Week	Topic	Content
1	Physical quantities and units	• Fundamental quantities • Derived quantities • Measurements • Dimensions of physical quantities
2	Motion	• Types of motion • Causes of motion • Types of forces • Relative motion • Circular motion
3.	Motion: solid friction	• Types of friction • Laws of friction • Reducing friction
4.	Motion: liquid friction	• Viscosity • Laws of fluid friction • Applications of viscosity • Terminal velocity.
5.	Scalar and vector quantities	• Concept of scalar and vector • Concept of position, distance and displacement • Distinction between distance and displacement • Concept of speed and velocity • Distance – time graph • Displacement – time graph
6.	Rectilinear acceleration	• Concept of acceleration • Uniform and non – uniform acceleration • Equation of uniform accelerated motion • Equation of motion under gravity
7.	Rectilinear acceleration	• Velocity – time graph
8.	Work, energy and power	• Concept of work, energy and power • Force – distance graph • Workdone in a force field • Types of energy and energy conversion • Renewable and non – renewable energy sources

Introduction to Physics

Definition: Physics is a branch of science that deals with or study space, time, matter and energy and their interaction in different branches.

Branches of physics

1. Mechanics: this deals with the action of forces on material object with mass.
2. Optics
3. Electricity
4. Magnetism
5. Thermodynamics
6. Modern physics

Importance of physics:

The importance of physics has help us to develop our society in the following ways:

1. **Construction of building**: physics helps us understand which material are most affected by heat, light and water
2. **Providing energy**: it is the knowledge of physics that makes water from kainji dam to be able to supply electricity to our homes.
3. **Stimulating the economy** in terms of job opportunity. Opportunities available for physicist among others include being an engineer pilot, teacher, nurse, etc.
4. **Maintenance of our health** e.g., X – rays which are products of physics, is used to detect broken bones as well as for cancer treatment.

Assignment

1. List three (3) other job opportunities available for physics.
2. List three (3) other areas of life where physics is useful.

Fundamental Quantities and units.

Fundamental quantities: are defined as the basic quantities that are independent of others and cannot be defined in terms of other quantities or derive from them. In other words, they are the basic quantities upon which most (though not all) quantities depend e.g.

Length: this is defined as the extent of space or distance extended.

Mass: is defined as the quantity of matter contained in a substance.

Time: is defined as that which in which events are distinguishable with reference to before or after. In other words, is that quantity in which events are differentiable with reference to before and after.

Fundamental units: are the basic unit upon which other units depend. They are units of the fundamental quantities.

Examples are shown in the table below:

S/N	**Quantity**	**Unit**	**Unit abbreviation**
1.	Length	Metre	M
2.	Time	Second	S
3.	Mass	Kilogram	Kg
4.	Electric current	Ampere	A
5.	Temperature	Kelvin	K
6.	Amount of substance	Mole	Mol
7.	Luminous intensity	Candela	Cd

The unit above are in the S.I (system international) unit.

Derived quantities and units:

Derived quantities and units are those obtained by some combination of the fundamental quantities and units. They are thus, dependent on the fundamental quantities and units.

Examples are shown in the table below:

S/N	Quantity	Derivation	Unit
1.	Area	Length X breadth	m^2
2.	Volume	Lenth X breadth x height	m^3
3.	Density	$\frac{mass}{volume}$	kgm^{-3}
4.	Velocity(v)	$\frac{displacement}{time}$	ms^{-1}
5.	Acceleration	$\frac{change\ in\ velocity}{time}$	ms^{-2}
6.	Force	Mass x acceleration	N or $kgms^{-2}$
7.	Energy or work	Force x distance	Joule (J)
8.	Power	$\frac{work}{time}$	Js^{-1} or watt, W
9.	Momentum	Mass x velocity	$kgms^{-1}$ Ns

10.	Pressure	$\frac{force}{area}$	Nm^{-2} (pascal, pa)
11.	Frequency(f)	$\frac{number\ of\ oscillations}{time}$	Hz or per second

Measurements:

Measurement: is defined as the process of finding the size, degree or quantity of matter, e.g., length, volume, mass, weight, time etc.

Measurement of length.

We use the following to measure length in the laboratory; metre rule, calipers, vernier calipers and micrometer screw gauge.

a. **The metre rule:**

The metre rule is graduated in centimetres and millimetres. The smallest graduation is 1mm or 0.1 cm. This is its reading accuracy.

b. **The calipers**:

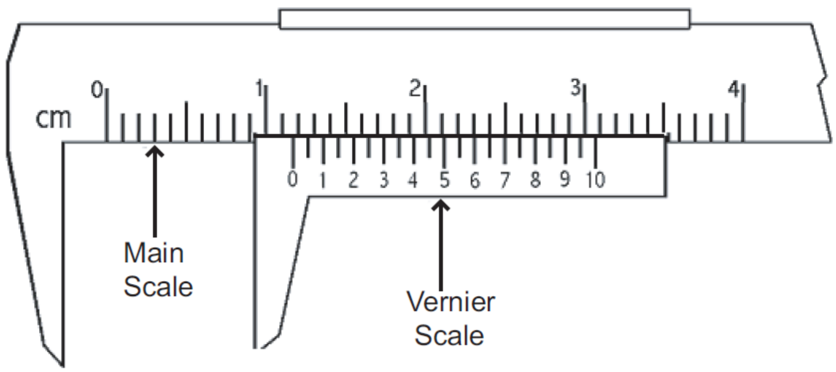
Calipers are used to measure lengths on solid objects that are in a cylindrical form. The jaws of the calipers are adjusted until they touch the object in the correct positions. The length between the jaws is measured on a graduated scale.

c. **The vernier calipers:**

These can measure length more accurately than the metre rule. To measure small lengths to the nearest 0.1 mm e.g., thickness of a metre rule, the internal diameter of a rod, we use the vernier calipers.

It has two sets of jaws and two scales, the main and the vernier scale. For any measurement, the readings on both the main and vernier scales are added together to get the total reading of the length. The reading accuracy is 0.1mm 0r 0.01cm.

Example:



In the above diagram;

Main scale reading = 0.9 cm

Vernier scale = $\frac{6}{100}$ = 0.06 cm

Actual reading = ms + vs = 0.9 + 0.06 = 0.96cm

d. The micrometer screw gauge:

The micrometer screw gauge is used for accurate measurements of still smaller lengths such as the diameter of a wire, the diameter of a small ball (e.g., a pendulum bob) or the thickness of a piece of paper, we use the micrometer screw gauge. Its reading accuracy is 0.01 mm or 0.001 cm.

The readings on both the main scale and the vernier scale are added to get the length of the material.

Example

[redacted]

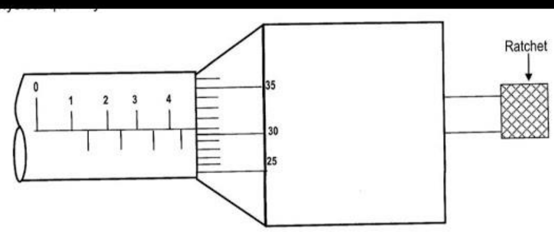


Figure 1.1

(a) What is the reading shown on the micrometer?

______________________________ [1]

[redacted]

in the diagram above;

main scale = 4.5mm

vernier scale = $\frac{31}{100}$ = 0.31mm

actual reading = 4.5 + 0.31 = 4.81mm

Measurement of volume:

i. **Rectangular block**: we can obtain the volume of the rectangular block by measuring its length (l) breadth (b) and height (h). the volume is given by

$$v = l \times b \times h$$

ii. **Irregular solid:** the volume of an irregular solid (e.g., a glass stopper) is obtained by immersing it completely in a measuring cylinder containing a liquid in which the solid is insoluble. The volume of the liquid displaced, gives the volume of the solid.

iii. **A sphere**: we can measure the diameter (d) with a micrometer screw gauge and obtain the volume by;

$$v = \frac{4}{3}\pi r^3 \text{ where } r = \frac{d}{2}$$

iv. **Cylindrical wire:** we measure the length (l) of the wire using a metre rule and the diameter (d) of the wire using micrometer screw gauge. We measure the diameter at different points of the wire and calculate the mean diameter.

$$v = \pi r^2 l \text{ or } v = (\frac{d}{2})^2 l$$

$$v = \pi \frac{d^2 l}{4}$$

Mass and weight:

Mass is defined as the quantity of matter or 'stuff' contained in a body;

While **weight** is the force or pull with which the earth attracts the body towards the centre of the earth.

The mass of a body is measured with a balance of which there are various types, namely:

i. Beam balance
ii. Chemical balance
iii. Lever balance
iv. Spring balance
v. A direct reading balance.

Difference between mass and weight.

S/N	MASS	WEIGHT
1.	It is the quantity of matter in a body	It is a force exerted on a body by the earth

2.	Its S.I unit is kilogram (kg)	Its S.I unit is Newton (N) or $kgms^{-2}$
3.	It is the same from place to place	Weight varies from place to place
4.	It is a scalar quantity	It is a vector quantity
5.	It is measured with chemical or beam balance	It is measured with spring, lever or direct reading balance

TIME:

Time is the inevitable progression into the future with the passing of the present events into the past.

All day-to-day activities involve the idea of time. To measure time, instruments are needed. In the school laboratory, time is measured with stopwatches and stop clocks.

However, stopwatches are more accurate than clocks. At home, time is measured with instruments called wrist watch, wall clocks, pendulum clock etc. other uncommon ways of measuring time are; the use of heart beat, sand clock, tickers timer etc. the general name for the device used in measuring time is called **chronometer.**

Stop watch enables us to measure time to 0.1s.

The S.I unit is seconds with multiple units as:

60 seconds = 1minute

60 minute = 1 hour

24 hours = 1 day

Example

Calculate how many seconds are in:

a. 2 hours
b. 3 months of July
c. 2 years

Dimensions of physical quantities:

Any quantity which can be measured in units of length is said to have the dimension of length (L), and any quantity which can be measured in units of mass is said to have a dimension of mass (M) and any quantity which can be measured in units of time is said to have dimension of time (T).

