UACE PHYSICS PAPER 2000 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

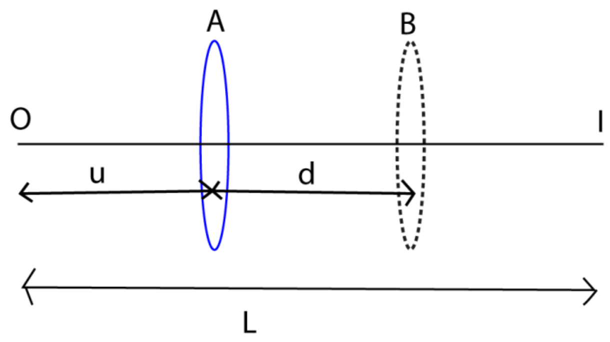
Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 x10^{-19}C$
Electron mass	$9.11 \times 10^{-31}kg$
Plank's constant, h	$6.6 \times 10^{-34}Js$
Speed of light in the vacuum, c	$3.0 \times 108ms^{-1}$
Specific heat capacity of water	$4.200Jkg^{-1}K^{-1}$
Avogadro's number, N_A	$6.02 \times 10^{23}mol^{-1}$
The constant, $\frac{1}{4\pi\varepsilon_0}$	$9.0 \times 10^9F^{-1}m$
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) Define the principal focus of a converging lens. (1mark)
   The principal focus of a converging lens is the point on the principal axis at which paraxial rays converge after refraction by the lens.

   (b) A converging lens of focal length, f, is placed between a finite object and a screen. The position of the screen is adjusted until a clear magnified image is obtained on the screen. Keeping the screen fixed in this position, a distance L from the object, the lens is displaced through a distance, d, to obtain a clear diminished image on the screen.

   (i) Draw a ray diagram to show the formation of the image in the two cases. (02marks)



(ii)Show that $L^2 - d^2 = 4df$ (05marks)

Lens A forms an image of O at I
By the principle of reversibility of light, an object at I forms an image at O. When the object and the screen are fixed, another clear image can be formed by the lens when moved from A to B.

From the diagram
OB = IA and OA =IB
OA + BI = L-d
OA + OA + L-d (since OA + IB)
2OA = L-d
AO = $\frac{L-d}{2}$ = u ……………………(i)

Also, AI = AB + BI
AI = AB + OA (since OA = BI
AI = d +$\frac{L-d}{2} = \frac{L+d}{2}$ = v
Using the formula $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$$\frac{1}{f} = \frac{1}{\frac{L-d}{2}} + \frac{1}{\frac{L+d}{2}}$$

$$\frac{1}{f} = \frac{4L}{L^2-d^2}$$

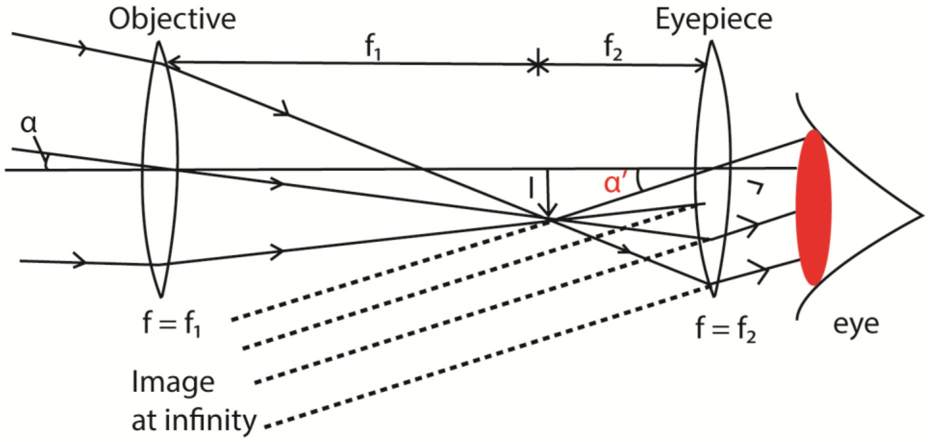
(iii) Find the product of the magnifications produced in the two cases. (02marks)

$M_1 = \frac{(L+d)/_2}{(L-d)/_2} = \frac{L+d}{L-d}$

$M_2 = \frac{(L-d)/_2}{(L+d)/_2} = \frac{L-d}{L+d}$

$M_1M_2 = \frac{L+d}{L-d} \times \frac{L-d}{L+d} = 1$

(c) (i) Draw a ray diagram to show how two converging lenses, one of long focal length, f_1, and the other of shorter focal length, f_2, can be arranged to make an astronomical telescope in normal adjustment. (02marks)



(ii) Derive the expression for the magnifying power of the telescope in this setting. (03marks)

For an aided eye (using the instrument)

For small angle, tanα' ≈ α' for small angle in radians

$\alpha' = \frac{h}{f_e}$ …………………………………………. (i)

Where, h, is the height of image I, f_e is the focal length of eye piece

For unaided eye

$\alpha = \frac{h}{f_0}$ …………………………………………….. (ii)

f_0 is the focal length of objective lens

Combining equations (i) and (ii)

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

(d) The objective of a compound microscope has focal length of 2.0cm while the eyepiece has a focal length of 5.0cm. An object is placed at a distance of 2.5cm in front of the objective. The distance of the eyepiece from the objective is adjusted so that the final image is 25cm in front of the eyepiece. Find the distance between the objective and the eyepiece. (05marks)

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

Action of eyepiece

$\frac{1}{5} = \frac{1}{u} - \frac{1}{25}$, u = 4.2cm

Action of objective

$\frac{1}{2} = \frac{1}{2.5} + \frac{1}{v}$, v = 10.0cm

Separation = u + v= 10.0 + 4.2 = 14.2cm

2. (a) (i) What is meant by refraction of light? (01mark)

Refraction is the bending of light rays at the interface between two media of different optical densities.

