OCR A Level Physics

Your notes

Use of Measuring Instruments & Electrical Equipment

Contents

Using Appropriate Instruments & Techniques

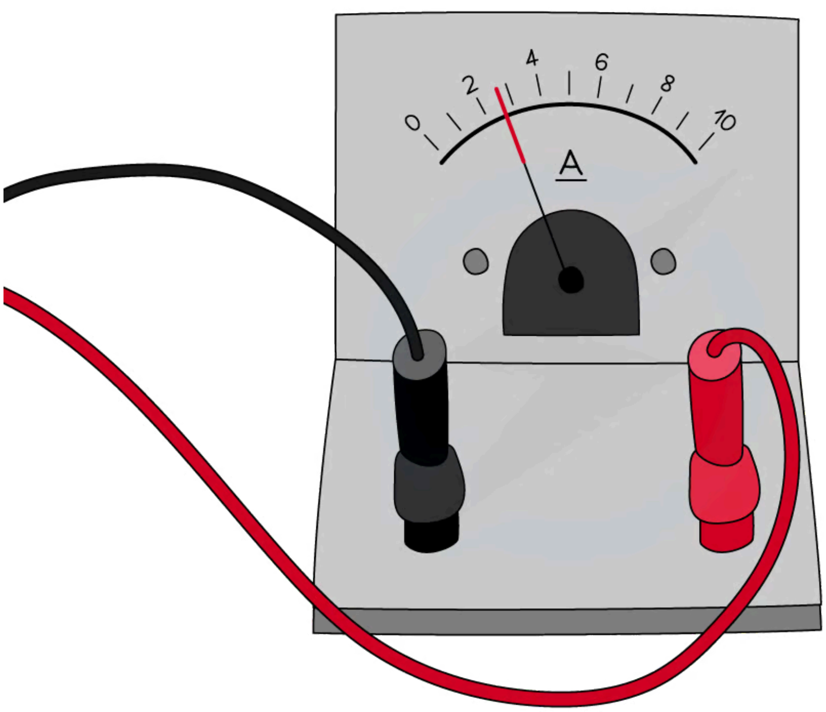
Your notes

Using Appropriate Instruments & Techniques

- Being familiar with how to use a wide range of experimental and practical instruments is essential for both practicals and written exam questions
- Scientific instruments can be **digital** or **analogue**

Analogue

- Analogue scientific instruments transfer information through electric pulses of varying amplitude
  - This means they cannot be read easily by a computer
- Analogue instruments are cheaper but they have lower **accuracy** and **resolution**
- They are also more **sensitive**, which can make it difficult to read fluctuating values
- An analogue display normally involves a pointer which indicates a value depending on its position or angle on the scale



Analogue meter

- The measurements taken on this analogue ammeter are restricted over a range e.g. 0 - 10 A and a resolution of 1 A
- Analogue meters are subject to zero errors
  - This means the marker must be double-checked before each reading. If it is not at zero, then the value but be subtracted from all the measurements
- They are also subject to parallax error
  - Always read the meter from a position directly perpendicular to the scale
- A potentiometer is an example of a sensitive analogue meter

Digital

- Digital scientific instruments translate information into binary (0 or 1) format which can then be read and analysed by a computer
- They are more expensive but have greater accuracy and resolution than analogue
- Digital displays show the measured values as digits
- They're easy to use because they give a specific value and are capable of displaying more precise values

Digital meter

- The measurements taken on this digital ammeter have a much wider range and a resolution of 0.01 A
- Digital meters are also subject to **zero error**
  - Make sure the reading is zero before starting an experiment, or subtract the "zero" value from the end results

- Most digital meters have an auto-range function, this means it can show very low or very high values depending on the readings
    - This saves time selecting an instrument with the correct range and precision for your experiment
- A digital multi-meter is an example of a digital meter

Your notes

Your notes

Analogue Apparatus & Interpolation

Analogue Apparatus

- The type of analogue apparatus needed depends on the measurements to be made:

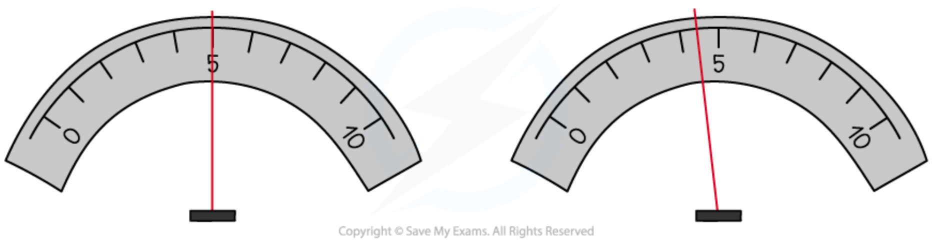
Analogue Apparatus Table

Measurement	Apparatus
Length / Distance	Metre ruler (large distances e.g. length of a wire) Micrometer or vernier calliper (small distances e.g. diameter of a wire)
Temperature	Thermometer Thermistor Thermocouple
Pressure	Pressure guage
Force	Newton meter
Angles	Protractor
Volume	Measuring cylinder Graduated beaker

- A large disadvantage of analogue instruments is **parallax error**
- This occurs when a scale reading is not read directly from the needle, but at an angle, therefore, seeming like a slight difference in reading
  - This can be fixed by a mirror behind the needle. When the needle and its mirror image are aligned, then the reading is correct

Your notes

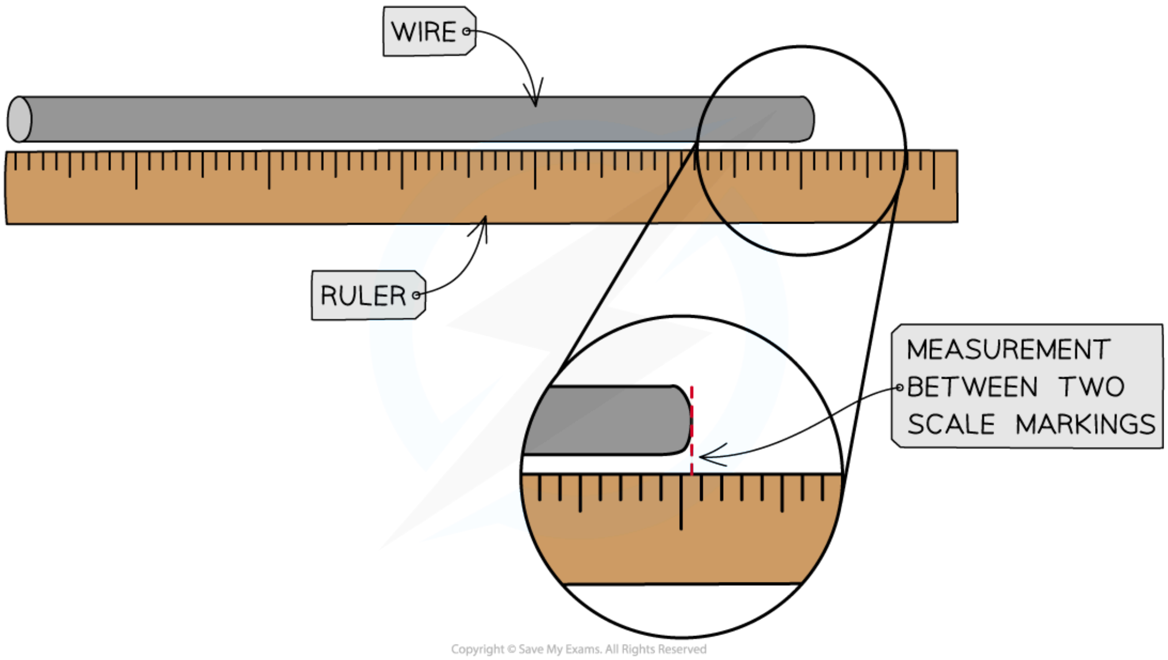
- Parallax error is minimised by reading the value on a scale only when the line of sight is perpendicular to the scale readings (ie. at eye level)
- Examples of where parallax error is common are:
  - Determining the volume of liquid
  - Making sure two objects are aligned
  - Reading the temperature from a thermometer



Reading the value of the needle head-on (left image) looks different to reading it from the right (right image). This is parallax error

Interpolation

- Sometimes a pointer on an analogue meter can fall between two scale markings
  - In which case, **interpolation** between the scale markings is needed
- Interpolation is the processes of estimating unknown values that fall between known values
  - For example, if a straight line passes through two points of known value, the point midway between them can be estimated
- This is why calibration is very important
- For example, a vernier caliper includes the main scale with certain scale markings
  - To then read between these markings, a vernier scale is used for accurate interpolation between the smallest divisions on the main scale
  - This means a reading can be obtained to a greater number of decimal places



The length of the wire falls between two scale markings

Your notes

Use of Digital Instruments

Use of Digital Instruments

- The type of digital instrument needed depends on the measurements to be made:

Digital Instruments Table

Measurement	Apparatus
Time	Digital timer
Current	Digital ammeter or multimeter
Voltage	Digital voltmeter or multimeter
Resistance	Ohmmeter or multimeter
Mass	Top-pan electronic balance

- Note that the top-pan balance doesn't necessarily measure the mass of an object directly, but its weight
  - The mass can then be calculated using the equation $W = mg$ where W is the weight and g is the acceleration due to gravity (9.81 m s^{-2})

