UACE PHYSICS PAPER 2014

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	$1.2 \times 10^{-6}\Omega m$

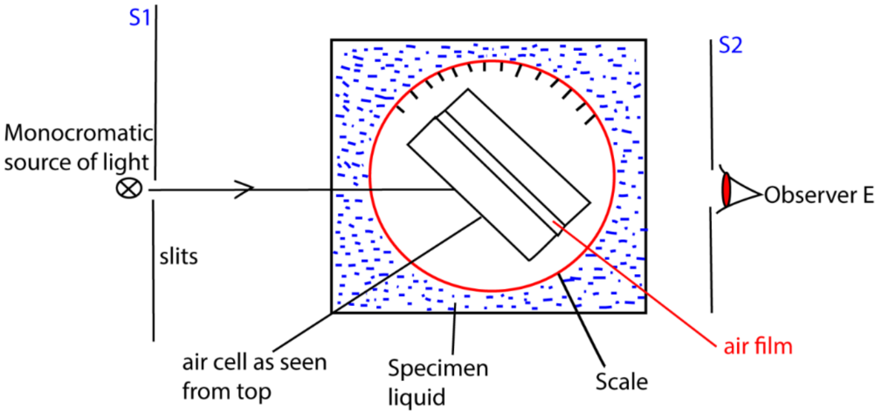
SECTION A

1. (a) (i) 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.

   (ii) State the conditions for total internal reflection to occur. (02marks)

   - Angle of incidence must be greater than the critical angle.
   - Light must be moving from a denser to less dense medium

   (b) (i) Describe an experiment to determine refractive index of a liquid using air cell. (06marks)



- The air cell is immersed in a liquid under test.
- A beam of monochromatic light is directed onto the air cell and then observed through the cell from the opposite side at **E**.
- The cell is then rotated on one side until light is suddenly cut off and the angular position **θ1** is noted.
- The cell is again rotated in the opposite direction until light is suddenly cut off and the angular position **θ2** is noted.

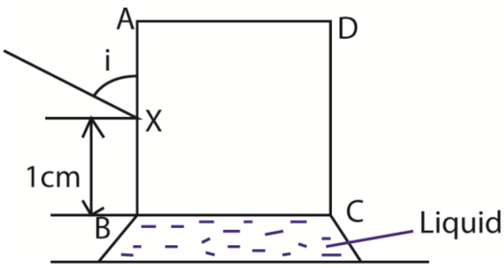
- The refractive index of the liquid can then be calculated from

$$n = \frac{1}{\sin\theta} \quad \text{where } \theta = \frac{\theta 1 + \theta 2}{2}$$

(ii) Explain the difficulty encountered in the experiment described in (b)(i) if white light is used (02marks)

White light does not give sharp extinction of light due to dispersion.

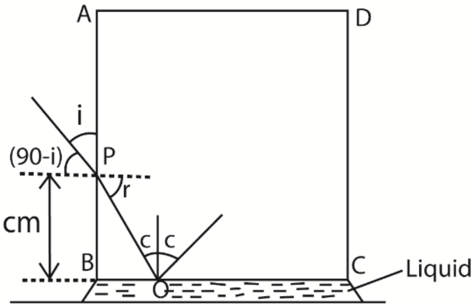
(c) A cube of glass of side 3cm and refractive index 1.5 is placed on a thin film of liquid as shown in the figure below



A ray of light in the vertical plane strikes AB of the glass cube at an angle i = 410. After refraction at X, the ray is reflected at the critical angle for glass-liquid interface.

(i) Calculate the critical angle for glass –liquid interface. (03marks)

Solution



From nsin i = constant

sin (90 – 41) = 1.5sin r

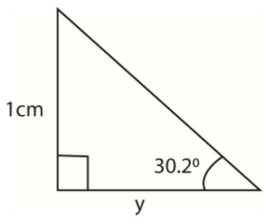
$r = 30.2^0$

At point Q

$r + c = 90^0$

$c = 90^0 - 30.2^0 = 59.8^0$

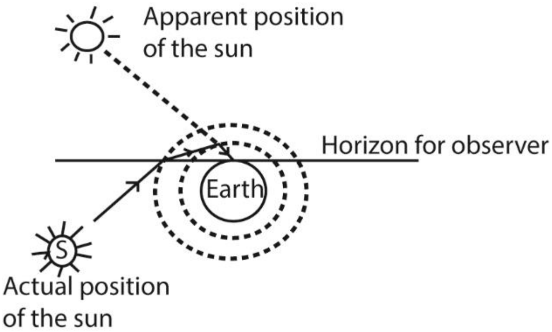
(ii) Find the position from B where the ray strikes the glass-liquid interface



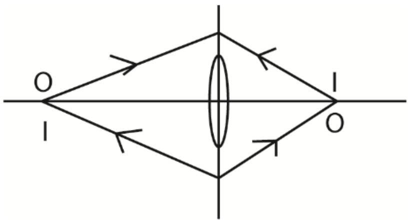
$y = \frac{1}{\tan 30.2} = 1.7\text{cm}$

(d) Explain why the rays from the sun can still be seen shortly after sunset (03marks)

As the sun sets, layers of air near the earth gets cooler and therefore optically denser than layers of the air above. This causes total internal refraction of light rays from the sun towards the earth.



