UACE PHYSICS PAPER 2004 GUIDE

Instructions to the candidates:

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

Any additional question (s) will not be marked.

Mathematical tables and squared paper will be provided

Non programmable calculators may be used.

Assume where necessary

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

SECTION A

1. (a) What is meant by the following terms as applied to a telescope?

(i) magnifying power (01mark)

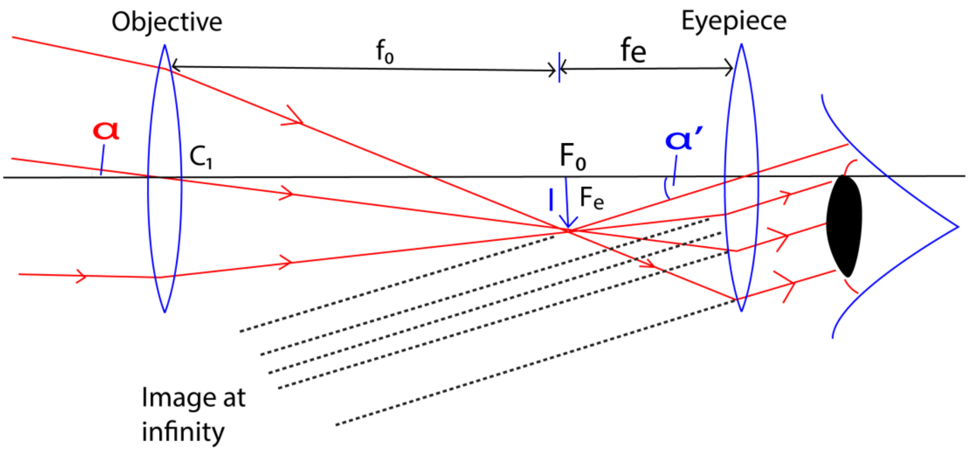
This is the ratio of the angle α' subtended at the eye by the image when using an a telescope to the angle, α, subtended at unaided eye by the object.

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

(ii) eye-ring (01mark)

It is the image of objective in the eye piece. It is the best position for the eye to see the image clearly.

(b) (i) Draw a ray diagram to show the formation of the final image by an astronomical telescope in normal adjustment. (03marks)



Telescope in nornal use

(ii) With the aid of the diagram in (b) (i), derive an expression for the magnifying power of an astronomical telescope in normal adjustment. (04marks)

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

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)

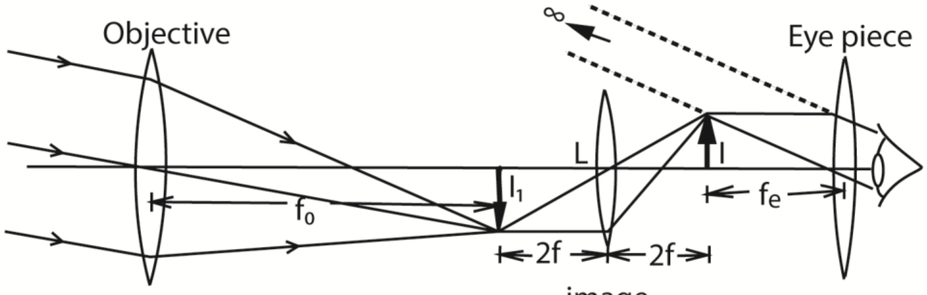
f_0 is the focal length of objective lens

Combining equations (i) and (ii)

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

(iii) Give the disadvantage of the telescope in (b)(i) when used to view distant objects on earth. Describe how the telescope can be modified to overcome this disadvantage. (04marks)

- It forms inverted image. This can be overcome by using an erect lens or converting it into a terrestrial telescope as shown in the figure below.



