TOPICS COVERED

SCIENTIFC INVESTIGATION

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- STANDARD FORM (SCIENTIFIC NOTATION)
- PREFIXES FOR UNITD
- MEASUREMENT OF LENGTH
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- MEASUREMENT OF VOLUME
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SCIENTIFIC INVESTIGATION AND SKILLS

UNIT ONE

MEASUREMENTS

Fundamental Quantities

- Are quantities which are not defined in terms of other quantities.
- Are also called basic quantities.

Ser. No.	Examples of quantities	SI Unit	Symbol
1	Length	Metre	M
2	Mass	Kilogram	Kg
3	Time	Second	S
4	Thermodynamic temperature	Kelvin	K
5	Electric current	Ampere	A
6	Luminous Intensity	Candela	Cd
7	Amount of substance	Mole	mol.

Derived Quantities

- Are quantities which are expressed in terms of the fundamental quantities.

Ser. No.	Examples of quantities	SI Unit	Symbol	Base Unit
1	Moment	Newtonmetre	Nm	Kgm^2/s^2
2	Work	Joule	J	Kgm^2/s^2
3	Energy	Joule	J	Kgm^2/s^2
4	Power	Watt	W	Kgm^2/s^3
5	Pressure	Pascle	Pa	Kgm^2/s^3

6	Charge	Coulomb	C	As
7	Current	Ampere	A	C/s

Standard Notation (Scientific Notation)

- Is the simplest way of writing quantities where all quantities have a single whole number and others are expressed decimal fractions.

Example

- Express 0.000000001 in standard notation.

  1. Shift the decimal point to the right so that there is only one whole number.

  2. Multiply the number by 10 raised to the power equivalent to the number of shifts to
  the right.

  3. Since the decimal is shifting to the right, the power should become a negative one.

  0.000,000,001 = 1.00 x 10^{-9}

- Express 1,000,000,000 in standard notation.

  Do steps 1 to 3 but now to the left.

  1,000,000,000 = 1.00 x 10^{9}

Prefixes and SI units

- These are symbols used to describe a certain unit of quantity.

Prefix	symbol	Magnitude
atto	A	10^{-18}
femto	£	10^{-15}
pico	P	10^{-12}

nano	ɿ	10^{-9}
micro	U	10^{-6}
mill	M	10^{-3}
centi	C	10^{-2}
deci	D	10^{-1}
deca	Da	10^{1}
hecto	H	10^{2}
kilo	K	10^{3}
Mega	M	10^{6}
Giga	G	10^{9}
Tera	T	10^{12}
Peta	P	10^{15}
Exa	E	10^{18}

Measurement of length

- Is measured in metres (m).
- Measured using tape measure, metre rule, etc.
- The above instruments only measure large length.
- Very small length is measured using
  - ➢ Vernier calliper
  - ➢ Micrometer screw gauge

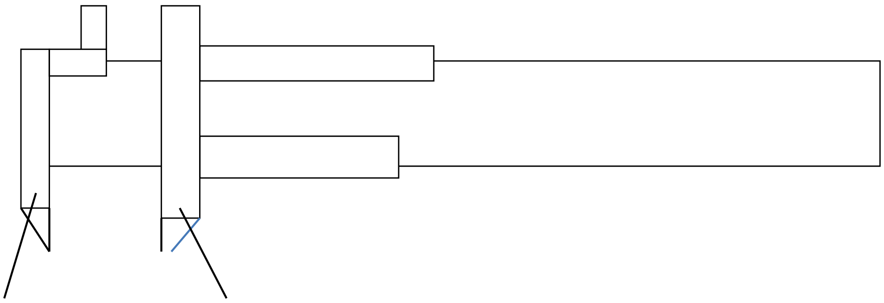
Challenges of using a metre rule to measure length

- It fails to measure the second digit of a decimal fraction
  - ➢ 2.2cm can be seen easily.

- 2.24cm is difficult because it does not show 0.04 on it,

Vernier calliper

- Was invented in 17th century by French technician called Pierre Vernier.
- Is used to measure short distances such as a diameter of a small ball bearing, thin rod, etc.
- It has a fixed jaw and sliding jaw.
- Sliding jaw is centrally aligned by a thin flat bar.
- It has the spring-loaded button used to prevent the sliding jaw from moving unnecessarily.

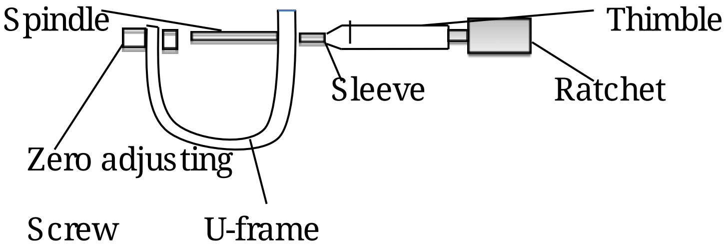


Using a vernier calliper

- It has a scale of 9mm.
- These are divided into ten equal divisions.
- Each division is of 0.9mm.
- The difference between one division and another is o.1mm or 0.01cm.
- 0.1mm is called least count (LC).
- The second decimal value is obtained by identifying a mark on the vernier scale which coincides with a mark on the scale called vernier coincidence (VC).
- Multiplying VC with 0.01cm = (VC x LC).

Micrometer screw gauge

- Is another instrument for measuring very small length such as diameter of a wire, thin rods, thickness of a paper.
- Was first made by an astronomer called William George in 17th century.



- U-frame
  - Holds an anvil at one end and a spindle at the other end.
- Sleeve
  - Has a linear main scale (sleeve scale) marked in millimetres or half millimetres.
- Thimble
  - Has a circular scale.
  - Is calibrated from 0 to either 50 or 100 divisions.
  - Is called head scale (thimble scale).
  - When thimble is rotated the spindle can move either forward or backwards.
- Ratchet
  - Prevents the operator from exerting too much pressure on the object to be measured.
- Zero adjusting screw
  - Is used to clear zero error.

Reading a micrometer screw gauge

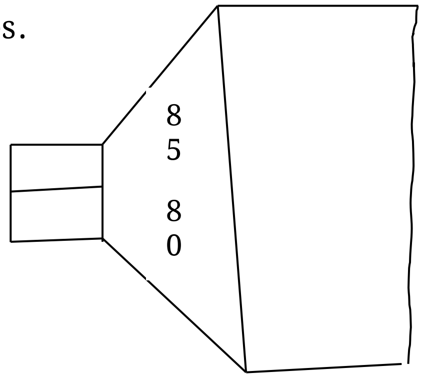
- Movement of the thimble is controlled by a screw called pitch.
- These are of 1mm and 0.5mm.
- 1mm pitch has 100 divisions called head scale divisions.
- In this case each division is 0.01mm with least count (LC) as 0.01mm.

$$LC = \frac{1mm}{100} = 0.01mm$$

- A 0.5mm pitch has 50 divisions with the LC as 0.01mm.

$$LC = \frac{0.5mm}{50} = 0.01mm$$

- The thimble reading called the head scale coincidence (HSC) is the value of the mark on the thimble that coincides with horizontal line on the sleeve.
- The main scale reading is taken by considering the reading of a mark on the fixed that is immediately before the sleeve enters the rim of the head scale.
- The linear main scale on the sleeve is calibrated in millimetres or half millimetres.



- The least count is 0.01mm
- The micrometer screw gauge reading = MSR + (HSC x LC)

  = 4.0 + (80 x 0.01)

  = 4.0 + 0.8

  = 4.8mm

Measurement of time

- Time is the interval between two distinct events.
- The SI unit of time is the second (s).
- Can be measured using stopwatch, stop clock and digital clocks.
- Digital stop watch is commonly used in our laboratories.
- Digital stop watches can display hours, minutes, seconds and milliseconds.

Measuring time interval using a simple pendulum

- A pendulum is a small mass called bob suspended by a light inextensible string from a fixed pivot.

- It undergoes oscillatory motion.

An Activity

Aim:

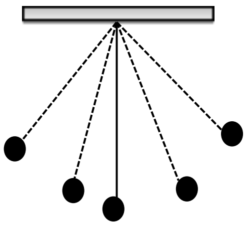
- To measure time interval using a pendulum

Materials

- Bob (mass)
- String
- Nail or fixed point

Procedure

- Tie the bob to the string and string to the point or to the nail.
- Display the suspended bob through a small angle and release it.

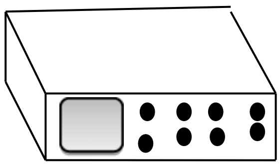


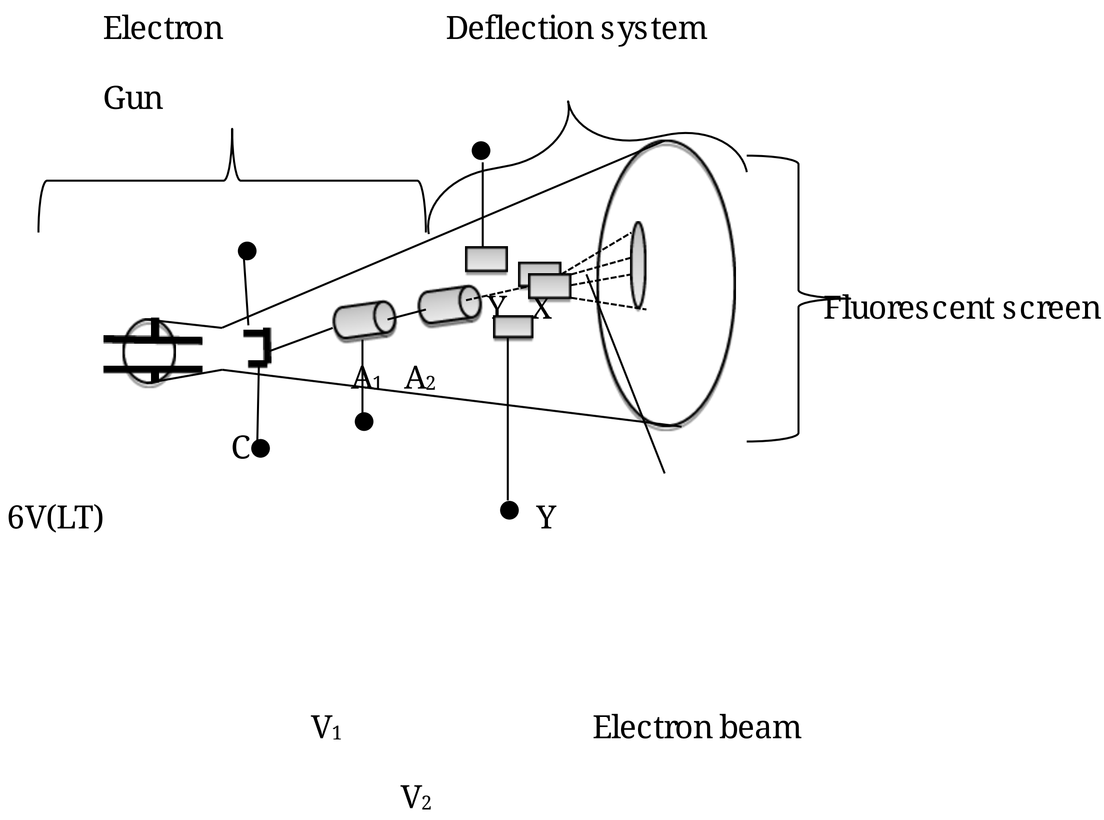
- Use the stopwatch to time 20 oscillations of the pendulum.
- Repeat steps 2 and 3 two more times and get the average value of time.
- Define the time for one oscillation.

$$\text{Period} = \frac{\text{Time}}{\text{Number of oscillations}}$$

Measuring time using cathode ray oscilloscope

- Cathode ray oscilloscope (C.R.O) uses cathode rays to display wave forms on a fluorescent screen



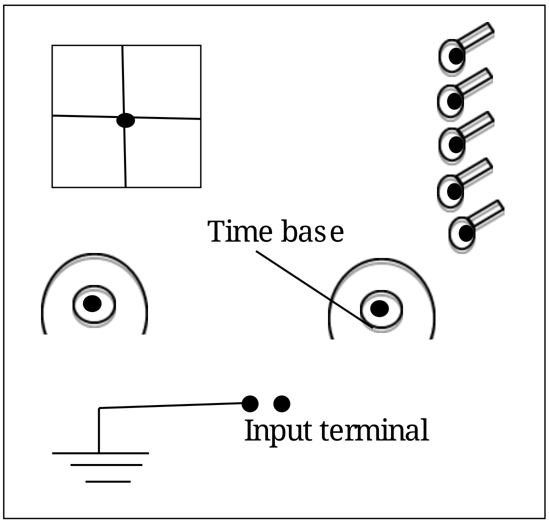


- **Electron gun**
  - ➢ Consists of a filament (F) which is surrounded by a cathode C, two anodes A_1 and A_2 and a third electrode (control grid).
- **Deflecting system**
  - ➢ Consists of two pairs of plates.
    - ✓ A horizontal pair called Y-plate.
    - ✓ A vertical pair called X-plate,
  - ➢ At the end of evacuated glass tube is the fluorescent screen coated with material like phosphor and zinc sulphide.
  - ➢ When cathode is heated by current from a low emitted (L.T) supply, free electrons are emitted from its surface.
  - ➢ These emitted electrons are accelerated and focused by anode A1 and A2 maintained at a positive voltage to the cathodes.
  - ➢ The electric fields between the cathodes converge the beam into a

fine spot on the fluorescent screen.

- **Brightness of the spot**
    - ➢ This is controlled by a control grid.
    - ➢ Making the grid more negative in potential with respect to the cathode decreases number of electrons passing through per second.
    - ➢ This reduces the brightness of the spot.
    - ➢ Therefore, the brightness of the spot depends on the increase of number of electrons passing through per second.

Basic control on a laboratory cathode ray oscilloscope



- The X-plates are connected to the time-base circuit.
- X and Y-control knob (last two lower knobs) are used to shift the spot manually to the X and Y direction.

Procedure for operating cathode ray oscilloscope.

- Switch on the oscilloscope when the time-base knob is off.
- Adjust the X-shift and Y-shift (last two lower knobs) till the spot appears.
- Set the spot to the centre of the screen using X and Y shifts adjustments.
- Adjust focus and brightness control knobs to obtain sharp and bright spot.

The Y-deflection plate

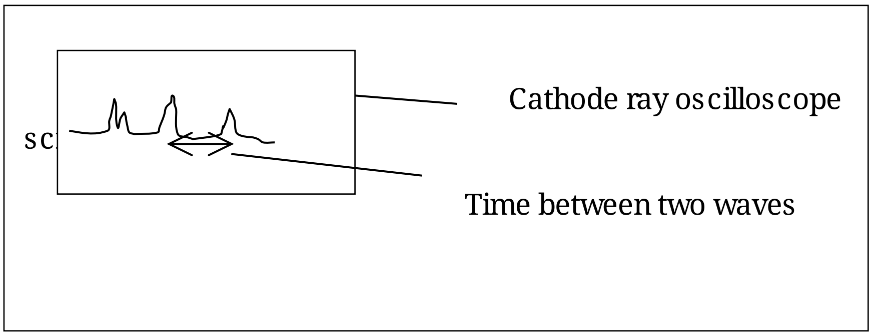
- When the time base is switched off, a potential difference is applied to the Y-plate.
- The electron spot is deflected up or down along the Y-axis.
- Sometimes the spot produced on Y-axis is too small.
- The Y-gain can be used to adjust the deflection.

The X-deflection plates

- X-plates are connected to the time-base circuit.
- This creates an electric beam that moves from left hand side of the screen to the right hand side when the voltages rise to maximum and to the left
- The mechanism sweeps the spot along the X-axis.
- The time-based knob can be used to adjust the spot along the X-axis.

Measurement of small time interval

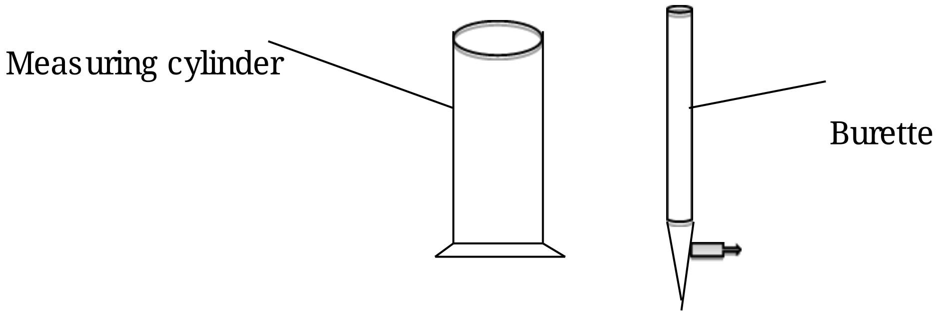
- Events occurring within a short interval of time e.g. sound wave can be detected by a microphone.
- Microphone converts sound energy into electrical energy.
- These signals are fed to the cathode ray oscilloscope whose time-base is on.
- These are seen on the screen of the cathode ray oscilloscope.



- The time interval between the two waves can be calculated if you know the time base of the cathode ray oscilloscope and the distance between the two signals.

Measurement of volume

- Volume is defined as an amount of space occupied by an object.
- SI unit of volume is cubic metre (m^3).
- Volume is measured using instruments such
  - Measuring cylinder
  - Burette
  - Pipette
  - Measuring flask



- When taking the volume reading, the measuring instrument must be up-right.

Factors to consider when choosing the appropriate instrument for measurement of volume.

- Nature of the substance
- The amount of the substance

Investigation

Aim

- To investigate the volume of a drop of water.

Materials

- Burette
- Water

Procedure

- Fill the burette to the level and record its volume as volume one. (V_1).
- Run out 10 drops of water.
- Note and read the new level as volume two (V_2).
- Subtract V_2 by V_1 i.e. $V_2 - V_1$. This is the volume of 10 drops of water.
- Divide 10 drops into the volume of 10 drops of water found in 4. This is the volume of one drop of water.

$$\text{Volume of one drop of water} = \frac{\text{volume of n drops of water}}{\text{n drops of water}}$$

Measurement of mass

- Mass is measured using beam balances
  - Triple beam balances
  - Digital beam balances

Triple beam balance

- First bean is calibrated in 100-gram marks.
- Second beam is in 10-gram marks.
- Third beam is in 1-gram marks.
- The triple beam balance can be used to :
  - Measure the required mass of a quantity from the given sample.
  - Determine the mass of a given sample of a substance.

UNIT TWO

SCIENTIFIC INVESTIGATION

Scientific investigation

- Is the systematic way used by the scientists to find solution to the problem or an answer to a question.
- A scientist must plan for the investigation.

Scientific investigation design

- State the topic or problem to be solved
  - The statement should be precise and focused to make it manageable.
- Suggest a hypothesis on the problem to be solved.
  - Is a proposed explanation given on the basis of limited evidence as a starting point for further investigation.
- Outline SMART objectives for the investigation
  - S-specific
  - A-achievable
  - R-realistic
  - T-time bound
- Identify the variables involved in the investigation
  - These are of three types namely
  - Independent variables
    - ✓ Is the one that researcher has a control over
    - ✓ The control is to bring a change in another variable.

