UACE PHYSICS PAPER 2003 GUIDE

Instructions to the candidates:

Answer **five** questions taking at least one from each of the sections **A, B, C** and **D**, but not more than one question should be chosen from either section **A** or **B**

Any additional question (s) will not be marked.

Mathematical tables and squared paper will be provided

Non programmable calculators may be used.

Assume where necessary

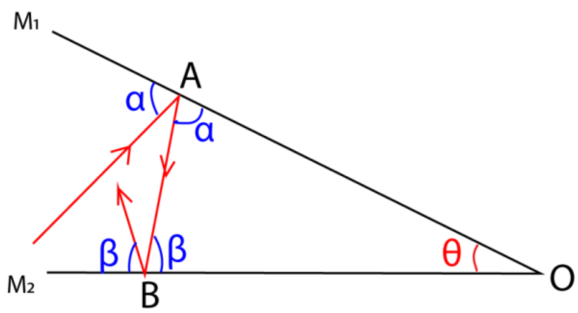
Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 \times 10^{-19}C$
Electron mass	$9.11 \times 10^{-31}kg$
Plank's constant, h	$6.6 \times 10^{-34}Js$
Speed of light in the vacuum, c	$3.0 \times 108ms^{-1}$
Specific heat capacity of water	$4.200Jkg^{-1}K^{-1}$
Avogadro's number, N_A	$6.02 \times 10^{23}mol^{-1}$
The constant, $\frac{1}{4\pi\varepsilon_0}$	$9.0 \times 10^{9}F^{-1}m$
Permittivity of free space, μ_0	$4.0\pi \times 10^{-7}Hm^{-1}$
Permittivity of free space, ε_0	$8.85 \times 10^{-12}Fm^{-1}$
One electron volt	$1.6 \times 10^{-19}J$
Resistivity of Nichrome wire at 25^0C	$1.2 \times 10^{-6}\Omega m$

SECTION A

1. (a) (i) State the laws of reflection of light. (02marks)
   - The incident ray reflected ray and the normal at the point of incidence all lie in the same plane
   - Angle of incidence is equal to the angle of reflaction.

   (ii) Show that an incident ray of light reflected successively from two mirrors inclined at an angle θ to each other, is rotated through 2θ. (04marks)

   Consider an incident ray of light reflected successively from mirrors M_1 and M_2 inclined at an angle θ to each other at O as shown below

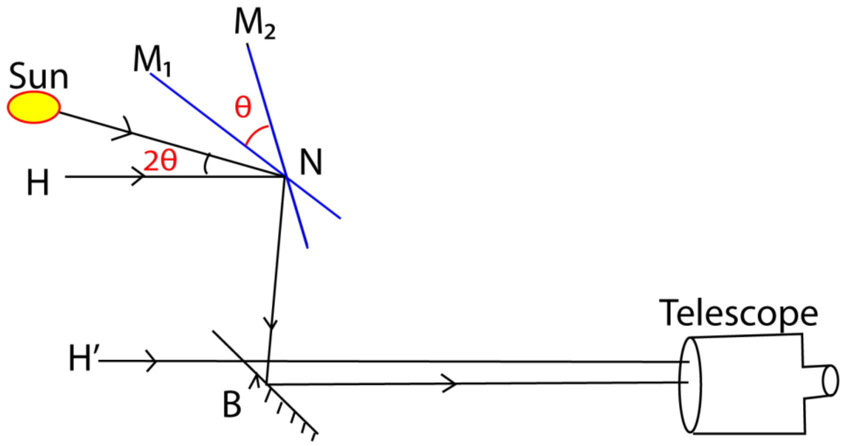


Let the glancing angles at A and B be α and β respectively
Deviation by M_1 = 2α (clockwise direction)
Deviation by M_2 = 2β (clockwise direction)
Total deviation = 2α + 2β)
= 2(α + β) .... (i)
But, α + β + θ) = 180^0 (angle sum of a triangle)
⇨ α + β = (1800 – θ) .... (ii)

Combining (i) and (ii) gives
Total deviation = 2(1800 – θ) (clockwise direction)
= 3600 - 2θ (clockwise direction)
= 2θ (anti-clockwise)

(b) Describe how a sextant is used to measure the angle of elevation of a sun. (05marks)

The principle of a sextant is that, when the ray of light is reflected from two mirrors in succession in the same plane, then the angle between the incident and reflected ray is two times the angle between the mirrors.



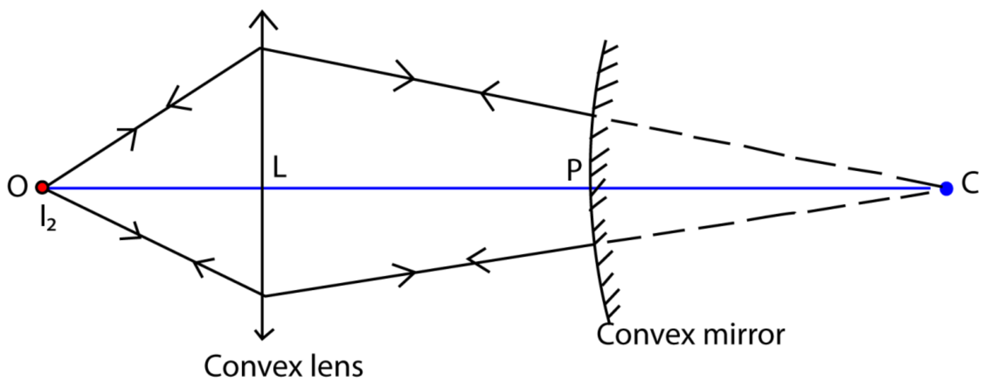
- A sextant consists of a fully silvered mirror M1which can be rotated about a horizontal axis and a fixed half silvered mirror B.
- Mirror M1 is adjusted to become parallel to B by rotating it until the image of the horizon (the line at which the earth's surface and the sky appear to meet), H' is seen directly through the unsilvered part of mirror B by successive reflection in mirror M_1 and B respectively

  Note that, if the two mirrors are parallel, the incident ray from any observed body must be parallel to the observer's line of sight through the horizon glass
- The mirror M_1 is rotated to position M_2 such that the image of the horizon H, and the sun coincides at H'
- The angle of rotation is measured from the scale on the instrument. The elevation of the sun is 2θ.

(c) (i) Describe an experiment to measure the focal length of a convex mirror. (05marks)

Determination of focal length of a convex mirror.

Method (1) Using a convex lens.

