



Dr. Bbosa Science

Sponsored by
The Science Foundation College
Uganda East Africa
Senior one to senior six
+256 778 633 682, 753 802709
Based On, best for science

digitalteachers.co.ug



 Nurture your dreams 

UACE PHYSICS PAPER 2 2024 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 | $1.6 \times 10^{-19}\text{C}$ |
| Electron mass | $9.11 \times 10^{-31}\text{kg}$ |
| Plank's constant, h | $6.6 \times 10^{-34}\text{Js}$ |
| Speed of light in the vacuum, c | $3.0 \times 10^8\text{ms}^{-1}$ |
| Specific heat capacity of water | $4.200\text{Jkg}^{-1}\text{K}^{-1}$ |
| Avogadro's number, N_A | $6.02 \times 10^{23}\text{mol}^{-1}$ |
| Gas constant, R | $8.31\text{Jmol}^{-1}\text{K}^{-1}$ |
| Charge to mass ratio, e/m | $1.8 \times 10^{11}\text{Ckg}^{-1}$ |
| The constant, $\frac{1}{4\pi\epsilon_0}$ | $9.0 \times 10^9\text{F}^{-1}\text{m}$ |
| Permittivity of free space, μ_0 | $4.0\pi \times 10^{-7}\text{Hm}^{-1}$ |
| Permittivity of free space, ϵ_0 | $8.85 \times 10^{-12}\text{Fm}^{-1}$ |
| One electron volt | $1.6 \times 10^{-19}\text{J}$ |
| Resistivity of Nichrome wire at 25°C | $1.2 \times 10^{-6}\Omega\text{m}$ |

SECTION A

1. (a) (i) With the aid of diagrams, differentiate between regular and irregular reflection (03marks)
(ii) Show that if two plane mirrors are inclined at an angle, x , then the total deviation of a light ray produced is $2x$ after reflection once in each mirror. (03 marks)
- (b) Describe an experiment to determine the focal length of a concave mirror using a plane mirror and a pin. (04marks)
- (c) (i) Sketch a ray diagram to show how a concave mirror forms a magnified real image of a real object. (02marks)
(ii) A concave mirror of radius of curvature 48cm produces a real image whose size is three times that of the object. Determine the position of the object. (02marks)
- (d) Describe an experiment to determine the refractive index of a liquid using a concave mirror. (04marks)
- (e) Explain the meaning of a caustic curve. (02 marks)
2. (a)(i) What is meant by visual angle? (01 mark)
(ii) An observer views a series of electric poles in a straight line. Explain why the pole nearer the observer appears taller than the rest. (03marks)
- (b)(i) With the aid of a ray-diagram, describe how a telescope consisting of a convex lens and a concave lens can be adjusted to form a final image at infinity. (05 marks)
(ii) What are the advantages and limitations of a telescope in (b)(i) (02marks)
- (c)(i) Describe how you can modify an astronomical telescope to produce an erect image at infinity. (02marks)
(ii) Give two major disadvantages of the modification. (01marks)
- (d) The objective of an astronomical telescope in normal adjustment has a diameter of 20cm and a focal length of 200cm. The eye-piece has a focal length of 2cm. Calculate the;
(i) magnifying power of the telescope (02marks)
(ii) position of the eye-ring (02marks)
(iii) diameter of the eye-ring (02marks)

SECTION B

3. (a) (i) What is an amplitude of a wave? (01mark)
(ii) what is the difference between transverse and longitudinal waves? (01mark)
- (b) Describe, with the aid of a diagram, an experiment to show how the fundamental frequency varies with tension in a given wire (06marks)
- (c) A glass tube open at the top, is held vertically and filled with water. A tuning fork vibrating at 264Hz, is held above the tube and water is allowed to flow out slowly. The first resonance occurs when the water level is 31.5cm from the top while the second resonance occurs when the water level is 96.3cm from top. Find the;
(i) Speed of sound in air. (04marks)
(ii) End correction. (02marks)
- (d) (i) What are beats? (01mark)
(ii) Describe an experiment to determine the frequency of a note using beats. (05marks)

4. (a) With the aid of a diagram, explain what happens when waves move from less dense to dense media. (03 marks)
- (b) Use Huygens' construction to show that the refractive index, n , of medium is given by $n = \frac{c}{v}$ where c is the velocity of light in air, and v is the velocity of light in the medium. (05 marks)
- (c) (i) Explain how interference patterns are formed. (03 marks)
- (ii) Describe how the wavelength of light may be determined using Young's double slit experiment. (05 marks)
- (d) A diffraction grating has 500 lines per mm and illuminated normally with monochromatic light of wavelength 589nm. Find the maximum number of diffraction image obtained. (04 marks)

SECTION C

5. (a) Explain the sources of energy loss in a transformer when in use. (03 marks)
- (b) A machine rated 200W is operated at 230V. The resistance of the transmission line from the power station to the machine is 3Ω .
- (i) Calculate the power lost in the cables if the transmission is done at 230V. (03marks)
- (ii) Explain how this power can be transmitted to the machine with minimum loss using the same cable. (03marks)
- (c) A rectangular coil of N turns, each of area A is rotated at constant angular velocity, ω , with its plane perpendicular to a Uniform magnetic flux B . Derive an expression for e.m.f in the coil. (04marks)
- (d)(i) What is meant by the statement that two coils have a mutual inductance of 1 henry? (01mark)
- (ii) The Mutual inductance of two coils is 30henrys. A current of 11,5A in the primary coil is reduced at a steady rate to zero in a period of 0.002s. Calculate the e.m.f induced in the secondary coil. (03marks)
- (e)(i) Explain what is meant by back e.m.f in a motor. (02 marks)
- (ii) State one advantage of back e.m.f in a motor (01mark)
6. (a) Define
- (i) Magnetic field (01mark)
- (ii) Magnetic saturation (01mark)
- (b)(i) Draw the magnetic field pattern for a bar magnet placed with its north pole facing the earth's north pole. (01mark)
- (ii) Describe an experiment to determine the angle of dip at a given place using an earth inductor. (04marks)
- (c)(i) Define an Ampere. (01mark)
- (ii) A rectangular frame $XVWY$ is pivoted about a horizontal axis XY such that the length PQ is equal to the length YW . The end VW lies half-way inside the solenoid of n turns per meter. The solenoid is arranged so that its magnetic field of flux density B is perpendicular to VW and the metal frame is connected in series with the solenoid as shown in figure 1.

