UACE PHYSICS PAPER 2015 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.

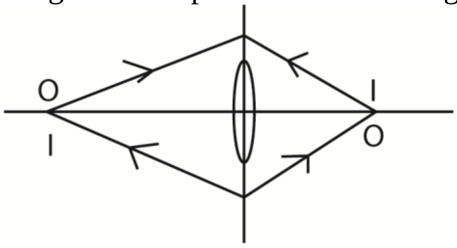
Assume where necessary

Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 x10^{-19}C$
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

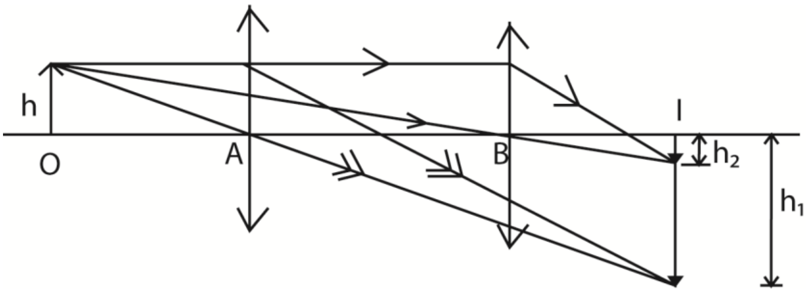
1. (a) Explain what is meant by conjugate points. (02marks)

These are two points, O and I. each on the opposite side of a convex lens such that an object and its image at these points are interchangeable.



(b) A converging lens forms an image of height, h_1 on a screen of an object O of height, h. When the lens is displaced towards the screen, an image of height, h_2 is formed on the screen.

(i) Sketch a ray diagram to show the formation of the images on the screen. (02marks)



(ii) Show that h = $\sqrt{h_1 h_2}$ (04marks)

O and I are conjugate points with respect to the lens

OB = AI and OA = BI

At point A, linear magnification, Ma = $\frac{AI}{OA} = \frac{h_1}{h}$ ……………………. (i)

At point B, linear magnification, Mb = $\frac{BI}{OB} = \frac{h_2}{h}$ ……………………. (ii)

But AI = OB

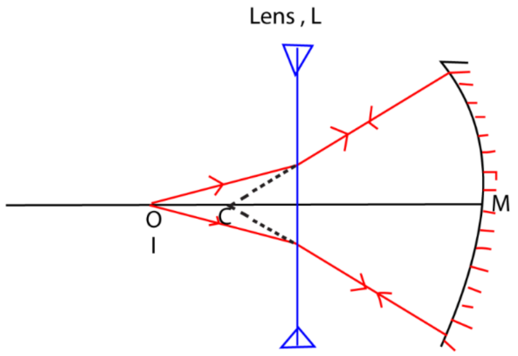
$\frac{h}{h_1} = \frac{h_2}{h}$

$h^2 = h_1h_2$

h =$\sqrt{h_1 h_2}$

(c) Describe an experiment to determine focal length of a diverging lens using a concave mirror of known focal length.

Determination of focal length of concave lens using concave mirror.



(i) An illuminated object is placed beyond the center of curvature of a concave mirror of known radius of curvature, r.

(ii) A diverging less L is placed between O and M and its position is adjusted until a clear image I is formed besides O.

(iii) Distance LI and LM are measured and recorded.

(iv) For the lens, object distance, u = -CL = - (r-LM); image distance, v =LI or LO

The focal length, f, is calculated from $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

(d) The objective of astronomical telescope in normal adjustment has a diameter of 150mm and focal length of 3.0m. The eyepiece has focal length of 25.0mm. Calculate

(i) the position of the eye ring (03marks)

$u = f_0 + f_e = 3000 + 25 = 3025mm$

$f = f_e = 25mm$

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

$\frac{1}{25} = \frac{1}{3025} + \frac{1}{v}$; v = 25.2mm

∴ position of eye-ring = 25.2mm

(ii) diameter of the eye-ring (03marks)

Angular magnification, M = $\frac{diameter\ of\ objective}{diameter\ of\ eye-ring} = \frac{f_e}{f_0}$

$$\frac{150}{D_e} = \frac{3000}{25}$$

$D_e = 1.25mm$

(c) Give one advantage of placing the eye at the eye-ring (01mark)

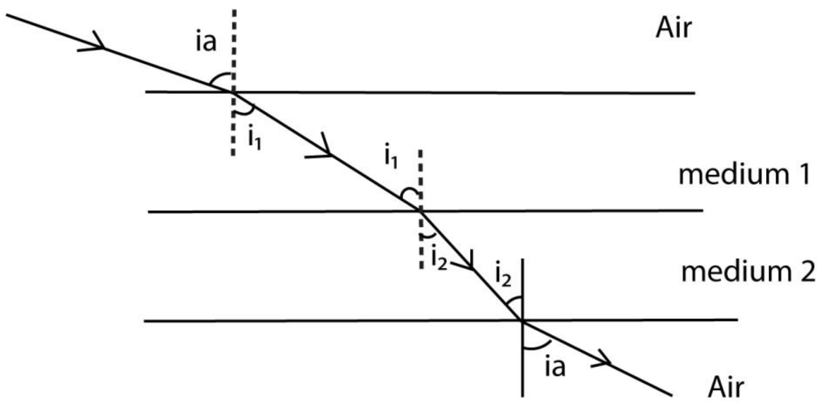
A clearest image is observed.

2. (a) show that for a ray of light passing through layers of transparent media separated by parallel boundaries,

nsini = a

where a is a constant and n is the refractive index of the medium containing angle i. (04marks)

Consider a ray of light moving from air through a series of media **1, 2** and then finally emerge into air as shown.



