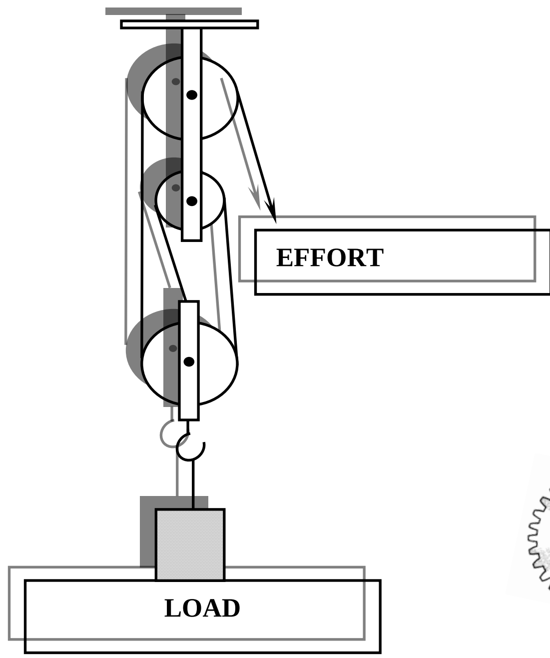

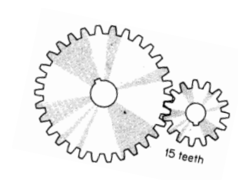

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PHYSICS PAPER 1

QUICK REVISION NOTES WITH OVER 200 WORKED EXAMPLES AND QUICK PRACTICE QUESTIONS

O . S . O

ST. THERESA'S NYANGUSU GIRLS' SEC.

Physics is not as easy as you think! No…….! It's easier than that!

PHYSICS PAPER 1

QUICK REVISION NOTES: (*Definitions, laws and important formulae*)

TOPIC S COVERED IN THIS PAPER/ CONTENTS:

THE THREE B's DIMENSIONAL ATTACK:

Believe.................................Begin.................................Become!

1. TOPIC 1: MEASUREMENTS (1 & 2)

LENGTH

Length is the distance between two points

- Length is measured using the metre rule
- SI unit for length is **metres,** (m)
- Other units for length

Unit	Symbol	Equivalence in metres
Micrometer	µm	0.000001m
Millimetre	mm	0.001 m
kilometre	km	1000 m

MASS

Mass is the quantity of matter in an object

- Mass is measured using the beam balance
- SI unit for mass is **kilogram,** (kg)
- Other units for mass

Unit	Symbol	Equivalence in gram	Equivalence in kilogram
Microgram	µg	0.000001 g **(1×10^{-6} g)**	0.000000001 kg **(1×10^{-9} k g)**
Milligram	mg	0.001 g **(1×10^{-3}g)**	0.000001 kg **(1×10^{-6} k g)**
HGram	g	1 g **(1×10^{0} g)**	0.001 kg **(1×10^{-3} k g)**
Tonne	t	1000000 g **(1×10^{6} g)**	1000 kg **(1×10^{3} k g)**

VOLUME

Volume is the amount of space occupied by matter

SI unit for volume is **cubic metres**, (m^3)

DENSITY

Density is defined as mass per unit volume

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

- SI unit for density is **kilogram per metre cubic,** kg/m^3
- $1000\ kg/m^3 \equiv 1\ g/cm^3$

Worked Example 1

A block of wood has dimensions 4 cm by 5 cm by 10 cm. Give that the mass of the block is 160 grams; determine the density of the wood giving your answer in the SI units

Answer:

$$\text{Volume of the block} = l \times w \times h$$

$$= 200\ cm^3$$

$$\text{Density} = \frac{(160)}{200}$$

$$= 0.8\ g/cm^3$$

In SI units,

$$1\ g/cm^3 \equiv 1000\ kg/m^3$$

$$0.8\ g/cm^3 = \frac{(0.8 \times 1000)}{1}$$

$$\underline{\text{Density} = \mathbf{800\ kg/m^3}}$$

Quick Practice Questions

1) *Liquid kerosene was poured into a cylindrical container of base area 2 cm^2 and the mass of the kerosene in the container as found to be 12 grams. Given that the density of kerosene is 800 kg/m^3, determine the height of the kerosene in the container.* ***(Answer: 7.5 cm)***

2) *100 cm^3 of fresh water of density 1000 kg/m^3 is mixed with 100 cm^3 of sea water of density 1030 kg/m^3. Calculate the density of the mixture.* ***(Answer: 1015 kg/m^3)***

RELATIVE DENSITY

- Relative density is the ratio of the density of a substance to that of water

$$\text{Relative density} = \frac{\text{Density of a substance}}{\text{Density of water}}$$

- Relative density can also be calculated as:

$$\text{Relative density} = \frac{\text{Mass of a substance}}{\text{Mass of an } \underline{\textit{equal volume}} \text{ of water}}$$

- **NOTE:** ***Relative density has no units***

Worked Example 2

The mass of an empty density bottle is 20 grams. Its mass when filled with water is 40.0 grams and 50.0 grams when filled with liquid **X***. Given that the density of water is 1000 kg/m*^{3}*, calculate:*

a) *The volume of the bottle*
b) *The density of liquid* **X**

Answer

a) Mass of water only $= (40.0 - 20.0)$ g

$= 20.0$ grams

$= 0.02$ kg

Therefore, volume of the water $= \dfrac{\text{mass}}{\text{Density}}$

$= \dfrac{0.02}{1000}$

$= \underline{0.00002\ m^3 \textbf{ OR } 20\ cm^3}$ (This is the volume of the bottle)

b) Mass of liquid **X** only $= (50 - 20)$g

$= 30.0$ grams

$= 0.03$ kg

Volume of liquid **X** = volume of the bottle $= 0.00002\ m^3$

Therefore, density of liquid **X** $= \dfrac{\text{mass}}{\text{Volume}}$

$= \dfrac{0.03}{0.00002}$

Density of liquid **X** = $\underline{\mathbf{1500\ kg/m^3}}$

Quick Practice Questions

1. *The mass of a density bottle is 20 grams when empty, 70 grams when full of water and 55.0 grams when full of a second liquid. Calculate the density of the liquid.* ***(Answer: 700 kg/m***^{3}***)***

2. *In an experiment to determine the density of a liquid, the following readings were made.*

Mass of empty density bottle	=	20 g
Mass of bottle filled with water	=	70 g
Mass of bottle filled with a liquid	=	695 g

a) Find the density of the liquid, given that density of water is 1000kgm^{-3}

THE VERNIER CALLIPERS

- Vernier callipers give measurements of length up to ***four decimal places when expressed in metres*** (The SI units), ***two decimal places when expressed in centimetres (cm)*** and ***one decimal place when expressed in millimetres (mm)***. It has a sensitivity of 0.01 cm

    (i) Main scale reading, is the last reading on the main scale, opposite the zero mark of the vernier scale

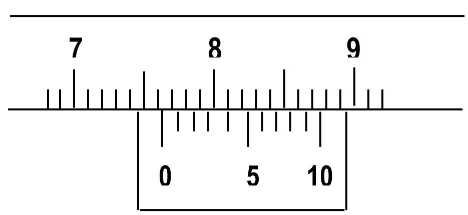
    (ii) Vernier scale reading is a mark on the vernier scale that coincides exactly with a main scale mark.

- *A NEGATIVE ZERO ERROR on a vernier calliper* ***is corrected by*** *ADDING* ***the zero error value*** *to the reading obtained*

- *A POSITIVE ZERO ERROR on a vernier calliper* ***is corrected by*** *SUBTRACTING* ***the zero error value*** *from the reading obtained*

Worked Example 3

The figure below shows a vernier callipers scale



State the correct reading of scale if the instrument has a zero-error of –0.02cm

Answer

Reading = main scale + vernier scale

= 7.6 + (0.01 x 4)

= 7.64 cm

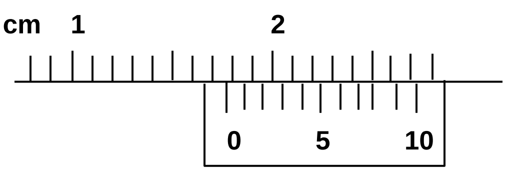
Correct reading = 7.64 + 0.02

Correct reading = 7.66 cm

In SI units = 0.0766m

Quick Practice Questions

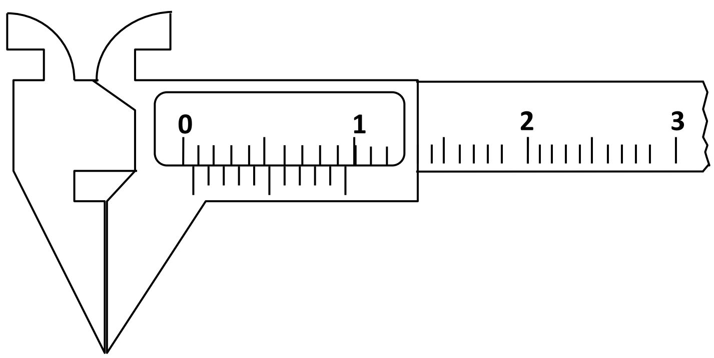
1. *The figure below shows the scales a pair of vernier callipers being used to measure the length of a pipe, whose radius is 1.20 cm. The zero error of the device is −0.13 cm.*



a) *Determine the actual length of the pipe.* ***(Answer: 1.91 cm)***

b) *Given that the radius of the pipe is 1.20 cm, find its volume.* ***(Answer: 8.642 cm³)***

2. *The figure below shows vernier callipers with the jaws closed. When an object is placed between the jaws, the vernier calliper reads 2.33 cm.*



What is the actual length of the object? ***(Answer: 2.27 cm)***

THE MICROMETER SCREW GAUGE

- Micrometer screw gauge gives measurements of length up to ***five*** *decimal places when expressed in* ***metres***, **three** *decimal places when expressed in* ***cm*** or *two decimal places when expressed in* ***mm***. It has a sensitivity of 0.001 **cm** or 0.01 **mm**

  1. Sleeve scale is read at the edge of the thimble in mm and 0.5 mm.

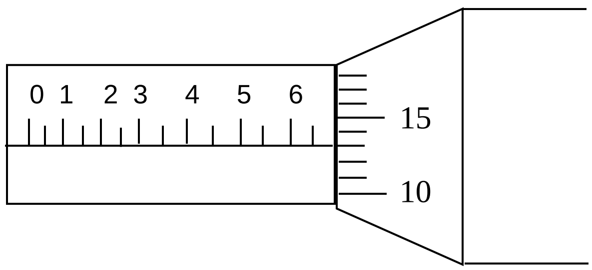
2. Thimble scale is reading is the mark in the thimble which coincides with the centre line on the sleeve and is read in two decimal places.

   - *A* NEGATIVE ZERO ERROR *on a Micrometer screw gauge* ***is corrected by*** ADDING ***the zero error value*** *to the reading obtained*

   - *A* POSITIVE ZERO ERROR *on a Micrometer screw gauge is* ***corrected by*** SUBTRACTING ***the zero error value*** *from the reading obtained*

Worked Example 4

The diagram below shows a micrometer screw gauge used by a student to measure the thickness of her hair. If it has a zero error of +0.04mm, what is the actual thickness of the hair?

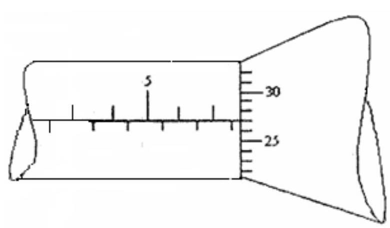


Answer

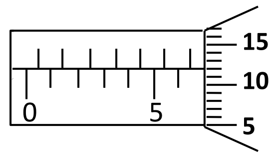
Reading on figure	*= 6.5 + (13 x 0.01)*
	= 6.5 + 0.13
	= 6.63 mm
Actual reading	*= (6.63 – 0.04)*
Actual reading	***= 6.59 mm***

Quick Practice Questions

1. *The figure below shows a micrometer screw gauge being used to measure the diameter of a metal rod. The thimble scale has 50 divisions. What is the reading shown?* ***(Answer: 7.77 mm)***



2. *The diagram below shows a portion of a micrometer screw gauge used to measure the diameter of a metal pipe. The reading on the gauge when the jaws were fully closed without the pipe was 0.012cm.*



ESTIMATION OF THE SIZE OF A MOLECULE (THE OIL DROP EXPERIMENT)

- Volume of one drop of oil is calculated as

$$\textbf{Volume of one oil drop} = \frac{\textbf{total volume of oil drops}}{\textbf{Number of oil drops}}$$

- Thickness of the oil molecule is estimated as follows:

Volume of one drop = volume of the circular patch

$$\frac{4}{3}\pi r^3 = \pi R^2 t$$

Therefore, thickness of patch, $t = \dfrac{\text{volume of 1 oil drop}}{\text{Area of circular patch}}$

Where: **t** – *is the thickness of the oil molecule*

r – *Radius of one drop of oil*

R – *Radius of the circular patch*

Assumptions made in this calculation:

1) Volume of one drop of oil is equal to the volume of the circular patch
2) One oil drop is perfectly spherical while the oil patch is perfectly circular
3) No evaporation of the oil occurs during the experiment

Worked Example 5

In an experiment to estimate the size of a molecule of olive oil, a drop of oil of volume $0.12cm^3$ was placed on a clean water surface. The oil spread on a patch of area 6.0×10^6 mm^2.

a) *Calculate the size of the molecule*

b) *State an assumption made in the above calculations.*

Answer

a) *Volume,* $\boldsymbol{V}$ *= Area,* $\boldsymbol{A}$ *x Thickness,* $\boldsymbol{t}$

Therefore, thickness, $\boldsymbol{t} = \dfrac{\text{volume, } \boldsymbol{V}}{\text{Area, } \boldsymbol{A}}$

$= \dfrac{0.12cm^3}{}$

Quick Practice Questions

An oil drop has a volume of 0.01mm^3 when it is placed on the surface of some water; it spreads out to form a circular patch of area 500 cm^2

a) Calculate the thickness of the oil film. ***(Answer: 2×10^{-10}m OR 2×10^{-7}mm OR 2×10^{-8}cm)***

b) What two assumptions you have made above.

2. TOPIC 2: FORCE

Force is a push or a pull on an object

- SI unit of force is the **newton**, (N)

DEFINITION OF THE NEWTON AS A UNIT OF FORCE

One newton is the force required to give a body of mass 1 kg an acceleration of 1 m/s^2

Force (N) = mass (kg) x acceleration (m/s^2)

$$\boxed{F = ma}$$

F – Force in newtons (N) **m** – Mass in kilograms (kg) **a** – Acceleration in m/s^2

Worked Example 6

Calculate the force needed to give an object of mass 200 grams an acceleration of 3 m/s^2

Answer *Mass = 200 grams*

$= \left(\frac{200}{1000}\right)$ kg

$= 0.2$ kg

$F = ma$

Quick Practice Question

A force of 0.2N is applied on a body of mass 50 grams. What is the acceleration produced?
(Answer: 4m/s²)

WEIGHT

Weight is the pull of gravity on a body

- Weight is measured using a spring balance.
- SI unit of weight is **newtons**, (N)
- Weight is a vector quantity and its direction is towards the centre of the earth
- Weight of a body is not always constant. It varies from place to place.
- The weight of a body is calculated as**:**

Weight (N) = mass (kg) x gravitational field strength (m/s^2 or N/kg)

$$\boxed{W = mg}$$

Where:

W – Weight in newtons (N) **m** – Mass in kilograms (kg) **g** – Acceleration due to gravity (m/s^2)

Worked Example 7

A pail of water weighs 60N on earth where the gravitational field strength is 10N/kg. The moon has gravitational field strength $^1/_6$ times that on earth. How many newtons will the pail weigh on the moon?

Answer

$$W = mg$$
$$60\ N = m \times 10$$
$$m = \frac{(60)}{10}$$
$$m = 6\ kg$$

Gravitational field strength on the moon, $\mathbf{g'} = \frac{1}{6} \times 10$

$$= \frac{10\ N/kg}{6}$$

Therefore, weight W' on the moon $= m \times g'$

$$= \frac{6 \times 10}{6}$$

Quick Practice Question

A body weighs 600N on earth where the gravitational field strength is10N/kg and 1140 N on the planet Jupiter. Determine the gravitational field strength on planet Jupiter ***(Answer: 24.783 N/kg)***

- **A vector quantity is a quantity which has both magnitude and direction**
- **A scalar quantity is a quantity which has magnitude only but no direction**

Examples

VECTOR QUANTITY	SCALAR QUANTITY
Force	Time
Acceleration	Speed
Velocity	Mass
Weight	Temperature
Momentum	Electric current

3. TOPIC 3: PRESSURE

Pressure is force *acting perpendicularly* on a surface per unit area

$$\text{Pressure } (N/m^2) = \frac{\text{Force (N)}}{\text{Area } (m^2)}$$

$$\boxed{P = \frac{F}{A}}$$

P – Pressure in N/m^2 or pascals (Pa) **F** – Force in newtons (N) **A** – Area in m^2

- Pressure is a scalar quantity
- SI units of pressure is **newton per metre squared**, N/m^2, which is also called **pascal** (Pa)
- Pressure can also be measured in:

(i) Atmospheres

(ii) mmHg

- Pressure exerted by solids depends on two factors:

(i) The Area of Contact:

- The smaller the area of contact, the greater the pressure exerted

$$\text{Greatest / maximum pressure} = \frac{\text{Force / weight}}{\text{Smallest Area}}$$

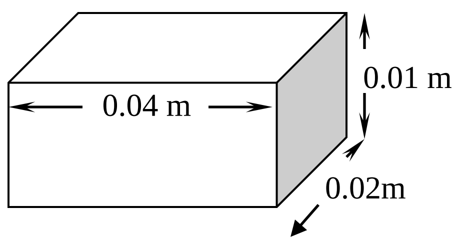
(ii) The Force Applied

- The bigger the force applied, the greater the pressure exerted

$$\text{Least / Minimum Pressure} = \frac{\text{Force / Weight}}{\text{Greatest Area}}$$

Worked Example 8

The figure below shows a block of wood of mass 250 grams placed on a flat horizontal surface



Work out:

a) *The maximum pressure it can exert on the surface*

b) *The minimum pressure it can exert on the surface* $(g = 10\ m/s^2)$

Answer

a) $$\text{Maximum pressure} = \frac{\text{weight}}{\text{Smallest Area}}$$

$$\text{Weight} = mg$$

$$= \frac{250}{1000} \times 10$$

$$= 2.5N$$

$$\text{Smallest area} = 0.02 \times 0.01$$

$$= 0.0002\ m^2$$

$$\text{Therefore, maximum pressure} = \frac{2.5}{0.0002}$$

$$\underline{\underline{= 12500\ N/m^2}}$$

b) $$\text{Minimum pressure} = \underline{\text{weight}}$$

Largest Area

Weight = mg

$$= \frac{(250)}{1000} \times 10$$

$$= 2.5N$$

Largest area = 0.04 x 0.02

$$= 0.0008\ m^2$$

Therefore, minimum pressure = $\left(\frac{2.5}{0.0008}\right)$

$$\underline{= 3125\ N/m^2}$$

Quick Practice Question

1. *A block of glass measures 2 cm by 3cm by 5 cm. Given that the density of glass is 2.5 g/cm³, determine:*
   - *i) Lowest pressure it can exert on a flat surface* ***(Answer: 500 N/m²)***
   - *ii) The highest pressure it can exert on a flat surface.* ***(Answer: 1250 N/m²)***
2. *Calculate the maximum pressure of a glass block of density 2.5g/cm³ would exert on a horizontal surface, if the block measured 20 x 10 x 5cm.* ***(Answer: 5000N/m²)***

PRESSURE IN FLUIDS

- Pressure exerted by a fluid (liquid or gas) depends on ***three*** factors:

(i) Height of the fluid column

- *The greater the height of the fluid column, the greater the pressure exerted*

(ii) The density of the fluid

- *Denser fluids exert more pressure than less denser ones.*

(iii) Gravitational field strength

- *Liquid pressure is high where gravitational field strength is high.*

- Pressure exerted by liquids is calculated as:

$$\boxed{P = h \rho g}$$

P – Pressure in N/m^2 (or Pa) **h** – Height of the liquid column in metres (m)

ρ - Density of the liquid in kg/m^3 **g** – Acceleration due to gravity (m/s^2)

Worked Example 9

The height of mercury in a barometer at a place is 64 cm. What would be the height of water in a barometer at the same place? (Density of water = 1000 kg/m^3; density of mercury = 13600 kg/m^3)

Answer

Since atmospheric pressure is the same, then:

Pressure due to mercury = pressure due to water

$h_1 \rho_1 g = h_w \rho_w g$ *(where: 1- refers to mercury and **w**- refers to water)*

$\frac{64}{100} \times 13600 \times 10 = h_w \times 1000 \times 10$

Therefore, $h_w = \frac{0.64 \times 13600 \times 10}{1000 \times 10}$

$h_w = 8.704$ m

Quick Practice Question

A hole of area 2.0 cm^2 at the bottom of a tank 2.0m deep is closed with a cork. Determine the force on the cork when the tank is filled with water. Density of water = 1000 kg/m^3, and g = 10 m/s^2. ***(Answer = 4N)***

TRANSMISSION OF PRESSURE IN FLUIDS (PASCAL'S PRINCIPLE)

Pascal's principle states that pressure exerted at any point on an enclosed fluid is transmitted equally throughout the fluid.

- Pascal's principle is applied in hydraulic machines / systems such as:

  (i) **Hydraulic lift**

  (ii) **Hydraulic press**

  (iii) **Motor vehicle braking system**

- *For a hydraulic machine, pressure on the small piston = pressure on the big piston, i.e* $P_1 = P_2$*, thus*

$$\boxed{\frac{F_1}{A_1} = \frac{F_2}{A_2}}$$

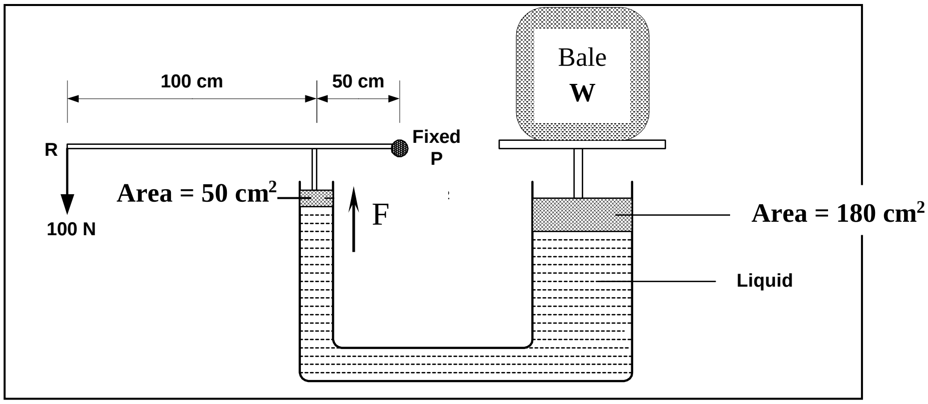
F_1 – force on the small piston (N) F_2 – Force on the big piston (N)

A_1 – cross section area of small piston A_2 – cross section area of big piston

Worked Example 10

Ff

*The Figure **below** shows a hydraulic press system using a lever of negligible mass on the side of a small piston pivoted at point **P**. A force of 100N is applied at **R**.*



a) *Calculate the force **F** exerted by small piston on the liquid.*

b) *Find the weight of the Bale supported by the large piston.*

Answer

a) *Taking moments about **P**:*

Sum of clockwise moments = sum of anticlockwise moments

$$F \times 0.5\ m = 100\ N \times 1.5\ m$$

$$F = \frac{(100 \times 1.5)}{0.5}$$

$$\underline{\underline{F = 300N}}$$

b) *The weight **W** of the bale:*

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\frac{W}{180\ cm^2} = \frac{300N}{50\ cm^2}$$

$$W = \frac{(300 \times 180)}{50}$$

$$\underline{\underline{W = 10800\ N}}$$

- **Properties of a good hydraulic fluid**

  (i) *Should be incompressible*

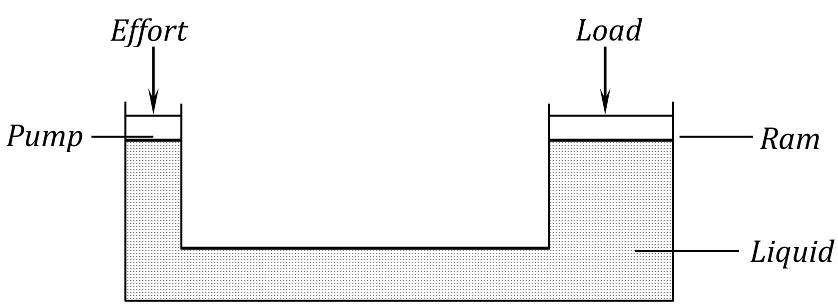
  (ii) *Should have a high boiling point*

  (iii) *Should have a low freezing point*

  (iv) *Should not be corrosive*

Quick Practice Question

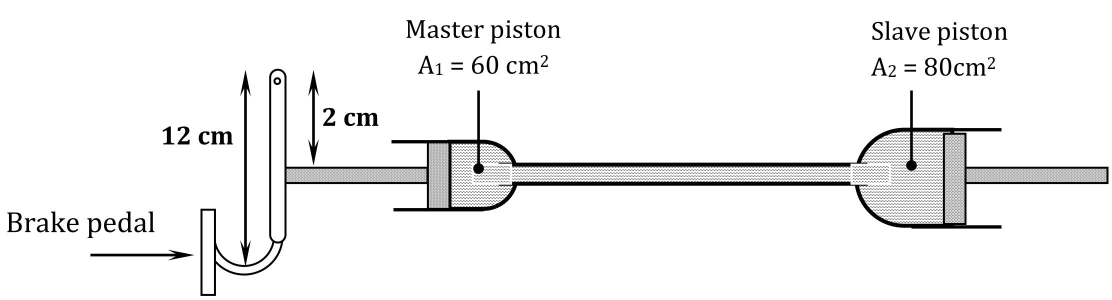
1) *The diagram below shows a hydraulic machine used in lifting heavy objects.*



The pump piston has an area of 0.25m² while the ram piston has an area of 1000m². Find the minimum effort that can raise a load of 4 x 10⁵ N ***(Answer: 100N)***

2) *In a hydraulic press the diameter of the larger piston is 30cm and the diameter of the smaller piston is 5cm. Calculate the force exerted by the larger piston when a force of 20N is applied to the smaller piston.* ***(Answer: 720N)***

3) *The diagram below represents a motor car hydraulic braking system*



a) *State the property of the liquid used as brake fluid*

b) *Explain briefly how the system works.*

c) *An effort of 200N is applied on the brake pedal, calculate*

(i) *The force applied to the master piston* ***(Answer =1200N)***

ATMOSPHERIC PRESSURE

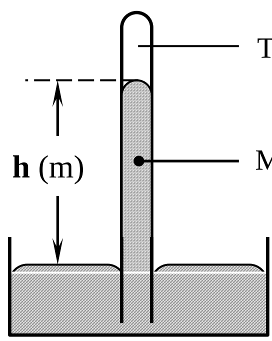
- This is pressure exerted by the atmosphere due to the weight of air.
- Atmospheric pressure decreases as height increases because of less gases upwards
- Atmospheric pressure is measured by use of a barometer. These include:

  (i) **Mercury / simple barometer**

  (ii) **Fortin barometer**

  (iii) **Aneroid barometer**

THE SIMPLE BAROMETER



h is the barometric height

- The barometric height (height of liquid used) depends on:

  (i) **The density of the liquid used (ρ)**

  - *The more dense the liquid used, the* ***lower*** *the barometric height*

  (ii) **The atmospheric pressure (P)**

  - *The greater the atmospheric pressure, the greater the barometric height*

  (iii) **The gravitational field strength (g)**

  - *The barometric height is lower in places of higher gravitational field strength*

NOTE: **1.** *The barometric height is* ***not affected*** *even if the tube is tilted*

2. *If air is allowed to enter the vacuum, the height will be lowered.*

- For the simple barometer, Pressure readings are expressed in terms of the height of the liquid used e.g. 760 mmHg
- These readings can be converted to N/m^2 by using the formula:

$$\boxed{P = h\rho g}$$

P – Pressure in N/m^2 (or Pa)

ρ - Density of the liquid in kg/m^3

h – Height of the liquid column in metres (m)

g – Acceleration due to gravity (m/s^2)

Worked Example 11

The normal atmospheric pressure is 760 mmHg. What is this pressure reading in N/m^2?
(Density of mercury = 13600 kg/m^3, g = 10m/s^2)

Answer

$$P = h\rho g$$

$$= \frac{760}{1000} \times 13600 \times 10$$

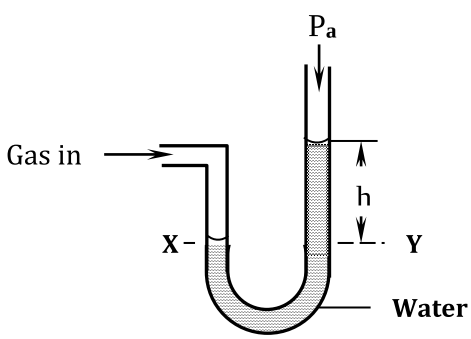
$$\underline{\underline{P = 103360\ N/m^2}}$$

Quick Practice Questions

1. *The atmospheric pressure at a certain region on the earth's surface is 129200 Pa. If the pressure is measured using the mercury manometer, what would be the height of the mercury column in the manometer.* ***(Answer: 950 mm OR 95 cm OR 0.95m)***
2. *Explain how the height of mercury column in a mercury barometer would change if the barometer is taken on top of a high mountain*

TH

- This is used to measure gas pressure



- For the U – tube manometer:

Gas pressure, P, = h ρ g + P_A

Where:

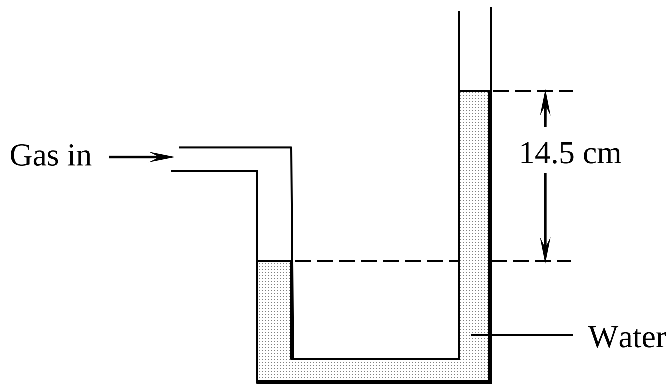
P – Pressure in N/m^2 (or Pa) **h** – Height differences between the two columns (m)

ρ - Density of the liquid in kg/m^3 **g** – Acceleration due to gravity (m/s^2)

P_A - atmospheric pressure in N/m^2 (or Pa)

Worked Example 12

One end of an open U –tube manometer is connected to a gas tap using a rubber tube. When the gas tap is turned on the difference in the two arms is 14.5cm of water. Calculate the pressure exerted by the gas expressing your answer in SI units. (Atmospheric pressure = 1.02 x 10^5 Pa; density of water = 1000 kg/m^3)



Answer

$P_g = P_{atm} + \rho hg$

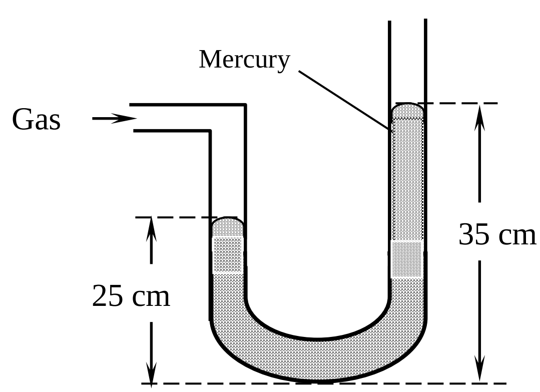
$P_g = 1.02 \times 10^5 + 1000 \times \frac{14.5}{100} \times 10$

$= 102000 + 1450;$

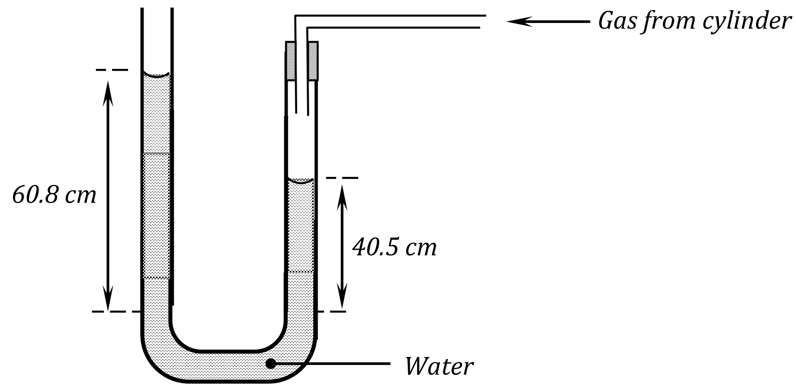
$\underline{P_g = 103450 \text{ Pa}}$

Quick Practice Questions

1. *The figure below shows a U – tube manometer measuring the pressure of a certain gas. Given the atmospheric pressure is760mmHg, determine the pressure of the gas in SI units. (Take density of mercury to be 1.36 x 10^4 kg/m^3)* ***(Answer: 116960 N/m^2)***



2. *Water is poured into a long glass tube to a height of 55 cm. Given that the atmospheric pressure is 102000N/m^2, determine the pressure at the bottom of the tube. Density of water = 1000*



4. TOPIC 4: PARTICULATE NATURE OF MATTER

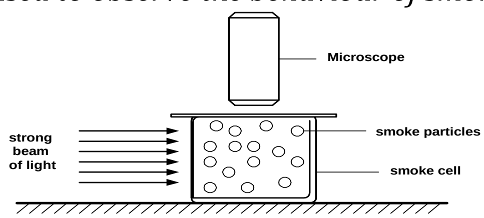
- Matter is anything which has mass and occupies space
- Matter exists in three physical states:
  1. *Solids*
  2. *Liquids*
  3. *Gases*
- ***The kinetic theory of matter states that the particles of matter are always in a state of continuous random motion***
- The motion of the particles of matter increases with an increase in temperature
- Particles of matter have spaces between them which are partly filled by others, for example, when a substance dissolves. This explains why when equal volumes of ethanol and water are both mixed; the final volume of the mixture is less than expected.