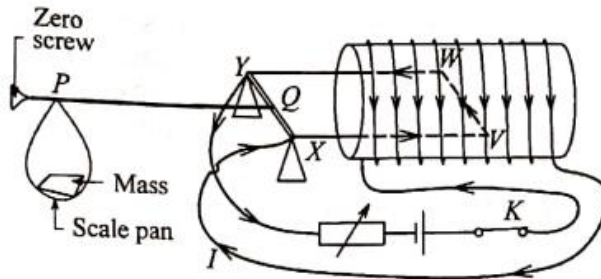


Fig. 1

When switch K is closed, the coil balances when the mass on the pan is m . Show that the current I , flowing is given by

$$I = \frac{mg}{\mu_0 n l} \text{ where } l \text{ is length of the side VW (03mark)}$$

- (d) Figure 2 shows two wires P and R carrying currents of 9A and 5A out of paper

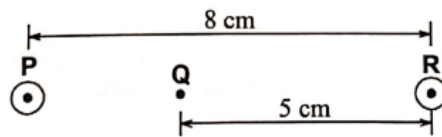


Fig. 2

Find the

- (i) Magnetic flux density at point Q. (04marks)
 - (ii) Force per meter acting on the wire P. (03marks)
- (e) State four factors which determine the current sensitivity of a moving coil galvanometer. (02mark)
7. (a) What is meant by the following;
- (i) Root mean square value of an alternating current, (01mark)
 - (ii) reactance (01mark)
 - (iii) Impedance (01 mark)
- (b) Show that the average value of power dissipated in a capacitor in completely cycle is zero. (03marks)
- (c) A capacitor of $20\mu\text{F}$ is connected in series with a resistor of 100Ω across an a.c source of frequency 30Hz and peak voltage 60V. Determine the root mean square of the current that flows. (05marks)
- (d) (i) On the same axes, draw graphs of voltage $V = V_0 \sin \omega t$ and the resulting current against time for a circuit in which the a.c supply is connected across a capacitor. (02mark)
- (ii) Explain the values of I when $V = V_0$ and when $V = 0$. (02marks)
- (e) Describe the mode of operation of a repulsive type ammeter. (05marks)

SECTION D

8. (a) What is meant by the following:
- (i) Electric field (01mark)
 - (ii) Electric flux (01mark)
- (b) Show that the electric field intensity at a distance from a charged plane conductor is independent of the distance from the conductor. (03 marks)
- (c)(i) Figure 3 shows two oppositely charged long parallel metal plates at a separation of 2cm with a p.d of 20kV between them.

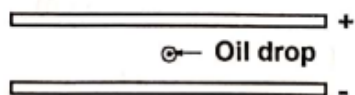


Fig. 3

When a negatively charged oil drop of mass $5,9 \times 10^{-14}$ kg is introduced in the space between the plates, it remains suspended in space. Estimate the number of electrons in the oil drop. (04marks)

- (iii) Explain how a neutral material placed between the plates in figure 3 can be shielded from the electric field. (03marks)
- (d) Explain how the presence of a neutral conductor near a negatively charged material affects the potential of the material. (04 marks)
- (e) Explain why a charged spherical conductor loses charge faster when a pin is placed on it with the sharp point sticking out. (04marks)
9. (a) Define the following
- (i) Temperature coefficient of resistance. (01mark)
- (ii) Electrical resistivity (01mark)
- (b)(i) Describe an experiment to measure an unknown resistance using a meter bridge (05marks)
- (ii) Explain why the balance point of a meter bridge should be close to the middle of the slide wire. (03marks)
- (c) A piece of wire of length 200cm and cross-sectional area 0.001cm^2 has a resistivity of $4.4 \times 10^{-7}\Omega\text{m}$. The ends of the wire are joined together to form a loop. Terminals T1 and T2 are fixed across the diameter of the loop and connected to two cells in parallel, each of e.m.f 1,5V and internal resistance 1Ω as shown in figure 4

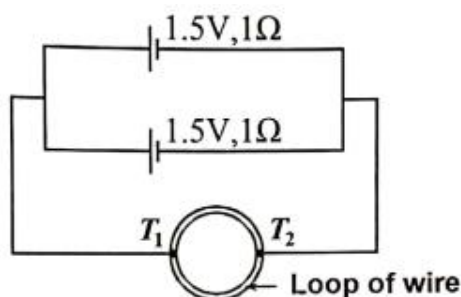


Fig. 4

Find the total current that flows in the circuit. (06 marks)

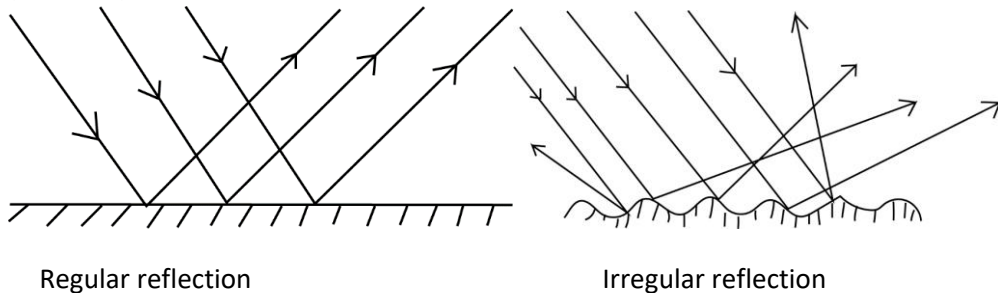
- (d) Show that a given source of e.m.f delivers maximum power for a load when the resistance of the load is equal to internal resistance of the source. (04 marks)
10. (a) Define the following:
- (i) Dielectric constant (01mark)
- (ii) Dielectric strength (01 mark)
- (b) Explain using molecular theory, the effect of a dielectric material on the capacitance of a capacitor. (05 marks)
- (c) A capacitor of $50\mu\text{F}$ is charged fully to a p.d of 45V. The capacitor is disconnected and a dielectric material of dielectric constant 2 is inserted between its plates. If it is then connected across an uncharged capacitor of $60\mu\text{F}$, determine the;
- (i) p.d across the combination (04marks)
- (ii) change in energy initially stored in both capacitors. (04marks)
- (d)(i) Describe how a ballistic galvanometer can be used to compare capacitance of two capacitors. (04marks)

- (ii) State any two functions of a dielectric material in a capacitor. (01 mark)

SUGGESTED ANSWERS

SECTION A

1. (a) (i) With the aid of diagrams, differentiate between regular and irregular reflection (03 marks)



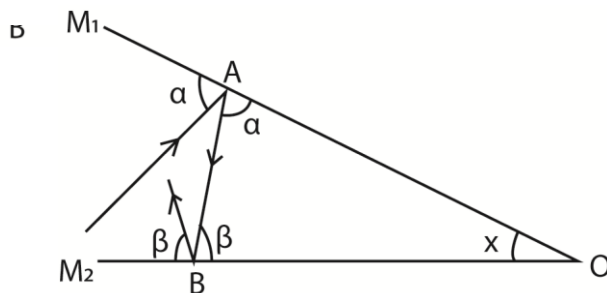
Differences between regular and irregular reflection

| Regular reflection | Irregular reflection |
|--|--|
| Occurs on smooth surface | Occurs on a rough surface |
| Parallel incident beam is reflected parallel | Parallel incident beam is scattered after reflection |
| Reflected beam is very bright | Reflected beam is dull |

