UACE PHYSICS PAPER 2014 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	$1.2 \times 10^{-6}\Omega m$

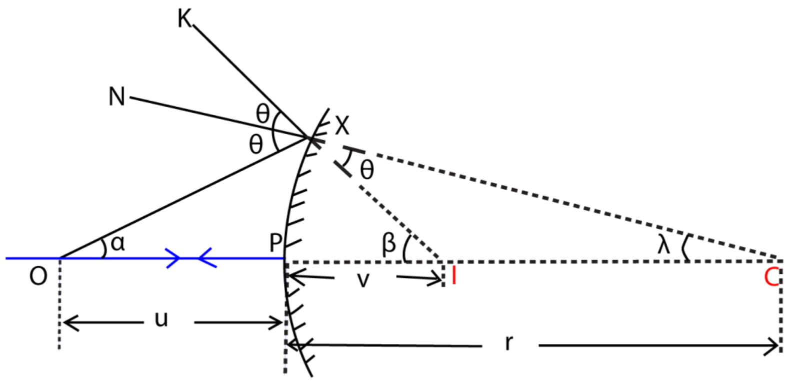
SECTION A

1. (a) Distinguish between a real and virtual image (02marks)

A real image is formed by actual intersection of rays and can be formed on a screen while a virtual image is formed by apparent intersection of rays and cannot be formed on a screen.

(b) Derive an expression relating the focal length, f, of a convex mirror to the object distance, u and image distance, v.

Consider the incidence of ray **OX** on to a convex mirror from a point object **O** placed along the principle axis and then suddenly reflected in the direction **XK** making an angle q with the normal **XN**.



From triangle XIC, θ + λ = β

⇨ θ = β – λ .... (i)

From triangle OXI, α + β = 2θ .... (ii)

Substituting (i) into (ii)

α + β = 2(β – λ)

⇨ α – β = -2λ .... (a)

If X is very close to P. then

$\alpha \approx \tan\alpha = \frac{XP}{u}$, $\beta = \frac{XP}{-v}$ (I is virtual) and $\lambda \approx \tan\lambda = \frac{XP}{-r}$ (C is virtual)

Equation (a) becomes

$$\frac{XP}{u} - \frac{XP}{-v} = \frac{-2XP}{-r}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{2}{r}$$

But 2 = 2f

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

(c) A convex mirror forms an image half the size of the object. The object is then moved towards the mirror until the image is three quarter that of the object. If the image is moved by a distance of 0.6cm, calculate

(i) focal length of the mirror. (03marks)

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

Initially, $\frac{v}{f} = \frac{1}{2} + 1 = \frac{3}{2}$ …………………… (i)

When the object was displaced

$\frac{v+0.6}{f} = \frac{3}{4} + 1 = \frac{7}{4}$ …………………………… (ii)

Eqn. (i) and Eqn. (ii)

$\frac{0.6}{f} = \frac{7}{4} - \frac{3}{2} = \frac{1}{4}$; f= 2.4cm

(ii) new potion of the object (03marks)

v + 0.6 = $\frac{7}{4}\ x\ f = \frac{7}{4}\ x$ 2.4 = 4.2 cm

$\frac{4.2}{u'} = \frac{3}{4}$

u' = 5.6cm

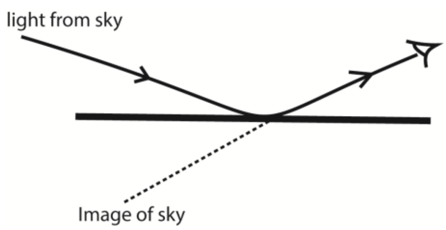
The object is 5.6 cm from the mirror.

(d) (i) What is critical angle? (01mark)

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

(ii) Explain how mirage is formed (04marks)

On a hot day, layer on air near the ground are hotter and lens dense than layers above. This leads to total internal reflection of rays of light from the sky. And mirage is the image of the sky to the eye by total internal reflection



(e) State four applications of total internal reflection (02marks)

- in radio broadcasting
- determination of refractive index if material
- in optical fiber transmission
- in refracting prisms in binoculars and periscopes

2. (a) State laws of refraction. (02marks)
   - The incident ray, the refracted ray and the normal at the point of incidence all lie in the same plane

- The ratio of the sine of angle incidence to the angle of refraction is constant for a given pair of the media.

(b) (i) The deviation, d, by small angle prism of refractive angle A and refractive index, n, is given by

d = A(n-1)

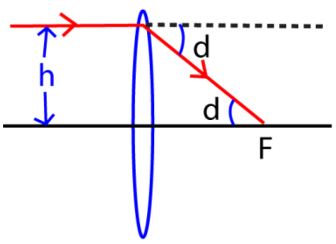
Use this expression to show that the focal length, f, of a thin converging lens of refractive index, n, is given by

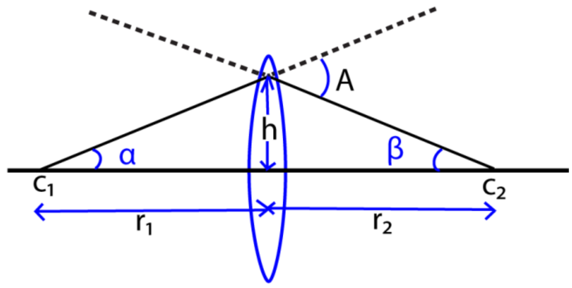
$$\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right),$$

where r_1 and r_2 are radii of curvature of the lens surfaces (05marks)

