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PREPARATORY GUIDE PHYSICS

BY

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CHAPTER ONE

Physical Quantities and Measurement

Physical quantities are classified into two:

i. Fundamental quantities
ii. Derived quantities

Fundamental quantities: are the quantities on the basis of which other quantities are expressed.

Examples of fundamental quantities are:

Length – meter (m)

Mass – kilogramme (kg)

Time – second (s)

Electric current – Ampere (A)

Temperature – Kelvin (k)

Amount of substance – mole (mol)

Luminous intensity – candela (cd)

Derived quantities: are expressed in terms of base (fundamental) quantities.

Examples of derived quantities are:

Quantity	SI Derived Unit	Symbol Unit		SI Base Unit
frequency	hertz	Hz	-	s^{-1}
force	newton	N	-	$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
electric charge, quantity of electricity	coulomb	C	-	$s \cdot A$
electric potential difference, electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$

Scalar and vector quantity

Scalar quantity: Quantity with only magnitude

Vector quantity: Quantity with both magnitude and direction

Examples of scalar quantity are: distance, speed, mass, time, energy, temperature, potential difference, density, area, etc.

Vector quantity: Displacement, velocity, acceleration, force, momentum, electric field strength, magnetic field strength, gravitational field strength, etc.

Worked Examples

Question 1

Which of the following consists entirely vector quantities? {UTME 2001}

A. Work, pressure and moment B. Velocity, magnetic flux and reaction. C. Displacement, impulse and power.   D. Tension, magnetic flux and mass.

Solution

Option A – pressure is scalar, work is scalar, moment is vector

Option B – velocity is vector, magnetic flux is vector, reaction is vector

Option C – displacement is vector, impulse is scalar, power is scalar

Option D – tension is vector, magnetic flux is vector, mass is scalar

Therefore, B is the correct option

CHAPTER TWO

KINEMATICS

Definition of terms

Displacement: It is the distance moved in a particular direction. It is a vector quantity. The S.I unit is (m)

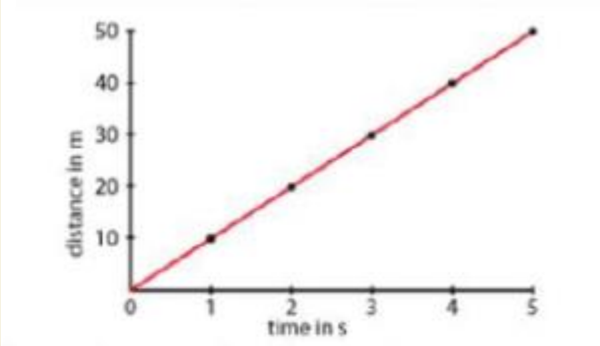
Velocity: It is the rate of change of displacement. It is a vector quantity. The S.I unit is (ms^{-1})

Speed: It is the rate of change of distance. It is a scalar quantity. The S.I unit is (ms^{-1})

Acceleration: It is the rate of change of velocity. It is a vector quantity. The S.I unit is (ms^{-2})

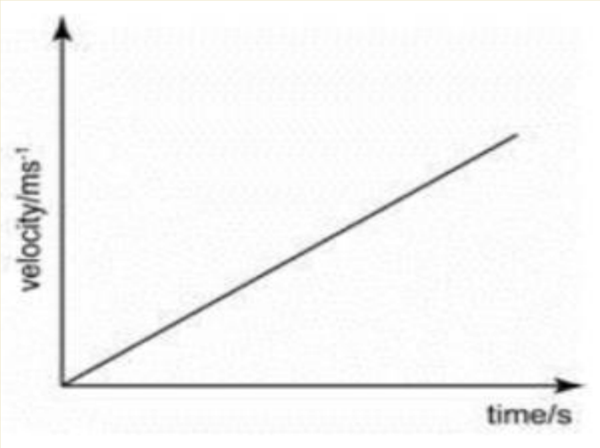
Uniform Speed: This is equal distance at equal time interval

Graphical representation of Uniform Speed



Uniform Acceleration: This is equal velocity at equal time interval

Graphical representation of uniform acceleration



Mathematical Expressions

Speed = distance/ time = d / t

Velocity = displacement / time = d / t

Average speed: Total distance/ total time taken

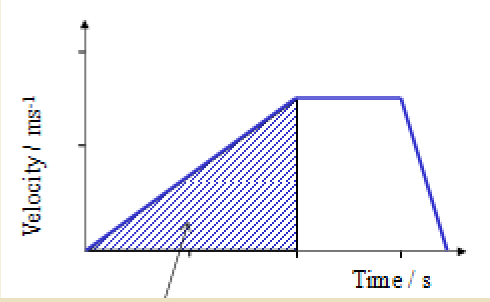
Acceleration = change of velocity / time = (v – u) / t

v = Final velocity

u = initial velocity

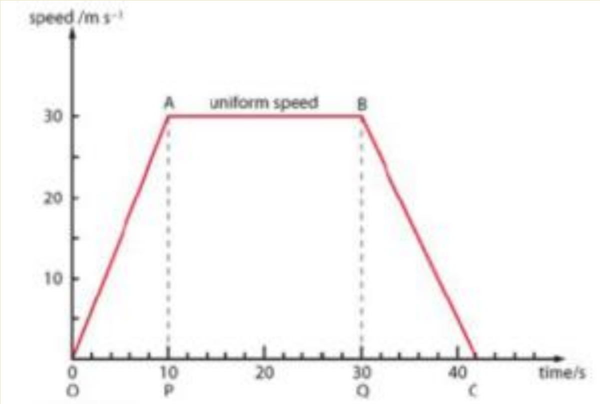
Velocity – time Graph

The area under the graph of a velocity – time graph is displacement



Since the diagram is a trapezium, we can calculate the total distance using the area of a trapezium

Let look at an example



From the diagram above

(i) What is the distance travelled during the first 10s
(ii) The total distance travelled
(iii) The average speed for the whole journey

Solution

i Using triangle AOP = 1/2 * OP * AP = 1/2 * b * h = 1/2 * 10*30 = 150m

ii Using Trapezium AOCBA = 1/2 *(AB + OC) * AP = 1/2 *(20 + 42) *30 = 1/2 * 62 *30 = 930m

ii Average speed = total distance / total time taken

Total time taken is 42s

Average speed = 930 / 42 = 22.1 ms-1

Derive, from the definitions of velocity and acceleration, equations that represent uniformly accelerated motion in a straight line

v =u+at

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

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

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

v = final velocity

u = initial velocity

t = time taken

s = distance covered

a = uniform acceleration

From the definition of acceleration

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

Cross multiply and rearrange

v = u + at

From average velocity,

Average velocity = s / t

Average velocity = *(v +u)/2*

Equate the two equations together, you get

s / t = (v +u)/2

Cross multiply and rearrange

s = [(v + u)t]/2

Taking ***v = u + at*** ………i , and ***s = [(v + u)t]/2***….*ii*

Substiturte v = u + at in eqn i into eqn ii, so you get,

s = ut + 1/2at²

Taking ***v = u + at…….i*** and ***s = [(v – u)t]/2***…. ii

Make t the subject of the eqn in eqn i

t = (v – u) / a …………iii

substitute eqn iii into eqn ii, you get

v²=u²+2as

Motion of bodies falling in a uniform gravitational field without air resistance

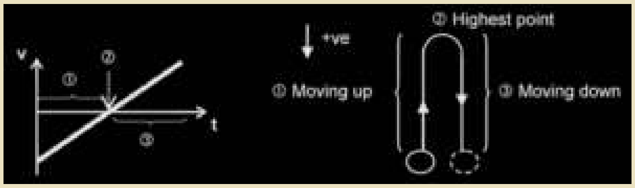
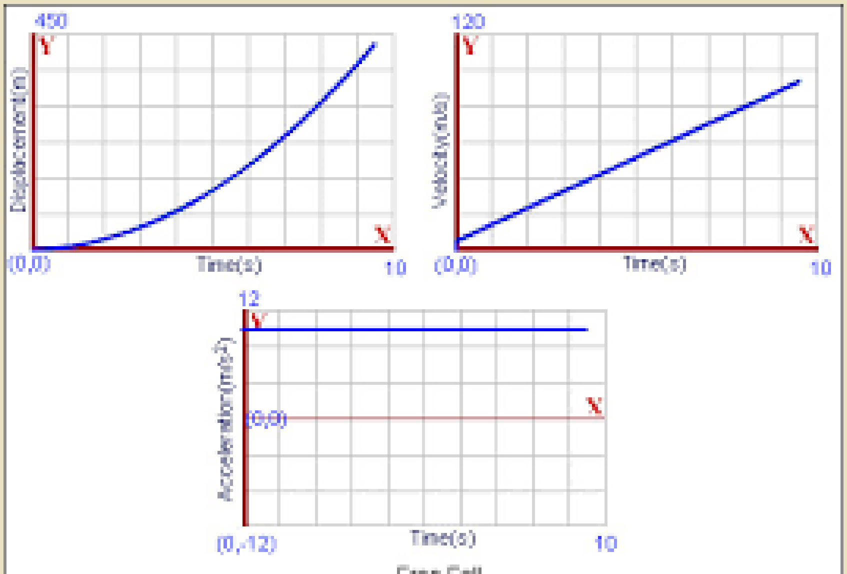


Image from xtremepapers.com

In a uniform gravitational field, the gravitational field strength is constant. The gravitational field strength is also referred to as acceleration due to gravity (g).

Without air resistance means the air resistance is negligible or the drag force

The displacement – time graph, velocity – time graph, acceleration – time graph of such a motion is shown below



Free Fall

Always remember that the gradient or slope of displacement – time graph is velocity, the gradient of velocity-time graph is acceleration.

From the graph above, the acceleration-time graph shows that it is a uniform acceleration or a constant acceleration.

In this case all you have to do is make a = 9.81ms-2, which the value of acceleration due to gravity. But in some cases you can be ask to make a = 10ms-2

The motion of bodies falling in a uniform gravitational field with air resistance

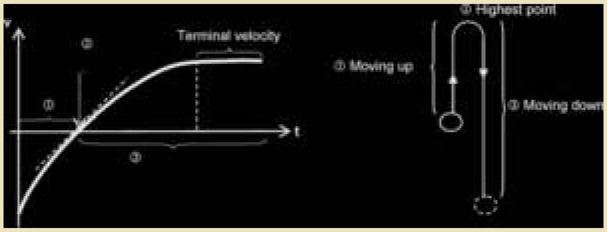


Image of xtremepapers.com

When any object moves through air, the air offers a frictional resistance (drag) to the motion. This causes the object to decelerate. The deceleration is not constant but depends on the velocity of the object.

Graphical representation of this kind on motion is shown below

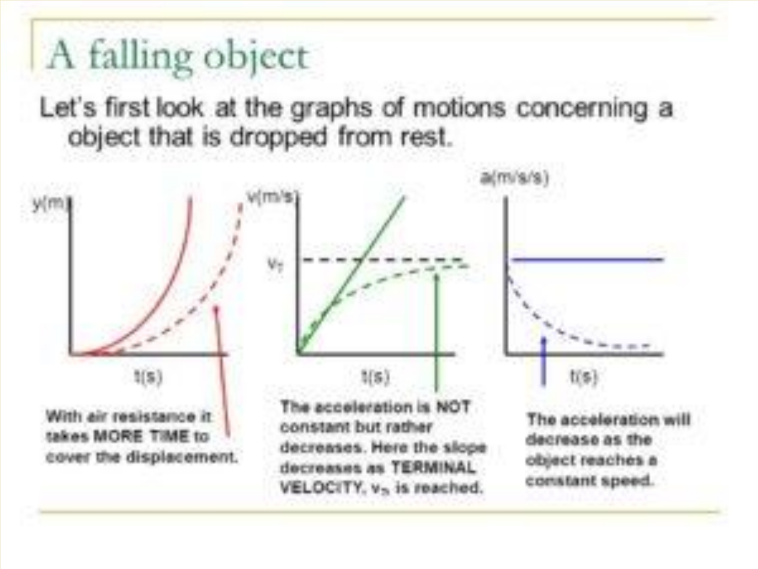


Image from slideplayer.com

Where the arrow pointed shows the graph of displacement-time graph, velocity-time graph, acceleration-time graph when there is air resistance.

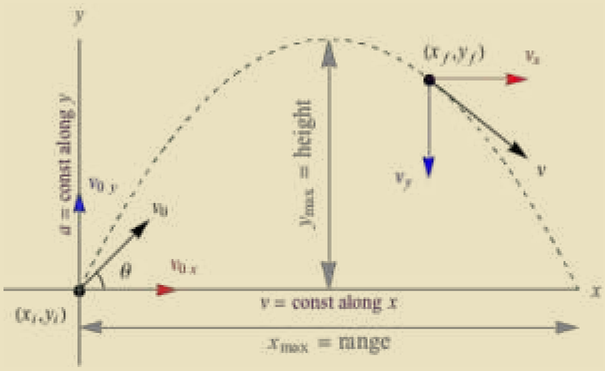
For displacement-time graph: it takes more time to cover because of the air resistance compared with when there is no air resistance

For velocity: the acceleration isn't constant because as the speed increases the air resistance increases until a time is reached when the weight of the object equals the drag force (air resistance), at this point no resultant force acting on the body and it will fall with a constant_speed, called the terminal velocity (this has being explained when i discussed dynamics)

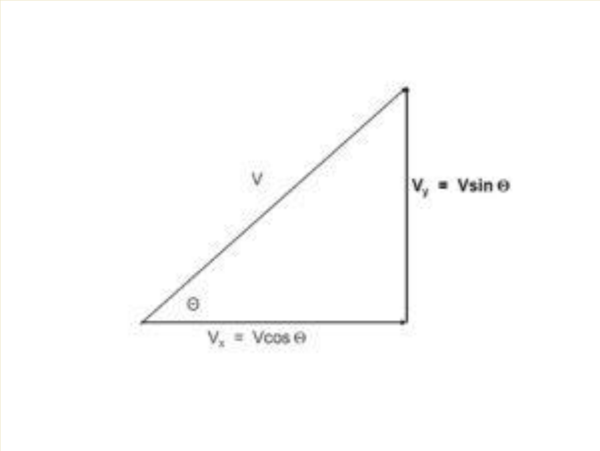
Terminal velocity is the point at which the resultant force is zero.

Motion due to a uniform velocity in one direction and a uniform acceleration in a perpendicular direction.

The type of motion to discuss here is a Projectile. Projectile is any object that is given an initial velocity and then follows a path determined entirely by gravitational acceleration.



The initial velocity is at an angle of θ. This initial velocity will be resolve into both vertical component and horizontal component.



Using your SOHCAHTOA

The vertical component of the velocity will be usinθ

The horizontal component of the velocity will be ucosθ

Horizontal component of the velocity has no force acting so it is constant

Vertical component of the velocity has a constant force acting so there is a constant acceleration.

Derivations

To calculate the time to reach the maximum height

$v = u - at$

At maximum height $v = 0$

$0 = u\sin\theta - at$

$t = u\sin\theta / a$

$a = 9.81ms^{-2}$

Time of flight = $2*t = 2u\sin\theta / a$

To calculate maximum height

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

At maximum height $v = 0$

$u = u\boldsymbol{\sin\theta}$

$a = 9.81ms^{-2}$

s = maximum height

If you substitute you get your maximum height

Horizontal distance (range)

$v = d / t$

The reason for this formula is because there is no force acting on it, which implies a uniform velocity

d= horizontal distance

v = horizontal component of velocity = $u\cos\theta$

t = time to complete the parabolic path (which can sometimes time of flight or time to reach the maximum height depending on the projectile diagram given). If it is a full diagram you use time of flight. If it is half of the full diagram you use time to reach the maximum height). The diagram above is a full diagram.

$u\cos\theta = d / t$

Worked Examples

Question 1

A ball is thrown vertically down towards the ground with an initial velocity of 4.23 m s–1. The
ball falls for a time of 1.51 s before hitting the ground. Air resistance is negligible.
(a) (i) Show that the downwards velocity of the ball when it hits the ground is 19.0 m s–1.
(ii) Calculate, to three significant figures, the distance the ball falls to the ground.

(b) The ball makes contact with the ground for 12.5 ms and rebounds with an upwards
velocity of 18.6 m s–1. The mass of the ball is 46.5 g.
(i) Calculate the average force acting on the ball on impact with the ground

Solution

$v = u + at$

$u = 4.23$ ms-1

$t = 1.51$ s

$a = 9.81$

$v = 4.23 + 1.51 * 9.81$

$v = 19.04$ ms-1

ii

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

$$s = 4.23 \times 1.51 + \frac{1}{2} \times 9.81 \times 1.51^2$$

s = 17.57 m

b

$$f = \frac{m(v - u)}{t}$$

Since ball moves in opposite direction after the rebound

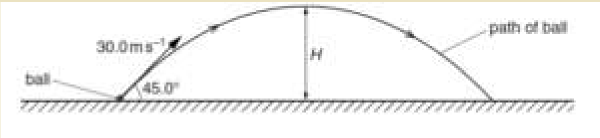
$$f = \frac{m(v + u)}{t}$$

$$f = \frac{0.0465(19 + 18.6)}{0.0125}$$

F = 140 N

Question 2

A ball of mass 400 g is thrown with an initial velocity of 30.0 m s–1 at an angle of 45.0° to the
horizontal, as shown in fig below (Cambridge past question may / june 2014 p22 q4)



Air resistance is negligible. The ball reaches a maximum height H after a time of 2.16 s.
(i) Calculate
1. the initial kinetic energy of the ball,
2. the maximum height H of the ball

Solution

Ek = 1/2 m v2

m = 400g = 0.4kg

v = 30ms-1

Ek = 1/ 2 * 0.4 * 30 ^2 = 180 J

To calculate the maximum

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

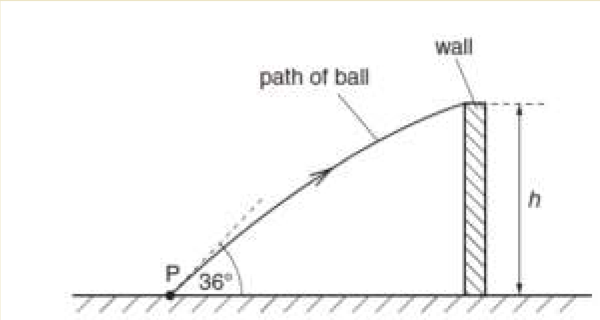
v = 0

u is the vertical component of the velocity = usinθ = 30 sin 45 = 21.21 ms-1

s = 21.21^2 / 2* 9.81 = 22.94m

Question 3

A ball is thrown from a point P, which is at ground level, as illustrated in figure below



The initial velocity of the ball is 12.4 m s–1 at an angle of 36° to the horizontal.
The ball just passes over a wall of height h. The ball reaches the wall 0.17 s after it has been
thrown. (Cambridge past question oct / nov 2010 p22 que 2)
Assuming air resistance to be negligible, calculate
(i) the horizontal distance of point P from the wall,
(ii) the height h of the wall.

Solution

The horizontal distance is

v = d/t

$v = u\cos\theta = 12.4 \cos 36 = 10.03$ ms-1

$d = vt = 10.03 * 0.17 = 1.7$ m

The height h

$s = ut - 1/2\ a\ t^2$

The u here is the vertical component of the initial velocity $u\sin\theta = 12.4 \sin 36 = 7.29$ ms-1

$s = 7.29 * 0.17 - 1/2 * 9.81 * 0.17^2 = 1.24 - 0.14 = 1.1$ m

Question 4

An object is projected from a height of 80m above the ground with a velocity of 40ms-1 at an angle of 30o to the horizontal. The time of flight is
A. 16s B. 10s C. 8s D. 4s
[g = 10ms-2]

Solution

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

$T = 2 * 40 * \sin 30 / 10$

$T = 40 / 10$

$T = 4$ s

CHAPTER THREE

Dynamics, motion and conservation of linear momentum

Momentum and Newton's laws of motion

a) Understand that mass is the property of a body that resists change in motion

Mass: is a measure of the amount of matter in a body, and is the property of a body which resists change in motion

In kinematics, the motion of a body is independent of its mass, it is a change in its state of motion that is affected by/ depends on its mass

b) Recall the relationship $F = ma$ and solve problems using it, appreciating that acceleration and resultant force are always in the same direction

c) Define and use linear momentum as the product of mass and velocity

Linear momentum: of a body is defined as the product of its mass and velocity i.e. p = m v

Momentum = Mass x velocity

p (kgms-1) = m (kg) x v (ms-1)

d) Define and use force as rate of change of momentum

Force: is defined as the rate of change of momentum,

i.e. F = [m (v – u)] / t = ma or F = v dm / dt
The {one} Newton: is defined as the force needed to accelerate a mass of 1 kg by 1 m s-2.

F=Dp/Dt

e) State and apply each of Newton's laws of motion

Newton's First Law
It states that everybody continues in a state of rest or uniform motion in a straight line unless a net (external) force acts on it.

When no external unbalanced (resultant) force acts on a body, its velocity remains constant.

An external force is required to change the velocity of a body. Internal forces do not have effect on an object motion.
Object remains at rest or in a straight line motion with constant velocity, unless acted upon by external unbalanced forces.

The external force must be unbalanced i.e., two equal opposing forces will not change a body's velocity. The vector sum of the forces must be greater than or less than zero

Newton's Second Law
The rate of change of momentum of a body is directly proportional to the net force acting on the body, and the momentum change takes place in the direction of the net force

1. When an external, unbalanced force acts on an object, the object accelerates, in the same direction as the net force F on the object.

The acceleration a, varies directly as the net force F, and inversely as the mass of the object, m

a a F, for m is constant.

a a 1/m, for F constant

Thus, Newton's 2nd law is a special case of law1, when F = 0,a = 0, and v is constant. Note that F, a, and v, are in the same direction.

In nature, the only situation in which there is only one force acting on a body is when it is falling through vacuum. In other cases, more than one force acts, though the directions may differ.

Concept of inertia

This is a fundamental property of a body that measures its reluctance to a change in its state of motion i.e. ability of a body to resist changes in its state of motion (the reason for law 1 occurrence).

The mass of a body is a measure of the inertia of that body. The more massive a body is the more its inertia.

Newton's Third Law
When object X exerts a force on object Y, object Y exerts a force *of the same type* that is equal in magnitude and opposite in direction on object X.

The two forces ALWAYS act on different objects and they form an action-reaction pair.

If they were to act on the same body, we could never have accelerated motion, because the resultant force on anybody would be zero.

The acceleration of the two objects are different if their masses are different, so that,

$F_1 = – F_2$

Becomes,

$m_1a_1 = – m_2a_2$

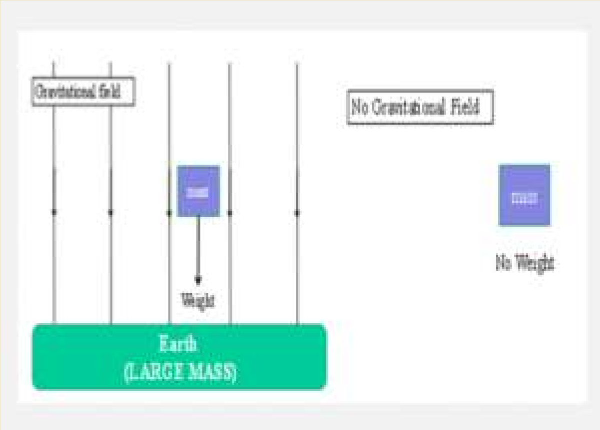
The acceleration now depends on the inertia mass of the objects. Therefore, though there are equal and opposite forces, the forces may NOT be balanced, causing resultant motion/acceleration of the two bodies. This is typical of masses in a gravitational field of the earth, where the earth seems not to be accelerating and the masses accelerate

Forces always occur in pair.

The interaction between one body and another is due to the forces between them

Non-uniform motion

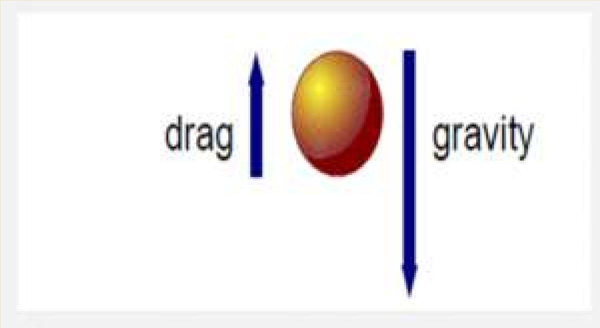
a) Describe and use the concept of weight as the effect of a gravitational field on a mass and recall that the weight of a body is equal to the product of its mass and the acceleration of free fall



Weight = force of gravity exerted on an object (or the force on a supporting scale)

Weight (N) = mass (kg) x g (N/kg) g=gravitational field strength

b) Describe qualitatively the motion of bodies falling in a uniform gravitational field with air resistance



When any object moves through air, the air offers a frictional resistance (drag) to the motion. This causes the object to decelerate. The deceleration is not constant but depends on the velocity of the object.

Therefore, if a body falls under gravity, air resistance opposes the fall and the downward acceleration is therefore reduced. This means that bodies falling through air take longer to fall the same distance than in vacuum

State the principle of conservation of momentum

When objects of a system interact, their total momentum before and after interaction are equal if no **net** (external) force acts on the system

The total momentum of an isolated system is constant

$m_1u_1 + m_2 u_2 = m_1v_1 + m_2 v_2$ if net F = 0 {for all collisions}

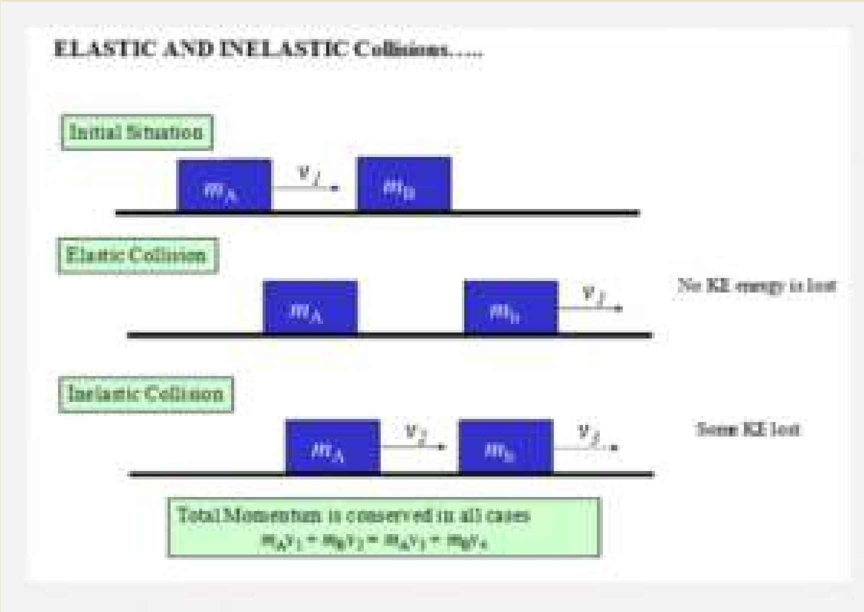
NB: Total momentum DURING the interaction/collision is also conserved

(Perfectly) elastic collision:

Both momentum & kinetic energy of the system are conserved.

Inelastic collision:

Only momentum is conserved, total kinetic energy is not conserved and the particles stick together after collision (i.e. move with the same velocity)

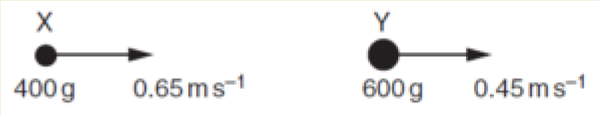


In inelastic collisions, total energy is conserved but Kinetic Energy may be converted into other forms of energy such as sound and heat energy

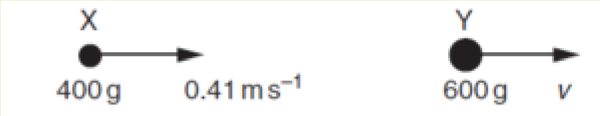
Worked Examples

Question 1

A ball X and a ball Y are travelling along the same straight line in the same direction, as
shown in the fig below



Ball X has mass 400 g and horizontal velocity 0.65 m s–1.
Ball Y has mass 600 g and horizontal velocity 0.45 m s–1.
Ball X catches up and collides with ball Y. After the collision, X has horizontal velocity 0.41 m s–1
and Y has horizontal velocity v, as shown below



Calculate
(i) the total initial momentum of the two balls,
(ii) the velocity v,
(iii) the total initial kinetic energy of the two balls.
(iv) Explain how you would check whether the collision is elastic

(v) Use Newton's third law to explain why, during the collision, the change in momentum of X is
equal and opposite to the change in momentum of Y.

Before collision, the balls are moving in the same direction, therefore, total momentum before collision = $m_1u_1 + m_2u_2$

= 0.4*0.65 + 0.6*0.45 = 0.53kgms^{-1}

The total initial momentum of the two balls = 0.53kgms^{-1}

After collision, the balls also moved in the same direction

Total momentum after collision = $m_1v_1+m_2v_2$

= 0.4*0.41 + 0.6*v

Total momentum before collision = total momentum after collision (law of conservation of linear momentum)

0.53 = 0.16 +0.6v

0.6v = 0.37

v = 0.37/0.6

v = 0.617

iii) The total initial kinetic energy of the two balls

$1/2\ m_1 u_1^2 + 1/2\ m_2 u_2^2$

$1/2 * 0.4 * 0.65^2 + 1/2 * 0.6 * 0.45^2$

0.145 J

iv) How you would check whether the collision is elastic

Check whether the relative speed of approach equals relative speed of separation

Or

Total final kinetic energy equals the total initial kinetic energy

v) Use Newton's third law to explain why, during the collision, the change in momentum of X is
equal and opposite to the change in momentum of Y

Newton's Third Law
When object X exerts a force on object Y, object Y exerts a force *of the same type* that is equal in magnitude and opposite in direction on object X.

Change in momentum of x = m_1(v-u) = 0.4(0.41-0.65) = -0.1kgms-1

F = dp/dt

Change in momentum of y = m_2(v-u) = 0.6(0.617-0.45) = 0.1kgms-1

The two balls will have the same time of impact during collision

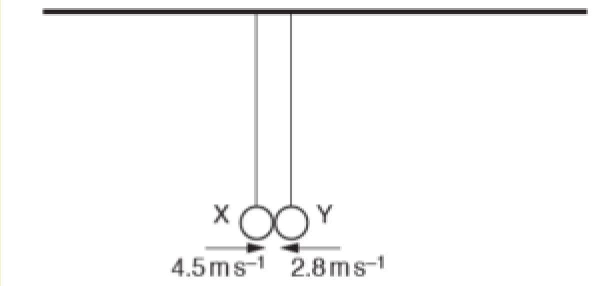
Therefore, $-F_x = F_y$ ………. this satisfy Newton's third law of motion

It can be put in this way:

The forces on the two bodies (or on X and Y) are equal and opposite time same for both forces and force is change in momentum / time

Question 2

Two balls X and Y are supported by long strings, as shown below



The balls are each pulled back and pushed towards each other. When the balls collide at the
position shown in Fig. 3.1, the strings are vertical. The balls rebound in opposite directions

Figure below shows data for X and Y during this collision.

ball	mass	velocity just before collision/ms^{-1}	velocity just after collision/ms^{-1}
X	50g	+4.5	−1.8
Y	M	−2.8	+1.4

The positive direction is horizontal and to the right.
Use the conservation of linear momentum to determine the mass M of Y.

From the key points given

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

In the question given, before collision the objects move in opposite direction toward each other and that is the reason for the negative velocity included in the question

Therefore, total momentum before collision is

$m_1u_1 – m_2u_2 = 0.05 * 4.5 – M * 2.8$

Note that the mass is in gramme (50g) but it has been converted to kilogramme (0.05), so that all the units will be in S.I base unit.

After collision, the total momentum is

$m_2v_2 - m_2v_2$ = M* 1.4 – 0.05 *1.8

From law of conservation of linear momentum

0.05 *4.5 – M *2.8 = M* 1.4 – 0.05 *1.8

Collecting like terms

0.225 +0.09 = 4.2M

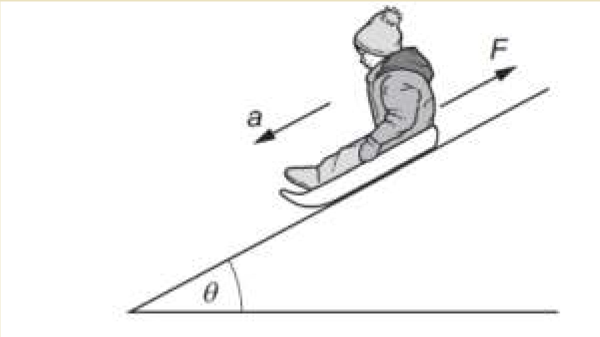
0.315 = 4.2M

M = 0.315/4.2

M = 0.075Kg 0r 75g

Question 3

A child on a sledge slides down a hill with acceleration a. The hill makes an angle θ with the
horizontal



The total mass of the child and the sledge is m. The acceleration of free fall is g.
What is the friction force F ?
A m(g cosθ – a)
B m(g cosθ + a)
C m(g sinθ – a)
D m(g sinθ + a)

According to Newton's first law of motion

Object remain at rest or in a straight line motion with constant velocity, unless acted upon by external unbalanced forces

Therefore, there are two unbalanced forces acting on the boy, which are force down the slope and the frictional force.

The body accelerate uniformly down the slope because of there is a resultant force or net force

The net force = ma

Therefore,

F -Fr = ma

F is the force down the slope

Fr is the frictional force opposing the motion of the boy

F = mgsinθ

mgsinθ – Fr = ma

Fr = mgsinθ -ma

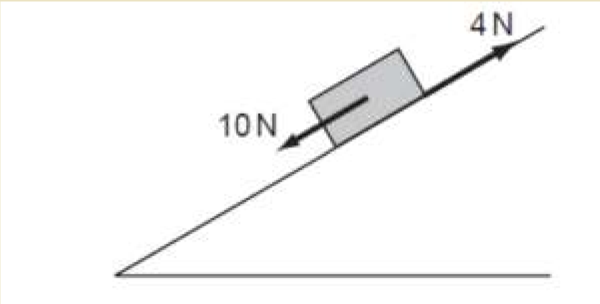
factorise, we then have

Fr = m(gsinθ -a)

The correct answer is C

Question 4

A brick weighing 20 N rests on an inclined plane. The weight of the brick has a component of 10 N
parallel with the plane. The brick also experiences a frictional force of 4 N.



What is the acceleration of the brick down the plane? Assume that the acceleration of free fall g is
equal to 10 m s–2.

Solution

weight of the box is 20N

weight = mg

20 = m * 10

m = 2kg

Since the box slide down the plane, it means there is a resultant force or net force

F – Fr = ma

F = force parallel to the plane = 10N

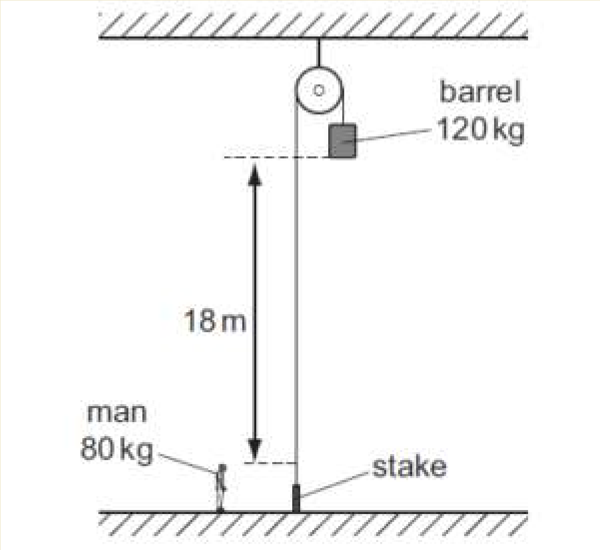
10 – 4 = 2 * a

6 = 2a

a = 3 ms-2

Question 5

The diagram shows a barrel suspended from a frictionless pulley on a building. The rope
supporting the barrel goes over the pulley and is secured to a stake at the bottom of the building



A man stands close to the stake. The bottom of the barrel is 18 m above the man's head. The
mass of the barrel is 120 kg and the mass of the man is 80 kg.
The man keeps hold of the rope after untying it from the stake and is lifted upwards as the barrel
falls.
What is the man's upward speed when his head is level with the bottom of the barrel? (Use
g = 10 m s–2.)

Solution

The forces acting in this question are the weight of the man, the weight of the barrel and the tension on the rope.

As the man moves upward, this is what happens. The tension on the rope acting upward is greater than the weight of the man acting downward. So this gives a resultant force

Mathematically,

$T - w_m = m_1a_1$……..eqn i

w_m represents the weight of the man

m_1 is the mass of the man

a_1 is the acceleration of the man

As the barrel moves downward, the tension on the rope acting upward is less than the weight on the barrel acting downwards. So this gives a resultant force, don't forget that weight (gravitational force) is always acting downwards to the centre of the earth.

Mathematically,

$w_b - T = m_2a_2$……..ii

w_b = weight of the barrel

m_2 = mass of the barrel

a_2 = acceleration of the barrel

Combining eqn i and ii and eliminate T, you will have

$w_b - w_m = m_2a_2 + m_1a_1$

Note the two objects will have the same acceleration

$a_2 = a_1$

$w_b - w_m = (m_1 + m_2)\, a_1$

$w_b = 120*10 = 1200N$

$w_m = 80 *10 = 800N$

$1200 - 800 = (120 + 80)* a_1$

$400 = 200*a_1$

$a_1 = 2\ ms^{-2}$

Recall,

$\boldsymbol{v^2=u^2+2as}$

The man and the barrel would have covered half of the distance when his head is level with the bottom of the barrel

i.e.   s = 9m

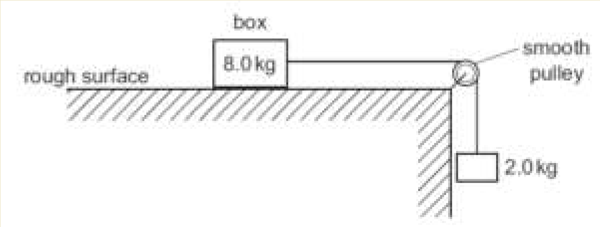
$\boldsymbol{v^2} = 0 + 2 * 2 * 9$

$\boldsymbol{v^2} = 36$

v = 6 ms-1

Question 6

A box of mass 8.0 kg rests on a horizontal, rough surface. A string attached to the box passes
over a smooth pulley and supports a 2.0 kg mass at its other end



When the box is released, a frictional force of 6.0 N acts on it. What is the acceleration of the box?

The same approach we use in Q5 is applicable here

w_b – fr = (m1 + m2)a_1

w_b = is the weight of the box

m_1 is the mass of the box, m_2 is the mass at the other end

20 – 6 = 10 * a

14 = 10a

a = 1.4 ms^{-2}

Question 7

The momentum of an object changes from 160 kg m s^{-1} to 240 kg m s^{-1} in 2 s. What is the mean resultant force on the object during the change?

Solution

Change in momentum = $p_1 - p_2$

Change in momentum = 240 – 160 = 80kgms-1

Resultant force = change in momentum / time = 80 / 2 = 40N

Question 8

Two spheres approach each other along the same straight line. Their speeds are $u1$ and $u2$
before collision. After the collision, the spheres separate with speeds $v1$ and $v2$ in the directions
shown below.