At air – medium 1 interface, Snell's law gives $\frac{\sin i_a}{\sin i_1} = n_1$

⇨ $\sin i_a = n_1 \sin i_1$ .... (i)

At air – medium 2 interface, Snell's law gives $\frac{\sin i_a}{\sin i_2} = n_2$

⇨ $\sin i_a = n_2 \sin i_2$ .... (ii)

Equating equation (i) and (ii) gives

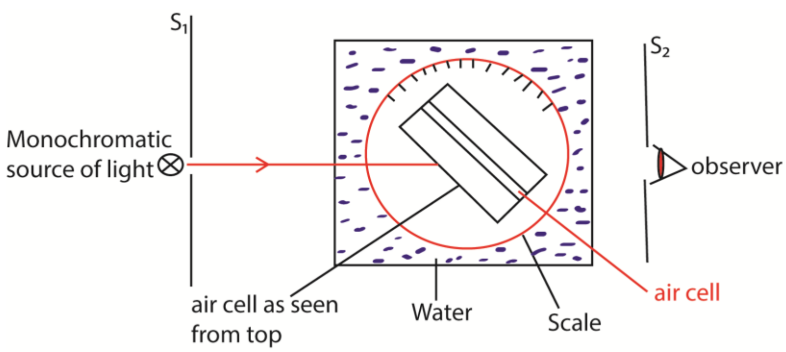
$n_1 \sin i_1 = n_2 \sin i_2$.

∴ n sin i = a constant.

(b) (i) What is meant by critical angle? (01mark)

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

(ii) Describe an experiment to determine the critical angle for a water-air boundary. (05marks)

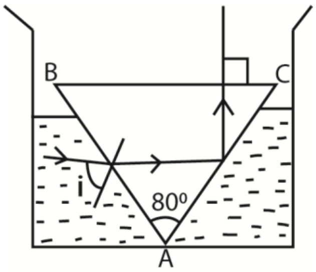


- The air cell is immersed in water.

- A beam of monochromatic light is directed onto the air cell and then observed through the cell from the opposite side at **E**.
- The cell is then rotated on one side until light is suddenly cut off and the angular position **θ1** is noted.
- The cell is again rotated in the opposite direction until light is suddenly cut off and the angular position **θ2** is noted.

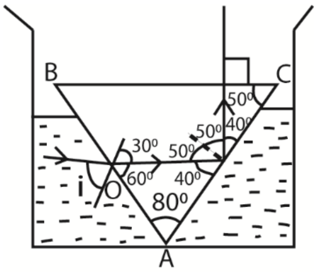
Critical angle, C $=\frac{\theta}{2}$, where **θ** = $\frac{\boldsymbol{\theta 1 + \theta 2}}{\mathbf{2}}$

(c) The figure below shows an isosceles prism ABC of refractive index 1.51, dipped in a liquid with refractive edge downwards. A ray of light incident on the prism at an angle i = 34.6^0 emerges perpendicularly through the base.



Calculate the refractive index of the liquid (04marks)

Solution



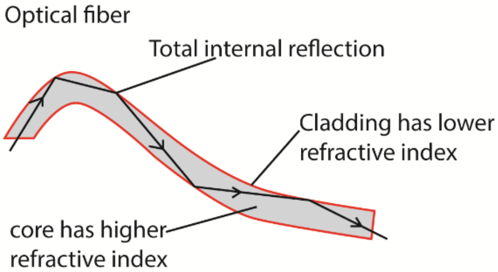
The angles are represented on the diagram above, r = 30^0

From nsin i = constant

nsin34.6 = 1.51sin30

n = 1.33

(d) Explain how an optical cable transmits light. (03marks)



An optical fiber is made of a transparent material coated with another less optically dense material. Light entering the pipe strikes the boundary of the media at an angle of incidence greater than the critical angle. Total internal reflection thus occurs. This takes place repeatedly in the pipe until the light beam emerges from the pipe.

(e) An optical pin held above a concave mirror containing water of refractive index 1.33, coincides with its image at a distance of 12cm above the mirror. When the water is replaced by a little quantity of a certain liquid, the point of coincidence of the object and the image becomes 13.3cm. Calculate the refractive index of the liquid. (03marks)

Let the radius of curvature of the mirror be r

$\eta_w = \frac{r}{h_w}$ and $\eta_l = \frac{r}{h_l}$

⇨ $\frac{\eta_l}{\eta_w} = \frac{h_w}{h_l}$

⇨ $\frac{\eta_l}{1.33} = \frac{12}{13.3}$

$\eta_l = 1.2$

SECTION B

3. (a) Distinguish between progressive and stationary waves

Progressive waves	Stationary waves
(i) There is energy flow along the wave	(i) No energy flow
(ii) Vibrations have the same amplitudes and frequency	(ii) Amplitudes are different and depend on position along the wave
(iii) Phases of vibrations changes for different points along the wave	(iii) Some points are permanently fixed
(iv) Particles in phase are nλ apart where n = 1,2,3 …….	(iv) Particles at distance $\frac{3\lambda}{2}$ apart are in phase

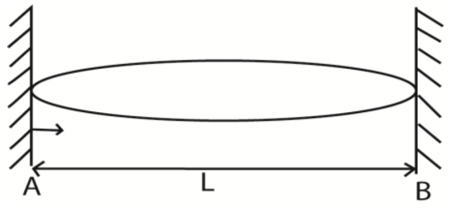
(b)(i) What are overtones?

Overtones are notes of higher frequencies produced by an instrument after fundamental (or main) notes.

(i) Explain why a music tone played on one instrument sound differently from the same note played on another instrument.

