3rd Term scheme of work SSS1

Week	Topic	Content
1	Elastic properties of solid	(1) Hooks law, Young Modulus (2) work done in a spring and elastic string
2	Fluids at rest and in motion	Surface tension; Definition, effect and their application Capillarity, cohesion, adhesion. Viscosity Definition, terminal velocity and application of viscosity
3	Physics in technology	Units in industry, electrical continuity testing, solar energy, solar panel or solar collector for energy supply.
4	Equilibrium of forces	Resultant and equilibrant forces- Parallel forces. moment of force
5	Center of gravity	Stability of an objects Stable , unstable and neutral
6	Equilibrium of bodies in liquid	Archimedes principle, and law of floatation, Density and relative density, hydrometer
7	Linear momentum	Momentum and impulse. Newton laws of motion, conservation of linear momentum, and application of newton's laws of motion.
8	Mechanical energy	Application of mechanical energy, Machines : Force ratio, velocity ratio and efficiency. Types of machines: lever, inclined plane, wedge, screw, wheel and axle, gear wheels
9	Projectiles	Concept of projectiles, ways of projecting an object, (1)Vertical projection (2) horizontal projection (3) projecting to an angle to the horizontal. simple problems involving range, height and time of flight
10	Circular motion	Uniform circular motion: Centripetal force and centripetal acceleration. Centrifugal force, angular speed and velocity. Example of circular motion
11	Simple harmonic motion	Definition of simple harmonic motion, Displacement, velocity and acceleration of simple harmonic motion. Force vibration and resonance

WEEK 1

TOPIC: ELASTIC PROPERTIES OF SOLID

INTRODUCTION:-

A body is said to be elastic if it regains its original size and shape after being compressed or stretched by external force.

HOOK'S LAW

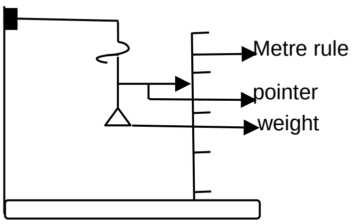
Hook's law states that provided the elastic limit of a material is not exceeded, the force or load applied is directly proportional to the extension mathematically, Hooks law is stated as F = ke

Where, F is the applied force in Newton (N)

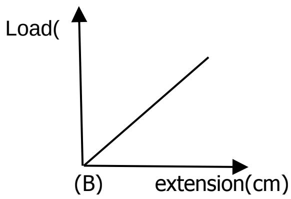
e is the extension in metres (m)

K is the elastic constant known as the stiffness of the material in Newton per metre (N/m)

NB: the stiffness of the material or elastic constant is the force required to produce a unit extension. It is a measure of how weak or strong a spring is.



(A)



(B)

Load(g)	extension(cm

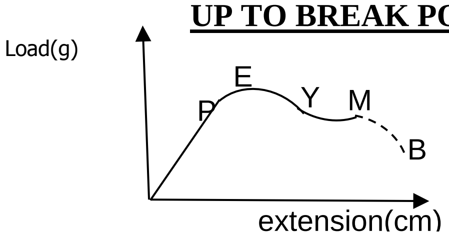
(C)

Diagram (a) is the experimental setup for the verification of Hook's law

Diagram (b) Is the graph of load against extension

Diagram (c) is the table of values for the experiment.

GRAPH OF LOAD AGAINST EXTENSION UP TO BREAK POINT



P = Proportionality limit

E = Elastic limit: This is the limit force beyond which the wire does not return to its original size.

Y= Yield point. Beyond this point, the material loses its elasticity completely and becomes plastic.

M = maximum load: - Beyond this point, the material can cut at any point. It is the maximum load the wire can sustain.

B = Breaking Point: - At breaking point, the were cuts

YOUNG MODULUS (έ)

If a wire of length l (m) and cross sectional area A (m^2) as extended to extension (m) by a force F (N); the ratio of the force to the area (F/A) fs called the stress of the material in N/m^2, i.e. stress F/A. the ratio of extension to the length (e/l) is called strain. It has no unit.

Stating Hook's law; we have it that stress is directly proportional to strain i.e.

Stress ∝ strain

Stress = έ x strain

έ = stress/ Strain

The ratio of stress to strain is called young modulus.

$$\varepsilon = \frac{\frac{F}{A}}{\frac{e}{l}} = \frac{Fl}{Ae}$$

But A= π d^2 /4

$$\therefore, \varepsilon = \frac{4Fl}{\pi^2 d^2 e}$$

CALCULATIONS

A force of 10N stretches an elastic spring by 5cm calculate the elastic constant

SOLUTION

F = ke

F = 10N, e = 5cm = 5/100 = 0.05m

K =?

Applying the above formula

10 = 0.05×k

K = 10/0.05 = 200N/m.

2. A wire of length 10cm, radius 1.26cm is extended by 2cm by a force of 0.8N. Calculate the young modulus

Solution

έ=?

F = 0.8N

L = 10cm = 10/100 = 0.1m

e = 2cm = 2/100 = 0.02m

A = $\pi d^2/4 = \pi r^2$

r = 1.265cm = 0.01265m

A = 22/7 x $(0.01265)^2$

A = 5.0 x 10^{-4} m^2

έ = Fl/Ae

$$\varepsilon = \frac{0.8 \times 0.1}{5 \times 10^{-2} \times 0.02}$$

έ = 8000N/m^2

WORK DONE IN ELASTIC SPRING AND ELASTIC MATERIALS

Work done in a spring is same as energy stored or elastic potential energy of a material.

A stretched or compressed string or elastic material possesses potential energy due to its extension or compression.

The energy stored in a spring is equal to the work it will do when released or its kinetic energy

Work done = Average force x extension

i.e. W = ½Fe ……. (1)

From Hooks law, F = ke ……. (2)

Substituting (2) into (1), we have

W = ½ ke…… (3)

Equations (1) and (3) are used in calculating work done

CALCULATIONS

1. A spring of force constant 1500N/m is acted upon by a constant force of 75N calculate the potential energy in the spring.

SOLUTION

K = 1500N/m

F = 75N

W =?

W = $^1/_2$ ke^2 = ½ Fe

But e = F/K from Hooks law

W = ½ k $(F/k)^2$ = ½ F^2/k

W = ½ x 75 ^{2}/1500

= 1.875J

= W = 1. 875J

2. A stone of mass 20g is released from a catapult whose rubber has been stretched to 4cm. if the force constant of the rubber is 200N/m calculate the velocity with which the stone would leave the catapult.

SOLUTION

Work done = Kinetic energy

K = 200N/m

$e = 4cm = 4/100m$

$m = 20g = {}^{20}/_{1000}$ kg

${}^{1}/_{2}\ ke^2 = ½\ mv^2$

$½ \times 200 \times ({}^{4}/_{100})^2 = ½ \times {}^{20}/_{10000} \times v^2$

$V^2 = 200 \times {}^{1000}/_{20} \times {}^{16}/_{10\,000}$

$V^2 = \sqrt{16}$

$V = 4m/s$

EVALUATION

1. An elastic cord can be stretched to its elastic limit by a load of 2N if a 35cm of length is extended by 0. 6cm by a force of 0.5N what will be the length of the cord when the stretching force is 2.5N?

2. A spring loaded with a piece of metal extends by 10.5cm in air. When the metal is fully submerged in water, the spring extends by 6.8cm. Calculate the relative density of metal.

WEEK 2

TOPIC: FLUIDS AT REST AND MOTION

INTRODUCTION.

A needle of density greater than that of water when gently placed on the surface of still water will rest there as if it were being supported by an elastic skin. Some insects like pond skater can walk on the surface of water without sinking.

These are as a result of a phenomenon called surface tension.

Surface tension therefore is the force acting on the surface of a liquid, causing the liquid surface to behave like a stretched elastic skin.

APPLICATION OF SURFACE TENSION

1. A needle resting on water surface when gently placed.
2. Pond skater walking on the surface of water
3. Uneasy penetration of pure water on fabric of material that are soaked in water.
4. The movement of a toy boat across water when a piece of camphor is attached to one side of the boat.

N.B:Surface tension can be reduced by the use of detergent or introduction of impurities into water body.

COHESION FORCE

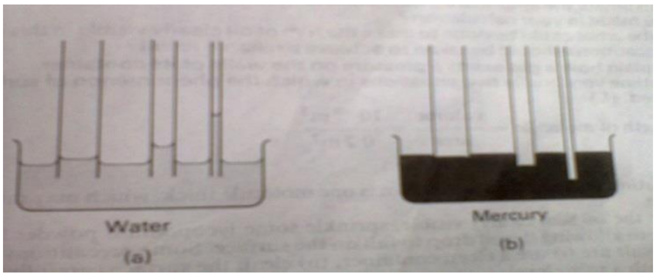
Cohesion is the force of attraction between molecules of the same substance, e.g. attraction between molecules of water.

ADHESION FORCE

Adhesion is the force of attraction between molecules of different substances, e.g. attraction between molecules of water and mercury.

CAPILLARITY

Capillarity or capillary action is the tendency of a liquid to rise and fall in a narrow tube. If a small tube is inserted in a beaker of water, we will observe the rise of water in the beaker and the surface is concave to air inside the tube. Similarly, if an identical tube is placed in a beaker of mercury the mercury will be depressed below in the tube and the surface is convex to air on the tube.



APPLICATIONS OF CAPILLARITY

i. Water rising in the stem of a plant.
ii. Ink held on the nib of a pen.
iii. Blood spreading through the tiny capillary channels in the body.
iv. Liquid candle wax rising up the wick of the candle.
v. Liquid rising up through fine pores enabling blotting papers to soak up the liquid.

VISCOSITY

PREAMBLE

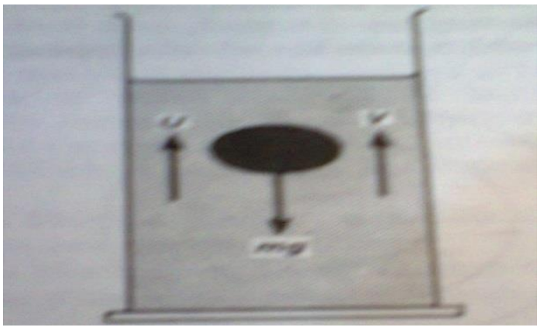
A little stone dropped in a cylinder of water gets to the bottom of the cylinder faster than when the same stone is dropped into a cylinder containing engine oil. This difference is due to a property called viscosity.

Viscosity therefore, is the internal friction between layers of liquid or gas in motion.