Terrestrial telescope

(c) Find the separation of the eye-piece and objective of an astronomical telescope of magnifying power 20 and in normal adjustment, if its eyepiece has a focal length of 5cm. (04marks)

Focal length of objective,

M = $\frac{f_0}{f_e}$

⇨ f0= 20 x 5 = 100cm

Separation = $f_0 + f_e$ = 100 + 5 = 105cm

(d) State three advantages of a reflecting telescope over a refracting telescope. (03marks)

Advantages of reflecting telescopes

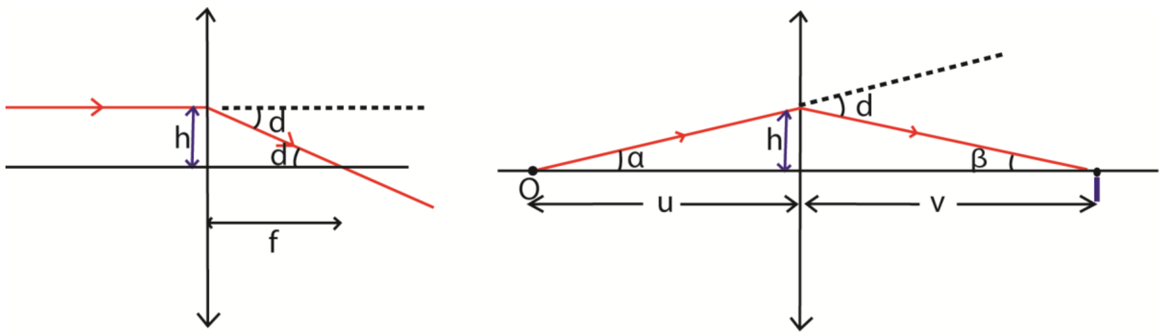
(i) There is no chromatic aberration since no refraction occurs at the objective
(ii) There is no spherical aberration since a paraboloidal mirror is used.
(iii) It is cheaper to construct since only one surface requires grinding.
(iv) When curved mirrors of large diameter are used, a greater resolving power is obtained.

2. (a) Define the terms principal focus and power of a lens. (02marks)

Principal focus "F" of a lens is a point on the principal axis where paraxial rays incident on the lens and parallel to the principal axis converge or appear to diverge from after refraction by the lens.
Power lens is the reciprocal of the focal length in meters

(b) Derive the relation between the focal length, f, objective distance, u, and image distance, v, for a thin lens. (07marks)

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



(i) (ii)

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

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

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

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

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

Equating equations (i) and (ii) gives

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

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

(c) A thin converging lens, P, of focal length 10cm and a thin diverging lens, Q, of focal length 15cm are placed coaxially 50cm apart. If an object, O, is placed 12cm from P on the side remote from Q.

(i) find the position, nature and magnification of the final image. (07marks)

Action of P

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

$$\frac{1}{u} = \frac{1}{10} - \frac{1}{12}; \ u = 60\text{cm}$$

Action of Q

u = 50 -60 = -10cm

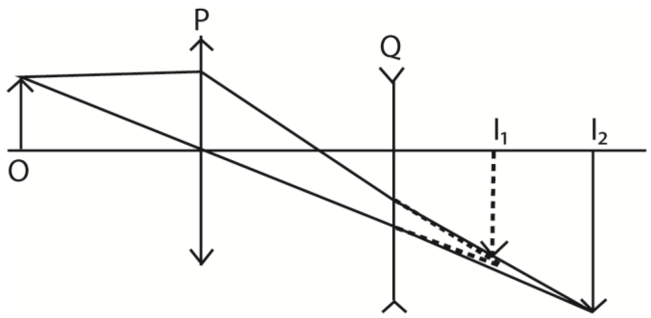
$$\frac{1}{v} = -\frac{1}{15} - \left(-\frac{1}{10})\right), \ v = 30\text{cm}$$

The image is real 30cm from Q

Magnification, M = M_1 x M_2

$$= \frac{v_1}{u_1} x \frac{v_2}{u_2} = \frac{60}{12} x \frac{30}{10} = 30$$

(ii) Sketch a ray diagram to show the formation of the final image. (02marks)



(d) Explain why lenses of narrow aperture are preferred to lenses of wide aperture in optical instruments (02marks)

Lenses with narrow aperture minimize spherical aberration because they only allow paraxial rays to be focus to one spot