- When an instrument is played, all the allowed vibration take place producing different frequencies.
- The quality of the musical note is determined by the number and strength (intensity) of the overtones.
- Thus when the note played on an instrument has fewer overtones, it sounds different from the same note played on different instrument with more overtones.

(c) A stretched string of length L, is fixed at both ends and then set to vibrate in its allowed modes. Derive an expression for frequency of the second overtone in terms of fundamental frequency.

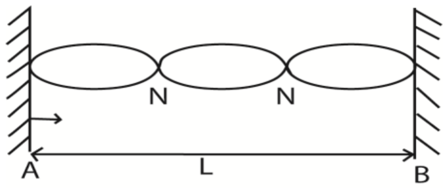


When the string is vibrating with fundamental frequency, the number of waves between A and B is $\frac{1}{2}$

L = $\frac{1}{2}\lambda$ i.e. λ =2L

Let the velocity of the wave be v, then frequency of fundamental note, $f_0 = \frac{v}{\lambda} = \frac{v}{2L}$

When vibrating with 2nd overtone, the number of waves made by the length of the string between A and B is $\frac{3}{2}\lambda$.



L = 2λ i.e. λ =$\frac{2}{3}$L

The $f_2 = \frac{v}{\lambda} = \frac{v}{\frac{2}{3}L}$

$= \frac{3v}{2L} = 3(\frac{v}{2L})$

∴ $f_2 = 3f_0$

(d) A wire of length 0.60m and mass 9 x 10^{-4}kg is under tension of 135N. The wire is plucked that it vibrates in its third harmonic. Calculate the frequency of the third harmonic.

$$\mu = \frac{m}{l} = \frac{9 \, x \, 10^{-4}}{0.6} = 1.5 \, x \, 10^{-3} kgm^{-1}$$

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{135}{1.5 \, x \, 10^{-3}}} = 300ms^{-1}$$

The frequency of the third harmonic

$$f_2 = 3f_0 = \frac{2v}{2l} = \frac{2 \, x \, 300}{2 \, x \, 0.6} = 750Hz$$

(e) Describe the variation of pressure with displacement of air in a closed pipe vibrating with fundamental frequency.

At the mouth, air is free to move and therefore the displacement of air molecules is large and the pressure is low. At the closed end, the molecules are less free and the displacement is minimal (or zero) and the pressure is high.

4. (a) What is meant by the following as applied to waves

(i) Phase difference

It is the difference in phase angles of two waves at a given time. Or it is a difference in phase angles of two points in a wave.

(ii) Optical path difference

It is $n_1x_1 - n_2x_2$, where n_1 and n_2 are refractive indices of media and x_1 and x_2 are the respective geometrical paths.

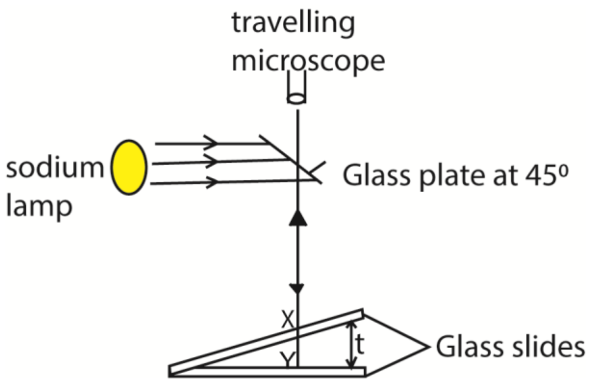
Or

It is the difference in the length of paths taken by two light waves from the source to the point of meeting.

Or

It is the difference in length of paths taken by two wave trains from coherent sources in the same time interval.

(b)(i) Explain how interference fringes are formed in an air wedge.



- Light from the lamp is reflected by the inclined glass plate so that it is incident on the wedge normally.
- On reaching X, some of the light is reflected at the bottom part of the top glass slide while part is transmitted and some is reflected at Y on the top part of the bottom glass slide.
- The two reflected waves are coherent and interfere.
- The wave reflected at x suffers no phase change while that from Y reflected from at boundary with a denser medium suffers a phase change of π due to reflection which is equivalent to an additional path of $\frac{\lambda}{2}$
- Therefore a dark band is formed at the point of contact of the slide.
- Where the path difference is an integral multiple of wavelength, a bright band is formed; i.e. when (2t =$\left(m \pm \frac{1}{2}\right)\lambda$, where m = 0, 1, 2, 3 … due to reinforcement.
- Where the path difference is an odd multiple of half the λ, a dark band is formed (i.e. 2t = mλ); where m = 0, 1, 2, 3, …

(ii) Two glass slides are separated by a thin wire to form an air wedge. When the wedge is illuminated normally by light of wavelength 5.6×10^{-7}m, a total of 20 fringes occupying a distance of 15mm are obtained. Calculate the angle of the wedge.

tan ϕ =$\frac{\lambda}{2y}$; y = $\frac{15}{20}\ x\ 10^{-3}$ = 0.75 $\times 10^{-3}$m

$= \frac{5.6 \, x \, 10^{-7}}{2 \, x \, 0.75 \, x \, 10^{-3}} = 5$

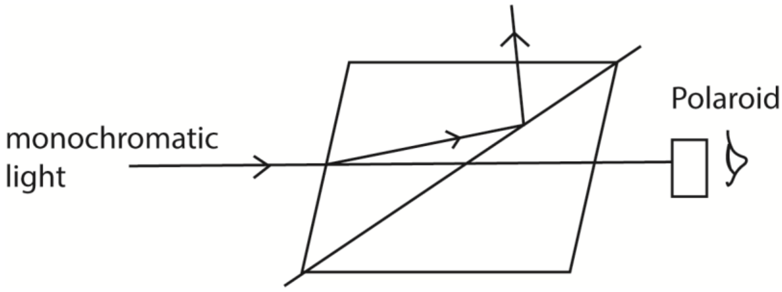
ϕ = 0.021^0

(c) In Young's double slit experiment, 21 bright fringes occupying a distance of 3.6mm were visible on the screen. The distance of the screen from double slit was 29cm and the wavelength of the light used was 5.5 x 10^{-7}m.Calculate the separation of the slit.

