P510/2
PHYSICS
Paper 2
July / Aug. 2022
2 ½ hours

UGANDA TEACHERS' EDUCATION CONSULT (UTEC)

Uganda Advanced Certificate of Education

PHYSICS

Paper 2

2 hours 30 minutes

INSTRUCTIONS TO CANDIDATES:

Attempt only __Five__ questions with at least __one__ question from each of the four sections A, B, C and D. Do not attempt more than one question from each of the sections A and B.

Silent Non – programmable electronic scientific calculators may be used.

Where necessary assume the following constants;

Acceleration due gravity, g	=	$9.81\ m\ s^{-2}$
Speed of light in vacuum, c	=	$3.0 \times 10^{8}\ m\ s^{-1}$
Speed of sound in air	=	$330\ m\ s^{-1}$
Electronic charge, e	=	$1.6 \times 10^{-19}\ C$
Electronic mass, m_e	=	$9.11 \times 10^{-31}\ kg$
Permeability of free space, μ_o	=	$4.0\pi \times 10^{-7}\ H\ m^{-1}$
Permittivity of free space, ε_0	=	$8.85 \times 10^{-12}\ Fm^{-1}$
The Constant, $\frac{1}{4\pi\varepsilon_o}$	=	$9.0 \times 10^{9}\ F^{-1}\ m$

SECTION A

1. (a) (i) State the **laws of refraction** of light. (02 marks)

(ii) State the conditions under which total internal reflection occurs. (02 marks)

(b) A ray of light is refracted through a spherical glass marble, whose refractive index is n in such a way that it passes through the extremeties of two radii which make an angle, θ, with each other. If γ is the deviation of the ray caused by its passage through the sphere.

(i) Draw a ray diagram to show the path of the ray of light through the marble. (02 marks)

(ii) Derive an expression for the refractive index in terms of θ *and* γ. (04 marks)

(c) (i) Explain the meaning of critical angle and total internal reflection. (03 marks)

(ii) Describe one natural phenomenon due to total internal reflection. (04 marks)

(d) Light from luminous point on the lower face of a rectangular glass, 2.0cm thick, strikes the upper face and the totally internally reflected rays outline a circle of 3.2cm radius on the lower face. Calculate the refractive index of the glass material. (03 marks)

2. (a) (i) What is meant by **magnifying power** of an optical instrument. (01 mark)

(ii) Draw a ray diagram to show the path of light through a compound microscope in normal adjustment. (03 marks)

(iii) Use the diagram above to obtain an expression for the magnifying power of the compound microscope in terms of the focal length of the objective and the eye – piece lens.

(b) A compound microscope has an eye – piece of focal length 2.50cm and an objective of focal length 1.60cm. If the distance between the objective and the eye piece is 22.1cm. Calculate the magnifying power produced when the final image is at infinity. (03 marks)

(c) Describe with the aid of a diagram, the functions of the essential parts of a photographic camera. (04 marks)

(d) A telephoto lens in a camera consists of a convex lens of focal length 10.0cm with a concave lens of focal length 5.0cm placed 7.0cm behind it. The object to be photographed is 5.0cm in front of the convex lens. Calculate;

(i) the total length of the camera from the convex lens to the film when the image is in focus on the film. (03 marks)

(ii) the magnification produced. (02 marks)

SECTION B

3. (a) (i) What is meant by the terms wave front and a progressive wave. (02marks)

(ii) Derive a relationship between the speed , v, frequency , f, and were length λ of a progressive wave. (02 marks)

(b) A plane progressive wave in a medium along x – direction is described by the equation;

$y = 2.0\ x\ 10^{-3} \sin\left(100\pi t - \frac{1.03\pi x}{12}\right)$ where y is displacement in metres, t the time in seconds and x *the distance from* the origin in metres. Calculate:

(i) Frequency (02 marks)

(ii) Wave length (01 mark)

(iii) Speed of the wave (01 mark)

(iv) Phase difference between points 0.25cm and 0.32cm from the origin. (02 marks)

(c) (i) Explain how beets are formed. (02 marks)

(ii) Derive an expression for the beat frequency. (03 marks)

(d) Explain why the amplitude of a wave goes on decreasing as the distance from the source increases. (05 marks)

4. (a) (i) What is meant by **interference.** (01 mark)

(ii) State two conditions for observable interference effects to be obtained. (02 marks)

(b) In a young double slit experiment, the two yellow slit sources have a wavelength 600nm, a separation of 0.6mm and they are 0.8m from a white screen. Calculate the separation of bright bands on the screen. (03 marks)

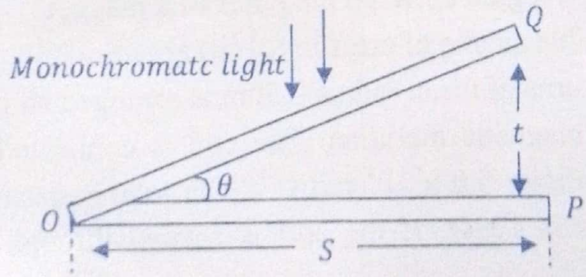
(c) Describe the appearance of the screen in (b) above if the;

(i) yellow sources are replaced by blue sources? (03 marks)

(ii) screen is moved farther from the sources. (02 marks)

(iii) slits are made slightly narrower. (02 marks)

(d) The figure below shows a wedge shaped air film illuminated by monochromatic light of wave length, λ, normally incident on the top surface of the wedge.



(i) Explain the formation of interference fridges. (04 marks)

(ii) Show that $\tan\theta = \frac{\lambda}{2a}$ where a is the fringe separation. (04 marks)

SECTION C

5. (a) (i) Derive an expression for the force per unit length between two long straight wires in a vacuum carrying currents I_1 and I_2 and are a distance x apart. (04 marks)

(ii) Define the ampere using the expression above. (07 marks)

(b) Two long parallel wires P and Q are in a vacuum and are 10cm apart. The wires carry currents 15A and 2A respectively in the same direction.

(i) Sketch the resultant magnetic field pattern due to the two currents, clearly indicating the directions of the field and force on the two wires. (02 marks)

(ii) At what point from wire, P, is the magnetic flux density zero? (03 mark)

(c) (i) What is meant by current sensitivity of a moving coil galvanometer? (01 mark)

(ii) Describe, with the aid of a diagram, the structure and mode of action of a moving – coil galvanometer. (05 marks)

(d) The coil of a moving coil galvanometer has resistance 100Ω and 200 turns of mean area $2cm^2$. The coil is situated in a radial magnetic field of flux density $3.0 \times 10^{-2}T$. If the coil suspension exerts a restoring torgue of 6.0×10^{-7} $Nmrad^{-1}$, find the voltage sensitivity of the galvanometer. (03 marks)

6. (a) State the laws of electromagnetic induction. (02 marks)

(b) (i) With the aid of a labeled diagram, describe how a simple a.c generator works. (05 marks)

(ii) What are the main energy loses in practical a.c. generator and how are they minimized? (03 marks)

(c) (i) Explain how the design of a moving coil galvanometer can be modified to produce a ballistic galvanometer. (02 marks)

(ii) Describe how a ballistic galvanometeri s used to measure the magnetic flux density in a region between the poles of a magnet. (04 marks)

(iii) State one possible source of error in (c) (ii) above. (01 mark)

(d) A circular coil of 50 turns of mean radius 0.50m is arranged so that its plane is perpendicular to the magnetic meridian. The coil is connected to a ballistic galvanometer of sensitivity 5.0×10^4 rad C^{-1}. The total resistance of the coil and the galvanometer is 100Ω. If the coil is rotated through 180° about a vertical axis, the ballistic galvanometer deflects through 0.8 radius. Calculate the horizontal component of the earth's magnetic flux density. (03 marks)

7. (a) (i) Define root mean square value of an alternating current. (01 mark)

(ii) Distinguish between impedence and reactance as applied to a.c. (02 marks)

(b) (i) Show that an alternating current passing through an inductor lags on the applied p.d. by $\frac{\pi}{2}$ radians.

(ii) Sketch the variation of the current and voltage with time. (02 marks)

(iii) Derive the expression for the inductive reactance X_L in terms of the frequency $, f, \text{ and inductance }, L,$ for b(i) above. (02 marks)

(c) (i) What is meant by the term **full wave refraction**. (01 mark)

(ii) Explain how a bridge rectifier works to provide full wave rectification. (04 marks)

(d) A flat circular coil with 200 turns and each of radius 40cm is rotated at a uniform rate of 480 rev/min about its diameter at right angles to a uniform magnetic field of flux density 5.0×10^{-4}T. Calculate;

(i) the r.m.s of the induced e.m.f. (02 marks)

(ii) instantaneous value of induced e.m.f when the plane of the coil makes an angle of 60° with the field direction. (03 marks)

(e) Explain why a capacitor allows the flow of alternating current but not direct current yet it conducts direct current.

