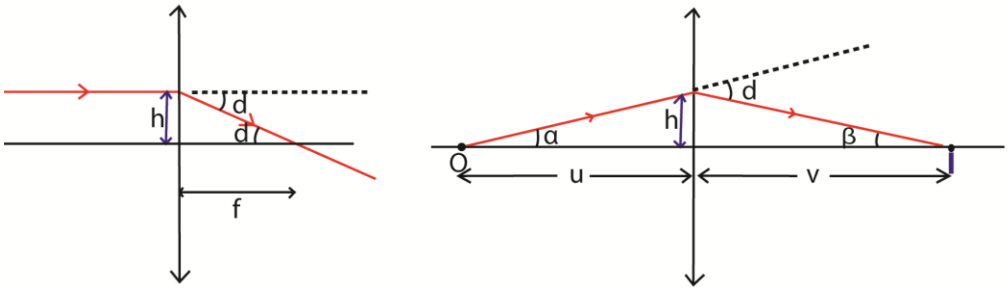
UACE PHYSICS PAPER 2 2019 GUIDE

SECTION A

1. (a) (i) derive the relationship, $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ for convex lens, where u is the object distance, v is the image distance and f is the focal length of the lens. (04marks)

Solution

Consider in each case a ray incident on the same lens at a small height **h** above the principal axis as shown:



(i) (ii)

From Fig (i), the ray parallel and close to principal axis is converged to the focal point **F** and suffer a **small** deviation **d**

where **d** $\approx$ tan d = $\frac{h}{f}$---------------------------------- (i)

From Fig (ii), the ray from a point object **O** suffers the same small deviation **D** to give rise to a point image **I**.

From geometry, d = α + β where α ≈ tanα = $\frac{h}{u}$ and β ≈ tan β = $\frac{h}{v}$

d = $\frac{h}{u} + \frac{h}{v}$ ----------------------------- (ii)

Equating equations (i) and (ii) gives

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

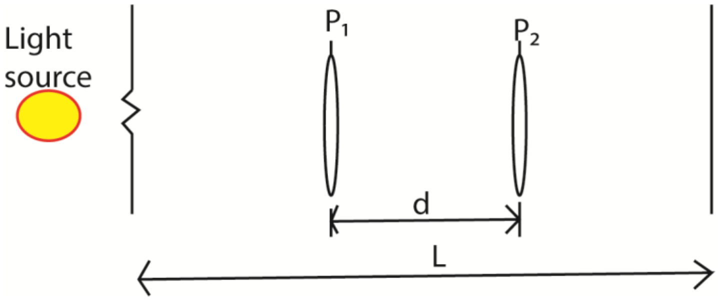
Thus $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

(ii) State three possible reasons under which an image of real object may not be formed by a convex lens on the screen. (03marks)

- When the object is placed between the lens and optical center.
- When the distance between the object and the screen is four times the focal length of the lens
- When the object is at the principal focus
- When the screen is between the lens and its principal focus.
-

(b) Describe an experiment to determine the focal length of a convex lens fixed inside a short cylindrical tube (05marks)

Solution
Illustration

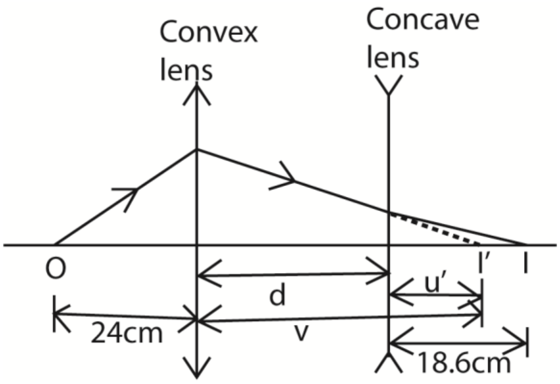


- The tube is placed between an illuminated object and a screen a distance l slightly more than 4 times the approximate focal length of a lens to form a clear magnified image at the screen. The position of the front part P_1 is noted

- The tube is moved towards the screen until a clear diminished image is formed on the screen and position P_2 of the front part is noted

- The displacement, $d = P_2 - P_1$ is noted
  The focal length, f of the lens = $\frac{l^2-d^2}{4l}$

(c) A convex lens of focal length 10cm is arranged coaxially with a concave lens of focal length 18cm. the lens system is used to focus an object placed 24cm from the convex lens on the side remote from the concave lens. the final image is formed on a screen placed 18.6cm from the concave lens. Calculate the;
(i) separation between the lenses. (05marks)



Let the separation between the lenses be d.
For convex lens
$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$
$\frac{1}{10} = \frac{1}{24} + \frac{1}{v}$; v = 17.14cm

For concave lens

$\frac{1}{-18} = \frac{1}{u'} + \frac{1}{18.6}$, u' = -9.15cm (-ve because object is virtual)

Separation, d = v-u' = 17.14 – 9.15 = 7.99cm

(ii) Magnification (03marks)

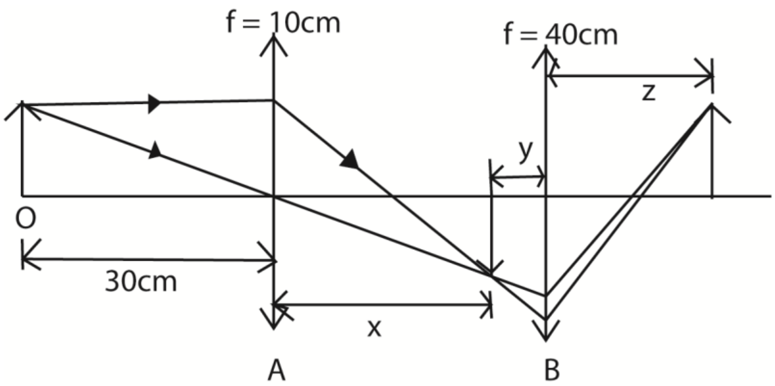
M =M_1 x M_2

$= \frac{v}{u}\ x\ \frac{V'}{u'}$

$= \frac{17.14}{24}\ x\ \frac{18.6}{9.15}$ = 1.45

2. (a) (i) State the laws of refraction of light. (02marks)
   - The incident ray, refracted ray and the normal at the point of incidence all lie in the same plane
   - The ratio of the angle of incidence to the sine of angle of refraction is constant for a given pair of media.