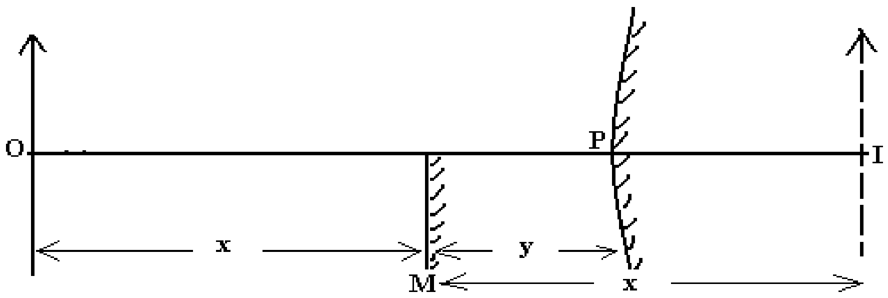


- The apparatus is arranged as shown above
- An object, O is placed in front of a convex lens L and its image formed at C
- The distance LC is measured and recorded.
- The convex mirror whose focal length, f, is required is placed is placed between L and C with its reflecting surface facing the lens.
- The lens is then moved along the axis, OC until a converging beam incident normally on the mirror forms its image at O

- Distance LP is measured
  PC = LC – LP thus, f can be determined from $f = \frac{PC}{2}$

Or

Method (2) using No parallax.



(i) An object pin **O** is placed in front of a convex mirror as shown in the diagram above

(ii) A virtual diminished image is formed at **I**.

(iii) A plane mirror **M** is placed between **O** and **P** so as to intercept half the field of view of the convex mirror.

(iv) Mirror **M** is adjusted until its own image of **O** coincides with **I** by no parallax method.

(v) Measure the distances **x** and **y.**

(vi) The focal length of the mirror is calculated from $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

Where u = (x + y) and v = (y-x)

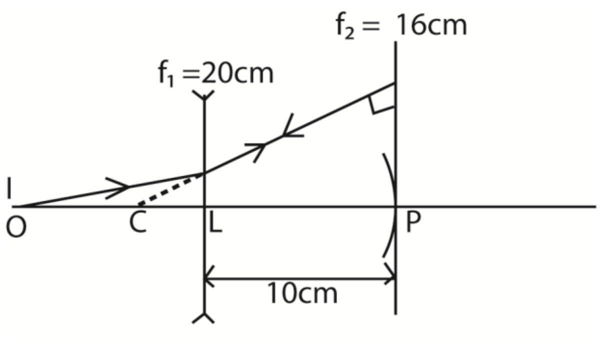
Note:

(i) The two images coincides when they are as far behind the plane mirror as the object is in front.

(ii) Substituting for u = x + y and v = y – x in the mirror formula gives $f = \frac{y^2 - x^2}{2y}$

(ii) A concave lens of focal length 20cm is placed 10cm in front of a concave mirror of focal length 16cm. Calculate the distance from the lens at which an object would coincide with its image. (04marks)

Ray diagram



The object to coincide with the image if the rays strike the concave mirror normally i.e. CP = $2f_2$ = 16 x 2 = 32cm

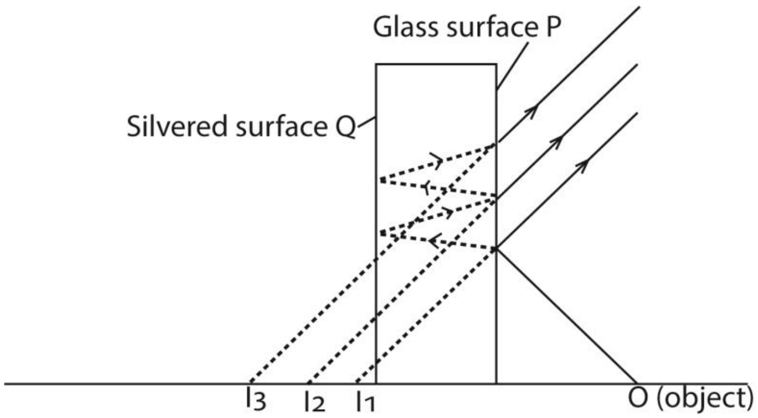
but LP = 10cm

⇨ CL = 22cm
For concave mirror
Object distance be = u
Image distance = -22cm
From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$$-\frac{1}{22} = \frac{1}{u} - \left(\frac{-1}{22}\right);\ u = -220\text{cm}$$

2. (a) Explain with aid of a diagram, why a thick plane mirror forms multiple images. (04marks)

Formation of multiple images in thick plane mirror

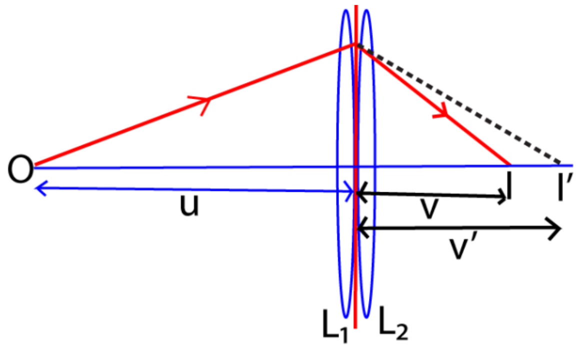


Multiple images are formed due to partial reflection and refraction at the non-silvered surface of the mirror.

- İmage I_1 is formed by reflection on the glass surface P
- The image I_2 (the brightest is formed by reflection of the most light on the silvered surface Q
- Others by partial refraction

(b) Derive an expression for the focal length of a combination of two thin converging lenses in contact, in terms of their focal lengths. (05marks)

Consider two thin lenses L_1 and L_2 of focal length f_1 and f_2.