SECTION D

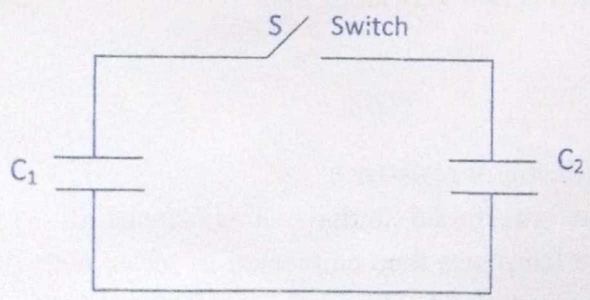
8. (a) Define the following:

(i) The farad (01 mark)

(ii) Relative permittivity (01 mark)

(b) A capacitor is labeled "$3000\mu F, 25V$". Explain the meaning of the labeling. (02 marks)

(c) A capacitor C_1 is charged to a p.d. V_o with the aid of a battery. The battery is then removed and the capacitor is connected to an uncharged capacitor C_2 as shown below.



Find the expression for:

(i) The final p.d. V across the combination on closing switch **S**. (03 marks)

(ii) The energy stored before and after the switch **S** is closed. (03 marks)

(iii) The final energy if $C_1 = C_2$. (02 marks)

(d) A parallel plain air capacitor is charged to a p.d of 300V. It is then connected in parallel with another uncharged capacitor of equal dimensions with rubber as a dielectric between its plates. The p.d of the combination is found to be 75V. Calculate;

(i) the dielectric constant of the rubber. (04 marks)

(ii) the total energy stored in the two capacitors. (03 marks)

(iii) Account for the difference in the initial and final energy stored. (01 mark)

9. (a) What is meant by the following terms?

(i) Electrostatic induction? (01 mark)

(ii) Electric point discharge? (01 mark)

(b) (i) Describe, with the aid of a labeled diagram a Van de Graaf generator. (05 marks)

(ii) The high voltage terminal of such a generator consists of a spherical conducting shell of radius 50cm.
Calculate the maximum potential to which it can be raised in air for which electrical break down occurs when the electric intensity exceeds $3.0 \times 10^4 Vcm^{-1}$. (03 marks)

(c) A needle is mounted vertically, point upwards on the cap of a gold leaf electroscope, the blunt end being in contact with the cap. Explain what is observed.

(i) When a negatively charged body is brought close to the needle point without touching it, and is then quickly withdrawn. (03 marks)

(ii) When the negatively charged body is again brought near the needle point and left there for sometime and is withdrawn. (03 marks)

(d) Three charges $-1\mu C, 2\mu C,$ and $3\mu C$ are placed respectively at the corners A, B and C of an equilateral triangle of side 2m. Calculate the electric field intensity at a point X which is half way along BC. (04 marks)

10. (a) Define the terms;

(i) Resistivity (01 mark)

(ii) Temperature coefficient of resistance. (01 mark)

(b) A carbon lamp filament was found to have a resistance of 375Ω at the temperature of 20oc. The lamp was then connected in series with an ammeter and a d.c. supply, and a voltmeter of resistance 1050Ω was connected in parallel with the lamp. The ammeter and voltmeter indicated 0.76A and 100V respectively. The temperature of the carbon filament was estimated to be 1200°C.

(i) Find the mean value of the temperature coefficient of resistance of carbon between 20°C and 1200°C. (04 marks)

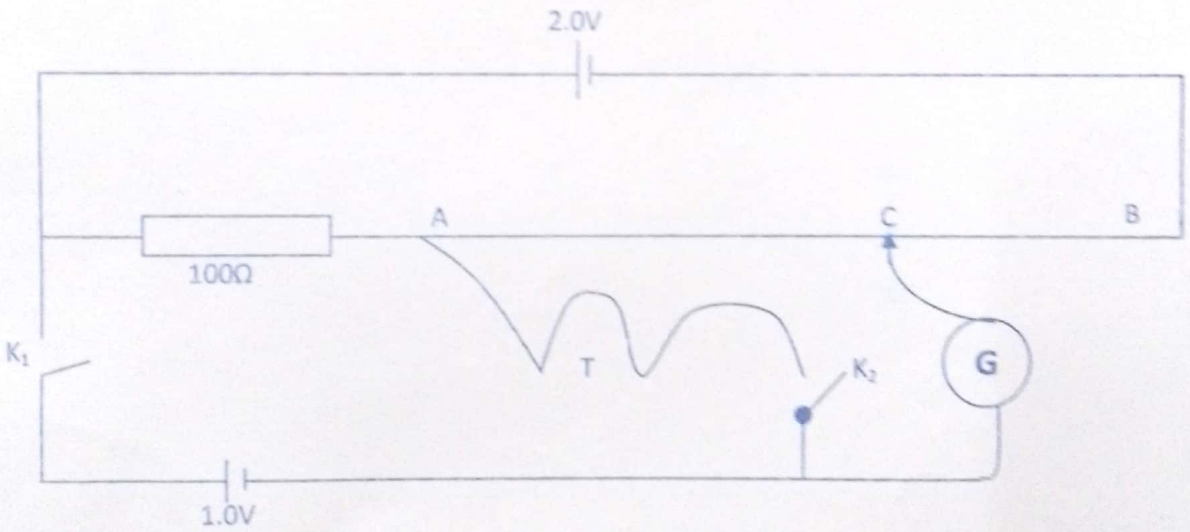
(ii) Comment on the result obtained in (b) (i) above. (01 mark)

(c) (i) Describe how the potentiometer can be calibrated. (03 marks)

(ii) Describe how the potentiometer can be used to compare two resistances. (04 marks)

(d) (i) In the measurement of thermoelectric e.m.f a high resistance is connected in series with the resistance wire of the potentiometer. Explain why this is so. (02 marks)

(ii)



The circuit above is used to measure the e.m.f of a thermo couple T. AB is a uniform wire of length 1.0m and resistance 2.0Ω. With K_1, open and K_2 closed, the balance length is 45cm. What is the e.m.f of the thermocouple? (04 marks)

END

MARKING GUIDE 2022

UTEC physics P510/2 (A-level)

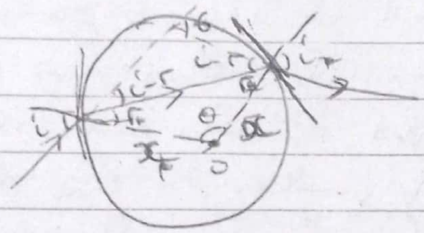
1(a)(i) - The incident ray, the refracted ray and the normal, at the point of incidence, all lie in the same plane

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

(ii) - The ray of light must be travelling from denser media to a less dense media

- The angle of incident must be greater than the critical angle.

(b) (i)



(ii) From the sketch;

$$\delta = i - r + i - r = 2(i - r)$$

$$\delta = 2i - 2r$$

and $180 = \theta + 2r \Rightarrow 2r = 180 - \theta$

$$r = 90 - \frac{\theta}{2}.$$

$$\Rightarrow \delta = 2i - (180 - \theta)$$

$$2i = \delta + 180 - \theta$$

$$2i = 180 + (\delta - \theta)$$

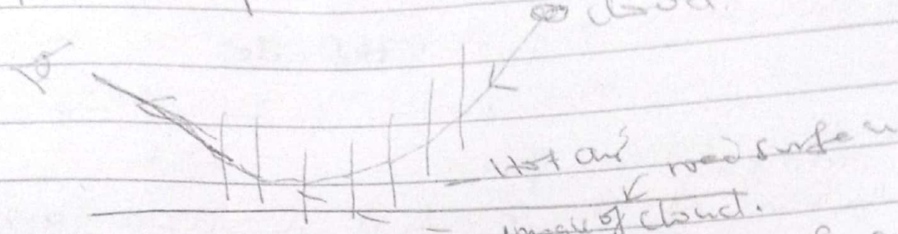
$$i = \left(90 + \left(\frac{\delta - \theta}{2}\right)\right)$$

Apply $\sin i = n \sin r$

$$\sin\left(90 + \frac{(\delta - \theta)}{2}\right) = n \sin\left(90 - \frac{\theta}{2}\right)$$

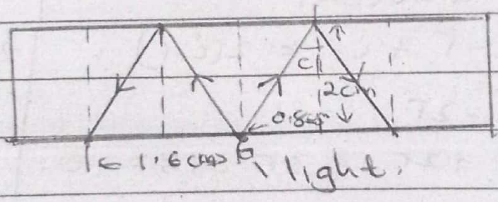
$$\cos\left(\frac{\delta - \theta}{2}\right) = n \cos\frac{\theta}{2}.$$

c (i) critical angle is the angle of incident in a denser media for which the angle of refraction in a less dense media is 90°, beyond which the ray is reflected in the denser media which phenomenon is called total internal reflection c (ii) Natural phenomenon is formation of mirage



- On a hot day, the road surface becomes hot and heats up the air near it. The density of the air reduces gradually downwards to the road surface (air density increases upwards from the road surface). The ray from the cloud is gradually refracted from the normal as it reaches the road surface until it undergoes total internal reflection. The observer receives this reflected light and sees the image of the cloud as a pool of water on the road surface.

