UACE PHYSICS PAPER 2018 GUIDE

SECTION A

1. (a) Define the following as applied to telescope
   (i) Eye-ring (01marks)
   Eye-ring of a telescope is the image of objective formed by the eyepiece.
   (ii) Magnifying power(01mark)
   Magnifying power is the ratio of the angle subtended by the final image at the eye when using the telescope to the angle subtended by the object at unaided eye.

(b) What is the significance of the eye-ring of an astronomical telescope? (01mark)

It is the best position for best view in a telescope

(c) State two advantages of a reflecting telescope over a refracting telescope (02marks)

- there is no chromatic aberration
- there is no spherical aberration
- it is relatively cheap since only one face of the objective needs grinding
- Has high resolving power since the objective may have a high field of view.
- The image is brighter.

(d) The figure below shows an optical system consisting of two thin converging lenses arranged coaxially. Lens A has a focal length of 40mm and lens B has a focal length of 375mm. an object O of height 5mm is placed 50mm from A. I_1 is the real image of O and I_2 is the virtual image of I_1 in B and is 250mm from B.

(i) Determine the value of distance, Y of image I_1 from lens A (02marks)
Using $\frac{1}{f} = \frac{1}{u} + \frac{1}{V}$
⇨ $\frac{1}{40} - \frac{1}{50} = \frac{1}{y}$; y = 200mm

(ii) Calculate the distance, x, between the images I_1 and I_2. (02marks)
$\frac{1}{u} = \frac{1}{f} - \frac{1}{v}$

$= \frac{1}{375} - \frac{1}{(-250)}$

u = 150mm

distance x = v-u = 250 – 150 = 100mm

(iii) Find the linear magnification produced by the lens system. (02marks)
$M = M_1 \times M_2 = \frac{200}{50}\ x\ \frac{250}{150} = 6.7$

(e) Name one defect of the image formed by a lens and explain how the defect is minimized in practice. (03marks)

(i) Chromatic aberration can be minimized by placing the eye very close to the lens. This insures that images due to different colors subtend the same angle at the eye. Or by use of chromatic doublet in which the dispersion produced by one lens is reversed by another.

Or

(ii) Spherical aberration can be minimized by using a stopper which allows only central rays to form a sharp image. Or by grinding the lens to suitable shape. Or using a narrow aperture

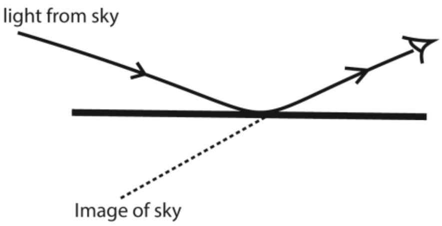
(f) Explain the following

(i) total internal reflection (03marks)

If a ray of light is incident from a denser to less dense medium, there is partial reflection and partial refraction. When the angle of incidence exceeds the critical angle, all the incident light is reflected back into the denser medium. This is called total internal reflection.

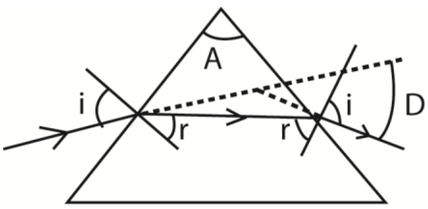
(ii) Formation of mirages (03marks)

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



2. (a) State the laws of refraction of light. (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) Derive an expression for refractive index of a prism in terms of the refractive angle A and the angle of minimum deviation D. (05marks)



Minimum deviation, D, occurs when a ray passes symmetrically through the prism when the angle of incidence, i, is equal to the angle of emergence as shown above.

D = 2i -2r

But 2r = A, hence, r = $^{A}/_{2}$

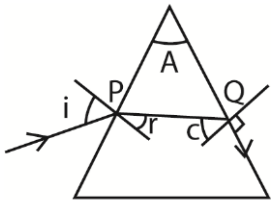
∴ D = 2i – A

⇨ $i = \frac{D+A}{2}$

From Snell's law, n = $\frac{\sin i}{\sin r}$

$$n = \frac{\sin\frac{D+A}{2}}{\sin\frac{A}{2}}$$

(c) A ray of light is refracted through a prism in a plane perpendicular to its edge. The angle of incidence is 30^0 and the refractive index of the prism is 1.50. Calculate the angle of the prism such that the ray does not emerge when it strikes the second face. (05marks)



At P

r = $\sin^{-1}(\frac{\sin 30}{1.5}) = 19.5^0$

At Q

c = sin-1 $(\frac{1}{1.5}) = 41.8^0$

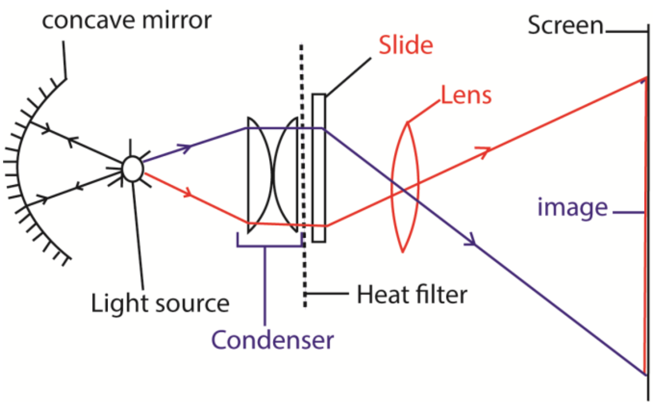
Angle of the prism = c + r = 19.5 + 41.8 = 61.3^0

(d) (i) Describe with the aid of a labelled diagram, the structure and operation of projection lantern. (04marks)

Projection lantern

A **projector** is an instrument used to produce a large image of a small object.

