Focus 1: Physical Quantities

- A physical quantity consists of a numerical magnitude and **unit** (e.g. <u>25</u> **ms^{-1}**).
- Physical quantities are classified into

(a) Base Quantities

Base Quantity	Name of SI Unit	SI Unit
Length	metre	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Current	ampere	A
Amount of Substance	mole	mol

(b) Derived Quantities

Derived Quantity	Relation with Base Quantity	Symbol for Unit
area	length x width	m^2
speed	distance / time	m/s or m s^{-1}
density	mass / volume	kg/m^3 or kg m^{-3}

Prefixes for SI Units

Name	Factor	Symbol
giga	10^9	G
mega	10^6	*M*
kilo	10^3	*k*
deci	10^{-1}	*d*
centi	10^{-2}	*c*
milli	10^{-3}	*m*
micro	10^{-6}	*μ*
nano	10^{-9}	n

E.g. 3215 **kg** = 3125 x **10^3** g = 3125000 g or 3.125 x **10^6** g
700 **nm** = 700 x **10^{-9}** m = 0.000000700 m or 7.00 x **10^7** m
0.000032 s = 32 x **10^{-6}** s = 32 μs

Conversion of Units

(a) kg and g

kg → x 10^3 → g ; g → ÷ 10^3 → kg

E.g. 2.1 kg = 2100 g

(b) mg and g

mg → ÷ 10^3 → g ; g → x 10^3 → mg

E.g. 25 g = 25000 mg

(c) ms^{-1} and kmh^{-1}

ms^{-1} → x 3.6 → kmh^{-1} ; kmh^{-1} → ÷ 3.6 → ms^{-1}

E.g. 20 ms^{-1} = 72 kmh^{-1}

(d) gcm^{-3} and kgm^{-3}

gcm^{-3} → x 10^3 → kgm^{-3} ; kgm^{-3} → ÷ 10^3 → gcm^{-3}

E.g. 7900 kgm^{-3} = 7.9 gcm^{-3}

- The follow tables show the orders of magnitude (approximation expressed in powers of ten) of some masses and lengths.

Mass / kg	Order of Magnitude
Electron	10^{-30}
Proton	10^{-27}
Ant	10^{-3}
Human	10^1
Earth	10^{24}
Sun	10^{30}

Length / m	Order of Magnitude
Radius of a proton	10^{-15}
Radius of an atom	10^{-10} m = 0.1 nm
Height of an ant	10^{-3}
Height of a human	10^0
Radius of the Earth	10^7 m = 10 Mm
Radius of the Sun	10^9

Scalars and Vectors

- Def<u>N</u>: A scalar quantity has magnitude but no direction**.** E.g. mass, time, distance, speed, work, energy, power, pressure.
- Def<u>N</u>: A vector quantity has magnitude and direction**.** E.g. displacement, velocity, acceleration, force.
- The resultant of adding 2 vectors can be determined using 3 methods (see Unit 3 – Forces for further elaboration)

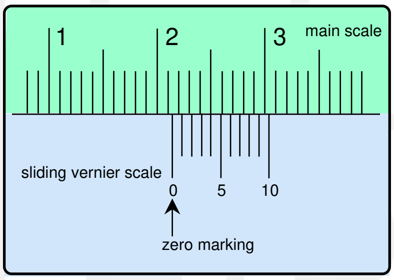
1. Tip-to-tail
2. Parallelogram
3. Trigonometric (in some IP schools only)

Focus 2: Measurement of Length

- SI unit : metre (m)
- Precision is the smallest unit an instrument can measure.
- To measure the length of an object, the instrument with the highest precision in which the object can fit within its range is chosen.

