UACE PHYSICS PAPER 2014 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

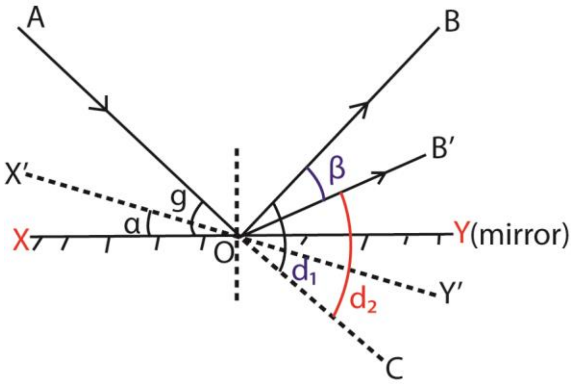
Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 \text{ x}10^{-19}C$
Electron mass	$9.11 \text{ x } 10^{-31}kg$
Plank's constant, h	$6.6 \text{ x } 10^{-34}Js$
Speed of light in the vacuum, c	$3.0 \text{ x } 108ms^{-1}$
Specific heat capacity of water	$4.200Jkg^{-1}K^{-1}$
Avogadro's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

SECTION A

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

(ii) A ray of light is incident on a plane mirror. The mirror is then turned through an angle α keeping the direction of the incident ray constant. If a reflected ray turned through angle β, find the relationship between α and β.

Let XY be the initial position of the mirror with ray AO making a glancing angle g. By keeping the direction of the incident ray fixed, the mirror is rotated through an angle **α** to a new position X'Y' as shown.



Case 1 (mirror in position XY)

Glancing angle = g

Deviation $d_1 = 2g$……… (i)

Case 2**(mirror in position X'Y')**

Glancing angle = $(g - \alpha)$

Deviation $d_2 = 2(g - \alpha)$ …..(ii)

$\beta = d_1 - d_2$

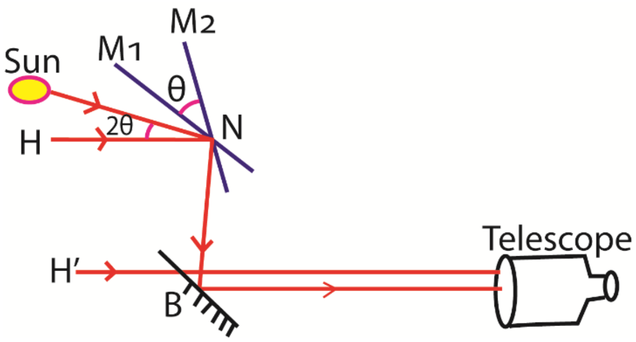
$= 2g - 2(g - \alpha)$

$= 2g - 2g + 2\alpha$

$= 2\alpha$

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

Setup

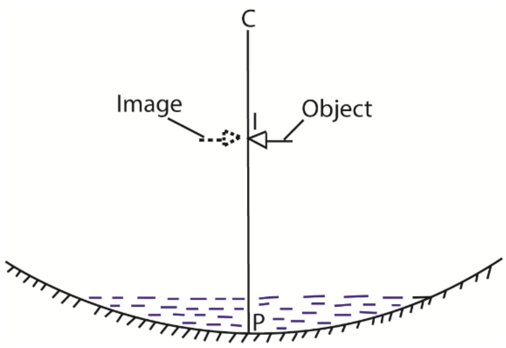


- A sextant consists of a fully silvered mirror M_1 which can be rotated about a horizontal axis and a fixed half silvered mirror B.
- Mirror M_1 is adjusted to become parallel to B by rotating it until the image of the horizon, H' is seen directly through the unsilvered part of mirror B by successive reflection in mirror M_1 and B respectively

- 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.

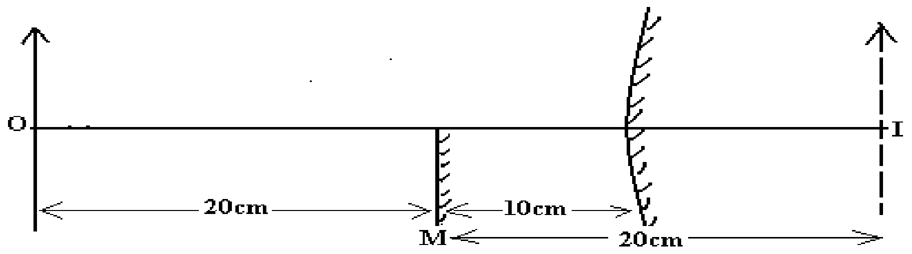
(c) Describe an experiment to determine the refractive index of a small quantity of a liquid using a concave mirror. (05marks)

An experiment to determine refractive index of a liquid using a concave mirror



- A clamped pin with its tip along the principal axis above the concave mirror is coincided with its image at C and distance PC is measured
- A small quantity of the liquid under test is poured into a concave mirror and a new point I at which the object pin coincides with its image is obtained.
- Distance IP is measured.
- The required refractive index of a liquid, $\boldsymbol{n_l} = \frac{\boldsymbol{PC}}{\boldsymbol{IP}}$

(d) A plane mirror is placed 10cmin front of a convex mirror so that it covers about half of the convex mirror surface. A pin placed 20cm in front of the plane mirror gives an image which coincides with that of the pin in the convex mirror. Find the focal length of the convex mirror. (04marks)



Consider the action of a convex mirror

u = 30cm and v = - (20 - 10) = -10cm "The image formed is virtual "