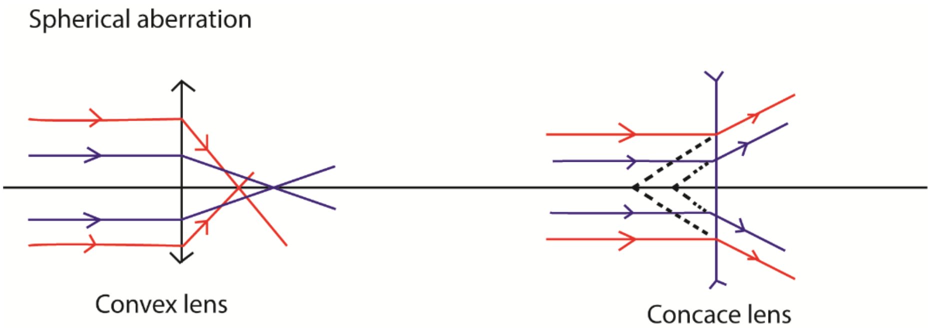
2. (a) with the aid of ray diagram, explain the following as applied to lenses
   (i) conjugate points. (02marks)



These are two points; O and I, on the opposite side of a convex lens such that an object and its image at these points are interchangeable.

(ii) spherical aberration (02marks)

Spherical aberration

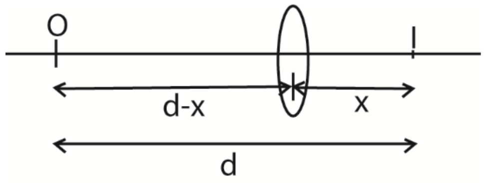


Spherical aberration occurs when the lens fails to focus all rays falling on it to the same point. Thus images formed by the lens at large apertures are therefore unsharp or blurred at the edges.

(b) An object, O, placed in front of a converging lens forms a real image, I, on the screen. The distance between the object and its real image is d. while that of the image from the lens is x.

Derive the expression for the least possible distance between the object and its real image (05marks)

Solution



u = d-x   v = x

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

$\frac{1}{f} = \frac{1}{d-x} + \frac{1}{x} = \frac{d}{dx - x^2}$

$x^2 - dx + fd = 0$

$x = \frac{d \pm \sqrt{d^2 - 4fd}}{2}$

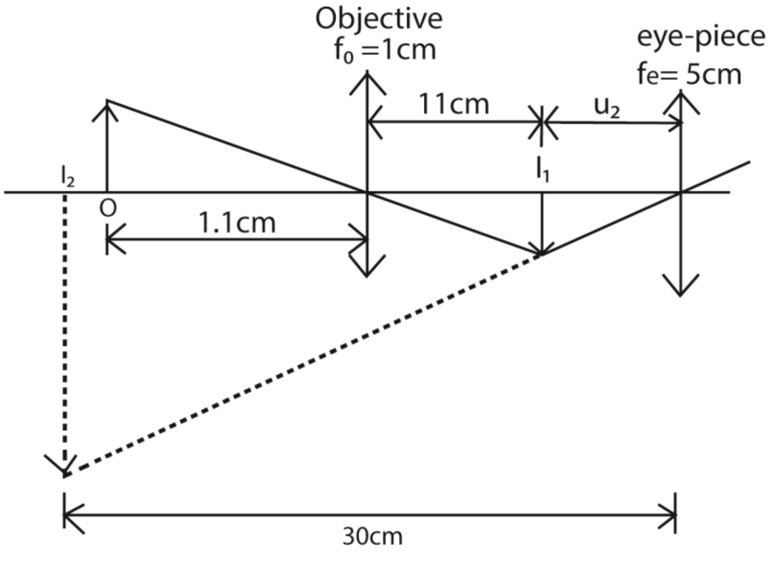
for real roots, $d^2 > 4fd$ or $d > 4f$

(c) Give the properties of lenses in achromatic combination. (03marks)-

- One lens should be concave and the other convex
- The lenses should be of different materials
- The dispersion caused by the concave lens should be completely cancelled by the convex lens. the dispersive power of the materials be $\frac{f_1}{f_2} = \frac{-w_1}{w_2}$
- The radii of curvature of concave and convex lenses should be numerically equal

(d) A compound microscope consists of two converging lenses of focal lengths 1.0cm and 5.0cm respectively. An object is placed 1.1cm from objective and the microscope is adjusted so that the final image formed 30cm from the eye- piece. Calculate

(i) the separation of the lenses (03marks)



Objective lens

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

$\frac{1}{1.0} = \frac{1}{1.1} + \frac{1}{v}$; v = 11cm

Eye piece

$\frac{1}{5.0} = \frac{1}{u_e} - \frac{1}{30}$; u_e = 4.3cm

$Separation = v + u_e$ = 11 + 4.3 =15.3cm

(ii) the magnifying power of the lenses. (03marks)

m = $\left(\frac{v_e}{f_e} - 1\right)\left(\frac{v_0}{f_0} - 1\right)\frac{D}{v_e} = \left(\frac{-30}{5.0} - 1\right)\left(\frac{11}{1} - 1\right)\frac{25}{-30}$ = 58.3

(e) State two differences between a compound microscope and an astronomical telescope. (02marks)

Compound microscope	Astronomical telescope
- view near objects	- views distant objects
- objective lens has smaller focal length	- objective has longer focal length
- in normal adjustment, final image is at near point	- in normal adjustment final image is at infinity
- has greater resolving power	- has smaller resolving power

SECTION B

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3. (a) What is meant by the following terms as applied to sound?