For lens L_1,

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

$\frac{1}{f_1} = \frac{1}{u} + \frac{1}{v'}$ ………………………..(i)

For L2, I' acts as the object

$\frac{1}{f_2} = \frac{1}{-v'} + \frac{1}{v}$ ……………………..(ii)

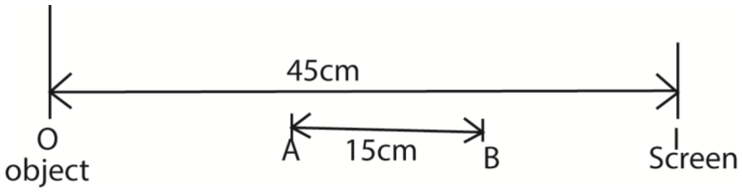
Eqn. (i) + Eqn. (ii)

$\frac{1}{f_2} + \frac{1}{f_2} = \frac{1}{u} + \frac{1}{v} = \frac{1}{F}$

$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

Where F is the focal length of combined lens,

(c)



In the diagram above, the image of the object is formed on the screen when a convex lens is placed at A or B. if A and B are 15cm apart, find the

(i) Focal length of the lens. (03marks)

Since O and I are conjugate points, then for position A

u = OA = $\frac{1}{2}(45 - 15)$ = 15cm

v = 45- 15 = 30 cm

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

$\frac{1}{f} = \frac{1}{15} + \frac{1}{30}$

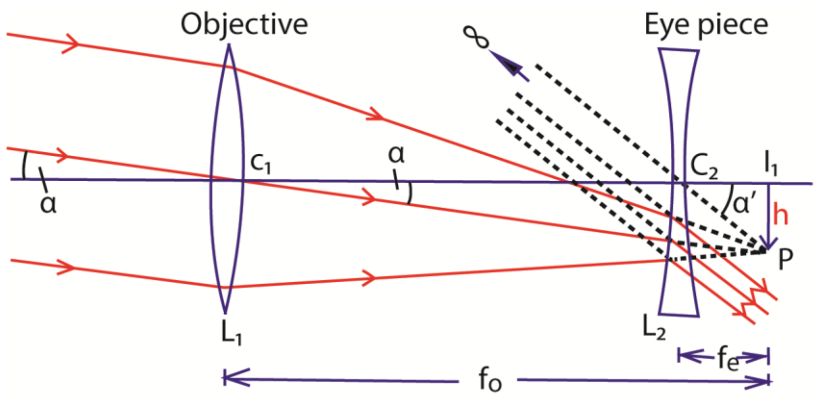
f = 10cm

(ii) Magnification of the image formed when the lens is at B. (03 marks)

u = 30.0cm, v = 15cm

M = $\frac{v}{u} = \frac{15}{30} = 0.5$

(d) Draw a ray diagram of a Galilean telescope and derive the expression for magnifying power when in normal adjustment. (05marks)



Galilean telescope in normal adjustment

Magnifying power, m = $\frac{\alpha'}{\alpha}$

For small angles, α and α' are measured in radians

$\alpha \approx \tan\alpha = \frac{h}{fe}$ and $\alpha' \approx \tan\alpha = \frac{h}{fo}$

Substituting for α and α'

Magnifying power, m = $\frac{\alpha'}{\alpha} = \frac{h}{fe} \div \frac{h}{fo} = \frac{\boldsymbol{fo}}{\boldsymbol{fe}}$

3. (a) Define wavelength of a wave (01mark)

This is the distance between two successive crests or trough.

(b) A source of sounding moving with velocity $\boldsymbol{u_s}$ approaches an observer moving with velocity $\mathbf{u_0}$ in the same direction, derive an expression for frequency of sound heard by the observer. (05mark)

f-waves occupy a distance c-u_s; where c is the speed of sound in air.

Apparent wavelength of the wave = $\frac{c - u_s}{f}$

Speed of waves relative to observer, v_a = c-u_0

Apparent frequency, $f_a = \frac{v_a}{\lambda_a} = \frac{c - u_0}{\frac{c - u_s}{f}} = \left(\frac{c - u_0}{c - u_s}\right) f$

(c) Explain what happens to the pitch of the sound heard by the observer in (b) above when

(i) Observer moves faster than the source (02marks)

Pitch depend on frequency as experienced by the listener, i.e. high frequency produces a high pitched note and the vice versa.

From $f_a = \frac{v_a}{\lambda_a} = \left(\frac{c - u_0}{c - u_s}\right) f$

When $u_0 > u_s$; $(c-u_0) < (c-u_s)$

Hence $f_a < f$

Therefore the apparent frequency is low and thus the pitch of sound will be detected.

(ii) Observer's velocity is equal to that of the sound. (02marks)

If u_0 = c, then f_a = 0Hz or no sound is detected by the observer.

(d) State and explain one application of Doppler Effect. (05marks)

Used in radar speed trap.

Microwaves of frequency f_0 from stationary radar are sent directly towards a motor vehicle moving with a speed, v.

The microwaves reflected from moving car are detected by the radar set.

The reflected signal mixes with the transmitted signal to obtain beats.

The beat frequency of f which is equal to the difference between the frequency of the received and transmitted signal is determined.

The speed of the vehicle is determined from, v = $\frac{\Delta f}{2f_0}$

Measurement of plasma temperature

The broadening Δλ of a spectral line emitted by the plasma is determined using a diffraction grating

$$\frac{\Delta\lambda}{\lambda} = \frac{2v}{c}$$

Assuming v = $v_{r.m.s}$ then $\frac{1}{2}Mv^2 = \frac{3}{2}RT$ where M is the molar mass.

$$v = \left(\frac{3RT}{M}\right)^{\frac{1}{2}}$$

$$T = \frac{M}{12R}\left(\frac{\Delta\lambda}{\lambda_0}\right)^2 c^2$$

Measurement of the speed of star

The wavelength, λ, of light emitted by the star is measured.

The absorption spectrum of an element known to be in the star is examined.

The wavelength, λ', of the missing line is measured. If u_s is the speed of the star, the Doppler Effect shift = (λ' –λ)

Thus, $\left|\frac{\lambda' - \lambda}{\lambda}\right| = \frac{u_s}{c}$

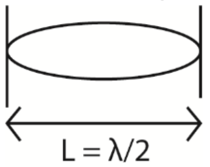
$u_s = c\left|\frac{\lambda' - \lambda}{\lambda}\right|$

(e) The wire of the guitar of length 50cm and mass per meter 1.5 x 10 $^{-3}$kg is under tension of 173.4N. If it is plucked at the middle point, find the

(i) Frequency (03marks)

$$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}} = \frac{1}{2 \times 0.5}\sqrt{\frac{173.4}{1.5 \times 10^{-3}}} = 340\text{Hz}$$

(ii) The wavelength of the fundamental note (02marks)



λ = 2L = 2 x 0.5 = 1.0m

4. (a) (i) What is meant by interference of waves? (02marks)

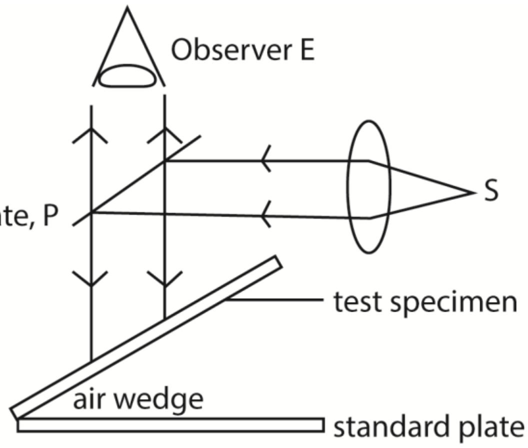
Interference of waves is the superposition of waves from two coherent sources to produce alternate regions of maximum and minimum intensity.