BROWNIAN MOTION

- **Brownian motion is the continuous random zig-zag motion of particles**

Worked Example 13

The figure shows apparatus used to observe the behaviour of smoke particles in a smoke cell.



a) State and explain what was observed

- *Bright specks are seen moving in a continuous random motion. This is due to the uneven bombardment of the smoke particles by air molecules inside the smoke cell.*

b) ***Explain what happens if the temperature was raised.***

- *Rate of collision increases due to increase in overall kinetic energies of air molecules*

1. ***Diffusion is faster in gases than in liquids***

   Reason: *This is because the particles of gases are far apart with weak forces of attraction between them.*

2. ***The rate of diffusion of particles increases with an increase in temperature***

   Reason: *When temperature is increased, the kinetic energy of the particles is also increased. This causes the particles to move and hence diffuse faster than at lower temperature.*

5. TOPIC 5: THERMAL EXPANSION

Temperature is the degree of hotness or coldness of a body

Temperature is measured by using the thermometer

ck Practice Questions

In Brownian motion experiment, smoke particles are observed to move randomly. ***Explain*** *how this motion is caused*

(a) In an experiment to show Brownian motion, smoke was placed in an air cell and observed to move randomly.

(i) Explain the observation.

(ii) Give a reason for using small particles such as a smoke in this experiment.

(iii) If the temperature of the air cell was raised explain the new observation.

b) (i) Distinguish between liquid and gaseous states of matter in terms of molecular forces.

(ii) Distinguish between cohesion and adhesion.

- It does not wet glass
- It has a high boiling point (357°C
- It is a good conductor of heat
- It expands uniformly
- It is opaque and silvery, hence easily visible

ADVANTAGES OF ALCOHOL

- It has a low freezing point; therefore it can be used to measure lower temperatures

UPPER AND LOWER FIXED POINTS

(i) The upper fixed point is the temperature of steam from water boiling at normal atmospheric pressure

(ii) Lower fixed point is the temperature of pure melting ice

IMPORTANT POINTS TO NOTE

1. *For the* ***upper fixed point****, it is normally* ***not advisable*** *to dip the bulb in boiling water when getting the upper fixed point.*

MERCURY THERMOMETER

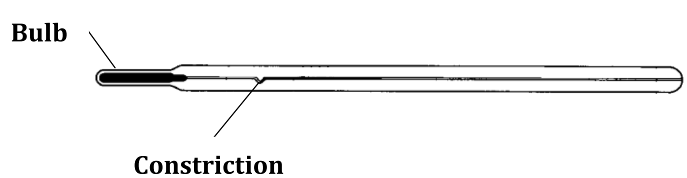
- In this thermometer, mercury expands in a capillary tube when the bulb is heated
- The sensitivity of a mercury thermometer ensured by:
  - **(i) Using a very narrow capillary tube**
  - **(ii) The bulb is made of very thin glass so that heat can be conducted faster**

CLINICAL THERMOMETER

- This is used to measure body temperature
- It has a short scale of 35°C – 45 °C. Because of this, *clinical thermometer is not sterilised using boiling water. Boiling water has temperature which is much higher than the highest temperature which can be measured using the clinical thermometer. This can cause the thermometer to break*
- Clinical thermometer has a narrow constriction to prevent the back flow of mercury

Worked Example 14

(a) The figure below shows a clinical thermometer. State the function of the constriction



Answer

Prevents the column of mercury beyond the constriction from going back to the mercury bulb hence allowing reading at one's own convenience

(b) Clinical thermometer can be used to measure very small temperature changes. State two features of the thermometer responsible for this property of the thermometer

Answer

Quick Practice Question

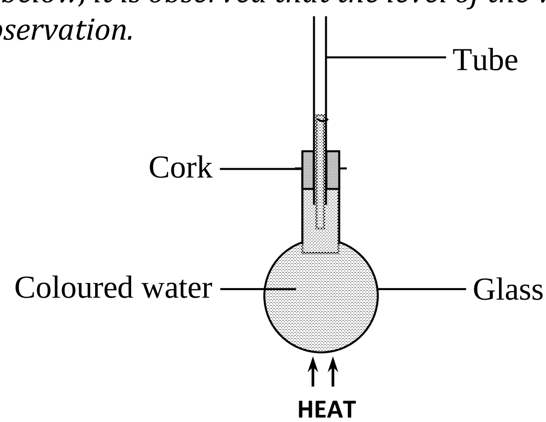
Explain the two features of a clinical thermometer stated below:

a) Constriction:

b) Thin walled bulb:

Worked Example 15

In the set up shown below, it is observed that the level of the water initially drops before starting to rise. Explain this observation.



Answer

Glass flask expands first, creating more volume for water. Water then expands increasing its level in the tube.

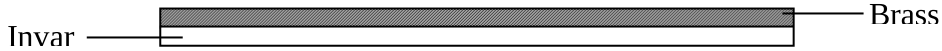
- This consists of two metals, which expand differently, joined together
- When either heated or cooled the bimetallic strip bends in a particular way, depending on the metals used.
- Bimetallic strip is used in:

  (i) Bimetallic thermometers

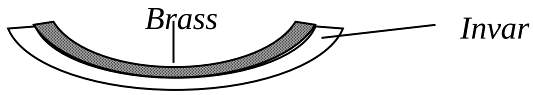
  (ii) Thermostats to regulate temperatures e.g. of an iron box

Worked Example 16

a) *The figure below shows a bimetallic strip of brass and invar at 300k. Given that brass expands faster than invar, Sketch and briefly explain the appearance of the strip at 270K*

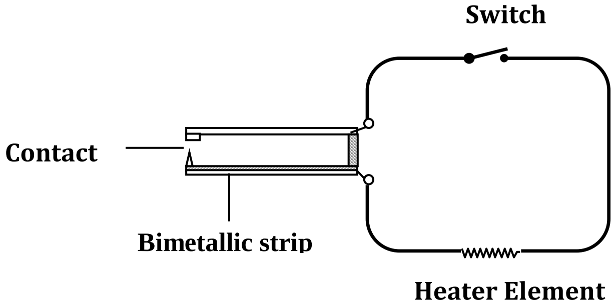


Answer



- *Since Brass expands faster than invar, it also contracts faster than invar and hence becomes shorter at lower temperatures, causing the bimetallic strip to curve as shown.*

b) *The figure below shows a circuit diagram for controlling the temperature of a room.*



(i) State and explain the purpose of the bimetallic strip

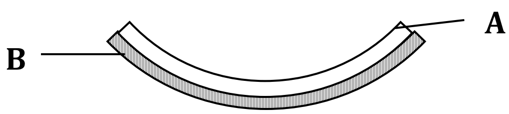
- *To make and break the circuit, it bends and straightens*

(ii) Describe how the circuit control the temperature when the switch S is closed

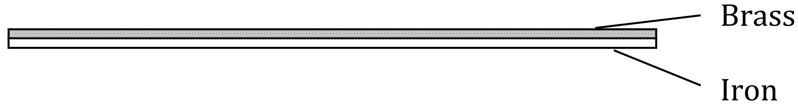
- *Current flows and heating takes place, temperature rises, the strip is heated and bends away from contact, the heater is disconnected, the temperature drops and the circuit is completed once more*

Quick Practice Question

2. *The diagram below shows a bimetallic strip after it has been heated from room temperature of 26 °C to 40 °C. Draw a possible shape of the bimetallic strip if its temperature is decreased from 40 °C to 39°C.*



3. *The figure below shows a bimetallic strip at room temperature. Draw the shape of the strip when it is heated to 80°C and when it is cooled to -10°C.*



APPLICATIONS OF EXPANSION OF SOLIDS

- Expansion of solids is applied in:
  - ***(i)*** *Construction of railways lines*
  - ***(ii)*** *When fixing telephone and electricity wires*
  - ***(iii)*** *When constructing steel bridges*

Worked Example 17

(a) *Why is concrete reinforced with steel in constructing beams?*

Answer

- *Concrete and steel expand and contract at the same rate. They have the same linear expansivity.*

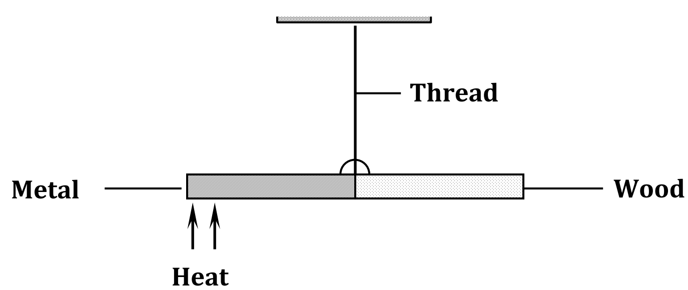
(b) *Explain why glass container with thick walls is more likely to crack than the one with a thin wall when a very hot liquid is poured into them*

Answer

- *The non-uniform expansion between the inner and outer surface of thick glass caused by the temperature difference between inner and outer surface. Thin glass expands uniformly.*

Quick Practice Question

The figure below shows a rod made of wood on one end and metal on the other end, it is suspended freely with a piece of thread so that it is in equilibrium.

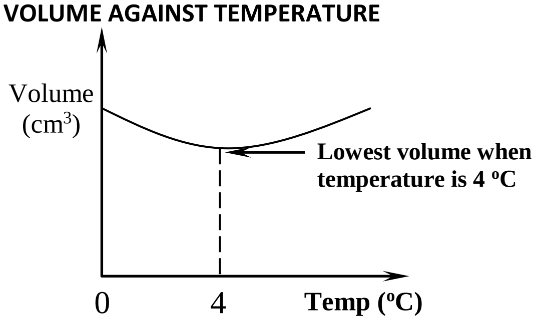


The side made of metal is now heated with a bunsen flame and the rod tips to the left. Explain.

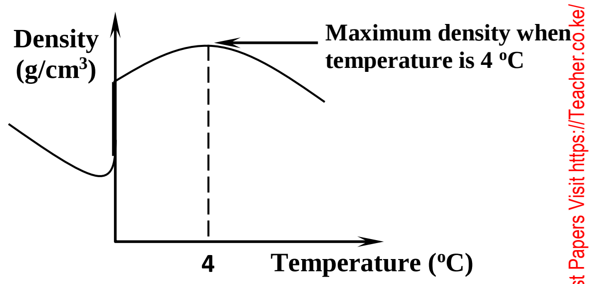
ANOMALOUS EXPANSION OF WATER

- This is the unusual expansion of water
- The unusual behaviour occurs between the temperatures of 0 ºC and 4 ºC
- When heated from 0 ºC to 4 ºC, water contracts instead of expanding and vice versa

VOLUME AGAINST TEMPERATURE



DENSITY AGAINST TEMPERATURE



Advantages

- Fish and other aquatic life can exist under the layers of ice
- Leads to weathering of rocks, thus facilitating to the formation of soil

Disadvantage

- Water pipes burst during winter / very cold seasons
- Leads to cracking of buildings

Worked Example 18

a) *Aquatic animals are observed to survive in frozen ponds. Explain this observation.*

Answer

- *Water freezes and the ice formed floats on water because it's less dense than water insulating the water below the water temperatures increases down the ponds because of anomalous expansion of water.*

b) *Explain why ice floats in water*

Quick Practice Question

a) *Give a reason why liquids generally expand more than solids*

b) *State three properties of a good thermometric liquid*

c) *State one biological importance of anomalous expansion of water*

d) *Equal masses of water and ice at 0^0C are added separately into two identical beakers containing equal amount of water. State the reason why ice may cause a greater change of temperature.*

6. TOPIC 6: HEAT TRANSFER

Heat is a form of energy that flows as a result of temperature difference between two regions

There are three modes of heat transfer:

(i) Conduction

(ii) Convection

(iii) Radiation

CONDUCTION

- **This involves heat transfers in solids**

FACTORS AFFECTING CONDUCTION:

a) Cross sectional area of the conductor

- *The greater the cross sectional area (thickness) of a conductor, the faster heat is conducted*

b) Temperature difference between the ends of the conductor

- *The greater the temperature difference, the faster heat is conducted*

c) Length of the conductor

- *The shorter the conductor, the faster heat is conducted*

d) Nature of the material used

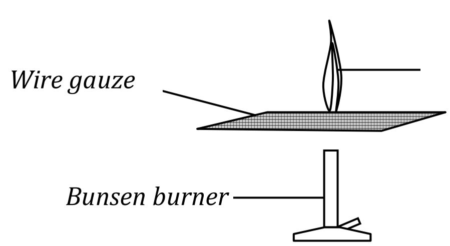
- *Different materials / metals conduct heat differently, e.g. copper conducts better than iron*

USES OF GOOD AND BAD CONDUCTORS

- *Good conductors are used to make cooking utensils, soldering materials e.t.c*
- *Bad conductors are used to make handles for cooking pots, fire fighting equipment e.t.c*

Worked Example 19

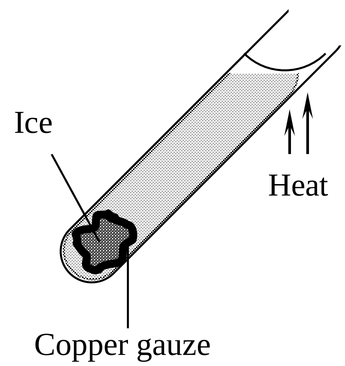
A Metal gauze is placed above a Bunsen burner. The gas is put on and the burner is lit as shown in the figure below. Explain why the gas burns only above the gauze.



Answer

Quick Practice Question

In the experiment set up shown below, the ice remains intact for several minutes as heating progresses. Give a reason for this observation.



CONVECTION

- **This is the process by which heat is transmitted through fluids (liquids and gases)**

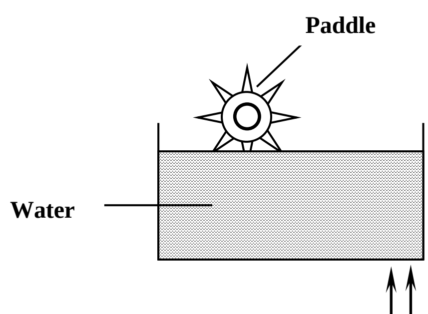
Experiments to demonstrate convection currents

(i) Using potassium permanganate and water (in liquids)

(ii) Using a smoke box (in gases)

Quick Practice Question

The figure below shows a paddle wheel made of light material. Show on the diagram the direction of its rotation when heat is applied at one end of the container as shown. Give a reason for your answer.



APPLICATIONS OF CONVECTION

(i) Motor car radiators for cooling car engines

(ii) Domestic hot water system for supplying hot water in house

(iii) Ventilation holes in houses are placed near the roof to allow for free circulation of fresh air

Worked Example 20

State two facts which shows that heat from the sun does not reach the earth surface by convection

Answer

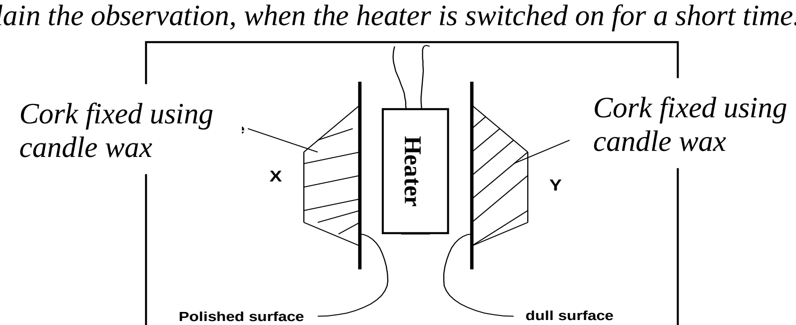
- *Convection takes place in air upwards direct due to density effect;*
- *Convection requires a material medium but the space between the sun and the earth i.e. space of between the sun and the earth i.e. space of the atmosphere has no material medium;*

RADIATION

- **This is the flow of heat from one point to the other by means of electromagnetic waves (infra red waves)**
- Dull / black surfaces are good absorbers (i.e. they absorb heat faster) than shiny / polished surfaces
- Good absorbers are also good radiators i.e. they also lose heat quickly

Worked Example 21

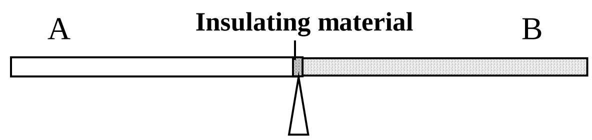
*The figure below shows two corks **X** and **Y** fixed on a polished plate and a dark plate with candle wax respectively. Explain the observation, when the heater is switched on for a short time.*



Polished surface *Dull surface*

Quick Practice Question

*A thin metal bar made of the two parts is connected at the ends with insulating materials. Side **A** of the bar is brightly polished while side **B** is painted black. The bar is in equilibrium as shown in the diagram below. State and explain what will be observed on the equilibrium of the bar if it is placed outside on a hot day*



Applications of radiation

(i) Electric kettles, iron boxes and cooking pans have polished surfaces to reduce heat loss through radiation

(ii) Houses in hot regions are painted white to minimise heat absorption through radiation

(iii) Green houses act as heat trap by preventing longer wavelength radiations from passing through glass

(iv) Cloudy nights are warmer than clear nights because clouds reflect radiation back to the earth

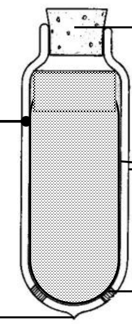
Worked Example 22

Explain why plants in greenhouse, experience higher temperature than the ones outside

Answer

The, radiations of heat from the green house are trapped by the roofs and walls of the house and remain within hence keeping the place warm

THE VACUUM FLASK



- This is a device designed to keep the temperature of its contents constant by minimising heat transfer into and out of the flask

  (i) Heat transfer through radiation is minimised by the silvery surfaces

  (ii) Heat transfer through convection is minimised by the vacuum between the double walls

  (iii) Heat transfer through conduction is minimised by the vacuum between the double walls and the rubber stopper

  (iv) Heat loss through evaporation is minimised by a well fitting rubber stopper

Quick Practice Questions

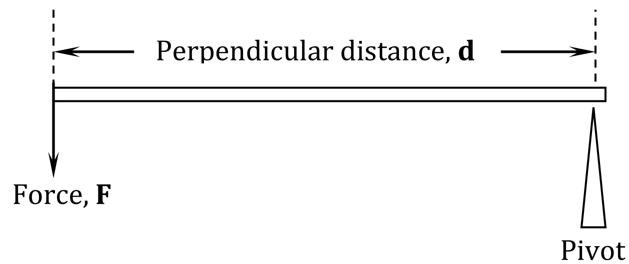
1) *In a vacuum flask, the walls enclosing the vacuum are silvered on the inside. State the reason for this.*

2) *State **three** ways heat losses in a vacuum flask are minimised and explain each.*

7. TOPIC 7: TURNING EFFECT OF FORCE

Moment of a force is the product of the force and the perpendicular distance from the turning point to the line of action of the force.

Moment of a force (Nm) **=** Force (N) x Perpendicular distance from the pivot (m)



Moment of force = F x d

F – Force in newtons (N)

d – Perpendicular distance from the pivot (N)

- SI unit of moment of a force is **newton-metre,** (Nm)

FACTORS AFFECTING THE MOMENT OF A FORCE

- Moment of a force depends on:

(i) The magnitude of the force applied

- *The bigger the force applied, the greater the turning effect*

(ii) The perpendicular distance measured from the point of support (pivot)

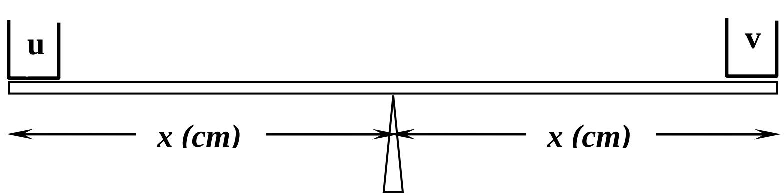
- *The longer the distance from the turning point, the greater the turning effect*

(iii) The angle at which the force is applied

- *Greatest turning effect is obtained when the force is applied at an angle of 90°*

Worked Example 23

*The figure below shows a horizontal beam pivoted at the centre. Explain briefly what happens to the horizontal beam when equal volume of water and paraffin is poured into the identical containers **u** and **v** respectively.*

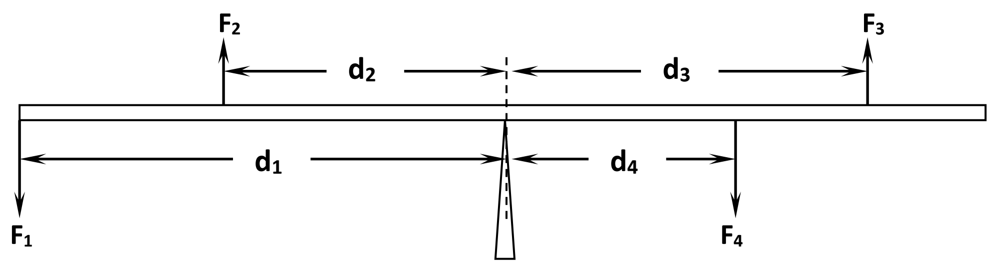


PRINCIPLE OF MOMENTS

Principle of moments states that *when a body is in equilibrium*, the sum of clockwise moments about a point is equal to the sum of the anticlockwise moments about the same point.

NOTE: *When applying the Principle of moments to solve numerical problems, all distances must be measured from the turning point / fulcrum / pivot*

Example



- *Forces producing clockwise moments are* $\mathbf{F_2}$ and $\mathbf{F_4}$

  Therefore, ***sum of clockwise moments*** = $(F_2 \times d_2) + (F_4 \times d_4)$

- *Forces producing anticlockwise moments are* $\mathbf{F_1}$ and $\mathbf{F_3}$

  Therefore, ***sum of anticlockwise moments*** = $(F_1 \times d_1) + (F_3 \times d_3)$

  By principle of moments:

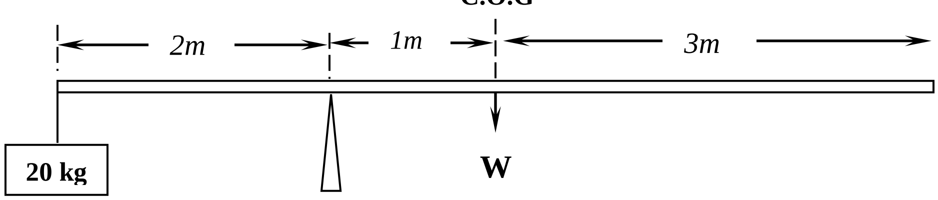
  Sum of clockwise moments = Sum of anticlockwise moments

  That is:

$$(F_2 \times d_2) + (F_4 \times d_4) = (F_1 \times d_1) + (F_3 \times d_3)$$

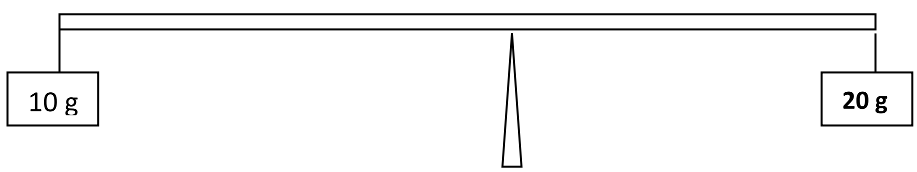
Worked Example 24

An object of mass 20kg balances on a uniform plank of length 6m as shown below. Determine the weight of the plank

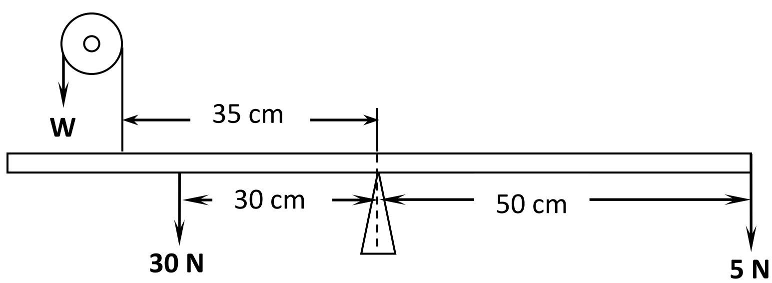


Quick Practice Question

1. *A uniform metre rule of mass 100g is balanced by suspending a 10g mass and a 20g mass on its ends as shown* ***below****. Determine the position of the pivot.* ***(Answer: 58.3 cm mark)***



2. *The figure below shows a uniform bar pivoted at its centre and is at equilibrium. Determine the value of* ***W*** ***(Answer: 18.57N)***



8. TOPIC 8: EQUILIBRIUM AND CENTRE OF GRAVITY

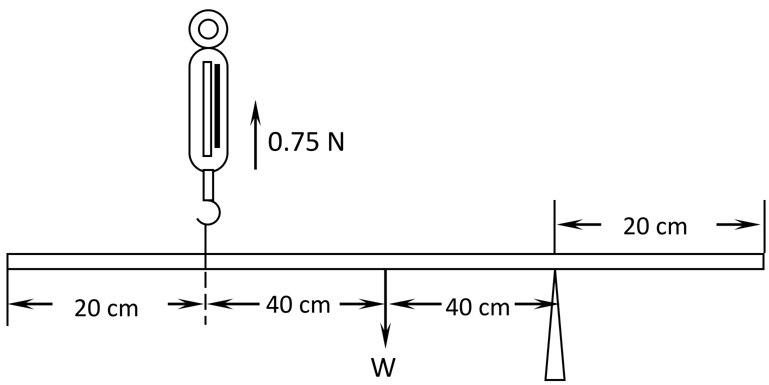
1. **Centre of gravity is the point where the whole weight of a body seems to be concentrated.**
2. **Centre of gravity is the point of application of the resultant force due to the earth's gravitational pull**

Note:

1. A body pivoted at its centre of gravity will always balance
2. For *regular* / uniform shaped bodies, the centre of gravity is at their geometrical centres

Worked Example 25

The figure below shows a uniform beam of length 1.2 m pivoted near one end. The beam is kept in equilibrium by a spring balance as shown. Given that the reading of the spring balance is 0.75N; determine the weight of the beam.



Answer

*Since the beam is uniform, its weight **W** act at geometrical centre (0.6 m from either ends of the beam)*

Taking moments about the pivot

Clockwise moments = 0.75 N x 0.8 = 0.6 Nm

*Anticlockwise moments = **W** x 0.4 = 0.4**W** Nm*

But by principle of moments,

Anticlockwise moment = Clockwise moment, therefore:

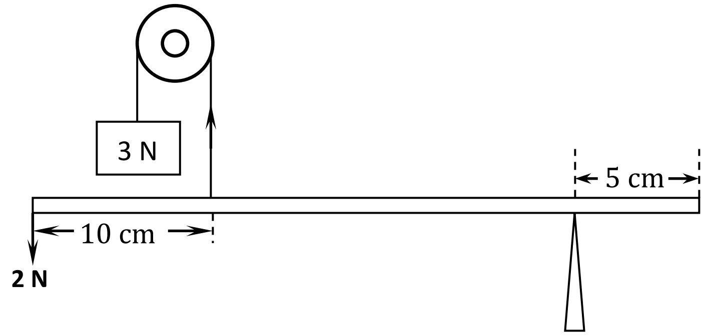
$$W \times 0.4 = 0.6$$

$$W = \frac{0.6}{0.4}$$

$$\mathbf{W = 1.5\ N}$$

Quick Practice Question

1. *A uniform half meter rule is supported by force of 3N and 2N as shown in the figure below. Determine the weight of the half meter rule* ***(Answer: Weight = 0.75N)***



TYPES OF EQUILIBRIUM AND STABILITY

- *Equilibrium refers to a state of balance*
- *Stability refers to how easy or difficult it is for a body to topple over when a force is applied on it*
- There are three states of equilibrium

(a) Stable equilibrium

- This is where an object returns to its original position after being displaced slightly
- The centre of gravity is very low and below the object
- *Example: a Bunsen burner resting on its base*

(b) Unstable equilibrium

- This is where when an object is displaced slightly; it does not return to its original position but occupies a new position
- The centre of gravity is high and far from the base
- *Example: a bus with a lot of luggage on top*

(c) Neutral equilibrium

- This is where when an object is displaced slightly; it does not change its position of centre of gravity.
- The centre of gravity is in the middle, and the body just rolls over

- *Example: a football rolling on the ground*

FACTORS AFFECTING STABILITY

1. Position of the centre of gravity

- If the centre of gravity is high, the object becomes more unstable

2. Area of the base

- A broad base makes an object more stable, while a narrow base makes the object unstable

- *A body is therefore more stable if:*
  - ***i)*** *The centre of gravity is as low as possible*
  - ***ii)*** *The area of the base is as wide as possible*

NOTE*: If the vertical line drawn from the centre of gravity of a body falls outside the base, then body will topple over. If it falls within the base, then the body* ***will not*** *topple over*

Example

Bus ***will not*** *topple over since the line drawn from the C.O.G is still within the base*

Bus ***will*** *topple over since the line drawn from the C.O.G falls outside the base*

Quick Practice Question

A bus carrying standing passengers has a higher chance of overturning than one with sitting passengers. Explain.

APPLICATIONS OF STABILITY

(i) Racing cars have wider wheel base in order to lower their centre of gravity

(ii) Buses have their luggage compartments below the passenger's seats and not at the top so as to lower the centre of gravity

(iii) Passengers are not allowed to stand in the upper deck of a double decker bus so that they don't raise the centre of gravity.

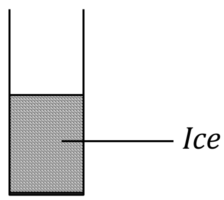
Worked Example 26

a) The stability of a body can be increased by increasing the base area and lowering its centre of gravity. State one way of lowering its centre of gravity.

Answer

- *Increase the weight of the base to lower the centre of gravity*

b) The diagram below shows a tall tube half filled with frozen ice at 0^0 C. If the tube is warmed up to 4^0C, state and explain the effect of this on the stability of the tube

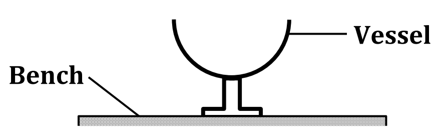


Answer

- *The tube becomes more stable between 0^0C and 4^0C water contracts when heated. This lowers the centre of gravity hence increasing its stability*

Quick Practice Question

The figure below shows a vessel resting on a horizontal bench. State and explain the effect on the stability of the vessel when it is filled with water.