Using the lens formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ give

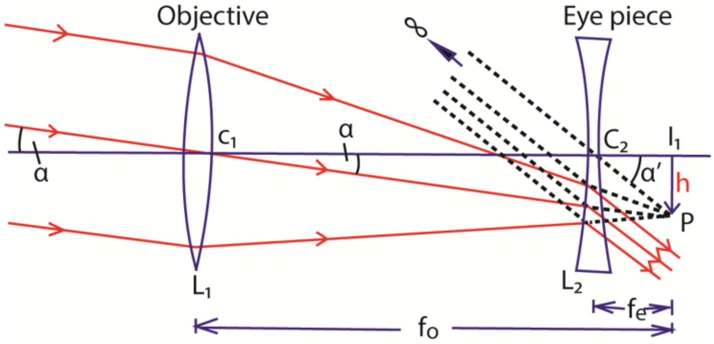
Image distance v of the lens = $\frac{fu}{u-f} = \frac{-10\ x\ 30}{30-10} = -15cm$

2. (a) Define **angular magnification** of an optical instrument. (01marks)

This is the ratio of the angle subtended at the eye by the image when using an instrument to the angle subtended at unaided eye by the object.

M = $\frac{\alpha'}{\alpha}$ where α' and α are in radians

(b) (i) Describe with the aid of a ray diagram, the operation of telescope made of a converging lens and a diverging lens when used in normal adjustment. (05mrks)



Galilean telescope in normal adjustment

Light from distant object incident on objective lens is refracted to form real inverted image at its principal focus f_0. In normal adjustment, the principal focuses of both lenses coincide. The eye piece therefore forms the final image of the object at infinity.

To obtain the magnification, m, we assume the eye is very close to the eye piece.

m = $\frac{\alpha'}{\alpha}$

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

$\alpha \approx \tan \alpha = \frac{h}{f_e}$ and $\alpha' \approx \tan \alpha = \frac{h}{f_0}$

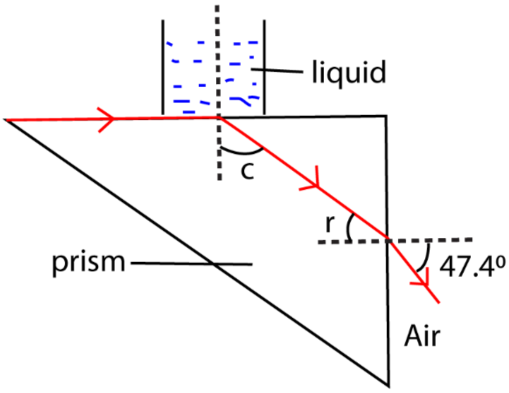
Substituting for α and α'

Magnifying power, $m = \frac{\alpha'}{\alpha} = \frac{h}{f_e} \div \frac{h}{f_o} = \frac{\boldsymbol{f_0}}{\boldsymbol{f_e}}$

(ii) State two limitations of this type of telescope. (01marks)

- it has virtual eye-ring
- It has a small field of view
- It produces less clear image

(c) The diagram in the figure below shows a path followed by a ray of monochromatic light through a right angled prism of refractive index 1.52. The light emerges in air at an angle of 47.4^0.



Find the refractive index of the liquid. (06marks)

Solution

Note: A ray on the boundary is grazing ray.

Let the refractive index of the liquid and air be and c is the refractive index of glass.

From

n_g sini = na sin 47.6^0

1.52 sin r = 1sin 47.6^0

r = 29^0

r + c = 90^0

c = 61^0

$n_L \sin 90^0 = n_g \sin c$

$n_L = 1.52 \sin 61^0 = 1.33$

(d) Explain the following as applied to lenses.

(i) chromatic aberration (02marks)

It is a failure of a lens to focus all colors to the same point due to different refractive indices for the different color wavelength.

(ii) spherical aberration (02marks)

It is the failure of the lens to focus all rays through the lens to the same point leading blurred image

(e) Explain how chromatic and spherical aberration are minimized in a reflecting telescope (03marks)

Correction of chromatic aberration

- Use **lenses** made of low-dispersion glasses, especially those containing fluorite
- By using combination of lenses of opposite nature (convex & concave) or chromatic doublet such that the dispersion produced by one lens is reversed by another.
- Placing the eye close to the lens such that images due to different colours subtend the same angle at the eye.

Means of reduction of spherical aberration

- Using lenses with an aspheric surface
- Using lens of small aperture.
- Using a stopper such that only light incident on the middle of the lens pass, but this method reduces the brightness of the image since it reduces the amount of light energy passing through the lens.

SECTION B

3. (a) What is meant by the following as applied to wave motion?

(i) Wavelength

This is the distance between two successive particles in phase

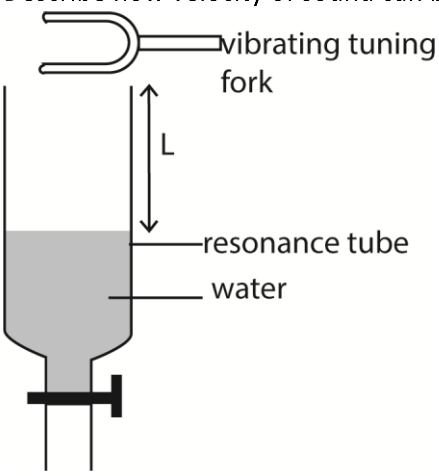
(ii) Wave front

This is a section through advancing wave on which all particles are in phase.

(b) (i) Define Resonance

Resonance is a condition obtained when the forcing frequency of an oscillation is equal to the natural frequency of an oscillating (vibrating) object.

(iii) Describe how velocity of sound can be determined using a resonance tube.



