IGCSE & O Level

PHYSICS

Revision Guide

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Contents

1 Physical Quantities, Units and Measurement

After reading this unit, you will be able to

(a) state that a physical quantity needs magnitude along with a unit
(b) state that there are two types of physical quantities, base and derived quantities.
(c) recognise and use of System International (SI) units and their prefixes.
(d) differentiate between the terms scalar and vector.
(e) list the vectors and scalars from distance, displacement, length, speed, velocity, time, acceleration, mass and force.
(f) determine the resultant of two vectors by a graphical method.
(g) describe how to measure a variety of lengths with appropriate accuracy using tapes, rules, micrometers and callipers.
(h) describe how to measure a variety of time intervals using clocks and stopwatches.

Key Definitions

physical quantity	any measurable characteristic of an object
magnitude	a numerical value that represents a measurement
unit	a part of a physical quantity that is used as a standard while measurement
prefix	a term used for multiple or sub-multiple of 10
scalar	a physical quantity that has magnitude but no direction
vector	a physical quantity that has both magnitude and direction
parallax error	an error in a measurement that occurs because of wrong positioning of eye
least count	minimum value of a measurement that can be observed accurately with the help of a measuring device
oscillation	of a clock pendulum is its journey from one extreme position to the other and then back to the first.
frequency	number of complete oscillations made in 1 s
period	time taken for 1 complete oscillation

1.1 Physical Quantities and Units

- **Physics** is the study of matter and energy and the interrelationship between them.
- Major branches of physics are general physics, thermal physics, waves, electricity, magnetism, and atomic physics.
- Any measurable characteristic of an object is called **physical quantity**. Some of the commonly used physical quantities are distance, mass, time, force, speed, volume, temperature, electric current and pressure.
- A physical quantity is expressed using **magnitude** which is a number along with an appropriate unit.

fig. 1.1

- Physical quantities are of two types:
  - i. **Base quantities** are the physical quantities in terms of which other physical quantities can be described. Distance, mass and time are examples of base quantities.
  - ii. **Derived quantities** are the physical quantities which can be described in terms of base quantities. Velocity, acceleration and force are examples of derived quantities.
- A **unit** is a part of a physical quantity that is used as a standard while its measurement.
- Units are of two types:
  - i. **Base units** are the units for base quantities, *e.g.* meter (m), kilogram (kg), second (s) *etc.*
  - ii. **Derived units** are the units for derived quantities, *e.g.* meter per second (m/s), newton (N), watt (W) *etc.*

SI Units

- A set of base and derived units is called **system of units**. **British Engineering System** and **System International units (SI units)** are two examples of system of units.
- System International units (SI units) have been adopted internationally for the efficient measurement of physical quantities. The table. 1.2 shows a list of seven base quantities and their corresponding SI units.

Quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	Kelvin	K
Electric Current	Ampere	A
Intensity of Light	Candela	Cd
Amount of Substance	mole	mol

table 1.2

Derivation of Derived Units

- Derived units are expressed in terms of base units by means of mathematical symbols of multiplication and division.

2 Kinematics

After reading this unit, you will be able to

(a) state what is meant by rest and motion, and discuss different types of motion.
(b) state how displacement is different from distance.
(c) state what is meant by speed and velocity.
(d) state what is meant by acceleration and calculate the value of an acceleration using change in velocity/time taken.
(e) discuss uniform and non-uniform acceleration.
(f) plot and interpret speed-time and distance-time graphs.
(g) calculate the area under a speed-time graph to determine the distance travelled for motion with uniform speed or uniform acceleration.
(h) state that the acceleration of free-fall for a body near to the Earth is constant and is approximately 10 m/s^2.
(i) describe the motion of bodies falling with and without air resistance (including reference to terminal velocity).

Key Definitions

distance	length of the path between two points
displacement	shortest distance between two points
speed	rate at which distance changes
velocity	rate at which displacement changes
acceleration	rate at which velocity changes
gradient	a line's rise divided by its run
acceleration of free fall	acceleration experienced by an object when it falls freely under the influence of gravity
terminal speed	maximum speed gained by an object while moving through a fluid (liquid or gas)

Mechanics

- **Mechanics** is the branch of physics that deals with the study of objects in motion. The subject of mechanics is divided into two sub-branches: **kinematics** and **dynamics.**
- **Kinematics** deals with the motion of objects without discussing the agents causing motion while in **dynamics** the motion of objects is studied with reference to the agents causing motion.

