UACE PHYSICS PAPER 2009 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

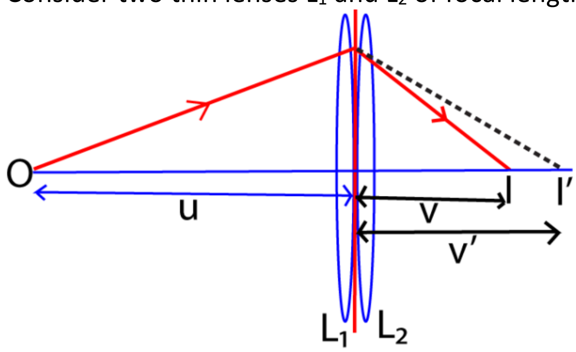
Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 x10^{-19}C$
Electron mass	$9.11 \times 10^{-31}kg$
Plank's constant, h	$6.6 \times 10^{-34}Js$
Speed of light in the vacuum, c	3.0 x 108ms^{-1}
Specific heat capacity of water	$4.200Jkg^{-1}K^{-1}$
Avogadro's number, N_A	$6.02 \times 10^{23}mol^{-1}$
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) (i) Show that the effective focal length, f, of two thin lenses in contact is given by

$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$, where f_1 and f_2 are the foal lengths of the individual lenses. (04marks)

Consider two thin lenses L_1 and L_2 of focal length f_1 and f_2.



For lens L_1,

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

$\frac{1}{f_1} = \frac{1}{u} + \frac{1}{v'}$ ....(i)

For L_2, I' acts as the object

$\frac{1}{f_2} = \frac{1}{-v'} + \frac{1}{v}$ .... (ii)

Eqn. (i) + Eqn. (ii)

$\frac{1}{f_2} + \frac{1}{f_2} = \frac{1}{u} + \frac{1}{v} = \frac{1}{F}$

$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

Where F is the focal length of combined lens,

(ii) A compound lens consists of two lenses in contact having powers of +12.5D and -2.5D. Find the position and nature of the image of an object placed15.0cm from the compound lens. (03marks)

$f_1 = \frac{1}{12.5} = 0.08m = 8cm$

$f_2 = \frac{1}{-2.5} = 0.4m = -40cm$

From $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{8} - \frac{1}{40}$

Combined focal length f = 10cm

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

$\frac{1}{v} = \frac{1}{10} - \frac{1}{15}$; v = 30cm

The image is real (v is +ve) and magnified (v greater than u) (b)(i) Define refractive index (01marks)

Refractive index is the ratio of the speed of light in vacuum to the speed of light in a medium

Or

The ration of sine of angle of incidence of a ray moving from vacuum to the sine of angle of refraction in a medium

(ii) An equi-convex lens is placed on a horizontal plane mirror and a pin held vertically above the lens is found to coincide with its image when positioned 20.0cm above the lens. When a few drops of liquid is placed between the lens and the mirror, the pin had to be raised 10.0cm to obtain coincidence with the image. If the refractive index of the lens is 1.5, find the refractive index of the liquid. (05marks)

Solution

f_g = 20cm, f_c = 30cm, f_L =?

From $\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$

$$\frac{1}{30} = \frac{1}{20} + \frac{1}{f_L}$$

$$\frac{1}{f_L} = \frac{-1}{60}$$

$$Also, \frac{1}{f_g} = \left(n_g - 1\right)\frac{2}{r}$$

$$\frac{1}{20} = (1.5 - 1)\frac{2}{r}$$

$$\frac{1}{r} = \frac{1}{20}$$

For the liquid lens, $\frac{1}{f_L}\ (n_L - 1)\frac{1}{r}$

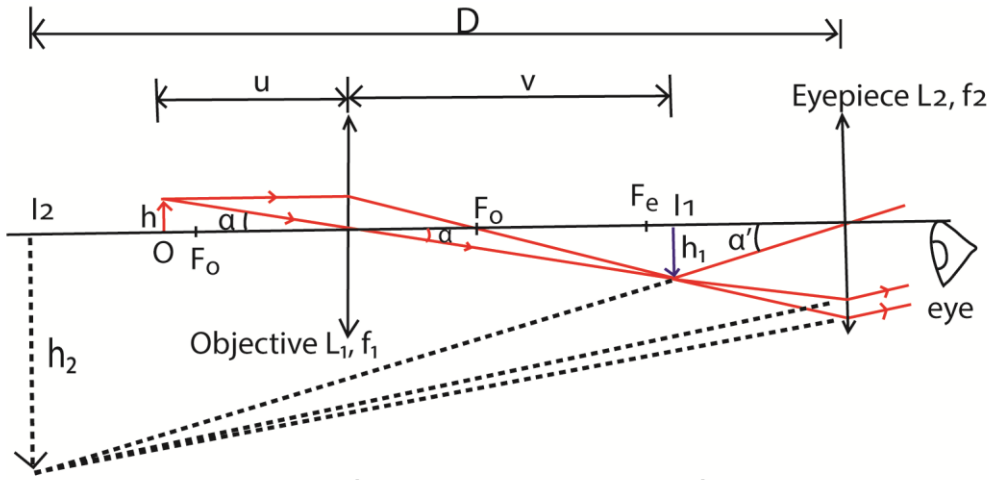
$$\frac{-1}{60} = (n_L - 1)\frac{1}{20}$$

$$n_L = 1.33$$

(c) (i) What is meant by magnifying power of optical instrument? (01mark)

Magnifying power of optical instrument is the ratio of the angle subtended by the final image at the eye when using optical instrument to the angle subtended by the object at the naked eye.