a = $\frac{\lambda D}{x}$ where x = $\frac{3.6 \, x \, 10^{-3}}{2L}$

$= \frac{5.5 \, x \, 10^{-7} \, x \, 0.29}{3.6 \, x \, 10^{-3}} \, x2L = 9.304 \, x \, 10^{-4} m$

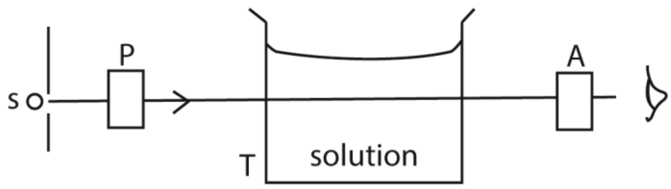
(d)(i) Describe how plane polarized light can be produced by double refraction



- A narrow beam of monochromatic light is made incident on nicol prism and viewed from the opposite side as shown above
- The angle of incidence is gradually increased or change and at each angle, the Polaroid is rotated about an axis through its plane.
- At one point, the emergent light is plane polarized.

(ii) Describe practical use of polarized light

- **Polarized light is used in measurement of the concentration of sugar in a solution**



s - source of nomochromatic light
P and A are nicol prism
T- glass vessel

The apparatus are arranged as above

First without the solution, the prism A called analyzer is rotated until the emergence light from T is completely extinguished. This orientation is noted.

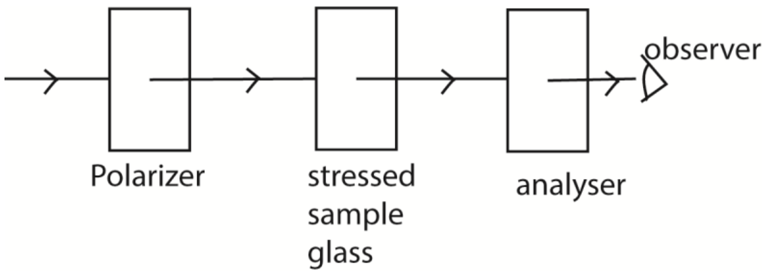
T is filled with sugar solution, on looking through A, light can now be seen.

A is then again rotated until light is extinguished. This point is noted.

The angle θ between the two positions is noted.

The angle of rotation θ is proportional to the concentration.

- **It is used in stress analysis**



The apparatus is arranged as above

The polarizer and analyzer are Polaroid which are crosses with respect to each other so that light does not pass through.

When a piece of stressed glass is placed between the Polaroid, a pattern of interference fringes can be seen.

The intensity of light depends on the degree if stress and hence the region and degree of stress is determined.

SECTION C

5. (a) What is meant by the following as applied to the earth's magnetic field?

(i) Magnetic meridian (01 mark)

Magnetic meridian is the vertical plane through the magnetic north and south poles of earth's magnet.

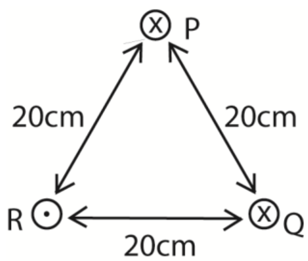
(ii) Angle of dip (01marK)

Angle of dip is the angle between the resultant earth's magnetic field and horizontal.

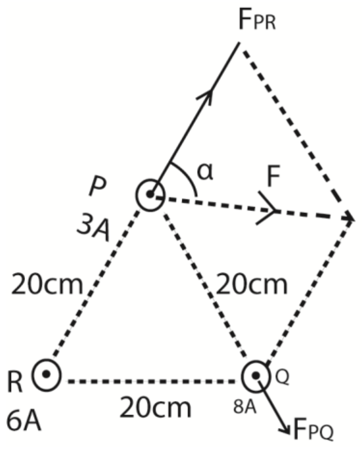
(b) (i) Define the ampere (01mark)

The ampere is steady current flowing in negligible cross-section, one meter apart in vacuum when the force between them is $2 \times 10^{-7} NM^{-1}$.

(ii) there conductors P, Q and R carrying currents 3A, 6A and 8A respectively are arranged as shown in the figure below



Calculate the force experienced by conductor P. (06marks)



$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi r}$

$F_{PR} = \frac{4\pi\ x\ 10^{-7}\ x\ 3\ x\ 8}{2\pi\ x\ 0.2}$ x 2.4 x 10^{-5}

$F_{PQ} = \frac{4\pi\ x\ 10^{-7}\ x\ 6\ x\ 3}{2\pi\ x\ 0.2}$ x 1.8 x 10^{-5}

$F^2 = F_{PR}^2 + F_{PR}^2 - 2F_{PR}F_{PQ}cos\theta$

$F^2 = (2.4\ x\ 10^{-5})^2 + (1.8\ x\ 10^{-5})^2 - 2$ x $(2.4\ x\ 10^{-5})x\ (1.8\ x\ 10^{-5})\cos 60^0$

$F = 2.16\ x\ 10^{-5} N$

$\frac{sin\alpha}{1.8\ x\ 10^{-5}} = \frac{\sin 60^0}{2.16\ x\ 10^{-5}}$

$\alpha = 46.2^0$ where α is the angle between F and F_{PR}.

