P510/2

PHYSICS

HeLP UACE PHYSICS 2 FACILITATION PROPOSED SOLUTIONS

SECTION A

Question 1

(a) Define the following terms as applied to convex lens.

(i) Principal axis

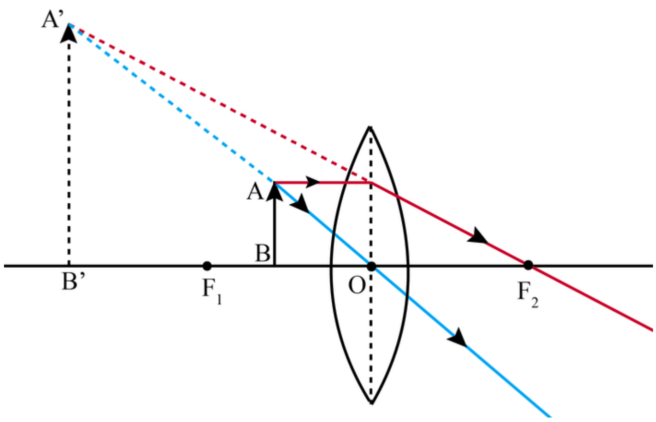
This is the line passing through the centres of curvature of the lens.

(ii) Focal length

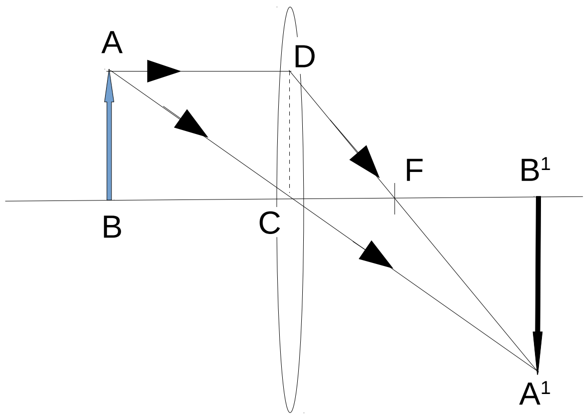
This the distance between the optical centre and the principal focus.

(b) A finite object is placed between the principal focus and optical centre of a converging lens.

(i) Draw a ray diagram to indicate the image formed



(ii) Use a ray diagram, derive the lens formula. (5 marks)



Triangles A^1B^1C and ABC are similar

$$\frac{A^1B^1}{AB}=\frac{CB^1}{CB}.........(i)$$

Also, triangles A^1B^1F and CDF are similar

$$\frac{A^1B^1}{AB}=\frac{FB^1}{CF}......(ii)$$

From equations (I) and (ii);

$$\frac{CB^1}{CB}=\frac{FB^1}{CF}\rightarrow\frac{CB^1}{CB}=\frac{CB^1-CF}{CF}$$

But $CB=u$ (object distance), $CB^1=v$ (image distance) and $CF=f$ (focal length)

$$\rightarrow\frac{v}{u}=\frac{v-f}{f}$$

$$uv=fv+fu$$

Diving both sides by ufv

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

(c) Describe an experiment to determine the focal length of a concave lens using a plane mirror, a converging lens and an illuminated object. (5 marks)

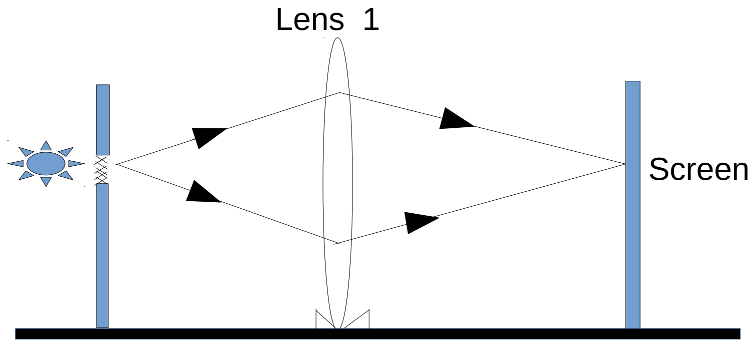


Figure a

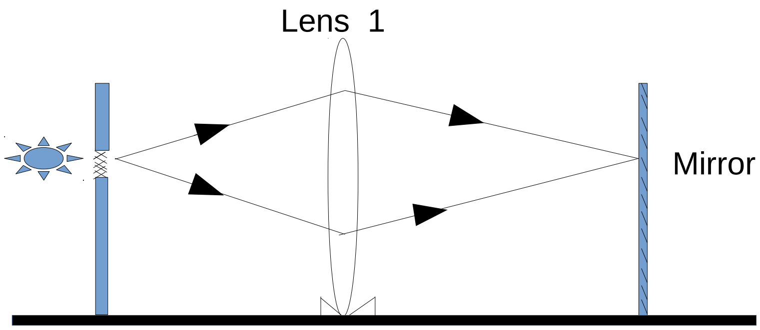


Figure b

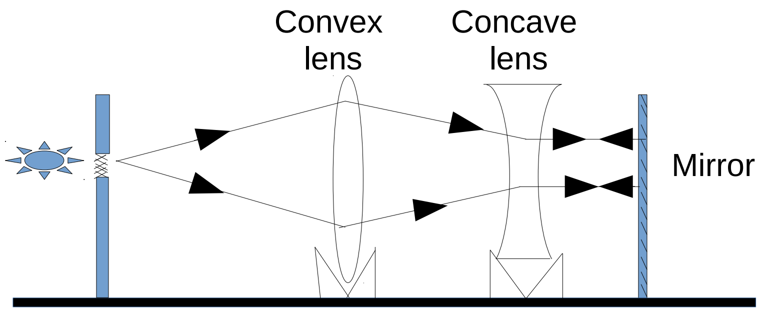


Figure c

A sharp image of light source is projected on a screen by converging lens.

The screen is then replaced with a plane mirror

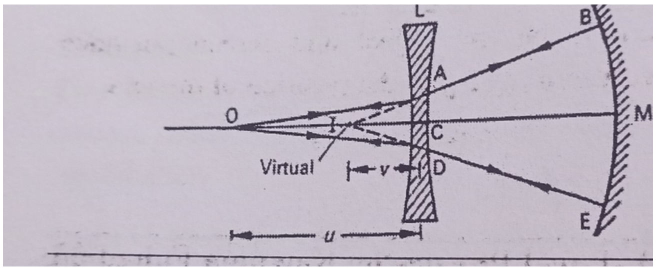
A diverging lens whose focal length is required is placed between the converging lens and the plane mirror.

Light will then be reflected by the mirror back through the compound lens system and an image will be formed on the screen nearer the light source.

The image is made sharp by adjusting the distance between the diverting lens and the mirror.

The distance between the diverting lens and the mirror at which the image is clearest is equal to the focal length.

(d) A point object is placed 20cm infront of a diverging lens and on other side of the lens is a concave mirror coaxial with it and of focal length 20cm. If the final image coincides with the object, calculate the focal length of concave lens if the distance between the lens and the mirror is 30cm (4 marks)



Given $v=IM-CM \rightarrow v=-(r-30)\,cm$, $r=40\,cm$ Therefore,

$v=-10\,cm(\text{since image is virtual})$, $u=20\,cm$

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

$$\frac{1}{f}=\frac{1}{20}+\frac{1}{-10}$$

$f=-20\,cm$

(e) Explain why parabolic mirrors are used in car head lamps. (2 marks)

Car head lamps have parabolic mirrors which have a property of reflecting light rays that originate from their focal point into parallel beams. This increases the intensity of the light output.

Question 2

(a) What is the eye ring of a telescope? (1 mark)

The eye ring is an image of the face of the objective lens formed by the eyepiece. Or It is the circular image of the objective formed by the ye piece.

Or. It is the best position for the eye when viewing an image through the instrument.

