *gravity*. An object affected by Earth's gravity, which is near Earth's surface accelerates toward the centre of the Earth at a rate of 9.8 m/s^2. This quantity, is called the *acceleration of free fall* and is denoted mathematically as g.

1.2.11. *Calculate speed from the gradient of a distance–time graph*

The gradient of a graph results in the division of the variable on the vertical axis divided by the variable on the horizontal axis. The quantities' units too, are divided. Knowing this, we see the gradient of a distance-time graph gives, (m)/(s) = m/s, the unit for speed.

The gradient at a point on a curve can be found by drawing a tangent to the point, taking two convenient coordinates through which the tangent passes, let's say (x_1, y_1) and (x_2, y_2). Hence the gradient would be:

$$\frac{y_2 - y_1}{x_2 - x_1} = \frac{y_1 - y_2}{x_1 - x_1}$$

For a straight line, the line itself is its tangent, so taking two convenient points from it, or extending it to get more convenient points, and applying them into the above formula gives the gradient.

1.2.12. *Calculate the area under a speed–time graph to determine the distance travelled for motion with constant speed or constant acceleration*

The distance under a graph multiplies the horizontal and vertical variables, and hence their units. In case of a speed-time graph, (m/s)(s) = m, the unit of distance. Therefore, area under a speed-time graph gives distance travelled.

Geometry may be used to find the gradient under a graph.

1.2.13. *Calculate acceleration from the gradient of a speed–time graph*

Using principles discussed in Section 1.2.11, the gradient of a speed time graph can be found, which gives acceleration since (m/s)/(s) = m/s^2.

1.3 Mass and weight

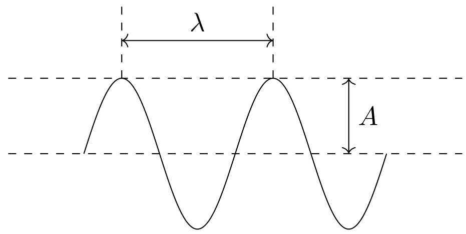

Figure 7: A wave

2 Waves

2.1 General properties of waves

2.1.1. *Know that waves transfer energy without transferring matter*

2.1.2. *Describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by experiments using water waves*

The waves themselves never move. The particles that make up the wave oscillate, (move periodically back and forth) without movement of the wave itself. This can be illustrated by the movements of a rope, when one end is moved up and down periodically. In case of a spring, forward and backward movements at one end of a spring compress and expand parts of the spring, these parts move along the spring, which is wave movement.

2.1.3. *Describe the features of a wave in terms of wavefront, wavelength, frequency, crest (peak), trough, amplitude and wave speed*

The wave crests and troughs of multiple parallel waves form lines, called *wavefronts*.

The wavelength, frequency and amplitude are defined in following subsections.

The *crest* is the maximum displacement of a particle in a wave. The *trough* is the minimum displacement of a particle in a wave.

2.1.4. *Define the terms:*

(a) frequency as the number of wavelengths that pass a point per unit time

(b) wavelength as the distance between two consecutive, identical points such as two consecutive crests

(c) amplitude as the maximum distance from the mean position

The *wavelength* and *amplitude* are shown in Figure 7 as λ and A, respectively. Frequency is denoted f.

2.1.5. *Recall and use the equation*

$$\text{(wave speed)} = \text{(frequency)} \times \text{(wavelength)}$$

$$v = f\lambda$$

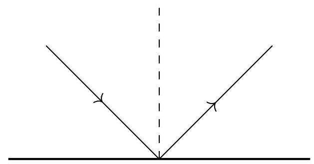

Figure 8: Reflection, refraction and diffraction of waves

2.1.6. *Know that for a transverse wave, the direction of vibration is at right angles to the direction of the energy transfer, and give examples such as electromagnetic radiation, waves on the surface of water, and seismic S-waves (secondary)*

2.1.7. *Know that for a longitudinal wave, the direction of vibration is parallel to the direction of the energy transfer, and give examples such as sound waves and seismic P-waves (primary)*

2.1.8. *Describe how waves can undergo:*

(a) reflection at a plane surface

(b) refraction due to a change of speed

(c) diffraction through a gap

3 Electricity and magnetism

3.1 Simple magnetism and magnetic fields

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3.1.1. *Describe the forces between magnetic poles and between magnets and magnetic materials, including the use of the terms north pole (N pole), south pole (S pole), attraction and repulsion, magnetised and unmagnetised*

3.1.2. *Describe induced magnetism*

3.1.3. *State the difference between magnetic and non-magnetic materials*

3.2 Electrical quantities

3.2.1 Electrical charge

3.2.1.1. *State that there are positive and negative charges and that charge is measured in coulombs*

Matter is made of subatomic particles, two of which are *protons* and *electrons*. These are positively and negatively charged, respectively. The magnitude of their charges are measured in *coulombs* (C), the unit of *charge*.

