CIE Physics IGCSE

Topic 1: General Physics

Summary Notes

Length and time

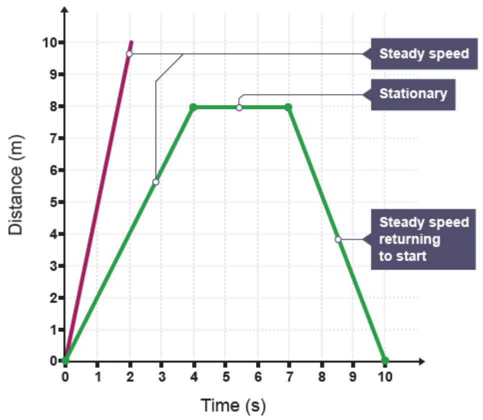
- A ruler (rule) is used to measure the length of an object between 1mm and 1m.
- The volume of an object of irregular shape can be measured by placing it into a measuring cylinder full of water. This causes the water level to rise, and this rise is equal to the volume of the object.
- **A micrometer screw gauge is used to measure very small distances that a rule cannot measure.**
- Analogue and digital clocks and devices are used to measure time intervals.
- An average value for a small distance and for a short time interval can be found by measuring multiples (including the period of a pendulum).

Motion

- Speed is defined as the distance traveled per unit time. If the speed of something is changing, it is accelerating. The acceleration of free fall near to the Earth is constant.
- $average\ speed = \frac{total\ distance}{total\ time}$ $v = \frac{d}{t}$
- Distance is measured in mm, cm, m or km and time measured in ms, s, minutes or hours. Remember to convert units to make sure everything is equivalent! For example if distance is in km and time is in $hours$, then calculate $\frac{distance}{1000}$ and $time \times (60 \times 60)$to get everything in metres and seconds.
- **Velocity is the speed in a given direction.**
- **Acceleration is the rate of change of velocity:** $\boldsymbol{acceleration = \frac{change\ in\ velocity}{time}}$ $\boldsymbol{a = \frac{v-u}{t}}$

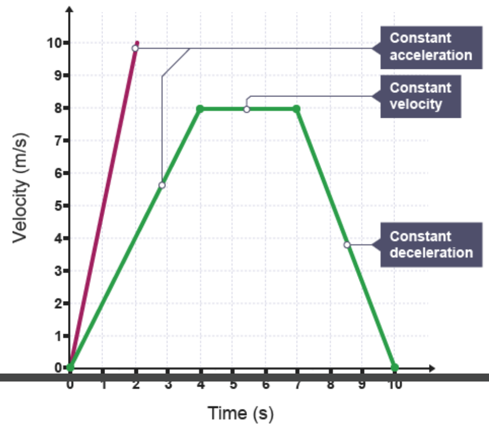
In a distance-time graph:

- **The gradient is velocity**
  - **Negative gradient is returning back to the starting point**
- A horizontal line means it is stationary
- If the distance is zero, it is back at the starting point
- **A curved line means that the velocity is changing and it is accelerating.**



In a speed-time graph:

- The gradient is acceleration
  - **Negative gradient (i.e. negative acceleration) is deceleration**
- If the speed is zero, it is at rest
- A horizontal line means constant speed
- The area under the line is the distance travelled
- **A curved line means that the acceleration is changing.**



Mass and weight

Mass:

- Mass is a measure of how much matter is in an object.
- **It is a property that resists change in motion.**

Weight:

- Weight is a gravitational force **(the effect of a gravitational field on a mass)** measured in Newtons: $weight = mass \times gravitational\ field\ strength = mg$
- The gravitational field strength on Earth is $10Nkg^{-1}$.
- Weights (and hence masses) can be compared using a balance.

Same object on two different planets:

- The mass is the same
- The gravitational field strength g on the two planets will be different (i.e. not 10 for both) so the weight is different.

Acceleration in free fall is due to gravity, and is the same as g, i.e. $10ms^{-2}$

Density

- The density is defined as the mass per unit volume: $density = \frac{mass}{volume}$ $\rho = \frac{m}{V}$
- The density ρ is in kilograms per metre cubed, kg/m^3, the mass m is in kilograms, kg, and the volume V is in metres cubed, m^3.

To find the density of a liquid:

- Find the mass of the measuring cylinder by placing it on a balance, then fill it with the liquid and measure the new mass. The difference in masses is the mass of the liquid.
- The volume can be read from the cylinder and the density calculated using the equation.