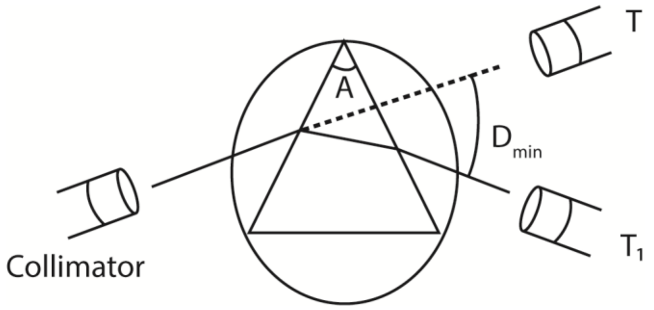
Or

It is the change n velocity of light at the interface between two media of different optical densities

(ii) State laws of refraction (02marks)

- Incident ray, refracted ray at the point of incidence all lie in the same plane
- the ration of the sine of incident angle to the sine of angle of refraction is constant for a given pair of the medium
-

(b) Describe how the refractive index of a material of a glass prism of known refractive angle can be determined using a spectrometer (06marks)



Before the spectrometer is put in to use, 3 adjustments must be made onto it and these include,

(i) The collimator is adjusted to produce parallel rays of light.
(ii) The turntable is leveled.
(iii) The telescope is adjusted to receive light from the collimator on its cross wire

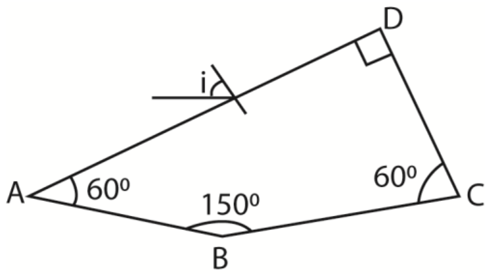
- A prism of know refractive angle A is placed on the table with refractive angle facing away from the collimator
- The table is turned in the direction of the base of the prism until light is seen.
- Keeping the light in view. The prism, table and telescope are turned until light moves in opposite direction. Position T_1 is noted.
- The table is fixed and prism is removed,
- The telescope is turned in opposite direction until the parallel light is incident at the cross wire. Position T and

angle of minimum deviation D_{min} are noted.

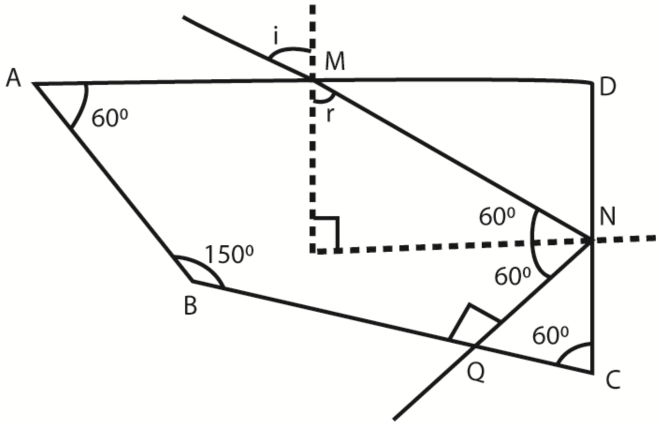
- The refractive index of glass is obtained from

$$n = \frac{sin\frac{(A+ D_{min})}{2}}{\sin\frac{A}{2}}$$

(c)



A ray of light is incident on face Ad of a glass bloc as shown in the figure above. The refractive index of the material of the glass block is 1.52. If the ray emerges normally through face BC after total internal reflection, calculate the angle, i. (05marks)



From the diagram r = 30^0

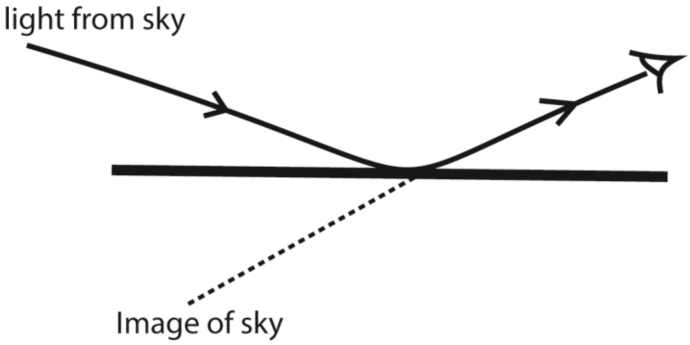
From Snell's law, nsini = constant

$$1\sin i = 1.52\sin 30$$

$$i = 49.5^0$$

(d) Explain how a mirage is formed. (03marks)

Mirage is what is observed as a pool of water on a tarmac road at some distance a head on a hot day. It is formed by total internal reflection because on hot day, the hot air near the earth surface has lower refractive index than cool air above it.