Instrument	Measuring range	Example	Precision (in cm)	Precision (in mm)
Measuring Tape	Several metres	Vehicles	0.1 cm	1 mm
Metre Rule	Several cm to 1 m	Length of a Book	0.1 cm	1 mm
Vernier Calipers	Between 1 cm to 10 cm	Diameter of test tubes	0.01 cm	0.1 mm
Micrometer Screw Gauge	Less than 2 cm	Thickness of wires	0.001 cm	0.01 mm

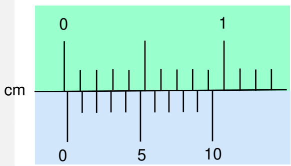
Vernier Calipers



How to Read
Main scale reading is **2.1** cm. The **4**th marking on the sliding vernier scale is aligned with the marking on the main scale. Therefore, reading is
2.1 + 0.04 = 2.14 cm

Zero Error Correction

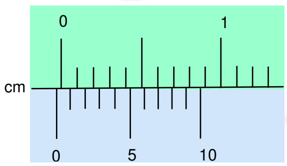
Positive Zero Error:



Zero error = +0.02 cm

Corrected Reading
= L - (+0.02)

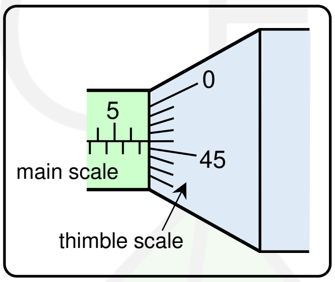
Negative Zero Error:



Zero error = -0.03 cm
(read from the 10, leftward)

Corrected Reading
= L - (-0.02)

Micrometer Screw Gauge

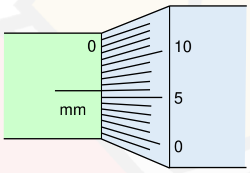


How to Read
Reading on the main scale is **6.5** mm.
Reading on the thimble scale is **0.46** mm.

Therefore, reading is
6.5 + 0.46 = 6.96 mm

Zero Error Correction

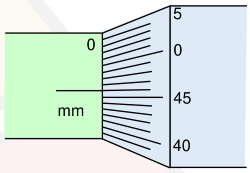
Positive Zero Error:



Zero error = +0.06 mm

Corrected Reading
= L - (+0.06)

Negative Zero Error:



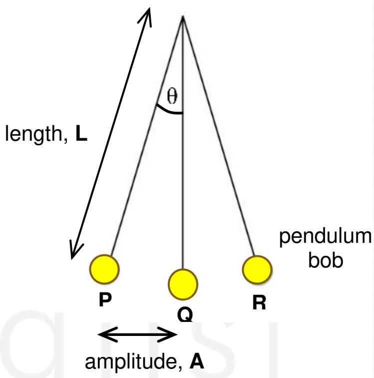
Zero error = -0.04 mm

Corrected Reading
= L - (-0.04)

Focus 3: Measurement of Time

- SI unit : seconds (s)

Pendulum



- A complete to and fro motion is one oscillation. *(e.g. P– Q – R– Q – P)*
- The distance from P to Q is called the amplitude of the oscillation, **A**.
- The pendulum will complete every oscillation at regular time intervals called the period.
- Def<u>N</u>: The period, **T** is the time taken for one complete oscillation.
- The frequency, **f** refers to the number of complete oscillations in one second.
  SI Unit: Hertz (Hz)
- The frequency **f** of a pendulum is related to its period **T** by the following equation

$$f = \frac{1}{T}$$

<u>Determining the Period of a Pendulum</u>

1. Set the pendulum to oscillate. This is done by displacing the pendulum bob at a small angle of θ less than 10° and release.
2. When the motion is steady, start the stopwatch when the swing is at one end of its motion (e.g. at P)
3. Stop the stopwatch after 20 oscillations. Record the time t_1.
4. Repeat steps 2-3 for another set of reading t_2.
5. Take average $<t> = \frac{t_1 + t_2}{2}$.
6. The period T is given by $T = \frac{<t>}{20}$.

Focus 1: Kinematics Terms and Equations

Distance and Speed

- Scalar quantities
- Distance is the total length covered between two points.
- DefN: Speed is the change in distance per unit time.
  For objects moving at constant speed, its value it given by:

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

For objects moving at non-constant speed, the average speed is given by:

$$\text{average speed} = \frac{\text{total distance covered}}{\text{total time taken}}$$

- SI Unit: m/s or m s^{-1}

Displacement, Velocity and Acceleration

- Vector quantities
- Displacement is distance moved in a specified direction
- DefN: Velocity is the change in distance in a specified direction (displacement) per unit time.