(d)

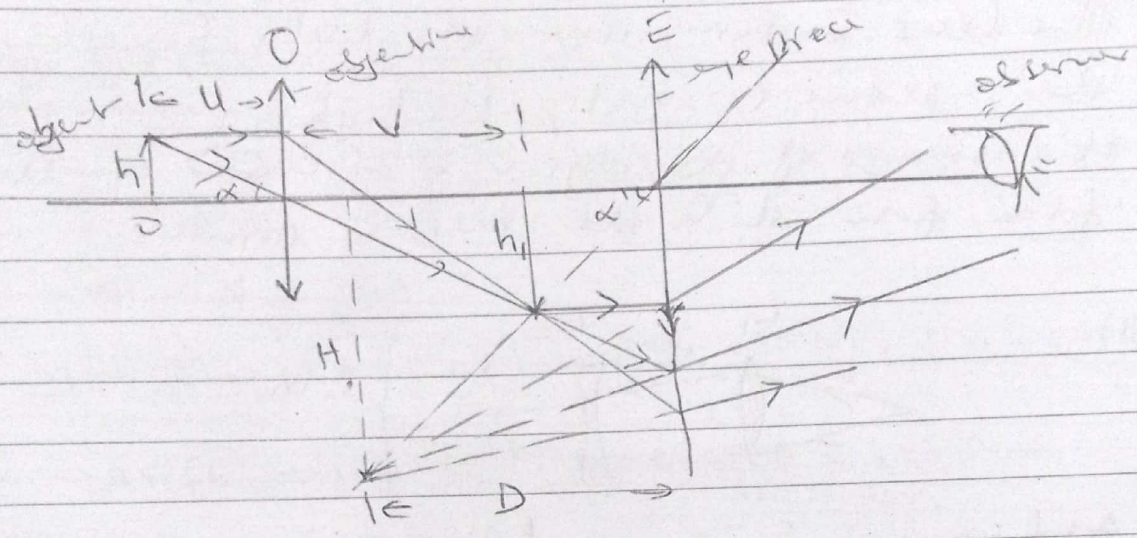


from the diagram, $\tan C = \frac{0.8}{2} = 0.4 \Rightarrow C = \_\_\_\_$

refractive index $n = \frac{1}{\sin C} = \frac{1}{\sin(\ )} = \_\_\_\_$.

2 a(i) Magnifying power is the ratio of the angle subtended by the final image to the eye when instrument is in use to the angle subtended by the same object to the naked eye.

a(ii)



From the sketch;

$\tan\alpha' = \frac{H}{D}$, $\tan\alpha = \frac{h}{D}$

α' and α are very small such that in radians

$\tan\alpha' \approx \alpha'$, $\tan\alpha \approx \alpha$

~~Magnification~~ $M = \frac{\alpha'}{\alpha} = \frac{H/D}{h/D} = \frac{H}{h} = \frac{H}{h'} \times \frac{h'}{h}$.

But $\frac{H}{h'} = \frac{D}{f_e} - 1$ and $\frac{h'}{h} = \frac{v}{f_o} - 1$

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

(b) microscope not in normal adjustment,

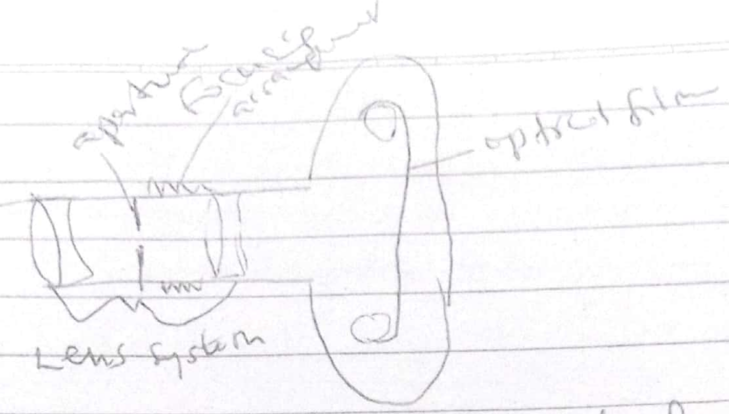
$M = \left(\frac{v}{f_1} - 1\right)\left(\frac{D}{f_2}\right)$

$v = 22.1 - 2.5 = 19.6$ cm.

$f_1 = 1.60$ cm, $f_2 = 2.50$ cm

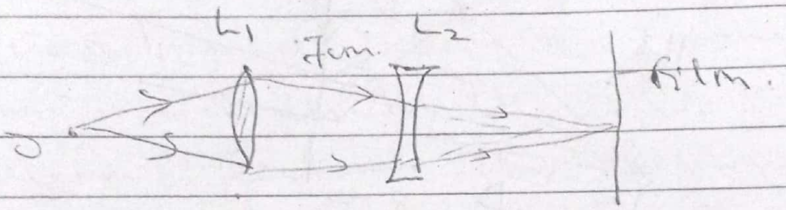
$\Rightarrow M = \left(\frac{19.6}{1.6} - 1\right)\left(\frac{12.5}{2.5}\right) = 11.25 \times 10 = 112.5$

(c)



- The lens system receives the light from the object
- the aperture centralizes the light for the object
- the image of the object is focused on the film from which the image is printed.

(d) (i)



Applying $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ on L_1;

$$\frac{1}{10} = \frac{1}{5} + \frac{1}{v}; \quad v = -10\text{cm}.$$

Applying $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ on L_2;

$$\frac{1}{-5} = \frac{1}{17} + \frac{1}{v'}; \quad v' = -\frac{85}{22}.$$

The image won't be formed on the film.

(ii) Magnification $M = m_1 \times m_2$

$$= \frac{10}{5} \times (\quad) =$$

SECTION B

3a(i) - Wave front is line in the wave path on which all points are in phase

- Progressive wave is a wave whose profile remains constant throughout the motion.

(ii) Suppose a progressive wave has n complete cycles in t second and it covers distance d in this time by definition, λ is distance for one complete cycle.

$$\Rightarrow d = n\lambda.$$

$$\frac{d}{t} = \frac{n}{t}\lambda. \quad \text{But } \frac{d}{t} = v, \text{ and } \frac{n}{t} = f.$$

$$\Rightarrow v = f\lambda$$

(b) $y = 2.0 \times 10^{-7} \sin\left(100\pi t - \frac{1.03\pi x}{12}\right)$ c.f $y = a\sin\left(\omega t - \frac{2\pi x}{\lambda}\right)$

(i) $2\pi f t = 100\pi t$

$f = 50Hz,$

(ii) $\frac{1.02\pi}{12} = \frac{2\pi}{\lambda}$

$\Rightarrow \lambda = \_\_\_\_\_\_ m$

(iii) Speed $v = f\lambda = 50 \times (\quad)$

$= \_\_\_\_\_\_ ms^{-1}$

(iv) phase diff $\phi = \frac{2\pi}{\lambda}(x_2 - x_1) = \frac{1.02\pi}{12}\left(\frac{0.32 - 0.25}{100}\right)$

$= \_\_\_\_\_\_$ rads

(c) Beats are formed when two notes of slightly different frequencies are sounded together resulting in periodic rise and fall of sound. this is because of gradual reinforcement and cancellation of notes.

(ii) Suppose the two notes have frequencies f_1 and f_2, and that from one periodic rise (maximum) sound to the next loud sound is t.

No of cycles made by $f_1 = f_1 t$.