(ii) Derive an expression for magnifying power of a compound microscope in normal adjustment. (05marks)



Compound microscope in normal use

For an aided eye (using the instrument)
For small angle, tanα' ≈ α' for small angle in radians
$\alpha' = \frac{h_2}{D}$ ………………………………………… (i)
For unaided eye
$\alpha = \frac{h_1}{D}$ ………………………………………… (ii)
Magnifying power, $m = \frac{\alpha'}{\alpha} = \frac{h_2}{D} \div \frac{h_1}{D} = \frac{\boldsymbol{h_2}}{\boldsymbol{h_1}}$

Or

Linear magnification can also be expressed as, $m = \frac{h_2}{h} \times \frac{h}{h_1} = m_e \times m_o$.
Where, m_e and m_o are linear magnifications of the eye piece and objective lenses respectively.
$m_o = \frac{v}{f_0} - 1$ and $m_e = \frac{-D}{fe} - 1$

$m = (\frac{-D}{fe} - 1)(\frac{v}{f_0} - 1)$

(iii) Why should the objective and eye piece of a compound microscope have short focal length? (01 marks)

To achieve a big magnification

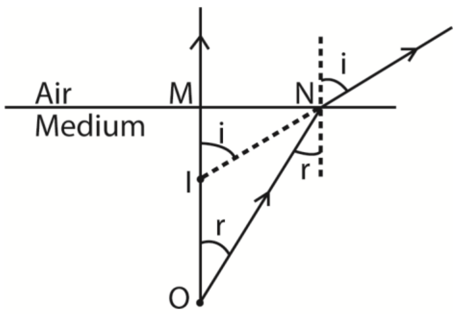
2. (a) What is meant by the following terms as applied to optics
   (i) refraction (01mark)

   Refraction is the bending of light rays as they travel from one medium to another of different optical densities

   (ii) critical angle (01mark)

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

(b) Show that the refractive index, n, of a medium is given by, $n = \frac{real\ depth}{apparent\ depth}$ (04marks)



A ray of light from object O, incident on the boundary at N is refracted and appears to come from I

From Snell's law, the refractive index of the medium, n = $\frac{\sin i}{\sin r}$

But sin i = $\frac{NM}{IN}$ and sin r= $\frac{MN}{ON}$

n = $\frac{NM}{IN} \div \frac{MN}{ON} = \frac{ON}{IN}$

when N is close to M; ON≈ OM and IN≈ IM

∴ n = $\frac{OM}{IM} = \frac{real\ depth}{apparent\ depth}$

(c) A scratch is made at the bottom of a thick glass container which is filled with water. The scratch appears displaced by 0.5cm when viewed from above the water. If the refractive indices of water and glass are 1.33 and 1.50 respectively, find the apparent displacement when water is removed and the scratch is again observed from above. (05marks)

Let t_1 and t_2 be the thickness of water and glass respectively

d = $t_1\left(1-\frac{1}{n_w}\right)+\ t_2\left(1-\frac{1}{n_g}\right)$

= $t_1\left(1-\frac{1}{1.33}\right)+\ t_2\left(1-\frac{1}{1.5}\right)$

= $0.248t_1 + 0.333t_2 = 0.5$

When the water is removed, displacement = $0.5 - 0.333t_2$

(d) A ray of light incident at an angle, I, on a prism of an angle, A, passes through it symmetrically.

(i) Write the expression for deviation, d, of the ray in terms of i and A, (01mark)

d = 2i -A

(ii) Find the value of d if the angle of the prism is 60^0 and the refractive index of glass is 1.48. (03marks)

$$n = \frac{\sin\left(\frac{d+A}{2}\right)}{\sin\frac{A}{2}}$$

$$1.48 = \frac{\sin\frac{d+60}{2}}{\sin\frac{60}{2}}$$

$$\frac{(d+60)}{2} = 47.73$$

$d = 35.5^0$

(e) Describe how you would determine experimentally the angle of minimum deviation produced by a prism. (05marks)

Using a spectrometer

A. the spectrometer is adjusted as follows
- the telescope is adjusted to receive parallel rays.
- The collimator is adjusted to produce parallel rays
- The table is levelled

B. The angle is measured as follows
- The prism is placed on the table with its refracting edge facing away from collimator
- The telescope is turned to receive the refracted light from the opposite side of the prism.
- The table is turned while keeping the refracted light in view, until a point when the ray begins to move backwards. The position of the telescope on the scale is marked.
- The prism is now removed and the telescope turned to receive light directly from the collimator. The position of the telescope is again marked.
- The angle between the two positions is the angle of minimum deviation.

3. (a)(i) A progressive wave represented by y = $a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$is reflected along the same path. Show how the overlap of the two waves may give rise to a stationary wave. (03marks)

$y_1 = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$

A wave travelling in opposite direction is given by

$y_2 = a\sin 2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right)$

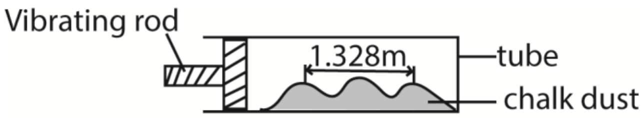
When the two waves superpose, the resultant displacement is $y = y_1 + y_2$.

$y = a\sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right) + a\sin 2\pi\left(\frac{t}{T} + \frac{x}{\lambda}\right)$

$= 2a\cos\frac{2\pi x}{\lambda}\sin\frac{2\pi t}{T}$

This is stationary wave with amplitude $2a\cos\frac{2\pi x}{\lambda}$

(ii) In an experiment to determine the speed of sound in air n a tube, chalk dust settled in heaps as shown below



If the frequency of the vibrating rod is 252Hz and the distance between three consecutive heaps is 1.328m, calculate the speed of sound in air.

From the diagram.

$\frac{\lambda}{2} = \frac{1.328}{2}$; λ = 1.328m

$v = f\lambda$

= 252 x 1.328 = 334.7ms^{-1}.