Which equation must be correct if the collision is perfectly elastic?
A $u1 – u2 = v2 + v1$
B $u1 – u2 = v2 – v1$
C $u1 + u2 = v2 + v1$
D $u1 + u2 = v2 – v1$

Solutions

Before collision, the balls move in opposite direction to each other

After collision, the balls move in the same direction

Recall that,

Relative speed of approach = relative speed of separation

$u_1 – u_2 = v_2 – v_1$ (when they are moving in the same direction both before and after collision)

But in this case, they move in opposite direction before collision, in this case

$u1 + u2 = v2 – v1$

The answer is D

OR

If you look closely, $u1$ and $v1$ are in the same direction, that means

$u1 + v1$

u_2 and v_2 are in opposite direction, that means

$v_2 - u_2$

Using conservation of linear momentum

$u_1 + v_1 = v_2 - u_2$

Rearrange

$u_1 + u_2 = v_2 - v_1$

D is the correct answer

CHAPTER FOUR

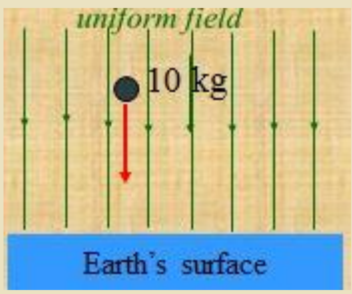
Moment of a force, couple and inclined plane

4.1 Forces on Masses in Gravitational Fields

Gravitational field is a region of space in which a mass experiences an (attractive) force due to the presence of another mass.

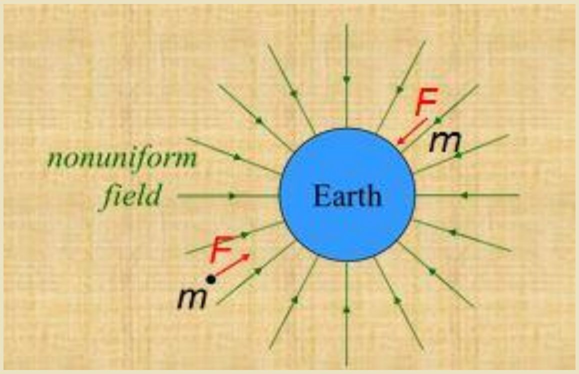
$$F \propto \frac{m_1 m_2}{r^2}$$

The Earth's gravitational field is represented by parallel lines on small scales on objects like balls, cars and planes e.t.c



The parallel lines indicate a uniform gravitation field where gravitational field strength is constant. The weight of an object is always directed towards the center of the earth.

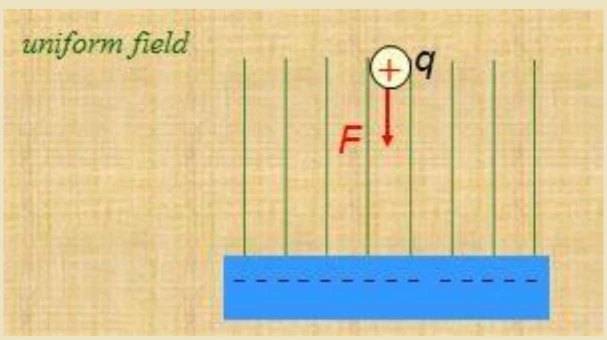
Newton's law of gravitation:
Any two point masses attract each other with a force that is proportional to each of their masses and inversely proportional to the square of the distance between them.



This diagram represent a non-uniform field. The field strength is inversely proportional to the squares of the distance of separation.

$$g = \frac{F}{m} = \frac{GMm/r^2}{m} = \frac{GM}{r^2}$$

Forces on Charge in Electric Fields:
A region of space where a charge experiences an (*attractive* or *repulsive*) force due to the presence of another charge.



A uniform electric field is represented by parallel lines that are equally spaced in two parallel plates. The electric field strength in a uniform electric field is constant.

Particle	Field	Effect
Uncharged mass	Gravitational	Attracted in direction of field line
Uncharged mass	Electric field	No effect
Charged mass	Gravitational field	Attracted in direction of field line
Positive charge	Electric field	Attracted in direction of field line
Negative charge	Electric field	Repelled in opposite direction to field line

4.2 Show an understanding of the origin of the upthrust acting on a body in a fluid

Upthrust: An upward force exerted by a fluid on a submerged or floating object; arises because of the difference in pressure between the upper and lower surfaces of the object.

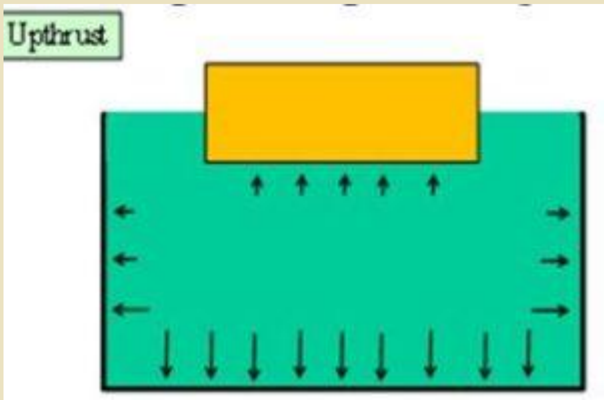
Archimedes' Principle:

Upthrust = weight of the fluid displaced by submerged object.

Upthrust = Volume (submerged) x ρ(fluid) x g

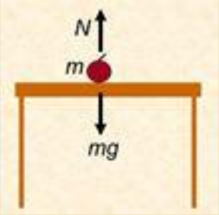
ρ represents density

Liquid has its own weight, this causes pressure on the wall on the container in which liquid is held, it also causes pressure on any object immersed in the liquid



4.3 Show a qualitative understanding of frictional forces and viscous forces including air resistance (no treatment of the coefficients of friction and viscosity is required)

When an object lies on a table or on the ground, the table or the ground must exert an upward force, otherwise it would be accelerated by gravity. This force is known as Normal force.

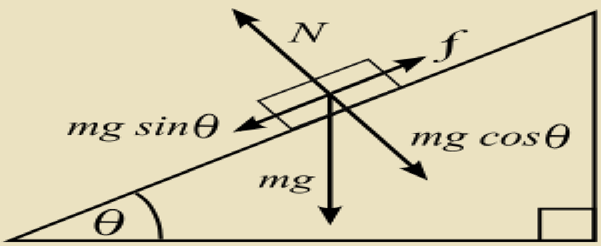


FRICTIONAL FORCES: Frictional forces are forces that act against the direction of motion

In this case,

Resultant force = force applied – frictional force = 15 – 3 = 12 N

For inclined plane



Viscous forces

i. A force that opposes the motion of an object in a fluid

ii. Only exists when there is (relative) motion

iii. Magnitude of viscous force increases with the speed of the object

Air resistance

Although we often ignore it, air resistance, *R*, is usually significant in real life.

R depends on:

i. speed (approximately proportional to v 2)

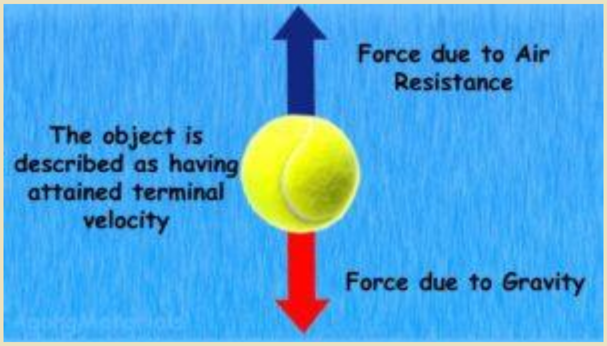
ii. Cross-sectional area

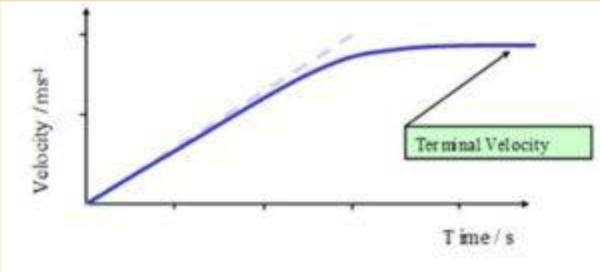
iii. Air density

iv. Other factor like shape

R is not a constant; it increases as the speed increases and vice versa

When any object moves through air, the air offers a frictional resistance (drag) to the motion. This causes the object to decelerate. The deceleration is not constant but depends on the velocity of the object. You can experience this when an apple is dropped from the top of a building. At first v = 0, so R = 0 too, and $a = -g$. As the apple speeds up, R increases, and his acceleration diminishes. If he falls long enough his speed will be big enough to make R as big as mg. When this happens the net force is zero because the weight of the apple equals the air resistance, so the acceleration must be zero too. At this point you have what is called terminal velocity.





Understand that the weight of a body may be taken as acting as at a single point

Centre of Gravity of an object is defined as that point through which the entire weight of the object may be considered to act.

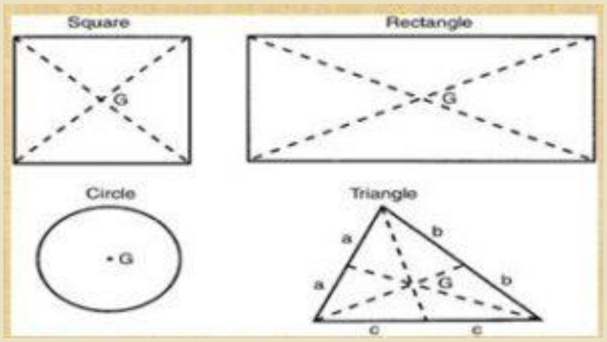
Finding the center of gravity requires that the object is under the influence of gravity

TYPES OF OBJECTS/BODY

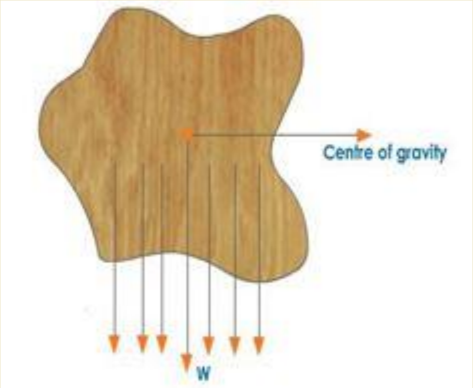
i. Regular/uniform body

ii. Irregular/ non uniform bodies

The centre of gravity of a uniform or regular object is at its geometrical centre



Centre of gravity for irregular object



Turning effect of a force

The turning effect of a force is called the moment of the force. The moment is calculated by multiplying the force by the distance from the pivot.

The turning effect of a force depends on two things;

i The size of the force

ii The distance from the pivot (axis of rotation)

Moments

The moment of a force about a turning point is the force multiplied by the perpendicular distance to the force from the turning point.

Moments are measured in newton metres (Nm).

Moment = F d

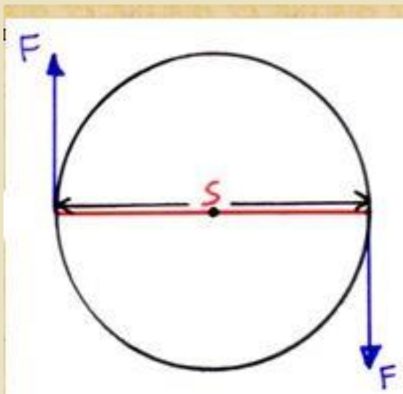
F = the force in Newton (N)

d = perpendicular distance in metres (m)

What is a couple?

A Couple is defined as two Forces having the same magnitude, parallel lines of action, and opposite.

Diagram of a couple



In this situation, the sum of the forces in each direction is zero. so a couple does not affect the sum of forces equations. A force couple will however tend to rotate the body it is acting on.

Two couples will have equal moments if

$$F_1 d_1 = F_2 d_2$$

Torque

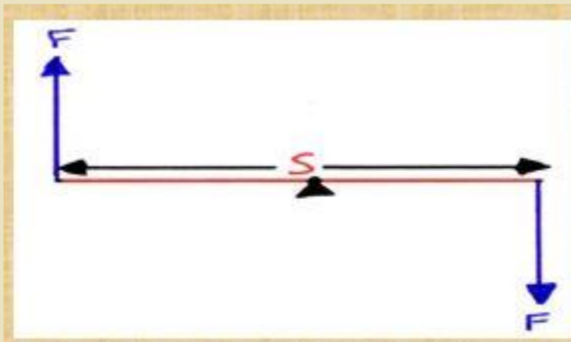
The turning effect of a couple is known as its torque

By multiplying the magnitude of one Force by the distance between the Forces in the Couple, the moment due to the couple can be calculated.

Torque:

moment of a couple= one force(N) × perpendicular distances between the forces(m)

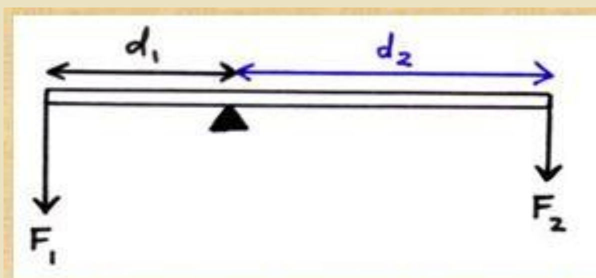
The unit is Newton metre (Nm)



The principle of moments

When an object is in equilibrium the sum of the anticlockwise moments about a turning point must be equal to the sum of the clockwise moments.

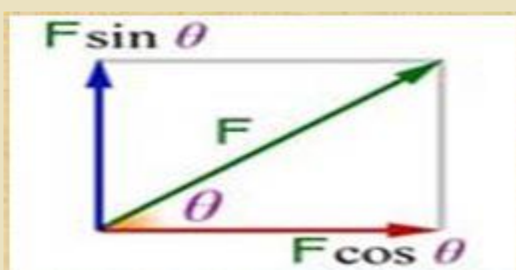
sum of anticlockwise moments = sum clockwise moments



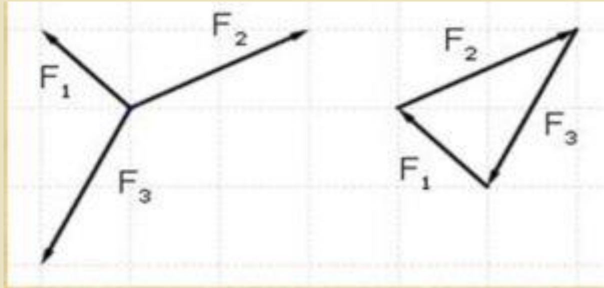
sum of anticlockwise moments = sum clockwise moments

$$F_1 \times d_1 = F_2 \times d_2$$

Resolution of forces



When 3 coplanar forces acting at a point are in equilibrium, they can be represented in magnitude and direction by the adjacent sides of a triangle taken in order.



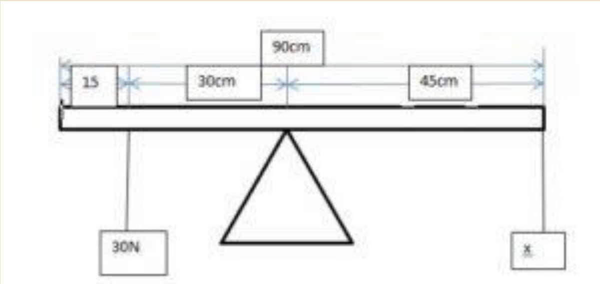
Worked Examples

Question 1

A 90cm uniform lever has a load of 30N suspended at 15cm from one of its ends. If the fulcrum is at the centre of gravity, the force that must be applied at its other end to keep it in horizontal equilibrium is{UME 2003 Type 9}

A. 15N B. 20N C. 30N D. 60N.

Solution



sum of clockwise moment = sum of anti-clockwise moment

x * 45 = 30 * 30

45x = 900

x = 900 / 45

x = 20N

B is the correct option

Question 2

A 100kg box is pushed along a road with a force of 500N. If the box moves with a uniform velocity, the coefficient of
friction between the box and the road is{UME 2004 Type S}

A. 0.5 B. 0.4 C. 1.0 D. 0.8

solution

F – fr = ma

Since it moves with a uniform velocity acceleration = 0

F = fr

F = μR

μ is the coefficient of friction

F is the force applied

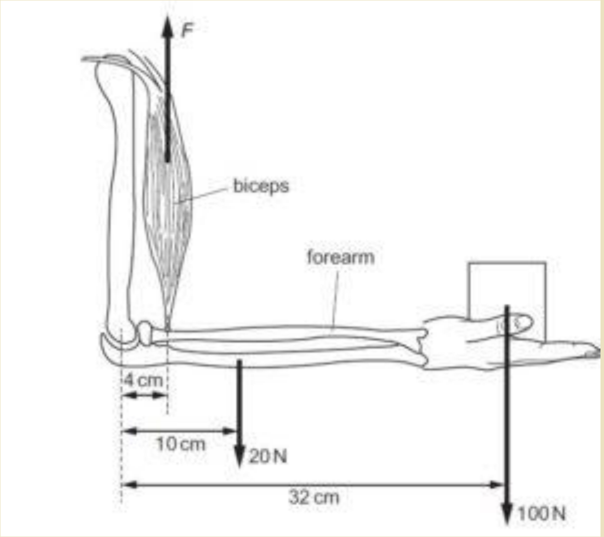
R is the normal reaction which is equal to the weight = mg = 100*10 = 1000N

μ = F/R = 500 / 1000 = 0.5

A is the correct option

Question 3

A man holds a 100 N load stationary in his hand. The combined weight of the forearm and hand is
20 N. The forearm is held horizontal, as shown {Cambridge may/june 2014 p11 ques 12}



What is the vertical force F needed in the biceps?

A 750 N B 800 N C 850 N D 900 N

Solution

moment of a force = force x perpendicular distance

Sum of clockwise moment = sum of anti-clockwise moment

the 100N load will make a clockwise direction

the 20N combined weight of the hand and forearm will make a clockwise direction

the force F in the biceps will make anti-clockwise direction

F*4 = 20*10 + 100*32

4F = 200 +3200

4F = 3400

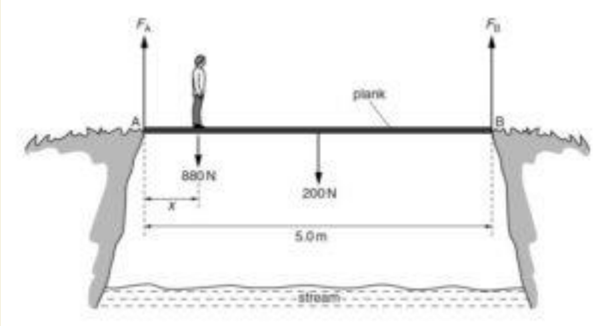
f = 3400/4

F = 850N

C is the correct option

Question 4

A uniform plank AB of length 5.0 m and weight 200 N is placed across a stream, as shown below



A man of weight 880 N stands a distance x from end A. The ground exerts a vertical force FA on the plank at end A and a vertical force FB on the plank at end B.
As the man moves along the plank, the plank is always in equilibrium
{Cambridge may/jun 2014 p21 q3}

The man stands a distance x = 0.50 m from end A. Use the principle of moments to
calculate the magnitude of FB.

Solution

sum of clockwise moment = sum of anti-clockwise moment

Taking your moment about FA

Since it is a uniform plank, the weight of the plank will be at the mid-point of the plank

FB will make an anticlockwise direction

The man will make a clockwise direction

The weight of the plank will make clockwise direction

FB*5 = 200*2.5 +880*0.5

5FB = 500 +440

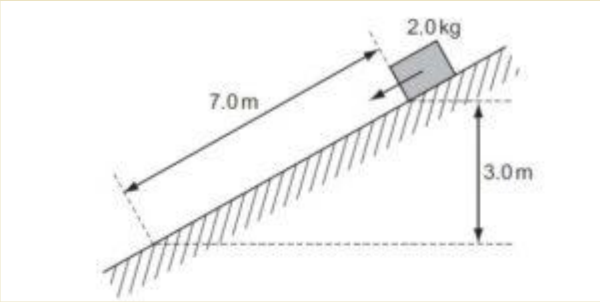
5FB = 940

FB = 940 / 5

FB = 188N

Question 5

A block of mass 2.0 kg is released from rest on a slope. It travels 7.0 m down the slope and falls a vertical distance of 3.0 m. The block experiences a frictional force parallel to the slope of 5.0 N {Cambridge may/june 2011 p11 que15}



What is the speed of the block after falling this distance?
A 4.9 m s–1 B 6.6 m s–1 C 8.6 m s–1 D 10.1 m s–1

Solution

mgsinθ – fr = ma

sinθ = opposite / hypothenus = 3 /7

g = 9.81 ms-2

2*9.81*3/7 – 5 = 2*a

8.41 – 5 = 2a

3.41 = 2a

a = 3.41 /2

a = 1.7 ms-2

using

v2 = u2 + 2as

initially it is at rest so

u = 0ms-1

distance covered is 7m

v2 = 2*1.7*7

v2 = 23.86

find the square root of both sides

v = 4.9ms-1

A is the correct option

CHAPTER FIVE

Circular Motion: Periodic Motion

The radian: This can be defined as the angle subtended at the center of a circle by an arc of length equal to the radius of the circle.

$\pi = 180°$

$2\pi = 360° - Total\ angular\ displacement$

Why a body moving in a circle at constant speed has acceleration

- Direction is changing so velocity is changing
- Change in velocity produces acceleration

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

$\omega = 2\pi f$

$\boldsymbol{uniform\ speed = \frac{d}{t} = \frac{2\pi r}{t} = \omega r}$

$v = \omega r$

Angular velocity is defined as the angle swept out per unit time, or the angular displacement per unit time

$\boldsymbol{Centripetal\ acceleration = \frac{v^2}{r}}$

$\boldsymbol{a = \frac{\omega^2 r^2}{r} = \omega^2 r}$

Centripetal force F $= m\omega^2 \boldsymbol{r} = \frac{\boldsymbol{mv^2}}{\boldsymbol{r}}$

Centripetal force is the resultant force acting on a body to keep it in a circular path and it is always directed towards the center of the circle.

Note:

- Velocity is always tangential to the path
- The direction of force is always perpendicular to the direction of a linear speed
- Force and acceleration is that right angles to the linear speed

Worked Example

Question 1

A particle in circular motion performs 30 oscillations in 6 seconds. Its angular velocity is {UTME2002}

A. 5 rad s^{-1} B. 6 rad s-1 C. 5πrad s^{-1}
D. 10πrad s^{-1}

Solution

$\omega = 2\pi f$
$\omega = 2\pi \times \frac{30}{6}$

$\omega = 10\pi\ rads^{-1}$
D is the correct answer

Question 2

A car of mass 1500 kg goes round a circular curve of radius 50m at a speed of $40ms^{-1}$. The magnitude of the centripetal force on the car is {UTME2007}

A. 1.2×10^2N B. 1.2×10^3N C. 4.8×10^3N D. 4.8×10^4N

Solution

$$f = m\omega^2 r = m\frac{v^2}{r}$$
$$f = 1500 \times \frac{40^2}{50}$$

$$f = 48000N$$
$$f = 4.8 \times 10^4 N$$

D is the correct option

Question 3

A force F is required to keep a 5kg mass moving round a cycle of radius 3.5m at a speed of $7ms^{-1}$. What is the speed, if the force is tripled?{UTME2008}

A. $4.0ms^{-1}$ B. $6.6ms^{-1}$ C. $12.1ms^{-1}$
D. $21.0ms^{-1}$

Solution

$$f = m\frac{v^2}{r}$$

Keeping the mass and the radius of the ball constant, since the same ball is being used

$$\frac{f}{v^2} = \frac{m}{r}$$

So the relation will now be,

$$\frac{f_1}{{v_1}^2} = \frac{f_2}{{v_2}^2}$$

From the question,

$$f_2 = 3f_1$$

Substitute

$$\frac{f_1}{7^2} = \frac{3f_1}{{v_2}^2}$$

$${v_2}^2 = 49 \times 3$$
$${v_2}^2 = 147$$

Find the square root of both sides

$$v_2 = 12.1ms^{-1}$$

C is the correct option

Question 4

If a wheel 1.2m in a diameter rotates at one revolution per second, calculate the velocity of the wheel.{UTME2008}

A. $3.6ms^{-1}$ B. $3.8ms^{-1}$ C. $4.0ms^{-1}$

D. $7.5ms^{-1}$

Solution

Frequency = one revolution per second, since frequency is number of oscillation per unit time.

$$\omega = 2\pi f$$

$$\omega = 2 \times 3.142 \times 1 = 6.284\, rads^{-1}$$
$$v = \omega r$$
$$radius = \frac{diameter}{2} = \frac{1.2}{2} = 0.6m$$
$$v = 6.284 \times 0.6 = 3.77 = 3.8ms^{-1}$$

B is the correct answer

Question 5

What is the frequency of vibration if the balance wheel of a wristwatch makes 90 revolutions in 25s?{UTME2008}

A. 0.01Hz B. 0.04Hz C. 2.27Hz D. 3.60Hz

Solution

$$frequency = \frac{no\ of\ oscillation}{unit\ time} = \frac{90}{25} = 3.6Hz$$

D is the correct option

Question 6

An object of mass 2kg moves with a velocity of 10ms^{-1} round a circle of radius 4m. Calculate the centripetal force on the object. {UTME 2011}

A. 40 N B. 25 N C. 100 N D. 50 N

Solution

$$f = m\frac{v^2}{r}$$
$$f = 2 \times \frac{10^2}{50}$$

$$f = 40N$$

A is the correct option

Question 7

An object moves in a circular path of radius 0.5m with a speed of 1ms^{-1}. What is its angular velocity?{UTME 2012}

A. 8 rads^{-1} B. 4 rads^{-1} C. 2 rads^{-1}

D. 1 rads^{-1}

Solution

$$\omega = \frac{v}{r}$$

$$\omega = \frac{1}{0.5} = 2rads^{-1}$$

C is the correct option

Question 8

A simple pendulum of length 0.4m has a period 2s. What is the period of a similar pendulum of length 0.8m at the same place?{UTME 2013}

A. $\sqrt{2}s$ B. 8s C. 4s D. $2\sqrt{2}s$

Solution

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

Since the question says similar pendulum, that implies 2π and g will be constant. Squaring the equation and making some arrangement,

$$\frac{T^2}{l} = \frac{4\pi^2}{g}$$

Therefore,

$$\frac{{T_1}^2}{l_1} = \frac{{T_2}^2}{l_2}$$

$$\frac{2^2}{0.4} = \frac{{T_2}^2}{0.8}$$

Cross multiply and make T_2 the subject of the formula

$${T_2}^2 = 8$$

$$T_2 = 2\sqrt{2}s$$

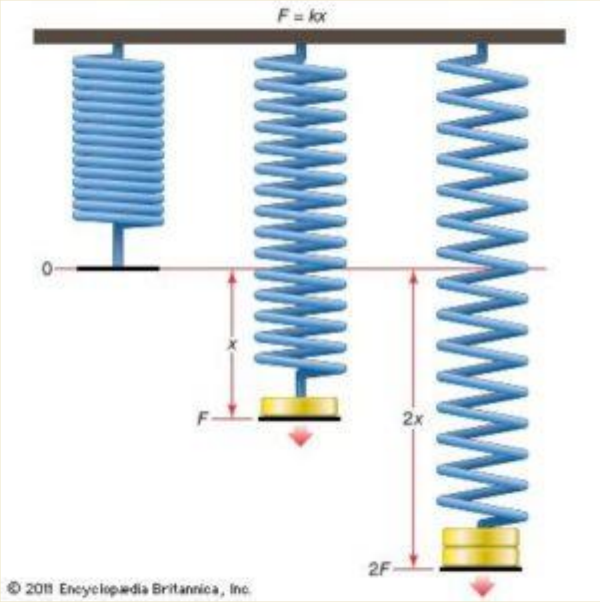
D is the correct answer

CHAPTER SIX

DEFORMATION OF SOLID: ELASTICITY

Deformation can be referred to as change of shape. For this kind of deformation either a tensile force which is responsible for stretching or compressive force which is responsible for squashing must be applied for deformation to occur.

Hooke's Law



It states that provided the elastic limit is not exceeded, the extension (e) is directly proportional to the force applied

Mathematically

F a e

F = Ke

F = force applied (N)

K = force constant (Nm^{-1})

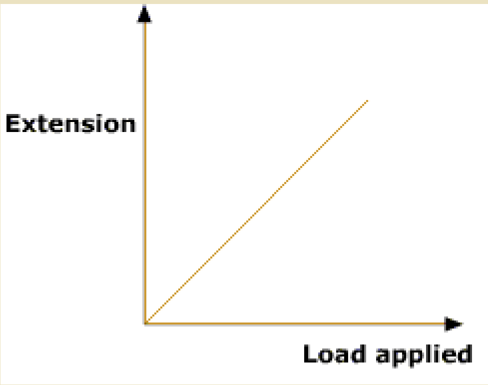
e = extension (m)

It means before a material extends there must be force applied. This implies that extension depends on the force applied.

Extension: It is the change in length of a spring

Load: The weight attached to the spring

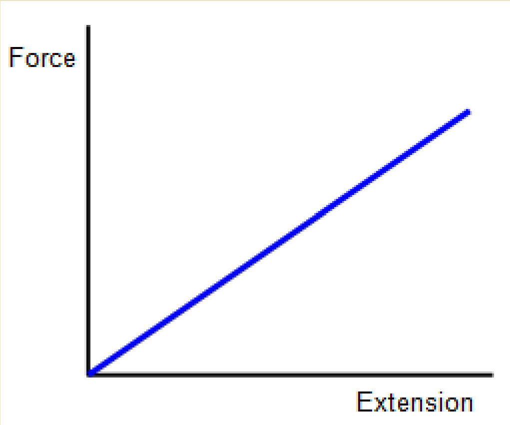
Graphically



From this graph

Force constant(k) = inverse of the graph's slope

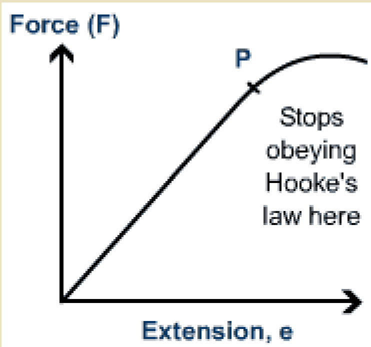
Another Hooke's law graph



Force constant = the slope of the graph

The two graphs represent Hooke's law. The only difference is how to calculate the force constant from the graphs.

Elastic limit: It is the maximum point where an elastic material can still return to its original size, shape, length and position if the force or load of distortion is removed.

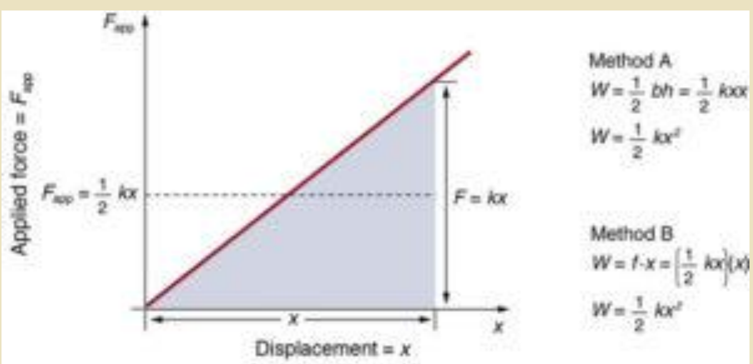


p is the elastic limit

Elastic deformation can be define as the change in shape/size/length/dimension when force is removed and its returns to original shape/size

Plastic deformation it is point beyond the elastic limit where an elastic material losses its elastic properties.

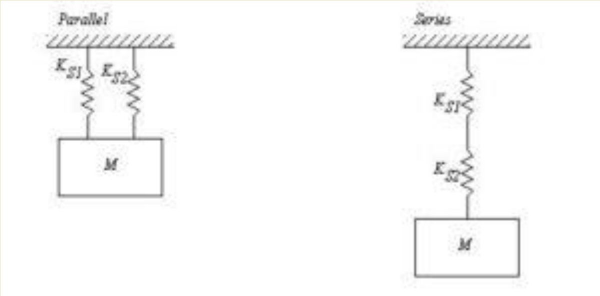
Strain energy: when an object has its shape changed by forces acting on it, the object is said to be strained. Strain energy is energy stored in a body due to change of shape.



$$w = \frac{1}{2}kx^2$$

x = extension

Arrangement of spring in series and parallel



For the second springs arranged in series

The total extension =

$$e_T = e_1 + e_2$$

Total force constant =

$$\frac{1}{k_T} = \frac{1}{k_1} + \frac{1}{k_2}$$

For the first springs arranged in parallel

Total extension =

$$\frac{1}{e_T} = \frac{1}{e_1} + \frac{1}{e_2}$$

Total force constant =

$$k_T = k_1 + k_2$$

Young's Modulus

It represents how easy it is to deform (stretch a material) or the measure of the stiffness of a material.

It can be define as the ratio of tensile stress to tensile strain provided the limit of proportionality is not exceeded.

The Young's modulus does not depend on the length of the wire but on the material that made the wire i.e. increase on decrease in length of the wire doesn't affect the young modulus

$$Young\ modulus = \frac{stress}{strain}$$

$$stress = \frac{Force\ applied}{cross - sectional\ area}$$

$$stress = \frac{F}{\frac{\pi d^2}{4}}$$

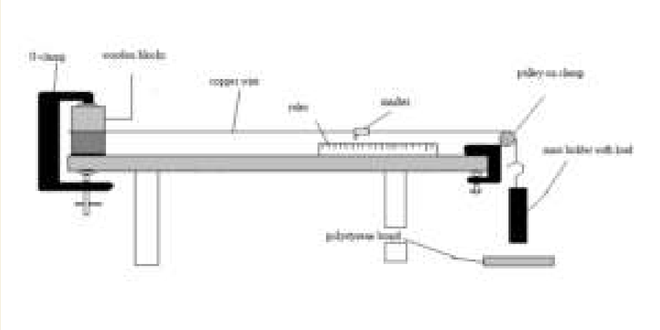
$$strain = \frac{extension}{initial\ length}$$

$$strain = \frac{e}{l}$$

Stress is the force per unit cross-sectional area of the wire

Strain is the fractional increase in the original length of the wire

Measurement of the Young Modulus

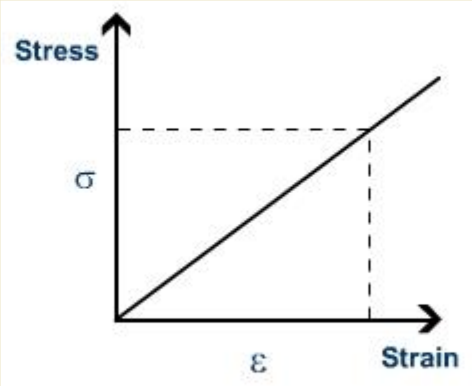


The Young's modulus of this wire can be measured using this set up. The extension varies as the slotted masses changes. The extension can be detected as the marker on the wire changes position, and the new position being measured on the rule

What to measure and the measurement instrument

- initial length: A meter rule to measure the initial length
- diameter : A micrometer screw gauge to measure the diameter of the wire
- extension: A marker and ruler to measure the extension
- force : A spring balance

Graphical representation of Young's modulus

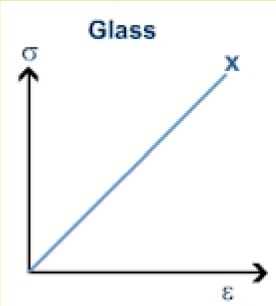


To calculate Young's modulus, you will find the slope of the graph i.e the slope of the graph = Young's modulus

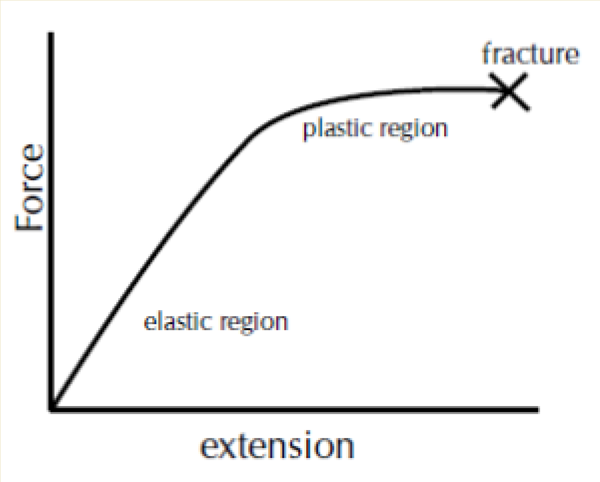
Types of material

- Brittle: Materials break at the elastic limit. Example glass
- Ductile: Materials become permanently deformed if they stretched beyond the elastic limit i.e they show plastic behaviour. Example Copper

Graph for brittle



Graph for ductile



Worked Example

Question 1

Given that Young's modulus for aluminum is 7.0×10^{10} Nm^{-2} and density is $2.7 \times 10^3 kgm^{-3}$, find the speed of the sound produced if a solid bar is struck at one end with a hammer. {UTME 2003}

A. $5.1 \times 10^3 ms^{-1}$ B. $4.2 \times 10^3 ms^{-1}$ C. $3.6 \times 10^3 ms^{-1}$ D. $2.8 \times 10^3 ms^{-1}$

Solution

$v^2 = \frac{\gamma}{\rho}$

V is velocity

ρ is density

γ is young modulus

$v^2 = \frac{7 \, x \, 10^{10}}{2.7 \, x \, 10^3}$

$v^2 = 25.9 \, x \, 10^6$

V = $5.09 \times 10^3 ms^{-1}$

A is the correct option

Question 2

A spring balance consists of a spring of length 20.0 cm with a hook attached. When a fish of mass 3.0 kg is suspended from the hook, the new length of the spring is 27.0 cm. What is the spring constant of the spring? {Cambridge may/june 2016 p12}

A 4.2 N m^{-1} B 43 N m^{-1} C 110 N m^{-1} D 420 N m^{-1}

Solution

F = ke

E = 27 – 20 = 7.0 cm = 0.07 m

K = f/e

F = ma = 3 x 9.81= 29.43N

K = 29.43/0.07 = 420 Nm^{-1}

D is the correct answer

CHAPTER SEVEN

WORK, ENERGY, AND POWER

Workdone by a force is defined as the product of the force and the distance moved in the direction of the force.

$W = F \times s$

F is the force

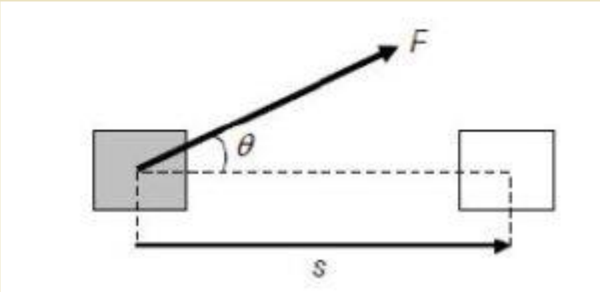
s is the displacement in the direction of the force

w is the workdone

The unit of workdone is joules

Doing work is a way of transferring energy

Joule is defined as the amount of workdone when a force of 1 newton moves a distance of 1 meters in the direction of the force.



The horizontal component of the force is $F\cos\theta$

workdone = $F\cos\theta \times s$

workdone = $Fs\cos\theta$

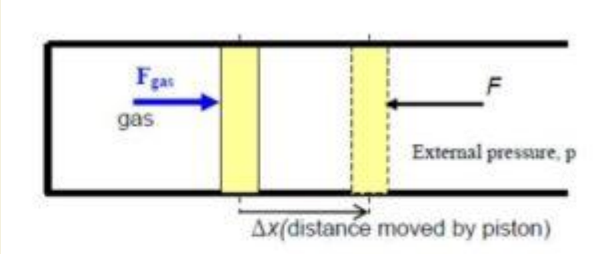
Energy

- Energy can neither be created nor destroyed, but can be converted from one form to another (or others).
- The total amount of energy in any closed system is constant
- There is no change in the total energy of the Universe
- Energy and work are both scalar quantities, and have the unit Joule.