" $f_2 = f_2 t$

if $f_2 > f_1 \Rightarrow f_2 t - f_1 t = 1$

$f_2 - f_1 = \frac{1}{t}$; $\frac{1}{t}$ = beat frequency f_b.

$\therefore f_b = f_2 - f_1$

4 a(i) Interference is the superposition of ~~a bright~~ coherent light waves with ~~same~~ constant phase difference resulting into regions of bright and dark bands (lines)

(ii) – Coherent

– In phase or constant phase difference.

b $\lambda = 600\times10^{-9}$ m, $d = 0.6\times10^{-3}$ m, $D = 0.8$.

Separation $y = \frac{\lambda D}{a} = \frac{600\times10^{-9}\times 0.8}{0.6\times10^{-3}} =$ ______ m

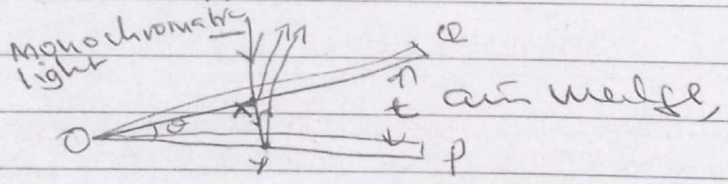
c(i) – the bright bands appear blue

– the separation of the bands decreases because blue light has ~~higher~~ lower wavelength than yellow.

(ii) – the separation ~~increases~~ of the bright band increases as observed from $y = \frac{\lambda D}{a}$ and brightness diminishes.

(iii) – this reduces slit distance a and in turn increases the separation of the bands thus they appear more clearly.

d(i)



– When monochromatic light is incident on the air, the ray is partly reflected and partly refracted ~~at~~ the lower surface of the upper slide. the refracted ray is then reflected on the upper surface of the lower slide. These constitute two rays ~~on~~ originating from the same source. This rays are coherent and in phase or with constant phase difference resulting into interference hence formation of fringe bands in the wedge.

(ii) if the separation of the bands is ~~a~~,

then $\tan\theta =$

5 a (i) Force, F, on a current carrying conductor of length L, carrying current I_1, placed normal to magnetic flux density B:

$F = BI_1L$. Suppose B is due to another conductor carrying current I_2 placed parallel at distance x,

then $B = \frac{\mu_0 I_2}{2\pi x}$.

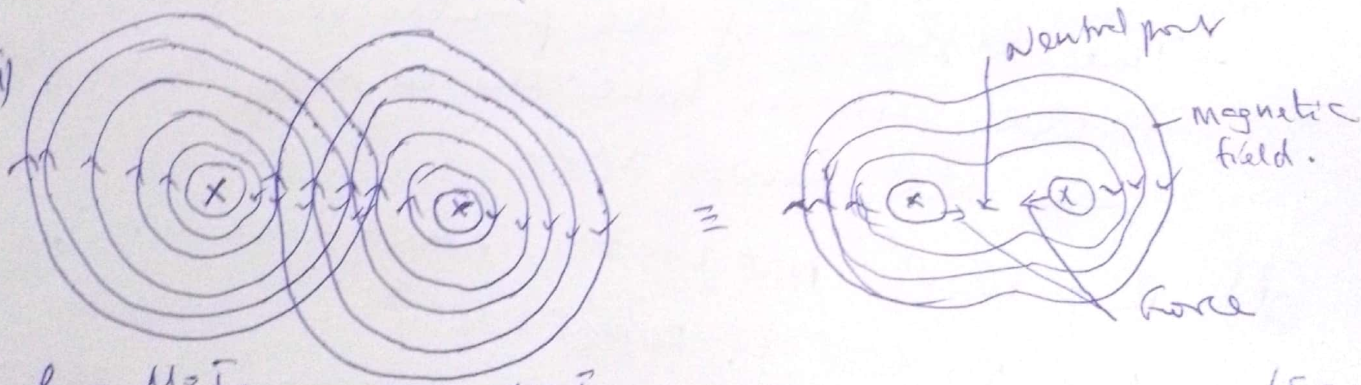
$\Rightarrow F = \frac{\mu_0 I_1 I_2 L}{2\pi x} \Rightarrow \frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi x}$.

(ii) Ampere is the current which when passed through each of two infinitely long, straight, parallel wires with negligible x-sectional area and are 1m apart in a vacuum, causes a force of 2×10^{-7} N between them.

i.e. $x = 1m$, $L = 1m$, $I_1 = I_2 = 1A$, $\mu_0 = 4\pi \times 10^{-7}$ H m⁻¹,

$\Rightarrow \frac{F}{1} = \frac{4\pi \times 10^{-7} \times 1 \times 1}{2\pi \times 1} = 2 \times 10^{-7}$ N.

(b) (i)

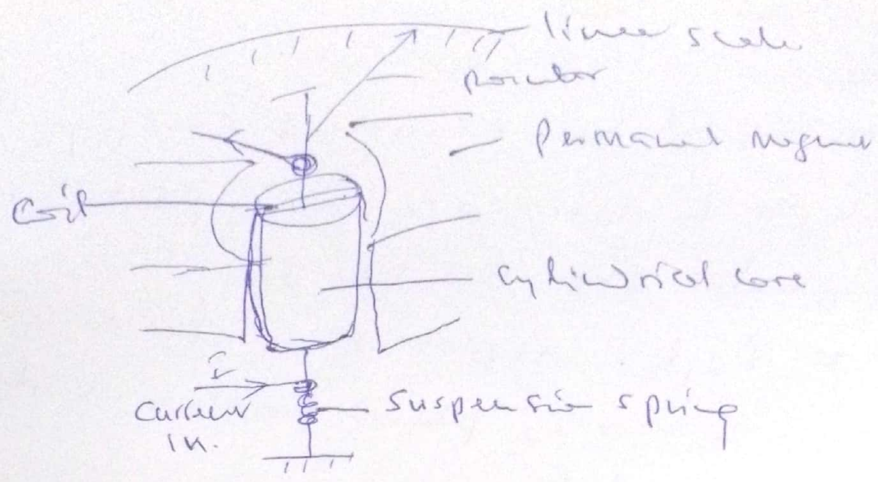


(ii) $B_1 = \frac{\mu_0 I_1}{2\pi x}$, $B_2 = \frac{\mu_0 I_2}{2\pi (0.10 - x)}$ $\Rightarrow \frac{\mu_0 I_1}{2\pi x} = \frac{\mu_0 I_2}{2\pi (0.1 - x)}$

$\Rightarrow 15(0.1 - x) = 2x \Rightarrow 17x = 1.5 \quad x = \underline{0.088}$ m

C (i) Current sensitivity; $S_I = \frac{\theta}{I}$; deflection per ampere.

c(ii)



- current I is passed through the ~~coil~~, springs to the coil causing the wires in the coil to experience a force in opposite directions constituting a couple. The radial magnetic field provides constant force.
- The couple causes a Torque which causes the coil to rotate causing the point on the suspension wire to rotate. The cylindrical core is brought back by the force in the springs.
- The deflection of the pointer is directly proportional to the current hence the current can be obtained from the linear scale.

(d) $R = 100\Omega$, $N = 200$ turns, Area $A = 2\times10^{-4} m^2$

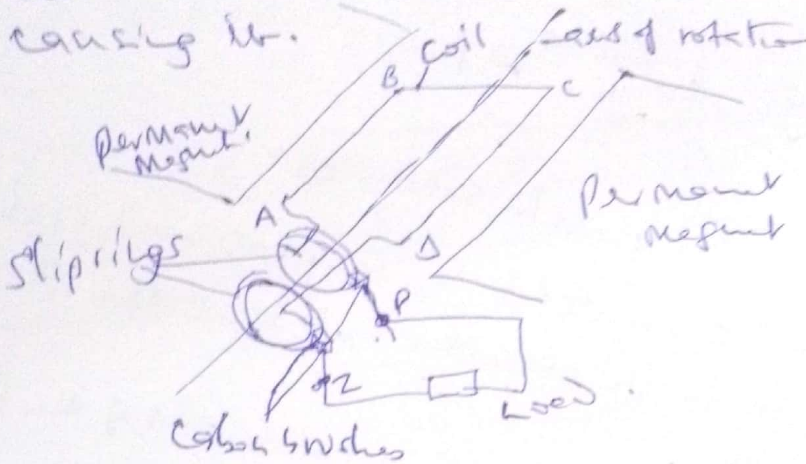
$B = 3.0\times10^{-2}T$. $C = 6.0\times10^{-7}$

Voltage sensitivity $S_V = \frac{BAN}{CR} = \frac{3\times10^{-2}\times2\times10^{-4}\times200}{6\times10^{-7}\times100}$

$S_V = \_\_\_\_\_\_$ rad V^{-1}

6 (a) - Magnitude of the induced emf in a conductor/circuit is directly proportional to the rate of change of flux-linkage or to the rate of cutting of magnetic flux.
- The direction of the induced emf is such that the current which it causes to flow opposes the change causing it.