2.1 Speed, Velocity and Acceleration

Rest and Motion

- If an object does not change its position with respect to its surroundings, then it is said to be at **rest**, but if an object changes its position with respect to its surroundings, then it is said to be in **motion**.
- Rest and motion are relative terms. This means that the state of rest or motion of an object always needs another object with respect to which its position is compared. For example, when a bus moves on a road, the bus as well as the passengers sitting inside change their positions with respect to a person standing on the road side. However, the passengers sitting in the bus do not change their positions with respect to each other. So they are at rest with respect to each other.

fig. 2.1

- Motion of an object can be one of the following types:
  - **i. translatory motion**
  - **ii. rotatory motion**
  - **iii. vibratory motion**
  - **iv. random motion**

Translatory Motion

- The type of motion in which every particle of a moving object displaces by the same amount is called **translatory motion**.
- Translatory motion of an object can also be either of the following two types:
  - **i. Linear Motion:** If an object moves along a straight line, then its motion is called **linear motion**. For example, the motion of a freely falling object, the motion of a car on a straight road, the motion of an aeroplane before taking off *etc*.
  - **ii. Circular Motion:** If an object moves along a curved path, then its motion is called **circular motion**. For example, the motion of planets around the sun, the motion of a car at a road corner *etc.*

fig. 2.2

Rotatory Motion

- If an object moves around a fixed axis or a point, then its motion is called **rotatory motion**. For example, the motion of the blades of a ceiling fan, the rotation of earth about its own axis, the rotation of wheel of a stationary cycle *etc*.

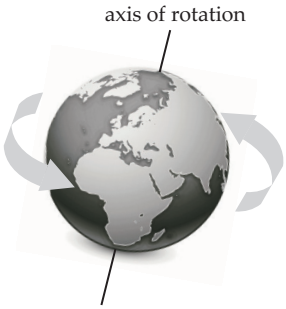


fig. 2.3

3 Dynamics

After reading this unit, you will be able to

(a) state different types of forces and their effects on the motion of objects.
(b) describe the effect of balanced and unbalanced forces on a body.
(c) recall and use the equation *force = mass × acceleration*.
(d) state and explain Newton's laws of motion.
(e) explain that friction is a force that impedes motion and produces heat.
(f) discuss the effect of friction on the motion of a vehicle in the context of tyre surface, road conditions, braking force, braking distance, thinking distance and stopping distance.
(g) describe qualitatively motion in a circular path due to a constant perpendicular force, including electrostatic forces on an electron in an atom and gravitational forces on a satellite.

Key Definitions

force	an interaction that tends to change the state of rest or motion of an object in a straight line
newton (N)	SI unit of force; a force of 1 N produces an acceleration of 1 m s^{-2} in an object of mass 1 kg
contact force	a type of force that requires a physical contact for its action
field force	a type of force that does not require a physical contact for its action
balanced forces	forces when added cause no acceleration
unbalanced forces	forces when added cause acceleration
friction	a type of contact force that resists the motion of one object over the surface of another object
stopping distance	minimum distance a vehicle requires to stop completely
thinking distance	distance travelled by a vehicle during the driver's reaction time
breaking distance	distance travelled by a vehicle once the brakes are applied until it stops
centripetal force	a force that compels an object to move along a curved path

3.1 Balanced and Unbalanced Forces

Force (*F*)

- **Dynamics** is the branch of mechanics that deals with the motion of objects under the action of forces.
- A **force** is a push or pull that an object exerts on another. In a broader sense, a **force** is an interaction that tends to change the state of rest or motion of an object in a straight line.
- Force is a vector quantity and its SI unit is **newton** (N).
- One newton (N) is the amount of force that produces an acceleration of 1 m s^{-2} in an object of mass 1 kg.
- Following are the effects of forces on the motion of objects
    i. a stationary object can start moving
    ii. a moving object gains speed
    iii. a moving object loses speed
    iv. a moving object changes its direction of motion
- Besides change in motion, a force can also change the size and shape of an object.
- Force is usually measured with the help of spring balance or newton-meter.