(e) An object at a depth of 3.0m below the surface of water is observed directly from above the surface. Calculate the apparent displacement of the object if the refractive index is 1.33. (03marks)

Refractive index = $\frac{Real\ depth}{Apparent\ depth}$

1.33 = $\frac{3.0}{Apparent\ depth}$

Apparent depth = 2.25

Displacement = 3 – 2.25 = 0.75cm

3. (a) State the principle of superposition of waves (1mark)

The total displacement of any particle by waves is the sum of their individual's displacements.

(b) Two loud speakers producing sound of the same frequency are placed 50m apart facing each other. An observer walks from one speaker to the other along the line of the speaker.

(i) What does the observer hear? (2marks)

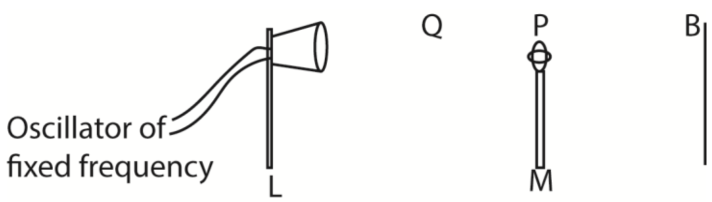
The observer hears alternate loud and soft sound. The loud and soft sounds come at equal distance along the observer's path.

(ii) Explain the observation in (b)(i) (4marks)

The two waves superpose to form interference pattern. Loud sound is heard when the path difference of the waves is an integral even multiple of a half wavelength

The soft or no sound is formed when the path difference in an integral odd multiple of half a wavelength.

(c) Describe with the aid of a diagram how you can determine the velocity of sound in air by a method which uses interference of sound. (6marks)



The loud speaker, L is connected to an oscillator of constant frequency, f.
A microphone, M is connected to the Y-plates of a cathode ray tube.
The microphone is moved away from B towards L until the amplitude of the wave on C.R.O is maximum.
The position P of the microphone is noted and distance BP is measured.
The microphone is move farther away from B to Q where another maximum amplitude of wave front is obtained. Distance BQ is measured and recorded.
The distance between two successive maxima d= BQ – BP = $\frac{\lambda}{2}$ where λ is the wavelength
Velocity of sound = fλ = 2df.

(d) A progressive wave and stationary wave each has a frequency of 240Hz and speed of $80ms^{-1}$. Calculate

(i) Phase difference between two vibrating points in progressive waves, which are 6cm apart. (04marks)

f = 240Hz, v = $80ms^{-1}$

Phase angle ϕ = $\frac{2\pi x}{\lambda}$

Phase difference ϕ = $\frac{2\pi x_1 - x_2}{\lambda}$

$$\Delta\phi = \frac{2\pi\Delta x}{\lambda}$$

Δx = 6cm = 6×10^{-2}m

⇨ $\Delta\phi = \frac{2\pi x\ 6\ x\ 10^{-2}}{\lambda}$

But v = fλ

$$\lambda = \frac{v}{\lambda} = \frac{80}{240} = \frac{1}{3}m$$

⇨ $\Delta\phi = \frac{2\pi x\ 6\ x\ 10^{-2}}{1/3}$ = 1.13 rad

(ii) Distance between nodes in stationary wave. (03marks)

Distance between nodes = $\frac{\lambda}{2}$

But λ = = $\frac{v}{\lambda} = \frac{80}{240} = \frac{1}{3}m$

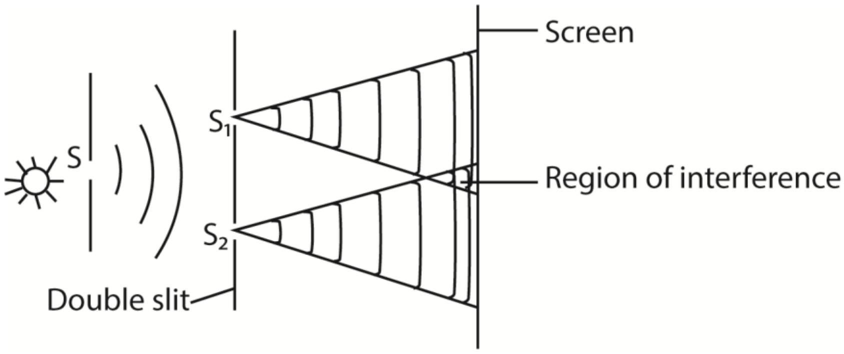
Hence distance between nodes = $\frac{1}{3} \div 2 = \frac{1}{6}m\ or\ 0.17m$

4. (a) What is meant by coherent source of light? (03marks)

Coherent sources are sources with the same frequency and nearly the same amplitude and constant phase difference between them

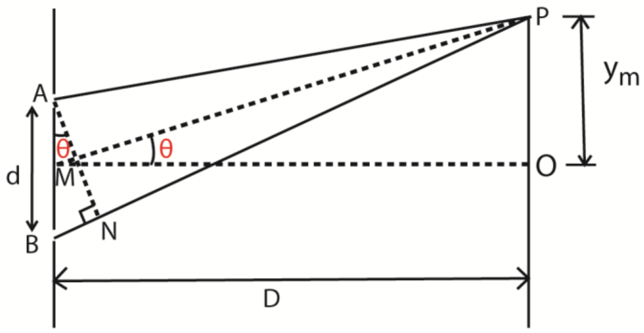
(e) (i) outline the principles of Young's double slit interference and derive the expression for fringe separation. (07marks)

The principles of Young's double slit interference



A wave from source, S, is incident on the double slits where division of wave front occurs.
This makes S1 and S2 coherent sources,
Waves S1 and S2 superpose and where a crest meets a crest or a trough meets a trough, maximum intensity is obtained.
In between the maxima are points of minimum intensity.