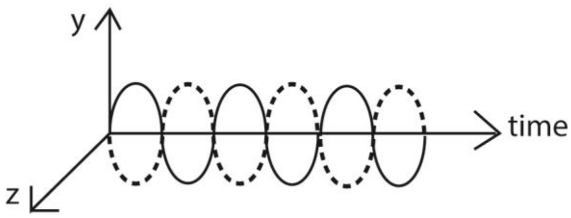
3. (a) (i) What is meant by polarized light

Polarized light is one which is transmitted by vibrations in only one particular plane

(ii) Describe how plane polarized light can be produced (02marks)

- **Selective absorption:** a sheet of Polaroid is placed with its plane perpendicular to the direction of light rays. Only light vibrations of a particular orientation to the axes of the crystal are transmitted.
- Reflection: unpolarized light is made incident on the surface of glass or water at a certain angle such that reflected light is perpendicular to refracted light. The reflected light is totally polarized.
- Double reflection: when unpolarized light is incident on a crystal of calcite, it is split into two rays called ordinary and extraordinary. The two rays are plane polarized perpendicular to each other.

(iii) Sketch the time variation of electric and magnetic vectors in plane polarized light.

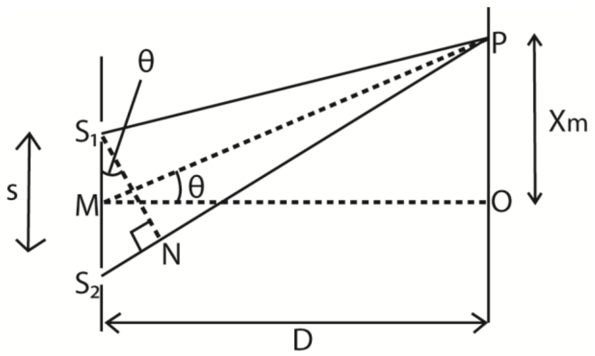


(b) Two coherent sources a distance, S, apart produce light of wavelength λ which overlap at a point on a screen at distance D from the sources to form interference pattern.

(i) What is meant by coherent sources? (02marks)

Two sources are said to be coherent when they have the same frequency and nearly the same amplitude, their vibrations are always in phase with each other.

(ii) Show that fringe width, ω, is given by ω = $\frac{\lambda D}{S}$ (04marks)



Let P be the position of the mth bright fringes, the

$S_2P - S_1P = m\lambda$ ……………………………………….…… (i)

The path difference between the waves arriving at P from S_1 and S_2 is

$S_2N = S_2P - S1P$ ………………………………………..(ii)

Since S_1S_2 is very small, and $PM >> S_1S_2$ is nearly perpendicular to S_2P such that

$S_2N \approx S\sin\theta$

For small values of θ, $\sin\theta \approx \tan\theta = \frac{X_m}{D}$

Hence $S_2N \approx \frac{SX_m}{D}$ ……………………………………………………………. (iii)

From eqn. (i), (ii) and (iii)

$m\lambda = \frac{SX_m}{D}$

From (m -1)th bright fringe , $X_{m-1} = \frac{(m-1)\lambda D}{S}$

∴ Fringe width $X_m - X_{m-1} = \frac{\lambda D}{S}$

(iii) If $\lambda = 5.46 \times 10^{-7}$m, $S = 5 \times 10^{-5}$m and D = 0.3m, find the angular position of the first dark fringe on the screen.(04marks)

For dark fringe, $Xm = \left(\frac{2m-1}{2}\right)\frac{\lambda D}{S}$

1st dark fringe $X_1 = \frac{0.5 \times 5.46 \times 10^{-7} \times 0.3}{5 \times 10^{-5}}$

But angular position $\theta = \frac{X_m}{D} = \frac{0.5 \times 5.46 \times 10^{-7}}{5 \times 10^{-5}}$ = 5.46×10^{-3} rad or 0.312^0.

(c) (i) What is meant by diffraction of light? (02marks)

Diffraction is the spreading of light beyond its geometrical shadows leading to interference.