- The slide, or film, is placed behind the **projector** lens outside its focal length and is illuminated buy a small but powerful source of light from concave reflector through condensing lenses.
- A magnified, real and inverted image on the screen



Area magnification = $\frac{Area\ of\ the\ image}{Area\ of\ the\ object}$

(ii) A projector produces an image of area $2m^2$ on a screen placed 5m from the projection lens. If the area of the object slide is $8cm^2$, calculate the focal length of the projection lens. (02marks)

Area magnification = $\frac{Area\ of\ the\ image}{Area\ of\ the\ object} = \frac{2}{8\ x\ 10^{-4}}$ = 2500

Linear magnification = $\sqrt{2500}$ = 50

From M = $\frac{v}{f} - 1$

$50 = \frac{5}{f} - 1$

$f = \frac{5}{51}$ = 0.098m = 9.8cm

SECTION B

3. (a) define the following as applied to wave motion

(i) Amplitude (01mark)

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

(ii) Frequency (01mark)

This is the number of complete cycles per second.

(iii) Wavelength (01mark)

This is the distance between two successive wave particles that are in phase or the distance between two successive troughs or crests.

(iv) Derive the relationship between velocity, wavelength and frequency of a wave (03marks)

Consider a wave moving with speed, V. if in time T it covers a distance λ (one wave length)

Then distance = speed x time

λ = VT

but T = $\frac{1}{f}$

then V = λf

(b) The displacement, y, of a progressive wave is given as y= 2cos π(t-$\frac{x}{20}$); where x is horizontal distance in meters and t is time in seconds.

Determine the

(i) Velocity of the wave (03marks)

Comparing with y = Acos 2π$\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

$\frac{2\pi t}{T}$ =πt

$\frac{1}{T} = \frac{1}{2} = 0.5$

∴ f = 0.5Hz

Also, $\frac{2\pi x}{\lambda} = \frac{\pi x}{\lambda}$; λ = 40m

$V = f\lambda = 40 \times 0.5 = 20ms^{-1}$

(ii) Maximum velocity of particles of the medium. (02marks)

Velocity of the particles = $\frac{dy}{dt} = -2\pi \sin \pi \left(t - \frac{x}{20}\right)$

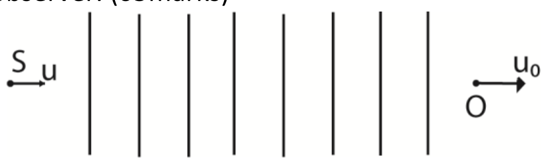
Velocity is maximum when $\sin \pi \left(t - \frac{x}{20}\right) = 1$

∴ maximum velocity= $|-2\pi|$=6.28ms^{-1}

(c) (i) What is meant by the Doppler effect? (01marks)

It is the apparent change in frequency of a wave motion due to relative motion between the source and observer.

(ii) A source of sound moving with velocity, u. approaches an observer moving with velocity u_0 in the same direction. Derive the expression for frequency of sound heard by observer. (05marks)



Let c be the velocity of sound from a source of frequency, f.

Apparent wave length, λ' = $\frac{c-u}{f}$

Apparent velocity c'= c-u_0

∴ Apparent frequency = $\frac{c'}{\lambda'} = \frac{(c - u_0)}{\frac{(c-u)}{f}} = \left(\frac{c-u_0}{(c-u)}\right) f$

(d) Two whistles are sounded simultaneously. The wavelengths of the sounds emitted are 5.5m and 6.0m respectively. Find the beat frequency if the speed of sound is 330ms^{-1}.

For 1st sound $f_1 = \frac{V}{\lambda_1} = \frac{330}{5.5} = 60Hz$

For 2nd t sound $f_2 = \frac{V}{\lambda_2} = \frac{330}{6} = 55Hz$

Beat frequency $f_b = f_1 - f_2 = 60 - 55 = 5Hz$

4. (a) What is meant by the following as applied to light waves

(i) Diffraction (01mark)

It is the spreading of light around an obstacle in geometrical shadow leading to interference

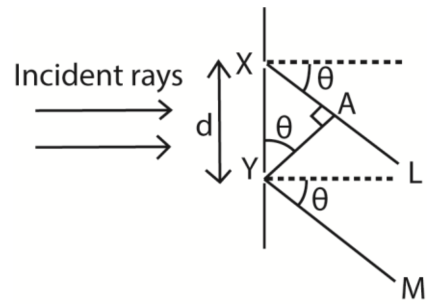
(ii) Polarization (01mark)

It is a process by which vibration of light (electric vector) photons are restricted in one plane perpendicular to the direction of propagation of light.

(b) A diffraction grating of spacing d, is illuminated normally with light of wavelength, λ.

(i) Derive the condition for concurrence of diffraction maxima. (03marks)

Consider a parallel beam of monochromatic light incident on a grating of spacing d.



The path difference XA = dsinθ
For constructive interference, diffraction maxima occurs when the path difference is an integral multiple of wavelength, λ.
i.e. path difference = nλ
thus dsinθ = nλ where n = 0, 1, 2, 3, ……….

(ii) Describe briefly the intensity distribution on screen placed beyond the grating (02marks)

The central principle maxima is the most intense; the intensity decreases on the either side.