- Dependent variables
  - ✓ Is the one that changes as a result of the change in the variable that is

    varied by the researcher.
  - ✓ This responds to changes in the independent variable.
- Controlled variables
  - ✓ Is the quantity that the researcher wants to remain constant so that it

    does not affect the dependent variable.
  - ✓ The researcher deliberately keep the controlled variable constant by

    varying independent variable.
  - ✓ This is done to obtain the corresponding change in the dependent

    variable.

- Identify apparatus/resources to be used to carry out the research.
  - These should be able to give readings and results to the expected degree of

    accuracy to minimize errors
- Outline the procedure of carrying out the experiment
  - These should include logical steps set up diagrams and precautionary measure

    where necessary.
- Identify the appropriate methods of collecting data
  - These methods should be
    - ✓ Efficient
    - ✓ Apply standard procedures
    - ✓ Enhance collection of primary data
  - They should also be cost effective.

- Speculate or identify any possible constraints, risks and suggested ways to handle them.
- Suggest methods and tools of data analysis that will be used.
  - These include graphs and charts.
- Incorporate the use of secondary source of information to validate the results obtained.
  - These include books, magazines, journals and internet links.

Exercise

Prepare a scientific investigation design that you should use t investigate how the temperature of a fixed mass of water varies with time from $0^{o}C$ until it boils.

Carrying out a scientific investigation

- This is the second stage after designing a scientific investigation.
- To get appropriate and accurate data consider the following
  - Carry out the outlined procedures and trails.
    - ✓ Make sure that the procedures followed can give accurate results.
    - ✓ However observe health, safety and environmental measures.
  - Collect and record the data to the right precision as you carry out the procedures
    - ✓ Methods of recording data include tables, charts, photographing and recording of sound.

Exercise

Present the information collected below that was obtained in the investigation to determine how pressure affects the volume of a mixed volume of a fixed mass of gas at constant temperature.

Pressure (x 10^5pa)	Volume (cm^3)
1.00331	7.339

1.02180	7.241
1.03907	7.143
1.02565	7.038
1.07390	6.88
1.08481	6.83
1.09388	6.78
1.011137	6.67
1.12196	6.63

Data analysis in a scientific investigation

- The raw data collected and recorded need to be analysed.
- This is in order to give meaningful information.
- Analysis may include
    - ➢ Organizing the data and studying the trend
        - ✓ This is to determine how it is varying or it remains constant.
    - ➢ Draw graphs and charts
        - ✓ This is to show the trend in the set of data.
    - ➢ Calculating required values that are representation of the data.
    - ➢ Interpreting the graphs, charts and the calculated values to derive meaningful information.
    - ➢ Identifying sources of errors in experiment.

Guidelines on how to draw graphs

- A graph
    - ➢ Is a diagram that shows the relationships between two or more quantities.
    - ➢ It has horizontal axis called x-axis and vertical axis called y-axis

- Features of a graph
  - Title
  - Axes
  - Scale
  - Plotting points
  - Line/curve of the best fit
  - Slope (gradient)
- Title
  - Indicates the variables whose relationship is represented in the graph.
  - The first quantity in the statement of the title should be represented on the Y-axis (vertical axis)
  - The second quantity in the statement of the title should be represented on the X-axis (horizontal axis).
  - Normally, the dependent variable takes the vertical axis while the independent variable takes the horizontal axes.
- Axes
  - These are drawn perpendicular to each other with arrows indicating the direction of the increasing values.
  - Axes should be labelled with the symbols of the quantities represented on them.
  - Both axes must have a starting value at the point of their intersection.
  - Most of the time the starting point is zero.
- Scale
  - Choice of scale enables one to plot all the points obtained or given to get a graph of a reasonable size.
  - Vertical scale and horizontal scale does not necessarily be the same.
  - It is important to choose a convenient scale which enables one to represent and read all possible values data on the grid.

Note

- A standard graph paper used should have 1 cm grid.

How to determine the scale

- $\frac{V_{h} - V_{l}}{n}$ Where
  - ➢ V_h is the highest value in the column
  - ➢ V_l is the lowest value in the column
  - ➢ n length in centimetres along the axis where the points will be plotted.

Plotting points

- Use small x or an encircled do.
- These should not be too big but small.
- It is important to confirm the plotting for each point.

Line/ curve of the best fit

- In both line and curve graph, join only the best fit.
- Leave the rest outside the line.
- Drawing of the line or curve of the best fit minimizes errors.

Slope

- Is the measure of the extent to which the variable in the vertical axis changes in relation to the change in the variable on the horizontal axis.
- Slope = $\frac{\text{Change in the nertical axis}}{\text{Change in the horizontal axis}}$

$G = \frac{\Delta Y}{\Delta X}$ where $\Delta Y = Y_f - Y_i$ and $\Delta X = X_f - X_i$

$G = \frac{Y_f - Y_i}{X_f - X_i}$

Determination of key quantities

- In some experiments a slope is not enough to lead us to make conclusion.
- Such experiments might require to calculate some other quantities.
- These quantities can be calculated using the expression given.

Example

- After plotting a graph of y(sin r) and x (sin i), you need also to calculate the refraction index (n) of the slope (s).
- Finding reciprocal of the slope of the graph gives the refraction index i.e. $n = \frac{1}{s}$ where
  - n should be expressed to the same significant figures.
  - The working at this stage should be done in SI units where the units exist.
  - If the units of a slope are standard units convert them before being used.

Determination of experimental errors

- An error is the variance between a measurement and the true or accepted value.

Terms related to error

- Uncertainty
  - Is the interval around a value such that any repetition of the measurement will produce a new result that lie within this interval.
- Precision
  - Is the degree to which repeated measurements under unchanged condition show the same results.
- Accuracy
  - Is the degree of closeness of a measurement to the actual value.

Classes of experimental error

- Absolute error
  - Is the difference in magnitude between value of the measurement obtained and actual value.
  - Is deviation of the measurement from the actual value.

    i.e. measured value – actual value.
  - Sometimes, it is defined as half of the least value (count) that can be

measured using the given instrument.

- ➢ Absolute error can be minimised by being more accurate when taking any measurement.

- Relative error

  - ➢ Is the ratio of the absolute error to the true value, usually expressed as a percentage.

    $$\text{Relative error} = \frac{\text{Absolute error x 100}}{\text{actual value}}$$

  - ➢ Relative error can be minimized by minimizing absolute error.

- Systematic error

  - ➢ Is the one that arises from the error in measuring instrument.
  - ➢ The value remains the same.
  - ➢ Systematic error can be corrected by
    - ✓ correcting the position of zero or
    - ✓ using error-free instruments.

- Zero error

  - ➢ Is the reading that an instrument gives when it is supposed to give a reading of zero.
  - ➢ Sources of zero error can be

  ✓ Using a maladjusted instrument (an instrument that is to be reset to zero before

  using it)

  ✓ Using wrongly calibrated instrument.

  ✓ Using a damaged measuring instrument.

➢ Zero error can be minimized by

✓ Resetting measuring instruments to zero reading before using them.

✓ Using instruments that are correctly calibrated.

Note

- ✓ When the zero error is negative, actual reading is found by adding the magnitude of the error.
- ✓ When the error is positive, the actual reading is found by subtracting the value of an error.

- Environmental errors
  - ➢ Are those errors arise due to conditions that are external to the measuring instrument.
    - ✓ Temperature.
    - ✓ Humidity.
    - ✓ Pressure.
    - ✓ Magnetic field.
    - ✓ Electric field.
  - ➢ Can be minimized by controlling the external environment where possible.
- Random errors
  - ➢ Errors arise from the inconsistency in the repeated measurements of the quantity.
  - ➢ Due to unpredictable fluctuations in the
    - ✓ readings of a measuring instrument.
    - ✓ Inaccurate taking of readings from measuring instrument.
  - ➢ Can be minimized by taking the average of numbers of repeated observations..
- Parallax errors
  - ➢ Also called observational errors.
  - ➢ Due to reading of wrong value on an instrument
    - ✓ Due to wrong positioning of the eyes.
    - ✓ Poor vision by the observer.
  - ➢ Can be minimized by

- ✓ Correct poisoning of eyes when reading the value in the instrument.

Drawing conclusions from an investigation.

- Is a summary of what was established through investigation.
- Researcher compares hypothesis and the findings to give a statement.
- The statement firms the hypothesis true or not true.

Presentation of the results of a scientific investigation.

- All findings of the scientific investigation have to be communicated in a formal way to the interested parties.

Important guidelines on how to present the results of scientific investigation.

- Identify the audience.
    - ➢ Will assist in choice of presentation methods and tools.
- Presentation should be well organised.
    - ➢ Should have title, objective, hypothesis, introduction, experiment and straight to the point.
- Presentation should be summarised and straight to the point.
- Level of language used should be suitable to the point.
- Presentation should be made clearly and concisely.
- Audial/visual aids should be used effectively.
    - ➢ Should be audible/visible.
- Complete the presentation within a reasonable time.
- At the end, the audience should comment or ask questions.

Methods of presentation

- Oral presentation.
- Power point presentation.
- Poster presentation.

- Video conferencing.
- Scientific journal and publications and reports.

Evaluating a scientific investigation

- Researcher should evaluate the entire process of the investigation against the objectives outline before the commencement of the investigation.
- The researcher should
    - ➢ Determine whether the objectives of the investigation were met or not.
    - ➢ Highlight the challenges that affected particular stages of the investigation.
    - ➢ Discuss ways of addressing the challenges encountered during the investigation.
    - ➢ Point out areas that would require further investigation.
    - ➢ Suggest the report should be submitted for peer review before the report is adopted.

Laboratory report

- Explains what you did in an experiment, what you learned and what the results meant.
- Simple report should have
    - ➢ Title - two type of them.
        - ✓ The title page
            - ❖ Not all reports have title pages.
            - ❖ The title page is a single page that contains
                - o Title of the experiment.
                - o Name of the researcher and laboratory partner.
                - o Teacher's name (supervisor).

        - Date when the lab was performed or the date report was established.

    - Title
        - ✓ Says what you did in brief i.e aim for ten words or less.
        - ✓ Describe the main point of the experiment or investigation.

- The aim
    - Is the purpose of carrying out the experiment.
    - May be one or many.
    - For instrumental-based practical, the apparatus used are normally mentioned.
- Introduction.
    - Is a single paragraph that states the objective of the experiment.
    - Provides the reader with background to the experiment.
    - Sometimes a brief summary on how the experiment was performed, results obtained and conclusion.
    - In this paragraph, the hypothesis is also stated.
- Materials
    - Is a single list of everything needed to complete your experiment.
    - Make sure that it is accurate and complete.
- Methods
    - Are steps/procedures that show how you carried out the experiment.
    - The description of steps should be detailed but precise so that anyone can read this section and duplicate it.
    - Steps should be clear and figure to diagram your experimental ste up should be provided.
- Results
    - This contains the raw data that you obtained.
    - Data should be summarised in the forms of

- ✓ Tables
- ✓ Figures
- ✓ Graphs
- ✓ Photographs

- ➢ All these forms of summarising the data should have titles.
- ➢ Label the axes on the graph and include units of measurements.

- Discussion
  - ➢ Is the most important part of the report.
  - ➢ Is where you explain, interpret and analyse data.
  - ➢ You determine whether or not a hypothesis was accepted.
  - ➢ Please explain the logic that allows you to accept or reject the hypothesis.
  - ➢ All mistakes made should be discussed.
  - ➢ Describe ways of improving the experiment.
  - ➢ List future experiments that might clarify areas of doubt in your results.
- Conclusion
  - ➢ Is where you sum up what happened in the experiment, whether your hypothesis was rejected and what does this mean.
  - ➢ Most of the times a single paragraph.
- References
  - ➢ Includes list of books, journals, websites etc used in your research on the process of carrying out your experiment and writing a report.

UNIT THREE

PROPERTIES OF MATTER

THE KINETIC THEORY OF MATTER

- States that matter is made up of tiny discrete particles that are always in random motion.
- "Kinetic" is derived from Greek word "Kineo" which means "I move".
- So, particles in a substance are in constant motion regardless of its state of matter.
- The theory explains that particles are packed in solids, liquids or gases and are bound by different attractive forces between them.
- They observe the effect of temperature on them.
- So, the arrangement of particles of matter and the way they move determines the state of a substance i.e. solid, liquid or gaseous state.

Kinetic theory of solids

- Solids have strong cohesive force of attraction between particles.
- Molecules are closely packed in fixed positions by attractive forces.

- Have the highest density compared with liquids and gases.
- Have definite shapes.
- Large force is needed to change the size and shape.
- Require a lot of heat energy to melt into liquid.
- Particles or molecules vibrate continuously in a fixed or mean position.
- When solids are heated
  - Kinetic of particles increases.
  - Particles vibrate vigorously in their fixed positions.
  - Cohesive forces between molecules are weakened.
  - Intermolecular forces become weak.
  - Particles start to flow.
    - ✓ The temperature at which these particles start to flow is called melting point.
    - ✓ The process of changing of state from solid to liquid is called melting.

Kinetic theory of liquids

- Have moderate intermolecular force of attraction between particles.
- Particles are loosely packed.
- Have lower density compared to solids.
- Particles are free to move randomly (flow while sticking together).
- Do not have definite shape (Takes the shape of the container)
- When liquids are heated
  - Particles acquire more kinetic energy And move faster.
  - The intermolecular force is weakened.
  - Molecules escape through the surface of a liquid.
    - ✓ The temperature where particles start to escape from top of the liquid is boiling point.

- ✓ The process of changing from liquid to gas is evaporation.

Kinetic theory of gases

- Have very weak intermolecular forces experienced upon collision.
- Have no definite shape.
- Fill the container.
- Molecules move rapidly and freely.
- Increase in temperature increases kinetic of particles.
- Particles of gas move more vigorously in different directions. (This is called kinetic theory of gases)
- Vigorous movement of gas particles directed to one point gives large force.
- This creates possible force that rotate turbines in geothermal electric plates.

Causes of gas pressure

- Pressure is force exited per unit area.
- Gas molecules are in continuous motion.
- They constantly collide with each other and the walls of the container.
- Container experiences an outward push each time a molecule strikes it and bounces off.
- Constant hitting per second produces a steady outward force per give area.
- This is what is being defines pressure.

Factors affecting gas pressure

- Number of molecules (particles) in the container.
- Temperature of the gas.
- Size of particles of the gas.
- Volume of the container in which particles are.

EFFECT OF TEMPERATURE ON THE MOLECULAR SPEED

- Particles/molecules of fluids and solids are always moving randomly or vibrate about a mean position.

- Higher temperature makes the molecules move faster than before.

Absolute zero temperature

- Is the temperature where molecules stop moving (have zero energy) and the gas sample has zero volume.
- At -273°C theoretically molecules have zero energy.
- This is equal to absolute zero since it is equal to 0 Kelvin (0K).

UNIT FOUR

ROPERTIES OF MATTER

THERMOMETRY

TEMPERATURE SCALES

- Is a range of values for measuring the degree of hotness or coldness.
- The degree of hotness or coldness is called temperature.
- Temperature is expressed in
    - Degrees Celsius also called centigrade.
    - Degrees Fahrenheit.
    - Kelvin.
- Kelvin scale is the SI unit for the temperature.
- Degree Celsius and kelvin are commonly used.

The Celsius scale

- Uses the degree Celsius (°C) as a unit of measuring temperature.
- Has two fixed value
    - Melting point for ice °C.
    - Boiling point of water 100°C.
- This only under standard atmospheric pressure of 101325pa.
- These two points are called the lower and the upper fixed points.
- Was invented by Swedish inventor, Anders Celsius in 1742.

- It was named under his name.

The Kelvin scale

- Uses Kelvin as a unit of measuring temperature.
- Uses absolute zero (-273°C).
- -273°C = 0 K.
- Was invented by Professor William Thomas, a lecturer at Glasgow University.
- Was a British Physicist.
- He was given the title of Boron Kelvin of Logos in 1892.
- He used his title as a unit of measurement.

Relationship between Celsius and Kelvin scales

- To convert Celsius to Kelvin we add 273 to the given degree Celsius temperature scale.
    - 32°C to Kelvin = 32 + 273 = 305K.
- To convert Kelvin to Celsius we subtract 273 to Kelvin temperature scale.
    - 305K = 305 -273 = 32°C

Thermometers

- A thermometer is an instrument for measuring temperature.

Thermometric substance

- Is the substance used in the construction of thermometers.
- Define the temperature scale by assigning fixed lower forced point and upper forced point.
- Thermometric substance can be liquid, gas or solid.
- But their properties change uniformly with temperature.

Thermometric properties of a substance

- Should remain constant if temperature is constant.
- Should change uniformly with change in temperature.

- Should change uniformly for every 1°C change in temperature.
- Should acquire thermal equilibrium as quickly as possible, when temperature measurements are needed.
- Should cover a wide range (should not freeze or boil at normal temperature).
- Should be able to register the rapid changing temperature.
- Should have a large change even if the change in temperature is small.
- Should be such that the temperature can be taken easily without waiting for a long time.

Types of thermometers

- Liquid – in – glass thermometer.
- Electrical resistance thermometer.
- Digital thermometer.
- Constant volume gas thermometer.
- Thermocouple thermometer.

Liquid-in-glass thermometer

- Uses mercury or coloured alcohol.
- Liquid is filled into the base of the thermometer called a bulb.
- Bulb is connected to the calibrated capillary tube through which the liquid rises with increase in temperature.

Mercury-in-glass thermometer

- Is the one in which its thin walled bulb is filled with mercury.

- Pre cautions when constructing it.
  - ➢ The walls of the bulb should be thin to ensure that mercury can be heated easily.
  - ➢ Quantity of mercury should be small so that it should take little time to warm up.

- The thin capillary tube should be of uniform cross-section so that the mercury level changes uniformly along its length.

- Advantages of using mercury as thermometric substance
  - Mercury is shiny opaque liquid that its meniscus can easily be seen and readings taken without difficulties.
  - Mercury does not wet glass so it cannot stick to the sides of the capillary tube.
  - Mercury is easily obtained as a pure substance.
  - Mercury has a large increase in volume for 1°C rise in temperature.
  - Mercury-in-glass thermometer has a wide range of temperature since mercury freezes at -39°C and boils at 357°C.
  - Mercury has ability to transfer heat energy easily.
- Disadvantages of using mercury as a thermometric substance.
  - Usually t is only the bulb which is in contact with the body when taking the temperature.
  - There is a change in initial pressure due to the different positions of the thermometer i.e. the reading of the mercury level is lower when the tube is vertical as compared to the reading when in horizontal position.
  - Mercury takes some time to contract to the original volume. The same thermometer cannot be used to measure a low temperature soon after high temperature.
  - They may be non-uniformity in the capillary bore of tube.
  - It is no suitable to measure temperature.