   (ii) A small object is placed at a distance of 30.0cm from a converging lens of focal length 10.0cm. Calculate the distance from the first lens where a second converging lens of focal length 40.0cm must be placed in order to produce an erect image of the same size as the object. (05marks)



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

$\frac{1}{10} = \frac{1}{30} + \frac{1}{x}$; x = 15cm

Magnification, $M_1 = \frac{v}{u} = \frac{15}{30} = \frac{1}{2}$

Magnification, $M_2 = \frac{z}{y}$

But m = M_1 x M_2

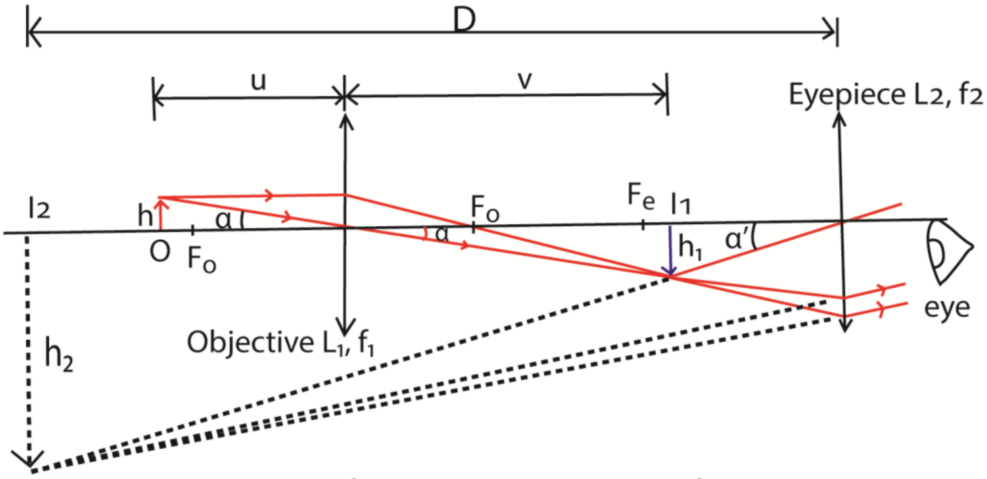
$1 = \frac{1}{2}\ x\ \frac{z}{y}$; z = 2y

Action of second lens

$\frac{1}{40} = \frac{1}{y} + \frac{1}{2y}$; y =60cm

Position = x + y= 15 + 60 = 75cm from the first lens

(b) (i) Draw a diagram to show the formation of an image by a compound microscope in normal adjustment and use it to derive an expression for the magnifying power. (06marks)



Compound microscope in normal use

Linear magnification can also be expressed as, m = $\frac{h_2}{h} x \frac{h}{h_1}$ = m_e x m_o.

Where, m_e and m_o are linear magnifications of the eye piece and objective lenses respectively.

$m_o = \frac{v}{f_0} - 1$ and me = $\frac{-D}{fe} - 1$

m = $(\frac{-D}{fe} - 1)\ (\frac{v}{f_0} - 1)$

(ii) A microscope has an objective of focal length 10.0cm and eye piece of focal length 20.0cm. If the distance between the objective and eye piece is 20 cm, calculate the magnifying power of the microscope. (03marks)

Given, f_0 = 10cm, f_e = 20, D = -25cm

$v_0 + v_e$ = 20.0cm

Using eye piece lens;

$\frac{1}{fe} = \frac{1}{u_e} + \frac{1}{D}$

$\frac{1}{20} = \frac{1}{u_e} + \frac{1}{-25}$

$u_e = 11.11$

$v_o + u_e = 20$

v_0 = 20 – 11.11 = 8.89cm

Using m = $(\frac{-D}{fe} - 1)\ (\frac{v}{f_0} - 1) = \left(\frac{-25}{20} - 1\right)\left(\frac{8.89}{10} - 1\right) = 0.2475$

(c) What is meant by the following:

(i) total internal reflection (01mark)

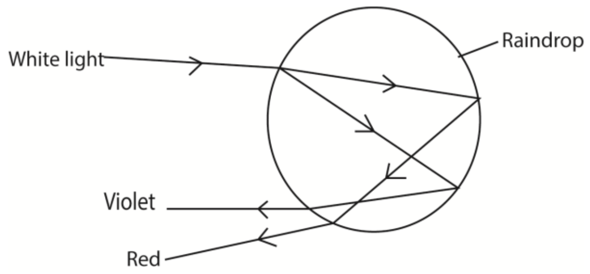
Total internal reflection is the bouncing back of all incident light into the more dense medium when the angle of incidence exceeds the critical angle for a ray originally travelling from the more dense to a lens dense medium.

(ii) critical angle (01mark)

Critical angle is the angle of incidence in more optically denser medium for which the angle of refraction in the less dense medium is 90^0.

(d) Briefly explain why an observer sees a spectrum of colors through rain drops when it is raining on a sunny day. (02marks)

White light from the sun undergoes dispersion as it enter into the rain drops of water in the sky. Total internal reflection takes place at the opposite side of the rain drop and different colors emerge from the raindrop after refraction. Hence the observer sees a spectrum of colors through raindrops when it is raining on sunny day.



Section B

3. (a) What is meant by interference pattern as applied to waves. (03marks)

When two sound waves meet they superpose. The interference pattern produced depends on the path difference.

If the path difference is a whole number, multiples of wavelength of wave, reinforcement takes place resulting into bright fringes. i.e. path difference, $\Delta = n\lambda$, n = 0, 1, 2, …..

If the path difference in an odd number, multiple of half-wavelength, cancellation takes place resulting into regions of dark fringe; i.e. path difference, $\Delta = (2n+1)\frac{\lambda}{2}$, n= 0, 1, 2, ….

If the sources are coherent, permanent alternative regions of bright and dark fringes are formed and are called interference pattern. Thus interference has occurred.

(b) Explain why it is necessary to use a common source when demonstrating interference in light (03marks)

To produce observable fringes,

- The waves should have constant phase difference between them.
- The amplitude of the waves should also be equal or nearly equal

  Since emission of light is always spontaneous; the above conditions are only possible if the source is the same.