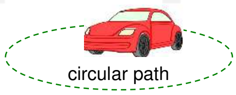
$$\text{average velocity} = \frac{\text{displacement}}{\text{total time taken}}$$

- DefN: Acceleration is the change in velocity per unit time.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time}} \quad \text{i.e.} \quad a = \frac{v - u}{t}$$

- SI Unit: m/s^2 or m s^{-2}
- Acceleration occurs when a body is

(a) changing magnitude of its speed (b) changing direction

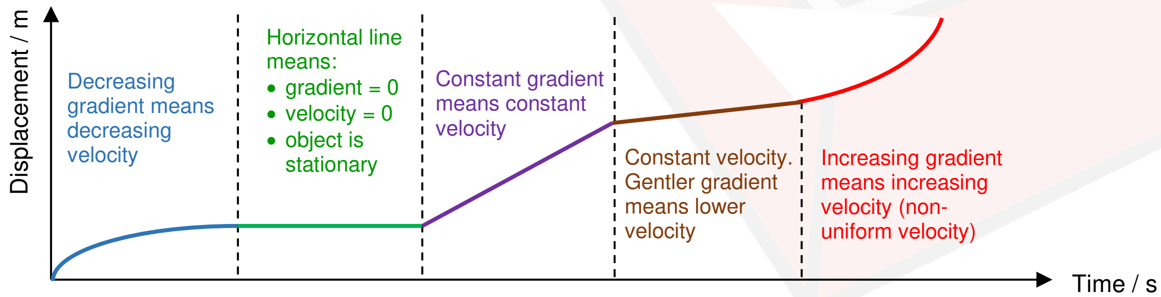


- A body moving with uniform acceleration experiences a constant rate of change of velocity.

Focus 2: Motion Graphs

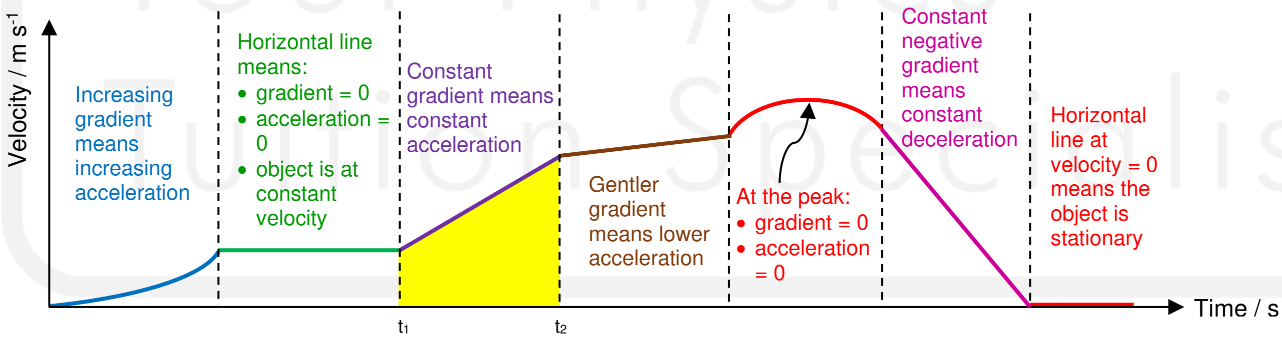
Displacement-Time Graph

- The average velocity can be calculated using average velocity $= \frac{\text{change in displacment}}{\text{time taken}}$.



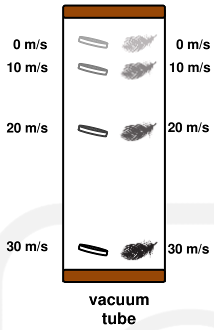
Velocity-Time Graph

- The gradient of velocity-time graph gives the acceleration.
- Area under the velocity-time is equivalent to the displacement of the object.



Area under the graph between t_1 and t_2 gives the displacement between t_1 and t_2.

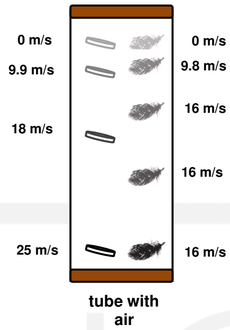
Objects falling without Air Resistance



- In the absence of air resistance, all falling objects fall with the same constant acceleration.
- This acceleration is known as acceleration of freefall and is determined to be 10 m/s^2.