- A glass tube which can be drained from bottom is filled with water.
- A sounding tuning fork of frequency f is brought to the mouth of the tube.
- The water is slowly drained until a loud sound is heard. The tap is closed and length L_1 is measured.
- The tuning fork is again sounded at the mouth of the tube and the water drained further until a loud sound is heard and distance L_2 is noted
- Velocity, v, of sound in air = $2f(L_2-L_1)$

(c) (i) Explain how stationary waves are formed.

When two waves of nearly equal frequency and similar amplitude are sounded together, they superpose.

When they meet in phase, constructive interference takes place and loud sound is heard.
When they meet completely out of phase destructive interference takes place and soft sound is heard.
The periodic rise and fall in intensity of sound heard is called beats.

(ii) A tuning fork of 760Hz is sounded near the open and closed pipe of length 40 cm. f sir in the tube resonates with the tuning fork, determine the mode vibration and the end correction. (Velocity of sound in air is 300ms^{-1}).

Assuming negligible end correction

Resonance frequency, f = $\frac{nV}{4L}$

$$n = \frac{4fL}{V} = \frac{4\ x\ 760\ x\ 0.4}{330} = 3.68$$

But n = 1, 2, 3 …

This implies that resonance occurs in the 2nd overtone or 5th harmonic (n = 5)

If end correction is c, then L + c = $\frac{nV}{4f}$

$$c = \frac{nV}{4f} - L$$

$$= \frac{5\ x\ 330}{4\ x\ 760} - 4$$

$$= 0.1428\text{m}$$

(d)(i) Explain reverberation as applied to sound waves

Reverberation is the prolongation of sound after the sound source has been stopped due to large number of reflected waves which can be perceived by the brain as a continuous sound

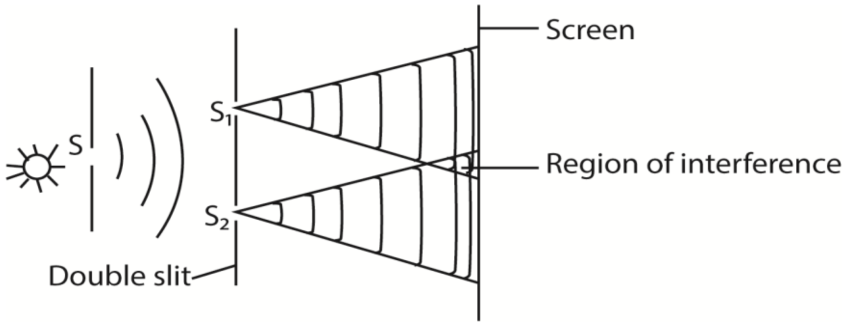
(ii) Explain how reverberation can be minimized in a large hall.

Reverberation can be reduced by using materials such as fibre board, heavy curtains, plastics that absorb sound as it reaches the walls and ceiling of the room and t prevent reflection sound

4. (a) (i) state **two** conditions necessary for interference patterns to be formed.
   - The two sources must be coherent; i.e. they must have the same wavelength and be in phase or have constant phase difference.
   - The sources must be close to each other.

(ii) With the aid of a diagram, describe how interference can be produced by division of wave front.

Solution



S, S_1 and S_2 are narrow slits parallel to each other. S diffracts light that falls on it and also illuminates both S_1 and S_2.

Diffraction also takes place at S1 and S2 and interference occurs in the region where light from S_1 overlaps that from S_2.

Since S is narrow, the light which emerges from S_1 and s_2 comes from the same wave front from S and thus coherent.

NB: The coherent sources are obtained by dividing the wave front, originating from a common source, by employing mirrors, biprisms or lenses. This class of interference requires essentially a point source or a narrow slit source.

(b) In Young's double slit experiment, the slits are 0.5mm apart and interference is observed on the screen placed a distance of 100cm from the slits. It is found that the 9th bright fringe is at a distance of 8,84cm from the second dark fringe from the center of the fringe patterns. Find the wavelength of light used.

Solution

The distance of nth bright fringes from the central fringe, y = $\frac{n\lambda D}{a}$

For the 9th bright fringe, y = $\frac{9\lambda D}{a}$ ………………………………………………………… (i)

The distance of the nth dark fringe from the central fringe, y' = $\left(n - \frac{1}{2}\right)\frac{n\lambda}{a}$

The 2nd dark fringe from the central fringe, y' = $\left(2 - \frac{1}{2}\right)\frac{n\lambda D}{a} = \frac{3\lambda D}{2a}$ ………… (ii)

From eqns. (i) and (ii)

Y9 – y'2 = $\frac{9\lambda D}{a} - \frac{3\lambda D}{2a} = \frac{15\lambda D}{2a}$ = 8.84×10^{-2}

λ = $\frac{8.84\ x\ 10^{-3}\ x\ 2\ x\ 0.5\ x\ 10^{-3}}{15\ x\ 1}$ = 5.59×10^{-6}m

(c) Explain what is observed on the interference pattern fringes in Young's double experiment when the monochromatic source of light is replaced by a source of white light?

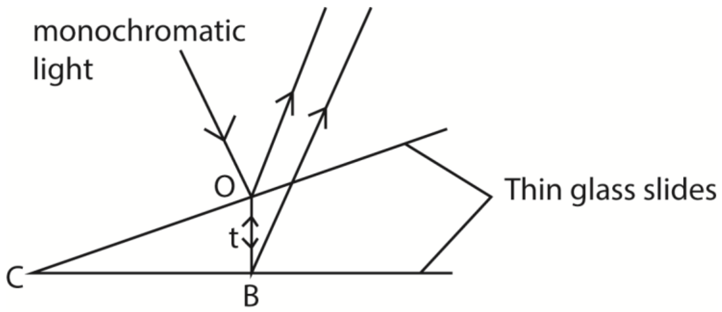
A central white fringe with colored edges is observed.