- (ii) Show that if two plane mirrors are inclined at an angle, x , then the total deviation of a light ray produced is $2x$ after reflection once in each mirror. (03 marks)

Deviation by successive reflections at two inclined mirrors

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



Let the glancing angle at A and B be α and β respectively

Deviation by $M_1 = 2\alpha$ (clockwise direction)

Deviation by $M_2 = 2\beta$ (clockwise direction)

Total deviation = $2\alpha + 2\beta$
 $= 2(\alpha + \beta)$ (i)

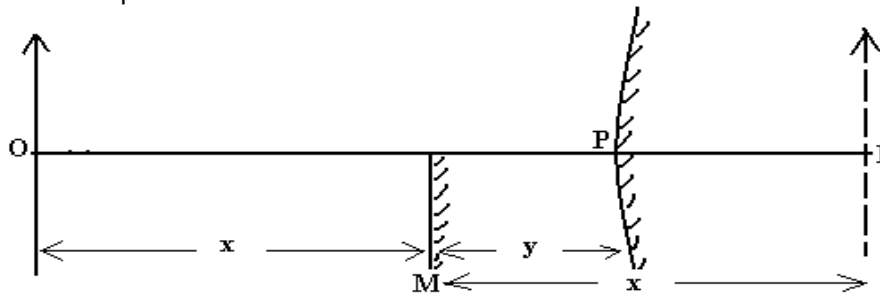
But $\alpha + \beta + x = 180$ (Angle sum of a triangle)
 $\alpha + \beta = 180 - x$ (ii)

Combining (i) and (ii)
 Total deviation = $2(180 - x)$ (clockwise)
 $= 360 - 2x$ (clockwise)

$= 2x$ (anticlockwise)

Thus, the deviation produced by two inclined mirrors is twice the angle between the mirrors when a ray undergoes two successive reflections.

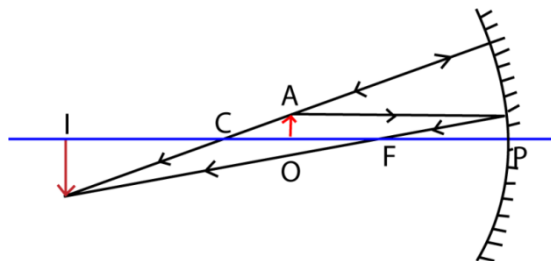
- (b) Describe an experiment to determine the focal length of a convex mirror using a plane mirror and a pin. (04marks)
The setup is shown below



- (i) An object pin **O** is placed in front of a convex mirror as shown in the diagram above
- (ii) A virtual diminished image is formed at **I**.
- (iii) A plane mirror **M** is placed between **O** and **P** so as to intercept half the field of view of the convex mirror.
- (iv) Mirror **M** is adjusted until its own image of **O** coincides with **I** by no parallax method.
- (v) Measure the distances **x** and **y**.
- (vi) The focal length of the mirror is calculated from $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$$\text{Where } u = (x + y) \text{ and } v = (y - x)$$

- (c) (i) Sketch a ray diagram to show how a concave mirror forms a magnified real image of a real object. (02marks)



Note that the object is between F and C while the image is real and inverted beyond C

- (ii) A concave mirror of radius of curvature 48cm produces a real image whose size is three times that of the object. Determine the position of the object. (02marks)

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

$$\Rightarrow \frac{u}{24} = 1 + \frac{1}{3}$$

$$\Rightarrow u = 32\text{cm}$$

Or

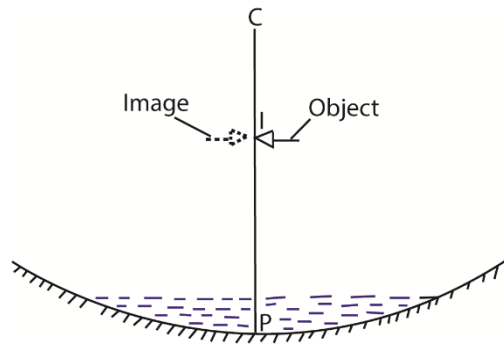
$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

$$\Rightarrow \frac{1}{24} = \frac{1}{u} + \frac{1}{3u}$$

$$\Rightarrow u = 32\text{cm}$$

- (d) Describe an experiment to determine the refractive index of a liquid using a concave mirror. (04marks)

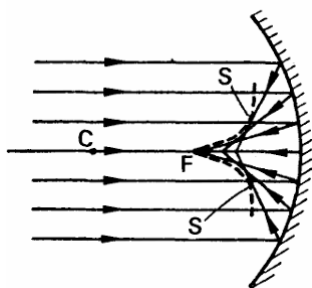
An experiment to determine refractive index of a liquid using a concave mirror



- A concave mirror is placed on a horizontal table with its reflecting surface facing upwards.
- 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, $n_l = \frac{PC}{IP}$

- (e) Explain the meaning of a caustic curve. (02 marks)

When a wide parallel beam of light is incident on a converging mirror, the reflected rays converge at different points along the axis of the mirror. A curve, S, called a caustic curve, with an apex or cusp at principal focus, F is formed which passes through the points of intersection of the reflected and incident rays.



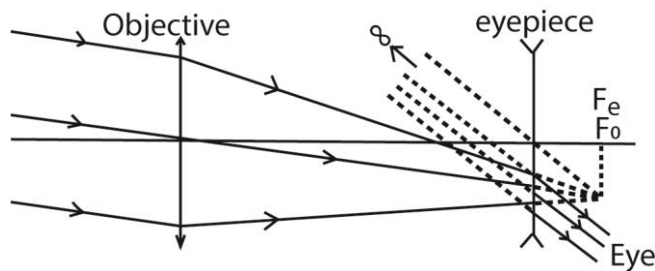
2. (a)(i) What is meant by visual angle? (01 mark)

Visual angle is the angle subtended by an object or image at the eye.

- (ii) An observer views a series of electric poles in a straight line. Explain why the pole nearer the observer appears taller than the rest. (03marks)

The apparent size of an object or image is proportional to the visual angle. An object nearer the eye subtends a larger angle at the eye than a distant one, hence a nearer pole appears taller.

- (b)(i) With the aid of a ray-diagram, describe how a telescope consisting of a convex lens and a concave lens can be adjusted to form a final image at infinity. (05 marks)



The objective lens is arranged with the eyepiece such that their principal foci coincide. The objective forms a real image of a distant object on their common focal point F_o or at its principal focus, and the eyepiece forms a final virtual image at infinity.

- (ii) What are the advantages and limitations of a telescope in (b)(i) (02marks)

Advantages

- It forms an upright image
- It is short and portable.

Limitation

- Has virtual eye ring
- Has a narrow field of view
- Form less bright and less clear image

- (c)(i) Describe how you can modify an astronomical telescope to produce an erect image at infinity. (02marks)

A convex lens is inserted between the objective and eyepiece such that it is $f_o + 2f$ from objective and $f_e + 2f$ from the eyepiece.