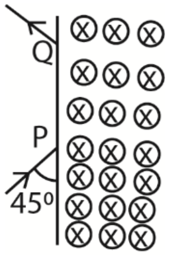
(d) (i) Define magnetic flux and magnetic flux density (02marks)

Magnetic flux is the product of the magnetic flux density and the projection of the area normal to the magnetic field.

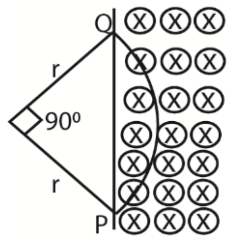
Or

Magnetic flux density is the force acting on a conductor of length 1m carrying current of 1A placed perpendicular to magnetic field.

(ii) A charge particle of mass 1.4 x 10^{-27}kg and charge 1.6 x 10^{-19}C enters a region of uniform magnetic field of flux density 0.2T at point P and emerges at a point Q as shown in the figure below



If the speed of the particle is 10^7ms^{-1}, calculate the distance PQ. (04marks)



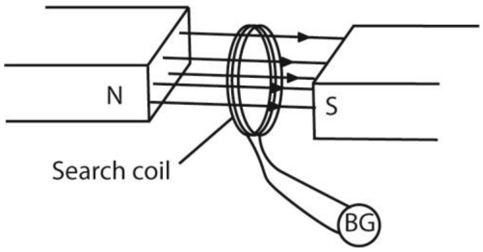
The conductor describes a circle of radius, r.

F = BQV = $\frac{mV^2}{r}$

r = $\frac{mV}{BQ} = \frac{1.4 \, x \, 10^{-27} \, x \, 10^{7}}{0.2 \, x \, 1.6 \, x \, 10^{-19}}$ = 0.4375m

PQ = $\sqrt{r^2 + r^2}$ = $\sqrt{0.4375^2 + 0.4375^2}$ = 0.62m

(d) Describe an experiment to measure the magnetic flux density between the pole pieces of a strong magnet. (05 marks)



A search coil is connected to a ballistic galvanometer. The coil is then placed with its plane normal to the magnetic field whose magnetic flux density, B is required.

The coil is then pulled completely out of the field and deflection θ_1 of ballistic galvanometer is noted

$\frac{NAB}{R} = CQ$, where R = resistance of the coil

A capacitor of known capacitance Q is charged to a p.d. V and is then discharged through the ballistic galvanometer. The deflection θ_2 is noted

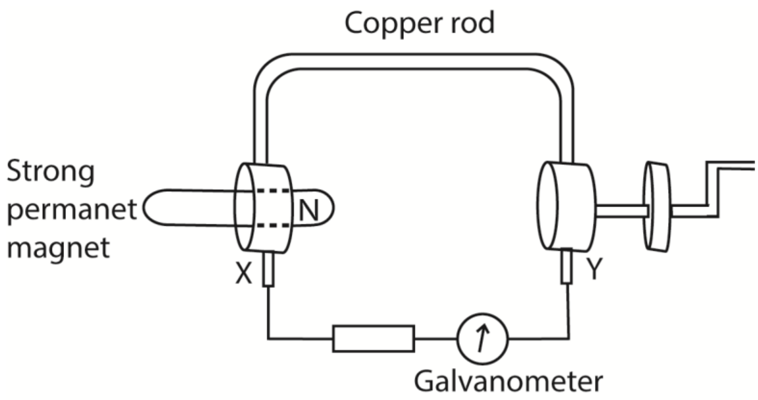
CV = Cθ_2

The magnetic flux density B is now calculated from B = $\frac{CVR\theta}{NA\theta\prime}$ 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.

6. (a) (i) state the laws of electromagnetic induction (02marks)

- **Lenz's law of electromagnetic induction**; the induced e.m.f acts in such a direction as to oppose the change causing it
- Faraday's law of electromagnetic induction; the magnitude of induced e.m.f in a conductor is directly proportional to the rate of change of magnetic flux linking it.

(ii) Describe with aid of a diagram, an experiment to verify Faraday's law of electromagnetic induction (05marks)



X and Y are brush contact.

A copper rod which can rotate round the north pole of permanent magnet is connected as shown above.

The wheel is turned steadily until the deflection of the galvanometer is constant.

The time, t, for N rotations is measured and the number of revolution (n) per second is determined from n = $\frac{N}{t}$. The deflection θ of the galvanometer is also noted.

The experiment is repeated at different speed of rotation of the wheel and values of n and θ tabulated.

A graph of θ against n is plotted.

A straight line graph is obtained implying that $\theta \propto n$

Since $\theta \propto$ e.m.f induced and $n \propto$ speed of rotation of the rod, then the induced e.m.f is proportional to the rate of change of flux linkage.

(b) Explain

(i) Why when a plate of copper is pushed into a strong magnetic field between the poles of a powerful electromagnet, considerable resistance to the motion is felt, but no such effect is felt with a sheet of glass.

When the copper plate cuts the magnetic field and Eddy currents are induced in it

The magnetic field due to Eddy currents interacts with the applied field opposing the motion.

Glass is an insulator no eddy current is induced in it hence no resistance to its motion.

(ii) How damping is achieved in moving coil galvanometer (03marks)

The coil is wound on an iron core. When the coil (together with the core) rotates in the magnetic field, Eddy currents are induced in the core. The magnetic field due to the

Eddy currents interacts with the applied field causing retardation (opposing the rotation) of the coil. So the coil comes to rest sooner than it would for accurate reading.

(c) An aero plane of wing span 30m flies horizontally at a speed of $1000kmh^{-1}$.