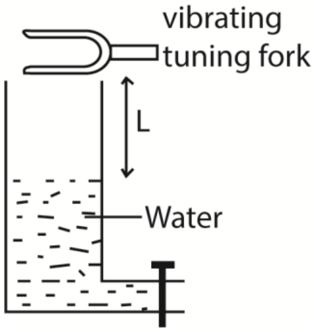
(i) Resonance

Resonance is said to occur when a system is set to oscillate at own natural frequency as result of impulses received from another system vibrating at the same frequency,

(ii) Fundamental frequency

This is the lowest frequency an instrument can produce.

(b) Describe an experiment to determine end- correction of resonance tube.



- A sounding tuning fork of known frequency s is held over open end of a tube filled with water
- The water is gradually lowered until a loud sound is heard.
- The length L of air column is measured,
- The procedure is repeated using tuning forks of different frequencies and corresponding length L measured and recorded.
- The results of L, f and $\frac{1}{f}$ are tabulated

- A graph of L against $\frac{1}{f}$ give an intercept c, the end correction of resonance tube.

(c) A wire of length 50cm, density $8.0gcm^{-3}$ is stretched between two points. If the wire is set to vibrate at fundamental frequency of 15Hz, calculate

(i) The velocity of the wave along the wire

$L = \frac{\lambda}{2}$ or $\lambda = 2L = 2 \times 0.5 = 1m$

$V = \lambda f = 1 \times 15 = 15ms^{-1}$

(ii) The tension per unit area of cross section of wire.

$V = \sqrt{\frac{T}{\mu}}$; $\mu = \frac{m}{L} = \rho A$

$V^2 = \frac{T}{\rho A}$

$\frac{T}{A} = V^2\rho = 15^2 x\ 8000 = 1.8\ x\ 10^6\ Nm^2$

(d) Explain using the principle of superposition of wave the formation of

(i) Beats

When two waves of nearly equal frequencies and similar amplitudes are sounded together, they superpose. When they meet in phase constructive interference takes place and loud sound is heard. When they meet completely out of phase, destructive interference takes place and soft sound is heard. A periodic rise and fall in intensity of sound is heard referred to as beats.

(ii) Stationary waves

When two waves of the same frequency, equal wavelength and equal amplitude are propagating in the same medium in opposite direction they meet and superpose; the resultant displacement of particles in medium at any point is the sum of displacements due to each of the waves at that point.

At point where waves meet in phase, the amplitude is maximum. These are antinode. Where the waves meet out of phase a minimum amplitude is formed. The resultant wave is a stationary wave.

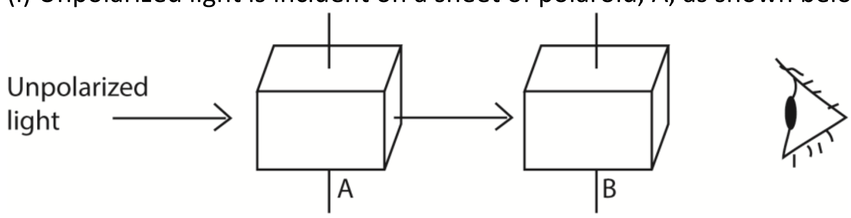
4. (a) (i) what is plane polarized light?

Plane polarized light is one in which the variation of electric vector takes place in one plane only.

(ii) Why is it not possible to polarize sound waves?

Sound waves are longitudinal waves whose vibrations are parallel to the direction of propagation of the wave.

(e) (i) Unpolarized light is incident on a sheet of polaroid, A, as shown below

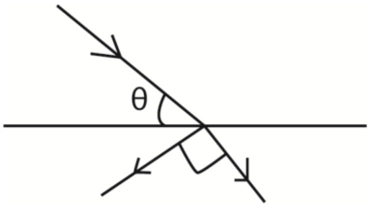


Explain what would be observed if a second polarized sheet B is rotated about an axis perpendicular to the direction of incidence.

Solution

Bright light will be seen or no light will be seen. If the orientation of B is the same as A, bright light is viewed and even when rotated, the bright light remain because the orientation of B does not change its orientation with respect to plane of its polarization

(iii) Sunlight is reflected off a glass window of refractive index 1.55. What should be the elevation of the sun be if the reflected light is to be completely polarized?