Gas doing work

Gas exert pressure on the wall of their container. if a gas expands, the walls are pushed outwards – the gas has done work on it surrounding.

Work done by a gas that is expanding against a constant external pressure: $W = p\,.V$



Pressure = force / area

cross multiply

force = pressure x area

F = pA

workdone = F X S

substitute for the force

workdone = p x A X S

but the quantity A x s is the increase in volume of the gas, which is Δv

$w = p\Delta v$

Assuming that pressure p does not change as the gas expands. This will be true if the gas is expanding against the pressure of the atmosphere, which changes only very slowly.

Derive, from the equations of motion, the formula $E_k = \frac{1}{2}mv^2$

Kinetic Energy gained by an object is equal to the work done on that object

potential energy is the energy an object has because of its position or shape workdone by a net force = change in kinetic energy of the body

Recall that **$v^2 = u^2 + 2as$**

Make as the subject of the equation **$as = \frac{1}{2} v^2 - \frac{1}{2} u^2$**

Multiple both sides by m which is the mas **$mas = \frac{1}{2} mv^2 - \frac{1}{2} mu^2$**

F=ma , so **$Fs = \frac{1}{2} mv^2 - \frac{1}{2} mu^2$**

I f an object is starting from rest u = 0

Fs = **$\frac{1}{2} mv^2$**

Ek = **$\frac{1}{2} mv^2$**

Kinetic energy = energy associated with a moving object

Distinguish between gravitational potential energy, electric potential energy and elastic potential energy

Gravitational potential energy: it is the stored energy available to do work due to position of mass in a gravitational field

Elastic potential energy is the energy stored in an object which have had their shape changed elastically

G.P.E = mgh

Elastic potential = 1/2 k x^2

Show an understanding of the concept of internal energy

Internal energy: is the sum of the random potential and kinetic energies of all the molecules in a body

Internal Energy = Total Potential Energy + Total Random Kinetic Energy

Random Kinetic Energy = Translational Kinetic Energy + Rotational Kinetic Energy

Translational energy is the energy associated with the whole molecule moving in a certain direction.

Rotational energy is the energy associated with the molecule rotation around a certain point.

Potential energy is the energy associated with intermolecular forces

Efficiency = (useful output energy / total input energy) x 100%

Define power as work done per unit time and derive power as the product of force and velocity

Power is defined as the rate of workdone

Power = w / t

watt is the unit of power

watt is defined as a rate of working of 1 joule per second

Worked Examples

Question 1

A hammer with 10 J of kinetic energy hits a nail and pushes it 5.0 mm into a plank. Both the hammer and nail come to rest after the collision. What is the approximate average force that acts on the nail while it moves through 5.0 mm?{ Cambridge A level may/june 2016 p11}

A 0.050 N B 2.0 N C 50 N D 2000 N

Solution

workdone by a net force = change in kinetic energy of a body

F x s = Ek

F x s = 10

F x 0.005 = 10

F = 10 / 0.005

F = 2000N

D is the correct option

Q2, 3 and 4 are from cambridge A level may/june 2016 p13

Question 2

An object of mass 0.30 kg is thrown vertically upwards from the ground with an initial velocity of 8.0 m s–1. The object reaches a maximum height of 1.9 m. How much work is done against air resistance as the object rises to its maximum height?

A 4.0 J B 5.6 J C 9.6 J D 15 J

Solution

workdone by a net force = change in kinetic energy of a body

workdone = 1/2 m v2

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

$v^2 = 64 - 2*9.81*1.9$

$v^2 = 64 - 37.278$

$v^2 = 26.722$

workdone = 1/2 * 0.3 * 26.722

workdone = 4.0 J

A is the correct option

Question 3

A racing car has an output power of 300 kW when travelling at a constant speed of 60 m s–1. What is the total resistive force acting on the car?

A 5 kN B 10 kN C 50 kN D 100 kN

solution

power = force x velocity

300000 = force x 60

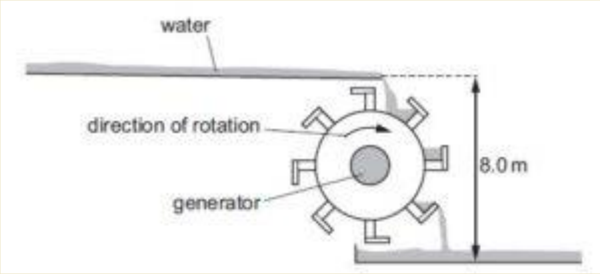
force = 300000 / 60

force = 5000 = 5KN

A is the correct option

Question 4

The diagram shows the design of a water wheel which drives a generator to produce electrical power. The flow rate of the water is 200 kg s–1. The generator supplies a current of 32 A at a voltage of 230 V.



Ignoring any changes in kinetic energy of the water, what is the efficiency of the system?

A 14% B 16% C 22% D 47%

Solution

efficiency = power output / power input

power output = IV

power output = 32*230 = 7360

power input = flow rate * a * h

a is the acceleration due to gravity

power input = 200*8*9.81 = 15696

efficiency = (7360 / 15696)*100%

efficiency = 47%

(Q 5 and 6are from Cambridge A level may/june 2016 p12)

Question 5

A boy on a bicycle starts from rest and rolls down a hill inclined at 30° to the horizontal. The boy and bicycle have a combined mass of 25 kg. There is a frictional force of 30 N, which is independent of the velocity of the bicycle.
What is the kinetic energy of the boy and the bicycle after rolling 20 m down the slope?
A 1850 J B 2450 J C 3050 J D 3640 J

Solution

mgsinθ – fr = ma

25 * 9.81*sin30 – 30 = ma

122.625 – 30 = ma

92.625 = ma

ma is the net force

the kinetic energy = net force X distance

kinetic energy = 92.625 * 20 = 1852 J = 1850J

A is the correct answer

Question 6

An escalator in an underground station has 250 people standing on it and is moving with a velocity of 4.3 m s–1. The average mass of a person is 78 kg and the angle of the escalator to the horizontal is 40°.
What is the minimum power required to lift these people?
A 54 kW B 64 kW C 530 kW D 630 kW

Solution

the vertical force = mgsinθ = 250*78*9.81*sin40 = 122962 N

minimum power = vertical force x velocity = 122962 x 4.3 = 530 Kw

C is the correct option

Question 7

Calculate the apparent weight loss of a man weighing 70kg in an elevator moving downwards with an acceleration of $1.5ms^{-2}$.{2013 UTME Physics – Type U}
A. 105N B. 686N C. 595N D. 581N

solution

when an elevator is moving down

net force = ma

net force = 70*1.5

net force = 105 N

the weight loss = net force

the weight loss = 105 N

A is the correct option

CHAPTER EIGHT

Oscillation

Oscillation is one complete movement from the starting or rest position, up, then down and finally back up to the rest position.

Examples are pendulum, the beating of the heart, vibration of a guitar string, the motion of a child on a swing e.t.c.

Free Oscillation

A free oscillation means

- No energy loss
- No external force acting
- Constant energy
- Constant amplitude

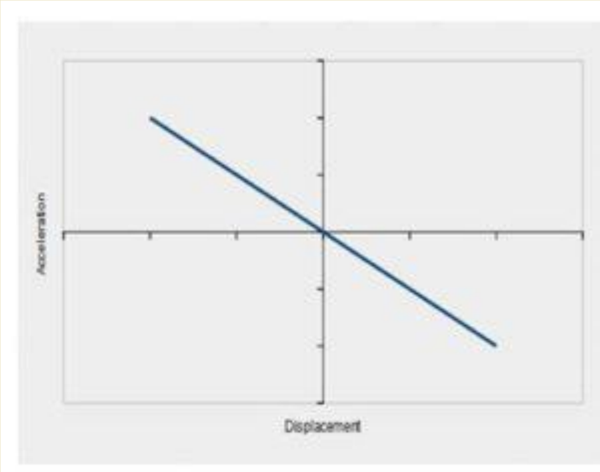
Understanding of terms
Period: it is the time taken for one complete oscillation
Frequency: it is the number of oscillations per unit time
Amplitude: it is the maximum displacement from the rest position.
Displacement: it is the distance from the equilibrium position
F= 1/T unit is Hertz (Hz)
F is frequency, T is period

Simple harmonic motion
It is defined as the motion of a particle about a fixed point such that its acceleration, a, is proportional to its displacement x from the fixed point, and is directed towards the point.
Mathematically,

$$a = -\omega^2 x$$

$\omega = 2\pi f$

The negative sign tells us that the acceleration is always in opposite direction to the displacement x



The slope or gradient of this graph = ω^2

Conditions necessary for a body to execute S.H.M

- when the body is displaced from equilibrium, there must exist a restoring force
- this restoring force must be proportional to the displacement of the body

(it is always directed to the equilibrium position)

.a is acceleration

. x is the displacement

Changes in displacement, velocity and acceleration during simple harmonic motion

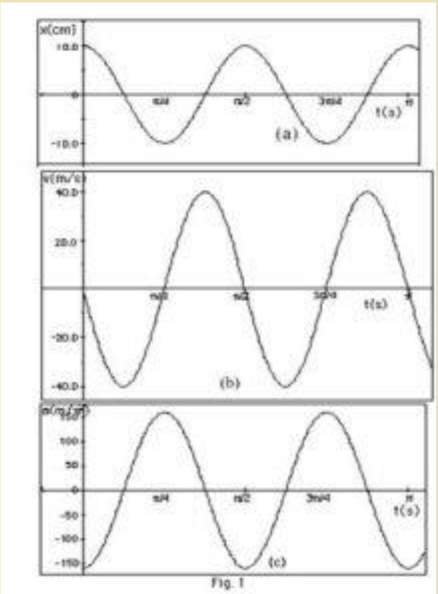


Fig. 1

This means when displacement is maximum, velocity is zero and acceleration maximum but in opposite direction.

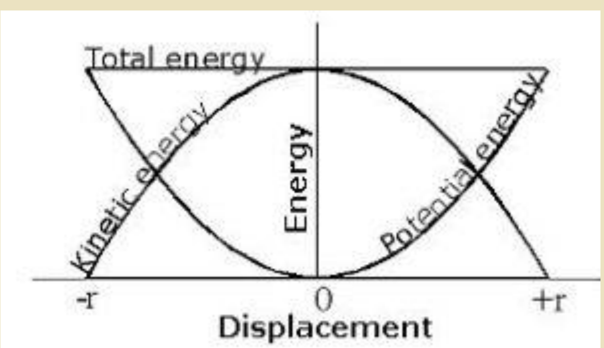
$v_o = x_o\omega$

v_o **is the maximum speed**

x_o **is the amplitude**

$$v = \pm\omega\sqrt{{x_o}^2 - x^2}$$

V is the instantaneous speed
Interchange between Kinetic and potential energy
K. E is maximum when displacement is zero
P.E is maximum when the displacement is maximum



$$E_k = \frac{1}{2}m\omega^2(x_o{}^2 - x^2)$$

$$E_p = \frac{1}{2}m\omega^2x^2$$

Total Energy = $E_k + E_p = \frac{1}{2}m\omega^2x_o{}^2$

Maximum P.E = Maximum K.E = Total energy = $\frac{1}{2}m\omega^2x_o{}^2$

Damping: This is an influence within or upon an oscillatory system that has the effect of reducing oscillations

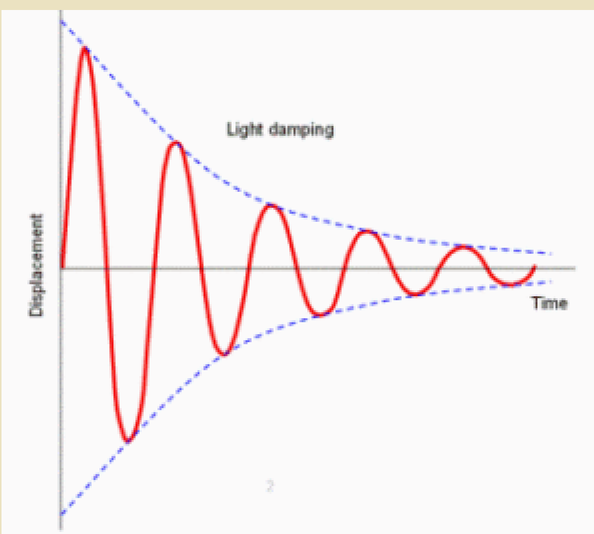
It can now be properly define as reduction in energy of oscillations/ reduction in amplitude due to force opposing motion/ resistive force.

Note

During damping amplitude of oscillation does not decrease linearly also the frequency of the oscillations does not change as the amplitude decreases.

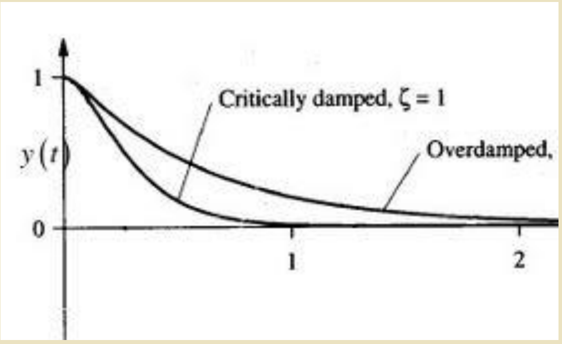
Types of Damping

Light damping: Amplitude decreases gradually as the oscillations continues for a long time



Critical damping: displacement decreases to zero in the shortest time without oscillation

Over damping: displacement decreases to zero in a longer time than for critical damping without any oscillation



Forced oscillation

This occur when an external force is applied to the original frequency causing a change in the frequency of the oscillation

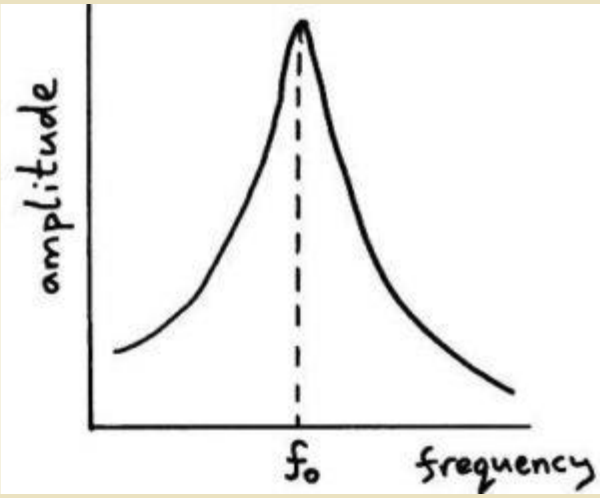
For resonance to occur there must be a system capable of oscillating freely and also have a way in which the system is forced to oscillate.

Forced frequency: frequency at which object is made to vibrate

Natural frequency of vibration: frequency at which object vibrates when free to do so

Resonance

Resonance occurs when the natural frequency of vibration of an object is equal to the driving frequency giving maximum amplitude of vibration



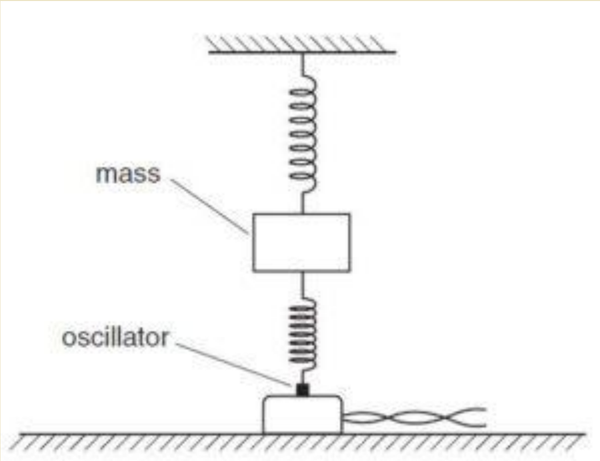
Uses of resonance

- oscillation of a child's swing
- microwave to cook food
- tuning of radio receiver
- Problems of resonance
- high-pitched sound waves can shatter fragile object
- metal panels on machinery vibrate

Worked Examples

Question 1

Two vertical springs, each having spring constant k, support a mass. The lower spring is
attached to an oscillator as shown below (Cambridge oct/nov 2006 p4)



The oscillator is switched off. The mass is displaced vertically and then released so that it
vibrates. During these vibrations, the springs are always extended. The vertical acceleration
a of the mass m is given by the expression
$ma = -2kx$,
where x is the vertical displacement of the mass from its equilibrium position.
Show that, for a mass of 240 g and springs with spring constant $3.0 N cm^{-1}$, the frequency of vibration of the mass is approximately 8Hz

Solution

mass = 240g = 0.24kg

k = 3.0 Ncm-1 = 300 Nm-1

ma = –2kx

$a = -\omega^2 x$ ……….i

0.24*a = -2* 300* x

a = -600x / 0.24

a = 2500x

substitute for a in equ i

$$-2500x = -\omega^2 x$$

$$2500 = \omega^2$$

Find the square root of both sides

$$\omega = \sqrt{2500}$$

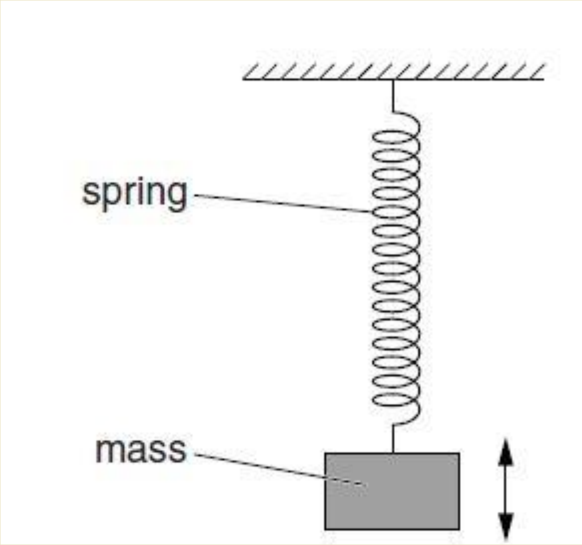
$\omega = 50$

$$\omega = 2\pi f$$

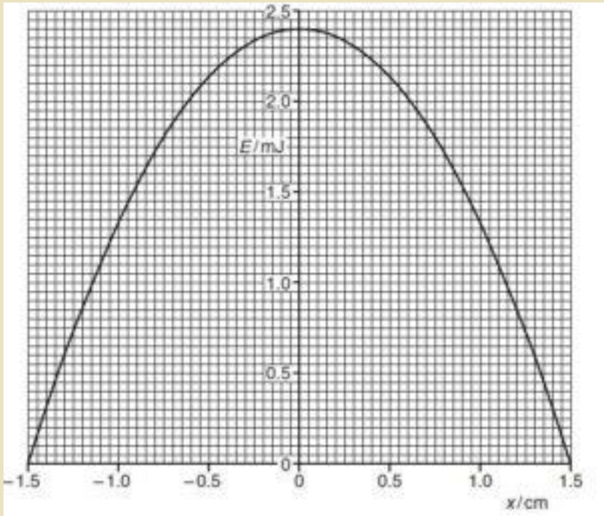
$$f = \frac{50}{2\pi}$$

f = 8 Hz

A student investigates the energy changes of a mass oscillating on a vertical spring, as shown below



The student draws a graph of the variation with displacement x of energy E of the oscillation, as shown below (Cambridge may/june 2014 p41)



The student repeats the investigation but with a smaller amplitude. The maximum value of E
is now found to be 1.8 mJ.
Use graph above to determine the change in the amplitude

Solution

From the graph the maximum kinetic energy = 2.4 mJ

Change in Kinetic energy = 2.4 – 1.8 = 0.6 mJ

$$E_{k\,max} = \frac{1}{2}m\omega^2 x_0{}^2$$

$$\frac{1}{2}m\omega^2(x_{01})^2 = 0.0024$$

Amplitude = 1.5 cm = 0.015 m

$$\frac{1}{2}m\omega^2(0.015)^2 = 0.0024$$

$$\frac{1}{2}m\omega^2 = \frac{0.0024}{(0.015)^2} = 10.67$$

When the amplitude change maximum energy E is 1.8m J

$$\frac{1}{2}m\omega^2(x_{02})^2 = 0.0018$$

$$10.67 \times (x_{02})^2 = 0.0018$$

$$(x_{02})^2 = \frac{0.0018}{10.67}$$

$$(x_{02})^2 = 0.00016869$$

$$x_{02} = 0.013\ m = 1.3\ cm$$

Change in Amplitude = 1.5 cm – 1.3 cm

Change in amplitude = 0.2 cm

CHAPTER NINE

WAVE MOTION

A wave allows energy to be transferred from one point to another without any particle of the medium travelling between the two points.

Wave motion can be classified base on:

- Mode of Propagation

The class of waves under this is

Mechanical wave: this requires a material medium for propagation

Electromagnetic wave: This travels in a vacuum

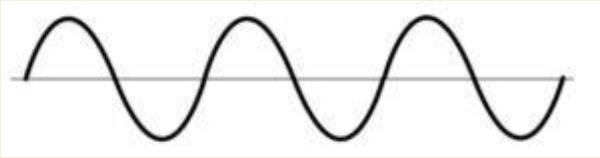
- Mode of vibration

The class of waves under this is:

Longitudinal waves

Transverse waves

Diagrammatic representation of waves



Definition of terms

Period (T): it is the time taken for a particle to undergo one complete cycle of oscillation.

Frequency (f): it is the number of oscillations performed by a particle per unit time.

Wavelength (λ): it is the distance between any two successive particles that are in phase, e.g. it is the distance between 2 consecutive crests or 2 troughs.

Wave speed (v): The speed at which the waveform travels in the direction of the propagation of the wave.

Wave front: A line or surface joining points which are at the same state of oscillation, i.e. in phase, e.g. a line joining crest to crest in a wave.

Displacement: it is the Position of an oscillating particle from its equilibrium position.

Amplitude: it is the maximum magnitude of the displacement of an oscillating particle from its equilibrium position.

To deduce V = fλ

$$v = \frac{distance}{time}$$

$$period(T) = \frac{time}{no\ of\ cycle}$$

$$wavelenght(\lambda) = \frac{distance}{no\ of\ cycle}$$

no of cycle = n

time = Tn

distance = **λ**n

substitute all into the velocity = distance/time

$$v = \frac{\lambda n}{Tn}$$

$$v = \frac{\lambda}{T}$$

Note

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

F is the frequency and the S.I base unit is Hertz (Hz)

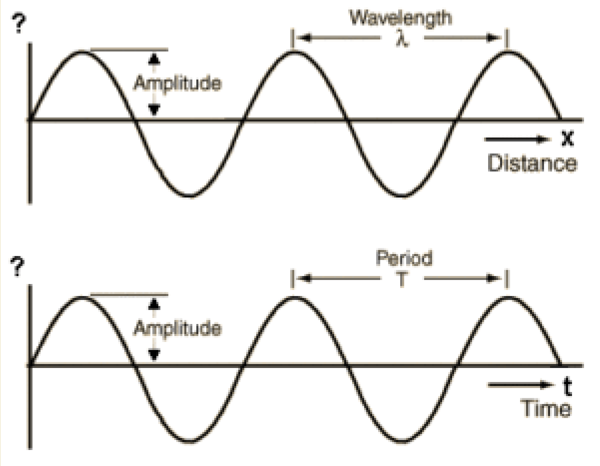
T is the period and the S.I base unit is second(s)

λ is the wavelength and the S.I base unit is meter(m)

Therefore,

V = fλ

Displacement-distance graph and Displacement-time graph



The first graph is a displacement-distance graph. On this graph you can find wavelength and amplitude

The second graph is a displacement-time graph. On this graph you can find period, frequency and amplitude

The only difference between the two graphs is what you can calculate from it.

Phase difference: this is an amount by which one oscillation leads or lags behind another. it measures in degree or radian.

Phase difference between waves that are exactly out of phase is π radians or 180 degrees

$$phase\ difference = \frac{2\pi}{T}$$

Or

$$phase\ difference = \frac{2\pi}{\lambda}$$

Progressive wave: it is a propagation of energy as a result of vibrations of waves which move energy from one place to another.

Intensity: it is defined as power incident per unit area. The intensity of wave generally decreases as it travels along. The two reasons for this are:

- The wave may spread out
- The wave may be absorbed or scattered

As wave spread out, its amplitude decreases

The unit of intensity is wm^{-2}

$$I \,\alpha\, A^2$$

$$I \,\alpha\, f^2$$

$$I \,\alpha\, \frac{1}{r^2}$$

I is the intensity

A is amplitude

f is frequency

r is the distance from the source

Difference between Longitudinal waves and Transverse waves

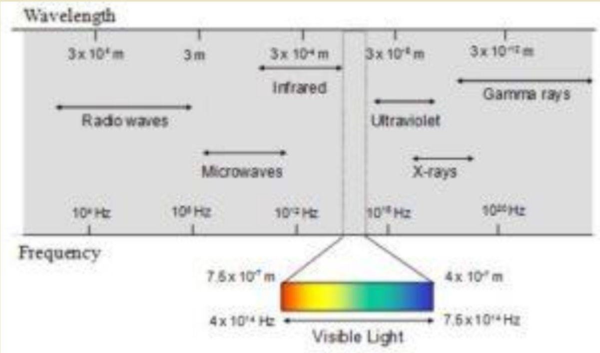
Transverse waves: A wave in which the oscillations of the wave particles are perpendicular to the direction of the propagation of the wave. Light wave is an example of transverse waves

Longitudinal waves: A wave in which the oscillations of the wave particles are parallel to the direction of the propagation of the wave. Sound wave is an example of longitudinal wave

Transverse waves can be plane polarized while longitudinal waves cannot be plane polarized.

Electromagnetic waves travel with the same speed in space

The speed of electromagnetic wave is $3 \times 10^{8}\ ms^{-1}$



Doppler Effect

Doppler Effect is the apparent change in frequency when there is a relative motion between the source and the observer.

As the source approaches

$$F' = \left(\frac{v}{v - v_s}\right) f_s$$

As the source moves away or recedes

$$F' = (\frac{v}{v + v_s})f_s$$

V is the speed of sound

V_s is the sped of the source

F_s is the frequency of the source

F’ is the observed frequency by the stationary observer

The Doppler Effect for electromagnetic waves such as light is of great use in astronomy and results in either a so-called redshift or blue shift. It has been used to measure the speed at which stars and galaxies are approaching or receding from us; that is, their radial velocities.

Red and blue shift

As the star moves away from the earth there will be increase in wavelength and decrease in frequency, this is redshift

As the star moves away towards the earth the wavelength will decrease and frequency will increase, this is blue shift.

Worked Examples

Question 1

Given the progressive wave equation {UTME 2008}

$$Y = 5\sin(2000\pi t - 0.4x)$$

Calculate the wavelength.
A. 12.4m B. 15.7m C. 17.5m D. 18.6m

Solution

Using the wave equation

$$Y = A\sin(wt - kx)$$

Compare this wave equation with the one given in the question

K is the phase difference

$$k = \frac{2\pi}{\lambda}$$

$$0.4 = \frac{2\pi}{\lambda}$$

$$\lambda = \frac{2\pi}{0.4}$$

$$\lambda = 15.7m$$

B is the correct option

Question 2

If a light wave has a wavelength of 500nm in air, what is the frequency of the wave?{UTME 2009}
A. 3.0×10^{14} Hz B. 6.0×10^{14} Hz C. 6.0×10^{12} Hz D. 2.5×10^{14} Hz
[c = 3×10^8 ms-1]

v = fλ

nanometer = 10^{-9} m

$3 \times 10^8 = f \times 500 \times 10^{-9}$

$f = 3 \times 10^8 / 500 \times 10^{-9}$

$f = 6.0 \times 10^{14}$ Hz

B is the correct option

Question 3

The wavelength of a wave travelling with a velocity of 420ms-1 is 42 m. What is its period? {UTME 2010}
A. 1.0s B. 0.1s C. 0.5s D. 1.2s

Solution

v = ג / T

T = ג / v

T = 42 / 420

T = 0.1 s

B is the correct option

Question 4

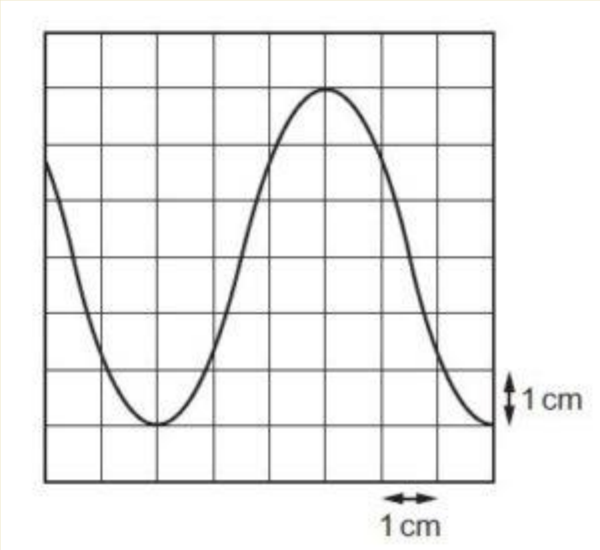
The property that is propagated in a traveling wave is?

A. frequency B. amplitude. C. energy D. wavelength

The correct option is C because it is energy that is transferred from one vibrating particle to another, whereby the vibrating particle remains in their mean position.

Question 5

A microphone connected to the Y-plates of a cathode-ray oscilloscope (c.r.o.) is placed in front of a loudspeaker. The trace on the screen of the c.r.o. is shown below {Cambridge may/june 2016 p12}



The time-base setting is 0.5 ms cm–1 and the Y-plate sensitivity is 0.2 mV cm–1. What is the frequency of the sound from the loudspeaker and what is the amplitude of the trace on the c.r.o.?{Cambridge may/june 2016 p12}

	frequency /Hz	amplitude /mV
A	330	0.6
B	330	1.2
C	670	0.6
D	670	1.2

Solution

The y-sensitivity will measure the amplitude which is on the y-axis

The time-base setting will measure the period which is on the x-axis

From the graph representation a full cycle occupies 6 boxes and one box to the x-axis o.5ms period (T) = no of boxes x value of one box (which is 0.5 ms)

T = 6 X 0.5 = 3 ms

Frequency (f) = 1 /T

f = 1 / (3 x 10^{-3}) = 333 Hz = 330 Hz approximately

From the graph the amplitude occupies 3 boxes i.e. maximum displacement from the rest position and one box to the y-axis o.2 mv

Amplitude = no of boxes x no of one box (which is 0.2mv)

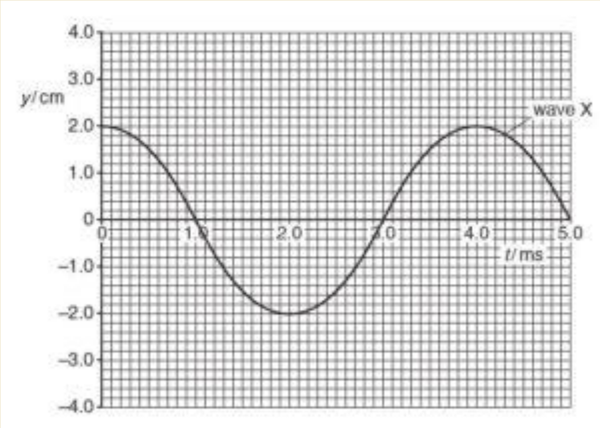
A = 3 x 0.2mv

A = 0.6 mv

A is the correct option

Question 5

The variation with time t of the displacement y of a wave X, as it passes a point P, is shown in



Use the diagram to determine the frequency of wave X.{ Cambridge may/june 2016 p12}

From the graph the period is 4.0 ms

f = 1 / T

f = 1 / (4 x 10^-3)

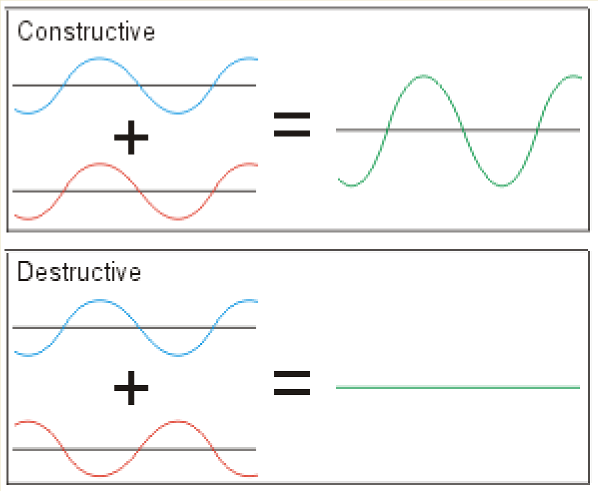
f = 250 Hz

CHAPTER TEN

STATIONARY WAVE, INTERFERENCE, AND DIFFRACTION

Principle of superposition

The Principle of Superposition states that when two or more waves meet at a point, the resultant displacement at that point is equal to the sum of the displacements of the individual waves at that point.



For constructive interference: the resultant displacement is always higher than the displacement of the individual waves.

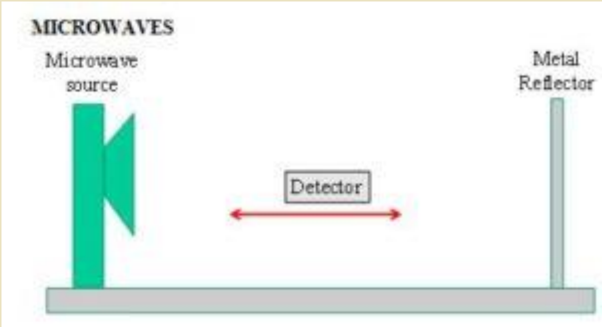
For destructive interference: the resultant displacement is always smaller than the displacement of the individual waves.

Stationary waves

A stationary wave is formed by two progressive waves of the same type, amplitude and frequency travelling in opposite directions superpose.

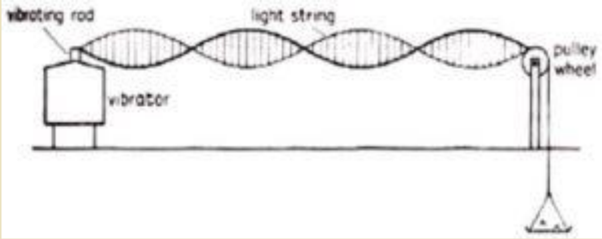
Show an understanding of experiments that demonstrate stationary waves using microwaves, stretched strings and air columns

Microwaves

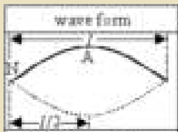
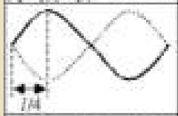
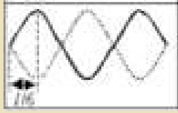


The Microwave source generate the wave signal while the metal reflector reflect the wave back, by this there the two progressive waves will superpose.

Stretched string



Explain the formation of a stationary wave using a graphical method, and identify nodes and antinodes

wave form	wavelength	frequency	name
	$\lambda_0 = 4\frac{l}{2} = 2l$	$f_0 = \frac{v}{\lambda_0} = \frac{v}{2l}$	fundamental (or 1st harmonic)
	$\lambda_1 = 4\frac{l}{4} = \frac{2l}{2} = \frac{\lambda_0}{2}$	$f_1 = \frac{v}{\lambda_0/2} = 2f_0$	1st overtone (or 2nd harmonic)
	$\lambda_2 = 4\frac{l}{6} = \frac{2l}{3} = \frac{\lambda_0}{3}$	$f_2 = \frac{v}{\lambda_0/3} = 3f_0$	2nd overtone (or 3rd harmonic)

For the first waveform: it is the first harmonic or the fundamental

$$l = \frac{\lambda}{2}$$

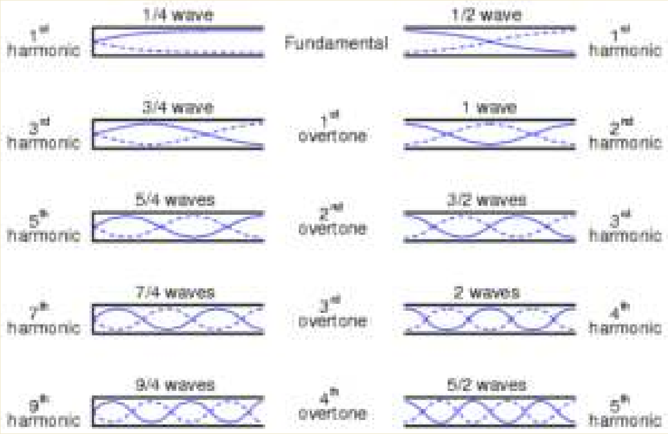
For the second waveform: it is the second harmonic or the first overtone

$$l = \lambda$$

For the third waveform: it is the third harmonic or the second overtone

$$l = \frac{3\lambda}{2}$$

Pipes closed at one end and pipes open at both ends



Pipes on the left hand side are open at one end

For the first harmonic

$$l = \frac{\lambda}{4}$$

Pipes on the right hand side are open at both end

For the first harmonic

$$l = \frac{\lambda}{2}$$

Node: it is a point of zero amplitude

Antinode: it is a point of maximum amplitude

Recall,

$$v = f\lambda$$

Differences between stationary and progressive waves

Stationary waves

1. No energy is transported by the wave
2. the wave profile does not advance
3. amplitude varies from maximum at the anti-nodes to zero at the node

Progressive waves

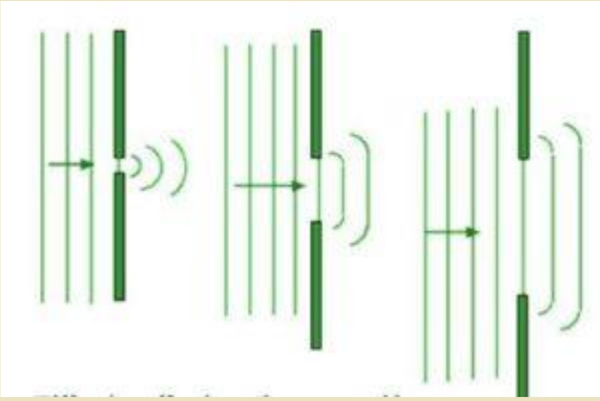
1. energy is transported in the direction of the wave
2. wave profile advances
3. amplitude is the same for all particles in the wave

Diffraction

Diffraction is the spreading of waves through an aperture or round an obstacle.

- The bending of waves around an obstruction
- As the size of the aperture or the object decreases the effects of diffraction increase
- The wavelength needs to be similar to the size of the aperture for diffraction to be noticeable

The smaller the size of the aperture, the greater the spreading of the waves (if the width of the aperture is about the same size as the wavelength, λ, the diffraction effect is very considerable).

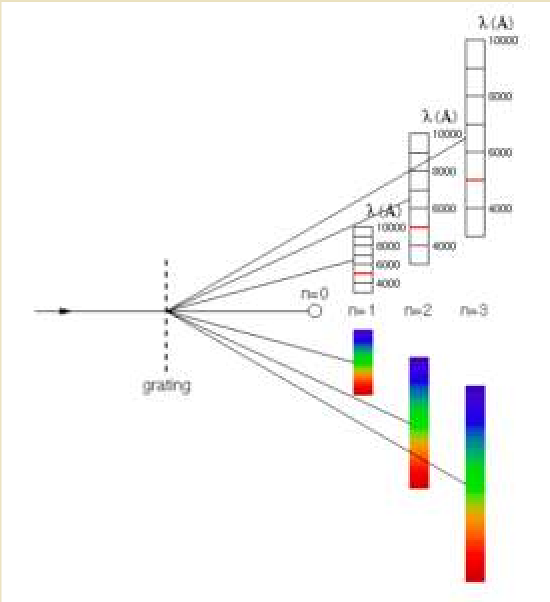


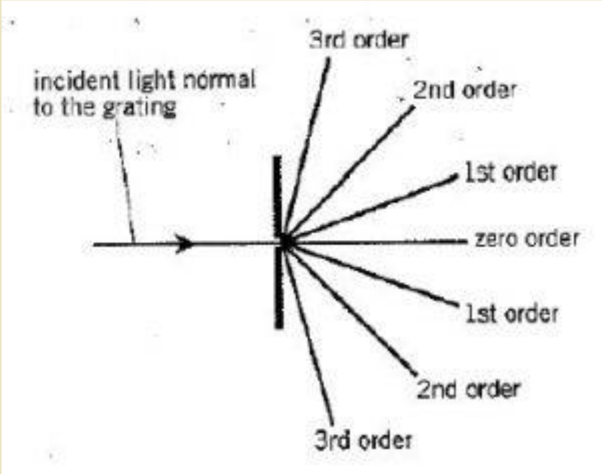
Diffraction grating

A diffraction grating is a plate on which there is a very large number of identical, parallel, very closely spaced slits.