What is the p.d across the tips of its wings, if the horizontal component of the earth's magnetic field is $1.46 \times 10^{-4}T$? (Angle of dip at the place is 70^0) (03marks)

$E = B_V Lv$; but $Bv = B_H \tan 70^0$

$E = B_H \tan 70^0 Lv$

$= 1.46 \times 10^{-4} \times \tan 70^0 \times 30 \times \frac{1000 \ x \ 1000}{1 \ x \ 60 \ x \ 60} = 3.34V$

(d) A coil of 500 turns and area $80cm^2$ is rotated at 1200 revolution per minute about an axis perpendicular to its plane and magnetic field of flux density 0.25T.

Calculate the maximum e.m.f induced in the coil (03marks)

E.m.f = BANω

= BAN.2πf

$= 0.25 \times 80 \times 10^{-4} \times 500 \times 2\pi \times \frac{1200}{60}$

= 126V

7. (a) (i) Define root mean square (r.m.s) current of an a.c (01mark)

It is a steady current which converts electrical energy to other forms of energies in a given resistor at the same rate as the alternating current.

(ii) Derive an expression for capacitive reactance (04marks)

Applied voltage = $V_0 \sin \omega t$

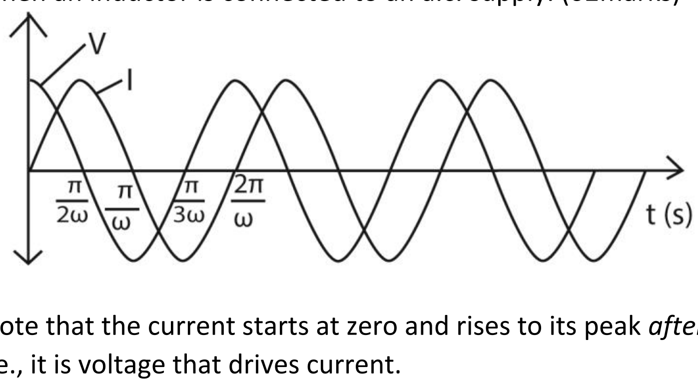
$Q = CV = C V_0 \sin \omega t$

$I = \frac{dQ}{dt} = \frac{d(CV_0 sin\omega t}{dt}$

⇨ $I_0 = CV_0\omega$

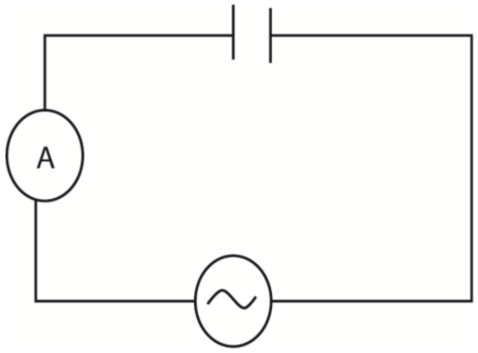
$Xc = \frac{V_0}{I_0} = \frac{1}{C\omega}$ or $\frac{1}{2\pi fc}$

(iii) Sketch on the same axes, the graphs showing variation of applied p.d and current when an inductor is connected to an a.c. supply. (02marks)



Note that the current starts at zero and rises to its peak *after* the voltage that drives it, i.e., it is voltage that drives current.

(b) (i) A capacitor of capacitance, C, and an ammeter are connected in series across an alternating voltage, V, of frequency f. Explain why current apparently flow through the capacitor. (03marks)

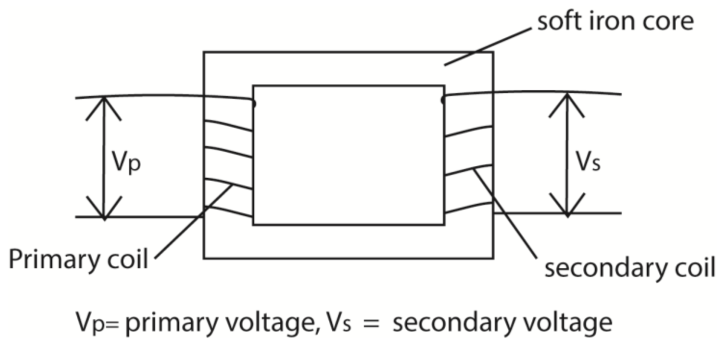


- When the circuit is completed, the ammeter deflects indicating that current is flowing in it.
- When the circuit is closed, the capacitor charges and discharges in opposite direction alternatively. Charge (current) therefore flows in the circuit continuously and the capacitor appears to conduct current.
- In the first quarter, capacitors charges to maximum and in second quarter, it discharges.
- In the third quarter, it charges again but with charge on the plate interchanged.
- In the fourth quarter, it discharges.
- It is repeated at the frequency of the a.c.
- The charging and discharging current flows throughout the circuit though no charge passes across the capacitor.