Alcohol – in – glass thermometer

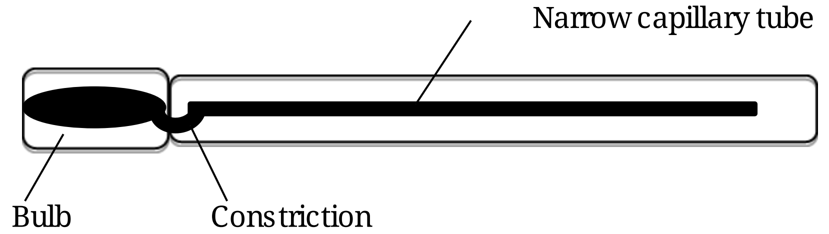
- This uses coloured alcohol instead of mercury.
- The volume of alcohol changes uniformly and easily when heated.
- The change is six times that of mercury.
- The range of temperature that can be measured with this thermometer is limited i.e. boils at 78°C and freezes at -112°C.
- It is ideal for measuring low temperatures.

- Advantages of using alcohol as a thermometric substance
    - Has a very low freezing point of 112°C hence its suitable in thermometer to record very low temperatures.
    - Can be coloured brightly by adding dye that makes it clearly visible through the glass.
    - Has uniform expansion and contraction than even mercury.
    - Is good thermal conductor, cheap and easily available.

- Disadvantages of using alcohol as a thermometric substance
    - Alcohol sticks to the walls of the glass thus wetting it. This makes it difficult to read the temperature accurately.
    - Alcohol has low boiling point and cannot be used to measure high temperatures.

Clinical thermometer

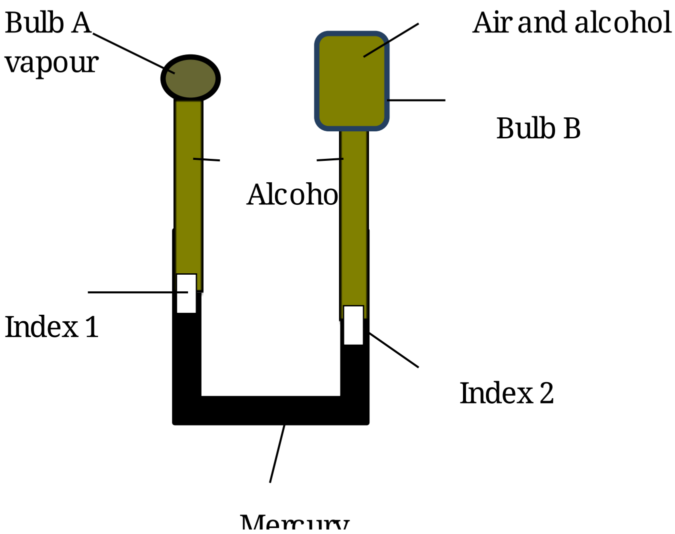
- It is an instrument designed to measure human body temperature.
- It has the following:
    - A thin walled bulb containing mercury.
    - A capillary bore is very narrow and uniform diameter.
    - Has a limited range from 35°C to about 43°C.
    - The normal body temperature is about 36.9°C.



Six's Maximum and Minimum Thermometer

- Is used to measure maximum and minimum temperature of a place during the day.

- Was invented by physicist called John Six.
- It has a U-tube connect to two bulbs.
- The U-tube contains mercury.
- The two bulbs contain alcohol which occupies the full volume of one bulb leaving the other bulb with a space.
- Has two indices fitted with light fine spring.



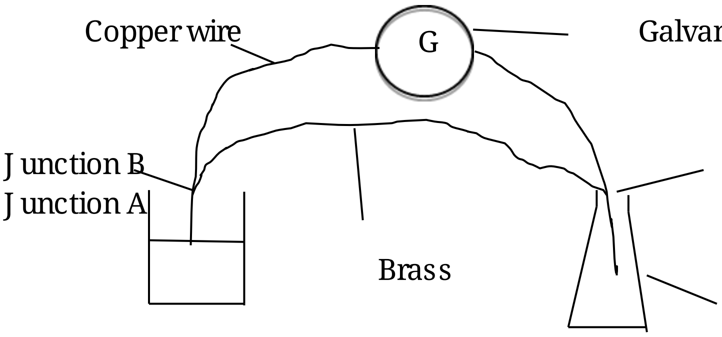
- When the temperature is very high, mercury pushes the index$_2$ to the maximum.
- The position index$_2$ is the maximum.
- Use the magnet to reset the indices to the same level.
- When the temperature is very low, mercury pushes the index$_1$ up.
- The position of index$_1$ is the minimum.

Thermocouple thermometer

- This uses the thermocouple effect.
- Was discovered by a German physicist called Thomas Seebeck (1170-1831).
- He used the relationship between heat flow and electric current.
- He discovered that when two ends of metal pieces are at different temperatures,
    - electric current flows from the hot end to the cold end.

- The amount of current that flows depends on the temperature difference between the two ends.
- Different amount of electric current flows through different types of metals.

- The current can be measured by connecting a galvanometer at some point in the loop.
- The value of current can be used to determine the temperature at one end if the temperature at the other end is known.
- Thermocouple thermometer is used to measure very high temperature which ordinary thermometers cannot measure.



- Uses of thermocouple
  - Is used in industries to determine if the required temperature is reached.
  - Can be used in homes, offices and business places as the temperature sensor in thermostats.
  - Are used as flame sensor in safety devices.
  - Are used to measure very high temperature.

UNIT FIVE

PRESSURE

- Is force exerted per unit area.

$$P = \frac{f}{A}$$

- Force is measured in newton (N) and area in square metre (m^2).
- Pressure is measured in N/m^2.
- Unit for pressure is Pascal (pa).

Pressure in solids

- Pressure in solids depends on the force exerted by the solid and the area of contact with the solid.
- The larger the particle the greater the pressure and the small the particle the low the pressure.

Pressure in liquids

- Liquids exert pressure on all the walls of the container.
- Liquid pressure has the following properties:
  - Liquid pressure increases with increase in depth.
  - Liquid pressure at equal level is the same.
  - Liquid pressure increases with increase in density.
  - Liquid finds its own level.

Formula for pressure in liquids

$$P = \frac{f}{A}$$

But F = mg

$$P - \frac{mg}{A}$$

But m = ev and v = Ah

m =eAh

$P = \frac{eAhg}{A} = ehg$; where e is density, h is height (depth) and g is gravitational field strength.

Example

- Calculate the pressure at the bottom of a beaker when it is filled with water to a height of 12cm. take the density of water as $1g/cm^3$ and g = 10N/kg.

  $P = egh$

  $e = 1g/cm^3 = 1000kg/m^3$

  $g = 10N/kg$

  $h = 12cm = 0.12m$

  $p = 1000kg/m^3 \times 10N/kg \times 0.12m$

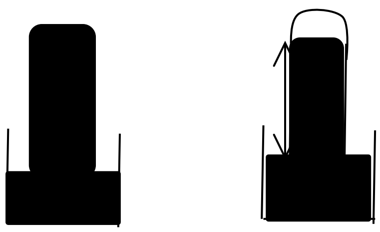
  $p = 1200Nm^2$

Application of liquid pressure

- Water supply system.
- Drinking straw.
- Hydraulic machines
  - Hydraulic car brake.
  - Hydraulic jack
  - Hydraulic oil pump

Atmospheric pressure

- Is the pressure exerted by air particles in the atmosphere.
- Is measured
  - Mercury barometer
    - The air column subtracted gives the value of the pressure exerted.



P - heg

- Since g = 10N/kg, convert all the reading to kg, m^3.

Example

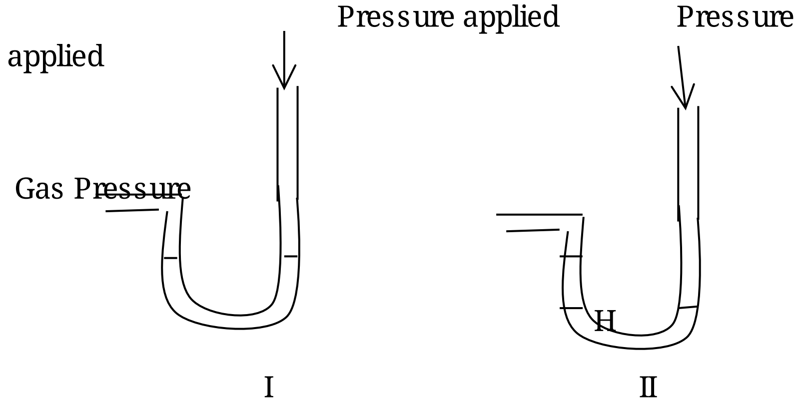
- If h in the diagram above is 75mm, find the pressure exerted.

    - e = 13600kg/m^3
    - g = 10N/kg
    - h = 75mm = 0.075m
    - p = heh

      = 0.075m x 15600kg/m^3 x 10N/kg

      =10200N/m^2

    - Manometer
        - Is an instrument used to measure gas pressure.
        - Has a transparent tube containing a liquid.
        - One end is left open with the other end is usually connected to the gas whose pressure is measured.



- In I the level of the mercury is the same in both sides.
- This implies that gas pressure is equal to atmospheric pressure.

  $P_g = P_A$

- When $P_g > P_A$, $P_g = P_A$ + Pressure due to mercury column

  $P_2 = P_A + heg$

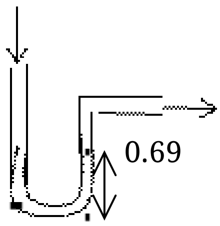
- When $P_A > P_g$, $P_A = P_g$ + pressure due to mercury

  $P_A = P_g + heg$

  $\therefore P_g = P_A - heg$

Example

Below is a U-tube manometer used to determine the pressure of the gas used to inflate the tyre. Density of the mercury is 13600kg/m^3 and gravity is 10N/kg with atmospheric pressure of 1.02 x 10^{5}pa. Calculate the pressure of the gas.



$P_A > P_g$

$\therefore p_g = P_A - heg$

$= 1.02 \times 10^5\text{pa} - (0.69\text{m} \times 13600\text{kg/m}^3 \times 10\text{N/kg})$

$= 1.02 \times 10^5\text{pa} - 93840\text{pa}$

$= 8160\text{pa}$

$\therefore$The pressure of the gas used to inflate the tyre is 8160pa.

Fluids

- These are made up of liquids and gases.

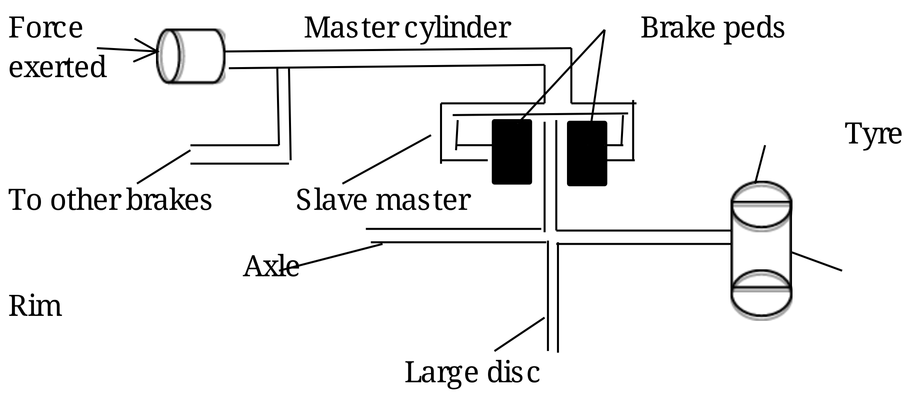
Application of pressure in fluids

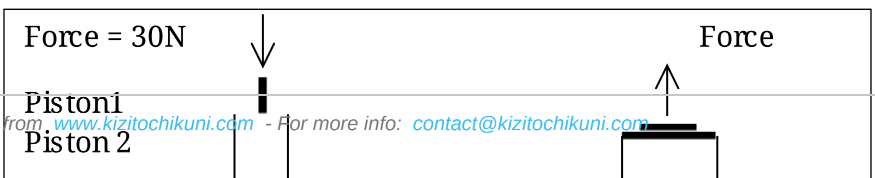
- Hydraulic brakes
- Hydraulic press
- Drinking straw

- Syringes
- Lift pump
- Force pump
- Bicycle pump
- Siphon

Hydraulic brakes

- Uses the principle of transmission of pressure.
- When a small force is applied on the brake pedal of the car, it pushes the piston in the master cylinder.
- This produces pressure that is equally transmitted to the piston in the slave cylinder.
- The pressure forces the brake pads to come into contact with large disk and slows or stops the car.
- The piston in the master cylinder are smaller in diameter than the piston in the clave cylinder.
- The small force applied is multiplied by the large piston in the slave cylinder.



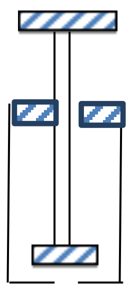


Drinking straw

- Sucking through a straw reduces the air pressure inside the straw.
- The atmospheric pressure forces the liquid into the mouth through the straw.

Syringes

- Consist of a tight-piston in barrel.
- Is used by doctors.
- When the piston is pulled, the space is created in the barrel.
- This lowers the pressure inside and allows air to occupy the space.
- Pushing the piston reduces the piston reduced the space inside and pushes air out.



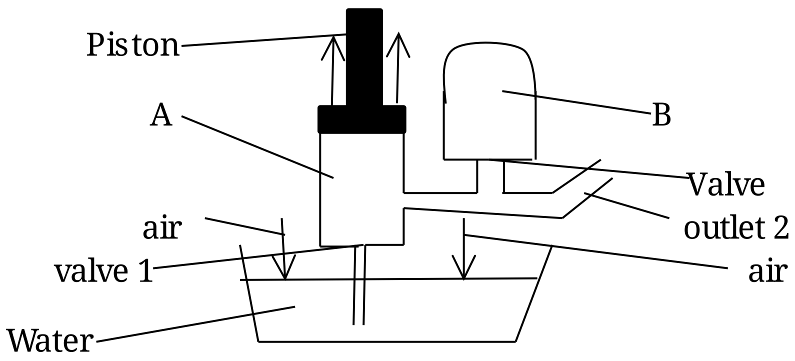
Lift pump

- Is used to raise liquid from a low level to a high level.
- Is has cylindrical metal barrel with a delivery tube.
- A piston is placed inside the barrel with two valves.

- The pump is operated by means of levers.

Force pump

- Consists of two valves, a solid piston, two compartments A and B and the outlet tube.
- The pump is opened by moving the solid piston up and down using a lever system.

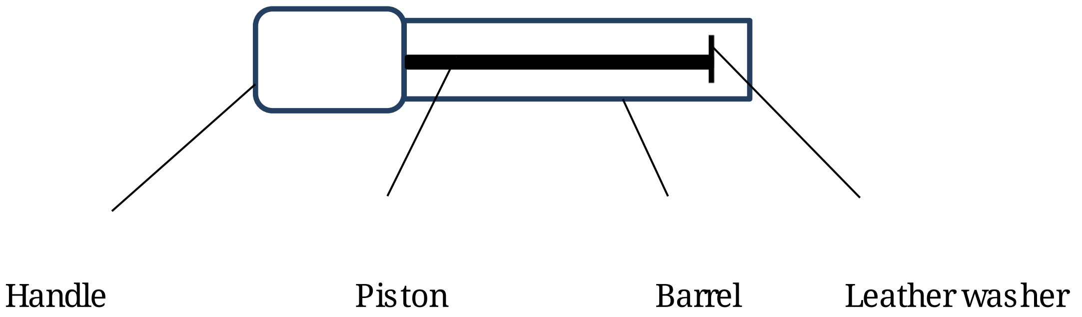


- During upstroke
  - When the piston moves up, it creates an empty space in compartment A.
  - The air between the piston and valve 1 expands to fill the space.
  - This reduces the pressure of the air in compartment A below the atmospheric pressure.
  - The atmospheric pressure on the water surface forces the water up past valve 1 into the compartment A.
  - Valve 2 does not open since pressure above it is atmospheric.
- During down stroke
  - Valve 1 close due to weight and that of the water above it.
  - Increase in pressure in compartment A, opens valve 2.
  - This allows water out through the outlet tube via compartment B.
  - Air is trapped in compartment B.

Bicycle pump

- Consists of a flexible leather washer at one end of the piston inside a barrel.

- The pump is used to inflate tubes or balloons whose materials are not too hard to expand.
- The flexible leather washer acts as valve as a piston.



- The pump is operated by hands.
- The piston is pushed in and out within the barrel.
- Pushing in makes the air out of the pump into the tube.

Siphon

- Is a flexible tube used to empty container e.g. petrol tank.
- To empty the liquid in the container, the siphon is first filled with liquid.
- One end is pushed into the liquid and the other one left hanging.

UP THRUST

- Is the upward force exerted by water on the body immersed in it.

FACTORS AFFECTING THE MAGNITUDE OF UP THRUST

- Density
  - As the density of the liquid increases, the up thrust increases and vice versa
- The volume of the body immersed in the liquid
  - The greater the height and hence the volume of the portion of the object submerged into liquid, the greater the up thrust exerted on the body
  - Up thrust is equal to the weight of the liquid displaced

ARCHIMEDES' PRINCIPLE

- States that when a body is wholly or partially immersed in a fluid, it experiences an up thrust which is equal to the weight of the fluid displaced.
- Up thrust is equal to the weight of fluid displaced minus apparent loss in weight.

TAKE NOTE

- The same effect is observed for a partially immersed cube.
- The forces on the sides are equal but act in opposite directions hence the net force on the sides of the cube is zero.

THE LAW OF FLOATATION

- States that a freely floating body displaces a fluid of weight which is equal to its own weight.

APPLICATION OF FLAOTATION

- Manufacturing of ship
    - Ship is made up of metal and air. This makes the ship float on water.
    - When the ship is loaded it displaces more water than when it is not loaded.
- Submarines
    - Is the type of ship that can float on water and sink in water.
    - Submarines have internal tanks called ballast tank.
    - Ballast tank can be filled with water or air.
    - When water is allowed to fill, it can sink in water and when filled with air it floats.

APPLICATION OF ARCHIMEDE'S PRINCIPLE AND RELATIVE DENSITY

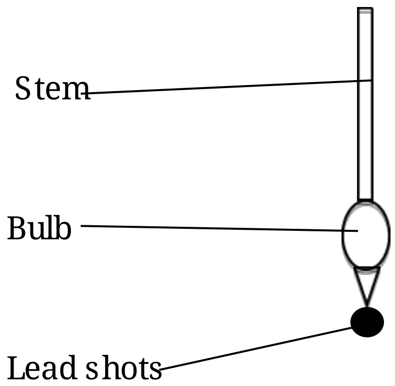
- Used in finding relative density
    - Find the mass of the solid in air.
    - Immerse it in a container full of water.
    - Collect the displaced water and find its mass.
    - Divide the mass of the object by mass of displaced water.

$$\text{Relative density of solid} = \frac{\text{mass of solid in air}}{\text{mass of displaced water}}$$

$$\text{Relative density of liquid} = \frac{\text{up thrust in liquid}}{\text{up thrust in water}}$$

HYDROMETER

- Is an instrument for measuring the relative density of a liquid directly.
- It consists of an upper tem and lower bulb.
- Both the stem and the bulb contain air.