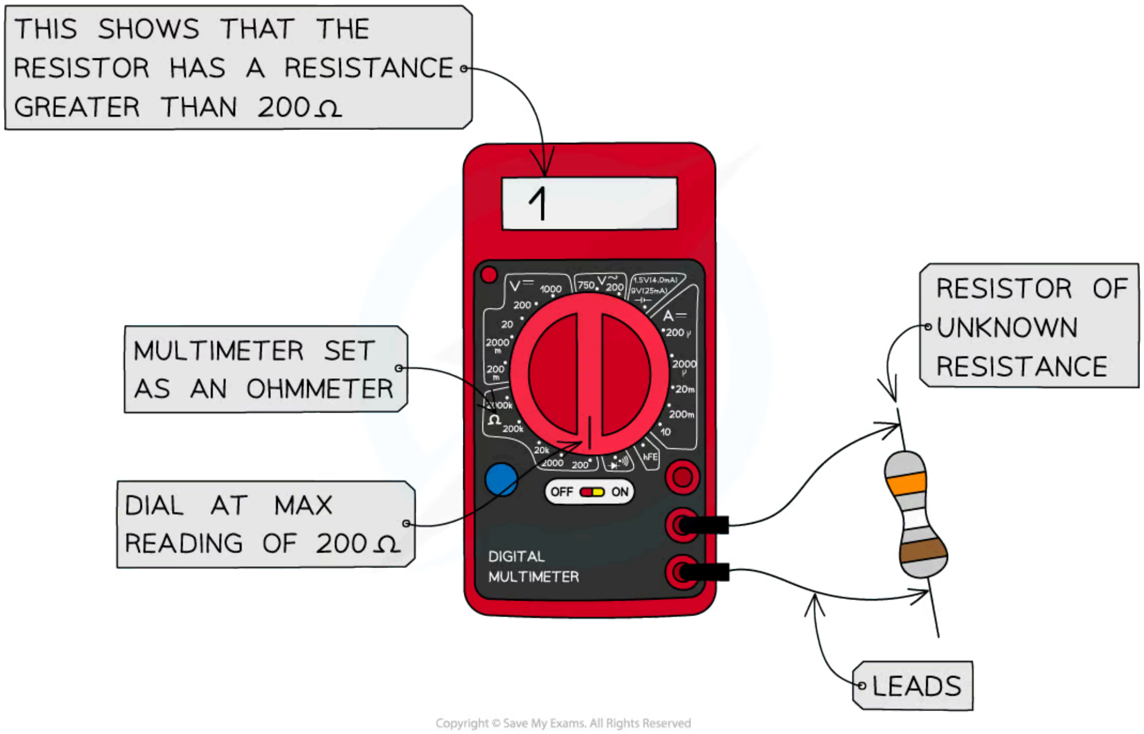
Digital Multimeter

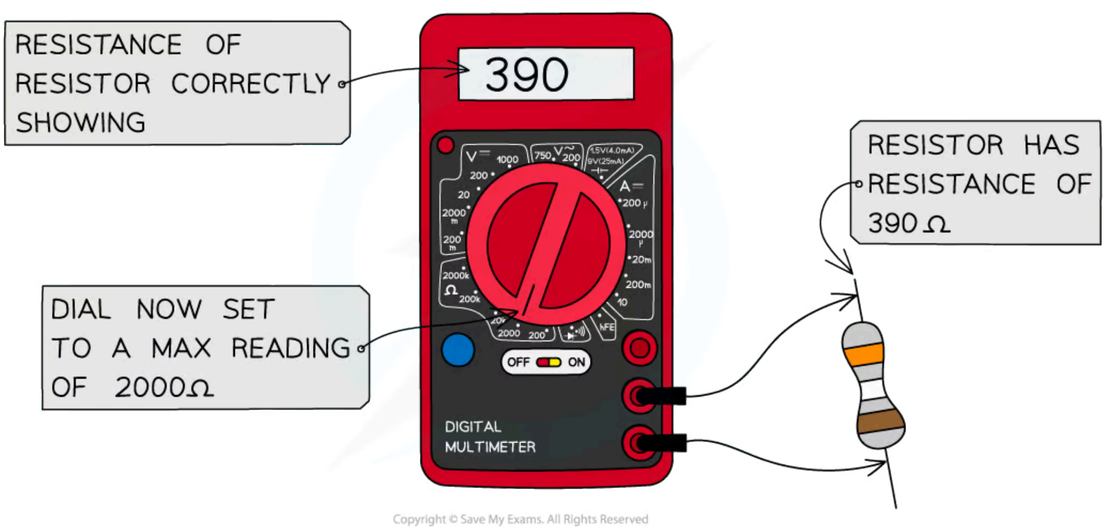
Your notes

A digital multimeter

- A digital multimeter is capable of measuring **voltage**, **current** and **resistance**
  - Therefore, it can be used as a **voltmeter**, **ammeter** or **ohmmeter**
- These are often used because it is very hard to measure very small currents and voltages on standard digital ammeters and voltmeters (especially of the order of mA or μA)
- The advantage of a multimeter is that it can measure a greater **range** of readings from μA to kA (same for volts and Ω)
- This is done by turning a dial in the middle to the appropriate ammeter, voltmeter or ohmmeter setting
  - However, if the dial is set at a small current setting, but a very large current is measured instead, this will blow the fuse in the multimeter and it will have to be replaced
  - Therefore, it is important the correct range of currents or voltages is estimated before setting the dial
- Most of the time, the multimeter will be set to measure a DC voltage
- It is important to remember to turn off the multimeter after use so the battery doesn't run out

Your notes





How to use a multimeter to measure the resistance of a resistor

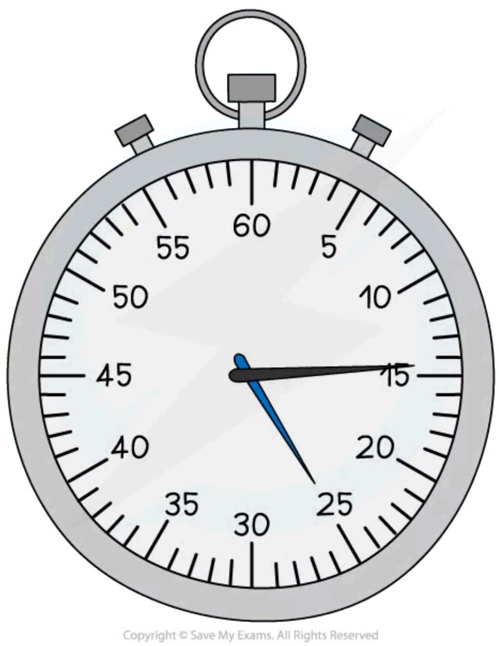
Your notes

Stopwatch & Light Gates

Stopwatch & Light Gates

- A stopwatch or light gates are common physics instruments used for measuring time
  - For example, the time taken for a ball to fall a certain distance

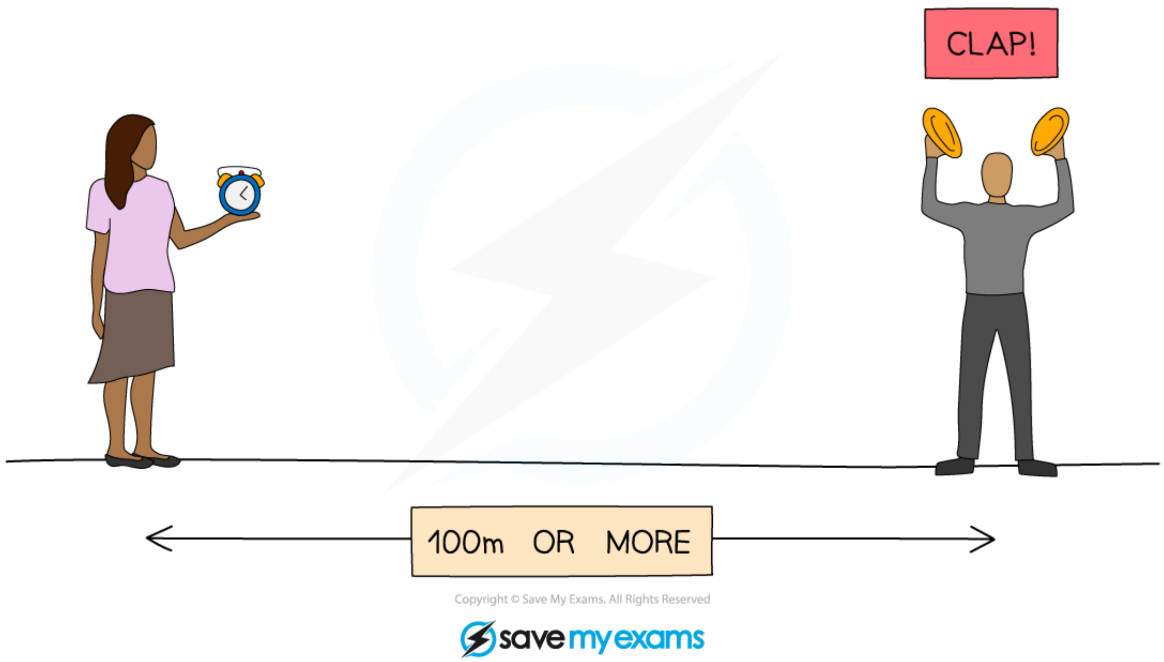
Stopwatch



A stopwatch is used to measure time

- A stopwatch is used to measure the time interval of an event
  - It is a type of watch that is much more precise and accurate, with a resolution of up to **0.01 s**
- A digital stopwatch is often preferred, as laps can also be tracked and the values are easier to read

Your notes



A stopwatch is used to measure the time interval between the clap and when the sound is heard

- The disadvantage of keeping time manually using a stopwatch is there will be a large error in the reading
- This is caused by:
  - Human reaction time (on average, about 0.25 s)
  - The mechanism of the stopwatch (older stopwatches may have a slight delay)
  - Accidentally pressing the start or stop button too many times
  - Consistently starting the stopwatch too late or too early
- Therefore, repeat readings are very important for experiments that require timekeeping

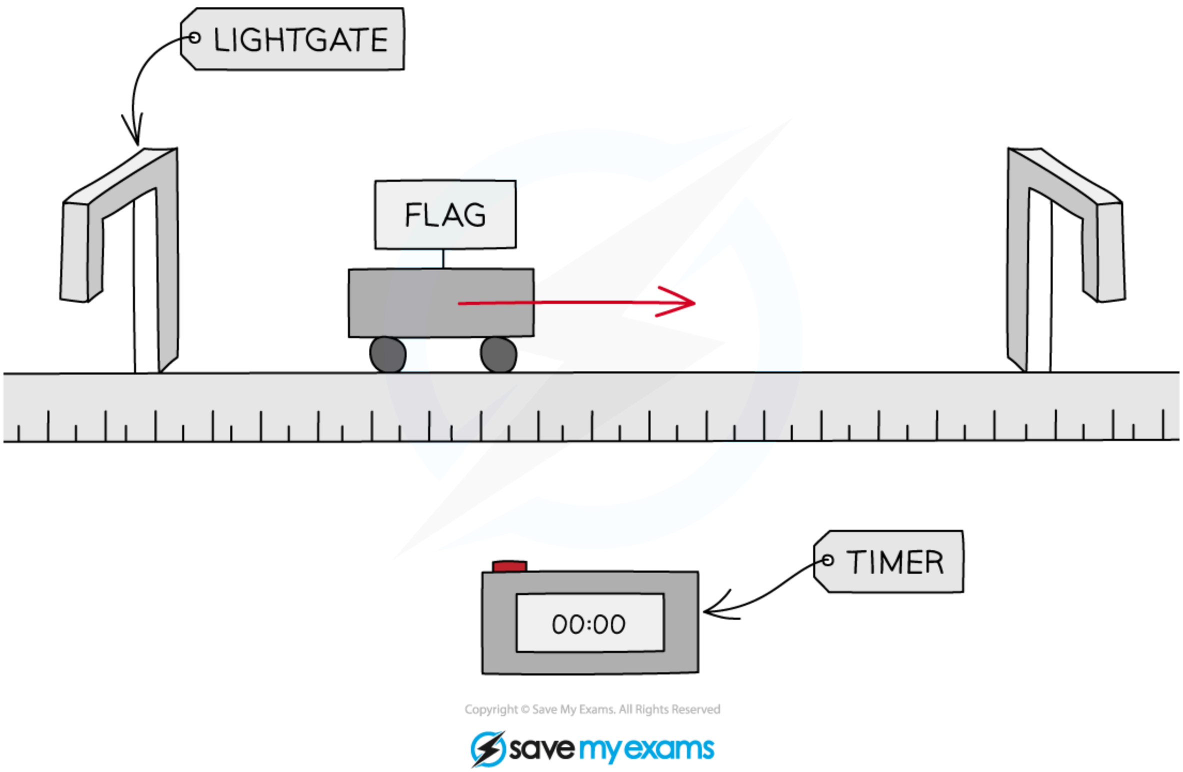
Light Gate

- A light gate is a digital switch-type sensor also used in time experiments
  - They consist of an infrared transmitter and receiver between the 'gate'
  - When this signal is obstructed by an object, a timer can either be started or stopped depending on its configuration

- If the distance between two light gates is known, the time interval between an object passes through both gates can then be used to measure its speed using the equation:

speed = distance ÷ time

- This is assuming the object is not accelerating



The first light gate starts a timer, and the second stops the timer when the flag passes between them. This is used to determine the speed of the object

- A light gate is much more accurate than a stopwatch, as it removes the errors caused by human reaction time
- They can also be connected to a digital timer or datalogger, which then output the time in which the signals are obstructed for data analysis

Examiner Tips and Tricks

Your notes

If a manual or digital stopwatch is unavailable at school during an experiment, it is best to ask your teacher whether you can use the one built-in on your smartphone. However, the experiment is more reliable if everyone uses the same type of device, therefore this often may be discouraged.