(ii) State conditions for observation of an interference pattern (02)

- Sources must be coherent
- Amplitudes must be nearly equal
- The sources must be close to each other.

(iii) Describe how interference can be used to test for flatness of the surface.

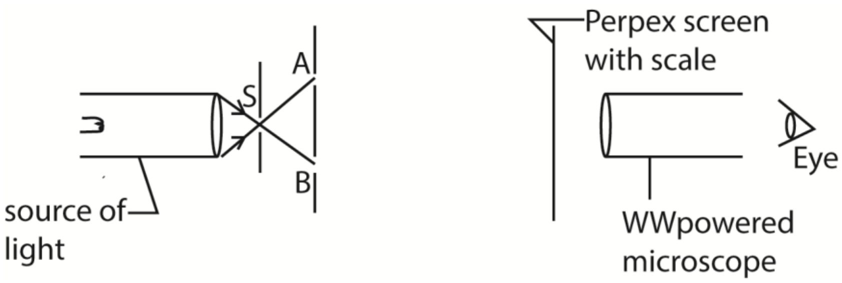
The surface under test is made to form an air-wedge with a plane glass surface of standard smoothness.



A parallel beam of monochromatic light from source, S, is reflected from a glass plate, P to fall normally to the air wedge.
Light reflected by the air wedge is observed.
Irregularity in the surface of test specimen will show up as irregularity in the fringe pattern.

(b) Describe with the use of a diagram, how the wavelength of monochromatic light can be measured using Young's double slit method (05marks)

Monochromatic light from a small lamp is made to illuminate the double slit A and B as shown below.



The fringe separation, y, is found by traversing a known number of fringes using a microscope which is moved along the perpex ruler; (note that fringes are equally spaced.

The slit separation a is measured using a travelling microscope.
The wavelength of light used; $\lambda = \frac{ay}{d}$

(c) Two microscope slides are in contact at one end and are separated by a thin piece of paper at the other end. Monochromatic light is directed normally on the wedge.

(i) What types of fringes will be observed? (02marks)

Alternate bright and dark fringes that are equally spaced and parallel to the line along which slides make contact will be observed.

(ii) Explain what will be observed if a liquid is introduced between the slides (02mark)

From refractive index, $n_l = \frac{c}{v_{liquid}} = \frac{f\lambda_{air}}{f\lambda_{liquid}}$

$$\therefore \lambda_{liquid} = \frac{f\lambda_{air}}{n_{liquid}}$$

where c and v_{liquid} are velocities of light in air and liquid and λ_{air} and λ_{liquid} are are wavelength of light in air and liquid. Respectively.

Fringe separation, y= $\frac{\lambda_{air}}{2\tan\theta}$ where θ is the wedge angle.

The new fringe separation, y' =$\frac{\lambda_{liquid}}{2\tan\theta} = \frac{\lambda_{air}}{2n\tan\theta}$

Hence fringe separation is reduced by a factor of n in relation to that of air wedge.

(d) When monochromatic light of wavelength 5.8×10^{-7}m is incident normally on a transmission grating. The second order diffraction line is observed at an angle of 27^0. How many lines per centimeter does the grating have? (04marks)

From dsinθ = nλ, where d is the grating spacing.

d = $\frac{2 \ x \ 5.8 \ x \ 10^{-7}}{\sin 27}$ = 2.56×10^{-6}m

Number of line spacing per cm = $\frac{1 \ x \ 10^{-2}}{d} = \frac{1 \ x \ 10^{-2}}{2.56 \ x \ 10^{-6}} = 3.91 \ x \ 10^3$ lines per cm

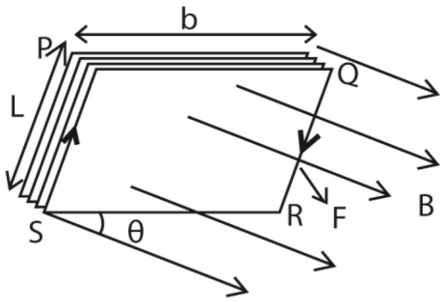
SECTION B

5. (a) (i) Write down the expression for the force exerted on a straight wire of length, L meter carrying a current, I amperes at right angles to magnetic field of flux density B tesla (01marks)

F = BIL

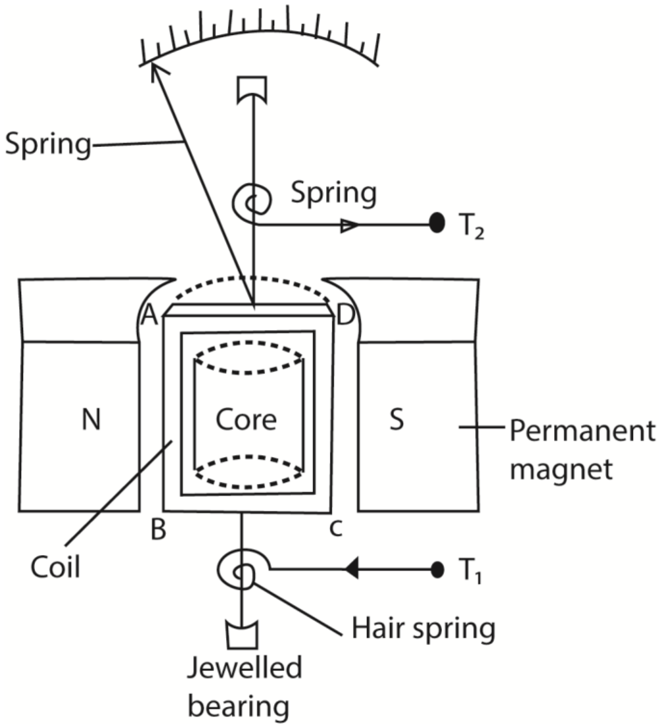
(ii) A rectangular coil of N-turns and area A m^2 is suspended in a uniform magnetic field of flux density B tesla. Initially the plane of the coil is at right angles to the magnetic field. Derive an expression for the initial couple on the coil when a current I amperes flows through the coil. (05marks).