(b) The speed of sound in air is given by $v = \sqrt{\frac{\gamma P}{\rho}}$ where P is the pressure, l the density and γ the ratio of the principal heat capacities of air.

Use this expression to explain the effect of temperature on the speed of sound in air (03marks)

Solution

When the temperature of air is increased, the pressure increases. If the air is not restricted in volume, it expands leading to a reduction in density. From the above expression, a reduction in density leads to increase in velocity. Hence increase in temperature leads to increase in velocity of sound.

Or

$$v = \sqrt{\frac{\gamma P}{\rho}}$$

From PV = mRT, where R is constant.

If the air is restricted in volume, ρ is constant so that P ∝T. from the above expression, speed of sound in air increases with increase with temperature.

(c)(i) A train moving with uniform velocity, v_1 sounds a horn as it passes a stationary observer. Derive expression for the apparent frequency of sound detected by the observer. (03marks)

f waves occupy a distance v +v_1 in one second.

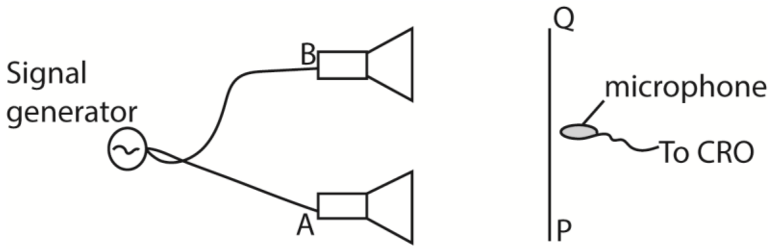
Apparent wavelength $\lambda_a = \frac{u + u_1}{f}$

∴ Apparent frequency, $f_a = \left(\frac{v}{v + v_1}\right) f$; where v is the speed of sound in air, and f is the true frequency of the note sounded.

(ii) If the frequency of the sound detected by the observer after the train passes is 1.2times lower than the frequency detected in (c)(i), find the speed of the train. [Speed of sound in air =330ms^{-1}]

NOT POSSIBLE

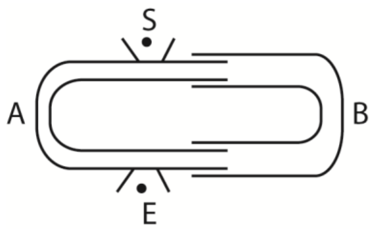
(d) Describe a simple experiment to show interference of longitudinal waves. (04marks)



Two loud speaker A and B were connected to a signal generator. A microphone connected to the y-plates of s C.R.O with the time base switched off.

As the microphone is moved along the line PQ which is parallel to the line joining the loud speaker, the vertical trace on the screen of CRO is seen to increase to maximum and reduce to minimum at equal distances. The alternative maximum and minimum intensity are interference pattern.

Or



Tube A is fixed while B is free to move. A note is sounded at S and detected at E. Tube B s then pulled out slowly. It is noted that the sound detected E increases to a maximum and reduces to minimum intensity at equal intervals of the length of the tube. The alternate maximum and minimum intensity formed are interference pattern.

4. (a) State three differences between mechanical and electromagnetic waves (03marks)

Mechanical wave	Electromagnetic waves
- Need material medium for propagation - Propagate at relatively low speed - Have longer wavelength - Are due to vibration or oscillation of particles in transmitting medium.	- Can propagate in vacuum - Propagate as very high speed - Shorter wavelength - Are due to vibration in electric and magnetic field

(b)(i) State the principal of superposition of waves (01mark)

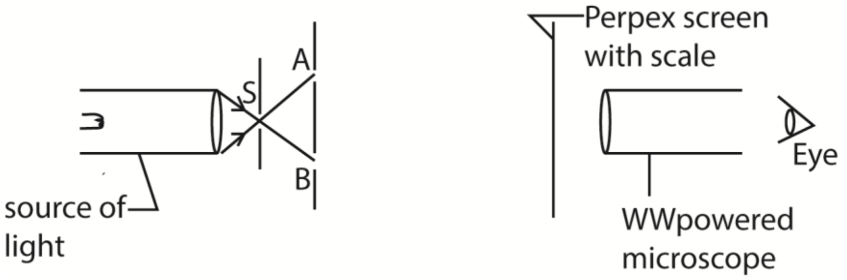
The resultant displacement at any point is the sum of displacements due to the separate waves.

(ii) Explain how interference pattern is formed (03marks)

When two waves from coherent source sources cross they superpose. Where the path difference is odd multiple of a half a wavelength, cancellation occurs resulting in minimum intensity.

Where the path difference is equal to integral multiple of a full wavelength, reinforcement occurs resulting in maximum intensity. This leads to formation of alternate permanent regions of maximum and minimum intensity called interference.

(c)



A source of light, a single slit, S, and a double slit (A and B) are arranged as shown in figure 2.

(i) Describe what is observed on the screen through the microscope when white source of light is used. (02marks)

Sets of numerous colored fringes are seen on screen. The central fringe is white with colored fringes on either side. For each set, blue fringe is nearest to the central one while red is farthest.

(ii) How would you use the set up above to compare the wavelength of red and blue light? (04marks)

A source of white light is used. A red filter is placed in front of the slits. The number of bright fringes in fixed length on the screen is counted and fringe separation, y_r is determined. The red filter is replaced by a blue filter and experiment repeated and fringe separation y_b is determined. It is found $y_r > y_b$

Since fringe separation y is proportional to wave length, from $y = \frac{\lambda D}{d}$

It implies that the wavelength of red light is greater than wavelength of blue light.

(iii) Explain what is observed when slit, S, is gradually widened. (03marks)
Fringes gradually disappear. A large slit S is equivalent to many narrow slits that the fringes overlap to form uniform illumination.