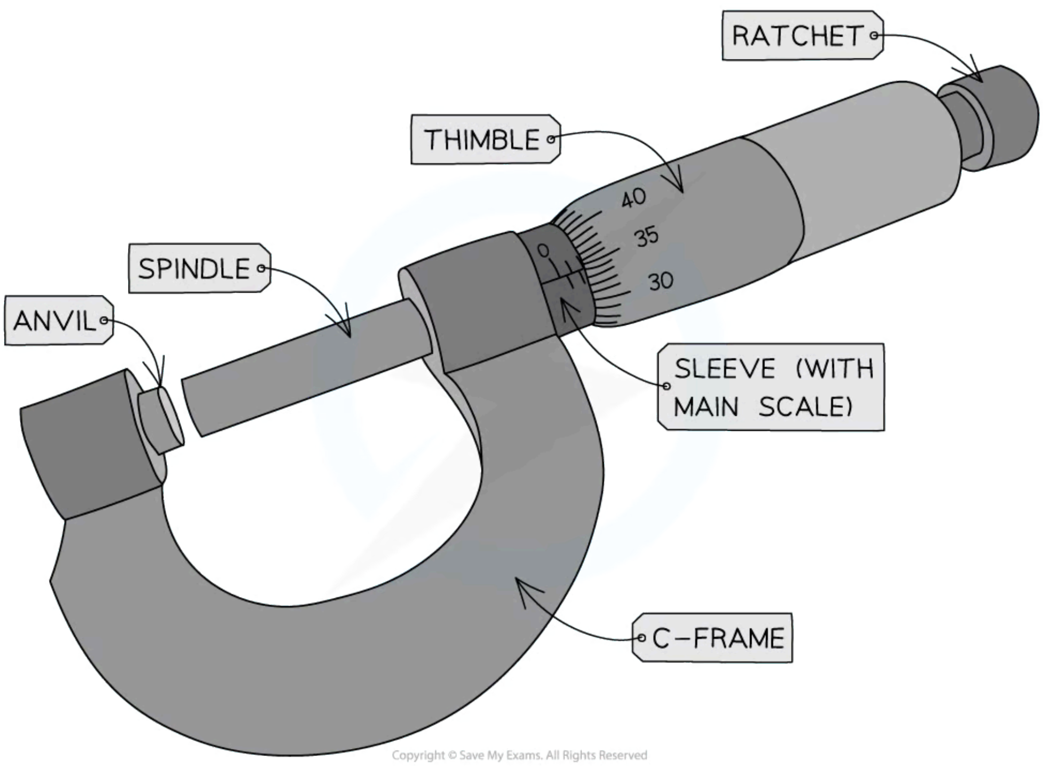
Your notes

Your notes

Calipers, Micrometers & Vernier Scales

Micrometer Screw Gauge

- A micrometer, or a micrometer screw gauge, is a tool used for measuring small widths, thicknesses or diameters
  - For example, the diameter of a copper wire
- It has a resolution of **0.01 mm**
- The micrometer is made up of two scales:
  - The main scale - this is on the sleeve (sometimes called the barrel)
  - The thimble scale - this is a rotating scale on the thimble

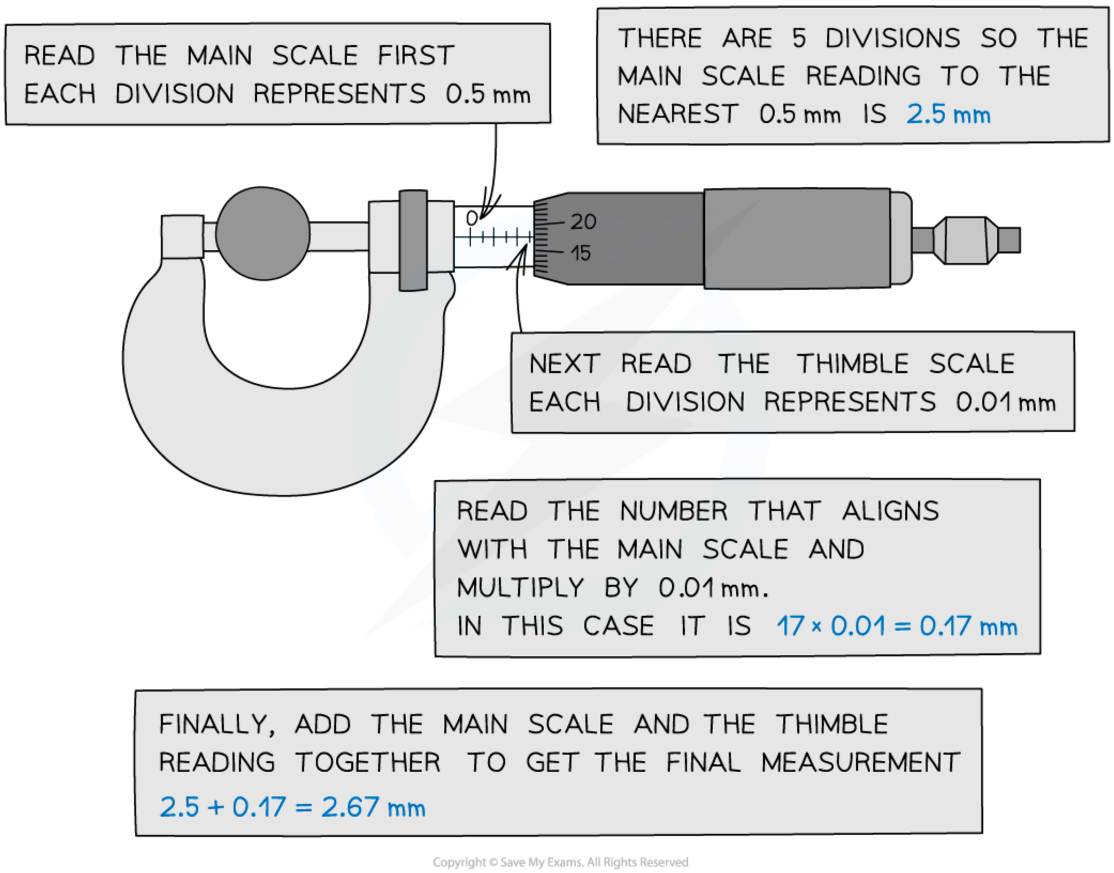


Components of a micrometer

- The spindle and anvil are clamped around the object being measured by rotating the ratchet

Your notes

- This should be tight enough so the object does not fall out but not so tight that is deformed
- **Never** tighten the spindle using the **barrel**, only using the **ratchet**. This will reduce the chances of overtightening and zero errors
- The value measured from the micrometer is read where the thimble scale aligns with the main scale
  - This should always be recorded to 2 decimal places (eg. 1.40 mm not just 1.4 mm)

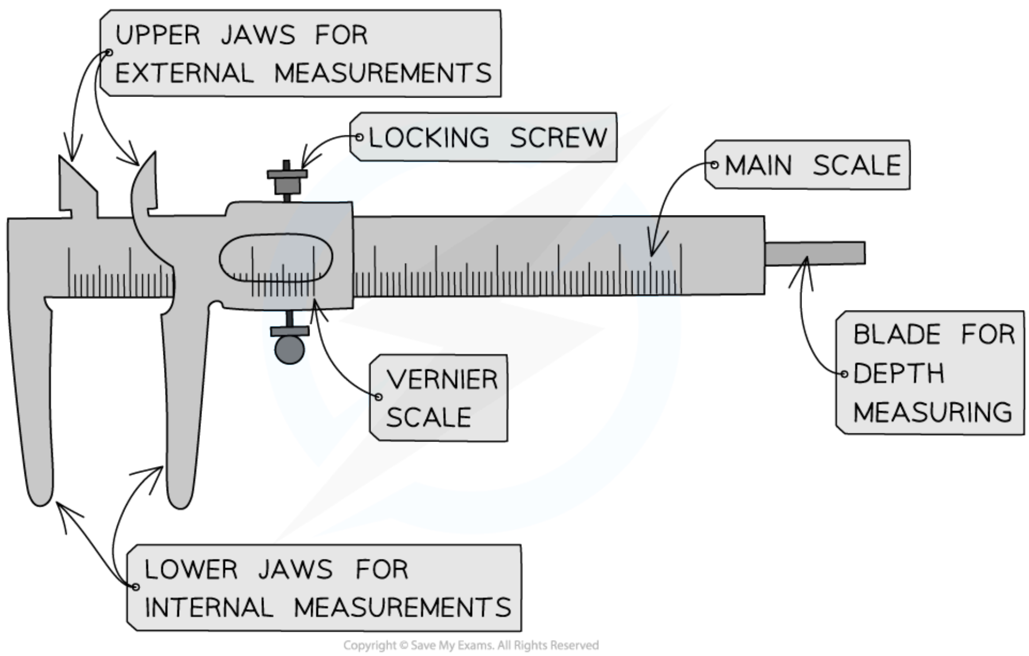


The micrometer reading is read when the thimble scale aligns with the main scale

Vernier Calipers

- Vernier calipers are another distance measuring tool that uses a sliding vernier scale
  - They can also be used to measure diameters and thicknesses, just like the micrometer
  - However, they can also measure the length of small objects such as a screw or the depth of a hole
- Vernier calipers generally have a resolution of **0.1 mm**, however, some are as small as 0.02 mm - 0.05 mm

- The calipers are made up of two scales:
    - The main scale
    - The vernier scale
- The two upper or lower jaws are clamped around the object
    - The sliding vernier scale will follow this and can be held in place using the locking screw

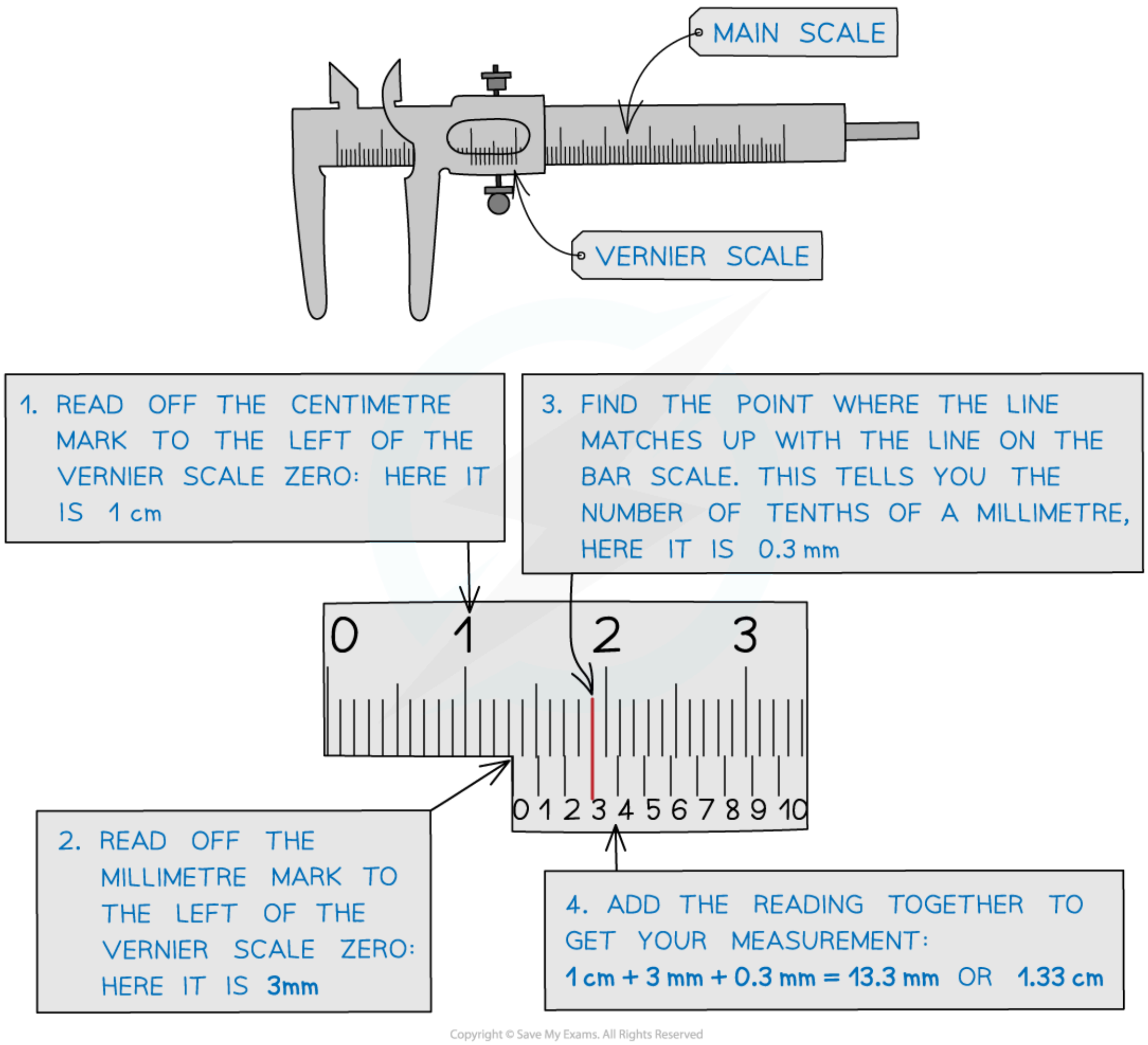


Components of a vernier caliper

- The value read from the caliper when the vernier scale aligns with the main scale
    - This should always be recorded to at least 1 decimal place (eg. 12.1 mm not just 12 mm)