(c) In an experiment to determine wavelength of light using Young's method, two slits, a separation of 1.2mm were used. When the screen was placed 18.0cm from slits, 30 bright fringes occupying a distance 2.5mm was obtained,

(i) Find wavelength of light used (04marks)

Slit separation, a= 1.2×10^{-3}m

Number of bright fringes, n =30

Distance from center of nth fringe, $x_n = 2.5 \times 10^{-3}$m

Distance from the slits to screen, D = 18.0cm = 0.18m

Using $x_n = \frac{n\lambda D}{a}$

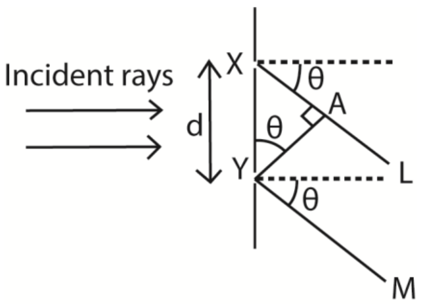
$2.5 \times 10^{-3} = \frac{30 \, x \, \lambda \, x \, 0.18}{1.2 \, x \, 10^{-3}}$; $\lambda = 5.56 \times 10^{-7}$m

(ii) List the changes that would be observed if the distance of the screen from the slits was increased (02marks)

If the distance, D, of the screen from slits is increased, it follows from $y = \frac{\lambda D}{d}$ that the fringe separation, y, also increases, keeping wavelength, λ and slit separation, a constant. Hence fringes occupy a bigger area on screen but their brightness reduce (become less distinct.

(d)(i) Derive the expression for angular position of n^th order principal maximum produced by transmission diffraction grating.

Solution



Suppose X and Y are corresponding points in consecutive slits where XY = d, and the grating is illuminated normally by monochromatic light of wavelength, λ, the direction, θ, the diffracted ray XL, and YM have path difference, XA

From $\sin \theta = \frac{XA}{d}$; XA = dsin θ

The path difference for all corresponding points in the two slits have the same path difference, dsinθ. So other pairs of slits throughout the grating are treated the same way.

Also for bright or principle maxima to be obtained, the path difference = nλ.

∴ dsin θ = nλ; where d= slit separation, λ = wavelength, θ = angular momentum

(ii) Light of two wavelength 5.4×10^{-7}m and 5.7×10^{-7}m incident normally on transmission grating with spacing 2.00×20^{-6}m. Find the angular separation of second order principal maxima.

$\lambda_1 = 5.4 \times 10^{-7}$m and $\lambda_2 = 5.7 \times 10^{-7}$m, d = 2.00×20^{-6}m

from $\sin\theta = \frac{n\lambda}{d}$; $\theta = \sin^{-1}(\frac{n\lambda}{d})$

$\theta_1 = \sin^{-1}\left(\frac{2 \times 5.4 \times 10^{-7}}{2 \times 10^{-6}}\right) = 0.54$

$\theta_2 = \sin^{-1}\left(\frac{2 \times 5.7 \times 10^{-7}}{2 \times 10^{-6}}\right) = 0.57$

Angular separation = 0.57 – 0.54 = 0.03

(iii) Suppose white light is used in (d)(ii) , describe the positions of the red and violet lights in the order principal maximum relative central maxima (01mark)

Violet will nearer to central maximum while red will be farther off.

4. (a) Define the following

(i) Transverse waves

It is a wave in which the wave particles vibrate perpendicular to the direction of the wave motion

(ii) Longitudinal waves

It is a wave in which the wave particles vibrate parallel to the direction of the wave motion.

(b) When a plane wave transverse a medium, the displacement of the particle is given by

$y = 0.01\sin 2\pi(2t-0.01x)$, where y and x are in meters and t in seconds

Calculate the

(i) Frequency of the wave (02marks)

Form $y = A\sin 2\pi(\omega t-kx)$

A= 0.01m, $\omega = 2\pi(2)$, $x = 2\pi(0.01)$

Frequency, f, of a wave is given by $\omega = 2\pi f$

$4\pi = 2\pi f$

$f = 2$Hz

(ii) Wave velocity (03marks)

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

$0.02\pi = \frac{2\pi}{\lambda}$

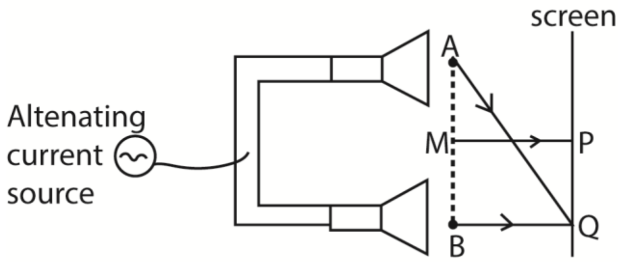
$\lambda = 100$m

$v = f\lambda = 2 \times 100 = 200\text{ms}^{-1}$

(iii) Phase difference at a given instant of time between two particles 50m apart. (02marks)

Phase difference, $\phi = \frac{2\pi x}{\lambda} = \frac{2\pi \times 50}{100} = \pi$

(c) Describe an experiment to determine the velocity of sound in air by an interference method. (06marks)



Two small loud speakers A and B about 1m apart are connected to the same oscillator so that both emit sound waves of frequency, f, in phase.

A sensitive detector is moved parallel to the line AB along PQ and it detects a maximum wave at P on perpendicular bisector MP of AB and another maximum wave when it first reaches a point Q directly opposite to B.

Constructive interference of sound wave occurs at P and Q, so the wavelength of sound wave is given by $\lambda = AQ - BQ$

The speed of sound in air is then calculated from $V = f\lambda$.

Alternative 1
A long tube is filled with water.
A vibrating turning fork of known frequency f is held over the mouth of the tube.
Water is gradually removed until a loud sound is heard.
The length l_1 of air column is measured.
Water is allowed out until a loud sound is heard again.
The length l2 of air column is measured
The velocity of sound in air is calculated from $V = 2f(l_2 - l_1)$

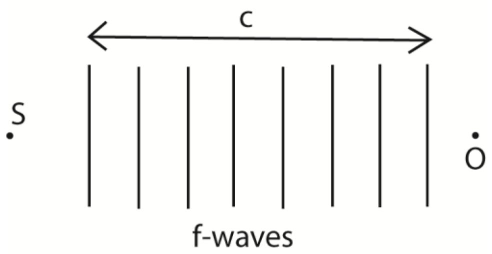
Alternative 2
(i) Along tube is filled with water.
(ii) A vibrating turning fork of known frequency f is held over the mouth of the tube.
(iii) Water is gradually removed until a loud sound is heard.
(iv) The length L of air column is measured.
(v) (i) to (iv) is repeated with five other different turning forks
(vi) The results are tabulated including values of $\frac{1}{f}$
(vii) A graph of L against $\frac{1}{f}$ is plotted and slope S is determined.
(viii) The speed of sound, v = 4S.