White light consists of several component colours. The interference pattern due to the different component colors of white light overlapping.

At the center of screen, the path difference is zero for all colors. Hence at the center there is a white fringe. Since the violet color has the lowest wavelength, then a violet fringe will be the first fringe on the either side of the central white fringe. The farthest fringe is red

After a few fringes, the fringe pattern become invisible due to much overlapping.

(d) Describe how interference fringes are formed in wedge shaped film of air.



A monochromatic light incident normally at O is partially reflected and partially transmitted at the bottom of the top glass slide.

Part of the transmitted light is reflected at B on the top of the lower glass slide.

The two reflected wave trains are coherent and when they superpose above the upper side of top glass slide, they produce interference pattern in form of alternative dark and bright fringes parallel to the line of intersection of the slide.

The path difference is 2t where t is the small thickness of the air film at O.

At C where the path different is apparently zero, a bright fringe is expected, however, a dark fringe is observed. This is due to phase change of π radians (equivalent to path difference of $\frac{\lambda}{2}$) that occurs when a wave is reflected at a denser medium.
Hence for constructive interference (bright fringes) $\left(2t + \frac{\lambda}{2}\right) = n\lambda$, for n = 1, 2, 3, …
Destructive interference (dark fringes) 2t = $n\lambda$, for n = 1, 2, 3, …

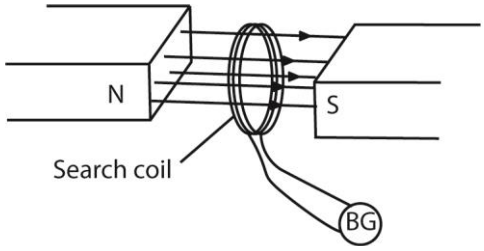
SECTION C

5. (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) Describe a method of measuring the magnetic flux density in the region between the poles of a magnet. (06marks)

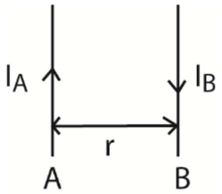
Solution



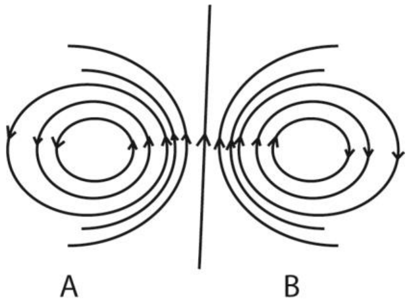
A search coil is connected in series with a ballistic galvanometer, B.G and a resistor.

The search coil is placed between the poles pieces of the magnet with its plane normal to the magnetic field.
When the ballistic galvanometer pointer settles, the coil is completely withdrawn from the field and the first deflection θ of the B.G is noted.
A capacitor of known capacitance C is charged to a p.d V and then discharged through the ballistic galvanometer and the corresponding θ' is noted.
The magnetic flux density B is now calculated from B = $\frac{CVR\theta}{NA\theta'}$ where A is the area of the coil, N is the number of turns in the coil and R is the resistance of the coil circuit.

(c) Two straight parallel wires A and B carrying steady currents IA and IB respectively are placed close to each other as shown in figure below



(i) Sketch the resultant magnetic field pattern (02marks)



(ii) Explain what happens when the current I_A and I_B are steady currents. (04marks)

When the two circuit carrying conductors are placed near each other, the conductors repel each other. If the current IA and IB are steady, the resultant magnetic field is constant.
The force acting per meter length, $\frac{F}{L} = \frac{\mu_0 I_A I_B}{2\pi r}$
Therefore the force is constant.

(iii) Find the force per unit length of the wires when IA = 8.0A , I_B =11.0A and r = 3.0cm (04marks)

The magnetic flux density which A produces at B is given by
$\frac{\mu_0 I_A}{2\pi r} = \frac{4\pi \, x \, 10^{-7} \, x \, 8}{2\pi \, x \, 3 \, x \, 10^{-2}}$ = 5.30 x 10^{-5}T
Force exerted by A on B, F = BI_BL

$\frac{F}{L} = BI_B$ = 5.30 x 10^{-5} x 11 = 5.85 x 10^{-4}Nm^{-1}.

Or

$\frac{F}{L} = \frac{\mu_0 I_A I_B}{2\pi r} = \frac{4\pi \, x \, 10^{-7} x \, 8 \, x \, 11}{2\pi \, x \, 3 \, x \, 10^{-2}}$ = 5.85 x 10^{-4}Nm^{-1}

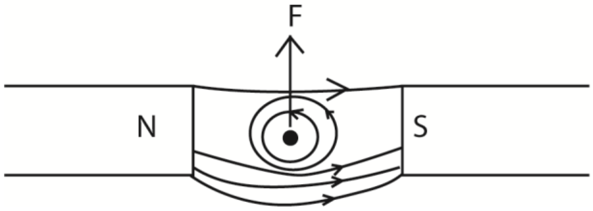
(d) Explain how eddy currents are produced (02marks)

When a conductor cuts through a magnetic field, the magnetic flux linking it changes. This cause small currents to flow in loops in the conductor. These induced currents are called Eddy currents

6. (a) (i) Write an expression for the force exerted on a straight wire of length, L meters carrying a current, I, amperes, placed at right angles to a uniform magnetic field flux density B teslas. (01 marks)

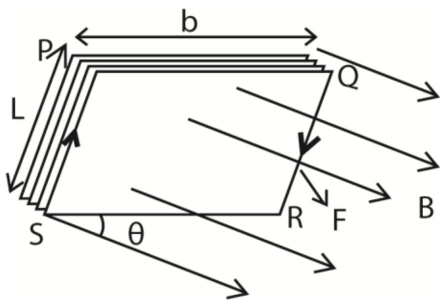
F = BIL

(ii) Explain the origin of the force n (a) (i). (04marks)



- The current sets up a magnetic field around the wire.
- When the field due to current interacts with external magnetic field, the resultant magnetic field has greater flux density on one side than the other; in the diagram above, high flux density is created below than above.
- The wire moves from a region of greater to lower flux density; thus it move up in this case.