UPPER STEM

- Consists of a hallow narrow glass tube and scale on the inside of the tube.
- The scale is graduated in relative densities no evenly spaced out.
- The thin stem gives the instrument a greater sensitivity.

LOWER BULB

- Consists of a wide bulb which is loaded with lead shots to keep the hydrometer upright in the liquid.
- The bulb displaces a reasonable amount of the liquid making it experience a reasonable amount of up thrust.

TYPES OF HYDROMETER

- Lactometer
  - ➢ Is the one to test the purity of milk.
  - ➢ Is for checking whether any water has been added to milk.
  - ➢ Has a range from 1.015 to 1.045.

- Pure milk has a relative density of 1.030.
- It is graduated in percentage of purity of milk.
- W is used for 0% pure while M is used for 100% purity of pure milk.

- Spirit/wines/beer hydrometer
  - For determining percentage of alcohol in beers, wines and spirits.

- A car acid hydrometer
  - For testing the state of charge of acid batteries.
  - Is done by measuring the relative density of sulphuric acid in the battery.
  - Is enclosed in glass tube fitted with a rubber bulb.
  - The rubber bulb is squeezed to expel the air from the glass tube to reduce pressure.
  - When releasing the bulb, the atmospheric pressure forces the acid up into the glass tube.
  - The hydrometer is made to float and relative density can be read.
  - When fully charged the relative density is 1.25.
  - If the relative density of the acid is 1.18, the battery needs recharging.
  - It has a red band around the top of the stem.
  - Is acid level reaches this band, the battery requires charging.

UNIT SIX

GAS LAWS

GAS LAWS

- These are the laws which describe the relationship of two variables among temperature, pressure and volume when one variable is kept constant.
- The quantities which explain the behaviour of a fixed mass of gas are pressure, temperature and volume.
- There are three gas laws
  - Boyle's Law
  - Charles' Law
  - Pressure Law

PRESSURE LAW

It states that for a fixed mass of gas at constant volume, pressure is direct proportion to its temperature in Kelvin scale.

i.e. $P \propto T$

$P = KT$

$K = \frac{P}{T}$

Given two positions, (P_1, T_1) and (P_2, T_2),

$K = \frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$P_1T_2 = P_2T_1$

Example

A gas whose original temperature and pressure are 30K and 300KN/m^2 is expanded until its new pressure is 60KN/m^2 while its volume remains constant. What is its temperature?

Solution

Given: P_1= 300KN/m^2, T_1 = 30K, P_2 = 60KN/m^2, T_2 = ?

$P_1T_2 = P_2T_1$

$T_2 = \frac{P_2T_1}{P_1}$

$T_2 = \frac{60KN/m^2 \times 30}{300KN/m^2}$

$= 6K.$

Exercise

1. An electric light bulb has volume of 200cm^3. It contains argon gas at pressure of 1.1 x
 10^5pa and temperature of 289K. When the light is switched on, the pressure increased
~ steadily to 1.8 x 10^5pa. What is the temperature of the argon in the electric light bulb that
 created this new steady pressure?
2. A gas whose original pressure and temperature were 17pa and 34K is expanded until its
 newpressure is 51pa while its volume remains constant. What is its temperature?

BOYLE'S LAW

It states that for the fixed mass of gas at constant temperature, the volume is inversely proportional to its pressure.

i.e. $V \propto \frac{1}{P}$

$V = \frac{K}{P}$

$K = VP$

Given two positions (V_1P_1) and (V_2P_2)

$K = V_1P_1 = V_2P_2$

Example

If a certain amount of gas occupies 100litres at 100Kpa. What is the pressure required to occupy it into 10litres at the same temperature.

Solution

Given:

$V_1 = 100l$, $P_1 = 100kpa$,

$V_2 = 10l$, $P_2 = ?$

$V_1P_1 = V_2P_2$

$P_2 = \frac{V_1P_1}{V_2}$

$= \frac{100l \times 100kpa}{10l}$

$= 1000kpa.$

Exercise

1. A gas whose original pressure and volume were 300pa and $14m^2$ is expanded until its new pressure is 60pa while its temperature remains constant. What is its new volume?
2. A quantity of gas whose original volume and pressure were 35l and 12pa were compressed its volume reduced to 7l while its temperature remains constant. Find the new pressure of the gas.

CHARLES' LAW

It states that for the fixed mass of gas at constant pressure, volume is directly proportional to its temperature in Kelvin.

i.e. $V \propto T$

$V = KT$

$K = \frac{V}{T}$

Given two positions (V_1T_1) and (V_2T_2),

$K = \frac{V_1}{T_1} = \frac{V_2}{T_2}$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_1T_2 = V_2T_1$$

Example

A quantity of gas whose initial temperature and volume are 576K and20m^3 respectively is cooled at a constant pressure until its new volume is 10m^3. Find the final temperature of the gas.

Solution

Given:

$V_1 = 20cm^3$, $T_1 = 576K$,

$V_2 = 10cm^3$, $T_2 = ?$

$V_1T2 = V_2T_1$

$$T_2 = \frac{V_2T_1}{V_1}$$

$$= \frac{10m^3}{20m^3} x576K$$

$$= 288K$$

Exercise

1. Calculate the volume occupied by a sample of gas at 42°C if it occupies 5litres at 22°C.
2. A quantity of gas whose initial temperature and volume are 244K and 12m^3 respectively is cooled at a constant pressure until its volume is 24m^3. Find the final temperature of the gas.

THE IDEAL GAS EQUATION

It is formed when the pressure law, Boyle's law and Charles' law are combined. This is an equation showing the relationship among the temperature, pressure and volume when they all vary.

i.e. $V \propto T$ and $V \propto \frac{1}{P}$

$$V \propto \frac{T}{P}$$

$$V = \frac{KT}{P}$$

$$K = \frac{VP}{T}$$

Given two positions ($V_1P_1T_1$) and ($V_2P_2T_2$),

$$K = \frac{V_1P_1}{T_1} = \frac{V_2P_2}{T_2}$$

$$V_1P_1T_2 = V_2P_2T_1$$

Example

The pressure of 15ml of oxygen gas at 8°C is 12atm. What is the volume if the pressure is 770torr and temperature is 20°C.

Solution

Given: V_1 = 15ml, P_1 = 12atm, T_1 = 8°C, P_2 = 770torr, T_2 = 20°C and V_2 = ?

In this problem, you are required to convert pressure to one unit, either into torr or atm and temperature to Kelvin.

i.e. $P_1 = \frac{12\text{atm x } 760\text{torr}}{1\text{atm}}$ = 9120 torr,

T1 = 8 +273 = 281K

T2 = 20 + 273 = 293K

$$V_1P_1T_2 = V_2P_2T_1$$

$$V_2 = \frac{V_1P_1T_2}{P_2T_1}$$

= 185.25ml

= 185ml

Exercise

1. The volume of air in a container is 24m^3 and has a pressure of 16atm when the temperature
is 21°C. Calculate its pressure when the volume is reduced to 12m^3 and its temperature to
171°C.

KINETIC THEORY OF MATTER

- Is the theory that explains the behaviour of gases.

- It states that gases are made up of tiny particles which are always in motion.

ASSUMPTIONS MADE IN KINETIC THEORY OF GASES

- A gas is made up of tiny, identical, solid particles which are in constant, rapid and random motion.
- The particles move in a straight line and their motion is only affected by collisions.
- All collisions are perfectly elastic.
- The time that the particles are actually in contact with each other or with the walls of a container is negligible compared with the time between two successive collisions with the walls.
- The force of attraction between the particles is negligible.
- The actual volume of the particles is negligible compared with the space in which the particles move.
    - If the gas obeys all the assumptions above, is called ideal gas.

UNIT SEVEN

MACHANICS

SCALERS AND VECTORS

SCALERS

- These are quantities with magnitude (size) only.
    - Pressure
    - Speed
    - Temperature
    - Distance
    - Mass
    - Density
    - Area
    - Energy

- Volume

VECTORS

- These are quantities with both magnitude and direction.
    - Displacement
    - Velocity
    - Acceleration
    - Momentum
    - Magnetic field
    - Temperature gradient

REPRESENTING VECTORS

- Are represented by a line with an arrow head ($\longrightarrow$)
- The length of the line represents the magnitude and an arrow head shows the direction.
- The length may be drawn to a given scale.

PROPERTIES OF VECTORS

- They have magnitude.
- They have directions
- They can be moved from one position to another as long as the magnitudes and directions are maintained.
- When the vector is reversed, it is assigned a negative value.

ADDITION AND SUBTRACTION OF VECTORS

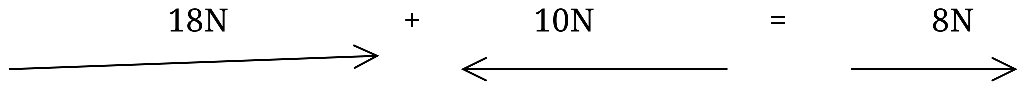
VECTOR ADDITION

- The sum of the vectors is called resultant.

ADDITION OF PARALLEL VECTORS

$$\xrightarrow{7N} \quad + \quad \xrightarrow{\quad 12N \quad} \quad = \quad \xrightarrow{\qquad 19N \qquad}$$

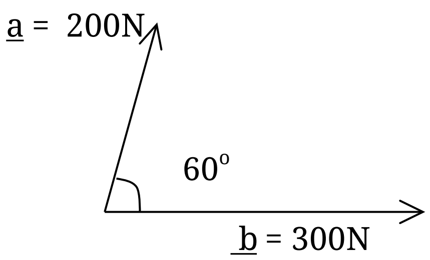
ADDITION OF VECTORS TO OPPOSITE DIRECTION



ADDITION OF VECTORS USING TRIANGLE RULE

- This is a scale diagram.
- The following steps should be followed
    - Reduce the magnitude of the two coplanar vectors to the size that can suit the space to be drawn.
    - Draw one vector to the converted length with the head pointing to one direction.
    - From the head of this vector construct the given angle.
    - Through the given angle draw the second vector to the converted units.
    - Join the tail of the first vector and head of the second vector by drawing a straight line.
    - This line is the resultant and measure it using your ruler.
    - Convert your reading to (N) using the scale you are using.
- Example

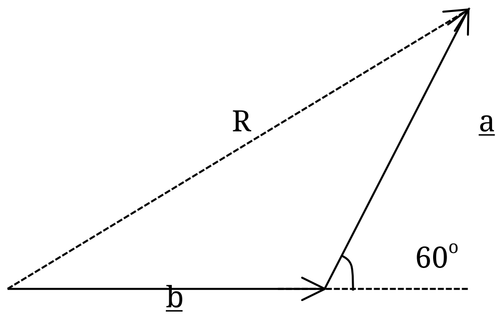
  Find resultant force in the figure below



- Using a scale of 100N = 1cm

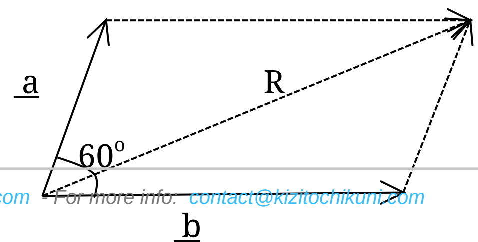
200N = 2cm and 300N = 3 cm

- Draw the triangle as shown below which has a = 2cm and b = 3cm.
- Maintain the angle at the point shown as shown below.



RESOLVING VECTORS USING PARALLELOGRAM RULE

- This is another scale drawing in which resultant is the diagonal of the parallelogram.
- You complete the remaining two sides of the parallelogram using the given two coplanar forces and then draw the diagonal from the given angle to the angle where heads of the drawn vectors meet.
- The following steps should be followed;
  - Convert the units to the scale that can suit the paper to be used.
  - Copy the two forces with the magnitude found after converting the units but maintain the angle's magnitude and position.
  - Use construction rules to complete vectors parallel to the drawn vectors to form a parallelogram.
  - From the given angle, draw a diagonal to meet the heads of the constructed vectors, measure it and convert the units found using the given scale.
  - This becomes the resultant force.
  - Using the example in the triangle rule and the same scale, it will be as shown below.

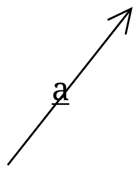


RESOLVING VECTORS USING VECTOR COMPONENTS

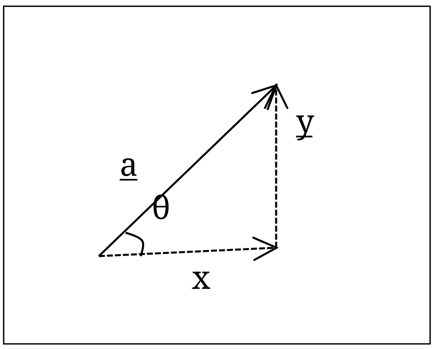
- A single vector has two components; horizontal component and vertical component.
- Sometimes the forces acting against the body can be two or more.
- These will still give a single resultant.
- These are resolved by breaking each vector into horizontal and vertical components.
- All horizontal components are added and vertical components are also added giving the sum of horizontal components and the sum of vertical components.

Example

- Using vector a below to find horizontal and vertical components.



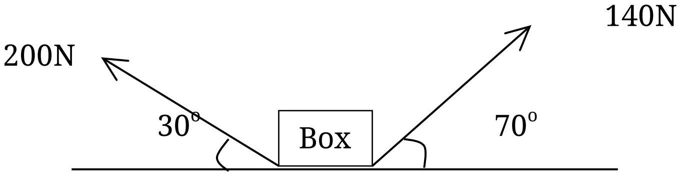
- Vector a has components indicated in the figure below using triangle rule.



- a has a horizontal component x and vertical component y.
- to find a using angle θ; $\sin\theta = \frac{y}{a}$ hence $y = a\sin\theta$ and $\cos\theta = \frac{x}{a}$ hence $x = a\cos\theta$.
- Using Pythagoras theorem $a = \sqrt{\sum(x)^2 + \sum(y)^2}$
- To find direction of the resultant use $\tan\theta = \frac{\sum \text{vertical components}}{\sum \text{horizontal components}}$.

Example

Resolve the following vectors



Vector	Horizontal component	Vertical component
200N 140N	$-200N\cos 30^\circ = -153.209N$ $140N\cos 70^\circ = 47.883N$	$200N\sin 30^\circ = 100.000N$ $140N\sin 70^\circ = 131.557N$
$\sum$	$= -105.326N$	$= 231.557$

$\therefore$ Resultant $= \sqrt{(-105.326)^2 + (231.557)^2}$

$= 8.044N$

Direction ; $\tan\theta = \frac{231.557}{105.326}$; $\theta = \tan^{-1}\frac{231.557}{105.327} = 66^\circ$

R = 8.04N 66° below x-axis.

UNIT EIGHT

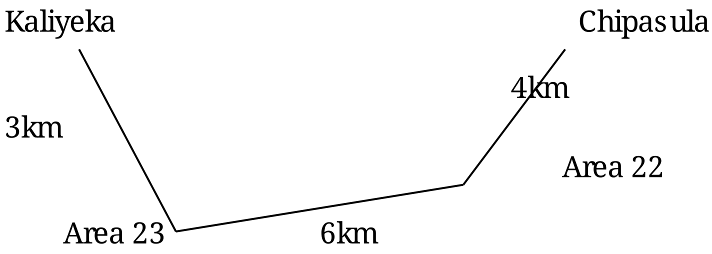
LINEAR MOTION

LINEAR MOTION

- Is a motion made by a body as it moves from one place to another.
- This involves time taken, distance covered, speed, velocity and acceleration of the motion and relationships amongst them.

DISTANCE

- Is the total length of the path between two points.
- Is measured in units of length such as km, m, cm etc.
- Determining the distance between two points, the direction is not considered.



- Distance covered from Kaliyeka to Chipasula through Area 23 and Area 22

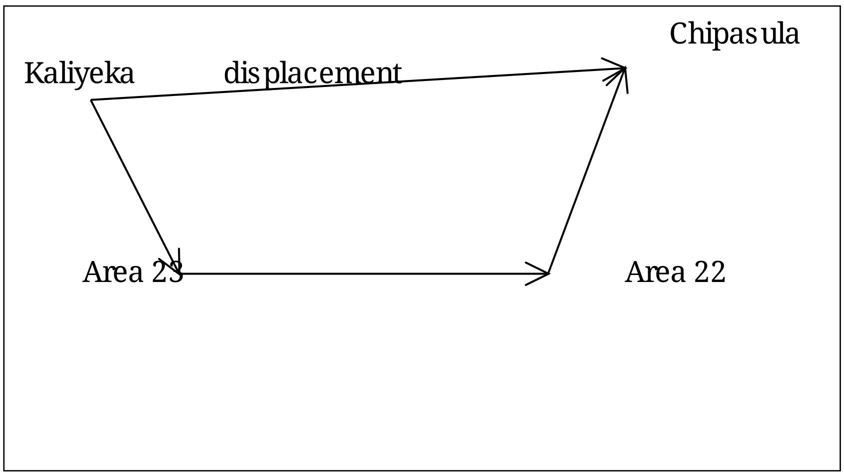
  = 3km + 6km + 4km

  = 13km

- If there were the length from one area to another, the person would move a distance of 13km from Kaliyeka to Chipasula if the route to Area 23 and Area 22 is followed.

DISPLACEMENT

- Is the straight line distance between two points in the direction of motion. (More direct route from one point to another in the direction stated).



- Shortest route from Kaliyeka to Chipasula is the displacement.
- The arrow indicates the direction of motion.
- The SI unit for displacement is metre (m).

SPEED

- Is the distance moved by the body per unit time.

$$\text{Speed} = \frac{\text{distance moved}}{\text{time taken}}$$

- Direction is not considered.
- SI unit of speed is metres per second (m/s).

UNIFORM SPEED

- Is when the body covers equal distances in unit time intervals.
- Normally the body moving between two points moves with varying speed.
- This is called non-uniform speed.
- The speed between two points is called average speed.

$$\text{Average speed} = \frac{\text{Total distance covered}}{\text{Total time taken}}$$

Example

What is the speed of a racing car in metres per second if the car covers 360km in 2hours?

$$\text{Speed} = \frac{\text{Distance covered}}{\text{Time taken}} = \frac{360\text{km}}{2\text{hrs}} = 180\text{km/hrs}$$

Change the km to m and hours to seconds.

$$\text{Speed} = \frac{180 \times 1000}{1 \times 60 \times 60} = 50\text{m/s}$$

VELOCITY

- Is the change of distance in a particular direction.

$$\text{Velocity} = \frac{\text{Distance moved in a particular direction}}{\text{Time taken}}$$

- Is the displacement covered in a unit time or the rate of change of displacement and time.

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

- In some cases the velocity of a moving body keeps on changing. In such cases, it is better to find average velocity.

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time taken}}$$

- When the velocity in a particular direction is constant, the velocity is called uniform velocity.

Displacement (m)	0	4	8	12
Time taken (s)	0	2	4	6

- The SI unit for velocity is metres per second (m/s).
- When sketching the velocity of the body, the direction should be included.