Despite having different masses, both coin and feather will fall with the same acceleration.

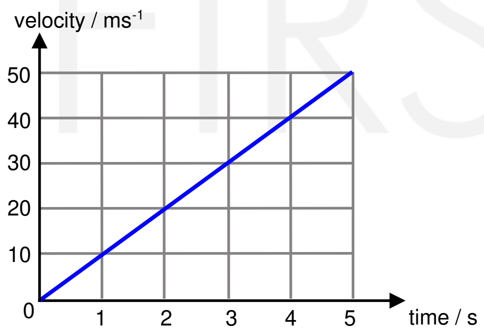
Objects falling with Air Resistance



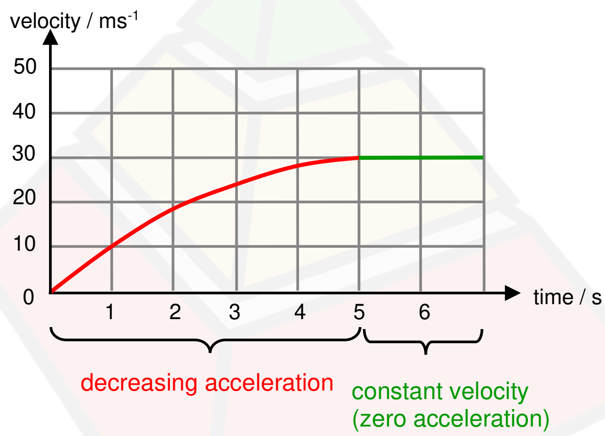
- When the feather is released, it accelerates under the influence of gravity.
- As it speeds up, the air resistance increases.
- This causes the resultant downward force acting on the feather to decrease. As a result, the acceleration decreases.
- Eventually, the magnitude of the upward air resistance equals the magnitude of the downward weight.
- This leads to the resultant force acting on the feather to be zero. The acceleration also becomes zero and the feather reaches it maximum velocity called the terminal velocity.

The feather has less weight is subjected to greater air resistance due to its larger cross-sectional area. As a result, it reaches a lower terminal velocity is a shorter time.

Velocity-time graph of a free-falling object



Velocity-time graph of a falling object through air



- Free fall is defined as the motion of an object under the influence of gravity only i.e. the only force acting on the object is its own weight.
- Air resistance tends to slow down a moving object. It has the following properties.

  (a) It always opposes the motion of objects.
  (b) It increases with the speed of the object.
  (c) It increases with cross-sectional area of the object.

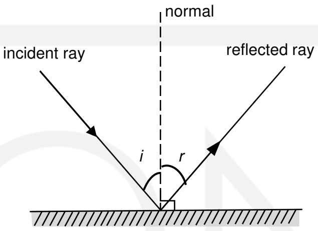
Focus 1: Reflection of Light

- Reflection is the bouncing of light as it hits upon a surface.

Laws of Reflection

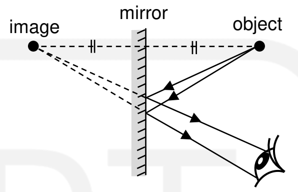
1st Law of Reflection
The incident ray, the reflected ray and the normal to the reflecting surface all lie in the same plane.

2nd Law of Reflection
The angle of incidence *i* is equal to the angle of reflection *r*.



Mirrors

- An image formed in a plane mirror is
  1. laterally inverted,
  2. upright,
  3. at the same distance from the mirror as the object,
  4. the same size as the object,
  5. virtual.



Locating an image formed by a mirror

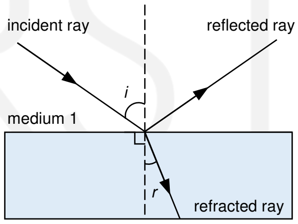
Focus 2: Refraction of Light

- When a ray of light travels from a transparent medium to another at a certain angle, part of the light will be reflected at the boundary. The rest of the light will bend into the other medium. This bending of light is known as refraction.