(ii) Light of wavelength 6×10^{-7}m is incident on diffraction grating with 500 lines per cm. find the diffraction angle for the first order image. 03marks)

$\lambda = 6 \times 10^{-7}$m; $d = \frac{10 \times 10^{-3}}{500} = 2 \times 10^{-5}$m

$d\sin\theta = m\lambda$

since θ is very small, $\theta = \frac{m\lambda}{d}$

for 1st order image $\theta = \frac{\lambda}{d} = \frac{6 \times 10^{-7}}{2 \times 10^{5}}$ = 3 x 10^{-2}rad = 1.72^0

4. (a)(i) Distinguish between longitudinal and transverse waves (02marks)

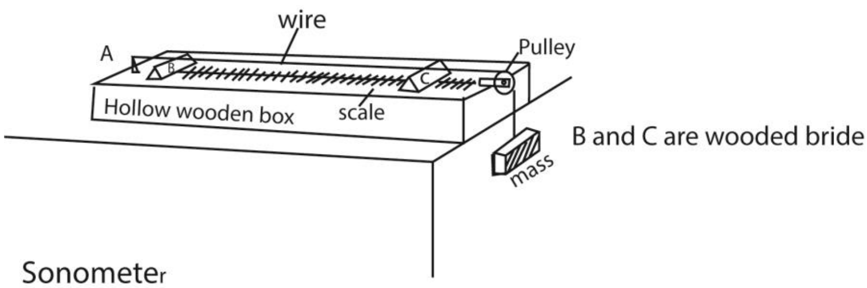
Transverse waves are those which propagate by vibrations perpendicular to the direction of travel of the wave. While in longitudinal waves the vibrations occur in the same direction as the direction of travel of the wave.

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

Wavelength of a wave is the distance between two successive particles in phase. Or the distance between two successive crests or trough.

(b) Describe with the aid of a diagram, an experiment to show the fundamental frequency varies with the tension in a given wire.

A sonometer below is used.



The length L between the bridges is fixed.
A suitable mass, m, is attached to the free end of the wire.
The wire is plucked in the middle and a tuning fork of known frequency, f, is sounded
The mass m corresponding to the frequency, f, are recorded in the table including values of f^2.
The procedure is repeated for different values of f.
A graph of f^2 against m is plotted.
A straight line graph is obtained through the origin, implying that $f^2 \propto m$
But $m = \frac{T}{g}$
$\therefore f = \sqrt{\frac{T}{g}}$ thus increase in tension, T, increases the frequency, f, of the wire.

(c) A sound wave propagating in the x-direction is given by the equation y = 2 x 10^{-7}sin(sin 8000t-25x) meters. Find

(i) Amplitude (01mark)
= 2 x 10^{-7}m

(ii) The speed of the wave (05marks)
Compare with $y = a\sin 2\pi(ft - \frac{x}{\lambda})$

$25x = \frac{2\pi x}{\lambda}$ or $\lambda = \frac{2\pi}{25}$

Also $2\pi ft = 8000t$

$f = \frac{8000}{2\pi}$

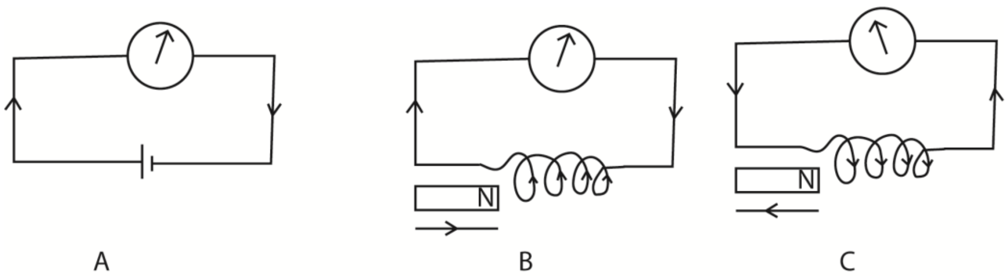
$v = f\lambda f = \frac{8000}{2\pi} = \frac{2\pi}{25} = 320ms^{-1}$

(d) Explain why the amplitude of a wave goes on decreasing as the distance from the source increases