(d) A diffraction grating of 500 lines per mm is illuminated normally by light of wavelength 5.26×10^{-7}m. Find the total number of images seen. (04marks)

Sin $\theta_{max} = \frac{n_{max}}{d} = 1$

$$n_{max} = \frac{d}{\lambda} = \frac{\frac{1}{500} x\ 10^{-3}}{5.26\ x\ 10^{-7}} = 3.8$$

∴ total number of images seen is 7.

SECTION B

5. (a) Define the terms magnetic flux and magnetic flux density. (02marks)

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

Magnetic flux density is the force acting on a 1m long conductor carrying current of 1A in a direction perpendicular to magnetic field.

(b) A straight wire of length 20cm and resistance 0.25Ω lies at right angles to a magnetic field of flux density 0.4T. The wire moves when a p.d of 2.0V is applied across its ends. Calculate the;

(i) initial force on the wire

$$F = BIL = 0.4 \times \frac{2}{0.25}\ x\ \frac{20}{100} = 0.64N$$

(ii) force on the wire when it moves at a speed of $15ms^{-1}$. (02marks)

Induced e.m.f, E = BLV

$= 0.4 \times 0.2 \times 15 = 1.2V$

$I = \frac{V-E}{R} = \frac{2-1.2}{0.25} = 3.2A$

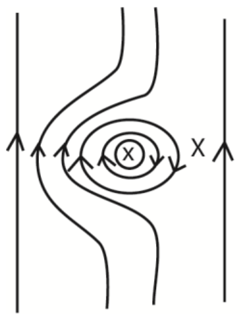
F = BIL

$= 0.4 \times 3.2 \times 0.2 = 0.256N$

(iii) Maximum speed attained by the wire (02marks)

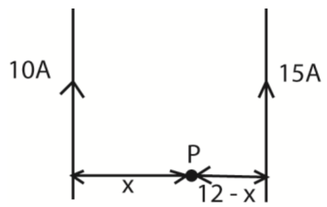
At maximum speed, force, F = 0
Induced e.m.f = applied p.d
But E = Blu = V
Speed $u = \frac{V}{BL} = \frac{2}{0.4\ x\ 0.2} = 25ms^{-1}$

(c) (i) sketch the magnetic field pattern around a vertical straight wire carrying a current in the earth's magnetic field and use it to explain a neutral point in magnetic field. (03marks)



A neutral point is appoint where the resultant magnetic flux (density) is zero

(ii) Two long parallel wires placed 12cm apart in air carry currents of 10A and 15A respectively in the same direction. Determine the position where the magnetic flux is zero. (04marks)



Let P be the point where the resultant magnetic flux is zero

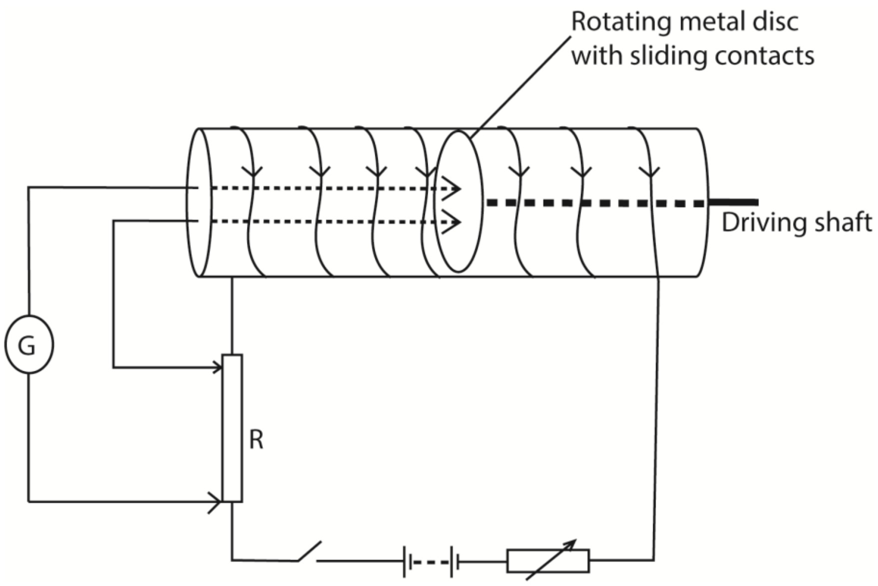
Then, $\frac{\mu_0 1_1}{2\pi x} = \frac{\mu_0 1_2}{2\pi(12-x)}$

$\frac{10}{x} = \frac{15}{12-x}$

x = 4.8cm

P is 4.8cm from 10A current and 7.2 cm from the 15A current carrying conductor.

(d) Describe with the aid of a diagram, an absolute method of determining resistance. (05mark).



The circuit is connected as above. The metal disc of known radius r, is placed at the center of solenoid carrying current with the plane of the disc perpendicular to magnetic field. The disc is rotated using the driving shaft. The speed of rotation of the disc is adjusted until the galvanometer shows no deflection. The number of revolutions for a given interval of time is counted and the frequency, f, determined.

