UACE PHYSICS PAPER 2017 GUIDE

Instructions to the candidates:

Answer **five** questions taking at least one from each of the sections **A, B, C** and **D**, but not more than one question should be chosen from either section **A** or **B**

Any additional question (s) will not be marked.

Mathematical tables and squared paper will be provided

Non programmable calculators may be used.

Assume where necessary

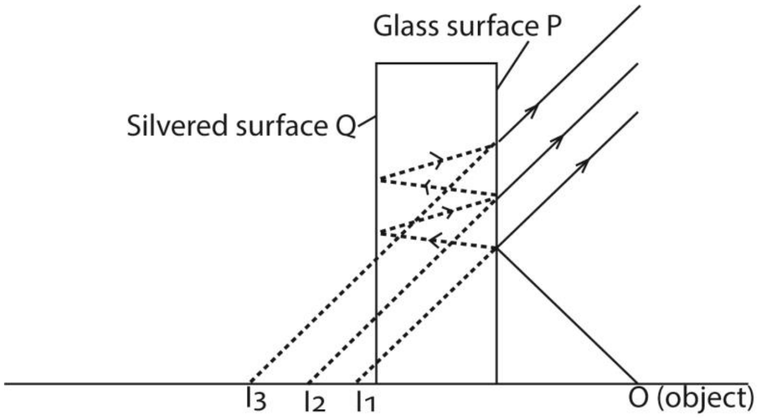
Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 \times 10^{-19}C$
Electron mass	$9.11 \times 10^{-31}kg$
Plank's constant, h	$6.6 \times 10^{-34}Js$
Speed of light in the vacuum, c	$3.0 \times 108ms^{-1}$
Specific heat capacity of water	$4.200Jkg^{-1}K^{-1}$
Avogadro's number, N_A	$6.02 \times 10^{23}mol^{-1}$
The constant, $\frac{1}{4\pi\varepsilon_0}$	$9.0 \times 10^{9}F^{-1}m$
Permittivity of free space, μ_0	$4.0\pi \times 10^{-7}Hm^{-1}$
Permittivity of free space, ε_0	$8.85 \times 10^{-12}Fm^{-1}$
One electron volt	$1.6 \times 10^{-19}J$
Resistivity of Nichrome wire at 25^0C	$1.2 \times 10^{-6}\Omega m$

SECTION A

1. (a) (i) State two differences between real and virtual images (02marks)
A real image is formed by actual intersection of rays and can be formed on a screen while virtual image is formed by apparent intersection of rays and cannot be formed on a screen.

(ii) Explain with the aid of a diagram how thick plane mirror forms multiple images (04marks)

Formation of multiple images in thick plane mirror



Multiple images are formed due to partial reflection and refraction at the non-silvered surface of the mirror.

- İmage I_1 is formed by reflection on the glass surface P
- The image I_2 (the brightest is formed by reflection of the most light on the silvered surface Q
- Others by partial refraction

(b) A convex mirror forms a real image which is three times the linear size of the object. When the object is displaced though a distance y, the real mage formed is four times the linear size of he object. If the distance between the two image positions is 20 cm, find the

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

$M_1 = \frac{v_1}{f} - 1$ and $M_2 = \frac{v_2}{f} - 1$

$M_2 - M_1 = \frac{v_2 - v_1}{f}$

$4 - 3 = \frac{20}{f}$

f = 20cm

(ii) distance, y. (03marks)