Uses of diffraction grating

1. it is use to determine the wavelength of light
2. it can be used to make spectrometer





Diffraction grating equation can be represented by

$$n\lambda = dsin\theta$$

n is the number of order

λ is the wavelength

d is the slit sepation

ø is the angle of diffraction

Interference

Interference is the superposing of two or more waves to give a resultant wave whose displacement is given by the principle of superposition.

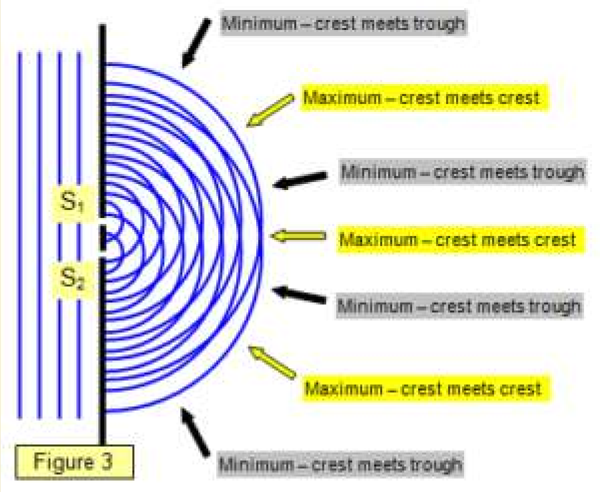
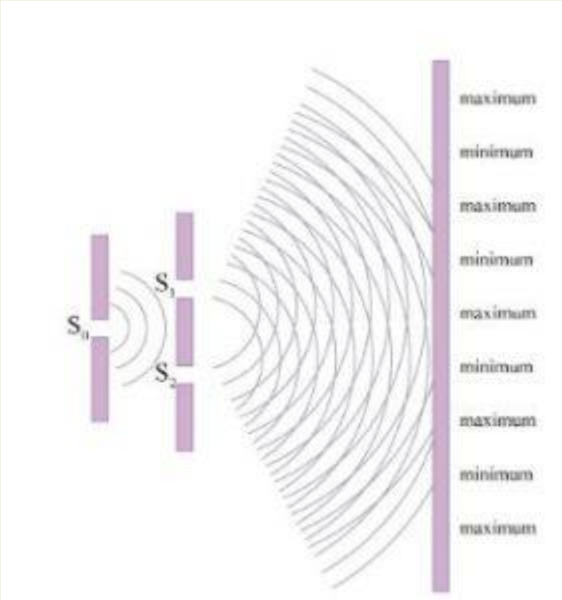


Figure 3

At regions of maxima, constructive interference occurs (i.e the waves arrive at these points in phase), resulting in maxima amplitude, hence high intensity

At regions of minima, destructive interference occurs (i.e the waves arrive at these points in anti-phase), resulting in minima or zero amplitude, hence low or zero intensity.

Young's double slit experiment



Monochromatic light talks about light with one wavelength, example red light

Polychromatic light consists more than one wavelength, example visible or white light

Coherent source: waves coming from them are always at a constant phase difference

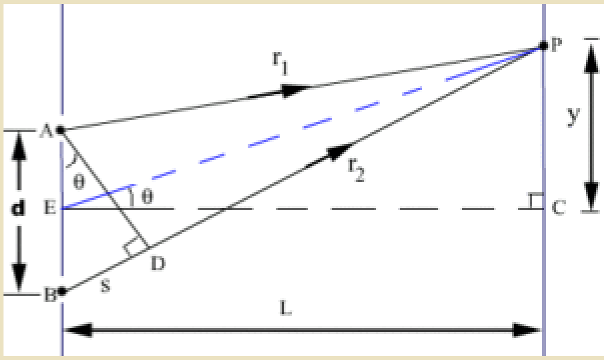
Bright fringes are formed due to constructive interference (i.e. the waves arrive at these point in phase), while

Dark fringes are due to destructive (i.e. the waves arrive at these points is anti-phase (180 degree) - no resultant amplitude, which then appear dark)

For interference fringes to be observable

1. The source must be coherent; that is they must maintain a constant phase difference
2. The source must have the same frequency (for light waves, this mean that they must be monochromatic)
3. The principle of superposition must apply(the source must produce the same type of waves)
4. The source must have approximately the same amplitude

Condition for constructive interference



$$Bp - Ap = n\lambda$$

B is the second source

A is the first source

Condition for destructive interference

$$Bp - Ap = (n + \frac{1}{2})\lambda$$

$$\lambda = \frac{ax}{D}$$

λ is the wavelength

a is the separation of the slits

x is the fringe separation

D is the separation between the screen and the double slit

Worked Examples

Question 1

A parallel beam of light of wavelength 450 nm is incident normally on a diffraction grating which has 300 lines / mm. What is the total number of intensity

maxima observed?{ Cambridge A level may/jun 2016 p11)
A 7 B 8 C14 D15

Solution

$n\lambda = dsin\theta$

d is the slit separation in meters

300 line is 1 mm

1 mm is 10^-3 m

1 line = 10^-3 / 300 m

d = 10^-3 / 300

wavelength = 450nm = 450 x 10^-9 m

the angle of diffraction = 90 in order to calculate the total number of maxima

n x 450 x 10^-9 = 10^-3 / 300 x sin 90

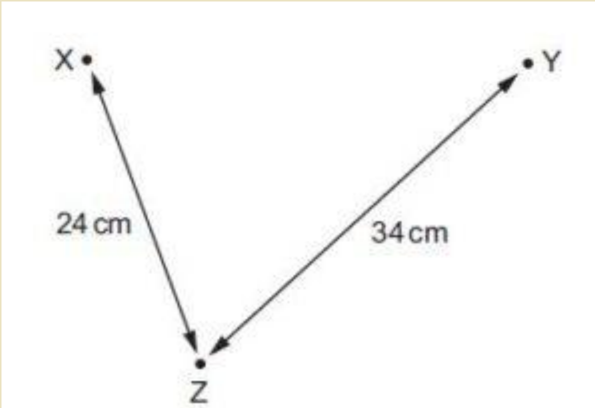
n = 7, which is the number of order

The total number of maxima = 2 x 7(7 order up and 7 order down) + 1(zero order) = 15

D is the correct option

Question 2

Wave generators at points X and Y produce water waves of the same wavelength. At point Z, the waves from X have the same amplitude as the waves from Y. Distances XZ and YZ are as shown.



When the wave generators operate in phase, the amplitude of oscillation at Z is zero. What could be the wavelength of the waves?{ Cambridge A level May/jun 2015 p13}

A 2 cm B 3 cm C4cm D 6 cm

Solution

since the amplitude at z is zero, it means it is a destructive interference

yz – xz = (n + 1/2)ג

34 -24 = (n + 1/2)ג

10 = (n + 1/2)ג

n =1, 2, 3,4, ……..

using n = 2

10 = 2.5 ג

ג = 10/2.5

ג = 4 cm

Question 3

A parallel beam of white light passes through a diffraction grating. Orange light of wavelength 600 nm in the fourth order diffraction maximum coincides with blue light in the fifth order diffraction maximum. What is the wavelength of the blue light? {Cambridge A level may/jun 2014 p11}

A 450 nm B 480 nm C 500 nm D 750 nm

Solution

when one light coincides with another in diffraction grating

$$n_1\lambda_1 = n_2\lambda_2$$

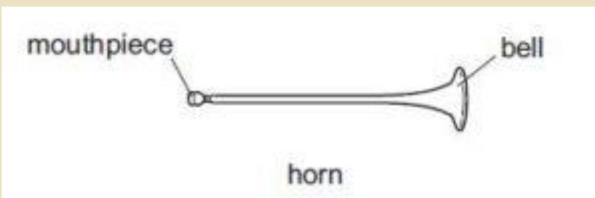
600 * 4 = 5 * ג

ג = 480 nm

B is the correct option

Question 4

The basic principle of note production in a horn is to set up a stationary wave in an air column.



For any note produced by the horn, a node is formed at the mouthpiece and an antinode is formed at the bell. The frequency of the lowest note is 75 Hz. What are the frequencies of the next two higher notes for this air column?

	first higher note /Hz	second higher note /Hz
A	113	150
B	150	225
C	150	300
D	225	375

{Cambridge A level may/jun 2014 p11}

Solution

A node is formed at the mouthpiece and an antinode is formed at the bell means, one end is closed and the other end is opened.

For the lowest frequency (first harmonic)

$$l = \frac{\lambda}{4}$$

ג =4l

v = fג

v = 4lf

f = v / 4l

fo = 75 Hz

for second harmonic

L = 3ג / 4

ג = 4l / 3

v = fג

v = 4lf / 3

f = 3v / 4l

f = 3f0

f = 3 * 75 = 225 Hz

For 3rd harmonic

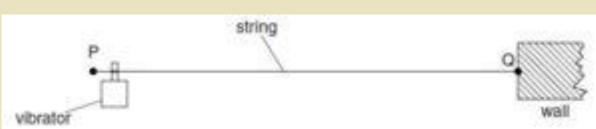
f = 5fo

f = 5* 75 = 375 Hz

D is the correct option

Question 5

Fig below shows a string stretched between two fixed points P and Q.



A vibrator is attached near end P of the string. End Q is fixed to a wall. The vibrator has a frequency of 50 Hz and causes a transverse wave to travel along the string at a speed of 40 m s–1.

Calculate the wavelength of the transverse wave on the string.{ Cambridge A level may/june 2013 p22)

Solution

v = f ג

40 = 50 * ג

ג = 40 / 50

ג = 0.8 m

Question 6

Light of wavelength 600 nm is incident on a pair of slits. Fringes with a spacing of 4.0 mm are formed on a screen. What will be the fringe spacing when the wavelength of the light is changed to 400 nm and the separation of the slits is doubled? { Cambridge A level may/ june 2013 p 11}

A 1.3 mm B 3.0 mm C 5.3 mm D 12 mm

Solution

$$\lambda = \frac{ax}{D}$$

D is constant

$$\frac{\lambda_1}{x_1 a_1} = \frac{\lambda_2}{x_2 a_2}$$

600 / 4*1 = 400 / 2x

x = 4 * 400 / 600 * 2

x = 1600 / 1200 =1.3 mm

CHAPTER ELEVEN

SIMPLE MACHINE

MACHINES

A machine is any device by means of which work can be done more conveniently.

Mechanical Advantage (M.A.)

The M.A. of a machine is defined as the ratio of load to the effort

Mechanical Advantage (M.A.) = load / effort

Velocity Ratio (V.R.)

The velocity ratio V.R. of a machine is defined as the distance moved by the effort to the distance moved by the load.

Velocity Ratio (V.R.) = distance moved by the effort / distance moved by the load

Efficiency

The efficiency of a machine is the ratio of the useful work done by a machine to the total work put into the machine.

i.e. Efficiency = (workout / workinput)*100%

Also, Efficiency = (M.A /V.R)*100%

THE LEVER

A lever is a simple machine. It consists of a rigid body which is pivoted about a point called the fulcrum. The lever is based on the principle of moment. The V.R is the ratio of the two arms of the lever.

1st class Lever

The fulcrum (F) is between the load (L) and the effort (E). The velocity ratio is usually greater than 1 but could be less than or equal to 1.

Examples of First Order Lever are: See-saw, crowbar, claw hammer, pliers, a pair of scissors or pincers.

2nd Class Lever

The load is between the fulcrum and the effort. M.A and V.R are always greater than 1.

Examples of Second order lever are: nutcracker and wheelbarrow.

3rd Class Lever

The effort is between the fulcrum and the load. M.A and V.R are less than 1.

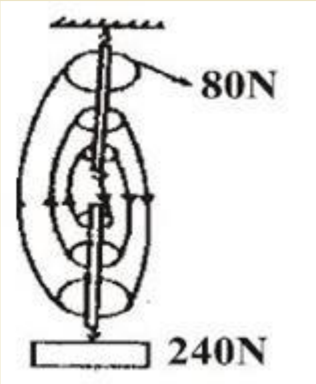
Examples of third order lever are: forearm, forceps, sugar tongs, and table knife.

THE PULLEYS

A pulley is a wheel with a grooved rim, and there can be several of these mounted in a framework called a block. The effort is applied to a rope which passes over the pulleys.

THE BLOCK AND TACKLE

The block and tackle is the type of pulley system used in cranes and lifts. It consists of two blocks each with one or more pulleys



In a block and tickle system the V.R is always equal to the total number of pulleys in the two blocks together.

INCLINED PLANE

A heavy load may be raised more easily by pulling it along a sloping surface than by lifting it vertically. If l is the length of the plane and h its height, then;

V.R = L /h

For a perfect inclined plane, Load x distance moved by load = Effort x distance moved by effort

In the right–angle triangle

V.R = 1 /Sin θ

THE WHEEL AND AXLE

V.R = R / r = radius of wheel / radius of axle

Worked Examples

Question 1

A wheel and axle is used to raise a load of 500 N by the application of an effort of 250N. If the radii of the wheel and
the axle are 0.4cm and o.1cm respectively, the efficiency of the machine is {2002}
A. 20% B. 40% C. 50% D. 60%

Solution

velocity ratio = radius of wheel / radius of axle = 0.4 / 0.1 = 4

mechanical advantage = load / effort = 500 / 250 = 2

efficiency = m.a /v.r *100% = 2/4 *100% = 50%

C is the correct option

Question 2

A machine whose efficiency is 60% has a velocity ratio of 5. If a force of 500N is applied to lift a load P, what is the
magnitude of P?{utme 2004}
A. 750N B. 4166N C. 500N D. 1500N

Solution

efficiency = m.a /v.r *100%

60/100 = m.a/5

cross multiply

m.a = 300/100 = 3

m.a = load / effort

3 = p / 500

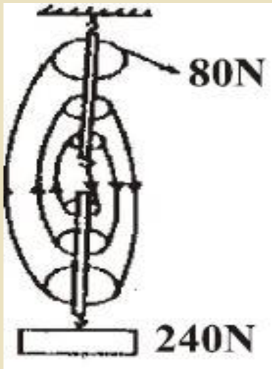
p = 1500N

D is the correct answer

Question 3

The diagram below is a block-and-tackle pulley system in which an effort of 80N is used to lift a load of 240N. The efficiency of the machine is {2001}

A. 40% B. 33% C. 60% D. 50%.



Solution

Velocity ratio = number of pulleys = 6

$$M.A = \frac{load}{effort} = \frac{240}{80} = 3$$

$$efficiency = \frac{M.A}{V.R} \times 100 = \frac{3}{6} \times 100 = 50\%$$

D is the correct answer

CHAPTER TWELVE

Optics

Transmission of light

Light can travel through a solid, liquid and gas or vacuum. Therefore, it does not need a maternal medium for its transmission.

Types of object/substance

1 Opaque object**:** These are objects that do not allow light to pass through them, e. g wood, stone, table, wall, etc.

2 Transparent objects**:** Transparent objects are those which allow some light energy to pass through them, e. g plane glass, clean and clear water, etc.

3 Translucent object**:** This allow some light to pass through them, but object cannot be seen clearly through them, e. g some window panes, cloth.

Rectilinear Propagation of Light

Rectilinear propagation of light is the phenomenon of light travelling in a straight line. The phenomenon can be demonstrated by using a candle flame, a string and three pieces of cardboard.

The pinhole camera

This operates on the principle that light travels in a straight line. It consists of a light-tight box, one end of which has a small hole made with a pin or needle point. If the pinhole is small, the image is bright (sharp) but when it is large a brighter but blurred image is obtained. A wide hole will produce several images that overlap that are seen as single blurred image. When the object distance is far from the pinhole, it produces a invented but diminished image. Also, when the distance between the pinhole and the screen is increased, the image is enlarged but less bright.

Magnification produced by a pinhole camera = image distance / object distance = image height/ object height

Laws of Reflection

- The angle of incidence is equal the angle of reflection

- The incident ray, the reflected ray and the normal at the point of incidence all lie in the same plane.

Formation of image by a plane mirror

The images formed by a plane mirror has the following characteristics

- It is erect
- It is far behind the mirror as the object is in front
- It is virtual
- It has the same size as the object
- Laterally inverted

Image formed by inclined mirror

When two mirrors are inclined at a certain angle to each other, and an object is placed in front of them, the number of images seen is given by

$N = (360/\theta) - 1$

Where the angle of inclination and N is the number of images formed

Uses of the plane mirror

- As looking glass
- In the periscope of two plane mirrors inclined at and fixed facing each other
- Plane mirror can be used as kaleidoscope. It consists of three plane mirrors inclined at to each other and a piece of ground glass set at the bottom.

Curved or spherical mirror

Curved mirror are produced by cutting out a part of a spherical shell: it is called concave mirror when light is reflected from the inside and convex mirror when light is reflected from the outside.

A concave mirror can form invented, real and magnified image of the object or real, inverted and diminished image or erect, virtual and magnified image depending on where the object is located.

- When the object is beyond C – Nature of image is real, inverted and diminished
- When the object is at C – Nature of image is real, inverted and same size
- When the object is between F and C – Nature of image is real, inverted and magnified
- When the object is at f – Nature of image is real, inverted, but formed at infinity
- When the object is between p and f – Nature of image is virtual, erect and magnified

C is the centre of curvature

F is the principal focus

p is the pole

Use of the curved mirror

- Convex mirror is used as car driving mirrors because they form upright image and also has a wild field of view.
- Convex mirror is also use in a super market to see round corners.

Concave mirrors

- Used as shaving mirror.
- Used as the distance
- Used in focusing starts for astronomical studies when used in the astronomical telescope.

Mirror formula can also be used to find the nature of the image formed by concave and convex mirror

$$\frac{1}{V}+\frac{1}{U}=\frac{1}{F}$$

Where V = image distance U = object distance F = focal length, F = r/2

Example

An object 8cm high placed 30cm from a concave mirror of radius of curvature 10cm. Calculate the (i) image distance (ii) image height

solution

U = 30cm f = 20/2 = 10cm

using the mirror formula

1/f = 1/u + 1/v

1/5 = 1/30 + 1/v

1/v = 1/5 – 1/30

1/v = 6/30

v = 5 cm

image distance = 5 cm

image distance/object distance = image height / object height

5/30 = x/8

x = 40 / 30

x = 1.3 cm

image height = 1.3 cm

Refraction

A ray of light refracts or deviates from its original path as it passes from one optical medium to another because the speed of light changes.

Laws of refraction

- The incident ray, the refracted ray and the normal to the point of incidence all lie on the same plane
- For any two given pair of medium, the ratio of sine of the angle of incidence to the sine of the angle of refraction is a constant. This is referred to as Snell's law

$$\boldsymbol{\eta = \frac{sini}{sinr}}$$

Where η is the refractive index of the second medium with respect to the first medium.

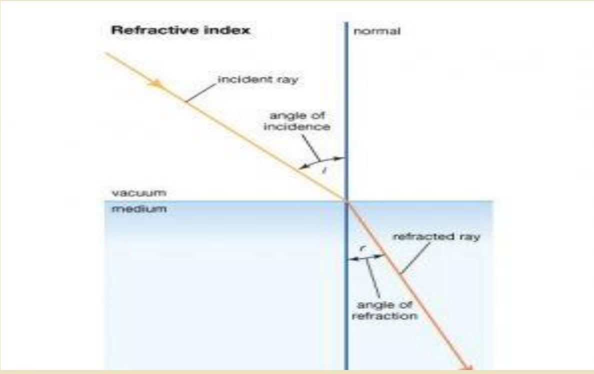
Refractive index is defined as the ratio of the speed of light, c, in vacuum to the speed of light, v, in the material.

$\boldsymbol{\eta = \frac{c}{v}}$

Refractive index of a medium depends on the following

- The nature of the medium
- The colour or wavelength of refractive indices

Refractive index



Total internal reflection

Conditions to satisfied for total internal reflection to take place are

- The ray of light must travel from a denser medium to a dense medium
- The angle of incidence must be greater than the critical angle for those two medium

$\boldsymbol{\eta = \frac{1}{sinc}}$

C is the critical angle

Critical angle is that angle of incidence for which a ray of light while moving from a denser to a rarer medium just grazes over the surface of separation of the two media i.e. angle of refraction is 90^{o}

Lenses

Lenses can be classified as

Convex lens or converging lens

Concave lens or diverging lens

Formation of images by a convex lens

- When the object is beyond $2f_1$ – Nature of image is real, inverted and diminished
- When the object is at $2f_1$ – Nature of image is real, inverted and same size
- When the object is between F and $2f_1$ – Nature of image is real, inverted and magnified
- When the object is at f_1 – Nature of image is real, inverted, diminished but formed at infinity
- When the object is between o and f_1 – Nature of image is virtual, erect and magnified

f_1 is the first focal length.

Lens equation: it is applicable to both convex and concave lens

$$\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$$

F is the focal length

U is the object distance

V is the image distance

Human eye

Eye lens is a convex lens made of a transparent jelly-like proteinaceous material.

Important parts of the eye and their function

Cornea: light enters the eye through cornea

Irish: it regulates the amount of light entering the eye by adjusting the size of the pupil.

Pupil: is the small circular opening

Retina: the inner back surface of the eye ball

Ciliary muscle: it helps in changing the curvature and focal length of the eye lens

Blind spot: it is a spot at which the optic nerve enters the eye and is insensitive to light

Eye defects

Hypermetropia or longsightedness: it is the defect of the eye due to which the eye is not able to see clearly the nearby objects although it can see the distant objects clearly. It can be corrected using a **convex lens**

Myopia or shortsightedness: it is the defect of the eye due to which the eye is not able to see the distant objects clearly. It can be corrected using a **concave lens**.

The range of vision of a normal healthy eye is from infinity to 25cm from the eye.

More worked Examples

Question 1

A ray of light strikes a plane mirror at an angle of incidence of 35^o. If the mirror is rotated through 10^o, through what angle is the reflected ray rotated? {UTME 2001}

A. 45^o B. 20^o C. 70^o D. 25^o

The reflected ray will rotate through the angle = 2* angle through which the mirror rotate = 2*10 =20

B is the correct option

Question 2

A concave mirror of radius of curvature 40cm forms a real image twice as large as the object. The object distance is

{UTME 2002}

A. 10cm B. 30cm C. 40cm D. 60cm.

Solution

Radius = 2f

f = 40/2 = 20cm

v = image, u = object

v = 2*u = 2u

1/f = 1/u + 1/v

1/20 = 1/u + 1/2u

1/20 = 3/2u

cross multiply

2u = 60

u = 60/2 = 30cm

B is the correct answer

Question 3

To produce an enlarged and erect image with a concave mirror, the object must be positioned {UTME 2002}
A. at the principal focus. B. beyond the centre of curvature C. between the principal focus and the centre of curvature. D. between the principal focus and the pole.

D is the correct option

Question 4

By what factor will the size of an object placed 10cm from a convex lens be increased if the image is seen on a screen placed 25cm from the lens?{utme 2003}
A. 15.0 B. 2.5 C. 1.5 D. 0.4

Solution

Magnification = image distance / object distance = 25 / 10 = 2.5

B is the correct option

Question 5

If an object is placed between two parallel plane mirrors with their reflecting surfaces facing each other, how many images of the object will be formed?
A. Infinite B. Eight C. Four D. Two.

Solution

N =(360/θ) – 1

Where the angle of inclination and N is the number of images formed

angle between two parallel mirrors is 0

N = 360/0 -1 = infinity

A is the correct option

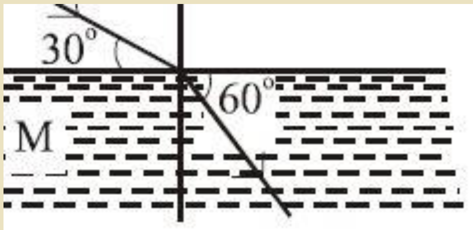
Question 6

At what position will an object be placed in front of a concave mirror in order in order to obtain an image at infinity? {UTME 2003}
A. At the pole of the mirror. B. At the principal focus. C. At the centre of curvature D. Between the principal focus and the centre of curvature.

Solution

B is the correct option

Question 7



The refractive index of the medium M in the diagram above is {UTME 2004}

A. $\frac{2}{\sqrt{3}}$ B. $\frac{1}{\sqrt{3}}$ C. $2\sqrt{3}$ D. $\sqrt{3}$

Solution

$$\boldsymbol{\eta} = \frac{\boldsymbol{sini}}{\boldsymbol{sinr}}$$

..i is 90 – 30 = 60°

..r is90-60 = 30°

$$\boldsymbol{\eta} = \frac{\boldsymbol{sin60}}{\boldsymbol{sin30}} = \frac{\frac{\sqrt{3}}{2}}{\frac{1}{2}} = \sqrt{3}$$

D is the correct option

Question 8

A person can focus an object only when it lies within 200cm from him. Which spectacles should be used to increase his maximum distance of distinct vision to infinity?
A. Concave lens B. Plane glasses C. Binoculars D. Convex lens.

Solution
This person is suffering from shortsightedness, it is the defect of the eye due to which the eye is not able to see the distant objects clearly. It can be corrected using a **concave lens**

A is the correct option

Question 9

If u is the object distance and v the image distance, which of the following expressions gives the linear magnification produced by a convex lens of focal length f?

A. $\frac{u}{v} + f$ B. . $\frac{u}{f} - f$ C. . $\frac{v}{f} - 1$ D. . $\frac{v}{f} + 1$

Solution

$\boldsymbol{\frac{1}{f} = \frac{1}{v} + \frac{1}{u}}$ **...........eq i**

F is the focal length

U is the object distance

V is the image distance

Note:

In convex lens (u is negative, v is positive when it is real and negative when it is virtual, and f is positive when it is real and no virtual focus)

$magnification = \frac{v}{u} = v \times \frac{1}{u}$ ....eq 2

Make u the subject of the equation

$\frac{1}{u} = \frac{v-f}{fv}$ ....eq 3

$\frac{1}{u} = \frac{v-f}{fv}$ -----eq 4

Substitute equ4 into eq 2

$$magnification = \frac{v}{u} = v \times \frac{1}{u} = v \times \frac{v-f}{fv} = \frac{v-f}{f} = \frac{v}{f} - 1$$

C is the correct option

CHAPTER THIRTEEN

Current of Electricity

Electric charge Q passing a point is defined as the product of the (steady) current at that point and the time for which the current flows.

$Q = It$

$Q = ne$

I is the current

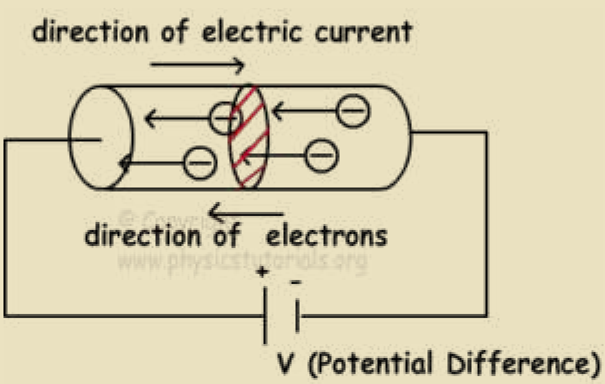
t is the time taken

When charges flow, there is electric current I, therefore,

Electric current is the rate of flow of electric *charge*

$I = \Delta Q/\Delta t$

The conventional direction of current is that of the +ve charge i.e current moves from the positive terminal to the negative terminal



One coulomb: is defined as the charge flowing per second past a point at which the current is one ampere.

Potential difference: Potential difference is defined as the energy transferred from electrical energy to other forms of energy e.g heat, light, sound e.t.c, when unit charge passes through an electrical device.

$W = QV$

W is the workdone

Q is the electric charge

v is the potential difference

V = W/ Q, the unit is JC^{-1} or volt

The volt: is defined as the potential difference between two points in a circuit in which one joule of energy is converted from electrical to non-electrical energy when one coulomb passes from one point to the other, i.e 1 volt = 1 JC^{-1}.

Resistance: is defined as the *ratio* of the potential difference across a component to the current flowing through it, provided temperature (and other physical conditions like resistivity, area of cross section, and length of wire remains constant.)

The Ohm: is the resistance of a resistor if there is a current of 1 A flowing through it when the p.d across it is 1 V, i.e,
1 Ω = One volt per ampere

R = V/I

Power is the rate of energy expended

P = E / t

E = Pt

V = W/Q

Substitute for E

V = Pt / Q

Q = It

t = Q / I

Substitute for t

V = PQ/IQ

V = P /I

P = IV ……….i

Note

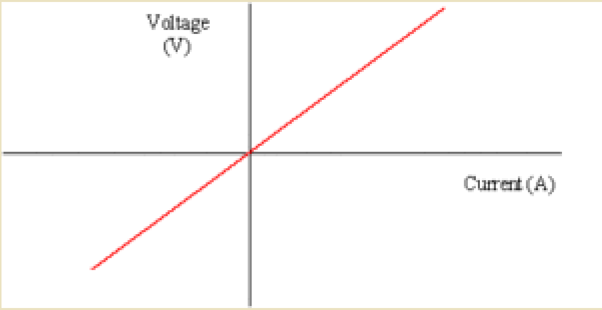
$V = IR$

substitute for V

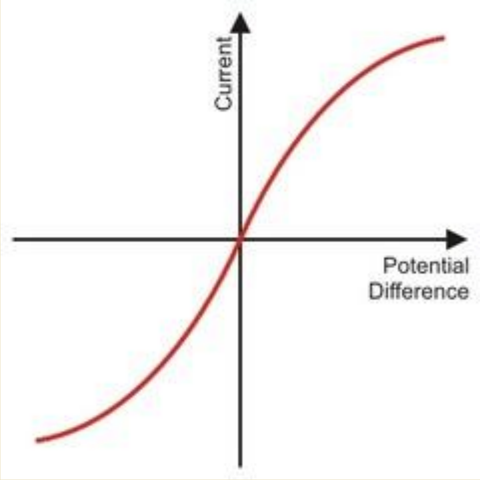
$P = I^2 R$

sketch and explain the *I-V* characteristics of a metallic conductor at constant temperature, a semiconductor diode and a filament lamp

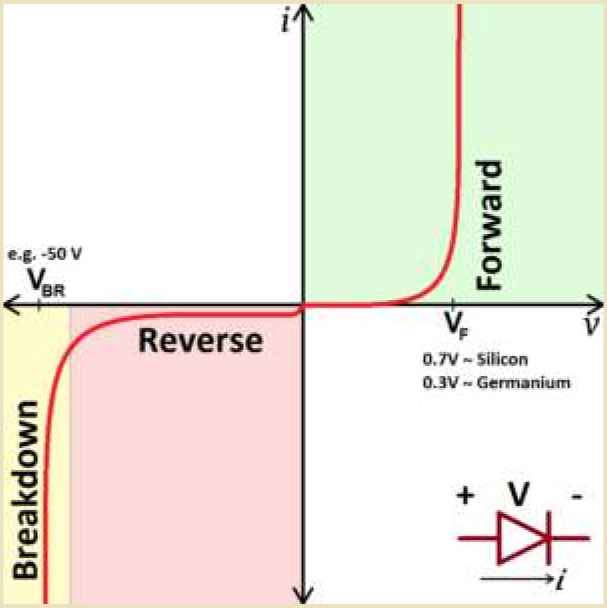
For Metallic conductor



For filament lamp



For semiconductor



Ohm's Law: The current flowing through a piece of metal is proportional to the potential difference across it providing the temperature remains constant

From the ohm' law equation for ohmic conductors,

(1) as R increases, the p.d drawn by the load increases, and vice versa, but R is inversely proportional to I, so current decreases because, as resistance increases, current decreases and vice versa.

(2)for a resistor and/(variable) resistor, as the R of one decreases, the p.d of the other increases, its current also increases, because, the

(3)V/I is always a constant value at the same temperature

Resistivity

Resistivity is defined as the resistance of a material of unit cross-sectional area and unit length.

$$R = \frac{\rho L}{A}$$

R = Resistance

r = Resistivity of material

L = Length of conductor

A = Area

E.m.f and P.d

Electromotive force ε is defined as the(total) energy transferred / converted from non-electrical forms into electrical energy when unit charge is moved round a complete circuit.

Distinguish between e.m.f. and p.d. in terms of energy considerations

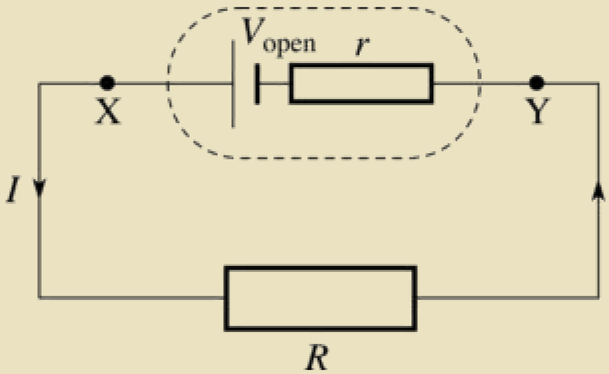
e.m.f. = (energy converted from other forms to electrical) / charge

p.d. = (energy converted from electrical to other forms) / charge

Internal resistance

Internal resistance is the resistance to current flow within the power source. It reduces the *potential difference* (not the emf) across the terminal of the power supply *when it is delivering a current*.

Consider the circuit below



E.m.f = I(R +r)

E.m.f = IR +Ir

IR is the terminal P.d

Ir is the lost volt

The greater the internal resistance, then the greater percentage loss in energy per unit charge, and the lower the terminal p.d V(= IR), and vice versa. So reducing the internal resistance of a battery increases the effective/useful energy delivered per unit charge across the external load.

Examples

Question 1

A heater is made from a wire of resistance 18.0 Ω and is connected to a power supply of
240 V. The heater is switched on for 2.60 Ms.{Cambridge A level 2013 p22}
Calculate
(i) the power transformed in the heater,

(ii) the current in the heater,

(iii) the charge passing through the heater in this time,

(iv) the number of electrons per second passing a given point in the heater.

Solution

i. P = v2 / R = 240 *240 / 18 = 3200 watt

ii. v = IR

I = v / R = 240 / 18 = 13.3 A

iii. Q = It

Q = 13.3 * 2.6 x 1o^6 = 34.7 x 10^6 c

iv It = ne

n/t = I/e = 13.3 / 1.6 x 10^-19 = 8.33 x 10^6 s-1

Question 2

An iron wire has length 8.0 m and diameter 0.50 mm. The wire has resistance R. A second iron wire has length 2.0 m and diameter 1.0 mm. What is the resistance of the second wire?{Cambridge A level 2012 p11}
A. R / 16 B. R/8 C. R / 2 D. R

solution

Since they are of the same material, they will have the same resistivity

R1A1 /L1 = R2A2 / L2

$$\frac{R_1 \pi {d_1}^2}{4 l_1} = \frac{R_2 \pi {d_2}^2}{4 l_2}$$

$$\frac{R_1 {d_1}^2}{l_1} = \frac{R_2 {d_2}^2}{l_2}$$

R * 0.5 * 0.5 / 8 = R2 * 1 * 1 / 2

R2 = 2*R*0.5*0.5 / 8

R2 = R / 16

A is the correct option

Question 3

An electric heater is to be made from nichrome wire. Nichrome has a resistivity of 1.0 × 10–6 Ω m at the operating temperature of the heater. The heater is to have a power dissipation of 60 W when the potential difference across its terminals is 12 V.
(a) For the heater operating at its designed power,
(i) calculate the current,

(ii) show that the resistance of the nichrome wire is 2.4 Ω.

(b) Calculate the length of nichrome wire of diameter 0.80 mm required for the heater.

(c) A second heater, also designed to operate from a 12 V supply, is constructed using the same nichrome wire but using half the length of that calculated in (b). Explain quantitatively the effect of this change in length of wire on the power of the heater. {Cambridge A level 2010 p21}

Solution

P = Iv

60 = I * 12

I = 60 / 12

I = 5 A

ii.

V = IR

R = v / I

R = 12 / 5

R = 2.4 Ω

b.

R = pl /A

l = RA/ p

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

l =(2.4 * 3.142 * 0.8 x 10^-3 * 0.8 x 10 ^-3) / 4 * 1 x 10^-6

L = 1.21 m

C.

The resistance and the length are directly proportional

When the length is halved, the resistance will be halved

Resistance and current are inversely proportional

Reduction in value of resistance means more current will flow. Since the resistance has been halved, the current will be doubled.

Since second heater also operated on a 12v supply, the power will be doubled because the current has been doubled i.e they are directly proportional.

Question 4

A source of e.m.f. of 9.0 mV has an internal resistance of 6.0 Ω. It is connected across a galvanometer of resistance 30 Ω. What will be the current in the galvanometer? {Cambridge A level 2010 p11}

A 250 μA B 300 μA C 1.5 mA D 2.5 mA

Solution

E.m.f = I(R + r)

9 x 10^-3 = I(6 + 30)

0.009 = 36I

I = 0.009 / 36

I = 0.00025 A = 250μA

A is the correct answer

Question 5

A 12 V battery is charged for 20 minutes by connecting it to a source of electromotive force (e.m.f.). The battery is supplied with 7.2 × 104J of energy in this time. How much charge flows into the battery?{Cambridge A level 2009 p1}

A 5.0 C B 60 C C 100 C D 6000 C

Solution

Energy = power x time

power = Iv

E = Ivt

Q = It

E = Qv

Q = E /v

Q = 7.2 x 10^4 / 12

Q = 6000 C

D is the correct answe

CHAPTER FOURTEEN

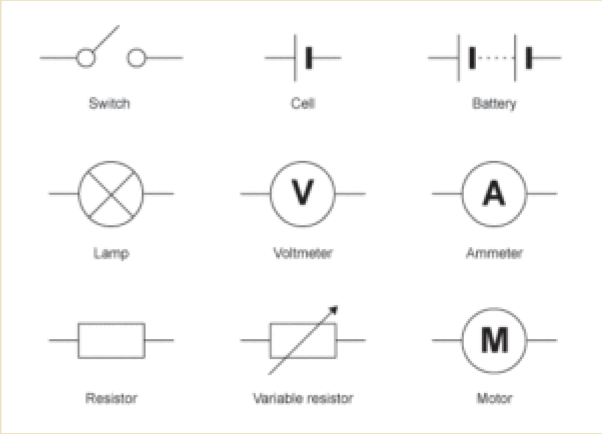
Direct Current

Direct current: flow of charges in the circuit is in the same direction all the time from higher potential to lower potential.