(b)

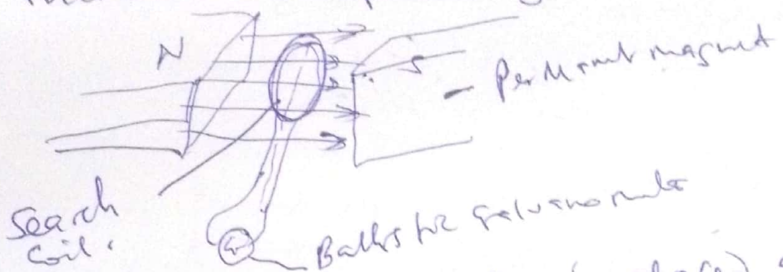


- When a rectangular coil is made to rotate ~~there~~ in a magnetic field, current flows through the coil.
- When the sides of the rectangular coil changes (switches) positions, the direction of the current in the coil also changes by ~~the~~ FLH rule.
- The contact of the coil to slip rings doesn't change the current through (output terminals P&Q) the load causing the current to change.
- This repeats itself on every complete revolution of the coil causing the direction of the through the load to change on every revolution.

(ii) - The iron core is laminated to prevent eddy currents.
- Energy loss to friction between slip rings and carbon brushes, the magnets is made to rotate about the coil,
- Flux leakages - uses of radial magnetic fields.

6 c(i) - The should be wound on a non conducting frame to eliminate the damping caused by eddy currents.
- the coil is made heavy and suspension thin to increase the period of oscillation.

(ii)



- A search coil, connected to G, is placed at right angle to the field to be measured so that the flux enters the coil normally.
- The coil is then pulled completely out of the field at once.
- the deflection, θ, of the G is noted.
- the magnetic flux, B, of the field is then obtained from

$$B = \frac{RC\theta}{NA}$$

- A - Cross sectional area of the coil
- R - resistance of the galvanometer
- N - number of turns of the coil
- C - quantity per unit deflection of the coil.

Knowing R, C, θ, N, A, B can be calculated.

(iii) - delay in pulling the coil completely out of the field.
- ~~Maintain~~ - change in the plane of the coil as its pulled out.

(d) charge $Q = C\theta = 5.0\times10^{4}\times0.8 = 4.0\times10^{4}\ C$.

But $Q = \frac{\Delta\phi}{R} = \frac{BAN-(-BAN)}{R} = \frac{2BAN}{R}$

$\Rightarrow \frac{2B\times(\pi 0.5^2)\times 50}{R00} = 4.0\times10^{4}$

$\Rightarrow B_H =$ ______ T

Question 7

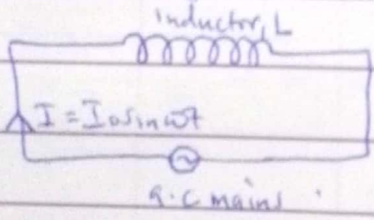
(a) (i) Root mean square value of an alternating current is the value of the steady/direct current which dissipates heat energy in a given resistor at the same rate as the alternating current.

(ii) Impedence is the total opposition to the flow of alternating current in a circuit comprising of resistive and reactive components.

While

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

b) (i) Suppose an inductor of inductance, L, is connected to an a.c source and an alternating current $I = I_0 \sin \omega t$ flows through it



Back e.m.f, $E = -L\frac{dI}{dt}$ —(i)
induced in coil

Also ~~V — E~~

$E = -V$ --(ii)

where V is the applied alternating voltage.

Eqn(i) = Eqn(ii)

$-V = -L\frac{dI}{dt}$

CANDIDATE'S NAME:........................ INDEX No........................
SUBJECT:........................ PAPER:.................. SIGNATURE........................

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$\Rightarrow \quad V = L\frac{dI}{dt}$

$\Rightarrow \quad V = L\frac{d}{dt}(I_0 \sin\omega t)$

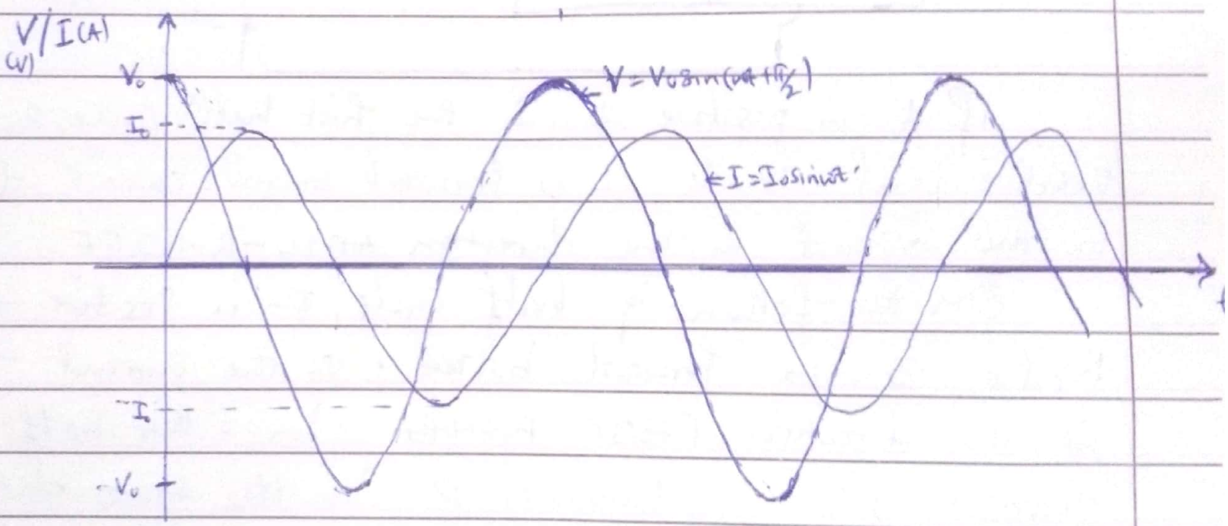
$\Rightarrow \quad V = LI_0 \frac{d}{dt}(\sin\omega t)$

$V = LI_0\omega \cos\omega t$, But $LI_0\omega = V_0$

$\Rightarrow \quad V = V_0 \cos\omega t \Rightarrow V = V_0 \sin(\omega t + \frac{\pi}{2})$

By comparison with $\Rightarrow I = I_0 \sin\omega t$; It implies that alternating current passing through an inductor lags on the applied p.d by $\frac{\pi}{2}$ radians.

b (ii)



b(iii) From $LI_0\omega = V_0$

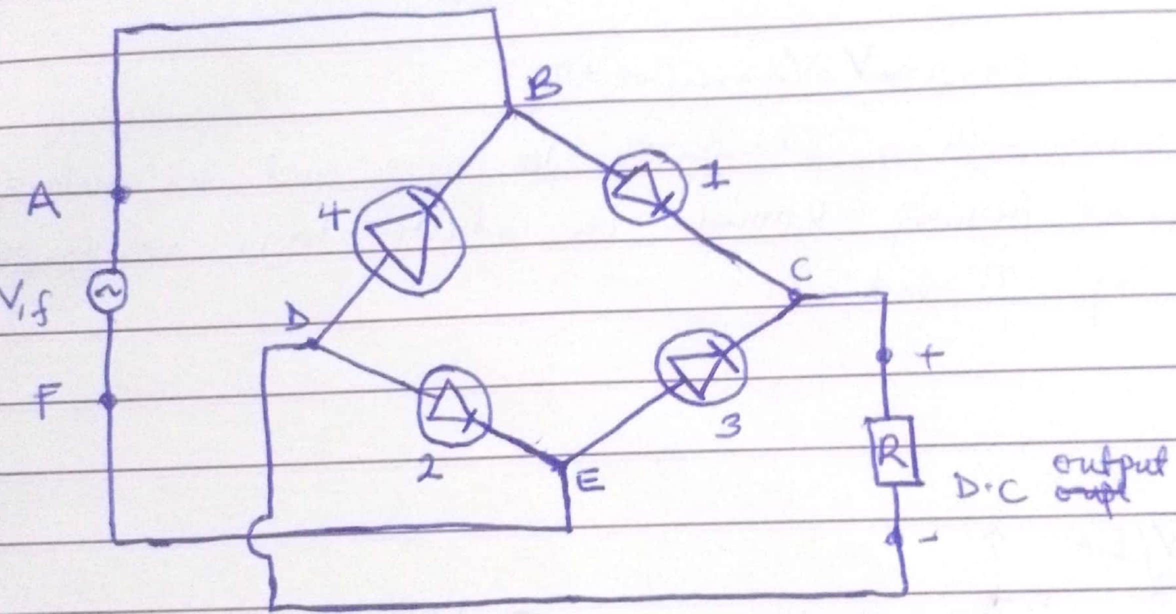
$L\omega = \frac{V_0}{I_0}$, where $\frac{V_0}{I_0} = X_L$

$\therefore X_L = L\omega$,

$\therefore X_L = 2\pi f L$, Since $\omega = 2\pi f$.