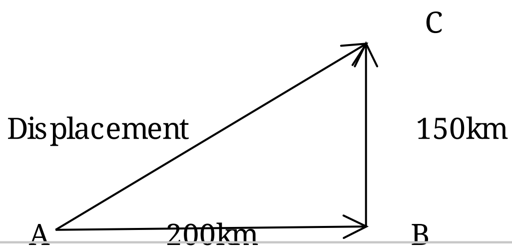
Example

A car travelling from town A to town B 200km east of A in 3hours. The car changed direction and travelled a distance of 150km due north from town B to town C in 2hours. Calculate:

(a) $\text{Speed} = \frac{\text{Total displacement covered}}{\text{Total time taken}}$

$$= \frac{200\text{km} + 150\text{km}}{3\text{h} + 2\text{h}} = \frac{350\text{km}}{5\text{h}} = 70\text{km/h}$$

(b) $\text{Average velocity} = \frac{\text{Displacement}_{\overrightarrow{AB}}}{\text{Time taken}}$



Displacement = $\sqrt{(AB)^2 + (BC)^2}$

$= \sqrt{200^2 + 150^2}$

= 250km

Average velocity = $\frac{250km}{3h + 2h} = \frac{250km}{5h}$ = 50km/h

MEASURING VELOCITY

- Can be measured in a number of ways such as using ticker-tape-timer.

TICKER-TAPE-TIMER

- Is an electrical vibrator which moves a metal pin up and down 50 times every second.
- This gives one complete vibration as 1/50 second = 0.02s.
- As the pin moves downwards, it presses a dot on the carbon paper disc.
- The tape is attached to a moving body.
- Each successive pair of dots represents a time interval of 0.02 second.
- The distance between any two successive pair of dots is the distance the object has moved in 0.02 second.
- Therefore, the tape records the distance moved and time taken by a moving body.
- Since the dots are equally spaced, the velocity if the same at all points on the tape.

  Velocity of the tape = $\frac{\text{Displacement}}{\text{Time taken.}}$

ACCELERATION

- Is the rate of change of velocity.

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

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

- The SI unit of acceleration is metres per square second (m/s^2).
- When acceleration is positive, it means that its velocity is increasing commonly called acceleration.
- When the acceleration is negative, it means that its velocity is decreasing commonly called deceleration.

UNIFORM ACCELERATION

- Is when the rate of change of velocity with time is constant.

Example

A car accelerates from rest to a velocity of 20m/s in 5 seconds. Thereafter, it decelerates to a rest in 8 seconds. Calculate the acceleration of the car

a. In the first 5 seconds

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}} = \frac{20m/s - 0m/s}{5s} = \frac{20/s}{5s} = 4m/s^2$$

(acceleration)

b. In the next 8 seconds

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}} = \frac{\frac{0m}{s} - 20m/s}{8s} = \frac{-20m/s}{8s} = -2.5m/s^2$$

(deceleration)

ACCELERATION DUE TO GRAVITY

- Is the acceleration due to pull of the earth on the object.
- All freely falling bodies near the earth's surface are attracted towards the centre of the earth with an acceleration.

- This acceleration is called the acceleration of the free fall.

FREE FALL BODY

- Is the body that has been allowed to fall freely.

  $$\text{Speed} = \frac{\text{Distance covered}}{\text{Time taken}} = \frac{s}{t}$$

- $$\text{Constant acceleration} = \frac{\text{Final velocity} + \text{Initial velocity}}{2}$$

  $$\text{Speed} = \frac{V + U}{2} = \frac{s}{t}$$

  $$s = \frac{t(V + U)}{2}$$

  for a free fall body U = 0,

  $$\therefore s = \frac{tv}{2}$$

  But v = gravitational pull (g)

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

  $$\text{speed} = x,\ x = \frac{gt^2}{2} \text{ and } g = \frac{2x}{t^2}$$

- If you have speed and time, you can calculate gravitational pull over the body.
- g has two meanings
  - the gravitational field strength which is 10 newtons per kilogram

    (g = 10N/kg).
  - the acceleration of a free fall body which is 10metres per second per second

    (g = 10 m/s^2).

ACTIVITY

Aim

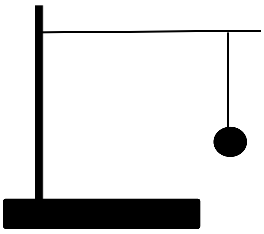
- to determine acceleration due to gravity using a simple pendulum.

Apparatus

- stop watch
- pendulum
- stand and clamp
- table

procedure

- Assemble the apparatus as shown below.



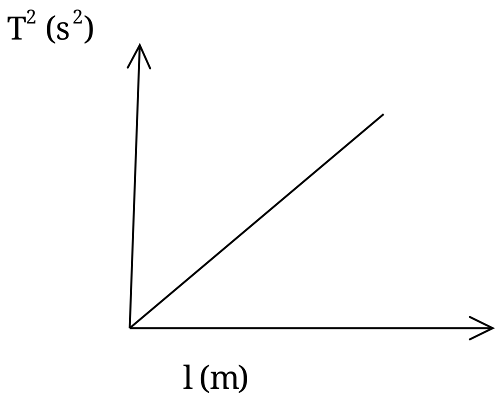
- Displace the pendulum through a small angle $\theta < 10^{o}$ and release it.
- Use the stop watch to time 20 oscillations of the pendulum. Repeat the experiment and calculate the average time for 20 oscillations. Do for at least six different lengths. Record your results in the table below.

Length (m)	Time taken (t) for 20 oscillations(s)	Average time (t) for 20 oscillations (s)	Period (T) = $\frac{t}{20}$	T^2 (s^2)
0.60				
0.70				
0.80				
0.90				
1.00				
1.10				

- Draw a graph of T^2 against l.
- Draw the line of both best fit through the points.
- Determine the gradient.

Discussion

- Plotting the graph of T^2 against l will look like the one below.



- The gradient will be $\frac{\Delta T^2}{\Delta l}$

- For a simple pendulum oscillating with a small amplitude, the period (T) is given by two pie square root of length over gravity.

  $T = 2\pi\sqrt{\frac{l}{g}}$

  $\sqrt{\frac{l}{g}} = \frac{T}{2\pi}$

  $\frac{l}{g} = \left(\frac{T}{2\pi}\right)^2 = \frac{T^2}{4\pi^2}$

  $g = \frac{4\pi^2 l}{T^2}$

- To calculate acceleration due to gravity is given by

  $g = \frac{4\pi^2 l}{T^2}$

  but $T^2 = \frac{4\pi^2 l}{g}$ and $y = mx + c$

- In the graph $T^2 = y$, $l = x$ values

  $Y = mx + c \quad \Rightarrow \quad T^2 = mx + c$

  At $c = 0$, $T^2 = ml$

Substituting $T^2 = \frac{4\pi^2 l}{g}$

$$\frac{4\pi^2 l}{g} = ml$$

$$\therefore m = \frac{4\pi^2 l}{gl} = \frac{4\pi^2}{g}$$

- Gradient of the graph (m) = $\frac{4\pi^2}{g}$

$$\therefore g = \frac{4\pi^2}{m}$$

- Gravity = $\frac{4\pi^2}{\text{gradient of the graph}}$

Exercise

1. The following results were obtained in a certain experiment to determine factors affecting the period of a pendulum.

Length	0	5	10	15	20	25	30	35	40
Time (t) for 10 oscillations	0	1.7	3.2	4.4	5.5	6.5	7.4	8.2	8.6
Period (T) = $\frac{t}{10}$ (s)									

   a. Complete the table by determining the period of each time for 10 oscillations.

   b. Plot a graph of period (T) in seconds against length (l) in centimetres.

2. A form three student performed an experiment to determine the oscillation due to gravity by timing on oscillating pendulum and obtained the following results.

Length of pendulum (m)	0.12	0.13	0.14	0.15	0.16	0.17	0.18
Time (t) for 20 oscillations	30.5	32.0	36.7	40.2	45.0	48.6	50.3

   a. Explain how the length of the pendulum is measured.

   b. Plot the graph of t^2 against L.

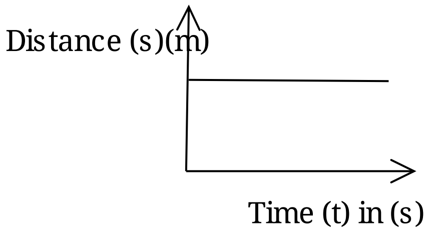
c. Determine acceleration due to gravity.

d. List the precautions you would take in this experiment to measure accurate results.

MOTION – TIME GRAPHS AND THEIR INTERPRETATIONS

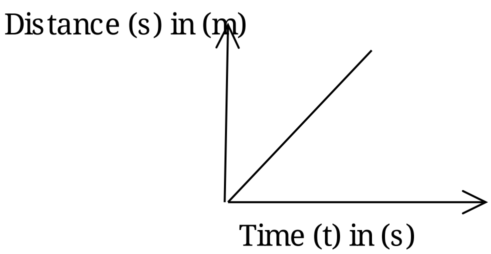
DISTANCE-TIME GRAPHS

- A body at rest.



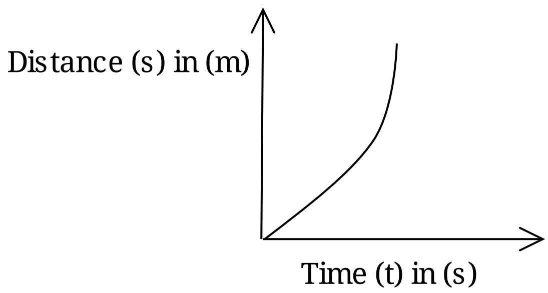
  - This shows that the distance covered by the body does not change with time.
  - So, the body is at rest (is not moving).

- Moving body with constant acceleration.



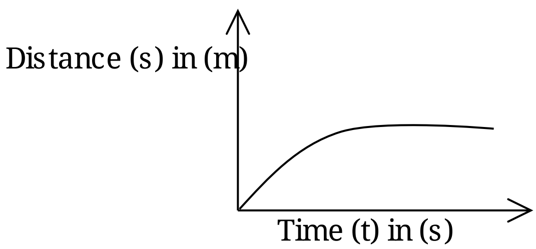
- This shows that as the distance travelled by the body increases, the time is also increasing.
- It this case, speed can be presented by
    - ✓ Speed = $\frac{\Delta s}{\Delta t}$.
    - ✓ But gradient = $\frac{\Delta s}{\Delta t}$.
    - ✓ ∴ gradient = speed.
- This shows that the body is moving with constant (uniform) speed.

• Speed increasing with time.



- This shows that the speed is increasing (not uniform).
- This implies that the object is accelerating.
- Examples may include;
    - ✓ Body rolling down an inclined plane.
    - ✓ A car accelerating uniformly from rest.

• Speed decreasing with time.

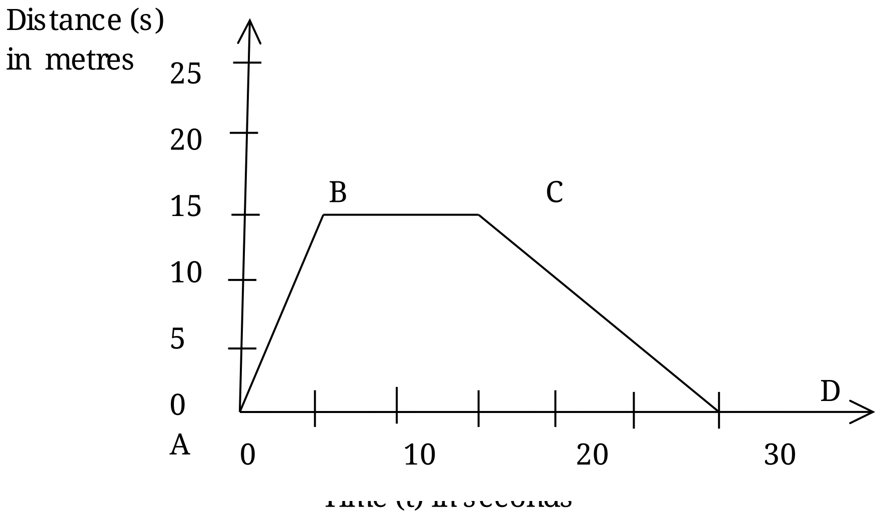


- This shows that the speed is decreasing (not uniform).
- This implies that the body is decelerating.

- Examples may include;
    - ✓ A body thrown vertically upwards.
    - ✓ A body rolling up hill or an inclined plane.
    - ✓ A car decelerating to the rest.

Example

Below is a distance – time graph for a motorist. Use it to answer questions that follow.



1. How far was the motorist from the starting point after 10 seconds?

   This is distance AB.

   A is at 0m and B is at 15m

   $\therefore$ AB = 15m – 0m =15m

   AB = 15m

2. Calculate the average speed of the motorist for the first 10 seconds.

   Speed = gradient

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

   Speed = $\frac{(15 - 0)m}{(10 - 0)s}$

Speed = $\frac{15}{10}$ = 1.5m/s

Speed = 1.5m/s

3. Describe the motion of the motorist in

   a. BC

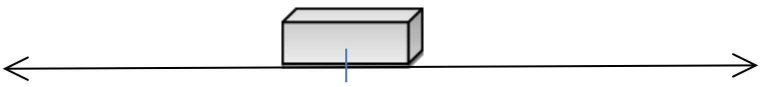
      At BC, the motorist is at rest because the distance does not change no matter the time is changing.

   b. CD

      At CD, the motorist is moving at a constant speed down to the starting point. (The motorist is decelerating.)

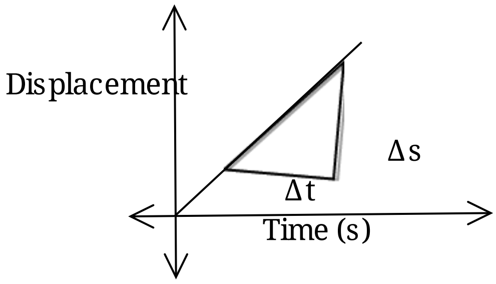
DISPLACEMENT-TIME GRAPHS

- Displacement of the body has a starting point and direction of motion.



0 – this is reference point.

- Positive uniform increase in displacement with time to the right hand direction

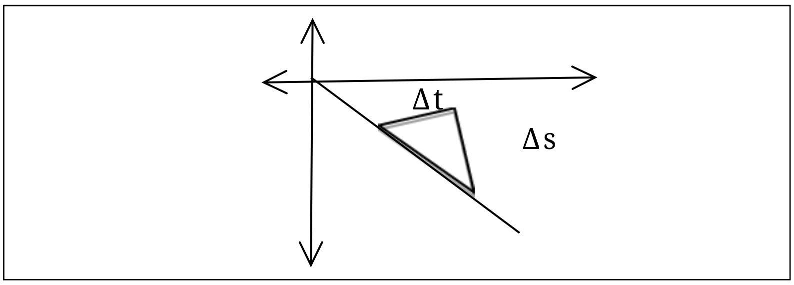


  - When the body moves to the right of the number line, both displacement and time are increasing.
  - On the graph, it is shown on the first quadrant.
  - The gradient of the displacement-time graph gives velocity of the

body.

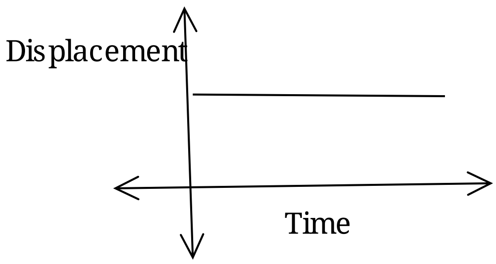
$$V = \frac{\Delta s}{\Delta t}$$

- Negative uniform increase in displacement with time to the left direction.



  - When the body moves to the left of the number line, displacement is decreasing while time is increasing .
  - On the graph, it is shown on the fourth quadrant.
  - You could see from the graph that y-values are decreasing but time is increasing.

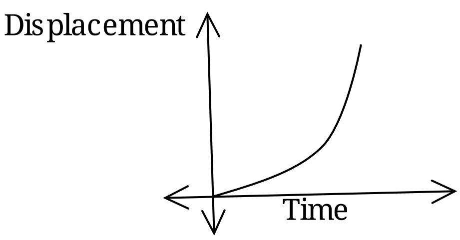
- Object at rest



e.

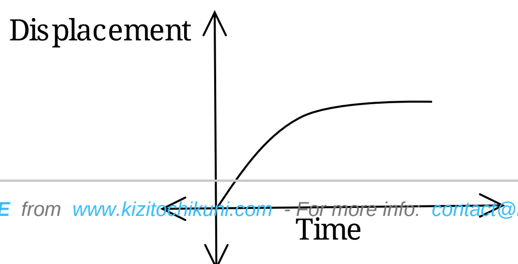
  - The body is at rest (stationary).

- Displacement increases non-linearly with time.



  - The gradient (velocity) is increasing.
  - The body is accelerating.

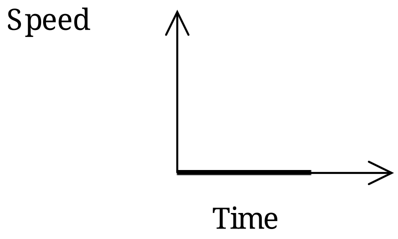
- Displacement decreases non-linearly with time



- The velocity is decreasing.
- The body is decelerating.

SPEED – TIME GRAPHS

- Object at rest.

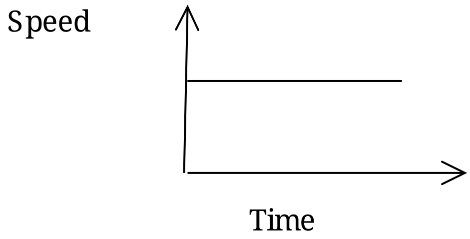


- At rest the body covers no distance since it is not moving.
- The speed is therefore zero (0m/s).
- The graph will move along x-axis.
- However, change in speed and time is called acceleration.

$$a = \frac{\Delta \text{ speed}}{\Delta \text{ time}}$$

- Acceleration is therefore the gradient of speed-time graph.
- The object at rest gives an acceleration (gradient) of zero.

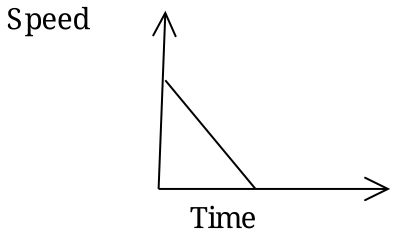
- A body moving with uniform speed.



- The gradient for this graph is zero (0m/s).

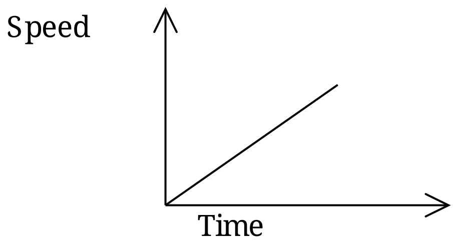
- This one has uniform speed.

- A body moving with non-uniform speed.