Solution



- When current flows through the coil, the conductor experiences a magnetic force.
- Force on side PQ = NBIb (downwards) while Force on side RS = NBIN (upwards). The two forces cancel out due to rigidity of the coil.
- Side PS experiences force NBIL perpendicularly into the page while RQ experiences force NBIL perpendicularly out of page. The two forces constitute a couple whose moment of force
  $\tau = F \times b$
  $= NBILb$
  $= NBIA$ (where is the area = $L \times b$)

(b) Draw a labelled diagram of a moving coil galvanometer and explain how it works (06 marks)



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

(c) A small circular coil of 10 turns and mean radius 2.4cm is mounted at the center of a long solenoid of 750 turns per meter with its axis at right angles to the axis of the solenoid. If the current in the solenoid is 2.0A, calculate the initial torque on the circular coil when a current of 1.0A is passed through it. (05marks)

Solution

For a solenoid, B = $\mu_0 nI = 4\pi \times 10^{-7} \times 750 \times 2 = 1.88 \times 10^{-3}$T

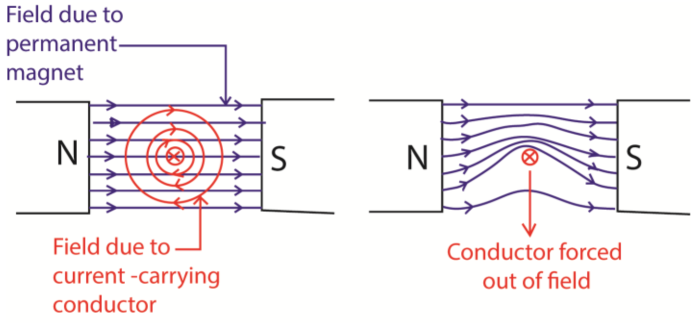
Initial torque, τ = BIAN

$= 1.88 \times 10^{-3} \times 1 \times (\pi\ (2.4 \times 10^{-2})^2) \times 10$

$= 3.69 \times 10^{-5}$Nm

(d) Explain why a current carrying conductor placed in a magnetic field experience a force. (03marks)

Solution



(a) Individual fields

(b) Combined field causing force on conductor

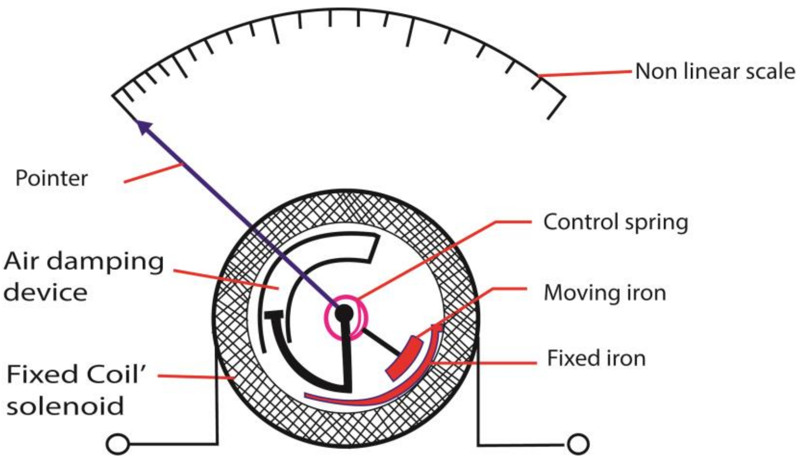
The current in the wire setup a magnet field around the wire. When the field due to the wire interacts with the external magnetic field. The resultant magnetic field has greater flux density above the wire than below it.

The wire moves from a region of greater magnetic flux density. Hence the wire moves downwards.

6. (a) (i) What is meant by the root mean square value of alternating current? (01mark)

Root mean square value of an a.c is the value of steady current which dissipates heat at the same rate in a given resistor as a.c.

(ii) Describe with the aid of a labelled diagram, the structure and action of a moving iron meter. (05marks)



When a current is passed through the coil, the iron rods magnetize in the same poles adjacent to each other in whatever the direction of current. Hence they repel and the pointer move in the same direction until it is stopped by the restoring spring.

Since the magnetic force is proportional to the square of the average current, hence, the deflection is proportional to the square of average current.

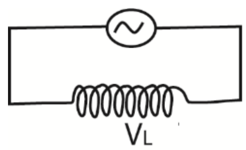
Advantage: it measured both direct and alternating current.

Disadvantage: it has nonlinear scale

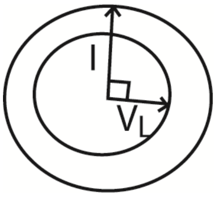
(iii) What is meant by the term reactance? (01mark)

Reactance is the opposition to the passage of alternating current through a capacitor.

(b) In the diagram below, V_L is the voltage drop across the inductor.

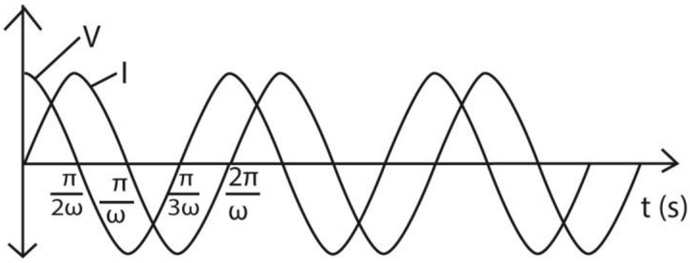


(i) Draw a vector diagram to show the orientation of V_L with respect to current I (01mark)

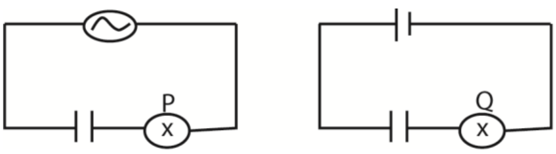


Note that vector diagrams are also called phase diagrams since they indicate phase angle and quantities. In this case VL leads I by π/2

(ii) Using the same axes, sketch graphs to show the variation of V_L with current I with time (02marks

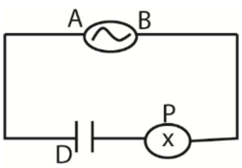


(c)



The bulb P and Q have the same rating. P is connected in series with a capacitor across an a.c source while Q is connected in series with an identical capacitor across a d.c., source of e.m.f equal to root mean square voltage of the a.c as shown in the figure above. Explain why bulb P light continuously while bulb Q does not. (05marks)

Solution

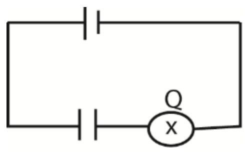


During the half cycle when end A is positive, plate D of the capacitor is charged positively.