TERMINAL VELOCITY

When a stone falls through a viscous liquid, it is subjected to three forces which are its weight(w) acting downwards, up thrust(u) of the liquid on the stone acting upwards and viscous force (v) opposing the stones motion i.e. acting upward.

MOTION OF A STONE IN A VISCOUS LIQUID



We can therefore write the equation of motion of the stone as w – u – v = ma.

Where, a as acceleration of the stone through the liquid. M as the mass.

It is observed that at a certain stage, the ball ceases to accelerate but moves with uniform velocity, this velocity is called terminal velocity. At terminal velocity, a = 0

$w - u - v = ma = 0$

$w - u - v = 0$

$v = w - u$, OR

$v = mg - u$

The above equation is used to calculate the viscosity.

APPLICATIONS OF VISCOSITY

i. Oils, grease and air used as lubricants because of their viscosity.

ii. It is because of viscosity of air that the bob of a swinging pendulum comes to rest more quickly with a cord attached.

SIMILARITIES BETWEEN VISCOSITY AND FRICTION

i. Both forces oppose relative motion between surfaces

ii. Both depend on the nature of the material

DIFFERENCES

FRICTION	VISCOSITY
Friction does not depend on surface area of contact	Viscosity depends on surface area of contact
Friction is dependent on normal reaction	Viscosity is independent of normal reaction
Friction occurs in solids	viscosity occurs in liquid and gas
Friction does not depend on relative velocity between two layers	viscosity depends on the relative velocity between two layers

EVALUATION

1.

i. Explain the following terms:

(a) Viscosity (b) Terminal velocity

ii. Draw a diagram to show the forces acting on a steel ball falling through a viscous liquid

iii. Sketch the graph.

2.

i. Explain the term adhesion and cohesion

ii. Describe two applications of surface tension

iii. Why does water wet glass but mercury does not?

WEEK 3

TOPICS: PHYSICS IN TECHNOLOGY

UNITS IN INDUSTRY

INTRODUCTION: In the physics course emphases are laid on the ability to observe and take measurements of physical quantities such as mass, length and time as entrenched with regards to standard and units, the S.I unit such as the kilograms metre and second are used respectively for mass, length and time. This system is otherwise known as the mks (meter, kilograms and second) system which originated from the French system of measurement.

Though the French system of measurement has become globally accepted as standards of measurement because of its simple method of conversion in terms of tens, yet some of these British modes of measurements are still prevalent in most industrial and technological sectors. They constitute the others units of measurement.

We shall be looking at the following industrial quantities and units

Quantity	Industrial Units	Conversion factor from industrial to S.I unit	Conversion factor from industrial to S.I
Temperature	Fahrenheit(^oF)	$F={}^{9C}/_{5}+32$ [$100^oC=212^oF$)]	$212^oF = 373k$
Pressure	Bar	1bar = $10^5 N/m^2$	1bar = 10^5 Pascal
Power	Horse Power (H.P)	1hp = 750W	1h.P = 0.75kw
Mass	Tonnes	1 tonne = 1000kg	1tonne = 2205 hp
Volume	Barrel	1barrel = 158.987 liters	-
Area	Acres	1Acre = 1048.58m^2	1Acre = 0.00405km^2
Area	Hectares	1Hectare = 10008m^2	1Hectare = 0.01km^2
Length	Miles	1mile = 1609.34m	1mile = 1.609km
Length	Neutical Miles	1neutical mile = 1852m	1neutical miles=1.852km

Electrical Continuity Testing:

Circuits

A circuit is a closed conducting path through which electric current flows or is intended to flow.

TYPES OF FAULTS

The various types of faults include

(i) Short – circuit faults: This is a fault caused by the bridging of current carrying bare wires by a conducting object

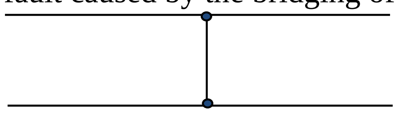


Fig: Short circuit fault.

(ii) **Open – Circuit Fault:** This is a fault caused by line or conductor breaks as a result of accident.

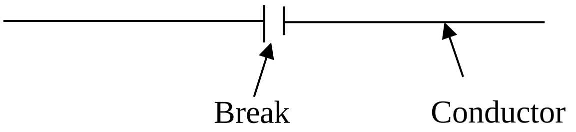
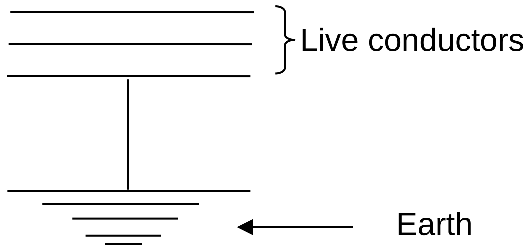


Fig: Open – circuit fault

(iii) **Earth Fault:** This is a fault caused by a contact between a live conductor and the earth.



CAUSES OF COMPONENT FAILURE:

1. High temperature **2**. High humidity 3. Mechanical shock and vibration
4. High or low pressure **5**. Corrosive chemicals **6**. Dust in the air
7. Ageing
8. High voltage pulses **9**. Mechanical wear.

Solar Energy

The sun is an enormous energy source. This energy from the sun is known as solar energy. Although this energy is plentiful, it is however thinly distributed over a large area and can be harvested or collected using collectors or panel.

The sun is a vast ball of hot glowing gas. The temperature at the core of the sun is high as about 15million degrees centigrade ($15\times10^{6}\,^{o}c$), but at the surface, the temperature is about $6000^{o}c$.

Solar Collector or Solar Panels.

Two types of devices are used to intercept solar radiation and convert it to solar energy. They are the flat plate collector and the focusing collector

A flat plate collector is a large shallow metal box typically mounted on a roof or high stand that heats water using solar energy.

Application of solar panels

The main use of solar panel technology is for providing a cheap and clean source of hot water.

(a) In homes with a large family or in hospital where hot water supply is in high demand for washing plates, clothing and bathing, solar plates are cheaper alternative to kerosene or electricity.

(b) Commercial applications include use in big laundry establishments, big hotels, car washes, military laundry facilities and in cafeteria and other eating house.

(c) Solar panels are also used to heat swimming pools during cold weather and for space heating

(d) Heat from flat plate collector or panel is used for evaporation of salt water to produce salt and for distillation of salt water or brackish water to produce clean drinking water

WEEK 4

TOPIC: EQUILIBRIUM OF FORCES

VECTOR REPRESENTATION AND ADDITION

INTRODUCTION:

In our last lesson, we distinguished that scalar quantities are those quantities with magnitude but no direction while vector quantities are those quantities with both magnitude and direction. We also stated that scalars are added by ordinary arithmetic method while vectors are added by geometrical method.

In this lesson, we shall show how vectors are represented and added.

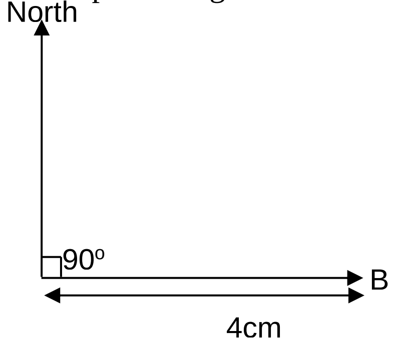
VECTOR REPRESENTATION

Since a vector quantity has both magnitude and direction, it is represented by a straight line which has an arrow head indicating the direction of the given vector. The length of the line is drawn proportional to the magnitude of the vector.

Since displacement and velocity are vector quantities a displacement of 400km to the east can be presented by a straight line AB, 4cm long which points towards the east from the chosen origin.

This can be represented below and the scale used is 1cm representing 100km.

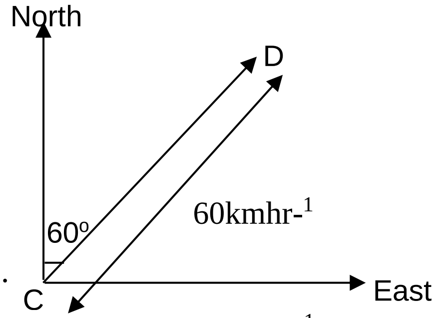
a.



Scale: 1cm : 100km

Also a velocity of 60kmhr-[1] in a direction N 60° E (or 60° east of north) using a scale of 1cm to 10kmhr-[1] can be represented below:

b.

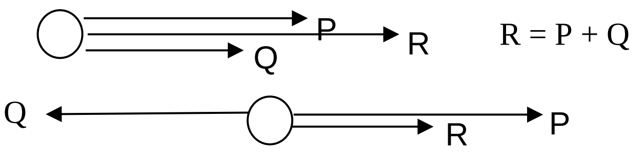


Scale: 1cm : 10kmhr-[1]

ADDITION OF VECTORS (VECTOR RESULTANT)

Vectors are quantities with magnitude and direction, they must be added in a special way. If two vectors P and Q are in the same direction their sum or resultant is given by R = P + Q.

The direction of R is the common direction of P and Q. if P and Q are in opposite direction and if P is greater than Q, their resultant R = P – Q. these are shown below.



R = P – Q

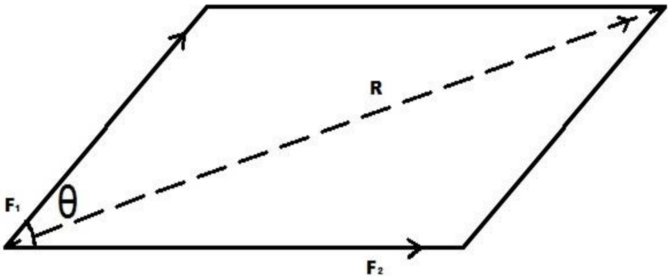
Q in the direction of P since P>Q.

When two vectors are inclined at a certain angle, the resultant of the two vectors can be determined. The resultant, R, of two vector inclined at a certain angle is that single vector which would have the same effort in magnitude and direction as the original vectors acting together.

Generally, there are two methods of adding or compounding vectors to find the resultant. These are (i) The parallelogram method and (ii) The Triangular method

DETERMINATION OF RESULTANT OF TWO VECTORS INCLINED AT AN ANGLE.

The Parallelogram Method



Parallelogram laws of vectors

Parallelogram law of vector addition states that when two vectors F_1 and F_2 are represented in magnitude and direction by the adjacent sides of a parallelogram, the resultant vector, R, is represented in magnitude and direction by the diagonal of the parallelogram originating from the point of intersection of the two vectors.