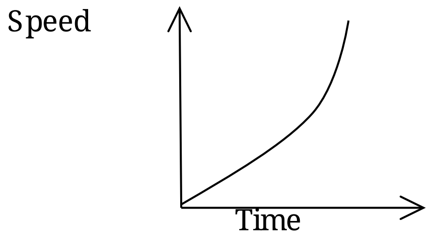
  - If we take ground as our reference point,
    - ✓ Upwards is a positive direction.
    - ✓ It starts with some speed which then start to decrease to zero.
    - ✓ Then the stone starts dropping as its speed starts increasing from zero.
    - ✓ The stone now moves to opposite direction (downwards).
    - ✓

- An object moving with uniform increase in speed.



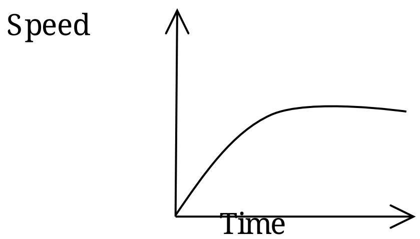
  - When a body moves with uniform acceleration, its speed changes by equal amount in equal interval time.
  - The speed-time graph for a uniform changing will be a straight line.

- A body moving with non-uniform acceleration.



- ➢ Consider a body falling in air.
- ➢ As the body falls through air, the speed increases but not regularly.

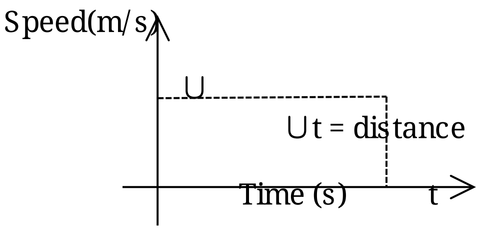
- A body moving with non-uniform deceleration.



- ➢ Consider a body falling in water.
- ➢ As then body falls, the speed accelerates and then reduces.
- ➢ If the acceleration is reducing non-linearly, the body is said to be undergoing non-uniform random motion.

AREA UNDER SPEED-TIME GRAPH

- Uniform speed.



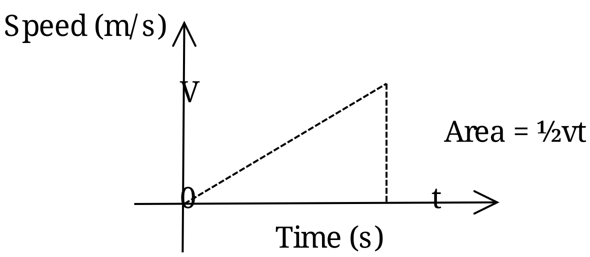
- ➢ Consider a body moving at constant speed of U m/s for a time, t seconds, the distance x travelled by a body moving with a speed U for a time t is given by;

  Distance (x) = constant speed (U) x time (t)

  X = Ut

- ➢ The product Ut is the area under speed-time graph.
- ➢ The area under a speed-time graph gives us the distance covered by the object.

- Uniform acceleration.

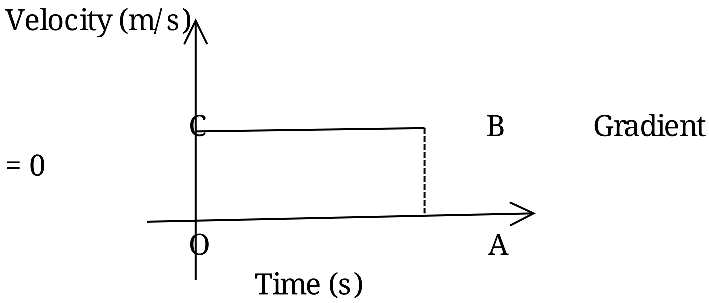


- Distance covered = ½v x t = area under the velocity time graph.
- Can be presented with the graph below.

VELOCITY-TIME GRAPHS

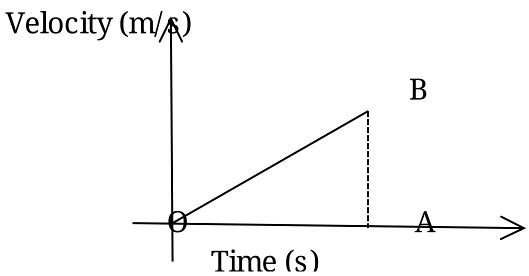
- A velocity-time graph tells us how the speed and direction of an object changes.
- Where there is no change in direction a velocity-time graph looks like speed-time graph.
- The gradient of the velocity-time graph is numerically equal to acceleration.
- The area under velocity-time graphs gives the distance covered by the object.

- A body moving at constant velocity.



- The area in this case, a rectangle OABC gives the distance covered by the body.
- Distance covered = Area of OABC = OC x OA.

- A body moving with steady acceleration from rest.

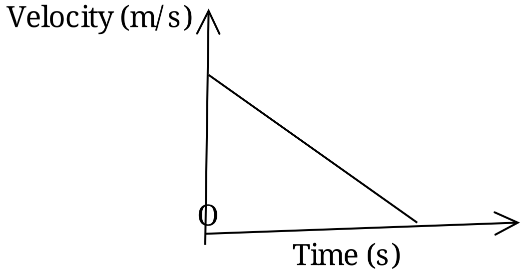


- The gradient of velocity-time graph represent the acceleration.

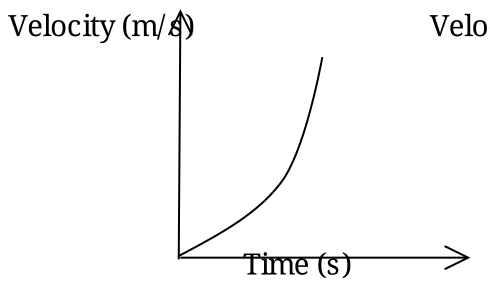
- Gradient = $\frac{\text{change in velocity } (\Delta v)}{\text{change in time } (\Delta t)}$ = acceleration
- The rate of change of velocity (acceleration) is uniform.
- The area under the graph, i.e. area of ΔOAB, gives the distance covered by the car.

  i.e. distance covered = area of ΔOAB = ½ (OA x AB)

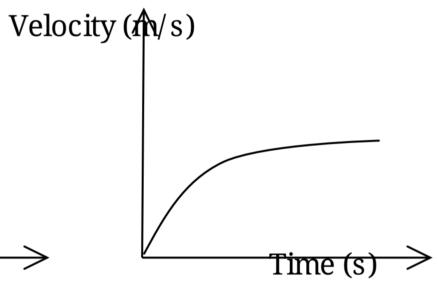
- A body decelerating uniformly.
  - If the brakes are applied, the body decelerates uniformly to rest.



- A body moving with non-acceleration.
  - Sometimes acceleration is not uniform.
  - It may be increasing or decreasing.



Increasing acceleration



Decreasing acceleration

EFFECTS OF AIR RESISTANCE ON THE MOTION OF A BODY FALLING THROUGH AIR

Investigation:

Aim :

- To investigate the motion of a body falling through the air.

Apparatus:

- Burette
- Glycerine
- Three steel balls
- Complete stand
- Clamp

Procedure:

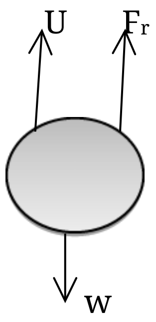
- Clamp the burette vertically. Carefully fill the burette with glycerine using a funnel.
- Carefully drop one steel ball from above the liquid surface (The ball should not slide along the walls of a burette).
- Observe the movement of the ball through the glycerine.
- Repeat this for two more times using the other remaining steel balls.

Observation:

- Initially the speed of the ball increases and eventually becomes constant.

Discussion

- When an object is falling in air or any other fluid, three forces act on it.
- These are weight of the body (w), up-thrust (u) and viscous drug (fluid friction) (F_r).



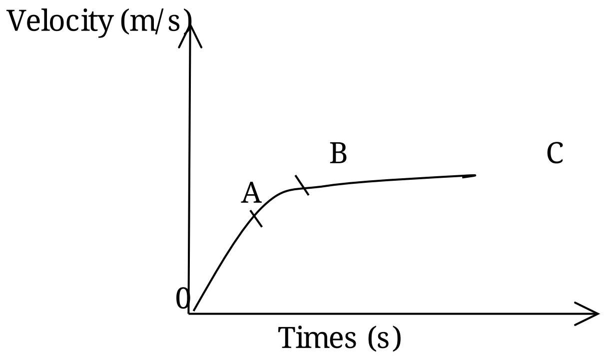
- The viscous drag increases with increase in speed of the falling body.

Initially w $> (u + F_r)$

- Hence the body accelerates downwards.
- As viscous drag (F_r) increases, it reaches a point where ($U + F_r$) = W.
- The resultant force is zero.
- The body moves at uniform (constant) velocity.
- This constant velocity is called terminal velocity (V_t).

TERMINAL VELOCITY

- Is the maximum downward velocity possible for a particular object falling through a fluid.

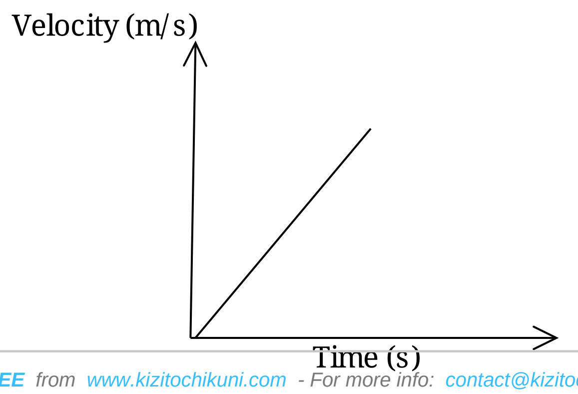


DESCRIPTION OF THE MOTION IN THE GRAPH

- OA – velocity increases with time (constant acceleration).
- AB – acceleration decreases to zero up to terminal velocity.
- BC – body at constant velocity (terminal velocity).

MOTION OF THE BODY IN THE VACUUM

- The body falls freely.
- The motion is due to its weight only.
- There is no air resistance and up-thrust.
- The velocity of the body is increasing with time.
- Tl ce of gravity (g).



EQUATION OF UNIFORMLY ACCELERATED MOTION

- Let the initial velocity at point P be (u) and final velocity at Q be (v).
- The distance travelled PQ in time (t) is (s).

$$\text{Acceleration} = \frac{\text{Change in velocity}}{\text{Time taken}}$$

$$= \frac{\text{Final velocity (V) - initial velocity (U)}}{\text{Time take (t)}}$$

$$a = \frac{V - U}{t}$$

$$V = U + at$$

- $\text{Average velocity} = \frac{\text{displacement (s)}}{\text{Time taken (t)}} = \frac{s}{t}$ .... (i)

$$\text{Average velocity} = \frac{\text{Initial velocity} + \text{final velocity}}{2} = \frac{U + V}{2} \text{ ....(ii)}$$

Equation (i) = equation (ii)

i.e. $\frac{s}{t} = \frac{U + V}{2}$

$$s = \frac{(U + V)t}{2}$$

but $V = U + at$

$$s = \frac{[U + (U + at)]t}{2}$$

$$s = \frac{Ut + Ut\ at^2}{2}$$

$$s = \frac{2Ut + at^2}{2} = Ut + ½at^2$$

From equation V = U + at, $t = \frac{V - U}{a}$

$$\frac{s}{t} = \frac{V + U}{2}$$

$$\frac{s}{\frac{V - U}{a}} = \frac{V + U}{2}$$

$$\frac{as}{V - U} = \frac{V + U}{2}$$

$2as = (V + U)(V - U)$

$2as = V^2 - U^2$

$V^2 = U^2 + 2as$

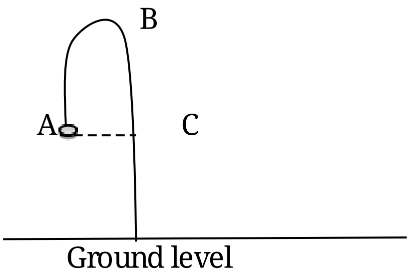
The equations

- ✓ $V = U + at$
- ✓ $s = Ut + ½at^2$
- ✓ $V^2 = U^2 + 2as$

Are referred to as the equations of uniform accelerated motion.

EQUATION OF MOTION UNDER GRAVITY

- o If the stone is thrown vertically upwards from point A with initial speed u, it experiences a deceleration of $10m/s^2$ if there is no air resistance until the speed reduces to zero at the maximum height B.
- o After that, it accelerates as it falls down due to gravity at $10m/s^2$.



- o When an object is thrown upwards, its acceleration due to gravity becomes negative.
- o When downwards, its acceleration is positive.

- Thus, the equation V = U + at becomes V = U – gt.
- Motion downwards, (point B to point C) accelerates $a = g = -10m/s^2$.

  V at point B = 0m/s, V = U + gt, V = 0m/s + gt, V = gt.
- If the maximum height above the starting point is H,

  $S = Ut + ½at^2 \quad \Rightarrow \quad H = Ut + ½gt^2$

  For upward $H = ½gt^2$ since U = 0m/s.
- For motion upwards, $V^2 = U^2 + 2as$ becomes $U^2 = -2gH$ and $V^2 = 2gh$ for downwards.

UNIT NINE

WORK AND ENERGY

WORK

- Is the product of force and distance moved in the direction of the force.

  $W = F \times d$

- SI unit is joule (J)

Examples

1. A stationary trolley was hit by another trolley on the same horizontal flat surface with a force of 20N. If the stationary trolley moved 15m in the direction of the force, calculate the work done.

   $W = F \times d$

   $W = 20N \times 15m$

   $W = 300j$

2. A towing truck was used to tow a broken car through a distance of 30m. the tension in the towing chain was 2000N. if the total friction is 150N, determine

   a. Work done by the pulling force.

      $W = Fd$

      $W = 2000N \times 30m$

      $W = 60{,}000j$

   b. Work done against friction.

      $W = F_r d$

      $W = 150N \times 30m$

      $W = 4500j$

   c. Useful work done.

      $W_{net} = Fd - F_r d$

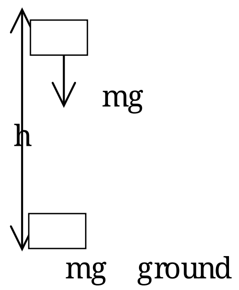
      $W_{net} = 60{,}000j - 4500j$

      $W_{net} = 55500j$

WORK DONE AGINSTFORCE OF GRAVITY

- The gravitational force (weight) acting on a body of mass (m) is equal to the product of mass and acceleration due to gravity.

i.e W = mg



- Work done against gravity to lift a body through height is given by

  Work = Force x Vertical height

  W = mgh

Example

1. Calculate the work done by a weight lifter in raising a weight of 400N through a vertical distance of 1.4m.

   W = mgh

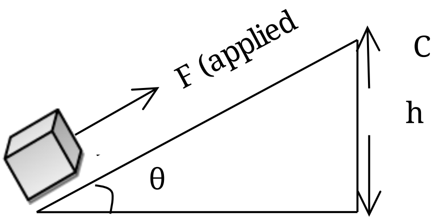
   mg = 400N, h = 1.4m

   W = 400N x 1.4m

   W = 560j

WORK DONE DUE TO INCLINED PLANE

- Consider the inclined plane below of a body of mass (m) moved up by a force (F) through a distance (d).



- Work done by the applied force,

  Work done = force x distance

  W = fd

- Work done against the gravitational force,

  Work done = weight of object x vertical height

  W =mgh

- In case the vertical plane is frictionless force;
  - Work done by applied force = work done against gravity.
- In case there is some frictional force opposing the sliding of the object along the plane
  - Work done by the applied force > work done against gravity.
  - Work done against friction = work done by applied force – work done against gravity.
- Efficiency of the system = $\frac{\text{work done against graivity x 100}}{\text{work done by the applied force}}$

Exercise

1. A box of mass 100kg is pushed by a force of 920N up an inclined plane of length 10m. The box is raised through a vertical distance of 6m.

   a. Calculate

   (i) The work done by the applied force.

   (ii) The work done against the gravitational force.

   b. Why do the answers to (i) and (ii) differ?

WORK DONE BY A FORCE ACTING AT AN ANGLE

- Assuming the applied force is F and the distance d:

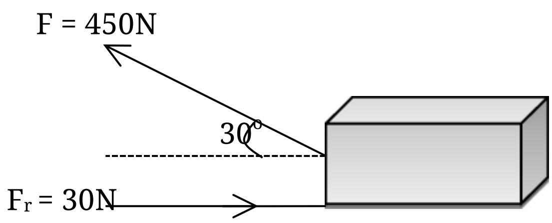
  To calculate work done, find the horizontal component and multiply it with distance moved.

i.e. Horizontal component = $F\cos\theta$

Work done = $F\cos\theta \times d$

Exercise

1. A student pushed a lawn roller with a force of 800N at an angle of 39° to the lawn surface. Calculate the work done if the roller is pushed for 30m.
2. A person pushed a block along a horizontal rough surface as shown in the figure below. The surface has a friction of 30N against the motion of the block. The block moved through a distance of 12m. Calculate work done.



MECHANICAL ENERGY

- Are two classes of mechanical energy:
  - Potential energy: is energy of height

    e.g. gravitational potential energy, elastic (strain) potential energy.

    - ✓ Gravitational potential energy
      - Is the energy possessed by a body by virtue of its vertical position.
      - When a body of mass (m) is raised through a vertical height (h), the work done against gravity is equal to the potential energy gained by the body.

        P.E. = work done against gravity

        PE =mgh

Example

1. A crane is used to lift a body of mass 40kg through a vertical height of 5m.

calculate mmmthe gravitational P.E. stored in the body. Take g = 10m/s^2.

Gravitational P.E. work done = against gravity.

= mhg

= 40kg x 10n/kg x 5m

= 2000j.

2. A stone of mass 100g is projected vertically upward with a velocity of 20m/s. Find the gravitational P.E. at the maximum height reached by the stone. Take g = 10m/s^2

From the equation motion;

$V^2 = U^2 + 2as$

$0^2 = 20^2 + 2(-10)h$

$0 = 400 - 20h$

20h = 400m

h = 20m

Gravitational P.E. = mgh

= 0.100 x 10 x 20

= 20j

- ✓ Elastic potential (strain) energy
  - Is the energy passed by or possessed by a compressed of stretched spring.
  - This energy is due to the state of strain of the object.
  - Work done in stretching the spring :

    = Elastic P.E. gained by the spring

    = average force x extension

    $= \frac{0 \ \ +F}{2}(e)$

$= \frac{1}{2}Fe$

- Work done is stored as elastic potential energy.

Note:

- Since the force is not uniform (F increases from 0 to F), we should use the average force in calculating the work done.

Example

1. Calculate the elastic gravitational P.E. stored in a spring when stretched through 4cm by a force of 2N.

   Elastic P.E. $= \frac{1}{2}Fe$

   $= \frac{1}{2} \times 2 \times 0.04$

   $= 0.04$j

2. Calculate the kinetic energy of a car of mass 1200kg moving with velocity of 40m/s.

   Kinetic Energy $= \frac{1}{2}mv^2$

   $= \frac{1}{2} \times 1200 \times 40^2 = 960{,}000$j.