Also $\frac{1}{M} = \frac{u}{f} - 1$

$\frac{1}{3} = \frac{u_1}{f} - 1$

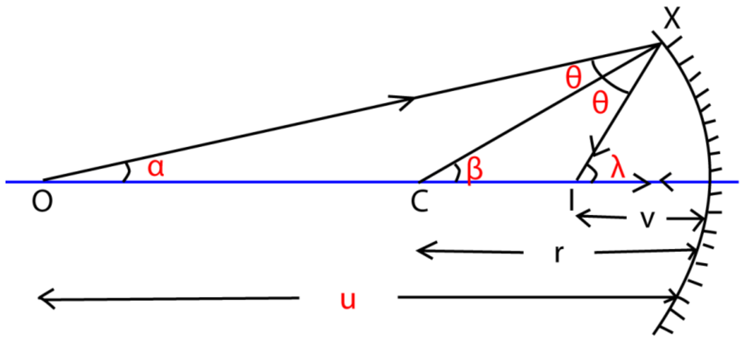
$\frac{1}{4} = \frac{u_2}{f} - 1$

$\frac{1}{3} - \frac{1}{4} = \frac{u_1 - u_2}{f} = \frac{y}{20}$

y = 1.67cm

(c) Use a geometrical ray diagram to derive the relation, $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ for concave mirror. (05marks)

Consider the incidence of ray **OX** on to a concave mirror from a point object **O** placed along the principal axis and then suddenly reflected in the direction XI making an angle □ with the normal CX.



Ray OP strikes the mirror incident normally at P and thus reflected back along its own path. The point of intersection **I** of the two reflected rays is the image position.

From Δ OXC, α + θ = β ………………. (i)

From Δ CXI β + θ = λ ………………… (ii)

Eliminating θ from eqn. (i) and eqn. (ii)

α + λ = 2β …………………………………. (iii)

If X is very close to P, then

$\alpha \approx \tan\alpha = \frac{XP}{u}$, $\beta \approx \tan\beta = \frac{XP}{r}$, $\lambda \approx \tan\lambda = \frac{XP}{v}$ Equation (a) becomes = $\frac{XP}{u} + \frac{XP}{v} = \frac{2XP}{r}$

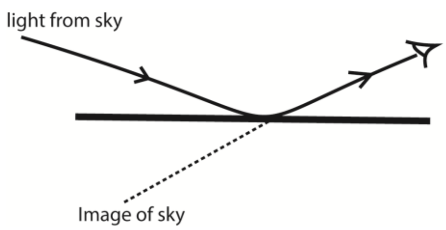
$= \frac{1}{u} + \frac{1}{v} = \frac{2}{r}$

But 2 = 2f

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

(d) Explain how mirage is formed. (03marks)

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



2. (a) Define the following as applied to a converging lens;

(i) Principal focus (01mark)

The principal focus of converging lens is the point on the principal axis to which paraxial rays converge after refraction from the lens.

(ii) center of curvature (01mark)

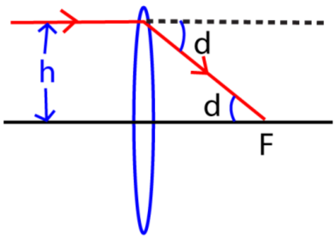
The center of curvature of lens is the center of the sphere of which one of the spherical surfaces of the lens form part.

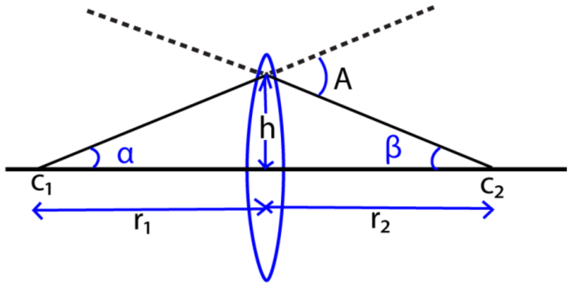
(b) Find the power of a lens of focal length 15 cm (02marks)

Power of lens = $\frac{1}{f(m)} = \frac{1}{0.15}$=6.67D

(c) Derive an expression for focal length of a lens in terms of the radii of curvature of its surfaces and refractive index (05marks)

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





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

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

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

For small angle

$\alpha \approx \tan\alpha = \frac{h}{r_1}$ and $\beta \approx \tan\beta = \frac{h}{r_2}$

Substitution α and β in equation (iii)