(b) Give one advantage and one disadvantage of each of the following telescope in their use as optical instruments.

(i) Terrestrial telescope (2 marks)

Advantages

- The final image formed is erect

Disadvantages

- The erecting lens decreases the intensity of light through the eyepiece.
- The instrument is longer by 4f where f is the focal length of the erecting lens.

(ii) Galilean telescope (2 marks)

Advantages

They are shorter than the terrestrial telescope and astronomical telescope

The final image is erect.

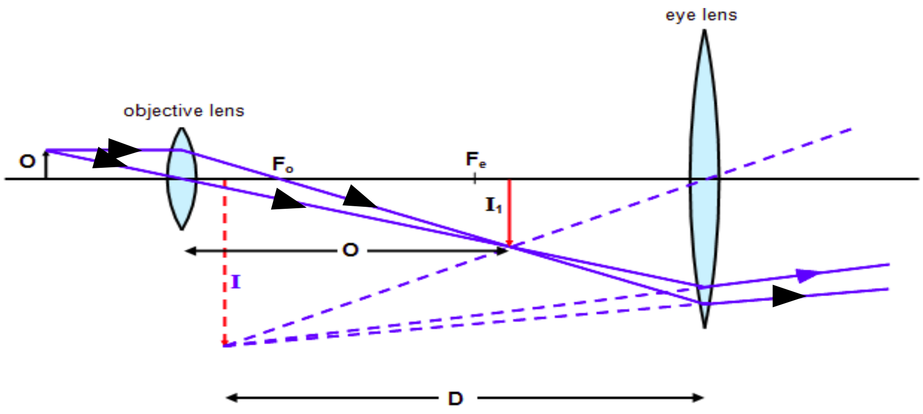
Disadvantage

It has a small (narrow) field of view

It has a virtual eyering

It produces unclear images(less bright)

(c) (i) Draw a ray diagram and use it to derive an expression for angular magnification of a compound microscope in normal use. (5 marks)



The intermediate image is formed formed at point nearer the eyepiece than the principal focus Fe hence the eyepiece acts as a magnifying glass.

The observers eye is taken to be close to the eyepiece so that visual angle $\alpha^{\prime}$ is taken as the angle subtended at the eye by the final virtual image.

The image is formed at the least distance of distinct vision from th eye.

For the aided eye;

$\tan\alpha^1 = \frac{h_2}{D}$ For small angles, $\tan\alpha^1 \approx \alpha^1$

$$\alpha^1 = \frac{h_2}{D}$$

If α is the angle subtended at the naked eye by the object when the object is at the near point. For unaided eye, $\tan\alpha = \frac{h_1}{D}$. But $\tan\alpha \approx \alpha$ (for small angles expressed in radians)

$$\alpha = \frac{h_1}{D}$$

Magnifying power $M = \frac{\alpha^1}{\alpha}$

$$M = \frac{h_2}{D} \div \frac{H_1}{D}$$

$M = \frac{h_2}{h_1}$ (lateral magnification m)

But $M = \frac{h_2}{h} \times \frac{h}{h_1} \rightarrow M = M_o \times M_e$ …………*

Where M_o and M_e are the linear magnifications produced by the objective lens and eyepiece respectively.

But $M_o = \frac{v}{f_o} - 1$ And $M_e = \frac{D}{f_e} - 1$

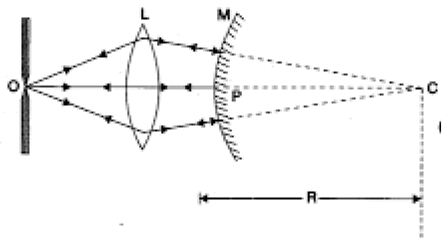
Substituting in equation *

$$M = \left(\frac{v}{f_o} - 1\right)\left(\frac{D}{f_e} - 1\right)$$

(ii) How can high magnification be achieved? (1 mark)

By using lenses of small focal lengths

(d) Describe an experiment to determine the focal length of a convex mirror using a convex lens. (4 marks)



Using a convex lens, a real image I of an object O is formed at C with the mirror absent.

Distance LC is measured and recorded.

The mirror is then placed between L and C and its position adjusted until O coincides with its own image.

This occurs when the light from O is incident normally on the curved mirror after refraction by the lens. Thus, C is the centre of curvature of the mirror.

Distance LP is measured

Since $r = 2f = PC = LC - LP$

Therefore

$$f=\frac{LC-LP}{2}$$

(e) A slide projector is required to produce a real image 648mm wide from an object 36mm wide. If the distance of the object from the screen is to be 2000mm, calculate:

(i) The distance of the lens from the object (3 marks)

$$m=\frac{648\,mm}{36\,mm}=18 \quad , \quad m=\frac{v}{u}\rightarrow 18=\frac{2000-u}{u} \quad , \quad \rightarrow u=105.26\,mm$$

(ii) The focal length of the lens required. (2 marks)

using $\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$, $\frac{1}{f}=\frac{1}{105.26}+\frac{1}{1894.74}$

$f=99.72\,mm$ or $f=9.972\,cm$

SECTION B

Question 3

(a) Define

(i) An overtone (1 mark)

An overtone is *a type of harmonic with a frequency higher than a sound's fundamental frequency.*

(ii) Ultra sound (1 mark)

Ultrasound is defined as *sound with frequencies that are higher than the range of human hearing*

(b) (i) State one application of ultra sound. (1 mark)

- Bats utilize ultrasound just to detect obstructions in their route.
- Drilling holes through materials such as glass and cleaning small things.
- Defect detection throughout metals.

(ii) Explain why the same note played on different instruments sounds different. (3 marks)

Its because the harmonic overtones and envelope of each instrument is unique. When a frequency is played, other frequencies, called harmonics, are created.

(c) A wire of length 400mm and mass $1.2\times10^{-5}kg$ is under tension of 120N. What is

(i) The fundamental frequency of vibration. (3 marks)

$f_o=\frac{1}{2L}\sqrt{\frac{T}{m}}$ where , m is mass per unit length $m=\frac{1.2\,x\,10^{-5}}{400\,x\,10^{-3}}$,

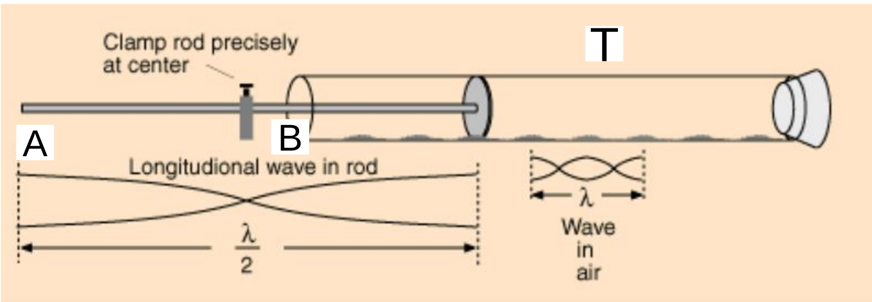
$m=0.00003\,kgm^{-1}$

$f_0=\frac{1}{2\,x\,400\,x\,10^{-3}}\sqrt{\frac{120}{0.00003}}$ $f_o=2500\,Hz$

(ii) The frequency of the third harmonic (2 marks)

$f_3=3f_o \rightarrow f_3=7500\,Hz$

(d) Describe an experiment to determine the velocity of sound in air by the dust tube method. (5 marks)



Sprinkle some chalk dust along the tube T.

Clamp the rod AB at its midpoint but with one end projecting into the tube T.

A disc is connected to this end so that it just clears the sides of the tube.

Strike the rod with a compact cloth in the direction AB until the powder in the tube settles into heaps.

Measure distance l_2 between the heaps and the length l_1 of the rod.

The velocity of the sound in the rod in given by,

$v_r=\frac{v_a l_1}{l_2}$, where v_a is the speed of sound in air which is the tube.