Your notes

Your notes



The vernier caliper reading is read when the vernier scale aligns with the main scale

- In general, the micrometer has a smaller measuring range than a vernier caliper
- However, the micrometer has a better accuracy (due to better resolution)
- The vernier caliper is quicker to use, whilst the micrometer involves rotating the thimble
  - Therefore, to take many measurements, a caliper would be easier to use

Your notes

Examiner Tips and Tricks

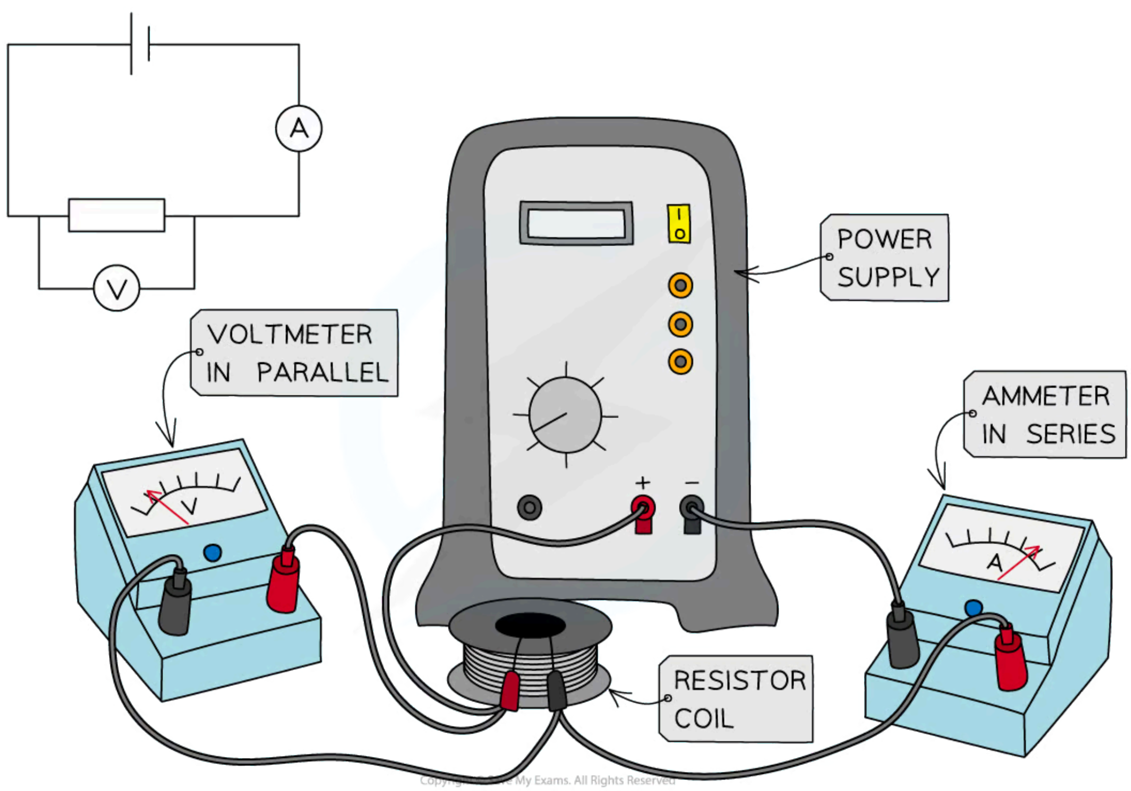
Make sure you're comfortable with reading from a micrometer or vernier caliper scale. This will be expected not just in your practical endorsement, but also in written practical questions.

Your notes

Circuits

Constructing Circuits

- Constructing, designing and checking circuits are an essential practical skill in physics
- There are some important points to consider with all circuits:
  - If the current is to be measured, an **ammeter** must be connected in series
  - If the potential difference is to be measured, a **voltmeter** must be connected in parallel to the required component
  - If the current is to change between two paths (eg. charging and discharging a capacitor) a **switch** must be present
  - A diode must always be facing the direction of the current flow
  - Make sure each component is able to handle the amount of current in the circuit. Otherwise, they could fuse, be damaged, or spark

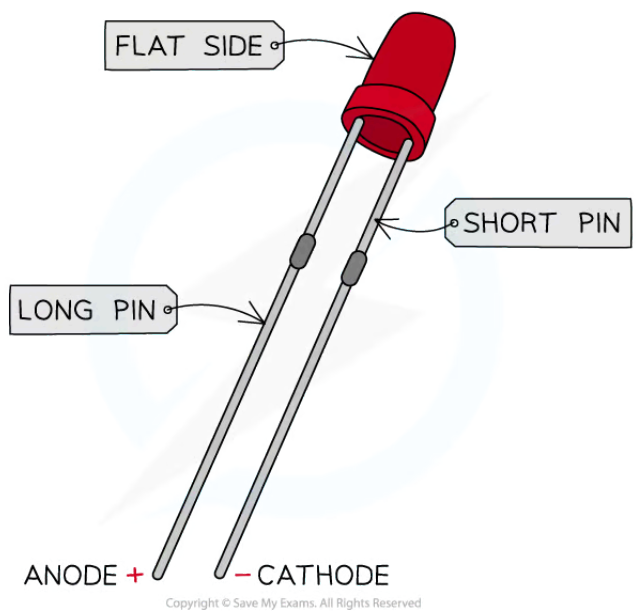


Circut with corresponding circuit diagram

Your notes

Polarity

- The polarity of an electrical component means that it will function differently depending on the direction in which it is connected
  - In other words, a non-polarised components, such as a lamp can be connected in any direction it will still light up
- A polarised component can only be connected in a circuit in one direction
  - If not, it will either not work, work incorrectly or break
- Common polarised electrical components include:
  - Cell / batteries / any power supply
  - Diodes
  - LEDs (light-emitting diodes)
  - Electrolytic capacitors
- The positive and negative terminal on a battery is normally clearly marked
  - If not, the negative side has a larger metal area
- LEDs, and diodes consist of two pins or 'legs'
  - The longer leg is the **positive** (anode) pin
  - The shorter leg is the **negative** (cathode) pin
- The polarity can sometimes be checked by multimeters and leads connected to the appropriate pins



Polarity of an LED is shown by the longer or shorter pin

Your notes

Examiner Tips and Tricks

Remember to always keep the number of wires, leads and crocodile clips to a minimum. Otherwise it can become confusing as to which component is connected to which in a practical experiment

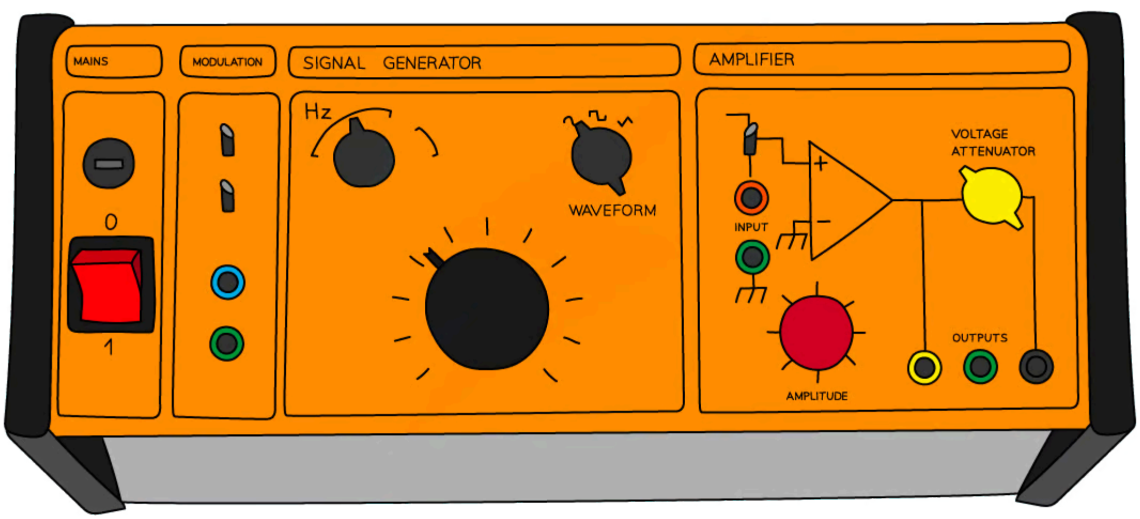
Your notes

Signal Generators & Oscilloscope

Signal Generators & Oscilloscope

Signal Generator

- A signal generator is an electronic test instrument used to create repeating or non-repeating waveforms
  - They can be adjusted for different shapes and amplitudes
- These are often used for designing and repairing electronic devices, to check they are working as expected
- Signal generators are used to create signals to then show on oscilloscopes

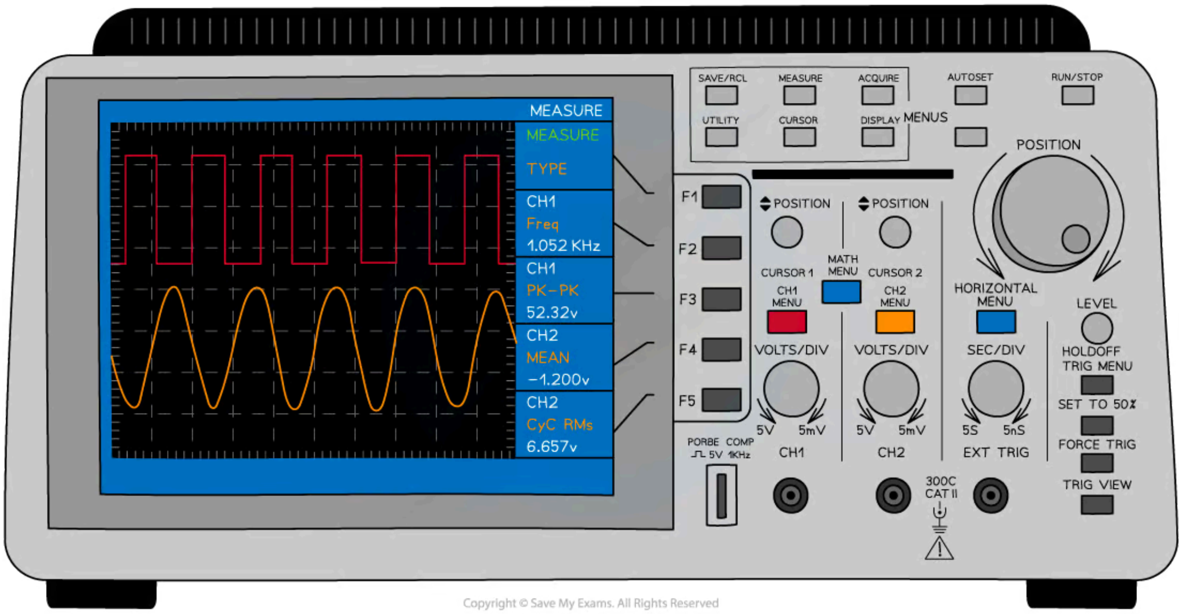


A signal generator can be used to create signals for a CRO

Cathode-Ray Oscilloscope

- A Cathode-Ray Oscilloscope (CRO) is a laboratory instrument used to display, measure and analyse waveforms of electrical circuits
  - It can therefore be used as an a.c and d.c voltmeter