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

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

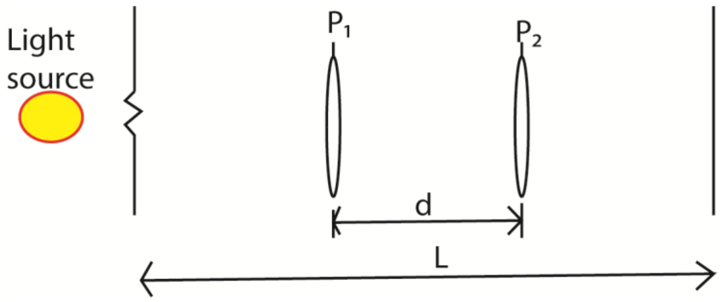
$\frac{h}{f}$ = (n-1) $\left(\frac{h}{r_1} + \frac{h}{r_2}\right)$

Dividing by h

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

(d) Describe an experiment to determine the focal length of a thin converging lens mounted inside a short cylindrical tube. (05marks)

Illustration



- The tube is placed between an illuminated object and a screen a distance l slightly more than 4 times the approximate focal length of a lens to form a clear magnified image at the screen. The position of the front part P_1 is noted

- The tube is moved towards the screen until a clear diminished image is formed on the screen and position P_2 of the front part is noted

- The displacement, $d = P_2 - P_1$ is noted

  The focal length, f of the lens = $\frac{l^2 - d^2}{4l}$

(e) A compound microscope consists of two thin lenses, an objective of focal length 1.0cm and eye piece of focal length 5.0cm. The objective forms an image of an object placed in front of it at a point 16.0cm away. If the final image is formed at the near point of the eye, calculate the

(i) Separation of the lenses (03marks)

Consider the eyepiece lens, using $\frac{1}{f} = \frac{1}{u} + \frac{1}{V}$

$\frac{1}{5} = \frac{1}{u_e} + \frac{1}{-25}$; $u_e = 4.17$m

Separation of lenses = $v_0 + u_e = 16.0 + 4.17 = 20.17$cm

(ii) magnifying power of the instrument (03marks)

M = $(\frac{-D}{f_e} - 1)(\frac{v}{f_0} - 1) = (\frac{-25}{5} - 1)(\frac{1}{1} - 1) = -90$

SECTION B

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

(i) Amplitude

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

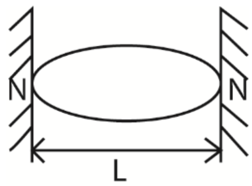
(ii) Wavelength (01mark)

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

(b)(i) State the conditions for the formation of standing wave (02marks)

- Two waves must be travelling in opposite direction.
- The waves must have the same speed, frequency and approximately the same amplitude

(ii) A string fixed at both ends is made to vibrate in different modes. If the frequencies of n^{th} harmonic and fundamental note are f_n and f_l respectively. Show that $f_n = nf_l$.

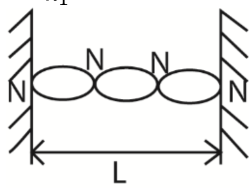


$\frac{\lambda_1}{2} = L$

⇨ $\lambda_1 = 2L$

⇨ $V = f_1\lambda_1$

$f_1 = \frac{V}{\lambda_1}$



$\frac{3\lambda_3}{2} = L$

⇨ $\lambda_3 = \frac{2L}{3}$

⇨ $V = f_3\lambda_3$

$f_3 = \frac{V}{\lambda_3} = 3\left(\frac{V}{2L}\right) = 3f_1$

if the vibration produced n loops, then frequency, $f_n = nf_1$

(c) The mass of a vibrating length of sonometer wire is 1.20g. a note of frequency512Hz is produced when the wire is sounding in second over note. If the tension in the wire is 100N. Calculate the vibrating length of the wire. (04marks)