C (i) Full wave rectification is a process whereby both halves of the input alternating current cycles are converted to direct current using a rectifier (diode).

(ii)



If A is positive during the first half cycle, B is also positive and Diode 1 is forward biased, current flows in the circuit in the direction AB1C–R–D2EF.

On the following half cycle, F is positive and Diode 3 is forward biased. So the current flows in the direction FE3C-RD4BA. In either half cycles current flows through R in the same direction through it fluctuates in magnitude.

d) $V = NAB\omega \sin\omega t$

(i) $V_{rms} = \frac{V_0}{\sqrt{2}}$, But $V_0 = NAB\omega$, $\omega = 2\pi f$

$= 2\pi NABf$

$= 2\pi \times 200 \times \pi \times (\frac{40}{100})^2 \times 5.0 \times 10^{-4} \times \frac{480}{64}$

$= 2\pi^2 \times 200 \times 5 \times 8 \times 0.16 \times 10^{-4}$

$= 2\pi^2 \times 1.28 \times 10^{-1}$

$= 2.56\pi^2 \times 10^{-1} = 0.256\pi^2 V$

$= \frac{0.256\pi^2}{\sqrt{2}}$

$= 1.79 V$

From instantaneous e.m.f, $E = V = NAB\omega \sin\theta$. $\theta = 60°$

(ii) $V = NAB\omega \sin\theta$

$= 0.256\pi^2 \times 0.866$

$= 0.221696\pi^2$

$= 2.186V$

7 (e) When a capacitor is connected to a d.c source, the ~~there~~ capacitor charges and when fully charged, the current stops flowing.

When the capacitor is connected to an a.c source, the capacitor charges when the voltage is increasing and the capacitor also discharges when the voltage is decreasing. Since increase and decrease in voltage is continuous, there is a continuous flow of current (charge) in the circuit hence the capacitor appears to allow flow of a.c.

SUBJECT:........................ PAPER:.............. SIGNATURE..................

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Question 8

(a) (i) The farad is the capacitance of a capacitor with any one of its plates having a charge of 1Coulomb and a pd of 1Volt across its plates.

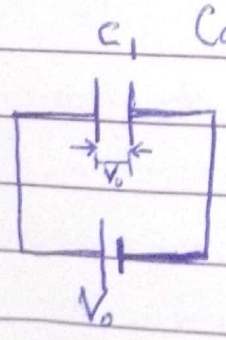
(ii) Relative permittivity is the ratio of the permittivity of a material (dielectric material) to the permittivity of free space/vacuum.

OR

is the ratio of the capacitance of a capacitor with all the space btn its plates filled with a dielectric material to the capacitance of the same capacitor with air/vacuum filling all ~~the space~~ between its plates.

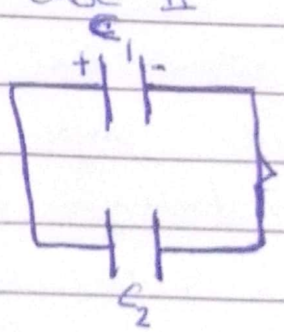
(b) "3000μF, 25V" capacitor means that each plate of the capacitor a magnitude of charge 3000μC in every one volt ~~of a b~~ when a battery of 25V is connected across it.

Case I



Total Charge stored, $Q_1 = C_1V_0$

Case II



Total Charge stored $Q_2 = (C_1 + C_2)V$

where V is the final pd across C_1 and C_2

(i) Applying principle of conservation of charge

Total charge, Q_1 stored in case 1 = Total charge, Q_2 stored in case 2

$\Rightarrow \quad C_1V_0 = (C_1+C_2)V$

$\Rightarrow \quad V = \dfrac{C_1V_0}{(C_1+C_2)}$

$\therefore$ Final p.d, $V = \dfrac{C_1V_0}{(C_1+C_2)}$

From Energy, $E = \frac{1}{2}CV^2$

(ii) $\Rightarrow$ Energy stored before switch is closed, $E_1 = \frac{1}{2}C_1V_0^2$

$\Rightarrow$ Energy stored after switch is closed, $E_2 = \frac{1}{2}C_{eff}V^2$ But $C_{eff} = C_1 + C_2$

$$= \frac{1}{2}(C_1+C_2)\cdot\left(\frac{C_1V_0}{(C_1+C_2)}\right)^2$$

$$= \frac{1}{2}(C_1+C_2)\cdot\frac{C_1^2V_0^2}{(C_1+C_2)^2}$$

$$\boxed{E_2 = \frac{1}{2}\frac{C_1^2V_0^2}{(C_1+C_2)}}$$

(iii) If $C_1 = C_2$, then From $E_2 = \frac{1}{2}\frac{C_1^2V_0^2}{(C_1+C_2)}$

$$\Rightarrow E_2 = \frac{1}{2}\frac{C_1^2V_0^2}{(C_1+C_1)} = \frac{1}{2}\frac{C_1^2V_0^2}{2C_1}$$

$$\boxed{\therefore E_2 = \frac{1}{4}C_1V_0^2}$$

(d) Let C_1 be the Capacitance of plain air capacitor
C_2 be the Capacitance of uncharged capacitor with rubber.

~~capacitance with dielectric~~

~~From $\varepsilon_r = \frac{C}{C_0}$~~

Total charge stored before = Total charge stored after

$$C_1 V_0 = (C_1 + C_2)V \quad \text{where } V_0 = 300V,\ V = 75V$$

$$C_1 V_0 = C_1 V + C_2 V$$

$$C_1 V_0 - C_1 V = C_2 V$$

$$C_1 (V_0 - V) = C_2 V$$

$$\Rightarrow \frac{C_2}{C_1} = \frac{(V_0 - V)}{V}, \quad \text{But } C_1 = \frac{\varepsilon_0 A}{d},\ C_2 = \frac{\varepsilon A}{d}$$

$$\Rightarrow \frac{\frac{\varepsilon A}{d}}{\frac{\varepsilon_0 A}{d}} = \frac{300 - 75}{75}$$

$$\Rightarrow \frac{\varepsilon}{\varepsilon_0} = \frac{225}{75}$$

$$\frac{\varepsilon}{\varepsilon_0} = 3, \quad \text{But } \frac{\varepsilon}{\varepsilon_0} = \varepsilon_r.$$

$\therefore$ Dielectric constant of rubber, $\varepsilon_r = 3$

SUBJECT:.................... PAPER:............ SIGNATURE....................

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(ii) From Energy, $E = \frac{1}{2}CV^2$

Initial energy stored in Capacitor, C_1

$$E_1 = \frac{1}{2}C_1V_0^2 \quad , \quad \text{where } V_0 = 300V, \quad C_1 = \frac{\varepsilon_0 A}{d}$$

$$\Rightarrow E_1 = \frac{1}{2}\frac{\varepsilon_0 A}{d} \times 300^2$$

$$= \frac{1}{2} \times 8.85 \times 10^{-12} \times 300^2 \times \frac{A}{d}$$

$$E_1 = \frac{3.9825 \times 10^{-7} A}{d} \text{ Joules}$$

Final energy stored in the two capacitors after connection.

$$E_2 = \frac{1}{2}(C_1 + C_2) \times V^2 \quad , \quad \text{where } C_1 = \frac{\varepsilon_0 A}{d}, \quad C_2 = \frac{\varepsilon A}{d} = \frac{\varepsilon_0 \varepsilon_r A}{d}, \quad V = 75V$$

$$\Rightarrow E_2 = \frac{1}{2}\left(\frac{\varepsilon_0 A}{d} + \frac{\varepsilon_0 \varepsilon_r A}{d}\right) \times 75^2$$

$$= \frac{1}{2}\frac{\varepsilon_0 A}{d}(1 + \varepsilon_r) \times 75^2$$

$$= \frac{1}{2} \times \frac{8.85 \times 10^{-12} A}{d} \times 4 \times 75^2$$

$$E_2 = \frac{9.95625 \times 10^{-8} A}{d} \text{ Joules}$$

(iii) Difference in the energies, $\Delta E = E_1 - E_2$

$$= \left(\frac{3.9825 \times 10^{-7} A}{d} - \frac{9.95625 \times 10^{-8} A}{d}\right)$$

$$\Delta E = \frac{2.986875 \times 10^{-7} A}{d} \text{ J}$$. This was converted to heat energy in the connecting wires joining the two capacitors. NB: Area, A, and separation distance, d were not provided/known

SUBJECT .... PAPER .... SIGNATURE

Question 9

(i) Electrostatic induction is a process whereby a conductor acquires charge when a charged body is brought closer to it but not into contact.