- (ii) Give two major disadvantages of the modification. (01marks)

- It decreases the brightness of the final image
- It makes the telescope long and bulky
- It gives a narrow field of view.

- (d) The objective of an astronomical telescope in normal adjustment has a diameter of 20cm and a focal length of 200cm. The eye-piece has a focal length of 2cm. Calculate the;

- (i) magnifying power of the telescope (02marks)

$$m = \frac{f_o}{f_e} = \frac{200}{2} = 100$$

- (ii) position of the eye-ring (02marks)

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

$$\frac{1}{2} = \frac{1}{202} + \frac{1}{v}$$

$$\Rightarrow v = 2.02 \text{ cm}$$

- (iii) diameter of the eye-ring (02marks)

Linear magnification of eyepiece, $m = \frac{v}{u} = \frac{D_e}{D_o}$

$$\frac{2.02}{202} = \frac{D_e}{20}$$

$$D_e = 0.2 \text{ cm}$$

SECTION B

3. (a) (i) What is an amplitude of a wave? (01mark)

This is the maximum displacement of a wave particle in the wave from its equilibrium position.

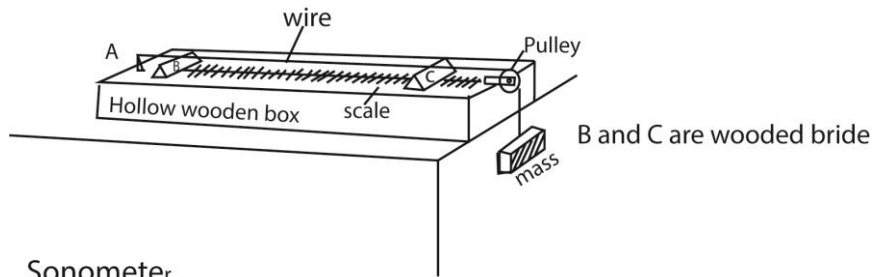
(ii) what is the difference between transverse and longitudinal waves? (01mark)

Transverse waves are waves which propagate by vibrations perpendicular to the direction of travel of the wave while longitudinal waves are waves which propagate by vibrations which occur parallel to the direction of travel of the wave.

Or

Transverse waves propagate by formation of crests and troughs while longitudinal waves propagate by formation of rarefactions and compressions.

(b) Describe, with the aid of a diagram, an experiment to show how the fundamental frequency varies with tension in a given wire (06marks)



- The experiment is setup as shown above.
- The length L of the wire between B and C is fixed
- A suitable mass, m , is attached to the free end of the wire and the wire is plucked in the middle and a tuning fork of known frequency, f is sounded and held near the wire.
- The mass is varied until the vibrations of the wire resonate.
- The mass, m and corresponding frequency, f , are recorded in the table including the value of f^2 .
- The procedure is repeated with tuning forks of different frequencies.
- A graph of f^2 against m gives a straight line through the origin implying the $f^2 \propto m$.
- But $T = mg$ or $m = \frac{T}{g}$, hence, $f^2 \propto T$ or $f \propto \sqrt{T}$ since g is constant. Thus the fundamental frequency is proportional to the tension of the wire.

(c) A glass tube open at the top, is held vertically and filled with water. A tuning fork vibrating at 264Hz, is held above the tube and water is allowed to flow out slowly. The first resonance occurs when the water level is 31.5cm from the top while the second resonance occurs when the water level is 96.3cm from top.

Find the;

(i) Speed of sound in air. (04marks)

$$l_1 + c = \frac{\lambda}{4} \dots\dots\dots(i)$$

$$l_2 + c = \frac{2\lambda}{4} \dots\dots\dots(ii)$$

$$l_2 - l_1 = \frac{\lambda}{2}$$

$$\lambda = 2(l_2 - l_1)$$

But $v = f\lambda$

$$v = 2f(l_2 - l_1)$$

$$= 2 \times 264(0.963 - 0.315)$$

$$= 342 \text{ms}^{-1}$$

(ii) End correction. (02marks)

$$l_1 + c = \frac{v}{4f}$$

$$0.315 + c = \frac{342}{4 \times 264}$$

$$c = 0.009 \text{m}$$

(d) (i) What are beats? (01mark)

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

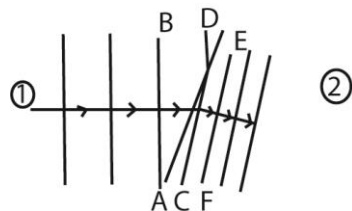
(ii) Describe an experiment to determine the frequency of a note using beats. (05marks)

The test note is sounded together with a standard note of frequency, f_1 , the number, n , of loud sounds heard in a given time, t . The beat frequency, $f_b = \frac{n}{t}$. The frequency of the standard note is reduced slightly and experiment repeated. The new beat frequency f_b' is determined. If $f_b' > f_b$, the frequency $f_2 = f_1 + f_b'$. If $f_b' < f_b$, the frequency $f_2 = f_1 - f_b'$

Or

- A signal generator is sounded together with test note to produce beats.
- The frequency of the generator is adjusted such that the time between loud sounds increases.
- Further adjustment is done until it takes longer to hear the next loud sound (for sound to die out or fade)
- The frequency of the signal generator is recorded, and this is the frequency of the test note.

4. (a) With the aid of a diagram, explain what happens when waves move from less dense to dense media. (03 marks)



$$BD = v_1 t$$

$$AC = v_2 t$$

$$\therefore v_2 < v_1 \text{ and } AC < BD$$

The direction of travel of the wave changes, hence refraction.

Or

As the wave moves from medium ① into ② the wavelength reduces.

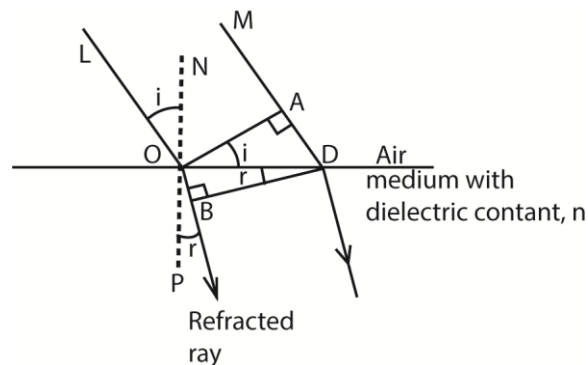
⇒ $DB > CF$

Hence the new wave front gets inclined. Hence direction of the wave changes which is refraction.

- (b) Use Huygens' construction to show that the refractive index, n , of medium is given by $n = \frac{c}{v}$ where c is the velocity of light in air, and v is the velocity of light in the medium. (05 marks)

Huygens construction

Consider a beam of parallel rays between LO and MD incident on the plane surface of the medium from air in the direction shown, and suppose that a plane wave front has reached the position OA at a certain instant; every point on OA acts as a secondary source of wavelets.



In time t , secondary wavelets from O travels a distance $OB = vt$ (where $v =$ velocity of light in the medium).