(d) (i) state two applications of Doppler effect. (02marks)

- Estimation of speed of distant objects like star and planets
- To detect objects moving in a circular track, for example a car negotiating a corner towards or away from an observer.
- Used in some types of radars to measure the velocity of detected objects, for example a motor car. The police use radar to detect speeding motorist as it approaches or recedes from a radar source
- In measurement of plasma temperature.

(ii) Derive an expression for frequency, f, of sound as heard by stationary observer when the source of sound of frequency, f, approaches with uniform speed, u_s (03marks)

Suppose c is the speed of sound in air, u_s is the speed of source, S, of sound, f is the frequency of source
If the source S were stationery, the f-wave sent out in 1s towards observer would cover a distance, V, and wavelength, $\lambda = \frac{c}{f}$



If the source is moving towards a stationary observer, O.

Where u_s is the speed of sound towards O. the sent wave occupy a shorter distance (c-u_s) because S has moved a distance u_s, towards O in 1s. So the wave length λ' of waves reaching O is given by $\lambda' = \frac{c-u_s}{f}$
The speed of the waves relative to stationary observer is c.

Apparent frequency, f';
$$f' = \frac{velocity\ of\ sound\ relative\ to\ O}{wavelength\ of\ the\ waves\ reaching\ O} = \frac{c}{\lambda'}$$
$$f' = \frac{c}{\frac{c-u_s}{f}}$$
$$=\left(\frac{c}{c-u_s}\right)f$$
Since (c-u_s) is less than c, the frequency tends to increases as source approaches observer.

SECTION C

5. (a)(i) Write down an expression for the force on a charge, q coulombs moving with velocity, u, at an angle, α, to a uniform magnetic field of flux density B.(01mark)

F = Bqusinα

(ii) Use the expression in (a)(i), to deduce the force on a conductor carrying a current in magnetic field. (03marks)

Using F = Bqusinα

q = It

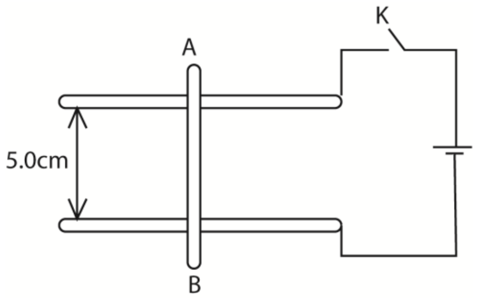
=> F= BItusinα

Where t is the time and I the current flowing

Since tu = L, the length of a conductor

Then, F = BILsinα

(b) Figure below shows an aluminium bar AB resting on two horizontal aluminium rails connected to a battery through switch K. a magnetic field of flux density 0.10T acts perpendicularly into paper.

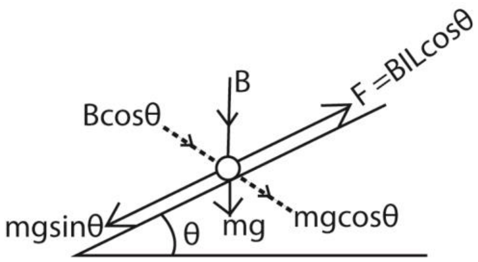


(i) Explain what happens to AB when switch K is closed(03marks)

Current flows in the bar in the direction BA. From the Fleming's left hand rule, the bar BA will experience a magnetic force and it will move towards the right.

(ii) Calculate the angle to horizontal to which the rail must be tilted to keep AB stationary if its mass is 5.og, current in it is 4.0A and the direction of the field remains unchanged. (04marks)

Let the angle be θ



At equilibrium, F= mgsinθ

BILcosθ = mgsinθ

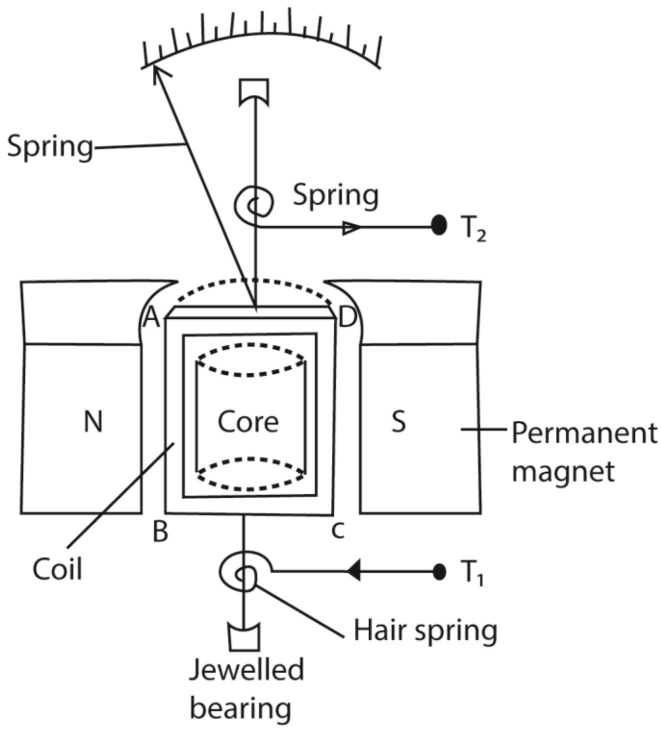
$0.10 \times 4 \times 5 \times 10^{-2}\cos\theta = 5 \times 10^{-3} \times 9.81 \sin\theta$

$\frac{sin\theta}{cos\theta} = \frac{5 \ x\ 10^{-3} \ x\ 9.81}{0.1 \ x\ 4\ x\ 10^{-2}}$

$tan\theta = 0.40775$

$\theta = 22.18^0$

(c)(i) With the aid of a labelled diagram, describe the structure and mode of operation of a moving coil galvanometer. (06marks)



Structure

- It consist of a rectangular coil of fine insulated copper wire wound on an aluminium frame to provide electromagnetic damping.
- The coil together with the frame of aluminium are mounted over a soft iron cylindrical core and freely pivoted on jeweled bearing to minimize friction at contact.
- The suspension torsion wire suspending the coil is attached to a pair of control hair springs T_1 and T_2 for feeding current in and out of the coil and control rotation of the coil.
- The coil is then suspended between concave pieces of a strong magnet to provide magnetic field.