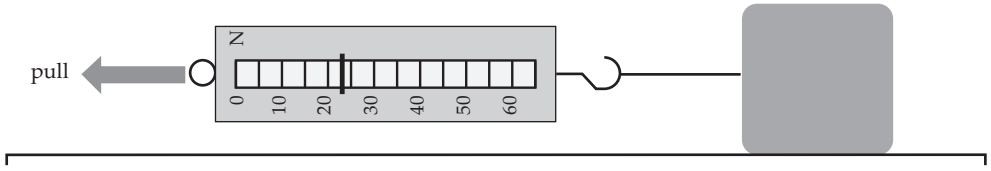


fig. 3.1

Types of Forces

- Variety of forces exist aound us which can be put into two major categories:
    i. Contact Forces
    ii. Field Forces
- A **contact force** is a force that requires a physical contact for its action.
- Some common types of contact forces are:

Name of Contact Force	Example
friction	type of contact force that resists the motion of one object over the surface of another object
tension	the pull at both ends of a stretched string or spring
normal force	the force exerted on an object perpendcularly by a flat surface
viscous force	the opposing force found in fluids like water and oil
forward thrust	the force that causes a vehicle to move forward
spring force	the force exerted by a compressed or stretched spring upon any object that is attached to it

table 3.2

4 Mass, Weight and Densities

After reading this unit, you will be able to

(a) state that mass is a measure of the amount of substance in a body.
(b) state that the mass of a body resists change from its state of rest or motion.
(c) state that a gravitational field is a region in which a mass experiences a force due to gravitational attraction.
(d) state that weight of an object is the force of gravity on it by the Earth.
(e) use the equation *weight = mass × gravitational field strength*.
(f) describe how to measure mass and weight by using appropriate balances.
(g) define density and recall and use the formula *density = mass/volume*.
(h) state why do some objects float while others sink.
(i) describe how to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in water (volume by displacement).

Key Definitions

mass	measure of the amount of matter in an object; the characteristic of an object that resists change from its state of rest or motion
inertia	a characteristic of mass that resists any change in its state of rest or of uniform motion
gravity	a force of attraction that exists naturally between any two material objects; also known as gravitational force
weight	the gravitational force acting on an object by the Earth
gravitational field	a region of space in which a mass experiences a force due to gravitational attraction
gravitational field strength	gravitational force acting per unit mass on an object; near the surface of the Earth, its numerical value is 9.8 N/kg (10 N/kg)
density	mass per unit volume of a substance

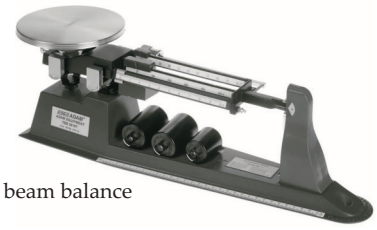
4.1 Mass & Weight

Mass (*m*)

- The **mass** (*m*) of an object is a measure of the amount of matter contained in it.
- The amount of matter an object has, depends upon the number and composition of atoms and molecules that make up the object.

- Mass is, in fact, that characteristic of an object which determines the magnitude of acceleration produced when a certain force acts upon it.
- It is a characteristic of an object that cannot be changed by its location, shape and speed.
- It is a scalar quantity.
- Instruments like pan balance, beam balance or electronic balance are used for measuring mass of objects.

pan balance



beam balance

electronic balance

fig. 4.1

- The SI unit of mass is kilogram (kg). Other commonly used units of mass are tonne, gram and milligram.

1 tonne = 1000 kg

1 kg = 1000 g

1 g = 1000 mg

Inertia

- Owing to their mass, all material objects possess a characteristic due to which they resist any change in their state of rest or uniform motion. This characteristic is called **inertia**.
- The inertia shown by an object is directly related to its mass. More the mass of an object, greater the inertia it has, and thus it is harder to make the object start moving, slow down, move faster or change direction.
- Some everyday examples of this feature of mass are:
    i. It is difficult to push a loaded trolley as compared with an empty trolley.
    ii. When a card with a heavy coin on top placed on a glass is flicked sharply, the coin drops down while the card flies off.
    iii. Passengers lurch forward when a vehicle stops suddenly. Similarly, they fall backward when a vehicle starts or gears up suddenly.
    iv. When a car makes a sharp turn, the passengers move to the inner side of the turn.
    v. In order to avoid an elephant, one is advised to move in a zig-zag manner.