Note that, though the particles have oppositely signed charge, the magnitudes of their charges are equal, which is 1.6×10^{-19} C.

3.2.1.2. *State that unlike charges attract and like charges repel*

As in magnetism, only, here the the signs of the charges are to be the factors that cause attraction or repulsion. Oppositely signed charges attract (positive and negative) and equally signed charges repel.

3.2.1.3. *Describe experiments to show electrostatic charging by friction*

As described before, charge is caused by the presence of protons and electrons. Protons are present in the nuclei of atoms, and are largely immobile. Electrons are present on the outskirts of each atom and are very prone to movement.

In a *electrically neutral* object, the number of protons equals the number of electrons, their opposite charges cancelling out, producing a net charge of zero. However, for an object with a *lack of electrons* such that there are more protons than electrons, the object will have a net charge that is positive. An object with an *excess of electrons* has an overall negative charge.

There are generally two types of materials in terms of how freely electrons can traverse them. These are *conductors* and *insulators*. In an electrical conductor, the electrons can easily move through the object, but for electrical insulators, the electrons are bound very strongly to their nuclei, making it difficult for them to move through the solid.

We can bring about a lack or excess of electrons by applying friction amongst two electrical insulators. Rubbing two insulators together causes electrons to

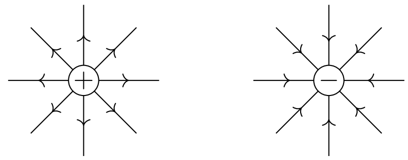

Figure 9: Electric field around point charges

move from one to the other. This causes an excess of electrons in one object, and a lack of electrons in the other. As a result, the objects become oppositely charged. Bringing these close together, we find that they are attracted to each other.

This is only possible in insulators, as, if an electrostatic charge was brought into a metal and it contacted any object, the excess electrons would flow out of it or electrons would be conducted into it from the surroundings to undo the charge.

3.2.1.4. *Explain that charging of solids by friction involves only a transfer of negative charge (electrons)*

3.2.1.5. *Describe an electric field as a region in which an electric charge experiences a force*

3.2.1.6. *State that the direction of an electric field line at a point is the direction of the force on a positive charge at that point*

A charged object has an *electric field* around it. This is a region in space where a charge will experience a force. The direction of an electric field at a point is identical to the direction of the force experienced by a positive charge at that point.

Since a positive charge is always repelled away from another positive charge and attracted to negative charges, electrical field lines always have an outward direction from positive charges and an inward direction from negative charges.

3.2.1.7. *Describe simple electric field patterns, including the direction of the field:*

(a) around a point charge

(b) around a charged conducting sphere

(c) between two oppositely charged parallel conducting plates (end effects will not be examined)

Observe Figures 7 and 8.

Electric fields around point charges and charged, conducing spheres are identical; directed radially outward and radially inward for positive and negatively charged spheres respectively.

3.2.1.8. *State examples of electrical conductors and insulators*

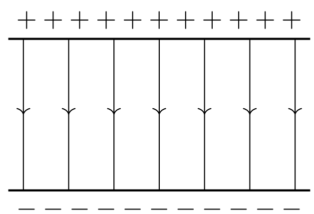

Figure 10: Electric field between oppositely charged conducting plates

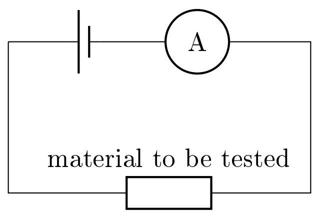

Figure 11: Circuit to see conductivity of material

All metals are great electrical conductors, whereas non metals are all insulators. Copper and gold are phenomenal conductors whereas poly(ethene) and wood are insulators.

3.2.1.9. *Describe an experiment to distinguish between electrical conductors and insulators*

Observe Figure 9, the resistor here, is the material to be tested. The ammeter will show the extent of current that can flow through it. That reading indicates the extent of conductive characteristic the material shows.

3.2.1.10. *Recall and use a simple electron model to explain the difference between electrical conductors and insulators*

3.2.2 Electrical current

3.2.2.1. *Define electric current as the charge passing a point per unit time; recall and use the equation*

$$\textit{(electric current)} = \frac{\textit{(charge)}}{\textit{(time)}}$$

$$I = \frac{Q}{t}$$

3.2.2.2. *Describe electrical conduction in metals in terms of the movement of free electrons*

Something that conducts electricity has free electrons that can move through it.

3.2.2.3. *Know that current is measured in amps (amperes) and that the amp is given by coulomb per second (C/s)*

An ampere of current is identical to one coulomb of charge flowing through a point every second. The shortened form of ampere is (A).