EXAMPLE:

Find the resultant of two vectors of 5 units and 6 units acting at a point, O, inclined at an angle of 60^o with each other.

SOLUTION:

This can be done in two ways

First, by scale drawing and

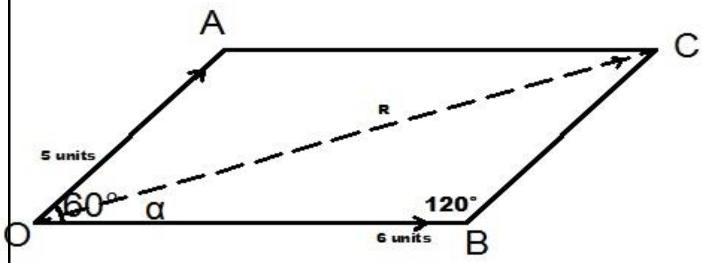
Second, by analytical method

BY SCALE DRAWING:

Choose a suitable scale, say 1cm to 1 unit and draw the vectors OA and OB to represent 5 units and 6 units at an angle of 60^o with each other.

The parallelogram is completed by drawing AC parallel to OB and BC parallel to OA. OC is joined and measured. OC represents the resultant vector in magnitude and direction. Angle α is also measured using the protractor.

BY ANALYTICAL METHOD



Through this method, the resultant vector is obtained by cosine rule.

$|OC|^2 = |OB|^2 + |OB|^2 + 2\ (OA \times OB)\ Cos60$

$= |OB|^2 + |OA|^2 + 2\ (OA\ X\ OB)\ Cos\ 60$

$= 6^2 + 5^2 + 2x5x6\ Cos\ 60$

$= 36 + 25 + 60\ Cos\ 60$

$OC = \sqrt{91}$

$OC = 9.54$ units

To determine α, we use the sine rule.

Since BC is equal to OA,

$$\frac{Sin\ \alpha}{BC} = \frac{Sin\ 120}{OC}$$

$$Sin\ \alpha = \frac{BC\ \times\ Sin120}{OC}$$

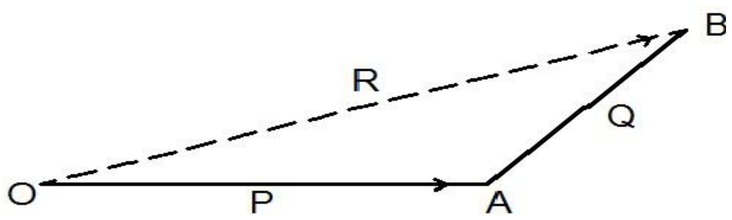
$$Sin\ \alpha = \frac{5\ \times 0.8660}{9.54}$$

$\alpha = 26.99^o = 27^o$

FINDING THE RESULTANT OF TWO VECTORS BY TRIANGLE METHOD.

The steps for finding this resultant using the triangle method are as follows:

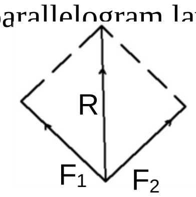
1. Starting from a point O, draw OA (according to scale) to represent P.
2. Next, draw the second vector Q to scale, placing its tail at the tip of the first vector P, ensuring that its magnitude and direction are correct.



3. Finally, draw OB to complete the triangle as shown above. OB represents R, the resultant vector in magnitude and direction.

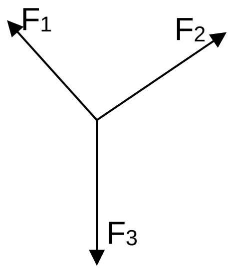
RESULTANT AND EQUILIBRANT FORCES

Resultant force is that single force which would have the same effect in magnitude and direction as two or more forces acting together. It can be determined using the parallelogram law of vectors.



Equilibrant of two or more forces is that single force which will balance all the other forces taken together.

In other words, it is equal in magnitude but opposite in direction to the resultant force.



F_1 is the equilibrant of F_2 and F_3. Also, F_2 is equilibrant Of F_1 and F_3. F_3 is the Equilibrant of F_1 and F_2

EXAMPLE: Two forces 20N each are inclined at 150°. Find the single force that will replace the given system of force balance the force system

SOLUTION:

Applying cosine rule, we have

$R^2 = 20^2 + 20^2 + 2 \times 20 \times 20 \cos 150^o$

$R^2 = 400 + 400 + 400 \cos 150$

$R^2 = 800 + 400 \times (-0.8660)$

$R^2 = 800 - 246.4$

$R^2 = 453.59$

$R = \sqrt{453.59}$

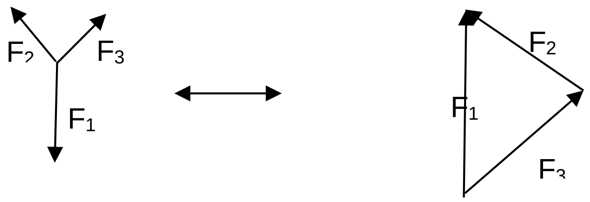
$R = 21.3N$

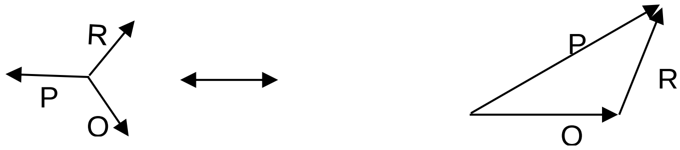
Equilibrant force is equal but opposite to the resultant force. Thus, Equilibrant force = 21.3N

Equilibrium of three forces acting at a point – triangle of forces

When three forces are in equilibrium, they can be represented in magnitude and direction by the three sides of a triangle taken in order. This is the principle of triangle of force.

R is the resultant force of F_1 and F_2





EXAMPLE

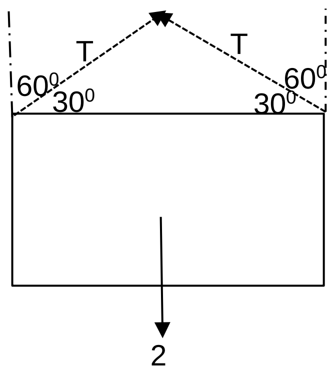
A wooden frame weighing 2N is hung on a nail using two ropes which are at 60^0 to the vertical. Find the tension, T on the ropes

$2T \cos 60^o = 2$

$T \cos 60^o = 1$

$T = 1/\cos 60°$

T = 2N



PREAMBLE:

When we turn on a tap, we are exerting a turning force and producing a turning effect about a point or along an axis. There are conditions governing parallel and non-parallel forces in equilibrium.

Every object has a point on its body where the resultant weight concentrates.

Equilibrium can equally be achieved in fluids.

MOMENT OF A FORCE

There are two quantities that are involved in moment of a force:- (1) The magnitude of the force applied and (ii) the perpendicular distance of its line of action from the axis or pivot about which the turning effect is felt.

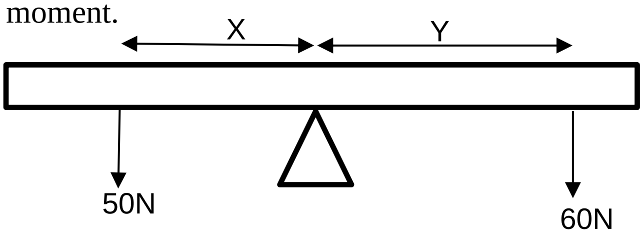
Hence, moment of a force about a point is the turning effect of the product of the force and the perpendicular distance of its line of action from the point.

Moment = Force x perpendicular distance of point from the line of action of the force.

S.1 unit of moment is Newton-metre (Nm) and it is a vector quantity.

Calculation of moment

For a beam to be balanced horizontally, clockwise moment must be equal to the anticlockwise moment.

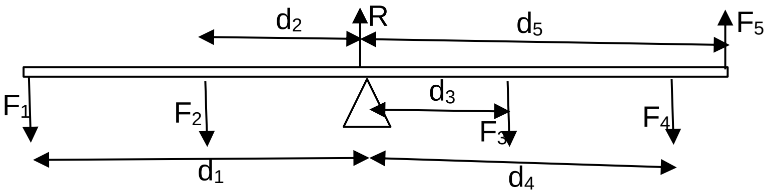


Clockwise Moment = 60y;

Anticlockwise moment = 50x

Clockwise moment = Anticlockwise moment 60y = 50x

POSITIVE AND NEGATIVE MOMENTS



Malimech production

Let anticlockwise moment be positive and clockwise moment be negative

Clockwise moments about C are

$F_1 d_1 + F_2 d_2 + F_5 d_5$

Thus, algebraic sum of moment about C

$= F_1 d_1 + F_2 d_2 + F_5 d_5 - (F_3 d_3 + F_4 d_4)$

$= F_1 d_1 + F_2 d_2 + F_5 d_5 - F_3 d_3 - F_4 d_4$

Condition of Equilibrium under the action of parallel coplanar forces.

Parallel forces are forces whose line of action are parallel to each other.

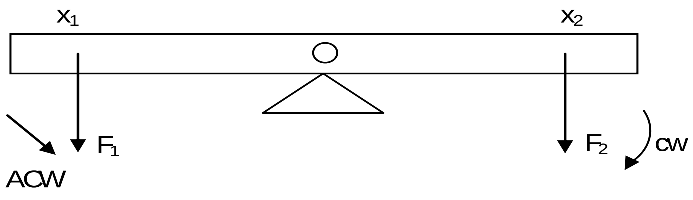
Coplanar forces are forces that lie in the same plane.

Thus, for a body to be in equilibrium, the sum of forces acting in one direction (downwards) must be equal to the sum of forces acting in opposite direction (upwards).

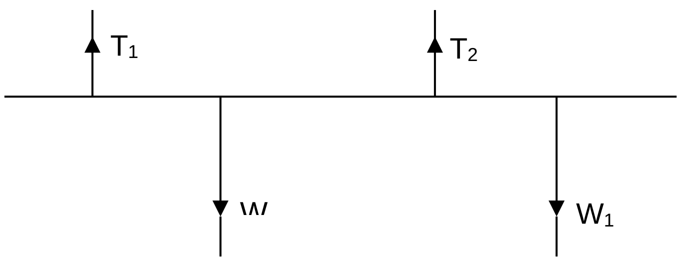
Thus, there are two major conditions for equilibrium of parallel coplanar forces.

1. The algebraic sum of moments of all forces about any point on the body must be equal to zero. This means that total clockwise moments of forces about any point must be equal to total anticlockwise moment of forces about the same point.