(e) (i) Explain reverberation as applied to sound waves. (2 marks)

Reverberation is the persistence of sound after it has been stopped due to multiple reflections from surfaces such as furniture, people, air, etc., within a closed surface. These reflections build up with each reflection and decay gradually as they are absorbed by the surfaces of objects in the enclosed space.

(ii) Explain how reverberation may be minimized in a large hall. (2 marks

To reduce reverberation, the roof and walls of the auditorium are generally covered with sound-absorbent materials like compressed fibre board, rough plaster or draperies.

Question 4

(a) Distinguish between sound waves and light waves. (3 marks)

Light waves can propagate through vacuum as they do not disappear after some time and hence do not require medium for propagation. **While**

Sound waves are types of mechanical waves which require a medium for production and propagation.

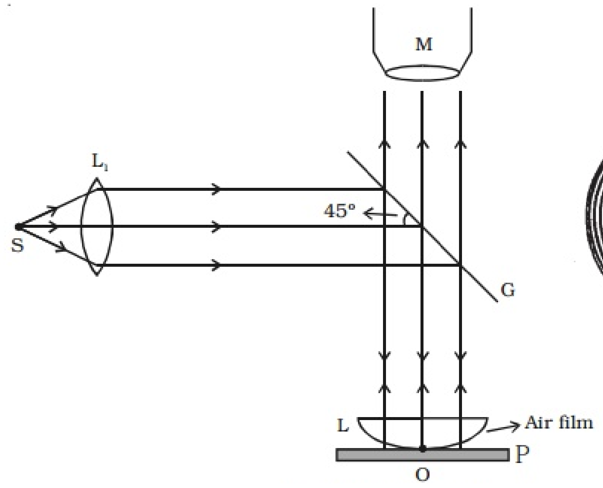
(ii) State two conditions necessary for interference patterns to be formed. (2 marks)

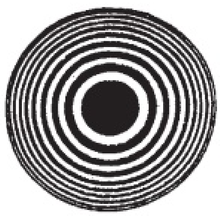
- The sources of the waves must be coherent, which means they emit identical waves with a constant phase difference.
- The waves should be monochromatic. I.e They should be of a single wavelength.

(b) A Plano convex lens is placed on top of a glass plate. When a traveling microscope is focused on the lens, alternate dark and bright rings are observed.

(i) Explain the formation of rings. (5 marks)

Light from a monochromatic source (sodium lamp) is allowed to fall on the convex lens through a broad slit which renders it into a nearly parallel beam. Now it falls on a glass plate inclined at an angle 45° to the vertical, thus the parallel beam is reflected from the lower surface. Due to the air film formed by a glass plate and a plano convex lens of large radius of curvature, interference fringes are formed which are observed directly through a traveling microscope. The rings are concentric circles.





(ii) The space between the glass plate and the lens is filled with a liquid whose refractive index is higher that that of the lens but less than that of the glass plate. Explain what happens to the appearance of the rings. (4 marks)

Pouring a liquid of refractive index μ between the lens whose radius of curvature is known and the plate will change the path difference to $2\mu t$ and thus for the nth dark ring

$$n\lambda=\frac{\mu r_n^2}{R}$$

The radius of any given ring will be less with the liquid in place than without it. This effect may be used to measure the refractive index of the liquid.

(c) In Young's double slit experiment, Light of wavelength 644nm was used. The double slits are separated by 0.75mm and the screen is 80cm from the slits.

(i) Find the fringe width (3 marks)

Using $x = \frac{\lambda D}{a}$ $x = \frac{(644\times10^{-9})\times80\times10^{-2}}{0.75\times10^{-3}} \rightarrow x = 6.869\times10^{-4}m$

(ii) One of the slits is covered with a glass material of thickness 3.6mm and refractive index 1.5. Calculate the displacement of the material of the central band. (3 marks)

The shift in the central fringe can be obtained by

$S = \frac{(\mu-1)tD}{a}$ Where, t is the thickness of the glass material.

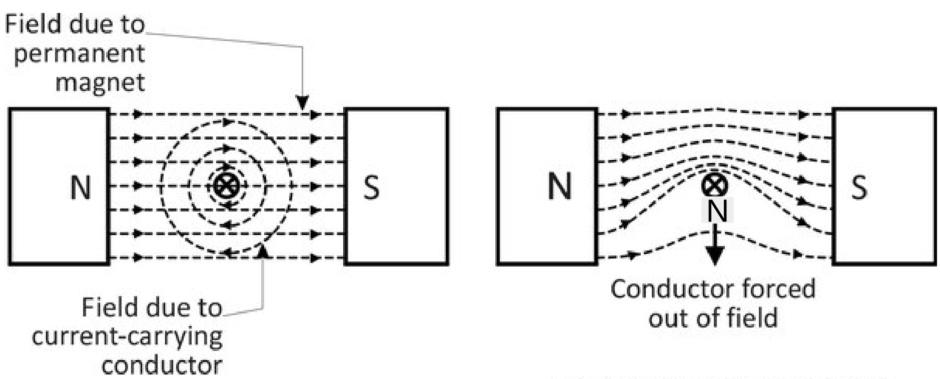
$$S = \frac{(1.5-1)\times3.6\times10^{-3}\times80\times10^{-2}}{0.75\times10^{-3}}$$

$S = 1.92\,m$

SECTION C

Question 5

(a) Sketch the magnetic field pattern around a vertical current carrying straight wire in the magnetic field and use it to explain the neutral point in a magnetic field. (3 marks)



(a) Individual Fields
(b) Combined Fields Causing Force on Conductor

Consider a current carrying conductor carrying current into the paper in region of magnetic field as shown above.

The field is stronger on one side of a conductor where there is high concentration of field lines and weaker on the side of the conductor where there are fewer field lines.

A resultant force is created from the side with a stronger field to the side with a weaker field and it is this force that tends to move the conductor.

The direction of the force can be determined by the Flemings left hand rule.

(b) (i) Explain the factors that affect the magnitude of force on a conductor carrying current I in the region of magnetic field of flux density B. (4 marks)

Current through a conductor: Current is directly proportion to force exerted on a conductor.

Length of a conductor: The length of the conductor is directly proportional to the force on a conductor.

Magnetic field strength: Force on a magnetic field is directly proportional to the strength of the magnetic field.

(ii) A straight horizontal rod of mass 150g and length 0.5 m is placed in a uniform horizontal magnetic field of 0.2T perpendicular to it. Calculate the current through the rod if the force acting on it just balances its weight. (4 marks)

$$Magnetic\ force = Weight\ of\ a\ conductor$$
$$F_B = W$$
$$BIL = mg \rightarrow I = \frac{mg}{BL}$$
$$I = \frac{150 \times 10^{-3} \times 9.81}{0.2 \times 0.5}$$
$$I = 14.715\,A$$

(c) A rectangular coil of N turns and area A m^2 is suspended in a uniform magnetic field of flux density B Tesla. Initially the plane of the coil is parallel to the magnetic field. Derive the expression for the initial couple on the coil when a current of I amperes flows through it. (5 marks)

Consider a rectangular coil of one turn, whose plane makes an angle α with a uniform magnetic field B. A current I passes through the coil of sides $PQ=a$ .and $PS=b$

Forces on the vertical sides, $F_1=BIL=BIa$, where a is the length of the coil.

Forces on the horizontal sides, $F_3=BIb\sin\alpha$, where b is the width of the coil.

The forces F_2 and F_4 are equal and opposite and thus cancel out.