3.2.2.4. *Know the difference between direct current (d.c.) and alternating current (a.c.)*

Current whose direction changes is said to *alternating*, otherwise it is *direct*. The direction of current depends on the sign, change in sign means change in direction of flow of current.

3.2.2.5. *State that conventional current is from positive to negative and that the flow of free electrons is from negative to positive*

Free electrons flow from negative to positive terminals, whereas *conventional current* is considered to flow form positive to negative. This is a historical mistake.

3.2.2.6. *Describe the use of ammeters (analogue and digital) with different ranges*

Ammeters measure the amount of current flowing through them. In a circuit, they must always be connected in series to the branch of whose current is being measured.

Given a range of possible values, the ammeter to be chosen is selected depending on which has a greater maximum range, but the least difference between the greatest maximum range and the greatest possible anticipated value.

3.2.3 Electromotive force and potential difference

3.2.3.1. *Define e.m.f. (electromotive force) as the electrical work done by a source in moving a unit charge around a complete circuit; recall and use the equation*

$$(e.m.f.) = \frac{(work\ done\ (by\ a\ source))}{(charge)}$$

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

3.2.3.2. *Define p.d. (potential difference) as the work done by a unit charge passing through a component; recall and use the equation*

$$(p.d.) = \frac{(work\ done\ (on\ component))}{(charge}$$

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

3.2.3.3. *Know that e.m.f. and p.d. are measured in volts and that the volt is given by joule per coulomb (J/C)*

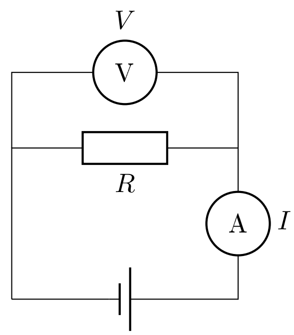

Figure 12: Experiment to determine resistance of component

The symbol of the volt is (V).

3.2.3.4. *Describe the use of voltmeters (analogue and digital) with different ranges*

Identical to Section 2.2.2.6, only here, the voltmeters must be connected parallel to the component whose voltage is being measured.

3.2.3.5. *Calculate the total e.m.f. where several sources are arranged in series*

Given there are n source, with electromotive forces of E_1, E_2, E_3, ... E_n, their total electromotive force equals:

$$E_1 + E_2 + E_3 + ... + E_n$$

3.2.3.6. *State that the e.m.f of identical sources connected in parallel is equal to the e.m.f. of one of the sources*

3.2.4 Resistance

3.2.4.1. *Recall and use the equation*

$$\textit{(resistance)} = \frac{\textit{(p.d.)}}{\textit{(current)}}$$

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

The resistance of a component is the voltage required to push one unit of charge through the component. It is measured in ohms, whose symbol is (Ω).

3.2.4.2. *Describe an experiment to determine resistance using a voltmeter and an ammeter and do the appropriate calculations*

Observe Figure 10. Here, the component whose resistance, R is being determined is in series to an ammeter and a source, and parallel to a voltmeter. The ammeter gives reading I and the voltmeter gives reading V. Hence,

$$R = V/I$$

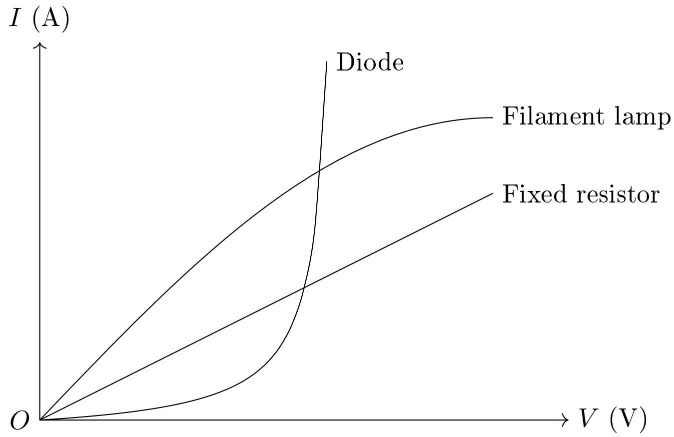

Figure 13: Current-voltage graphs for constant resistance and a filament lamp

3.2.4.3. *Recall and use, for a wire, the direct proportionality between resistance and length, and the inverse proportionality between resistance and cross-sectional area*

Consider the case of a conducting wire. Its resistance to current will depend on its physical dimensions. That is, the longer the wire, the more resistant it will be, the thicker the wire (the larger the cross section) the less resistant it will be. Symbolically

$$R \propto L$$

$$R \propto 1/A$$

where L is the length of the wire and A is its cross sectional area.