Example

Deduce the dimension of the following

1. Area

Solution

Area = length x breadth

= L X L = L^2

2. Volume

Solution

Volume = length x breadth x height

= L X L X L = L^3

3. Velocity

Solution

Velocity = $\frac{displacement}{time}$

= $\frac{L}{T}$ = L/T or LT^{-1}

4. Acceleration

Solution

Acceleration = $\frac{velocity}{time}$

= $\frac{L/T}{T} = \frac{L}{T} \div \frac{T}{1}$

= $\frac{L}{T} \times \frac{1}{T} = \frac{L}{T^2}$ = LT^{-2}

5. Force

Solution

Force = mass x acceleration

= M X LT^{-2} = MLT^{-2}

6. Work

Solution

Work = force x distance

= MLT^{-2} X L = ML^2T^{-2}

7. Power

$$\text{Power} = \frac{work}{time}$$

$$= \frac{ML^2T^{-2}}{T} = \frac{ML^2}{T^2} \div \frac{T}{1}$$

$$= \frac{ML^2}{T^2} \times \frac{T}{1} = \frac{ML^2}{T} = ML^2T^{-1}$$

Classwork

Deduce the dimension of the following;

i. Density
ii. Pressure
iii. Momentum

Exercise

1. What is the S.I unit of k so that the equation; velocity = k x density is dimensionally correct? Give your answer in terms of the basic units ($kg^{-1}m^4s^{-1}$)

   Solution

   Velocity = k x density

   $\therefore k = \frac{velocity}{density}$

   Dimensions:

   Velocity = LT^{-1}

   Density = ML^{-3}

   $$\therefore k = \frac{LT^{-1}}{ML^{-3}} = \frac{L}{T} \div \frac{M}{L^3} = \frac{L}{T} \times \frac{L^3}{M} = \frac{L^4}{MT}$$

   $K = M^{-1}L^4T^{-1}$

   $\therefore k = kg^{-1}m^4s^{-1}$

2. The period (T) of oscillation of a simple pendulum is related to its mass (m), length (l) and acceleration due to gravity (g) by:
   $T = km^xl^yg^z$ ……………… (1)
   Where x, y and z are unknown numbers and k is a constant. Using your knowledge of dimension analysis, determine the values of x, y and z and hence show the correct form of the equation.
   Solution
   $T = km^xl^yg^z$ ………………… (1)
   Dimensions;

k is a constant, so it has no dimension

m = M, l = L and g = acceleration = LT^{-2}

Substitute the dimensions in to (1)

$$T = M^x L^y (LT^{-2})^z$$
$$T = M^x \times L^y \times L^z \times T^{-2z}$$
$$T = M^x \times L^{y+z} \times T^{-2z}$$
$$\therefore M^0 L^0 T^1 = M^x L^{y+z} T^{-2z}$$

Equating the index of each term

$$x = 0 \ldots\ldots\ldots\ldots\ldots (2)$$
$$y + z = 0 \ldots\ldots\ldots (3)$$
$$-2z = 1 \ldots\ldots\ldots\ldots (4)$$

From (4), $z = -\frac{1}{2}$

Substitute z = $-\frac{1}{2}$ in (3)

$$y - \frac{1}{2} = 0$$
$$y = \frac{1}{2}$$
$$\therefore x = 0, y = \frac{1}{2} \ and \ z = -\frac{1}{2}$$

put the values of x, y and z in (1)

$$T = km^0 l^{1/2} g^{-1/2}$$
$$T = kl^{1/2} \times \frac{1}{g^{1/2}}$$
$$T = k\left(\frac{l}{g}\right)^{\frac{1}{2}}$$
$$\therefore T = k\sqrt{\frac{l}{g}}$$

<u>Assignment</u>

1. The effective potential energy, E of a lunar satellite of mass m_1, moving in an elliptical orbit around the moon of mass m_2, is given by;
$$E = \frac{k^2}{2m_1 r^2} = \frac{Gm_1 m_2}{r}$$
Where r is the distance of the satellite from the moon and G is the universal gravitational constant of dimensions, $M^{-1}L^3T^{-2}$. Determine the dimensions of the angular momentum, k of the satellite using dimension analysis.
2. A sphere of radius r moving with a velocity v under streamline conditions in a viscous fluid experience a retarding force, F, given by F = krv where k is a constant. Derive the S.I units of k in terms of the basic units

MOTION

Motion involves the change in position of a body with time.

Mechanics is the branch of physics that studies forces and their effects on the motion of objects. There are two branches of mechanics;

Kinematics: is the description of how objects move without regard to forces causing their motion.

Dynamics: deals with why objects move as they do

Types of motion

There are four types of motion;

1. **Random motion**: Random motion is the movement of object in an irregular manner or haphazardly with no preferred direction or orientation
   Examples include:
   i. the movement of gas molecules,
   ii. pollen grains in water during ***Brownian motion***,
   iii. dust particles suspended in air.
   iv. Smoke particles suspended in air.
2. **Translational (or linear) motion:** is the movement of object from one point in space to another without rotating.
   Examples include:
   i. A car moving from Abuja to Lagos
   ii. A boy running a race
   iii. an elevator moving up or down
   iv. a train on a straight track
   v. a person walking on a straight path
   vi. a ball thrown straight up and falling back down.
3. **Rotational motion:** is the movement of object about concentric circles.
   Examples include:
   i. The earth rotating about its axis
   ii. A cricket ball spinning about its axis
   iii. The wheels of a moving car
   iv. The rotation of the blades of an electric fan.
4. **Oscillatory (or vibratory) motion:** this is the to and fro movement of object, reversing the direction of its motion and returning regularly to its original position.
   Examples include:
   i. The motion of a pendulum as it swings back and forth.
   ii. A diving board

iii. The strings of a plucked guitar
iv. The motion of a rocking chair

Causes of motion

Force causes motion. force can move a body, change its direction, slow its

motion or stop its motion.

Types of force.

There are two types of forces, which are,

1. Contact force
2. Force fields

- **Contact force:** These are forces which are in contact or in touch with the body to which they are applied. Examples are: push, pull, tension, reaction and frictional forces.
- **Force fields:** These are forces whose sources do not require contact with the body to which they are applied. Examples are gravitational force, electric force, magnetic force.

RELATIVE MOTION

Relative motion can be defined as the motion of a body with respect to another. All objects moving on the earth surface have relative motion with respect to the earth which is assumed to be stationary. If a boy is standing on a moving train, his speed, with respect to the earth, is the speed of the train. If the boy in the train runs inside the train towards the direction of the train, then his speed with respect to the earth, is the speed of the train plus the speed of the boy. If the boy runs backward, opposite to the direction to the train, then his speed with respect to the earth is the speed of the train minus the speed of the boy.

Example:

Consider two cars A and B approaching each other in the opposite direction. If A moves with a speed of $40Kmh^{-1}$ while B moves at $50kmhr^{-1}$ then the speed with which they approach each other is $40 + 50 = 90kmhr^{-1}$. On the other hand, if both A and B are moving in the same direction at their respective speeds stated above with A ahead of B, then the speed with which B approach A is $50 - 40 = 10kmhr^{-1}$.

Exercise:

Two cars P and Q travelling in opposite directions along the same highway at uniform velocities $110kmh^{-1}$ and $90kmh^{-1}$ respectively pass each other at a certain point. The velocity of X relative to Y at the time they pass each other is?

Circular motion:

An object moving with a uniform speed along a circular path is said to undergo uniform circular motion. Examples of circular motion are:

1. A stone tied to a string and whirled round a horizontal circle.
2. A stone tied to a string and whirled round a vertical circle.
3. A satellite e.g., the moon moving round the earth
4. The earth moving round the sun.

Angular speed and velocity:

Consider a body moving round a circular path as shown in the figure below;

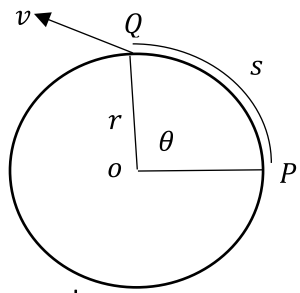


Fig.1

θ = angular displacement

r = radius

v = linear velocity

s = distance of the particle from P to Q

$$\boxed{\theta = \frac{s}{r}}$$

θ is measured in radians, 1 complete revolution in radian is 2π; (i.e., 360° = 2π)

Angular velocity (ω) is defined as the angle turned through, divided by the elapsed time.

$$\omega = \frac{\theta}{t}$$

Relationship between angular speed (ω) and linear velocity (v) is given by;

V = $r\omega$

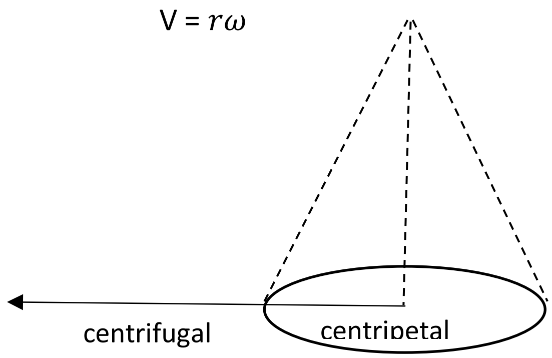


Fig. 2

Centripetal Force

Centripetal force is that inward force required to keep an

object moving with a constant speed in a circular path.

$F_T = \frac{mv^2}{r}$

Where m = mass of moving object

Centrifugal force.

centrifugal force is an equal but opposite force which balances the centripetal force to keep the object moving in a circular path.

Centripetal acceleration:

Centripetal acceleration is given by;

$a = \frac{v^2}{r}$

Where v = speed or velocity

r = radius of circular path

Angular acceleration (α): of a body is the time rate of increase of its angular velocity (ω). The S.I unit is rad/s^2 or rads^{-2}.

$\alpha = \frac{\omega_2 - \omega_1}{t}$

linear acceleration is related to angular acceleration by;

a = αr

linear acceleration(a) is related to the angular velocity;

a = $\omega^2 r$

Example

1. A stone is whirled round a circular path of radius 15cm. If the stone makes 30 oscillations in 10seconds, calculate the angular speed of the stone. [π=3.14]

Solution

Data:

r = 15cm = $\frac{15}{100}$ = 0.15m

$\theta = 30 \times 2\pi = 60\pi\, rev$

t = 10s, $\pi = 3.14$

$$\omega = \frac{\theta}{t}$$

$$\omega = \frac{60\pi}{10} = 6\pi$$

$$= 6 \times 3.14$$

$$= 18.84 rad/s$$

2. Calculate the magnitude of the centripetal force on a particle of mass 5.0×10^{-6} kg revolving round the earth with a radial acceleration of 6.0×10^{7} ms^{-2}.

Solution

Data:

m = 5.0×10^{-6}kg

a = $6.0 \times 10^{7} ms^{-2}$

$$F_T = \frac{mv^2}{r} \text{ since } a = \frac{v^2}{r}$$

$$\therefore F_T = ma$$

$F_T = 5.0 \times 10^{-6} \times 6.0 \times 10^{7}$

$= 30.0 \times 10^{-6+7}$

$= 30.0 \times 10^{1}$

= 300N

3. A stone tied to a string is made to revolve in a horizontal circle of radius 4m with an angular speed of 2 radians per second. With what tangential velocity will the stone move off the circle if the strings cuts.

Solution

Data:

r = 4m, $\omega = 2rad/s$

$$v = \omega r$$

$$= 2 \times 4$$

$= 8m/s$

4. A body is rotating in a horizontal circle of radius 2.5m with an angular speed of 5 $rads^{-1}$. Calculate the magnitude of the radial acceleration of the body.

Solution

Data:

$\omega = 5\ rads^{-1}$, $r = 2.5m$

Radial acceleration $a = \omega^2 r$

$a = 5^2 \times 2.5$

$= 25 \times 2.5$

$= 62.50ms^{-2}$

Class work

1. A body weighing 100N moves with a speed of $5ms^{-1}$ in a horizontal circular path of radius 5m. calculate the magnitude of the centripetal force acting on the body. ($g = 10ms^{-2}$).

Assignment.

1. a particle of mass $10^{-2}kg$ is fixed to the tip of a fan blade which rotates with angular velocity of 100 $rads^{-1}$. Calculate the acceleration of the body towards the centre of the circle.
2. A body moves along a circular path with uniform angular speed of 0.6 $rads^{-1}$ and at a constant speed of $3.0ms^{-1}$. Calculate the acceleration of the body towards the centre of the circle.

Motion: Solid friction

Friction:

Friction is the force which acts at the surface of separation between two bodies in contact and tends to oppose the motion of one over the other.

Types of friction:

Static Friction

Static or limiting friction is the maximum force that must be overcome before a body can just begin to move over another.