This is known as the principle of moments.



2. Sum of forces acting in one direction must be equal to the sum of forces acting in opposite direction.



Principle of moment states that for a body to be in equilibrium, under the action of parallel coplanar forces, the sum of the clockwise moments must be equal to the sum of anticlockwise moment about the same point.

Example

A metre rule is pivoted at its mid-point C with a vertical force of 20N hanging from the distance 40cm from C. at what distance must a 10N force hang to balance the ruler horizontally? (To be solved in the class)

Conditions of equilibrium under the action of non-parallel coplanar forces

1. For moments, the algebraic sum of the moments of all the forces about any axis perpendicular to the plane of the forces must be zero. Hence, sum of clockwise moments about any axis equals sum of anticlockwise moments about the same axis.
2. For Forces, the algebraic sum of both the horizontal and vertical components of the forces must be zero. Thus, $\Sigma F_x = 0$ and $\Sigma F_y = 0$

CLASS WORK

A see – saw consists of a uniform bar 4m long and of mass 2kg. A boy of weight 42N sits at end A of the see-saw, while another boy of weight 38N sits at the end B of the see-saw. At what point must the see-saw be pivoted if it is to balance?

COUPLES

Such a system of forces which can only cause a body to undergo rotation, and will not produce any linear motion is a couple.

Thus, a couple is a system of two parallel and equal but opposite forces not acting along the same line.

The resultant force is zero but the resultant moment is force x perpendicular distance between the lines of action of the two forces.

The moment of a couple is the product of one of the forces and the perpendicular distance between the lines of action of the two forces. This is known as Torque.

Moment of a couple = F x d where d is the arm of the couple which is the distance between the two equal forces.

Applications of the effect of couples in life.

Turning the steering wheel of a vehicle

Turning a tap on or off

EVALUATION:-

Evaluate students by asking them to state the parallelogram law of vector addition. They should also solve the problem below using triangular method.

Two forces 4N and 5N are inclined to each other at 30^o. Find the resultant force by the triangular method.

Explain moment of a force about a point

State the conditions of equilibrium under the actions of parallel and non-parallel coplanar forces

Explain couple and moment of couple

Explain dynamic and static equilibrium

Differentiate between resultant and equilibrium forces

Explain triangle of forces

Two forces of 20N and 40N, act at a point and the angle between them is 30^0. Find the resultant forc

WEEK 5

Topic: CENTRE OF GRAVITY

INTRODUCTION:

The centre of gravity of any object or body is defined as the point through which its resultant weight acts.

CLASS WORK

A metre rule is found to balance at the 48cm mark. When a body of mass 60g is suspended at the 6cm mark, the balance point is found to be at 30cm mark.

Calculate

The mass of the metre rule.

The distance of the balance point from the zero end, if the body were moved to the 13cm mark.

STABILITY OF OBJECTS

There are three types of equilibrium.

Stable equilibrium (2) unstable equilibrium (3) Neutral equilibrium.

(1) **STABLE EQUILIBRIUM**: - An object is said to be in stable equilibrium if when disturbed slightly displaced, will fall back to its original position e.g. a ball placed inside a bowl, a cone standing on its base, a racing car.

(2) **UNSTABLE EQUILIBRIUM**: - A body is said to be in an unstable equilibrium if when slightly displaced does not return to its original position e.g. a cone standing on its pointed end or apex, a ball placed on an inverted bowl, a tight-rope walker.

(3) **NEUTRAL EQUILIBRIUM**: - An object is said to be in a neutral equilibrium if it is slightly displaced, will remain in its new displaced position. The centre of gravity will neither be raised nor fall (remains at the same height) e.g. a cone resting on its curved surface, a cylinder resting on its side, a ball placed on a smooth horizontal table.

Centre of Gravity: The centre of gravity of a body defined as the point through which it resultant weight acts. For examples:

the centre of gravity of a metre rule is at the 50cm mark, if the meter rule is of uniform cross-section,

the centre of gravity of a circular object is at the centre of the circle

the centre of gravity of a sphere is at the centre of the sphere

the centre of gravity of a rectangular object or square or a parallelogram is at the point of intersection of the diagonals,

the centre of gravity of a cylinder is at the centre of the cylinder.

WEEK 6
TOPIC: EQUILIBRIUM OF BODIES IN LIQUIDS.

A body immersed in a liquid.

Archimedes showed that when an object tied to a rope is immersed in water, upward force acts on it. This upward force is called up thrust, U, of the water on the object. He also found out that there is a resultant pull as tension, T, on the rope when the rope is in water. If the weight of object in air is W_1, and the apparent weight due to tension is W_2.

Upthrust, $U = W_1 – W_2$.

$W_2 = W_2 - U$

The value of the upthrust depends on the volume of the solid immersed and the density of the liquid into which it is immersed.

Archimedes principle states that when an object is partially or wholly immersed in a fluid, it experiences an upthrust or loss in weight, which is equal to the weight of the fluid displaced.

Note that any object that is wholly immersed in a liquid displaces a volume of liquid equal to the volume of the object.

Upthrust (force) is equal to the weight of the volume of the liquid displaced.

Upthrust = volume of object x density of liquid x acceleration due to gravity.

$$\boxed{\text{i. e, } U = \rho v g}$$

FLOATATION

Due to upthrust, objects such as balloons, waxes and ice cubes float on water.

Law of floatation

This states that when an object floats in a fluid, the upthrust exerted upon it by the fluid equals the weight of the object.

Forces acting on any floating object in equilibrium are 1. The weight of the object acts down wards. (2) Upthrust of the liquid acts upwards.

NOTE:

No matter the density of a body, if it can be shaped to displace its own volume in a liquid, it will float.

A floating object is acting upon by the force-weight acting downwards and upthrust acting upwards.

Ships do not sink because its large volume displaces a large volume of water whose weight counter balances the weight of the ship

A balloon floats in air if the weight of the balloon and its content equal to upthrust of air on it.

Density:- Density of an object is the mass, m of the object per unit volume, V.

Mathematically, $Density = Mass/volume$

The symbol for density is ρ (Rho)

$$\boxed{\rho = M/V}$$

Its S. 1 unit is Kgm^{-3}

Also, relative density, R.D is given by

$$\boxed{\text{R. D} = \frac{Mass\ of\ substance}{Mass\ of\ equal\ volume\ of\ water}}$$

$$\boxed{\text{R. D} = \frac{Weight\ of\ substance}{Weight\ of\ equal\ volume\ of\ water}}$$

$$\boxed{\text{R. D} = \frac{\text{Up thrust in liquid}}{\text{Up thrust in water}}}$$

EVALUATION:-

Evaluate the students by asking them thefollowing questions:-

Define centre of gravity

A metre rule is found to balance at the 48cm mark. When a body of mass 80g is suspended at the 8cm mark, the balance point is found to be at 35cm mark.

Calculate (i) The mass of the metre rule (ii) The distance of the balance point from the zero end, if the body were moved to the 13cm mark.

Explain the three types of equilibrium with respect to stability of an object.

State Archimedes principle and law of floatation.

WEEK 7

TOPIC: MOMENTUM, IMPULSE AND NEWTON'S LAWS OF MOTION

Bodies in motion are in some cases being affected or governed by unbalanced forces. When bodies collide, each experiences a blow which consists of a large varying force acting for a very short time. These bodies exert forces on each other at impact and there are laws governing such collisions.

MOMENTUM

This is defined as the product of mass and velocity. Every object that undergoes collision possesses momentum due to its mass and velocity. In other words, momentum, P = mass x velocity its S. 1 unit is $Kgms^{-1}$

Hence, P = MV.

Momentum is a vector quantity. This means that it has magnitude which is the product of mass and velocity, and direction which is the direction of the velocity, V

The product, M x V is sometimes called linear momentum and this distinguishes it from a similar quantity known as angular momentum. Thus, a body of mass 2kg moving with the velocity of mass has the same momentum as a body of mass 5kg moving with a velocity of $4ms^{-1}$

IMPULSE

This is the product of the average force acting on a body and the time during which its acts.

Since momentum is the product of mass and velocity, change in momentum must involve the final and initial velocities of the moving body. Thus, change in momentum = (MV – MU)

Ideally, impulse is equal to change in momentum. The S.I unit of impulse is Newton second (NS). Since the impulse is in Newton second (NS) which means is given by (force x time) is equal to momentum change, the S.I unit of momentum is also Newton Second (NS)

Impulse is a vector quantity which means that it has both magnitude and direction. Its magnitude is the product of force and time (Ft) and it takes the direction of force.

Thus, impulse = F x t

To show that impulse = change in momentum.

Unit of impulse = Ns = force x time

= mass x acceleration x time

$$\boxed{= kg \times m/s^2 \times s}$$

$$\boxed{= kg\,m\,s^{-1}}$$

Also, change in momentum is expressed as $Kgms^{-1}$. Thus, impulse = change in momentum

EXAMPLES

1. A constant force of 5N which acts on a body for 5 seconds possess 5 x 5 = 25 Ns as its impulse.
2. A resultant force of 20N acts on a body of mass 5kg for 5 seconds. The impulse is **I** = F x t = 20 x 5 = 100 Ns.
3. A force of 10N acts for 20s, what is the change in momentum of the body?

Impulse = change in momentum

Change in momentum = F x t = 10 x 20

= 200 $Kgms^{-1}$ (Ns)

PREAMBLE:

In one of our previous lesson, it was stated that motion is caused by force. How force is related to motion was first discovered by Sir Isaac Newton (1642 – 1727), who stated three important laws of motion known as Newton's laws of motion.

NEWTON'S FIRST LAW OF MOTION

Newton's first law of motion states that everybody continues in its state of rest or of uniform motion in a straight line, unless external force acts on it.

The tendency of a body to remain in its state of rest or of uniform linear motion in the absence of external forces is known as inertia.

Since mass is a measure of inertial, the more large an object is, the more inertial it has.

NEWTON'S SECOND LAW OF MOTION

Newton's second law of motion states that the rate of change of momentum is proportional to the impressed force and takes place in the direction of the force.

Mathematically,

$$F \propto \frac{\text{Change in momentum}}{\text{Time taken for the change}}$$

Since momentum = MV where V is the final velocity, considering the initial velocity, U.

Change in momentum = mv – mu

$$Thus, F \propto \frac{\text{mv}-\text{mu}}{\text{t}}$$

$$\therefore, F \propto \frac{\text{m(v}-\text{u)}}{\text{t}}$$

$$but, a = \frac{\text{(v}-\text{u)}}{\text{t}}$$

$$Thus, F \propto ma$$

$\longrightarrow$ F = K ma where K is the constant of proportionality.