Answer

- *Stability is reduced*
- *Filling the vessels with water makes the upper part heavier; this raises the c.o.g of the vessel, reducing stability*

CONDITIONS FOR EQUILIBRIUM

- For a body in equilibrium under the action of parallel forces, the following conditions must apply:
  - (i) *Sum of forces in one direction must equal the sum of forces in opposite direction (i.e. net force on the body must be zero)*
  - (ii) *The sum of clockwise moments must equal the sum of anticlockwise moments, taken about the same point.*

9. TOPIC 9: HOOKES LAW

Hooke's law states that ***provided the elastic limit is not exceeded***, the extension of a spring is directly proportional to the applied force.

$$\boxed{F = ke}$$

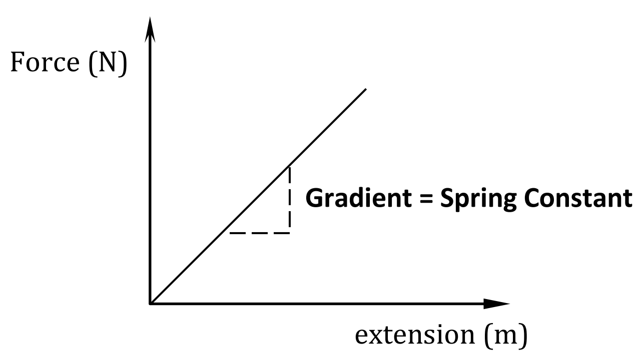
Where:

F – Applied force in newtons (**N**)

k – Spring constant in **N/m**

e – Extension in **m**

- A graph of force (y – axis) against extension (x – axis) is a straight line through the origin, whose gradient represents the spring constant



Worked Example 27

A light spring fixed at one end extends by 2.0cm when a stone of mass 120g is suspended from the free end. Find its spring constant. (g = 10 m/s²)

Answer *Weight of stone = mg*

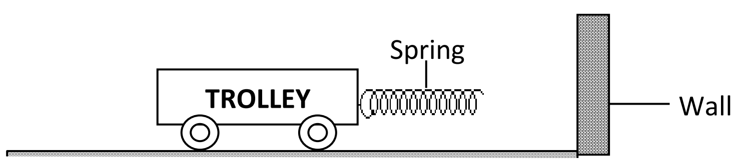
$= (\underline{120}) \times 10$

Quick Practice Question

1) *A light spiral spring which obeys Hooke's law has unstretched length of 22 cm. It is attached at its upper end to a fixed support and when a piece of metal of mass 2 kg is hung from the lower end, the spring extends to a length of 27.4 cm. Find the force needed 10 produce an extension of 10 mm.* ***(Answer: 3.7N)***

2) *A vertical spring of unstretched length 30 cm is rigidly clamped at its upper end. When an object of mass 100 grams is placed in a pan attached to the lower end of the spring, its length becomes 36 cm. For an object of mass 200 grams in the pan the length becomes 40 cm. calculate the mass of the pan* ***(Answer: 50 grams)***

3) *The figure below shows a frictionless trolley of mass 2kg moving with uniform velocity towards a wall. At the front of the trolley is a spring whose spring constant is 25Nm. The trolley comes to rest momentarily after compressing the spring by 3cm and then rebounds from the wall.*



(i) *Determine*

I. *The force exerted on the wall by the spring.* ***(Answer: 0.75N)***

II. *The maximum acceleration of the trolley as it rebounds from the wall.* ***(Answer: 0.375m/s²)***

(ii) *State the reason why the trolley acquires a constant velocity after it rebounds.*

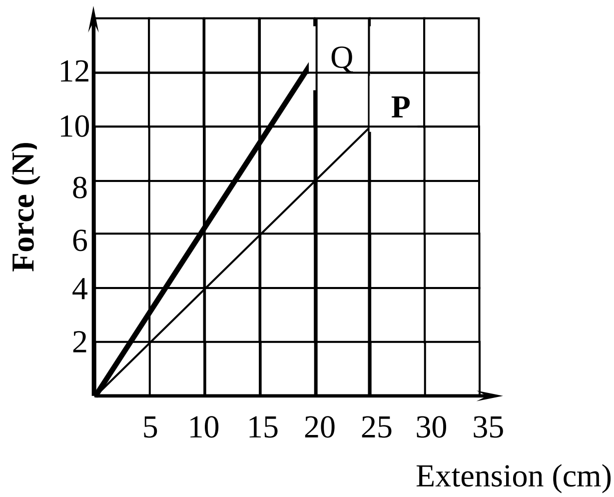
- The spring constant depends on:

1) The material from which the spring is made

2) The cross-sectional area of the spring
3) Thickness of the wire used to make the spring
4) Length of the spring
5) Number of turns per unit length

Worked Example 28

a) *The figure below shows a graph of force against extension for spiral spring **P**. Determine the spring constant of the spring.*



Answer:

k = gradient of the graph

$= \frac{(10 - 0)}{(25 - 0)}$

k = 0.4 N cm^{-1} OR 40 N/m.

b) *On the same axes sketch the graph for spring Q whose spring constant is greater than 64 Nm^{-1}.*

***Answer**: (Shown on the graph using bold line and labelled Q)*

c) *Give possible physical differences between the springs **P** and **Q***

***Answer**:*

- ***P** is longer than **Q***
- ***P** is Thinner than **Q***
- ***P** is made of thinner wire than **Q***

SPRINGS IN PARALLEL AND IN SERIES

a) Spring constant for Springs in series

- When springs are arranged in series, the spring constant decreases.
- For *identical* springs in series, combined spring constant is given by:

$$k_s = \frac{k}{n}$$

k$_s$ – Combined spring constant for the springs in series

k – Spring constant for one spring only **n** – Number of springs connected in series

Worked Example 29

a) *Two identical Springs **X** and **Y** are connected in series and a stretching force of 10 N is applied. Given that the spring constant of each is 0.64N/cm, determine the resulting extension.*

Combined spring constant for the two springs, $k_s = \frac{k}{n}$

$$= \frac{(0.64)}{2}$$

$$k_s = 0.32 N/cm$$

$$F = k_s e$$

$$10 = 0.32 \times e$$

$$e = \frac{10}{0.32}$$

$$\underline{e = 31.25 \text{ cm}}$$

b) *Two **non identical** Springs **A** and **B** are connected in series and a stretching force of 10 N is applied. Given that **A** has spring constant 0.64N/cm, and **B** spring constant 1.0 N/cm determine the resulting extension.*

The two springs connected in series will stretch independent of each other, since they are non identical:

*For spring **A**:* $F = ke$

$$e = \frac{F}{k}$$

$$= \frac{10}{0.64}$$

$$e_1 = 15.625 \text{ cm}$$

*For spring **B**:* $F = ke$

$$e = \frac{F}{k}$$

$$= \frac{10}{1}$$

$$e_2 = 10 \text{ cm}$$

Total extension of the two springs $= (e_1 + e_2)$

$$= 15.625 + 10$$

$$= \underline{25.625 \text{ cm}}$$

- When springs are arranged in parallel, the spring constant increases.

- For *identical* springs in parallel, combined spring constant is given by:

$$\boxed{k_p = n\,k}$$

Where:

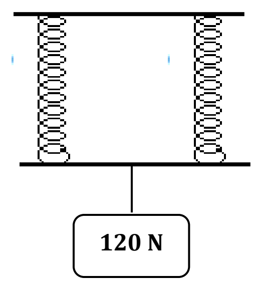
k_p – Combined spring constant for the springs in parallel

k – Spring constant for one spring only

n – Number of springs connected in parallel

Worked Example 30

The figure below shows two identical springs arranged in parallel. Determine the total extension produced by the arrangement, given that a single spring extends by 2 cm when supporting a 40 N weight



Answer

$$F = ke$$

$$40\text{ N} = \boldsymbol{k} \times 2$$

$$2\boldsymbol{k} = 40$$

$$\boldsymbol{k} = \frac{40}{2}$$

$\boldsymbol{k} = 20$ N/cm *(this is the spring constant for one spring)*

Therefore, $k_p = nk$

$k_p = (2 \times 20)$ $= \mathbf{40\ N/cm}$

But, $F = k_p e$

$$120\text{N} = 40 \times e$$

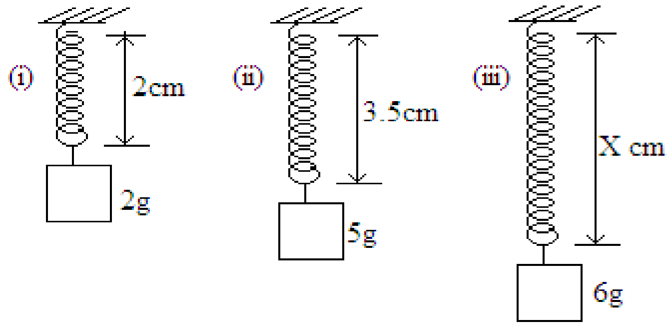
$$40e = 120\text{N}$$

$$e = \frac{120}{40}$$

$$\underline{e = 3\text{ cm}}$$

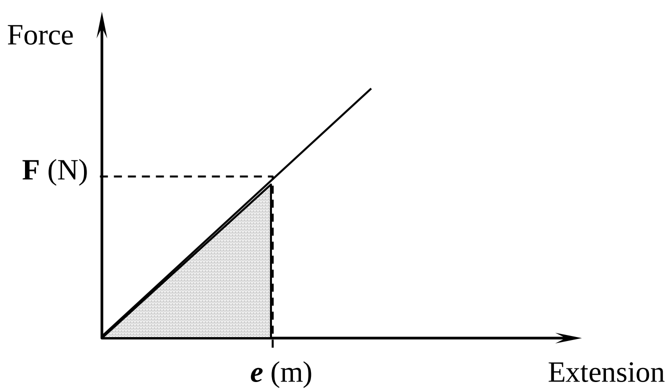
Quick Practice Question

The diagram below shows three identical springs which obey Hooke's law. ***Determine*** *the length X.* ***(Answer: X = 4 cm)***



ENERGY STORED IN A SPRING / WORK DONE IN STRETCHING A SPRING (*ELASTICS MATERIALS*)

- The work done in stretching a spring through an extension, ***e***, (m) when a force of **F** (N) is applied is given by the area under a force against extension graph.



Work done = ½ x base x height

= ½ x F x ***e***

Therefore: **Work done = $\frac{1}{2}$ F*e***

Where

F – Applied force in newtons (**N**)

k – Spring constant in **N/m**

- ***This work done will be stored in the form of elastic potential energy in the spring***
- ***The work done in stretching a spring / elastic potential energy stored in the spring, can also can be calculated as:***

Work done = $\frac{1}{2}$ k*e*^{2}

Where:

k – Spring constant in **N/m**

e – Extension in **m**

Worked Example 31

A force of 7.5N stretches a certain spring by 5.0cm. How much work is done in stretching this spring by 8.0cm?

Answer

Method 1

If 5 cm $\xrightarrow{\text{Requires}}$ 7.5 **N**

Then 8 cm $\xrightarrow{\text{Will require}}$ $\frac{8 \times 7.5}{5}$

$= 12.0\ N$

Work done = ½ Fe

$e = \left(\frac{8}{100}\right)$

$= 0.08\ m$

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

Therefore,

Work done = ½ x 12 x 0.08

Work done = 0.48 joules

Method II

$F = ke$

$e = \frac{5}{100}$

$= 0.05\ m$

$7.5 = k \times 0.05$

$k = \left(\frac{7.5}{0.05}\right)$

$k = 150\ N/m$

Work done $= \frac{1}{2} ke^2$

$W = \frac{1}{2} \times 150 \times \left(\frac{8}{100}\right) \times \left(\frac{8}{100}\right)$

Work done = 0.48 joules

SEE ALSO WORKED EXAMPLE 51 AND QUESTION ON PAPGE 79 BELOW

Quick Practice Question

1. *A man uses a bow to fire an arrow of mass 0.2kg vertically upwards into the air. He stretches the bow by 0.15m with a maximum force of 100N. Calculate the energy transferred to the arrow.* ***(Answer: 7.55 joules)***

2. *A force of 7.5N stretches a certain spring by 5.0cm. How much work is done in stretching this spring by 8.0cm?* ***(Answer: 0.48 joules)***

10. TOPIC 10: FLUID FLOW

- A streamline flow is a curve whose tangent at a point of flow is along the direction of the displacement of the particle at that point

- There are two types of fluid flow:
  - (i) Streamline flow and
  - (ii) Turbulent flow

1. ***Streamline flow****, also referred to as* ***steady, orderly*** *or* ***uniform flow*** *is when the fluid particles that pass any point follow the same path at the same speed*

2. ***Turbulent flow*** *also known as* ***disorderly flow*** *is when the speed and direction of the fluid particles passing any given point vary with time.*

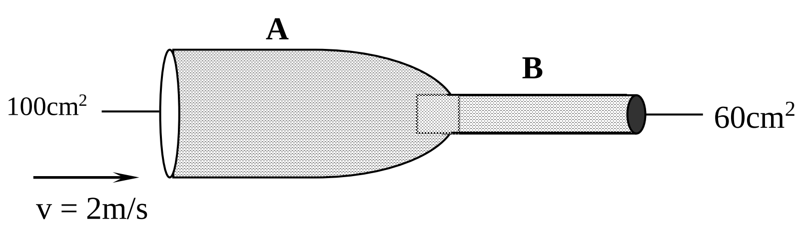
EQUATION OF CONTINUITY

$$A_1v_1 = A_2v_2$$

A_1 – cross sectional area of the wider end (m^2)
A_2 – cross sectional area of the narrower end (m^2)
v_1 – fluid velocity at the wider end (m/s)
v_2 – fluid velocity at the narrower end (m/s)

Worked Example 32

Water flows through a horizontal pipe of varying cross-section area as shown in figure below. The velocity of water in pipe ***A*** *is 2m/s. Determine the velocity of water in pipe* ***B****.*



$$A_1v_1 = A_2v_2$$

$$v_2 = \frac{A_1v_1}{A_2}$$

$$= \frac{100 \times 2}{60}$$

$$\underline{v_2 = 3.333 \text{ m/s}}$$

Rate of fluid flow (volume flow rate / volume flux)

- ***This is the volume of a fluid passing through a section in one second***
- Rate of fluid flow (***volume flux***) is calculated as

Rate of fluid flow = cross sectional area x velocity

$$\boxed{\text{Rate of fluid flow} = Av}$$

Where:

A – Cross sectional area (m^2) ***v*** – fluid velocity (m/s)

Worked Example 33

Water flows in through a horizontal pipe of cross – sectional area 100cm². At the outlet section, the cross- sectional area is 5 cm². If the velocity of water at the larger cross- section is 1.25 m/s

a) *Find the volume of water leaving the pipe in the second*

Volume per second = cross sectional area, ***A****, x velocity,* ***v***

$$= \frac{(10 \times 1.25)}{10\ 000}$$

$$\underline{\textbf{Volume per second} = 1.25 \times 10^{-3}\ m^3}$$

b) *Calculate the velocity of water in the smaller pipe*

$$A_1 v_1 = A_2 v_2$$

$$v_2 = \frac{A_1 v_1}{A_2}$$

$$= \frac{(1.25 \times 10^{-3})}{5 \times 10^{-3}}$$

$$\underline{v_2 = 0.25\ m/s}$$

Quick Practice Question

Sea water of density 1.04g/cm³ is being pumped into a tank through a pipe of uniform cross-sectional area of 3.142cm². If the speed of water in the pipe is 5m/s, determine the mass flux in S.I unit. ***(Answer: 1.634 kg/s)***

Mass flow rate (mass flux)

- ***This is the mass of a fluid crossing a point in one second***
- Mass flow rate (***mass flux***) is calculated as:

$$\textbf{Mass flow rate} = \frac{\textbf{mass of fluid (kg)}}{\textbf{Time (seconds)}}$$

- SI unit of mass flow rate is **kilogram per second**, kg/s
- Since mass = density x volume, then mass flow rate can also be calculated as:

Mass flow rate = volume flow rate x density

$$\boxed{\textbf{Mass flow rate} = \rho A v}$$

A – Cross sectional area (m^2) ***v*** – fluid velocity (m/s) **ρ** - Density of the liquid in kg/m^3

Worked Example 34

Water flows in through a horizontal pipe of cross – sectional area 50 cm^2 with a velocity of 1.25 m/s. determine the mass flow rate of the water. (Density of water = 1000 kg/m^3)

Answer

Mass flow rate $= \rho A v$

$A = 50\ cm^2$

$= \frac{(50)}{10000} m^2$

$= 0.005\ m^2$

Mass flow rate $= \rho A v$

$= 1000 \times 0.005 \times 1.25$

Mass flow rate = 6.25 kg/s

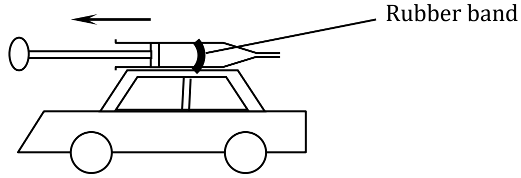
Quick Practice Question

Water flows along a horizontal pipe of cross-section area 40 cm^2 which has a constriction of cross-section area 5cm? If the speed at the constriction is 4ms^{-1}, calculate;

a) *The speed in the wide section* ***(Answer: 0.5m/s)***
b) *Mass flux of water (Take density of water = 1000^{k}g/m^3)* ***(Answer: 2kg/s)***

Quick Practice Question

The figure below shows a toy car on which a syringe filled with water has been fixed with cello tape. The car rests on a horizontal bench



A rubber band fitted on the syringe is used to push the piston so that water jets out of the syringe at a speed of 5 m/s initially. The total initial mass of syringe, water and toy car is 200g and the jet has diameter of 0.4 mm determine

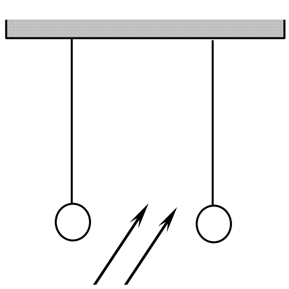
a) *The volume of water initially leaving through the jet per second*
(Answer= 6. 28 x 10^{-7} m^3 / s)

b) The mass of water leaving through the jet per second (density of water is 1000 kg/ m^3)
*(**Answer= 6.28 x 10^{-4} kg s^{-1}**)*

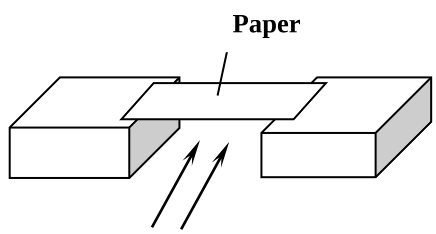
BERNOULLI'S PRINCIPLE

For a fluid that is incompressible, non viscous and of streamline flow, an increase in its velocity results into a corresponding decrease in its pressure and vice verse

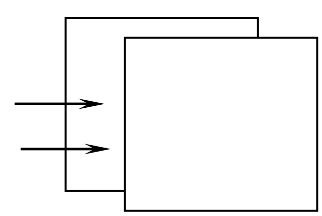
Practical Examples



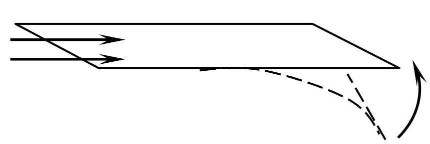
Procedure: *Blow Air*
Observations: *Balls come together*



Procedure: *Blow Air*
Observations: *Paper curves downward*



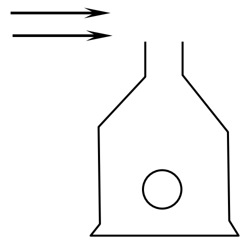
Procedure: *Blow Air between the papers*
Observations: *Come together*



Procedure: *Blow Air above the paper*
Observations: *Paper flips up*

Worked Example 35

*The figure below shows a light **body floating** in a container when air is blown over the mouth of the container*



a) *Explain the observation made when the stream of air is blown over the mouth of the container as shown*

Answer

High speed of air reduces pressure above the mouth of the container. Higher pressure below the body pushes it up

b) *Explain why the base of the cylinder is wider*

Answer

To increased stability

APPLICATIONS OF BERNOULLI'S PRINCIPLE

- Some of the devices whose working relies on Bernoulli's Principle are:
  1. Spray guns
  2. Bunsen burners
  3. Aerofoils
  4. Car carburettors
  5. Spinning ball

HAZARDS OF BERNOULLI'S PRINCIPLE

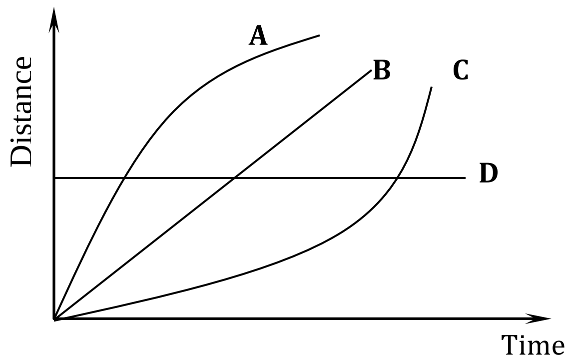
1. Accidents when vehicles are passing each other at very high speeds
2. Blowing off of roofs from houses

11. TOPIC 11: LINEAR MOTION

1. Distance is the length of the path covered by a body
2. Displacement is the distance covered in a specified direction
3. Speed is the rate of change of distance with time
4. Velocity is the rate of change of displacement with time
5. Acceleration is the rate of change of velocity

MOTION GRAPHS

(i) Distance – time graphs



A – Body moving with decreasing speed

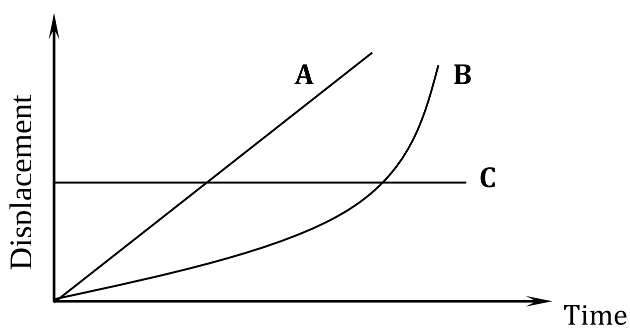
B – Body moving with uniform speed

C – Body moving with decreasing speed

D – Stationary body at some distance from the origin

Note: the slope (gradient) of a distance – time graph gives the speed

(ii) Displacement – time graph



A – Body moving with uniform velocity

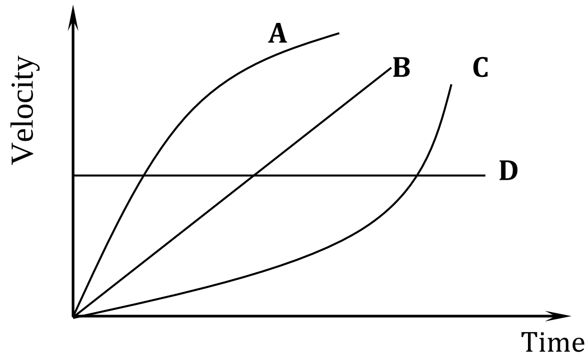
B – Body moving with increasing velocity i.e. body is accelerating

Ff

C – Body at rest i.e. stationary body at some distance from the origin

Note: The gradient (slope) of a displacement – time graph gives the velocity

(iii) **<u>Velocity – time graph</u>**



A – Acceleration decreases with time

B – Velocity changing uniformly with time, i.e. uniform acceleration

C – Acceleration increases with time

D – Body moving with a uniform velocity i.e. acceleration is zero

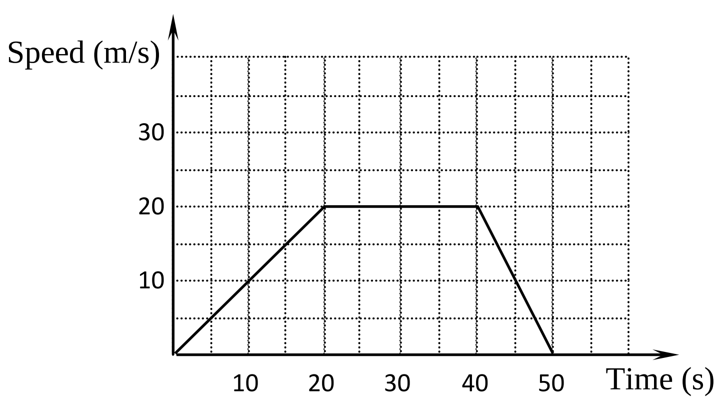
Note:

(i) The slope (gradient) of a velocity – time graph gives the acceleration

(ii) The area under a velocity – time graph gives the displacement

<u>Worked Example 36</u>

The figure below shows a speed-time graph for part of the journey of a bicycle. Calculate the total distance travelled.



Distance travelled = Area under the Speed – Time graph

$= \frac{1}{2}(a + b)h$

$= \frac{1}{2}(50 + 20) \times 20$

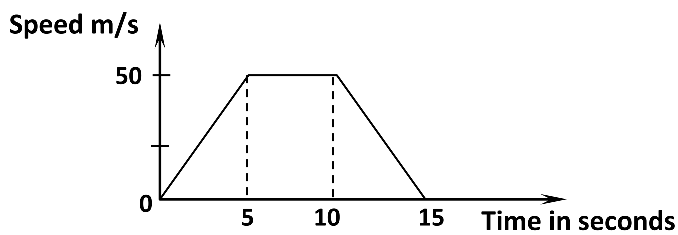
$= \frac{1}{2} \times 70 \times 20$

<u>Distance = 700 metres</u>

Quick Practice Questions

1. *A body is thrown vertically upwards with an initial velocity of 10m/s. It moves for 2s. Sketch a velocity time graph for the motion*

2. *Below is a velocity-time graph of a public service vehicle.*



Determine the:

a) *Acceleration of the vehicle in the first 5 seconds* ***(Answer: 10 m/s²)***

b) *Total distance covered.* ***(Answer: 500 m)***

EQUATIONS OF LINEAR MOTION

1. First equation: **$v = u + at$**
2. Second equation: **$s = ut + \frac{1}{2} at^2$**
3. Third equation: **$v^2 = u^2 + 2as$**

v – Final velocity (m/s)   **s** – displacement   **u** – Initial velocity (m/s)

a – Acceleration (m/s^2)   **t** – Time (s)

NOTE THE FOLLOWING:

1. For a body ***starting from rest***, the *initial velocity, **u,** is **0 m/s**,* and for a body ***going to rest***, the *final velocity, **v,** is **0m/s**.*

2. For a body which is moving with a ***reducing velocity*** (i.e. a body which is undergoing retardation / deceleration), *the acceleration, **a,** is a **negative value**.*

3. For a body which is moving with ***increasing velocity***, *the acceleration, **a,** is a **positive value**.*

4. For a body moving in the vertical direction, the acceleration is the same as the acceleration due to gravity, **g** (in most cases this is taken to be **10 m/s²**), and:

   (a) *If the body moving **vertically upwards**, the **acceleration is a negative value**, i.e. **–g***

   (b) *If the body is moving **vertically downwards**, the **acceleration is a positive value***

Worked Example 37

A body starts from rest and moves with a constant acceleration of 2 m/s² for 25 seconds. Find:

(a) the total distance moved

(b) the final velocity of the body

***Answer* :** *Since the body starts from rest, its initial velocity = 0 m/s*

$u = 0$ m/s

$v = v$ m/s

$a = 2$ /ms²

$t = 25$ seconds

(a) *Using 2nd equation of motion:*

$s = ut + \frac{1}{2}at^2$

$s = 0 \times 25 + \frac{1}{2} \times 2 \times 25^2$

$s = 0 + 625$

$\underline{\boldsymbol{s = 625\ m}}$

(b) *Using 1st equation of motion:*

$v = u + at$

$v = 0 + 2 \times 25$

$\underline{\boldsymbol{v = 50\ m/s}}$

Quick Practice Questions

1. *A car can be bought to rest from a speed of 20ms⁻¹ in a time of 2 seconds. Calculate the average deceleration.* ***(Answer: a = 10m/s²)***
2. *A motorist travelling at 90 km/h applies brakes and comes to rest with uniform retardation in 20 seconds. Calculate the retardation in m/s²)* ***(Answer: 1.25 m/s²)***
3. *A lorry moving at 20 km/h accelerates to a speed of 30 km/h in 20 seconds. Find:*
   a) *the average acceleration in m/s²* ***(Answer: 0.14 m/s²)***
   b) *the distance travelled in metres during the period of acceleration* ***(Answer: 139 meters)***
4. *A car starts from rest and is accelerated uniformly at a rate of 2 m/s² for 6 seconds. It then maintains a constant speed for half a minute. The brakes are then applied and the vehicle uniformly retarded to rest in 5 seconds.*
   (i) *Find the maximum velocity reached in km/h* ***(Answer: 43 km/h)***
   (ii) *Work out the total distance covered in metres* ***(Answer: 426 metres)***

Always remember this..........

- *When the three equations of linear motion are applied on a body moving in the* ***vertical direction****, (either upwards or downwards) the acceleration is the same as the acceleration due to gravity,* ***g****.*

(i) *If the body moving vertically* ***upwards****, the* ***acceleration is a negative value****, i.e.* **–g**

(ii) *If the body is moving vertically* ***downwards****, the* ***acceleration is a positive value*** *i.e.* **+g**

Worked Example 38

A stone is thrown vertically upward with an initial velocity of 25m/s. ($g = 10\ m/s^2$)

(a) Determine the time taken to reach the highest point

At the highest point of its motion, the instantaneous velocity of the stone, ***v****, is zero*

$v = 0\ m/s$

$u = 25\ m/s$

$a = -g$ (since the stone is moving upward)

$= -10\ m/s^2$

Therefore, substituting these in 1st equation of motion:

$v = u + at$

$0 = 25 - 10t$

$10t = 25$

$\underline{\boldsymbol{t = 2.5}\ \textbf{seconds}}$

(b) What is the maximum height covered by the stone

Using the third equation of motion:

$v^2 = u^2 + 2as$

At the highest point of its motion, the instantaneous velocity of the stone, ***v****, is zero*

$v = 0\ m/s$

$u = 25\ m/s$

$a = \boldsymbol{-g = -10\ m/s^2}$ (since the stone is moving upward)

Therefore, substituting these in the 3rd equation of motion

$0^2 = 25^2 + (2 \times -10 \times s)$

$0 = 625 - 20s$

$20s = 625$

$\underline{\boldsymbol{s = 31.25\ m}}$

Quick Practice Questions

1. *A stone is thrown vertically upwards with a velocity of 50m/s from the ground. What is the maximum height reached by the stone?*

2. *An object is projected vertically upwards from a cliff 80 m above the ground with an initial velocity of 50m/s.*
   a) *Sketch the velocity-time graph for the motion of the body.*
   b) *Determine how long it takes the object to hit the ground.*
   c) *Determine the velocity of the object as it hits the ground.*
   d) *Determine the height of the object above the ground after the first 4 seconds.*

EQUATION OF FREE FALL

$$\mathbf{s = \tfrac{1}{2} gt^2}$$

Where: **s** – Height in metres (m) **g** – Acceleration due to gravity in m/s^2 **t** – Time taken in seconds

For bodies undergoing Free Fall, one assumption that is always made is that there is no air resistance.