(ii) A sinusoidal p.d of r.m.s value of 20V and frequency50Hz is applied across a 100μF capacitor. Calculate the capacitive reactance of the circuit. (02 marks)

$$X_C = \frac{1}{2\pi fc} = \frac{1}{2\pi \, x \, 50 \, x \, 100 \, x \, 10^{-6}} = 31.8\Omega$$

(c) Describe the mode of operation of a transformer. (04marks)



- Transformer consists of two coil of insulated wire, the primary and secondary wound on laminated soft iron core.
- When alternating voltage, V_p is connected to primary coil, it drives alternating current in the primary coil.
- The alternating current produces a varying magnetic flux ϕ_p that link the primary coils inducing a back e.m.f E_B in the primary.
- The varying magnetic flux, ϕ_s links the secondary coil by mutual induction/inducing alternating voltage, V_s in the secondary

$V_p = N_p\frac{d\phi_p}{dt}$ ……………………….(i)
$V_s = N_s\frac{d\phi_p}{dt}$……………………….(ii)
Eqn (i) ÷Eqn (i)
$\frac{V_p}{V_s} = \frac{N_p}{N_s}$

When $N_s > N_p$ the transformer is a step up

$N_s < N_p$ the transformer is a step down

(d) A transformer connected to a.c supply of peak voltage 240V is to supply a peak voltage of 9.0V to a mini-lighting system of resistance 5Ω. Calculate the

(i) r.m.s current supplied to the lighting system (02marks)

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

$I_{r.m.s} = \frac{V_{r.m.s}}{R} = \frac{V_0}{\sqrt{2}R}$

$= \frac{9.0}{5\sqrt{2}} = 1.27A$

(ii) average power delivered to the lighting system. (02marks)

$P = I^2R$

$= I_{r.m.s}^2R$

$= (1.27)^2 \times 5$

$= 8.1W$

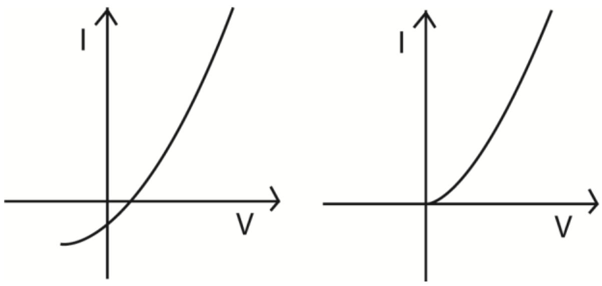
SECTION D

8. (a)(i) Define temperature coefficient of resistance (01mark)

Temperature coefficient of resistance is the fractional change in resistance at 0^0C for every degree Celsius rise in temperature.

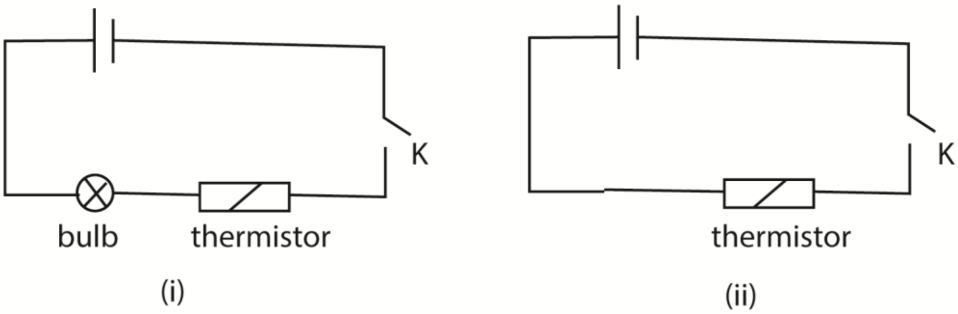
(ii) Explain the origin of the heating effect of electric current in metal conductor. (03marks)
During the flow of current, electrons moving through the metal conductor may collide with the positive ions in the metallic lattice. On collision, the kinetic energy possesses by electron is transferred into heat.

(iii) Describe with the aid of an I-V sketch the variation of current with p.d across a semiconductor diode. (02marks)



When the diode is forward biased, the current increases rapidly as the p.d is increased. When the reversed biased little or no current flows

(b) A cell, a bulb, a switch and a thermistor with negative temperature coefficient of resistance are connected as shown in the figures (i) and (ii) below



(i) Explain what would happen when in figure (i) switch K is closed (04marks)

At room temperature, the resistance of thermistor is high, current flowing is thus small and bulb lights dimly. As current flows, the thermistor heats up (temperature increases) and the resistance decreases leading to increase in current and brightness of the bulb.

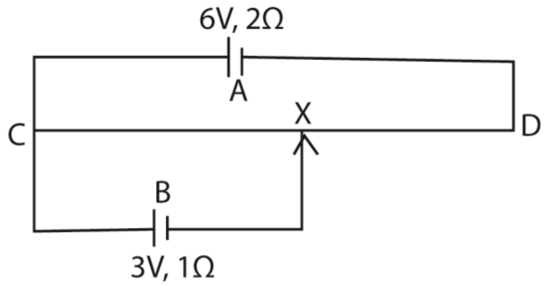
(ii) If the bulb in figure (i) is removed and the circuit connected as shown in figure (ii), explain what would happen when switch K is closed (03marks)

On closing K, the thermistor heats up and its resistance reduces. The reduction in resistance causes high current through the cell. High current in the cell and due to internal resistance, overheating occurs destroying the cell

(c) State the law of conservation of current at the junction (01mark)

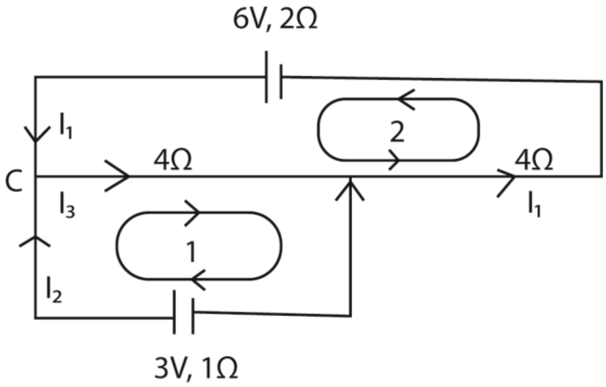
The law of conservation of current at a junction states that the algebraic sum of current at the junction is zero