OR is the introduction of charge onto a conductor by bringing it nearer but not in contact to a charging/charged body

(ii) Electric point discharge is the apparent loss of charge at the sharp ends of a ~~conduct~~ charged body due to ionisation of the air molecules around the sharp end.

(b)(ii) $\cdot r = 50cm \quad E = 3.0\times10^{4} V cm^{-1}$

$E = \frac{KQ}{r}$

$3.0\times10^{4} = \frac{9.0\times10^{9} Q}{(50)^2}$

$\frac{9.0\times10^{9} Q}{9.0\times10^{9}} = \frac{750\times10^{4}}{9.0\times10^{9}}$

$Q = \cancel{1.667\times10^{-5}}$ 833.33×10^{-5}

$Q = 1.667\times10^{-4} C$

$= 8.33\times10^{-3} C$

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

$= \frac{9.0\times10^{9} \times 8.33\times10^{-3}}{50}$

$= 1.4994\times10^{6} V$

OR

$E = \frac{V}{d} =$

$V = 3.0\times10^{4}\times50$

$= 1.5\times10^{6}$

$= 1.5\times10^{6}$

CANDIDATE'S NAME:...

SUBJECT:.................................. PAPER:.................. SIGNATURE.................................

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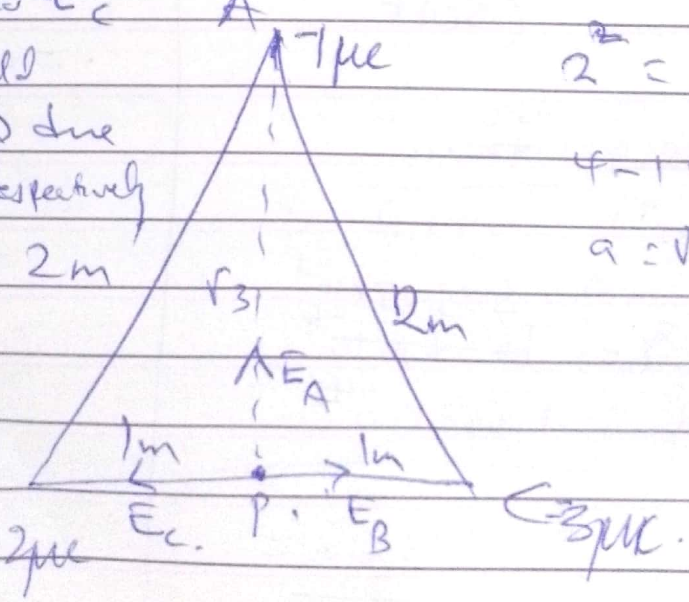
C (i) The leaf of the G.L.E will deflect momentarily and collapse. This is because when the negatively charged body is brought close, ~~the~~ positive charges are induced ~~at the~~ sharp end of the pin and negative charge to the leaf, which causes it to deflect. When the body is taken away quickly, the leaf collapses because since the charges in the pin fall back to their original positions.

(ii) ~~The leaf of the G.L.E will deflect and remains diverged even the body has been taken away.~~ If the body is brought for a longer time, induction of positive charge at the sharp end occurs and negative charge to the blunt end of the leaf with the plate.

- At the sharp end of the pin, Accumulation of charge occurs creating a strong electric field around the sharp point, this causes ionisation of air molecules around and negative ions are attracted to the sharp point neutralising some of the positive charge there. Process continues until all the positive charge is neutralised and the pin together with the G.L.E are left with a net negative charge. This makes the leaf to remain diverged after the body is removed.

Let E_A, E_B and E_C be electric field intensities at P due to A, B and C respectively



$2^2 = a^2 + 1^2$

$4 - 1 = a^2$

$a = \sqrt{3}$

SUBJECT.................. PAPER.............. INDEX No.............. SIGNATURE..............

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

$E_A = \frac{9.0\times10^9 \times 1\times10^{-6}}{(\sqrt{2})^2}$

$=$

$E_B = \frac{9.0\times10^9 \times 2\times10^{-6}}{1^2}$

$= 1.8\times10^4 NC^{-1}$

$E_c = \frac{9.0\times10^9 \times 3\times10^{-6}}{1^2}$

$= 2.7\times10^4 NC^{-1}$

Resolving along x-axis

$\vec{E_x} = E_B - E_c$

$= (1.8 - 2.7)\times10^4 NC^{-1}$

$= -0.9\times10^4 NC^{-1}$

$= -9.0\times10^3 NC^{-1}$

$= 9.0\times10^{+3} NC^{-1}$ to the left

vertically $\vec{E_y} = E_A =$

Resultant field at P $E_R = \sqrt{E_x^2 + E_y^2}$

$=$

Direction

$\theta = \tan^{-1}\left(\frac{E_y}{E_x}\right)$

$=$

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CANDIDATE'S NAME:.. INDEX No.........................

SUBJECT:.. PAPER:................... SIGNATURE.............................

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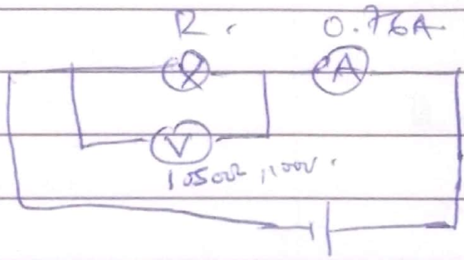
Question 10

a)(i) Resistivity is the resistance across opposite faces of a sample of material of length 1m and cross-sectional area $1m^2$.

(ii) Temperature Coefficient of resistance is the fractional change in resistance of a material at 0°C per every degree celsius/kelvin rise in temperature.
Or is the fractional change in the resistance of a material per every degree celsius/kelvin rise in temperature over the resistance of ~~a~~ material at 0°C.

b) $R_{20} = 375\Omega$,



$$\frac{R \times 1050}{R + 1050} \times 0.76 = 100V$$

$$\frac{1050R \times 0.76}{R + 1050} = 100$$

$$\frac{798R}{R + 1050} = 100$$

$$798R = 100R + 105{,}000$$

$$698R = 105{,}000$$

$$R = 150.43\Omega$$

CANDIDATE'S NAME:.. INDEX No..........................

SUBJECT:.. PAPER:.................. SIGNATURE..........................

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$$R_\theta = R_0(1+\alpha\theta)$$

$$R_{20} = R_0(1+20\alpha)$$

$$375 = R_0(1+20\alpha) \quad -(1)$$

$$150.43 = R_0(1+1200\alpha) \quad -(2)$$

$$\frac{375}{150.43} = \frac{1+20\alpha}{1+1200\alpha}$$

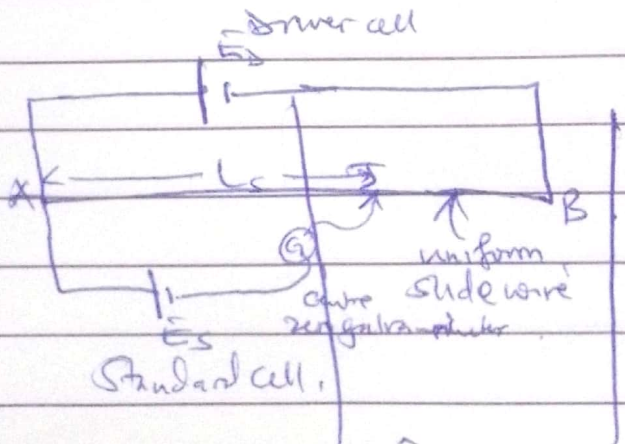
$$150.43 + 3008.6\alpha = 375 + 450{,}000\alpha.$$

$$\frac{-446{,}991.4\alpha}{-446{,}991.4} = \frac{224.57}{-446{,}991.4}$$

$$\alpha = -5.024 \times 10^{-4}\,{}^{\circ}C^{-1} / K^{-1}$$

(ii) Negative temperature Coefficient of resistance implies Carbon is a Semi-conductor.