Kinetic Friction

Kinetic or dynamic friction is the force that must be overcome so that a body can move with uniform speed over another body.

Advantages of friction

1. It enables us to walk
2. It enables vehicle tyre to make a firm grip with the road.
3. It is used in belt drives, transmitting motion from one pulley to another without slipping.
4. It enables screws and nails to remain in place after being fastened.
5. It enables brakes of vehicles to hold.
6. It is used in grinding stones to sharpen objects because of their abrasive (rough) surfaces.

Disadvantages of friction:

1. It causes wear and tear in machine parts
2. It leads to loss of energy and hence reduces efficiency in machines.
3. It causes the heating of machine parts or engines because the energy used to overcome friction is converted to heat.

Methods of Reducing Friction

1. Use of lubricants such as oil and grease.
2. Use of ball or roller bearings.
3. By streamlining the body. That is by shaping the body so that it can move through other bodies such as air, water, wood etc. with ease. Modern cars, ships and aeroplanes have streamline body.
4. By polishing the surface(s).

Laws of solid friction:

Results of experiments lead to the following laws of solid friction:

1. Friction opposes relative motion between two surfaces in contact.
2. Frictional force increases to the same extent as the force which tends to start the motion.
3. Frictional force depends on the nature of the two surfaces in contact.
4. It is independent of the area of the surfaces in contact.
5. It is directly, proportional to the normal reaction R.

Calculations on friction:

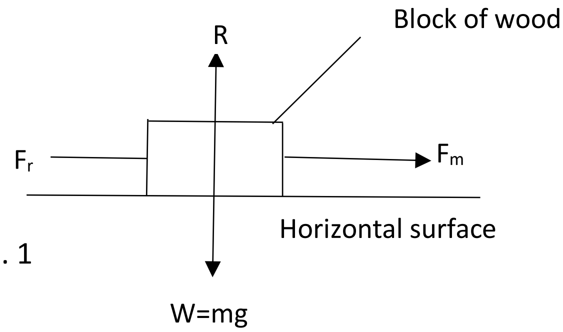


fig. 1

Where F_r = frictional force

F_m = moving force

R = normal reaction

W = weight of the block

The coefficient of static friction(μ) is given by;

$$\mu = \frac{F}{R} = \frac{Frictional\ force}{Normal\ reaction}$$

Thus, coefficient of static friction is defined as the ratio of frictional force F to the normal reaction R.

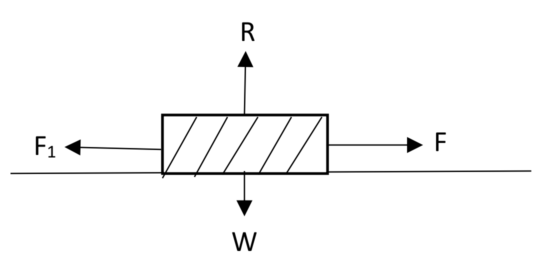
The normal reaction, R is equal to the weight, W of the block i.e.

R = W = mg

F= μR

Example

1. A force of 20N applied parallel to the surface of a horizontal table is just sufficient to make a block 4kg move on table. Calculate the coefficient of friction between the block and the g =10ms^{-2}
   Solution
   Data:
   F = 20N, m = 4kg, g = 10ms^{-2}
   $\mu = \frac{F}{R}$
   $R = W = mg = 4 \times 10 = 40N$
   $\mu = \frac{20}{40}$
   $= \frac{1}{2}$
   $= 0.5$



2. The diagram above illustrates a body of mass 5.0kg, being pulled by a horizontal force F. If the body accelerates at $2.0ms^{-2}$ and a frictional force of 5N, calculate the:
   (i) Net force on it
   (ii) Magnitude of F
   (iii) Coefficient of kinetic friction. [$g = 10ms^{-2}$]

Solution:

(i) Net force = Resultant force, F_r
$F_r = ma$
m = mass of body = 5.0kg, a = acceleration of body = $2.0ms^{-2}$
$F_r = 5.0 \times 2.0 = 10.0N$

(ii) F = applied force
F_r = resultant force (net force) = 10.0N
F_1 = frictional force opposing the applied force = 5N
$F = F_r + F_1$
$F = 10 + 5$
$= 15.0N$

(iii) $\mu = \frac{F_1}{R}$
μ = coefficient of kinetic friction =?
F_1 = kinetic frictional force = 5N
R = Normal reaction of the surface (on which the body moves) on the body.
R = W = weight of body
and W = mg
$R = mg = 5 \times 10 = 50N$
$\therefore \mu = \frac{F_1}{R}$
$= \frac{5}{50}$
$= 0.1$

3. A moving car of mass 800kg experiences a frictional force of 200N. If it accelerates at $2ms^{-2}$, calculate the magnitude of the force applied to the car.
   <u>Solution</u>
   Data:
   m = mass of car = 800kg
   a = acceleration of car =$2ms^{-2}$
   let F_r = resultant force
   $F_r = ma$
   $F_r = 800 \times 2 = 1600N$
   Let P = applied force;

F = frictional force = 200N

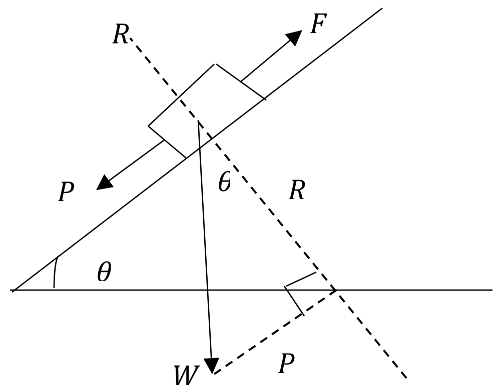
Now P = F_r + F

$\therefore$ P = 1600 + 200 = 1800N

Friction of an incline plane:

The coefficient of static friction, μ between two surfaces in contact, say, between two wooden surfaces can be determine, using inclined plane as follows;

Consider the diagram below;



Where;

W = Weight of block

R = Normal reaction of plane on block

F = Static frictional force

P = force tending to slide the block down the plane

Now $sin\theta = \frac{P}{W}$

P = $Wsin\theta$

But F = P

$\therefore$ F = W sin θ -------------------(1)

Also, $cos\theta = \frac{R}{W}$

$\therefore$ R = $Wcos\theta$ ------------------------ (2)

But $\mu = \frac{F}{R}$ as earlier defined.

$\therefore \mu = \frac{F}{R} = \frac{W\sin\theta}{W\sin\theta} = \frac{\sin\theta}{\cos\theta}$

But $\frac{\sin\theta}{\cos\theta}$ = tan θ

$\therefore\ \mu = \frac{F}{R}$ = tanθ -----------------------(3)

Thus, the coefficient of static friction using inclined plane is given by

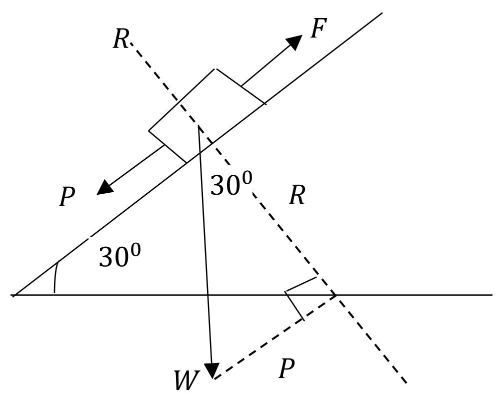
μ = tanθ

Example

A crate of drinks of mass 20kg is placed on a plane inclined at 30^0 to the horizontal. If the crate slides down with a constant speed, calculate the;

(i) co–efficient of kinetic friction
(ii) magnitude of frictional force acting on the crate. [g = $10ms^{-2}$]

solution

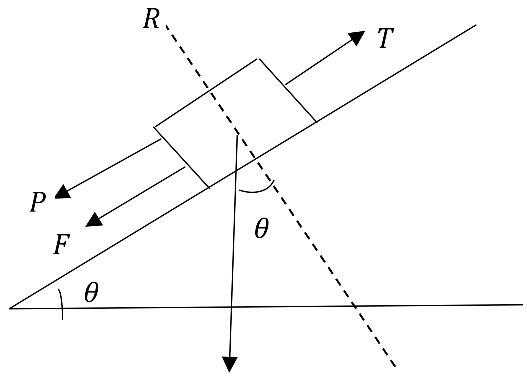


(i) The coefficient of kinetic friction is given as
μ = tan θ
μ = tan 30^0
= 0.577

(ii) Since the crate slide down with constant speed then
F = P = frictional force acting on the crate
but P = component of the weight of crate along the plane
P = mg sinθ
= 20 × 10 × sin 30^0
= 200 × 0.5 = 100N
∴ F = 100N

When the block is to be moved up the inclined plane

When the block is to be moved up the inclined plane, the force parallel to the plane which will just move the block up the inclined plane is obtained as follows:



W = weight of block

R = Normal reaction of plane on block

F = Static frictional force

P = Force parallel to the plane which tend to pull the block down the plane – component of gravitational force

T = Force parallel to the plane which will just move the block up the plane.

But T = P + F

Now P = $WSin\,\theta$

But W = mg

$\therefore$ P = mg sin θ ----------------------(4)

m = mass of block

g = acceleration due to gravity

From (3), F = μR

$\therefore$ T = mg sin θ + μR ---------------(5)

But μ = tan θ and

R = W cos θ

R = mg cos θ

T = mg sin $\boldsymbol{\theta}$ + µ$\boldsymbol{mg\cos\theta}$

$\therefore$ T = mg sin $\boldsymbol{\theta}$ + tan$\boldsymbol{\theta}$ $\boldsymbol{mg\cos\theta}$

Since T = F = ma, (5) becomes;

$ma = mgsin\theta + \mu R$

$\therefore a = \frac{mgsin\theta + \mu R}{m}$ ----------------(6)

Force parallel to the plane which tend to pull the block down the plane.

P = T – F

$\therefore \boldsymbol{P} = \text{mgsin}\theta \ - \text{F}$ **---------------(7)**

$\text{P} = \text{mgsin}\theta - \ \mu R$

$P = mgsin\theta - \mu mgcos\theta$

$P = mgsin\theta - tan\theta mgcos\theta$

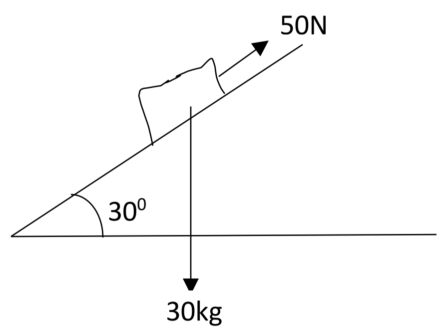
$\therefore a = \frac{mgsin\theta - \mu R}{m}$ --------------(8)

Example

1. The diagram below shows a body resting on an inclined plane. If the body slides down the plane, calculate the;

   (a) the force that makes the object to slide down the plane.

   (b) acceleration (g = 10 ms^{-2}).