3.2.4.4. *State Ohm's law, including reference to constant temperature*

Ohm's law states that current across a resistor, at a constant temperature, will vary directly with the voltage applied across it. Mathematically,

$$V \propto I$$

$$V = IR$$

Here, the constant of proportionality is resistance.

3.2.4.5. *Sketch and explain the current–voltage graphs for a resistor of constant resistance, a filament lamp and a diode*

Observe Figure 11. A *diode* allows flow of infinite voltage once a sufficient voltage has been applied.

For a <u>*filament lamp*</u>, the filament heats up as voltage across it is increased. As a result of this increase in temperature, resistance across it also increases, inhibiting increase in voltage.

The <u>*fixed resistor*</u> shows the ohmic property of $V \propto I$.

3.2.1. *Describe the effect of temperature increase on the resistance of a resistor, such as the filament in a filament lamp*

Increase in temperature increases resistance as the vibrating particles of the wire inhibit smooth flow of charge.

3.3 Electric circuits

3.3.1 Circuit diagrams and circuit components

3.3.1.1. *Draw and interpret circuit diagrams with cells, batteries, power supplies, generators, oscilloscopes, potential dividers, switches, resistors (fixed and variable), heaters, thermistors (NTC only), light-dependent resistors (LDRs), lamps, motors, ammeters, voltmeters, magnetising coils, transformers, fuses, relays, diodes and light-emitting diodes (LEDs), and know how these components behave in the circuit*

Refer to the syllabus for these symbols.

3.3.2 Series and parallel circuits

3.3.2.1. *Recall and use in calculations, the fact that:*

(a) the current at every point in a series circuit is the same

(b) the sum of the currents entering a junction in a parallel circuit is equal to the sum of the currents that leave the junction

(c) the total p.d. across the components in a series circuit is equal to the sum of the individual p.d.s across each component

(d) the p.d. across an arrangement of parallel resistances is the same as the p.d. across one branch in the arrangement of the parallel resistances

3.3.2.2. *Calculate the combined resistance of two or more resistors in series*

For n resistors that are in series, the sum of their resistances is

$$R_1 + R_2 + R_3 + ... + R_n$$

3.3.2.3. *Calculate the combined resistance of two resistors in parallel*

For n resistors in parallel, the sum of their resistances is

$$\left(R_1^{-1} + R_2^{-1} + ...R_n^{-1}\right)^{-1}$$

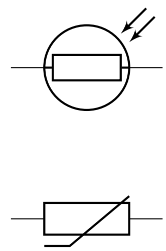

Figure 14: Light dependent resistor and thermistor

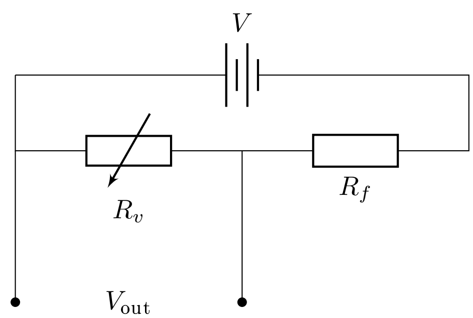

Figure 15: A potential divider circuit

3.3.3 Action and use of circuit components

3.3.3.1. *Describe the action of negative temperature coefficient (NTC) thermistors and light-dependent resistors and explain their use as input sensors*

Observe Figure 12, which show the circuit symbols for a *light dependent resistor* and a *thermistor* (the light dependent resistor should not have a circle around it, refer to the syllabus).

A thermistor's resistance *increases as heat decreases* and vice versa. An LDR's resistance *increases as light intensity decreases* and vice versa. With increase in *input* intensity, resistance decreases.

3.3.3.2. *Describe the action of a variable potential divider*

A *potential divider* divides the e.m.f. of a source into two, using the principle of series circuits where voltages are divided amongst resistors according to their resistances. Figure 13 shows such a circuit.

Here, the total resistance across the circuit is $\sum R = R_v + R_f$, where R_v can be changed as it is that of a variable resistor. Since R_v can change, it can take up more or less of a fraction of total resistance. The e.m.f. provided by the source, V does not change, but the voltage, V_{out} across the variable resistor changes when R_v changes. Here,

$$V_{\text{out}} = \frac{R_v}{\sum R}$$

3.3.3.3. *Recall and use the equation for two resistors used as a potential divider*

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

In a series circuit, the ratio of voltage across two resistors equals the ratio of their resistances.

3.4 Practical electricity

3.4.1 Uses of electricity

3.4.1.1. *State common uses of electricity, including heating, lighting, battery charging and powering motors and electronic systems*

3.4.1.2. *State the advantages of connecting lamps in parallel in a lighting circuit*

Each lamp lights brighter as all of them are exposed to the same voltage. If one lamp goes out of order, the others are unaffected.