From Brewster's law, tan θ =n = 1.55

$\theta = 57.2^0$

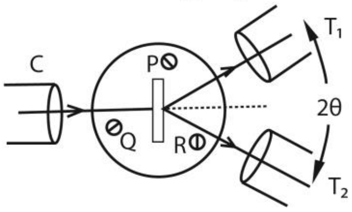
(c) Given the diffraction grating and spectrometer, describe how you would use them to measure the wavelength of light from a given source.

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 λ = d sin θ, 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 $\lambda = d \sin {}^{\theta}/_{2}$.

(d) A parallel beam of monochromatic light of wavelength 650nm is directed normally to diffraction grating which has 600 lines per mm. Determine

(i) the number of diffraction image.

$d = \frac{1}{600} = 1.67 \times 10^{-3}\text{mm} = 1.67 \times 10^{-6}\text{m}$

$\frac{d}{\lambda} = \frac{1.67 \times 10^{-6}}{650 \times 10^{-9}} = 2.57$

The highest order is 2 and total number of images is 5

(ii) the angle of diffraction of the highest order diffraction image.

$\text{Sin } \theta = \frac{m\lambda}{d} = \frac{2 \times 650 \times 10^{-9}}{1.67 \times 10^{-6}}$

$\theta = 51.1^0$

SECTION C

5. (a) Define the following:

(i) Weber (01mark)

The weber is magnetic flux that passes normally though an area of $1m^2$. When the magnetic flux density is 1T.

(ii) Ampere (01mark)

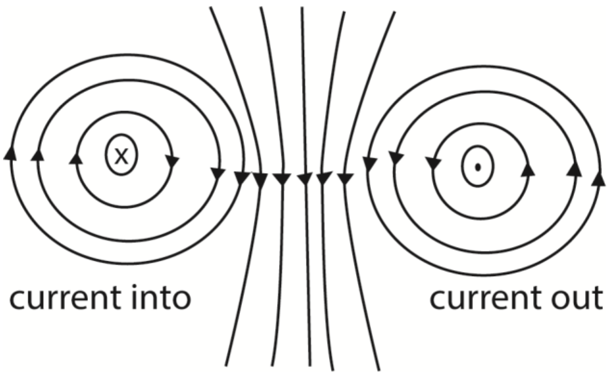
The ampere is a steady current which when flowing in each of two infinitely long straight wire parallel conductors of negligible cross section area and 1 meter apart in a vacuum produces between the wires a force of 2.0 x 10^{-7}N per meter of the length.

(b) A circular coil of N turns, each of radius R carries a current I.

(i) Write an expression for the magnetic flux density at the center of the coil (01mark)

B =$\frac{\mu_0 NI}{2R}$ where μ_0 is permittivity of free space.

(ii) Sketch the magnetic field pattern associated with the coil. (02marks)



(c) Describe how deflection magnetometer can be used to investigate the variation of magnetic flux density at the center of a circular coil with the current flowing through the coil. (06marks)

The circular coil is set with its plane in the earth's magnetic meridian. A deflection magnetometer is mounted on a vertical axis at the center of the circular coil, with its pointer initially at the zero mark. The coil is then connected through a reversing switch to a battery, rheostat and an ammeter. Adjust the rheostat so that the ammeter a suitable value of I.

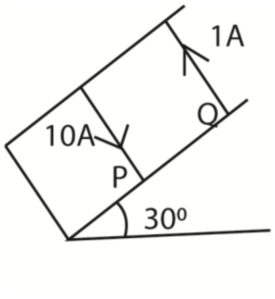
The deflection θ_1 and θ_2 are noted. The procedure is repeated for other suitable values of I and the results tabulated including values of θ = $\frac{\theta_1+\theta_2+\theta_3+\theta_4}{4}$ and tan θ.

A graph of tan θ against I is plotted and it is linear. This shows that tan θ is proportional to I

Since B = $B_H$tan θ, where BH is horizontal component of the earth's magnetic flux density.

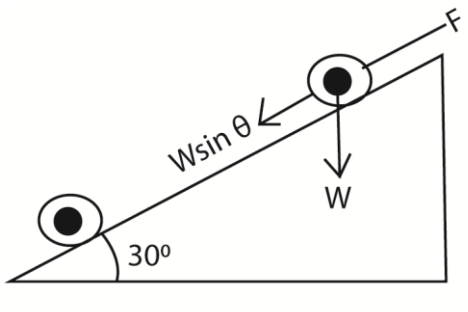
This implies that B ∝ I

(d) Two parallel wires P and Q, each of length 0.2m carry currents of 10A and 1A respectively



The distance between the wires is 0.04m. If both wires remain stationary and the angle of the plane with the horizontal is 30^0. Calculate weight of Q.