Laws of Refraction

1st Law of Refraction
The incident ray, the normal and the refracted ray all lie in the same plane

2nd Law of Refraction (also known as Snell's Law)



For two particular medium, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. That is $\frac{\sin i}{\sin r} = \text{constant}$

Refractive Index, n

- DefN: The refractive index of a medium n is defined as the ratio of speed of light in vacuum c to the speed of light in the medium, v.

$$n = \frac{c}{v}$$

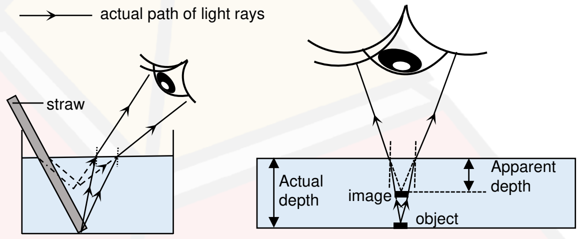
- n is also the ratio of the sine of angles between the rays and normal in vacuum(or air) to the medium.

$$n = \frac{\sin (\measuredangle \text{ in air})}{\sin (\measuredangle \text{ in medium})}$$

- The medium with a larger RI is said to be optically denser. As light travels into an optically denser medium, it bends towards the normal.

- For simplicity, the RI of air is taken to be equal to the RI of vacuum i.e. 1. The speed light in air and vacuum are both taken to be 3 x 10^8 m/s.

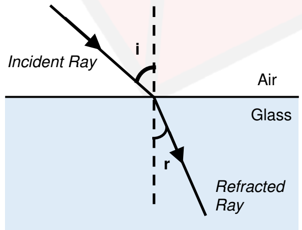
- Visual effects of refraction



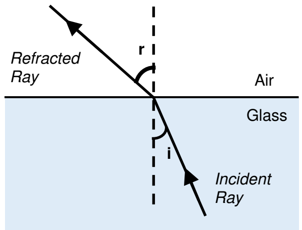
The straw appears bent. The water appears shallower than it is.

Principle of Reversibility

- The principle of reversibility of light states that a ray of light will take the same path if its direction of travel is reversed.



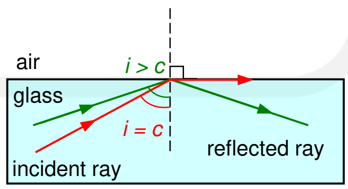
$$n = \frac{\sin i}{\sin r}$$



$$n = \frac{\sin r}{\sin i}$$

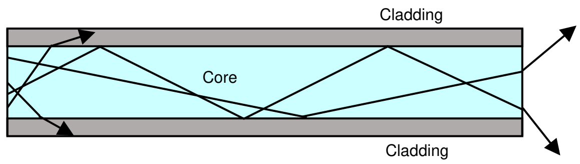
Total Internal Reflection

- DefN: The critical angle c is the angle of incidence in an optically denser medium that gives an angle of refraction of 90 º in the optically less dense medium.
- The relationship between critical angle c and the refractive index n is $\sin c = \frac{1}{n}$



- DefN: Total internal reflection refers to the complete reflection of a light ray incident on an interface with a less dense optical medium when the angle of incidence is greater than the critical angle.
- The following 2 conditions leads to total internal reflection (TIR),
  1. Light is travelling from optically denser medium to optically less dense medium, and
  2. the angle of incidence i is larger than the critical angle c.

- One application of TIR is optical fibres. Optical fibres are made up of a core of glass or plastic with high RI, coated by another material of lower RI. Light travels along a fibre by total internal reflection at the boundary.
- In the communication industry, optical fibres can carry laser light which carries information such as telephone conversations, computer data and television pictures.
- Advantages of using optical fibres:
    - they can carry light round bends and in places where it would be difficult or dangerous to supply electricity (e.g. under the sea).
    - they can carry information over great distances at high speed.
    - they can carry more information than a copper wire cable.