$f_n = \frac{n}{2l}\sqrt{\frac{T}{\mu}}$

But $\mu = \frac{1.2 \times 10^{-3}}{l}$

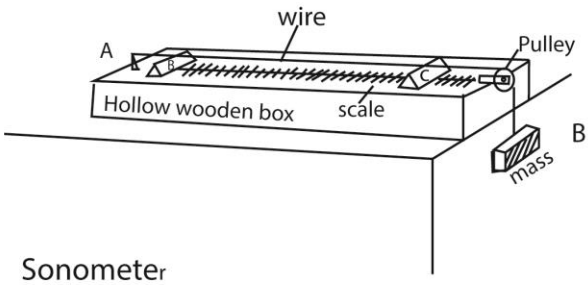
$512 = \frac{3}{2l}\sqrt{\frac{100l}{1.2 \times 10^{-3}}}$; l = 1.987m

(d) Explain why the quality of a note from an open pipe is preferred to that given by closed pipe (03marks)

Closed pipes give only odd harmonic while open pipes give both odd and even harmonic tones. The more overtone the better the quality of sound.

(e) Describe an experiment to investigate the variation of frequency with length for vibrating wires (05marks)

A sonometer below is used



- The wooden bridges B and C vary the effective length of the wire, L.
- Constant tension in the wire is maintained by the fixed mass
- A paper rider is place on the wire in the middle of BC and a sounding fork placed near it.
- The position of the bridge C is varied until sound is heard.
- The distance between the bridges L and the frequency, **f**, of the tuning fork is noted.
- The procedure is repeated for various tuning forks and values of L, **f** and $\frac{1}{L}$ are tabulated
- A plot of **f** against $\frac{1}{L}$ gives a straight line showing that the frequency of vibration of the wire is inversely proportional to length.

4. (a) Define an optical path (01mark)

This is the product of the refractive index of a medium and the geometrical path length.
Or
It a length of a vacuum that contains the same number of waves as a given length in a medium.

(b) With reference to Young's double slit experiment,

(i) Explain how interference pattern is formed.

When two coherent waves travel in a medium, they meet and superimpose.
Where they meet in phase, constructive interference takes place and intensity is increased (or maximum)
Where they meet out of phase, cancellation takes place and intensity reduces (minimum)

Patterns of alternative regions of maximum and minimum intensities are formed that form interference pattern.

(ii) State what happens to the fringes when the source of light is moved nearer to the slits.

The intensity of fringes increase

(iii) state what happens to fringes when the separation of slits is changes

Increase in separation of slits reduces fringe separation.

(iv) describe the appearance of fringes when white light is used

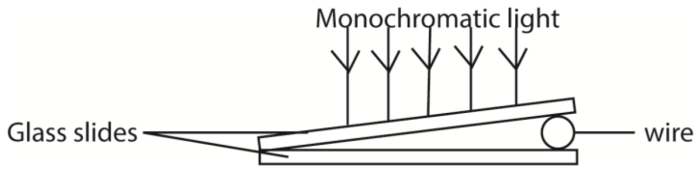
When white light is used, colored fringes are observed. The central fringe is white, followed by blue and red fringes further off. Outwards the color overlap leading to white illumination

(v) calculate the separation of the slits if the distance from slits to the screen is 800mm and the 8th bright fringe is formed 5mm from the center of the fringe system given that the wavelength of light is 6.2 x 10^{-7}m

$y = \frac{n\Delta\lambda}{d}$

$d = \frac{n\Delta\lambda}{y} = \frac{8 \times 800 \times 10^{-3} \times 6.2 \times 10^{-7}}{5 \times 10^{-2}}$ = 7.94 x 10^{-4}m

(c) An air wedge is formed by placing two glass slides of length 5.0cm in contact at one end and separated by a wire on the other end as shown below



When the slides are illuminated with light of wavelength 500nm, 10 dark fringes are observed to occupy a distance of 2.5mm

(i) Explain how the fringes are formed (03marks)

- Light is partly reflected and partly transmitted at the lower surface of the top slide.
- The transmitted light is partly reflected on the top of the lower slide.
- The two waves meet and superpose.
- Where the geometrical path difference is an integral multiple of a full wavelength, a dark fringe (band) is formed.
- Where the geometrical path difference is an odd multiple of half wavelength, a bright band is formed. This is because the wave reflected at the surface of the lower slide suffers a phase change of π (180^0) equivalent to extra path of $\frac{\lambda}{2}$.