Your notes



A cathode-ray oscilloscope displays the signal generated by the signal generator

- An **a.c** voltage on an oscilloscope is represented as a **transverse wave**
  - Therefore you can determine its frequency, time period and peak voltage
- A **d.c** voltage on an oscilloscope is represented as a **horizontal line** at the relevant voltage
- The x-axis is the **time** and the y-axis is the **voltage (**or **y-gain)**

Your notes

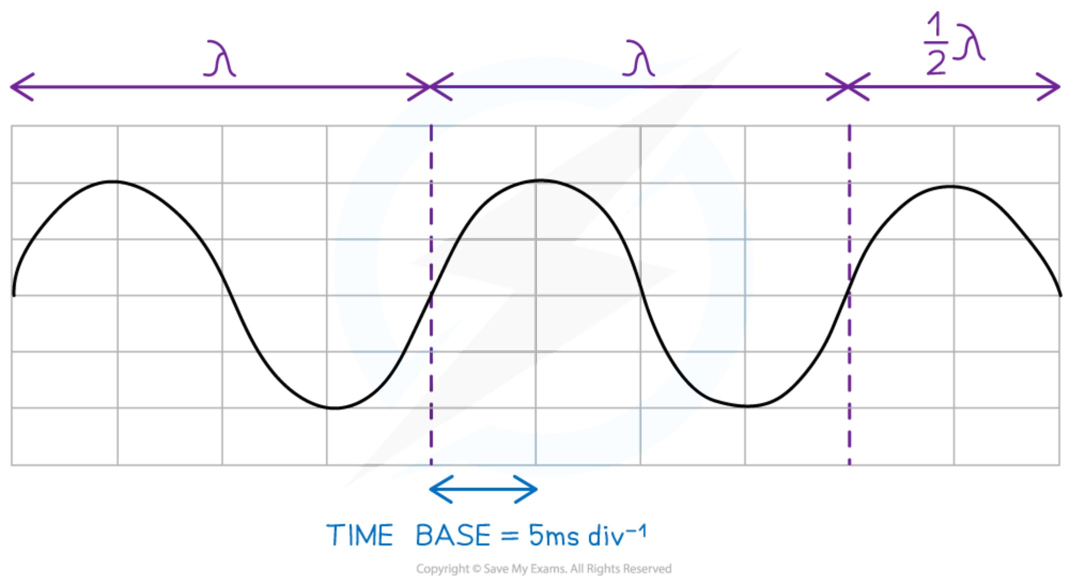


Diagram of Cathode-Ray Oscilloscope display showing wavelength and time-base setting

- The period of the wave can be determined from the **time-base**
  - This is **how many seconds each division represents** measured commonly in **s div^{-1}** or **s cm^{-}**

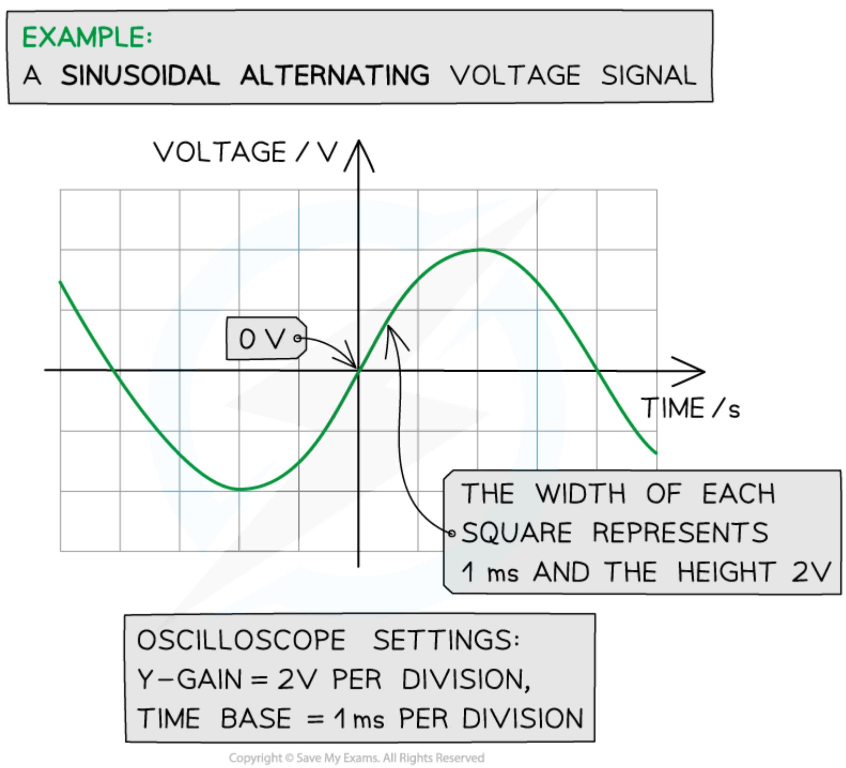
C.R.O Controls for an A.C waveform

- Time-base
  - When the time-base is switched off, only a vertical line on the voltage-gain axis is seen with its relevant amplitude
  - When the time-base is switched on, a wave will appear across the whole screen and the time period can be measured
  - This control has units of time cm^{-1} or time div^{-1} and has a range of 100 ms – 1 μs per cm, or division
- Voltage-gain (sensitivity)
  - This controls the vertical deflection, or amplitude, of the wave
  - The **peak voltage** (V_0) is the maximum vertical displacement measured from the time axis
  - The **peak-to-peak voltage** is the vertical displacement between the minimum and maximum values of voltage
  - When the voltage-gain is switched off, only a horizontal line on the time axis will be seen

- This control has units of volts cm^{-1} or volts div^{-1}

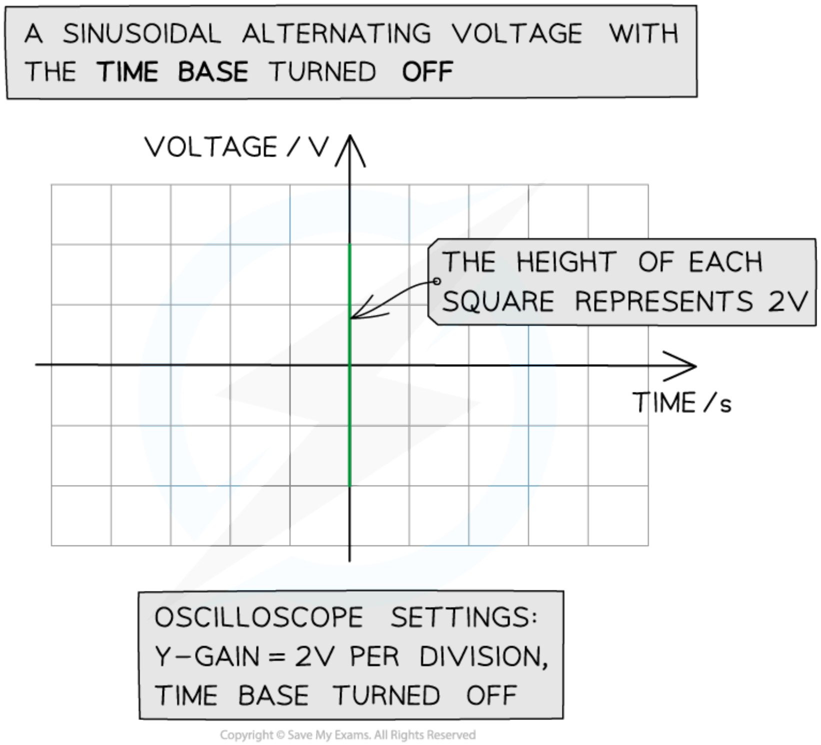
C.R.O Controls for a D.C waveform

- For a d.c waveform, only a horizontal line is displayed at the relevant voltage
  - The time-base settings are irrelevant since there is no time period
  - The voltage-gain setting **is** relevant since this is used to read the value of the d.c voltage



Your notes

Your notes


A SINUSOIDAL ALTERNATING VOLTAGE WITH THE TIME BASE TURNED OFF
VOLTAGE / V
THE HEIGHT OF EACH SQUARE REPRESENTS 2V
TIME / s
OSCILLOSCOPE SETTINGS:
Y−GAIN = 2V PER DIVISION,
TIME BASE TURNED OFF
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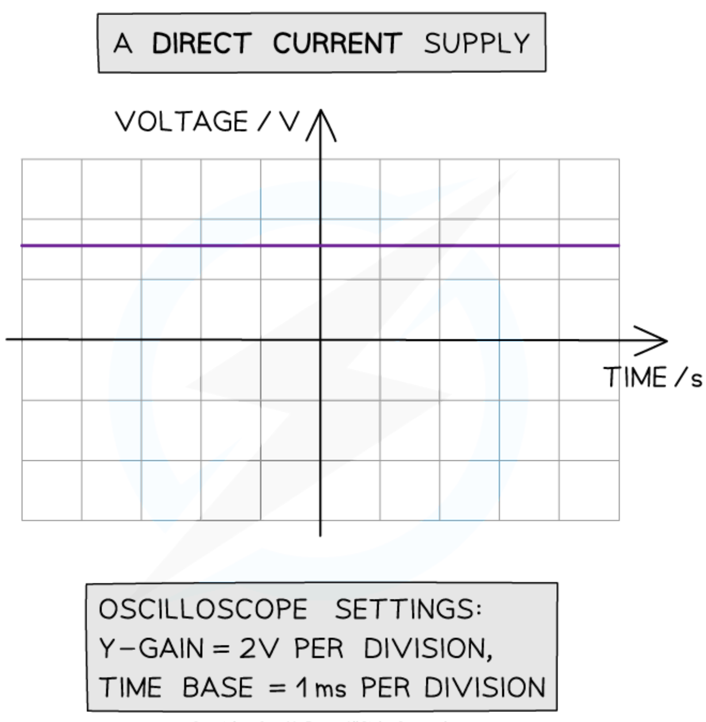
A DIRECT CURRENT SUPPLY
VOLTAGE / V
TIME / s
OSCILLOSCOPE SETTINGS:
Y−GAIN = 2V PER DIVISION,
TIME BASE = 1 ms PER DIVISION
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Examples of an alternating and direct voltage on a CRO with and without the time base