Solution

Consider a ray close and parallel to the principal axis, incident at height, h.





tan d = $\frac{h}{f}$ d is small in radian, d = $\frac{h}{f}$.....................................(i)

For small angle prisms d = (n-l)A .... (ii)

From the diagram above, α + β =A .... (iii)

For small angle

α ≈ tanα = $\frac{h}{r_1}$ and β≈tanβ =$\frac{h}{r_2}$

Substitution α and β in equation (iii)

$\left(\frac{h}{r_1} + \frac{h}{r_2}\right)$ = A ....(iv)

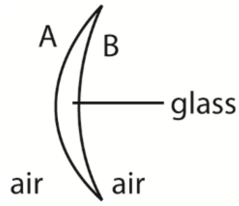
Substituting equation (i) and (iv) in equation (ii)

$\frac{h}{f}$ = (n-1) $\left(\frac{h}{r_1} + \frac{h}{r_2}\right)$

Dividing by h

$\frac{1}{f}$ = (n-1) $\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$

(ii) The figure below is a glass convex lens in air with surfaces A and B having radii of curvature 10cm and 15cm respectively.

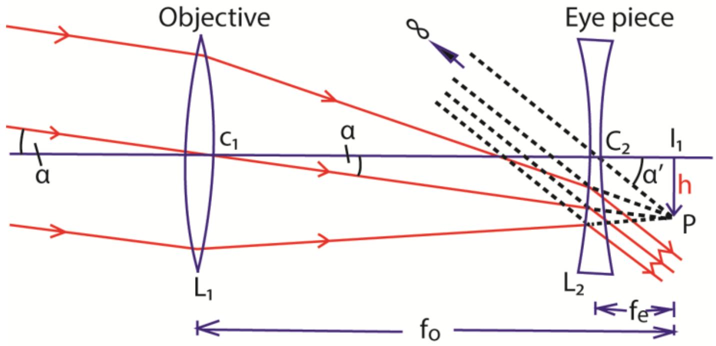


If the refractive index of the glass material is 1.50. Calculate the power of the lens. (03marks)

r_1= 10cm = 0.1m, r_2 = -15cm = -0.15m

Using $\frac{1}{f}$ = (n-1) $\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$ = (1.5 – 1) $\left(\frac{1}{0.1} + \frac{1}{0.15}\right)$ = 1.67D

(c) (i) with the aid of a ray diagram, describe the structure and action of a Galilean telescope in normal adjustment. (05marks)



Galilean telescope in normal adjustment

Light from distant object incident on objective lens is refracted to form real inverted image at its principal focus f_0. In normal adjustment, the principal focuses of both lenses coincide. The eye piece therefore forms the final image of the object at infinity.

(ii) Derive an expression for angular magnification of the telescope in (c)(i). (03marks)

Magnification, m = $\frac{\alpha'}{\alpha}$

For small angles, α and α' are measured in radians

$\alpha \approx \tan\alpha = \frac{h}{f_e}$ and $\alpha' \approx \tan\alpha = \frac{h}{f_o}$

Substituting for α and α'

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

(d) Explain the disadvantage of a Galilean telescope over refracting type. (02marks)

- Eye-ring is virtual
- Image less bright and less clear

SECTION B

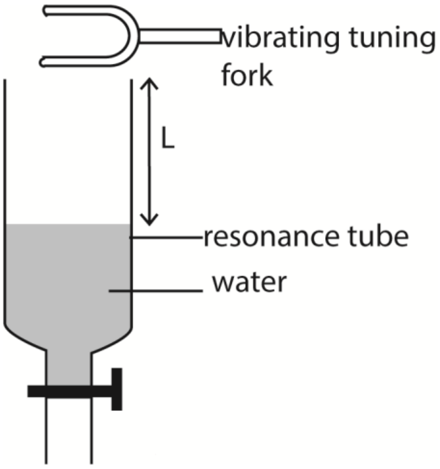
3. (a) (i) Distinguish between free oscillation and damped oscillation.

Free oscillation are oscillations in which the total energy of oscillating system is constant (and the amplitude of oscillation is constant) while a damped oscillation is where the energy of the system decreases with time and the amplitude decreases.

(ii) What is meant by resonance as applied to sound?

Resonance is said to occur when a system is set to vibrate at its natural frequency due to impulses received from nearby system vibrating at the same frequency.

(b) Describe an experiment to determine the velocity of sound in air using tuning forks of different frequencies and resonate tube.



A resonance tube is place to stand in a tall jar full of water.
Starting with a short length air column, a vibrating tuning fork is held over the mouth of resonance tube. The tube is raised until a point where a loud sound is heard. The length L of the air column and frequency f of tuning fork are recorded.

The experiment is repeated with other five tuning forks of different frequencies
Values of L, f and $\frac{1}{f}$ are tabulated.
A graph of L against $\frac{1}{f}$ is plotted and slope S is determined
The velocity, v, of sound = 4S.