During the next half cycle, plate D loses its positive charge and becomes negatively charged.

Current moves to and fro in the wires connected to the capacitor.

Since the filament of the bulb heats up regardless of the direction of current through it, the bulb light continuously.



Q lights initially because the initial rate of charge flow is high and then goes out because the p.d that develops across the plates of the capacitor oppose flow of current. In fact when the capacitor is fully charged no current flows through it.

(d) A 240V, 60W alternating voltage is applied across a capacitor of capacitance 10μF. Calculate the

(i) root mean square value of the current which flows (04marks)

$I_{r.m.s} = \frac{V_{r.m.s}}{X_C}$

$But\ X_C = \frac{1}{2\pi f C}$

⇨ $I_{r.m.s} = 2\pi f C V_{r.m.s}$

Also, $V_{r.m.s} = \frac{V_0}{\sqrt{2}}$

Thus, $I_{r.m.s} = 2\pi f C \frac{V_0}{\sqrt{2}}$ = $\frac{2\pi\ x\ 60\ x\ (10\ x\ 10^{-6})x\ 240}{\sqrt{2}}$ = 0.64A

(ii) power expended. (01marks)

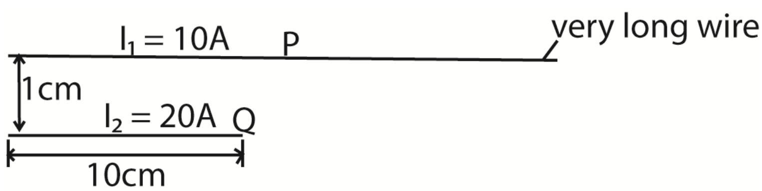
Power expended = 0

A capacitor is worthless component in an a.c. circuit

7. (a) (i) Define ampere (01mark)

The ampere is the current which when maintained in two parallel conductors of negligible cross section area and a separation of 1m cause a force of 2 x 10^{-7}N per meter between them.

(ii)



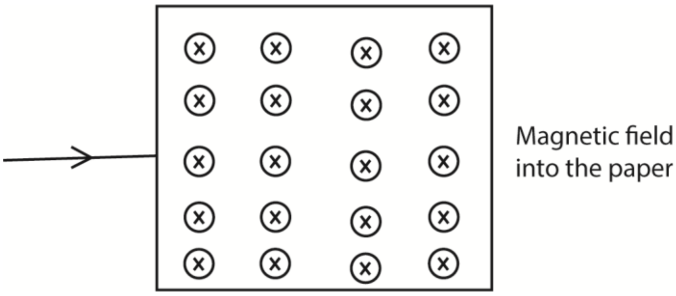
The diagram in the figure above show a parallel wire P and Q placed 1cm apart and carrying current currents of 10A and 20A respectively in the same direction. If wire Q is 10cm long, find the magnetic force acting on it. (04marks)

Force, F = BI_1L

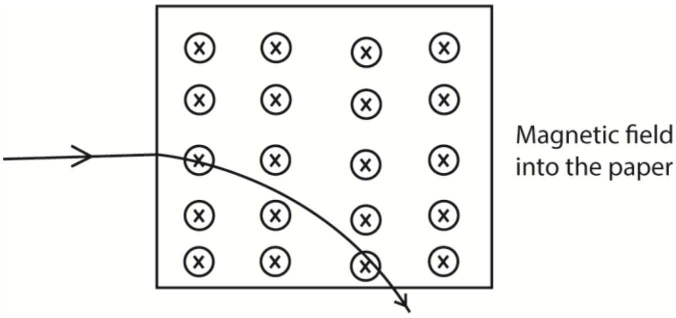
But B = $\frac{\mu_0 I_2}{2\pi r}$

Thus, F = $\frac{\mu_0 I_1 I_2 L}{2\pi r} = \frac{4\pi\ x\ 10^{-7}\ x\ 10\ x\ 20\ x\ 10\ x\ 10^{-2}}{2\pi\ x\ 1\ x\ 10^{-2}}$ = 4 x 10^{-4}N (from Q towards P)

(b) A stream of electrons enter normally, a uniform magnetic field which is perpendicular to and directed into the plane of the page as shown below



Explain, with the aid of a diagram, the path of electrons while inside the field and after leaving it (06marks)



Current flows in the direction opposite to that of electrons. Applying Fleming's left hand rule, electrons are deflected downwards, i.e. electrons are deflected downwards describing a circular path.

When electrons move out of the field, the magnetic force become zero. The electrons now move in a straight line tangential to the circle at the point of exit

(c) Explain why, when a current is switched off in some circuits, a spark is seen across the gap of the switch. (03mark)

When current is switched off, there is a sudden change in magnetic flux from a large value to zero in a very short time.

Consequently, a high voltage is induced across the open switch. The high voltage ionizes the air in the gap. Then positive ions and negative ions combine violently causing a spark.

(d) Show that the total charge which passes through a coil depends only on the resistances of the coil and the total flux linked. (06marks)

Consider a coil of N turns and total resistance, RΩ, in which the flux linking each turn is changing and has a value of ϕ at time t.

The induced e.m.f, E = $-\frac{d(N\phi)}{dt}$

Induced current, I = $\frac{E}{R} = -\frac{N}{R}\left(\frac{d\phi}{dt}\right)$

But I is the rate of change of charge,

$\therefore$ I = $\frac{dQ}{dt}$

⇨ = $\frac{dQ}{dt} = -\frac{N}{R}\left(\frac{d\phi}{dt}\right)$

If the flux charges, say from ϕ_1 to ϕ_2, the total charge, Q, that passes is given by

$$\int_0^Q dQ = -\frac{N}{R}\int_{\phi_1}^{\phi_2} d\phi$$

$$Q = -\frac{N(\phi_2 = \phi_1)}{R} = -\frac{change\ inmagnetic\ flux}{R}$$

Therefore the total charge which passes through a coil depends only on the resistance of the coil and the total flux linkage.