The resistance is then calculated from;

$R = \mu_0 n\pi r^2 f$;

Where n is the number of turns per meter of the solenoid

6. (a) Derive an expression for the charge, Q, induced in a coil of N turns when the magnetic flux through it changes. (04marks)

Instantaneous induced e.m.f $E = \frac{-d\,(N\phi)}{dt}$

Instantaneous current $I = \frac{E}{R} = -\frac{-1}{R}\frac{d(N\phi)}{dt}$

But $I = \frac{dQ}{dt}$

$\therefore \frac{dQ}{dt} = \frac{-N}{R}\frac{d\phi}{dt}$

$dQ = \frac{-N}{R}d\phi$

Suppose when time in zero flux linkage is ϕ_0

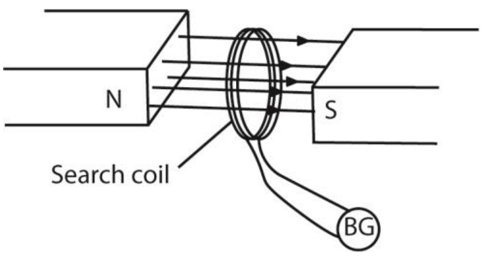
And when time is t, flux linkage is ϕ_1. Then total

Induced charge $Q = -\frac{N}{R}\int_{\phi_0}^{\phi_1} d\phi$

$= \frac{N}{R}(\phi_0 - \phi_1)$

(b) (i) Describe how a ballistic galvanometer of an unknown charge sensitivity can be used to measure magnetic flux density in a region between the poles of a magnet. (05marks)

Solution



A search coil is connected in series with a ballistic galvanometer, B.G and a resistor.

The search coil is placed between the poles pieces of the magnet with its plane normal to the magnetic field.

When the ballistic galvanometer pointer settles, the coil is completely withdrawn from the field and the first deflection θ of the B.G is noted.

A capacitor of known capacitance C is charged to a p.d V and then discharged through the ballistic galvanometer and the corresponding θ' is noted.

The magnetic flux density B is now calculated from $B = \frac{CVR\theta}{NA\theta'}$ where A is the area of the coil, N is the number of turns in the coil and R is the resistance of the coil circuit.

(ii) State the possible sources of error in above experiment. (02mark)

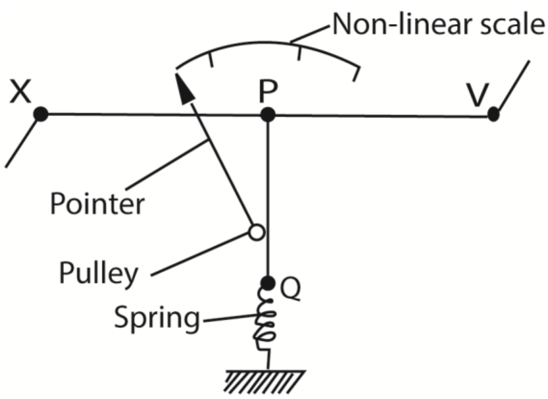
- It may not be possible to get the coil completely out of the field
- Improper position of the search coil
- Inaccuracy of ballistic galvanometer
- Influence of earth's magnetic flux

(c) A flat circular coil with 2000turns, each of radius 50cm, is rotated at a uniform rate of 600 revolutions per minute about its diameter at right angle to a uniform magnetic flux density 5 x 10^{-4}T. Calculate the amplitude of the induced e.m.f. (03marks)

$E_0 = 2\pi fNAB$

$= 2\pi \times \frac{600}{60} \; x\ 2000\ x\ \pi\ x\ 0.5^2\ x5\ x\ 10^{-4}$ = 49.3V

(d) Describe with the aid of a labelled diagram, the structure and action of a hot wire ammeter. (06marks)

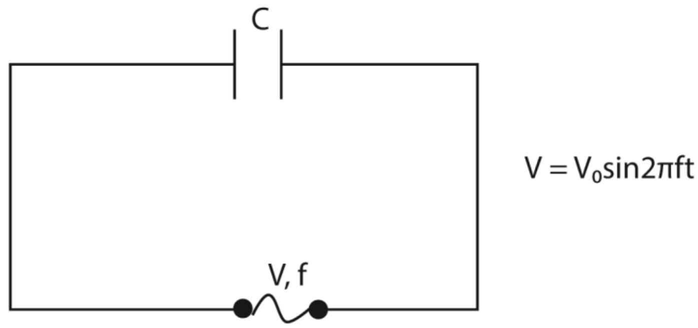


- The current flows through a fine resistance-wire XY, which it heats.
- The wire warms up to such a temperature that it loses heat-mainly by convection-at a rate equal to the average rate at which heat is developed in the wire.
- The rise in temperature of the wire makes it expand and sag; the sag is taken up by a second fine wire PQ, which is held taut by a spring.
- The wire PQ passes round a pulley attached to the pointer of the instrument, which rotates as the wire XY sags.
- The deflection of the pointer is roughly proportional to the average rate at which heat is developed in the wire XY; it is therefore roughly proportional to the average value of the square of the alternating current, and the scale is a square-law one.

7. (a) (i) what is meant by peak value of a sinusoidal current? (01mark)

The peak current of a sinusoidal current is the maximum value of the current.

(ii) A source of sinusoidal voltage of amplitude V_0 and frequency f is connected across a capacitor of capacitance, C. Derive an expression for instantaneous current which flows (03marks)

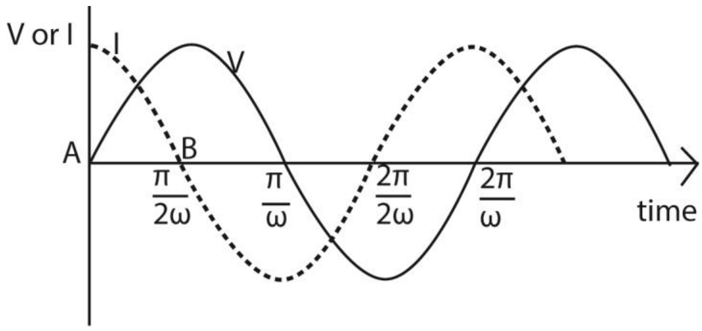


Instantaneous charge on the capacitor, $Q = CV = CV_0\sin 2\pi ft$

But $I = \frac{dQ}{dt} = \frac{d(Cv_0 \sin 2\pi ft)}{dt}$

$= 2\pi fCV_0\cos 2\pi ft$

(iii) With reference to the circuit in (a)(ii), sketch using the same axes, graphs to show the variation of voltage and current with time. (02marks)



Explanation

The current I through (not across) a capacitor is $C\frac{dV}{dt}$. This is the slope of the voltage.