Solution



Force F between the two wires is given by

F = $\frac{\mu_0 I_1 I_2 L}{2\pi a} = \frac{4\pi\ x\ 10^{-7}\ x\ 10\ x\ 1\ x\ 0.2}{2\pi\ x\ 0.4}$ = 1.0 x 10^{-3}N

But for equilibrium, the component of the weight along the slop is balanced by the magnetic force on the wire i.e. F = Wsinθ

$$=> W = \frac{F}{\sin\theta} = \frac{1.0\ x\ 10^{-3}}{\sin 30} = 2\ x\ 10^{-3}N$$

(e) (i) State why the damping in the ballistic galvanometer should be as small as possible. (01mark)

When the oscillation in the ballistic galvanometer is damped, the deflection is not proportional to the charge.

(ii) Describe how the damping can be reduced in practice (03marks)

Damping in ballistic galvanometer is reduced in the following ways

- Winding the coil on non-conducting frame
- Using a heavy coil so that it has a large inertia
- Using a fine suspension so as to increase the period of oscillation.

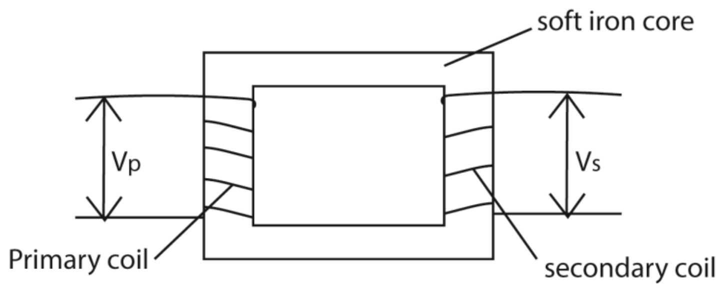
6. (a)(i) Define the terms self-induction and mutual induction. (02marks)

Self-induction is a process of generating e.m.f in a coil due to changing current in the same coil.
Mutual induction is a process of generating e.m.f in a coil due to changing current in neighboring coil.

(ii) State Faraday's law of electromagnetic induction (01mark)

It states that the magnitude of induced e.m.f is directly proportional to the rate of change of magnetic flux linking it.

(b) (i) Describe the structure and action of a.c transformer. (06marks)



Vp= primary voltage, Vs = secondary voltage

- 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 why the voltage at a generating power station must be stepped up to very high value for long distance transmission (03marks)

Transmission is at high voltage to reduce power loss

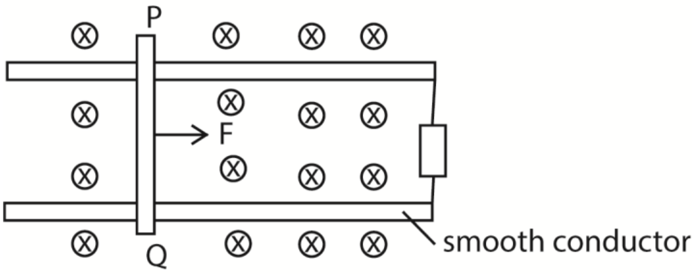
Note that

Power supplied, P =IV

$I = \frac{P}{V}$

Hence when V is high, I is small. From power loss, $P' = I^2R$, when I is small power loss is reduced.

(c) In the figure below, a conducting rod PQ of length 20mm rests on a smooth conducting frame to form a complete circuit of resistance 4.0Ω. When a force, F, is applied, the rod moves at a constant velocity of $6.0ms^{-1}$ perpendicular to a uniform magnetic field of flux density 1.5T.



(i) Explain why the rod PQ moves with constant velocity. (03 marks)

As PQ moves, it cuts the magnetic field and an e.m.f is induced across it. Since the rod is a closed circuit, induced current flows through it. By Fleming's left hand rule, magnetic force acts on the rod in such a way as to oppose the motion. When magnetic force = applied force, then the resultant force is zero. Therefore PQ moves with constant velocity.

(ii) Calculate the amplitude of the induced e.m.f (02marks)

E = BLV= 1.5 x 20 x 10-3 x 6.0 = 0.18V

(iii) Calculate the magnitude of the force, F. (03marks)

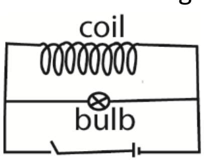
F = BIL and $I = \frac{E}{R} = \frac{0.18}{4}$ =0.045A
$F = 1.5 \times 0.045 \times 20 \times 10^{-3} = 1.35 \times 10^{-3}V$

7. (a) Define the term peak value and root mean square value of an alternating current. (02 marks)

Peak value is the maximum value of alternating current.

Root mean square value is the value of direct current which dissipates heat in a given resistor at the same rate as the a.c.

(b) A coil of many turns of wire is connected in parallel with an electric bulb to a d.c supply as shown in the figure below.



At the instant switch K is closed, the bulb flashes briefly for a short time and then goes off. Explain the observation.

When switch K is closed, current begins to flow through the coil and the changing magnetic flux due to the change in current induces a back e.m.f in the coil thus most of the current flows through the bulb making it to flash. Latter back e.m.f decay to zero and most of the current then flows through the coil

(c) A sinusoidal alternating voltage of 20V (r.m.s) and frequency 60Hz is applied across a coil of wire of inductance 0.2H and negligible resistance.