As the wave progresses, energy is continuously absorbed by the medium

SECTION B

5. (a) with the aid of a diagram, describe briefly an experiment to illustrate Lenz's law of electromagnetic induction (05marks)



- The galvanometer is first connected in series with a battery and the direction for a given direction of current is determined.
- The battery is disconnected and is replaced by a coil of known winds.
- A strong permanent magnet is brought towards the coil with N-pole facing the coil, the galvanometer deflects in a direction for which the side of the coil facing the magnet is N-pole.
- When the magnet is move away from the coil, the galvanometer deflects in opposite direction, implying that the pole near the coil is a S-pole.
- In the first case, the pole due to the induced current was repelling the approaching magnet, while in the second case, the pole was attracting the receding magnet.
- The induced current therefore is in such as to oppose the change causing it, which is Lenz's law.

(b) Explain the main precautions taken in the construction of an a.c. transformer. (04marks)

The main precaution

- Low resistance copper wire are used to reduce I^2R losses.
- Laminated core reduce Eddy currents
- Use of soft iron core reduce hysteresis
- Winding secondary coil on top of primary to reduce magnetic flux leakage.

(c) Explain the effect of the following on the voltage across the secondary coil of a.c transformer.

(i) A fall in the supply frequency of the current in the primary (04marks)

Transformer works on the principal of mutual induction i.e. induced e.m.f in the secondary.

$E_S = \frac{d\,(N\phi)}{dt} = \frac{d\,(NAB)}{dt}$

But B + KI_0sin2πft

∴ $E_S = NAI_0 \frac{d\,(\sin 2\pi ft)}{dt}$

= $NAKI_0$.2πftcos 2πft

E_0 = $NAKI_0$.2πft

Hence when the supply frequency falls, the output voltage also falls.

(i) A reduction in the primary turns. (02marks)

$\frac{N_p}{N_f} = \frac{N_p}{V_S}$

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

Hence a reduction in primary turns causes an increase in secondary voltage.

(d) A transformer whose secondary coil has 60 turns and primary 1200 turns, has its secondary connected to a 3Ω resistor. If its primary is connected to a 240V a.c supply, calculate the current flowing in the primary assuming that the transformer is 80% efficient. (05marks)

$V_S = \frac{N_S V_P}{N_P} = \frac{60\ x\ 240}{1200}$ = 12V

$I_S = \frac{V_S}{R} = \frac{12}{3} = 4.0A$

$V_S I_S = 0.8 V_P I_P$

$1^2\ x\ 4 = 0.8\ x\ 240\ x\ I_P$

$I_P = 0.25A$

6. (a) When can an alternating current be referred to as being sinusoidal?(01mark)

An alternating current is referred to as sinusoidal when its variation with time can be represented by a sine wave.

(b) Define

(i) the root mean square value of an alternating current (01mark)

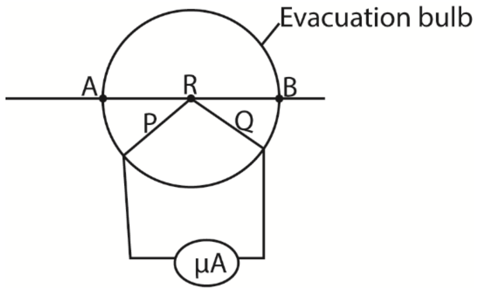
Root mean square value of an a.c is the value of steady current which dissipates heat at the same rate in a given resistor as a.c.

(ii) reactance (01mark)

Reactance is non resistive opposition to the flow of a.c through an inductor or capacitor.

(c) Describe the structure and action of a meter that makes use of a thermocouple in measuring the root mean square value of an alternating current. Why this meter does has high sensitivity. (05marks)

Solution



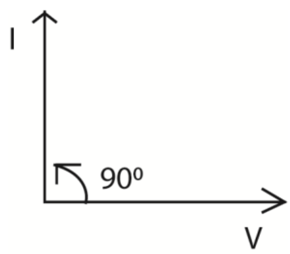
P and Q are dissimilar wires
Current to be measured is passed through the wire AB and heats the junction R of the thermocouple. The thermoelectric effect generated at R causes a direct current to flow through the micrometer calibrated to measure the r.m.s value of current.