When a capacitor is connected to an AC voltage (at the zero crossing) the maximum current flow will occur immediately, i.e. t = 0, $\frac{dV}{dt}$ will approach infinity instantly and then repeat as a sinusoidal waveform.

There will be a peak current at every zero crossing of the voltage waveform. The current waveform will lead the voltage waveform 90 degrees.

(b)(i) Explain why an alternating current apparently flow through a capacitor whereas a direct current does not. (03marks)

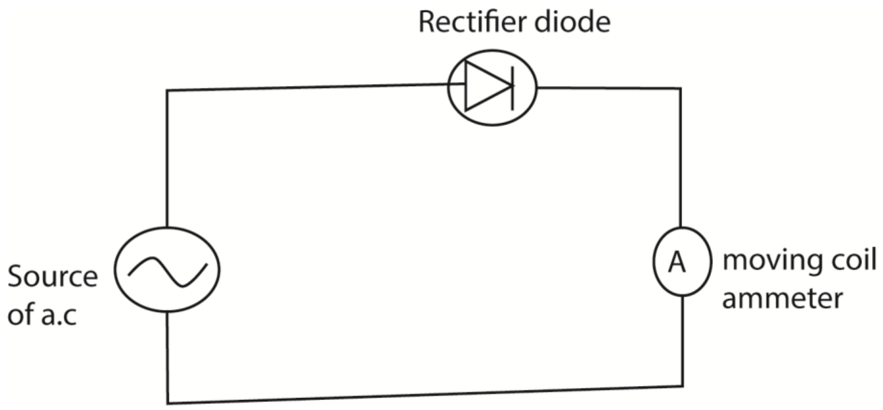
When a capacitor is connected to a d.c source, the capacitor charges fully and current stops flowing.

When the capacitor is connected to a.c voltage supply, the voltage increases and decreases alternatively. When the voltage increases the capacitor charges and when the voltage decreases the capacitor discharges. Hence continuous flow of charge (current) in the circuit.

(ii) Explain the advantages of a.c over d.c in power transmissions. (02marks)

- a.c can easily be stepped up and down
- a.c is easy to generate
- a.c can be transmitted with low power loss.

(c) With the aid of a diagram, describe how a half wave rectifier type of meter works. (04marks)



Current to be measured is fed to the meter through rectifier diode in which current flows in only one direction. So a direct current of varying magnitude flows through the meter. The moving coil meter is calibrated to measure the average current (or $I_{r.m.s}$)

(c) A sinusoidal voltage V = 339sin100πt is connected across 40Ω resistor. Find the;

(i) amplitude of the current through the resistor. (02marks)

$I_0 = \frac{V_0}{R} = \frac{339}{40}$ = 8.475A

(ii) average power developed in the resistor. (03marks)

Average power, P = $\frac{V_0 I_0}{2} = \frac{V_0^2}{2R} = \frac{339^2}{2 \times 40}$ = 1436.5W

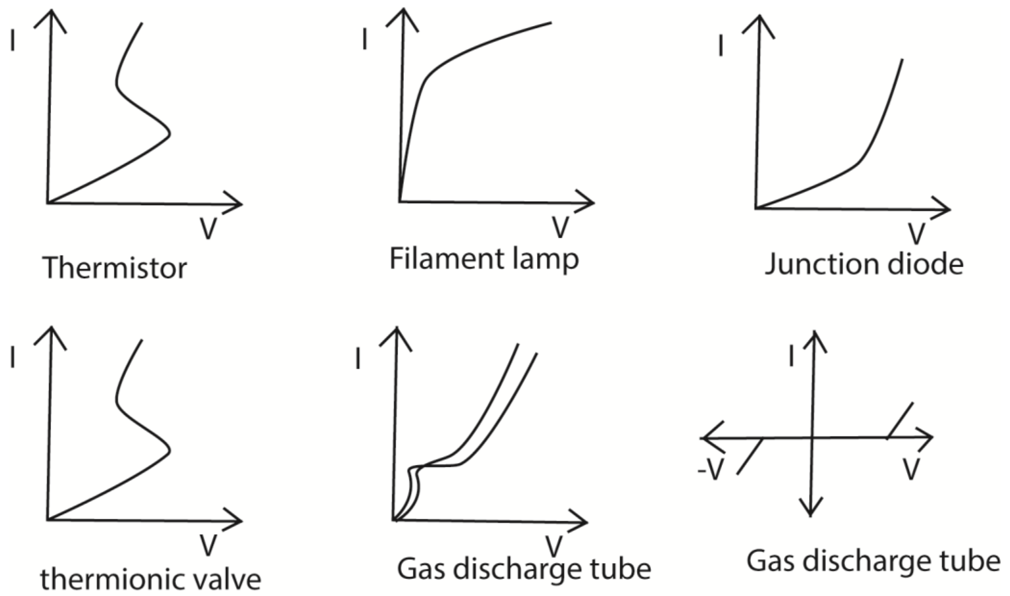
SECTION C

8. (a) (i) State Ohm's law. (01mark)

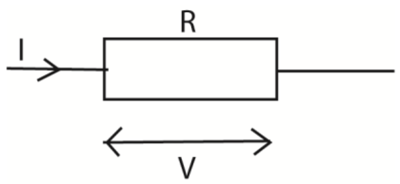
Ohm's law states that the current flowing through a given conductor is directly proportional to the potential different difference between its ends provided the physical conditions remain constant.