(i) Find the reactance of the coil at this frequency. (03marks)

$X_L = 2\pi fL$
$= 2\pi \times 60 \times 0.2$
$= 75.4\Omega$

(ii) Calculate the r.m.s value of the current which passes through the coil (02marks)

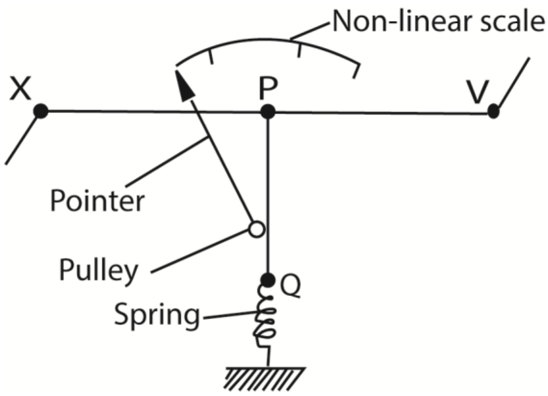
$$X_L = \frac{V_{r.m.s}}{I_{r.m.s}}$$

⇨ $I_{r.m.s} = \frac{20}{75.4} = 0.265A$

(iii) Explain why on average the power delivered to the inductor in one cycle is zero. (03marks)

During the first quarter cycle, when current increases, work is done against the back e.m.f. The energy supplied by the source is stored in the magnetic field of the coil. During the second quarter cycle, as current begins to decay, the magnetic field begins to collapse and energy is returned to the source. The same process is repeated in the next half cycle. Hence the energy supplied in the cycle to the coil is zero.

(d) Describe with 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.

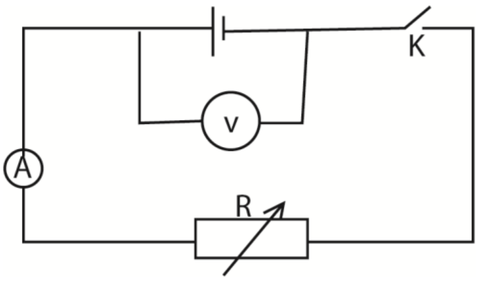
- The rise in temperature of the wire makes it expand and sag; the sag is taken up by a second fine wire PQ, which is held taut by a spring.
- The wire PQ passes round a pulley attached to the pointer of the instrument, which rotates as the wire XY sags.
- The deflection of the pointer is roughly proportional 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.

SECTON D

8. (a) What is meant by electromotive force of a cell? (01mark)

e.m.f is work done in moving a positive 1C charge around a circuit in which a cell is connected.

(b) Describe an experiment to determine e.m.f and internal resistance of a cell using ammeter, a resistance box and voltmeter. (05marks)



- The circuit is connected as above
- Switch K is closed, R is adjusted to suitable value of I. Ammeter reading I and voltmeter reading V are noted and recorded.
- The rheostat is varied for other four sets of value of I and V
- The values of I and V are tabulated
- A graph of V against I is plotted.
- The slope S is the internal resistance of the cell while intercept V_0 on the V axis is the e.m.f of the cell

Or

- The circuit is connected as above.
- With K open, the voltmeter reading V_0 is recorded.
- K is closed and a rheostat is adjusted to a suitable value
- The ammeter reading I and voltmeter reading V are recorded.
- Internal resistance, r = $\frac{V_0 - V}{I}$

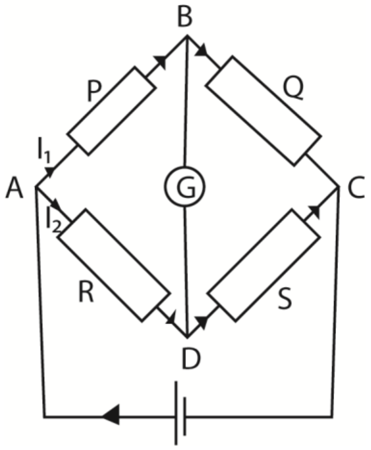
(c) (i) Define temperature coefficient of resistance (01mark)

Temperature coefficient of resistance is the fractional change in resistance at 0^0 per degree Celsius rise in temperature

(ii) Explain why the resistance of a thermistor reduces when current is passed through it. (02marks)

The current is passed through a thermistor heat is generated. As the temperature rises the loosely bound electrons are released for conduction which reduces resistance.

(d) (i) Derive the balance conditions for Wheatstone bridge. (04marks)



- The resistance P, Q, R, and S are adjusted until $I_G = 0$
- This implies that the potential at B = potential at D, hence p.d across P = p.d across R
  $I_1P = I_2 R$ ……………………………. (i)
- Current through Q is therefore I_1 and through S is I_2
- P.d across Q = p.d across S
  $I_1Q = I_2S$ ……………………………. (ii)
  From equation (i) and (ii)
  $\frac{P}{Q} = \frac{R}{S}$

(ii) Explain one reason other than faulty apparatus and poor electrical contact, why it may not be possible to obtain balance in a Wheatstone bridge in an experiment to compare two resistances. (02marks)

When the resistance of one resistor is too high or too low compared to others, more current flows through other resistors than that particular resistor and I_G fails to be zero. Thus the balance state cannot be achieved.