(iii) What is the effect on diffraction pattern when grating with larger number of lines is used (02marks)

The diffraction maxima (image) becomes narrower and shaper

(c) Light of wavelength 5.8 x 10^{-7}m is incident on diffraction grating of 500 lines per mm. Find the

(i) Diffraction angle for second order image (03marks)

$d = \frac{l}{N} = \frac{1 x 10^{-3}}{500}$ = 2 x 10^{-6}m

from dsinθ =nλ

$\sin\theta = \frac{n\lambda}{d} = \frac{2.0 x 5.8 x 10^{-7}}{2 x 10^{-6}}$ = 0.58

θ = 35.5^0

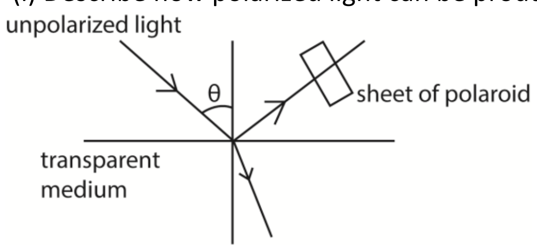
(ii) Maximum number of images formed. (02marks)

d = $n_{max}\lambda$

$n_{max} = \frac{d}{\lambda} = \frac{2 x 10^{-6}}{5.8 x 10^{-7}}$ = 3.4

∴ n_{max} = 3

(d) (i) Describe how polarized light can be produced by reflection. (04marks)



- Unpolarized light is made incident on a transparent medium at an angle θ.
- The reflected light is viewed through a sheet of polaroid while turning the sheet about an axis perpendicular to its plane

- The procedure is repeated for various angles of incidence until the reflected ray is cut off from object.
- At this particular angle θ, the reflected light is completely polarized.

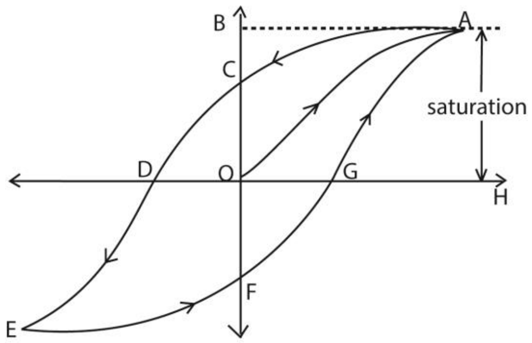
(ii) List for used of polarized light.

- Measurement of sugar concentration
- Determination of stress distribution in materials like glass
- In film to give illusion of three dimension (orography)
- In liquid crystal display

SECTION C

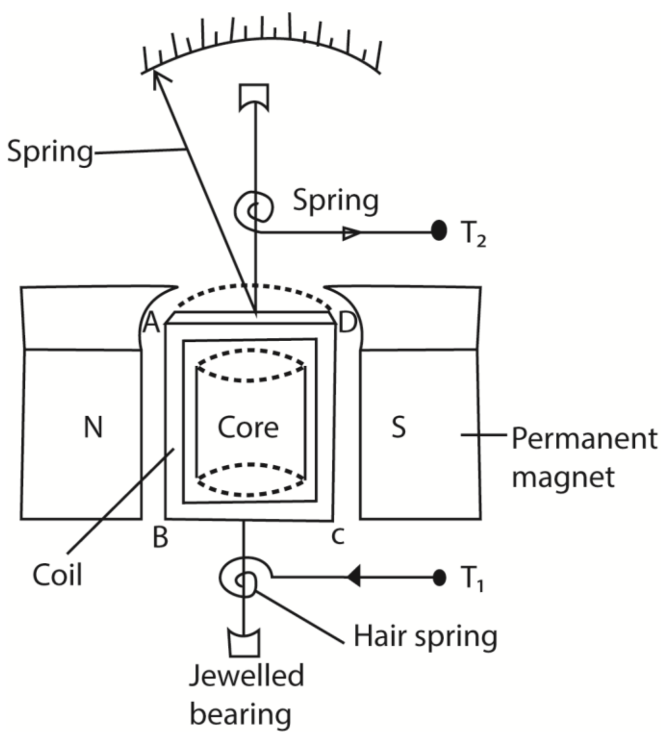
5. (a) With the aid of a sketch graph, explain the hysteresis curve for ferromagnetic material (07mark)

Solution



- When a magnetic field is applied to a ferromagnetic material, the magnetic domains tend to align with the applied field. The magnetic flux density increases along OA until saturation. When the magnetizing field is reduced to zero, there is residue magnetization at C. This is due to failure of the dipoles to respond instantly. Energy is lost.
- To bring the dipoles to their original orientation, a magnetic field OD is applied in opposite direction. As the magnetic field is increased in this reversed direction, saturation is attained at E
- When reversed magnetic field is reduced to zero, state F is attained. Reversal of dipoles requires an increase of magnetic field in opposite direction to state EF. The cycle is then repeated on further increase of magnetic field
- The curve of B verses H is called a hysteresis curve

(b)(i) Describe with the aid of a labeled diagram, the structure and mode of action of a moving coil galvanometer (06marks)



Structure

- It consist of a rectangular coil of fine insulated copper wire wound on an aluminium frame to provide electromagnetic damping.
- The coil together with the frame of aluminium are mounted over a soft iron cylindrical core and freely pivoted on jeweled bearing to minimize friction at contact.
- The suspension torsion wire suspending the coil is attached to a pair of control hair springs T_1 and T_2 for feeding current in and out of the coil and control rotation of the coil.
- The coil is then suspended between concave pieces of a strong magnet to provide magnetic field.