The meter has high sensitivity because of its low inductance and capacitance

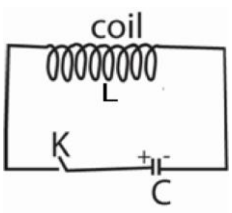
(d) (i) Show that current leads voltage by 90^0 when a sinusoidal voltage is applied across a capacitor. (05marks)

Solution
Let p.d across the capacitor at time t be V
V = V0sin2πft
Charge on the capacitor is Q = CV, where C is the capacitance of the capacitor.
The instantaneous current flowing through the capacitor,
$I = \frac{dQ}{dt}$
$= \frac{d(CV_0 \sin 2\pi f t)}{dt}$
$= 2\pi f C V_0 \cos 2\pi f t$
From trigonometry, $\cos 2\pi f t = \sin (2\pi f t + \frac{\pi}{2})$
⇨ $I = 2\pi f C V_0 \sin(2\pi f t + \frac{\pi}{2})$
Hence current leads voltage by $\frac{\pi}{2} = 90^0$.

(ii) Sketch a phase diagram to illustrate the orientation of the current vector with respect to voltage vector in (d)(i) above. (01mark)



(e)



An inductor, L, a capacitor, C and switch, K, are connected as shown above. Explain, briefly what happens when the switch K is closed (06marks)

When switch K is closed, the charged capacitor begins to discharge and current flows. A magnetic field now begins to build up around L, and by Lenz's law, an e.m.f is induced in L so as to oppose the current, C therefore discharges slowly. When it is completely discharged, the electrical energy originally stored in the electric field between the capacitor plates has been transferred to magnetic field around L.

At this instant, the magnetic field begins to collapse and a p.d is induced in L which tries to maintain the field. Current therefore flows in the same direction as before and C gets charged in the reverse sense creating a magnetic field of opposite polarity.

Discharge again occurs in opposite direction to attain the initial charge on either plates and the whole process is repeated over and over again.

7. (a) What is meant by magnetic meridian? (01mark)

Magnetic meridian is the vertical plane through the earth containing the earth's magnetic axis. Or it is a vertical plane in which a freely suspended magnet sets.

(b)(i) Describe the effect of eddy currents in a dynamo and state how they can be reduced? (03mark)

Eddy currents cause heating up of the dynamo armature core. This reduces efficiency since some of the energy input is converted into heat. This problem is reduced by laminating the core to prevent circulation of these currents.

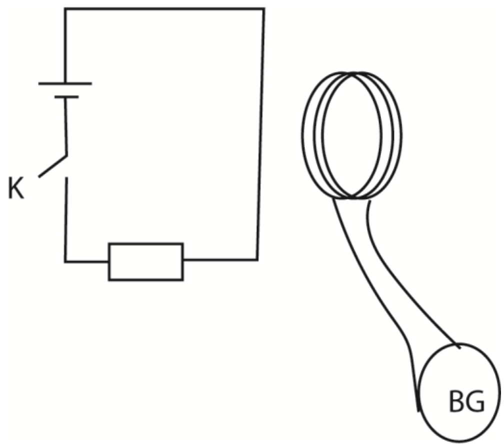
(ii) Explain why eddy currents are useful in a moving coil galvanometer. (03marks)

In a moving coil galvanometer, eddy currents damp the oscillation of the coil. This makes the pointer to settle at point quickly. It is desirable for quick and accurate reading.

(ii) What is the difference between a motor and dynamo? (02marks)

A motor converts electrical into mechanical energy while a motor converts mechanical into electrical energy.

(c) Describe how a search coil and calibrated ballistic galvanometer can be used to measure magnetic flux density at a given point near a wire carrying current. (06marks)



A search coil of know geometry connected in series with a ballistic galvanometer BG is placed close and with its plane parallel to the wire under test.

Switch K is closed and deflection θ_1 on BG is taken.

K is then opened and deflection θ_2 on BG is taken again.