(e) In an experiment to investigate the variation of resistance with temperature, a nickel wire and a 10Ω standard resistor were connected in the left-hand gap and right-hand gap respectively of Meter Bridge. When the nickel wire was at 0^0C, a balance point is 40cm from the end of the bridge adjacent to the nickel wire. When the nickel wire is at 100^0C, the balance point is 50cm from the same end of the bridge.

Calculate the temperature of the nickel wire if the balance length is 42cm. (05marks)

From $\frac{R_0}{L_1} = \frac{R_S}{L_2}$

$R_0 = \frac{40}{60} x\ 10 = \frac{20}{3}$

$R_{100} = \frac{50}{50} x\ 10$ = 10Ω

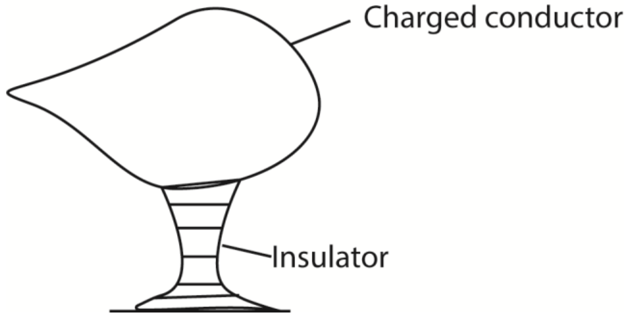
$R_\theta = \frac{42}{58} x\ 10 = \frac{420}{58}$

$\theta = \left(\frac{R_\theta - R_0}{R_{100} - R_0}\right) x\ 100$

$= \left(\frac{\frac{420}{58} - \frac{20}{3}}{10 - \frac{20}{3}}\right) x\ 100$

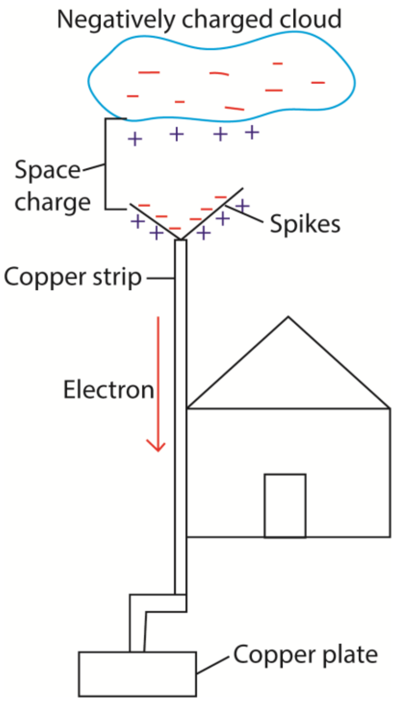
$= 18.2^0$

9. (a) (i) What is meant by electric field intensity at a point? (01mark)
Electric field intensity is the force acting on 1C of positive charge placed at a point in electric field.
(ii) Describe how distribution of charge on a charged conductor of the shape shown below can be investigated.



- An insulated metal can is connected to the cap of a gold leaf electroscope.
- Then proof planes that fit different parts of the charge conductor are pressed on the corresponding parts of the conductor and then lowered into the can one at a time.
- The deflection of the gold leaf for each case is noted.
It is observed that the deflection is greatest for the proof plane pressed at the sharpest point of the charged conductor.
Hence the charge concentration is greatest at the sharpest points.

(iii) Explain how a lightning conductor protects a house from lightening. (04marks)



Action

(i) When a negatively charged cloud passes over lightning conductor, it induces positive charges on the spikes by repelling electrons to the grounds through copper conductor.

(ii) A high electric field concentration of positive ions on the spikes ionizes air around it causing positively charged ions and negatively ions.

(iii) The negatively charged ions are attracted and discharged at the spikes while the positively charged ions are repelled to form a space charges which neutralizes the negative charge on the cloud. In this way the harmful effect of the cloud is reduced.

(b) (i) what is electric field line?

It is the path (or direction) taken by a small positive charge placed in a field.

(ii) Derive an expression for electric potential at a point a distance, a, from an isolated charge of magnitude Q in air.

The force on 1C of a charge, F = $\frac{Q}{4\pi\varepsilon x^2}$

Work done to move the charge through Δx against the field Δw = -FΔx

Total work done to bring the charge from infinity to a point a distance a from charge Q

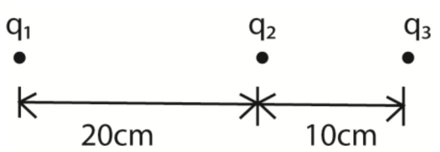
w = $\int_{\infty}^{a} -F dx$

$= \int_{\infty}^{a} \frac{-Q}{4\pi\varepsilon x^2} dx$

$= \frac{-Q}{4\pi\varepsilon}\left[\frac{-1}{x}\right]_{\infty}^{a}$

$= \frac{Q}{4\pi\varepsilon a}$

(c) The figure below shows charges q_1, q_2 and q_3 of +46.3μF, -34.7μF and +23.4μF respectively, placed in straight line in air.