(c) A uniform tube of 80cm long is filled with water and a small loudspeaker connected to signal generator is held over the open end of the tube. With the signal generator set at 600Hz, the water level in the tube is lowered until resonance is first obtained when the length of air column is 13cm. If the third resonance is obtained when the air column is 69.8cm long; calculate the

(i) Velocity of sound

L_1 = 13cm, L_3 = 69.8

Now L1 + e = $\frac{\lambda}{4}$ ………………………………………………. (i)

And L3 + e = $\frac{5\lambda}{4}$ ……………………………………………. (ii)

Eqn. (ii) – eqn. (i)

λ = 69.8 – 13 = 56.8cm or 0.56m

Velocity of sound in air, v = λf = 0.56 x 600 = 340.8ms^{-1}

(ii) Fundamental frequency for the tube is it were open at both ends.

Solution

If the tube is open at both ends

$\frac{\lambda_0}{2} = L + 2e$

$e = \frac{\lambda_0}{4} - L = \frac{0.568}{4} - 0.13 = 0.012.$

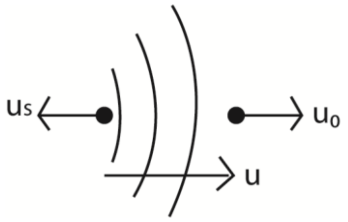
$\lambda_0 = 2(L + 2e) = 2(0.8 + 0.024) = 1.648m$

$f_0 = \frac{v}{\lambda_0} = \frac{340.8}{1.648} = 206.8Hz$

(d) (i) What is meant by Doppler Effect?

This is the apparent change in the frequency of a wave, when there is relative motion between the source and observer.

(ii) A motor cyclist and police car are approaching each other. The motor cyclist is moving at 10ms^{-1} and the police car at 20ms^{-1}. If the police siren is sounded at 480Hz. Calculate the frequency of the note heard by the cyclist after the police car passes by.



Apparent wavelength reaching the observer, $\lambda' = \frac{v + u_s}{f}$

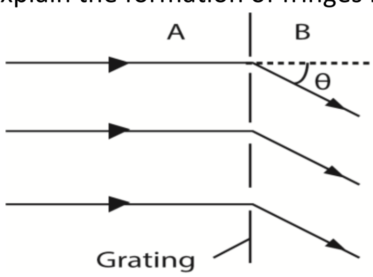
Apparent velocity of sound received, $v' = v - u_0$

Apparent frequency of sound received, $f' = \frac{v'}{\lambda'} = \frac{v - u_0}{v + u_s} f = \frac{340-10}{340+20} \times 480 = 440Hz$

(iii) Give two applications of the Doppler Effect.

- Determining directional motion of stars
- Estimating speed of stars
- Estimating speed of cars using a speed gun
- Determination of plasma temperature.

4. (a) Explain the formation of fringes by transmission gratings.



Consider a transmission grating illuminated normally by monochromatic light.

Light is diffracted through the clear space of the grating into a region B where they superpose. Where the resultant path difference of waves through pairs of consecutive slits is an integral multiple of full wavelength; constructive superposition occurs and a bright band is formed.

Where the resultant path difference is an odd multiple of half a wavelength, destructive superposition occurs and a dark band is formed.

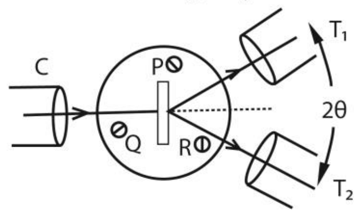
(b) Describe how the wavelength of monochromatic light can be measured using a diffraction grating and a spectrometer.

Solution

Make the following adjustment

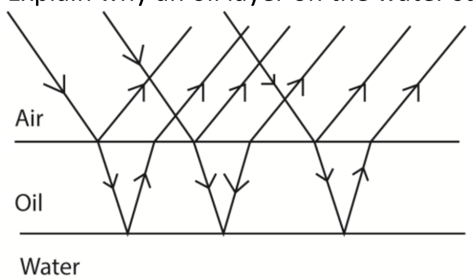
- The collimator C is adjusted such that parallel rays emerge from it.
- The telescope is adjusted so that parallel rays entering it are brought to a focus at the cross wire near its eyepiece.
- The table is levelled so that the plane of P is parallel to the axis of rotation of the telescope.

Measurement of wavelength by diffraction grating



- The grating is placed on the table so that its plane is normal to incident light
- The readings of the first diffraction image are observed on both sides of the normal at T_1 and T_2.
- The angular difference is 2θ, and the wavelength is calculated from $\lambda = d \sin \theta$, where d is the spacing of the slits, obtained from the number of lines per centimeter of the grating.
- If a second order image is obtained for a diffraction angle θ, then $\lambda = d \sin {}^{\theta}/_{2}$.

(c) Explain why an oil layer on the water surface appears colored on a rainy day.



Then white light incident on the oil film, is partly reflected and partly refracted.
Dispersion occurs due to refraction.
The dispersed rays are reflected at oil-water interface.
The light reflected from both surface meet and superpose in air.
Constructive superposition of colored rays give colored fringes. Hence colored oily surface.

(d) Explain

(ii) What is meant by plane polarized light

Plane polarized light is one whose electrical vectors varies in only one plane perpendicular to the direction of travel of the wave.