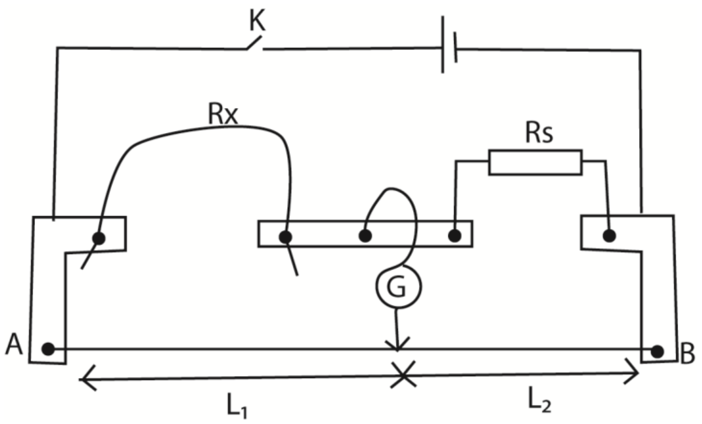
SECTION C

8. (a) (i) Define electrical resistivity and the ohm. (02marks)

Electrical resistivity is the electrical resistance across opposite faces of a cube of a material of length 1m

An Ohm is the resistance of a conductor through which 1 ampere flows when the potential difference across it is 1 volt.

(ii) Describe an expression to determine the electrical resistivity of a material in form of a wire using a meter bridge. (07marks)



A length Lx of the wire under test is connected in the left hand gap of the Meter Bridge and standard of resistance Rs in the right hand gap as shown above. Switch K is closed and the jockey tapped at different points along the uniform wire AB until a point is found where the galvanometer shows no deflection. Distance L_1 and L_2 are measured and recorded.

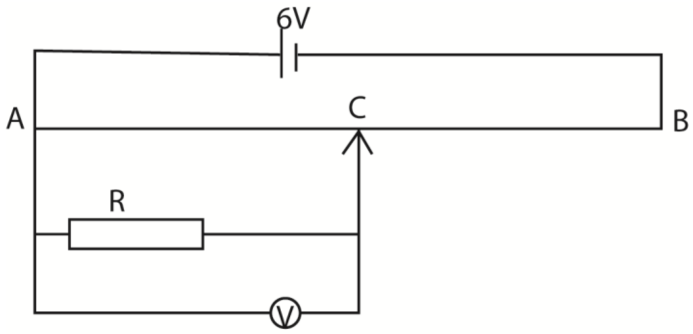
The procedure is repeated for different length of Lx and the results tabulated including the values of Rx = $\frac{L_1}{L_2}Rs$

A graph of Rx against Rx against Lx is plotted and slope S is determined.

The average diameter, D, of the wire is measure from different points of the wire.

Resistivity, ρ =$S\left(\frac{\pi D^2}{4}\right)$

(b)



In the figure above wire AB of length 1.00m has a resistance of 10Ω. If point C is the midpoint of AB, and the voltmeter reading is 2.0V, find the value of R. (06marks)

Resistance R_{AC} of AC = $\frac{10}{2} = 5\Omega$

Resistance R_{BC} of BC =$\frac{10}{2} = 5\Omega$

AC is in parallel with R, thus p.d across AC = p.d across R = 2V

p.d. across CB = 6-2 = 4V

current in CB = I_{CB} $= \frac{V}{R} = \frac{4}{5}A$

current in AC = I_{AC} $= \frac{V}{R} = \frac{2}{5}A$

Current in R, $I_R = \frac{V}{R} = \frac{2}{R}$

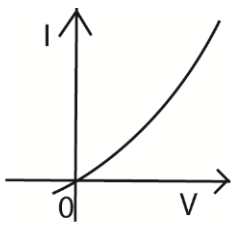
From Kirchhoff's law, $I_{AC} + I_R = I_{CB}$

$\frac{2}{5} + \frac{2}{R} = \frac{4}{5}$

R =5Ω

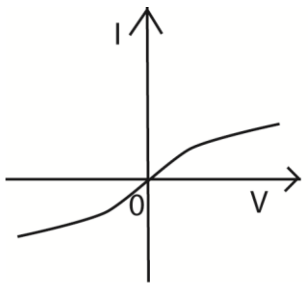
(c) Describe the current versus voltage characteristics of a

(i) semi-conductor diode (02marks)



Current flows when p.d is applied in one direction but the current is almost when the p.d is applied in the opposite direction.

(ii) filament lamp (02marks)



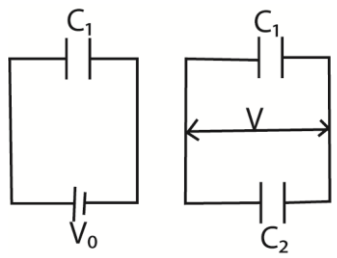
For low voltage, current, I, varies linearly with V. But for high values of V, a given value of V causes a small change in current. So the curve bends.

Hence the resistance dV/dI of the filament increases with temperature.

(d) Why does Ohm's holds at constant temperature only? (01mark)

Because change in temperature alters resistance of a material

9. (a) Define the terms dielectric constant and capacitance (02marks)
Dielectric constant of a medium is the ratio of capacitance of a capacitor with the space between its plates filled with the medium to the capacitance of the same capacitor when the space between its plates is a vacuum.
(b) An air capacitor of capacitance 400μF is charged to 180V and then connected across an uncharged capacitor of capacitance 500μF.



(i) find the energy stored in the 500μF capacitor. (04marks)
Total charge before connection of 500μF = total charge after connection of 500μF

$Q_0 = Q_1 + Q_2$

$Q_0V_0 = Q_1V + C_2V$

$Q_0V_0 = V(C_1 + C_2V)$

$V = \frac{C_1V_0}{C_1 + C_2}$

$V = \frac{400\ x\ 10^{-6}\ x\ 180}{(500+400)10^{-6}} = 80V$

Energy stored = $\frac{1}{2}CV^2 = \frac{1}{2}\ x\ 500\ x\ 10^{-6}\ x\ 80^2 = 1.6J$

(ii) With the capacitor still connected a dielectric of dielectric constant 1.5 is inserted between plates of the 400μF capacitor.
If the separation between the plates remains the same find the new p.d across the two capacitors. (03marks)
After insertion of a dielectric, 400μF capacitance become = 1.5 x 400 = 600μF

$$Q_0V_0 = Q_1V + C_2V$$
$$Q_0V_0 = V(\varepsilon_r C_1 + C_2V)$$
$$V = \frac{C_1V_0}{\varepsilon_r C_1 + C_2}$$
$$V = \frac{400\ x\ 10^{-6}\ x\ 180}{(600+500)10^{-6}} = 65.45V$$