(d) Two cells A of e.m.f 6V and internal resistance 2Ω and B of e.m.f3V and internal resistance 1Ω respectively are connected across a uniform resistance wire Cd of resistance 8Ω as shown in the figure below



If X is exactly in the middle of the wire CD, Calculate the

(i) Power dissipated in CX.(04marks)



$I_3 = I_1 + I_2$ …………………………………… (i)

Consider loop 1

$3 = I_2 + 4I_3$ ………………………………….. (ii)

Consider loop 2

$6 = 2I_1 + 4I_3 + 4I_1$

$6 = 6I_1 + 4I_3$………………………… (iii)

Eqn. (ii) and eqn. (i)

$3 = I_2 + 4(I_1+I_2)$

$= 5I_2 + 4I_1$ ………………………………… (iv)

Eqn. (iii) and eqn. (i)

$6 = 6I_1 + 4(I_1 + I_2)$

$= 10I_1 + 4I_2$

$3 = 5I_1 + 2I_2$……………………… (v)

Eqn. (v) x 5 – eqn. (iv) x 2

$9 = 17I_1$

$\therefore\ I_1 = 0.55A$

Substituting I_1 in equation (iii)

$6 = 6 \times \frac{9}{17} + 4I_3$

$I_3 = \frac{12}{17} = 0.71A$

Power = $I^2R = \left(\frac{12}{17}\right)^2 x\ 4 = 1.993W$

(ii) P.d across the terminals of cell A.(02marks)

Terminal p.d = $6-2I_1$

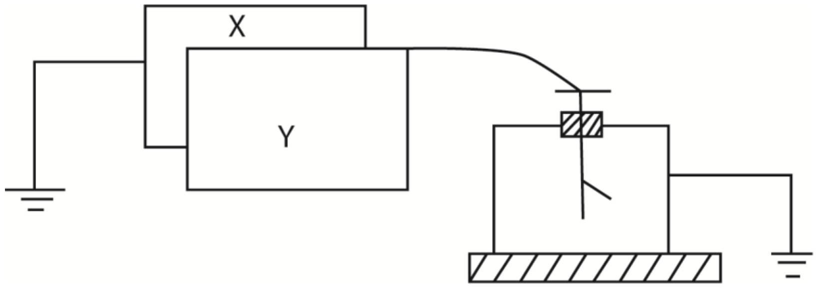
$= 6 - 2 \times \frac{9}{17}$

$= 4.94V$

9. (a)(i) Define capacitance of a capacitor (01mark)

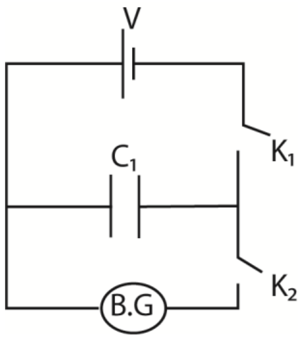
Capacitance of a capacitor is the ratio of the magnitude of charge on either plate of the capacitor to the potential difference across the plates.

(ii) Describe briefly an experiment to show the effect of placing a sheet of glass or mica between the plates of a capacitor on capacitance. (05marks)



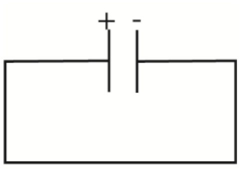
- Two plates X and Y are placed close to each other but not touching as shown above.
- Plate Y is given a charge, Q, by means of an electrophorus and divergence of the leaf of the electroscope noted.
- A sheet of glass or mica is placed between the plates; the divergence of the leaf is observed to decrease, implying than the new p.d between the plates has decreased and the capacitance has increased since C = $\frac{Q}{V}$ and Q is constant.

(b) Describe how the unknown capacitance of a capacitor can be determined using a ballistic galvanometer. (04marks)



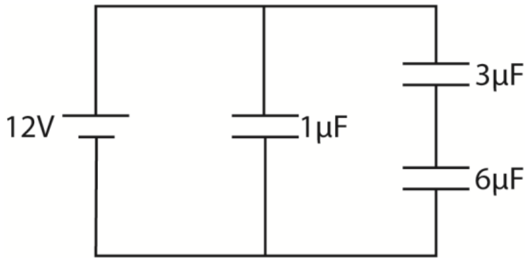
- The circuit is connected as shown with a capacitor of known capacitance C_1.
- Switch K1 is closed and K_2 is opened. The capacitor of capacitance C_1 is charged by the battery of e.m.f V.
- K_1 is opened and K_2 is closed to discharge the capacitor through the ballistic galvanometer, B.G. the first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

(c) Explain briefly how a charged capacitor can be fully discharged. (02marks)



The wire is connected from the positive plate to the negative plate. Electrons flow from the negative plate to the positive plate neutralizing the positive charges. The follow of electrons continues until all the capacitor is fully neutralized.

(d) A 3µF capacitor is connected in series with a 6µF capacitor. The combination is then connected in parallel with 1µF capacitor to 12V battery as shown in the figure below



Calculate

(i) Charge stored on each capacitor (05marks)

Charge stored on 1µF

Q = CV = $1 \times 10^{-6} \times 12 = 10 \times 10^{-6}$C

Total capacitance in series

C = $\frac{6\ x\ 3}{6+3} = 2\mu F$

∴ The charge stored in combination

$Q = CV = 2\ x\ 10^{-6}\ x\ 12 = 2.4\ x\ 10^{-6} C$

The charge on either 6µF or 3µF capacitor is 2.4µC

(ii) Energy stored in the 6µF capacitor when fully charged (03marks)

E = $\frac{Q^2}{2C} = \frac{(2.4\ x\ 10^{-6})^2}{2\ x\ 6\ x\ 10^{-6}}$ = 4.8×10^{-5}J

END