(ii) Determine the diameter of the wire(04marks)

Thickness, t

$\Delta X = \frac{\lambda s}{2t}$

$t = \frac{\lambda s}{2\Delta X} = \frac{500 \times 10^{-9} \times 5 \times 10^{-2}}{2 \times 2.5 \times 10^{-3}}$ = 5 x 10^{-5}m

SECTION C

5. (a) Define magnetic flux density. (01mark)

Magnetic flux density is the force acting on conductor of length 1m and carrying of 1A placed perpendicular to magnetic field.

(b) Write the expression for the

(i) Magnetic flux density B at a distance r from long straight wire currying current I. (01mark)

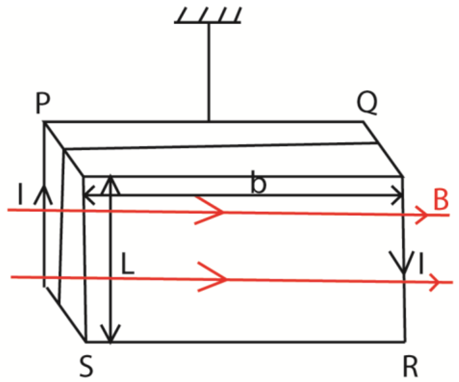
$B = \frac{\mu_0 I}{2\pi r}$

(ii) Force F on a straight wire of length L carrying current I perpendicular to a uniform magnetic field of flux density B.

F = BIL

(c) A moving-coil galvanometer consists of a rectangular coil of N-turns each of area A suspended in a radial magnetic flied of flux density B.

(i) Derive an expression for the torque on the coil when a current I passes through it (04marks)



The is no force on the sides PQ and SR since they are parallel to the field

Applying Fleming's left hand rule, the force initially on PS, F = μBIL (into the plane)

The force initially on QR, F = μBIL (out of the plane)

These force constitute a couple whose moment is given by

Torque, τ = F x b

= μBIL x b

But L x B = A

∴ torque, τ = μBIA

(ii) If the coil is suspended by a torsion wire for which the couple per unit twist is C, show that the instrument will have a linear scale.(03mark)

Torque on the coil, τ = μBIA

Torque due to torson wire, τ = Cθ

At balance, Cθ = μBIA

⇨ $\theta = \frac{\mu BIA}{C}$

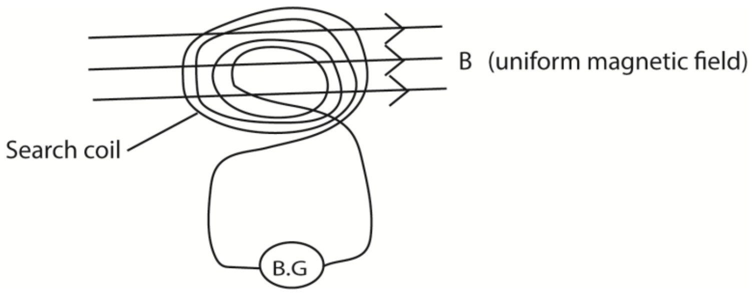
Since, μ, B, C and A are constant

$\theta \propto I$, the scale is linear

(i) How can current sensitivity of the instrument be measured? (02marks)

The instrument is connected in series with an ammeter to a voltage source. The current measured, and the deflection, θ, of the instrument is recorded.
Current sensitivity is given by, $S_I = \frac{\theta}{I}$

(d) Describe an experiment to determine the magnetic flux density of a uniform magnetic field using a search coil and ballistic galvanometer



A search coil of cross section area A and number of turns, N, is connected in series with ballistic galvanometer. The search coil is then placed in uniform magnetic field such that the plane of the coil is perpendicular to the magnetic field. The coil is then pulled completely out of the field. The first deflection of the ballistic galvanometer noted θ_1.