(iii) One application of polarized light.

- Determination of the concentration of sugars
- In sun glasses to reduce glare.

SECTION C

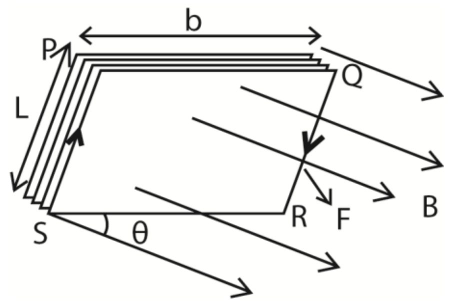
5. (a) Define the following:
   (i) Magnetic flux density (01mark)

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

   (ii) Magnetic flux linkage (01mark)

   Magnetic flux linkage is the product of the magnetic flux density and the area it links perpendicularly.

   (b) (i) A rectangular coil of N turns, length, L and breadth, b, carrying a current, I, is placed with its plane making an angle, θ, to a uniform magnetic field of flux density, B. Derive the expression for torque exerted on the coil. (05marks)



- When current flows through the coil, the conductor experiences a magnetic force.
- Force on side PQ = NBIbsinθ (downwards) while Force on side RS = NBINsinθ (upwards). The two forces cancel out due to rigidity of the coil.
- Side PS experiences force NBIL perpendicularly into the page while RQ experiences force NBIL perpendicularly out of page. The two forces constitute a couple whose moment of force
  τ = F x bcosθ
  = NBILbcosθ

(ii) A current of 3.25A flows through a long solenoid of 400 turns and length 40.0cm.

Determine the magnitude of force exerted on a particle of charge 15.0µC moving at 1.0 x 10^3ms^{-1} through the center of the solenoid at an angle of 11.5^0 relative to the axis of the solenoid. (04marks)

Magnetic flux density, B = $\mu_0 nI$

$= 4.0\pi \times 10^{-7} \times \frac{400}{40 \, x \, 10^{-2}} \times 3{,}25T$

$= 4.084 \times 10^{-3}T$

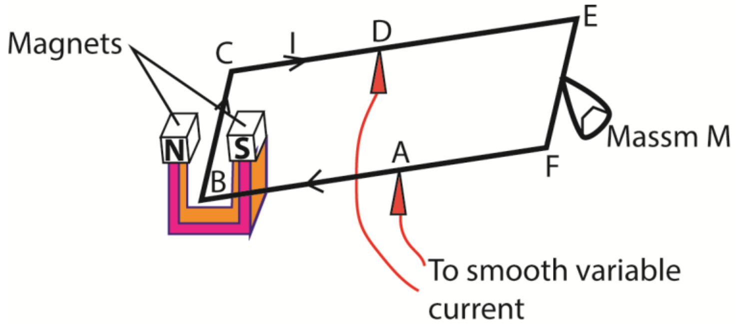
Force, F = BCVsin θ

$= 4.084 \times 10^{-3} \times 15 \times 10^{-6} \times 1.0 \times 10^{3} \sin 11.5$

$= 1.22 \times 10^{-5}$N

(c) Describe with the aid of a diagram, an absolute method of measuring current. (06marks)

Current balance is based on principles of moments



The apparatus setup is as above, AB = AF, length BC = L and the current through the wire is A

The magnets provide a uniform magnetic field, B, perpendicular to wire BC.

At equilibrium when the frame BCEF is balanced

The force exerted on the wire = weight of the mass

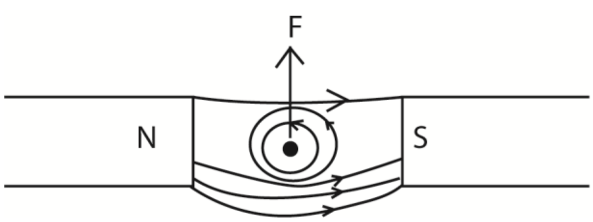
$$BIL = Mg$$

$$\text{Current } I = \frac{Mg}{BL}$$

Sources of error

- Accuracy of length L
- Rigidity of the frame
- To avoid overheating, the current should be switched off as soon as measurements have been taken.
- Shield the set-up from the disturbance of wind.

(d) Explain why a current carrying conductor placed in a magnetic field experiences a force. (03marks)



- The current sets up magnetic field around the wire.
- When the field due to current interacts with external magnetic field, the resultant magnetic field has greater flux density on one side than the other; in the diagram above, high flux density is created below than above.
- The wire moves from a region of greater to lower flux density; thus it move up in this case.

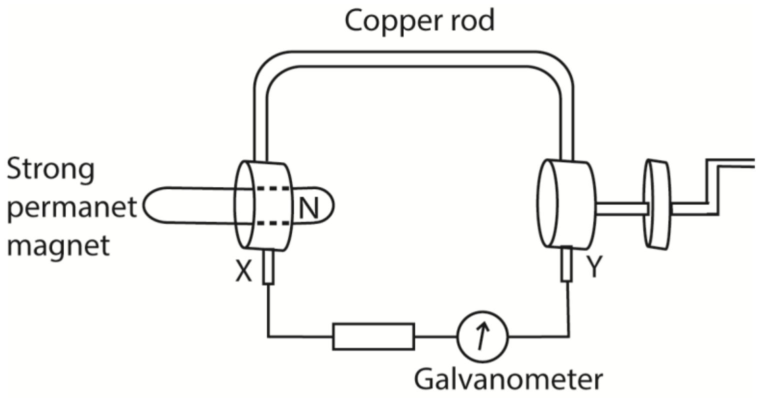
6. (a) (i) State Lenz's law of electromagnetic induction (01mark)

The Induced current flows always in such a direction as to oppose the change which is giving rise to· it.