Worked Example 39

A small iron ball is dropped from the top of a vertical cliff and takes 2.5 seconds to reach the sandy beach below. Find:

(a) *The velocity with which it strikes the sand ($g = 10m/s^2$)*

(b) *The height of the cliff*

$u = 0$ m/s

$a = g = 10$ m/s^2 (+10 because the body is moving downwards)

$v = v$

$t = 2.5$ seconds

(a) *Using 1st equation of motion:* $\mathbf{v = u + at}$

$= 0 + 10 \times 2.5$

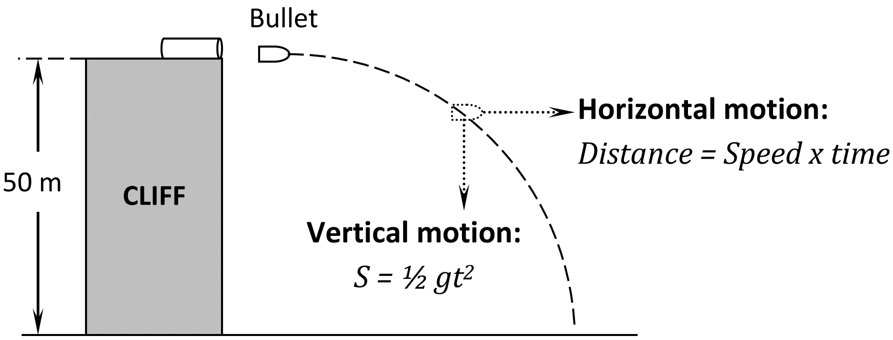
$\underline{\mathbf{v = 25\ m/s}}$

(b) *Using equation of free fall:* $\mathbf{s = \tfrac{1}{2} gt^2}$

$= \tfrac{1}{2} \times 10 \times 2.5^2$

Worked Example 40

A bullet is fired horizontally at a velocity of 400m/s from a cliff which is 50m tall as shown below.



a) *Find the time taken for the bullet to hit the ground.*

b) *Find the range.*

Answers

***Hint**: The bullet has motions in the horizontal and vertical directions. The two motions should be treated independently.*
The vertical motion is a free fall and is therefore governed by the equation ***$s = \frac{1}{2}gt^2$*** *whereas in the horizontal direction, the velocity is constant therefore the horizontal distance covered (**range**) is given by* ***Distance = Speed x time***

a) *Time taken to hit the ground*

$$s = \tfrac{1}{2}gt^2$$

$$50 = \tfrac{1}{2} \times 10 \times t^2$$

$$100 = 10t^2$$

$$t^2 = \frac{100}{10}$$

$$t^2 = 10$$

$$t = \sqrt{10}$$

Time taken to hit the ground, t, = 3.162 seconds

c) *The range.*

$$\text{Distance} = \text{speed} \times \text{time}$$

$$= 400 \times 3.162$$

Range = 1264.8 metres

Quick Practice Question

1. *An object is projected vertically upwards with a velocity of 25m/s. How long will it take to return to the same level of projection?* ***(Answer: = 5.0 seconds)***

2. *A jet fighter flying at a height of 2 km with a horizontal velocity of 40 m/s drops a bomb to hit a target. Determine:*

   a) *The time taken before the bomb hits the ground (g = 10 m/s²)* ***(Answer: 20 seconds)***

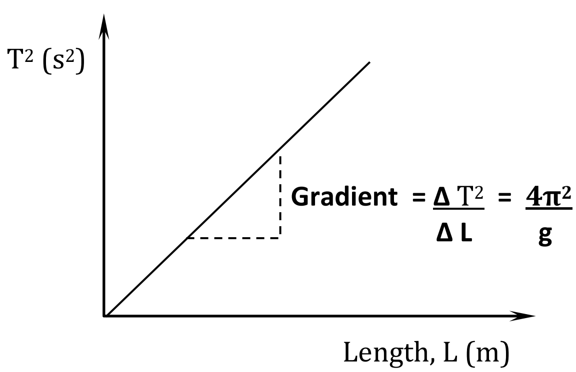
   b) *The **vertical** velocity with which it hits the ground* ***(Answer: 200 m/s)***

   c) *The horizontal distance covered by the bomb by the time it hits the ground* ***(Answer: 800 m)***

   d) *State **one** assumption made in this calculation*

DETERMINATION OF ACCELERATION DUE TO GRAVITY USING A PENDULUM

- A graph of periodic time squared, $\mathbf{T^2}$ (s^2) against length of the pendulum, **L**(m) is plotted



- The graph obtained is a straight line through the origin
- The gradient of the graph is then equal to the quantity $\frac{4\pi^2}{g}$

TICKER TIMER

- The time interval between ***two dots*** is given by

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

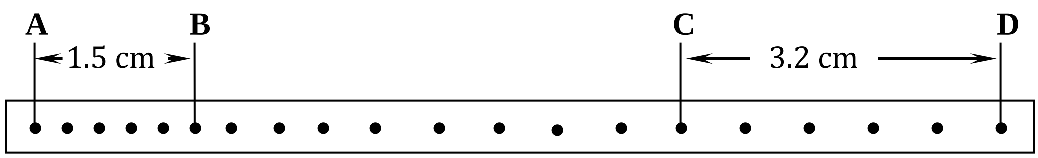
Ff

f

Where *f* is the frequency of the ticker timer

Worked Example 41

A tape attached to a moving trolley is run through a ticker-timer, producing a tape as shown below.



If the frequency of ticker-time is 50Hz, Calculate:

(a) *The average velocity of the trolley at intervals AB and CD*

(b) *The average acceleration of the trolley*

Answer:

$$\text{Time interval between two dots} = \frac{1}{50}$$

$$= 0.02 \text{ seconds}$$

$$1 \text{ tick} = 0.02 \text{ seconds}$$

$$5 \text{ tick} = 0.02 \times 5$$

$$\mathbf{T = 0.1 \text{ second}}$$

(a)

$$\text{Velocity } \mathbf{AB} = \frac{1.5}{0.1}$$

$$\mathbf{v_{AB} = 15 \text{ cm/s}}$$

$$\text{Velocity } \mathbf{CD} = \frac{3.2}{0.1}$$

$$\mathbf{V_{CD} = 32 \text{ cm/s}}$$

(b)

$$\text{Average acceleration} = \frac{(v - u)}{t}$$

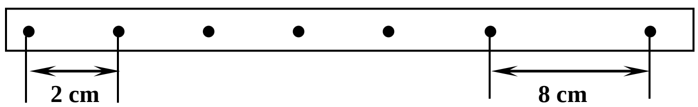
$$= \frac{(v - u)}{(19 \times 0.02)}$$

$$a = \frac{(32 - 15)}{0.38}$$

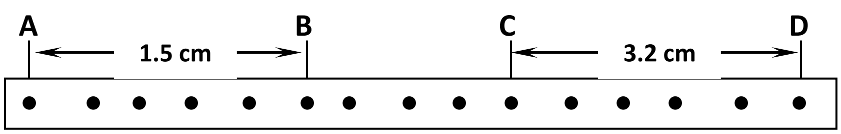
$$\underline{\mathbf{a = 44.74 \text{ cm/s}^2}}$$

Quick Practice Question

1. *The tape in the figure (not to scale) was obtained from an experiment using a timer of frequency 50Hz. Calculate the acceleration of the body whose motion is represented in the tape.* ***(Answer: 3000cm/s² OR 3m/s²)***



2. *A paper tape was attached to a moving trolley and allowed to run through a ticker timer. The figure below shows the section of the tape.*



If the frequency of the tape is 100Hz, determine:

*(i) Velocity at **AB** and **CD*** ***(AB: Answer: 30 cm/s; CD: 64cm/s)***

(ii)** The average acceleration* ***(Answer: 3.7778m/s²)

12. TOPIC 12: NEWTON'S LAWS OF MOTION

1. Newton's first law of motion

- *Everybody continues in its state of rest or uniform motion in a straight line unless acted upon by an external force*

2. Newton's second law of motion

- *The rate of change of momentum is directly proportional to the external force acting on the body and takes place in the direction of the force*

3. Newton's third law of motion

INERTIA

- This is the tendency of a body to remain at rest if it was stationary, or to continue moving if it was in motion.

Daily life Example:

- *Passengers in a fast moving vehicle fall forwards when the vehicles stop suddenly. For this reason, People are advised to used safety belts so that they don't hit anything should the car stop suddenly*

MOMENTUM

Momentum is the product of mass and velocity

Momentum (kgm/s) = mass (kg) x velocity (m/s)

- SI unit of momentum is **kilogram metre per second,** kgm/s
- Momentum is a vector quantity

Worked Example 42

A body of mass 40 grams rolls on a frictionless surface with a constant velocity of 12 cm /s. Work out the momentum of the body

Answer

$$Mass = \frac{(40)}{1000} kg$$

$$= 0.04kg$$

$$Velocity = 12\ cm/s$$

$$= \frac{(12)}{100} m/s$$

$$= 0.12\ m/s$$

$$Therefore,\ momentum = (mass\ x\ velocity)$$

Worked Example

The diagram below represents two identical hollow spheres. Sphere X is completely filled with water while Y is partially filled as shown;

When the two spheres are rolled gently along a horizontal surface, it is observed that sphere Y stops early before sphere X. Explain this observation.

Answer

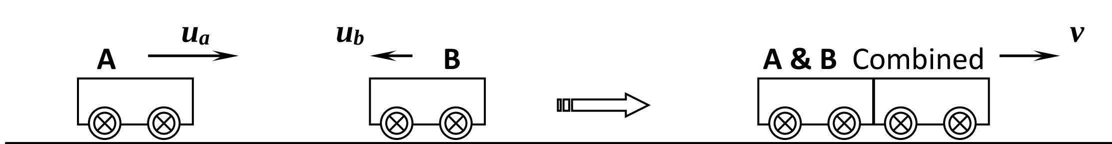
*In sphere **X**, particles have uniform momentum hence have a constant force. While in sphere Y the momentum of particles keep changing hence the resultant force reduces motion.*

LAW OF CONSERVATION OF LINEAR MOMENTUM

The law of conservation of momentum states that when two or more bodies collide, the total momentum remains constant provided no external force acts on the bodies.

This law implies that, for a system of colliding bodies ***where no external forces acts:***

Total momentum before collision = Total momentum after collision



Mass of A = m_a Mass of A = m_b Total mass of = (m_a + m_a)

Total momentum before collision = Momentum of A + Momentum of B

= (m_a x u_a) +(m_b x $-u_b$) ***(-ve because A and B are moving in opposite directions)***

= $m_a u_a - m_b u_b$

Total momentum after collision = (m_a+m_b) x v

$= (m_a v + m_b v)$

Therefore, by principle of conservation of momentum :

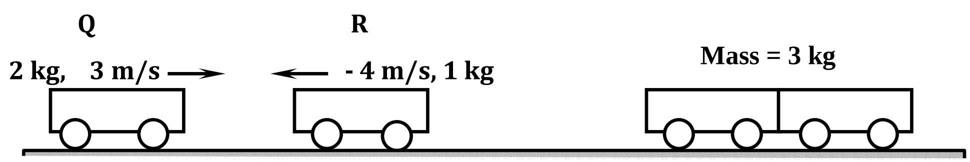
Total momentum before collision = Total momentum after collision

i.e.

$$(m_a u_a - m_b u_b) = (m_a v + m_b v)$$

Worked Example 43

*A toy car **Q**, of mass 2.0 kg, moving at 3 ms^{-1}, collides head on with another toy car, **R** of mass 1.0 kg moving in the opposite direction at 4 ms^{-1}. If the objects stick together after collision, calculate their common velocity after collision.*



Total momentum before collision = (2kg x 3m/s) + (1kg x -4m/s)

– 4m/s because it is moving in the **opposite direction** to the first toy

= (6 – 4) kgm/s

= 2 kgm/s

*Total momentum after collision = (3kg x **v** m/s)*

*= 3**v** kgm/s*

Total momentum before collision = Total momentum after collision

*2 kgm/s = 3**v** kgm/s*

$$v = \frac{2}{3}$$

$$\underline{v = 0.667 \text{ m/s}}$$

IMPULSE

Impulse of a force is the product of force and time

Impulse (Ns) = force (N) x time (s)

- SI unit of impulse is **newton second,** Ns
- Impulse is a vector quantity

Impulse can also be calculated as:

Impulse = change in momentum

Ff

Impulse = final momentum – initial momentum

$$\boxed{Ft = m(v - u)}$$

F – Force acting (N) **m** – mass (kg) **u** – initial velocity

t – Time (s) **v** – final velocity

Worked Example 44

A car of mass 2000kg travelling at 5m/s collides with a minibus of mass 5000kg travelling in the opposite direction at 7 m/s. the vehicles stick and move together after collision. If the collision lasts 0.1 seconds

(a) *Determine the velocity of the system after collision to 3 decimal places*

(b) *Calculate the impulsive force on the minibus*

Answer

(a) *Total momentum before collision* = (2000 x 5) + (5000 x **-7**)

= -25000 kgm/s

NOTE**: Since the car and the minibus are moving in **opposite directions**, the velocity of **one of them must be assigned a negative value.

Total momentum after collision = ***v*** (2000 + 5000)

= 7000 ***v***

Total momentum after collision = Total momentum before collision

Law of conservation of linear momentum

7000 ***v*** = -25 000

$v = -\frac{25\ 000}{7000}$

$\mathbf{v = -3.571\ m/s}$

(b) $Ft = m(v - u)$

$Ft = 5000 \times (-3.571 - -7)$

$Ft = 5000 \times 3.429$

$Ft = 17145$

$F \times 0.1 = 17145$

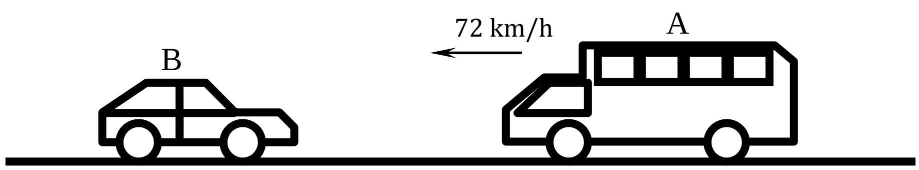
$F = \frac{17145}{0.1}$

F = 171,450 N

Quick Practice Questions

1. *An object **A**, of mass 2.0 kg, moving at 3 ms^{-1}, collides head on with an object, **B** of mass 1.0 kg moving at 4 ms^{-1}. If the objects stick together after collision, calculate their common velocity after collision.*
(*Answer:* 0.667 m/s)

2. *The figure below shows a system where matatu **A** of mass 1500kg travelling at a velocity of 72km/hr towards a stationary car **B** of mass 900kg.*



*If **A** collides with **B** in an impact that takes 2 seconds before the two move together at a constant velocity for 20 seconds, calculate*

a) *The common velocity* ***(Answer: 12.5m/s)***

b) *The distance moved after impact.* ***(Answer: 250m)***

3. (a) *Define impulse in terms of momentum.*

(b) *A trailer of mass 30 tonnes travelling at a velocity of 72km/hr rams onto a stationary bus of mass 10 tonnes. The impact takes 0.5 seconds before the two vehicles move off together at a constant velocity for 15 seconds. Determine.*

(i) *The common velocity.* ***(Answer: 15m/s)***

(ii) *The distance moved after the impact.* ***(Answer: 225m)***

(iii) *The impulsive force on the trailer on impact.* ***(Answer: 300,000N)***

TYPES OF COLLISIONS:

- There are two types of collisions:

Elastic and ***inelastic collisions***

(i) ***<u>Elastic collision</u>*** is a collision in which momentum and the kinetic energy are conserved.

(ii) ***<u>Inelastic collision</u>*** is a collision in which only the momentum is conserved. Kinetic energy is not conserved

WEIGHT OF A BODY IN A LIFT

1. Lift at rest	**W = mg**
2. Lift moving with *CONSTANT VELOCITY*	**W = mg**
3. Lift *Accelerating UPWARDS*	**W = m (g + a)**
4. Lift *Accelerating DOWNWARDS*	**W = m (g – a)**

W – Weight in the lift **g** – Acceleration due to gravity

m – Mass of the body **a** – acceleration of the lift

<u>Worked Example 45</u>

A girl of mass 40 kg stands on a scale balance in a lift. The lift is accelerating upward. If the acceleration of the lift is 2 ms^{-2}, determine the reading of the scale balance ($g = 10\ m/s^2$)

<u>Answer</u>

$W = m\,(g + a)$

$= 40(10 + 2)$

$W = 480\ N$

<u>Quick Practice Questions</u>

1) *A boy stands inside a lift on the second floor of an 18 storey building. If the lift is ascending upwards at an acceleration of $3ms^{-2}$ and he weighs 60kg, determine the reaction of the lift at the boy's feet.* ***(Answer: 780N)***

2) *A form four student of mass 40kg stands on a scale balance in a lift. At a particular instant, the lift is accelerating downwards at $2m/s^2$. Calculate the reading on the scale at that instant.* ***(Answer: 320N)***

FRICTION

- This is force that opposes intended motion
- There are two main types of frictional forces
  1. **Dynamic / kinetic friction**
  2. **Static friction**

COEFFICIENT OF FRICTION; μ

- This is the ratio of frictional force to normal reaction.

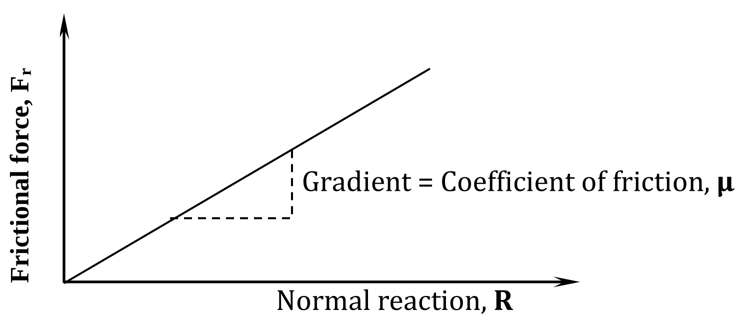
$$\boxed{\mu = \frac{F_r}{R}} \quad \textbf{OR} \quad \boxed{F_r = \mu R}$$

Where: **μ –** Coefficient of friction **F_r –** frictional force **R –** normal reaction

Note: *For a body placed on a flat horizontal surface, Normal reaction (**R**) is equal to weight, (**mg**). Therefore this formula can be written as:*

$$\mu = \frac{F_r}{mg}$$

- A graph of frictional force against normal reaction is a straight line, whose gradient gives the coefficient of friction



Worked Example 46

A block of metal of mass 40kg requires a horizontal force of 100N to drag it with a uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surfaces. (g=10m/s²)

Answer

$$\mu = \frac{Fr}{R}$$

R = weight = mg

= 40 x 10

= 400N

Quick Practice Question

(a) *A block of wood of mass 20 kg is pulled along a horizontal rough surface with a force of 150N. Given that the coefficient of friction between the block and the flat surface is 0.25, calculate:*

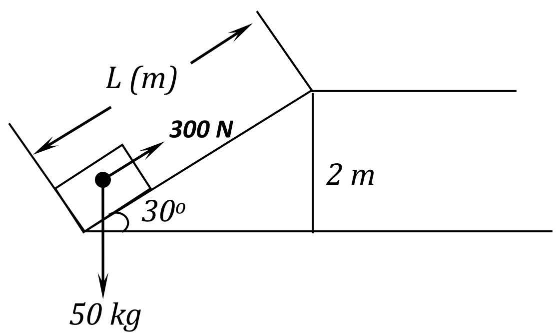
(i) *The frictional force between the block and the surface* ***(Answer: 50 N)***

(ii) *The acceleration of the block* ***(Answer: 5 m/s²)***

(b) *Given that the initial velocity of the block was 2 m/s, what will be the velocity after 12 seconds if the same force is applied for this period?* ***(Answer: 62 m/s)***

Worked Example 47

A block of mass 50kg is pulled up an inclined plane by a force of 300N until it gets to the top as shown below



a) *Find the work done by the force in moving the block up the incline.*
b) *Find the work done on the block against gravity.*
c) *Find the work done against Friction*
d) *Find the frictional force between the mass and the inclined plane*
e) *Find the coefficient of friction between the block and the inclined plane*

Answer:

a) $\sin 30^o = \frac{2}{L}$

$0.5 = \frac{2}{L}$

$L = \frac{2}{0.5}$ $= \mathbf{4\ m}$

Cont……

c) *Work done against friction = total work done – useful work done*

$= (1200 - 1000)$

Work done against friction = 200J

d) $\text{Friction force} = \dfrac{\text{work done against friction}}{\text{Distance moved}}$

$= \dfrac{200}{4}$

Friction = 50N

e) $\mu = \dfrac{F_r}{mg}$

$\mu = \dfrac{50}{(50 \times 10)}$

$\mu = 0.1$

ADVANTAGES OF FRICTION

- Braking of cars
- Walking
- Lighting matchstick

DISADVANTAGES OF FRICTION

- Loss of mechanical energy in form of heat, thus reduces efficiency of machines
- Wear and tear of moving parts of machines

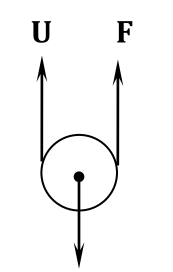
REDUCTION OF FRICTION

- Lubrication
- Use of rollers

VISCOSITY

- This is the frictional force that is exerted by fluids
- When a small steel ball falls through a fluid, three forces act on it. These are:

1. **Upthrust** due to the liquid **(U), acting upwards**
2. Frictional force / **Viscous drag (F), acting upwards**
3. **Weight** of the ball **(mg) acting downwards**



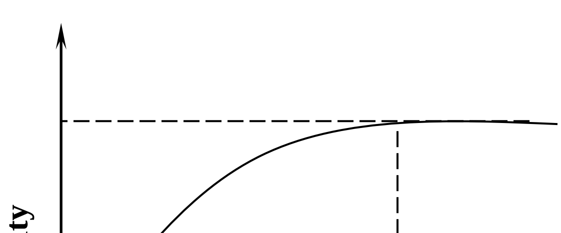
Weight = **mg**

- When the three forces balance, i.e. total upward forces equal the downward force, the body moves with **a constant velocity called the terminal velocity**, v_t

i.e. when mg = U + F, then velocity of a body equals the terminal velocity

TEMINAL VELOCITY:

Terminal velocity is the constant velocity at which a body falling through a medium such as air moves, when the net force acting on the body is zero (i.e. when the sum of force of resistance of the medium and the upthrust due to the fluid is equal in magnitude and opposite in direction to the force of gravity)



Ff

$\mathbf{v_t}$

Time (s)

At this point / time, **mg = U + F**

$\mathbf{v_t}$: is the terminal velocity

13. TOPIC 13: WORK POWER ENERGY AND MACHINES

Work is the product of force and the distance moved in the direction of the force

Work (J) = Force (N) x distance (m)

- Work is a ***scalar*** quantity
- SI unit of work is **joule** (J)
- 1 joule is the work done when a force of 1N moves through a distance of 1 m

Worked Example 48

A crane lifts a load of 2000kg through a vertical distance of 3.0m in 6 seconds. Determine the work done

Answer

For a body moving vertically upwards, the force used to lift it up is equal to its weight

Force used = weight of load

= mg

= (2000 x 10)

= 20 000N

Work done = force x distance

Work done = 20 000 x 3

Work done = 60 000J

ENERGY

Energy is the ability to do work

- Energy is a scalar quantity
- SI unit of energy is **joule** (J)

POTENTIAL ENERGY AND KINETIC ENERGY

a) KINETIC ENERGY

Kinetic energy is the energy possessed by a body in motion

- Kinetic energy is calculated as

$$\text{K.E.} = \tfrac{1}{2} m v^2$$

m – Mass in kg　　v – Velocity in m/s　　**K.E.** – kinetic energy in joules (J)

b) POTENTIAL ENERGY

- Potential energy is the energy possessed by a body by virtue of its position or state
- There are two types of potential energies:
  - ***(i)*** *Gravitational potential energy*
  - ***(ii)*** *Elastic potential energy*

I. Gravitational Potential Energy

- ***Gravitational potential energy is the energy possessed by a body in a raised position***
- Gravitational potential energy is given by

$$P.E. = mgh$$

Where:

m – Mass in kg

g – Acceleration due to gravity in m/s^2

h – Height in metres

P.E. – gravitational potential energy in joules (**J**)

LAW OF CONSERVATION OF ENERGY

- The law of conservation of energy states that energy cannot be destroyed. It is only converted from one form to another.

- A device which converts energy from one form to another is known as a **transducer**

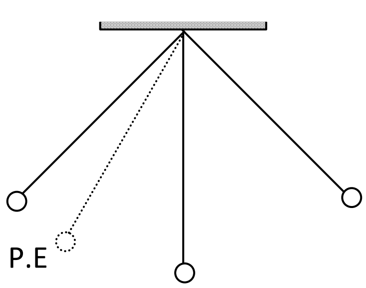
Examples of Transducers**:**

1. **Dry Cell** : *Converts chemical energy to electric energy*
2. **Microphone**: *Sound energy to electric energy*
3. **Loud Speaker**: *Converts electric energy to sound energy*
4. **Solar Cell**: *Converts solar energy to electric energy*

Example of energy transformations:

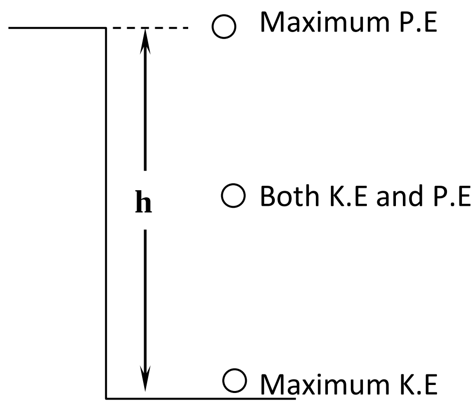
1. Swinging pendulum bob

- A swinging pendulum bob is an example of a body whose energy can either be **Kinetic**, **Potential** or a **Mixture of both**:



2. A stone falling from a height

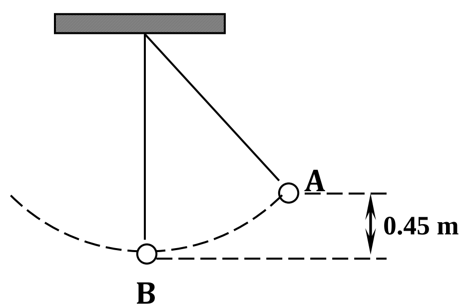
Ff



P.E – Potential Energy K.E – Kinetic energy

Worked Example 49

A bob of mass 10 kg is suspended using a string 2.0 m from a support and swings through a vertical height of 45cm as shown in the figure below.



a) *Determine the potential energy of the bob at position* ***A***

$$P.E = mgh$$

$$= 10 \times 10 \times 0.45$$

$$\underline{\underline{P.E = 45J}}$$

b) *Calculate the velocity with which the bob passes position* ***B***

Assuming that all the potential energy at ***A*** *is converted to kinetic energy at* ***B****, and that there is no air resistance, then:*

$$K.E.\ at\ B = P.E.\ at\ A$$

$$\tfrac{1}{2} mv^2 = P.E\ at\ A$$

$$\tfrac{1}{2} mv^2 = 45$$

$$mv^2 = 2 \times 45$$

$$10v^2 = 90$$

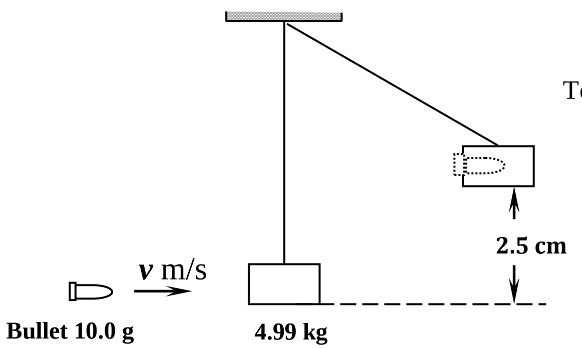
$$v^2 = \frac{90}{10}$$

Quick Practice Question

A body has a kinetic energy of 16 Joules. ***What*** *would be its kinetic energy if its velocity was doubled?* ***(Answer = 64J)***

Worked Example 50

A bullet of mass 10.0g is fired at a close range into a block of mass 4.99kg suspended from a rigid support by an elastic string and becomes embedded into the block. The block rises through a height of 2.5cm before momentarily coming to rest. Calculate initial speed of the bullet.



Total mass = mass of block + mass of bullet
= (4.99 + 0.01) kg
Mass = 5.00 kg

Answer

Assumption: All Kinetic energy just after impact is converted to potential energy

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

$$\tfrac{1}{2} \cancel{m}v^2 = \cancel{m}gh$$

$$v = \sqrt{2gh}$$

$$= \sqrt{(2 \times 10 \times 0.025)}$$

$$v = \sqrt{0.5}$$

$$\boldsymbol{v = 0.7071\ m/s}$$

Velocity of block and bullet just after collision = 0.7071 m/s

By law of conservation of linear momentum,

Momentum of bullet and block before collision = momentum of bullet and block after collision

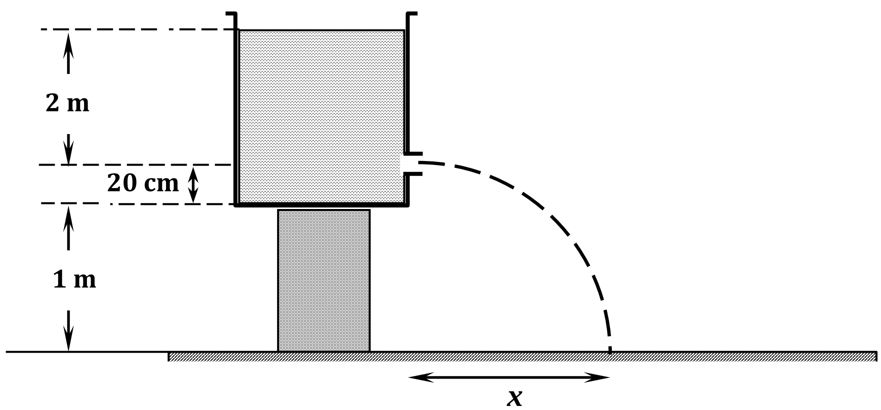
Momentum before collision = momentum of bullet + momentum of block

$$= (\boldsymbol{v} \times \frac{10}{1000} + 4.99 \times 0)$$

Quick Practice Questions

1. *A bullet of mass 2.0g is fired horizontally into a block of wood of mass 500g. The block is suspended from string so that it is free to move in a vertical plane. The bullet buries itself in the block. The system rises together through a vertical distance of 7.6cm. Determine the speed of the bullet before the impact with the block.* **(*Answer: v = 309.45m/s*)**

2. *A large tank contains water to a depth of 2m. Water emerges from a small hole on the side of the tank 20cm above the bottom of the tank as shown in the figure below*



Calculate

(i) *The speed at which water emerges from the hole.* ***(Answer: 6 m/s)***

(ii) *The time taken for water to reach the ground.* ***(Answer: 0.4899 seconds)***

(iii) *The value of **x**.* ***(Answer: 2.9394 meters)***

II. Elastic Potential Energy

- **This is the energy possessed by a stretched material e.g. a spring**
- Elastic potential energy is calculated as:

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

F – Applied force in newtons (**N**) **e** – extension in **m**

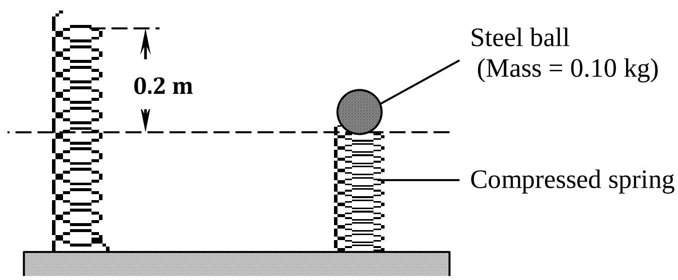
- Elastic potential energy can also be calculated as

Potential energy = $\frac{1}{2}$ ke^2

k – Spring constant in **N/m** ***e*** – Extension in **m**

Worked Example 51

A steel ball of mass 0.10 kg was placed on top of a level ground. The spring was then compressed by 0.20m with an average force of 10N.



a) *State the energy changes that take place when the compressed spring is released and the steel ball moves to its maximum height.*

Answer

Elastic Potential Energy $\longrightarrow$ *Kinetic Energy* $\longrightarrow$ *Gravitational Potential Energy*

b) *Calculate the maximum height the ball attains (Take g=10Nkg^{-1})*

Answer

Gravitational potential energy = elastic potential energy

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

$$(0.1 \times 10 \times h) = \frac{1}{2} \times 10 \times 0.2$$

$$\underline{\underline{h = 0.2m}}$$

POWER

Power is the rate of doing work

Power (W) = $\frac{\text{work done (J)}}{\text{Time taken (s)}}$ OR **Power (W) = $\frac{\text{Energy (J)}}{\text{Time taken (s)}}$**

- Power is a scalar quantity
- SI units of power is **watts** (W)

For a body moving with a known velocity, ***v***, due to a force, **F**, power can also be calculated as:

Power (W) = Force (N) x velocity (m/s)

Worked Example 52

A pump can raise 0.12 m^3 of water to a height of 10 m every minute. What is the power output of the pump? (Density of water = 1000 kg)

Answer

Mass of water raised every minute = density x volume

= 1000 x 0.12

= 120 kg

Gain in potential energy = mgh

= (120 x 10 x 10)

= 12 000J

Time taken = 1 minute

= 60 seconds

Therefore, power = $\frac{\text{Energy gained}}{\text{Time taken}}$

= $\frac{12\ 000}{60}$

Power = 200W

Quick Practice Questions

1. *A pump can raise 120 kg of water to a height of 10.0 m every minute. Determine the power of the pump.* ***(Answer: 200 watts)***

2. *A body of mass 0.5kg resting on a frictionless surface is acted on by a force of 3.2N for 3.5 seconds. Determine the power developed by the force.* ***(Answer: 71.68 watts)***

3. *A pump draws water from a tank and issues it from the end of a hosepipe which the water is drawn. The cross –sectional area of the hosepipe is $1.0 \times 10^{-3} m^2$ and the water leaves the end of the hosepipe at a speed of 5m/s .Calculate the power of the pump. (density of water = 1000Kkg/ m^3)* ***(Answer: 125 watts)***

SIMPLE MACHINES

- **A machine is a device that makes work easier**

a) Mechanical advantage

This is the ratio of load to effort

$$\text{M.A.} = \frac{\text{Load (N)}}{\text{Effort (N)}}$$

b) Velocity ratio

This is the ratio of distance moved by effort to the distance moved by the load

$$\text{V.R.} = \frac{\text{Distance Moved By Effort}}{\text{Distance Moved By Load}}$$

c) Efficiency

This is the ratio of work output to work input expressed as a percentage

$$\text{Efficiency} = \frac{\text{Work Output}}{\text{Work input}} \times 100$$

- Work output is the work done on the load, i.e.:

Work output = load x distance moved by the load

- Work input is the work done by the effort, i.e.