3.4.1.3. *Recall and use the equation*

$$\textit{(power)} = \textit{(voltage)} \times \textit{(current)}$$

$$P = VI$$

The power expended by a component equals the product of the current flowing through it and the voltage across it.

3.4.1.4. *Recall and use the equation*

$$\textit{(energy)} = \textit{(current)} \times \textit{(voltage)} \times \textit{(time)}$$

$$E = IVt$$

The product of power and time equals the energy expended over that time period.

3.4.1.5. *Define the kilowatt-hour (kWh) and calculate the cost of using electrical appliances where the energy unit is the kWh*

The kilowatt-hour is a unit of energy equivalent to the energy expended when one kilowatt of power is produced in an hour.

3.4.2 Electrical safety

3.4.2.1. *State the hazards of:*

(a) damaged insulation
(b) overheating cables
(c) damp conditions

(d) *excess current from overloading of plugs, extension leads, single and multiple sockets*

when using a mains supply

Damaged insulation will electrify metal parts of a device, such that when touched a current will flow through the body of he who touched it down to earth.

Overheating cables will melt.

Water conducts electricity

Too many plugs is bad because too much voltage being pulled to each appliance will overload and overheat the wire of the multiplug.

3.4.2.2. *Explain the use and operation of trip switches and fuses and choose appropriate fuse ratings and trip switch settings*

The function of *trip switches* and *fuses* is to *break the circuit* when too much current flows through it.

Fuses are lengths of thin wire, which will conduct current of a certain magnitude, but beyond a certain magnitude these fuses will melt and break the circuit. The maximum current a fuse will tolerate is called its *rating*. The fuse must hence be replaced each time it melts, feasible as the fuses are cheap.

Trip switches are mechanisms which disconnect a circuit when a current of certain magnitude flows through them. These are also called circuit breakers, and these do not need to be replaced after each disconnection. They are expensive, contrastingly to fuses.

3.4.2.3. *Explain what happens when a live wire touches a metal case that is earthed*

Current flows through the metal casing, through the least resistance path, down to earth.

3.4.2.4. *Explain why the outer casing of an electrical appliance must be either non-conducting (double-insulated) or earthed*

Non-conducting casings will never pass current onto user's body. Metal casings must be connected to earth, when the casing is electrified, the earth connection is always less resistance than the user's body, which causes current to flow down into earth, preventing an electric shock.

3.4.2.5. *Know that a mains circuit consists of a live wire (line wire), a neutral wire and an earth wire and explain why a switch must be connected into the live wire for the circuit to be switched off safely*

The live wire is what carries the alternating current, and the neutral wire is what allows the current to alternate, how exactly is out of the syllabus' scope. The earth wire connects to earth.

Since the live wire carries current, switching it on or off switches the appliance on or off.

3.4.2.6. *Explain why fuses and circuit breakers are connected into the live wire*

If large magnitude of current flows as a result of broken insulation or metal casing or whatever, they will flow through the live wire. As a result, circuit breaking mechanisms are connected to the current-carrying live wire.

4 Nuclear physics

4.1 The nuclear model of the atom

4.1.1 The atom

4.1.1.1. *Describe the structure of the atom in terms of a positively charged nucleus and negatively charged electrons in orbit around the nucleus*

4.1.1.2. *Describe how alpha-particle scattering experiments provide evidence for:*

(a) a very small nucleus surrounded by mostly empty space

(b) a nucleus containing most of the mass of the atom

(c) a nucleus that is positively charged

Alpha (α) particles are positively charged. They are emitted by certain sources. When emitted at a gold leaf, it is seen that almost all of the alpha particles continue in their straight path.

However, some particles are *deflected* and travel not in that straight line. This happens when the particle comes close to a nucleus of the gold atoms. The positive charges of the nucleus and alpha particle cause the alpha particle's trajectory to change due to repulsion.

These observations prove that,

(i) *Most of the atom is empty space* since the majority of alpha particles travel in the trajectory they were sent in as.

(ii) *The nucleus contains the mass of the atom* because empty space can't have weight.

(iii) *The nucleus is positively charged* because it repulses the positively charged alpha particles (like charges repulse).

4.1.2 The nucleus

4.1.2.1. *Describe the composition of the nucleus in terms of protons and neutrons*

The nucleus consists of two types of massive[1], subatomic particles. These are *protons* – particles that have a positive charge, of 1.602×10^{-19} C, and *neutrons* – particles which have no charge, but mass equal to that of a proton.