To find the density of solid:

- Measure the mass of the solid by placing it on a balance.
- If the solid is regularly shaped, measure its dimensions using a ruler or other measuring tool and then use a mathematical formula to find the volume.
- If the solid is irregularly shaped, immerse it in water and measure the volume of the water displaced. This is the volume of the solid.
- Find the density using the equation.

The density of water is $1g/cm^3$; if the density of an object is greater than this it will sink in water - if less, it will float.

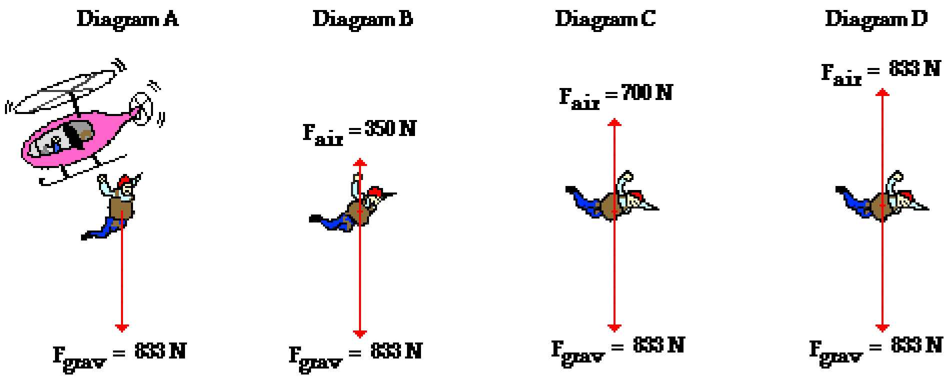
Forces

Effects of forces

- Newton's first law states that an object has a constant velocity unless acted on by a resultant force.
- **Newton's second law states that** $force = mass \times acceleration\ F = ma$
- Newton's third law states that every action force has an equal and opposite reaction force. For example, the force of the Earth's gravity on an object is equal and opposite to the force of the object's gravity on the Earth.

For example, motion of a body falling in a uniform gravitational field:

- **Initially, there is no air resistance and the only force acting on it is weight**
- **As it falls, it accelerates which increases its speed and hence air resistance**
- **This causes the resultant force downwards to decrease**
- **Therefore the acceleration decreases, so it is not speeding up as quickly**
- **Eventually they are equal and opposite and balance so there is no resultant force**
- **So there is no acceleration and the terminal velocity is reached**



Friction is a force between two surfaces which impedes motion and results in heating. Air resistance is a form of friction.

To find the resultant of two or more forces acting along the same line, they should be added together if in the same direction and subtracted if in the opposite direction.

For an object moving in a circle, with constant speed:

- **The speed is constant, but the direction is always changing**
- **This means the velocity is always changing**
- **Therefore it is accelerating and there must be a force perpendicular to its velocity towards the centre of the circle.**

A force may produce a change in size and shape of a body. This is called deformation:

- Elastic deformation:
  - The object returns to its original shape when the load has been removed, an example being a spring being stretched under normal usage.
- Plastic deformation:
  - The object does not return to its original shape when the load has been removed, an example being a spring that has been stretched too far.

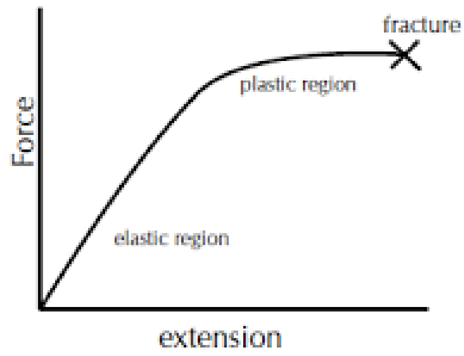
Hooke's law states that for a spring, $F = kx$ where F is the force applied to the spring in N, k is the spring constant in Nm^{-1}, and x is the extension in m.