Solution

Data:

$\text{F} = \text{frictional force} = 50\text{N}, \text{m} = 30\text{kg}, \theta = 30^0$

(a) P = Force parallel to the plane which tend to pull the block down the plane

$\boldsymbol{P} = \text{mgsin}\theta \ - \text{F}$

P = 30 x 10 x sin 30^0 – 50

= 300 x 0.5 – 50

= 150 – 50

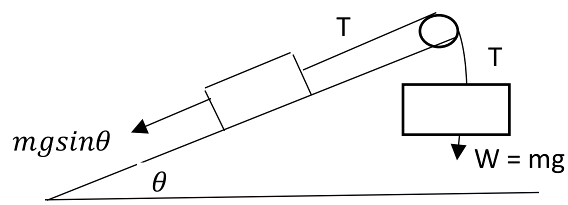
= 100N

(b) $a = \frac{mgsin\theta - \mu R}{m}$

$\therefore a = \frac{P}{m}$

$= \frac{100}{30} = 3.33ms^{-2}$

If a pulley is attached at the plane as shown below;



The tension (T) in the pulling the body up the plane is given by;

$T - mgsin\theta = ma$ ------(1)

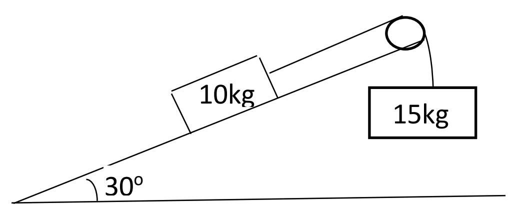
When the body is pulled vertically downwards along a pulley, the tension in the string is given by;

$W - T = ma$

$mg - T = ma$ --------(2)

(1) & (2) is combined to solve for the tension and acceleration.

Example



A body of mass 10kg on a smooth inclined plane is connected over a smooth pulley to a mass of 15kg as shown in the figure above. Calculate the acceleration of the system.

Solution

For 10kg mass, $T - mgsin\theta = ma$

$T - 10 \times 10 \times \sin 30 = 10a$

$T - 50 = 10a$ .... (1)

For 15kg mass, $mg - T = ma$

$15 \times 10 - T = 15a$

$150 - T = 15a$

Rearranging, $-T + 150 = 15a$ .... (2)

Add equation (1) & (2)

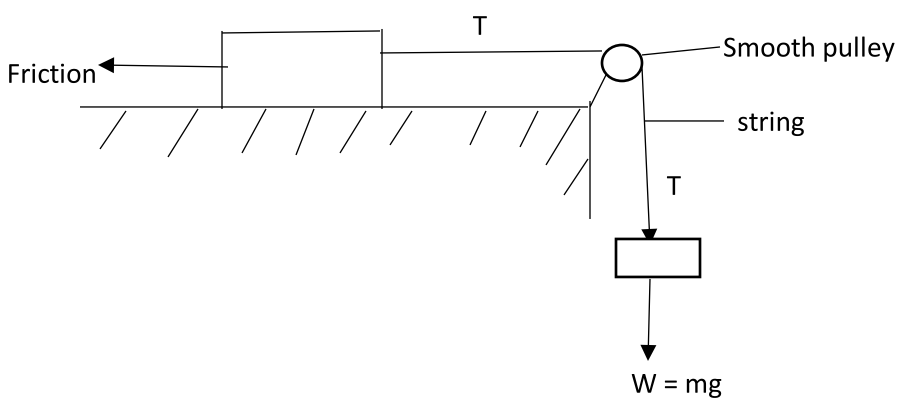
$$\begin{array}{r} T - 50 = 10a \\ \underline{-T + 150 = 15a} \\ 0 + 100 = 25a \end{array}$$

$\therefore 100 = 25a$

$a = \frac{100}{25}$

a = $4ms^{-2}$

If a pulley is attached in a smooth horizontal plane as shown below;



The tension on the string when the body is dragged horizontally is given by;

T - μR = ma -----------(1)

When the body is pulled vertically downwards, the tension is given by;

W – T = ma

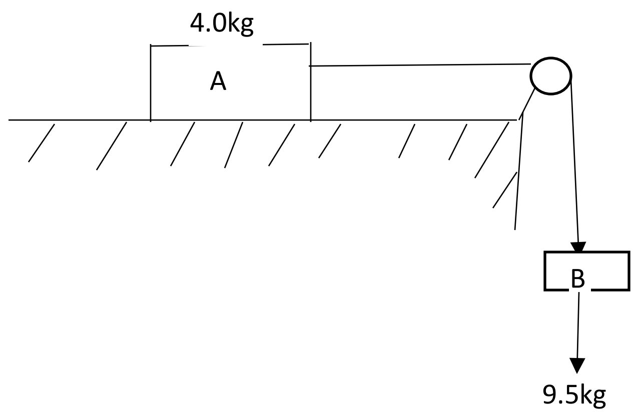
mg – T = ma ------------(2)

(1) & (2) is combined to solve for the tension and acceleration.

Example

Two bodies A and B of masses 4.0kg and 9.5kg respectively, are connected by a light inextensible string as illustrated in the diagram below. If A is placed on a rough surface of coefficient of friction 0.5, calculate the magnitude of the:

i. Normal reaction on A
ii. Frictional force between A and the surface,
iii. Tension in the string ($g = 10ms^{-2}$)



Solution

i. Normal reaction on A is, R = mg

  = 4 x 10 = 40N

ii. Frictional force, F = μR

  = 0.5 x 40 = 20N

iii. For 4kg mass, $T - \mu R = ma$

  $T - 0.5 \times 40 = 4a$

  $T - 20 = 4a$ .... (1)

  For 9.5kg mass, $mg - T = ma$

  $9.5 \times 10 - T = 9.5a$

  $95 - T = 9.5a$

Rearranging, $-T + 95 = 9.5a$ .... (2)

Add (1) & (2)

$$\begin{array}{r} T-20 = 4a \\ \underline{-T+95 = 9.5a} \\ 0+115 = 13.5a \end{array}$$

$\therefore 115 = 13.5a$

$a = \frac{115}{13.5}$

$= 8.52ms^{-2}$

Substitute a = 8.52 in (1)

$T - 20 = 4 \times 8.52$

$T - 20 = 34.08$

$T = 34.08 + 20$

$T = 54.08N$

Viscosity - friction in fluids

Viscosity is the internal friction between layers of a liquid or gas in motion. It is a measure of a liquid's resistance to flow.

Liquids which pour slowly and flow slowly are said to be more viscous than those which pour and flow faster. For example, palm oil is more viscous than water and engine oil is more viscous than kerosene.

Similarities between viscosity and solid friction

i. Both forces oppose relative motion between surfaces.
ii. Both depend on the nature of materials in contact.

Differences between viscosity (fluid friction) and solid friction

i. Solid friction does not depend on areas of surfaces in contact, while viscosity depends on area of surfaces in contact.
ii. Friction is dependent on normal reaction, while viscosity is not.
iii. Friction occurs in Solids while Viscosity takes place in fluids (Liquids and gases)
iv. Friction does not depend on the relative velocities between two layers, while viscosity depends on the relative velocity between layers.

Application of viscosity

1. Lubrication of machine parts
2. Paints and coatings
3. Adhesives
4. Ink
5. Hydraulic systems
6. Cosmetics

Effects of viscosity are:

1. Reduces the rate of flow: fluids with high viscosity flow more slowly than fluids with low viscosity. Example, honey flows more slowly than water.

2. Cause friction within the fluid: viscosity creates internal friction between layers of a moving fluid, resisting motion.
3. Converts mechanical energy to heat: due to internal friction, some energy is lost as heat when a fluid flows.
4. Affect the movement of object through fluids: high viscosity increases resistance (drag) experienced by objects moving through a fluid. Example a swimmer moves more slowly in syrup than in water.
5. Affects pumping and transportation: highly viscous liquids require more force and energy to pump through pipes.
6. Influences lubrication: fluids with the correct viscosity reduce wear and friction between moving machine parts. If the viscosity is too low or high, lubrication becomes less effective.
7. Influences settling of particles: particles settle more slowly in highly viscous liquids because the fluid offers greater resistance.

Factors affecting viscosity

1. Temperature:

    a. Liquids: as temperature increases, viscosity decreases because the molecules move more freely.

    b. Gases: as temperature increases, viscosity increases due to more frequent molecular collisions.

2. Molecular size and shape: fluids with larger or more complex molecules tend to have higher viscosity because the molecules resist flowing past one another.

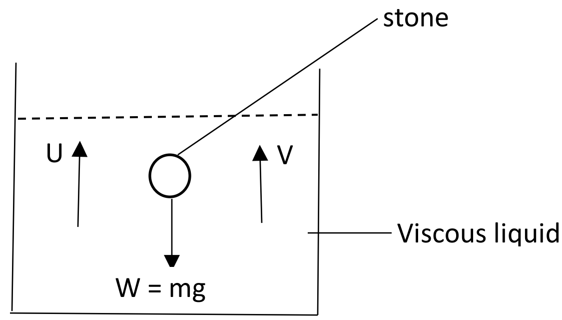
Other factors are; nature of the fluid, pressure, concentration dissolve suspended substance.

Laws of Liquid friction

1. Area of contact: fluid friction increases with the area of contact between the fluid and the surface it is interacting with.
2. Velocity gradient: fluid friction increases with the velocity gradient, which is the difference in speed between adjacent layers of the fluid.
3. Viscosity: the higher the viscosity of a fluid, the greater the frictional force. Viscosity is a fluids resistance to flow, with thicker fluids like honey having higher viscosity than less viscous fluids water.

Terminal Velocity

Terminal velocity is defined as the maximum constant velocity an object reaches when falling through a fluid.



When a stone falls through a viscous liquid, it is acted upon by three forces:

i. The weight W of the stone
ii. The upthrust U of the liquid on the stone
iii. The viscous force V opposing the motion of the stone.

W acts downwards while U and V act upwards. Initially the stone accelerates down the viscous liquid and the equation of motion is given as

$$W - V - U = ma$$

Where m = mass of stone,

a = acceleration of stone through the liquid.

But W = mg

However, as the velocity of the body increases, the viscous forces increase. A point is reached when the sum of viscous forces and upthrust balances the weight of the stone and it no longer accelerates but it moves with uniform velocity and the stone is said to attain terminal speed/velocity.

The new equation of motion is given as:

$$W - V - U = ma = 0$$

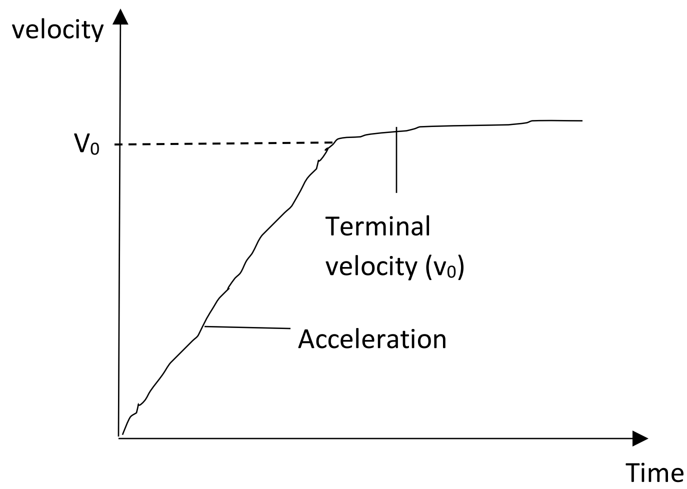
Since $a = 0$

$$\therefore\ W - V - U = 0$$

$W = V + U$ and

$$V = W - U$$

The velocity time graph of the motion is given below.



Raindrops whose motion is opposed by the viscosity of air attains a terminal velocity before reaching the ground. This is why it is not harmful when it strikes a person.