Work input = effort x distance moved by the effort

- Efficiency of a machine can also be calculated as

$$\text{Efficiency} = \left(\frac{\text{Mechanical Advantage}}{\text{Velocity Ratio}}\right) \times 100$$

OR

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

Worked Example 53

A simple machine has a velocity ratio of 314 and an efficiency of 40%. An effort of 25N is exerted on the machine.

a) *Determine the maximum load that can be raised*

b) *If the load is raised upward at a constant speed of 0.2 m/s, what is the power output of the machine?*

Answer

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

$$40 = \frac{M.A}{314} \times 100$$

$$M.A. = \frac{40 \times 314}{100}$$

$$M.A. = 125.6$$

But $$M.A = \frac{Load}{Effort}$$

$$125.6 = \frac{Load}{25}$$

$$Load = 125.6 \times 25$$

Load = 3 140N

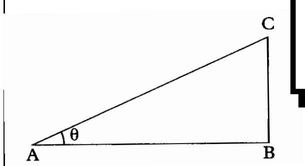
b) ***Power = Force x Velocity***

Power output = Load x velocity

= 3140 x 0.2

SOME SIMPLE MACHINES

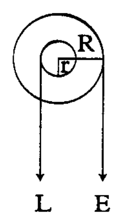
INCLINE PLANE



V.R = $\frac{\text{length of incline AC}}{\text{Height of inline BC}}$

$= \frac{1}{\text{Sin } \theta}$

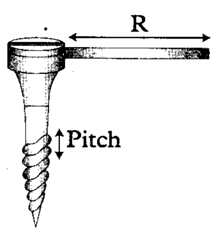
WHEEL AND AXLE



V.R = $\frac{\text{Radius of wheel (R)}}{\text{Radius of axle (r)}}$

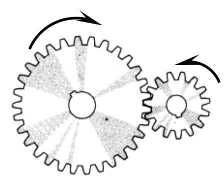
$= \frac{R}{r}$

SCREWS



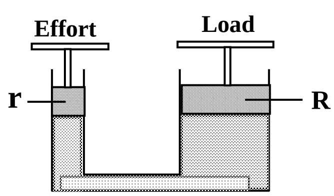
V.R. = $\frac{2\pi R}{\text{Pitch}}$

GEARS



V.R. = $\frac{\text{Number of teeth in driven wheel}}{\text{Number of teeth in driving wheel}}$

HYDRAULIC PRESS / LIFT

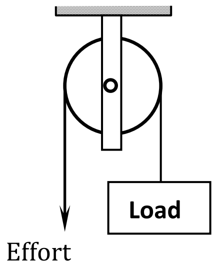


V.R. = $\frac{R^2}{r^2}$

PULLEYS

- *Pulleys can be: (i)* ***single fixed,*** *(ii)* ***single movable*** *or (iii)* ***block and tackle***

a) ***Single fixed pulley***

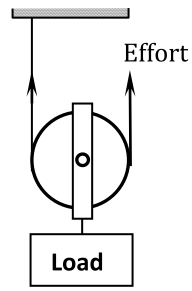


Single ***fixed*** *pulley have* ***V.R. = 1***

Effort used = Load

(**N/B**: *This is only for a pulley which is 100% efficient*)

b) ***Single movable pulley***

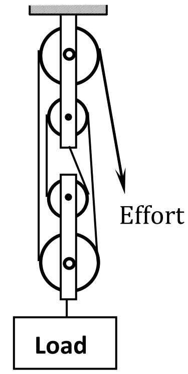


Single ***movable*** *pulley have* ***V.R. = 2***

Effort used = ½ Load

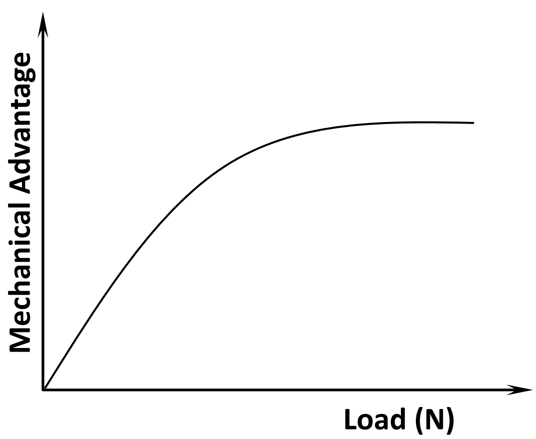
(**N/B**: *This is only for a pulley which is 100% efficient*)

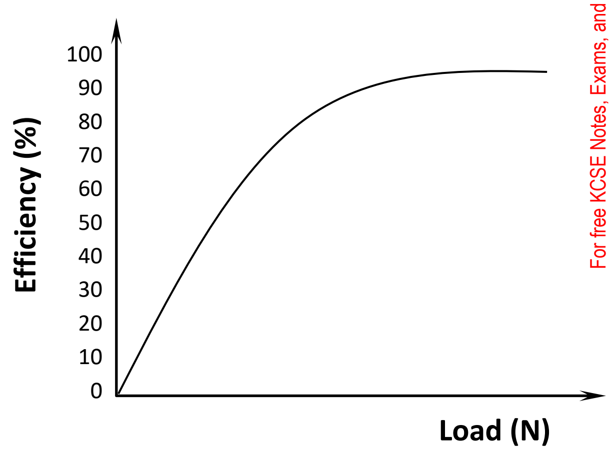
c) ***Block and tackle pulley system***



For ***block and tackle*** *pulley system, the V.R. is the same as the* ***number of strings supporting the load***

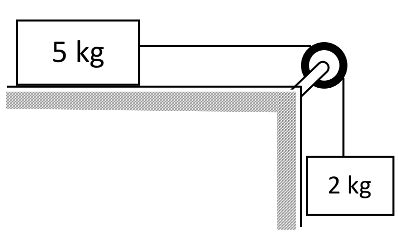
- For pulley systems, ***mechanical advantage and efficiency increase with increase in load***. i.e. the bigger the load, the greater the mechanical advantage and the efficiency
- The graphs for mechanical advantage against load and efficiency against load are of the form:





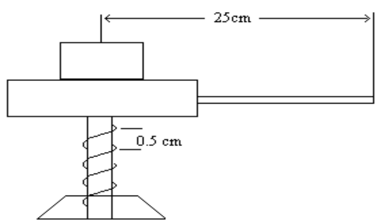
Quick Practice Question

Figure below shows a 5kg block attached to a 2kg mass by a light inextensible string which passes over a frictionless pulley. The force of friction between the horizontal table and the block is 4N. The block is released from rest so that both masses move through a distance of 0.5



Worked Example 54

The handle of screw jack shown below is 25cm long and the pitch of the screw is 0.5cm.



a) *What is the velocity ratio of the system?*

b) *What force must be applied at the end of the handle when lifting a load of 2500N if the efficiency of the jack is 60%.*

Answer

a) For a screw, $V.R = \frac{2\pi R}{\text{Pitch}}$

$$= \frac{2 \times 31.42 \times 25}{0.5}$$

$$V.R = 314.29$$

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

$$60 = \frac{M.A}{314.29} \times 100$$

$$M.A. = \frac{(60 \times 314.29)}{100}$$

$$M.A. = 188.574$$

But, M.A = Load

Quick Practice Question

1. *A machine with a wheel of diameter 1.2m and an axle of diameter 0.4m lifts a lot of mass 9kg with an effort of 100N. Given that the acceleration due to gravity is 10m/s² calculate.*
   b) *The velocity ratios of the machine* **(Answer : = 3)**
   c) *The mechanical advantage of the machine* **(Answer:0.9)**
   d) *The efficiency* **(Answer: 30 %)**

Worked Example 55

A bicycle has a driving cog wheel of radius 10cm with 24 teeth. The driver rear cog wheel has a radius of 4cm with 8 teeth. For the cog wheel system determine velocity ratio.

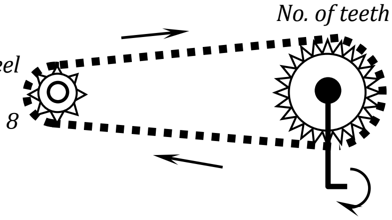
Answer

$$V.R = \frac{\text{number of teeth on driven wheel}}{\text{number of teeth on the driving wheel}}$$

$$= \frac{8}{24}$$

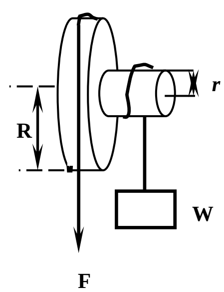
$$= {}^{1}/_{3}$$

$$\underline{V.R. = 0.3333}$$



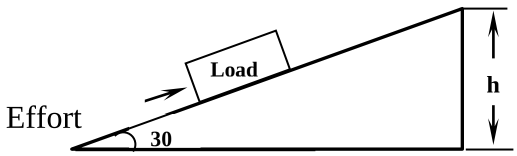
Quick Practice Question

1. *The figure below shows a wheel and axle being used to raise a load W by applying an effort E. The radius of the large wheel is R and of the small wheel* **r** *as shown*



a) *Show that the velocity ratio (VR) of this machine is given by* $^{R}/_{r}$

b) *Given that r = 5cm, R = 8cm, determine the effort required to raise a load of 20N if the efficiency of the machine is 80%* **(Answer: 15.625N)**



14. TOPIC 14: QUANTITY OF HEAT

HEAT CAPACITY (C)

Heat capacity is the quantity of heat required to raise the temperature of a substance by 1 kelvin

- SI unit of heat capacity is **joules per kelvin** (J/K)

$$C = \frac{Q}{\Delta\theta}$$ Therefore, $$Q = C\,\Delta\theta$$

Where: **C** – heat capacity in J/K **Δθ** – change in temperature **Q** – Quantity of heat in J

SPECIFIC HEAT CAPACITY (C)

Specific heat capacity is the quantity of heat required to raise the temperature of a unit mass of a substance by 1 kelvin.

- SI unit of specific heat capacity is **joule per kilogram kelvin** (J/kgK)

$$c = \frac{Q}{m\,\Delta\theta}$$ Therefore, $$Q = m\,c\,\Delta\theta$$

C – heat capacity in J/K **Δθ** – change in temperature **Q** – Quantity of heat in J **m** – mass in kg

Worked Example 56

Calculate the specific heat capacity of paraffin if 22 000 J of heat is required to raise the temperature of 1.5 kg of paraffin from 23 °C to 30 °C

Answer

$$Q = mc\Delta\theta$$

$$22\,000 = 1.5 \times c \times (30 - 23)$$

$$22\,000 = 1.5 \times c \times 7$$

$$22\,000 = 10.5c$$

$$10.5c = 22000$$

$$c = \frac{22000}{10.5}$$

$$\underline{c = 2095\ J/kgK}$$

DETERMINING SPECIFIC HEAT CAPACITY

- Two methods are used
  a) Method of mixtures
  b) Electrical method

a) Method of mixtures

Heat lost by hot substance = heat gained by cold substance

$$(m\,c\,\Delta\theta)_{lost} = (m\,c\,\Delta\theta)_{gained}$$

Assumption made when using this method:

1. *No heat is lost to the surrounding*
2. *Heat is not absorbed by any of the apparatus used to carry out this experiment.*

Precautions to be taken when carrying out such experiments

i) *Use a highly polished calorimeter so as to minimize heat loss by radiation*

ii) *The calorimeter should be heavily lagged so as to minimize heat loss by conduction*

iii) *The calorimeter should be covered with a lid of poor conductor so as to prevent heat loss by evaporation and convection.*

Worked Example 57

How many joules of heat are given out when a piece of iron of mass 50 grams and specific heat capacity 460 J/kgK cools from 80 °C to 20 °C?

Answer *Heat lost by the water* = $mc\Delta\theta$

$$= \frac{50}{1000} \times 4200 \times (80 - 20)$$

$$= 0.05 \times 460 \times 60$$

$$= 1380 \text{ joules}$$

Heat lost by the water = 1.38 kJ

-

Worked Example 58

1) *A block of metal of mass 5 kg is heated to 110 °C and then dropped into 1.5 kg of water. The final temperature is found to be 50 °C. What was the initial temperature of the water? (Specific heat capacity of metal = 460 Jkg^{-1}K^{-1})*

Answer *Let initial temperature of the water be* θ

Heat lost by block = $mc\Delta\theta$

$$= 5 \times 460\ (110 - 50)$$

$$= 5 \times 460 \times 60$$

$$= 138\ 000\text{J}$$

Heat gained by the water = $mc\Delta\theta$

$$= 1.5 \times 4200 \times (50 - \theta)$$

$$= 6300(50 - \theta)$$

Heat gained by the water = $315000 - 6300\ \theta$

Heat gained by water = Heat lost by the metal block

$$315\ 000 - 6300\ \theta = 138\ 000$$

$$-6\ 300\theta = 138\ 000 - 315\ 000$$

$$-6\ 300\theta = -177\ 000$$

$$\theta = \frac{177\ 000}{6300}\ ^{\circ}\text{C}$$

$$\underline{\theta = 28.01\ ^{\circ}\text{C}}$$

Quick Practice Questions

1. *The temperature of a brass cylinder of mass 100 grams was raised to 100 °C and transferred to a thin aluminium can of negligible heat capacity containing 150 grams of paraffin at 11 °C. If the final temperature after stirring was 20 °C, calculate the specific heat capacity of paraffin (Neglect heat losses, and take specific heat capacity of brass = 380 J/kgK)* **(Answer: 2281.5 J/kgK)**

2. *A bath contains 100 kg of water at 60 °C. Hot and cold water taps are then turned on to deliver 20 kg per minute each at temperatures of 70 °C and 10 °C respectively. How long will it take before the temperature in the bath has dropped to 45 °C? Assume complete mixing of the water and ignore heat losses (Take specific heat capacity of water = 4 200J/kgK)* **(Answer: 7.5 minutes)**

3. *A block of metal of mass 5 kg is heated to 110 °C and then dropped into 1.5 kg of water. The final temperature is found to be 50 °C. What was the initial temperature of the water?(specific heat capacity of metal = 460 $Jkg^{-1}K^{-1}$)* **(Answer= 28 °C)**

4. *A person needs water for use at 50 °C. How much water at 80 °C should be added to 60 kg of water at 10 °C to achieve the desired temperature?* **(Answer= 80 kg of water)**

b) Electrical method

Electrical energy supplied by heater = heat gained

$$VIt = m\,c\,\Delta\theta$$

Worked Example 59

A block of metal of mass 1.5 kg which is suitably insulated is heated from 30 °C to 50 °C in 8 minutes and 20 seconds by an electric heater coil rated 54 W. calculate:

a) *The quantity of heat supplied by the heater* **(Answer =27 000J)**

b) *The specific heat capacity of the block* **(Answer =900 J/kgK)**

Answer

a) *Heat Energy Supplied = power x time*

$= 54 \times [(8 \times 60) + 20]$

$= 54 \times (480 + 20)$

$= 54 \times 500$

Heat Energy supplied = 27 000J

b) $Q = mc\Delta\theta$

$27\,000J = 1.5 \times c \times (50 - 30)$

$27\,000 = 1.5 \times c \times 20$

Quick Practice Questions

1. *An immersion heater consumes a voltage of 240 V and a current of 5 A. If it is used to heat 2.5 kg of water at 20⁰C, find the temperature of the water after 7 minutes of heating (Take specific heat capacity of water = 4200 J/ kg K* ***(Answer: 68 ⁰C)***

2. *An electric kettle rated 2kW is filled with 2.0 kg of water and heated from 20 ⁰C to 98 ⁰C. Calculate the time taken to heat the water assuming that all the electrical energy is used to heat the water in the plastic kettle and the kettle has negligible heat capacity.* ***(Answer: 327.6 seconds OR 5 minutes 27.6 seconds)***

SPECIFIC LATENT HEAT OF FUSION L_f

Specific latent heat of fusion is the quantity of heat required to change a unit mass of a substance *from solid state to liquid state* without change in temperature.

$$L_f = \frac{Q}{m}$$ Therefore $$Q = mL_f$$

m *– Mass in kg* ***L_f*** *– specific latent heat of fusion* ***Q*** *– quantity of heat in joules (J)*

- SI unit for specific latent heat of fusion is **joule per kilogram** , J/kg

Worked Example 60

Calculate the quantity of heat required to covert 50 grams of ice at 0⁰C to water at 0⁰C. (Specific latent heat of fusion of ice = 3.4 x 10⁵ J/kg)

Answer:

$Q = mL_f$

$= \frac{50}{1000} \times 3.4 \times 10^5$

$= 17\,000 J$

$\underline{Q = 17 kJ}$

Worked Example 61

Quick Practice Questions

1. *32g of dry ice at 0 ^oC was added to 200g of water at 25^0C in a beaker of negligible heat capacity. When all ice had melted the temperature of water was found to be 10^0C. Calculate the specific latent heat of fusion of ice. (Take specific heat capacity of water to be 4000J/kgK)* ***(Answer: 335000J/kg)***

2. *Calculate the quantity of heat required to covert 50 grams of ice at 0^oC to water at 0^oC. (Specific latent heat of fusion of ice = 3.4 x 10^5 J/kg)* ***(17 000 joules)***

3. *Calculate the quantity of heat required to melt 4 kg of ice and to raise the temperature of the water formed to 50 ^oC (Specific latent heat of fusion of ice = 336 000 J/kg and specific heat capacity of water = 4 200 J/kgK)* ***(Answer: = 2184 kJ)***

4. *Calculate the quantity of heat required to change 0.50 kg of ice at –6 ^oC to water at 25 ^0C (Specific heat capacity of ice = 2 100 J/kgK; specific latent heat of fusion of ice = 3.36 x 10^5 J/kg and specific heat capacity of water = 4 200 J/kgK)* ***(Answer: 226800 joules OR 226.8 kJ)***

5. *50 grams of molten wax at a melting point of 62 ^oC was poured into a copper calorimeter of mass 40 grams with 80 grams of water at 15 ^oC. After stirring the final temperature was 44 ^oC. calculate the specific latent heat of fusion of the wax given that specific heat capacity of copper is 400 J/kgK, that of wax = 1 600 J/kgK and that of water = 4 200 J/kgK)* ***(Answer: 166080 J/kg)***

SPECIFIC LATENT HEAT OF VAPORISATION L_v

Specific latent heat of vaporisation is the quantity of heat required to change a unit mass of a substance from liquid state to vapour state without change in temperature.

$$\boxed{L_v = \frac{Q}{m}} \quad \text{Therefore} \quad \boxed{Q = mL_v}$$

m – Mass in kg   **L_v**– specific latent heat of vaporisation   **Q** – Quantity of heat in joules (J)

- SI unit for specific latent heat of vaporisation is **joule per kilogram**, J/kg

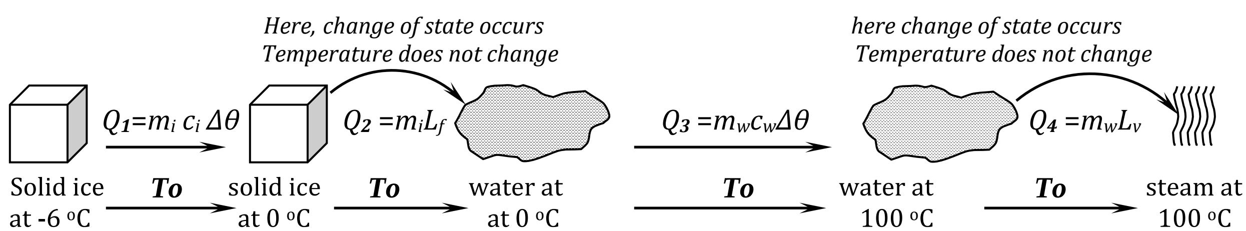
Worked Example 62

Calculate the quantity of heat required to completely convert 0.5 kg of ice at -6 ^oC steam at 100 ^oC

*(**Take:** Specific latent heat of fusion of ice = 336 000 J/kg and specific heat capacity of water = 4200 J/kgK, specific heat capacity of ice = 2100 J/kgK and specific latent heat of vaporisation of Water = 22.6 x 10 ^{5} J/kg)*

Answer:

The heat energy changes will occur in four stages as shown below:



Total heat required, Q_T = $m_i c_i \Delta\theta$ + $m_i L_f$ + $m_w c_w \Delta\theta$ + $m_w L_v$

Total heat required, Q_t $= m_i c_i \Delta\theta + m_1 L_f + m_w c_w \Delta\theta + m_w L_v$

Heat required to raise temperature of ice from -6 ^oC to 0 ^oC, Q_1 $= m_i c_i \Delta\theta$

$= 0.5 \times 2100 \times 6$

$= \underline{6\,300J}$

But, heat required to melt ice, Q_2 $= mL_f$

$= 0.5 \times 336\,000$

$= \underline{168\,000J}$

And, heat required to raise temperature of water, from 0°C to 100 °C, $Q_3 = m_w c_w \Delta\theta$

$= 0.5 \times 4\,200 \times 100$

$= \underline{210\,000\ J}$

Heat required to completely vaporise the water formed $Q_4 = mL_v$

$= 0.5 \times 22.6 \times 10^5$

$= \underline{1\,130\,000J}$

Therefore, total heat energy required is the sum of all these energies:

$= (6\,300 + 168\,000 + 210\,000 + 1\,130\,000)$

$= \underline{\mathbf{1\,514\,300J}}$

Total heat required Q_T = 1 514.3 kJ

Quick Practice Questions

1. *Given that:*

   Specific heat capacity of steam $= 200JKg^{-1}K^{-1}$
   Specific heat capacity of water $= 4200\ JKg^{-1}K^{-1}$
   Specific latent heat of vaporization of water $= 2.26 \times 10^6 JKg^{-1}$
   Specific heat capacity of glass $= 840JK^{-1}K^{-1}$

   What mass of steam initially at 130°C is needed to warm 200g of water in a glass container of mass 100g from 20°C to 50°C.? ***(Answer: 0.011kg or 11g)***

2. *Water at 24°C fall through a height of 72m to the bottom of a dam. Calculate the temperature of the water at the bottom of the dam. (Take specific heat capacity of water as $4200JKg^{-1}K^{-1}$)* ***(Answer: 24.17°C)***

3. *3kg of hot water was added to 9 kg of cold water at 10°C and the resulting temperature was 20°C. Ignoring heat gained by the container, determine the initial temperature of hot water. (Specific heat capacity of water = 4200J/kg/K)* ***(Answer: 50 °C)***

BOILING AND MELTING

A. FACTORS AFFECTING MELTING POINT:

1. Impurities

- Impurities **lower** melting point of a solid *(This explains why sea / salty water freezes at a much **lower** temperature than pure / distilled water)*

2. Pressure

- Increase in pressure lowers melting point of a solid

B. FACTORS AFFECTING BOILING POINT:

1. Impurities

- **Impurities raise the boiling point of liquids** *(This explains why sea water boils at a **higher** temperature than pure / distilled water)*

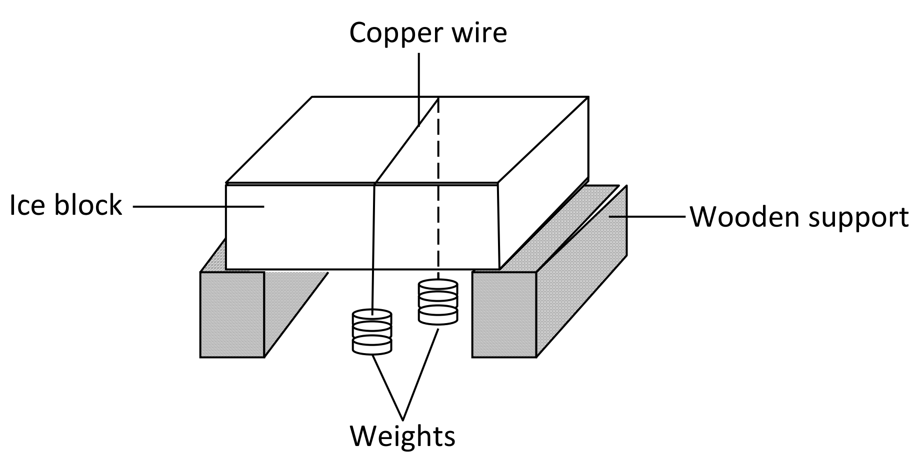
2. Pressure

- **Increase in pressure raises the boiling point of a liquid** *(This explains water boils at a **higher** temperature at sea level than at the top of a high mountain)*

*__NOTE__: Atmospheric pressure is **higher** at sea level than on mountain tops*

Worked Example 63

The figure below shows a block of ice with two heavy weights hanging such that the copper wire / string connecting them passes over the block of ice.



a) *It is observed that the wire gradually cuts its way through the ice block, but leaves it as one piece. Explain*

Answer:

- *Because of the hanging weights, the **wire exerts pressure** on the ice beneath*
- *This makes it melt at a temperature lower that its melting point.*
- *Once the ice has melted, the water formed flows over the wire and immediately*

EVAPORATION

- *Evaporation is change of state from liquid to vapour*

FACTORS AFFECTING RATE OF EVAPORATION

1. **Temperature**: *the higher the temperature, the higher the rate of evaporation*
   - **Practical Example:** *Wet clothes dry faster on a hot day than on a cold day*
2. **Surface area**: *the higher the surface area, the higher the rate of evaporation*
   - **Practical Example:** *Wet clothes dry faster when spread out than when folded together*
3. **Wind / air current:** *if air is blown over the surface of a liquid the rate of evaporation of the liquid increases*
   - **Practical Example:** *Wet clothes dry faster on a windy day than on a calm day*
4. **Humidity** (amount of moisture in the air): *the higher the humidity, the lower the rate of evaporation*
   - **Practical Example:** *Wet clothes dry faster during dry spells than on humid days (when there is a lot of moisture / water vapour in the air)*

COOLING EFFECT OF EVAPORATION

- Evaporation causes cooling

  Explanation:

  When evaporation occurs, the evaporating liquid absorbs latent heat of evaporation from the surrounding thus producing to the cooling effect

SOME DAILY LIFE EXAMPLES OF COOLING BY EVAPORATION

1. **Sweating**
   - *When sweat evaporates, it absorbs latent heat of vaporisation from the skin, producing a cooling effect*
   - *Dogs expose their tongues when it is hot so as to keep the body cool*
2. **Cooling water in a water pot**
   - *A porous pot has tiny pores (holes) through which water slowly seeps out. When this water evaporates, it absorbs latent heat of vaporisation from the pot and its contents thus cooling them*

APPLICATION

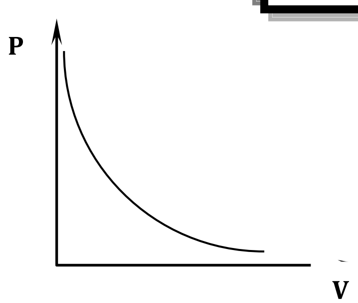
- *The **refrigerator** uses the principle of cooling effect of evaporation*
- ***Pressure cooker** uses the principle of pressure increase on boiling point*

15. TOPIC 15: GAS LAWS

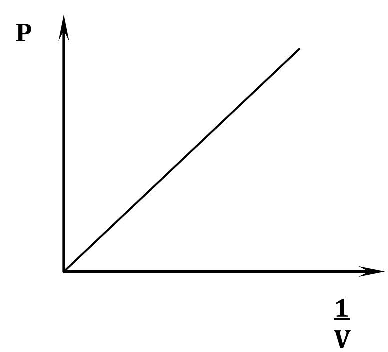
A. Boyle's law

Boyle's law states that the pressure of a fixed mass of a gas is inversely proportional to the volume provided the temperature is kept constant.

$$PV = \text{constant}$$



OR



- For two different conditions of pressure and volume ***at constant temperature***:

$$P_1V_1 = P_2V_2$$

Where:

P_1 – initial pressure **P_2** – Final pressure
V_1 – Initial volume **V_2** – Final volume

Worked Example 64

A gas occupies 250 cm³ when the pressure is 20 atmospheres. What will its volume be if pressure is reduced to 15 atmospheres while the temperature is kept constant?