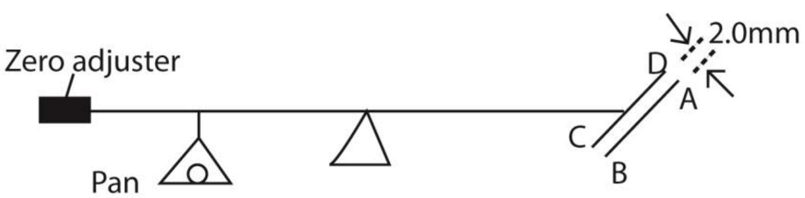
A capacitor of known capacitance C is then charged to a p.d. V and then charged through the ballistic galvanometer, θ_2 is noted

The magnetic flux density of uniform magnetic field is obtained from

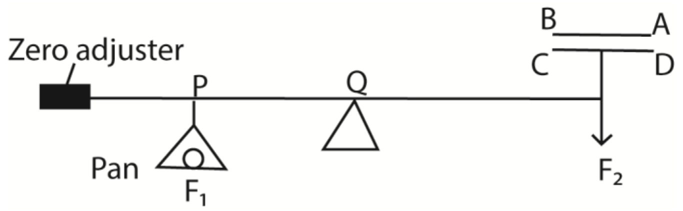
$B = \frac{CVR}{AN} x \frac{\theta_1}{\theta_2}$

Where R is the resistance of the whole circuit.

(e) Figure 2 shows an ampere balance, wires AB and CD each of length 100cm, lie in the same vertical plane and separated by 2.0mm.



When a current I is passed in opposite direction through the wires, a mass of 0.3g is placed in the pan to obtain balance. Find the value of the current I



Assumption made

- PQ = QR and AB is fixed
- AB is above CD

In equilibrium

F_1 x PQ = F_2 x QR

$F_1 = F_2$

mg = $\frac{\mu_0 I^2 L}{2\pi a}$

I = $\sqrt{\frac{2\pi mga}{4\pi \, x \, 10^{-7} \, x \, L}}$

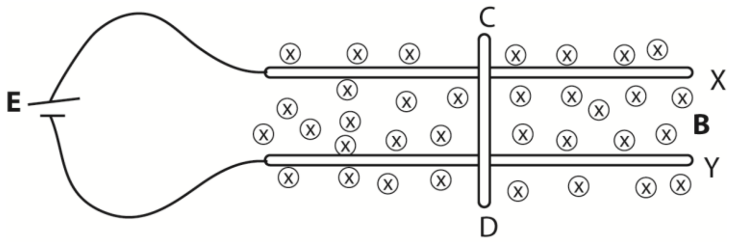
= $\sqrt{\frac{0.3x \, 10^{-3} \, x \, 9.81 \, x \, 2 \, x \, 10^{-3}}{2 \, x \, 1 \, x \, 10^{-7}}}$ =5.4A

Alternatively if CD is above AB force at P is downward and force R is upwards. Hence equilibrium will not be attained.

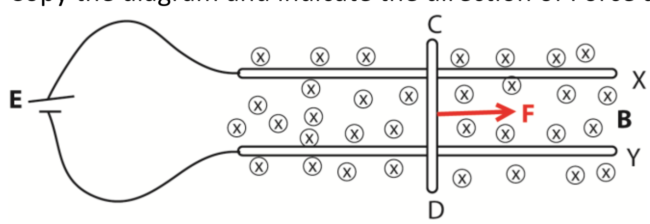
Or

Both forces produce a turning effect in the same direction. Equilibrium will not be attained.