Fringe separation



A and B are coherent sources.

Suppose waves from A and B superpose at P to form bright fringe

Path difference, BN = BP – AP = dsinθ

For D>>d, θ is small that sinθ = dtanθ

⇨ BN = dtanθ = $\frac{dy_m}{D}$

For the mth bright fringe, BN = mλ, where λ is the wavelength

⇨ $\frac{dy_m}{D}$ = mλ

$$y_m = \frac{m\lambda D}{d}$$

For (m + 1)th bright fringe, $\frac{dy_{m+1}}{D}$ = (m + 1)λ

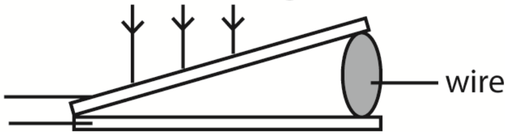
$$y_{m+1} = \frac{(m+1)\lambda D}{d}$$

Fringe separation, y = $y_{(m+1)}$ - y_m = $\frac{(m+1)\lambda D}{d} - \frac{m\lambda D}{d}$ = $\frac{\lambda D}{d}$

(ii) What would be the effect of replacing monochromatic light by white light in Young's double slit experiment. (03marks)

When monochromatic light is replaced with white light colored fringes are observed with the central fringe appearing white.
The distinct fringes are followed by blurred fringes which are followed with uniform illumination
The blue fringes are nearest to the central fringe while the red fringe is farthest.

(c) An air wedge is formed by placing two glass slides of length 5.0cm in contact at one end and a wire at the other end as shown in the figure below



Viewing from vertically above, 10 dark fringes are observe to occupy a distance of 2.5mm when the slides are illuminated with light of wavelength 500mm.

(i) Explain briefly how the fringes are formed. (03marks)

- Some of the light falling on the wedge is reflected upwards from the bottom of the top slide and some of that transmitted is reflected upwards from the top of the bottom slide.
- The light reflected from the top surface of bottom slide undergoes a phase change of π equivalent to additional path difference of $\frac{\lambda}{2}$
- The reflected waves trains superpose and dark fringes are observed when the path difference = nλ while a bright fringe is observed when the path difference = $\left(\frac{2n+1}{2}\right)\lambda$

(ii) Determine the diameter of the wire. (04marks)
For the first 10 dark fringes, L = 5.0cm = 5.0 x 10^{-2}m;

Solution

Fringe separation = $\frac{2.5 \ x\ 10^{-3}}{10}$ = 2.5 x 10^{-4}m

λ = 500nm = 5 x 10^{-7}m

tan θ = $\frac{\lambda}{2y} = \frac{5\ x\ 10^{-7}}{2\ x\ 2.5\ x\ 10^{-4}}$ = 1 x10^{-3}

θ =1 x 10_{-3} rad = 0.06^0

A beat is the periodic rise and drop in intensity of sound heard when two notes of nearly equal frequency are sounded together.

SECTION B

5. (a) Write down an expression for the magnetic flux density at

(i) A perpendicular distance, d, from a long straight wire carrying a current I, in vacuum. (01mark)

B = $\frac{\mu_0 I}{2\pi d}$

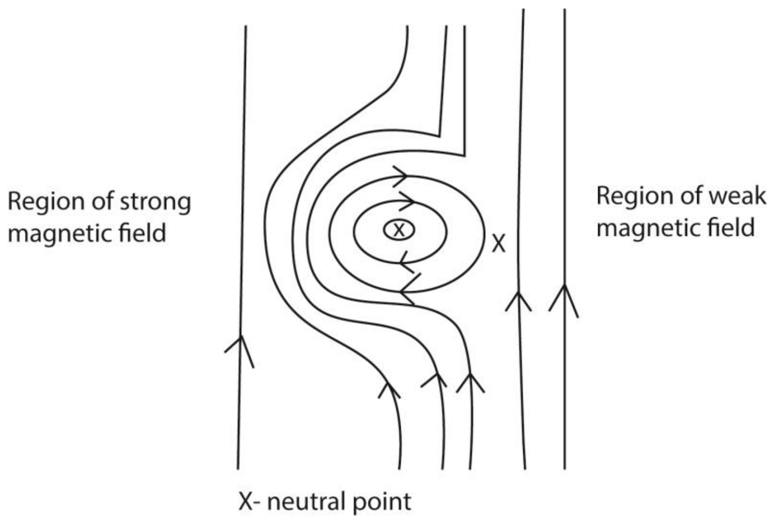
(ii) The center of a circular coil of N turn of radius, R, and carrying a current, I(01mark)

B = $\frac{\mu_0 NI}{2R}$

(iii) The center of an air-cored solenoid of a turns per meter each carrying a current I. (01mark)

B = $\mu_0 nI$

(b) Sketch the magnetic field pattern around a vertical current carrying straight wire in the earth's field and used it to explain a neutral point in a magnetic field. (04marks).



At the neutral point, X, the earth's magnetic field is equal and opposite of the magnetic field due to the current carrying wire.

(c) What is meant by terms:

(i) magnetic meridian (01mark)

Magnetic meridian is a vertical plane in which a freely suspended or pivoted magnet rests.