The masses of these particles, in actuality is 1.6727×10^{-24} g. A carbon-12 atom has 12 of these particles. Nuclear masses are measured relative to 1/12th that of a carbon-12 atom, so a neutron and proton have *relative masses* of 1 each. Charges are also measured relative to the charge of 1/6th of the charge of a carbon-12 nucleus.

[1]In physics, *massive* means anything that has mass, not that anything has a lot of mass.

4.1.2.2. *Describe how atoms form positive ions by losing electrons or negative ions by gaining electrons*

Protons, since they are massive and are present at the centre of an atom, they do not always move. Charge in an atom is brought about by the movement of *electrons*. These are particles that have opposite the charge of a proton, i.e., -1.602×10^{-19} C, or a relative charge of -1. These particles have immensely negligible mass and they orbit the nucleus, hence they can move around easily.

An *excess of electrons* causes a negative charge, and an *absence of electrons* causes a positive charge, since the resulting sums of charges are negative and positive respectively.

4.1.2.3. *Define the terms proton number (atomic number) Z and nucleon number (mass number) A and be able to calculate the number of neutrons in a nucleus*

The proton number of a given nucleus is denoted Z, and is the number of protons in that nucleus. The nucleon number of a nucleus is denoted A, it is also called mass number and it is the total number of protons and neutrons in that nucleus. So, for the number of neutrons in the nucleus:

$$A - Z$$

4.1.2.4. *Explain the term nuclide and use the nuclide notation* $^{A}_{Z}X$

A *nuclide* is simply a nucleus whose details are known. The nucleon and proton numbers of a nuclide X, A and Z is denoted $^{A}_{Z}\mathrm{X}$.

4.1.2.5. *Explain what is meant by an isotope and state that an element may have more than one isotope*

An *isotope* of an element is an atom of that element with a certain number of neutrons. Multiple of these atomic variations may exist per element.

4.2 Radioactivity

4.2.1 Detection of radioactivity

4.2.1.1. *Describe the detection of alpha particles (α-particles) using a cloud chamber or spark counter and the detection of beta particles (β-particles) (β-particles will be taken to refer to β^-) and gamma radiation (γ-radiation) by using a Geiger-Müller tube and counter*

Spark counters, are weird. Geiger Muller tubes are things that detect radiation and counters calculate and display the detections as counts/min.

4.2.1.2. *Use count rate measured in counts/s or counts/minute*

4.2.1.3. *Know what is meant by background radiation*

Radiation present from natural sources in the atmosphere is called *background radiation*.

4.2.1.4. *Know the sources that make a significant contribution to background radiation including:*

(a) radon gas (in the air)

(b) rocks and buildings

(c) food and drink

(d) cosmic rays

Food and drink are gotten from the soil, which can contain radioactive sources.

4.2.1.5. *Use measurements of background radiation to determine a corrected count rate*

When measuring radiation from a source, the count rate will show both background radiation and the radiation from the source itself. So, to get the radiation from only the source, first, the background radiation must be measured itself, then subtracted from the reading gotten from the source.

4.2.2 The three types of emission

4.2.2.1. *Describe the emission of radiation from a nucleus as spontaneous and random in direction*

Spontaneous, here, refers to the fact that it is unpredictable and cannot be influenced, the time of emission of radiation from a nucleus.

4.2.2.2. *Describe α-particles as two protons and two neutrons (helium nuclei), β-particles as high speed electrons from the nucleus and γ-radiation as high-frequency electromagnetic waves*

4.2.2.3. *State, for α-particles, β-particles and γ-radiation:*

(a) their relative ionising effects

(b) their relative penetrating powers

For α, β and γ, in that order:

- Alpha is the most ionising, gamma is the least.
- Alpha is the least penetrating, gamma is the most.

4.2.2.4. *Describe the deflection of α-particles, β-particles and γ-radiation in electric fields and magnetic fields*

Gamma radiation has no charge, so is unaffected in both electric and magnetic fields.

Direction of movement of alpha particles is the same as the movement of conventional current (movement of positive charge) and that of beta particles is opposite of conventional current (movement of electrons). Using this information, we can apply left hand rule in magnetic fields to find the deflections (forces) acting on these particles.

Since alpha particles are more massive, their relative deflection is less (greater moving inertia) than beta particles.

4.2.3 Radioactive decay

4.2.3.1. *Know that radioactive decay is a change in an unstable nucleus that can result in the emission of α-particles or β-particles and/or γ-radiation and know that these changes are spontaneous and random*

The instability of nuclei arises when a nucleus is too energetic or is too heavy. To shed this extra energy/mass, radiation is emitted in the form of alpha, beta or gamma.

4.2.3.2. *Use decay equations, using nuclide notation, to show the emission of α-particles, β-particles and γ-radiation*

4.2.3.3. *Use decay equations, using nuclide notation, to show the emission of α-particles β-particles and γ-radiation*

The nuclides for alpha and beta particles are as such: ${}^{4}_{2}\alpha$ and ${}^{0}_{-1}\beta$. Gamma has no nuclide notation because it is not a nuclide.