Answer

$P_1 = 20$ atm $P_2 = 15$ atm

$V_1 = 250$ cm³ $V_2 = V_2$

$$P_1V_1 = P_2V_2$$

$$20 \times 250 = 15 \times V_2$$

$$5000 = 15 V_2$$

$$V_2 = \frac{5\,000}{15}$$

$$V_2 = 333.33 \text{ cm}^3$$

Quick Practice Question

1. *A gas occupies 250 cm³ when the pressure is 20 atmospheres. What will its volume be if pressure is reduced to 15 atmospheres while the temperature is kept constant?*
   (Answer :333.33 cm³)

2. *At a pressure of 15 atmospheres, a given mass of a gas occupies a volume of 300 cm³. At what pressure will the gas have a volume of 800 cm³ assuming that the temperature is kept constant?* ***(Answer :5.625 atmospheres)***

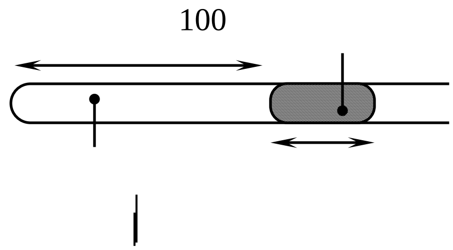
Worked Example 65

Air is trapped in a tube of uniform cross-action using mercury as shown below. Determine the length of the air column when the tube is kept vertical with the open end facing down (Atmospheric pressure = 750 mmHg)

80 mm *mercury*

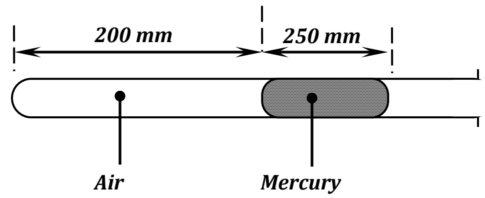
Air *50 mm*

Ff



Quick Practice Questions

The figure below shows dry gas trapped in the closed end of a horizontal glass tube by mercury. The atmospheric pressure is 750mmHg. What length of the tube does the trapped air occupy when the open end is raised until the tube is vertical with the open end facing up? ***(Answer: V_2 = 150 mm)***

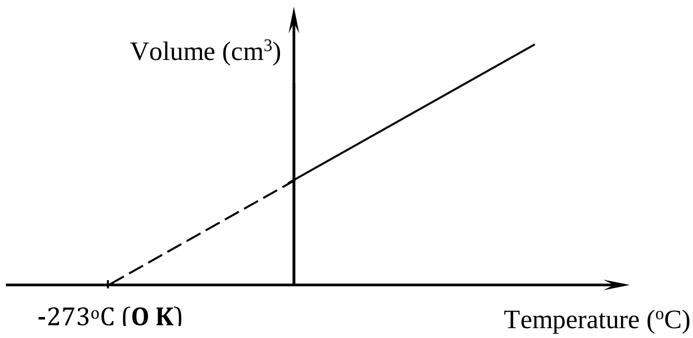


B. Charles's law

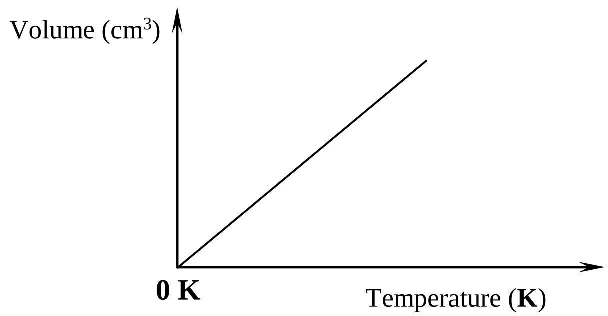
Charles law states that the volume of a fixed mass of a gas is directly proportional to its absolute temperature provided the pressure is kept constant

$$\frac{V}{T} = \text{constant}$$

<u>VOLUME vs. TEMPERATURE IN °C</u>



<u>VOLUME vs. TEMPERATURE IN KELVIN (K)</u>



- For two different conditions of temperature and volume ***at constant pressure*** :

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

Where:

V_1 – initial volume　　**V_2** – Final volume

T_1 – Initial temperature in K　　**T_2** – Final temperature in K

NOTE: The temperature **0 kelvin** (–273°C) is known as the ***<u>Absolute Zero</u>***

Absolute zero is the temperature at which all particles of matter possess zero energy

- *Theoretically* , this is the lowest possible temperature that can be attained by matter in the entire universe
- *Practically*, it is **not possible** to attain this temperature

<u>Quick Practice Questions</u>

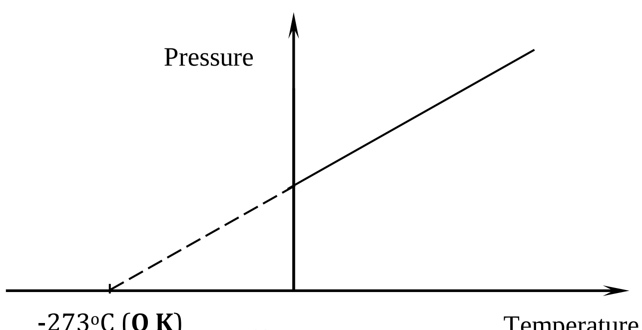
1. *A gas A was found to occupy 300 cm³ when the temperature is 47 °C. Calculate the volume which can be occupied by the gas if the temperature is increased by 20 °C and pressure kept constant* ***(Answer :318.75 cm³)***
2. *A gas occupies 500 cm³ at 27 °C. What volume will it occupy at 277 °C if pressure is kept constant?* ***(Answer :916.67 cm³)***

C. Pressure Law

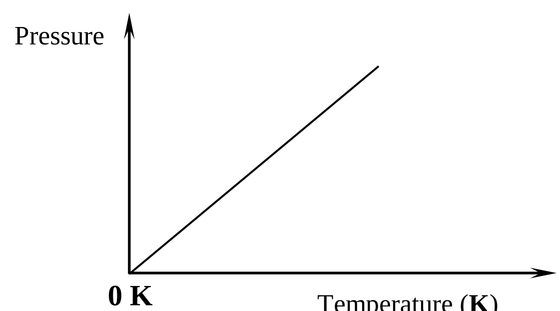
Pressure law states that the pressure of a fixed mass of a gas is directly proportional to the absolute temperature provided the volume is kept constant

$$\frac{P}{T} = \text{constant}$$

PRESSURE vs. TEMPERATURE IN °C



PRESSURE vs. TEMPERATURE IN KELVIN (K)



o For two different conditions ... d press ... constant

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

P_1 – initial pressure **P_2** – Final pressure

T_1 – Initial temperature in K **T_2** – Final temperature in K

Worked Example 66

A car tyre is at an air pressure of 4.0 x 10^5 Pa. at a temperature of 27 ^{0}C. While it is running, the temperature rises to 75 ^{0}C. What is the new pressure in the tyre? (Assume the tyre does not expand)

Answer

Since the tyre does not expand, this implies that the volume is constant

P_1 = 40 000Pa $P_2 = P_2$

$T_1 = (27+273)$ $T_2 = (75 + 273)$

= 300 K = 348K

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

Quick Practice Question

A sealed glass tube containing air at s.t.p was immersed in water at 123 °C. Assuming there was no increase in the volume of the glass tube due to expansion of the glass tube; calculate the pressure of the air inside the tube. (Standard pressure = 760 mmHg, standard temperature = 273 K)

(Answer : 1102.42 mmHg)

GENERAL GAS LAW EQUATION

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

P_1 – initial pressure
V_1 – initial volume
T_1 – Initial temperature in K

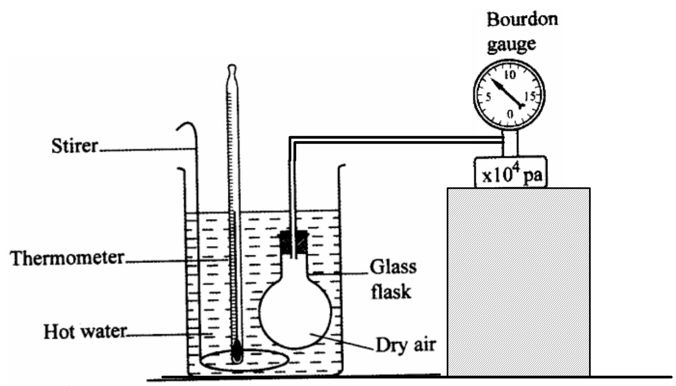
P_2 – Final pressure
V_2 – Final volume
T_2 – Final temperature in K

Quick Practice Question

1. *A gas **R** at 27°C and 750 mmHg was found to occupy 36 cm³. Calculate the temperature at which the same mass of **R** will occupy twice the volume at a pressure of 1000 mm Hg*

   (Answer : 800K OR 527 °C)

2. *The figure below shows a set up that may be used to verify Pressure law.*



   (i) State the measurements that may be taken in the experiment.

   (ii) Explain how the measurement in (i) above may be used to verify Pressure law

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16. TOPIC 16: UNIFORM CIRCULAR MOTION

RADIAN MEASURES

- A radian is the angle subtended by the arc whose length is equal to the radius of the circle

$$\theta^c = \frac{\text{arc length (s)}}{\text{Radius (r)}} \quad \textbf{OR} \quad \theta^c = \frac{s}{r}$$

Where: θ^c – angle in radians **S** – arc length **r** – Radius

- Angles in radians can be converted to degrees by using the relationship:

$$2\pi \text{ radians} = 360^o$$

Worked Example 67

The radius of a circle is 6m. Calculate the length of the arc of the circle, if the angle subtended by the arc, at the centre is 180º

Answer

$$\theta = \frac{s}{r}$$

$$\theta = \frac{180}{360} \times 2\pi$$

$$\theta = \pi \text{ radians}$$

Therefore, $\boldsymbol{s = r\theta}$

$$= 6 \times \pi$$

$$= 6 \times 3.142$$

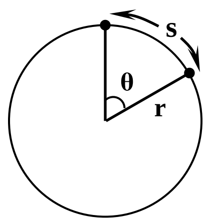
$$\underline{\boldsymbol{s = 18.852m}}$$

Quick Practice Question

The radius of a circle is 6m. Calculate the length of the arc of the circle, if the angle subtended by the arc, at the centre is 60° ***(Answer: 6.284 m)***

ANGULAR DISPLACEMENT

Angular displacement is the angle swept by the radius joining a particle to the centre of the circle



- *Angular displacement* θ^c *is measured in radians and is calculated as*

$$\theta^c = \frac{s}{r}$$

Where: **θ^c** – angular displacement in radians **S** – arc length **r** – Radius

Worked Example 68

(a) The radius of the path of a particle moving along a circular path sweeps through an angle of 60° at the centre of the circle. Calculate the angular displacement of the particle in radians

Answer *:* $360^o = 2\pi$ *radians*

$$60^o = \frac{(60 \times 2\pi)}{360}$$

$$= \frac{\pi}{3} \text{ radians}$$

$$= \frac{(3.142)}{3} \text{ radians}$$

Angular displacement θ^c = 1.0473 radians

(b) The radius of a circle is 15m. Calculate the length of the arc of the circle, if the angle subtended by the arc at the centre is 60°

Answer: $360^o = 2\pi$ *radians*

ANGULAR VELOCITY, ω

- **Angular velocity is the rate of change of angular displacement with time**

$$\boxed{\text{Angular velocity} = \frac{\text{angular displacement}}{\text{Time}}}$$

OR

$$\boxed{\omega = \frac{\theta^c}{t}}$$

- Angular velocity is measured in ***radians per second*** ($rads^{-1}$)

Worked Example 69

A bicycle wheel makes 300 revolutions per minute (rpm). Calculate the angular velocity of the wheel

Answer For 1 revolution, the angle swept = 360^o = 2π radians

Therefore, for 300 revolution angle swept = $\frac{(300 \times 2\pi)}{1}$

= 600π radians

$\omega = \frac{\theta^c}{t}$

$= \frac{600\,\pi}{60 \text{ seconds}}$

= $10\,\pi$ radians /second

ω = 31.42 radians /second

Quick Practice Questions

Calculate the angular velocity of the tip of the minute hand of a wrist watch

(Answer: $\left(\frac{2\pi}{60}\right)$ ***radians /second OR 0. 1047 radians /second)***

RELATIONSHIP BETWEEN ANGULAR VELOCITY AND LINEAR VELOCITY

$$\boxed{v = r\,\omega} \quad \textbf{OR} \quad \boxed{\omega = \frac{v}{r}}$$

v – Linear velocity in m/s **r** – Radius in metres (m) **ω** – angular velocity in rad/s

Worked Example 70

A car moves with a uniform speed of 2 m/s in a circular path of radius 0.4 m. Find the angular velocity of the car.

Answer:

$$\omega = \frac{v}{r}$$

$$= \frac{2m/s}{0.4\ m}$$

$$\omega = 5 \text{ rad. /second}$$

Quick Practice Question

A ball tied to a string is rotated with a uniform speed in a circle of radius 10 cm. It takes 1.5 seconds to describe an arc of length 6 cm. calculate its:

a) *Linear speed* ***(Answer: 4 cm /s OR 0.04 m/s)***

b) *Angular velocity* ***(Answer: 0.6667 rad. /s)***

RELATIONSHIP BETWEEN ANGULAR VELOCITY (ω) AND FREQUENCY (*f*)

$$\boxed{\omega = 2\pi f} \quad \textbf{OR} \quad \boxed{f = \frac{\omega}{2\pi}}$$

Where:

Where: ω – *angular velocity in rads*$^{-1}$ f – *frequency in Hz*

Worked Example 71

A model car moves round a circular track of radius 0.4 m with a velocity of 2 m/s. Find the angular velocity and the frequency of the car. (π = 3.142)

Answer:

$$\omega = \frac{v}{r}$$

$$= \frac{2\ m/s}{0.4\ m}$$

$$\underline{\omega = 5\ rads^{-1}}$$

$$\omega = 2\pi f$$

$$5 = 2\pi f$$

$$f = \frac{5}{2\pi}$$

$$= \frac{5}{2 \times 3.142}$$

$$= \frac{5}{6.284}$$

$$\underline{f = 0.7957\ Hz}$$

Quick Practice Question

1. *A giant wheel of radius 20m is rotating around about its own axis with a frequency of 5Hz. Find :*
   a) *The angular velocity in radians per second.* ***(Answer :10π rad./s OR 31.42 rad. / s)***
   b) *The linear speed of a point at a point on the rim of the wheel* ***(Answer : 628.4 m/s)***

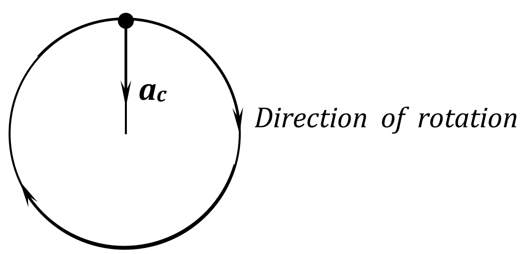
2. *A particle revolves at 2Hz in a circular path of radius 2m. Calculate:*
   a) *Its linear speed* ***(Answer : 50.272 m/s)***
   b) *Acceleration* ***(Answer : 1263.637 m/s²)***

3. *A satellite orbits the earth once every hour. Calculate;*
   a) *The angular velocity of the satellite* ***(Answer : 2.7778 x 10⁻⁴ rad / s)***
   b) *Given that the radius of the satellites orbit is 12 800km, find the linear speed of the satellite* ***(Answer : 3555.584 m/s)***

CENTRIPETAL ACCELERATION

Centripetal acceleration is the acceleration of a body towards the centre of the circle

- A body moving in a circular path is said to accelerate even though its speed is constant. *This is because its velocity keeps on changing as the direction changes*.
- Centripetal acceleration is a vector quantity. *The direction of Centripetal acceleration is towards the centre of the circular path*



a_c – Centripetal Acceleration

- Centripetal acceleration, **a**, is calculated as:

$$\boxed{a = \frac{v^2}{r}} \quad \textbf{OR} \quad \boxed{a = r\,\omega^2}$$

Where:

v – Linear velocity in m/s

r – Radius in metres (m)

a – centripetal acceleration in m/s^2

ω – Angular velocity in $rads^{-1}$

Worked Example 72

A point on the rim of a wheel has a velocity of 5.6 m/s. If the rim has a radius of 1.4m, calculate:

a) *The angular velocity of the point*

b) *Its centripetal acceleration*

Quick Practice Question

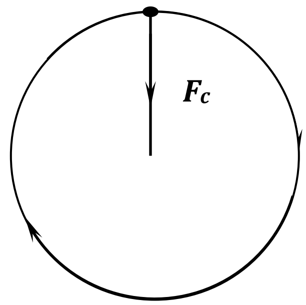
A turn table of a record player makes 45 revolutions per minute. Calculate:

a) *Its angular velocity in radians per second.* **_(Answer: 4.713 rad/sec)_**

b) *The linear velocity at a point 0.12m from the centre.* **_(Answer: 0.566 m/s)_**

CENTRIPETAL FORCE

- Centripetal force is the force acting on a body moving in a circular path, needed to keep it in the circular path.
- Centripetal acceleration is a vector quantity. The direction is towards the centre of the circular path



F_c – Centripetal Force

- Centripetal force is calculated as:

$$F = \frac{m v^2}{r}$$ **OR** $$F = m r \omega^2$$

v – Linear velocity in m/s **r** – Radius in metres (m) **m** – Mass in kilograms (kg)

a – Centripetal acceleration in m/s^2 **ω** – Angular velocity in $rads^{-1}$

Worked Example 73

A body of mass 0.5 kg is tied to a string and whirled in a ***horizontal circle*** *of radius 2.0 m with a speed of 3.16 m/s. Calculate the tension in the string*

Answer

Since the circle is in a horizontal plane, the tension in the string provides the centripetal force

$$\text{Tension} = \text{centripetal force}$$

$$= \frac{mv^2}{r}$$

$$= \frac{(0.5 \times 3.16^2)}{2.0}$$

$$= \frac{0.5 \times 9.9856}{2}$$

$$T = 2.4964N$$

Quick Practice Questions

1. *A stone of mass 100g is whirled in a* ***horizontal plane*** *making 2 revolutions per second in a circle of radius 0.4m*
   a) *Calculate the angular velocity of the stone.* ***(Answer: 4 π rads/sec)***
   b) *Calculate the centripetal force.* ***(Answer: 6.317 N)***

2. *A body of mass 0.2kg is tied to a string and whirled in a horizontal circle of radius 1.0m with a speed of $3.0ms^{-1}$ Calculate the tension in the string.* ***(Answer: 1.8 N)***

3. *(a) Define angular velocity and state its SI units*

   (b) A ball of mass 200g is attached on one end of the string and whirled round in a horizontal circle of radius 1m once every second. Calculate:

   (i) The circumference of the circle and hence speed of the ball in m/s.

FACTORS AFFECTING CENTRIPETAL FORCE

(a) Mass of the body

- *The bigger the mass, the bigger the centripetal force*

(b) Angular velocity of the object

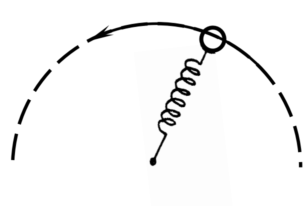
- *The higher the angular velocity, the bigger the centripetal force*

(c) Radius of the path

- *The smaller the radius of the path, the bigger the centripetal force*

Worked Example 74

The following figure represents a spiral spring being rotated in a horizontal circle at a constant speed. The length of the spiral spring including a mass of 100g at its ends is 0.4m. The spring constant of the spring is 0.5N/cm. Determine the extension produced when the spring is rotates at a constant speed of 4m/s and radius of 1.2 m.



$$F = ke \quad \{\text{Hooke's law}$$

Also, $$F = \frac{mv^2}{r}$$

Therefore $\frac{mv^2}{\ }$ = ke

CAR ROUNDING A LEVEL (FLAT) CIRCULAR BEND

- The frictional force acting on a car going round a ***level*** circular bend ***(i.e. circular bend which is not banked)*** is given by the equation:

$$\boxed{F_r = \frac{m v^2}{r}}$$

Thus:

$$\boxed{v = \sqrt{\frac{r \times F_r}{m}}}$$

v – Critical speed in m/s

r – Radius of the circular bend (m)

m – Mass in kilograms (kg)

$\mathbf{F_r}$ **–** frictional force between the wheels and the road (N)

Note: *If the speed of the car exceeds the critical speed, **then the car will skid off the track***

FACTORS AFFECTING CRITICAL SPEED ON A LEVEL CIRCULAR BEND

- The maximum velocity with which a car negotiates a level bend depends on:

i) Radius of the bend (r)

- The smaller the radius of the bend, the lower the critical speed.
  - *Thus a car going round a circular bend with smaller radius must do so at a lower speed as opposed to one going round a bend with a bigger radius*

ii) Condition of the road (frictional force due to the road surface, i.e. roughness of the road) (F_r)

- The greater the frictional force due to the road surface, the higher the critical speed.

- *Thus a car going round a circular bend on a rough road can do so at a much higher speed on a rough road than on a smooth road*

iii) The mass of the body moving round the circular bend (m)

- The greater the mass of the body, the lower the critical speed.
  - *Thus a car of a **higher mass** going round a circular bend must do so at a **lower speed** than a car of lower mass to avoid skidding*

Worked Example 75

A car of mass 1200kg is moving round a bend of radius 50m. If the coefficient of friction between the road and the tyre is 0.8, calculate the maximum of speed at which the car should be driven, at the bend without going off the road.

Answer

$$\mu = \frac{F_r}{R}$$

$$\mu = \frac{F_r}{mg}$$

$$F_r = mg \times \mu$$

$$= 1200 \times 10 \times 0.8$$

$$= 9600N$$

$$F_r = \frac{m v^2}{r}$$

$$9600 = \frac{1200 v^2}{50}$$

$$v^2 = \frac{(9600 \times 50)}{1200}$$

$$v^2 = 400$$

$$v = \sqrt{400}$$

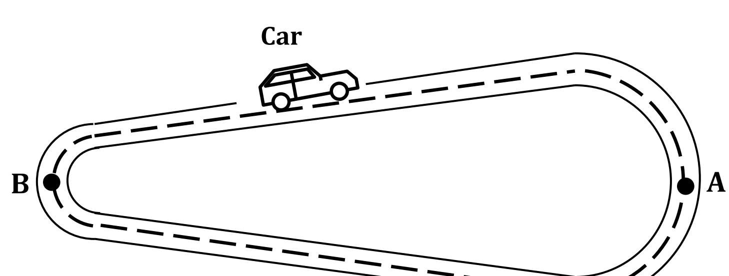
$$v = 20m/s$$

Quick Practice Questions

1. *A car of mass 1500kg negotiates a bend of radius 45m on a horizontal road. If the frictional force between the road and the tyres is 7200N, calculate the critical speed of the car on the road.*

(Answer: =38.73ms^{-1})

2. *The figure below shows a car of mass (m) moving along road with two curved ends at a constant speed.*



BANKED TRACKS

- **Banking of a road is the making the road such that the outer path is slightly raised above the inner side so that the track is slopping towards the centre of the curve.**

FACTORS AFFECTING CRITICAL SPEED ON A BANKED ROAD

- The maximum velocity with which a car negotiates a banked without skidding off the bend depends on:

i) Radius of the bend

- The smaller the radius of the bend, the lower the critical speed.

- ❖ *Thus a car going round a circular bend with smaller radius must do so at a lower speed so as not to skid off, as opposed to one going round a bend with a bigger radius*

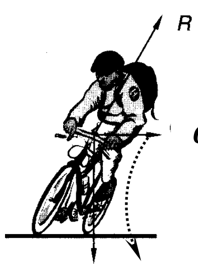
ii) Banking angle

- The smaller the angle of banking, the lower the critical speed.
  - ❖ *Thus a car going round a circular bend with smaller angle of banking must do so at a lower speed as opposed to one going round a bend with a bigger angle of banking*

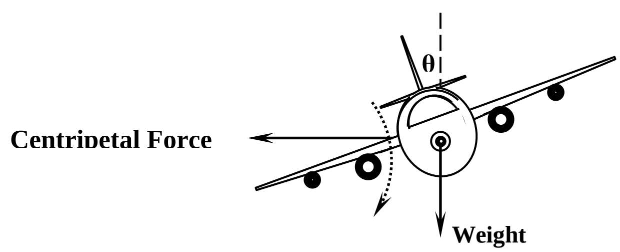
iii) Condition of the road (frictional force due to the road surface, i.e. roughness of the road)

- The greater the frictional force due to the road surface, the higher the critical speed.
  - ❖ *Thus a car going round a circular bend on a rough road can do so at a much higher speed on a rough road than on a smooth road*

Other Daily life Examples of Banking

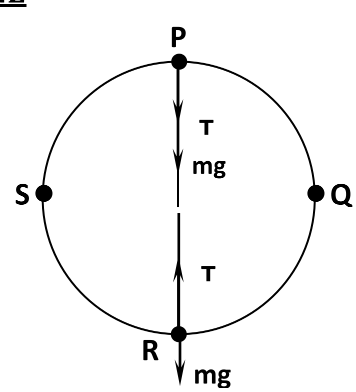


1. *Cyclist going round a circular bend leans inwards*



2. *An aircraft taking a circular turn*

MOTION IN A VERTICAL PLANE



1. At the highest point of the circle, **P**, tension in the string, **T**, is *minimum*, and is given by

$$T = \frac{m v^2}{r} - m g$$

∇ *It is at this position that a certain minimum speed must be maintained for the body to continue moving in the circular path. If this minimum speed is not maintained, the string will slacken*

∇ *Minimum speed needed to keep the string taut so that it does not slacken is given by:*

$$V_{min} = \sqrt{rg}$$

r – Radius in (m) ***g*** – Acceleration due to gravity (m/s^2)

V_{min} – Minimum speed needed to keep the string taut in m/s

2. At points **Q** and **S**, tension, **T**, in the string is given by:

$$T = \frac{m v^2}{r}$$

3. At point **R**, tension, **T**, is *maximum* and is given by

$$T = \frac{m v^2}{r} + m g$$

- It is at this point that the string is most likely to break

Where:

v – Velocity in m/s **r** – Radius in (m) **m** – Mass in (kg)
T – tension on the string (N) **g** – Acceleration due to gravity (m/s^2)

Worked Example 76

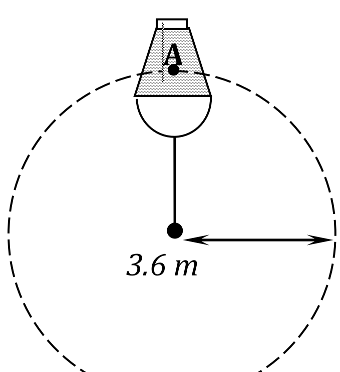
The breaking strength of a string 2.5m long revolving in a horizontal plane is 200N. What is the maximum revolutions per minute at which the string can retain a 2kg mass attached to its end?

Answer

—

Worked Example 77

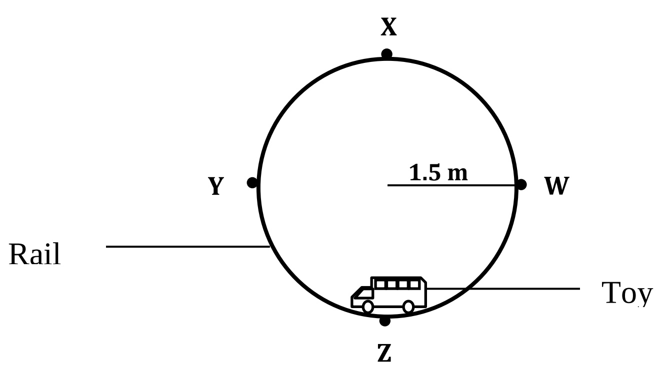
The figure below shows a bucket filled with water of mass 5kg tied to a string being rotated in a vertical circle of radius 3.6 m with a constant speed of V m/s



Ff

Quick Practice Questions

1) *The figure below shows a toy moving on a circular rail in a vertical plane.*

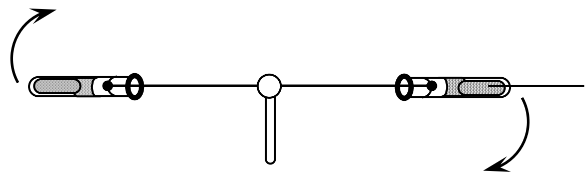


APPLICATIONS OF CIRCULAR MOTION

1. **Centrifuges**:
    - A centrifuge is a device that separates liquids of different densities or solid particles suspended in liquids.
    - In a centrifuge, solid particles with greater mass (or the more dense liquids) will require greater centripetal force; hence will be further away from centre
2. **Speed governors**: Used to control speed of a car by regulating fuel intake

Worked Example 78

The figure below shows a centrifuge being used in separating particles suspended in a liquid.



Insolvent particles of different masses M_1*, and* M_2*, are suspended in a liquid and system then rotated at high speed as shown.*

a) *Explain why the particles of different mass will be at different distances from the bottom of the tubes.*

Answer

- *Force on the particles is given by* $F = m\omega^2 r$ *;*
- *The angular velocity* ω *is constant;*
- *Greater mass will therefore require greater centripetal force hence will be further away from centre/ near the bottom (base) of the test tube.*

b) *If* M_1 *is greater than* M_2*, which particle will be further away from the* ***base*** *of the tube?*

Answer

M_2 *will be further away from the* ***base*** *of the tube*

c) *Would the particles separate if the tubes remained vertical during the rotation? Explain.*

Answer

- *No*
- *The radius is the same for all particles*

17. TOPIC 17: FLOATING AND SINKING

Archimedes principle states that when a body is totally or partially immersed in a fluid, it experiences an upthrust which is equal to the weight of the fluid displaced.

Upthrust = (actual weight – weight in a fluid)

Upthrust = weight of the fluid displaced *(According to Archimedes Principle)*

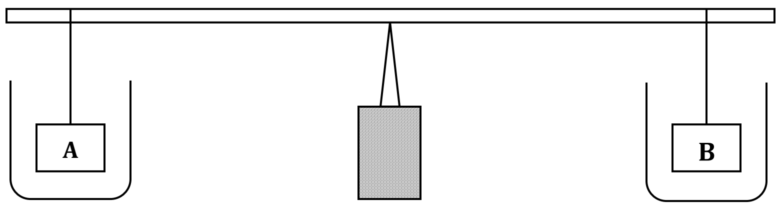
- Upthrust exerted by a liquid on a solid depends on ***two main factors***:

    3. **The density of the liquid.** *Denser liquids exert greater upthrust than less dense liquids.*

    4. **The depth to which the solid is immersed in the liquid.** *The greater the depth of immersion, the greater the up thrust*

Worked Example 79

The figure below shows a uniform bar in equilibrium.



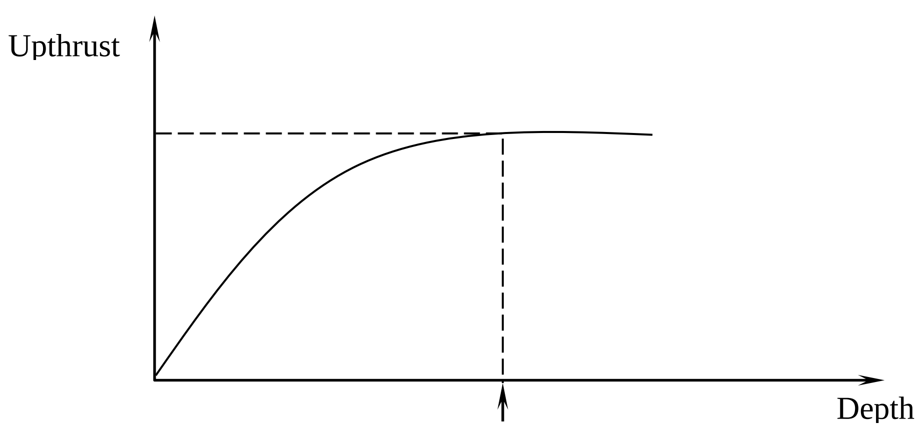
*Water is added into the beakers **A** and kerosene in beaker **B** until the weights are submerged; it's observed that the bar tips towards **B**. Explain this observation.*

Answer

- *Water is denser than kerosene so exerts higher upthrust on the weight **A** submerged in it. Apparent weight of **A** in water is therefore lower than weight of **B** in kerosene.*
- *The clockwise moments therefore become greater than the anticlockwise moments, making the bar to tilt towards **B***

- When a solid is gradually immersed in a fluid, the upthrust due to the fluid acting on the body increases gradually from zero to a ***maximum value when the solid is fully immersed*** in the fluid.

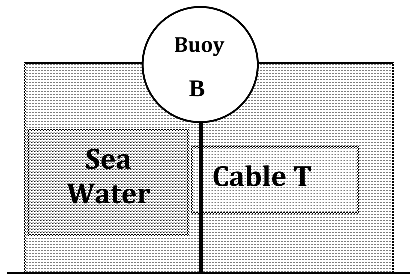
- Once the solid is fully inside the fluid, the upthrust acting on it remains constant, ***no matter how deeply the solid is immersed in the fluid.***



*This is the point at which the **solid is fully immersed** in the fluid. Therefore,*

Worked Example 80

*The figure below shows a buoy, **B**, of volume 40 litres and mass 10 kg. It is held in position in sea water of density 1.04 g cm^{-3} by a light cable fixed to the bottom so that ¾ of the volume of the buoy is below the surface of the sea water. Determine the tension **T** in the cable.*



Volume of water displaced = ¾ of the total volume of the buoy

= ¾ x 40

= 30 litres

= 0.03 m^3

*Weight of buoy = **mg***

= (10 x 10) ***= 100N***

Mass of sea water displaced = density of sea water **x** *volume displaced*

= (1040 x 0.03) ***= 31.2 kg***

Therefore, weight of sea water displaced = mg

= (31.2 x 10) ***= 312N***

But by Archimedes Principle, Upthrust = Weight displaced

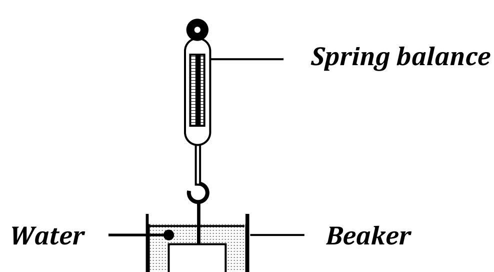
Tension T = Upthrust – Weight of buoy

= 312 – 100

T = 212N

Quick Practice Questions

1) *In the figure below, a stone of volume 120cm³ was lowered into water contained in a beaker. The weight of the stone in air was 2.4N. Determine the reading on the balance when the stone is immersed in water. (Density of water = 1000kg/m³)* ***(Answer: 1.2 N)***



- Archimedes principal can be used to determine the relative density of solids and liquids as follows:

a) **For a solid:**

$$\text{Relative density} = \frac{\text{Weight of solid in air}}{\text{Upthrust in water}}$$

b) **For a liquid**

$$\text{Relative density} = \frac{\text{Upthrust in liquid}}{\text{Upthrust in water}}$$

Worked Example 81

An object weighs 1.04N in air, 0.64N when fully immersed in water and 0.72N when fully immersed in a liquid. If the density of water is 1000 kg m⁻³, find the density of the liquid.