(ii) Describe an experiment to demonstrate Faraday's law of electromagnetic induction. (06marks)

Faraday's law of electromagnetic inductions states that the magnitude of induced e.m.f in a conductor is directly proportional to the rate of change of magnetic flux linking it.

Verification setup



X and Y are brush contact.

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

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

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

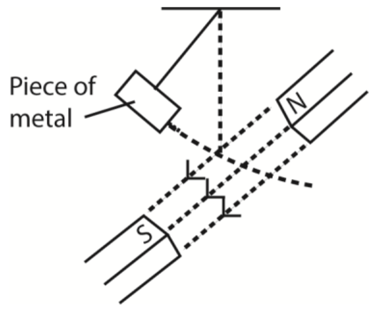
The experiment is repeated at different speed of rotation of the wheel and values of n and θ tabulated.

A graph of θ against n is plotted.

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

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

(b) The figure below shows a piece of metal swing in between opposite magnetic poles



Explain what will be observed after some period of time (04marks)

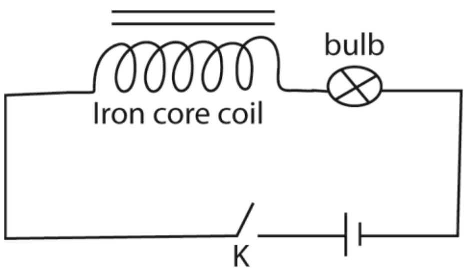
The amplitude of oscillation reduces gradually until oscillation stop because as the metal oscillated, it cuts the magnetic field between the poles. Eddy currents are induced in the metal whose magnetic field oppose the oscillation thus causing the oscillation to slow down.

(c)(i) Define the term self-induction and mutual induction. (02marks)

Self-induction is the process by which e.m.f is induced in a circuit due to changing current in the same circuit.

Mutual induction is the process by which e.m.f is induced in a circuit due change in current in the nearby circuit.

(ii) Describe an experiment which can be used to demonstrate self-induction. (03marks)



An iron cored coil is connected in series with a bulb, cell and switch as shown above. When K is closed, the bulb lights dimly and then its brightness is increased to maximum.

The initial current is small due to large back e.m.f and then increases to the maximum because back e.m.f finally reduce to zero.

(d) A search coil has 40 turns of wire and cross section area of 5cm^2. The coil is connected to a ballistic galvanometer and then with its plane perpendicular to uniform magnetic field of flux density B.

When the coil is withdrawn from the field, the galvanometer gives a deflection of 240 divisions. When a capacitor of 4μF is charged to 20V and then discharged through the circuit, the galvanometer deflection is 180 divisions. Find the value of B, if the total resistance of the circuit is 20Ω. (04marks).

N = 40, A = 5 x 10-4m^2, R = 20Ω, θ_1 = 240^0, C = 4 x 10^{-6}F, V = 20V, θ_2 =180^0

From $\frac{NAB}{R} = k\theta_1$; k = $\frac{NAB}{R\theta_1}$

But Q = CV = $k\theta_2$; k = $\frac{CV}{\theta_2}$

$\therefore \frac{NAB}{R\theta_1} = \frac{CV}{\theta_2}$

$B = \frac{CVR\theta_1}{NA\theta_2} = \frac{4\ x\ 10^{-6}\ x\ 20\ x\ 20\ x\ 240}{40\ x\ 5\ x\ 10^{-4}\ x\ 180}$ = 0.107T

7. (a) What is meant by the terms reactance and impedance as applied to alternating currents. (02marks)

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

Impedance is the resultant opposition to flow of a.c in circuit containing reactive and resistive components.

(b)(i) A source of sinusoidal current of amplitude I_0 and frequency, f, is connected across a pure inductor of inductance, I, Derive an expression for the peak voltage across the inductor. (04marks)

Induced e.m.f in the inductor E = -L$\frac{dI}{dt}$

= -L$\frac{d(I_0 sin\omega t}{dt}$

= ωLI_0 cos ωt

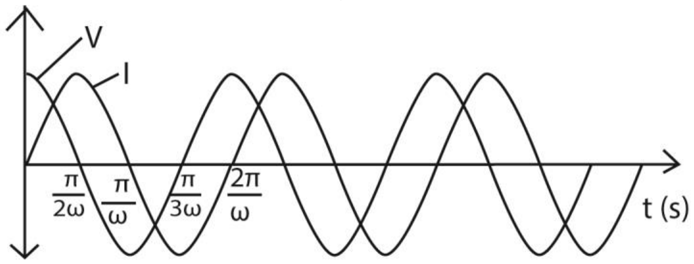
For infinite current flow through a pure inductor