  Mode of action
- Current I to be measured is passed into the coil via hair spring T_1.
- The current then causes the coil to experience a deflection torque, r = NABI due to a couple force causing rotation in a radial magnetic field.
- The coil turns with the pointer through angle θ until stopped by restoring torque, r = kθ provided by a pair of hair springs T_1 and T_2.
- At equilibrium, NABI = Kθ
- ∴ current I = $\left(\frac{k}{NAB}\right)\theta$
- I ∝ θ, hence the instrument has a linear scale

  Where B = magnetic field strength between the poles of the magnets
  A = area of the plane of the coil
  N = number of turns of the coil
  k = torsion constant of suspension wire

(i) Explain why eddy currents are useful in a moving coil galvanometer. (02marks)

Eddy current are induced in the core when the coil moves in magnetic field.

The eddy current damp the oscillations of the coil. This makes the pointer to settle at a point quickly. It is desirable for quick and accurate reading of the value.

(c) A conducting disc of radius 0.05m with its plane perpendicular to uniform magnetic field of flux density 0.25T, rotates at 15 revolution per second about an axis through its center and perpendicular to its plane.

Calculate

(i) Magnetic flux threading the disc at any time (03marks)

Magnetic flux, $\phi = BA$ but $A = \pi r^2$

- $\phi = B\pi r^2$

$= 0.25 \times 3.14 \times (0.05)^2 = 1.96 \times 10^{-3}$Wb

(ii) E.m.f generated between the center of the disc and any point on its rim.

$\varepsilon = B\pi r^2 f = 0.25 \times 3.14 \times (0.05)^2 \times 15 = 2.9 \times 10^{-2}$V

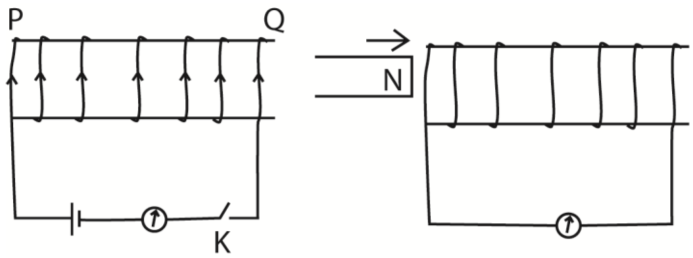
or $\varepsilon = \phi f = 1.96 \times 10^{-3} \times 15 = 2.9 \times 10^{-2}$V

6. (a) state **Faraday's law** of electromagnetic induction (01 mark)

The magnitude of e.m.f induced in the circuit is directly proportional to the rate of change of magnetic flux linked with the circuit

(b) With the aid of a diagram describe an experiment to illustrate **Lenz's law** of electromagnetic induction. (05marks)

Solution



- The galvanometer is first connected in series with the battery and the coil PQ. The switch K is closed. The direction of deflection of the galvanometer for which current flows in an anticlockwise direction at the end P of the coil is noted.
- The battery is then disconnected and the circuit containing the coil and the switch is made complete.
- A strong permanent magnet is brought towards the coil with a North Pole facing end P of the coil.
- The galvanometer deflects in such a direction indicating that the side of the coil facing the magnet is North Pole.
- When the magnet is moved away from the coil, the galvanometer deflects in the opposite direction implying that the pole of the coil near the magnet is a south pole.
- In the first case, the pole due to the increased current was repelling the approaching magnet while in the second case, the pole was attracting the receding magnet. The induced current therefore is in such a direction as to oppose the change causing it, which is Lenz's law

(c) Define **magnetic moment** of a coil. (01mark)

Magnetic moment is torque experienced by the coil per tesla of magnetic field acting along the plane of the coil.

Or

Magnetic moment of a coil is a couple exerted on a coil when it is placed with its plane parallel to a magnetic field of 1T

(d) A small circular coil of 20 turns of wire lies in a uniform magnetic field of flux density 5.0×10^{-2}T. The normal to the coil makes an angle of 30^0 with the direction of the magnetic field. If the radius of the coil is 4cm and the coil carries a current of 2.0A, find the

(i) magnetic moment of the coil (02marks)

$M = NIA = 20\pi \times (4 \times 10^{-2})^2 \times 2 = 0.2Am^2$

(ii) torque on the coil

$T = MB\sin\theta = 0.2 \times 5 \times 10^{-2}\sin 30^0 = 5.0\times 10^{-3}Nm$

(e) (i) State and define the unit of magnetic flux density.

One tesla (1 T) is defined as the field intensity generating one newton (N) of force per ampere (A) of current per meter of conductor:

(ii) Show that when the magnetic flux linking a coil changes, the total charge which passes through is depends only on the resistance of the coil and total flux linking it (05marks).

Consider a coil of N turns each linked by magnetic flux of ϕ_1.
Suppose the magnetic flux changes to ϕ_2.
When the magnetic flux ϕ changes, an e.m.f ε is induced in the coil.

$\varepsilon = \frac{-Nd\phi}{dt}$

$I = \frac{\varepsilon}{R}$; R = the resistance of the coil

$\varepsilon = IR$

Hence $IR = \frac{-Nd\phi}{dt}$

But $I = \frac{dQ}{dt}$; where Q is the induced charge

$\Rightarrow \frac{dQ}{dt} = \frac{-N}{R} \cdot \frac{d\varphi}{dt}$

$dQ = \frac{-N}{R}\, d\varphi$

The amount of the charge which passes through the coil when the magnetic flux changes from ϕ_1 to ϕ_2 is

$Q = \frac{-N}{R}\int_{\phi_1}^{\phi_2} d\phi = \frac{-N}{R}(\phi_2 - \phi_1)$

(iii) State any two factors which determine the efficiency of a transformer. (01mark)

- Resistance of wire used to make the primary and secondary coils/resistance of windings

- Coupling between the primary and secondary coil
- The design of the core/eddy current in the core

7. (a)(i) What is meant by **capacitive reactance**? (01mark)

Capacitive reactance is non-resistive opposition flow of a.c. through a capacitor.