Answer: *Upthrust in liquid = 1.04 – 0.72*
= 0.32N

Upthrust in water = 1.04 – 0.64

= 0.40

$$\textit{Relative density} = \frac{\textit{upthrust in liquid}}{\textit{Upthrust in water}}$$

= 0.32

Quick Practice Questions

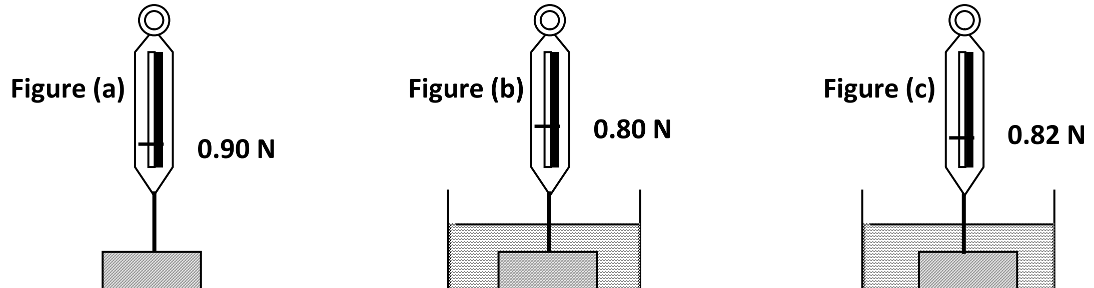
1. *(a) Define relative density of a substance.*

(b) A piece of cork weighs 0.012N in air when tied to a sinker; the weight of the system in water is 0.462N. The weight of the sinker alone in water is 0.50N. Find the relative density of the cork. ***(Answer: 0.24)***

2. *A piece of sealing wax weighs 3N in air and 0.22N when immersed in water, calculate the density of the wax.* ***(Answer: 1.079 x 1g/cm³)***

Practice Question

*The figure **below** shows the same block weighed in air, water and liquid. Given that the reading of the level of water becomes 150 cm^3 when the metal is fully immersed.*



LAW OF FLOATATION

Law of floatation states that a floating body displaces its own weight of the fluid in which it floats

Worked Example 82

A piece of wood has a volume of 30 cm³. It floats on a liquid of density 0.8 g/cm³ with ²/₃ of its volume immersed in the liquid. Determine the weight of the piece of wood.

Answer

Volume of wood immersed $= \frac{2}{3} \times 30$

$= 2 \times 10$

$= 20\ cm^3$ (This is the volume of the liquid displaced)

Mass of the liquid displaced $=$ density x volume

$= 0.8\ g/cm^3 \times 20\ cm^3$

$= 16$ grams

Therefore weight of liquid displaced $=$ **mg**

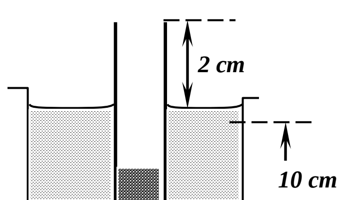
$= \frac{16 \times 10}{1000}$

$= 0.16\ N$

Therefore, the weight of the wood = 0.16 N

Worked Example 83

A simple hydrometer is set up with a test – tube of mass 10g and length 12cm with a flat base and partly filled with lead shots. The test tube has a uniform Cross – Sectional area 2.0cm² and 10cm of its length is under water as shown in the figure below. Taking the density of water as 1000Kg/m³, calculate the mass of the lead shots in the tube.



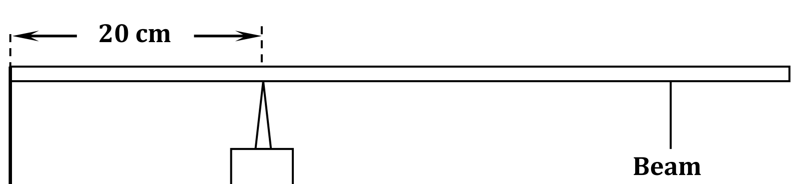
Quick Practice Question

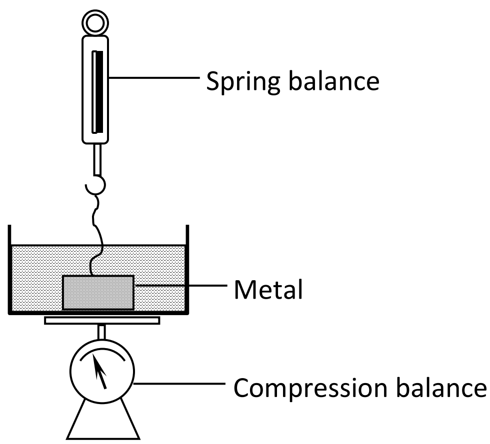
1. *A block of wood of mass 80kg floats in water with 0.6 of its volume in water. Calculate the number of rods each 20g that can be placed on the block so that its top is level with the surface of water* ***(Answer : 2 665 rods)***

2. *A piece of metal is suspended from a spring balance and the balance reads 80N. When the metal is immersed in a liquid of relative density 1.2 the spring reads 70N. Find*
   - *(i) The mass of the metal* ***(Answer : 8 kg)***
   - *(ii) The weight of the fluid displaced* ***(Answer : 10N)***
   - *(iii) The density of the metal* ***(Answer : 9600 kg/ m³)***

Quick Practice Questions

1. *The figure below shows a uniform beam one metre long and weighing 2N, kept in horizontal position by a body of weight 5N immersed in a liquid Determine the upthrust on the load* ***(Answer: = 2 N)***





APPLICATIONS OF ARCHIMEDES PRINCIPLE

1. Hydrometer

- This is used to determine the relative densities of liquids
- It is graduated with larger readings at the bottom and smaller readings at the top

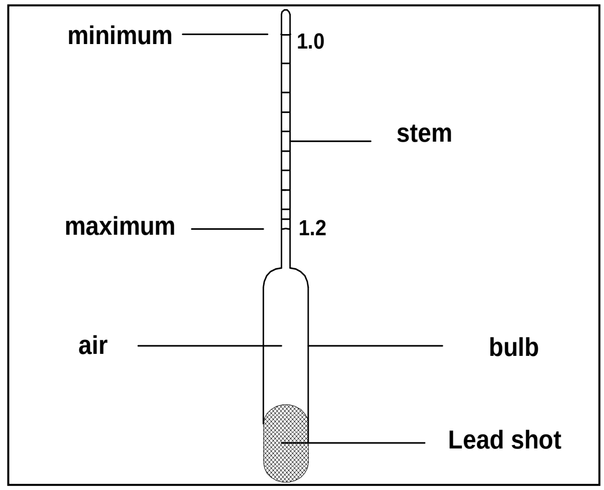
2. Ships

- Ships are designed to float in water by making them hollow
- This hollow space traps air

3. Submarines

- These can float and sink in water

A Hydrometer



- *Bulb is made wide so as displace much fluid to produce enough upthrust which will cause the hydrometer to float*
- *Lead shots lower the centre of gravity to increase stability so as to keep the hydrometer in an upright position*
- *The stem is made narrow to increase its sensitivity*

ADDITIONAL PRACTICE QUESTIONS

(NOTE: *Where necessary take $g = 10m/s^2$*)

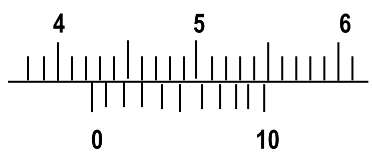
MEASUREMENTS

1) (a) An oil drop of volume of 6.546×10^{-5} cm^3 spread to form a circular patch of radius 9cm. Determine the diameter of the oil molecule ***(Answer: 2.57×10^{-7}cm)***

(b) State one assumption made when carrying out the oil drop experiment

2) ***x*** cm^3 of substance **A** which has a density of 800 kg/m^3 is mixed with100 cm^3 of water with a density of 1000 kg/m^3. The density of the mixture is 960kg/m^3. Determine the value of ***x***. ***(Answer: 25 cm^3)***

3) The figure below shows the scale of a vernier calliper. State the correct reading indicated on the calliper ***(Answer: 4.23 cm)***



4) An oil drop has a volume of $0.02mm^2$ when it is placed on the surface of water. It spreads out to form a circular patch of area $1000cm^2$.

(i) Calculate the size of the molecule of oil. ***(Answer: 2.0×10^{-8} cm)***

(ii) State one assumption made in (i) above

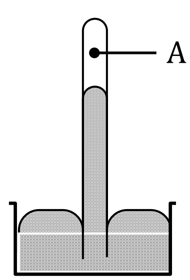
FORCE

5) A body weighs 1960 N on the surface of the earth. The same body weighs 1470 N on the surface of another planet. Determine the acceleration due to gravity on the surface of the planet. Take acceleration due to gravity on the surface of earth, g =10N/Kg. ***(Answer: $g_p = 7.5N/Kg$)***

6) An object is attached to a spring balance and its weight determined in air. It is then gently lowered into a liquid in a beaker. State and explain what you expect to happen to the reading.

PRESSURE

7) The diagram below shows a simple barometer



a) Name the part labelled **A**

b) Explain what would happen to the level of mercury in the tube if:

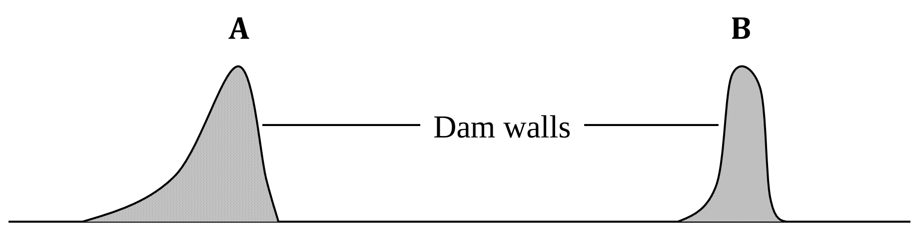
(i) The barometer was tilted slightly

(ii) The barometer was taken high up the mountain

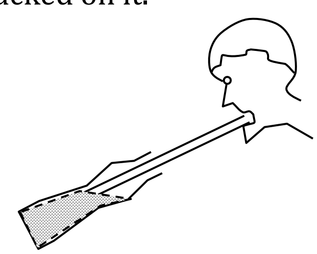
(iii) Air was allowed to enter the part labelled A

8) A partially inflated balloon at sea level becomes fully inflated at higher altitudes. Explain this observation.

9) With an appropriate reason, Identify the suitable cross- sectional shape of a dam wall



10) The figure below shows a student drinking a soda using a straw. Explain why the soda rises up a straw when the student sucked on it.



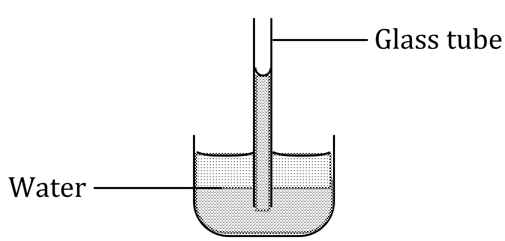
PARTICULATE NATURE OF MATTER

11) (a) What qualities make the smoke suitable for use in the smoke cell experiment?

(b) State and explain what is observed when smoke particles in an air cell is illuminated and viewed under a microscope

12) Explain why the density of a gas is much less than that of a solid or a liquid

13) The figure below shows the meniscus of water in a glass tube.



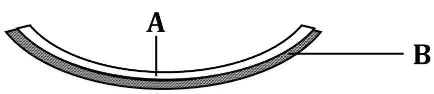
Explain why the meniscus of the liquid is shaped as shown.

14) A bottle containing ammonia solution is placed at the back of the laboratory. Give a reason why its smell may not be detected in other parts of the laboratory if the temperature of the solution is kept very low

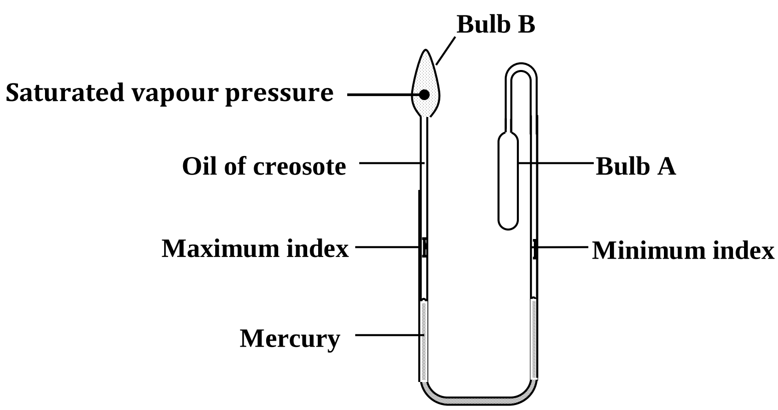
THERMAL EXPANSION

15) (a) State one way of increasing sensitivity of mercury –in-glass thermometer

(b) The diagram below shows a bimetallic strip after it has been heated from room temperature of 26 ᵒC to 40 ᵒC. Draw a possible shape of the bimetallic strip if its temperature is decreased from 40 ᵒC to 39 ᵒC.



16) The figure below shows a diagram of a six's maximum and minimum thermometer.

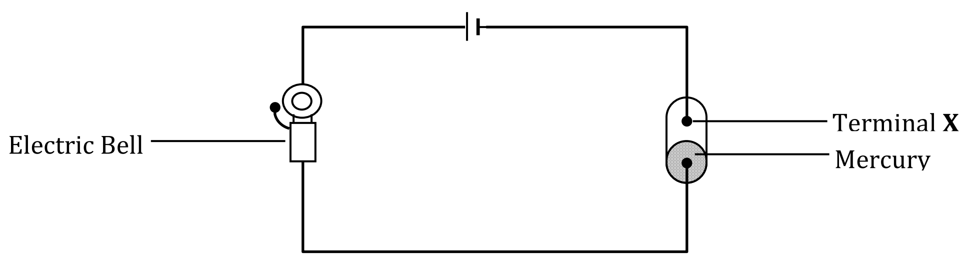


a) What is the thermometric substance in the thermometer?

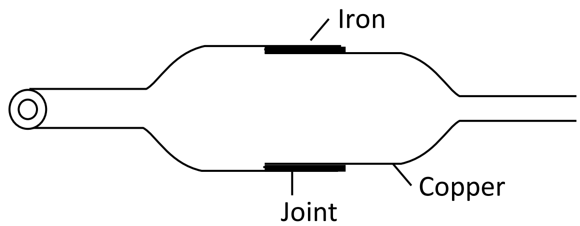
b) Explain why it is necessary for the vapour at the top of bulb **B** to be saturated

c) Explain how the thermometer measures the daily maximum and minimum temperatures in a place

17) The figure below shows a simple fire alarm. Briefly explain how the alarm functions.



18) The diagram **below** shows a metal tube made of iron and copper. The joint is tight at room temperature.

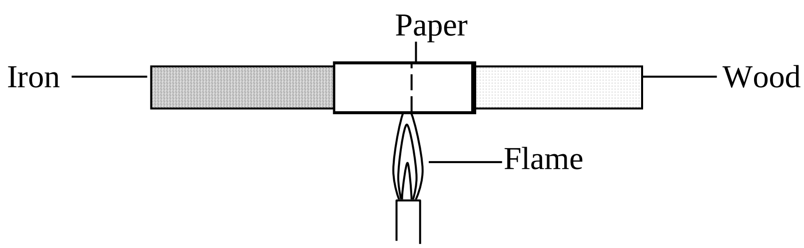


Explain how you would separate the two by changing the temperature given that copper expands more than iron for some change in temperature.

HEAT TRANSFER

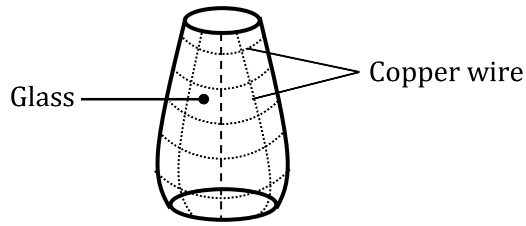
19) A stone floor feels very cold to bare feet in the morning but a carpet in the same room feels comfortably warm. Why is this?

20) In an experiment to compare the conductivity of iron and wood, the set-up below was used. State and explain what was observed when the flame was passed over the paper several times.

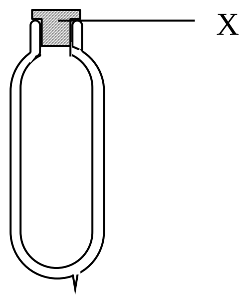


21) An electric kettle with a shiny outer surface would be more efficient than one with dull outer surface. Give a reason for this

22) The diagram below shows the glass shade of a lamp with a copper wire wound round it. It was observed that the glass is less likely to crack than when there is no copper wire wound around it. Explain this above observation



23) The figure shows a sketch of a vacuum flask



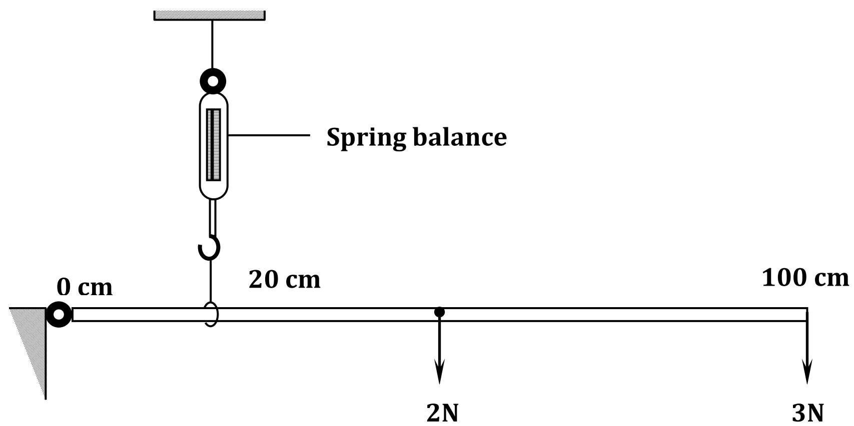
a) Name the material the part labelled **X** is made of.

b) A hot liquid is put in the flask and the stopper replaced. Explain how the flask is able to maintain the temperature of the liquid.

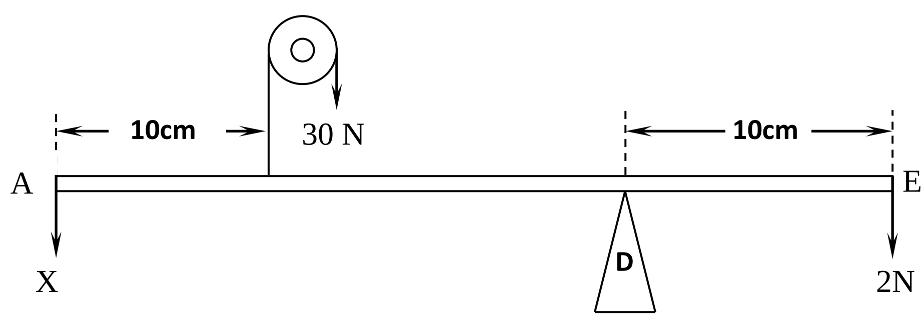
c) Explain why a larger amount of hot liquid is more likely to retain its high temperature than a small amount of liquid placed in the same flask.

TURNING EFFECT OF FORCE

24) The figure below shows a uniform meter rule of weight 2N kept at equilibrium by a vertical spring balance hung at 20 cm mark. A weight of 3N is hung at 100 cm mark and the other end pivoted by a hinge at 0 cm as shown. Calculate the reading of the spring balance ***(Answer: 20N)***



25) The figure below shows a uniform rod **AE** which is 40 cm long. It has a mass of 2 kg pivoted at **D**. If 2N is acting at point **E**, and 30N force is passed through a frictionless pulley.



Find the force (x) acting at end **A**. ***(Answer: 14N)***

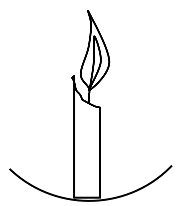
26) An object of mass 20kg balances on a uniform plank of length 6m as shown in the figure below. Determine the weight of the plank. ***(Answer: 400N)***

EQUILIBRIUM AND CENTRE OF GRAVITY

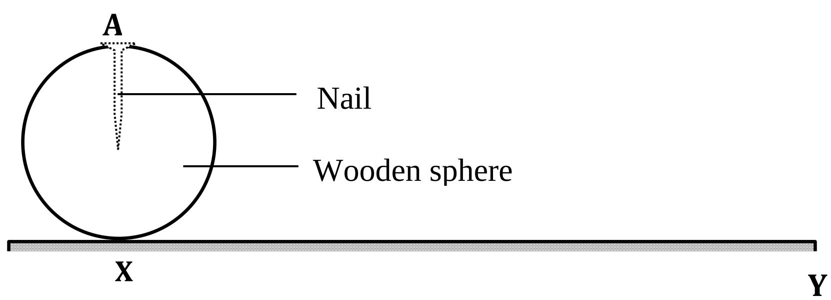
27) Explain why a *matatu* with standing passengers is less stable than one with sitting passengers.

28) Give a reason why the base of Bunsen burners are usually made heavy and wide.

29) The figure below shows a candle burning. What happens to the stability of the candle as it continues to burn

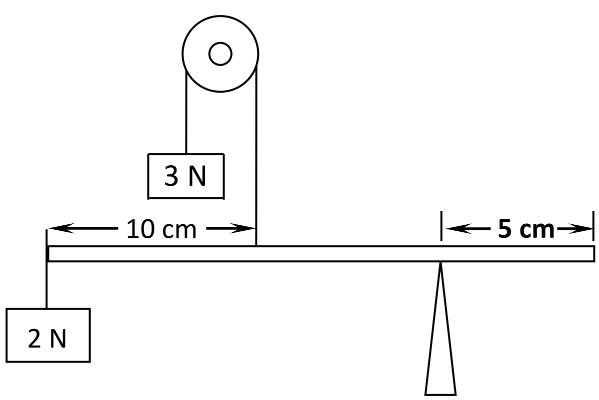


30) The figure below shows a wooden sphere with a nail hammered in to it at point **A** as shown below.



The sphere is rolled on a horizontal ground and comes to rest after some time at point **Y.** Draw the sphere after it comes to rest at point **Y.**

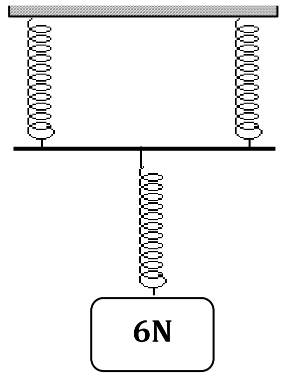
31) A uniform half meter rule is supported by force of 3N and 2N as shown in the figure below.



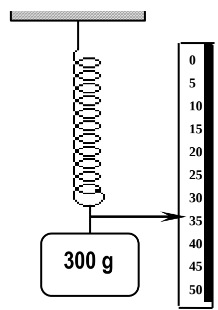
Determine the weight of the half meter rule ***(Answer: 0.75N)***

HOOKES LAW

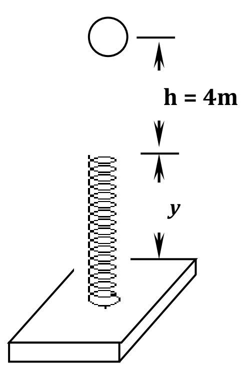
32) Three identical springs each of spring constant 10 N/m and negligible weight are used to support a load as shown. Determine the total extension of the system ***(Answer: 0.9 m)***



33) The figure below shows a set up used to determine the spring constant of a spring. If the initial pointer position before the mass was added was at the 20 cm mark, calculate the spring constant. ***(Answer: 20N/m)***



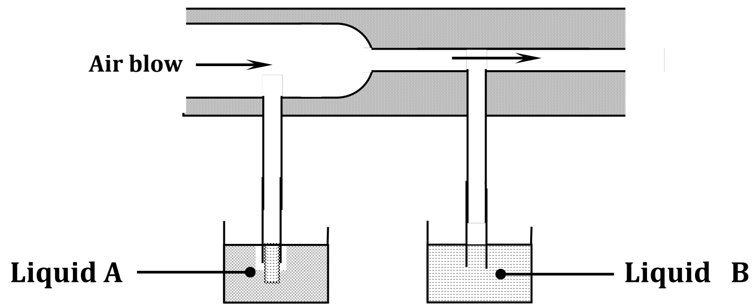
34) A ball of mass 1.5kg is dropped from a height, ***h*** = 4m and compresses a spring through a distance of ***y*** as shown in figure 5 below. The spring is of negligible mass and a spring constant **k** = 3000 N/m. Determine the distance ***y***. ***(Answer : 0.2 m OR 20 cm)***



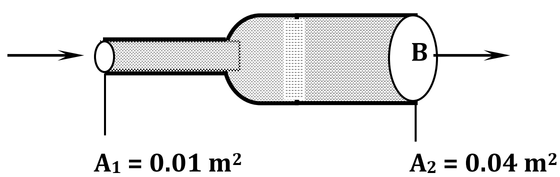
FLUID FLOW

35) Fast moving motor vehicles appear to e lighter than stationary vehicles. Explain this observation

36) The figure below shows air flowing through a pipe of non-uniform cross-sectional area. Two pipes **A** and **B** are dipped into liquids as shown. Indicate the levels of the liquids in Pipe **A** and pipe **B**. Explain your answer.



37) The figure below shows water entering a pipe at a velocity of 40 m/s. The pipe widens on the outlet.

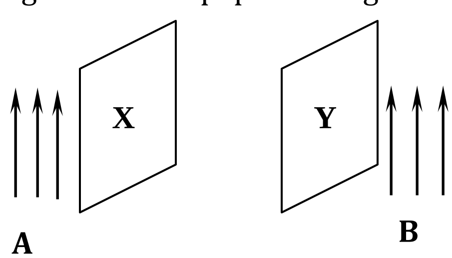


Calculate:

a) The velocity of water at **B** ***(Answer: 10 m/s)***

b) The mass of water flowing out of **B** per second (density of water = 1000 kg/m^3) ***(Answer: 400 kg/second)***

38) The figure below shows two light sheets of paper arranged as shown.



Explain the observation made when air is blown at the same speed and time at points **A** and **B.**

39) Two ships moving parallel close to each other are likely to collide. Explain

(iii) Water flows through a tube of length 50 cm and of cross-sectional area $50cm^2$ in 2.5 seconds. Calculate the rate of flow in cubic metres per second ***(Answer: 10 x $10^{-4}m^3/s$)***

LINEAR MOTION

40) A body is moving with uniform acceleration its velocity after 5 seconds is 26m/s and after 9 seconds it is 42m/s. Calculate

a) The acceleration of the body ***(Answer 4 m/s^2)***

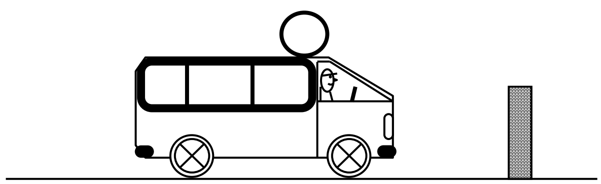
b) Its initial velocity ***(Answer: 6m/s)***

c) The average velocity between the fifth and ninth second and hence the displacement covered during this period ***(Answer: 34 m/s)***

d) Its displacement in 10 seconds ***(Answer: 136 m)***

41) A small iron ball is dropped from the top of a vertical cliff and takes 2.5 seconds to reach the sandy beach. Find the velocity with which it strikes the sand. ***(Answer: = 25 ms^{-1})***

42) A minibus, carrying a loose drum of oil and travels along a horizontal tarmac road at 60km/h as shown below.



The minibus then hits the concrete barrier and stops moving but the drum rolls off the minibus flies off the top.

a) Explain why the drum flies off when the minibus hits the barrier

b) Sketch the path of the drum after it flies off the minibus

c) Given that the top of the minibus is 3 meters above the ground, calculate:

(i) The time taken before the drum hits the ground (g = 10 m/s^2) ***(Answer: 0.7746 s)***

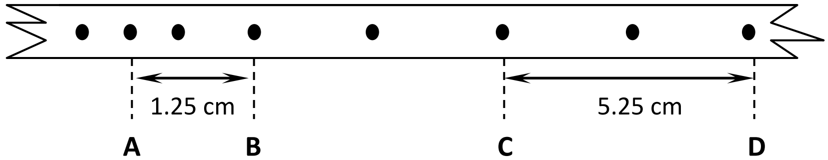
(ii) The horizontal distance covered by the drum after it flies off the top of the minibus ***(Answer: 12.91 meters)***

d) State one assumption made above

43) A bomber flying horizontally at 100m/s releases a bomb from the height of 200m.Calculate the time taken for the bomb to hit the ground. ***(Answer: 6.325 seconds)***

44) An object is projected vertically upwards with a velocity of 25m/s. How long will it take to return to the same level of projection? ***(Answer: 5.0 seconds)***

45) A tape attached to a moving trolley is run through a ticker timer. A section of it appeared as shown below;



If the frequency of ticker timer is 50 Hz, calculate the acceleration of trolley. ***(Answer: 10m/s²)***

46) (a) A car starts from rest accelerates uniformly at $2ms^{-2}$ for 5 seconds. It then travels at the velocity attained for the next 3 seconds before accelerating again at 2.5 ms^{-2} for 2 seconds. The car is then brought to rest in another 2 seconds.

(i) Draw a velocity – time graph for this motion.

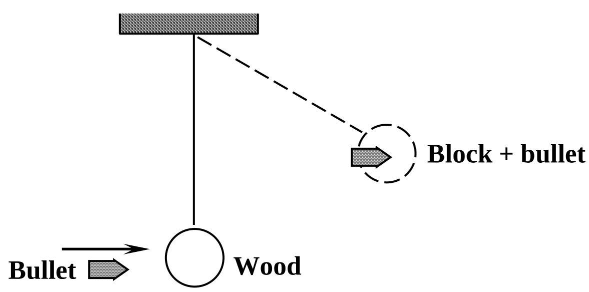
(ii) Calculate the total distance covered from your graph. ***(Answer: 95 metres)***

NEWTON'S LAWS OF MOTION

47) A rifle of mass 4.0kg fires a bullet of mass 12.0g with a muzzle velocity of $700ms^{-1}$. Assuming that the rifle is free to move, find the velocity of recoil. ***(Answer: 2.1m/s)***

48) Explain why un-boiled egg stops faster than a boiled egg when both are rolled together on a flat horizontal surface with same velocity.

49) A bullet of mass 30 g travelling at a speed of 200 m/s embeds itself in a block of wood of mass 970 g suspended so that it can swing freely, as shown in the figure below



Determine:

a) The velocity of the bullet and block immediately after collision. ***(Answer: 6.0 ms^{-1})***

b) The height through which the block rises. ***(Answer: 1.8 m)***

50) A bus of mass 2500 kg initially moving at 20 m/s is brought to rest over a distance at 20m. Calculate the force required to achieve this. ***(Answer: = 10m/s²)***

51) A block of metal of mass 40kg requires a horizontal force of 100N to drag it with a uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surfaces.

(Answer: 0.25)

52) (a) A boy throws a tennis ball vertically upwards from a truck moving at a constant velocity. Give the reason why the ball lands back exactly the same point where it was projected.

53) (a) Define impulse in terms of momentum.

(b) A trailer of mass 30 tonnes travelling at a velocity of 72km/hr rams onto a stationary bus of mass 10 tonnes. The impact takes 0.5 seconds before the two vehicles move off together at a constant velocity for 15 seconds. Determine.

(i) The common velocity. ***(Answer: 15 m/s)***

(ii) The distance moved after the impact. ***(Answer: 225 m/s)***

(iii) The impulsive force on the trailer on impact. ***(Answer: 300 000N)***

54) A trolley of mass 1kg moving at 1m/s collides head on with a stationary blocks of wood of mass 2kg. If the trolley and the block of wood are struck together and moved a distance of 0.1m before coming to rest, find the;

a) The velocity after collision ***(Answer: 0.33m/s)***

b) Kinetic energy after collision ***(Answer: 0.495J)***

c) The frictional force ***(Answer: 4.95 N)***

55) (a) Give the reasons why a safety seat belt used in a vehicle;

(i) Should have a wide surface area

(ii) Should be slightly extensible

(b) When a passenger jumps from a floating boat, the boat moves backwards. Give a reason for this.

(c) A steel ball is dropped into a cylinder containing oil. Sketch a graph showing the variation of acceleration with time.

WORK POWER ENERGY AND MACHINES

56) A driving gear having 25 teeth engages with a second wheel with 100 teeth. If the gear system is 85% efficient, find the mechanical advantage. ***(Answer = 3.4)***

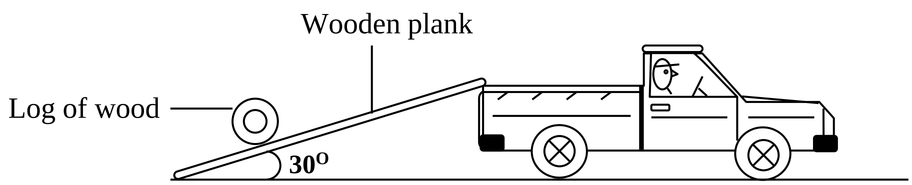
57) A pump is used to spray water from a pool to form fountain.