Factors influencing Terminal Velocity

1. Mass: The heavier object will have a greater gravitational force.
2. Shape and surface area: Objects with a larger surface area like parachute create more drag and thus have a lower terminal velocity
3. Fluid density: The denser the fluid (air), the greater the drag force and the lower the terminal velocity.

SCALARS AND VECTORS

Scalar quantities (scalars)

Scalar quantities are those which have only magnitude or numerical value but have no direction.

Examples of scalars are: Distance (length), mass, time, volume, density, speed, temperature, energy etc.

Vector quantities (vectors)

Vector quantities are those which have both magnitude and direction.

Examples of vectors are: Displacement, velocity, acceleration, weight, force, momentum, electric field etc.

Differences between scalars and vectors

Scalars	Vectors
1. Have magnitude only	Have both magnitude and direction
2. Can be described or specified completely by indicating only its magnitude	Cannot be specified or described completely with magnitude. Direction most be inclined

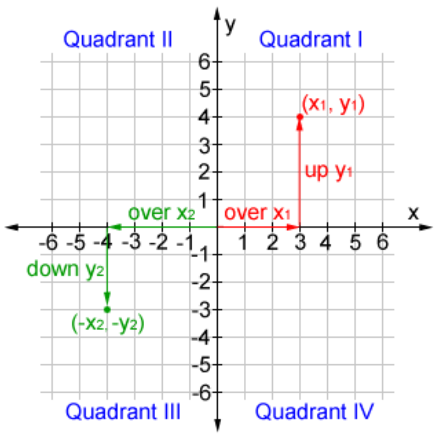
3. They are added by ordinary methods	They are added by geometrical method

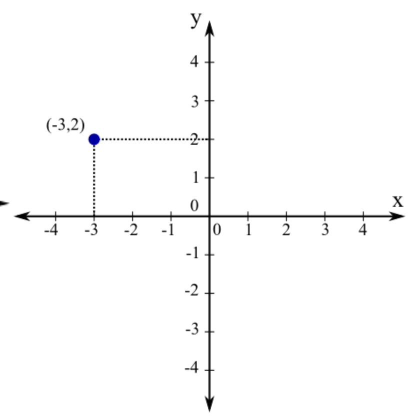
Concept of position distance and displacement.

Position.

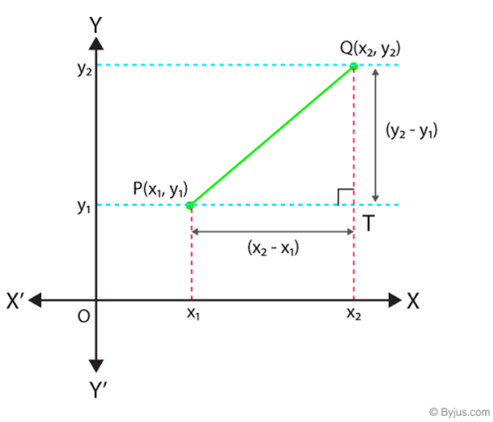
The position of an object or particle is its location or point in space. It is determined by its distance and direction from a reference point. The reference point is usually called the origin and is in terms of a particular frame of reference.

- The two-dimensional frame of reference (x, y coordinates)





Distance between two points in a cartesian plane:



The distance between P and Q is given by;

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$$

Example

Find the distance between the points P (5, –2) and Q (–3, 4).

Solution

$$d = \sqrt{(-3-5)^2 + (4-(-2))^2}$$

$$d = \sqrt{(-8)^2 + (6)^2}$$

$$d = \sqrt{64+36}$$

$$d = \sqrt{100}$$

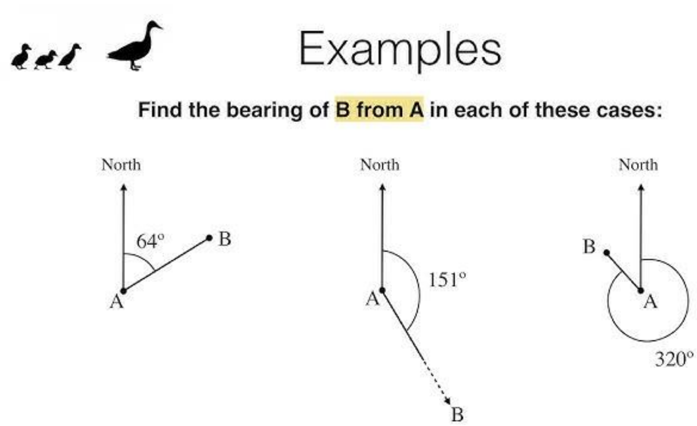
d = 10 units

Bearing

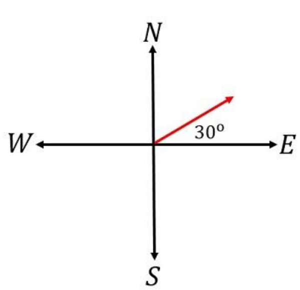
Bearing can be represented in two ways namely: -

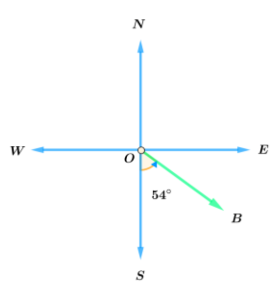
i. The three digits bearing or
ii. The compass bearing

The three digits bearing:



Compass bearing





$N30^0E$ $S54^0E$

Distance and Displacement

Distance

Distance is the difference/interval between one position and another. It is also how far a body has travelled from, the original position.

The S.I. unit of distance is metre(m).

In talking of distance, we do not consider direction because the magnitude of the change in position is enough to describe it, since it is a scalar quantity. Examples of distance are: 20km, 5km, 60m 40m etc.

Displacement

Displacement is defined as distance traveled in a specified direction. It is a vector quantity. Examples of displacement are; 50km North, 255km due East, etc.,

Differences between distance and displacement

Distance	Displacement
Distance is the total length of the actual path travelled by an object.	Displacement is the shortest straight-line distance between the initial and final positions of an object.
It is a scalar quantity (has only magnitude).	It is a vector quantity (has both magnitude and direction).
It has no direction.	It always has a specific direction.
It is always positive or zero.	It can be positive, negative, or zero, depending on the direction.
Distance is always greater than or equal to displacement.	Displacement is always less than or equal to distance.
It depends on the actual path taken.	It depends only on the initial and final positions.

Concept of speed and velocity

Speed

Speed is defined as the time rate of change of distance. It is distance travelled per unit time. It is a scalar quantity.

$$\text{Speed} = \frac{distance}{time}$$

$$\bar{v} = \frac{s}{t}$$

This speed is actually an average speed $\bar{v}$

s = distance covered

t = time taken to cover the distance

The S.I. unit of speed is metre per second (ms^{-1})

Example

What is the distance covered by a car which travels with a constant speed of $30.5ms^{-1}$ for 15s?

Solution

Given

Speed = 30.5ms-1 time = 15s distance =?

$$\text{Speed} = \frac{distance}{time}$$

∴ distance = speed x time

Distance = 30.5 x 15

= 457.5m

Uniform speed or constant speed

A body is said to undergo uniform speed when its time rate of change of distance is constant. That is, when it covers equal distances in equal time interval. E.g., A body starts from rest and cover 6m after 3s, 12m after 6s, 18m after 9s.

Velocity

Velocity is defined as the time rate of change of displacement. It is displacement per unit time.

$$\text{velocity} = \frac{displacement}{time}$$

$$v = \frac{s}{t}$$

where v is velocity

s = displacement

t = time.

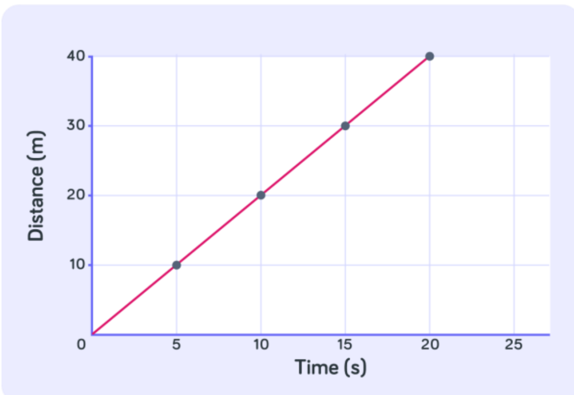
The S.I unit of velocity is metre per second (ms^{-1})

Uniform velocity or constant Velocity

A body is said to undergo uniform velocity when its time rate of change of displacement is constant. That is, the body displaces equal amounts in equal time intervals. E.g., a body starts from rest and displaces 4m after 2s, 8m after 4s, 12m after 6s, 16m after 8s and 20m after 10s.

Distance – time graph

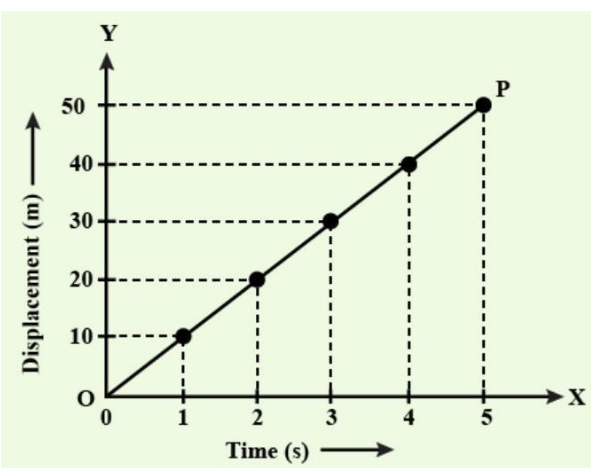
This is the graph of distance on the vertical axis against time on the horizontal axis.



The gradient or slope of a distance – time graph gives speed

Displacement – time graph

This is the graph of displacement on the vertical axis against time on the horizontal axis.



The gradient or slope of a displacement – time graph

Instantaneous velocity

Instantaneous velocity is defined as the velocity at any instant of time. The speedometers of moving vehicles indicate instantaneous velocity.

Rectilinear acceleration

Concept of acceleration

Acceleration

Acceleration is the time rate of increase in velocity. It is increase in velocity per unit time.

$$\text{Acceleration} = \frac{increase\ in\ velocity}{time\ taken\ for\ the\ increase}$$

The S.I unit of acceleration is $ms^{-2.}$

$$\text{Acceleration} = \frac{final\ velocity - initial\ velocity}{time}$$

Given that;

acceleration = a

Final velocity = v

Initial velocity = u

Time = t

$$a = \frac{v-u}{t}$$

Retardation

Retardation is the time rate of decrease in velocity. Retardation is negative acceleration. It is also called deceleration.

Uniform acceleration

A body is said to undergo uniform acceleration when the time rate of increase in velocity is constant. That is, the velocity increases by equal amount in equal time intervals. E.g., A body starts from rest and its velocity becomes $5ms^{-1}$ after 2s, $10ms^{-1}$ after 4s, $15ms^{-1}$ after 6s.