Your notes

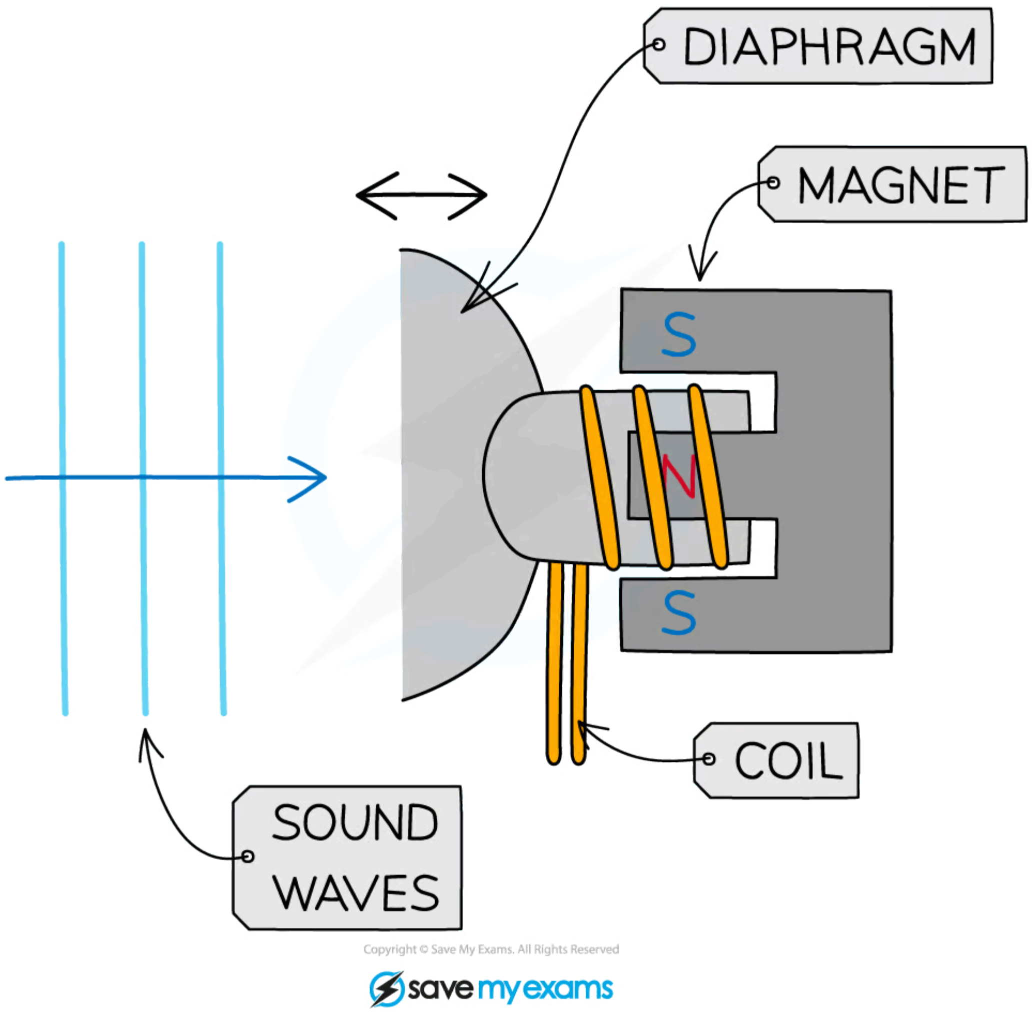
Generating & Measuring Waves

- Waves can be generated and measured using:
  - A microphone and loudspeaker
  - A ripple tank
  - A vibration transducer
  - A microwave / radio wave source

Microphone and Loudspeaker

- A microphone and loudspeaker can be used to create **sound waves**
- Microphones turn sound into electrical signals

Your notes

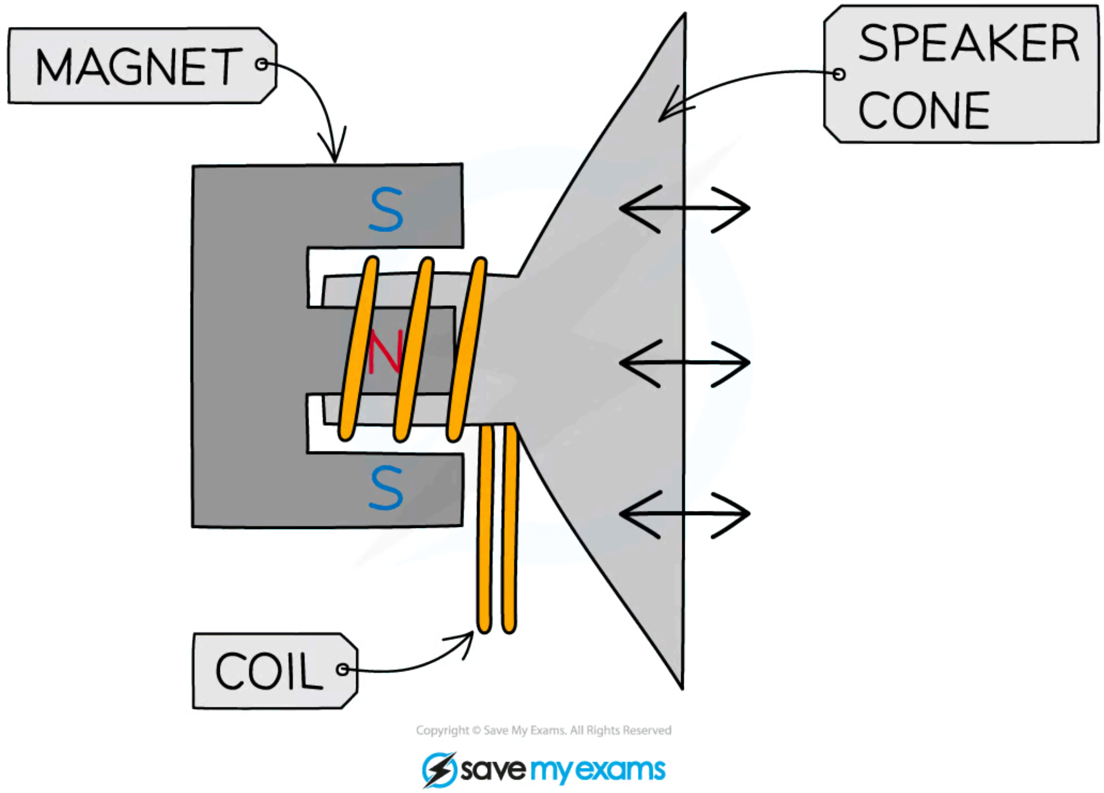


Sound waves entering a microphone

- When sound waves reach the microphone, for example, generated by a person's voice, the pressure variations cause the diaphragm to vibrate
- This in turn causes the coil to move back and forth, through the magnetic field
- The coil, therefore, cuts through the magnetic field lines, inducing an alternating e.m.f in the coil

- Loudspeakers turn electrical signals into sound

Your notes



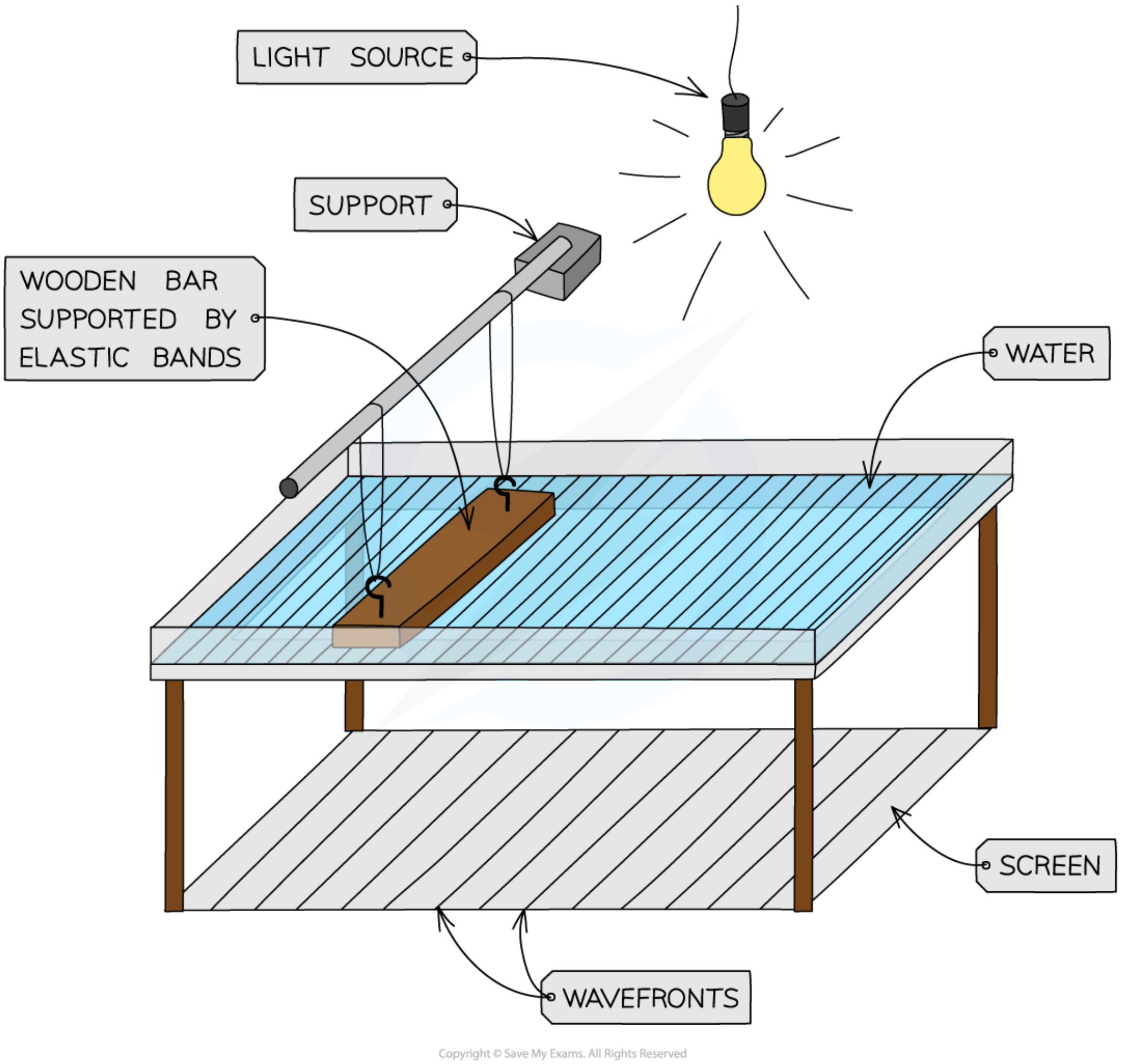
Cross-section of a loudspeaker

- An alternating current pass through the coils of the loudspeaker, which then creates a changing field around the coil
- This changing field interacts with the field from the permanent magnet, exerting a force on the coil
- This makes the coil and the speaker cone oscillate, making the air particles oscillate and therefore creating sound waves