Or

It is the vertical plan containing the earth's magnetic poles.

(ii) angle of dip? (01marks)

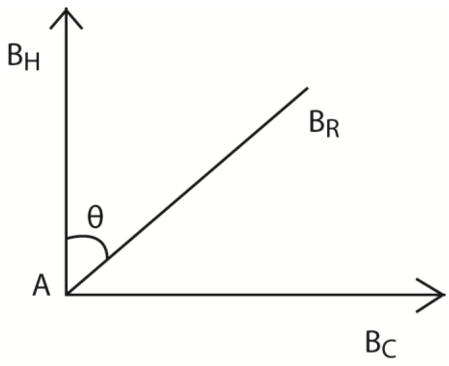
The angle dip is the angle between the horizontal and magnetic axis of freely suspended magnet.

(d) A circular coil of 10 turn and diameter 12cm carries current I. The coil is placed with its plane in the magnetic meridian. A small magnetic needle placed at the center of the coil makes 30 oscillation per minute about a vertical axis.

When the current is cut off, it makes 15 oscillations per minute. If the horizontal component of the earth's magnetic flux density is 2.0 x 10^{-5}T, calculate the magnitude of I.

(Assume that the square of frequency of oscillation is proportional to the magnetic flux density) (07marks)

Solution



BH = horizontal component of earth's magnetic field

BC =magnetic flux density due to current in the coil

BR = resultant magnetic flux density.

$\frac{B_R}{B_H} = \frac{30^2}{15^2} = 4$

$B_R = \sqrt{B_C^2 + B_H^2}$

But $B_R = 4B_H$

$B_R^2 = 16B_H^2$

$16B_H^2 = B_C^2 + B_H^2$

$B_C^2 = B_H\sqrt{15}$ = 2 x $10^{-5}\sqrt{15}$

But $B_C = \frac{\mu_0 NI}{2R}$

2 x $10^{-5}\sqrt{15}$ = $\frac{4\pi 4 \; x \; 10^{-7} \; x 10 \; x \; I}{12 \; x \; 10^{-2}}$ = 0.74A

(e) Explain what is meant by eddy currents and give four of their applications. (04marks)
When the magnetic flux cutting across a metal changes, an e.m.f is induced in the metal. This causes eddy currents to circulate within the metal. These currents flow in a direction as to oppose the magnetic flux threading the metal

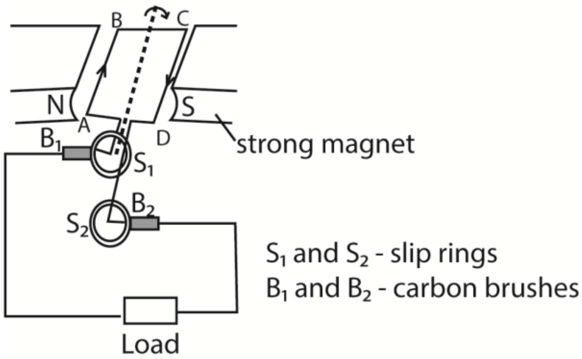
Applications

- Damping in the moving coil galvanometer
- Detection of cracks in metal
- In electromagnetic brake system
- Used in sorting metallic objects from solid wastes.

6. (a) State laws of electromagnetic induction. (02 marks)

Faradays law states that the magnitude of the induced e.m.f is directly proportional to the rate of change of the magnetic flux linked with the circuit.
Lenz's law states that the e.m.f induced in a circuit is in such a direction so as to oppose the change causing it

(b) (i) With the aid of a labelled diagram, describe the structure and mode of action of a.c. transformer (05mark)



How it works

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

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

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

(c) An a.c. transformer operates on a 240V mains. The voltage across the secondary which has 900 turns is 20V.

(i) Find the number of turns in the primary. (02marks)

V_P = 240V, V_S = 20V, N_S = 960 turns

$\frac{V_S}{V_P} = \frac{N_S}{N_P}$

$N_P = N_S \frac{V_P}{V_S} = \frac{960\ x\ 240}{20} = 11520\ turns$

(ii) If the efficiency of the transformer is 80%, calculate the current in the primary coil when a resistor of 40Ω is connected across the secondary. (04marks)

Efficiency = $\frac{Power\ output}{Power\ input}\ x\ 100\%$

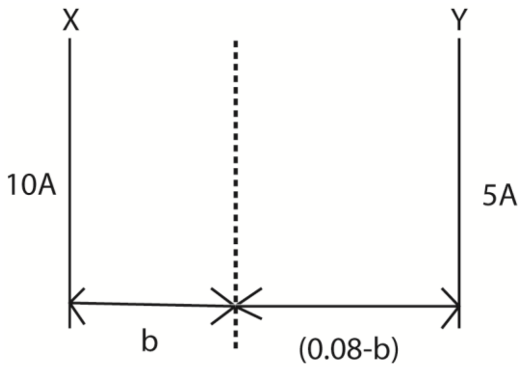
= $\frac{V_S^2/_R}{V_P^2/_{I_P}}$ x 100%

80 =$\frac{20^2/_{40}}{240^2/_{I_P}}$

I_P = 0.052A

(d) Two long parallel wires X and Y are separated by 8cm in a vacuum. The wires carry currents of 10A and 5A respectively in the same direction. At What points between the wires is the magnetic flux density is zero? (03marks)

Solution



Let b be the distance from wire X at which the resultant magnetic flux density is zero.