(c)



d) (i) A high resistance takes up a large p.d across itself and leaves a small p.d of the order of thermocouple emf to the slide wire potentiometer.

(ii) Resistance per cm, $r = \frac{2.0}{100} = 0.02\Omega cm^{-1}$

Driver current, $I_d = \frac{2.0}{100+2} = \frac{2}{102} = \underline{0.01961A}$

p.d per cm, $K = I_d r$

$= 0.01961 \times 0.02$

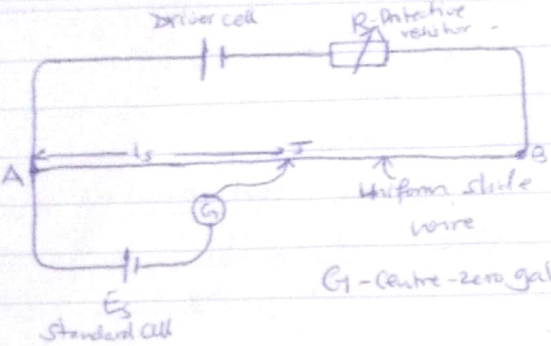
$= 0.0003922 Vcm^{-1}$

$E_T = Kl$

$E_T = 0.0003922 \times 45$

$= \underline{0.017649\ V} = \underline{1.765 \times 10^{-2} V}$

C(i)



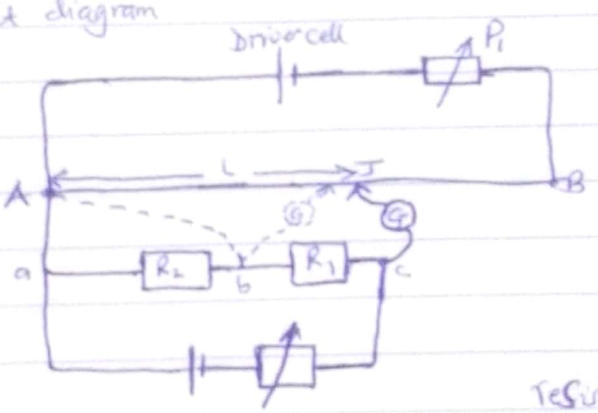
G - Centre-zero galvanometer.

- A standard cell of e.m.f, E_s, is connected in series with a centre zero galvanometer which is connected to the driver circuit as shown above.
- The circuit is first checked for a two-way deflection by tapping the sliding contact, J, near A and then near B.
- The Jockey, J, is then tapped at different positions along the wire until the galvanometer shows zero deflection ie $I_G = 0$.
- The balance length, l_s, is then measured and recorded
ie At balance point $Kl_s = E_s$.

$$\Rightarrow K = \frac{E_s}{l_s},$$ where K - is the Calibration constant

C(ii)

Circuit diagram



P_1 & P_2 - are Protective variable resistors

G - Centre zero galvanometer.

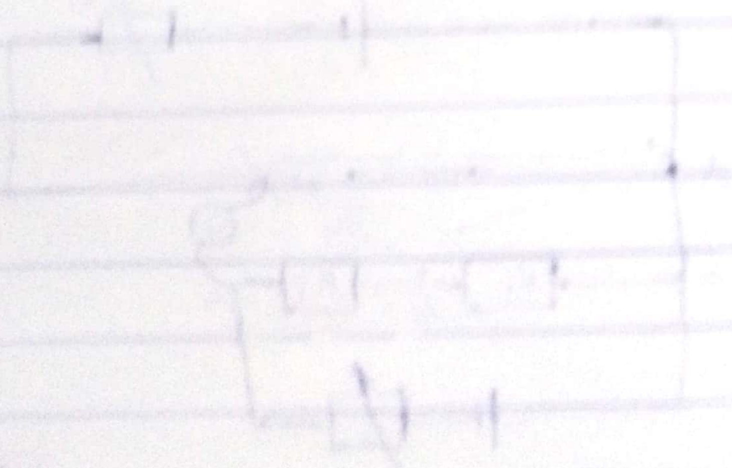
R_1 & R_2 - standard resistors to be compared.

- The circuit is connected as shown above.
with the galvanometer first connected ~~to~~ points b and Junction A to point a, the Jockey is tapped at different points along the wire until the galvanometer shows no deflection.
- The balance l_1 is measured and recorded.
ie At balance point, $I_t R_1 = Kl_1$ --(1)
- The galvanometer is now disconnected from point b and connected to point c while Junction A is disconnected from a, then transferred to b. The Jockey is again moved along the slide wire until the galvanometer shows zero deflection.
- The balance length, l_2, is measured and recorded
ie At balance point $I_t R_2 = Kl_2$ --(ii)

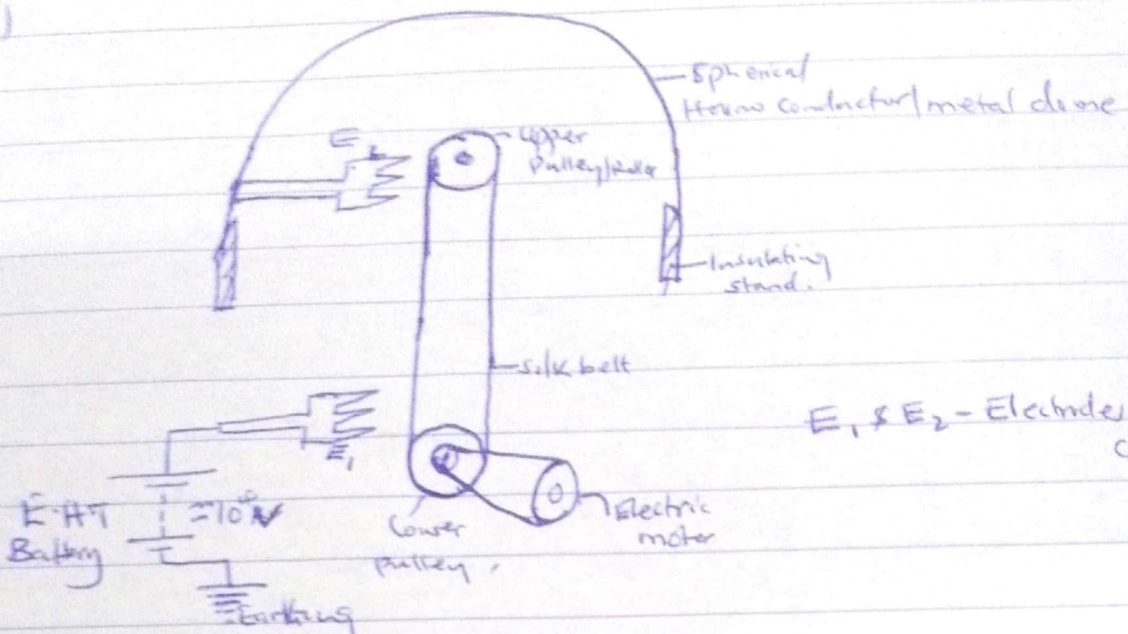
the from eqn's (i) and (ii)

$$\frac{I_1 R_1}{I_2 R_2} = \frac{K l_1}{K l_2}$$

from which the two resistances R_1 and R_2 can be compared from $\frac{R_1}{R_2} = \frac{l_1}{l_2}$



b (i)



E_1 & E_2 - Electrodes/metal combs.

Mode of operation.

Electrode E_1 is made to be at a high ~~Pote~~ positive potential of about 10^4V by the E.H.T with respect to the earth. At the spikes of E_1, there is high accumulation of charge setting a strong field intensity around E_1. Ionisation of air molecules occurs and positively charged ions are repelled onto the silk belt which carries them upwards, towards E_2 inside the metal dome as it is being by the motor. When positively charge ions approach the Electrode E_2, negative charges are induced at the sharp points of E_2 and positive charge induced/repelled to the far/blunt end of E_2 and the surface of the hollow conductor. At the electrode E_2, high accumulation at its spikes leads to a strong electric field intensity and air molecules around are ionised. The negatively charged ions are repelled onto the belt and neutralise the positive charge on the belt before it passes over the upper pulley. The process repeats ~~repeat~~ itself several times per second until the potential on the hollow conductor builds up to about 10^6V.