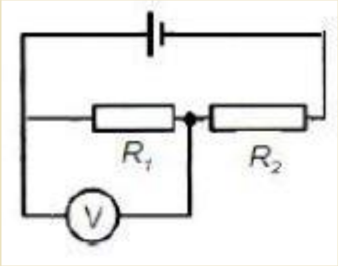
Appropriate circuit symbol

1. switch

2. Cell, voltmeter, ammeter, resistor, variable resistor etc



Circuit diagram

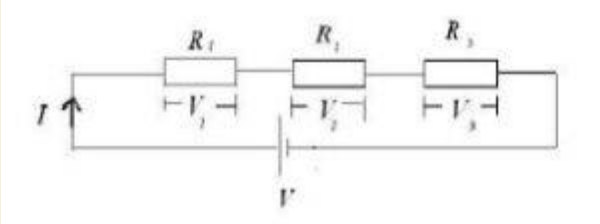


Kirchhoff's First Law: The sum of the currents entering a junction is always equal to the sum of the currents leaving it(conservation of electric charge)

Kirchhoff's Second Law: The sum of the electromotive forces in a closed circuit is equal to the sum of the potential differences (conservation of energy)

Derive, using Kirchhoff's laws, a formula for the combined resistance of two or more resistors in series

Series arrangement



Resistors are said to be connected in series if current can flow from one resistor to another without branching.

V = V1 + V2 + V3

V1 = IR1

V2 = IR2

V3 = IR3

V = IR

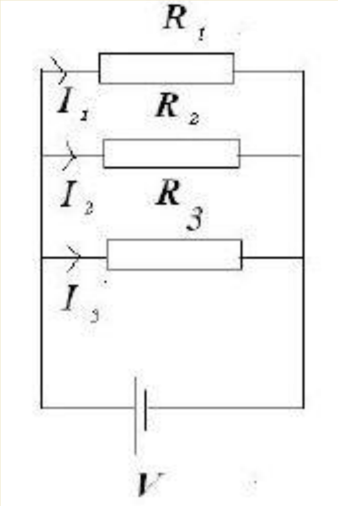
IRt = IR1 + IR2 + IR3

Note

in series arrangement same current flows through the resistors but different voltage

Rt = R1 + R2 + R3

Parallel arrangement



When resistors are connect in parallel current branches out but the voltage are the same for all the resistors

$I = I1 + I2 + I3$

$I1 = V / R1$

$I2 = V / R2$

$I3 = V / R3$

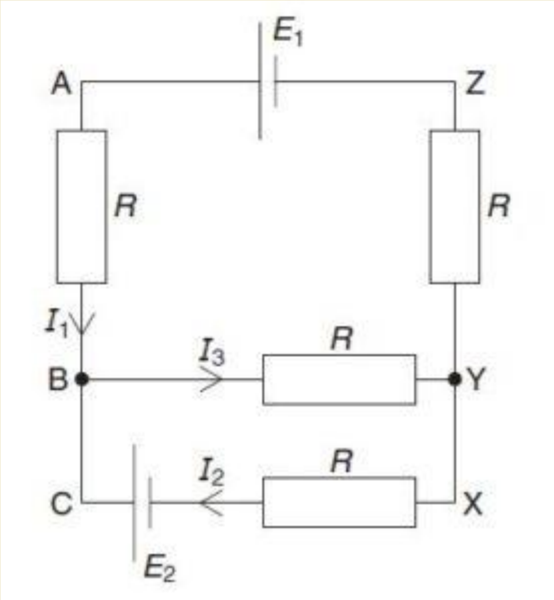
$I = V / Rt$

$V / Rt = V/R1 + V/R2 + V/ R3$

$1 / Rt = 1 / R1 + 1 / R2 + 1 / R3$

Example

Two cells of e.m.f. E1 and E2 and negligible internal resistance are connected into the network in the figure below



The currents in the network are as indicated in Fig. above
Use Kirchhoff's laws to state the relation
(i) between currents I1, I2 and I3,

(ii) between E2, R, I2 and I3 in loop BCXYB,

(iii) between E1, E2, R, I1 and I2 in loop ABCXYZA.

Solution

According to **Kirchhoff's First Law:** The sum of the currents entering a junction is always equal to the sum of the currents leaving it

Let junction B be our reference point

I1 is entering

I3 is leaving

I2 is entering

I3 = I1 + I2

(ii)

loop BCXYB

following anti-clockwise loop

Conventionally current moves from positive terminal and “enters” negative terminal

But in E_2 current leaves the negative terminal i.e E_2 will be negative

I_2 and I_3 will also be negative because it opposes the direction of the loop

$-E_2 = -I_2R - I_3R$

$E_2 = I_2R + I_3R$

(iii)

loop ABCXYZA

Following the anti-clockwise loop

Current leaves negative terminal of E_2 (this will give us $-E_2$) and enters the negative terminal of E_1 (this will give us $+E_1$)

I1 will be positive because it is in the direction of the loop

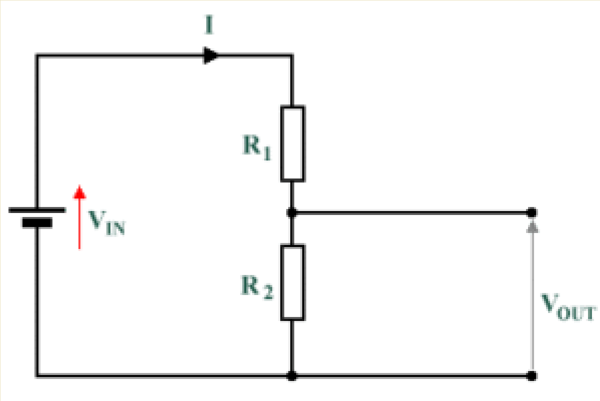
Resistors on A and Z are in series so current I_1 flows without branching

I_2 will be negative because it opposes the direction of the loop

$E_1 - E_2 = I_1R + I_1R - I_2R$

$E_1 - E_2 = 2I_1R - I_2R$

Show an understanding of the use of a potential divider circuit as a source of variable p.d.



Vin = V1 + V2

$V_1 = IR_1$

$V_2 = IR_2$

$V_{in} = IR_1 + IR_2$

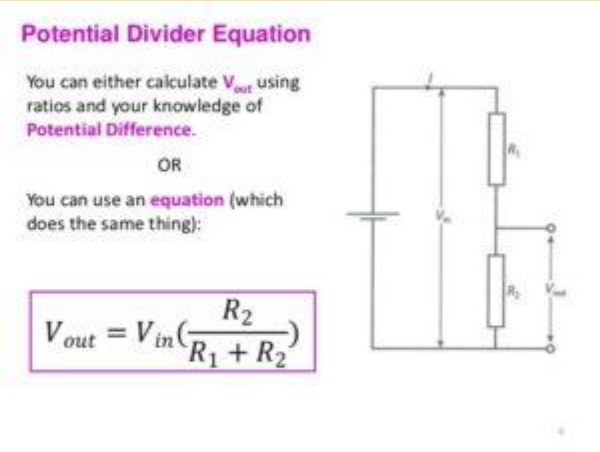
$V_{in} = I(R_1 + R_2)$

$I = V_{in} / (R_1 + R_2)$

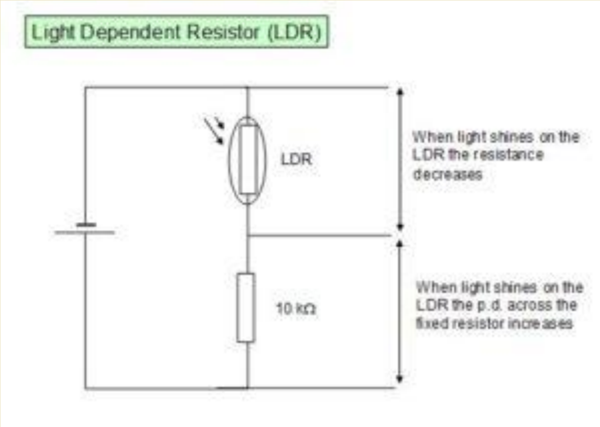
$V_2 = Vin / (R_1 + R_2) * R_2$

$V_2 = V_{out}$

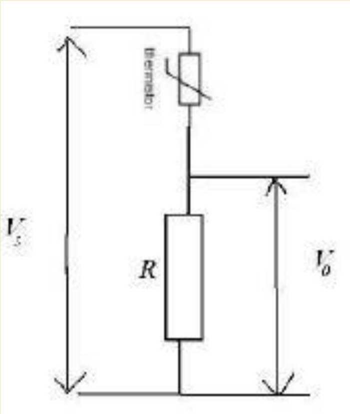
$V_{out} = R_2 / (R_1 + R_2) * V_{out}$



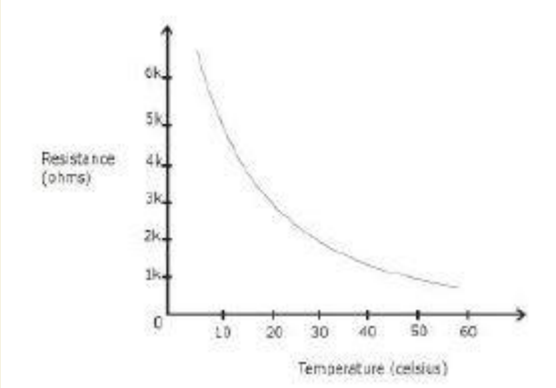
Use of thermistors and light-dependent resistors in potential dividers to provide a potential difference that is dependent on temperature and illumination respectively



Thermistor as temperature sensor



Temperature against the resistance of a thermistor



Worked Examples

Question 1

An electric generator has an e.m.f. of 240V and an internal resistance of 1Ω. If the current supplied by the generator is 20A when the terminal voltage is 220V, find the ratio of the power supplied to the power dissipated.{UTME 2008}
A. 11 : 1 B. 1 : 11 C. 12 : 11 D. 11 : 12

Solution

power supplied = IE

p= 20 * 240 = 4800

power dissipated = IV

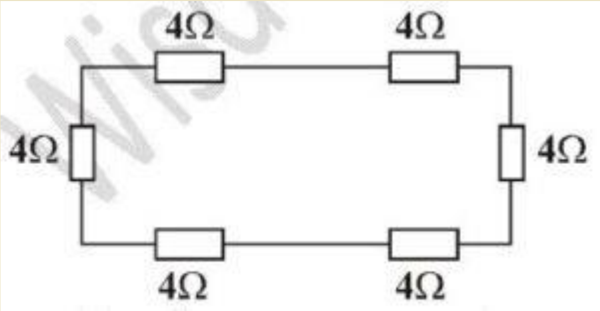
p = 20 * 220= 4400 watt

ratio = 4800 / 4400

12 : 11

A is the correct answer

Question 2



Find the effective resistance in the diagram above.{UTME 2008}
A. 6Ω B. 12Ω C. 16Ω D. 24Ω

solution

the arrangement is series because there is no branching of current

Rt = R1 + R2 + R3 + R4 + R5 + R6

Rt = 4 + 4 + 4 + 4 + 4 + 4

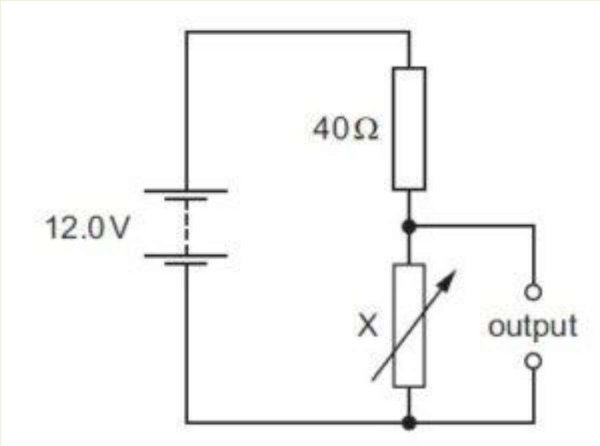
Rt = 24Ω

D is the correct option

Question 3 and 4 are from cambridge may/june 2016 p11

Question 3

In the circuit shown, X is a variable resistor whose resistance can be changed from 5.0 Ω to 500 Ω. The e.m.f. of the battery is 12.0 V. It has negligible internal resistance



What is the maximum range of values of potential difference across the output?
A 1.3 V to 11.1 V B 1.3 V to 12.0 V C 1.5 V to 11.1 V D 1.5 V to 12.0 V

Solution

Vout = (Rx / Rx + 40)* Vin

since Rx is a variable resistor, the vout will give a varying voltage

when Rx is 5Ω

Vout = (5 / 5 +40)* 12

Vout = 1.3 V

When Rx is 500 Ω

Vout =(500 / 500 + 40)* 12

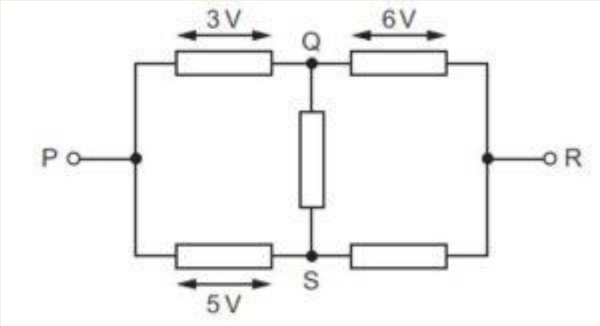
Vout = 11.1 V

so Vout will range from 1.3 v to 11.1 v

A is the correct option

Question 4

There is a current from P to R in the resistor network shown.



The potential difference (p.d.) between P and Q is 3 V.
The p.d. between Q and R is 6 V.
The p.d. between P and S is 5 V.
Which row in the table is correct?

	p.d. between Q and S	p.d. between S and R
A	2V	4V
B	2V	10V
C	3V	4V
D	3V	10V

Solution

potential difference between Q and S = p.d. between P and S is 5 V – potential difference (p.d.) between P and Q is 3 V.

potential difference between Q and S = PS – PQ

potential difference between Q and S = 5 – 3 = 2v

also,

potential difference between Q and S= The p.d. between Q and R is 6 V – potential difference between S and R

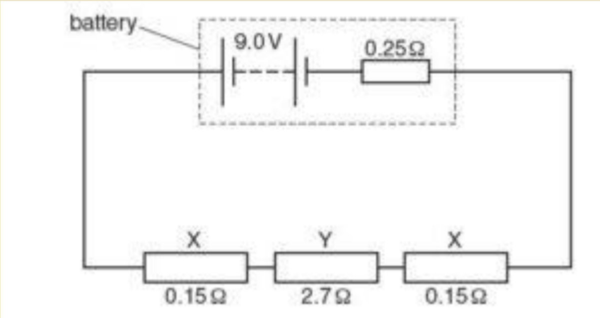
2 = 6 – SR

SR = 4 v

A is the correct option

Question 5

A battery of electromotive force (e.m.f.) 9.0 V and internal resistance 0.25 Ω is connected in series with two identical resistors X and a resistor Y, as shown in Fig below



The resistance of each resistor X is 0.15 Ω and the resistance of resistor Y is 2.7 Ω.
(i) Show that the current in the circuit is 2.8 A.

(ii) Calculate the potential difference across the battery.

(iii) Each resistor X connected in the circuit above is made from a wire with a cross-sectional area of 2.5 mm2. The number of free electrons per unit volume in the wire is 8.5 × 10^29 m–3. Calculate the average drift speed of the electrons in X.{cambridge may/ june 2016 p22}

Solution

the resistors are arranged in series

Rt = R1 + R2 + R3

Rt = 0.15 + 2.7 + 0.15

Rt = 3Ω

E = IR + Ir

9 = I (Rt + r)

9 = I (3 + 0.25)

9 = 3.25 * I

I = 9 / 3.25

I = 2.8 A

ii.

potential difference across the battery = IRt

p.d = 2.8 * 3

p.d = 8.3 v

iii

I = nevA

n is the number of charge

e is the electronic charge

v is the drift speed

A is the area

I is the current

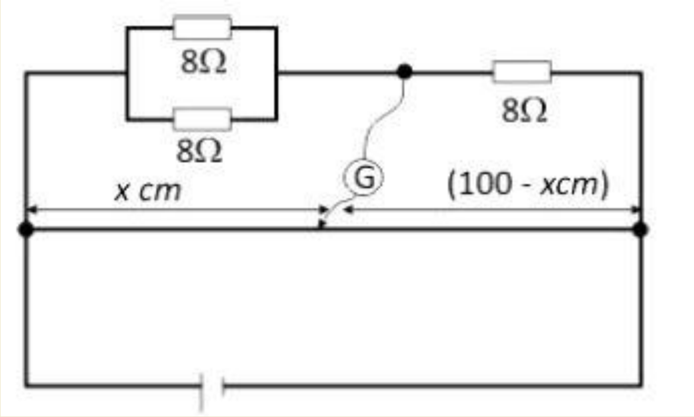
A = 2.5 mm^2 which in meters will be 2.5 x 10^-6 m^2

v = I / evA

v = 2.77 / (8.5 × 10^29 × 1.6 × 10^–19 × 2.5 × 10^–6)

v = 8.147 x 10^-6 ms-1

Question 6



The diagram above shows a balanced metre bridge, the value of x is {UTME 2010}

A. 66.7 cm B. 25.0 cm C. 33.3 cm D. 75.0 cm.

Solution

$\frac{R_1}{L_1} = \frac{R_2}{L_2}$

R1 – the resistors are in parallel i.e the effective resistance = 4Ω

R2 is 8Ω

$\frac{4}{x} = \frac{8}{100-x}$

2x = 100- x

3x = 100

X = 33.3 cm

C is the correct option

CHAPTER FIFTEEN

Electric Field

Electric field is a region of space where an electric charge body/object experiences an electric force.

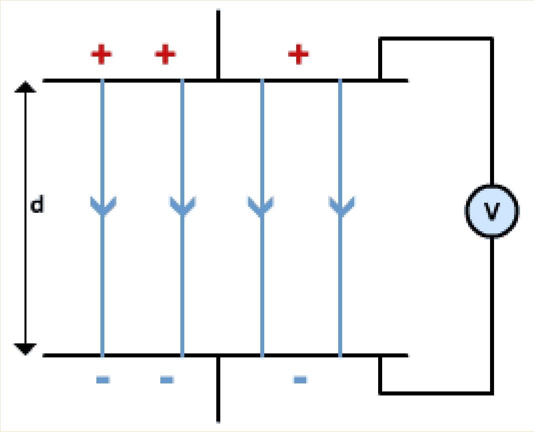
Field of force

Gravitational field – point mass

Electric field – charge

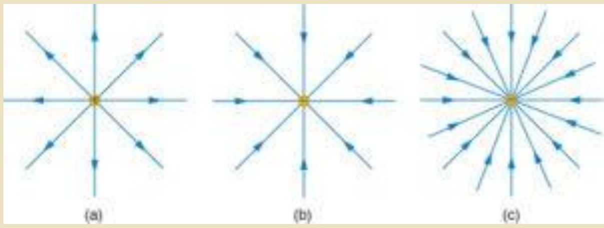
Magnetic field – current carrying conductor / charge

Field of force is a vector quantity because their field lines always show the direction. Electric field lines will always go in the direction from the positive to the negative region.



Positive point charge: the field lines are radially outward and are always in the direction of the force

Negative point charge: the field lines are radially inward



Point charges are spherical in shape and infinitesimal in nature

Electric field strength: at a point in an electric field is defined as the force per unit charge acting on a positive stationary charge at that point

E = f / q

cross multiply

F = qE

A 'test charge' should be positive. The direction it moves in then shows the direction of the electric field.

Uniform electric field

1.The field lines must be parallel

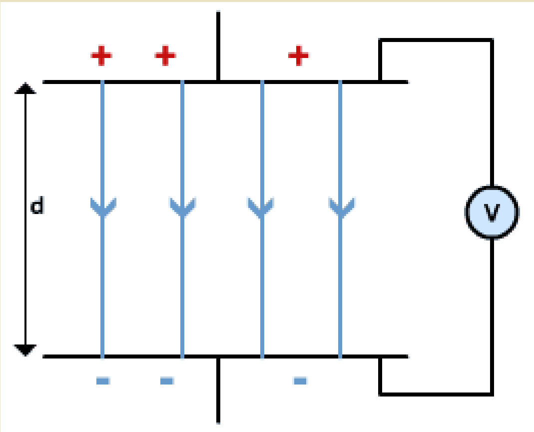
2.The field lines must be equally spaced

The electric field lines is from region of higher potential to a lower potential

The force acting on a charge inside a uniform electric field is constant at all point

The path of a charge inside a uniform electric field is always parabolic in path

Example of a uniform electric field is when you have two parallel plate of



E = v / d

E is the electric field strenght

v is the electric potential difference

d is the distance between the plates

Note that E can also be f / q

E = v / d = f / q

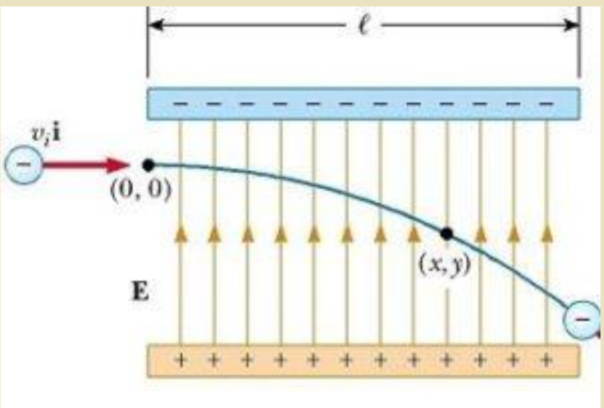
cross multiply

f.d = v . q

f . d = workdone

workdone = qv

Moving charge inside a uniform electric field



But a positive charge will deflect toward the negative charge in a parabolic path

E_k = qv

$E_k = 1/2mv^2$

Equate the two

$1/2\ m\ v^2 = qv$

$$vel = \sqrt{\frac{2qv}{m}}$$

Vel is the speed of the charge

v is the potential difference

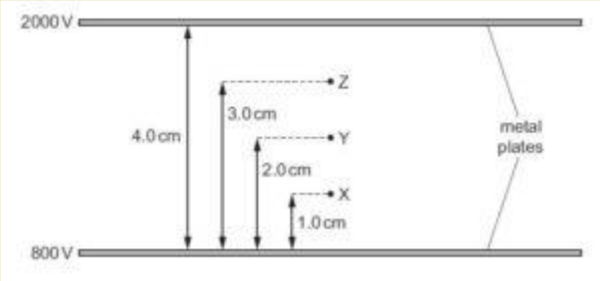
m is the mass of the charge

q is the charge

Worked Examples

Question 1

Two parallel metal plates, 4.0 cm apart, are at electric potentials of 800 V and 2000 V. Points X, Y and Z are situated in the space between the plates at distances of 1.0 cm, 2.0 cm and 3.0 cm from the lower plate



What is the electric field strength, in V m–1, at X, Y and Z?

	X	Y	Z
A	300	600	900
B	1100	1400	1700
C	3.0×10^4	3.0×10^4	3.0×10^4
D	5.0×10^4	5.0×10^4	5.0×10^4

{Cambridge A level may/june 2016 p12}

Solution

Electric field strength at any point in two parallel plate is constant i.e. it is a uniform electric field strength

E = V/d

V is the potential difference between the plate = 2000 – 800 = 1200 v

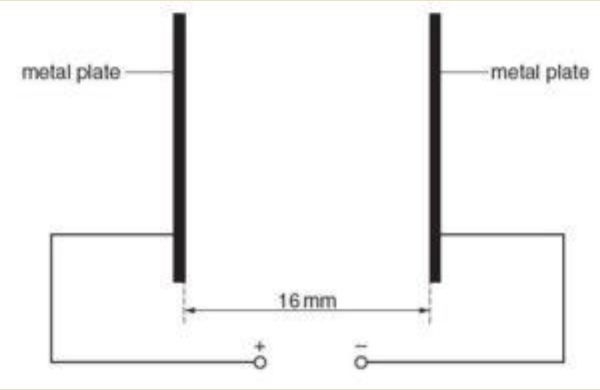
d is the distance between the plate = 4.0 cm = 0.04 m

E = 1200 / 0.04 = 30000 vm-1 = 3 x 10^4 vm-1

C is the correct answer

Question 2

Two parallel vertical metal plates are connected to a power supply, as shown in Figure below



An a-particle travels in a vacuum between the two plates. The electric field does work on the a-particle. The gain in kinetic energy of the a-particle is 15keV. Calculate the electric field strength between the plates {Cambridge A level 2016 may/june p22}

Solution

Work done = gain in kinetic energy

Work done = force x distance between the plates

Work done = qE x d

The charge on alpha particle = 2e

Work done = qEd = $3.2 \times 10^{-19} \times E \times 16 \times 10^{-3}$

Work done = 51.2×10^{-22} E

1eV = 1.6×10^{-19} J

1KeV = 1.6×10^{-16} J

15 KeV = 24×10^{-16} J

51.2×10^{-22} E = 24×10^{-16} J

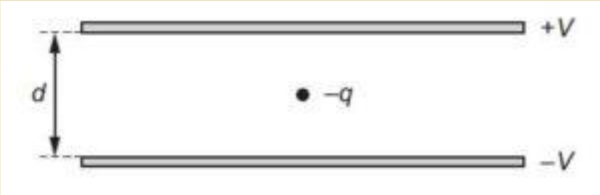
E = $24 \times 10^{-16} / 51.2 \times 10^{-22}$

E = 0.46875 x 10^6 Vm-1

E = 4.7 x 10^5 Vm-1

Question 3

An oil droplet has charge –q and is situated between two horizontal metal plates as shown in the diagram below.



The separation of the plates is d. The droplet is observed to be stationary when the upper plate is at potential +V and the lower plate is at potential –V.
For this to occur, what is the weight of the droplet? {Cambridge A level 2015 may/june p11}

A $\frac{Vq}{d}$ B $\frac{2Vq}{d}$ C $\frac{Vd}{q}$ D $\frac{2Vd}{q}$

Solution

The droplet is stationary because;

The weight on the droplet = the electric force on the droplet

The electric force = qE

E = potential difference / distance between the plate

Potential difference = V – (-V) = 2V

E = 2V / d

Electric force = 2Vq / d

Weight on the droplet = 2Vq/d

B is the correct option

CHAPTER SIXTEEN

Capacitance of Capacitor

Capacitance of a capacitor is the charge stored on one plate per unit of potential difference between the plates

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

c is the capacitance

Q is the charge

v is the potential difference

Farad is the unit of capacitance

Uses of capacitor

1. it stores energy
2. smoothing circuit
3. separate charges
4. blocking D.C
5. tuning circuit
6. preventing sparks
7. timing circuit
8. producing electrical oscillations

- Explain why the capacitor stores energy but not charge

– capacitor has equal magnitude of +ve and -ve charge

– total charge on capacitor is zero or no resultant charge

– energy stored because there is charge separation

- What determines the magnitude of capacitance

– distance between the two plates

– Area of overlap of the two plates

– dielectric material

$$c = \frac{\epsilon A}{d}$$

- An isolated metal sphere of radius R has charge +Q on it. The charge may be considered to act as a point charge at the centre of the sphere. Show that the capacitance C of the sphere is given by the expression

  $$c = 4\pi\epsilon R$$

$$c = \frac{Q}{V}$$

$$v = \frac{kQ}{r}$$

$$k = 4\pi\epsilon$$

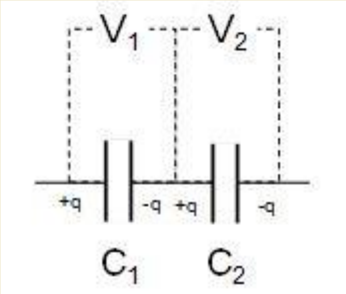
$$v = \frac{Q}{4\pi\epsilon r}$$

Substitute the expression for v in c = Q/v

$$c = \frac{Q}{\frac{Q}{4\pi\epsilon r}}$$

$$c = 4\pi\epsilon r$$

- **derive, using the formula *C= Q/V* , conservation of charge and the addition of p.d, formula for capacitors in series and in parallel**



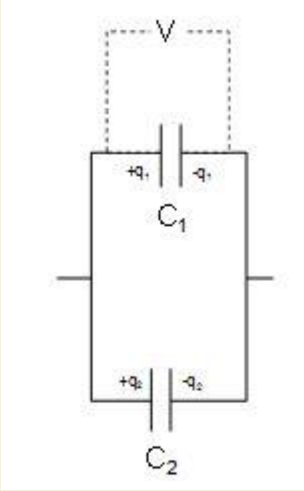
$V = V_1 + V_2$

$V_1 = q / C_1$ and $V_2 = q / C_2$ (q = charge induced on one plate)

$q / C = q / C_1 + q / C_2$

$1 / C = 1 / C_1 + 1 / C_2$

Parallel arrangement



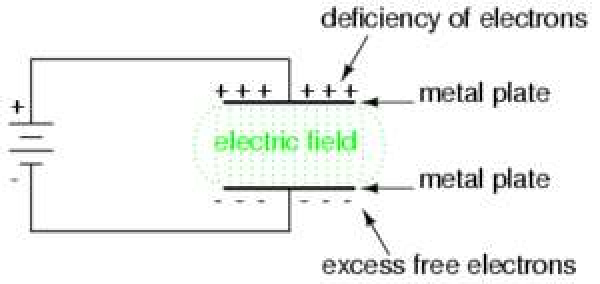
$q = q_1 + q_2$

$q_1 = C_1V$ $q_2 = C_2V$

$CV = C_1V + C_2V$

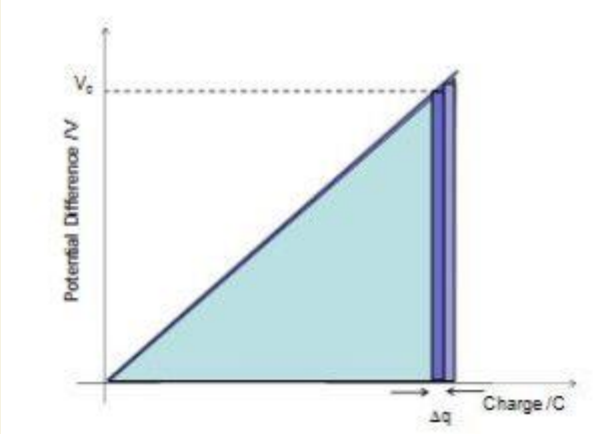
$C = C_1 + C_2$

Energy stored in a capacitor



In other to charge a capacitor work must be done to push electrons onto one plate and off the other. The current stops when the p.d across the capacitor is equal to the e.m.f of the supply. We then say that the capacitor is "fully charged"

Uncharge plate has equal amount of +ve and -ve charge. Connecting the capacitor to supply pulls charge +Q from one plate and transfers it to the other, leaving behind charge -Q. The supply does work in separating the charges. Since the two plates now store equal and opposite charges, the total charge on the capacitor is zero. When we talk about "charge stored" by capacitor, we mean the quantity Q, the magnitude of the charge stored on each plate.



Q = CV

W= E_p = VQ

$DE_p = V_0Dq$

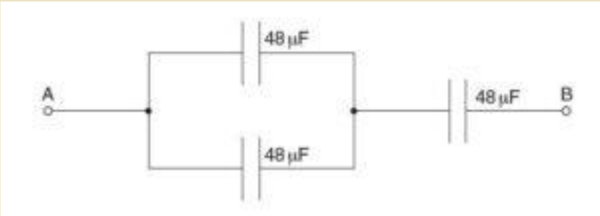
W = E_p = ½ QV

W = E_p = ½ CV^2

Worked Examples

Question 1

Three capacitors, each of capacitance 48 μF, are connected as shown in Fig below



(a) Calculate the total capacitance between points A and B.

(b) The maximum safe potential difference that can be applied across any one capacitor is 6 V. Determine the maximum safe potential difference that can be applied between points A and B.{Cambridge A level oct/nov 2014 p43}

Solution

For parallel arrangement

$c = c_1 + c_2$

c = 48 + 48 = 96uf

96uf is in series with the third 48uf

$1/c = 1/c_1 + 1/c_2$

1/c = 1/96 + 1/48

1/c = 3/96

c = 32uf

(b)

In parallel same voltage across the capacitors, while in series same charge across the capacitors

The total charge flowing through the circuit is

C = Q/V

48 x 10^-6 = Q/6

Q = 48*6 x 10^-6 = 288 x 10^-6 c

p.d across the capacitor connected in parallel will be

C = Q/V

96 x 10^-6 = 288 x 10^-6 / V

v = 288 / 96 = 3v

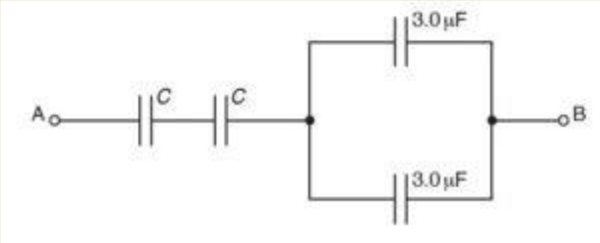
The maximum safe potential difference that can be applied between points A and B = 3 + 6 =9v

Or

p.d. across parallel combination is one half p.d. across single capacitor C1 total p.d. = 9 V

Question 2

The combined capacitance between terminals A and B of the arrangement shown in Fig below is 4.0 μF.



Two capacitors each have capacitance C and the remaining capacitors each have capacitance 3.0 μF. The potential difference (p.d.) between terminals A and B is 12 V.
(i) Determine the capacitance C

(ii) Calculate the magnitude of the total positive charge transferred to the arrangement

(iii) Use your answer in (ii) to state the magnitude of the charge on one plate of
1. a capacitor of capacitance C,
2. a capacitor of capacitance 3.0 μF.{Cambridge A level may/june p42}

Solution

(i)

3.0 μF and 3.0 μF are in parallel

c= 3 + 3

c = 6μF

6μF is in series with c and c

1/Ct = 1/6 + 1/c + 1/c

1/4 = 1/6 + 1/c + 1/c

1/4 – 1/6 = 2/c

1/12 = 2/c

C =24uf

(ii)

The potential difference between terminal A and B is 12v

Total capacitance = total charge / total p.d

4 × 10^-6 = Q / 12

Q = 48 × 10^-6 c

(iii)

The charge on capacitor c is the same as the total charge in the arrangement = 48×10^{-6} c

The charge on 3uf capacitor will be,

Firstly we need to know the p.d across the two capacitors arranged in parallel.

C = Q/v

6uf is the combined capacitance of the two capacitors

$6 \times 10^{-6} = 48 \times 10^{-6} / v$

V = 48/6 = 8v

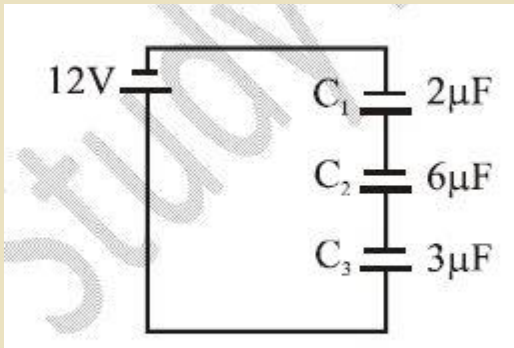
The charge on the 3uf capacitor will be

$3 \times 10^{-6} = Q/8$

Cross multiply

$Q = 24 \times 10^{-6}$ c

Question 3



The diagram shows three capacitors C1, C2 and C3 of capacitances 2 μF, 6 μF and 3 μF respectively. The potential differences across C1, C2 and C3 respectively are {UTME 2001}
A. 6V, 2V and 4V.
B. 6V, 4V and 2V.
C. 2V, 6V and 4V.
D. 4V, 6V and 2V.

Solution

The arrangements are in series, so the effective capacitance

$1 / c = 1/ C1 + 1/ C_2 + 1/ _{C3}$

$1 / C = 1/ 2 + 1/6 + 1/ 3$

$1 / C = (3+1+2)/6$

$1/ C = 1/1$

c = 1 μF

Note that,

Q = CV

Q = 1*12 =12 C

For series arrangement the same charge will flow through the capacitors

On C1,

12 = 2V

V = 6v

On C2,

12 = 6V

V = 2 v

On C3,

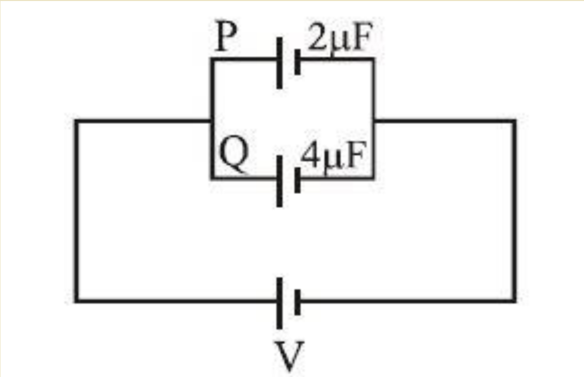
12 = 3V

V = 4 v

The potential difference = 6v, 2v, 4v

A is the correct option

Question 4



The diagram above shows two capacitors P and Q and capacitances 2μF and 4μF respectively connected to
a d.c. source. The ratio of energy stored in P to Q is {UTME 2001}
A. 1 : 2 B. 2 : 1 C. 4 : 1 D. 1 : 4

Solution

The arrangement is parallel, the implication of that is, the same voltage will be supplied across the capacitors

$E = 1/2\ CV^2$

$E_p = 1/2 * 2 * V^2 = V^2$

$E_q = 1/2 * 4 * V^2 = 2\ V^2$

Their ratio = $E_p / E_q = V^2 / 2V^2 = 1/2$

A is the correct answer

CHAPTER SEVENTEEN

Gravitational Field

According to Newton, all masses create a gravitational field in the space round them. The field gives rise to a force on any object having mass placed in this field. The moon orbits the earth because it experiences a gravitational force due to the earth's gravitational field. If an object is placed in a gravitational field, a force will act on the object because of its mass.

What is meant gravitational field?

A region where a mass/body experiences a force of attraction due its mass.

The Earth has a radial field of gravity, which means that the gravitational field is circular and acts from the center point.

The Earths radial gravitational field is represented by the lines

1. The arrows on the field lines show the direction of the gravitational force on a mass placed in the field
2. The spacing of the field lines indicates the strength of the gravitational field-the farther apart they are, the weaker the field

Gravitational field strength

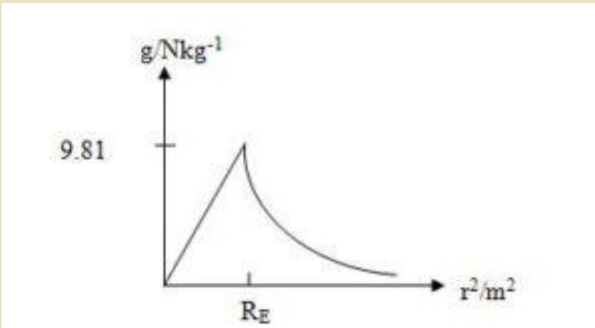
Gravitational field strength at a point is the gravitational force exerted per unit mass on a small object placed at that point.