Let's observe the emission of alpha and beta radiation from a theoretical nuclide, X, with atomic and nucleon numbers of 15 and 30 respectively.

$$
\begin{gathered}
{}^{30}_{15}\mathrm{X} \longrightarrow {}^{26}_{13}\mathrm{Y} + {}^{4}_{2}\alpha \\
{}^{30}_{15}\mathrm{X} \longrightarrow {}^{30}_{16}\mathrm{Y} + {}^{0}_{-1}\beta
\end{gathered}
$$

4.2.4 Fission and fusion

4.2.4.1. *Describe the process of fusion as the formation of a larger nucleus by combining two smaller nuclei with the release of energy, and recognise fusion as the energy source for stars*

4.2.4.2. *Describe the process of fission when a nucleus, such as uranium-235 (U-235), absorbs a neutron and produces daughter nuclei and two or more neutrons with the release of energy*

4.2.4.3. *Explain how the neutrons produced in fission create a chain reaction and that this is controlled in a nuclear reactor, including the action of coolant, moderators and control rods*

In a nuclear reactor, the release of energy during fission is extracted in a controlled manner. Uranium nuclei are arranged such that, when an initial neutron is thrown at one nucleus, the neutrons resulting from that fission go and cause fission of more nuclei, which repeats on and on.

The control of this *chain reaction*, comes down to the use of coolant, moderators and control rods. Fission releases tremendous amount of heat, which is controlled by the coolant as need be. Moderators slow down the neutrons released during fusion which can then be absorbed easier by control rods, hence controlling the rate of nuclear fission.

4.2.5 Half-life

4.2.5.1. *Define the half-life of a particular isotope as the time taken for half the nuclei of that isotope in any sample to decay; recall and use this definition in calculations, which may involve information in tables or decay curves*

For a given sample of a radioactive isotope, the time taken for the sample's mass to halve is known. So, given a sample of mass m, with half life h, which has been decaying for time t, the final mass m_f will be:

$$m_f = (m)\left(\frac{1}{2^{t/h}}\right)$$

4.2.5.2. *Describe the dating of objects by the use of* ^{14}C

Carbon-14 is a radioactive isotope of carbon. To find the age of ancient artifacts, the amount of carbon-14 present is compared to the initial amount present, to see how many half lives have passed and hence how much time has passed.

4.2.5.3. *Explain how the type of radiation emitted and the half-life of the isotope determine which isotope is used for applications including:*

(a) household fire (smoke) alarms

(b) irradiating food to kill bacteria

(c) sterilisation of equipment using gamma rays

(d) measuring and controlling thicknesses of materials with the choice of radiations used linked to penetration and absorption

(e) diagnosis and treatment of cancer using gamma rays

Household fire (smoke) alarms. Alpha particles travel only few centimetres in air. When smoke is in the way, that distance reduces further. In household smoke detectors, alpha particles are being continuously emitted and detected, and when smoke is in the way, the rate of detection lowers, signalling the presence of smoke and the alarm is set off.

Irradiating of food to kill bacteria. Food goes bad because of microbes that decompose them. Intense exposure to gamma radiation tends to kill single celled organisms. Food, in this way is irradiated, and made sterile. Such food lasts longer due to absence of microbes.

Sterilisation of equipment using gamma rays. In the same way as food irradiation, medical equipment can be made free of microbes by exposing them to intense gamma radiation.

Measuring and controlling thicknesses of materials with the choice of radiations used linked to penetration and absorption. In the production of paper or metal sheets, thickness of the sheets is made constant by use of penetration of beta radiation. Beta radiation is sent across the sheet, and decrease and increase in detection of the radiation signals the sheet being too thick and too thin, respectively. Alpha and gamma radiation is unsuitable for this since they would be absorbed completely or unaffected entirely, respectively.

Diagnosis and treatment of cancer using gamma rays. Cancer cells are often killed by directing intense gamma rays at the growth, killing them as with microbes.

4.2.6 Safety precautions

4.2.6.1. *State the effects of ionising nuclear radiations on living things, including cell death, mutations and cancer*

Radiation causes ionisation, which, when happens to the molecules of living tissue, causes the cells to die, as if they had been burned. These are called *radiation burns*. The DNA in the cell may be affected, and they will hence change. This is called *mutation*. Mutations in cell DNA may result in the growth of a cancer.