Equations of uniform accelerated motion

From the definition of acceleration

1. Acceleration = $\frac{increase\ in\ velocity}{time\ taken\ for\ the\ increase}$

$a = \frac{v-u}{t}$

$\therefore v - u = at$

$\boldsymbol{v = u + at}$ ---------------------------(1)

2. Under uniform acceleration average velocity $\bar{v}$ is given by $\bar{v} = \frac{v+u}{2}$

   But average velocity is also given as $\bar{v} = \frac{s}{t}$

   $\therefore \frac{v+u}{2} = \frac{s}{t}$

   $2s = (v + u)t$

   $\boldsymbol{s = \frac{(v+u)t}{2}}$ --------------------(2)

3. From equation (1) $\boldsymbol{v = u + at}$

   Put (1) in (2)

   $s = \frac{(u+u+at)t}{2}$

   $s = \frac{(2u+at)t}{2}$

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

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

   $\boldsymbol{s = ut + {}^{1}/_{2}\, at^2}$ ------------(3)

4. From equation (1)

   $v = u + at$

   $v - u = at$

   $\therefore t = \frac{v-u}{a}$

Substitute t in equation (2)

$s = \frac{(v+u)}{2} \frac{(v-u)}{a}$

$s = \frac{v^2-uv+uv-u^2}{2a}$

$s = \frac{v^2-u^2}{2a}$

$\therefore v^2 - u^2 = 2as$

$\therefore \boldsymbol{v^2 = u^2 + 2as}$ -------------(4)

<u>Examples</u>

1. A boy cycles continuously through a distance of 1.0km in 5 minutes. Calculate his average speed in ms^{-1}
2. A particle starts from rest and moves with a constant acceleration of $0.5ms^{-2}$. Calculate the time taken by the particle to cover a distance of 25m.
3. An aeroplane lands on a runway at a speed of $180kmh^{-1}$ and is brought to a stop uniformly in 30 seconds. What distance does it cover on the runway in ms^{-1} before coming to rest?
4. If a car starts from rest and moves with a uniform acceleration of $10ms^{-2}$ for ten seconds, the distance it covers in the last one second of motion is?
5. A bird flies at $10ms^{-1}$ for 3s, $15ms^{-1}$ for 3s, and $20ms^{-1}$ for 4s. Calculate the bird's average speed.

Class work

1. A car moving with a speed of $144kmhr^{-1}$ slow down with a uniform retardation of magnitude $10ms^{-2}$. How far will it travel before it comes to rest?
2. A car starts from rest and accelerates uniformly at a rate of $5.0ms^{-2}$. Calculate the magnitude of its velocity after moving through 100m.

Assignment

1. A body starts from rest and accelerates uniformly at $5ms^{-2}$. Calculate the time taken by the body to cover a distance of 1km.
2. If a car starts from rest and moves with a uniform acceleration of $9ms^{-2}$ for 10s. what distance does it cover in the:
   i. Last one second of motion
   ii. Fifth second of motion

Equation of motion under gravity:

When an object is thrown upward, Earth's gravitational force slows it down until it reaches its maximum height, after which it falls back to the ground. The object experiences retardation while moving upward and acceleration due to gravity (g) while moving downward. The value of g is approximately 9.81 m/s^2, but it is commonly taken as 10 m/s^2 for convenience.

When an object is moving upward g is negative because is moving against gravity and an object is moving downwards g is positive because it is moving with gravity.

Equations of motion under gravity are obtained by replacing ***s*** and ***a*** in equations (1), (3), and (4) with ***h*** and ***g*** respectively as follows:

	Upward motion -g	Downward motion +g
1.	$\boldsymbol{v = u - gt}$	$\boldsymbol{v = u + gt}$
2.	$\boldsymbol{h = ut - {}^{1}/_{2}\, gt^2}$	$\boldsymbol{h = ut + {}^{1}/_{2}\, gt^2}$

3. $v^2 = u^2 - 2gh$ $\qquad\qquad$ $v^2 = u^2 + 2gh$

Note that:

- When a body starts from rest, u = 0

- When a body is brought to rest, v = 0

Thus, for an upward motion, v = 0 at the maximum height reached. For downward motion, u = 0 at the height from which the object is released.

Example

1. An object is dropped from the top of a tower. If it takes 4s for it to reach the ground, calculate the height of the tower. [g = $10ms^{-2}$, ignore air resistance]
2. A bullet fired vertically upward reaches a height of 500m. Neglecting air resistance, calculate the magnitude of the initial velocity of the bullet. [g = $10ms^{-2}$]
3. An orange is dropped from a height of 100m above the ground level. Calculate the velocity of the orange just before it strikes the ground. [g = $10ms^{-2}$]
4. A stone is projected vertically upward with a speed of $30ms^{-1}$ from the top of a tower of height 50m. Neglecting air resistance, determine the maximum height it reached
5. A small metal ball is thrown vertically upwards from the top of a tower with an initial velocity of 20 ms^{-1}. If the ball took a total of 6 seconds to reach the ground level, determine the height of the tower. [g = 10 ms^{-2}]

Class work

1. An object is released from rest at a height of 25m. Calculate the time it takes to fall to the ground. [g = $10ms^{-2}$]
2. A stone of mass 0.7kg is projected vertically upwards with a speed of $5ms^{-1}$. Calculate the maximum height reached. [g = $10ms^{-2}$]

Assignment

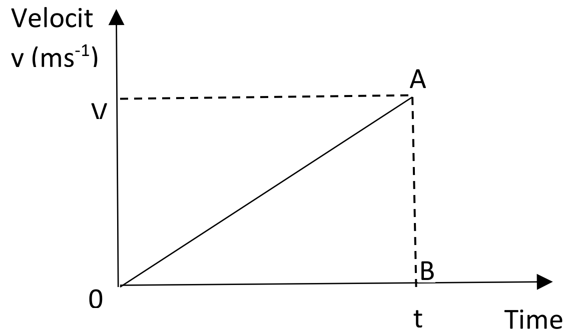
1. A body is projected vertically upwards with a speed of $10ms^{-1}$ from a point 2m above the ground. Calculate the total time taken for the body to reach the ground.
2. A bullet fired vertically upwards from a gun held 2m above the ground, reaches its maximum height in 4s. Calculate the;
   i. magnitude of the initial velocity of the bullet.
   ii. total distance the bullet travelled by the time it hit the ground [g = $10ms^{-2}$]

Rectilinear acceleration

Velocity – time graph

The velocity-time is a graph with velocity on the vertical axis and time on the horizontal axis e.g.

i. Velocity-time graph for a body which accelerates uniformly from rest to a velocity v



distance travelled is given by the area under the graph OA = area of triangle OAB

$= \frac{1}{2}$ OB × BA

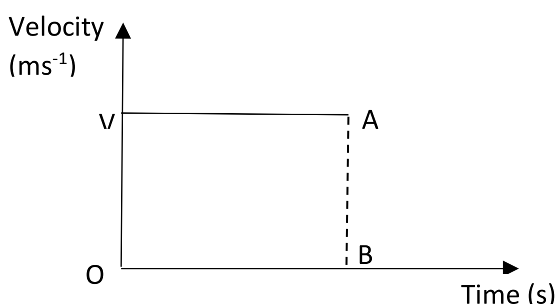
$= \frac{1}{2}$ tv

The uniform acceleration is given by the gradient of the graph OA

$$= \frac{BA}{OB}$$

$$= \frac{v}{t}$$

ii. Velocity-time graph for a body moving with uniform velocity v



Distance = area under graph VA

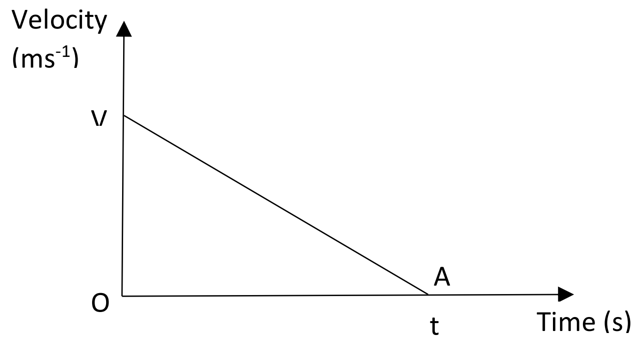
= area of rectangle OVAB

= OV × OB

= vt

Gradient of graph VA is zero and hence acceleration is zero

iii. Velocity time graph for a body which decelerates uniformly from a velocity v to rest

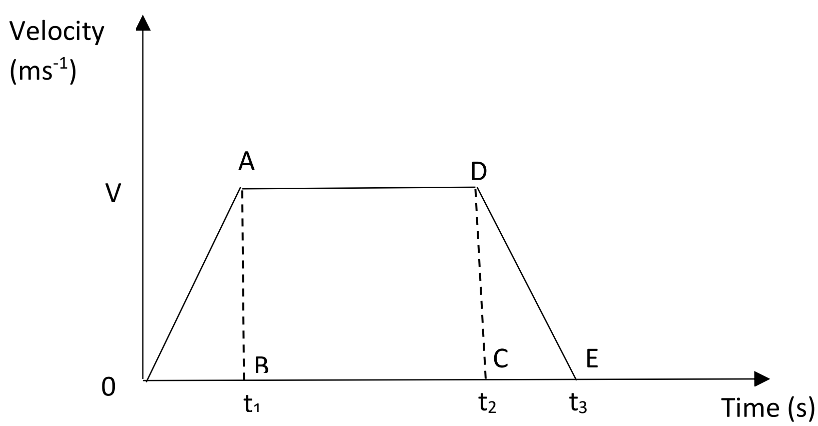


Distance = area of triangle OVA

Uniform retardation = gradient of VA

$= \frac{OV}{OA} = \frac{-V}{t}$

iv. Velocity-time graph of a body which accelerates uniformly from rest until it attains a velocity v. it then moves with this velocity v for some time before it decelerates uniformly to rest.



Distance = area under the graph

= area of trapezium OADE

= ½ (OE + AD) × OV

= ½ [t_3 + (t_2 - t_1)] v

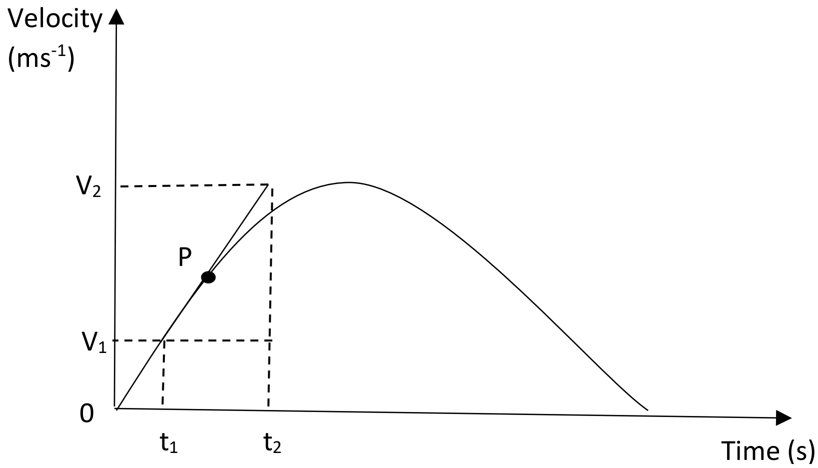
Uniform acceleration = gradient of OA = $\frac{V}{t_1}$

uniform velocity is represented by AD

uniform deceleration is the gradient of DE

$= \frac{0-V}{t_3-t_2}$

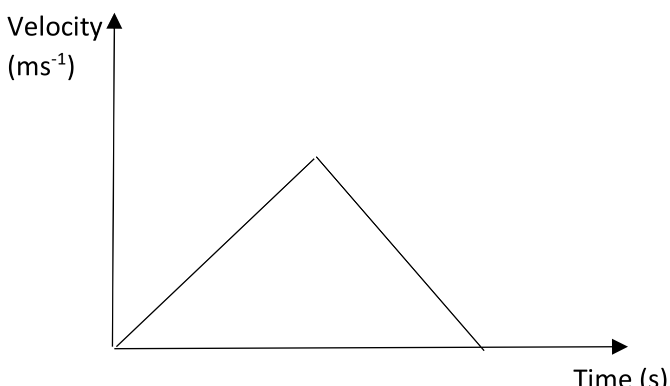
v. A body which accelerates non-uniformly from rest and then decelerates non-uniformly to rest