  Mode of action
- Current I to be measured is passed into the coil via hair spring T_1.
- The current then causes the coil to experience a deflection torque, r = NABI due to a couple force causing rotation in a radial magnetic field.
- The coil turns with the pointer through angle θ until stopped by restoring torque, r = kθ provided by a pair of hair springs T_1 and T_2.
- At equilibrium, NABI = kθ
- ∴ current I = $\left(\frac{k}{NAB}\right)\theta$
- I ∝ θ, hence the instrument has a linear scale

  Where B = magnetic field strength between the poles of the magnets
  A = area of the plane of the coil
  N = number of turns of the coil
  k = torsion constant of suspension wire

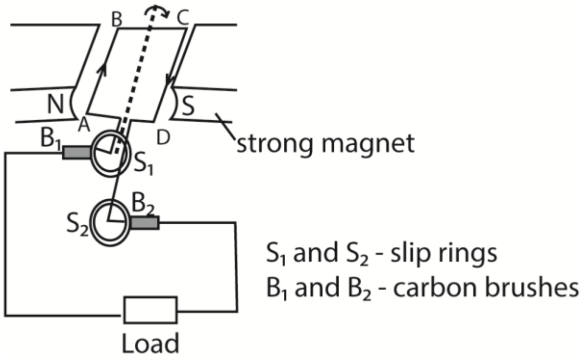
(iii) Discuss the factors which affect the current sensitivity of a moving coil galvanometer (03marks)

- Strength of magnet, current sensitivity is proportional to the strength of the magnets

- Number of turns, current sensitivity is proportional to the number of turns
- Nature of suspension torsion wire, current sensitivity is inversely proportional to the torsion constant of the suspension torsion wire.
- Area A of the plane of the coil; current sensitivity is proportional to the area of the plane of the coil
- Size of copper wire making the coil; current sensitivity is proportional to the size of copper wires making the coil since the bigger the wires the lower the resistance.

6. (a) State the laws of electromagnetic induction. (02marks)
    - **Faraday's law** states that the magnitude of the e.m.f induced in a circuit is directly proportional to the rate of change of magnetic flux linked with the circuit.
    - **Lenz's Laws** states that induced current flows always in such a direction as to oppose the change which is giving rise to· it.

(b)(i) With the aid of a diagram, describe how a simple a.c. generator works (04marks)



How it works

- The coil is rotated in a magnetic field, the magnetic field linked with it changes and hence e.m.f is led away by means of slip rings which press slightly against the carbon brushes.
- Applying Fleming's right hand rule, the induced current enters the coil AB and leave the coil via CD.
- Starting with the coil in the vertical position, the magnetic flux linking it is maximum and hence no induced e.m.f.
- The induced e.m.f increases with the position of the coil in the magnetic field until it becomes maximum with the coil in horizontal position and then decrease to zero as the coil rotates to the vertical position
- The force acting on the sides of the coil change as the coil passes over the position and hence he current flowing in the coil reverses. Hence an alternating e.m.f or current flows through the load.

(ii) What are the main energy losses in a practical a.c. generator and how are they minimized? (02marks)

- Eddy current loss are minimized by laminating the armature
- I^2R losses are minimized by use of low resistance winding wires
- loss due to friction minimized by lubricating the rubbing parts

(c) A circular coil having 20 turns each of radius 8.0cm is rotated about its vertical diameter with angular speed of 50 radians per second in a uniform horizontal magnetic field of magnitude 30mT.

(i) Calculate the r.m.s value of the e.m.f. induced in the coil (03marks)

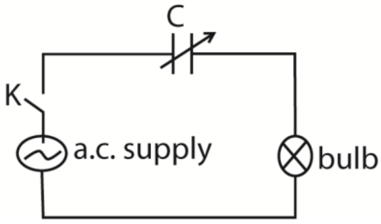
$E = NAB\omega = 20 \times [3.14 \times (8 \times 10^{-2})^2] \times (30 \times 10^{-3}) \times 50 = 0.603V$

$E_{r.m.s} = \frac{E_0}{\sqrt{2}} = \frac{0.603}{\sqrt{2}} = 0.426V$

(ii) If the coil forms a closed loop of resistance 10Ω, how much power is dissipated as heat in it? (02marks)

$P = \frac{V_{r.m.s}^2}{\sqrt{2}} = \frac{(0.426)^2}{\sqrt{2}} = 0.018W$

(d) The figure below shows a capacitor and a bulb connected to a.c supply



Explain

(i) Why the bulb lights when switch K, is closed (01marks)
The capacitor is continuously charging and discharging. This cause continuous charge (current) flow in the bulb

(ii) What would happen if the capacitance were reduced? (02marks)
When the capacitance is reduced the reactance increases and therefore the charging and discharging current is decrease. The bulb dims or goes off.

(e) Explain the following observation:

(i) A spark is seen at the switch when the circuit of a current carrying coil is broken (02marks)

When the switch is broken, the magnetic flux linking the coil collapses. A large e.m.f is induced between the contacts creating a high electric field intensity which ionizes the air there. The ions meet and neutralize violently producing sparks.

(ii) A magnetized iron bar dropped vertically through a hollow region of a thick cylindrical shell made of copper experiences a retarding force. (02marks)

Magnetic flux linking the shell changes inducing eddy currents that oppose motion of the bar magnet thus causing retardation.

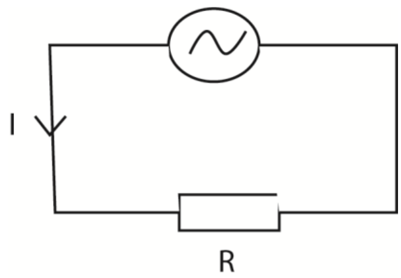
7. (a) Define the following

(i) Peak value(01mark)
Peak value of alternating current is the maximum value attained by such a current in a cycle.

(ii) Root mean square (r.m.s) value of alternating current.(01mark)
Root mean square (r.m.s) value of an alternating current, is the value of steady/direct current that would dissipate heat in a given resistor at the same rate as alternating current.

(b) Derive an equation relating peak value and r.m.s value of alternating current (03marks)

Consider an alternating current I = I0sinωt through a resistor, R.