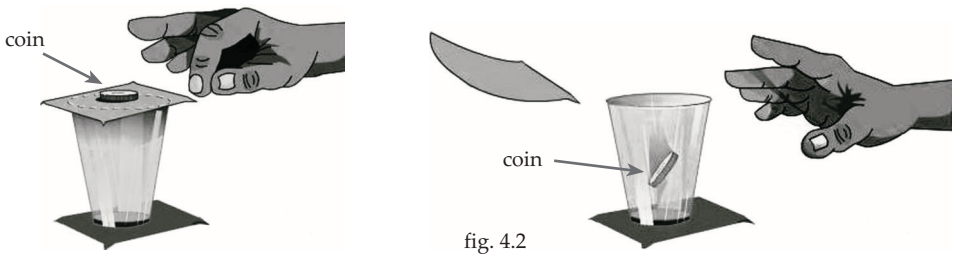


fig. 4.2

5 Turning Effect of Forces

After reading this unit, you will be able to

(a) describe the moment of a force in terms of its turning effect.
(b) recall and use the formula
moment = force × perpendicular distance from the pivot and the principle of moments
(c) state the principle of moments for a body in equilibrium.
(d) define centre of mass and describe how to determine the position of the centre of mass of a plane lamina.
(e) state what is meant by stability and describe qualitatively the effect of the position of the centre of mass on the stability of simple objects.

Key Definitions

moment of force	a measure of the turning effect of force about pivot; is the product of force and moment arm
moment arm	the perpendicular distance between the line of action of force and pivot
pivot	a point or a line about which an object rotates
principle of moments	sum of clockwise moments about a pivot is equal to the sum of anticlockwise moments about the same pivot
centre of mass	a point on or inside an object through which its whole weight appears to act
equilibrium	a steady state of an object when no resultant force and no resultant moment act on it
stability	a measure of how difficult it is to move an object from a position of equilibrium with respect to gravity

5.1 Moments

Moment of Force (*T*)

- The turning effect of a force about a fixed point or a fixed axis is measured by a quantity called **moment of force** or **torque**.
- The fixed point or the fixed axis about which an object rotates is called **pivot** whereas the perpendicular distance between line of action of force and the pivot is called **moment arm**.

⚠ Note that **moment of force** is sometimes simply referred to as **moment** only.

- The turning effect produced in a body depends upon two factors:
    i. **magnitude of the applied force**
    ii. **perpendicular distance of the applied force from the pivot (moment arm)**
- Greater is the magnitude of force applied on an object, greater will be the turning effect and vice versa. Similarly, greater is the perpendicular distance of the applied force from the pivot, greater will be the turning effect and vice versa.
- Based upon, the two factors mentioned above, moment of force is defined as follows:

    Moment of force is the product of the applied force *(F)* **and the perpendicular distance** *(d)* **between the line of action of force and pivot.**

    i.e.,

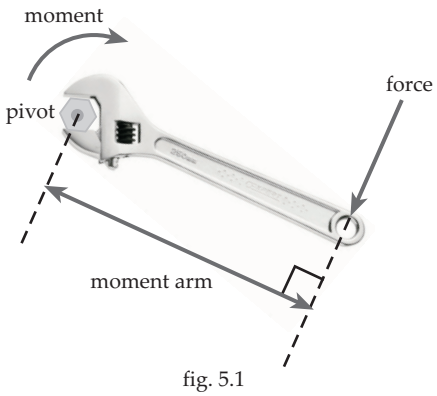


fig. 5.1

$$T = F \times d$$

- The SI unit of the moment of force is the **newton metre** (Nm).
- Moment of force is a vector quantity. The direction of moment of force can be either **clockwise** or **anticlockwise**.
- If there are more than one forces acting on an object, then there are also more than one moments about a given pivot. In this case, the resultant moment is calculated by the subtracting the sum of all the moments in clockwise direction from the sum of all the moments in anticlockwise direction.

$$T_{net} = T_{anticlockwise} - T_{clockwise}$$

Principle of Moments

- The **principle of moments** states that

    When a body is in equilibrium, the sum of clockwise moments about a pivot is equal to the sum of anticlockwise moments about the same pivot.

    Mathematically,

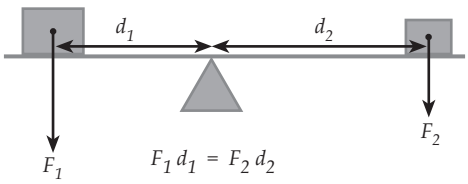


fig. 5.2

sum of clockwise moments = sum of anticlockwise moments

5.2 Center of Mass

- **Centre of mass** or **centre of gravity** of an object is the point through which its whole weight appears to act and if the object is supported at this point then it stands still without rotation.
- Centre of mass can exist inside or outside of the object depending upon its shape and distribution of its mass.