If K is very negligible so that K = 1,

F = Ma

In other words, $F = \frac{\text{m(v}-\text{u)}}{\text{t}}$

F. t = mv – mu

Where F.t = impulse

This shows that impulse, **I**, is equal to change of momentum

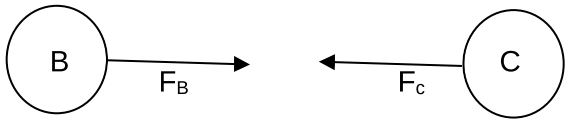
NEWTON'S THIRD LAW OF MOTION

Newton's third law of motion states that to every action, there is an equal and opposite reaction. Or simply action and reaction are equal and opposite.

This law implies that when a body B exerts a force, F_B on another body, C, then the body C also exerts a force, F_C on the body B.

This means that F_B and F_C have equal magnitude but they are opposite in direction.

Since force is a vector quantity, $F_B = F_C$ where F_B is the action force and F_C is the reaction force in detail, F_C can equally be the action force and F_B, the reaction force because both exert forces which are equal in magnitude but opposite in direction



Example:- If a mass of 300g is acted upon by a force, F, which impacts an acceleration of $4ms^{-2}$. Calculate the value of the force.

SOLUTION:-

F = Ma = 0.3Kg x 4 (ms^{-2}) = 1.2N

CONSERVATION OF LINEAR MOMENTUM

When two bodies B and C collide, body B with mass, 'M' moving with a velocity V, exerts momentum on body C, which reacts due to the action of body B, on it. The momentum of body B, brings about a reacting momentum on body C, after collision. This agrees with the Newton's third law of motion which states that the action of body B, and the reaction of body C, during collision, are equal and opposite.

LAW OF CONSERVATION OF LINEAR MOMENTUM

The principle of conservation of linear momentum can be stated as follows:-

When two or more bodies collide in an isolated or closed system, the total momentum before collision is equal to the total momentum after collision. OR in a closed or isolated system of colliding bodies, the total momentum is always constant; OR provided that there is no net external force acting on the system of colliding bodies or objects, the total momentum is always conserved.

A closed or isolated system is that when no. external forces act. Only forces due to collisions act in a closed system.

When two bodies, B and C, whose masses are M_B and M_C respectively moving with velocities U_B and U_C, collides and move with final velocities of V_B and V_C . By law of conservation of linear momentum;

$$\boxed{M_B V_B + M_C V_C = M_B U_B + M_C U_C}$$

Momentum before collision = $M_B U_B + M_C U_C$

Momentum after collision = $M_B V_B + M_C V_C$

Since momentum before collision = momentum after

Collision, $M_B U_B + M_C U_C = M_B V_B + M_C V_C$

COLLISIONS

There are two types of collisions – Elastic and inelastic collisions.

When the total kinetic energy of two colliding bodies is the same or constant before and after collision, the collision is said to be perfectly or completely elastic. In such a collision, kinetic energy and momentum are conserved.

Examples of perfectly elastic collision are the collisions of atoms and molecules, billiard balls, tennis ball, etc.

Two equations can be deduced from the law of conservation of kinetic energy and the law of conservation of linear momentum when bodies, M_1 and M_2 moving with velocities U_1 and U_2 and final velocities V_1 and V_2 undergo perfectly elastic collision.

From the law of conservation of energy,

$½ m_1 U_2 + ½ m_2 U_2^2 = ½ M_1 V_1^2 + ½ M_2 V_2^2$ -------- (1)

From the law of conservation of linear momentum

$M_1 U_1 + M_2 U_2 = M_1 V_1 + M_2 V_2$ ----------- (2)

Inelastic collision involves decreases in Kinetic energy after collision with only momentum being conserved. Thus, the two colliding bodies stick together and become one after collision. They possess the same final velocity.

In other words, $V_1 = V_2 = V$

Thus, from the law of conservation of linear momentum, $M_1 U_1 + M_2 U_2 = M_1 V_1 + M_2 V_2$

Since $V_1 = V_2 = V$

$$\boxed{M_1 U_1 + M_2 U_2 = (M_1 + M_2) V.}$$

From the law of conservation of Kinetic energy, before collision, $K.E_1 = ½ M_{,2} U_{,2} + ½ M_2 U_2^2$ After collision, $K.E_2 = ½ M_1 V_1^2 + ½ M_2 V_2^2 = ½ (M_1 + M_2) V^2$. For a perfectly inelastic collision, K. E, > K. E_2.

Example

Two bodies C & D of masses 6Kg and 3Kg move towards each other with velocities $5ms^{-1}$ and $3ms^{-1}$ and collide. If the collision is perfectly inelastic, find the velocity of the two bodies after collision. Hence, find the total Kinetic energy, K. E of the system before and after collisions, what is the energy loss?

From momentum conservation law,

$$(6 \times 5) - (3 \times 3) = (6 + 3) V$$

$$30 \quad - \quad 9 \quad = 9V$$

$$21 \quad = \quad 9V$$

$$V = 21/9 = 2.33ms^{-1}$$

K. E before collision is given by

K. E, = ½ x 6 x5^2 + ½ x 3 x 3^2

= 88.5 J.

K. E after collision is given by

$$K.E_2 = {}^1\!/_2\,(6+3) \times {}^{21^2}\!/_9 \; = 24.5j$$

Loss in Kinetic energy, K. E = 88. 5 – 24. 5

= 64J

MOMENTUM QUANTITIES AND WEIGHTLESSNESS

PREAMBLE:

Every object within the earth's gravitational field experiences the gravitational pull of the earth on it due to its mass.

Newton's first law of motion emphasizes on the continuity of a body at rest or in motion unless acted upon by an external force. The second law threw light on the rate of change of momentum being proportional to the impressed force. The third law explained the action and reaction of bodies as being equal and opposite. The law of conservation of linear momentum stressed that momentum is conserved in every isolated or closed system.

INERTIAL MASS AND WEIGHT

Inertia is the reluctance of a body to charge its state of rest or of uniform motion in a straight line. From Newton's first law of motion, inertial is an inherent property of matter.

The mass of a body or an object is a quantitative measure of the inertia of the body. It is simply the quantity of matter a body contains. The greater the mass of a body the greater its inertia. This property of matter in a body is known as the inertial mass. The mass of a body is measured with a beam or chemical balance and its unit is the kilogram. The mass of a body is constant all over the earth unlike the weight of a body.

The weight, W of a body is the force acting on the body due to the earth's gravitational pull. Thus, the weight of an object is a product of the mass, M, of the object and the acceleration, g, of the object due to gravity.

Hence, W = Mg

Weight of an object is measured with a spring balance and its unit is the Newton, the unit of force.

The weight of an object varies from place to place because the acceleration due to gravity upon which it depends, varies from place to place. The values of g and W are each greatest at the poles and least at the equator, because the earth is not a perfect sphere and the equatorial diameter is slightly greater than the polar diameter.

WEIGHT OF A BODY INSIDE AN ELEVATOR (LIFT)

A man standing in an elevator or a lift experiences two forces

The man's actual weight acting vertically downwards, W = Mg;

The reaction, R, acting upwards on the man from the floor of the lift

1. Whenever the elevator is stationary or moves with a constant velocity, the acceleration, a = 0 and W = Mg = R.

2. When the lift accelerates upwards with an acceleration, a, the man standing on the floor of the elevator is also accelerating with an acceleration a . Thus, F = Ma = R - Mg

R = F + Mg = Ma + Mg = M (a+g)

Thus, the apparent weight, W, will be greater than his true weight, W i.e. W_1 > W because he feels himself pressing downwards on the floor of the elevator with a larger force

3. When the elevator accelerates downwards with an acceleration, a, the force on the man is $F = Ma = Mg - R_2$

$W_2 = R_2 = M_g - F$

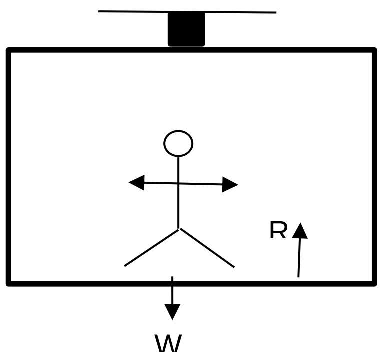
But $F=Ma$

$W_2 = Mg - Ma = M(g - a)$

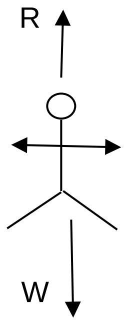
Hence, the man's true weight will be greater than his apparent weight.

4. When the elevator is falling freely with an acceleration $a = g$, $W_3 = m(g - a) = 0$

This happen when the cable of the elevator is cut and the man appears to have no weight. This is known as weightlessness. The man and the floor of the elevator are not exerting any force on each other.



Man on a lift



Force Diagram

APPLICATION OF NEWTON'S LAWS AND CONSERVATION OF MOMENTUM LAWS

1. **JET AND ROCKET PROPULSION:-** Discharged gases from the combustion chamber of the jet or rocket engine move downwards at very high speeds and this down ward force pushes the jet or rocket forward, thus, an equal and opposite momentum is given to the jet or rocket.

2. Walking is possible because action force exerted by the person on the ground is equal to the reaction force exerted by the ground on the person.

3. **RECOIL OF A GUN:-** Gun jerks back as bullet is released because the momentum of the gun is directed oppositely to that of the bullet.

EVALUATION

Ask the students the following questions:-

1. States the Newton's three laws of motion

2. When taking a free kick, a footballer applies a force of 45N for a period of 0.1s. If the of the ball is 0.09Kg, at what speed will the ball move?

Define momentum and impulse

Show that impulse equals change in momentum

A stationary ball is hit by an average force of 45N for a time of 3secs. What is the impulse experienced by the body?

State the law ,of conservation of linear momentum

Explain elastic and inelastic collisions.

A 3.00Kg rifle lays on a smooth table when it suddenly discharges, firming a bullet of 0.02Kg with a speed of $500ms^{-1}$ calculate the recoil speed of the gun.

1. Define inertial, mass and weight

2. A man whose mass is 80Kg stands on a spring weighting machine inside an elevator. What is the reading of the weighting machine when.

(i) The elevator is moving with a uniform an acceleration $2.0ms^{-2}$?