$g = f/m$

g = gravitation field strength

m = test mass

units = N kg^{-1} = ms^{-2}



Newton's law of universal gravitation: it states that any two point masses attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of their separation

$$F = \frac{Gm_1 m_2}{r^2}$$

G is the gravitational constant 6.67 x 10^{-7} $Nkg^{-2}m^2$

Since f= GMm/r2

g =f/m = GMm/mr2 = GM/r2 (This equation ***does not depend upon the mass of the small object***)

g is the gravitational field strength

Gravitational potential energy: at a point is the work done in bringing a mass from infinity to a point

Gravitational potential is always negative: because of the force of attraction that exist between two masses

- Zero of potential energy is at infinity
- Potential energy taken as a negative value
- The work done in moving a mass between two points in a gravitational field is independent of the path taken

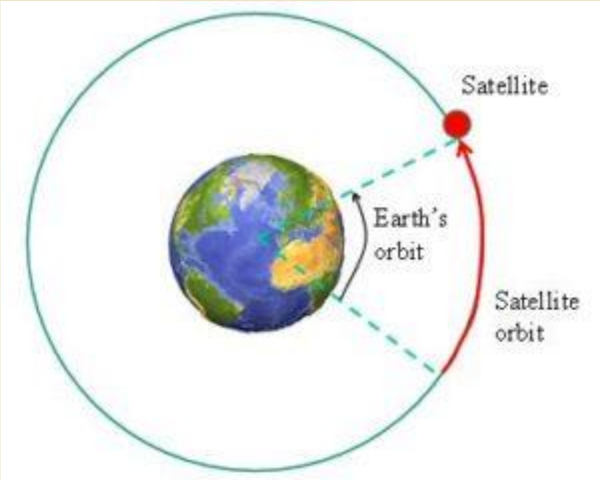
$$\phi = -\frac{Gm}{r}$$

Centripetal Acceleration

•For an orbiting satellite, the gravity provides centripetal force which keeps it in orbit

$$\frac{GM\cancel{m}}{\cancel{r^2}} = \frac{\cancel{m}v^2}{\cancel{r}}$$
$$v^2 = \frac{GM}{r}$$

Geostationary Orbits



•Geostationary satellite is one which is always above a certain point on the Earth

•For a geostationary orbit: T = 24 hrs. And orbital radius is a fixed value from the center of the Earth

By using r^3 / T^2 the radius of orbit needed for geostationary orbit can be calculated

$$GM = \left(\frac{2\pi r}{T}\right)^2 r = \frac{4\pi^2 r^3}{T^2}$$

Worked Examples

Question 1

The earth is four times the size of the moon and the acceleration due to gravity on the earth is 80 times that on the moon. The ratio of the mass of the moon to that of the earth is (UTME 2004)

A. 1 : 320 B. 1 : 1280 C. 1 : 80 D. 1 : 4

Solution

size of earth = 4 x size of moon

r(earth) = 4r(m00n)

G of earth = 80 x g of moon

g = GM/r2

GM(earth)/r2(earth) = 80 *GM(moon)/r2(moon)

M(earth)/16r2(moon) = 80 * M(moon)/r2(moon)

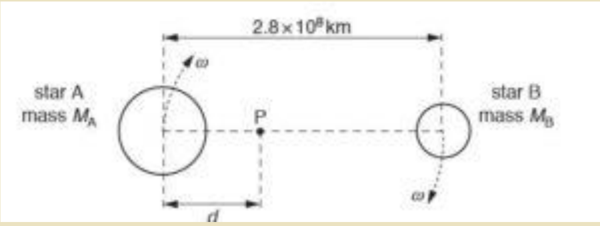
M(earth) = 80*16 M(moon)

M(moon) / M(earth) = 1 / 1280

B is the correct option

Question 2

A binary star consists of two stars A and B that orbit one another, as illustrated in Fig below



The stars are in circular orbits with the centres of both orbits at point P, a distance d from the centre of star A.

i. The period of the orbit of the stars about point P is 4.0 years. Calculate the angular speed ω of the stars

ii. The separation of the centres of the stars is 2.8 × 108 km. The mass of star A is MA. The mass of star B is MB.
The ratioMA/MB is 3.0. Determine the distance d.

iii. Use your answers in (i) and (ii) to determine the mass MB of star B.

May/June 2016 p42

Solution

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

$$\omega = \frac{2 \times 3.142}{4 \times 365 \times 24 \times 60 \times 60}$$

$$\omega = 4.982 \times 10^{-8} rads^{-1}$$

ii

since they orbit at the same point, there centripetal force will be the same

$$m_a\omega^2 r_a = m_b\omega^2 r_b$$

$$m_a r_a = m_b r_b$$

$$\frac{m_a}{m_b} = \frac{r_b}{r_a} = \frac{2.8 \times 10^8 - d}{d}$$

$$3 = \frac{2.8 \times 10^8 - d}{d}$$

Cross multiply

3d = 2.8 × 108 – d

3d + d = 2.8 × 108

4d = 2.8 × 108

d = 2.8 × 108 / 4

d = 7 x 10^7 km

iii

To calculate for the mass of star B, You must note that the gravitational force will be equal to the centripetal force for star B to orbit star A

$$\frac{Gm_a m_b}{(2.8 \times 10^{11})^2} = m_a \omega^2 d$$

$$m_b = \frac{\omega^2 \times d \times (2.8 \times 10^{11})^2}{G}$$

$$m_b = \frac{(4.982 \times 10^{-8})^2 \times (2.8 \times 10^{11})^2 \times 7 \times 10^{10}}{6.67 \times 10^{-11}}$$

$$m_b = 2 \times 10^{29} Kg$$

CHAPTER EIGTEEN

Nuclear Physics

Rutherford alpha particle scattering experiment: Experimental evidence for nuclear atom: Results of an experiment where a beam of alpha particles is fired at a thin gold foil (about 1μm thick): where n= number of alpha particles incident per unit time.

Alpha particles are helium atom particles. He bombarded positive alpha particle on thin foil of gold approximately 8.6 x 10^-6 cm thick and took observations of the screen Zns which was behind the gold foil.

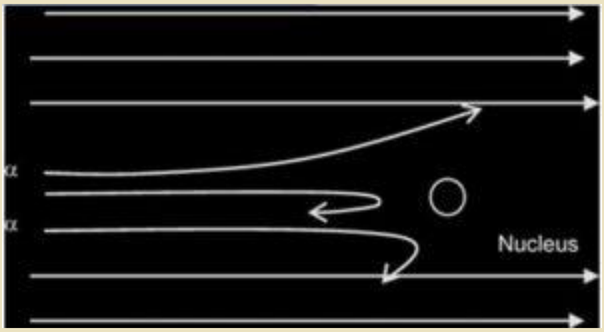
A gold foil was used because gold can be made into a very thin sheet or foil

Reasons why beta particle from a radioactive source would be inappropriate for this type of scattering experiment

1. beta particles have a range of energies
2. beta particles deviated by orbital electron
3. beta particle has very small size

Note

Change in Isotope of gold doesn't affect deviation because deviation depends on charge on the nucleus or electrostatic repulsion i.e. same charge since isotopes are element of the same proton number but different nucleon number, so no change in deviation



Observations

1. Most of the a-particles passed through the metal foil undeflected or deflected by(deviated through) very small angles less than 90

2. A very small proportion was deflected by large angles more than 90°(some of these approaching 180°)

Conclusion

1. the nucleus occupies only a small proportion of the available space in comparism with atom size (i.e. the atom is mostly empty space)
2. the nucleus is very small and heavy/dense/massive and +vely charged (since the positively-charged alpha particles are repelled/deflected).

The energy conversion in the a-particle scattering experiment:

The kinetic energy of the incoming a-particle is converted to the electrical potential energy when it stops at the point of closest approach and turns around.

So initial kinetic energy of a + nucleus (= 0) = maximum electrical potential energy of both particles i.e

$1/2 m_a v_a^2 = Q_a . Q_N / 4\pi\varepsilon r$

Where r is the distance (of closest approach) of a-particle to the nucleus,

$Q_a = 2e$, and $Q_N = Ze$, Z is proton number

Reasonable estimates:

*Nuclear diameter ≈10^{-15}m …10^{-13} to 10^{-15} m *Atomic diameter ≈ 10^{-10}m …..10^{-9} to 10^{-11}m

Nucleon: A particle within the nucleus; can be either a proton or a neutron; they are subatomic particles.

Nuclide: An atom with a particular number of protons and a particular number of neutrons

Proton number Z *{old name: atomic number}*: Number of protons in an atom

Nucleon number N *{mass number}*: Sum of number of protons and neutrons in an atom

Isotopes: are nuclei/atoms with the same proton number, but different nucleon/neutrons number

Density Calculation

Density = mass / volume

mass is mass of nucleus

v is the volume of nucleus

$$v = \frac{4}{3}\pi r^3$$

$$1\,u = 1.66 \times 10^{-27}\,kg$$

r is the radius of the nucleus

mass of a nucleus is measure in atomic mass unit because it is very small

Nuclear Energy

Mass Defect

Whenever a reaction results in a release of energy, there is an associated decrease in mass, called mass defect, which is converted to energy(in form of gamma radiation with $c = 3.00 \times 10^8$m/s).

The mass of a nucleus is always less than the total mass of its constituents (protons plus neutrons).

Mass defect is this difference between the mass of a nucleus and the total mass of its individual nucleons,

i.e

Mass defect = (total)mass of nucleons — (single)mass of nucleus

$= Zm_p + (A - Z)m_n$ – Mass ofNucleus

Mass defect = final mass – initial mass

Nuclear Binding Energy:

- This is energy that is required to completely separate the nucleons in a nucleus.

OR

The energy released **(**not energy lost) when a nucleus is formed from its constituent nucleons

The Binding Energy per nucleon is a measure of the stability of the nucleus since it represents the average energy needed to remove a nucleon. The higher the binding energy, the more stable the nucleus and vice versa

Energy & Mass are Equivalent and inter-convertible.

Thus, Binding Energy, the energy released during nuclear reaction is

E(J) = Mass defect(kg) × c^2

Mass defect of a nucleus is the difference between the total mass of a separate nucleus and the combined mass of the nucleus

E = Increase/decrease in binding energy

i.e Energy released = total B.E after — total B.E before

$$E = mc^2$$

Energy for 1u

Recall

$$1\,u = 1.66 \times 10^{-27} kg$$

$$c = 3 \times 10^8 ms^{-1}$$

$$E = 1.66 \times 10^{-27} kg \times (3 \times 10^{8})^{2}$$

$$E = 14.94 \times 10^{-11} J$$

Note

$$1\, ev = 1.6 \times 10^{-19} J$$

$$1\, Mev = 1.6 \times 10^{-13} J$$

To change

$14.94 \times 10^{-11} J$ to Mev

$$14.94 \times 10^{-11} J = \frac{14.94 \times 10^{-11}}{1.6 \times 10^{-13}} Mev$$

$$14.94 \times 10^{-11} J = 931 Mev$$

So

I u = 931Mev

E(Mev) = 931Mev/u × Mass defect(u)

E = Binding energy per nucleon × nucleon number

If binding energy is:

+ve,nucleus is stable, energy released appears as K.E of products

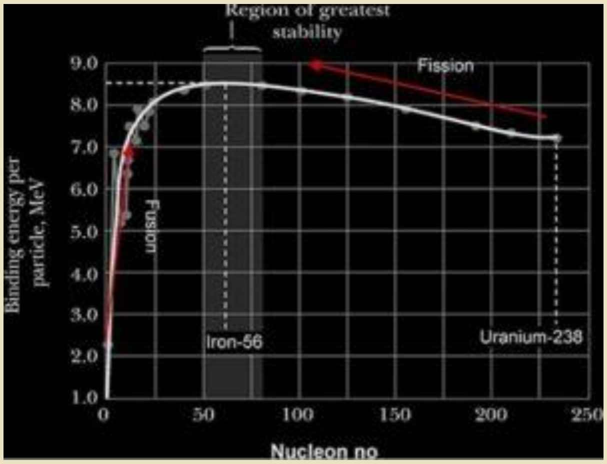
—ve, nucleus is unstable and will decay spontaneously, energy is needed to produce reaction

Nuclear fission:

The disintegration of a heavy nucleus into two lighter nuclei of approximately same mass. Typically, the fission fragments have approximately the same mass and neutrons are emitted

Nuclear fusion:

The joining together of two light nuclei of nearly equal mass to form a heavy nucleus.



Radioactive decay:

Radioactivity is the spontaneous and random decay of an unstable nucleus, with the emission of an *alpha* or *beta* particle, with or without the emission of a *gamma* ray photon.

Spontaneity:

*The emission is unaffected (not speeded up or slowed down) by factors outside the nucleus, e.g

1. chemical reactions(acids),
2. environmental factor/surrounding (heat, wind, cold, earth, pollution, weather)
3. all external factors.

Randomness:

*It cannot be predicted when the next emission will occur/which particular nuclei will decay next

*All nuclei have equal chance of decay i.e. constant probability of decay per time of a nucleus

Exponential Decay curve

For a large number of a particular nuclei/species, the rate of decay is directly proportional to the number of parent nuclei present.

i.e $-dN/dt$ α λ

$dN/dt = -\lambda N$ (Activity defined in Bq)

λ = +ve constant of proportionality/radioactive decay/disintegration constant in s^{-1}

Where N= number of undecayed/active/parent nuclei at that instant/remaining.

i.e the number of nuclei N remaining and/or activity after some time t, decreases exponentially.

Units: 1Bq = 1disintegration per second, 1Ci = $3.7 \times 10^{10} s^{-1}$

*Decay constant λ is defined as the probability of decay of a nucleus per (unit) time

*Activity is defined as the rate at which the nuclei are disintegrating/decay rate i.e number of decays per time (—ve…decreasing)

$A = dN/dt = -\lambda N$, and $A_0 = \lambda N_0$

Since number of undecayed nuclei ∝ Mass of sample,

Number of nuclei in sample = (Sample Mass / Mass of 1 mol) x N_A

Also, following the decay law,

$N = N_0 e^{-\lambda t}$, $A = A_0 e^{-\lambda t}$, $C = C_0 e^{-\lambda t}$

Half-life ,$T_{1/2}$

Half-life is defined as the (average) time taken for half the number {not: mass or amount} of undecayed nuclei in the sample to disintegrate,

or, the (average) time taken for the activity to fall to half of its original value.

$T_{½} = (\ln 2) / \lambda$

or $T_{1/2} = 0.6931/\lambda$

Worked Examples

Question 1

The gold nucleus 185Au79 undergoes alpha decay. What are the nucleon number and proton number of the nucleus formed by this decay?{cambridge A level may/june 2016 p12}

	nucleon number	proton number
A	183	79
B	183	77
C	181	77
D	181	75

Solution

Au undergoes alpha decay

185Au79 – 181X77 + 4He2

The above equation is conserved since the number of nucleon and proton are the same before and after decay

The nucleon numberof the nucleus formed is 181 and the proton number is 77

C is the correct option

Question 2

In a time of 42.0 minutes, the count rate from the sample of copper-66 is found to decrease from 3.62 × 104 Bq to 1.21 × 102 Bq. Calculate the half-life of copper-66. {Cambridge A level may/june 2016 p41}

Solution

$$c = c_o e^{-\lambda t}$$

$$1.21 \times 10^2 = 3.62 \times 10^4 e^{-42\lambda}$$

$$e^{-42\lambda} = \frac{1.21 \times 10^2}{3.62 \times 10^4}$$

$$e^{-42\lambda} = 0.3343 \times 10^{-2}$$

$$-42\lambda = -5.7$$

$$\lambda = 0.1357$$

$$T_{\frac{1}{2}} = \frac{0.693}{\lambda}$$

$$T_{\frac{1}{2}} = \frac{0.693}{0.1357}$$

$$T_{\frac{1}{2}} = 5.1\ minutes$$

Question 3

The diagram shows part of a radioactive decay chain in which the nuclide thorium-232 decays by a-emission into radium-228. This nuclide is also unstable and decays by β-emission into a nuclide of actinium. This process continues.{cambridge A leve oct/nov 2015 p11}

$${}^{232}_{90}\mathrm{Th} \xrightarrow{\alpha} {}^{228}_{88}\mathrm{Ra} \xrightarrow{\beta} {}^{X}_{89}\mathrm{Ac} \xrightarrow{Y} {}^{228}_{90}\mathrm{Th} \xrightarrow{\alpha} {}^{224}\mathrm{Z} \longrightarrow$$

What are X, Y and Z?

	X	Y	Z
A	228	α	Th
B	228	β	Ra
C	232	α	Th
D	232	β	Ra

Solution

Since Ra undergoes beta decay X will still be 228: beta decay does not affect nucleon number

Y is beta since Th nucleon number isn't affect and the proton increase by 1

Z is Ra since the proton number is 88, after Th has undergone alpha decay, having the same proton number with Ra making it an isotope of Ra

B is the correct option

Question 4

In a model of a copper atom of the isotope 63Cu29, the atom and its nucleus are assumed to be spherical. The diameter of the nucleus is 2.8 × 10–14 m. The diameter of the atom is 2.3 × 10–10 m.{Cambridge A level oct/nov 2015 p22} Calculate the ratio

$$\frac{\text{density of the nucleus}}{\text{density of the atom}}.$$

Solution

denisty of nucleus = mass of nucleus / volume of nucleus

volume of nucleus = $v = \frac{4}{3}\pi r^3$

Volume = 4/3*3.142*(2.8×10^-14)^3

mass of nucleus = 63u

density of atom = mass of atom / volume of atom

volume = 4/3*3.142*(2.3×10^-10)^3

mass of atom = 63u

mass of atom and mass of nucleus (approx.) equal

ratio

$$\frac{\dfrac{63u}{\frac{4}{3}\times 3.142\times(2.8\times 10^{-14})^3}}{\dfrac{63u}{\frac{4}{3}\times 3.142\times(2.3\times 10^{-10})^3}}$$

$$\frac{(2.3\times 10^{-10})^3}{(2.8\times 10^{-14})^3}$$

ratio = 5.5 x 10 ^11

Question 5

In the D-T reaction, a deuterium (2H1) nucleus fuses with a tritium (3H1) nucleus to form ahelium-4 (4He2) nucleus. The nuclear equation for the reaction iscambridge A level 2014 p41}

$${}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n + \text{energy}$$

Some data for this reaction are given in Figure below

	mass/u
deuterium (^2_1H)	2.01356
tritium (^3_1H)	3.01551
helium-4 (^4_2He)	4.00151
neutron (^1_0n)	1.00867

Use data from Figure above to determine the energy released in this D-T reaction.

Solution

total mass of the reactant = 2.01356 + 3.01551 = 5.02907 u

total mass of the product = 4.00151 + 1.00867 = 5.01018 u

mass defect = total mass of reactant – total mass of product = 5.02907 u – 5.01018 u

mass defect = 0.01889 u

note

1u is equivalent to 934 Mev

so,

0.01889 u = (933 * 0.01889) Mev

energy released in this D-T reaction = (934 * 0.01889) Mev = 17.6 Mev

Question 1

A piece of radioactive material contains 1000 atoms. If its half-life is 20 seconds, the time taken for 125
atoms to remain is {UTME 2012}
A. 20 seconds B. 40 seconds C. 60 seconds D. 80 seconds

Solution

N = N0 exp(-λt)

ג = 0.693/T

ג = 0.693/20

125 = 1000 exp(-0.03465t)

125/1000 = exp(-0.03465t)

1000/125 = exp(0.03465t)

8 = exp(0.03465t)

0.03465t = In 8

0.03465t = 2.0794415

t = 2.0794415 /0.03465 = 60 seconds

C is the correct option

Question 2

A radioactive isotope has a decay constant of 10-5s-1. Calculate its half-life. {UTME 2011}
A. 6.93 x 10-6s B. 6.93 x 10-5s C. 6.93 x 105s D. 6.93 x 104s

Solution

T = 0.693/ג

T = 0.693 / 0.00001

T = 6.93 x 10^4 s

D is the correct option

Question 3

The radioisotope $^{235}U_{92}$ decays by emitting two alpha particles, three beta particles and a gamma ray. What is the mass and atomic numbers of the resulting daughter element? {UTME 2010}
A. 91 and 227 B. 92 and 238 C. 227 and 91 D. 215 and 88.

Solution

You should note that in nuclear reaction, proton number and nucleon number must be conserved

$^{235}U_{92} = 2(^{4}He_{2}) + 3(^{0}e_{-1}) + \Upsilon + {}^{227}X_{91}$

$^{227}X_{91}$ means nucleon number (mass number) is 227 and proton number (atomic number) is 91.

C is the correct option

Question 4

A piece of radioactive material contains 10^{20} atoms. If the half-life of the material is 20 seconds, the number of
disintegrations in the first second is {UTME 2009}
A. 3.47×10^{18} B. 6.93×10^{20} C. 3.47×10^{20} D. 6.93×10^{18}

Solution

N = N0 exp(-ʎt)

ʎ = 0.693/T

ʎ = 0.693/20

$N = 10^{20} \exp(-1*0.03465)$

$N = 10^{20}/1.03536 = 9.658 \times 10^{19}$

The number of disintegrations in the first second is = $N0 – N = 10^{20} – 9.658 \times 10^{19}$

The number = $0.342 \times 10^{19} = 3.42 \times 10^{18}$

A is the correct answer

Question 5

If the decay constant of a radioactive substance is $0.231s^{-1}$, the half-life is {UTME 2009}
A. 3.00s B. 0.12s C. 0.33s D. 1.50s

Solution

T = 0.693/ʎ

T = 0.693 / 0.23

T = 3.01 s

A is the correct option

Question 6

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + X$$

In the equation above, the particle X is {UTME 2008}
A. a proton B. a neutron C. an a-particle D. a β-particle

Solution

In nuclear reaction, proton number and nucleon number must be conserved

On the reactant side, the total number of proton = 7 + 2 = 9, the total nucleon number = 14 + 4 = 18

For the product side to be conserve, the nucleon number on X must be 1 and proton number must be 1

That is, $^{1}X_{1}$ = proton

A is the correct option.

Question 7

A radioactive substance has a half-life of 20 days. What fraction of the original radioactive nuclei will remain after 80
days? {UTME 2007}
A. 1/16 B. 1/8 C. 1/4 D. 1/32

Solution

let the original value be N

N – N/2 …20 days

N/2 – N/4 … 40days

N/4 – N/8 ….60 days

N/8 – N/16 …. 80 days

after 80 days 1/16 0f the original radioactive nuclei will remain

A is the correct option

Question 8

The time it will take a certain radioactive material with a half-life of 50 days to reduce to 1/32 of its original number is {UTME 2005}
A. 150 days B. 200 days C. 250 days D. 300 days.

Solution

let the original value be N

N – N/2…50 days

N/2 – N/4 …100 days

N/4 – N/8 …150 days

N/8 – N/16 … 200 days

N/16 – N/32 … 250 days

It will take 250 days for a certain radioactive material with a half-life of 50 days to reduce to 1/32 of its original
number

C is the correct option

Question 9

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{144}_{56}Ba + ^{90}_{36}Br + 2X$$

In the reaction above, X is {UTME 2005}
A. proton B. neutron C. electron D. neutrino

Solution

In nuclear reaction, proton number and nucleon number must be conserved

On the reactant side, the total number of proton = 92 + 0 = 92, the total nucleon number = 235 + 1 = 236

On the product side, the total number of proton = 56 + 36 + A = 92, A = 0, the total nucleon number = 144 + 90 + 2Z = 236, Z =(236-234)/2 = 2/2 = 1

For the product side to be conserve the nucleon number on X is 1 and proton number is 0

$^{1}X_{0}$ = neutron

B is the correct option

CHAPTER NINTEEN

Ideal Gas

An ideal gas is one that obeys the gas laws, and equation of state for ideal gas, at all temperature, pressure and volume. This means Ideal gas obeys

$pV = nRT$

P = Pressure

V = Volume

T = Temperature

R = universal gas constant

n= number of moles

Infer from a Brownian motion experiment the evidence for the movement of molecules

Brownian motion: random movement of small particles caused be bombardment of invisible molecules

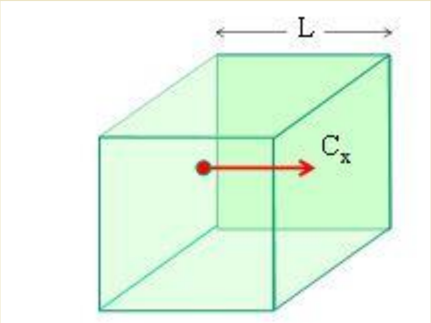
- Smoke (oil droplets) are seen to move randomly
- This motion is evidence that the air particles are also moving randomly and colliding with the smoke droplets
- The air particles cannot be seen but their motion can be understood by the smoke droplets which can be seen

Kinetic theory of gases

1. The attraction between molecules is negligible
2. The volume of the molecules is negligible compared with the volume occupied by the gas
3. The molecules are like perfectly elastic spheres
4. The duration of a collision is negligible compared with the time between collisions

Explain how molecular movement causes the pressure exerted by a gas and hence deduce the relationship $p = 1/3Nm/V < c^2 >$

(N = number of molecules)



- Consider a cube of space with length L
- Consider a particle moving in one dimension x with velocity c_x
- When the particle collides with the wall its velocity is reversed so its change in momentum is equal to…
  - $Dp_x = 2mc_x$
- The time between collisions with each wall of the cube is equal to…
  - Time between collisions = $2L / c_x$
- The rate at which momentum is transferred to the wall is…
  - Rate of change of momentum = $2mc_x / (2L/c_x) = mc_x^2 / L$
- If there are N particles in the cube the total force is…
  - Total force = Nmc_x^2 / L
- Pressure is force over area so pressure is…
  - Pressure on one wall is Nmc_x^2 / L^3
- L^3 is the volume so…
  - Pressure = Nmc_x^2 / V
- The average of c_x^2 can be written as $< c_x^2>$
- As all directions, x, y and z can be considered equal

- $< c_x^2 > = 1/3 < c^2 >$

- Hence
  - $P = 1/3 Nm < c^2 > / V$
- $$p = \frac{1}{3} \rho < c^2 >$$
- p(rho) = density of gas
- $<c^2>$ = mean square speed

$$c_{rms} = \sqrt{< c^2 >} = \sqrt{\frac{3kT}{m}}$$

It should be carefully noted that the pressure p of the gas depends on the "mean square" of the speed. This is because

1. The momentum change at a wall is proportional to the speed
2. The time interval before this change is repeated is inversely proportional to the speed

Compare *pV* = 1/ 3 *Nm* < c 2 > with *pV* = *NkT* and hence deduce that the average translational kinetic energy of a molecule is proportional to *T*.

- The average translational E_k of the particles can be expressed as …
  - $<E_k> = 1/2m < c^2>$
- Combining with $P = 1/3Nm<c^2> / V$ we get….
  - $pV = 2/3N(1/2m < c^2>) = 2/3N<E_k>$
- Combining this with pV = NkT we get…
  - $pV = 2/3N<E_k> = NkT$
  - $<E_k> = 3/2kT$
- Therefore, Temperature is proportional to Average translational kinetic energy

Note

$R/N = K$

K is the Boltzman's constant

R is the molar gas constant

CHAPTER TWENTY

Gas Law

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Boyle's law

Boyle's law states that the volume of a fixed mass of gas is inversely proportional to the pressure provided that the temperature remains constant.

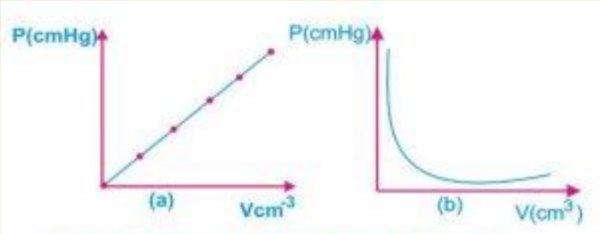
If p is the pressure, v the volume and t the temperature in the Kelvin, Then the law can be stated as follows:

P a 1/v   i.e p = k/v (k is constant)

PV = constant (k is constant).

If P1 and V1 are the initial pressure and volume of the gas respectably, and P2 and V2 are the final pressure and volume after the change, then Boyle's law can be written thus:

P1V1 = P2V2



The graph shows that boyle's law is obeyed

Charles' law

Charles' law state that the volume of a fixed mass of gas is directly proportional to its absolute temperature (T) provided the pressure remains constant. Mathematically,

V a T where V is the volume, T = absolute temp

V = kT(k is constant)

V/T =k(k= constant)

V1/T1 = V2/T2

Where V_1 and T_1 are the initial volume and temperature and V_2 and T_2 are the final volume and temperature respectively.

Pressure law

Pressure law or gay Lussa's law states that the pressure of a fixed mass of gas at constant volume is proportional to its absolute temperature.

Mathematically

P a T

$\frac{P}{T}$ = k(k = constant)

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

Where P_1 and T_1 are initial pressure and Temperature while P_2 and T_2 are final pressure and temperature respectively

The ideal gas equation (general gas equation)

The ideal gas equation is a combination of the three gas laws i.e. Boyle's law, Charley's law and the pressure law.

From Boyle's law we have PV = constant at constant temperature

From Charles' law we have V/T = constant at constant temperature

From pressure law we have P/T = constant at constant volume combining these three laws

Therefore PV/T = constant

$$\frac{P_1 v_1}{T_1} = \frac{P_{2v_2}}{T_2}$$

Example

An ideal gas has a pressure of 100cmHg at a temperature of 27 degree when its volume is 120cm^3. When the pressure and temperature are increased to 150cmHg and 127 degree respectively. Calculate the new volume of the gas.

Solution

The temperature must be converted to kelvin. 1.e

The first temperature 27 degree = 273+27 = 300 kelvin

The second temperature 127 degree = 273 + 127 = 400 kelvin

$$\frac{P_1 v_1}{T_1} = \frac{P_{2v_2}}{T_2}$$

100*120/300 = 150*V2/400

V2 = (100*120*400)/(300*150) = 106.67cm^3

The standard and temperature is 0 degree or 273k while the standard pressure is 760mmHg. The standard volume is 22.4 dm^3.

The kinetic theory and its explanation of the gas laws

The kinetic theory of gas is made up of larger number of molecules. These molecules move about in their container randomly with different velocity, colliding with one another and the container walls. As the gas molecules hit the walls of the container and their velocity change as well as their momentum. The wall experience some force as a result of change in momentum of the gas molecule. Therefore, some pressure is exerted on walls of the vessel used by the collision of the molecules, since pressure is force per unit area.

Worked Examples

Question 1

The pressure of a given mass of a gas changes from 300Nm-2 to 120Nm-2 while the temperature drops from 127oC to –73oC. The ratio of the final volume to the initial volume is{UTME 2001}
A. 2 : 5 B. 4 : 5 C. 5 : 2 D. 5 : 4

Solution

$$\frac{P_1 v_1}{T_1} = \frac{P_{2v_2}}{T_2}$$

127 degree = 273+127 = 400 k

-73 degree = 273-73 = 200 k

300*V_1/400 = 120*V_2/200

$300*200*V_1 = 120*400*V_2$

$V_1/V_2 = 120*400/300*200 = 24/30 = 4:5$

$V_2/V_1 = 5:4$

D is the correct option

Question 2

The pressure of 3 moles of an ideal gas at a temperature of 27°C having a volume of $10^{-3}m^3$ is{UTME 2002}
A. 2.49 x 105Nm-2 B. 7.47 x 105Nm-2 C. 2.49 x 106Nm-2 D. 7.47 x 106Nm-2
[R = 8.3J mol-1K-1]

Solution

PV = nRT

P = nRT/V

P = 3*8.3*(273+27)/10-3

P = 3*8.3*300/0.001

P = 7470000Nm-2 = 7.47 x 106Nm^{-2}

D is correct option

Question 3

Which of the following gas laws is equivalent to the work done? {UTME 2007}
A. Pressure Law B. Van der Waal's Law C. Boyle's Law D. Charles' Law

Solution

PV = K (k=constant), this is Boyle's Law and is equivalent to workdone

C is the correct option

Question 4

A sealed flask contains 600cm^3 of air at 27^{o}C and is heated to 35^{o}C at constant pressure. The new volume is {UTME 2008}
A. 508cm^3 B. 516cm^3 C. 608cm^3 D. 616cm^3

Solution

$V_1/T_1 = V_2/T_2$

600/(273+27) = V2/(273+35)

600/300 = V_2/308

2/1 = V_2/308

V_2 = 308*2 = 616cm3

D is the correct option

Question 5

At 40C, the volume of a fixed mass of water is{UTME 2009}
A. constant B. minimum C. maximum D. zero.

Solution

Anomalous behaviour of water is between 0 – 4 degree. At this temperature water contract i.e. volume of water decreases. So the volume will be minimum

B is the correct option

Question 6

The pressure of two moles of an ideal gas at a temperature of 270C and volume 10-2m3 is{UTME 2009}
A. 4.99 x 105 Nm-2 B. 9.80 x 103 Nm-2 C. 4.98 x 103 Nm-2 D. 9.80 x 105 Nm-2
[R = 8.313 J mol-1 K-1]

Solution

PV = nRT

P = nRT/V

P = 2*8.313*(273+27)/10-2

P = 2*8.313*300/0.01

P = 498780Nm^{-2} = 4.99 x 105 Nm^{-2}

A is correct option

Question 7

The pressure of one mole of an ideal gas of volume 10^{-2}m3 at a temperature of 27^0C is {UTME 2010}
A. 2.24 x 10^4 Nm^{-2} B. 2.24 x 10^5 Nm^{-2} C. 2.49 x 10^5 Nm-2 D. 2.49 x 10^4 Nm^{-2}.
[Molar gas constant = 8.3 Jmol-1K-1]

Solution

PV = nRT

P = nRT/V

P = 1*8.3*(273+27)/10-2

P = 1*8.313*300/0.01

P = 249000Nm-2 = 2.49 x 105 Nm^{-2}

C is correct option

Question 8

2000cm^3 of a gas is collected at 27^{o}C and 700mmHg. What is the volume of the gas at standard temperature and
pressure?{UTME 2012}
A. 1896.5cm^3 B. 1767.3cm^3 C. 1676.3cm^3 D. 1456.5cm^3

Solution

At s.t.p pressure = 760mmHg, temperature = 273K

$P_1V_1/T_1 = P_2V_2/T_2$

700*200/300 = 760*V_2/273

V_2 = 700*2000*273/(300*760) =1676.3cm^3

C is the correct option

Question 9

A gas at a pressure of 105Nm^{-2} expands from 0.6m^3 to 1.2m^3 at constant temperature, the work done is {UTME 2013}
A. 6.0 x 104J B. 7.0 x 107J C. 6.0 x 106J D. 6.0 x 105J

Solution

Work done = P(V2 – V1)

Work done = 100000(1.2 – 0.6) = 100000(0.6)

Work done = 60000 J = 6.0 x 104J

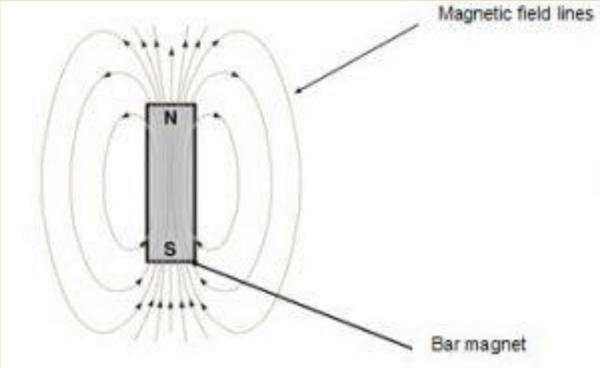
A is the correct option

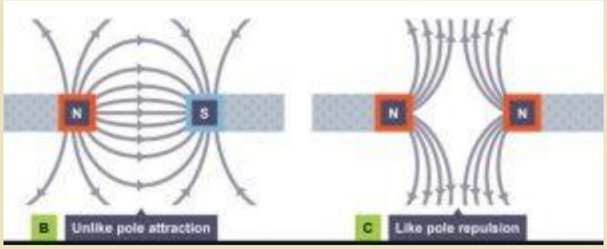
CHAPTER TWENTY ONE

Magnetic Field

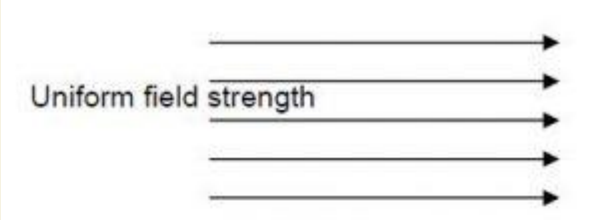
Magnetic field is a region of space where a magnet or a current carrying conductor or a moving charge experiences a magnetic force.

Magnetic field is directed from a North Pole to a South Pole.

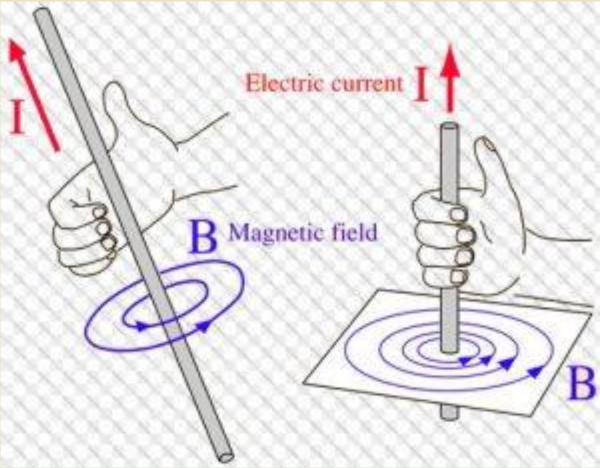


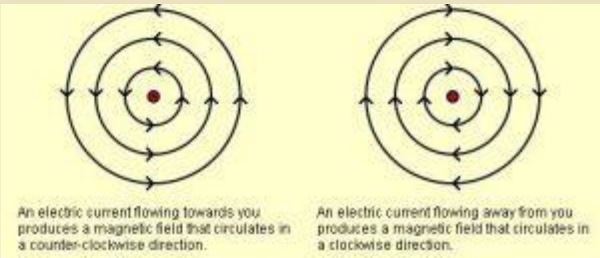


A uniform field, within which the field strength is the same at all points, could be represented as parallel lines that are equally spaced as shown above. The uniform field is stronger if the lines are closer to each other.



Magnetic field around a current carrying wire





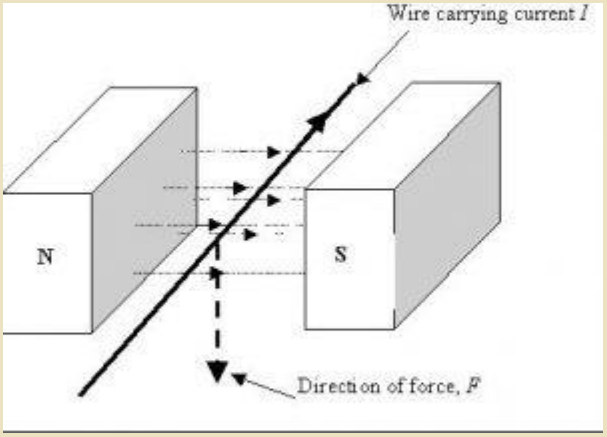
When an electric current flow towards you (out of the plane paper), it produces a magnetic field that circulates in anti-clockwise direction. When electric current flow away from you (into the plane paper), it produces field that circulates in a clockwise direction.

Out of the paper is represented by a dot **(.)**

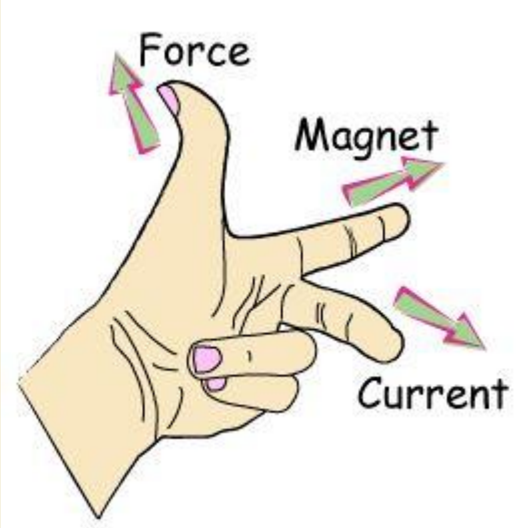
Into the plane paper is represented by a cross **(x)**

Electromagnetism

Force on a current carrying conductor



The direction of the force can be detect using Fleming's left hand rule



$$F = BIl \sin\theta$$

- Magnetic Field, B
- Current, I
- Length of conductor in magnetic field, l
- Angle between field and current, θ

For maximum force, θ = 90

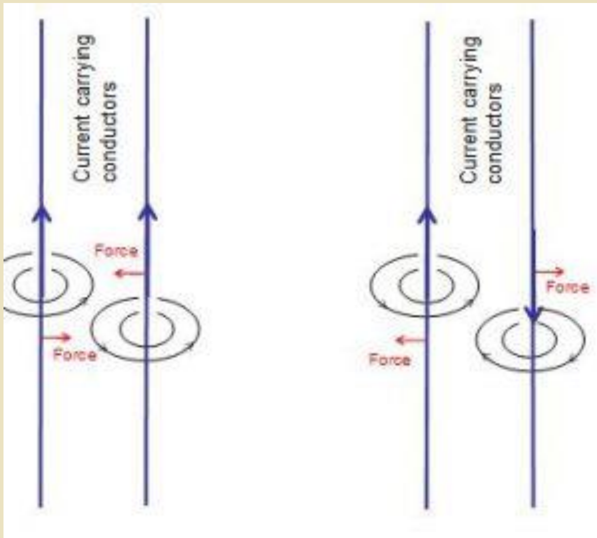
F = BIL

B is the magnetic field strength

Magnetic flux density in a magnetic field is defined as the force per unit length acting on a conductor carrying a unit current placed at right angles to the field.