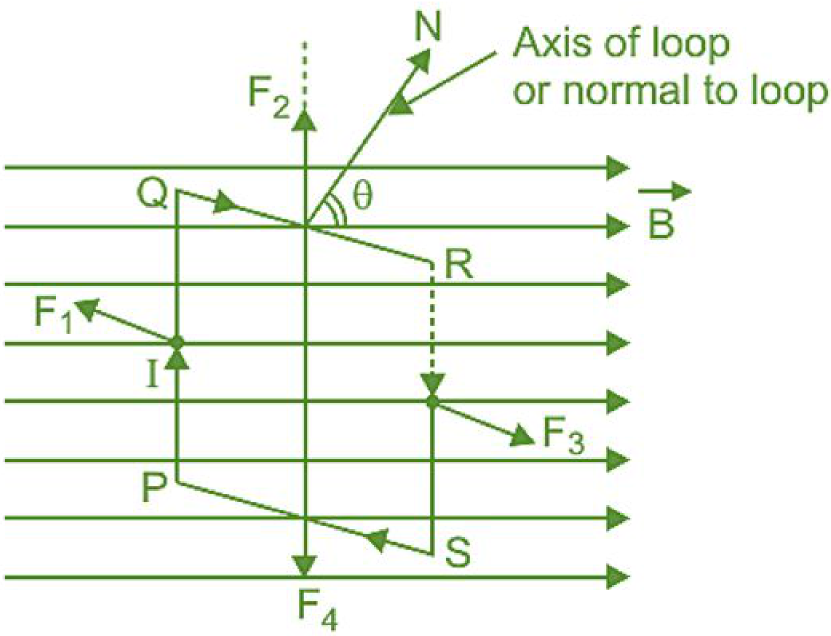
The forces, F_1 and F_3 set up a couple whose moment is given by;

$$\tau=F_1\times perpendicular\ distance$$
$$\tau=F_1\times b\cos\alpha$$
$$\tau=BIab\cos\alpha$$
$$\tau=BIA\cos\alpha$$ where A is the area of the coil.

If the coil has N turns, $\tau=NBIA\cos\alpha$

If θ is the angle between the field lines and the normal to the plane of the coil, then

$$\theta=90^0-\alpha$$



(d) A narrow vertical rectangular coil is suspended from the middle of its upper side with its plane parallel to the uniform magnetic field of 0.05T. The coil has 20 turns and the length of its vertical and horizontal sides are 0.4cm and 0.3cm respectively.

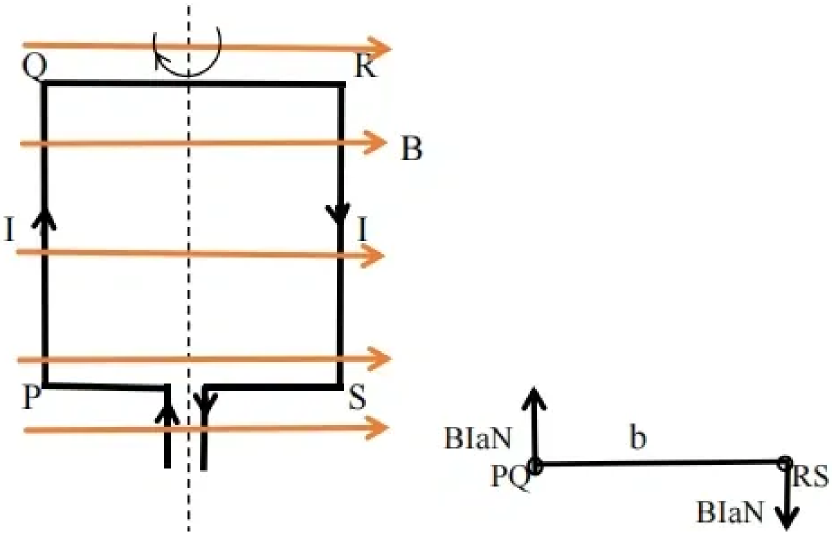
(i) Calculate the torque on the coil when the current of 2A is passed through it. (3 marks)

Using $\tau = NBIA$

$\tau = 20 \times 0.05 \times 2 \times 0.04 \times 0.03$

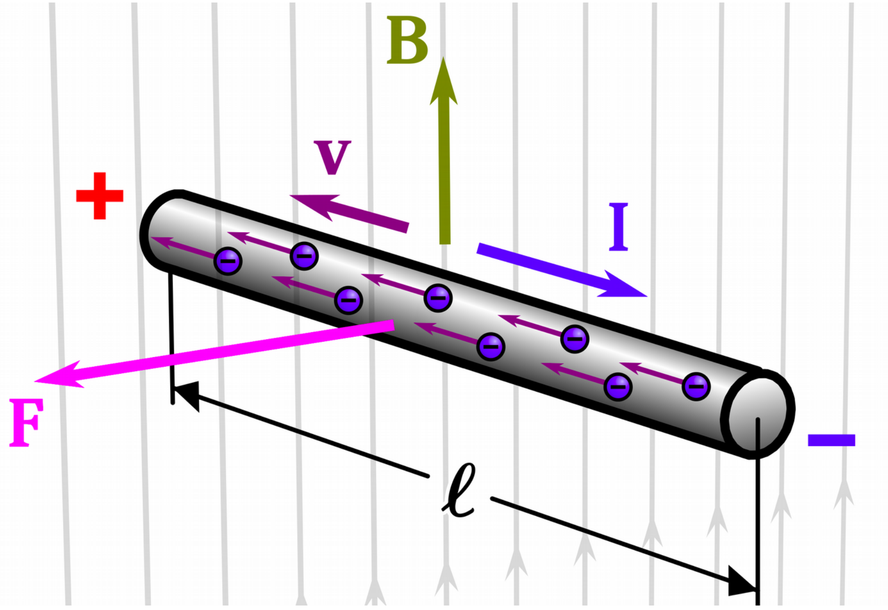
$\tau = 0.0024\,Nm$

(ii) Draw a sketch showing direction of current, field and torque. (1 mark)



Question 6

(a) (i) Derive the expression for the force experienced by an electron moving at an average velocity V in a wire placed at right angles to a magnetic field of flux density B. (4 mark)



Consider a conductor of length L having N electrons moving with an average drift velocity v.

The time required for all these electrons to emerge from the conductor is; $t=\frac{l}{v}$

The rate of flow of charge in the conductor (Current I) is;

$\frac{Q}{t}=\frac{Ne}{l/v}$ Therefore,

$I=\frac{Nev}{l}$

If the conductor is at right angles to a magnetic field of flux density B, then the force felt by all electrons.

Therefore $F=B(Nev)$

Substituting for Nev gives $F=BIl$

(ii) An electron beam moving with velocity of $100ms^{-1}$ passes through a uniform magnetic field of flux density 0.02T which is perpendicular to the direction of the beam. Calculate the force on each of the electron. (3 marks)

Using $F=B(Nev)$ where $B=0.02\,T, v=100\,ms^{-1}, N=1$ and $e=1.6\times10^{-19}C$

Therefore; $F=0.02\times1.6\times10^{-19}\times100$

$F=3.2\times10^{-19}N$

(b) (i) Write the formula for the force between two parallel straight wires of infinite length carrying currents I_1 and I_2 in the same direction. (1 mark)

$$F=\frac{\mu I_1 I_2 L}{2\pi d}$$

(ii) Use the formula above to define the ampere. (2 marks)

From $\frac{F}{L}=\frac{\mu I_1 I_2}{2\pi d}$ If $I_1=I_2=IA, d=1m$

$\frac{F}{L}=\frac{4\pi\times10^{-7}\times1\times1}{2\pi\times1}$ $\frac{F}{L}=2\times10^{-7}\,Nm^{-1}$

Definition

Ampere is the steady current which when flowing in each of two infinitely long straight parallel conductors of negligible cross sectional area and 1 m apart in a vacuum causes each conductor to exert a force of $2\times10^{-7}\,Nm^{-1}$

(ii) Two thin long parallel wires A and B carry currents of 2A and 3A respectively in opposite directions. If the wires are separated by a distance of 2.5cm in a vacuum. Calculate the force exerted by wire B on 1m of wire A. (3 marks)

Using $\frac{F}{L}=\frac{4\pi\times10^{-7}\times2\times3}{2\pi\times2.5\times10^{-2}}$ $\frac{F}{L}=4.8\times10^{-5}\,N$

(c) Describe the absolute measurement of current using an ampere balance. (5 marks)

A current balance consists of a wire frame PQNM pivoted about a horizontal axis XY.