Find the force on q_3.

From F =$\frac{kQ_1Q_2}{r^2}$, where k = 9.0 x 10^9F^{-1}m

F_1 = $\frac{9.0 \times 10^9 \times (46.3 \times 10^{-6}) \times (23.4 \times 10^{-6})}{(30 \times 10^{-2})^2}$ = 108.34N i.e.to the right

$F_2 = \frac{9.0 \times 10^9 \times (-34.7 \times 10^{-6}) \times (23.4 \times 10^{-6})}{(10 \times 10^{-2})^2}$ = -730.78N i.e. to the left

Resultant force F = $F_1 + F_2$

= 108.34 – 730.78 = -622.44N

So the resultant force on q3 is 622.44N towards the left

10. (a) Define the following terms

(i) The farad (01mark)

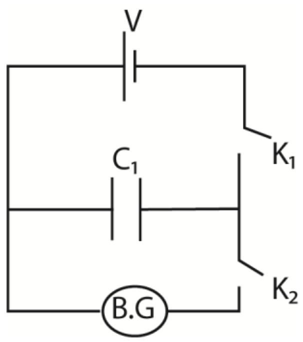
A farad id the capacitance of a capacitor when 1C of charge changes its potential difference by 1V

(ii) Relative permittivity (01mark)

Relative permittivity is the ratio of the capacitance of a capacitor with a dielectric material between its plates to the capacitance of the same capacitor with vacuum between the plates.

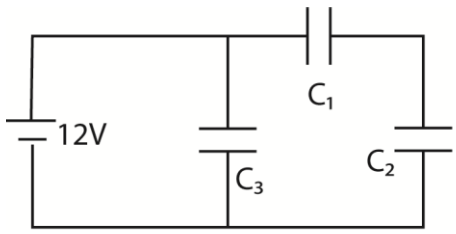
(b) You are provided with the following apparatus, a battery, two switches, a capacitor of known capacitance, a ballistic galvanometer and connecting wires.

Describe an experiment that can be carried out using the above apparatus to determine the unknown capacitance of a capacitor (05marks)



- The circuit is connected as shown with a capacitor of known capacitance C_1.
- Switch K_1 is closed and K_2 is opened. The capacitor of capacitance C_1 is charged by the battery of e.m.f V.
- K_1 is opened and K_2 is closed to discharge the capacitor through the ballistic galvanometer, B.G. the first deflectionof the B.G θ_1 is noted
- The capacitor is then is then replaced with the capacitor of unknown capacitance C_2.the experiement is repeated and deflection θ_2 is noted
- Hence $\frac{C_2}{C_1} = \frac{\theta_2}{\theta_1}$; $C_2 = C_1\frac{\theta_2}{\theta_1}$

(c) The diagram below shows arrangement of three capacitors C_1, C_2, and C_3 of capacitance 8μF, 2μF and 6μF respectively.



Calculate the total energy stored;

(i) In all capacitors when fully charged. (04marks)

Effective capacitance, C_4, of C_1 and C_2 in series $=\frac{C_1C_2}{C_1+C_2} = \frac{8\ x\ 2}{8+2} = 1.6\mu F$

Effective capacitance C_4 and C_3 in parallel = $C_4 + C_3$ = 1. 6μF + 6μF =7.6μF

Total energy stored in the network = $\frac{1}{2}CV^2 = \frac{1}{2}\ x\ 7.6\ x\ 10^{-6} x\ 12^2$ = 5.472 x 10^{-4}J

(ii) When the space between the plates of C_2 is filled with a dielectric of constant 1.25. (04marks)

New capacitance $C_2' = \varepsilon r C_2$ = 1.25 x 2 x 10^{-6}F = 2.5μF

Effective capacitance, C_5, of C_1 and C_2' in series $=\frac{C_1C_2'}{C_1+C_2} = \frac{8\ x\ 2.5}{8+2.5} = 1.905\mu F$

Effective capacitance C_5 and C_3 in parallel = $C_4 + C_3$ = 1. 905μF + 6μF =7.905μF

Total energy stored in the network = $\frac{1}{2}CV^2 = \frac{1}{2}\ x\ 7.905\ x\ 10^{-6} x\ 12^2$ = 5.69 x 10^{-4}J

(d) A capacitor of capacitance, C, is charged by a battery and then later isolated. When the plates of the capacitor are taken apart, deduce what happens to the potential difference between the plates. (03marks)

From C = $\frac{\varepsilon A}{d}$ and V = $\frac{Q}{C}$; it implies that C∝ $\frac{1}{d}$ and V∝ $\frac{1}{C}$.

Since ε, A and Q are constant, it implies that d∝ V, therefore separation increases with increase in p.d between the plates

(e) Explain what happens if a conductor instead of dielectric is placed between the plates of charged capacitor. (02marks)

Charge or p.d or capacitance reduces to zero on the plates. Electrons move from the negative to the positive plate in order to neutralize the charge.

END