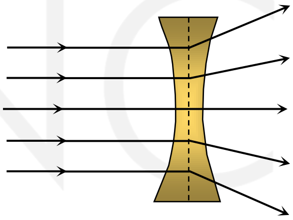


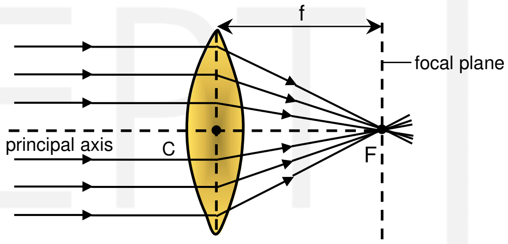
Focus 3: Refraction by Thin Lenses

- A lens is a piece of clear plastic or glass with curved surfaces.

Types of Lenses

<u>Diverging (Concave) Lens</u>





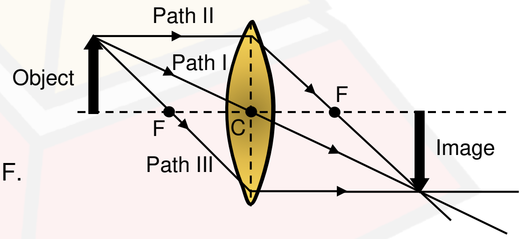
- A Diverging Lens is thinner in the middle.
- A parallel beam of light that passes through a diverging lens will spread out (diverge).

<u>Converging (Convex) Lens</u>

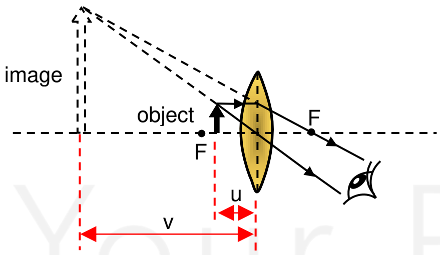
- A Converging Lens is thicker in the middle.
- A parallel beam of light that pass through converging lens will meet (converge) at a point called the focal point F.
- Terminology:
  (a) Optical Center (C) is the center of the lens.
  (b) Principal Axis is a line through the optical center of the lens and is perpendicular to the center of the lens.
  (c) When rays of light are traveling parallel and close to the principal axis pass through the lens, they will all bend and meet at one point on the principal axis. This point is called the principal focus, F.
  (d) Def<u>N</u>: Focal Length (f) is the distance between the principal focus (F) and the optical center (C) of the lens.

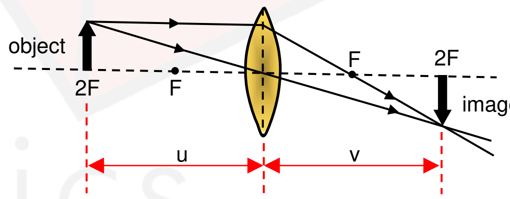
Ray Diagrams for Lenses

<u>Construction Rules for Ray Diagram</u>

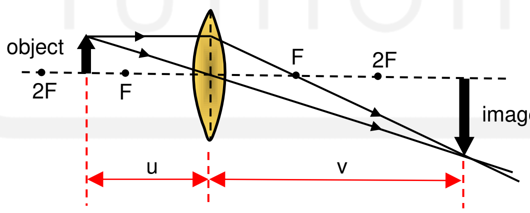


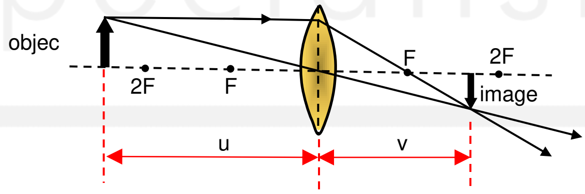
Path I - A ray through the optical centre will not be deviated.
Path II - A ray parallel to the principal axis is refracted by the lens to pass through F.
Path III - A ray through F is refracted parallel to the principal axis.





Object distance u	Image distance v	Image Description	Use	Object distance u	Image distance v	Image Description	Use
u < F	v > F on same side as object	enlarged, upright, virtual.	Magnifying Glass	u = 2F	v = 2F	same-sized, inverted, real	Photocopier – same-sized copies





Object distance u	Image distance v	Image Description	Use	Object distance u	Image distance v	Image Description	Use
F < u < 2F	v > 2F	enlarged, inverted, real	Projector	u > 2F	F < v < 2F	diminished, inverted, real	Camera