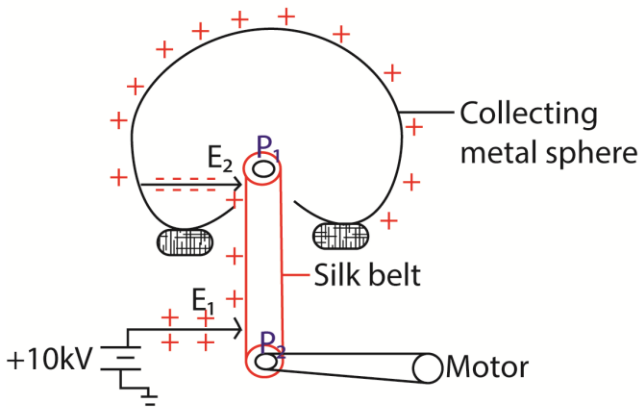
(c) (i) state the characteristics of an equipotential surface. (02marks)

- Along any direction line n the surface, there is no electric field
- Equipotential surfaces are always perpendicular to the lines of force
- Work done to move a charge from one point to another on equipotential surface is zero

(ii) Describe how a conductor can be charged at zero potential (03marks)

(d) Describe with the aid of a diagram how a high voltage can be generated using a Van de Graff generator. (06marks)

Van der Graff generator



Main features

a. It consists of a large hollow metal sphere (collecting sphere) supported on insulating stand.

b. A silk belt inside the tube driven by an electric motor possesses the sharply pointed electrode metal E_1, held at electric potential of about 10kV relative to the earth.

c. As the belt moves up, it passes another sharply pointed metal electrode E_2 connected inside the hollow sphere.

Mode of operation

(i) The metal rod E_1, is kept at a high positive potential of about 10kV with respect to the earth.

(ii) The high positive charge at the sharp ends ionizes the air around.

(iii) The positive ions are repelled to the silk belt carries then towards the collecting sphere.

(iv) At E_2, the silk belt induces negative charges on the sharp ends of E_1 and the positive charges on the outer of the sphere. The electric field at point ends E_2 ionizes the air around it.

(v) The negatively charged ions are repelled to the silk belt which is carrying positively charged ions

(vi) The positive ions are neutralized before passing over the upper pulley P_1.

(vii) The process of silk belt charging up and discharging is repeated many times per second and each time the belt passes, the sphere charges up positively until it has electric it has electric potential of about 10^6V relative to the earth.

10. (a) (i)State coulomb's law (01marks)

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 of separation of the charges.

(ii) Show that the electric flux through a spherical surface enclosing a charge in vacuum is Q/E_0

c and $A = 4\pi r^2$

If an electric flux ϕ is due to an electric field E, charge Q enclosed by a sphere of radius r, then

ϕ =E.A

$= \frac{Q}{4\pi\varepsilon_0 r^2} \, x \, 4\pi r^2$

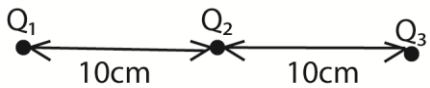
$= \frac{Q}{\varepsilon_0}$

(b) Define the term electric field intensity and electric potential (02marks)

Electric intensity s the force exerted on a positive charge of 1C placed in an electric field

Electric potential is the work done n moving a positive charge of 1C from infinity to a point in electric field.

(c)



Three point charges Q_1, Q_2, and Q_3 of magnitude +5μF, +6μF and -20μF respectively are situated along a straight line as shown in figure above. Calculate the electric field

(i) Intensity midway between Q_1 and Q_2 (03marks)

$E = \frac{Q}{4\pi\varepsilon_0 r^2}$

$E_x = E_{Q1} + E_{Q2} + E_{Q3}$

$E_1 = \frac{Q}{4\pi\varepsilon_0 r_1^2} = \frac{5 \, x \, 10^{-6} \, x \, 9 \, x \, 10^9}{(5 \, x \, 10^{-2})^2} = 1.8 \, x \, 10^7 NC^{-1}$

$E_2 = \frac{Q}{4\pi\varepsilon_0 r_2^2} = \frac{6 \, x \, 10^{-6} \, x \, 9 \, x \, 10^9}{(5 \, x \, 10^{-2})^2} = 2.16 \, x \, 10^7 NC^{-1}$

$E_1 = \frac{Q}{4\pi\varepsilon_0 r_3^2} = \frac{20 \, x \, 10^{-6} \, x \, 9 \, x \, 10^9}{(15 \, x \, 10^{-2})^2} = 0.8 \, x \, 10^7 NC^{-1}$

$E_x = (1.8 - 2.16 + 0.8) x \, 10^7 NC^{-1}$

$= 4.44 \, x \, 10^6 NC^{-1}$

(ii) Potential midway between Q_1 and Q_2 (03marks)

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$
$$V_x = V_{Q1} + V_{Q2} + V_{Q3}$$
$$E_1 = \frac{Q}{4\pi\varepsilon_0 r_1} = \frac{5\,x\,10^{-6}\,x\,9\,x\,10^{9}}{5\,x\,10^{-2}} = 9\,x\,10^{5}V$$
$$E_2 = \frac{Q}{4\pi\varepsilon_0 r_2^2} = \frac{6\,x\,10^{-6}\,x\,9\,x\,10^{9}}{5\,x\,10^{-2}} = 10.8\,x\,10^{5}V$$
$$E_1 = \frac{Q}{4\pi\varepsilon_0 r_3^2} = \frac{-20\,x\,10^{-6}\,x\,9\,x\,10^{9}}{15\,x\,10^{-2}} = -12.0\,x\,10^{5}V$$
$$E_x = (9 - 10.8 - 12.0)x\,10^{5}V$$
$$= 7.8\,x\,10^{5}V$$

(d) (i) Explain why two insulating bodies rubbed together acquire equal and opposite charges. (03marks)

For two insulators A and B , B with a lower work function loses electrons more easily than A. when A and B are rubbed together, heat is produced and B loses electron while A gains electrons; B becomes positively charged while a becomes negatively charged.

(ii) Describe how a gold leaf electroscope can be used to verify the observation in (d)(i) above (06marks)

A neutral metallic can is placed on the cap of neutral gold leaf electroscope and one of the body is lowered into the cap without touching it. The divergence θ_1 of the leaf is noted

The process is repeated with B and divergence θ_2 is noted.

It is observed that $\theta_1 = \theta_2$; this implies that the magnitudes of the two charges are equal.

A and B are now put into contact, and the composite body lowered into the can without touching it. No divergence is observed implying that the charges are equal and opposite.

END