The average $\theta = \frac{\theta_1 + \theta_2}{2}$ is determined

Now Q = kθ

Also, $Q = \frac{BAN}{R}$

$\therefore B = \frac{kR}{AN}$

Where A = Area of the coil

N = Number of turns

R- total resistance of the circuit

k = calibration constant

(d) An aircraft is flying horizontally at 800kmh^{-1} at a point where the earth's magnetic flux density is 2.31 x 10^{-5}T and angle of dip is 60^{0}. If the distance between the wing tips is 50m, calculate the potential difference induced between its wing tips. (05marks)

$B_V = 2.31 \times 10^{-5} \sin 60^0 = 2 \times 10^{-5}$ T

e.m.f induced = BLu = B_VLu = 2 x 10-5 x 50 x 800 x $\frac{1000}{3600}$ = 0.22V

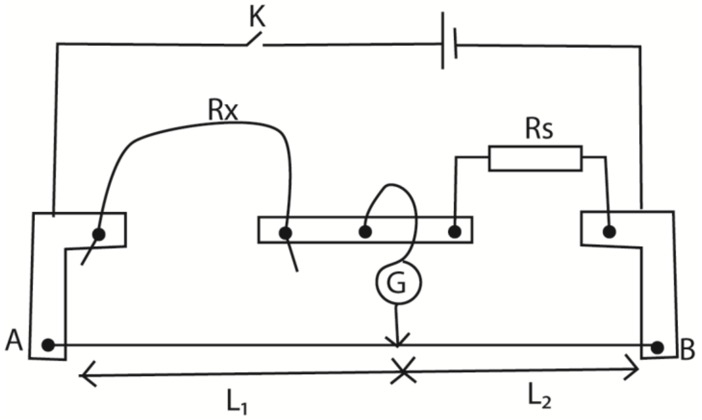
u = velocity in m/s

SECTION C

8. (a) (i) define electrical resistivity and state its units (02marks)

Electrical resistivity of a material is the resistance between opposite faces of 1m cube of the material. It is measured in Ohms (Ω)

(ii) Describe with the aid of circuit diagram, an experiment to determine the electrical resistivity of a given wire using a meter bridge. (07marks)



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

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

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

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

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

(iii) The resistivity of mild steel is 15 x 10^{-8}Ωm at 20^0C and its temperature coefficient is 50 x $10^{-4}K^{-1}$. Calculate the resistivity at 60^0C. (05marks)

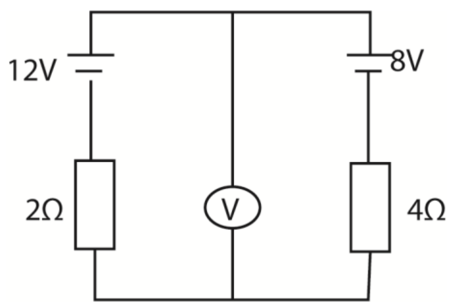
$\rho_\theta = \rho_0(1 + \alpha\theta)$

15 x 10^{-8} = ρ_0(1 + 20 x 50 x 10^{-4})

$\rho_0 = \frac{15\ 10^{-8}}{(1+20\ x\ 50\ x\ 10^{-4})}$ = 1.364 x 10^{-7}

$\rho_{60} = \frac{15\ 10^{-8}}{(1+20\ x\ 50\ x\ 10^{-4})}(1 + 60\ x\ 50\ x\ 10^{-4})$ = 1.77 x 10^{-7}

(b)



Resistors of 2Ω and 4Ω are connected in series with power supplies of 12V and 8V as shown in the figure above. Calculate

(i) The reading of voltmeter (04marks)

Net e.m.f = 12-8 =4V

Total resistance = 2 + 4 = 6Ω

$I = \frac{E}{R} = \frac{4}{6} = \frac{2}{3}A$

Reading of the voltmeter =12-IR (R = 2)

$= 12 - \frac{2}{3} x\ 2$

= 10.7V

(ii) The power dissipated in the 4Ω resistor (02marks)

$P = I^2R = \left(\frac{2}{3}\right)^2 x\ 4 = 1.78W$

9. (a) Define the following

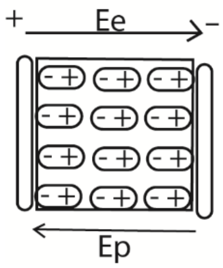
(i) Capacitance of capacitor (01mark)

Capacitance of a capacitor is the ratio of the magnitude of charge on one of the plates of the capacitor, to the potential difference between the plates.