Magnetic flux due to a wire carrying current I is B = $\frac{\mu_0 I}{2\pi r}$

B_1 = $\frac{10\mu_0}{2\pi b}$ and B_2 =$\frac{10\mu_0}{2\pi(0.08-b)}$

But the resultant magnetic flux density is zero when B_1 = B_2

Then, $\frac{10\mu_0}{2\pi b}$ =$\frac{10\mu_0}{2\pi(0.08-b)}$

B = 0.053

Hence the resultant magnetic field is zero at points that are perpendicular distance of 0.053m from a wire carrying 10A.

7. (a) Define the terms amplitude and root mean square (r.m.s) value an alternating current. (02marks)

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

(b) A sinusoidal current I = 4sin (100πt) amperes flows through a resistor of resistance 2.0Ω. Find the mean power dissipated in the resistor. Hence deduce the r.m.s value of the current. (04marks)

Solution

Power dissipated = I^2R = $(4\sin(100\pi t))^2 \times 2 = 32\sin^2(100\pi t)$

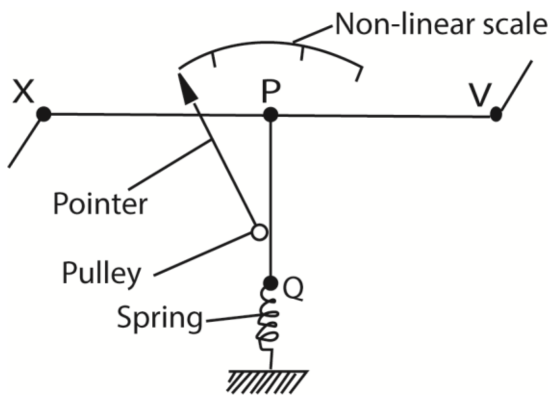
But $\sin^2(100\pi t)$ = ½

Then power = $32 \times \frac{1}{2}$ = 16W

Also, Power = $I_{r.m.s}^2\ x\ R$ = $2I_{r.m.s}^2$ = 16

$I_{r.m.s}^2$ = 8

(c) Describe, with the aid of a labelled diagram, how a hot wire ammeter works. (05marks)



- The current flows through a fine resistance-wire XY, which it heats.
- The wire warms up to such a temperature that it loses heat-mainly by convection-at a rate equal to the average rate at which heat is developed in the wire.
- The rise in temperature of the wire makes it expand and sag; the sag is taken up by a second fine wire PQ, which is held taut by a spring.
- The wire PQ passes round a pulley attached to the pointer of the instrument, which rotates as the wire XY sags.
- The deflection of the pointer is roughly proportional to the average rate at which heat is developed in the wire XY; it is therefore roughly proportional to the average value of the square of the alternating current, and the scale is a square-law one.

(d) An inductor of inductance, L is connected across a source of alternating voltage, V = V_0sinωt.

(i) Find the current which flows (03marks)

V = V_0sinωt.

The back e.m.f E in the inductor wire due to charging current I is E = $-L\frac{dI}{dt}$

Assuming the inductor has zero resistance, then for current to flow, the applied p.d, D must be equal and opposite to the back e.m.f, hence

V = -E

$= -L\frac{dI}{dt}$

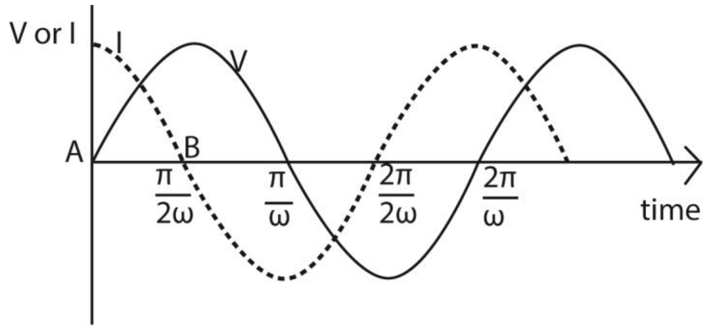
dI $= -\frac{V}{L}dt = \frac{V_0}{L}sin\omega tdt$

I $= -\frac{V_0}{L}\int \sin \omega t \,.\, dt$

I $= -\frac{V_0}{\omega L}\cos \omega t$

(ii) Sketch using the same axes, the variation with time of the voltage across the inductor and the current through it, and explain the phase difference between them (06marks)

Solution



V = $V_0 sin\omega t$ and I = $-\frac{V_0}{\omega L}\cos \omega t$

At A; Current lags behind voltage by a quarter a cycle or 90^0

At B; the current is zero but its rate of increase is at maximum, therefore for the inductor of constant inductance, the rate of change of flux is also at a maximum. Hence the back e.m.f is a maximum

SECTION C

8. (a) Distinguish between e.m.f and terminal p.d of a battery. (02marks)

Electromotive force of a battery is the energy supplied by the battery to transfer1C of charge across a complete circuit in which the battery is connected while terminal p.d is the p.d across external resistor in a circuit.

(b)(i) define electrical resistivity (01mark)

Electrical resistivity is the resistance across opposite faces of a $1m^3$ cube

(i) Explain any two factors on which the resistance of a conductor depends. (05marks)

- Temperature: an increase in temperature increases resistance of a conductor because increase in temperature increases the amplitude of vibration of the atoms in the conductor. This increases the rate of collision between drifting electrons and the atom which reduced the drift speed of electrons. Hence increases resistance.