(ii) Give two examples of non-Ohmic conductors and sketch their current-voltage characteristic. (03marks)

Non-Ohmic conductor include thermistor, filament lamp, junction diode, thermionic diode, gas discharge tube, dilute sulphuric acid electrolyte with platinum electrodes.



(b) (i) Derive an expression for electrical energy dissipated in a resistor of resistance, R ohms carrying current I ampere for t seconds. (03marks)



When current I flows through the resistor for a time T,

Total charge conveyed is Q = IT

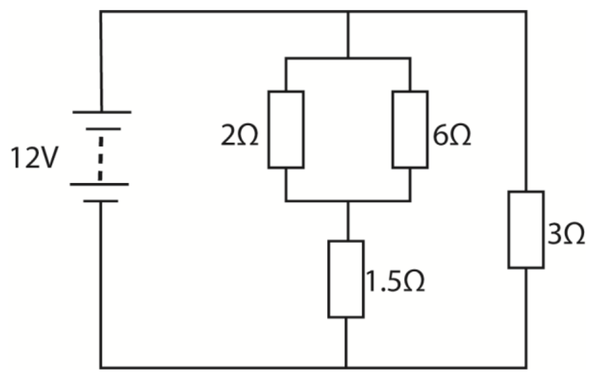
With a p.d V across R, the work done to transfer charge Q through R is

W = QV

But V = IR

W = It x IR= I^2R

(ii) A network of resistors of 2Ω, 6Ω, 1.5Ω and 3Ω are connected to a 12V d.c. supply of negligible internal resistance as shown below



Calculate the power dissipated in the 6Ω resistor. (04marks)

2Ω and 6Ω in parallel, effective resistance, R1 = $\frac{2 \; x \; 6}{2+6}$= 1.5Ω

p.d across the parallel network = 6V

Hence p.d across 6Ω is 6V

Power P = $\frac{V^2}{R} = \frac{6^2}{6} = 6W$

(c) (i) Define temperature coefficient of resistance (01mark)

Temperature coefficient of resistance is defined as fractional change in resistance at 00 for every degree Celsius rise in temperature.

(ii) Explain why semiconductors have negative temperature coefficient of resistance. (02marks)

Semi- conductor have few electrons available for conduction at room temperature. When current is passed through it, the material heats up and more electrons are set free. Thus the current increases and resistance decreases as temperature increases. Hence temperature coefficient of resistance is negative.

`(d) An electric heater consists of 5.0m of nichrome wire of diameter 0.58mm. When connected to a 240V supply, the heater dissipated 2.5kW and the temperature of the heater is found to be 1020^{0}C. If the resistivity of nichrome at 10^{0}C is 10.2x 10^{-7}Ωm, calculate

(i) The resistance of nichrome at 10^{0}C (03marks)

$R_{10} = \frac{\rho L}{A}$ = $\frac{10.2 \; x \; 10^{-7} \;\; x \; 5 \; x \; 4}{\pi(5.8 \; x \; 10^{-4})^2}$= 19.3Ω

(ii) The mean temperature coefficient of resistance of nichrome between 10^{0}C and 100^{0}C. (03marks)

At 1020^0, $\frac{V^2}{R_{1020}}$ = 2.5 x 10^3

⇨ $R_{1020} = \frac{240^2}{2.5 \; x \; 10^3}$ = 23.04Ω

$\frac{R_{1020}}{R_{10}} = \frac{1+1020\alpha}{1+10\alpha} = \frac{23.04}{19.3} = 1.194$

$1 + 1020\alpha = 1.194 + 11.94\alpha$

α = 1.92 x $10^{-4}K^{-1}$

9. (a) Define electric potential difference (01mark)

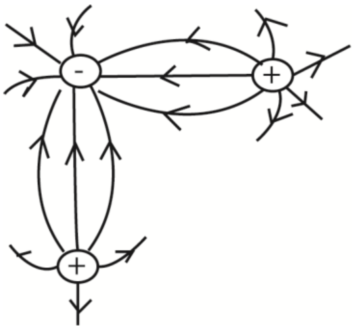
Electric potential difference between two points is the work done to transfer 1C of charge from one point to the other against electrostatic field.

(b) Explain briefly what happens to the potential energy as two point charges of the same sign are brought closer. (02marks)

Like charges repel. work has to be done against the repulsive forces between them to bring them closer.

(c) Three point charges of +5μC, -3μC and +2μC are placed respectively at three corners of a square of side 6.3cm in a vacuum.

(i) Sketch the electric field lines due to the charges. (02marks)



(ii) Calculate the electric filed potential at the fourth corner of the square (04marks)

Electric potential V = $\frac{KQ}{r}$

Total potential V = $V_1 + V_2 + V_3$

$$= K\left(\frac{Q_1}{r_1} + \frac{Q_2}{r_2} + \frac{Q_3}{r_3}\right)$$

$$= 9 \times 10^9\left(\frac{5 \times 10^{-6}}{6.3 \times 10^{-2}} - \frac{3 \times 10^{-6}}{\sqrt{(6.3 \times 10^{-2})^{-2} + (6.3 \times 10^{-2})^{-2}}} + \frac{2 \times 10^{-6}}{6.3 \times 10^{-2}}\right)$$

$= 6.97 \times 10^5$V

(iii) Find the electric potential energy, if a charge of -4μC is placed at the fourth corner. (02marks)

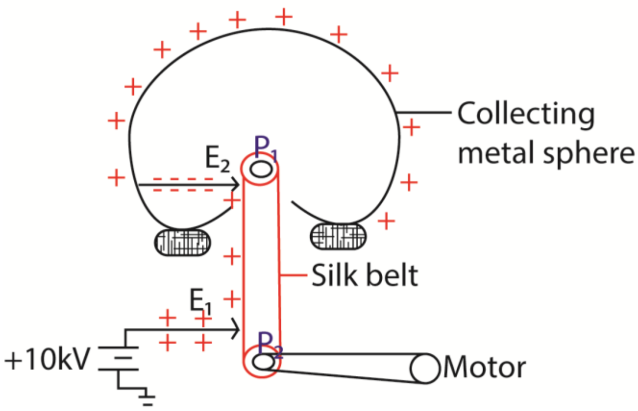
Electric potential energy, W = VQ

$= 6.97 \times 10^5 \times -4 \times 10\text{-}6$

= -2.79J

(d) Describe, with the aid of a diagram, how a high voltage can be generated using a Van de Graff 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 discharging 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.