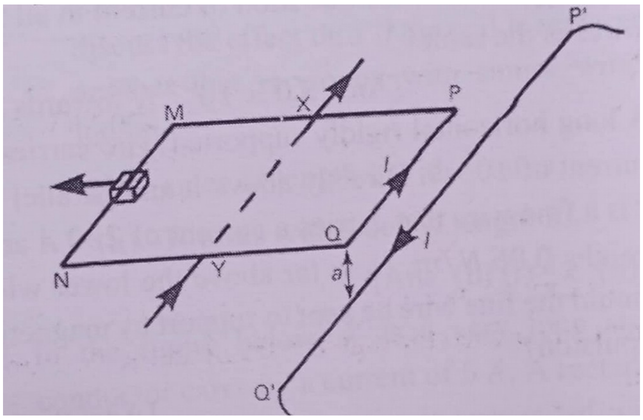
The pivots are such that current current can be fed into the frame at one of them and out at the other.

P^1Q^1 is a long fixed straight wire which is parallel to PQ and vertically below it.

The two wires are in series such that each carries the same current I.

The distances of MN and PQ from the horizontal axis XY are made equal.

Set up



Procedure

With no current flowing, the metal frame PQNM is made horizontal.

The current to be measured is switched on to pass through PQ and P^1Q^1 in opposite directions.

PQ feels a downward force whose magnitude is given by,

$$F=\frac{\mu_o I^2 L}{2\pi a}$$

where, a is the separation of PQ and P^1Q^1 and L is the length of PQ.

The frame is restored to the horizontal position by adding riders of mass m.

The length L of the wire PQ and the separation of the wires PQ and P^1Q^1 are measured.

$mg=\frac{\mu_o I^2 L}{2\pi d}$ Therefore $I=\sqrt{\frac{2\pi amg}{\mu L}}$

Since the values of a, m, L, g and μ_o are known, the current, I can be obtained.

(d) Write down the formula for magnetic flux density at the end of a solenoid of length L Currying current I and placed in a magnetic field in free space. Define all the terms. (2 marks)

$$B=n\mu_o I$$

where, n is number of coils per unit length, I is current flowing thought the coil and μ_o is the permeability of free space.

Question 7

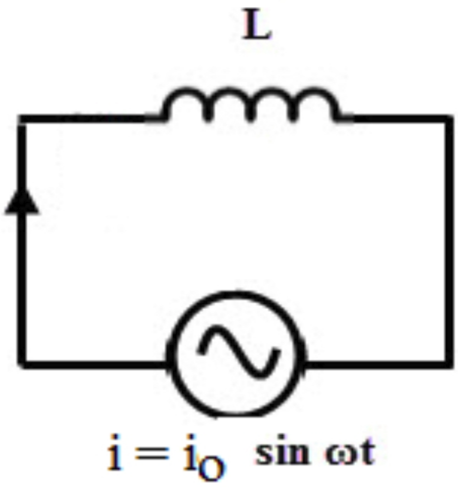
(a) Distinguish between electrical **resistance** and **reactance**. (2 marks)

Resistance is the opposition to the flow of current in a resistor.

While reactance is the non-resistive opposition to the flow of current through an inductor or capacitor.

(b) An alternating current I flows through a coil of inductance L. The instantaneous value of current is $I = I_o \sin 2\pi ft$, where I_o is the amplitude and f the frequency.

(i) Derive an expression for the voltage V across the coil. (4 marks)



The instantaneous value of i given by $i = i_o \sin 2\pi ft$, where $\omega = 2\pi f$, i_o is the amplitude of the the current and f if the frequency.

From $V = -L\frac{di}{dt}$, where L is inductance.

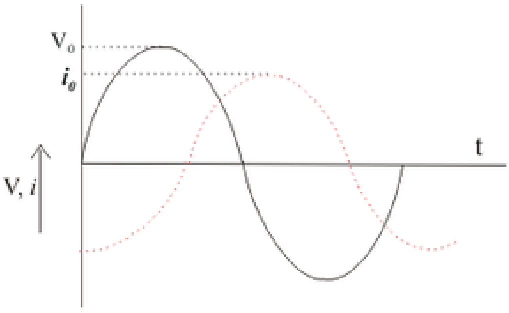
$$V = -L\frac{d(i_o \sin 2\pi ft)}{dt}$$

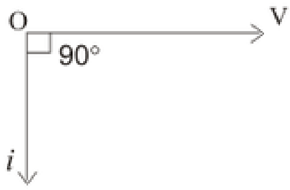
$$V = -Li_{od}\frac{d}{dt}(\sin 2\pi ft)$$

$$V = 2\pi fLi_o \cos 2\pi ft$$

(ii) State the phase of V relative to that of I. (1 mark)

Current lags the voltage by 90^o.

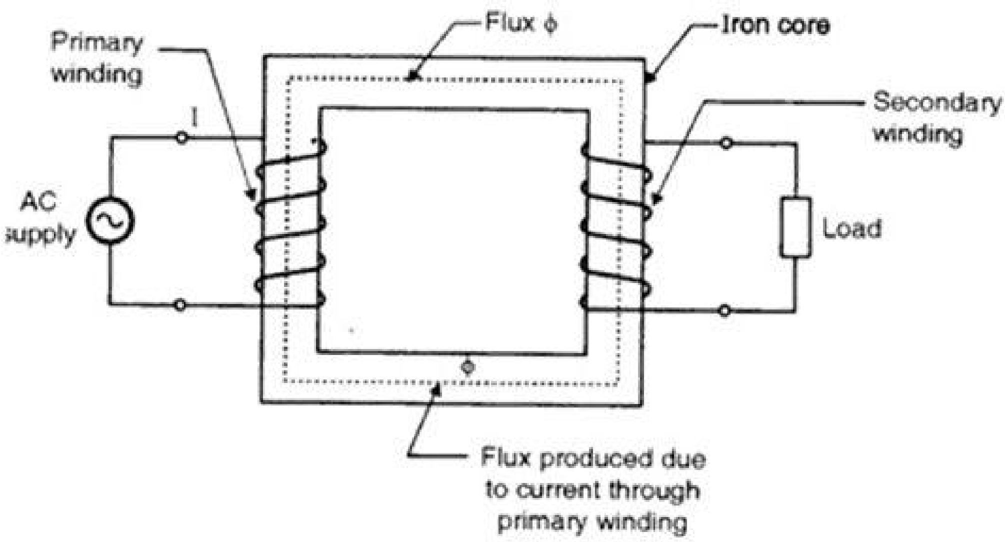




(iii) If the coil is a pure inductor, explain why it is non-dissipative. (3 marks)

The instantaneous power integrated over one power cycle will sum to zero because inductors and capacitors are energy storage elements. During half the power cycle, they store energy. During the second half, they return the stored energy back to the system. Since the net energy exchange over one period is zero, the average power is zero.

(c) With the aid of a diagram describe the structure and mode of operation of an a.c transformer. (5 marks)



A transformer consists of two coils electrically insulated from each other but wound on the same core.

Current is passed through the primary coil and emf is induced in the secondary coil. The flux passing through the primary and the secondary coil is the same.

If a changing current is passed through the primary coil, emf will be induced in both coils.

Let Φ be flux in the core passing through each turn.

Flux linkage through the secondary coil = $N_s\Phi$ where N_s is number of turns of secondary coil.