- Cross section area: A big cross section area increases the number of electrons that pass through in a unit time leading to higher current and low resistance
- Length: increase in length of a conductor leads to a longer path for electrons. This increases the number of collision, lower the drift velocity and thus increases resistance.

(c) Two wires A and B have length which are in ratio 4:5, diameter which are in ratio 2:1, and resistances in ratio of 3:2. If the wires are arranged in parallel and a current of 1.0A flows through the combination, find the

(i) Ratio of resistance of wire A to that of wire B (04marks)

$\frac{l_A}{l_B} = \frac{4}{5}$ and $\frac{d_A}{d_B} = \frac{2}{1}$

⇨ $\frac{A_A}{A_B} = \left(\frac{r_A}{r_B}\right); \frac{R_A}{R_B} = \frac{3}{2}$

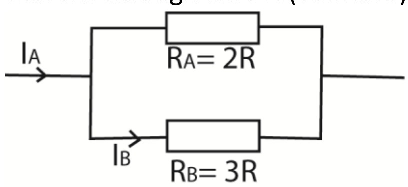
$R_A = \frac{\rho_A.L_A}{A_A}$ and $R_B = \frac{\rho_B.L_B}{A_B}$

$\frac{R_A}{R_B} = \frac{\rho_A}{\rho_B} \cdot \frac{L_A}{L_B} \cdot \frac{A_A}{A_B}$

$\frac{3}{2} = \frac{\rho_A}{\rho_B} \cdot \frac{4}{5} \cdot \left(\frac{2}{1}\right)^2$

$\frac{\rho_A}{\rho_B} = 0.47$

(ii) Current through wire A (03marks)



Total resistance across the parallel combination

$\frac{1}{R\prime} = \frac{1}{3R} + \frac{1}{2R} = \frac{5}{6R}$

R' = $\frac{6R}{5}$

V = I x R = $\frac{I\ x\ 6R}{5}$

I = $\frac{V}{R_A} = \frac{6R}{5} \cdot \frac{1}{3R}$ = 0.4A

(d) Explain why a wire becomes hot when current flows through it. (05marks)

The p.d applied across the wire increases the kinetic energy of the electrons; these electrons collide with the ions and lose their kinetic energy partially converted to heat.

9. (a)(i) State Ohm's law (01marks)

States that the current flowing through a conductor is directly proportional to the P.d. across it provided that there is no change in physical conditions such as temperature of the conductor.

(ii) State the factors which affect the resistance of a conductor. (02marks)

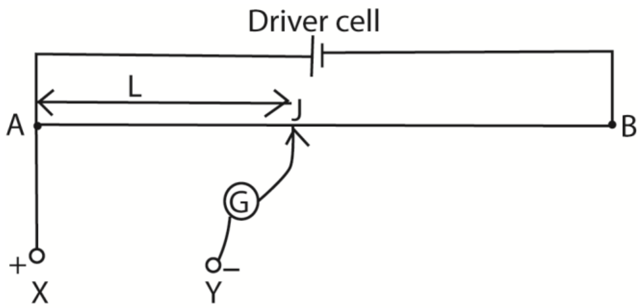
- Length of a conductor
- Cross-section area of the conductor
- temperature

(iii) A conductor of length L and cross section area A has free electrons per unit volume each of charge e. find the drift velocity, v, of these electrons if a current, I, flows through the conductor. (04marks)

In 1s electrons move through a distance v from Q, where v is the drift velocity.
Therefore charge crossing through cross-section area per second = (ne)vA
Current, I =nevA
v = $\frac{I}{neA}$
Alternatively
Volume of conductor = AL
Number of free electrons = nAL
Total charge drifting through the conductor = neAL
In a given time, t; I = $\frac{neAL}{t}$
= neAv (since v = $\frac{L}{t}$)
v = $\frac{I}{neA}$

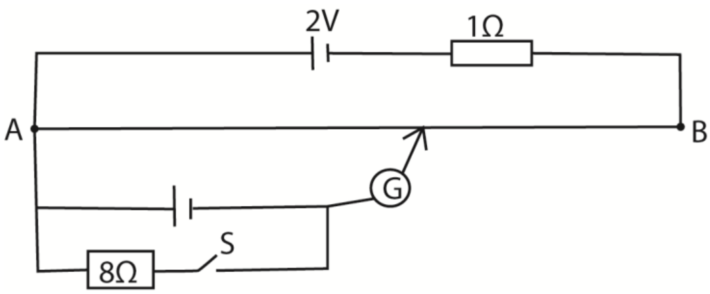
(b) Outline the principle of a slide wire potentiometer. (04marks)

A potentiometer consists of a uniform wire AB about 1m, and a driver cell, X that maintains a steady current I in the wire AB.



- The driver cell maintains a steady current through a uniform resistance wire AB.
- The p.d per unit length of the wire is therefore constant.
- At balance, when G shows no deflection, the p.d across length AJ = test p.d
  i.e. V = kL

(c)



In the figure above the slide wire AB is 1m long and has resistance 4Ω. When switch S is:

(i) Open the balance length Ac is 88.8cm. find the value of the e.m.f of the cell (03mark)

p.d across AB = 2 x $\frac{4}{5}$ = 1.6V

p.d per cm = $\frac{1.6}{100}$ Vcm^{-1}

e.m.f of the cell = $\frac{1.6}{100}\ x\ 88.8 = 1.42$V

(ii) Closed, the balance length is found to be 82.5cm.