V = -E = ωLI_0 cos ωt where V_0 = ωLI_0

Since ω = 2πf then V_0 = 2πf LI_0

So peak voltage, V_0 = 2πf LI_0

(ii) Sketch using the same time axis, graphs to show variations of the voltage across the inductor and current through it. (02marks)



(c) An alternating current I = 5sin 200πt, flows through a pure inductor of inductance 2.0H. Calculate the

(i) reactance of the inductor. (03marks)

X_L= 2πfL, From I = 5sin200πT, => f = 100Hz

Hence

X_L = 2π x 100 x 2 = 1256Ω

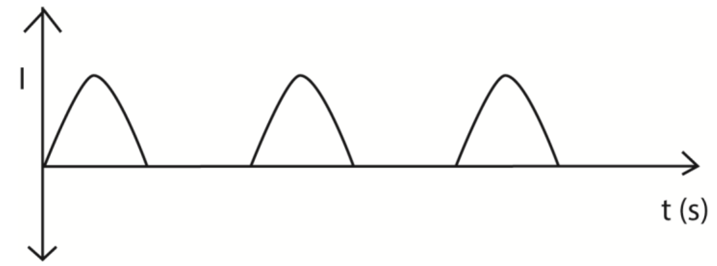
(ii) root mean square value of the voltage across the inductor. (03marks)

$V_{r.m.s} = \frac{V_0}{\sqrt{2}}$, but $V_0 = X_L I_0$ = 1256 x 5= 6280V

$V_{r.m.s} = \frac{6280}{\sqrt{2}}$ = 4440V

(d)(i) Explain how an alternating current can be measured using a rectifier meter (04marks)

When a.c is supplied to a rectifier meter, current flows in only one direction. Current flows in the half cycle for positive bias of the diode and in the next half cycle current flow is zero. The characteristics is shown below



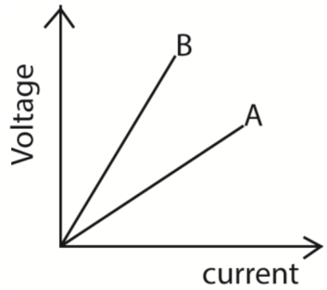
When the frequency is high, the ammeter reads a steady r.m.s value of the current.

(ii) Explain why a moving coil ammeter is unsuitable for measuring alternating current. (02marks)

When an a.c is passed through a moving coil ammeter, the direction of the couple changes every time the current reverses. With high frequency, the pointer only vibrates about the zero position hence the value of the current cannot be read

SECTION D

8. (a)The voltage versus current graphs for two wires A and B of the same material, same radii and at the same temperature are shown in the figure below



Account for the difference between the graphs

Current flowing through a homogenous conductor is proportional to the p.d. across.
The slope of the graph is equal to the resistance of the conductor.
This implies that the resistance of B is greater than that of A since B has a bigger slope than A
Since resistance is proportional to length, B is longer than A

(b) Three identical cells are connected in series with resistors of 3Ω and 5Ω. A current of 1.2A flows in the circuit. When the two resistors are connected in parallel across the three cells in series, the current in the circuit is 2.2A. Calculate the

(i) internal resistance of each cell(03marks)

For the resistors n series, R_{eff} = 3 + 5 = 8Ω

∴ 3E = 1.2(3r + 8) ……………………….. (i)

When in parallel, $R_{eff} = \frac{3 x 5}{3+5} = \frac{15}{8}\Omega$

∴ $3E = 2.2(3r + \frac{15}{8})$ ……………………….. (ii)

From Eqn. (i) and Eqn. (ii)

$1.2(3r + 8) = 2.2(3r + \frac{15}{8})$

r = 1.825Ω

(ii) e.m.f of each cell (1mark)

BE= 1.2 (3 x 1.825 + 8) =5.39V

(iii) power dissipated in the 3Ω resistor for parallel connection (04marks)

p.d across 3Ω resistor = 3E – 3IR

= 3 x 5.39 – 3 x 2.2 x 1.8

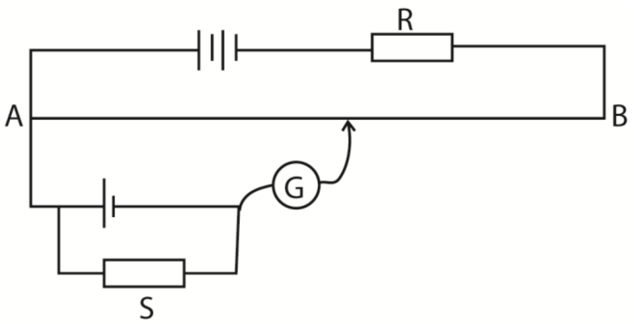
= 4.12V

Power = $\frac{V^2}{R} = \frac{4.125^2}{3} = 5.72V$

(c) Two students X and Y performed separate experiments using a potentiometer arranged as shown below and both obtained a balance point.