(ii) Peak value of an alternating voltage. (01mark)
Peak value of an alternating voltage is the maximum value of the alternating voltage

(iii) Show that the r.ms value of an alternating voltage is $V_{r.ms} = \frac{V_0}{\sqrt{2}}$, where V_0 is the peak voltage (03marks)

Instantaneous power $= \frac{V^2}{R}$, where V = $V_0 sin\omega t$

$$P_{inst} = \frac{V_0^2 sin^2\omega t}{R}$$

Average power, P = $\frac{V_0^2 sin^2\omega t}{R}$

But $sin^2\omega t = \frac{1}{2}$

For steady voltage, P = $\frac{V_{r.m.s}^2}{2R}$

=> $\frac{V^2}{R} = \frac{V_{r.m.s}^2}{2R}$

Hence $V_{r.m.s} = \frac{V_0}{\sqrt{2}}$

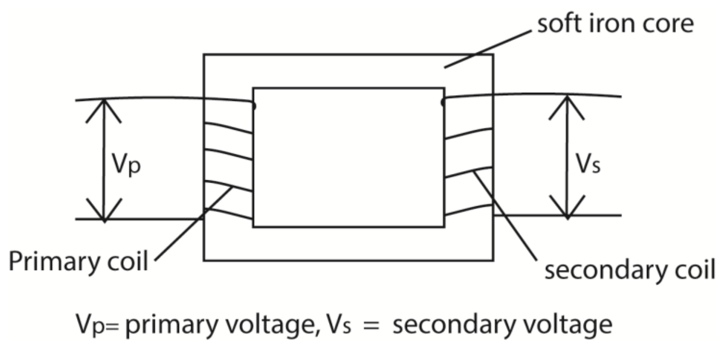
(b) Distinguish between mutual and self-induction. 02marks)

Mutual induction is a production of e.m.f in a conductor caused by change in magnetic field linking it due to change in current due to nearby circuit

while

Self- induction is the production of an e.m.f in a conductor caused by change in magnetic flux linking it due to the change in the current in the same conductor.

(c)(i) Describe with the aid of a diagram, the structure and working of a.c. transformer (02marks)



- Transformer consists of two coil of insulated wire, the primary and secondary wound on laminated soft iron core.
- When alternating voltage, V_p is connected to primary coil, it drives alternating current in the primary coil.
- The alternating current produces a varying magnetic flux ϕ_p that link the primary coils inducing a back e.m.f E_B in the primary.
- The varying magnetic flux, ϕ_s links the secondary coil by mutual induction/inducing alternating voltage, V_s in the secondary

  $V_p = N_p\frac{d\phi_p}{dt}$ ....(i)

  $V_s = N_s\frac{d\phi_p}{dt}$............................. (ii)

  Eqn. (i) ÷Eqn (i)

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

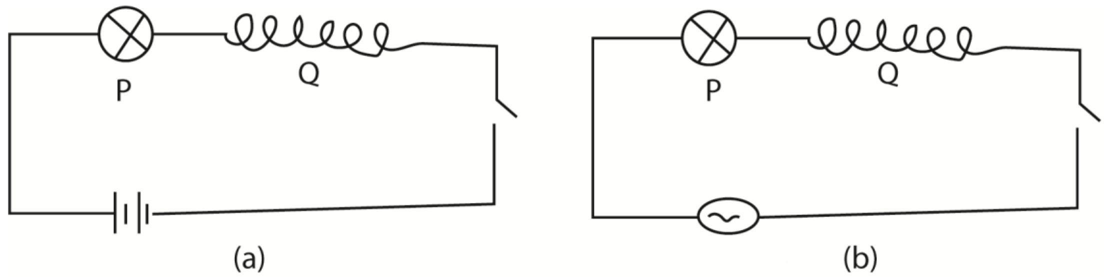
When $N_s > N_p$ the transformer is a step up

$N_s < N_p$ the transformer is a step down

(ii) Explain the steps taken to minimize power losses in electric power transformation. (03marks)

- Voltage generated is stepped up using a transformer so as to transmit high voltage and low current.
- Low resistance cables are used

(d) In figure below, P is a 6V lamp and Q is a coil of negligible resistance



(i) Explain which of the lamps in the figure above will be brighter when K is closed (02marks)

The bulb in (a) will be brighter.
When the switch is closed in (a), current flows and back e.m.f is induced. This limit s brightness of the bulb. When the current reaches the steady value, the back e.m.f is zero, the bulb lit brightest

In coil (b) the continuous change in direction and quantity of current induces continuous change in magnetic flux and thus back e.m.f and the bulb is dim.

(ii) Explain what happens when a soft iron core is introduced in the coil in each of the circuit (03marks)

When soft iron core is introduced, magnetic flux is enhanced in (a), the back e.m.f increases and the current decreases. The brightness of the bulb reduces.
The back e.m.f reduces to zero when the current increases to the maximum (and the change in charge reduces to zero) leading to increase in brightness of the bulb.

In (b) the back e.m.f increases and the current reduces. The brightness of the bulb thus reduces.

SECTION D

8. (a) Define the following as applied to a battery:

(i) Electromotive force

It is the energy supplied by the battery to transfer 1C of charge a round a complete circuit which includes the battery.