Emf Vs induced in secondary coil is given by;

$$V_s=\frac{-d(N\Phi)}{dt}=-N_s\frac{d\Phi}{dt}.........(i)$$

The changing flux through the primary coil induces a back e.m.f in the primary coil which opposes the applied p.d.

To keep the flux changing,

$$Applied\ p.d\ V_s=back\ Emf$$

Back e.m.f, $E_{back}=\frac{-d(N_p\Phi)}{dt}$ where, Np is number of turns of the primary coil.

$$V_p=\frac{-d(N_p\Phi)}{dt}=-N_p\frac{d\Phi}{dt}..........(ii)$$

Diving (I) by (ii) gives

$$\frac{V_s}{V_p}=\frac{N_s}{N_p}$$

(d) An 8.64kW transformer steps down Voltage from 240V to 30V. If the secondary coil has 150 turns and the transformer is 80% efficient, find;

(i) The number of turns in the primary coil. (2 marks)

Using $\frac{V_s}{V_p}=\frac{N_s}{N_p}$, $N_p=\frac{240\times150}{30}=1200$ turns

(ii) The current flowing in the primary coil. (3 marks)

From $P=IV$, $8640=240I$

Therefore $I=36A$

SECTION D

Question 8

(a) Define the term Dielectric. (1 marks)

A dielectric is a material which has poor electrical conductivity but inherits an ability to store an electrical charge

(b) (i) Describe the charging and discharging process of a capacitor (5 marks).

A capacitor can be charged by connecting it to a battery and discharged by disconnecting it from a battery.

Charging a capacitor.

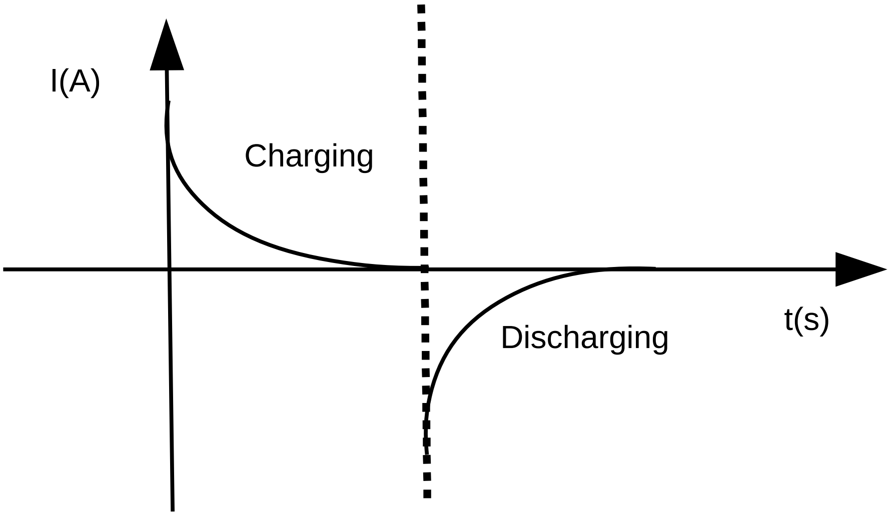
The electrons move from the negative terminal of the battery and accumulate on one plate of the capacitor and equal amount of positive charges is induced on the other plate. The process of charging the capacitor continues until the potential difference across the capacitor equals the emf of a battery.

If the resistance in charging the circuit is negligible, the charging is almost intant and the result is that charge is stored in the capacitor. The charge remains even after the battery is disconnected.

Discharging a capacitor.

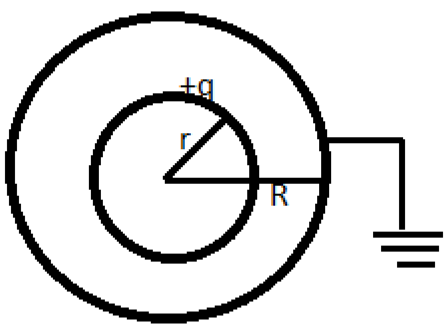
When the battery is disconnected, and the plates are joined together by a wire, electrons flow back from the negative plate to the positive plate until the positive charge on it is completely neutralized. The charges on the plates become zero.

(ii) Plot a graph of current against time for the charging and discharging process of capacitor. (2 mar)



(c) (i) Two concentric spheres A and B with radii a and b respectively are placed in free space. If A is charged Q+ and B is earthed. Show that the capacitance of the of the two concentric spheres is given by; $C=\frac{4\pi_0 rR}{R-r}$ (4 marks)

Consider two concentric conducting spheres of radii, r and R respectively. The outer surface of the bigger sphere is earthed while the inner sphere is given a positive charge.



If the charge +q is given to the inner sphere and a charge of -q is induced on the inner surface of the outer sphere.

The potential on the inner sphere, V_r is due to the charge on the surface of the sphere

+q, and charge on the inner surface of the outer sphere -q I.e

$$V_r = \frac{+q}{4\pi\epsilon_0 r} + \frac{-q}{4\pi\epsilon_0 R}$$

But the potential on the outer surface of the sphere is zero.

Therefore potential difference $V = V_r - V_R$

$$V = \frac{+q}{4\pi\epsilon_0 r} + \frac{-q}{4\pi\epsilon_0 R} - 0$$

$$V = \frac{+q}{4\pi\epsilon_0}\left(\frac{R-r}{rR}\right) \quad \text{But} \quad C = \frac{q}{V}$$

$$C = \frac{4\pi\epsilon_0 rR}{R-r}$$

(ii) Suppose $r = 5\,cm$ and $R = 2\,cm$ and the two concentric spheres are separated by a material of permitivity $8.0 \times 10^{-11} Fm^{-1}$. Find the capacitance of the concentric spheres. (2 marks)

$$C = \frac{4\pi\epsilon_0 rR}{R-r} \qquad C = \frac{4\pi \times 8.0 \times 10^{-11} \times 0.05 \times 0.02}{0.05 - 0.02} \qquad C = 3.35 \times 10^{-9} C$$

(a) (i) State the law of force between two point charges. (1 mark)

The force between two point charges is directly proportional to the product of the magnitudes of their charges and inversely proportional to the square of the distance between them.

(ii) Four charges of magnitude -4μC, +8μC, +3μC and +5μC act at corners A, B, C and D respectively of a square of sides 4cm. Find the resultant force on the charge at C. (4 marks)

$$F = k\frac{q_1 q_2}{r^2} \quad \text{where} \quad k = 9.0\times10^9$$

Force exerted on +3μC due to -4μC

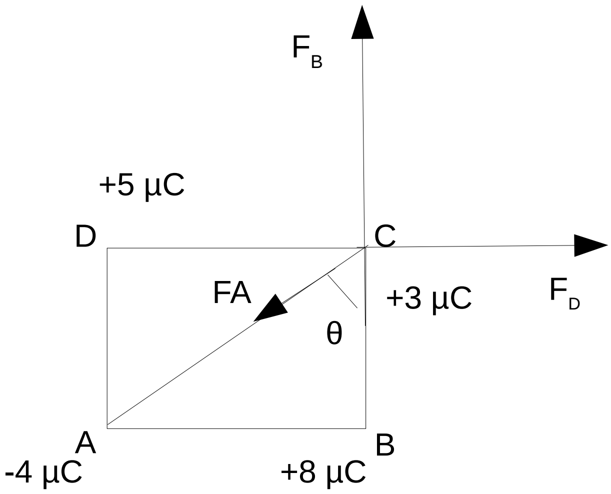
$$F_A = \frac{9\times10^9\times3\times10^{-6}\times4\times10^{-6}}{0.0032} = 33.75\,N$$

Force exerted on +3μC due to +8μC

$$F_B = \frac{9\times10^9\times3\times10^{-6}\times8\times10^{-6}}{0.04^2} = 135\,N$$

Force exerted on +3μC due to +5μC

$$F_D = \frac{9\times10^9\times3\times10^{-6}\times5\times10^{-6}}{0.04^2} = 84.375\,N$$



$\theta = \tan^{-1}(\frac{4}{4}) = 45^0$

$\sum F_x = F_D + -F_A \cos 45^0 \quad \sum F_x = 84.375 - 33.75 \cos 45^0 = 60.520\,N$

$\sum F_y = F_B + -F_A \cos 45^0 \quad \sum F_y = 135 - 33.75 \cos 45^0 = 111.135\,N$

$F_R = \sqrt{\sum F_X^2 + \sum F_y^2} \quad F_R = 126.545\,N$

$\theta = \tan^{-1}(\frac{111.14}{60.52}) = 61.43^0$

Therefore, the resultant force is 126.545 N in the direction of 61.43^0 to the positive x-axis.