The average rate at which heat is dissipated = I^2R

$$P = I_0^2 R sin^2 \omega t$$

$$= I_0^2 R \ x \ \frac{1}{2}$$

$$= \frac{I_0^2 R}{2}$$

Let I_d be the steady value of direct current that dissipates heat at the same rate as a.c. in a given resistance

Power = $I_d^2 R$

From definition of $I_{r.m.s}$

$I_d^2 R = \frac{I_0^2 R}{2}$

$I_d = \frac{I_0}{2}$

But $I_d = I_{r.m.s}$

Thus $I_{r.m.s} = \frac{I_0}{2}$

(c) An electric current flow through a coil of 4Ω immersed in 200kg of water placed in a container. If the temperature of the water rises by 1K per minute, calculate the peak value of current supplied. (03marks)

R = 4Ω, m =200g, Δθ = 1K, t = 60s

$\frac{m}{t}\ x\ c\ x\ \Delta\theta = I_{r.m.s}^{2}R$

$\frac{0.200}{60}\ x\ 4200\ x\ 1 = 4I_{r.m.s}^{2}$

$I_{r.m.s}^{2} = 1.871A$

Peak value, I_0 = $\sqrt{2}\ x\ I_{r.m.s}$ = $\sqrt{2}\ x\ 1.871 = 2.646A$

(d) What is meant by resonance in a circuit? (01mark)

Resonance is the condition that exists in a circuit when the inductive reactance and the capacitive reactance are of equal magnitude, causing electrical energy to oscillate between the magnetic field of the inductor and the electric field of the capacitor.

(e) A lamp of resistance 10Ω, a capacitor of capacitance 0.4μF and an inductor of inductance 0.4H are connected in series to an alternating voltage source of 0.01V (r.m.s). The frequency, f, is varied from low to high value while maintaining the amplitude of the applied voltage constant.

(i) Explain how the brightness of the lamp rises. (03marks)

Initially the brightness of the bulb increases as current through the circuit increases with increasing frequency. At resonant frequency, the current through the circuit becomes maximum and the brightness of the bulb becomes maximum. However, the brightness of the bulb dims until it dies off at frequencies greater than the resonant frequency since the current flowing reduces in it.

(ii) Calculate the resonance frequency. (03marks)

At resonant frequency, $X_C = X_L$

$2\pi f_0 L = \frac{1}{2\pi f_o C}$

$4\pi^2 LC f_0^2 = 1$

$f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.4\ x\ 0.4\ x\ 10^{-6}}}$ =397.9Hz

(iii) Find the voltage across the capacitor. (03marks)

Impedance, Z = R = 10Ω

V = IZ

0.01 = I x 10

$I = 1 \times 10^{-3} A$

Using $V_c = IX_c = \frac{1}{2\pi f C} = \frac{1 \times 10^{-3} \times 10^{6}}{2\pi \times 397.9 \times 0.4} = 1V$

(f) Explain why in an R-C circuit, power is only absorbed by resistive part of the circuit. (02marks)

In one quarter cycle as the capacitor charges, power is transferred from the source to the capacitor. In the next quarter cycle as the capacitor discharges, power is returned to the source.

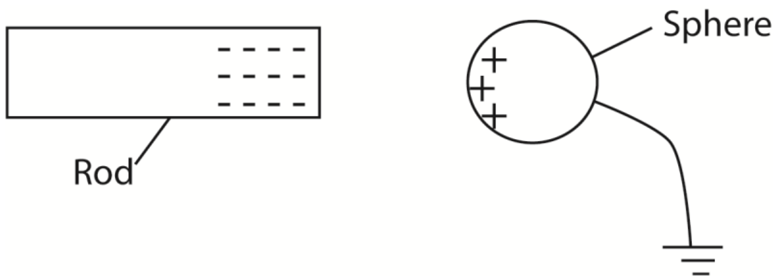
SECTION D

8. (a) State Coulomb's law of electrostatics (01marks)

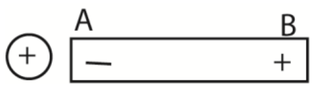
Coulomb's law states that the force between two point charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of the distance between the charges.

(b) (i) Describe how a conductor may be positively charge but remains at zero potential(03marks)

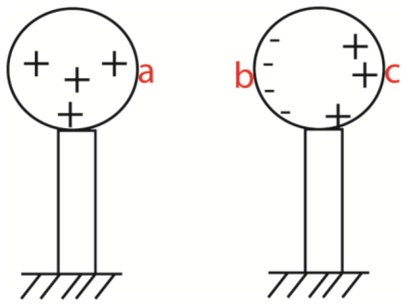
A negatively charged rod is brought near a neutral sphere. Distribution of charges occurs. The sphere is then earthed in the presence of the rod. Electrons flow to the earth. The sphere is positively charged and at zero potential. When the rod is remove the sphere remain positively charged.



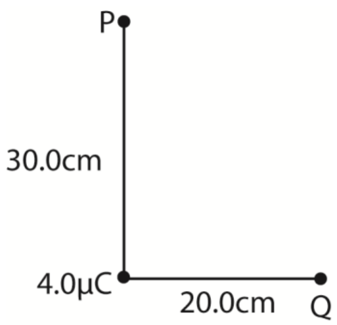
(ii) Explain how the presence of a neutral conductor near a charged conducting sphere may reduce the potential of the sphere.



When a positively charged insulated sphere A is placed close to a neutral insulted sphere B, negative charges are attracted to side close to A while positive charges are repelled to the far end. Potential at ab; V= $V_a + V_b + V_c$. Since V_b and V_c are of opposite sign and c is further from A, the negative charges at b effectively reduce the potential at a.



(c) In the figure below, points P and Q are at a distances 30.0cm and 20.0cm from a point charge of 4.0μC respectively.