Exercise

1. A body of mass 400g falls freely from a tower and reaches the ground after 4 seconds. Calculate the kinetic energy of the mass as it hits the ground. Take $g = 10m/s^2$
2. A car of mass 1000kg travelling at 36km/h is brought to rest by applying brakes. Calculate the distance travelled by the car before coming to rest, if the frictional force between the wheels and the road is 2000N.

CONSERVATION OF MECHANICAL ENERGY

- Energy can neither be created nor destroyed but can be only converted from one form to another.
- Loss in potential energy = gain in kinetic energy
- Loss in kinetic energy = gain in potential energy.

  P.E.= K.E.

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

$V_{max} = \sqrt{2gh_{max}}$

Example

1. What is the velocity of an object dropped from a cliff of height 20m just before it strikes the ground? Take g = $10m/s^2$.

   P.E. lost = K.E. gained

   $V = \sqrt{2gh}$

   $V= \sqrt{2 \times 10 \times 20}$

   V = 20m/s

Exercise

1. A girl of mass 25kg rolled down from appoint, A to a point B on the slide of 3m high going down. If the pull of gravity is 10kg/N. Calculate
   a. Potential energy of the girl.
   b. Kinetic energy of the girl.
2. A 150g ball falls vertically downwards from a height of 1.8m on a horizontal plate. On hitting the plate, the ball rebounds to a height of 1.25m. Find the
   a. Velocity of the ball just before hitting the plate.
   b. Kinetic energy of the ball as it hits the plate. Take g= $10m/s^2$.

ENERGY – WORK THREOREM

- The net work done by the net force on the rigid body is equal to the change in kinetic energy of the body.

DERIVATION OF THE ENERGY WORK THEOREM

W = mas

But F = ma

W = mas

But $a = \frac{m(V^2 - U^2}{2s}$

$= \frac{m(V^2 - U^2)}{2}$

Note:

- Note that force is a vector quantity hence a force applied to slow the speed of the object is in the opposite direction (negative) and the net work it does is also.
- The energy-work theorem does not apply if object being acted on by the net force is rigid as some of the energy is used to deform the object.

Example

1. If a constant force of 20N is applied on a trolley of mass;

   Net work = change in K.E.

   $F \times s = \frac{1}{2}m(V^2 - U^2)$

   Substituting for each of the values;

   $20 \times 1.5 = \frac{1}{2} \times 0.5(V^2 - 0^2)$

   $30 = 0.25V^2$

   $V^2 = \frac{30}{0.25} = 120$

   $V = \sqrt{120}$

   $V = 10.95 m/s$

Exercise

1. The frictional force between the wheel of a motor bike and the ground is 150N. The air resistance acting on the motorbike and the cyclist is 90N. A driving force of 960N is applied on the motorbike by the engine over a distance of 5m. If the total mass of the motorbike and the cyclist is 180kg, and it started from rest find the

   a. Resultant force on the motorbike.

   b. Final velocity of the motorbike.

   c. Acceleration of the motorbike.

UNIT TEN

MACHINES

MACHINES

- Is the device that makes work done easier.
- Machines which were discussed in form two were
  - Levers
  - Inclined plane
  - Pulley systems
- Mechanical advantage (M.A.)
  - Is the ratio of the load and effort.

    i.e. Mechanical advantage = $\frac{\text{Load}}{\text{Effort}}$

    M.A. = $\frac{L}{E}$
- Velocity ratio (V.R.)
  - Is the ration of the velocity of the effort to the velocity of the load.

    i.e. Velocity ratio = $\frac{\text{distance moved by the effort}}{\text{distance moved by the load}}$
- Efficiency
  - No machine is perfect.
  - In every machine, some energy is wasted in overcoming friction.

    i.e. energy input = energy output + energy lost against friction.
  - Output is always less than the input.

- Efficiency is the ratio of the energy out put of a machine to its energy input

i.e Efficiency $= \dfrac{\text{energy output x 100}}{\text{energyinput}}$

$= \dfrac{\text{useful work output x 100}}{\text{work output}}$

$= \dfrac{\text{load x distance moved by the load x 100}}{\text{effort x distance moved by effort}}$

$= \dfrac{\text{Load}}{\text{Effort}} \text{ x } \dfrac{\text{distance moved by the load x 100}}{\text{distance moved by effort}}$

But $\dfrac{\text{Load}}{\text{Effort}}$ is M.A, and $\dfrac{\text{distance moved by the load}}{\text{distance moved by effort}}$ is $\dfrac{1}{\text{V.R}}$

$\therefore$ efficiency $= \text{M.A x } \dfrac{1}{\text{V.R}} = \dfrac{\text{M.A x 100}}{\text{V.R}}$

Example

1. A machine is used to lift a load of 400N with an effort of 80N. Calculate;

a. The mechanical advantage of the machine.

M.A. $= \dfrac{L}{E}$

M.A. $= \dfrac{400N}{80N}$

M.A. = 5

b. The efficiency of the machine, if its velocity ratio is 8

Efficiency $= \dfrac{\text{M.A. x 100}}{\text{V.R}}$

Efficiency $= \dfrac{5 \text{ x } 100}{8}$

Efficiency = 62.5%

Exercise

1. An effort of 250N raise a load of 900N through a distance of 5m. If the effort moves through 25m, calculate
   a. The work done in raising the load.
   b. The work done by the effort.
   c. The efficiency of the machine.

TYPES OF MACHINES

- The force multiplier.
  - ➢ Are those that allow a small effort to move a large load
  - ➢ Examples
    - ✓ Levers
    - ✓ Screw jack of a car
    - ✓ Hydraulic press
    - ✓ Hydraulic machines
- The distance or speed multiplier.
  - ➢ Are those that allow a small movement of the effort to produce a large movement of the load.
  - ➢ Examples
    - ✓ Bicycle gears
    - ✓ Levers

LEVERS

- Is rigid bar capable of rotation about a fixed point called pivot (fulcrum).
- Are three types of levers depending on the position of the pivot with respect to the load to be overcome and effort applied.
  - ➢ First order lever
    - ✓ Pivot is between the load and the effort
    - ✓ Examples
      - ▪ Crowbar

- A pair of scissors
- Claw hammer
- See-saw
- spanner

➢ second order lever

✓ Load is between the pivot and effort.

✓ Examples

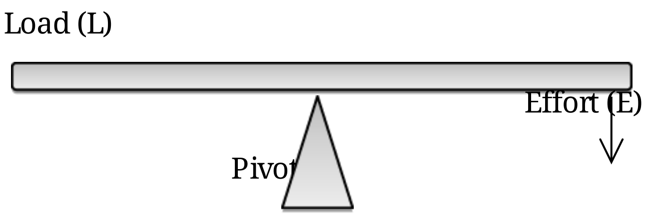
- Wheelbarrow
- Bottle opener

➢ Third order lever

✓ Effort is between the pivot and the load.

✓ Examples

- Fishing rod
- Tweezers
- Forces



INCLINES PLANE

- Is a shape or ramp that enables us to raise heavy loads to a certain vertical height.
- Suppose the load of mass 200kg is pulled along an inclined plane by a force of 1500N, and d = 5m, h = 3m, calculate

a. Mechanical advantage

$$M.A. = \frac{L}{E}$$

$$M.A. = \frac{200 \times 10}{1500}$$

$$M.A. = 1.33$$

b. Velocity ratio

$$V.R = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$$

$$V.R = \frac{5}{3}$$

$$V.R. = 1.67$$

c. Efficiency of the machine

$$\text{Efficiency} = \frac{M.A. \times 100}{V.R.}$$

$$\text{Efficiency} = \frac{1.33 \times 100}{1.67}$$

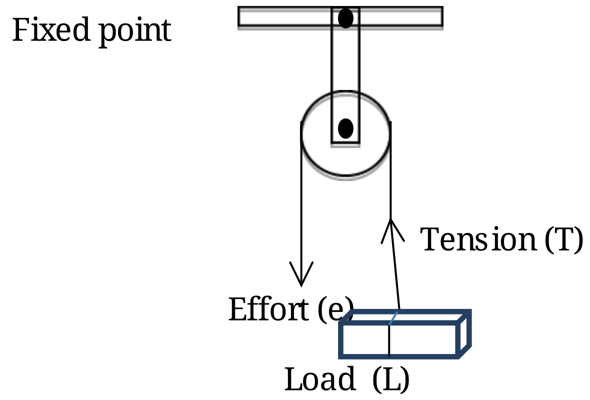
$$\text{Efficiency} = 80\%$$

PULLAYS

- Is usually a grooved wheel of rim.
- Pulleys are used to change the direction of force.

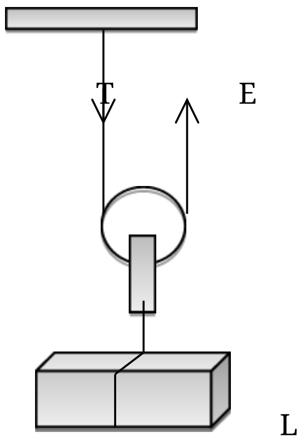
TYPES OF PULLEYS

- Single fixed pulley



- Has fixed support which does not move.
- The tension in the rope is the same throughout
- The load is equal to the effort if there is no loss of energy (no friction).
- The M.A. is therefore 1
- Fixed pulley has the following applications in everyday life
    - ✓ Raising flag.
    - ✓ Raising brick up by the builders.
    - ✓ Raising water from the well.
- Load (L) = tension in rope (T) = effort (E).

• Single moving pulley



- The total force supporting the load is given by the tension (T) plus effort (E).
- Tension force is equal to twice the effort. (2E).
- The load is equal to twice the effort (2E).

$$M.A. = \frac{L}{E}$$

$$M.A. = \frac{2E}{E}$$

M.A. = 2

- The effort move twice the distance moved by the load

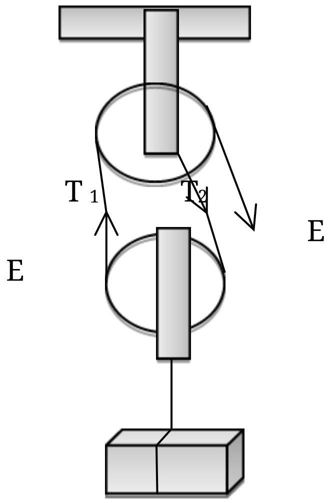
V.R. $\frac{\text{distance moved by effort}}{\text{distance moved by load}} = 2$

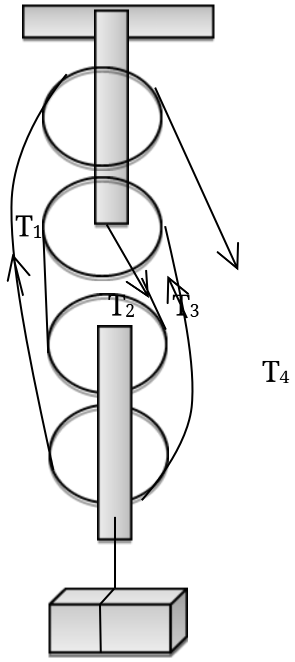
- 2T = L

T = E

2E = L

- Block and tackle pulley





- Consists of two pulley sets.
- One set is fixed and the other is allowed to move.
- Pulleys are usually assembled side by side in a block or frame on the same axle.
- The pulleys and ropes are called the tackle.
- 4T = L

T = L

4E = L

NOTE:

- In a perfect pulley system, the mechanical advantage is equal to the velocity ratio and both are equal to the number of sections of the string supporting the load.
- The weight of the block in the lower section of the system and fraction in the pulley reduces the mechanical advantage of the system.
- Velocity ratio of a pulley system is numerically equal to the number of string sections supporting the load.

SREWS AND BOLTS

- Are used daily to hold things together.

- The distance between the two successive threads is called pitch.
- When the screw is turned through one revolution by a force applied at the screw head, the lower end moves up or down through a distance equal to its pitch.
- The working of screws and bolts is based on the principle of an inclined plane.

THE WHEEL AND AXLE

- Screw driver, steering wheel, a box spanner, a brass and windless are examples of wheel and axle.
- Revolution of the wheel, effort moves through a distance $2\pi R$ while the load moves through a distance of $2\pi r$ where

  R = wheel radius

  R = axle radius.

- The velocity ratio = $\frac{\text{distanc covered by effort}}{\text{distance covered by load}}$

$$V.R. = \frac{2\pi R}{2\pi r}$$

$$V.R. = \frac{R}{r}$$

- Mechanical advantage may be calculated using the principle of conservation of energy

  i.e. Work done by effort = work done on the load

  Effort x $2\pi R$ = load x $2\pi r$

  $$M.A. = \frac{L}{E}$$

  $$M.A. = \frac{2\pi R}{2\pi r}$$

  $$M.A. = \frac{R}{r}$$

- In wheel and axle, M.A. = V.R.

GEARS

- Are toothed wheels of different diameters.
- They turn together with their axles.
- Are designed to raise or lower the speed of the rotation.
- Effort is applied on one axle while the load acts on another axle of the gear wheel.
- Input gear wheel / the driving wheel provides the effort.
- The output wheel/driven wheel works against the load.
- When the gears are fitted into each other, they are said to be engaged or meshed.
- The larger gear with more teeth always turns slowly.

RELATIONSHIP BETWEEN THE TWO GEARS

- $\frac{\text{Number of teeth on a small wheel}}{\text{Number of teeth on a large wheel}} = \frac{\text{speed of rotation of large wheel}}{\text{speed of rotation of smaller wheel}}$
- when the time of rotation is the same:

$$V.R. = \frac{\text{Speed of rotation of driving wheel}}{\text{Speed of rotation of the driven wheel}}$$

$$V.R. = \frac{\text{Revolution per second of the driving wheel}}{\text{Revolution per second of the driven wheel}}$$

$$V.R. = \frac{\text{number of teeth on the driven wheel (load}}{\text{Number of teeth on the driven wheel (Effort)}}$$

- Velocity ratio may be greater or less than one.
- In cars, V.R. can be changed at will.
- The gear box has a set of gears that can be combined in a number of ways.
- In climbing up a hill, the mechanical advantage and velocity ratio have to be high.
- A smaller gear should drive a large gear wheel.
- On flat road or going down the hill, the weight of the car is not part of the load.
- This requires lower mechanical advantage and low velocity ratio.

CHAINS AND BELTS

- A wheel can be driven by another wheel although they are not in direct contact.

  e.g. conveyor belts
- This has the same velocity ratio as that of a pair of gear wheel of radii but not in contact.
- The only difference is that the two wheels rotate in the same direction unlike the gear wheels.
- A toothed wheel can also be driven by another one not in contact.

  e.g. bicycle chain.
- The velocity ratio is obtained in the same way as in the gears system

HYDRAULIC MACHINE

- Consist of two pistons of different diameters and liquid contained in a vessel
- The bigger piston is called the vam piston while the smaller one is called the

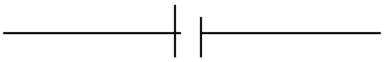
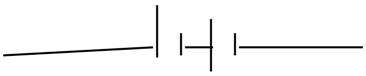
pump piston.

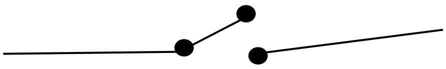
UNIT ELEVEN

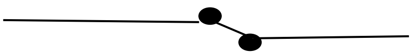
ELECTRIC CURRENT AND POTENTIAL DIFFERENCE

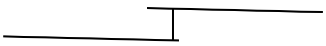
BASIC SYMBOLS

Name the following basic circuit symbols

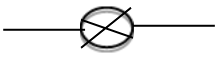
- Cell 
- Battery 
- Power supply 

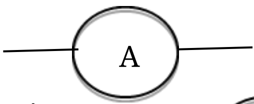


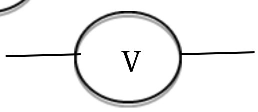
- Open switch 



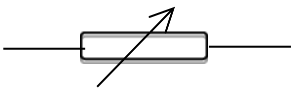
- Close switch

- Wire joined 

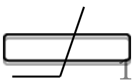


- Connecting wire 

- Lamp

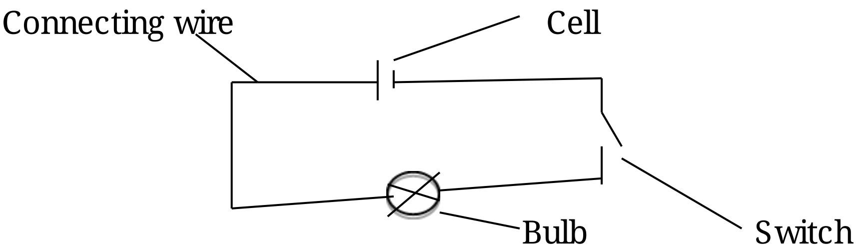


- Ammeter 



- Voltmeter
- Resistor
- Variable resistor
- Diode
- Thermostat
- Light depending resistor
- Light emitting diode (LED)

COMPONENTS OF A CIRCUIT



ELECTRIC CURRENT

- Is the rate of flow of charges
- Is the movement of charged particles called electrons.
- The conducting path through which electrons move is called electric circuit.

$$I = \frac{\text{Charge (Q)}}{\text{Time (s)}}$$

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

- The SI unit of current is the ampere (A).
- Ampere is the amount of charge per second.

$$A = \frac{\text{Coulomb}}{\text{Seconds}}$$

- Smallest current can be measured in milliamperes (mA) and microamperes (μA)

$1mA = 1 \times 10^{-3}A$

$1\mu A = 1 \times 10^{-6}A$

DETERMINING THE TOTAL CHARGE PASSING THROUGH A POINT IN A CIRCUIT

- Is (n) electrons pass through a point A and that each electron carries e coulombs of charge then the total charge (Q) passing through point A is equal to the (ne)

$Q = ne$

But $Q = It$

$\therefore It = ne$

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

Example

1. Calculate the amount of charge that passes through a point in a circuit in 3 seconds if the current in the circuit is 0.5A.

$Q = It$

$Q. = 0.5A \times 3sec$

$Q = 1.5C$

Exercise

1. How long would it take for a charge of 1200μC to flow when a current of 0.01A is flowing in a circuit.

2. Find the amount of current passing through a lamp if 600C of charge flows through it in 4 minutes.

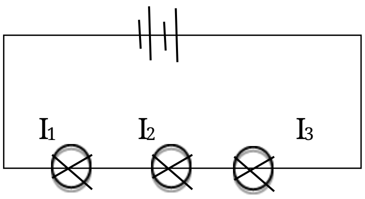
MEASURING OF ELECTRIC CURRENT

- Is measured using an instrument called an ammeter.
- An ammeter is connected in series in a circuit.
- Positive terminal of an ammeter is connected to a positive terminal of a cell/battery again with the negatives connected.

CURRENT IN SERIES CIRCUIT

- Is the same at any point in a circuit.