Tesla: The uniform magnetic flux density which, acting normally to a long straight wire carrying a current of 1 amp, causes a force per unit length of 1 Nm^{-1} on the conductor

Forces between current-carrying conductors and predict the direction of the forces



When the currents are moving in the same direction, the forces between the current carrying conductors is attractive. When the currents are moving in opposite direction, the force is repulsive.

Regardless of the current, the forces on the conductor will be the same.

$$f_1 = \frac{\mu_0 \, I_2 I_1 l}{2\pi x}$$

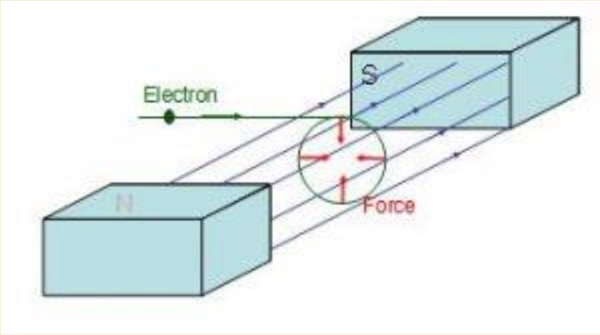
$$f_2 = \frac{\mu_0 \, I_1 I_2 l}{2\pi x}$$

$$f_1 = f_2$$

$$B = \frac{\mu_0 \, I}{2\pi x}$$

x is the distance between the two parallel conductors

A moving charge in a magnetic field

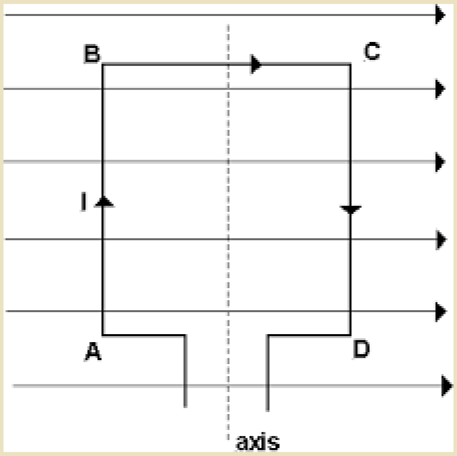


F = BQv sinθ

For a moving charge in a magnetic field

- Magnetic Field, B
- Charge, q
- Velocity of the charge, v
- Angle between field and velocity of charge, ***θ***

Rectangular ring in a uniform magnetic field



F = NBIL

N is the number of turns pivoted so that it can rotate about a vertical axis

Torque = force x perpendicular distance

Electromagnetic Induction

Faraday noticed that an E.M.F is induced in a circuit whenever there is change in magnetic flux linked with a circuit

$\varnothing = BA$

$\varnothing$ is the magnetic flux and A is the area

Magnetic flux is the product of magnetic flux density and the area normal to the magnetic flux. The unit is weber

$N\varnothing$ is the magnetic flux linkage

Faraday's law states that E.M.F induced is directly proportional to the rate of change of magnetic flux linkage.

E a $dN\varnothing/dt$

Lenz's law state that the induced E.M.F moves in such a way as to oppose the change producing it

$E = -Nd\varnothing/dt$

Lenz's law is the law of conservation of energy

$E = Blv$

E is the emf induced

B is the magnetic field strength

l is the length

v is the velocity

Worked Examples

Question 1

Induced emfs are best explained using {UTME 2013}
A. Lenz's law B. Ohm's law C. Faraday's law D. Coulomb's law

Solution

Although both Faraday and Lenz explained the induced emf

Faraday's law talk about the emf is induced as a result of the rate of change of magnetic flux linkage while

Lenz says the induced emf move in such a way as to oppose the change producing

Look at the two theory Faraday BEST explained induced emf
C is the correct option

Question 2

A conductor of length 1m moves with a velocity of 50ms-1 at an angle of 300 to the direction of a uniform magnetic
field of flux density 1.5 Wbm-2. What is the e.m.f. induced in the conductor?{UTME 2012}
A. 37.5V B. 50.5V C. 75.0V D. 80.5V

Solution

E = Blv sinQ

E = 1.5 * 1 * 50 sin30

E = 37.5 v

A is the correct answer

Question 3

A particle carrying a charge of 1.0 x10^{-8}C enters a magnetic field at 3.0 x10^{2} ms-1 at right angles to the field. If
the force on this particle is 1.8 x 10^{-8}N, what is the magnitude of the field?{UTME 2012}
A. 6.0 x 10^{-1}T B. 6.0 x 10^{-2}T C. 6.0 x 10^{-3}T D. 6.0 x 10^{-4}T

Solution

F = Bqv

B = F / qv

B = 1.8 x 10^{-8} / (1.0 x10^{-8} * 3 x 10^{2})

$B = 0.6 \times 10^{-2} = 6.0 \times 10^{-3}$ T

C is the correct option

Question 4

A step-down transformer has a power output of 50W and efficiency of 80%. If the mains supply voltage is 200V, calculate of the primary current of the transformer. {UTME 2008}
A. 0.31A B. 3.20A C. 3.40A D. 5.00A

Solution

Efficiency = power output / power input

80/100 = 50/power input

50*100 / 80 = power input

Power input = 62.5

Power input = $I_p V_p$

I_p = 62.5 / 200 = 0.31 A

A is the correct option

Question 5

Two long parallel wires X and Y carry currents 3A and 5A respectively. If the force experienced per unit length by X is 5×10^{-5}N, the force per unit length experienced by wire Y is{UTME 2007}
A. 3×10^{-5}N B. 3×10^{-6}N C. 5×10^{-4}N D. 5×10^{-5}N

Solution

$$f_1 = \frac{\mu_0 I_2 I_1 l}{2\pi x}$$

$$f_2 = \frac{\mu_0 I_1 I_2 l}{2\pi x}$$

$$f_1 = f_2$$

Following the above formula and supporting it with Newton's third law that states the if object X exert a force on object y, object y will exert the same force on X but in opposite direction.

For two parallel current carrying conductors, regardless of their current, they will exert the same force on each other but in opposite direction

D is the correct answer

Question 6

The force on a current carrying conductor in a magnetic field is greatest when the {UTME 2001}

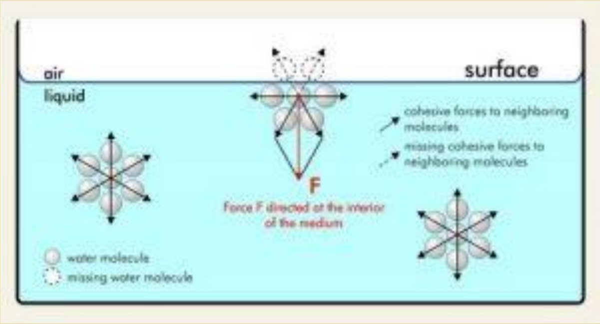
A. conductor is at right angles with the field. B. force is independent of the angle between the field and the conductor. C. conductor is parallel with the field. D. conductor makes an angle of 60° with the field.

Solution: A is the correct answer

CHAPTER TWENTY TWO

Surface Tension

The surface of the liquid behave like a membrane under tension, surface tension arises because the molecules of the liquid exert attractive forces on each other. There is zero net force in a molecule inside the volume of the liquid, but a surface molecule is drawn into the volume. Thus, the liquid tend to minimise its surface area, just as a stretched membrane does.



Three examples of surface tension

1. Water striders spend their life walking on water
2. Surface tension causes the drops at the ends of these pipettes to adopt a near-spherical shape
3. A paper clip rests on water, supported by surface tension

Coefficient of surface tension is defined as the force per unit length acting in the surface at right angle to one sides of a line drawn in the surface. The unit is Nm^{-1}

Adhesion and Cohesion

Cohesion is the force of attraction between molecules of the same kind. Adhesion is the force of attraction between molecules of different kind.

Cohesion and Adhesion explain the different action of water and mercury when spilled on a clean glass surface.

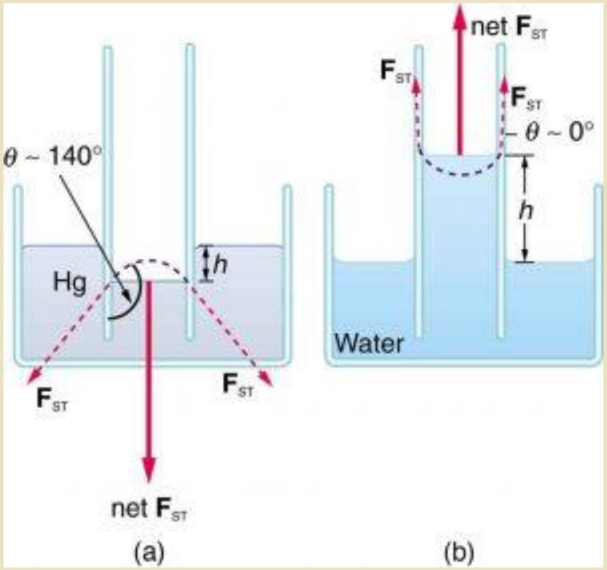
Water: The adhesion of water molecules to glass is stronger than the cohesion between water molecules, water spread out on a clean glass surface when sprinkled on it and wet the glass.

Mercury: The force of cohesion between two molecules of mercury is greater than the force of adhesion between a molecule of mercury and a molecule of glass; thus mercury gathers in pools when split on glass.

Angle of contact

The angle of contact is the angle between the tangent to the liquid surface and the tangent to the liquid surface, both drawn in the place at right angle to both surfaces and meeting at the point of contact measured within the liquid.

For a liquid in which the cohesive force is greater than the adhesive force, the angle of contact is obtuse e.g mercury. If the adhesive force exceeds the cohesive force of the liquid molecules, the angle of contact is very small or almost zero e.g water



Capillarity

It is the tendency of a liquid to rise or fall in a capillarity tube. Cohesion and adhesion as well as surface tension forces are responsible for the capillarity of liquids. In water and soap solution the surface of the liquid or its meniscus curves upward. But in mercury the meniscus is curved downwards away from the glass tube.

Capillarity explains why liquid candle wax rises up the wick of a candle or kerosene rises up the wick of a lamp.

Viscosity

It is the internal friction which opposes the motion of one portion of a fluid relative to another. Viscosity of all fluid are strongly temperature dependent; viscosity of gases increases as temperature increases while viscosity of liquid decreases as temperature increases

Note: water is not used as lubricant because it has low viscosity

Coefficient of viscosity, η, is defined as force acting normally in liquid per unit area per unit velocity gradient.

η S.I base unit is $kgm^{-1}s^{-1}$

Worked Example

Question 1

Water does not drop through an open umbrella of silk material unless the inside of the umbrella is touched. This is due to

A. capillarity B. osmotic pressure C. viscosity D. surface tension.

The correct option is surface tension (D)

CHAPTER TWENTY THREE

Heat Energy

The law of conservation of energy that the heat we supply does not just disappear. It is usually transformed into some other kind of energy. In this case, the heat supplied to the water is transformed to the internal energy of the water molecules. I shall focus on conservation principle of heat energy, heat capacity, specific heat capacity, latent heat.

Heat capacity

The heat capacity of a body is the heat required to raise the temperature of the body through 1K. The unit is joules per Kelvin (J/K).

Heat Capacity = mass of substance x specific heat capacity

Specific Heat Capacity

Specific heat capacity, a substance is the quantity of heat required to raise the temperature of unit mass (1kg) of the substance by 1K or 1°C. The S.I unit is J/kgk or J/kgC

$$c = \frac{Q}{M((\theta_2 - \theta_1)}$$

Example1 Calculate the quantity of heat required to raise the temperature of 4kg of copper from 25⁰C to 95⁰C [Take specific heat capacity of copper = 390 J/Kgk]

Quantity of heat $Q = Mc((\theta_2 - \theta_1)$

M = 4kg, C = 390J/Kgk, (= 95 – 25 =70

Q = 4 x 390×70

Q = 109200J

Determination of specific heat capacity of a solid

1. Method of Mixture

$$M_sC_s(\theta_s - \theta_2) = M_cC_c\ (\theta_2 - \theta_1) + M_wC_w\ (\theta_2 - \theta_1)$$

2. Electrical

$$1vt = Mc\theta$$

Example 2

A piece of copper block of specific heat capacity 400J/kgk falls through a vertical distance of 20m from rest, calculate the rise in temperature of the copper block on hitting the ground when all its energies are converted into heat.

$$Mgh = Mc\,\theta$$

$$M \times 10 \times 20 = m \times 400 \times \theta$$

$$\theta = \frac{200}{400} = \frac{1}{2} = 0.5^0 c$$

This potential energy is converted into kinetic energy as it falls and the kinetic energy to heat energy as it hits the ground.

Example3

A heating coil is rated 75W, calculate the time it will take this coil to heat 1.4kg of water at 30^0C to 100^0C (specific heat capacity of water =4200J/KgK)

Heat energy supplied by the heater = Heat absorbed by water

1vt = McQ

But p = iv pt = McQ

75 x t = 1.4 x 4200 x (100 – 30)

t = 54885 s

Change of state

Substance can exist in any three state of matter namely solid, liquid or gas. The state in which a substance exists depends on the temperature. Solid when heated change to liquid and when the liquid is further heated, it changes to gas.

Note: during change of state temperature remain constant.

The heat supplied to a solid (e. g ice) during change of state is used to overcome the attractive forces that hold the solid molecule together. It does not make the substance warmer and so it is not detected by a thermometer. The heat is used mainly in making the solid molecule move freely as in a liquid. Also the heats supply to a liquid at its boiling point is used to overcome the attractive forces that hold the liquid molecule together and push back the surrounding air molecule.

Q = ML (Joule)

Where L is called the specific latent heat

L = Q/M = J/kg

Linear Expansivity

Linear expansivity is defined as the increase in length, of the unit length of the material for one degree temperature rise.

In order to solve any question on linear expansity:

(i) Write down the formula

(ii) Write down the data given

(iii) Understand what you are asked to find

(iv) Make proper substitution

(v) Evaluate

Question 1

A wire of length 100.0m at 30^{0}C has a linear expansivity of 2 x 10-5K-1. Calculate the length of the wire at a temperature of -10^{0}C {UTME 2013}

A. 99.92m B. 100.08m C. 100.04m D. 99.96m

Solution

$$\propto = \frac{l_1 - l_0}{l_0 \theta}$$

l1 = new length

l0 = original length

Q = temperature change

0.00002 = change in length / 100(30-(-10))

0.00002 = change in length / 100*40

0.00002*4000 = change in length

change in length = 0.08

change in length = 100 – x

x = 100 – 0.08 = 99.92m

A is the correct option

Question 2

Two metals P and Q are heated through the same temperature difference. If the ratio of the linear expansivities of P to Q is 2: 3 and the ratio of their lengths is 3:4 respectively, the ratio of the increase in lengths of P to Q is{UTME 2012}
A. 1 : 2 B. 2 : 1 C. 8 : 9 D. 9 : 8

Solution

Temperature difference = (linear expansivity * length)/increase in length

For metal P,

Qp = (linear expansivity * length)p/increase in lengthp

For metal Q,

Qq = (linear expansivity * lengthq)/increase in lengthq

(linear expansivity * length)p/increase in length p = (linear expansivity * length q)/increase in length q

Increase in length of p: increase length q = (linear expansivity * length)p / (linear expansivity * length q)

Increase in length of p: increase length q = 2/3 *3 /4 = 6 / 12 = 1:2

A is the correct option

Question 3

A metal of volume 40cm3 is heated from 300C to 900C, the increase in volume is{UTME 2011}
A. 0.40cm3 B. 0.14cm3 C 4.00cm3 D. 1.20cm3.
[Linear expansivity of the metal= 2.0 x 10-5K-1]

Solution

cubic expansivity = 3* linear expansivity = 3 * 0.00002 = 0.00006

0.00006 = increase in volume / 40*(90 – 30)

0.00006 = increase in volume / 40*60

increase in volume = 0.00006*2400 = 0.144cm3

B is the correct answer

Question 4

A blacksmith heated a metal whose cubic expansivity is 6.3 x 10-6K-1. The area expansivity is {UTME 2007}
A. 6.3 x 10-6K-1 B. 4.2 x 10-6K-1 C. 2.1 x 10-6K-1 D. 2.0 x 10-6K-1

Solution

cubic expansivity = 3* linear expansivity

0.0000063 = 3*linear expansivity

linear expansivity = 0.0000063/3 = 0.0000021

Area expansivity = 2*0.0000021 = 0.0000042

B is the correct option

Question 5

Calculate the length which corresponds to a temperature of 20^0C if the ice and steam points of an ungraduated

thermometer are 400 mm apart
A. 80mm
B. 20mm
C. 30mm
D. 60mm

Solution

ice point = lower fixed point = 0^oC

steam point = upper fixed point = 100^oC

(100 -0)/(20 -0) = 400/(x – 0)

100/20 = 400 / x

20*400 = 100x

x = 8000/100

x = 80mm

A is the correct option

Question 6

A steel bridge is built in the summer when its temperature is 35.0°C. At the time of construction, its length is 80.00m. What is the length of the bridge on a cold winter day when its temperature is -12.0°C? (Linear expansivity of steel is 1.2 x10^-5)

Solution

$$\propto = \frac{l_1 - l_0}{l_0 \theta}$$

initial length = 80 m

initial temperature = 35.0°C

final length = ?

final temperature = -12.0°C

Change in temperature = final – initial = -12-35 = -47.0°C

let change in length = x

o.oooo12 = x/80(-47)

x = 0.000012*80*(-47) = -0.04512 m

note

x = final length – initial length

-0.04512 = final length – 80

final length = 80 -0.04512 = 79.95488 m

The length of the bridge on a cold winter day = 79.95488 m

Calculate the amount of heat energy required to change 20kg of ice water at 0^0C. Specific content heat of ice = 336 x 10^3 J/kg

Q = 20 x 366 x

Q= 732 x J

Q= 7.32 x J

More worked Examples

Question 1

A 2000W electric heater is used to heat a metal object of mass 5kg initially at 10oC. If a temperature rise of 30oC is
obtained after 10 min, the heat capacity of the material is{utme 2003}
A. 6.0 x 104JoC-1 B. 4.0 x 104JoC-1 C. 1.2 x 104JoC-1 D. 8.0 x 103JoC-1

Solution

p*t = mcθ

p is the power

θ is the temperature change

the time must be converted to seconds

2000*10*60 = 5*(30-10)*c

c = 1200000/100

c = 12000JoC-1

C is the correct option

Question 2

A 50W electric heater is used to heat a metal block of mass 5kg. If in 10 minutes, a temperature rise of 12oC is
achieved, the specific heat capacity of the metal is {utme 2004}
A. 500 J kg-1 K-1 B. 130 J kg-1 K-1 C. 390 J kg-1 K-1 D. 400 J kg-1 K-1

sol

p*t = mcθ

p is the power

θ is the temperature change

the time must be converted to second

50*10*60 = 5*12*c

c = 30000 / 60

c = 500J kg-1 K-1

A is the correct answer

Question 3

10^6J of heat is required to boil off completely 2kg of a certain liquid. Neglecting heat loss to the surroundings, the latent heat of vaporization of the liquid is {utme 2005}
A. 5.0 x 106 Jkg-1 B. 2.0 x 106 Jkg-1 C. 5.0 x 105 Jkg-1 D. 2.0 x 105 Jkg-1

Solution

Q = mL

L is the latent heat of vapourization

1000000 = 2L

L = 1000000 / 2

L = 500000 Jkg-1

Question 4

2 kg of water is heated with a heating coil which draws 3.5A from a 200V mains for 2 minutes. What is the increase in temperature of the water? {utme 2007}
A. 25oC B. 15oC C. 10oC D. 30oC

Solution

Ivt = mcθ

specific heat capacity of water is 4200jkg-1k-1

convert the time to second

3.5*200*2*60 = 2*4200*θ

θ = 10^oc

Question 5

The quantity of heat energy required to melt completely 1kg of ice at -30oC is {utme 2012}
A. 4.13 x 106J B. 4.13 x 105J C. 3.56 x 104J D. 3.56 x 102J
(latent heat of fusion = 3.5 x 105 Jkg-1, specific heat capacity of ice = 2.1 x 103 J kg-1 K-1)

solution

Q = mcθ + mL

Q = 1*(0-(-30))*2100 + 1*350000

Q = 63000 + 350000

$Q = 413000J$

B is the correct option

Question 6

Two liquids X and Y having the same mass are supplied with the same quantity of heat. If the temperature rise in X is twice that of Y, the ratio of specific heat capacity of X to that of Y is {UTME 2013}
A. 1 : 4
B. 2 : 1

C. 1 : 2
D. 4 : 1

Solution

$Q_x = Q_y$

$Q = mc\theta$

$M_x = M_y$

$mc\theta(x) = mc\theta(y)$

$\theta(x) = 2\theta(y)$

$C_x*2\theta(y) = C_y\theta(y)$

$C_x / C_y = 1 / 2$

C is the correct option

Question 7

Calculate the temperature change when 500 J of heat is supplied to 100g of water.
A. 12.1^oC
B. 2.1^oC
C. 1.2^oC
D. 0.1^oC
(Specific heat capacity of water = 4200Jkg-1K-1)

Solution

$Q = mc\theta$

100g = 0.1kg

$500 = 0.1 * 4200 * \theta$

$\theta = 500 / 4200$

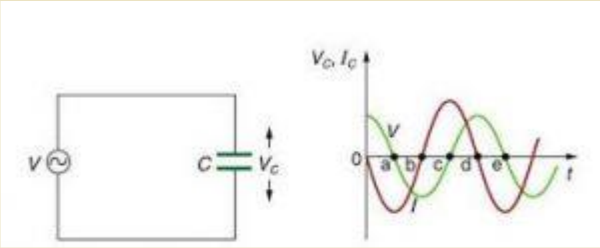
$\theta = 1.2$

C is the correct option

CHAPTER TWENTY FOUR

Alternating Current

A.C through a capacitor



An alternating voltage V = Vo sin wt when applied across a capacitor C, the current is given by:

$$I = Io \sin (wt + \pi / 2)$$

Both the experiment and theory show that the voltage (V) and the current (I) are out of phase. The current leads the voltage by 90 degree i.e. the current is ahead by the voltage. The voltage is said to lag on the current.

Capacitance Reactance Xc

The opposition offered by the capacitor to the flow of alternating current is known as the capacitance reactance Xc.

$$Xc = \frac{1}{wc} = \frac{1}{2\pi fc}$$

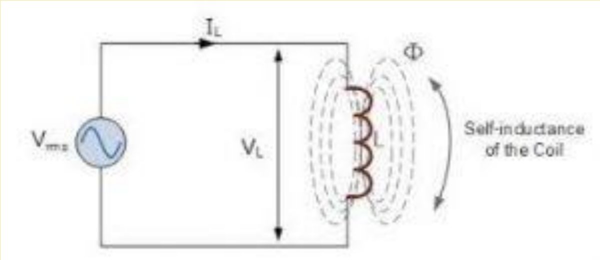
Peak and r.m.s values of A.C

The amplitude or peak value of the current Io is the maximum value of the current. The root mean square is that steady current that will develop the same quantity of heat, at the same time, and at the same resistance.

$$Irms = \frac{I_o}{2}$$

$$Vrms = \frac{V_o}{2}$$

Inductance in Alternating Current Circuit



When an inductor is connected to an alternating voltage source, $V_L = V_o \sin wt$ and the current

I is given by $I_L = I_o \sin (wt)$

The current is delayed behind the voltage in the circuit i.e the current lags the voltage by 90 degree.

$$X_L = 2\pi fL$$

Where the unit of L is Henry (H), f is in Hertz and X_L in ohms

Resistance (R) and, Inductor (L) series circuit

$$Z = \sqrt{R^2+X_L^2}$$

$$I = \frac{V}{\sqrt{R^2 + X_L^2}}$$

Capacitor- Resistor (C-R) series circuit

$$Z = \sqrt{R^2+X_c^2} \text{ and } I = \frac{V}{\sqrt{R^2+X_c^2}}$$

Series Circuit containing Resistance (R), Inductance (L) and Capacitance C

$$I_o = \frac{V_o}{\sqrt{R^2+ (X_L-X_C)^2}}$$

$$\text{If } Z = \sqrt{R^2+ (X_L - X_c)^2}$$

Example1

In an A.C circuit, if the peak voltage and current are 330volts and 80A what is the value of the root mean square voltage and current

Solution

$$Vrms = \frac{Vo}{\sqrt{2}} = \frac{330}{\sqrt{2}}$$

$$Vrms = 233.3v$$

$$Irms = \frac{I_o}{\sqrt{2}} = \frac{8}{\sqrt{2}} = 5.66A$$

Example 2

A series circuit consists of a resistance 600 ohms and an inductance of 5 Henry's An A.C voltage of 15 volts (r.m.s) and frequency 50Hz is applied across the series circuit calculate

1. The current flowing through the circuit
2. The voltage across the inductor

solution

(i) $X_L = 2\pi f L = 2x\pi x50x5 = 500\pi\Omega$

$$Z = \sqrt{R2 + XL2} = \sqrt{6002 + (500\pi)2}$$

$$Z = 1.69x10^3\ \Omega$$

(ii) $Irms = \frac{Vrms}{Z} = \frac{15}{1,69 \times 10^2}$

$= 8.88 \times 10^{-3} A$

$VL = IX_L$

$8.88 \times 10^{-3} \times 500\pi$

$= 4.44\pi$ volts

$= 14.95$volts

Worked Examples

Question 1

The current output form of an a.c. source is given as I = 10 sin w t. The d.c. equivalent of the current is {UTME 2012}
A. 5.0A B. 7.1A C. 10.0A D. 14.1A

Solution

I = I0 sin wt

Comparing this with the equation in the question

Io = maximum current = 10 A

The dc equivalent of the current = Irms

Irms = 0.7071*I0 = 0.7071 * 10 = 7.1 A

B is the correct answer

Question 2

In an a.c. circuit, the ratio of r.m.s value to peak value of current is {UTME 2011}
A. √2 B. 2 C. 1/2 D. 1/√2

Solution

$I_{rms} = (1/\sqrt{2})\ I_0$

Irms / I0 = 1/√2

D is the correct answer

Question 3

In alternating current circuit at resonance, the angle of lead or lag is {UTME 2010}

A. π/2   B. 0   C. π/3   D. π

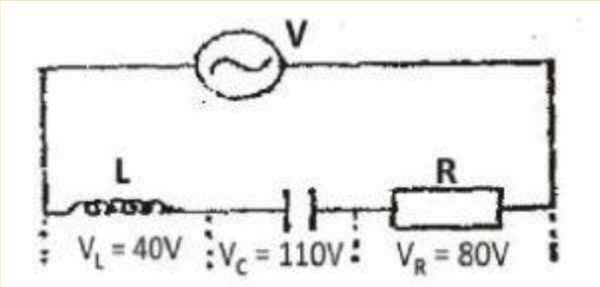
Solution

At resonance Xl(inductive reactance) = Xc(capacitive reactance)

The angle of lead or lag = 0

B is the correct option

Question 4



From the diagram above, if the potential difference across the resistor, capacitor and inductor are 80V, 110V and 40V respectively, the effective potential difference is{UTME 2009}
A. 116.3V   B. 50.0V   C. 230.0V   D. 106.3V

Solution

V^2 = Vr^2 + (Vc – Vl)^2

V = √(Vr^2 + (Vc – Vl)^2)

V = √(80^2 + (110-40)^2)

V = √6400 + 4900 = √11300

V = 106.3 v

D is the correct option

Question 4

The d.c. generator has essentially the same components as the a.c. generator except the presence of {UTME 2008}
A. slip-ring B. carbon brushes C. split ring D. armature

Solution

The only difference between a.c and d.c generator is that d.c uses split ring which enables current to be maintained in only one direction while a.c generator uses slip-ring which enables the cureent to flow sinusoidally.

d.c has split ring

C is the correct option

Question 5

The instantaneous value of the induced e.m.f. as a function of time is $\varepsilon = \varepsilon o$ sinwt where εo is the peak value of the
e.m.f. The instantaneous value of the e.m.f, one quarter of the period, is{UTME 2007}

A. εo B. $\varepsilon o/2$ C. $\varepsilon o/4$ D. 0

Solution

$w = 2\pi f$

$f = 1/T$

$w = 2\pi / T$

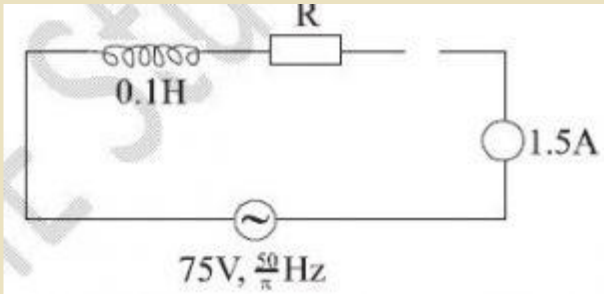
one quarter of the period will be

$w = 2\pi / (T/4) = 4 * (2\pi / T)$

$\varepsilon = \varepsilon o/4$

C is the correct option

Question 6



From the diagram, the inductive reactance and the resistance R are respectively {UTME 2007}
A. 10Ω and 50Ω B. 20Ω and 50Ω C. 25Ω and 50Ω D. 50Ω and 45Ω

Solution

Xl = 2πFL = 2*π*50/π * 0.1 =10Ω

V = IZ

75 = 1.5*Z

Z = 75 /1.5 = 50Ω

Z = √R^2 + Xl^2

50 = √R^2 + 10^2

50^2 = R^2 + 100

2500 = R^2 + 100

R^2 = 2400

R = √2400 = 49.98Ω approximately = 50Ω

A is the correct option

Question 7

A transformer is rated 240V. If the primary coil is 4000 turns and the secondary voltage 12V, determine the number of turns in the secondary coil.{UTME 2005}
A. 100 B. 150 C. 200 D. 250

Solution

Vp / Vs = Np / Ns

240 / 12 = 4000 / Ns

Ns = (4000 * 12) / 240

Ns = 200 v

C is the correct option

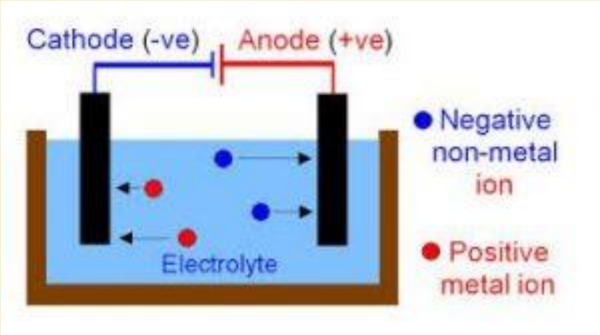
CHAPTER TWENTY FIVE

Conduction through Liquids

Electrolysis: Is the chemical change in a liquid due to the flow of electric current.

Electrolytes Are liquid that are good conductor of electricity.

Non-electrolytes are liquid that are poor conductor of electricity.



Application of Electrolysis

1. Electroplating: Is the process of coating metals with another metal in order to protect the metal from corrosion.
2. Purification of Metal: Electrolysis is important in purifying impure copper.

Faraday's Laws of Electrolysis

Faraday's First Law: States that the mass of a substance, M, of a substance liberated during electrolysis is strictly proportional to the quantity of electricity that has passed through the electrolyte.

Therefore:

M = Mass of a substance

Q = Quantity of electricity

M = zIt

Q = It

where z constant of proportionality which is the electrochemical equivalence

Faraday's Second Law: States that he masses of the different substance deposited or liberated by the same quantity of electricity are strictly proportional to the equivalent of the substance.

Example 1

At what time must a current of 20A pass through a solution fo zinc sulphate to deposit 3g of zinc? If the electrochemical equivalent z = 0.0003387gc^-1.

I = 20A

m = 3g

Z = 0.0003387

M = zit

t = M/ ZI

t = 3 / 0.0003387*20

t = 443s

Gases

Conditions under which gases conduct electricity

1. Low pressure
2. High potential difference

Thermionic Emission

Thermionic emission: This is the emission of electrons from the surface of a hot metal. Whenever a metal is heated to a greater temperature, electrons are emitted from the surface of the metal in a process known as thermionic emission.

Application of thermionic emission

The application of thermionic emission is in the cathode –ray oscilloscope used for studying all types of waveforms, it is also important in measuring frequencies and amplitudes of voltages of electronic devices.

CHAPTER TWENTY SIX

Basic Electronics

Conductors are substances that allow the passage of electricity through them. Insulation is a substance that will not permit the passage of electricity through them.

Insulators are materials that do not allow the passage of electricity through them.

Semi-conductors are materials having intermediate electrical conductivity between that of conductors and insulators.

Examples of Semiconductors

1. Silicon 2. Germanium

Intrinsic semi-conductors are semi-conductors in their pure state i.e. semiconductors that have not being doped.

Extrinsic semiconductors are semiconductors that have been doped.

Doping is the addition of impurities such as antimony, and germanium crystal to a semi-conductor. The aim of doping is to alter the structure of the semiconductor crystal.

Current is carried through a semiconductor by two types of carriers: (i) free electrons which have negative charges (ii) holes that have a positive charge

In semiconductors such as silicon and germanium, there are four electrons in the outermost shell – valence electrons.

Effects of Temperature on Semiconductors

The resistance of a semiconductor will be decreasing as the temperature increases. Unlike, in the case of a pure conductor where the temperature increases with the rise in conductivity.

Types of semiconductors

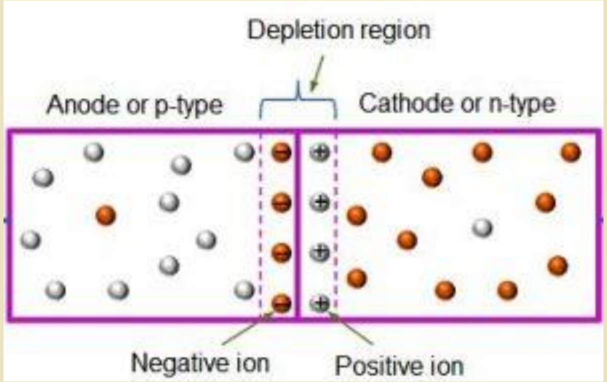
1. n-type semiconductor
2. p-type semiconductor

n-type semiconductor: it is the addition of pentavalent element such as antimony, and germanium crystal to a semi-conductor will lead to the formation of the n-type of the semiconductor. The majority carriers are electrons and minority carriers are holes.

p-type semiconductor is produced by "doping" pure germanium or silicon crystal with an impurity or elements that have three valence electrons(trivalent),e.g., boron and indium. the majority carriers in the p-type are the positively charged holes.

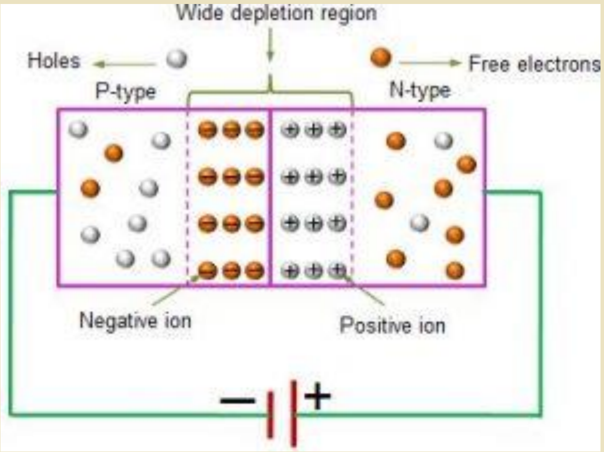
The p-n junction diode

The p-n junction semiconductor is a single semiconductor made up of a p-type semiconductor and n-type semiconductors. The two types form an alloy with a fragile junction between the two semiconductor types.



Reverse biase

In reverse biase the p-type is connected with the negative terminal while the n-type is connected to the positive terminal. This make the depletion layer to widen.



Forward biase

In forward biase the p-type is connected to the positive terminal of the battery while the n-type is connected to the negative terminal of the battery. This makes the depletion layer to narrows.

Uses of p-n junction diode

1. As a rectifier for alternating current and direct current voltage because its resistance can be varied from the forward biased to the reverse biased.
2. The potential difference requires to operate it is small,e.g., in a radio receiver, one can use 3v of battery.
3. Cheaper to manufacture
4. Smaller in size

Worked Examples

Question 1

The bond between silicon and germanium is {UTME 2013}

A. ionic B. dative C. covalent D. trivalent

Solution
C is the correct option

Question 2

Which of the following materials has an increase in resistance with temperature {UTME 2011}
A. Electrolyte B. Water C. Metals D. Wood.

Solution
D is the correct option

Question 3

The electrical properties of germination can be altered drastically by the addition of impurities. The process is referred to as {UTME 2011}
A. doping B. saturation C. bonding D. amplification.

Solution

A is the correct option

Question 4
A transistor functions mainly as a

A. rectifier and an amplifier. B. charge storer and an amplifier. C. charge storer and a switch. D. Switch and an amplifier.

Solution

D is the correct option

Question 5

Pure silicon can be converted to a ptype material by adding a controlled amount of
A. trivalent atoms B. tetravalent atoms C. pentavalent D. hexavalent atoms
(A is the correct option)

CHAPTER TWENTY SEVEN

Quantization of Energy

Max planck explained that energy from such bodies is emitted in separate or discrete packets of energy known as energy quanta or photo of amount hv where v is the frequency of radiation and he represents Planck's constant, then energy by the equation

$E = nhf$

$f = c/\lambda$

c is the speed of light

λ is the wavelength

f is the frequency

Atomic Energy Levels

The arrangement of electrons around their nuclei is in a position known as energy levels or electron orbits of electron shells. Electrons in orbit nearest to the nucleus have the highest energy and are said to be in the ground state or lowest levels.

When an electron jumps from one level, say E4 to a lower one E1 a photon of electromagnetic radiation is emitted with energy equal to the energy of the two levels.

$hv = E4 – E1$

$f = c/\lambda n$

$En - Eo = hfn = hc/ \lambda n$

En = energy in the excited state

Eo = ground state energy

Atomic Spectra, Colour and Light Frequency

When gas atoms are executed by heating or by sending an electrical discharged, they give off light which when analyzed consist of a vast number of spectral lines. The line consists of light of one wavelength or color. This type of spectrum is called a line spectrum or the atomic spectrum of the element.

A line spectrum – Is a number of well-defined lines each having a particular frequency or wavelength or colour.

The Photoelectric Effect: This occurs when light falls on metal surfaces, electrons are emitted the emitted electrons called photoelectrons.