(b) A rectangular coil of N turns each of length, L, and breadth, b, is inclined at an angle θ to a uniform magnetic field of flux density B. Derive an expression for torque of the coil when a current I is passed through it.



- When current flows through the coil, the conductor experiences a magnetic force.
- Force on side PQ = NBIbsinθ (downwards) while Force on side RS = NBINsinθ (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

  T = F x bcosθ

  = NBILbcosθ

(c) A single rectangular loop of wire with dimensions 35cm by 75cm is arranged such that part of it is inside a region of uniform magnetic field of flux density 0.45T and part of it is outside the field. The total resistance of the loop is 0.23Ω. Calculate the force required to pull the loop from the field at a constant velocity of $3.4ms^{-1}$ perpendicular to the field. (05marks)

Solution

Induced e.m.f on the loop on pulling out of the field is given by'

E = BLV = 0.45 x 35 x 10-2 x 3.4 = 0.5355V

Current, I, that flows in the loop = $\frac{E}{R} = \frac{0.5355}{0.23}$ = 2.328A

Mechanical power experienced = electrical energy developed.

- FV = IE
- F = $\frac{IE}{V}$ = $\frac{2.328\ x\ 0.5355}{3.4}$ = 0.367N

Alternatively

From

F =BIL .... (i)

I = $\frac{E}{R}$ .... (ii)

E = BLV .... (iii)

It follows that F = $\frac{B^2L^2V}{R}$ = $\frac{0.45^2 0.35^2 x\ 0.34}{0.23}$ = 0.367N

(d)(i) Define the term magnetic flux. (01marks)

Magnetic flux is the product of magnetic flux density and projection of the area at right angles to the magnetic field

(ii) An electron resolves in a circular orbit of radius 2.0 x 10^{-10}m at a frequency of 6.8 x 10^{15} revolution per second. Calculate the magnetic flux density at the center of the orbit (04marks)

The circulation of the electron constitute a current

I = $\frac{e}{t} = ef$

But $B_0 = \frac{\mu_0 ef}{2R} = \frac{4\pi\ x\ 10^{-7}\ x\ 1.6\ x\ 10^{-19}\ x\ 6.8\ x\ 10^{15}}{2\ x\ 2.0\ x\ 10^{-10}}$ = 3.4T

7. (a)(i) What is a sinusoidal alternating current? (01mark)

A sinusoidal a.c is aperiodic current whose time dependence is given by sine function.

(ii) Define peak value, root mean square (r.m.s) value and frequency of alternating current. (03marks)

Peak value is the maximum value of an alternating current.

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

Frequency of alternating current is the number of complete cycles which the current goes through in one second.

(b) A sinusoidal voltage of r.ms value 13.2V is connected across a 50μF capacitor.

(i) Find peak value of the charge on the capacitor (02marks)

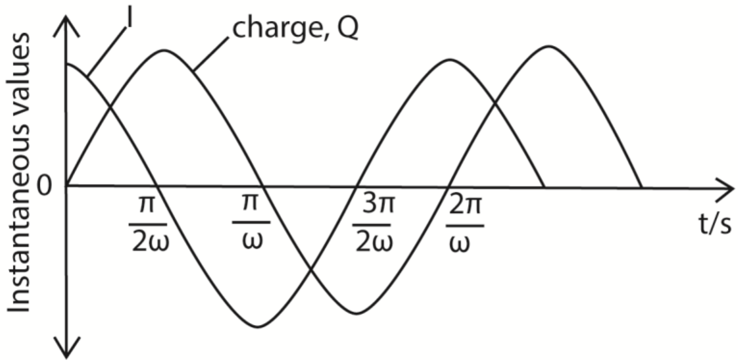
$Q_0 = CV_0$ but $V_0 = V_{r.m.s} x \sqrt{2}$

Hence $Q_0 = CV_{r.m.s}\ x\ \sqrt{2}$

= 50 x 10^{-6} x 13.2 x $\sqrt{2}$

= 9.333 x 10^{-4}C

(iii) Sketch using the same axes the graphs of charge Q on the capacitor and current I in the circuit against time. (02marks)



Explanation of the curve

The current I through (not across) a capacitor is C $\frac{dV}{dt}$. This is the slope of the voltage.

When a capacitor is connected to an AC voltage (at the zero crossing) the maximum current flow will occur immediately, i.e. t = 0, $\frac{dV}{dt}$ will approach infinity instantly and then repeat as a sinusoidal waveform.

There will be a peak current at every zero crossing of the voltage waveform. The current waveform will lead the voltage waveform 90 degrees.