Or

It is the ratio of the power the source generated to the current it delivers

(ii) Internal resistance

This is the opposition to the flow of current with the battery due to its chemical composition.

(b) A battery of e.m.f E and internal resistance, r, is connected across a load of resistance, R. Derive an expression for maximum power delivered to the load. (04marks)

Power delivered to the load, P = I^2R

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

=> P = $\frac{E^2R}{(R+r)^2}$

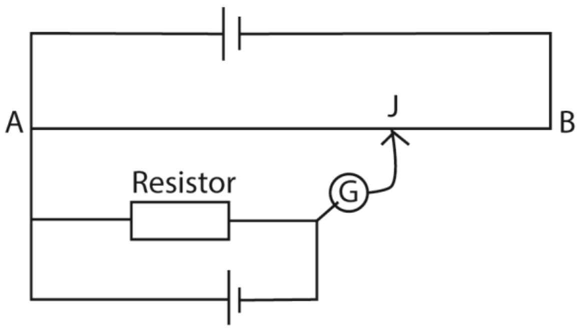
For maximum power, $\frac{dP}{dR}$ = 0

$\frac{dP}{dR} = \frac{E^2(R+r)^2 - E^2R.2(R+r)}{(R+r)^4}$ = 0

R = r

$P_{max} = \frac{E^2R}{(2R)^2} = \frac{E^2r}{4r^2} = \frac{E^2}{4r}$

(c) Determined how resistance of a resistor may be determined using a slide wire potentiometer (05marks)

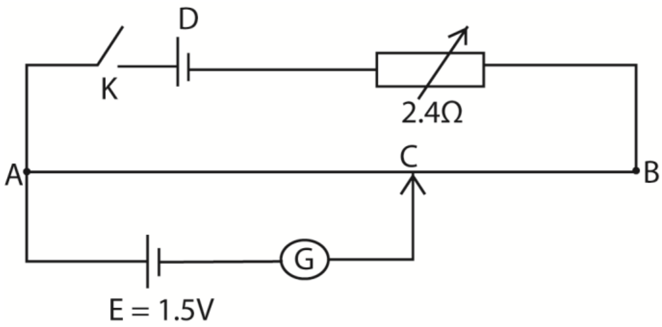


- A balance point AJ = L_s is determined is determined with a standard resistor, R_S.
- A balance point AJ = L is determined is determined with unknown resistor, R
- The unknown resistor, R = $\frac{L}{L_s} x\ R_S$

(d) Explain why the potentiometer is more suitable for measuring small resistance than Wheatstone bridge (02marks)

At balance point the current in a potentiometer wires is zero thus the resistance of the connecting wires does not affect the reading

(e) In the figure below, AB is a uniform resistance wire of resistance 2.0Ω, and length 100cm, E is a cell of e.m.f 1.5V and D is a driver cell of negligible internal resistance. When switch K is closed the balance length AC is 82.5cm.



(i) Find e.m.f of D (03marks)

$E_D = I(R_{AB} + R)$

$= I(2 + 2.4)$

$I = \frac{E_D}{4.4}$

p.d. across AB = $IR_{AB} = \frac{E_D}{4.4} x\ 2 = \frac{E_D}{2.2}$

p.d/cm, k = $\frac{E_D}{2.2}\ x\ \frac{1}{100} = \frac{E_D}{220}$

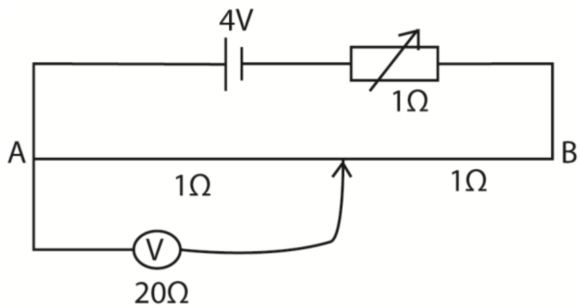
At balance p.d across AC = 1.5V

$kL_{AB} = 1.5$

$\frac{E_D}{220}\ x\ 82.5 = 1.5$

$E_D = 4V$

(ii) If E and the galvanometer are replaced by a voltmeter of resistance 20.0Ω, find the reading of the voltmeter when contact C is placed at the mid-point of AB and the value of R is 1.0Ω.



Combined resistance in parallel, $R_C = \frac{20 \, x \, 1}{20+1} = 0.95238\Omega$

Effective resistance, $R_E = 0.95238 + 1 + 1 = 2.95238\Omega$

Total current, $I = \frac{V}{R} = \frac{4}{2.95238} = 1.355A$

p.d across the parallel combination, V = IR = 1.355 x 0.95238 = 1.29V

∴ voltmeter reading = 1.29V

Or

Combined resistance in parallel, $R_C = \frac{20 \, x \, 1}{20+1} = 0.95238\Omega$

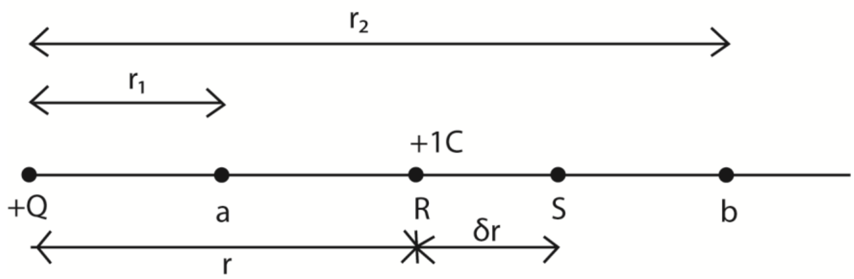
Effective resistance, $R_E = 0.95238 + 1 + 1 = 2.95238\Omega$

p.d across the parallel combination, $V_C = \frac{R_C}{R_E} \, x \, V = \frac{0.95238}{2.95238} \, x \, 4$ = 1.29V

9. (a) (i) Define electric field intensity and potential difference. (02marks)

Electric field intensity at a point is the force exerted on positive charge of 1C placed a point in an electric field.
The potential difference between two points is the work done to move 1C of positive charge from one point to another in electric field.