In the same time, t , the secondary wavelength in air travels a distance $AD = ct$

The tangent BD to the secondary wavelet is the new wavefront.

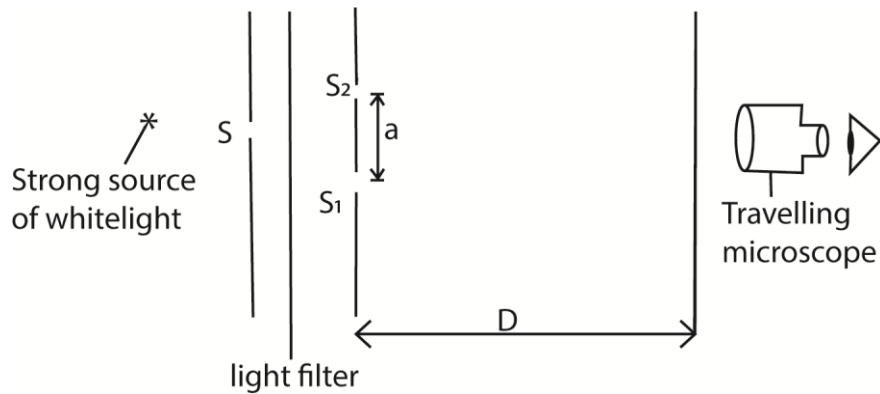
$$\sin i = \frac{AD}{OD} \text{ and } \sin r = \frac{OB}{OD}$$

$$\begin{aligned} \text{From snell's law, } n &= \frac{\sin i}{\sin r} \\ &= \frac{AD}{OD} \div \frac{OB}{OD} \\ &= \frac{AD}{OD} \times \frac{OD}{OB} = \frac{AD}{OB} = \frac{ct}{vt} = \frac{c}{v} \end{aligned}$$

- (c) (i) Explain how interference patterns are formed. (03 marks)

When two waves of equal frequency and equal wavelength (coherent sources) travel in the medium, they superpose where they meet in phase, reinforcement takes place resulting in a region of maximum intensity. Where they meet completely out of phase, cancellation takes place and a region minimum intensity form. Permanent alternate region of maximum and minimum intensity are therefore observed which is referred to as interference pattern.

- (iii) Describe how the wavelength of light may be determined using Young's double slit experiment. (05 marks)



The set up is as shown above, where S, S₁, and S₂ are narrow slits through which light diffracts forming interference fringes on a transparent screen. The position of the screen is adjusted until fringes are seen clearly. The number of fringes occupying a measured length along the screen is counted and the width y of a single fringe determined. The distance D , of the double slit from the screen is measured using a meter rule and the separation, a , of the double slit determined using a travelling microscope. The wavelength $\lambda = ay/D$

- (d) A diffraction grating has 500 lines per mm and illuminated normally with monochromatic light of wavelength 589nm. Find the maximum number of diffraction image obtained. (04 marks)

$$d = \frac{1 \times 10^{-3}}{500}$$

$$n = \frac{d}{\lambda} = \frac{1 \times 10^{-3}}{500 \times 589 \times 10^{-9}} = 2.39$$

\therefore the maximum order of diffraction = 3

SECTION C

5. (a) Explain the sources of energy loss in a transformer when in use. (03 marks)

- Heating in the coil causes loss of energy due to the electrical resistance of the wires
- Heating in the core causes loss of energy due to eddy currents.
- Heating in the core due to loss due to magnetic reversals
- Energy loss due to magnetic flux leakage

- (b) A machine rated 200W is operated at 230V. The resistance of the transmission line from the power station to the machine is 3 Ω .

- (i) Calculate the power lost in the cables if the transmission is done at 230V. (03marks)

$$\text{Current in the transmission wire, } I = \frac{P}{V} = \frac{200}{230} = 0.8696A$$

$$\begin{aligned} \text{Power loss, } P &= I^2R \\ &= (0.866)^2 \times 3 \\ &= 2.11W \end{aligned}$$

- (ii) Explain how this power can be transmitted to the machine with minimum loss using the same cable. (03marks)

At the power station the voltage is stepped up thereby reducing current. Power loss, $P = I^2R$ is thus minimized. At the machine, the voltage is stepped down to the required value to enable the operation of the machine

- (c) A rectangular coil of N turns, each of area A is rotated at constant angular velocity, ω , with its plane perpendicular to a Uniform magnetic flux B . derive an expression for e.m.f in the coil. (04marks)

Magnetic flux linking N turns of the coil, $\phi = BAN\cos\theta$ but $\theta = 0$

$$\Rightarrow \phi = BAN$$

$$\text{The induced emf } E = \frac{-d\phi}{dt} = \frac{-d}{dt}(BAN)$$

Since BAN is constant, $E = 0$

Or

$$\phi = BAN\cos\omega t$$

$$E = \frac{-d\phi}{dt} = -(BAN) \frac{d}{dt} \cos \omega t$$

$$= \omega BAN \sin \omega t$$

But $t = 0$

Hence, $E = 0$

- (d)(i) What is meant by the statement that two coils have a mutual inductance of 1 henry? (01mark)

Two circuits have a mutual inductance of 1 henry if the induced emf in the secondary coil is 1V when the current in the primary coil changes at a rate of 1A per second.

- (ii) The Mutual inductance of two coils is 30 henrys. A current of 1.5A in the primary coil is reduced at a steady rate to zero in a period of 0.002s. calculate the e.m.f induced in the secondary coil. (03marks)

$$E = -M \frac{dI}{dt} = -30 \frac{(0-1.5)}{0.002} = 22,500V$$

- (e)(i) Explain what is meant by back e.m.f in a motor. (02 marks)

When the armature of the motor rotates in the magnetic field, emf is induced in the coil. This emf opposes the supply (applied) Voltage. This emf is called back emf.

- (ii) State one advantage of back e.m.f in a motor (01mark)

- it reduces current which would have damaged the coil
- work done against back emf is converted into mechanical work. It increases efficiency of the motor

6. (a) Define

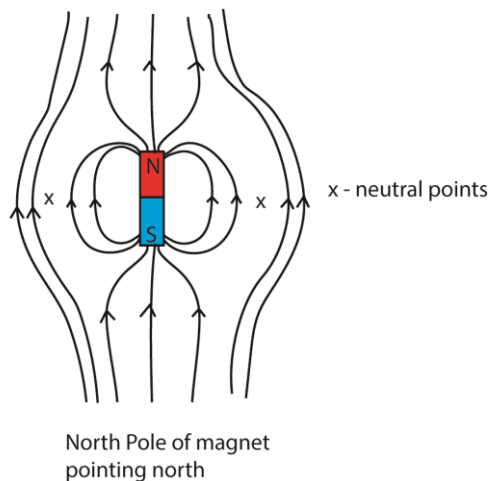
- (i) Magnetic field (01mark)

It is a region in space where magnetic force is experienced.

- (ii) Magnetic saturation (01mark)

Magnetic saturation occurs when a given material has attained its maximum magnetic strength such that further magnetization does not increase its magnetic strength.