Linear (straight line) force-extension graph:

- **Elastic deformation following Hooke's law**
  - **The point it stops being linear is called the limit of proportionality. From then on, it does not obey Hooke's law.**
- **Gradient is the spring constant, k**

Non-linear (curved line) force-extension graph:

- **Plastic deformation not following Hooke's law**
- **After the plastic region, it will fracture**

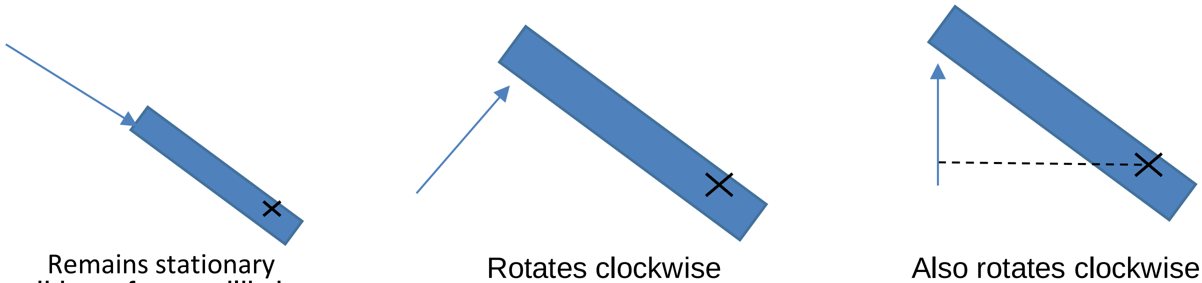


Turning effect

The moment of a force is a measure of its turning effect: $moment\ of\ a\ force = force \times perpendicular\ distance$ $\quad moment = Fd$

For example, when riding a bike, pressing your foot down on the pedal causes a moment about the pivot, turning the pedal arms.

- The pivot point is the point which the object can rotate about.
- If a force is applied in the same line as the pivot (see first example in diagram) the object will not rotate, and will remain stationary.
- If the force applied is in a different line to the pivot, it will rotate in the direction of the force.
  - If it is perpendicular to the object, then the perpendicular distance is the length of the object (see second example in diagram).
  - If it is not perpendicular to the object, then the perpendicular distance to the pivot must be found (see third example in diagram).



Conditions for equilibrium

An object is in equilibrium when the sum of clockwise moments equals the sum of anticlockwise moments (the principle of moments) and there is no resultant force.

The principle of moments can be applied to check whether something balances. **An experiment can be performed to show that there is no net moment on a body in equilibrium by pivoting a uniform ruler at its centre and placing different masses at different distances from the centre on either side until it balances, and showing that the clockwise and anticlockwise moments are equal.**

Centre of Mass

The centre of mass of a body is the point at which all of its mass can be considered to act. To calculate the centre of mass of a card:

1. Hang up the card and suspend a plumb line from the same place.
2. Mark the position of the thread.
3. Repeat the above steps with the card suspended from different places.
4. Where these lines intersect is the centre of mass.

If the centre of mass is below the point of suspension of an object, it will be in stable equilibrium (e.g. a hanging plant pot). If the centre of mass is above the point of suspension of an object, it will be in unstable equilibrium (e.g. a pencil placed on its sharp end). If the line of action of the object's weight moves outside the base, there will be a resultant moment and it will topple.

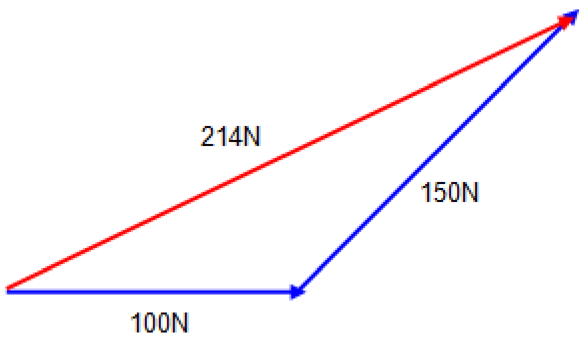
Scalars and vectors

- **A vector has a magnitude and a direction.**
- **A scalar has just a magnitude.**

Examples:

Scalars	**Vectors**
Distance	**Displacement**
Speed	**Velocity**
Time	**Acceleration**

- **Vectors can be represented by arrows. To determine the resultant of two vectors graphically, they must be placed head to tail; the line between the start and finish is the resultant.**



Momentum

- **Momentum is the product of mass and velocity:** $momentum = mass \times velocity \quad p = mv$
- **Impulse is the product of force and time, equal to the change in momentum:** $impulse = Ft = mv - mu$

In a collision, the total momentum before is equal to the total momentum afterwards, known as the principle of the conservation of momentum.

In elastic collisions, the total kinetic energy before is equal to the total kinetic energy after.