Ripple Tank

- Ripple tanks are used to create **water waves**

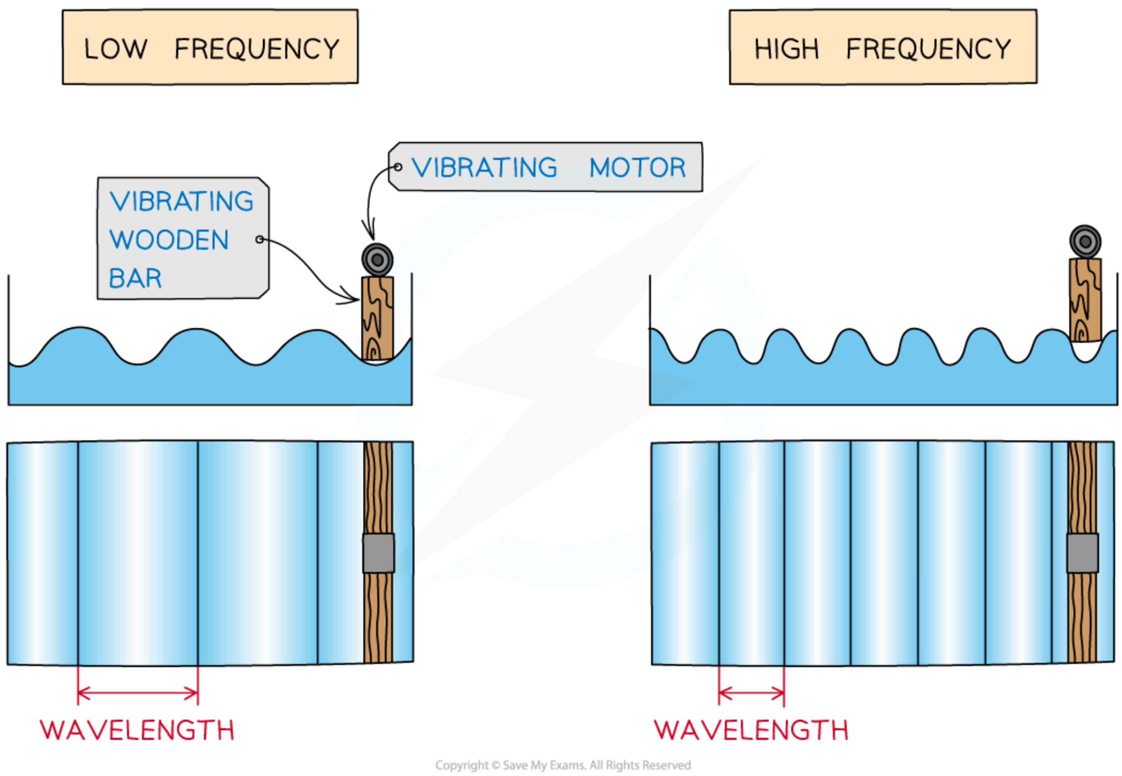
Your notes



Ripple tank creating wavefront seen on a screen

- In a ripple tank, a motorised wooden straight-edged bar produces plane (straight) waves while a small dipper produces circular waves
- When a light is shone from above, the bright bands seen on the screen below the tank show the wave crests (wavefronts)
- The diagram below shows how the wavelengths differ with frequency in a ripple tank
  - The **higher** the frequency, the **shorter** the wavelength
  - The **lower** the frequency, the **longer** the wavelength

Your notes

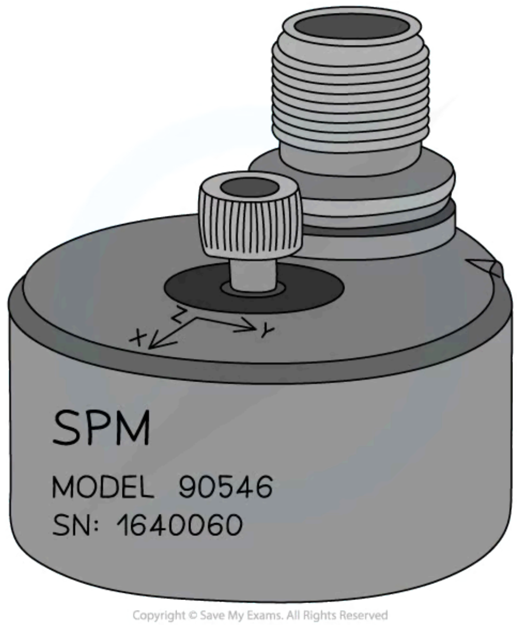


Ripple tank patterns for low and high frequency vibrations

Vibration Transducer

- Vibration transducers can detect vibrations in machines and transform them into a signal
  - These signals are then sent to a digital indicator to test machines
- These are particularly useful in industry to see how machines behave under vibrations before any damage can occur

Your notes

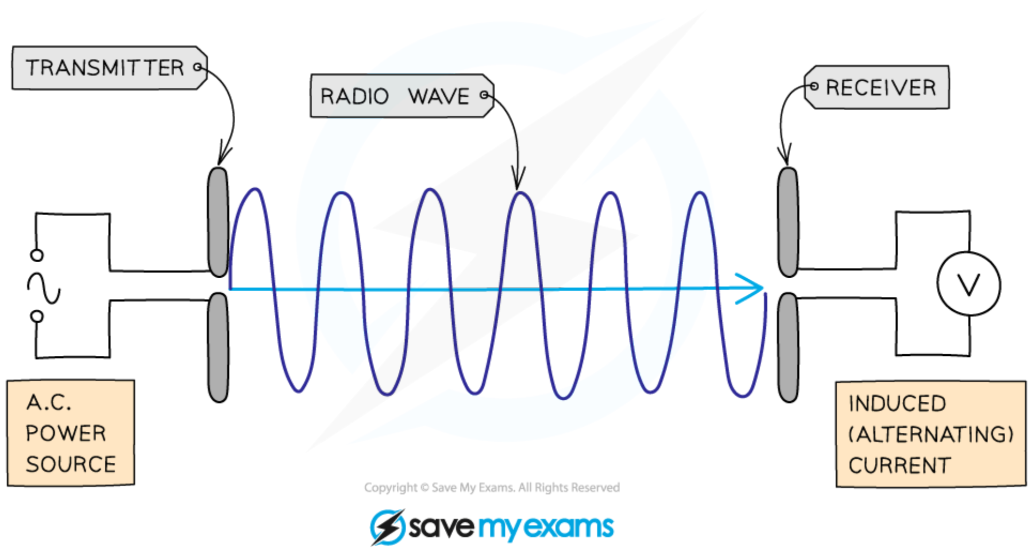


A vibration transducer

Microwave / Radio Source

- A microwave or radio source produces microwaves or radio waves to be used for diffraction and interference experiments
- Radio waves can be produced by connecting an antenna to a high frequency alternating current power source

Your notes



Radio waves are produced by high-frequency alternating currents and induce similar currents when they are received

- The charge, oscillating up and down the antenna, produces radio waves that can be absorbed by similar antennae some distance away
- When absorbed, the radio waves induce a similar alternating current in the receiving antenna, which can then be detected

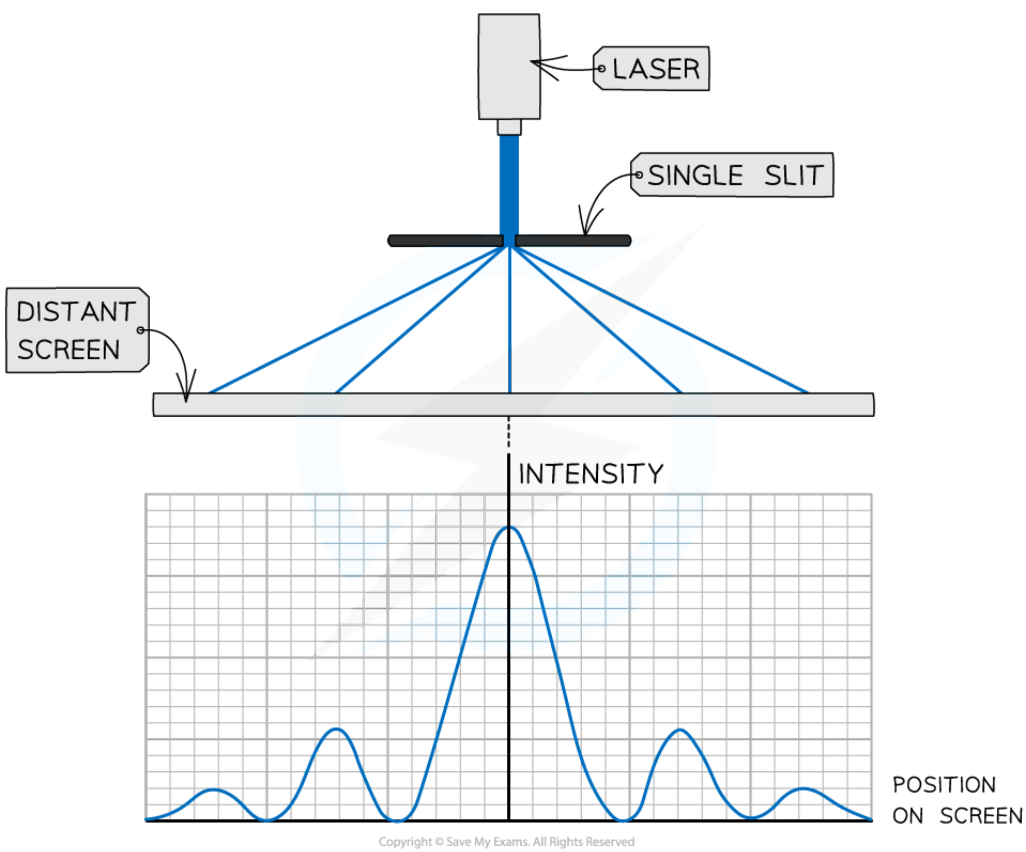
- A microwave source could be produced by artificial devices such as:
  - Circuits
  - Masers (microwave lasers)
  - Microwave ovens
  - Microwave signal generators
- Or, from natural sources such as the Sun or atoms and molecules

Your notes

Using a Laser or Light Source

Using a Laser or Light Source

- A laser or light source is used to investigate characteristics of light such as **interference** and **diffraction**
- A laser is preferred to a lamp since they produce coherent, monochromatic light
  - This produces a sharper and brighter interference pattern
- The contrast between the bright and dark fringes is much easier to see in laser light, compared to a lamp with a low intensity that emits light of all wavelengths
- In experiments such as Young's double-slit experiment, it is important to be able to see the fringes clearly to determine the fringe width
  - If these were not clear, there will be a large error in the measurement of the fringe widths

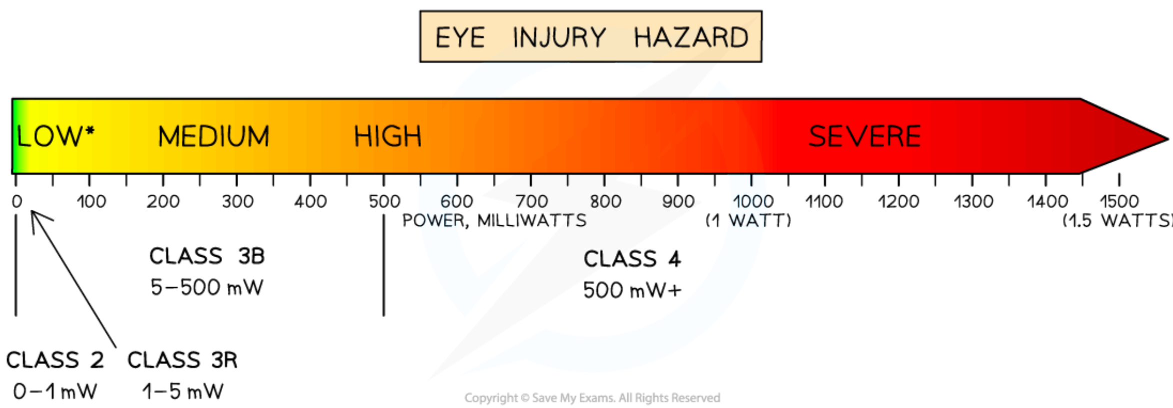


Single slit diffraction of a laser producing an interference pattern on the screen

Your notes

Safety Issues with Lasers

- Lasers produce a very high energy beam of light
- This intense beam can cause **permanent eye damage** or even blindness
- In schools, only class 2 lasers are allowed - these are lasers with a power output of less than 1 mW
  - However, more powerful lasers can reach outputs of more than 500 mW
  - These are known as class 4 lasers. They are so powerful they can make a person instantly blind and can even damage the skin



The four classes of laser: In a school laboratory, only Class 2 lasers may be used

Precautions with Lasers

- It's important to use lasers safely and follow the guidelines in all practicals:
  - **Never** look directly at a laser or its reflection
  - Don't shine the laser towards a person
  - Don't allow a laser beam to reflect from shiny surfaces into someone else's eyes
  - Wear laser safety goggles
  - Place a 'laser on' warning light outside the room
  - Stand behind the laser