(iv) If the frequency of the alternating current is 49.6Hz, calculate the r.m.s value of current through the capacitor. (03marks)

$\frac{V_{r.m.s}}{I_{r.m.s}} = \frac{1}{2\pi f C} = X_C$

$I_{r.m.s} = V_{r.m.s}\ x\ 2\pi f C$

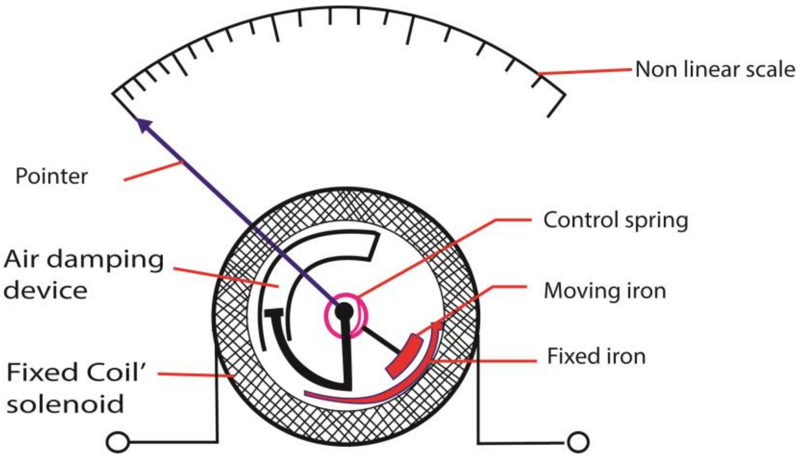
= 13.2 x 2π x 49.6 x 50 x 10^{-6} =0.206A

(c) Explain why a capacitor in a circuit blocks the flow of direct current but allows the flow of alternating current. (04marks)

When a capacitor is connected to a d.c. source the capacitor charges and when it is fully charged, current flow stops.

When it is connected to an a.c, it charges when the voltage is increasing and discharges when the voltage is decreasing. Since increase and decrease in voltage is continuous, there is continuous flow of current in the circuit. Hence a capacitor allows flow of a.c.

(d) Describe the structure and mode of operation of the repulsion type 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.

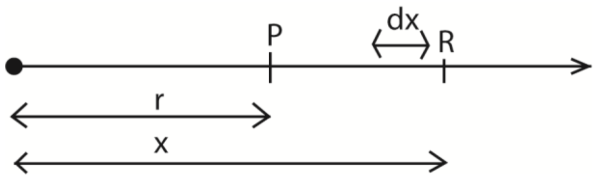
Disadvantage: it has nonlinear scale

SECTION D

8. (a) (i) Define the following; electric field intensity and electric potential at a point (02marks)

- Electric field intensity at a point is the force exerted on positive charge of 1C placed a point in an electric field.
- Electric potential is the work done in bringing 1C of positive charge from infinity to appoint against an electric field.

(ii) Show that the electric field intensity at a point is equal to the negative potential gradient at that point. (04marks)



The force experienced by the charge of +1C placed at R, F = K$\frac{Q\,x\,1}{x^2}$

The work done to move the charge a distance dx towards a fixed charge,

Δw = f.dx

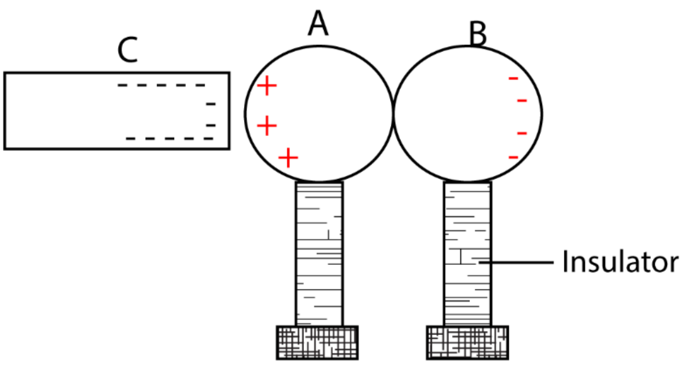
= $\frac{KQ}{x^2}dx$

The total work done to bring the charge to a point a distance r from a fixed charge

w = $\int_{\infty}^{r} -\frac{KQ}{x^2}dx$ = KQ$\left[\frac{1}{x}\right]_{\infty}^{r}$ = $\frac{KQ}{r}$

(b) (i) Explain with the aid of a diagram, how an insulated metal sphere can be charged by induction using a negatively charged rod. (03marks)

- Two insulated metal spheres A and B, arranged such that they touch one another.
- A negatively charged rod C is brought near A.



When the spheres are separated while C in position, A will be positively charged while B will be negatively charged.

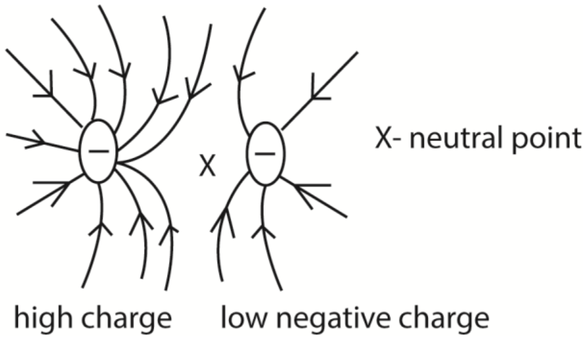
(ii) Describe how a gold leaf electroscope can be used to detect the presence of a charge on the body

- A gold leaf electroscope is first charged positively or negatively by bring either a negatively or positively charged rod close to the cap and the then earthed by touching.
- When a body with similar charge as that on the gold leaf electroscope is brought close to the cap the leaf diverges more.