Example:

- **A 10kg stationary gun is loaded with a 10g bullet. It is fired, with the bullet travelling at $100ms^{-1}$. What is the recoil speed of the gun?**

$$total\ momentum\ before = 0$$

$$total\ momentum\ before = total\ momentum\ afterwards$$

$$0 = 0.01 \times 100 + 10v$$

$$v = -0.1ms^{-1}$$

So the recoil speed is $0.1ms^{-1}$ (-0.1ms^{-1} is the velocity which is a vector, so we take the magnitude of it as we are finding the speed).

Energy, work and power

Energy transfers

Energy can be transferred between different forms including kinetic, gravitational potential, chemical, elastic potential, nuclear and internal energy as a result of an event or process.

- **Kinetic energy:** $E_k = \frac{1}{2}mv^2$
- **Gravitational potential energy:** $E_p = mgh$

Energy can be transferred in various ways including:

- Forces e.g. when gravity accelerates an object downwards and gives it kinetic energy.
- Electrical currents e.g. when a current passes through a lamp and it emits light and heat.
- Heating e.g. when a fire is used to heat up an object.
- Waves e.g. vibrations cause waves to travel through the air as sound.

Work is done when a force moves something through a distance. The work done is equal to the energy transferred.

- **Work done:** $\boldsymbol{work\ done = force \times distance \quad W = Fd}$

Power is the rate at which energy is transferred or the rate at which work is done. For example, a lamp with a greater power will be brighter because it transfers more energy from electrical energy to light and heat energy in a given time.

- **Power:** $power = \frac{energy\ transferred}{time} \quad P = \frac{E}{t}$

Energy is always conserved. The total energy before is equal to the total energy after.

For example, when a ball is dropped, gravitational potential energy becomes kinetic energy as it accelerates downwards. Upon impact with the floor, this kinetic energy will become thermal energy and sound energy.

In any event or process energy tends to become more spread out among the objects and surroundings (dissipated).

- The efficiency is the ratio of the useful work done to the total energy supplied, often expressed as a percentage.
    - **Efficiency:** $\boldsymbol{efficiency = \frac{useful\ energy\ output}{total\ energy\ input} = \frac{useful\ power\ output}{total\ power\ input}}$
- The efficiency of a system can be increased by:
    - Reducing waste output (lubrication, thermal insulation, etc.)
    - Recycling waste output (e.g. absorbing thermal waste and recycling it as input energy)

Energy sources

It is important to note that apart from geothermal, nuclear and tidal, the sun is the original source of all energy on earth, released by nuclear fusion.

- Renewable energy is energy which can be replenished as quickly as it is used. Examples include:
    - Biofuel
    - Wind
    - Hydro-electricity
    - Geothermal
    - Tidal
    - Solar
    - Water waves

  It is often more costly and less reliable than non-renewable energy (e.g. the wind is intermittent and solar energy relies on good weather).

- Non-renewable energy is used more for large-scale energy supplies due to the large energy output per kilogram of fuel. Examples include:
    - Fossil fuels (coal, oil, gas)
    - Nuclear fuel

  It is usually cheaper than renewable energy but is becoming less popular because one day it will run out and it is harmful for the environment (e.g. burning fossil fuels releases greenhouse gases which cause global warming).

Pressure

Pressure in fluids causes a net force at right angles to any surface and is measured in Pascals.

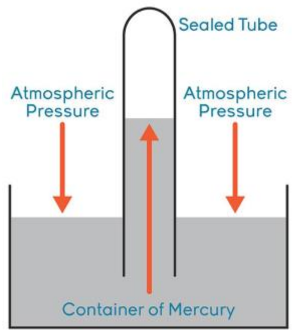
$$pressure = \frac{force}{area} \qquad p = \frac{F}{A}$$

For example, lying down on a bed of nails compared to a single nail:

- The force applied is the weight of your body
- The total area is either a single pin point or many points spread out over a larger area
  - So on a bed of nails, the pressure is lower as the area is greater.

Measuring pressure:

- A barometer consists of a tube filled with mercury with a vacuum at the top. Atmospheric pressure pushes down at the sides causing the mercury to rise. The height of the mercury is measured to find atmospheric pressure, where 760 mm or 29.92 in of mercury corresponds to 1 atm.
- A manometer consists of a U-tube filled with mercury and with a gas at either end. The difference in the height of the mercury on either side can be measured to find the pressure difference between the two ends of the tube.



The pressure beneath a liquid surface increases with depth and density.

- **It is given by $p = \rho g h$**