Your notes

Placing a laser warning sign outside of the door is one precaution that can be taken when using lasers

Computer Modelling & Data Logger

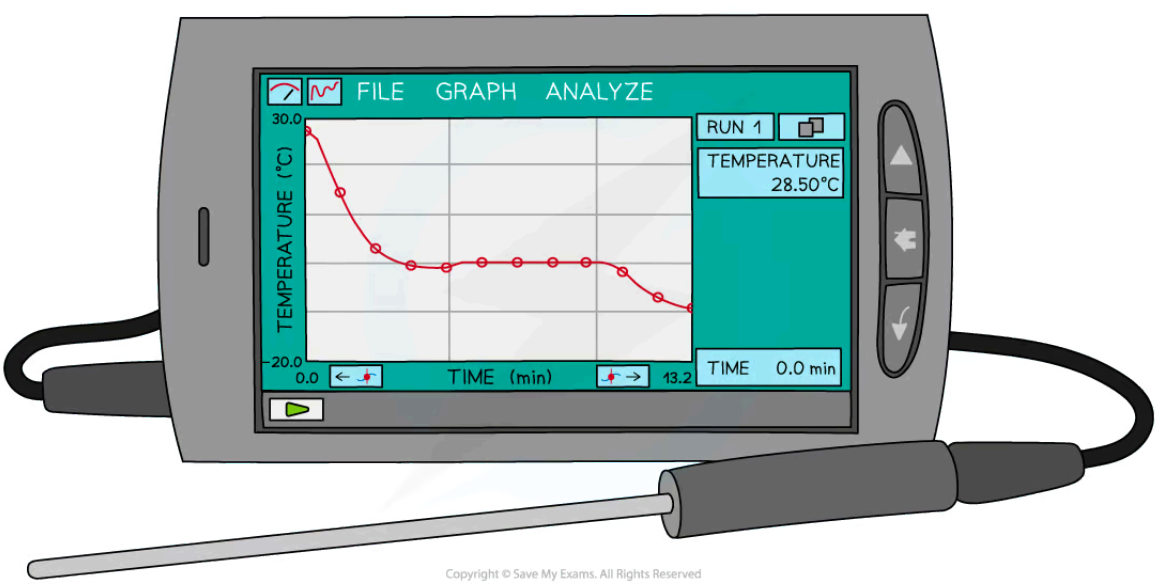
Your notes

Computer Modelling & Data Logger

- Computing modelling and using a data logger are essential in all scientific experiments for obtaining and analysing reliable results

Data Loggers

- Data loggers are a tool that allows for the **quick and efficient gathering of data**
  - The information contained within a data logger can be inputted into a computer and formatted into a **table**
  - After this is done the computer is able to calculate the **average** and **plot graphs** using the data and calculate gradients which quicker and more accurately than humans
- They are electronic devices that automatically monitor and record environmental parameters over time such as temperature, pressure, voltage or current
  - It contains multiple sensors to receive the information and a computer chip to store it



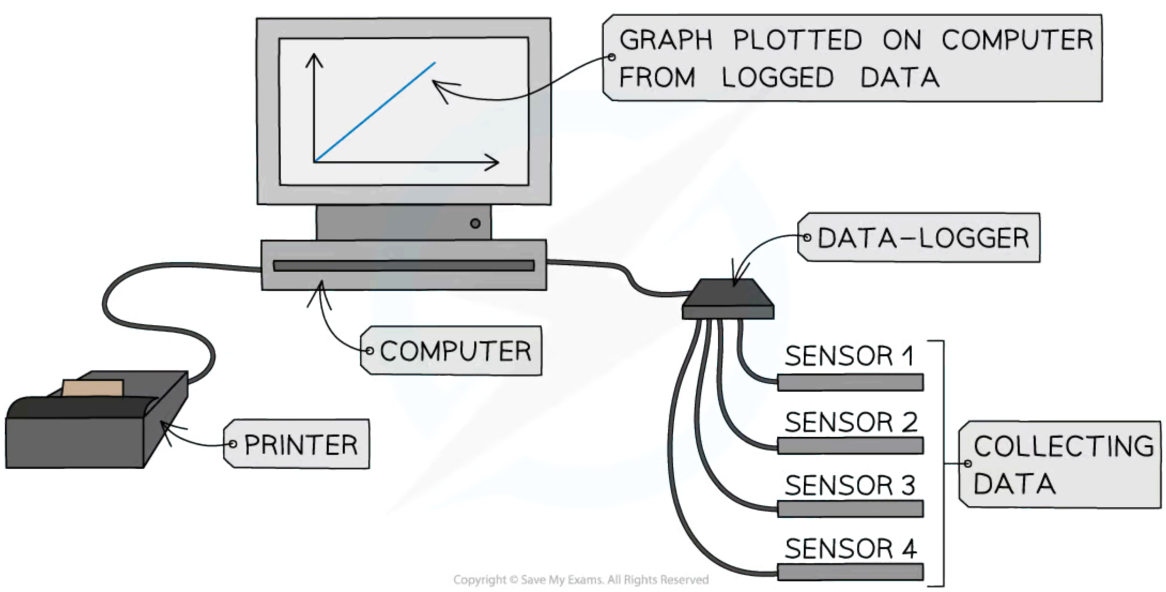
A data logger measuring and displaying temperature using a probe

- The benefits of using data loggers and ICT (information and communication technology) include:
  - Readings are taken with **higher** degrees of **accuracy**

- Reduction of **human error** (eg. human reaction times, subjectiveness)
- Readings can be taken over a **long period of time** eg. hourly readings of temperature over many days
- Readings can be taken in a **very short period of time**, which would be too quick for humans to see a difference
- Reduction in safety risks with **extreme conditions** such as measuring the temperature of boiling water

Computer Modelling

- Computer modelling is commonly done in conjunction with devices such as a data logger
  - Modelling is about processing the data collected from a physics experiment into software or a spreadsheet
- Graphs and charts can be generated from a table of values
  - These can then be exported to a scientific report
- One of the benefits of these computer programs is that **time** can be **sped up to predict the future outcome** of an experiment



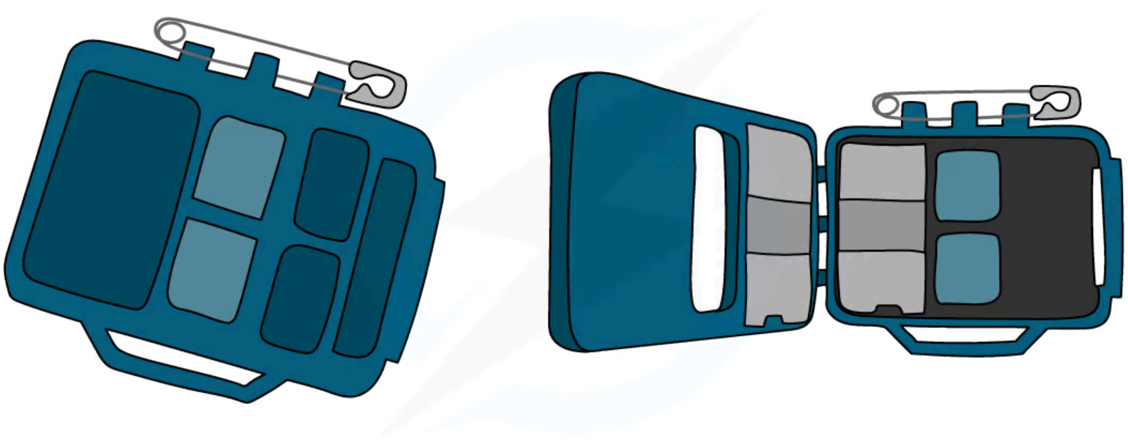
Computer modelling uses a computer and sensors to analyse and display data

Ionising Radiation & Detectors

Your notes

Ionising Radiation & Detectors

- Ionising radiation include alpha, beta and high-energy electromagnetic radiation such as X-rays, gamma rays and UV
- They are used in smoke detectors and in many medical applications, such as:
  - Disinfecting medical instruments
  - X-rays
  - Radiotherapy
  - CT scans
- These normally use X-rays, gamma rays or radioactive tracers
- In those areas of industry and medicine, where people are routinely working with ionising radiations, various safety procedures are put in place
- Workers are routinely monitored to check the levels of radiation that they are exposed to and strict limits are placed on what they can receive



A badge containing photographic film can be used to monitor a person's exposure to radiation

Your notes

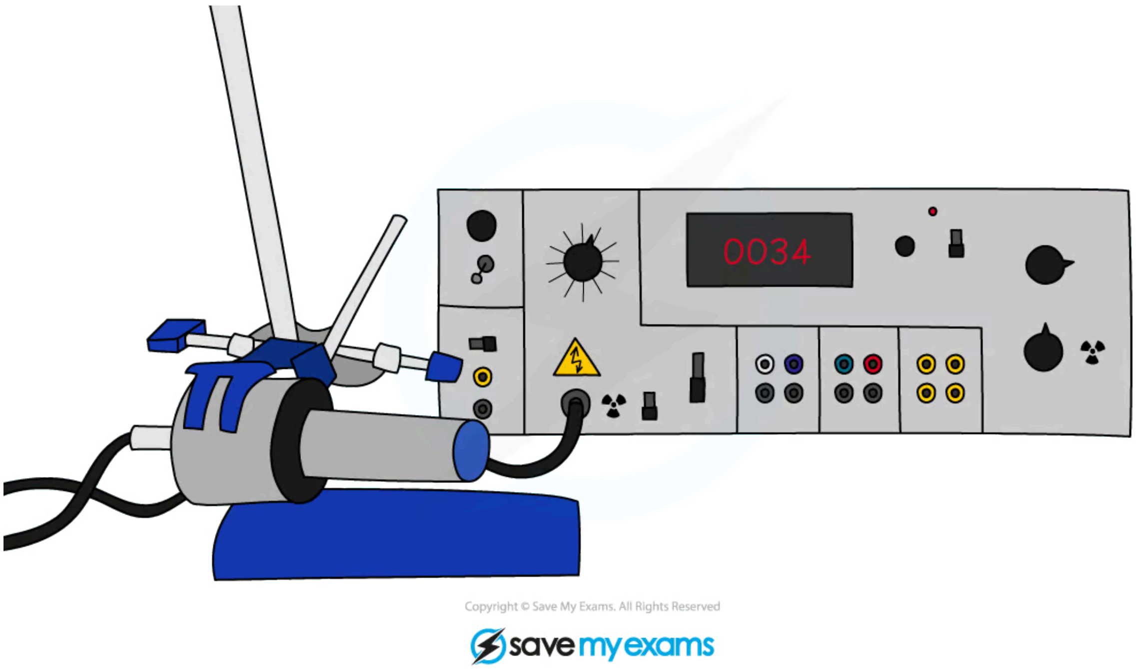
- Limits are often placed on the amount of time that workers can spend using radioactive materials.
- Where feasible, barriers will be placed between the worker and the source in order to absorb the radiation
  - Doctors, for example, will leave the room whilst carrying out certain procedures (including x-rays) in order to minimise exposure.
- Areas or containers that pose a radiation hazard should have the appropriate radiation hazard symbol

Radiation hazard symbol

- The universal radiation symbol is important, so people that speak any language can still understand its meaning

Radiation Detectors

- Radiation can be detected by a Geiger-Müller tube, or a geiger counter
- Geiger-Müller tubes are simple devices that detect the presence of the ions created by radiation entering the tube
- Connecting the tube to a counter allows the amount of radiation to be determined



A Geiger-Muller tube (or Geiger counter) is a common type of radiation detector

- The amount of radiation given off by an isotope each second is known as its activity and is measured in becquerels (Bq)
- An activity of one becquerel means that there is one decay per second