(ii) Dielectric constant (01mark)

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

(b) Explain the effect of dielectric on the capacitance of a capacitor. (04marks)



When a dielectric is placed between the plates of an insulated charged capacitor, it gets polarized with the sides near each plate bearing opposite charge to that on the plate.

These are bound charges which are not neutralized thus develop an electric field that oppose the applied electric field.

They lower electric field and voltage between the plates which increases capacitance of the capacitor.

(c) Derive an expression for energy stored in a capacitor of capacitance, c, charged to a voltage, V. (05marks)

Suppose the p.d between the plates at some instant is V. When a small charge of δq is transferred from the negative plate to the positive plat, the p.d increases by δV.

Work done to transfer the charge; δw = (V + δV)δq

≈ Vδq

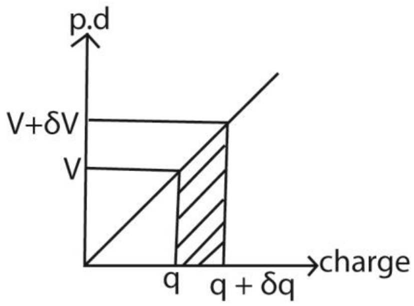
But $V = \frac{q}{C}$

$\therefore \frac{q}{C}\delta q$

Total work done=$\int_0^q \frac{q}{C}\delta q = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2$

Or

From q = CV, V is proportional to q, this gives the graph of V against q below



Shaded area = $\frac{1}{2}(V + V + \ \delta V)\ x\ dV$

= work done to increase charge on the capacitor by δq

∴ to charge a capacitor from q = 0 to q = Q

Work done, w = average voltage x charge

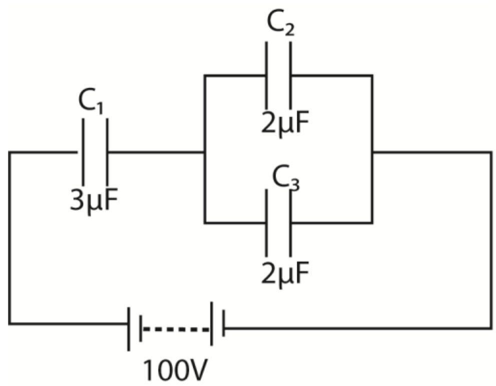
$= \frac{1}{2}(0 + V)x\ Q$

$= \frac{1}{2}QV$

But Q = CV

∴w = $\frac{1}{2}CV^2$

(d)



In the figure above, C_1, C_2, and C_3 are capacitors of capacitances 3μF, 2μF and 2μF respectively, connected to a battery of e.m.f 100V.

(i) Calculate the energy stored in the system of capacitors if the space between the plates of C_1 is filled with an insulator of dielectric constant 3, and the capacitors are fully charged. (06marks)

Net capacitance of C_2 and C_3 in parallel is $C_4 = C_2 + C_3 = 2 + 2 = 4$μF

After inserting dielectric, C_1 become $C_5 = 3C_1 = 3 \times 3 = 9$μF

Net capacitance C of C_4 and C_5 = $\frac{9\ x\ 4}{9+4}$ =2.77μF

Energy stored = $\frac{1}{2}CV^2 = \ \frac{1}{2}\ x\ 2.77\ x\ 10^{-6}x\ 100^2$ = 0.01385J

(ii) Account for the change in energy stored by an isolated parallel plate capacitor when the plate separation is doubled. (03marks)

E = $\frac{1}{2}cV^2 = \frac{Q^2}{2C} = \frac{Q^2d}{2\varepsilon_0 A}$

⇨ When the separation is doubled, the energy stored is doubled.

- To increase the separation, work is done n pulling the plates apart. This work done (energy) is stored as electrical energy between plates of the capacitor.

END