(c) (i) Write down the equation for the electrostatic force between two isolated point charges in a vacuum. (01mark)

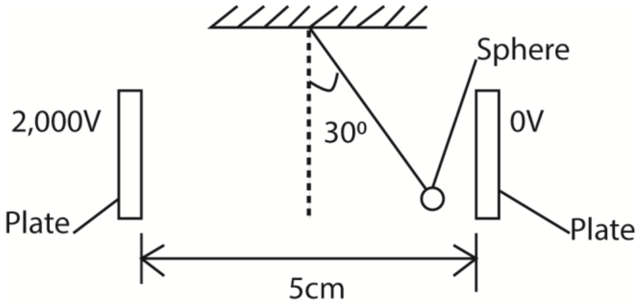
F= $\frac{1}{4\pi\varepsilon_0}\,x\,\frac{QQ_0}{r^2}$ where $\frac{1}{4\pi\varepsilon_0} = 9.0 \text{ x } 10^9$ and Q and Q_0 are charges of the point charges

(ii) Sketch the electric field lines between two negatively charged spheres carrying unequal charges and use the sketches to explain a neutral point. (02marks)

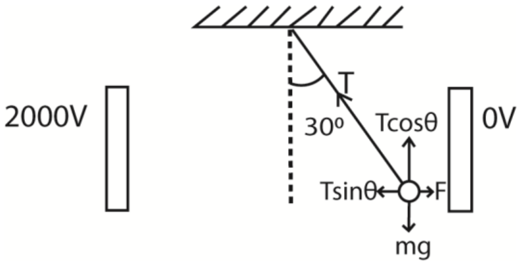


A neutral point in an electric field is a point where the resultant electric field intensity is zero.

(d) A charged polystyrene sphere of mass 2g is suspended by affine nylon thread between two plates 5cm apart as shown in the figure below



When a p.d of 2000V is supplied across the plates, the thread attached to a sphere deflects through an angle of 30^0. Calculate the charge on the sphere.



Resolving the force vertically Tcosθ = mg

$$T = \frac{2 \, x \, 10^{-3} \, x \, 9.81}{\cos 30^0}$$
$$= 2.27 \times 10^{-2}N$$

Resolving horizontally

F = $T\sin30^0$

= $2.27x\ 10^{-2}\sin 30$

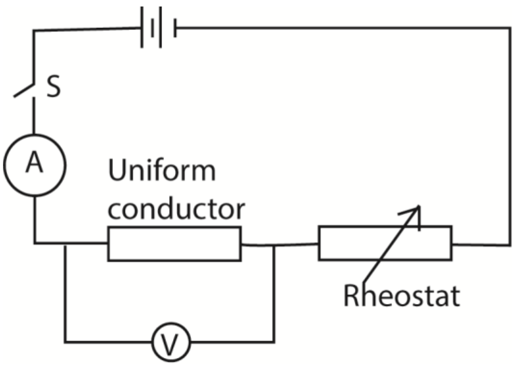
= $1.13 \times 10^{-2}N$

Electric field intensity, E = $\frac{V}{d}$

But F = EQ, where Q = charge

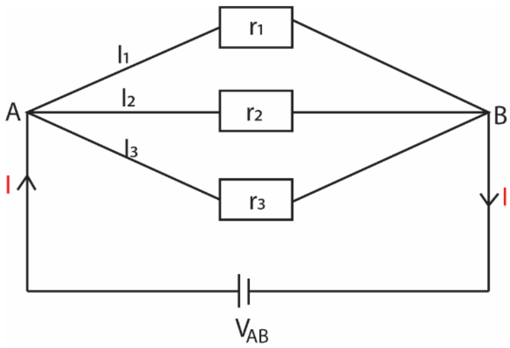
Q = $\frac{F}{E} = \frac{Fd}{V} = \frac{1.13 \, x \, 10^{-2} \, x \, 5 \, x \, 10^{-2}}{2000}$ = $2.825 \times 10^{-7}C$

9. (a) Describe an experiment to verify Ohm's law, (04marks)



- The circuit is shown above
- The switch, s is closed
- The Rheostat is adjusted to read suitable values of I and V of ammeter and voltmeter respectively
- The several values of I with corresponding values V are recorded.
- A graph of I against V is plotted.
- A straight line graph through the origin is obtained, hence Ohm's law is verified.

(b) Derive an expression for combined resistance of three resistors in parallel. (04marks)



The p.d. across each resistor is the same = V_{AB}

By conservation of current, I = $I_1 + I_2 + I_3$

From Ohm's law, I = $\frac{1}{R}$, where R is combined resistance of the resistors

$$\therefore I = \frac{V_{AB}}{r_1} + \frac{V_{AB}}{r_2} + \frac{V_{AB}}{r_3}$$

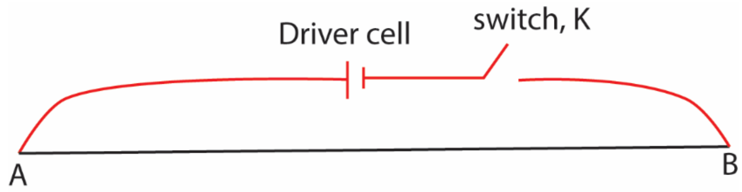
$$= V_{AB}\left[\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_2}\right]$$

$$\frac{1}{R} = \frac{I}{V_{AB}} = \left[\frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_2}\right]$$

(c)(i) Explain the principle of operation of a slide wire potentiometer. (04marks)

Potentiometer

It consist of a uniform slide wire which can be of any length (but usually 1m) connected in series with an accumulator or driver cell which maintains a steady current through the wire.



The driver cell supplies a uniform p.d across the wire and hence the p.d across any length of the wire is directly proportional to the length of the section.

Consequently, the p.d per unit length of the slide wire is constant.

By knowing the knowing the p.d per unit length of the slide wire, any p.d can be determined by balancing it against a known length of a wire.