Calculate

(i) Electric potential difference between P and Q (05marks)

Electric potential at P

$$V_p = \frac{KQ_P}{r_P} = \frac{(9\,x\,10^9)(4\,x\,10^{-6})}{30\,x\,10^{-2}} = 120{,}000V$$

$$V_p = \frac{KQ_Q}{r_Q} = \frac{(9\,x\,10^9)(4\,x\,10^{-6})}{20\,x\,10^{-2}} = 180{,}000V$$

Potential difference between P and Q

V_{PQ} = 180000 – 120000 = 60000V

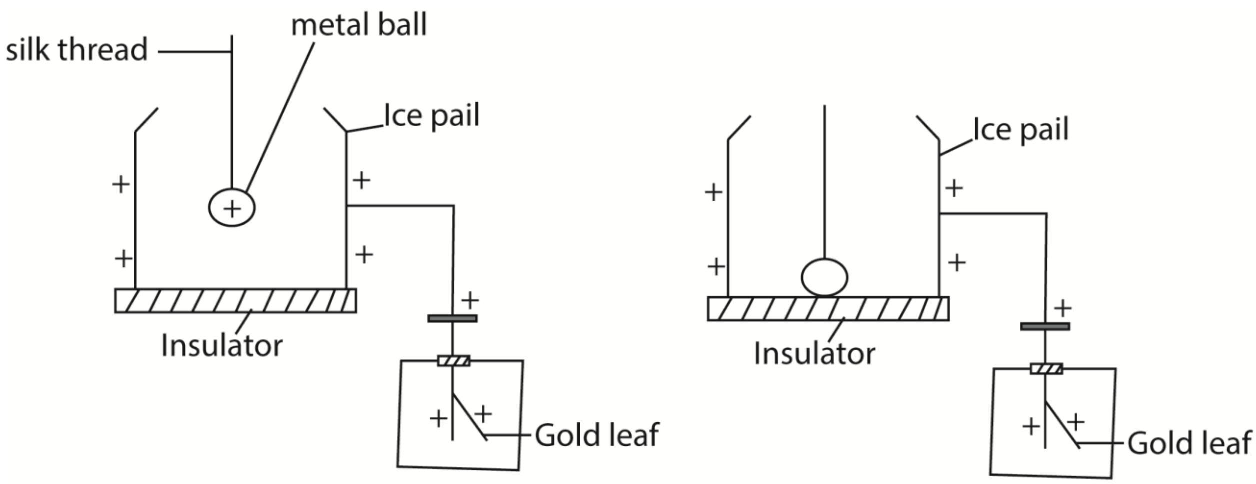
(ii) Energy required to bring a charge of +1.0μC from infinity to Q. (03marks)

Energy, E = QV

= 1 x 10^{-6} x 180000 = 0.18J

(d) Describe with the aid of a diagram an experiment to show that excess charge resides only on outside of hollow conductor.

Experiment to show that excess charge resides only on the outside of a hollow conductor.



- Ice pail is placed on an insulator and connected to a gold leaf electroscope
- A positively charged metal ball held on a long silk thread is lowered into the pail without touching the sided nor the bottom.
- Positive charges are induced on the outside of the pail and golf leaf diverges. The divergence does not change when the ball is moved about as long as it does not touch the pail.
- When the metal ball is allowed to touch the bottom, the divergence remains unchanged although it loses the charge.
- This shows that the charge induced inside the ice pail (hollow conductor) is of equal magnitude and opposite to the charge on the metal ball. Thus the total charge inside the hollow conductor is zero.
- Hence excess charge resides only on the outside of a hollow conductor.

9. (a)(i) Define e.m.f of a battery. (01marks)

E.m.f of a battery is energy supplied by the battery

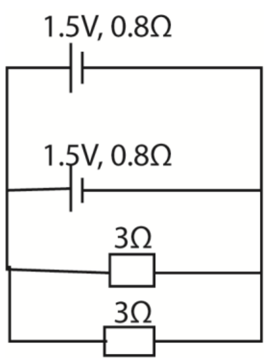
Or

It is the p.d across the terminals of the battery on an open circuit.

(ii) Explain why e.m.f of a battery left standing in a room for long decreases. (02marks)

Moisture in the room contains ions which allow electric conductions between the terminals of the battery and therefore the e.m.f of the battery reduces.

(b) The figure below shows a network resistors connected to show identical cells of e.m.f 1.5V and internal resistance 0.8Ω.



Calculate the current supplied by the cells (04marks)

From E = I(R+r)

The effective e.m.f of cells in parallel = e.m.f of one cell = 1.5V

Effective internal resistance, r = $\frac{0.8}{2} = 0.4\Omega$

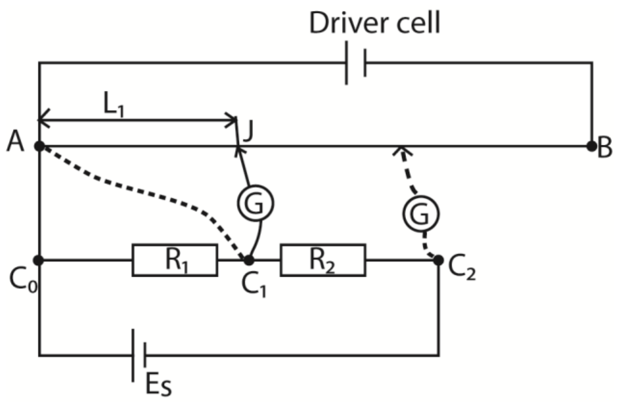
1.5 = I$\left(\frac{3\ x\ 3}{(3+3} + 0.4\right)$

I = 0.789A

The current flowing is 0.789A

(c) Describe an experiment which can be carried out to determine the resistance of a wire using a potentiometer. (06marks)

An experiment to determine resistance of a wire using a potentiometer



R_1 = known resistor

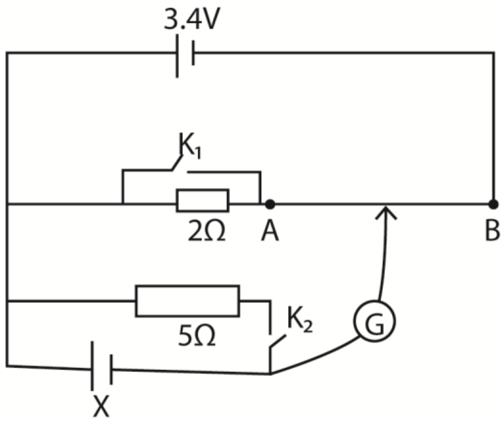
R_2 = wire of unknown resistance

AB – Uniform resistance slide wire

Es – standard cell

- The balance length L_1 from A is recorded
- A is disconnected from C_0 and galvanometer is disconnected from C_1
- A is connected to C_1 and galvanometer to C_2
- The balance length L_2 from A is recorded.
- The resistance R_2 = $\frac{L_2}{L_1} x\ R_1$

(d) The figure below shows a uniform resistance wire AB, 100cm long and resistance 4.0Ω connected with a 2.0Ω resistor through switch K_2. When K_1 is closed and K_2 open, the balance length is 53cm.