- (b)(i) Draw the magnetic field pattern for a bar magnet placed with its north pole facing the earth's north pole. (01mark)



- (ii) Describe an experiment to determine the angle of dip at a given place using an earth inductor. (04marks)

The inductor is placed with the plane of its coil horizontal. The coil is turned through 180° about the vertical diameter. The first deflection θ is noted. The coil is now placed with plane of the coil vertical such that its plane is perpendicular to N-S direction. The coil rotated through 180° . The first deflection θ_1 is noted. The angle of dip, ϕ now calculated from $\phi = \tan^{-1} \left(\frac{\theta}{\theta_1} \right)$

- (c)(i) Define an Ampere. (01mark)

The ampere is a steady current which when flowing in each of two infinitely long straight wire parallel conductors of negligible cross section area and 1 meter apart in a vacuum produces between the wires a force of $2.0 \times 10^{-7} \text{ N}$ per meter of the length.

- (ii) A rectangular frame XWVY is pivoted about a horizontal axis XY such that the length PQ is equal to the length YW. The end VW lies half-way inside the solenoid of n turns per meter. The solenoid is arranged so that its magnetic field of flux density B is perpendicular to VW and the metal frame is connected in series with the solenoid as shown in figure 1.

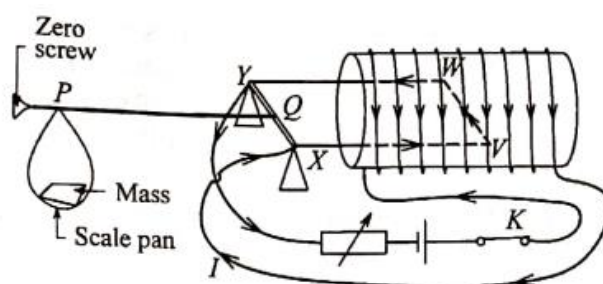


Fig. 1

When switch K is closed, the frame balances when the mass on the pan is m . Show that the current I , flowing is given by

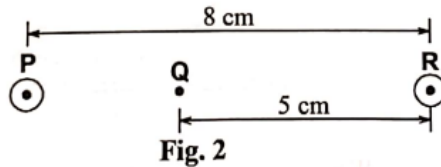
$$I = \frac{\sqrt{mg}}{\mu_0 n l} \text{ where } l \text{ is length of the side } VW \text{ (03mark)}$$

When Switch K is closed, current flows and wire WV experiences a force, $F = BIl$ downwards. Weight $F' = mg$ is placed in the scale.

At balance $F \times PQ = F' \times YW$

Since $PQ = YW$
 $mg = BIl$
 $= (\mu_0 nI)l$
 $\Rightarrow I = \sqrt{\frac{mg}{\mu_0 n l}}$

- (d) Figure 2 shows two wires P and R carrying currents of 9A and 5A out of paper



Find the

- (i) Magnetic flux density at point. (04marks)

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

$$B_Q = B_P - B_R = \frac{4\pi \times 10^{-7}}{2\pi} \left(\frac{9}{0.03} - \frac{5}{0.05} \right) = 4.0 \times 10^{-5} T$$

- (ii) Force per meter acting on the wire P. (03marks)

$$\frac{F}{L} = \frac{\mu_0 I_P I_R}{2\pi a} = \frac{4\pi \times 10^{-7} \times 9 \times 5}{2\pi \times 0.08} = 11.25 \times 10^{-3} N m^{-1}$$

- (e) State four factors which determine the current sensitivity of a moving coil galvanometer. (02mark)

B- magnetic flux density

A- Area of the coil

N- Number of turns

K- strength of the hairspring

7. (a) What is meant by the following;

- (i) Root mean square value of an alternating current, (01mark)

It is the value of steady/direct current that dissipates heat in a given resistor at the same rate as alternating current.

- (ii) reactance (01mark)

Reactance is non-resistive opposition to the flow of a.c in a circuit containing either an inductor or a capacitor.

- (iii) Impedance (01 mark)

Impedance is the total opposition to the flow of an alternating current in an a.c circuit containing resistive and reactive components.

- (b) Show that the average value of power dissipated in a capacitor in completely cycle is zero. (03marks)

Consider a capacitor connected to an a.c source of $V = V_0 \sin \omega t$ and $I = I_0 \cos \omega t$

$$P = IV$$

$$= I_0 \cos \omega t \times V_0 \sin \omega t$$

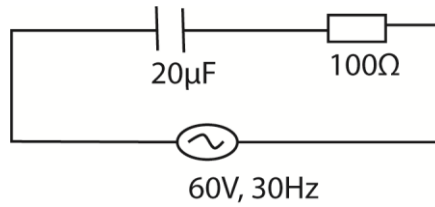
$$= I_0 V_0 \sin \omega t \cos \omega t$$

$$= \frac{1}{2} I_0 V_0 \sin 2\omega t$$

$$\langle P \rangle = \frac{1}{2} I_0 V_0 \langle \sin 2\omega t \rangle, \langle \sin 2\omega t \rangle = 0$$

$$\text{Hence } \langle P \rangle = 0$$

- (c) A capacitor of $20\mu\text{F}$ is connected in series with a resistor of 100Ω across an a.c source of frequency 30Hz and peak voltage 60V . Determine the root mean square of the current that flows. (05marks)



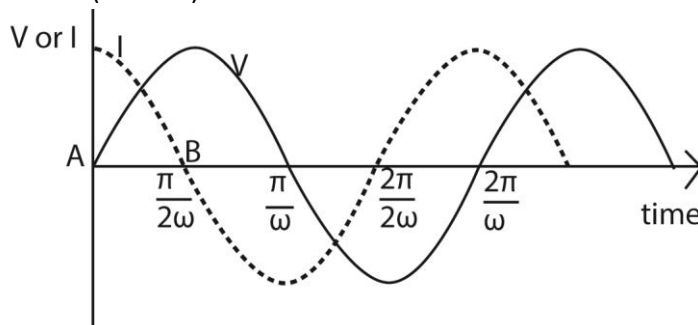
$$\text{For a capacitor, } X_C = \frac{1}{c\omega} = \frac{1}{20 \times 10^{-6} \times 2 \times 1.14 \times 30} = 265.4\Omega$$

$$Z = \sqrt{X_C^2 + R^2} = \sqrt{265.4^2 + 100^2} = 283.6\Omega$$

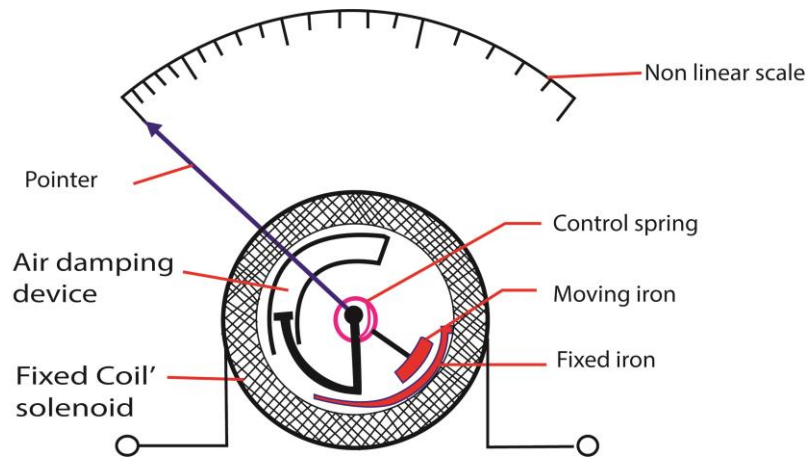
$$V = IZ \Rightarrow I_0 = \frac{V_0}{Z} = \frac{60}{283.6} = 0.212\text{A}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{0.212}{\sqrt{2}} = 0.15\text{A}$$