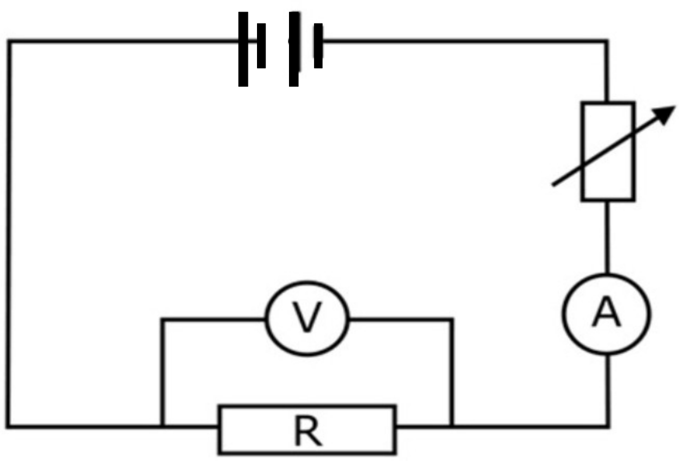
Question 9

(a) (i) State Ohm's law. (1 marks)

It states that the current through a conductor between two points is directly proportional to the potential difference across its ends.

(ii) Using a pair of dry cells, an ammeter, a switch, rheostat and a resistor and a voltmeter, describe an experiment to verify Ohm's law. (5 marks)

Experiment to verify Ohms law



The circuit is set up as shown above. The rheostat is adjusted so that the ammeter and voltmeter read suitable values of I and V respectively.

The ammeter and voltmeter readings are recorded.

The rheostat is adjusted and the procedure is repeated so as to get several values of readings for V and I.

The results are tabulate.

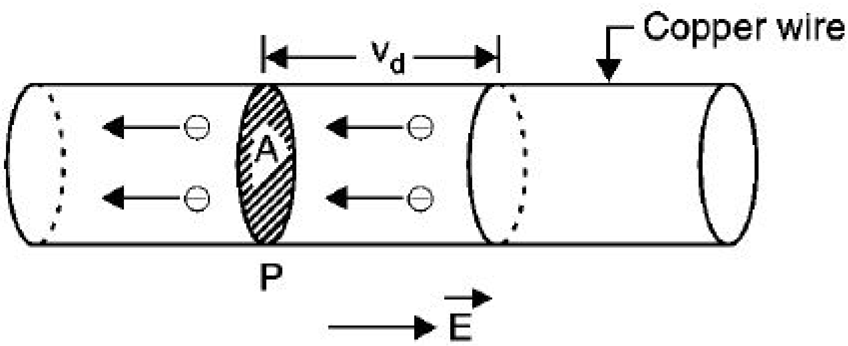
A graph of I against V is plotted.

A straight line graph passing through the origin is obtained which implies that V is directly proportional to I. This verifies Ohms law.

(b) (i) Explain why the temperature of a conductor increase when current passes through it. (3 marks)

When the conduction electrons flow through the material, the electrons transfer their energy to the conductor's atoms through collision. Due to this transfer of energy through collision, the heat is generated in the conductor. So, the temperature of the conductor increases because of the current flow through it.

(ii) A conductor of length L and cross sectional area A has n free electrons per unit volume each of charge e. Show that the formula for the drift velocity of the electrons if a current I flows through the conductor is given by $v = \frac{I}{neA}$. (4 marks)



Let n be the number of free electrons per m^3 of the wire.

Let e be the charge on each electron.

Volume of the wire $V = Al$

Number of electrons in that volume $N = nAl$

Total charge that crosses the plane in t seconds $\frac{Q}{t} = \frac{nAel}{t}$

But $\frac{l}{t} = v(velocity)$ $\rightarrow I = neVA$

Therefore $v = \frac{I}{neA}$ where, v is drift velocity.

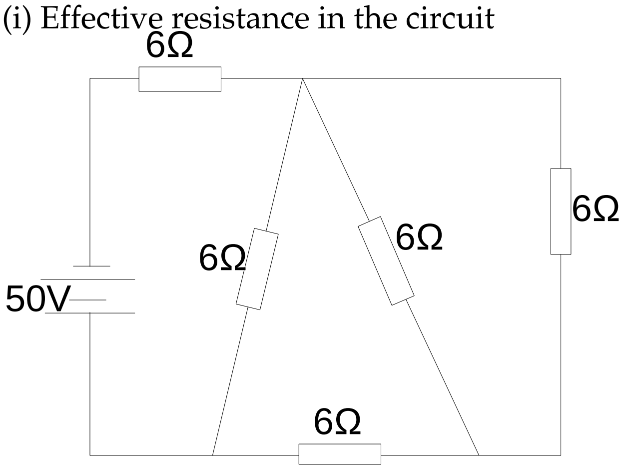
(c) (i) Write a formula for effective resistance R of three resistors arranged in parallel.

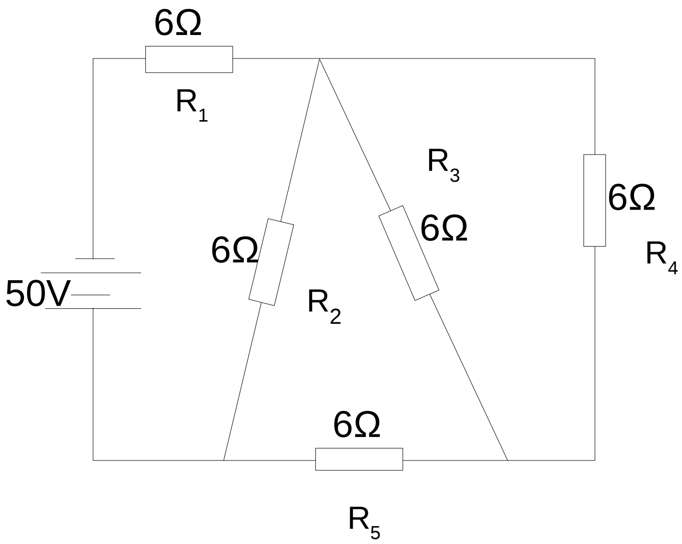
(1 marks)

From $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$, $R = \frac{R_1 R_2 R_3}{R_1 R_2 + R_1 R_3 + R_2 R_3}$

(d) The figure below shows a network of resistors connected to a battery of Emf 50V and internal resistance 0.4Ω calculate.