(i) Determine the minimum power of the pump if it ejects 50 litres of water per minutes and spray reached a height of 5metres.
(Answer:41.67 W)

(ii) Give a reason why water often returning to the pool has a different temperature from that which left the pump.

58) (a) Define the term efficiency as applied in simple machine.

(b) A man used a wooden plank to lift a log of wood from the ground to a stationary pick up on a flat ground as shown in figure below. The wooden plank was inclined at an angle of 30^{o} to the ground.



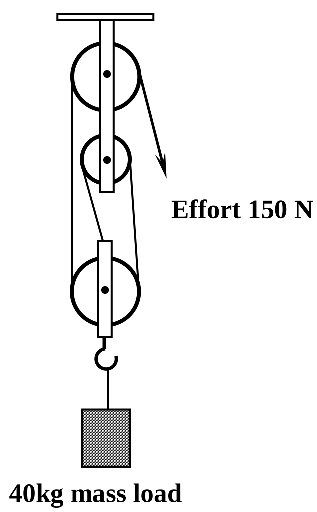
(i) Indicate with an arrow on the diagram, the direction of the effort and the load.

(ii) Calculate the velocity ratio of the set up. ***(Answer: 2)***

(iii) Calculate the mechanical advantages of the set up if its efficiency is 65%. ***(Answer: 1.3)***

59) A man of mass 60kg climbs up 30 steps each of 0.15m high in 50 seconds. Find his power output. ***(Answer: 54W)***

60) The figure below shows a pulley system. Calculate the efficiency of the system. ***(Answer: 89 %)***



61) A crane lifts a load of 2000kg through a vertical distance of 3.0m in six seconds. Determine

(i) Work done. ***(Answer: 60 000 joules)***

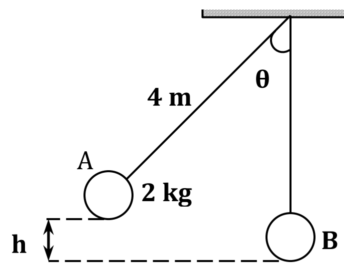
(ii) Power of the crane. ***(Answer: 10 000 watts)***

62) Name the transducer that is used to convert the following form of energies.

(i) Electrical to sound.

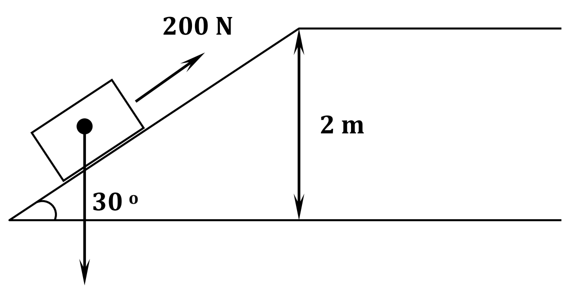
(ii) Electrical to kinetic.

63) A metal ball suspended vertically with a wire is displaced through an angle θ as shown in the diagram below. The body is released from **A** and swings back to '**B**'.



Given that the maximum velocity at the lowest point B is 2.5 m/s. find the height ***h*** from which the ball is released $\left(g = 10 m/s^2\right)$ ***(Answer :3.125 m)***

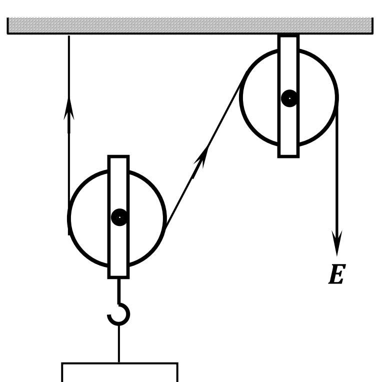
64) A block of mass 50kg is pulled up an inclined plane by a force of 200N until it gets to the top as shown below



(i) Find the work done by the force in moving the block up the incline. ***(Answer : 800 J)***

(ii) Find the work done on the block against gravity. ***(Answer : 1000 J)***

65) A man used the pulley system shown below to raise a 3 kg load through a height of 5 m using an effort of 25N



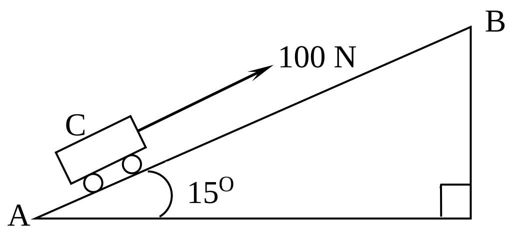
(i) Through what distance does the end **E** of the rope move ***(Answer: 10m)***

(ii) Given that the pulley system is frictionless and that the efficiency is 75 %, find:

I: the mechanical advantage of the system ***(Answer: 1.5)***

II: the mass of the lower pulley ***(Answer: 2 kg)***

66) The figure **below** shows an inclined plane, a trolley of mass 30kg is pulled up a slope by a force of 100N, parallel to the slope. The trolley moves so that the centre of mass C travels from points A to B.



a) What is the work done on the trolley against the gravitational force in moving from **A** to **B**.? ***(Answer: 3000J)***

b) Determine the work done by the force in moving the trolley from **A** to **B**.***(Answer: 3863.70J)***

c) Determine the efficiency of the system. ***(Answer: 77.57%)***

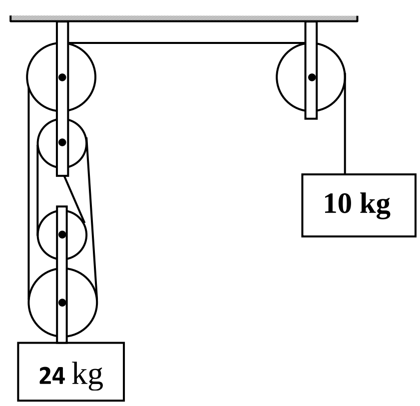
d) Determine the work done in overcoming the frictional force. ***(Answer: 863.7J)***

e) Determine the mechanical advantage of the system. ***(Answer: 1.5514)***

67) (a) State two factors that affect the efficiency of a pulley system

(b) Sketch a labelled diagram to show how arrangement of a single pulley may be used to provide a velocity ratio of 2.

68) The figure below shows a pulley system with the load rising at uniform speed.



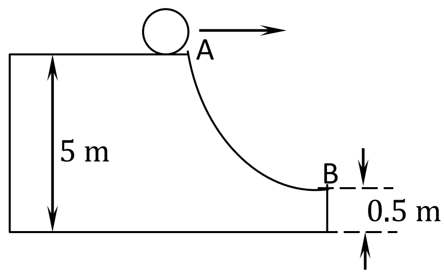
From the information given calculate;

(i) Velocity ratio of the machine *(Answer: 4)*

(ii) Mechanical advantage of the machine *(Answer: 2.4)*

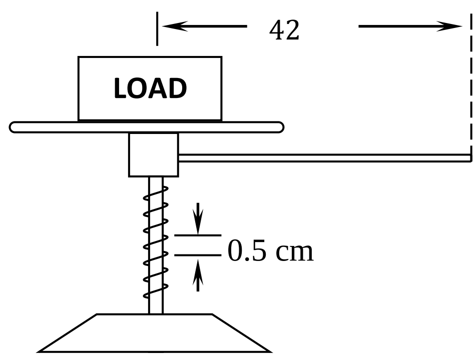
(iii) Efficiency of the machine *(Answer: 60%)*

69) The figure below shows a solid sphere moving on a platform 5cm above the ground. It rolls down a curved frictionless path in a point 0.5m above the ground.



Calculate its velocity at the lower point, position **B** *(Answer: 9.487m/s)*

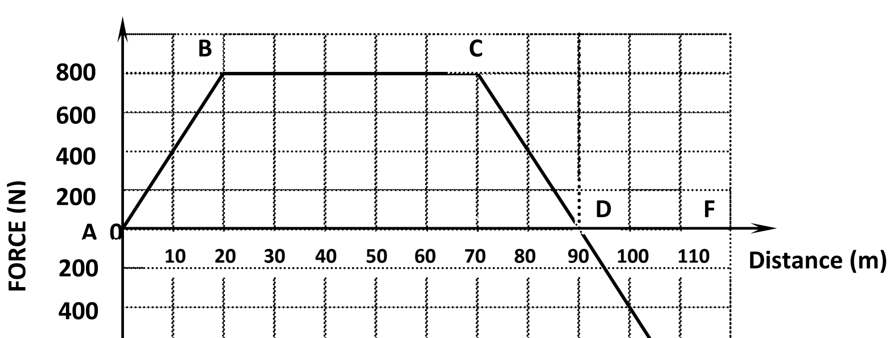
70) The handle of the screw- jack in the figure below is 42cm long and the pitch of the screw is 0.5cm.



What force must be applied at the end of the handle when lifting a load of 1188N if the efficiency of the jack is 50%? *(Answer: 4.5 N)*

71) (a) Define the term work.

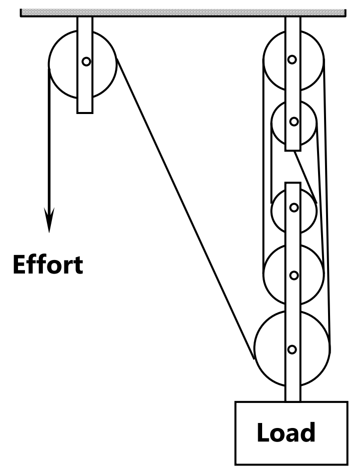
(b) The figure shows a force-distance graph for a car towed on a horizontal ground.



(i) Calculate the total work done. ***(Answer: 64000 joules)***

(ii) If the velocity just before reaching point C is 0.6m/s, calculate the power developed by the agent providing the force at this point. ***(Answer: 480 watts)***

72) The figure **below** shows a machine being used to raise a load. Use the information given in the figure to answer questions **below**.



(a) Determine the velocity ratio (**V.R**) of the machine. ***(Answer: 6)***

(b) If a load of 800N is raised by applying an effort of 272N, determine the efficiency of the machine. ***(Answer: 49.01%)***

73) A block and tackle system has 3 pulleys in the upper fixed block and two in the lower movable block, what load can be lifted by the effort of 200N if the efficiency of the system is 60%. ***(Answer: 600 N)***

QUANTITY OF HEAT

74) 83.6 kilojoules of heat was lost in cooling an amount of water at 15^0C to ice at -10^0C. Find mass of the water (specific heat capacity of water 4.2 x 10^{-3}J$kg^{-1}K^{-1}$ specific heat capacity of ice = 2.1 x 10^2J$Kg^{-1}K^{-1}$, Latent heat of fusion of water = 3.3 x 10^5JKg^{-1}) ***(Answer: 0.2 kg)***

75) (a) Define the specific heat capacity of a substance.

(b) A lead weight is dropped from a helicopter hovering at 100m above the ground. Assuming that all the energy is converted into heat energy, determine the rise in temperature of lead. Take specific heat capacity of lead to be 130J/kg K. ***(Answer: 7.69 ^oC)***

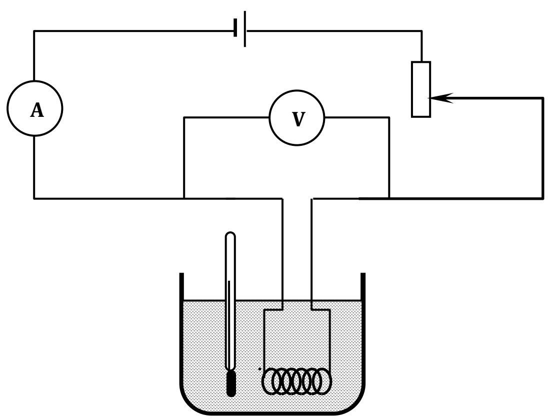
76) Explain why a drop of methylated spirit placed at the back of the hand feels colder than a drop of distilled water although are at same temperature.

77) A jet of dry steam at 100 ^0C is sprayed on to the surface of 100g of dried ice at 0 ^0C contained in a well-lagged calorimeter of negligible heat capacity, until all the ice has melted and the temperature begin to rise. The mass in the calorimeter when the temperature reaches 40^0C is found to be 120g.Assuming that the specific latent heat of fusion of ice is 336000JKg^{-1}, specific heat capacity of water is 4200$JKg^{-1}K^{-1}$, **Determine** the specific latent heat vaporization of water. ***(Answer: 2.27 x 10^{6}J/kg)***

78) Why is the scald from steam more hurting than that of boiling water?

79) (a) Define specific heat capacity

(b) The figure below shows a set up in an experiment to determine specific heat capacity of water.



The data below was obtained was obtained from the experiment

Voltage V across the heater	=	*12V*
Current I in the circuit	=	*1.4A*
Time (t) heating	=	*600s*
Mass m of water	=	*0.4kg*
Change in temperature ΔT	=	*6 ^oC*

(i) State ***two*** improvements that would be made in the set up to obtain accurate results.

(ii) Use the above results to determine the specific heat capacity of water.

(Answer : 4200 J/kgK)

80) A copper calorimeter of mass 60g is filled with 100g of water at 25 °C. Steam at normal temperature and pressure is passed through the water until a temperature of 40 °C is attained. The final mass of the calorimeter and the contents was found to be 163.5g. Calculate the specific latent heat of vaporization L_V of water. ***(Answer: 2298600J/kg)***

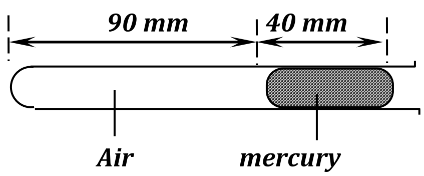
81) Give a reason why a hand feels cold if a little mythlated spirit is spilt on it.

GAS LAWS

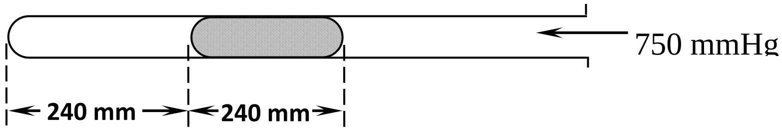
82) A certain mass of helium gas occupies a volume of 1.6 m^3 at a pressure of 1.5 x 10^5 Pa and 12^0C. Determine its volume when the temperature is 273 K at 1.0x10^5 Pa.
*(**Answer : 2.299 m^3**)*

83) An air bubble has a volume of 5.2mm^3 when at the bottom of water, reservoir 30m deep. Calculate the volume when it has risen to the surface of the reservoir, if the temperature remains constant. (Atmospheric pressure 1.02 x 10^5pa) ***(Answer: 20.494 mm^3)***

84) Air is trapped in a tube of uniform cross-action using mercury as shown below. Determine the length of the air column when the tube is kept vertical with the open end facing upward. (*Atmospheric pressure = 760 mmHg*) ***(Answer: 85.5 mm)***



85) Air is trapped inside a glass tube by a thread of mercury of 240mm long. When the tube is held horizontally the length of air column is 240mm.



Assuming that the atmosphere pressure is 750mmHg and the temperature is constant; calculate the length of air column when the tube is held vertical with open end up.
(Answer: 182mm)

UNIFORM CIRCULAR MOTION

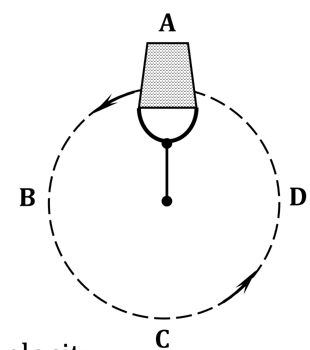
86) A wheel rotates at 45 revolutions per minute. What is the angular velocity in rad/s?
(Answer: 4.71 rad s^{-1})

87) In circular motion, there is acceleration yet the speed is constant. Explain.

88) Roads are normally banked at corners. Explain the importance of banking.

89) A child whirled a stone of mass 0.5kg in a vertical circle on the end of a string 40cm long. At the point where the string is likely to break, the velocity of the stone is 3 ms^{-1}. Determine the tension in the string at this point. ***(Answer : 16.25N)***

90) The figure below shows a pail of water being swung in a vertical circle. Explain why the water does not pour out when the pail is at position **A** as shown:



91) (a) Define the term angular velocity

(b) What is meant by the term "***Banking***" in roads?

(c) A wooden block of mass 200g is placed at a distance of 9cm from the centre of a turn table. When the turn table is rotated at constant angular velocity, the block begins to slide off the table. If the frictional force between the block and the turn table is 1.2N, determine:

(i) The co-efficient of friction between the block and the turn table ***(Answer: 0.6)***

(ii) The linear speed of the block ***(Answer: 0.73m/s)***

(iii) If the angular velocity is increased by 2π rad/s, what would be the force required to hold the block at the same place? ***(Answer: 3.75N)***

92) **(a)** A block of metal of mass 40kg requires a horizontal force of 100N to drag it with a uniform velocity along a horizontal surface. Calculate the coefficient of friction between the surfaces. ***(Answer: 0.25)***

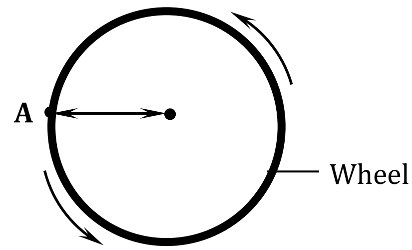
(b) (i) In circular motion, there is acceleration yet the speed is constant. Explain.

(ii) Roads are normally banked at corners. Explain the importance of banking.

(c) A child whirls a stone of mass 0.5kg in a vertical circle on the end of a string 40cm long. At the point where the string is likely to break, the velocity of the stone is 3 ms^{-1}. Determine the tension in the string at this point. ***(Answer: 16.25 N)***

93) **(a)** Explain why a pail of water can be swung in a vertical circle without the water pouring out.

(c) The figure below represents a wheel.



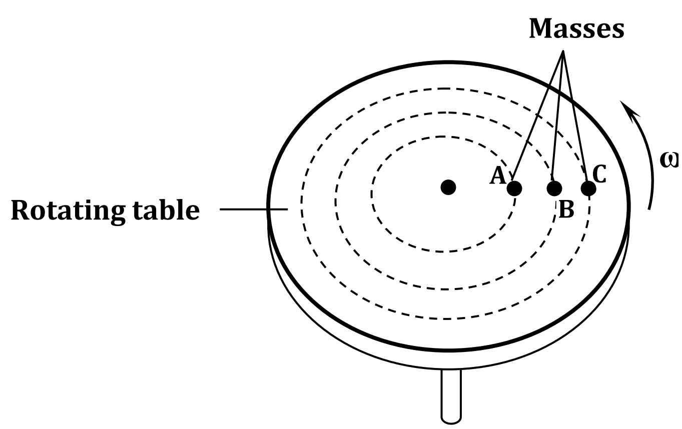
Point '**A**' on the rim of the wheel has a velocity of 5.6 ms^{-1}. If the rim has a radius of 4.0m, calculate:

(i) the angular velocity of the point ***(Answer: ω = 14 rads/s)***

(ii) Its centripetal acceleration ***(Answer: a = 78.4 m/s²)***

94) (a) State what is meant by ***centripetal acceleration***

(b) The figure shows masses, **A**, **B** and **C** placed at different points on a rotating table. The angular velocity, **ω**, of the table can be varied.



(i) State **two** factors that determine whether a particular mass slides off the table or not

(ii) It is found that the masses slide off at angular velocities ω_A, ω_B, and ω_C respectively. Arrange the values of ω_A, ω_B, ω_C in decreasing order.

(c) A block of mass 200g is placed on a frictionless rotating table while fixed to the centre of the table by a thin thread. The distance from the centre of the table to the block is 15 cm. If the maximum tension the thread can withstand is 5.6N. Determine the maximum angular velocity the table can attain before the thread cuts. ***(Answer: 13.663 rads/s)***

95) A model car moves round a circuit track of radius 0.4m at 2 revolution per second.

What is:

(i) Period T? ***(Answer: 0.5 seconds)***

(ii) Angular velocity ω? ***(Answer: 4 rads/s)***

(iii) Speed? ***(Answer: 5.027m/s)***

96) A small ball of mass 30g is spinning on a string of length 80cm in a horizontal circle.

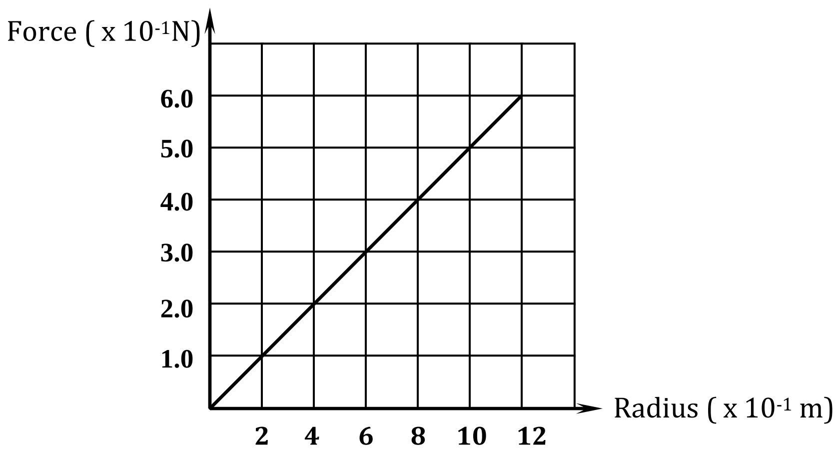
(i) Which type of force produces the centripetal force?

(ii) Explain why the speed of the ball is constant but the velocity is not.

97) (a) Define ***angular velocity***.

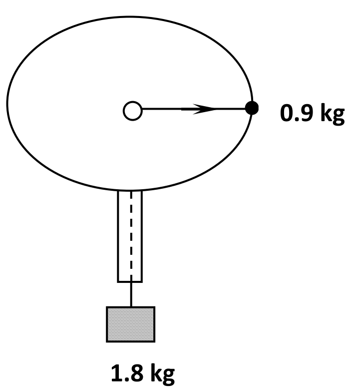
(b) A turn table of radius25cm is rotating at a speed of 0.875m/s. Calculate the angular velocity of a point on its circumference. ***(Answer: 3.5 rad/s)***

98) The figure below shows a graph that was plotted by a student investigating the variation of centripetal force with radius, r of the circular path in which a body rotates.



Given the mass of the body is a 100g, use the graph to determine the angular velocity, **ω** of the body. ***(Answer: 2.2361 rad/s)***

99) Two masses of 0.9kg and 1.8kg are attached on an inelastic string as shown below.

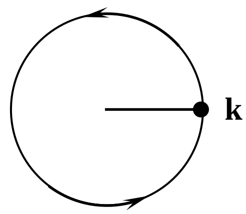


The radius of the circle through which the 0.9kg mass spins is 0.5m. Find the:

(i) Tensional force that will keep the system in circular motion. ***(Answer: 18 N)***

(ii) Angular velocity at which the 0.9kg mass must spin in order that the 1.8kg mass does not slide downwards. ***(Answer: 6.325 rad/s)***

100) An object **k** is at the edge of a turntable as shown below.



The table spins anticlockwise. What factors will affect the force acting on the object?

FLOATING AND SINKING

101) A body weighs 22N in kerosene and 20N in water. If it weighs 30N in air, find the relative density of kerosene. ***(Answer: 0.8)***

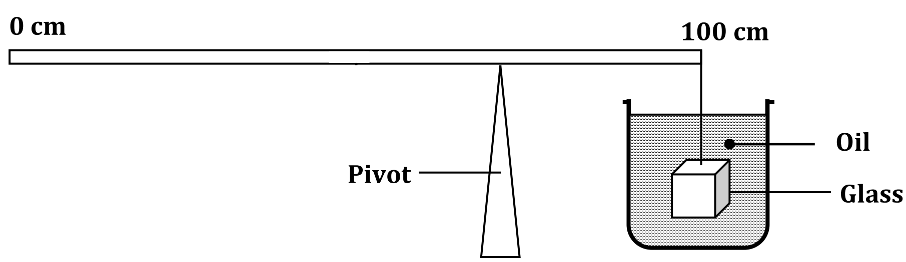
102) A solid metal block of cross sectional area 3cm^2 and of density 2.7g/cm^3 is fully immersed in water of density 1000 kg/m^3 at a depth of 10cm from the top surface of water.

a) Calculate the downward force acting on the top face of the solid ***(Answer: 0.3N)***

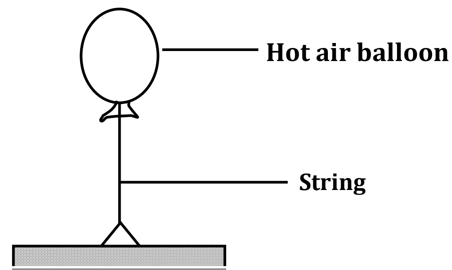
b) If the upward force acting on the bottom face is 1.2N, calculate the volume of the block in cubic centimetres ***(Answer: 90 cm^3)***

c) Calculate the apparent weight of the block in water (take g = 10m/s^2) ***(Answer: 1.53N)***

103) The figure below shows a uniform meter rule balanced by a rectangular glass block that is totally immersed in oil of relative density 0.89. The block has a volume of 2.1 x 10^{-2}m^3 and density of glass is 2500kgm^{-3}. Find the position of the pivot if the mass of rule is 97g. ***(Answer: 86 cm mark)***



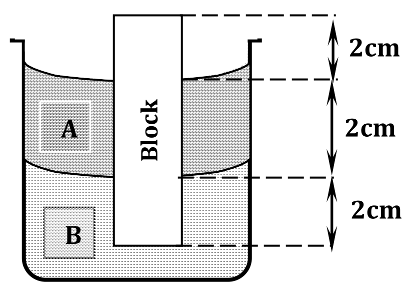
104) The figure below shows a hot- air balloon anchored to the ground. If the balloon is inflated to 1 000 000cm^3 and the total mass is 400g.



a) Find the tension in the string. (*density of air =1.25 kg/m³*) ***(Answer : 8.5 N)***

b) Calculate the acceleration with which the balloon begins to rise when the string cut. ***(Answer: 21.25 m/s²)***

105) The figure below shows a uniform block of uniform cross-sectional area of 6.0cm^2 floating on two liquids A and B. The lengths of the block in each liquid are shown. Given that the density of liquid A is 800kg/m^3 and that of liquid B is 1000kgm^{-3} determine the:

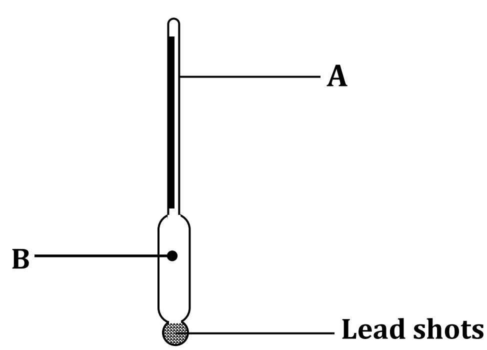


a) Weight of liquid **A** displaced. ***(Answer : 0.096N)***

b) Weight of liquid **B** displaced. ***(Answer : 0.12N)***

c) Density of block ***(Answer : 0.6 g/cm³ OR 600 kg/m³)***

106) The diagram below shows a hydrometer



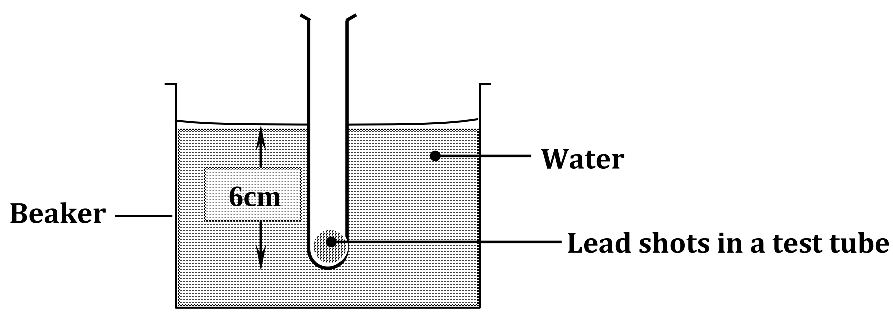
a) Give a reason why:

(i) The part marked **B** is made wider

(ii) The part labelled **A** is made narrow

b) Give a reason why the scale of the hydrometer is calibrated down(lowest reading at the top and the highest at the bottom)

107) A test tube of mass 10g and uniform cross-sectional area 4cm^2 is partly filled with lead shots and floats vertically in water with 6cm of its length submerged.

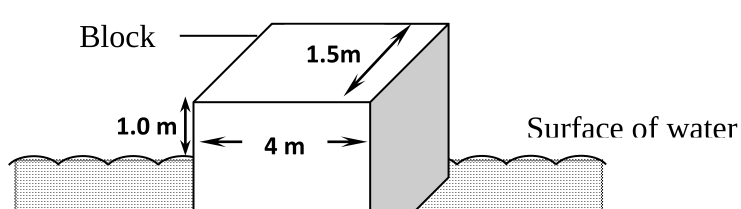


(i) Find the Mass of the lead shots ***(Answer: 14 grams)***

(ii) Determine the length of the test tube that would be submerged in a liquid of density 0.75 g/cm^3 ***(Answer: 8 cm)***

108) (a) State Archimedes' principle.

(b) The figure below shows a rectangular buoy of mass 4000kg tethered to the sea-bed by a wire. The dimensions are 4m x 1.5m x 2.2m.



Calculate the:-

(i) Weight of sea water displaced by the buoy (density of sea water = 1100kg/m^3) ***(Answer: 79, 200N)***

(ii) Upward force exerted on the buoy by the water ***(Answer: 79, 200N)***

(iii) Tension in the wire ***(Answer: 39 200 N)***

SOME BASIC LAWS AND PRINCIPLES OF PHYSICS ENCOUNTERED IN PHYICS PAPER 1

1. PASCAL'S PRINCIPLE

- *Pascal's principle states that pressure exerted at any point on an enclosed fluid is transmitted equally throughout the fluid.*

$$\boxed{\frac{F_1}{A_1} = \frac{F_2}{A_2}}$$

2. PRINCIPLE OF MOMENTS

- *Principle of moments states that when a body is in equilibrium, the sum of clockwise moments about a point is equal to the sum of the anticlockwise moments about the same point*

$$\boxed{F_1 d_1 = F_2 d_2}$$

3. HOOKE'S LAW

- *Hooke's law states that provided the elastic limit is not exceeded, the extension of a spring is directly proportional to the applied force.*

Force = Spring Constant X Extension

$$\boxed{F = ke}$$

4. BERNOULLI'S PRINCIPLE

- *For a fluid that is incompressible, non viscous and of streamline flow, an increase in its velocity results into a corresponding decrease in its pressure and vice verse*

5. LAW OF CONSERVATION OF LINEAR MOMENTUM

- *The law of conservation of momentum states that when two or more bodies collide, the total momentum remains constant provided no external force acts on the bodies.*

Total Momentum before Collision = Total Momentum after Collision

$$\boxed{M_1v_1 = M_2v_2}$$

6. NEWTON'S LAWS OF MOTION

(a) **Newton's first law of motion**

- *Everybody continues in its state of rest or uniform motion in a straight line unless acted upon by an external force*

(b) **Newton's second law of motion**

- *The rate of change of momentum is directly proportional to the external force acting on the body and takes place in the direction of the force*

$$\boxed{F = ma}$$

(c) **Newton's third law of motion**

- *For every action, there is an equal and opposite reaction*

7. GAS LAWS

a) Boyle's law

- *Boyle's law states that the pressure of a fixed mass of a gas is inversely proportional to the volume provided the temperature is kept constant.*

pV = constant (At constant T)

Thus we get:

$$\boxed{P_1V_1 = P_2V_2}$$ Provided Temperature is kept constant

b) Charles's law

- *Charles law states that the volume of a fixed mass of a gas is directly proportional to its absolute temperature provided the pressure is kept constant*

$\frac{V}{T}$ **= constant** (At constant P)

Thus we get:

$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$ Provided Pressure is kept constant

c) Pressure law

- *Pressure law states that the pressure of a fixed mass of a gas is directly proportional to the absolute temperature provided the volume is kept constant*

$\frac{P}{T}$ **= constant** (At constant V)

Thus we get:

$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$ Provided Volume is kept constant

8. ARCHIMEDES PRINCIPLE

- Archimedes principle states that when a body is totally or partially immersed in a fluid, it experiences an upthrust which is equal to the weight of the fluid displaced.

9. LAW OF FLOATATION

- Law of floatation states that a floating body displaces its own weight of the fluid in which it floats

Physicists live with their mistakes. Physicians (medical doctors) bury theirs…………………!