Calculate the internal resistance of a cell. (04marks)

$\frac{E}{V} = \frac{R+r}{R} = \frac{L_0}{L}$

$\frac{8+r}{8} = \frac{88.8}{82.5}$

r = 0.61Ω

(e) State two advantages of using a potentiometer for measuring voltage (02marks)

- It does not draw current from the p.d it measuring
- Can be used to compare small resistance

10. (a) What is a dielectric material

A dielectric is a material which does not possess conductible or free charges. It can withstand a high electric field before it conducts.

(b) A capacitor filled with a dielectric is charge and then discharged through a milliammeter. The dielectric is then withdrawn half way and the capacitor charged to the same voltage, and discharged through the milliammeter again, show that the relative permittivity, E_r of the dielectric is given by

$E_r = \frac{I}{2I'-I}$ where I and I' are the readings of the milliammeter respectively. (06marks)

Solution

- Initially, C = $\frac{\varepsilon_0\varepsilon_r A}{d}$, where A is area of the plates and d is the separation of the plates
- When the dielectric is withdrawn half way, the resultant capacitance is due to two capacitors connected in parallel, each with plate area that is half the original.
- Eventually, C = $C_1 + C_2$

$$= \frac{\varepsilon_0\varepsilon_r\frac{A}{2}}{d} + \frac{\varepsilon_0\frac{A}{2}}{d}$$

$$= \frac{\varepsilon_0 A}{2d}(\varepsilon_r + 1)$$

Initial charge on the plates is Q = CV

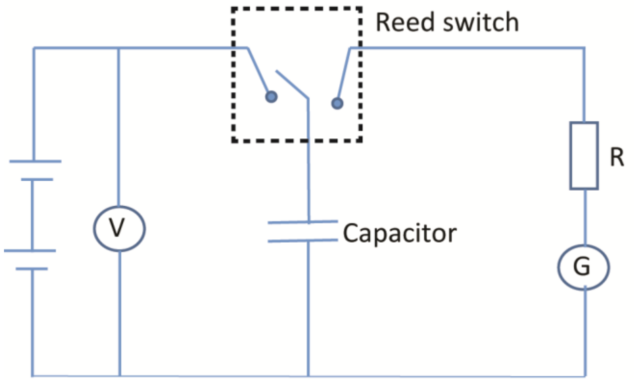
Final on the plates is $Q_1 = C_1V$

$$\frac{I}{I_1} = \frac{Q}{Q_1} = \frac{CV}{C_1V} = \frac{C}{C_1}$$

$$= \frac{\varepsilon_0\varepsilon_r A}{d} \div \frac{\varepsilon_0 A}{2d}(\varepsilon_r + 1)$$

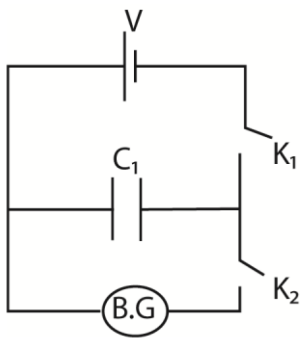
$$= \frac{2\varepsilon_r}{\varepsilon_r + 1}$$

(c) Describe with the aid of a diagram how you would determine the capacitance of a capacitor. (05marks)



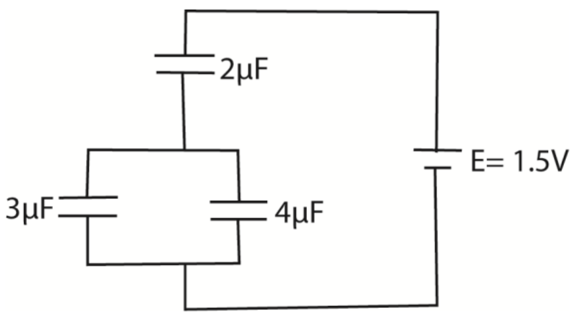
- The setup is shown above
- The is closed and the reading of current I and voltage V are noted at known frequency, f of the reed switch.
- The capacitance of a capacitor, C = $\frac{I}{fV}$

Alternatively



- The circuit is connected as shown with a capacitor of known capacitance C_1.
- Switch K_1 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 battery of e.m.f 15V is connected across a system of capacitors as shown above, find the

(i) Charge on the 4μF capacitor (04marks)

Effective capacitance, C of 3μF and4μF that are parallel = 3 + 4 = 7μF

Effective capacitance, C_1 of 7μF and 2μF in series = $\frac{7\ x\ 2}{7+2} = \frac{14}{9}$μF

Q =CV = $\frac{14}{9}\ x\ 10^{-6}\ x\ 1.5$ = 2.33×10^{-6}C

The charge on 2μF capacitor = 2.33×10^{-6}C

P.d across 2μF capacitor = $\frac{2.33\ x\ 10^{-6}}{2\ x\ 10^{-6}}$ = 1.165V

p.d on either 3μF or 4μF = 1.5 – 1.165 = 0.335V

Charge on 4μF capacitor = CV = $4 \times 10^{-6} \times 0.335 = 1.34 \times 10^{-6}$C

(ii) Energy stored in the 3μF capacitor. (04marks)

E = $\frac{1}{2}CV^2 = \frac{1}{2}\ x\ 3\ x\ 10^{-6}\ x\ 0.335^2$= 1.68×10^{-7}J

END