- (d) (i) On the same axes, draw graphs of voltage $V = V_0 \sin \omega t$ and the resulting current against time for a circuit in which the a.c supply is connected across a capacitor. (02mark)



- (ii) Explain the values of I when $V = V_0$ and when $V = 0$. (02marks)
 When $V = V_0$, $I = 0$ the capacitor is fully charged, and opposition to the flow of charge is maximum
 When $V = 0$, I is maximum because the opposition to the flow of charge is minimum or zero
- (e) Describe the mode of operation of a repulsive type ammeter. (05marks)

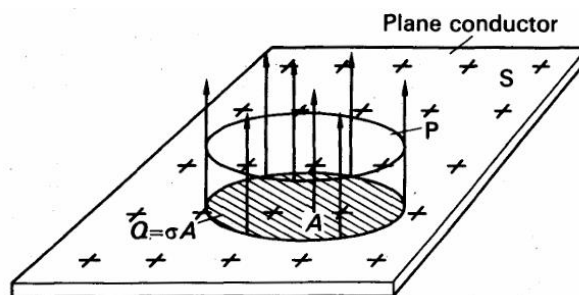


When a current is passed through the coil, the iron rods magnetize in the same poles adjacent to each other in whatever the direction of current. Hence they repel and the pointer move in the same direction until it is stopped by the restoring spring.

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

SECTION D

8. (a) What is meant by the following:
- (i) Electric field (01mark)
It is a region where an electric force is experienced.
 - (ii) Electric flux (01mark)
It is the product of electric field intensity and the area it links normally.
- (b) Show that the electric field intensity at a distance from a charged plane conductor is independent of the distance from the conductor. (03 marks)



Consider a plane surface P, drawn outside S of charged plane conductor, which is parallel to S and has an area A metre² and surface charge density, σ .

$$\text{From } \Phi = \frac{\text{Charge enclosed by P}}{\text{permittivity of the medium}}$$

$$E \times A = \frac{\sigma \times A}{\epsilon}$$

$$\therefore E = \frac{\sigma}{\epsilon}$$

- (c)(i) Figure 3 shows two oppositely charged long parallel metal plates at a separation of 2cm with a p.d of 20kV between them.

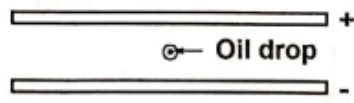


Fig. 3

When a negatively charged oil drop of mass 5.9×10^{-14} kg is introduced in the space between the plates, it remains suspended in space. Estimate the number of electrons in the oil drop. (04marks)

$$\text{Electric force on the drop} = qE = \frac{qV}{d}$$

$$\text{At equilibrium } \frac{qV}{d} = mg$$

$$\Rightarrow q = \frac{mgd}{V} = \frac{5.9 \times 10^{-14} \times 9.81 \times 2 \times 10^{-2}}{20 \times 10^3} = 5.7879 \times 10^{-19}$$

$$\text{From } q = ne$$

$$n = \frac{q}{e} = \frac{5.7879 \times 10^{-19}}{1.6 \times 10^{-19}} = 3.6$$

Hence $n = 3$ or 4 electrons

- (ii) Explain how a neutral material placed between the plates in figure 3 can be shielded from the electric field. (03marks)

The material is enclosed in a metal can and placed in the electric field. The charge (electric field) inside the can is zero. The electric field due to the metal plate only affects distribution of the charge on the outer surfaces of the metal can. Hence the material is shielded.

- (d) Explain how the presence of a neutral conductor near a negatively charged material affects the potential of the material. (04 marks)

Consider a negatively charged material A. when a neutral conductor BC is brought near it as shown above, positive charge is induced on its near side B and negative charge is induced near C as shown below



The potential A is the sum of the potentials due to its charge and the nearby charges. Since the positive charge is closer to A, the resultant potential due to the induced charge is positive. This reduces the negative potential of A.

- (e) Explain why a charged spherical conductor loses charge faster when a pin is placed on it with the sharp point sticking out. (04marks)

When the pin is placed on a charged conductor, high charge concentrates at the sharp point and ionizes the air around it. The opposed ions from the ionized air are attracted and neutralize the charges on the pin causing loss of charges from the conductor.

9. (a) Define the following

(i) Temperature coefficient of resistance. (01mark)

Temperature coefficient of resistance is fractional change in resistance at 0°C per Kelvin rise in temperature.

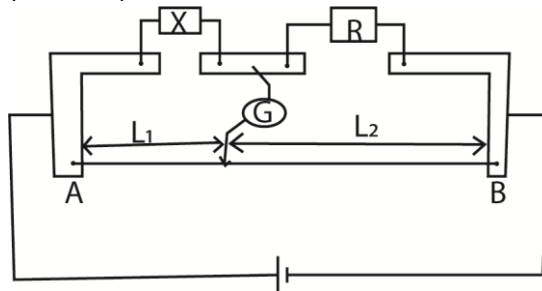
(ii) Electrical resistivity (01mark)

Resistivity is the resistance of a material of length 1m and cross sectional area of 1m^2 .

Or

Resistivity is the resistance across opposite faces of a cube of material of length 1m.

(b)(i) Describe an experiment to measure an unknown resistance using a meter bridge (05marks)



Unknown resistance X is connected in left hand gap of the bridge and standard resistance R is connected in right hand gap of the bridge as shown above. A balancing point is determined where the galvanometer G shown no deflection. The experiment is repeated with several values of R. The results are tabulated including values of $\frac{L_2}{L_1}$. A graph of R against $\frac{L_2}{L_1}$ is plotted. The resistance of unknown resistor X = slope of the graph S.

(iii) Explain why the balance point of a meter bridge should be close to the middle of the slide wire. (03marks)

When the balance point is near the middle, the ratio of the resistances in the two arms of the bridge remains closer to 1, leading to more consistent and proportional results. In such a situation, the errors that occur in the measured value of the resistance would comparatively be smaller.