4.2.6.2. *Explain how radioactive materials are moved, used and stored in a safe way, with reference to:*

(a) reducing exposure time

(b) increasing distance between source and living tissue

(c) use of shielding to absorb radiation

5 Space physics

5.1 Earth and the Solar System

5.1.1 The Earth

5.1.1.1. *Know that:*

- (a) *the Earth is a planet that orbits the Sun once in approximately 365 days*
- (b) *the orbit of the Earth around the Sun is an ellipse which is approximately circular*
- (c) *the Earth rotates on its axis, which is tilted, once in approximately 24 hours*
- (d) *it takes approximately one month for the Moon to orbit the Earth*
- (e) *it takes approximately 500 s for light from the Sun to reach the Earth*

5.1.1.2. *Define average orbital speed from the equation:*

$$v = 2\pi r/T$$

where r is the average radius of the orbit and T is the orbital period; recall and use this equation

Orbital period refers to the time taken for the body to orbit.

5.1.2 The Solar System

5.1.2.1. *Describe the Solar System as containing:*

- (a) *one star, the Sun*
- (b) *the eight named planets and know their order from the Sun*
- (c) *minor planets that orbit the Sun, including dwarf planets such as Pluto and asteroids in the asteroid belt*
- (d) *moons, that orbit the planets*
- (e) *smaller Solar System bodies, including comets and natural satellites*

In order of increasing distance from the Sun, the planets in the solar system are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune.

5.1.2.2. *Analyse and interpret planetary data about orbital distance, orbital period, density, surface temperature and uniform gravitational field strength at the planet's surface*

5.1.2.3. *Know that the strength of the gravitational field:*

(a) *at the surface of a planet depends on the mass of the planet*
(b) *around a planet decreases as the distance from the planet increases*

5.1.2.4. *Know that the Sun contains most of the mass of the Solar System and that the strength of the gravitational field at the surface of the Sun is greater than the strength of the gravitational field at the surface of the planets*

5.1.2.5. *Know that the force that keeps an object in orbit around the Sun is the gravitational attraction of the Sun*

5.1.2.6. *Know that the strength of the Sun's gravitational field decreases and that the orbital speeds of the planets decrease as the distance from the Sun increases*

5.1.3 The Sun as a star

5.1.3.1. *Know that the Sun is a star of medium size, consisting mostly of hydrogen and helium, and that it radiates most of its energy in the infrared, visible and ultraviolet regions of the electromagnetic spectrum*

5.1.3.2. *Know that stars are powered by nuclear reactions that release energy and that in stable stars the nuclear reactions involve the fusion of hydrogen into helium*

5.1.4 Stars

5.1.4.1. *State that:*

(a) *galaxies are each made up of many billions of stars*
(b) *the Sun is a star in the galaxy known as the Milky Way*
(c) *other stars that make up the Milky Way are much further away from the Earth than the Sun is from the Earth*
(d) *astronomical distances can be measured in light-years, where on light-year is the distance travelled in a vacuum by light in one year*

5.1.4.2. *Describe the life cycle of a star:*

(a) *a star is formed from interstellar clouds of gas and dust that contain hydrogen*
(b) *a protostar is an interstellar cloud collapsing and increasing in temperature as a result of its internal gravitational attraction*
(c) *a protostar becomes a stable star when the inward force of gravitational attraction is balanced by an outward force due to the high temperature in the centre of the star*
(d) *all stars eventually run out of hydrogen as fuel for the nuclear reaction*

(e) *most stars expand to form red giants and more massive stars expand to form red supergiants when most of the hydrogen in the centre of the star has been converted to helium*

(f) *a red giant from a less massive star forms a planetary nebula with a white dwarf at its centre*

(g) *a red supergiant explodes as a supernova, forming a nebula containing hydrogen and new heavier elements, leaving behind a neutron star or a black hole at its centre*

(h) *the nebula from a supernova may form new stars with orbiting planets*

5.1.5 The Universe

5.1.5.1. *Know that the Milky Way is one of many billions of galaxies making up the Universe and that the diameter of the Milky Way is approximately 100 000 light-years*

5.1.5.2. *Describe redshift as an increase in the observed wavelength of electromagnetic radiation emitted from receding stars and galaxies*

5.1.5.3. *Know that the light from distant galaxies shows redshift and that the further away the galaxy, the greater the observed redshift and the faster the galaxy's speed away from the Earth*

5.1.5.4. *Describe, qualitatively, how redshift provides evidence for the Big Bang theory*

It is seen that the redshift of objects, when observed after a time gap, is increasing at an increasing rate. This means that the objects are accelerating outward, working as proof for the Big Bang.

6 Overall

6.1 Quantitative notation

A change in a quantity x is represented Δx. The change in x is always its final value minus the initial.

$$\Delta x = x_f - x_i$$

where x_f is the final value and x_i is the initial.

6.2 Graphs

The tangent of a curve gives its gradient at that point.