X increased the value of R

Y decreased the value of S



Explain what happened to the position of balance point when

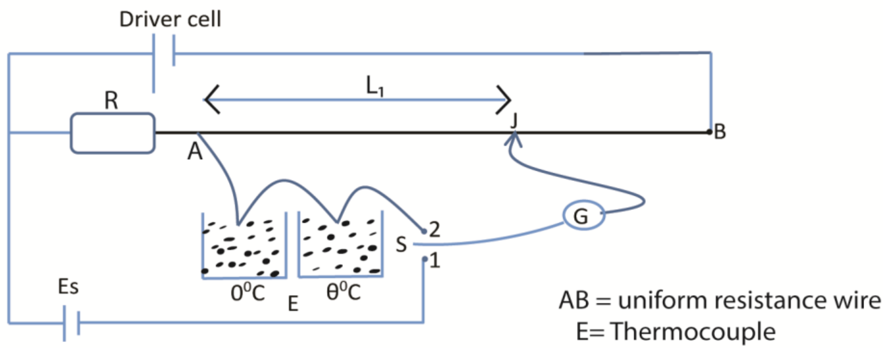
(i) X increases the value of R (02marks)

Increasing R reduces the current in driver circuit. Therefore the p.d per cm reduces and therefore the balancing length also increases.

(ii) Y decreases slightly the value of S from an initially large value (02marks)

Decreasing the value of S slightly does not change the current in the circuit appreciably and hence the p.d across S remains nearly constant. The position of null deflection is almost unaffected.

(d) Describe an experiment to determine the e.m.f of a thermocouple (06marks)



- With switch S in position 1, J is moved along AB until the galvanometer G shows no deflection. The balancing length L_1 is noted
- With switch S in position 2, J is moved along AB until the galvanometer G shows no deflection. The balancing length L_2 is noted
- The e.m.f of the thermocouple is $E = IkL_2$

  While $E_S = I(kL_1 + R)$

  $\therefore E = \frac{E_S k L_2}{R + kL_1}$ where k is the resistance per cm of the uniform resistance wire

9. (a) Define the following

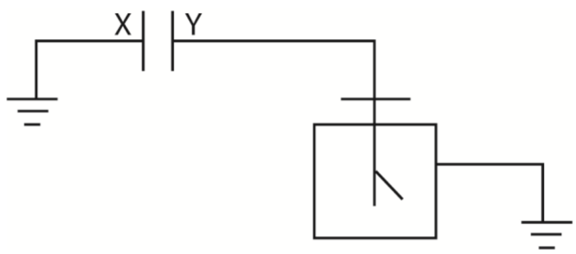
   (i) Capacitance (01mark)

   The capacitance of a capacitor is the ratio of the magnitude of charge on either plates of the capacitor to the potential difference between the plates

   (ii) Dielectric (01mark)

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

(b) Describe an experiment that can be used to show how capacitance of a capacitor depends on permittivity of dielectric. (04marks)



- The apparatus is set up as above, X and Y are capacitor plates
- Y is charged and the divergence of the leaf of electroscope is noted.
- A dielectric material in placed between the plates and divergence of the leaf is seen to reduce. This implies that the p.d, V, between the plates has reduced and capacitance increased.
- Thus $C \propto \varepsilon$ since permittivity of the material is greater than that of air.

(c) A capacitor of capacitance C, is fully charged from a 200V battery. It is then discharged through a small coil of wire embedded in thermally insulated block of heat capacity $250KJ^{-1}$. If the temperature rose by 0.4K, Calculate C. (04marks)

Energy stored = $\frac{1}{2}CV^2 = heat\ dissipated\ in\ the\ coil = C\theta$

$$\frac{1}{2}C\ x\ 200^2 = 250\ x\ 0.4$$

$$C = 5.0\ x\ 10^{-3}\text{F}$$

(d)(i) State three properties of an equipotential surface. (03marks)

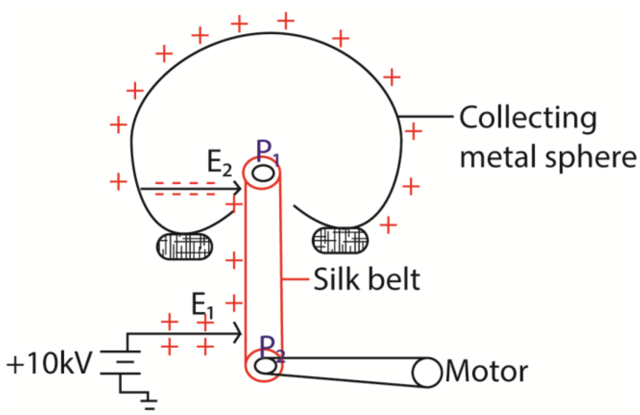
- All the parts at the surface are at the same potential
- Work done to transfer charge from point to another on the surface is zero
- Electric field is perpendicular to the surface

(ii) What is meant by charge quantization? (0marks)

Charge quantization is the product ne where e is the electronic charge and n is an integer.

(e) With the aid of a labelled diagram, describe the structure and action of a Van de Graaff generator. (06marks)

Van der Graff generator



Main features

a. It consists of a large hollow metal sphere (collecting sphere) supported on insulating stand.
b. A silk belt inside the tube driven by an electric motor possesses the sharply pointed electrode metal E_1, held at electric potential of about 10kV relative to the earth.
c. As the belt moves up, it passes another sharply pointed metal electrode E_2 connected inside the hollow sphere.