(ii) Derive an expression for electric potential difference between two points a and b in the field of a single point charge +Q (04marks)



The force exerted on +1C charge at R

F = $\frac{Q}{4\pi\varepsilon_{0r^2}}$

The work done to move +1C of charge from S to R through a small distance, δr is

δw = $\frac{-Q}{4\pi\varepsilon_{0r^2}}$δr

Over a small distance, δr, F is assumed to remain constant.

Total work done to move +1C from b to a is

w = $\int_{r_2}^{r_1} \frac{-Q}{4\pi\varepsilon_{0r^2}}$ δr = $\frac{-Q}{4\pi\varepsilon_0}\left[\frac{1}{r}\right]_{r_2}^{r_1}$

= $\frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

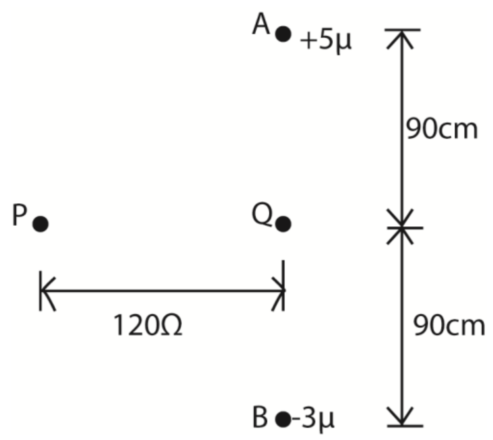
∴ p.d between a and b

$V_{ab} = \frac{Q}{4\pi\varepsilon_0}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$

(b) Describe an experiment to show that when two dissimilar dielectrics are rubbed together, they acquire equal but opposite charge.

- Wool is wrapped round on end of a polythene rod and several turns of thread wound over wool. The loose end of the thread is pulled so that the wool rubs the polythene making sure that the hands do not touch the wool.
- The end of the rod with wool is inserted in the metal can place on neutral electroscope. No divergence is observed.
- When the polythene is carefully pulled out to leave the wool, a divergence of the leaf of electroscope is observed.
- The wool is then withdrawn and the electroscope discharged, when the rod is placed inside the can, the electroscope is observed to diverge to the same extent as before.
- Therefore two dissimilar dielectric have acquired equal but opposite charges.

(c) Two point charges of +5µF and -3µF are placed at points A and B as shown in the figure below.



Calculate the

(i) Electric potential at P (03marks)

AP = BP = $\sqrt{(120^2 + 90^2)}$ = 150cm

Potential at P = $\frac{kQ}{r}$

$V_p = k\left[\frac{Q_A}{r_1} + \frac{Q_B}{r_2}\right]$ = $9 \; x \; 10^9 \left[\frac{5 \; x \; 10^{-6}}{150 \; x \; 10^{-2}} - \frac{3 \; x \; 10^{-6}}{150 \; x \; 10^{-2}}\right]$ = 12,000V

(ii) Work done in moving a charge -3μC from P to Q. (04marks)

Potential at Q = $k\left[\frac{Q_A}{r_a} + \frac{Q_B}{b}\right]$= $9 \; x \; 10^9 \left[\frac{5 \; x \; 10^{-6}}{90 \; x \; 10^{-2}} - \frac{3 \; x \; 10^{-6}}{90 \; x \; 10^{-2}}\right]$ = 20,000V

Potential difference between P and Q

V_{QP} = 20000 – 12000 = 8000V

Work done, w = QV_{QP} = -3 x 10^{-6} x 8000 = 0.024J

(d) State any two characteristics of an equipotential (02marks)

- The work done to move a charge along the surface is zero
- The field line are perpendicular to the surface.

10. (a) Define the following

(i) Capacitance (01mark)

It is the ratio of the magnitude of a charge on either plates of a capacitor to the potential difference between the plates.

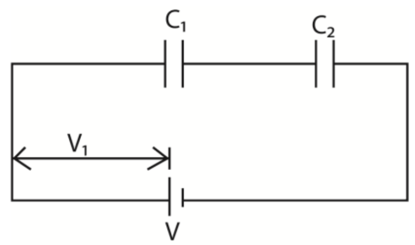
Or

It is the magnitudes of charge on a conductor to potential of the conductor.

(ii) Relative permittivity (01mark)

It is the ration of the permittivity of a material to permittivity of free space.

(b) Two capacitors of capacitances C_1 and C_2 are connected in series with a battery of e.m.f V as shown below.



If the p.d across the capacitor of capacitance C_1 is V_1 show that

$$\frac{1}{V_1} = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)\frac{C_1}{V}$$

Proof

Let the charge on each capacitor plates be Q and V_2 = p.d across C_2.