If the p.d per unit length is k and the balance length is L, then the required p.d = kL

(ii) Two cells A and B connected in series give a balance length of 80.0cm along a potentiometer wire. When Cell B is reversed, the balance length falls to 15.0cm. If the e.m.f of cell A is 1.5V, calculate the e.m.f of cell B. (04marks)

$E_A + E_B = kL$

=> $1.5 + E_B = 80k$ …………………… (i)

Also $1.5 - E_B = 15k$ ………………… (ii)

From Eqn. (i) and Eqn. (ii)

$95k = 3$

$k = \frac{3}{95}$

Substituting k in Eqn. (i)

$EB = 80\ x\ \frac{3}{95} - 1.5 = 1.0263V$

(d) A battery of e.m.f 20.0V and internal resistance 4.0Ω is connected to a resistor of resistance 10.0Ω. Calculate

(i) Power generated (02marks)

Power generated = IE, but $I = \frac{E}{R+r}$

Thus, power = $\frac{E^2}{(R+r)} = \frac{20^2}{10.0+4.0} = 28.75W$

(ii) Efficiency of the circuit (02marks)

$$\text{Efficiency, } \eta = \frac{I^2R}{IE}\ 100\%$$

$$= \frac{IR}{E}\ x\ 100\% = \frac{ER}{E(R+r)}\ x\ 100\%$$

$$= \frac{R}{(R+r)}\ x\ 100\%$$

$$= \frac{10}{10+4}\ x\ 100\%$$

$$= 71.4\%$$

10.(a)(i) Define **capacitance** and **dielectric constant**. (02marks)

The capacitance of a capacitor is the ratio of the magnitude of charge on either plates of the capacitor to the potential difference between the plates

Dielectric constant of a material is the ratio of capacitance of a capacitor when the space between the plates is filled with a dielectric material to the capacitance of the same capacitor when the space between it plate is a vacuum.

(ii) State the factors which affect the capacitance of a capacitor. (02marks)

- Separation of the plates
- Area of overlap of the plates
- Permittivity of the medium between the plates

(b) A capacitor of capacitance C_1 is charged by a battery of e.m.f, V_0. The charging battery is then removed and the capacitor is connected to uncharged capacitor of capacitance, C_2. Show that the loss of energy after connection is given by

$E = \frac{1}{2}\left[\frac{C_1C_2}{C_1+C_2}\right]V_0^2$ (05marks)

Energy stored in the capacitor, $E_0 = \frac{1}{2}CV^2$

Total charge before connection, $Q_0 = C_1V_0$

Total charge after connection, $Q = (C_1 + C_2)V$

Total charge before connection = total charge after connection

Hence Q = Q0

$\Rightarrow C_1V_0 = (C_1 + C_2)V$

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

Total energy before connection, $E_0 = \frac{1}{2}C_1V_0^2$

Total energy after connection, $E = \frac{1}{2}(c_1 + C_2)\left(\frac{C_1V_0}{(C_1+C_2)}\right)^2$

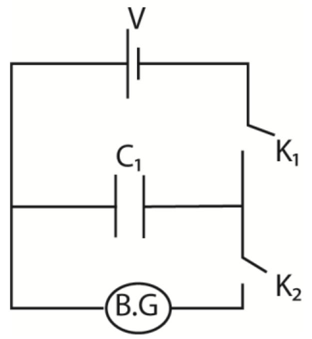
Energy loss = $E_0 - E$

$$= \frac{1}{2}C_1V_0^2 - \frac{1}{2}(c_1 + C_2)\left(\frac{C_1V_0}{(C_1+C_2)}\right)^2$$

Solving

Energy loss, $E = \frac{1}{2}\left[\frac{C_1C_2}{C_1+C_2}\right]V_0^2$

(c) Describe an experiment to measure the capacitance of a capacitor using a ballistic galvanometer. (05marks)

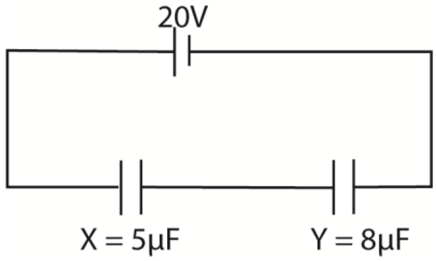


- The circuit is connected as shown with a capacitor of known capacitance C_1.
- Switch K1 is closed and K_2 is opened. The capacitor of capacitance C_1 is charged by the battery of e.m.f V.
- K_1 is opened and K_2 is closed to discharge the capacitor through the ballistic galvanometer, B.G. the first deflectionof the B.G θ_1 is noted
- The capacitor is then is then replaced with the capacitor of unknown capacitance C_2.the experiement is repeated and deflection θ_2 is noted
- Hence $\frac{c_2}{C_1} = \frac{\theta_2}{\theta_1}$; $c_2 = c_1\frac{\theta_2}{\theta_1}$

(d) A capacitor, X of 5.0μF and another, Y of 8.0μF are connected in series with a 20V supply.

Calculate the;

(i) Charge on X (04marks)



For capacitors in series, overall capacitance, C = $\frac{C_1C_2}{C_1+C_2}$

$$C = \frac{5 \times 10^{-6} \times 8 \times 10^{-6}}{5 \times 10^{-6}+8 \times 10^{-6}} = 3.08 \times 10^{-6}F$$

Since Q = CV

Then $Q = 3.08 \times 10^{-6} \times 20 = 6.16 \times 10^{-5}C$

(ii) Potential drop across X (02marks)

$V = \frac{Q}{C} = \frac{6.16 \times 10^{-5}}{5 \times 10^{-6}} = 12.3V$

END