Mode of operation

(i) The metal rod E_1, is kept at a high positive potential of about 10kV with respect to the earth.
(ii) The high positive charge at the sharp ends ionizes the air around.
(iii) The positive ions are repelled to the silk belt carries then towards the collecting sphere.

(iv) At E_2, the silk belt induces negative charges on the sharp ends of E_1 and the positive charges on the outer of the sphere. The electric field at point ends E_2 ionizes the air around it.

(v) The negatively charged ions are repelled to the silk belt which is carrying positively charged ions

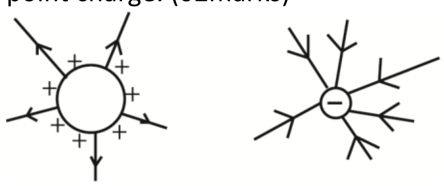
(vi) The positive ions are neutralized before passing over the upper pulley P_1.

(vii) The process of silk belt charging up and dis charging is repeated many times per second and each time the belt passes, the sphere charges up positively until it has electric it has electric potential of about 10^6V relative to the earth.

10. (a) (i) State Coulomb's law of electrostatics (01marks)

- The force between two point charges is directly proportional to the product of the magnitude of the charges and inversely proportional to the square of their separation

(ii) Sketch the electric field pattern for positively charged metallic sphere and for negative point charge. (02marks)



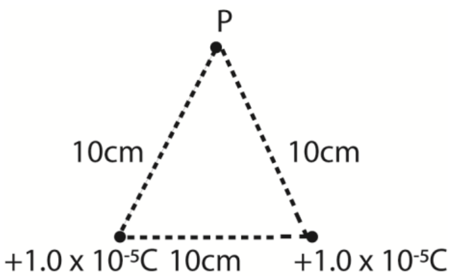
(b) (i) Define electric field intensity and electric potential at a point. (02marks)

- Electric field is the force acting on 1C of positive charge in an electric field.
- Electric potential at a point is the work done to bring 1C of positive charger from infinity to that point in the electric field.

(ii) What is the relationship between them? (01mark)

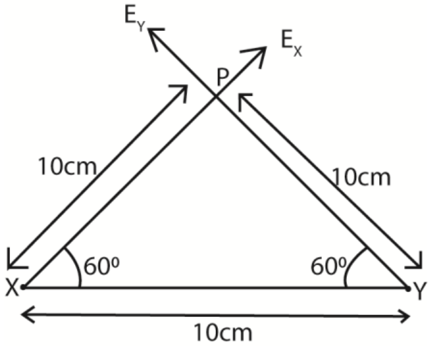
Electric field intensity is equal to the negative gradient of the electric potential.

(c) Two charges of 1.0×10^{-5}C are placed 10cm apart as shown in the figure below



Calculate the

(i) Electric field intensity at P (06marks)



$E_X = \frac{kQ}{r^2}$

$= \frac{9 \, x \, 10^9 x \, 10^{-5}}{0.1^2} = 9 \text{ x } 10^6 NC^{-1}$

$E_Y = \frac{9 \, x \, 10^9 x \, 10^{-5}}{0.1^2} = 9 \text{ x } 10^6 NC^{-1}$

The horizontal component, $E_H = E_X\cos 60^0 - E_y\cos 60^0 = 0$ (since $E_X = E_Y$)

Vertical component E_V = 2 x 9.0 x 106sin 60^0 = 1.5 x $10^6 NC^{-1}$

Electric potential at P, E_R = 1.5 x $10^6 NC^{-1}$ (vertically upwards)

(ii) Electric potential at P (03marks)

From $V = \frac{kQ}{R}$

$V_x = \frac{9 \, x \, 10^9 x \, 10^{-5}}{0.1} = 9 \text{ x } 10^5 V$

$V_y = \frac{9 \, x \, 10^9 x \, 10^{-5}}{0.1} = 9 \text{ x } 10^5 V$

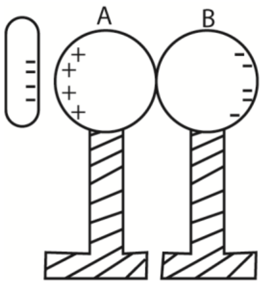
$V = V_x + V_y$

= (9 x 10^5 + 9 x 105)V

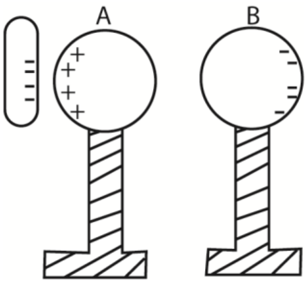
= 1.8 x 10^6V

(d) Two conducting spheres A and B supported on insulating stand are placed in contact. A negatively charged rod is then held near sphere A. the spheres are then separated after which the rod is removed. With the aid of suitable diagrams, explain the processes which occur. (05marks)

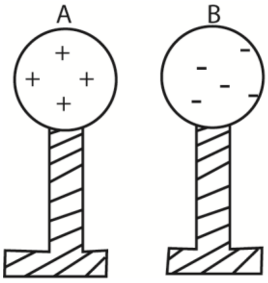
- When the spheres are placed in contact and the negatively charged rod brought near A, it repels negative charge to extreme end of B



- When the spheres are separated B moves with excess negative charges while A remains with excess positive charges



- When the charged body is removed, the charges on each sphere distributes uniformly



END