(ii) The elevator is moving with a uniform velocity?

(iii) The elevator is coming to rest with a retardation of $4.0ms^{-2}$?

3. State the applications of Newton's laws of motion and conservation of momentum laws.

WEEK 8
SIMPLE MACHINES

A simple machine is any device by means a small force called effort is applied at one end and can be used to overcome a larger force or resistance at some other end.

TYPES OF MACHINES

There are various types of machines. Some of them are: the lever, pulley, block and tackle pulley, inclined plane, wheel and axle, screw jack and wedge

TERMS USED IN DESCRIBING MACHINES

1. Effort (E): It is the force applied to a machine to overcome a load. It is measures in Newton (N).
2. Load (L): This is a force or resistance overcome by the machine. It is also measured in Newton(N).
3. Mechanical Advantage (M.A): This is the ratio of load to effort.

Mathematically,

$$M.A = Load/Effort = L/E$$

If a load of 60N is raised by an effort of 10N. The M.A. is

$$M.A = L/E = 60/10 = 6$$

4. Velocity Ratio (VR): This is the ratio of the distance moved by the effort to the distance moved by the load at the same time.

Mathematically,

$$Velocity\ Ratio = Distance\ moved\ by\ effort(e)/Distance\ moved\ by\ load(l)$$

5. Efficiency of a machine (E): This is defined as the ratio of the useful work done by the machine to the work put into the machine as a percentage.

Mathematically,

$$Efficiency = Work\ output/work\ input\ \times 100\%$$

The efficiency of a machine is not always 100% because some work is wasted in overcoming friction and raising moving parts.

<u>Relationship between M.A.,V.R and Efficiency (E)</u>

$$Efficiency(E) = \frac{useful\ work\ done\ by\ the\ machine}{work\ put\ into\ the\ machine} \times 100\%$$

Since, work = force X distance

$$Efficiency(E) = \frac{Load(L) \times Distance\ moved\ by\ load(l)}{Effort(E) \times Distance\ moved\ by\ effort(e)} \times 100\%$$

I.e $Efficiency(E) = \frac{L}{E} \times \frac{l}{e} 100\% = \frac{L}{E} \div \frac{e}{l} 100\%$

but, $L/E = M.A$ and $e/l = V.R$

$\therefore E = M.A/V.R \times 100\%$

<u>Pulley</u>

Pulleys are machines used by builders for lifting heavy loads to a higher floor e.g. cranes used at docks for lifting heavy cargoes in and out of ships are forms of pulleys.

A simple pulley is a fixed wheel hung on a suitable support with a rope passing round its groove in its rim.

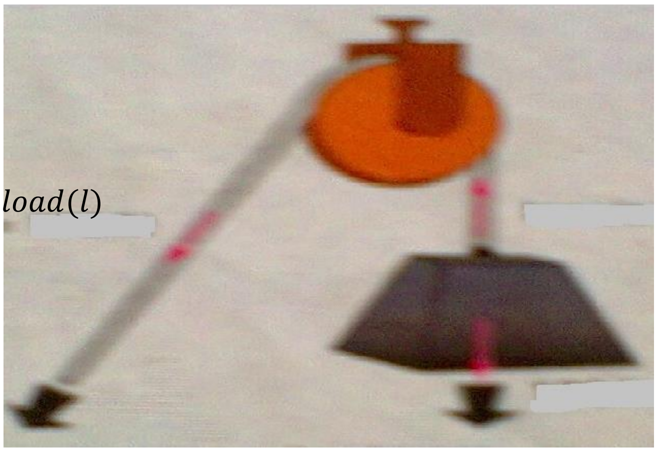


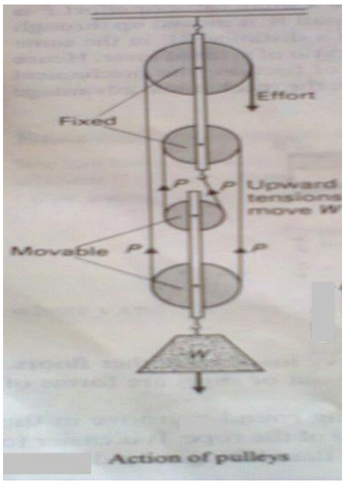
Fig: A simple fixed pulley

If the weight of the rope and frictional force is negligible, then the tension in the rope will be the same throughout and effort equals load. Hence,

L = E & M.A = 1; V.R = 1

Block and tackle system of pulley

This is a form practical form of pulley system which consists of number of pulleys and a continuous rope passing through them.



Block and tackle system of pulley

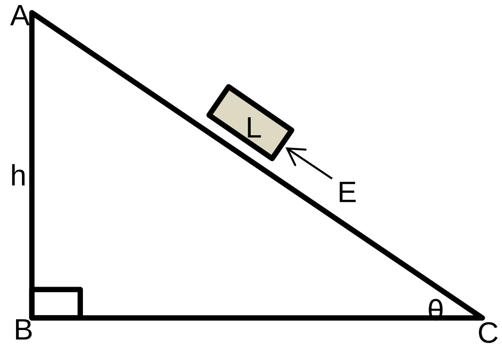
The pulleys has fixed and movable pulleys as arranged in the diagram in which the rope is continuously passing round the number of pulleys. When the effort E moves a distance ‘d’, the load moves ‘d/4. Since there are 4 strings supporting the load.

$$V.R = d/d/4 = \frac{d}{1} \times \frac{4}{d} = 4$$

The number of pulleys in this case, determines the V.R of the pulley. If there are 8 pulleys, it implies the V.R is 8 and so on.

INCLINED PLANE

This is a device (machine) that is used to raised heavy loads such as barrel of liquid or drum of oil up to a high floor of lorries. A sloping plank is an example of inclined plane.



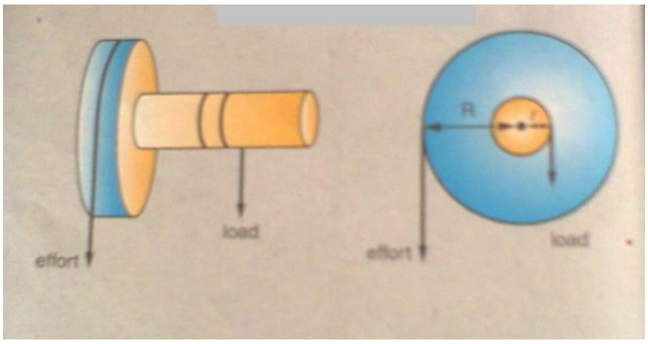
Let the angle of inclination be θ and the height AB = h. The force applied or effort (E) to move along AC, at an angle θ to the horizontal. The load, L, is lifted up through a vertical height AB. Therefore, the velocity ratio is given by

$$Velocity\ Ratio = \frac{Distance\ moved\ by\ effort(e)}{Distance\ moved\ by\ load(l)}$$

$${}^{AC}/_{AB} = 1/\sin\theta \quad \therefore V.R = 1/\sin\theta$$

WHEEL AND AXLE

This type of machine is used to lift liquid (water) from depth (deep well).



WHEEL AND AXLE

When the wheel is rotated through one complete cycle (revolution), the axle is also rotated through one complete cycle (revolution) at the same time interval. The distances moved by the effort and load re equal to $2\pi R$ and $2\pi r$ respectively i.e. The circumferences of the wheel and axle.

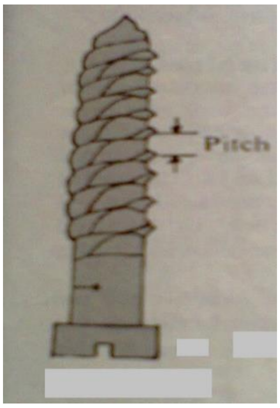
$$Velocity\ Ratio = \frac{Distance\ moved\ by\ effort(e)}{Distance\ moved\ by\ load(l)} = \frac{2\pi R}{2\pi r} = \frac{Radius\ of\ wheel}{radius\ of\ axle} = \frac{R}{r}$$

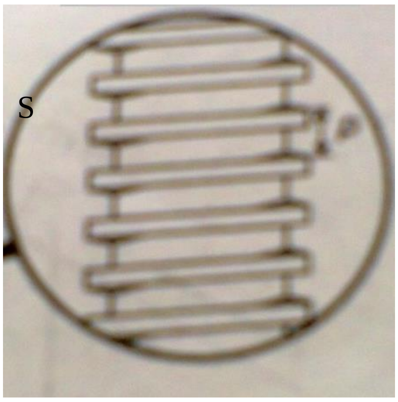
Hence, $V.R = \frac{R}{r}$

In the absence of friction, V.R = M.A

$$Hence, M.A = V.R = \frac{R}{r} = \frac{Radius\ of\ wheel}{radius\ of\ axle}$$

Screw Jack





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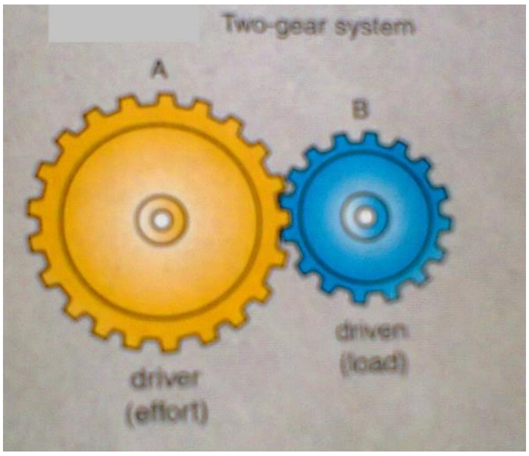
Screw and Screw Jack

The thread of screw jack can be regarded as a continuous inclined plane wrapped round a cylinder. The distance between successive screw thread is called the pitch ‘p’. When the screw head is turned by effort through one complete cycle(revolution), a distance of $(2\pi r)$ is covered, where r is the radius of the circle turned. At the same time, the screw (load) is turned through a distance equal to the pitch(p) the screw (head) moves forward through a distance equal to the pitch.