Find the

(i) Balance length when K_1 and K_2 are both open (04marks)

L_{AB} = 100cm, R_{AB} = 4Ω, E_d = 3.4V, r = 0Ω, L_{AJ} = 53cm

Considering upper circuit

$E_d = I_d (R + r)$

$3.4 = I_d(4 + 2 + 0)$

$I_d = \frac{3.4}{6} A$

e.m.f of cell X =p.d across the balance length

E_X = kL where k is p.d per centimeter of AB

$= \frac{3.4}{100}\ x\ 53 = 1.802V$

At balance

e.m.f of cell X = p.d across 2Ω + p.d across balance length

$1.802 = I_d \text{ x } 2 + I_d \text{ x } \frac{4}{100}\ x\ L$

$1.802 = \frac{3.4}{6}\ x\ 2 + \frac{3.4}{6}\ x\ \frac{4}{100} x\ L$

L = 29.4cm

(ii) Internal resistance of cell X if the balance length is 44.1cm when both K_1 and K_2 are closed (01marks)

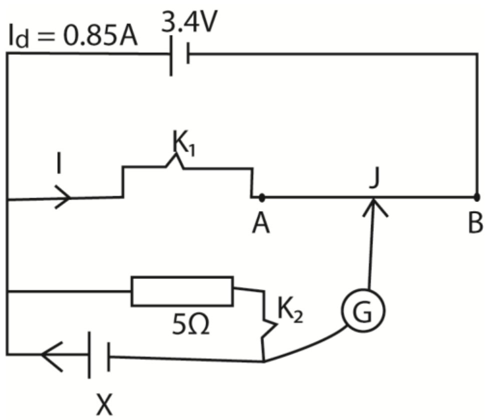
L_{AJ} = 44.1cm

Using upper circuit

$E_d = I_d(R+r)$

$3.4 = I_d(4 + 0)$

$I_d = 0.85$



At balance point

p.d across 5Ω = p.d across balance length AJ

$I \times 5 = I_d k L_{AJ}$

$5I = 0.85 \times \frac{4}{100} x\ 44.1$

I = 0.3A

Using lower circuit

$E_X = I(R + r)$

1.802 = 0.3(5+ r)

r = 1.0Ω

the internal resistance of a cell = 1.0Ω

or

$r = R_S\left(\frac{L_1}{L} - 1\right) = 5\left(\frac{53}{44.1} - 1\right) = 1.0\Omega$

10. (a)(i) Define farad. (01mark)

A faraday is the capacitance of a capacitor when a charge stored is 1C and potential difference is 1V.

(ii) Describe briefly the energy transformations that take place when charging a capacitor using a dry cell. (02marks)

Chemical energy in the cell → electrical energy → electrostatic potential energy when the charge is being stored on the capacitor plates + heat

(b)(i) What is meant by dielectric constant? (02marks)

Dielectric constant is the ratio of capacitance of a capacitor with a medium between its plates to the capacitance of the same capacitor with a vacuum between its plates.

Or

Dielectric constant is the ratio of permittivity of a medium to permittivity of space.

(ii) A parallel plane capacitor is connected to 100V and then isolated. When a sheet of a dielectric is inserted between the plates, the p.d. decreased to 30V. Calculate the dielectric constant of the dielectric. (03marks)

Let the capacitance of a capacitor be C

Charge stored, Q = CV

= C x 100 = 100C

When a material is inserted between the plates of the capacitor

Q = C'V'

$= E_r C \times 30$

By conservation of charge

$100C = E_r C \times 30$

$E_r = \frac{100}{30} = 3.33$

(c) A 60 µF is charged from a 120V supply. It is then connected across the terminals of a 20µF capacitor. Calculate the

(i) final p.d. across the combination (03marks)

Total charge = total charge after combination;

When the capacitor are joined, the p.d, V, across is the same

$C_1V_1 = C_1V + C_2V = (C_1 + C_2)V$

$60 \times 10^{-6} \times 120 = (20 \times 10^{-6} + 20 \times 10^{-6})V = 80 \times 10^{-6}V$

V = 90V

The final p.d = 90V

(ii) Difference in the initial and final energies stored in the capacitor and comment on the difference. (05marks)

Energy = $\frac{1}{2}CV^2$

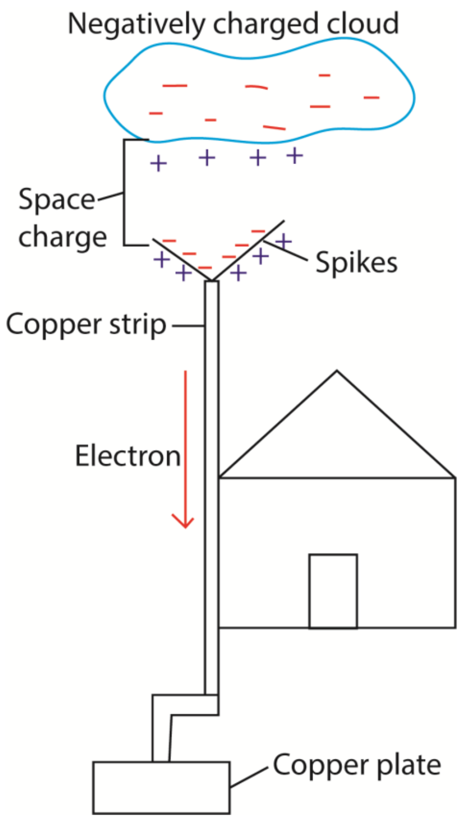
Initial energy = $\frac{1}{2}C_1V_1^2 = \frac{1}{2}\ x\ 60\ x\ 10^{-6}\ x\ 120^2$ = 0.432J

Final energy = $\frac{1}{2}\ (C_1 +\ c_2)V^2 = \frac{1}{2}(60\ x\ 10^{-6} +\ 20\ x\ 10^{-6})\ x\ 90^2$ = 0.324J

Energy difference = 0.432 – 0.324 =0.108J

Comment: Energy after is less because some energy is lost as heat in the connecting wires

(d) Explain the principles of operation of a lightning conductor. (05marks)



Action

(i) When a negatively charged cloud passes over lightning conductor, it induces positive charges on the spikes by repelling electrons to the grounds through copper conductor.

(ii) A high electric field concentration of positive ions on the spikes ionizes air around it causing positively charged ions and negatively ions.

(iii) The negatively charged ions are attracted and discharged at the spikes while the positively charged ions are repelled to form a space charges which neutralizes the negative charge on the cloud. In this way the harmful effect of the cloud is reduced.