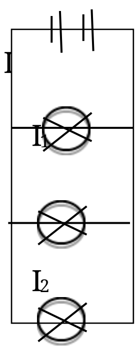
i.e. $I_1 = I_2 = I_3$



CURRENT IN PARALLELL CIRCUIT

- The total current in equal to the sum of the current components in the circuit.
- It is not the same at different points.

i.e. $I_T = I_1 + I_2 + I_3$



POTENTIAL DIFFERENCE (pd)

- Is the work done in moving one coulomb of charge from one point to another.
- The SI unit of potential difference is volt (V).

$$\text{Volt} = \frac{\text{Joule}}{\text{Coulomb}}$$

$$\therefore \text{pd (V)} = \frac{\text{work done (J)}}{\text{charge moved (C)}}$$

THE VOLT

- Is one joule needed to move one coulomb of charge from one point to another.
- Pd indicates the energy given to each coulomb of charge in a circuit.

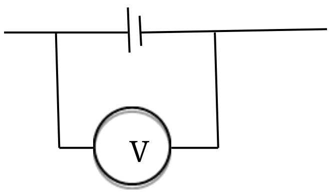
MEASURING POTENTIAL DIFFERENCE

- Is measured using and instrument called the voltmeter.
- Voltmeter is connected in parallel in the circuit because it has high resistance.

ELECTROMOTIVE FORCE (emf)

- Is the energy available between the terminals of the cell per coulomb for the complete circuit.

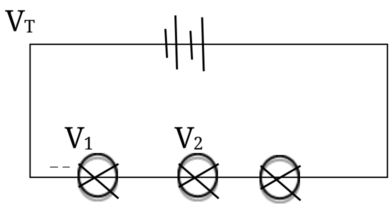
i.e.



VOLTAGE IN SERIES CIRCUIT

- The emf is equal to sum of the pd.

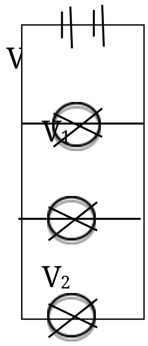
i.e. sum of the voltage in the circuit gives total voltage.



$V_T = V_1 + V_2 + V_3$

VOLTAGE IN PARALLEL CIRCUIT

- Is the same across the components in the circuit.



$V_0 = V_1 = V_2 = V_3$

UNIT TWELVE

ELECTRICAL RESISTANCE

ELECTRICAL RESISTANCE

- It is the opposition to the flow of an electric current in a circuit.
- It is the voltage per unit current.

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

- It is measured in ohms (Ω).

$$1\Omega = \frac{V}{A}$$

FACTORS AFFECTING RESISTANCE

- The length of a conductor.
- The cross sectional area of a conductor.

- Type of material a conductor is made of.
- Temperature.

OHM'S LAW

- States that the current (I) flowing in a conductor is directly proportional to the potential difference (V) across it if the temperature and other physical quantities of the conductor remain constant.

  $V \alpha I$

  $V = KI$

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

- Ohm's law established by George Simon Ohm.
- Most metals and some non-metals obey this law.

OHMIC CONDUSTORS

- Are all conductors that obey Ohm's Law.

NON-OHMIC CONDUCTORS

- Are all materials which do not follow Ohm's Law.

  $V \alpha I$

  $V = KI$

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

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

- Therefore, resistance is defined as the ratio of p.d (V) across the ends of a conductor to the current (I) passing through it.

TYPES OF RESISTORS

- Fixed resistors
  - ➢ Are the ones whose resistance is almost constant.
  - ➢ Are made from variety of materials.

- ✓ Carbon.
- ✓ Carrier materials.

➢ These are baked and covered with ceramic tube.

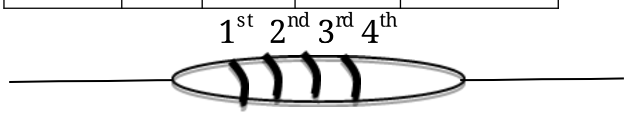
➢ Colour code for carbon resistors

- ✓ Has four colour codes.
- ✓ First code and second gives first and second digits from the left.
- ✓ The third gives number of zeros added to the two digits.
- ✓ The fourth colour gives tolerance.
- ✓ Table below shows colour codes and their values

Colour	Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Grey	White
Value	0	1	2	3	4	5	6	7	8	9

- ✓ Table below shows colour codes for tolerance

Colour	Red	Gold	Silver	No colour
±	2	5	10	20



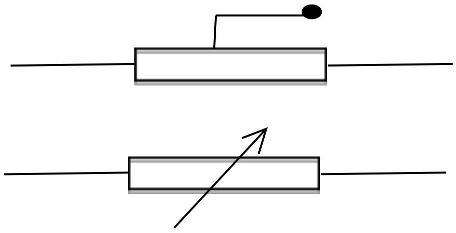
- ✓ If 1st is green, 2nd is blue, 3rd is green and 4th is silver, the resistor has the value of 5,600,000 ±10%

➢ Standard notation

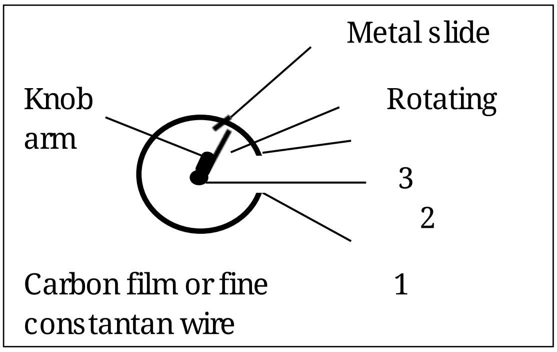
- ✓ In some fixed resistors, the resistance is printed on the resistor.
- ✓ To simplify coloured resistors, most of them have standard notations as follows
  - R27 = 0.27Ω
  - 2R7 = 2.7Ω
  - 3R0 = 3000Ω

- 47R = 47kΩ
- 2M2 = 2.2 MΩ

- Variable resistors
  - Are the ones whose resistances can be varied.
  - Uses the following symbols



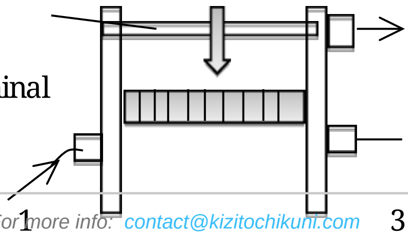
  - Are of two types namely
    - ✓ Circular type of rheostat



- A knob is connected to the rotating arm.
- The knob turns the rotating arm carbon film for small control of current.
- When it is connected to terminal 1 and 3, you get a maximum resistance which cannot be changed.
- Terminals 2 and 3 are used to control/vary the resistance.

    - ✓ Straight variable rheostat

- Most commonly used in the laboratories.
- Terminals 1 and 3 provide fixed resistance while 1 and 2 provide a variable resistance.



INTERNAL RESISTANCE (r)

- When the cell is driving current through itself, it loses some voltage called internal resistance.
- This results from properties of the substances used in the construction of the cell.

USES OF ELECTROMOTIVE FORCE

1. Driving the current through the cell to overcome internal resistance.
2. Driving the current through the external resistance (r).

- The total emf is given by p.d. across external resistance (R) + p.d. across internal resistance (r).

  $\varepsilon = IR + Ir$

  $\varepsilon = I(R + r)$

UNIT THIRTEEN

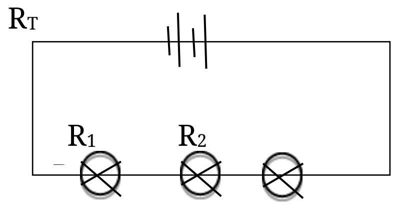
ELECTRIC CIRCUIT, ENERGY AND POWER

ELCTRIC CIRCUIT

- Is the rate of energy consumption by a device in a given time and cost.

ARRANGEMENTS OF RESISTORS IN A CIRCUIT

- Resistance in series circuit



$V_T = V_1 + V_2 + V_3$

But V = IR and I is the same at every point in series.

$\therefore IR_T = IR_1 + IR_2 + IR_3$

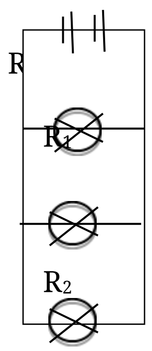
Divide by I at every point

$$\frac{IR_T}{I} = \frac{I(R_1 + R_2 + R_3)}{I}$$

$R_T = R_1 + R_2 + R_3$

- In series, the sum of the resistance in the components is equal to the total resistance in the circuit.

- Resistance in parallel circuit



$I_T = I_1 + I_2 + I_3$

But $I = \frac{V}{R}$ and V is the same at every point in parallel circuit.

$$\therefore \frac{V}{R_T} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{V}{R_T} = V\left(\frac{1}{R_T} + \frac{1}{R_T} + \frac{1}{R_T}\right)$$

Dividing by V both sides

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

- Sum of the inverse of the resistance in the components is equal to the inverse of the total resistance.

ELECTRICAL ENERGY

- Is the amount of work to be done.
- When current flows through the conductors, is converted into forms of energy such as heat, sound, light, etc.
- Most appliances give out heat.
- So, electricity has heating effect.

FACTORS AFFECTING HEATING EFFECT OF AN ELECTRIC CURRENT

1. Amount of current.
2. Resistance of a conductor (substance).
3. Time for which current flows.
4. The potential difference across a conductor.

FORMULA FOR ELECTRICAL ENERGY

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

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

$\therefore W = VQ$ ....(i)

But $I = \frac{Q}{t}$ where t is in seconds.

$\therefore Q = It$ ....(ii)

But $V = IR$

$\therefore W = I^2Rt$ .... (iii)

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

$\therefore W = (\frac{V}{R})^2Rt$

$W = \frac{V^2t}{R}$ ....(iv)

But $W = E$

$\therefore E = \frac{V^2t}{R}$

Exercise

1. A current of 2.0A is passed through a resistor of 20Ω for 1.0 hours. Calculate the electrical energy converted into heat energy in the resistor.
2. Find an electrical energy consumed in a circuit if the current was allowed to flow for 3 hours whose resistance is 1Ω and current of 3A.
3. An electric iron consumed 2.592mj of energy in 1 hour when connected to the mains power supply of 240V. Calculate the current through the filament in the electric iron.

ELECTRICAL POWER

- Is the rate of electrical energy into other forms of energy.

$$\text{Power} = \frac{\text{Energy}}{\text{time}}$$

$$P = \frac{E}{t} \text{ .... (i)}$$

But E = QV

$$P = \frac{QV}{t} \text{ ....(ii)}$$

But Q = It

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

$$P = IV \text{ ....(iii)}$$

When V = IR

$$P = I^2R \text{ ....(iv)}$$

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

$$P = \frac{V^2R}{R^2}$$

$$P \frac{V^2}{R} \text{ ....(v)}$$

Exercise

1. A torch bulb is labelled 2.5V, 0.3A. Calculate the power of the bulb.

2. An electric bulb labelled 40w, 240V. Calculate
   a. The resistance of the filament used in the bulb.
   b. The current through the filament when the bulb works normally.

POWER RATING

Appliance	Power rating
Filament	85w – 150w
Refrigerator	150w
Television	200w
Electric iron	750w
Room heater and grill	1 – 3kw
Electric kettle	2 – 3kw
Immersion heater	3kw
Electric cooker	3 – 5kw

COST OF ELECTRICAL ENERGY

- The commercial units of electrical energy are worked out from the equation E = Pt where P is power in kw and t in hours.
- Therefore, its unit is kilowatthour (kwh).
- In Malawi, ESCOM is responsible for charging the electrical energy used by any appliance or the houses.
- Amount of energy used is calculated by subtracting previous reading from current reading.
- This is multiplied by cost per kwh.
- Energy, Mines, Natural Resources and Energy (MAREP) charges tax of 4.5% and Malawi Energy Regulatory Authority (MERA) charges 1%.
- Surtax of 16.5% for consumption is charged on it.

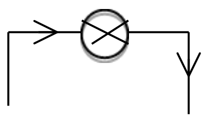
Exercise

1. What is the cost of heating water in a tank with a 3kw heater for 90 minutes if the cost of electricity is K25.4 per unit.
2. Calculate the total bill for using a television set rated 200w for 10 days, and electric kettle rated 2.5e for 30 days at the rate of K25.4 per unit and a surtax

of 16.5% of the consumption.

DOMESTIC WIRING

- The domestic supply is 240V ac with frequency of 50Hz.
- Is supplied by two cables from a local sub-station.
- Cables are live wire (L) and neutral wire (N).
- Live wire is linked to the positive terminal of a cell or battery while neutral wire to the negative terminal.



- The switch in the circuit must be fitted in the live wire.
- This is to switch on or off.

COLOUR CODES FOR WIRES USED IN THE HOUSE WIRING

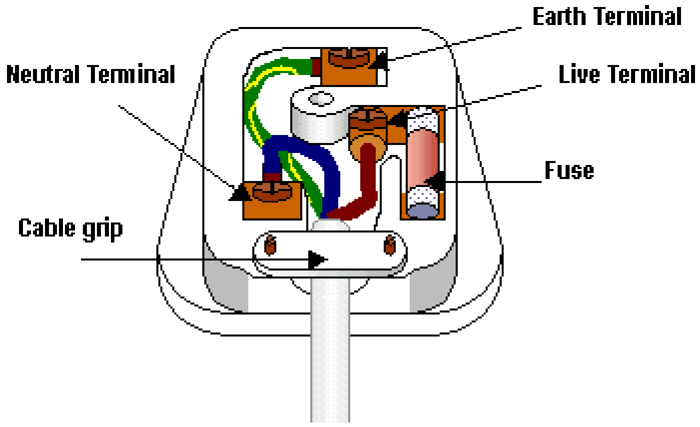
1. Brown for live (red is commonly used in Malawi)
2. Blue for neutral.
3. Green/yellow/green striped yellow for earth.

- Make sure that the earth lead goes to the metal case of the appliance.

FUSE

- Is a short thin piece of wire of low melting point.
- It melts as soon as the current exceeds its rated value.
- Is fitted in the circuit to prevent dangerously large current from flowing.
- Should be fitted in live wire like the switch.

THREE PIN PLUGS AND SOCKET



THREEE PIN PLUG SOCKET

THREEE PIN PLUG

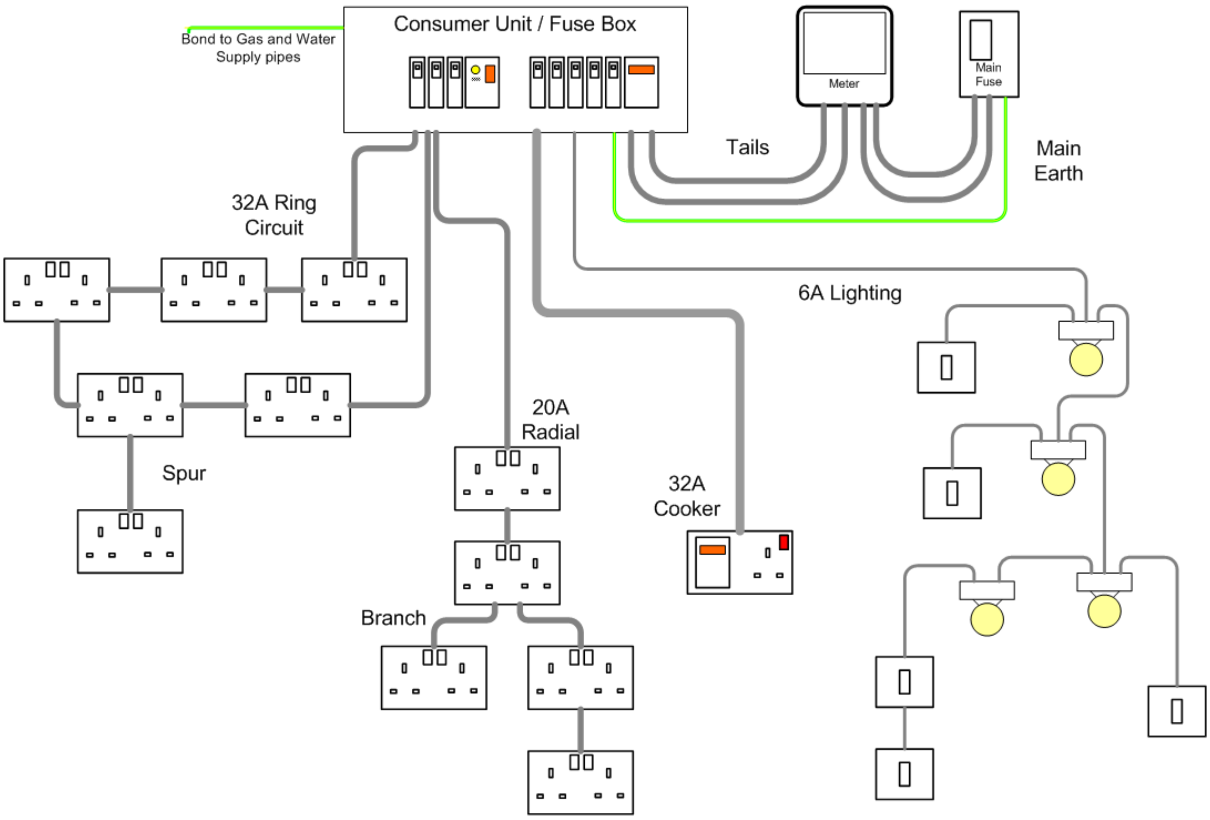
- Note that the earth pin is longer than the other pins.

- The live pin is on the right hand side of the plug when connect to the socket.

EARTH CONNECTION

- Earth connects the metal case of an appliance to the ground.
- This prevents it from becoming live (prevents shock).
- If there is no earthing (using two pin plug), a person who touches the metal case would get an electric shock.
- Appliances with non-metallic case can be connected using a two pin plug.

HOUSE HOLD WIRING



- Every circuit connected in parallel with power supply i.e. across live and neutral wire.
- This gives every circuit to 240V a.c.
- The electricity records the electrical energy consumed in the whole house.
- Consumer box distributes current to several separate circuits.
- Consumer box also houses the main switch.
- The lighting circuits contains all lights for the whole house.

- The ring main circuit provides parallel circuit connections to each electrical appliance plugged into the socket.

ELECTRICAL HAZARDS

- Hazards are all situations that pose a threat to life, health, property or environment.
- These include
  1. Poor wiring and defective electric wires.
  2. Water outlets being close to electric outlets.
  3. Pouring water on electric fire.
  4. Covering electrical cords and wires with heavy electrical cover can lead to overheating.
  5. Over loading the outlet leading to overheating and electrical fire.
  6. Use of long extension cords which can cause tripping or accident.
  7. Touching electrical appliance with wet hands leading to electrical shock.
  8. Broken sockets and electrical appliances leading to electrical shock.

ELECTRICAL SAFETY

1. Do not touch naked electric cables with bare hands to avoid electric shock.
2. Always pay attention to the warning signals given out by appliances.
3. Use the right size circuit breakers and fuse to avoid overloading.
4. Ensure that potential dangerous electrical devices or naked wires are out of reach of children.
5. You should avoid cube taps and other outlet-stretching devices.
6. Always replace broken plugs and naked wires.
7. Use the correct appliances in a correct socket to avoid overloading.