Einstein equation

Ek max = hf – wo

wo is the workfunction = hfo

Worked Example

Question 1

The energy associated with the photon of a radio transmission at 3×10^{5}Hz is

A. 2.00×10^{-28}J B. 1.30×10^{-28}J C. 2.00×10^{-29}J D. 1.30×10^{-29}J

[h = 6.63×10^{-34}Js]

Solution

E = hf

$E = 6.63 \times 10^{-34} * 3 \times 10^{5}$

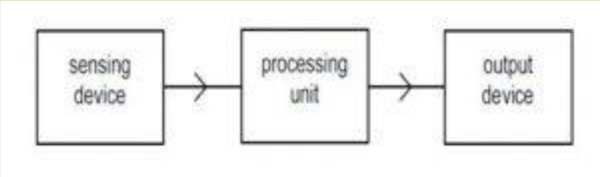
$E = 19.89 \times 10^{-29}$

Approximately 2.0×10^{-28}J (A is the correct option)

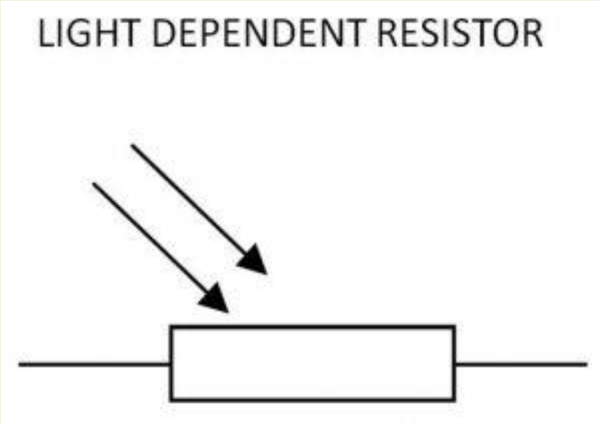
CHAPTER TWENTY EIGHT

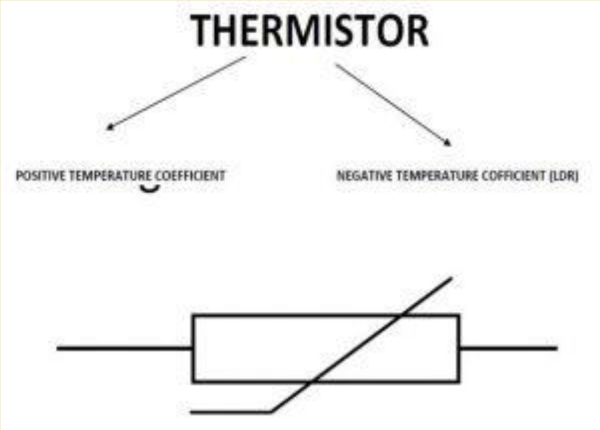
Application Physics

ELECTRONIC SENSOR



SENSING UNIT : This produce input voltage to processor depending on change in physical properties e.g. temperature, light or pressure.





Piezo electric Transducer

1. It converts energy from one form to another e.g. microphone
2. Quartz, a crystal has its positive and negative ion joined at the centre
3. When pressure is applied the shape of the crystal changes

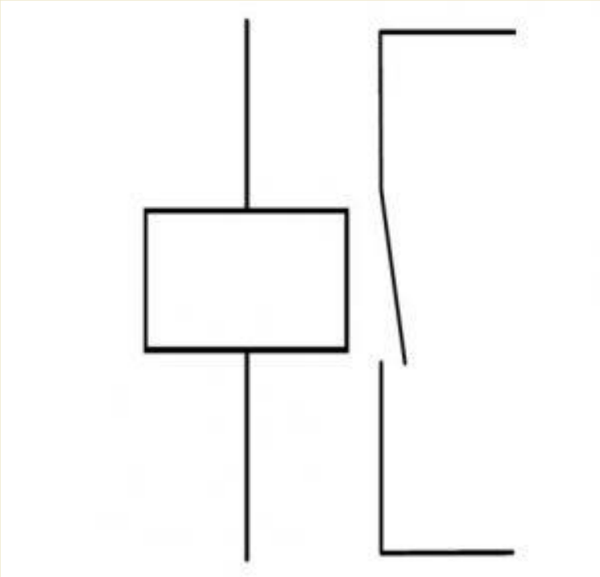
4. On move apart to set the P.D which is amplify as output
5. Voltage is positive when pressure is above the ambient pressure
6. Voltage is negative when pressure is below the ambient pressure

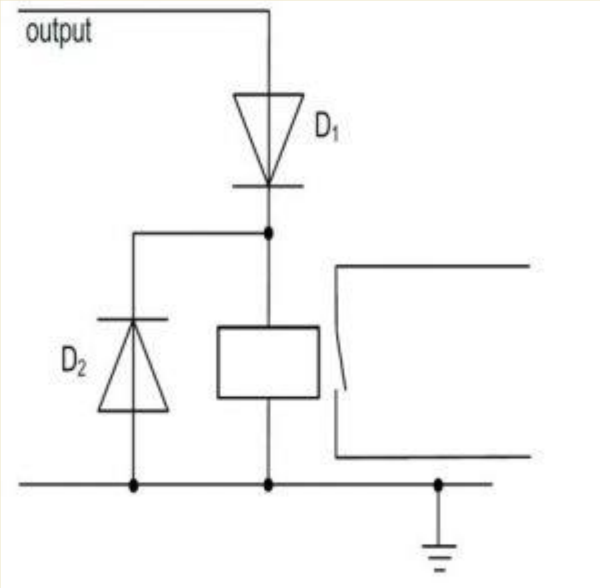
OUTPUT DEVICES

- RELAY
- LIGHT EMMITTING DIODE
- CALIBRATED DEVICES

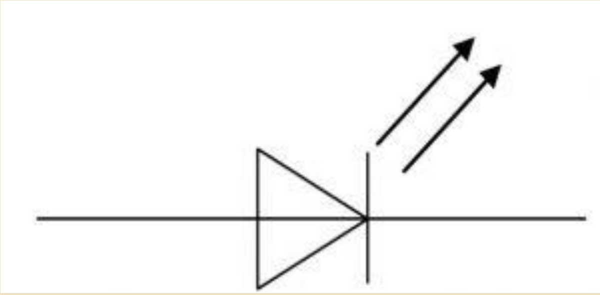
RELAY

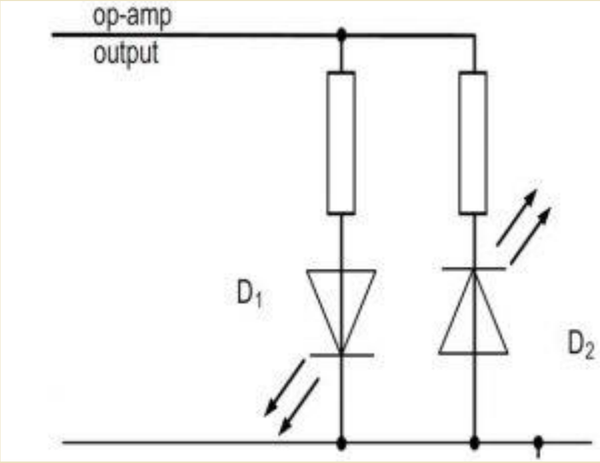
- A relay is an electromagnetic switch that uses a small current to switch on or off a larger current.
- It is also used to switch on large voltages by means of small voltages
- Isolate circuit from high voltage
- Remote switching



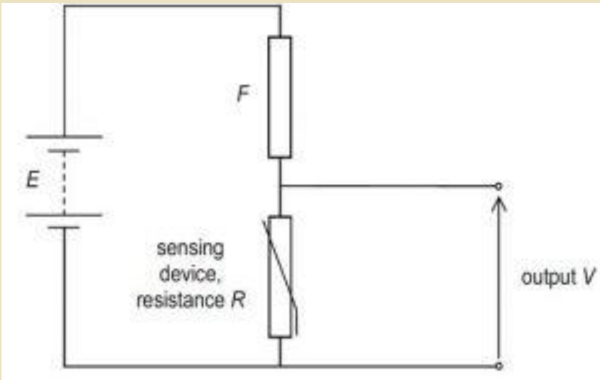


LIGHT EMMITTING DIODE

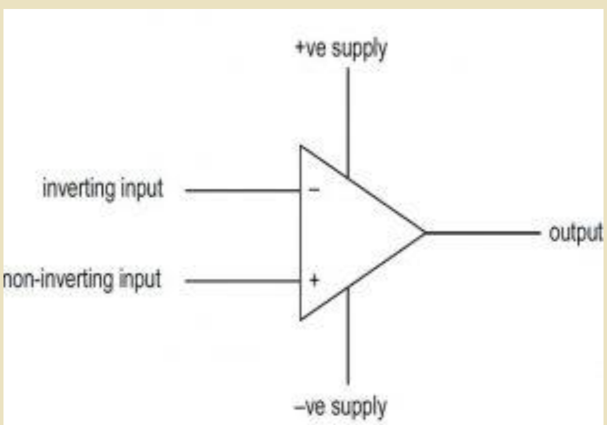




PROCESSING UNITS



$$V = \frac{R}{F + R} \times E$$



Vout = A0 (V^+ – V^–)

where A0 is the open-loop gain of the op-amp

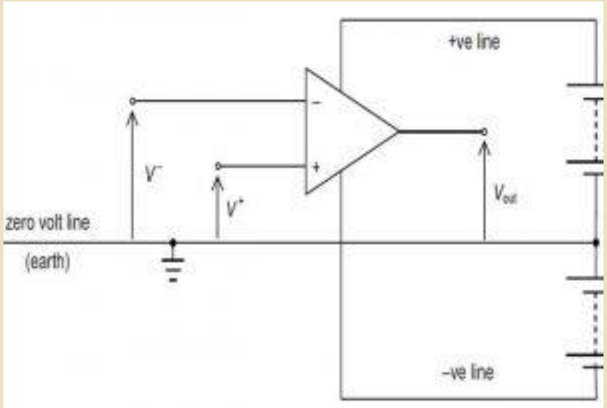
The ideal operational amplifier (op-amp) has the following properties:

- infinite input impedance
- infinite open-loop gain
- zero output impedance

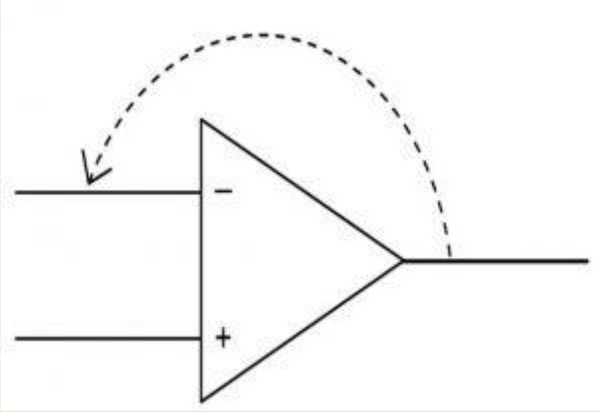
- infinite bandwidth
- infinite slew rate

MAJOR USES OF AN OPERATIONAL AMPLIFIER

1. Used as a comparator
2. Used as an inverting amplifier
3. Used as a non-inverting amplifier



NEGATIVE FEEDBACK
The process of taking some, or all, of the output of the amplifier and adding it to the input is known as feedback.

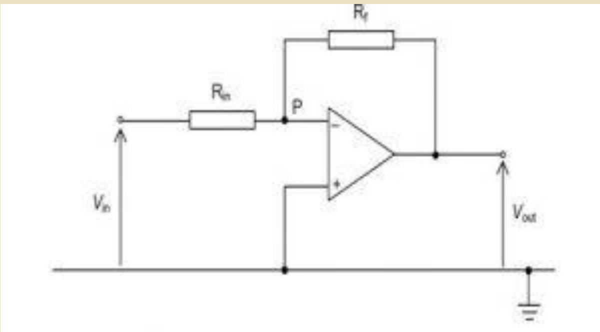


ADVANTAGES OF NEGATIVE FEEDBACK

- increased bandwidth,
- less distortion,

- greater operating stability

The circuit for an inverting amplifier is shown below



An input signal V_{in} is applied to the input resistor R_{in}. Negative feedback is applied by means of the resistor R_f. The resistors R_{in} and R_f act as a potential divider between the input and the output of the operational amplifier.

Assumptions
There are two basic assumptions

In order that the amplifier is not saturated, the two input voltages must be almost the same. The non-inverting input (+) is connected directly to the zero-volt line (the earth) and so it is at exactly 0 V. Thus, the inverting input (–) must be virtually at zero volts (or earth) and for this reason, the point P is known as a virtual earth.

The input impedance of the op-amp itself is very large, therefore, there is no current in either the non-inverting or the inverting inputs. It means the current in R_f is approximately equal to the current in R_{IN}

MORE WORKED EXAMPLES

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Question 1

The force *F* between two point charges *q*1 and *q*2, a distance *r* apart, is given by the equation

Where *k* is a constant.

$$F = \frac{kq_1q_2}{r^2}$$

What are the SI base units of *k* ? {Cambridge A level oct/nov 2016, ques 2, p11}

Solution

The SI base unit of force is Kgms-2

Charge *q*1 is As

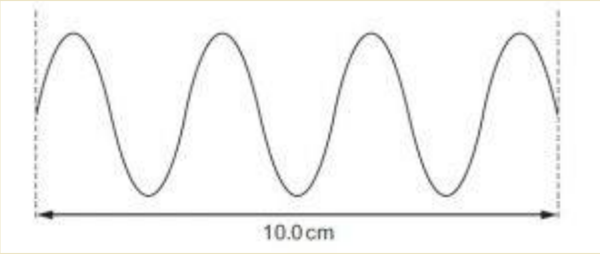
Charge q2 is As

distance r is m

SI base unit of k = (Kgms^{-2} x m) / (As x As) = Kgm^{2}s^{-4}A^{-2} (B is the correct option)

Question 2

A student uses a cathode-ray oscilloscope (C.R.O.) to measure the period of a signal. She sets the time-base of the C.R.O to 5 ms cm^{-1} and observes the trace illustrated below. The trace has a length of 10.0 cm.



What is the period of the signal? {Cambridge A level oct/nov 2016, ques 5, p11}

Solution

From the graph there are 3.5 oscillations

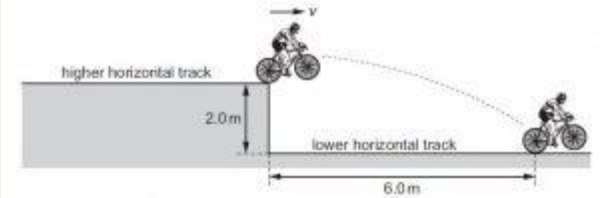
The distance to cover one oscillations = 10/3.5 cm

Since the time-base of the c.r.o is 5 ms cm–1

The period of the signal = (10/3.5) x 5 = 14.3 ms = 1.4 x 10-2 s (D is the correct option)

Question 3

A cyclist pedals along a raised horizontal track. At the end of the track, he travels horizontally into the air and onto a track that is vertically 2.0 m lower.



The cyclist travels a horizontal distance of 6.0 m in the air. Air resistance is negligible.

What is the horizontal velocity v of the cyclist at the end of the higher track? {Cambridge A level oct/nov 2016, ques 6, p11}

Solution

There are important points to note in this question:

The horizontal velocity v is used to calculate the horizontal distance

The time to reach the maximum height is the time to travel the horizontal distance

At maximum height u = 0

Using $H = ut + 1/2gt^2$

$2 = 0 + 1/2 \times 9.81 x t2$

(t=0.6395s)

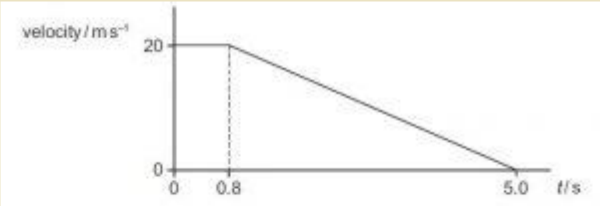
Horizontal distance = horizontal velocity(v) x time(t)

6 = 0.6395v

V = 9.4ms-2 (B is the correct option)

Question 4

A car is travelling at constant velocity. At time *t* = 0, the driver of the car sees an obstacle in the road and then brakes to a halt. The graph shows the variation with *t* of the velocity of the car.



How far does the car travel in the 5.0 s after the driver sees the obstacle? {Cambridge A level oct/nov 2016, ques 8, p11}

Solution

The distance travelled by the car = 20 x 0.8 + ½ x 20 x(5 – 0.8) =16 +42 = 58m (C is the correct option)

Question 5

A car has mass *m*. A person needs to push the car with force *F* in order to give the car acceleration *a*. The person needs to push the car with force 2*F* in order to give the car acceleration 3*a*.

Which expression gives the constant resistive force opposing the motion of the car? {Cambridge A level oct/nov 2016, ques 11, p11}

Solution

Resultant force = applied force – resistive force

Ma = F- R

R = F- ma —-i

3ma = 2F – R

R = 2F – 3ma —–ii

Substitute for R in eq i

2F – 3ma = F – ma

F = 2ma

Therefore, R = 2ma – ma = ma

Resistive force = ma (A is the correct option)

Question 6

A car travels at a constant speed of 25 m s–1 up a slope. The wheels driven by the engine exert a forward force of 3000 N. There is a drag force due to air resistance and friction of 2100 N. The weight of the car has a component down the slope of 900 N. What is the rate at which thermal energy is dissipated? {Cambridge A level oct/nov 2016, ques 20, p12}

Solution

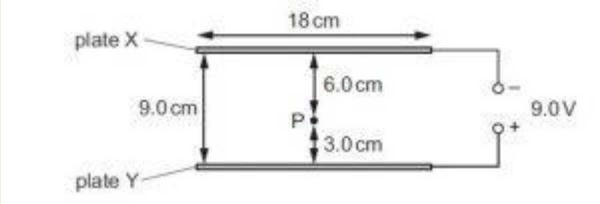
Rate at which thermal energy is dissipated = power loss

Power = force x velocity

Rate at which thermal energy is dissipated = drag force x velocity = 25 x 2100 = 5.3 x 104 W (C is the correct option)

Question 7

Two parallel circular metal plates X and Y, each of diameter 18 cm, have a separation of 9.0 cm. A potential difference of 9.0 V is applied between them.



Point P is 6.0 cm from the surface of plate X and 3.0 cm from the surface of plate Y.

What is the electric field strength at P? {Cambridge A level oct/nov 2016, ques 30, p12}

Solution

The kind of field in this this is a uniform electric field. Therefore, at any point in the field the electric field strength is constant.

Electric field strength = potential difference / distance between the plate = 9 / 0.09

Electric field strength at P = 100 Nc^{-1} (B is the correct option)

Question 8

If a current of 2.5A flows through an electrolyte for 3 hours and 1.8g of a substance is deposited, what is the mass of the substance that will be deposited if a current of 4A flows through it for 4.8 hours?{UTME 2013}
A. 4.8g B. 2.4g C. 3.2g D. 4.2g E. 4.6g

Solution

M = ZIt

Z = M / It = 1.8 /2.5*3 = 0.24 g/Ah

Z is electrochemical equivalence and it is a constant

If the current and the time changes

M = 0.24*4*4.8 = 4.6g

E is the correct option

Question 9

An electric device is rated 2000W, 250V. Calculate the maximum current it can take. {UTME 2013}
A. 6A B. 9A C. 8A D. 7A

Solution

P = Iv

2000 = 250*I

I = 2000/250

I = 8A

C is the correct option

Question 10

A house has ten 40W and five 100W bulbs. How much will it cost the owner of the house to keep them lit for 10 hours if the cost of a unit is N5?{utme2013}

A. N20 B. N90 C. N50 D. N45

Solution

Total power = 10*40 + 5*100 = 900W =0.9kw

Energy =power x time(hour)= 0.9*10 =9kwh

1kwh = N5

9kwh = N5 *9 = N45

D is the correct answer

Solution 11

A man 1.5m tall is standing 3m in front of a pinhole camera whose distance between the hole and the screen is 0.1m.
What is the height of the image of the man on the screen?{utme 2013}
A. 1.00m B. 0.05m C. 0.15m D. 0.30m

Solution

Image distance/object distance = image height/object height

0.1/3 = image height / 1.5

Image height = 1.5*0.1 /3 = 0.05 m

B is the correct option

Question 12

Two liquids X and Y having the same mass are supplied with the same quantity of heat. If the temperature rise in X is twice that of Y, the ratio of specific heat capacity of X to that of Y is{UTME 2013}
A. 1 : 4 B. 2 : 1 C. 1 : 2 D. 4 : 1

Solution

$m_x c_x Q_x = m_y c_y Q_y$

$m_x = m_y$

$Q_x = 2Q_y$

$c_x*2Q_y = c_y Q_y$

$c_x/c_y = 2/1 = 2:1$

B is the correct option

Question 13

Which of the following consists entirely vector quantities? {UTME 2001}
A. Work, pressure and moment B. Velocity, magnetic flux and reaction.
C. Displacement, impulse and power. D. Tension, magnetic flux and mass.

Solution

Vector quantities has both magnitude and direction

Option A – pressure and work are scalar quantities

Option B – they are all vector quantities

Option C- power is a scalar quantity

Option D – mass is a scalar quantity

B is the correct option

Question 14

A plane sound wave of frequency 85.5Hz and velocity 342ms-1 is reflected from a vertical wall. At what distance
from the wall does the wave have an antinode?{UTME 2001}
A. 0. 1m B 1m C. 2m D. 3m

Solution

V =fג

ג = V/f = 342/85.5 = 4 m

Distance to have an antinode = ג/4 = 4/4 = 1m

B is the correct option

Question 15

A string is fastened tightly between two walls 24cm apart. The wavelength of the second overtone is {UTME 2001}
A. 12cm B. 24cm C. 8cm D. 16cm

Solution

Third harmonic is the second overtone

Second overtone = ג/2 + ג/2 +ג/2 = 3ג/2

3ג/2 = 24

ג = 16 cm

D is the correct option

Question 16

Find the frequencies of the first three harmonics of a piano string of length 1.5m, the velocity of the waves on the string is $120ms^{-1}$.{UTME 2001}
A. 180Hz, 360Hz, 540Hz. B. 360Hz, 180Hz, 90Hz.
C. 40Hz, 80Hz, 120Hz. D. 80Hz, 160Hz, 240Hz.

Solution

First harmonic = F0 = v/2l = 120/2*1.5 = 120/3 = 40Hz

Second harmonic = 2f0 = 2*40 = 80Hz

Third harmonic = 3f0 = 3*40 = 120Hz

C is the correct option

Question 17

A gas with initial volume 2 x 10-6m3 is allowed to expand to six times its initial volume at constant pressure of 2 x $10^5 Nm^{-2}$. The work done is {UTME 2001}
A. 4.0J B. 12.0J C. 2.0J D. 1.2J

Solution

Work done = pdv

dv =V2 – V1 = (6*2 x 10-6) – 2 x 10-6

dv = 12 x 10-6 – 2 x 10-6 = 10 x 10-6

work done = 2 x 10^5 * 10 x 10-6 = 20 x 10^-1 = 2.0J

C is the correct answer

Question 18

The process of energy production in the sun is{UTME 2001}
A. radioactive decay B. electron collision.
C. Nuclear fission. D. Nuclear fusion

Solution

The answer is Nuclear Fusion

D is the correct option

Question 19

A student is at a height 4m above the ground during a thunderstorm. Given that the potential difference between the thunderstorm and the ground is 107V, the electric field created by the storm is {UTME 2001}

A. 2.0 x 106NC^{-1}. B. 4.0 x 107NC^{-1}.
C. 1.0 x 107NC^{-1}. D. 2.5 x 106NC^{-1}

Solution

E = V/d = 10^7 / 4 = 2.5 x 10^6

D is the correct option

Question 20

An object is weighed at different locations on the earth. What will be the right observation? {UTME 2010}
A. Both the mass and weight vary B. The weight is constant while the mass varies
C. The mass is constant while the weight varies D. Both the mass and weight are constant.

Solution

The mass of an object doesn't change but weight changes because the force of gravity varies from place to place on the surface of earth. There are two reasons behind this variation:
The shape of earth and the rotation of the earth.

C is the correct option

Question 21

In a hydraulic press, the pump piston exerts a pressure of 100 Pa on the liquid. What force is exerted in the second piston of cross-sectional area 3m^2? {UTME 2010}
A. 200 N B. 100 N C. 150 N D. 300 N

Solution

Pressure = Force /Area

100 = force/3

Force exerted = 300 N

D is the correct answer

Question 22

If the angle between two vectors P and Q is 0 degree, the vectors are said to
A. be perpendicular B. be parallel C. interest at angle 60o. D. intersect at angle 45^o. (UTME 2004)

Solution

The angle between two parallel lines is zero, therefore, B is the correct option

Question 23

What happens to the rays in a parallel beam of light?
A. They diverge as they travel. B. They meet at infinity. C. They intersect D. They converge as they travel. (UTME 2004)

Solution

Parallel beam of light meet at infinity

B is the correct option

Question 24

The process whereby a liquid turns spontaneously into vapour is called
A. boiling B. evaporation C. sublimation D. relegation. (UTME 2005)

Solution

Solid to gas is sublimation

Liquid to vapour at all temperature is evaporation

Liquid to vapour at a fixed temperature is boiling

Since the word spontaneous is used in the question which means occur without having been planned, therefore, evaporation is the best answer.

B is the correct option

Question 25

A bullet fired vertically upward from a gun held 2.0m above the ground reaches its maximum height in 4.0 s. calculate its initial velocity. {2009}

A.$10ms^{-1}$ B.$8ms^{-1}$ C. $40ms^{-1}$ D. $20ms^{-1}$

[g = 10ms^{-2}]

Solution

$$v = u - at$$
$$0 = u - 10 \times 4$$
$$u = 40ms^{-1}$$

C is the correct option

Question 26

An object of mass 80kg is pulled on a horizontal rough ground by a force of 500N. Find the coefficient of static friction. {2009}

A.0.8 B. 0.4 C. 1.0 D. 0.6

[g = 10ms^{-2}]

Solution

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

$$\mu = \frac{500}{80 \times 10}$$
$$\mu = 0.6$$

D is the correct option

Question 27

Two cars moving in the same direction have speeds of 100kmh^{-1} and 130kmh^{-1}. What is the velocity of the faster car as measured by an observer in the slower car? {2010}

A.130kmh^{-1} B. 230kmh^{-1} C. 200kmh^{-1} D. 30kmh^{-1}

Solution

You are to calculate the relative speed

$$u_2 - u_1 = 130 - 100 = 30kmh^{-1}$$

D is the correct option

Question 28

A car moves with an initial velocity of 25ms^{-1} and reaches a velocity of 45ms^{-1} in 10s. What is the acceleration of the car?{2010}

A. 5ms^{-1} B. 25ms^{-1} C. 20ms^{-1} D. 2ms^{-1}

Solution

$$v = u + at$$
$$45 = 25 + 10a$$
$$10a = 20$$
$$a = 2ms^{-2}$$

D is the correct option

Question 29

Two balls X and Y weighing 5g and 50kg respectively were thrown up vertically at the same time with a velocity of 100ms^{-1}. How will their positions be one second later? {2011}

A. X and Y will both be 500m from the point of throw

B. X and Y will be 500m from each other

C. Y will be 500 m ahead of X

D. X will be 500m ahead of Y.

Solution

The distance covered after one second

$$v^2 = u^2 - 2as$$
$$0^2 = 100^2 - 2 \times 10 \times s$$
$$s = \frac{10000}{20}$$

S = 500m

The position the two balls will be from the point of throw is independent on their mass.

A is the correct option

Question 30

If it takes an object 3s to fall freely to the ground from a certain height, what is the distance covered by the object?

A. 60 m B. 90 m C. 30 m D. 45 m.

[g = 10ms^{-2}]

Solution

Initial velocity = 0

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

$$s = 0 \times 3 + \frac{1}{2} \times 10 \times 3^2$$

S = 45m

D is the correct option

Question 31

Calculate the total distance covered by a train before coming to rest if its initial speed is $30ms^{-1}$ with a constant retardation of $0.1ms^{-2}$. {UTME 2012}

A. 5500m

B. 4500m

C. 4200m

D. 3000m.

Solution

V = 0

U =$30ms^{-1}$

a=$-0.1ms^{-2}$

The a is negative because the motion is retarding i.e. deceleration

$$0^2 = 30^2 + 2 \times -0.1 \times s$$
$$-0.2s = -900$$
$$s = \frac{-900}{-0.2}$$

S = 4500 m

B is the correct option

Question 32

A car starts from rest and moves with a uniform acceleration of $30ms^{-2}$ for 20s. Calculate the distance covered at the end of the motion. {UTME 2012}

A. 6km

B. 12km

C. 18km

D. 24km.

Solution

$$s = \frac{1}{2}at^2$$
$$s = \frac{1}{2} \times 30 \times 20^2$$

S = 6000m = 6km

A is the correct option

Question 33

An object of mass 20kg slides down an inclined plane at an angle of 30° to the horizontal. The coefficient of static friction is {2012}

A. 0.2 B. 0.3 C. 0.5 D. 0.6

[g = 10ms^{-2}]

Solution

$$\mu = tan\theta$$
$$\mu = coefficient\ of\ friction$$
$$\mu = \tan 30$$
$$\mu = 0.577 = 0.6$$

D is the correct answer

Question 34

A train with an initial velocity of $20ms^{-1}$ is subjected to a uniform deceleration of $2ms^{-2}$. The time required to bring the train to a complete halt is

A. 40s B. 5s C. 10s D. 20s

Solution

V = 0

U = 20

a= -2

$$v = u + at$$

$$0 = 20 - 2t$$
$$t = \frac{20}{2}$$
$$t = 10s$$

C is the correct option

Question 35

Calculate the apparent weight loss of a man weighing 70kg in an elevator moving downwards with an acceleration of $1.5ms^{-2}$. {UTME 2013}

A. 105N B. 686N C. 595N D. 581N

Solution

The apparent weight loss = ma = 70 * 1.5 = 105N

A is the correct option

Question 36

The coefficient of friction between two perfectly smooth surfaces is {UTME2013}

A. Zero B. Infinity C. One D. Half

Solution

A is the correct option

Question 37

The resultant of two forces is 50N. If the forces are perpendicular to each other and one of them makes an angle of 300 with the resultant, find its magnitude
A. 25.0N B. 100.0N C. 57.7N D. 43.3N

Solution

Since the two forces are perpendicular, it can be represented using a right-angle triangle. Also one of the forces makes an angle 30 degree with the resultant.

Using SOHCAHTOA

The resultant is the hypotenuse

cos θ = adj / hyp

cos 30 = x / 50

0.866 * 50 = x

x = 43.3 N

D is the correct option

Question 38

A simple pendulum of length 0.4m has a period 2s. What is the period of a similar pendulum of length 0.8m at the same place?

A. $\sqrt{2s}$
B. 8s
C. 4s
D. $2\sqrt{2s}$

Solution

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

$$\frac{T_1}{\sqrt{l_1}} = \frac{T_2}{\sqrt{l_2}}$$

$$\frac{2}{\sqrt{0.4}} = \frac{T}{\sqrt{0.8}}$$

Cross multiply

$$T_2 = 2\sqrt{2}$$

D is the correct option

Question 39

An object is moving with a velocity of 5ms-1. At what height must a similar body be situated to have a potential energy equal in value with the kinetic energy of the moving body?
A. 1.0m B. 25.0m C. 20.0m D. 1.3m
[g ≈ 10ms-2]

Solution

K.E = Mgh

1/2 mv^2 = mgh

1/2 * m * 5^2 = m * 10* h

25 / 2 =10h

h = 25 / 20

h = 1.25 m, approximately = 1.3 m

D is the correct option

Question 40

If a sonometer has a fundamental frequency of 450Hz, what is the frequency of the fifth overtone?
A. 75Hz B. 2700Hz C. 456Hz D. 444Hz

Solution for a sonometer box

First overtone = 2f0

Second overtone = 3f0

Third overtone = 4fo

Fourth overtone = 5f0

Fifth overtone = 6f0

Therefore,

Fifth overtone = 6 * 450 = 2700 Hz

B is the correct option

Question 41

An electric device is rated 2000W, 250V. Calculate the maximum current it can take.
A. 6A B. 9A C. 8A D. 7A

Solution

p = Iv

2000 = 250I

I = 2000 / 250

I = 8 A

C is the correct option

QUESTION 42

Calculate the total distance covered by a train before coming to rest if its initial speed is 30ms-1 with a constant {UTME 2012}
retardation of 0.1ms-2.
A. 5500m B. 4500m C. 4200m D. 3000m

Solution

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

Since the car is decelerating, the acceleration = – 0.1 ms-2

$0 = 30^2 – 2 * -0.1 * s$

0 = 900 – 0.2s

900 = 0.2 s

s = 900 / 0.2

s = 4500 m

B is the correct option

Question 43

An object moves in a circular path of radius 0.5m with a speed of 1ms-1. What is its angular velocity? {UTME 2012}
A. 8 rads-1 B. 4 rads-1 C. 2 rads-1 D. 1 rads-1

Solution

$v = \omega r$

1 = ω * 0.5

ω = 1 / 0.5

ω = 2 rads-1

C is the correct option

Question 45

An object of mass 20kg slides down an inclined plane at an angle of 30o to the horizontal. The coefficient of static friction is

A. 0.2 B. 0.3 C. 0.5 D. 0.6
[g = 10ms-2]

Solution

mgsinθ – μR = 0

μ = mgsinθ / R

R = mg

μ = mgsinθ / mg

μ = sinθ

μ = sin 30 = 0.5

C is the correct option

Question 46

The equation of a wave travelling in a horizontal direction is expressed as y=15 sin (60t-πx) what is its
wavelength?
A. 60m B. 15m C. 5m D. 2m

Solution

y = A sin (ωt – ∅)

∅ = 2π /ג

π = 2π / ג

ג = 2π / π

ג = 2 m

Question 47

Three similar cells each of E.M.F 2V and internal resistance 2Ω are connected in parallel, the total E.M.F and total internal resistance are respectively { UTME 2011}
A. 6 V, 0.7Ω B. 6 V, 6.0Ω C. 2 V, 0.7Ω D. 2 V, 6.0Ω

Solution

Since the cells are arranged in parallel

The E.M.F will be 2v

$1/r = 1/r_1 + 1/r_2 + 1/r_3$

$1/r = 1/2 + 1/2 + 1/2$

$1/r = 3/2$

$r = 2/3$

$r = 0.7\Omega$

C is the correct option

Question 48

The volume V of liquid that flows through a pipe in time t is given by the equation

$$\frac{V}{t} = \frac{\pi P r^4}{8Cl}$$

Where P is the pressure difference between the ends of the pipe of radius r and length l.
The constant C depends on the frictional effects of the liquid.
Determine the base units of C.

Solution

The base unit of pressure is

$$Kgm^{-1}s^{-2}$$

The base unit for radius = m

The base unit for length = m

Volume = m^3

t = s

The first thing to do is to make C the subject of the equation

$$C = \frac{\pi p r^4 t}{8lv}$$

Substitute all the base units

$$C = \frac{Kgm^{-1}s^{-2} \times m^4 \times s}{m \times m^3}$$

$$C = Kgm^{-1}s^{-1}$$

Question 49

A car travelling in a straight line at a speed of 30 m s–1 passes near a stationary observer while sounding its horn. The true frequency of sound from the horn is 400 Hz. The speed of sound in air is 336 m s–1.

What is the change in the frequency of the sound heard by the observer as the car passes? {Cambridge May/June 2017 p11}

A 39 Hz B 66 Hz C 72 Hz D 78 Hz

Solution

As the car passes the observer

$$F' = (\frac{v}{v + v_s})f_s$$

$$f' = \frac{336}{336 + 30} \times 400 = 367.21Hz$$

As the source approaches the observer

$$F' = \left(\frac{v}{v - v_s}\right) f_s$$

$$f' = \frac{336}{336 - 30} \times 400 = 439.22Hz$$

The change in the frequency of the sound heard by the observer as the car passes = (frequency of the sound as the car approaches the observer) – (frequency of the sound heard as the car recedes the observer)

= 439.22 – 367.21 = 72Hz

C is the correct answer.

Question 50

A sound wave has a frequency of 2500 Hz and a speed of 1500 m s–1.

What is the shortest distance from a point of maximum pressure in the wave to a point of minimum pressure? {Cambridge May/June 2017 p11}

A 0.15 m **B** 0.30 m **C** 0.60 m **D** 1.20 m

Solution

$$v = f\lambda$$

$$\lambda = \frac{v}{f} = \frac{1500}{2500} = 0.6m$$

The question requires us to find the shortest distance between maximum pressure (crest) and the minimum pressure (trough) = $\frac{\lambda}{2} = \frac{0.6}{2} = 0.3m$

B is the correct option

Question 51

The energy of a photon having a wavelength of 10^{-10}m is {UTME 2013}

A. 1.7 x 10^{-12}J

B. 2.0 x 10^{-15}J

C. 1.7 x 10^{-13}J

D. $2.0 \times 10^{-12}J$

Solution

$$E = h\frac{c}{\lambda} = 6.63 \times 10^{-34} \times \frac{3 \times 10^{8}}{10^{-10}} = 19.84 \times 10^{-16} = 2.0 \times 10^{-15}J$$

B is the correct option

Question 52

The particle nature of light is demonstrated by the {UTME 2013}

A. diffraction of light

B. photoelectric effect

C. speed of light

D. colours of light

B is the correct answer. Photoelectric effect and Einstein's explanation of it was what convinced physicists that light could behave as a stream of particle.

Diffraction and Interference of light only explains that light travels through space as a wave.

Question 53

If a current of 2.5A flows through an electrolyte for 3 hours and 1.8g of a substance is deposited, what is the mass of the substance that will be deposited if a current of 4A flows through it for 4.8 hours? {UTME 2013}

A. 4.8g

B. 2.4g

C. 3.2g

D. 4.2g

E. 4.6g

Solution

$$m = ZIt$$

$$1.8 = Z \times 2.5 \times 3$$

$$Z = \frac{1.8}{7.5} = 0.24$$

To calculate the mass when the current is now 4A and time 4.8hours, the same formula will be used

Note Z (electrochemical equivalence) is constant

$$m = ZIt$$

$$m = 0.24 \times 4 \times 4.8 = 4.6g$$

E is the correct option

Question 54

Calculate the force acting on an electron of charge 1.5 x 10^{-19}C placed in an electric field of intensity 10^5Vm-1.

A. 1.5 x 10^{-14}N

B. 1.5 x 10^{-11}N

C. 1.5 x 10^{-12}N

D. 1.5 x 10^{-13}N

Solution

$$F = Eq = 1.5 \times 10^{-19} \times 10^5 = 1.5 \times 10^{-14}N$$

A is the correct option

Question 55

A pencil is used to draw a line of length 30 cm and width 1.2 mm. The resistivity of the material in the pencil is 2.0 × 10^{-5} Ω m and the resistance of the line is 40k Ω. What is the thickness of the line? {Cambridge Oct/Nov 2014 P12}

A 1.25 × 10^{-10}m

B 1.25 × 10^{-8}m

C 1.25 × 10^{-7}m

D 1.25 $\times$ 10^{-5}m

Solution

$$R = \frac{\rho L}{A}$$

$$A = \frac{\rho L}{R} = \frac{2 \times 10^{-5} \times 0.3}{40000} = 1.5 \times 10^{-10} m^2$$

$$Area = width\ x\ thickness$$

$$t = \frac{A}{w} = \frac{1.5 \times 10^{-10}}{1.2 \times 10^{-3}} = 1.25 \times 10^{-7} m$$

C is the correct option

Question 56

The pair if physical quantities that are scalar only are {UTME 2013}

A. Impulse and time

B. Volume and area

C. Moment and momentum

D. Length and displacement

Solution

Option A: impulse is vector while time is scalar

Option B: volume is scalar, area is scalar

Option C: moment is vector, momentum is vector

Option D: length is scalar, displacement is vector

B is the correct option