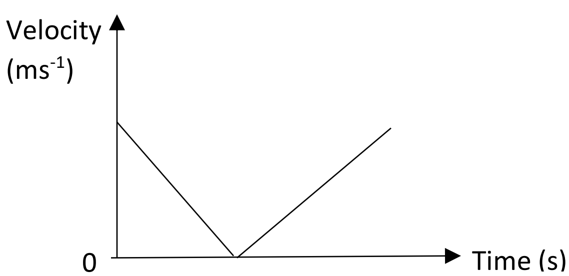
The acceleration at any instant is the gradient of the tangent to the curve at any point

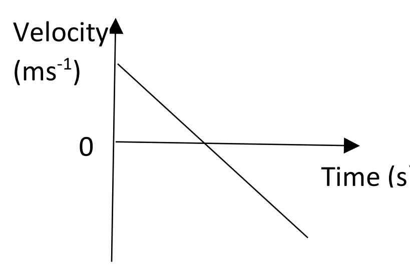
$$P = \frac{v_2 - v_1}{t_2 - t_1}$$

vi. A body which accelerates uniformly from rest and then decelerates uniformly to rest e.g., a lift moving from one floor to another floor of a tall building.



vii. A ball thrown vertically upwards and returns to the point of throw.

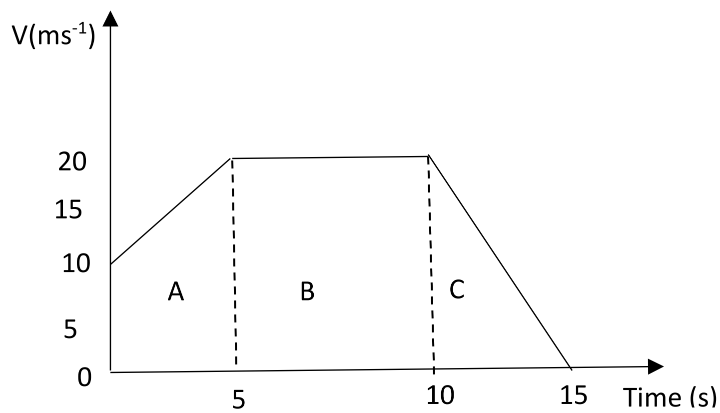




Here the direction of motion is not considered. Here the direction of motion is considered.

Example

1. A car starts from rest and accelerates uniformly for 5s, until it attains a velocity of 30ms–1. It then travels with uniform velocity for 15s before decelerating uniformly to rest in 10s.
    (i) Sketch the graph of the motion
    (ii) Using the graph in c(i) above calculate the
        a. acceleration during the first 5s.
        b. deceleration during the last 10s,
        c. total distance covered throughout the motion.
2. The diagram below illustrates the velocity – time graph of the motion of a body. Calculate the acceleration and the total distance covered by the body.



Classwork

1. A body at rest is given an initial uniform acceleration of $6.0ms^{-2}$ for 20s after which the acceleration is reduced to $4.0ms^{-2}$ for the next 10s. The body maintains the speed attained for 30s. Draw the velocity- time graph of the motion using the information given above. From the graph, calculate the
    a. maximum speed attained during the motion;
    b. total distance travelled during the first 30s;
    c. average speed during the same time interval as in (b) above

Assignment

1. A car starts from rest at a check point A and comes to rest at the next check point B, 6km away, in 3 minutes. It has first, a uniform acceleration for 40s, then a constant speed, and is brought to rest with a uniform retardation after 20s. Sketch a velocity – time graph of the motion. Determine
    (i) the maximum speed;
    (ii) the retardation

2. A body starts from rest and travels distances of 120, 300 and 180m in successive equal time intervals of 12s. During each interval the body is uniformly accelerated.
    a. Calculate the velocity of the body at the end of each successive time interval.
    b. Sketch a velocity-time graph for the motion.

Work, Energy and power

Work

Work is said to be done when a force applied to a body moves the body a distance in the direction of the force.

Work is also defined as the product of the force and the distance in the direction of the force. From the definition,

Work = force × displacement

$W = FS$

The S.I unit is joule (J)

Conditions to be made before work is said to be done:

1. A force must be applied.
2. The force must cause the body to which it is applied to move through a distance.
3. The distance moved must be in the direction of the force.

Examples

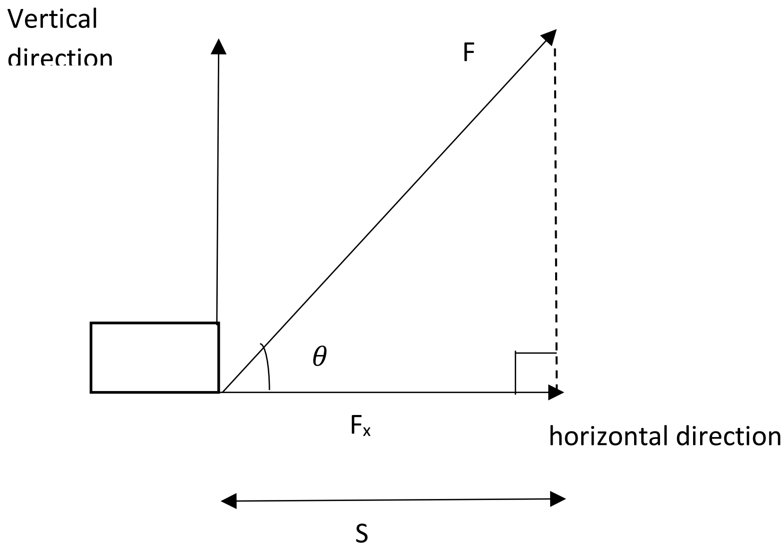
1. A table being pushed from one point to another on a floor.
2. A bucket of water being lifted from the ground.
3. A man climbing a tree.
4. A man climbing a set of steps.

WORK DONE IN A FORCE FIELD

Work done when the force is inclined

When the force, F applied to the body is inclined at angle to the horizontal as shown:

If the body moves through a horizontal distance, S then it is only the horizontal component of the force that has done the work.



The horizontal component of the force is F_x

Work done = F_xS

But $F_x = F cos\theta$ $\quad\quad\quad\quad$ ($cos\theta = \frac{F_x}{F}$)

Work done = ($Fcos\theta$) x S

= $Fcos\theta$ x S

= mg $cos\theta$ x S

If the box moves in the vertical direction, the work done (W) is

W = $Fsin\theta$ x S

W = mg sinθ x S

The box does not move in any direction, the displacement or distance is zero, therefore the work done (W) is

W = F x 0 = 0

That is, work done is zero or there is no work done even though force was applied.

Example

A load is pulled 5m along a horizontal floor by a constant force of 20N which acts at 30° to the floor. Calculate the work done by the force.

Workdone in a force field

1. Lifting a body: The weight of a body is the gravitational force exerted by the Earth on it. When a body is lifted, work is done against gravity, because the lifting force must overcome the body's weight. The work done is given by
   Work = mgh

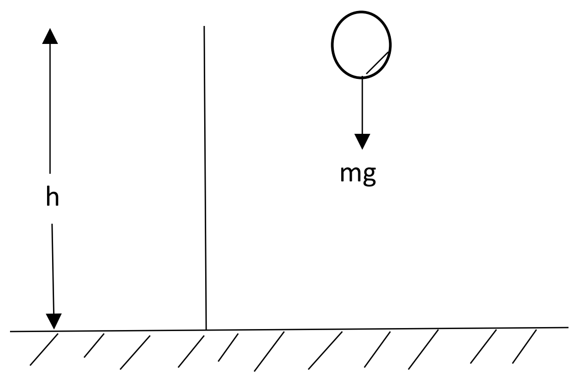
Where m = mass of the body

g = acceleration due to gravity

h = height through which the body was lifted

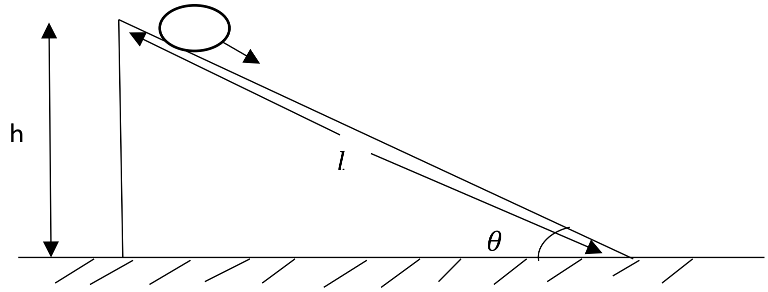
2. **Falling bodies:** When a body falls freely, the force of gravity does work on the body. The force of gravity is the weight of the body which pulls it downward. Three cases are possible.

i. A body falling vertically downwards:



Work = mgh

ii. A body falling down an incline plane.



It is the vertical height that is used to calculate work done.

But where the length l of the plane is given h can be obtained as follows:

$\sin\theta = \frac{h}{l}$

h = $l sin\theta$

θ = angle of inclination of the plane to the horizontal

∴ work done = $mgl sin\theta$

iii. climbing a set of steps:

Work done = mgh

Example

A load of mass 80kg fell down from the floor of a lorry which is 1.3m high. Calculate the work done by gravity on the load. [g = $10ms^{-2}$]

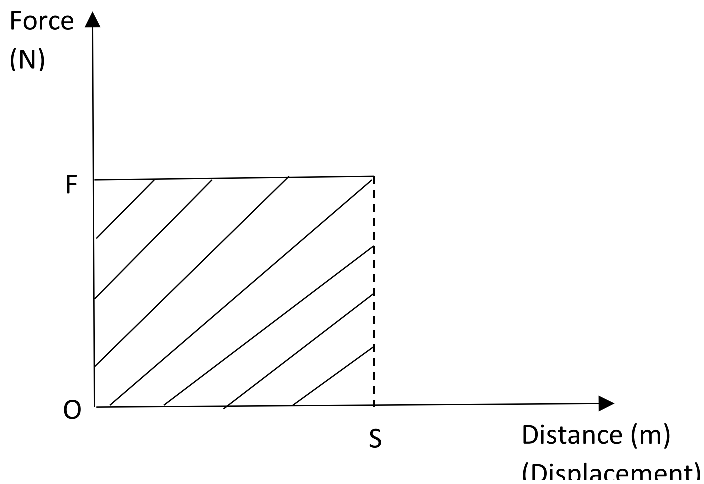
<u>Class work:</u>

A load of mass 125kg fell down from the floor of a lorry which is 5.8m high. Calculate the work done by gravity on the load. [g = $10ms^{-2}$]

FORCE – DISTANCE GRAPH

Force – distance graph is a graph with force on the vertical axis and distance on the horizontal axis. The area under a force distance graph gives work done. Two cases are shown below:

1. Force is constant throughout the distance moved.

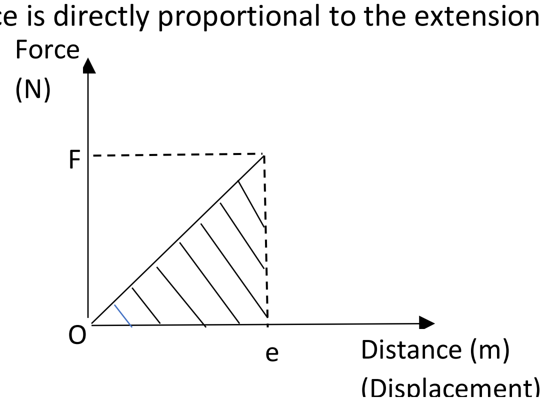


Work done = area of shaded rectangle under the graph

Work done = F x s

Example is a push or a pull

2. Force varies with the distance moved Here the distance is better called extension (e). The force is directly proportional to the extension



Work done = area of shaded triangle under the graph

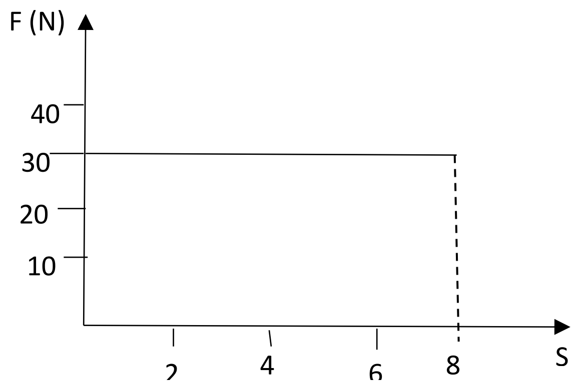
Work done = ½ e × F

= ½ Fe

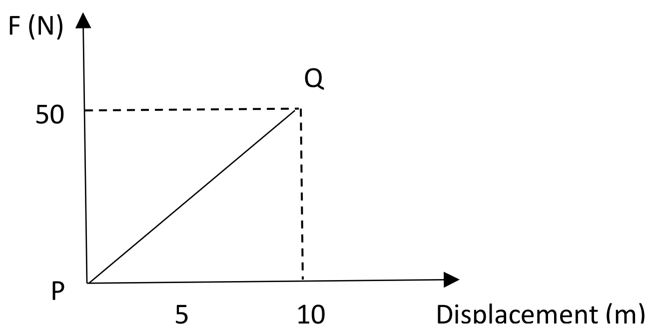
Example is the work done in stretching an elastic material e.g., catapult or spring.

Example:

1. The diagram below illustrates a force – distance graph for the motion of a wooden block. Determine the work done on the block when moved through a distance of 8m.

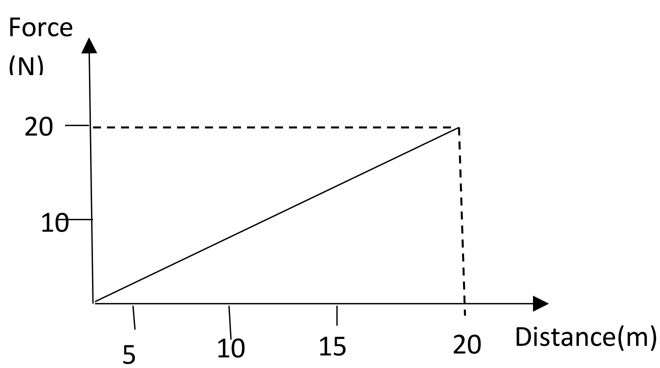


2.



using the force – displacement diagram above, calculate the workdone.

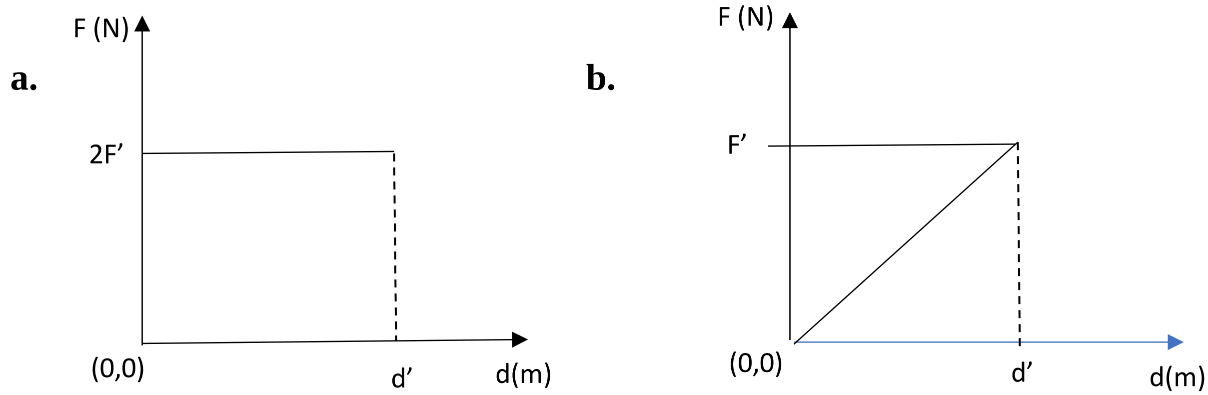
Classwork



A force varying linearly with the distance acts on a body as shown above. Calculate the work done on the body during 20 meters.

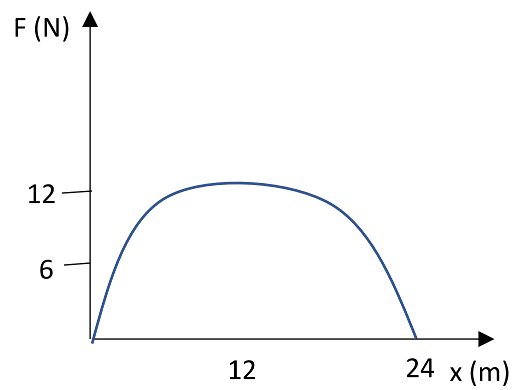
Assignment

1. Two force – displacement graphs (a and b) are represented as shown below:



Derive an expression for the difference in work done in both cases.

2.



A body is under the action of a force F, such that the force – displacement graph of the body is semicircle as shown above. Calculate the work done on the body by the force in moving through 24 meters.

Power

Power is defined as the time rate of doing work. Or The time rate at which energy is expended.

Power = $\frac{Work}{time}$ or Power = $\frac{energy\ expended}{time}$

The units of power is joule per second (Js^{-1}) which is also called watts(W)

1 Watt = 1 Joule per second

Now, Power = $\frac{Work}{time}$

But Work = F x S

$\therefore$ Power = $\frac{FS}{t}$

Power = F x $\left(\frac{s}{t}\right)$

But $\frac{S}{t} = v$

$\therefore$ Power = Fv

Where F = force applied

v = velocity of the body to which the force was applied.

Also, work = mgh

P = $\frac{mgh}{t}$

Where m = mass of the body

g = acceleration due to gravity

h = height of the object

Example;

1. A body is pulled through a distance of 500m by a force of 20N. If the power developed is 0.4KW, calculate the time for which the force acts.
2. A car travelling with a uniform velocity of $30ms^{-1}$ along a horizontal road overcomes a constant frictional force of 600N. Calculate the power of the engine of the car.
3. A man expends energy at the rate of $200Js^{-1}$ in ascending a vertical height of 44m. If his mass is 75kg, determine the time taken. [g = $10ms^{-2}$]
4. A girl whose mass is 20kg climbs up 25 steps each of height 15cm in 10seconds. Calculate the power expended. [g = $10ms^{-2}$]

Classwork

1. If a water pump at Kainji damp is capable of lifting 1000kg of water through a vertical height of 10m in 10s, calculate the power of the pump in KW.

Assignment

1. If a cage containing a truck of coal weighing 750kg is raised to height of 90m in 1 minute, what is the total power expended?
2. A girl of mass 48kg runs up 25 steps, each of height 0.2m to reach the first floor of a storey building. If the power expended by the girl is 400W, calculate the time taken [g = $10ms^{-2}$]

Efficiency of power and energy/work

The efficiency of any system is the ratio of the work output to the work input. It is expressed as a percentage.

Efficiency = $\frac{Work\ ouput}{work\ input} \times 100\%$

Efficiency = $\frac{power\ ouput}{power\ input} \times 100\%$

The efficiency of a machine is always less than one (less than 100%) because some of the work input is used to overcome friction in the moving parts

Example

1. 5000J of workdone on a machine result in the lifting of a load of 800N through a vertical distance 5m. Calculate the efficiency of the machine.
2. A steam engine of efficiency 70% burns 20g of coal to produce 10KJ of energy. If it burns 200g of coal per second, calculate its output power.

Assignment

A load of mass 120kg is raised vertically through a height of 2m in 30s by a machine whose efficiency is 100%. Calculate the power generated by the machine (g = 10ms–2)

Energy

Energy is defined as the capacity to do work. Energy has the same unit as work, thus the S.I unit of energy is the Joule (J)

TYPES OF ENERGY AND ENERGY CONVERSIONS

Forms of energy

There are many forms of energy, they are:

(i) Mechanical energy: mechanical energy is either potential or kinetic.
(ii) Heat (thermal) energy: This is the total internal energy of a body.
(iii) Light energy: This is energy which gives us sense of vision
(iv) Chemical energy: This is energy stored in fuels, food and cells/batteries.
(v) Electrical energy: this is the energy obtained from the flow of electric charges (current) through a conductor e.g., copper wire.
(vi) Atomic energy: this is energy stored in the nucleus of an atom. It is also called nuclear energy.
(vii) Solar energy: This is energy associated with the sun.
(viii) Sound energy: This is audible form of energy.
(ix) Magnetic energy: This is energy associated with a magnet.

Energy conversion and conservation

Energy can be converted from one form to another but it is neither created nor destroyed in the process. That is, energy is conserved.

The table below shows energy conversion from one form to another and the device used in each case.

S/N	From	To	Device
1.	Mechanical	Electrical	Generator
2.	Electrical	Mechanical	Electric motor
3.	Heat	Mechanical	Turbine
4.	Chemical	Heat	Burner
5.	Electrical	Heat	Resistor
	Heat	Electrical	Thermocouple
6.	Solar	Electrical	Photocell
7.	Chemical	Electrical	Cell/battery
8.	Atomic	Heat	Nuclear reactor
9.	Electrical	Sound	Television
10.	Sound	Electrical	Microphone

Sources of energy:

The sources of energy in the world are classified under two main headings namely:

- **i.** Renewable sources of energy and
- **ii.** non-renewable sources of energy.

Renewable sources of energy: These are sources of energy that are naturally and easily/readily replenished/replaceable as they are being depleted/used. i.e., they cannot be exhausted. Examples are:

- i. Solar energy (energy from the sun)
- ii. Wind Energy – wind is used to turn wind mills to produces electricity.
- iii. Hydro (water) energy – falling water is used to turn turbines in dams to produce electricity.
- iv. Ocean tides and ocean waves.

Non – renewable sources of energy: These are sources of energy that are not easily/readily replenished as they are being depleted/used. i.e., they can be exhausted. Examples are:

- i. Petroleum (fossil fuel)
- ii. Coal – it burns to produce heat

iii. Nuclear/Atomic energy
iv. Food eaten by man