(i) Effective resistance in the circuit (4 marks)





For R3 and R4 in parallel

$$R_7=\frac{R_3\times R_4}{R_3+R_4}=\frac{36}{12}=3\,\Omega$$

For R7 and R5 in series, $R_8=6\,\Omega+3\,\Omega=9\,\Omega$

For R8 and R2 in parallel $R_9=\frac{9\times 6}{9+6}=\frac{54}{15}=3.6\,\Omega$

Effective resistance $R=(3.6+6+0.4)\,\Omega=10\,\Omega$

(ii) Power dissipated in the battery. (2 marks)

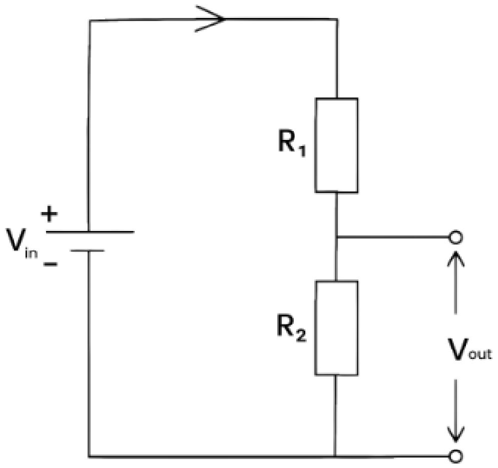
$$P=\frac{V^2}{R}=\frac{50^2}{10}=250\,W$$

Question 10

(a) (i) Define the term potential divider. (1 marks)

A potential divider is a circuit that divides a voltage into two or more smaller voltages

(ii) Derive the potential divider formula for two resistors of resistances R_1 and R_2 connected in series. (3 marks)



Consider a divider which contains of two unknown resistors R_1 and R_2 connected in series to voltage supply V_{in}. The potential difference V_{out} can then be connected to a load such as a lamp.

The current flowing is given by;

$$I=\frac{V}{R_1+R_2}$$

Potential difference across R_2, $V_{out}=IR_2$

$$V_{out}=\left(\frac{R_2}{R_1+R_2}\right)V$$, which is the fraction of the voltage of the supply.

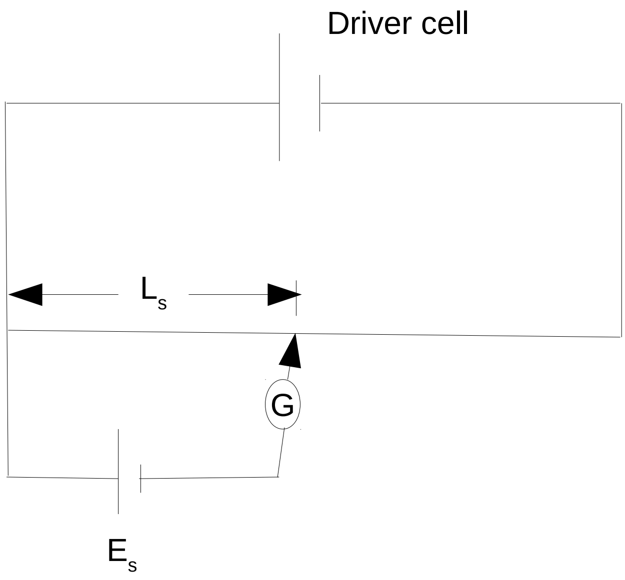
(b) A rheostat of resistance 100Ω is connected in series with a resistor of 20Ω and a battery of 10V. A voltmeter of resistance 5 is connected across a rheostat. If the slider is moved a quarter way the rheostat. Find the reading of the voltmeter. (5 marks)

$R_1=45\Omega$ and $R_2=\frac{75\times5}{75+5}=4.6875\,\Omega$

Using $V_2=\frac{R_2}{R_1+R_2}V_1 \rightarrow V_2=\frac{4.6875\times10}{45+4.6875}$

$V_2=0.94\,V$

(c) (i) With aid of a circuit diagram, explain how you would standardize a potentiometer using a standard cell. (4 marks)



E_s is a cell of known Emf

The circuit is connected as shown

The jockey J is then tapped at new point A and then near point B to check for the two way deflection of the galvanometer.

The jockey J is then moved along AB until the galvanometer shows no deflection.

Balance length L_s is then measured and noted.

$$V_{AJ}=KL_s$$

But at balance;

$$V_{AJ}=Emf\ of\ cell(F_s)$$

$$KL_s=E_s$$

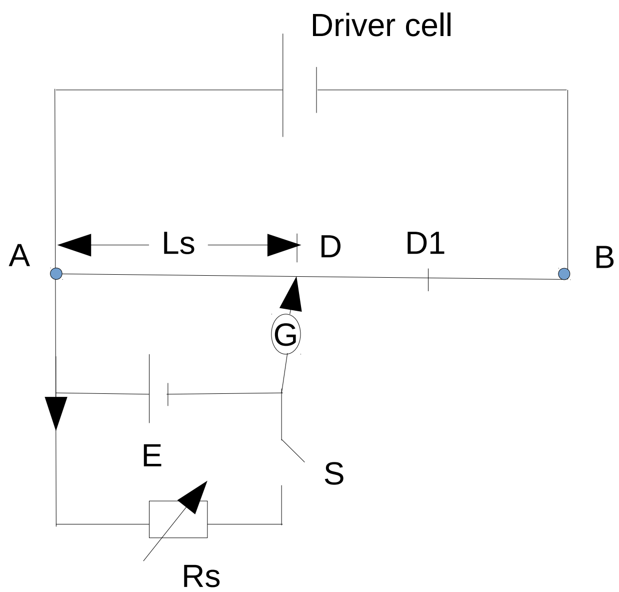
$k=\frac{E_s}{L_s}$, where K is the standardization constant.

(ii) Give any two advantages of a potentiometer over an ordinary voltmeter.

(2 marks)

The advantage of a potentiometer over the voltmeter is that the potentiometer doesn't draw any current from the circuit in which it is used for the measurement. Whereas the voltmeter draws some amount of current in case of high voltages, which results in some errors in the measurements done using a voltmeter.

(d) With aid of a circuit diagram describe how a slide wire potentiometer can be used in the determinations of the internal resistance of a dry cell. (5 marks)



E is a cell whose internal resistance is to be determined.

With S open, jockey D is moved along AB until galvanometer shows no deflection. Balance length L_1 is measured.

$V_{AD}=kL_1$ But $V_{AD}=E$ at balance point

$E=kL_1 \ldots\ldots\ldots\ldots(i)$

S is then closed and D moved along AB until galvanometer shows no deflection. New balance length L_2 is measured at D^1 .

$V_{AD^1}=kL_{2\ldots\ldots\ldots\ldots}(ii)$

But $V = IR_S$ and $E = I(R_S + R)$

From (ii) above: $V_{AD^1} = kL_2$

$IR_S = kL_2$ but $I = \frac{E}{R_s + r}$

$\frac{E}{R_s + r} \times R_S = kL_2 \ldots\ldots\ldots\ldots(iii)$

Equation (I) divide by equation (ii)

$$\frac{E}{\frac{E}{R_s + r} \times R_S} = \frac{kL_1}{kL_2} \ldots\ldots\ldots\ldots(iii)$$

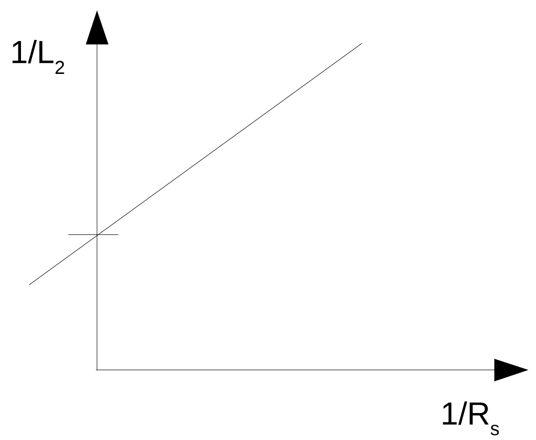
$$\frac{R_s + r}{R_S} = \frac{L_1}{L_2}$$

Therefore $r = R_S\left(\frac{L_1}{L_2} - 1\right)$

Alternatively

Using the rheostat, different values of Rs are used to obtain different values of Rs are used to obtain different values of L2

Tabulate results including values of $\frac{1}{L_2}$ and $\frac{1}{R_s}$ is plotted



$$slope = \frac{r}{L_o}, C = \frac{1}{L_o}$$

$$slope = \left(\frac{1}{L_o}\right) r$$

Therefore $slope = (C) r$

END