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

GEAR WHEEL

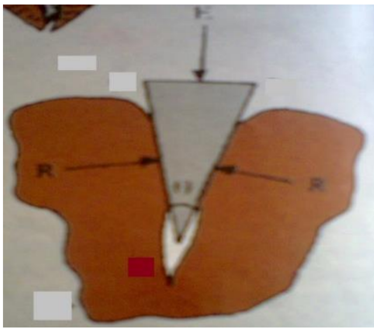
These are commonly seen in cars, bicycle etc. These can also be taken as toothed wheels of different radii connected by a belt and rotating on different shafts

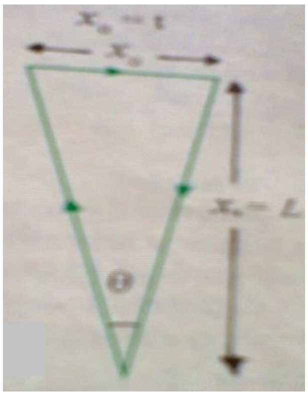


$$V.R = \frac{No\ of\ teeth\ on\ driven\ wheel(B)}{No\ of\ teeth\ on\ driving\ wheel(A)}$$

WEDGE

The wedge is a combination of two inclined planes. It is used to separate bodies which are held together by a large force.





$$M.A = \frac{L}{t} = \frac{Slant\ height\ of\ wedge}{thickness\ of\ wedge}$$

Example:

i. A block and tackle of 5 pulleys is used to raise a load of 400N through a height of 10m.If the work done against friction is 1000j. Calculate the work done by the effort.

ii. The efficiency of the system.

iii. The effort applied

Solution

i. Work done by effort = work used in raising load + work on friction

400 X 10 + 1000 = 4000 + 1000 = 5000j

$ii. \quad Efficiency = \frac{Work\ output}{work\ input} \times 100\%$

$Efficiency = \frac{400\times10}{5000} \times 100\%$

E = 4 X 20 = 80%

iii. $Since\ \ E = M.A/V.R \ \ \times 100\%$

$80 = M.A/5 \ \ \times 100\%$

M.A = 80 X $^{5}/_{100}$

M.A = $^{400}/_{100}$ = 4

i.e. $^{L}/_{E}$ = 4 (since M.A=$^{L}/_{E}$)

$^{400}/_{E}$ = 4

E = 400/4 = 100N

Example: What is the V.R of an inclined plane of length 6m with a vertical height of 2m above the ground? Used as a machine, the efficiency of the plane is 60%, calculate the M.A

Solution

V.R = 1/sin θ

= $Length\ of\ plane/Vertical\ height$

= 6/2 = 3

V.R = 3

$E = M.A/V.R \ \ \times 100\%$

$60 = M.A/3 \ \ \times 100\%$

M.A = 60 X $^{3}/_{100}$ = $^{18}/_{10}$ = 1.8

Example: The pitch of a screw jack is 0.5cm, the arm is 50cm long and its M.A is 250. What is the efficiency? (Leave your answer in terms of π)

Solution

$E = M.A/V.R \ \ \times 100\%$

$V.R = 2\pi r/p = 2\pi \times 50/0.5 = 200\pi$

M.A = 250

$Efficiency = \frac{250\times0.5}{200\pi} \times 100\%$

$E = 62.5\%/\pi$

WEEK 9

TOPIC: PROJECTILES

INTRODUCTION:

In life, there are several types of motion which do not follow straight paths. In this topic, there would be consideration on the fundamental laws of motion that apply to motions along curved paths such as the motion of projectiles along parabolic paths.

PROJECTILE

A projectile is an object or body launched into the air and allowed to follow or move freely under gravity in a parabolic path.

The parabolic path which the projectile follows is called trajectory. The curve or shape of the path which the projectile follows is called parabola.

Examples of projectile are:-

(i). An athlete doing the high jump

(ii). A fired bullet from a gun

(iii). Shot put or javelin thrown by an athlete

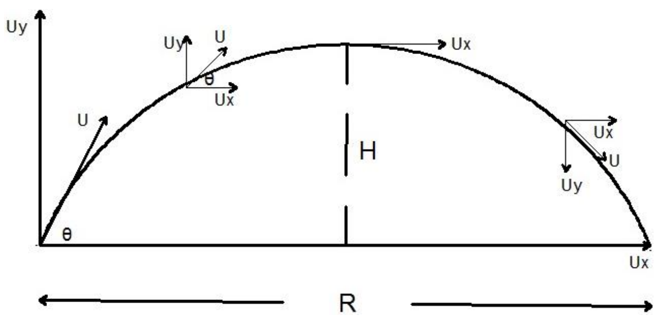
(iv). An arrow shot by a hunter

(v). A football kicked into the air by a footballer

(vi). A stone released from a catapult

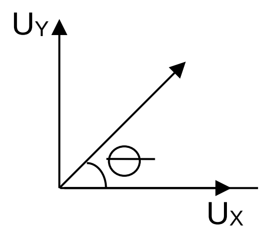
PROJECTILE MOTION

Every projectile undergoes two motions at a time (i) It moves horizontally with a constant speed (ii) It moves up or down with an acceleration, 'g'



R

Resolving the velocities into horizontal and vertical components, we have



The horizontal component of the velocity $U_X = U \cos\theta$

At time,t, distance, S, covered = U Cosθ x t (initial vertical component of the velocity)

$U_y = U \sin\theta$

At time, t, $U_y = U \sin\theta \pm gt$

Distance, S, covered = $U \sin\theta\, t \pm \frac{1}{2} gt^2$

DEFINITION:-

TIME OF FLIGHT:This is the time required for the projectile to return to the same level from which it was projected or projection plane.

MAXIMUM HEIGHT (H):- This is the highest vertical distance reached, as measured from the horizontal plane of projection.

RANGE:- This is the horizontal distance from the point of projection to the point where the projectile hits the projection plane.

Derivation of Time of flight, T, Range, R, and maximum height, H.

From $S = U \sin\theta \times t \pm \frac{1}{2} gt^2$

Considering the vertical motion along y – axis,

$Y = U \sin\theta \times t - \frac{1}{2} gt^2$

Let the time of flight be T.

After time T, y = 0

$0 = U \sin\theta \times T - \frac{1}{2} gT^2$

$2 u \sin\theta \times T = gT^2$

$$\frac{2 u \sin\theta \times T}{gT} = \frac{gT^2}{gT}$$

Thus, $T = \frac{2U\, Sin\theta}{g}$

Also, time of flight, T can be derived using V = U sinθ - gt

At maximum height, V = 0

$0 = U \sin\theta - gt.$

$t = U \sin\theta/g$

t is the time it takes to reach the maximum height. If the time from the maximum height back to the plane is also t, thus,

$T = 2t = 2 u \sin\theta/g$

Hence, $T = 2 u \sin\theta/g$ ------------- (1b)

Maximum height, H:-

From $v^2 = u^2 - 2gh$

Vertical component of velocity is given by

$u_y = u \sin\theta$

$v^2 = u^2 \sin\theta - 2gh$

At maximum height h = H, v = 0.

$0 = u^2 \sin^2 - 2gH$

$u^2 \sin^2\theta = 2gH$

$H = \frac{u^2 \sin^2\theta}{2g}$ --------------- (2)

Range, R,

Recall that the horizontal component of the velocity, $U_x = U \cos\theta$

Thus, horizontal distance, R; is covered at time, T, which is the time of flight.

Hence, $R = U \cos\theta \times T = U \cos\theta \times \frac{2 u \sin\theta}{}$

$R = 2u^2 \sin\theta \cos\theta/g$

From trigonometry, $\sin 2\theta = 2 \sin\theta \cos\theta$

Thus, $R = (u^2 \sin 2\theta)/g$

The range is maximum when sin 2θ is maximum.

Sin 2θ is maximum when the angle of projection is 45^0. Thus, when $\theta = 45^0$, $2\theta = 90^0$ and $\sin 90^0 = 1$. This will also make the range to be maximum.

Hence, maximum range is obtained when the angle of projection is 45^0.

Example

A stone is shot out from a catapult with initial velocity of $30ms^{-1}$ at an elevation of 60^0. Find the (a) Time of flight, T;

(b) Maximum height attained;

(c) Range. (Take $g = 10ms^{-2}$)

SOLUTION

(a) Time of flight, $T = (2 u \sin\theta)/g = (2 \times 30\sin60)/10$

T = 5.2secs

(b) Maximum height, $H = (u^2 \sin^2\theta)/2g$

$$= \frac{30^2 \sin^2 60}{2 \times 10} = \frac{900 \times (0.8660)^2}{20}$$

H = 33.75m

(c) Range, $R = (u^2 \sin 2\theta)/g = \frac{30^2 \sin (2 \times 60)}{10}$

$= (900 \sin 120)/10 = 77.9m$

<u>APPLICATION OF PROJECTILE</u>

Warfare:- In dropping a bomb, the pilot will have to veer off if he want to avoid the explosion since the bomb which follows a parabolic path is always underneath the aeroplane.

Projectile is also applied in firing of missiles

Sports:- Throwing of javelin, shot put and discus follow a parabolic path and hence have vertical and horizontal motion. The horizontal component is measured as the distance covered by throwing each of them.

<u>EVALUATION:-</u>

Evaluate the students by asking them the following questions:-

1.a. Define projectile and state its application

b. Define time of flight, maximum height and Range

2. A body is project from the ground with a velocity of $40ms^{-1}$ at an angle of 30^0 to the horizontal. If the acceleration of free fall due to gravity is $10ms^{-2}$, calculate the

(i) Time of flight;

(ii) Horizontal range;

(iii) Velocity with which the body strikes the ground

WEEK 10

TOPIC: CIRCULAR MOTION

INTRODUCTION

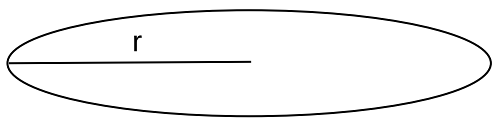
The motion of a body moving at constant speed round a circular curve is known as circular motion.

Examples are:

the moon circling the earth.

A stone tied to a string which is whirled in a horizontal or vertical circle.

The planet moving round the sun.



The speed of the object moving or whirled on a circular path is constant in magnitude but its velocity is changing and hence, it has acceleration directed towards the centre of the circular curve. This acceleration is called centripetal acceleration(a_c).

$a_c = v^2/r$

Since acceleration is directed towards the centre of the circle, there is a force associated with it and this force is called centripetal force (F_c)

$F_c = mv^2/r$

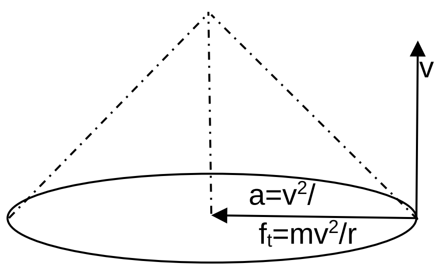
M is mass in kilogram(kg)

V is velocity in meter per second (m/s)

r is the radius of circular path in metre (m).