(e) Explain how two insulating bodies rubbed together acquire charge.

When two dissimilar insulators are rubbed together, heat is generated due to friction. Heat cause a material of lower function to lose electron to the other. The material that loses electrons becomes positively charged while the one that accepts electron becomes negatively charge.

10. (a) (i) Define capacitance of a capacitor. (01mark)

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

(ii) Drive an expression for energy stored in a capacitor of capacitance C charged to a p.d, V. (04marks)

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

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

≈ Vδq

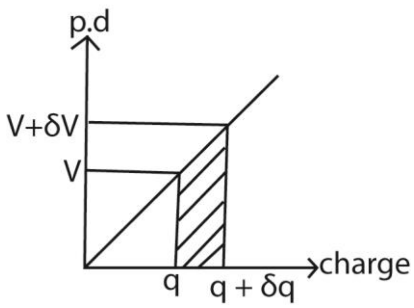
But $V = \frac{q}{C}$

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

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

Or

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



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

= work done to increase charge on the capacitor by δq

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

Work done, w = average voltage x charge

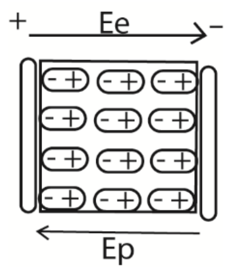
$$= \frac{1}{2}(0 + V)x\ Q$$

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

But Q = CV

∴w = $\frac{1}{2}CV^2$

(b)(i) Explain the effect of placing an insulator between the plates of a charged capacitor. (05marks)



When a dielectric is placed between the plates of a charged capacitor, the nucleus of the molecules of the dielectric are urged in the direction of the field and the electrons in opposite direction.

The molecules get polarized and the surface of the dielectric near the capacitor develops charges opposite to those on adjacent plates while the charges inside the dielectric cancel out.

Since the charge on the dielectric are not conductible, electric field intensity develops between the surfaces of the dielectric in the direction opposite to the supplied field. The resultant electric field intensity is thus reduced.

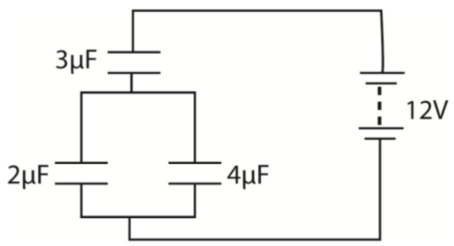
But E = $\frac{V}{d}$ hence the p.d between the plates V is reduced.

From C = $\frac{Q}{V}$; a reduction in A leads to increase in C

(ii) State two physical properties desirable in a material to be used as a dielectric in a capacitor. (02marks)

- Large dielectric constant
- High dielectric strength

(c)



A battery of e.m.f12V is connected across a system of capacitors as shown in the figure above. Find the

(i) Charge on the 3μF capacitor (03marks)

Effective capacitance in parallel, $C = C_1 + C_2 = (2 + 4)\mu F = 6\mu F$

Effective capacitance in series= $\frac{6 \times 10^{-6} \times 3 \times 10^{-6}}{(6+3) \times 10^{-6}}$ = 2×10^{-6}C

$Q = CV = 2 \times 10^{-6} \times 12 = 2.4 \times 10^{-5}$C

Hence the charge on 3μF capacitor = 2.4×10^{-5}C

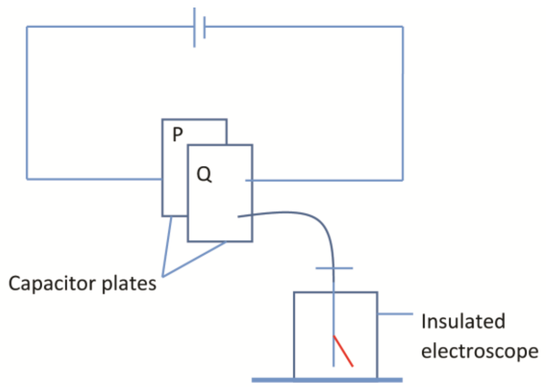
(ii) Energy stored in the 4μFcapacitor (03marks)

p.d across the 6μF, $V = \frac{Q}{C} = \frac{2.4 \times 10^{-5}}{6 \times 10^{-6}}$ = 4.0V

p.d across 4μF = 4.0V

energy store by 4μF capacitor = $\frac{1}{2}CV^2 = \frac{1}{2} \times 4 \times 10^{-6} \times 4^2$ = 3.2×10^{-5}J

(d) Describe a simple experiment to show that capacitance of a capacitor increases with surface area of the plates. (02marks)



A p.d is set across the capacitor plates P and Q, by connecting a cell across it. One plate Q is connected to the cap of electroscope. With the p.d constant and the plates in the above position with air in between them, the divergence of the leaf of electroscope is noted.

Place P is then slid relative to Q keeping the separation constant, hence reducing the effective area of the plate. The divergence is seen to decrease.

Since divergence is proportional to charge on the plates, which in turn is proportional to the capacitance, C, then, C is reduced.

This shows that $C \propto A$

END