Total p.d $V = V_1 + V_2$

$$V_1 = \frac{Q}{C_1} and\ V_2 = \frac{Q}{C_2}$$

$$V = \frac{Q}{C_1} + \frac{Q}{C_2} = Q\left[\frac{1}{C_1} + \frac{1}{C_2}\right]$$

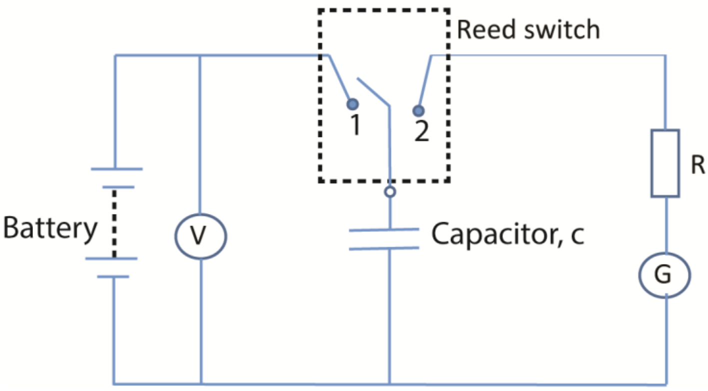
Charge onC_1 = $Q_1 = C_1V_1$

$$V = C_1V_1\left[\frac{1}{C_1} + \frac{1}{C_2}\right]$$

Dividing through by VV_1 gives

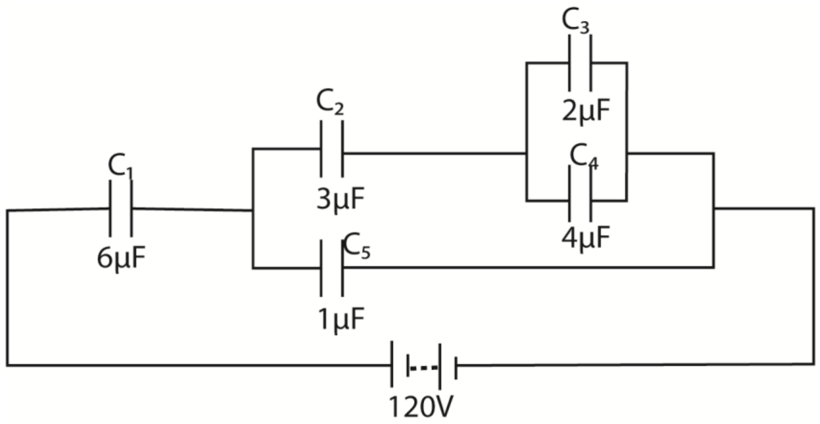
$$\frac{1}{v_1} = \frac{C_1}{V}\left[\frac{1}{C_1} + \frac{1}{C_2}\right]$$

(c) Describe an experiment to determine the capacitance of a capacitor using a vibrating reed circuit.



- The test capacitor of capacitance, C, to be determined is connected to the circuit as shown above
- The capacitor is alternatively charged and discharged through a sensitive light beam galvanometer, G by the reed switch.
- The frequency, f, of the reed switch, the voltmeter reading, V and ammeter reading I are recorded
- The capacitance of the capacitor is given by C =$\frac{I}{fc}$

(d) A battery of e.m.f120V is connected to a network of capacitors as shown in the figure below



Calculate the

(i) Charge on C_1 (04marks)

Combined capacitor C' of $C_3$and C_4 in parallel

C' = C3 + C4 = 2 + 4 = 6μF

Equivalent capacitance C'' of C' and C_2 in series

C'' = $\frac{C'C_2}{C'+C_2} = \frac{3\ x\ 6}{3+6}$ = 2μF

Combine capacitance, C''' of C'' and C5 in parallel

C''' = 2 + 1 = 3μF

Equivalent capacitance C'''' of C''' and C_6 in series

C'' = $\frac{C''''C_6}{C'''+C_6} = \frac{3\ x\ 6}{3+6}$ = 2μF

Total charge Q = CV = 120 x 2 x 10^{-6} = 2.4 x 10^{-4}C

Charge on C1 = 2.4 x 10^{-4}C

(ii) Energy stored in C_5 (03marks)

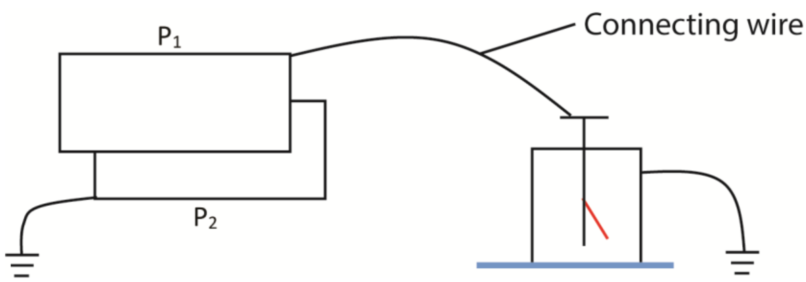
p.d across parallel network, V' = $\frac{Q}{C'''} = \frac{2.4\ x\ 10^{-4}}{3\ x\ 10^{-6}}$ = 80V

Energy stored in C_5 = E = $\frac{1}{2}CV^2$

= $\frac{1}{2}\ x\ 1\ x\ 10^{-6}\ \ x\ 80^2$

= 3.2 x 10^{-3}J

(e) Describe how the effect of a dielectric medium on the capacitance of a capacitor may be determined. (03marks)



- Two metal plates P1 and P2 are set close to each other but not touching.
- P_2 is earthed while P_1 is given charge Q and connected to the cap of electroscope.

- The divergence of the leaf is noted
- A dielectric (e.g. sheets of glass) is placed between the plates keeping the separation of P_1 and P_2 and area constant.
- The divergence of the leaf is seen to decrease implying a reduction of p.d across the plates.
- From C =$\frac{Q}{V}$, the capacitance increases in presence of dielectric.