(c) A piece of wire of length 200cm and cross-sectional area 0.001cm^2 has a resistivity of $4.4 \times 10^{-7}\Omega\text{m}$. The ends of the wire are joined together to form a loop. Terminals T_1 and T_2 are fixed across the diameter of the loop and connected to two cells in parallel, each of e.m.f 1.5V and internal resistance 1Ω as shown in figure 4

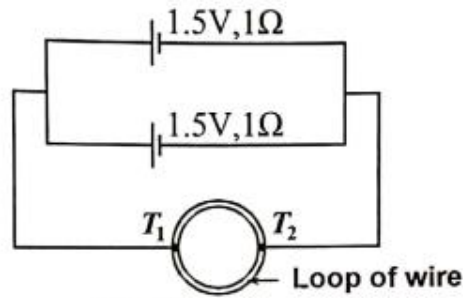


Fig. 4

Find the total current that flows in the circuit. (06 marks)

$$R = \frac{Ql}{A} = \frac{4.4 \times 10^{-7} \times 200 \times 10^{-2}}{0.001 \times 10^{-4}} = 8.8\Omega$$

$$R_1 = R_2 = \frac{R}{2} = \frac{8.8}{2} = 4.4\Omega$$

$$\text{Total resistance in the circuit, } R_T = \frac{4.4 \times 4.4}{4.4 + 4.4} + \frac{1 \times 1}{1 + 1} = 2.2 + 0.5\Omega = 2.7\Omega$$

$$I = \frac{e.m.f}{R_T} = \frac{1.5}{2.7} = 0.556A$$

- (d) Show that a given source of e.m.f delivers maximum power for a load when the resistance of the load is equal to internal resistance of the source. (04 marks)

$$P = I^2 R$$

$$\text{But } I = \frac{E}{R+r}$$

$$P = \left(\frac{E}{R+r}\right)^2 \cdot R = \frac{E^2 R}{(R+r)^2}$$

$$\frac{dP}{dR} = \frac{E^2[(R+r)^2 - 2R(R+r)]}{(R+r)^3} = \frac{E^2(r-R)}{(R+r)^2}$$

$$\text{For maximum power, } \frac{dP}{dR} = 0 \text{ or } r - R = 0$$

$$\text{Thus } r = R$$

10. (a) Define the following:
(i) Dielectric constant (01mark)

Dielectric constant is the ratio of the capacitance of a capacitor with a dielectric material to capacitance of the same capacitor without dielectric material

Or

Dielectric constant is the ratio of permittivity of dielectric to permittivity of free space

- (ii) Dielectric strength (01 mark)

Dielectric strength is the maximum electric field intensity or potential gradient that a material can withstand without breaking down and losing its insulating properties.

- (b) Explain using molecular theory, the effect of a dielectric material on the capacitance of a capacitor. (05 marks)

- when a dielectric is placed between the plates of a charged capacitor, its molecules get polarised.

- The charges inside the electric cancel each others and surface of dielectric acquires charges opposite to charge of the plate near the surface.
- since those are bound charges then cannot be neutralized
- an electric field intensity is developed between the surfaces of a dielectric in the direction opposite to that of applied field.
- The resultant electric field intensity reduces i.e. from $E = \frac{V}{d}$; p.d, V reduces.
Also from $C = \frac{Q}{V}$; capacitance of capacitor increases.

(c) A capacitor of $50\mu\text{F}$ is charged fully to a p.d of 45V . The capacitor is the disconnected and a dielectric material of dielectric constant 2 is inserted between its plates. If it is then connected across an uncharged capacitor of $60\mu\text{F}$, determine the;

(i) p.d across the combination (04marks)

$$\text{Charge stored, } Q = CV = 50 \times 10^{-6} \times 45 = 2.25 \times 10^{-3}\text{C}$$

After inserting the dielectric, capacitance $C' = 2 \times 50 \mu\text{F} = 100 \mu\text{F}$

Total capacitance, $C_T = (100 + 60) \mu\text{F} = 160 \mu\text{F}$

$$V = \frac{Q}{C_T} = \frac{2.25 \times 10^{-3}}{160 \times 10^{-6}} = 14.1\text{V}$$

Or

$$V = \frac{C_0 V_0}{C_1 + C_2} = \frac{50 \times 10^{-6} \times 45}{100 + 60} = 14.1\text{V}$$

Or

$$Q = C_1 V_1 = (C_1 + C_2) V_f$$

$$V_f = \frac{C_1 V_1}{C_1 + C_2} = \frac{50 \times 10^{-6} \times 45}{100 + 60} = 14.1\text{V}$$

(ii) change in energy initially stored and in both capacitors. (04marks)

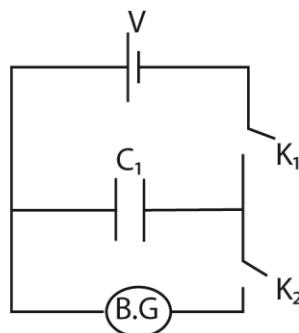
$$E_1 = \frac{1}{2} CV^2 = \frac{1}{2} \times 50 \times 10^{-6} \times 45^2 = 0.0506\text{J}$$

Energy stored in combination

$$E_2 = \frac{1}{2} \times 160 \times 10^{-6} \times 14.1^2 = 0.0159\text{J}$$

$$\text{Change in energy} = 0.0506 - 0.0159 = 0.0347\text{J}$$

(d)(i) Describe how a ballistic galvanometer can be used to compare capacitance of two capacitors. (04marks)



- 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 deflection of the B.G. θ_1 is noted

- The capacitor is then replaced with the capacitor of unknown capacitance C_2 . The experiment is repeated and deflection θ_2 is noted
- Hence $\frac{C_2}{C_1} = \frac{\theta_2}{\theta_1}$; $C_2 = C_1 \frac{\theta_2}{\theta_1}$

(ii) State any two functions of a dielectric material in a capacitor. (01 mark)

- **Increases Capacitance:** By introducing a dielectric material, the capacitor's ability to store charge increases. This is due to the dielectric constant (relative permittivity) of the material, which reduces the effective electric field and allows more charge to accumulate for a given voltage.
- **Prevents Short Circuiting:** The dielectric acts as an insulating layer between the capacitor's plates, preventing direct contact and ensuring that charge is stored safely without current flowing directly across the plates.
- **Enhances Energy Storage:** A dielectric material allows a capacitor to store more energy by enabling a higher charge storage for the same physical size. This makes capacitors more compact and efficient.
- **Reduces Electric Field Strength:** Through dielectric polarization, the internal electric field opposes the applied field, effectively reducing the net electric field. This helps maintain the capacitor's functionality under high voltage.
- **Enables High Voltage Operation:** Certain dielectric materials have high dielectric strength, allowing capacitors to operate at higher voltages without breakdown.

The new deflection θ_2 of BG is noted. ✓
 capacitances are compared from $C_1 = \theta_1$ ✓
 $C_2 = \theta_2$ ✓ 04

(ii) - it separates the capacitor plates ✓
 - increases capacitance of capacitor ✓
 - increases dielectric strength. ✓
 END