NB:

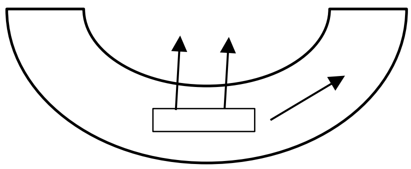
The centripetal acceleration and force act in the same direction (to the centre) and the direction is perpendicular to the direction of the velocity.



BANKING OF CURVES ON ROADS

When a car is moving along a circular path, friction between the tyres and the road provides the centripetal force needed by the car to make the turn. If the frictional force is not great enough (as on wet tarmac), sufficient force cannot be supplied and the car will skid out of the circular path. For this reason, curves on the road are banked.

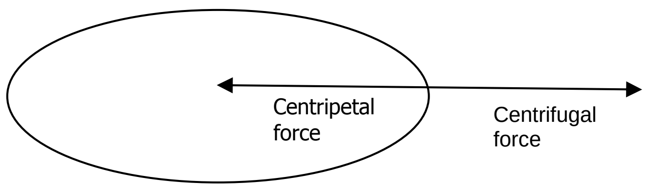
Banking of curves on road is the construction of curves on road so that they slope towards the inward edge.



Centrifugal force

Centrifugal force is the force that is equal in magnitude but opposite in the direction of centripetal force.

Example of centrifugal force is felt by people riding in a car as it turns around.



Angular velocity (ω) is defined as the angle turned by a body divided by the time taken to make that angle.

$\omega = \theta/t$

the relationship between angular velocity, ω, and linear velocity, v, is that, $V = r\omega$.

Where r is the radius of the circle or path in metre,

V is linear velocity in *m/s*,

ω is angular velocity in *rad/s*

t is time in *second*

θ is angle turned in *radia*

WEEK 11

TOPIC: SIMPLE HARMONIC MOTION

INTRODUCTION:-

A vibration or Oscillation is in general any motion which repeats itself or path at regular intervals. A familiar example is the simple pendulum in which a small mass at the end of a string suspended from a point moves to and fro. In the equilibrium position, the mass hangs straight down, but when slightly displaced from this position, it does not simply return to this equilibrium point, but instead swings to and fro in a regular repetitive manner.

<u>SIMPLE HARMONIC MOTION (S. H. M)</u>

DEFINITION:- Simple Harmonic motion is the periodic motion of a particle or body whose acceleration is always directed towards a fixed point (or centre of motion) and is directly proportional to its distance or displacement from that point.

Examples of simple Harmonic motion are

The motion of a body suspended from a spiral spring.

The motion of the strings in a musical instrument e.g. guitar.

The motion of the prongs of a sounding tuning fork.

The motion of the balance wheel of a watch.

The beating of the heart.

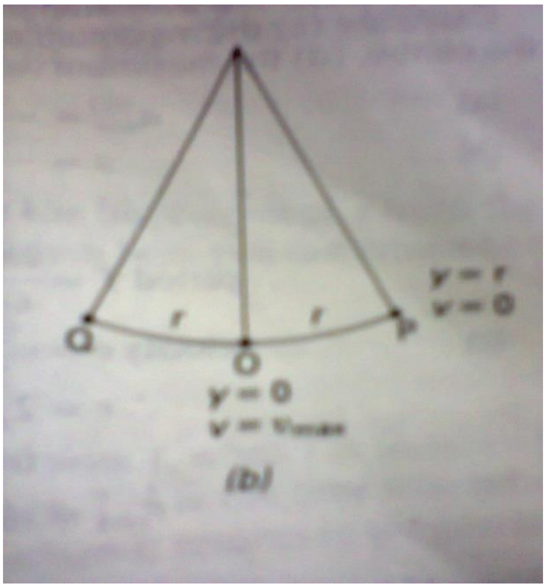
The motion of a child’s swing.

The motion of a pendulum clock.

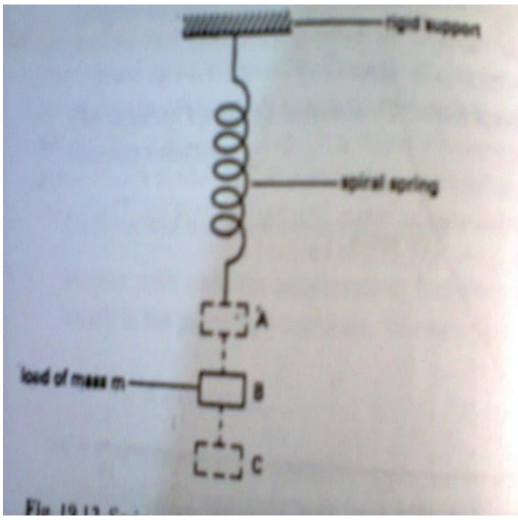
The motion of a loaded test tube Oscillating vertically in a liquid.

The motion of the pistons in a gasoline engine

The motion of the diving board in a swimming pool.



Simple Pendulum Bob

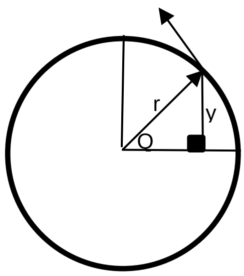


Loaded Spring

<u>SPEED AND ACCELERATION OF SIMPLE HARMONIC MOTION</u>

VELOCITY DURING SIMPLE HARMONIC MOTION:- The expression for the velocity, V, of an object moving with simple Harmonic motion is given by

Velocity, $V = \omega\sqrt{(r^2 - y^2)}$



Where r is the radius of the circle and $y = rSin\theta =$ distance or displacement of the object from a fixed point and ω = angular velocity.

The maximum velocity, V_m, corresponds to y = 0 and hence $Vm = r\omega$

Acceleration during simple Harmonic motion

Acceleration, ‘a’, towards a fixed point = $-\omega y^2$

Where ω = angular velocity and y = the distance of the object from a fixed point.

Relationship between

1. Linear speed, V, and angular speed, ω, is given by:

   $V = r\omega$, where r is the radius of the circle

2. Linear acceleration, a, and angular acceleration, α, is

$$\boxed{a = \alpha r = -\omega^2 r}$$

$$\boxed{a_{max} = -\omega^2 A}$$

PERIOD,FREQUENCY AND AMPLITUDE OF SIMPLE HARMONIC MOTION

PERIOD (T).

It is the time taken to make a complete revolution (to-and- fro movement of cycle).

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

(For a simple pendulum of length, L)

Where w is the angular velocity

$$\boxed{\omega = 2\pi f}$$

Frequency, f.

Frequency, f is defined as the number of cycles per second. The unit is hertz (Hz) the relationship between period and frequency is given by

Frequency, $\boxed{f = 1/T \text{ or } T = 1/f}$

Amplitude, (A or r)

The amplitude, A, of the motion is the maximum displacement on either side of the centre of oscillates.

Example

A small bob of mass 20g oscillates as a simple pendulum, with amplitude 5cm and period 2 seconds. Find the maximum velocity of the bob.

SOLUTION.

Maximum velocity V_m is given by

$$\boxed{Vm = r\omega}$$

Where r is the amplitude of 0 .05 m…..

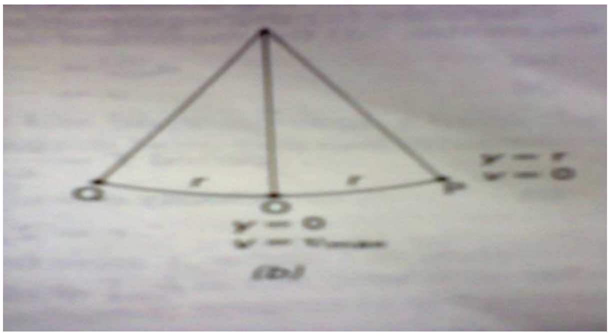
$$\boxed{T=\frac{2\pi}{\omega}}$$

$$\boxed{\omega=\frac{2\pi}{T} = \frac{2\pi}{2}= \pi\ rad/s}$$

$$\boxed{Vm = r\omega = \pi \times 0.05 = 0.16\, m/s}$$

Energy in Simple Harmonic motion

Total Energy = ½ $m\omega^2A^2$ where A is the amplitude, ω is the angular velocity and m is the mass.



When the body comes to rest, the total energy is potential energy = mgh. When the speed of the bob is maximum, height is zero i.e. h = 0, total energy is kinetic energy i.e. K.E = $\frac{1}{2}mv^2$

Example:

A steel strip, clamped at one end, vibrates with a frequency of 20Hz and an amplitude of 5mm at the free end, where a small mass of 2g is positioned calculate the maximum kinetic and potential energy of the mass.

Solution

K.E = ½ $m\omega^2A^2$. But $\omega = 2\pi f = 2\pi \times 20$ and A = 0.005m

Max K. E = ½ $m\omega^2A^2$ = ½ x 0.002 x $(0.005)^2 \times (2\pi \times 20)^2$

K.E = 0.0003951 J.

FORCED VIBRATION AND RESONANCE

FORCED VIBRATION: - When the system is acted upon by a periodic force whose frequency is not equal to its natural frequency, the vibrations are said to be forced vibrations. For example, we hear a louder sound when the fork is in contact with the table because the fork sets the table top into vibrations at the same frequency as itself. The vibrations of the table top are called forced vibrations.

RESONANCE:

It is a special case of a forced vibration (or a very large amplitude of vibration) which occurs when the forcing frequency is equal to the natural frequency.

Resonance is said to occur when the forcing frequency (f) of an external periodic force coincides with the natural frequency (f_o) of a body with which it is contact, causing the body to vibrate with a large amplitude

OR

Resonance is a phenomenon which occurs whenever a particular body or system is set in oscillation at its own natural frequency as a result of impulse or signal received from other systems or body which is vibrating with the same natural frequency.

Examples: -

1. Electrical circuit receiving radio waves from a distance transmitter, the frequency of the radio waves is equal to the natural frequency of the circuit.
2. A dark line in a continuous spectrum, an absorption line is an example of optical resonance
3. Resonance in a tube or a pipe
4. Resonance in two sound boxes each with an open end
5. Resonance in a ripple tank.

EVALUATION

Evaluate the students by asking them the following questions: -

1. With five examples, define simple Harmonic motion
2. A body of mass, 0.1Kg, which is moving simple harmonic motion, has a velocity of $0.15ms^{-1}$ and an acceleration of $0.25ms^{-2}$ when its displacement is