6. In the figure below X and Y are smooth conducting rails connected to a source of e.m.f, E. CD is a metal rod of length L m placed horizontally on X and Y perpendicular to magnetic field of flux density B



(i) Copy the diagram and indicate the direction of Force acting on the rod. (01mark)



(ii) Using the principle of conservation of energy, show that F = BIL, where I is the current supplied by the source. (04marks)

Induced e.m.f, ε = BLV where V is the velocity of the rod.

Let I be the current induced, electrical power generated = EI

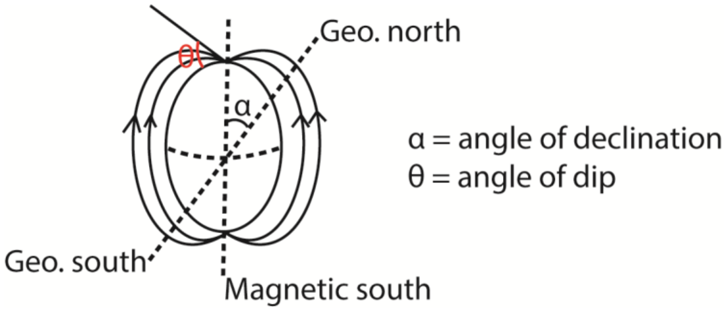
Mechanical power spent = FV

∴ From the principle of conservation of energy, FV = EI

= BIVL

Force, F = BIL

(b) (i) Describe the feature of earth's magnetic field (05marks)

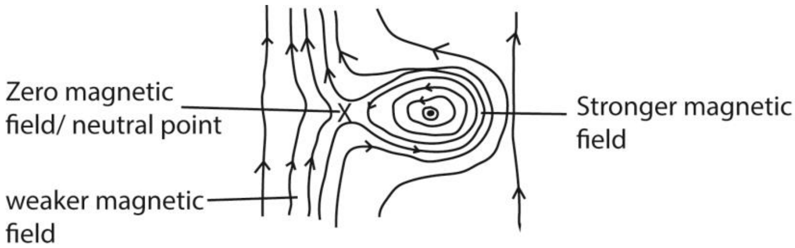


Geographical meridian is the vertical plane containing the geographical axis

Magnetic meridian is the vertical plane containing magnetic axis.

Angle of dip varies from 0^0 at the magnetic equator to 90^0 at the poles.

(ii) Sketch the resultant magnetic flux around a wire carrying current vertically upwards in in earth's magnetic field. (02marks)



(c) A circular coil of 50 turns and radius 0.5m is placed with its plane perpendicular to earth's magnetic meridian. It is connected to a ballistic galvanometer of sensitivity 5.7×10^3 $radC^{-1}$ and circuit resistance of 100Ω. When the coil is rotated through 180^0 about a horizontal axis, the galvanometer deflects through 0.8 rads.

Calculate

(i) Horizontal component of earth's magnetic flux density. (04marks)

$Q = \frac{2BAN}{R} = \frac{\theta}{\alpha}$

$B = \frac{R\theta}{2\alpha\mu A} = \frac{100 \, x \, 0.8}{2x \, 5.7 \, x \, 10^3 \, x \, 50 \, x \, \tau \, x \, (0.5)^2}$ = 1.79x 10^{-4}T

(ii) p.d across a solenoid of 2000 turns per meter and resistance 5Ω that produces the same magnetic flux density as calculated in (c)(i). (04marks)

$B = \mu_0 nI$ But $I = \frac{V}{R}$

$B = \mu_0 n \, x \, \frac{V}{R}$

$V = \frac{BR}{\mu_{0n}} = \frac{1.77 \, x \, 10^{-4} \, x \, 5}{4\pi \, x \, 10^{-7} x \, 2000}$ = 0.36V

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

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

(b)(i) Write down and expression for the e.m.f generated by a dynamo and use it to identify the factors which determine the maximum e.m.f. (04marks)

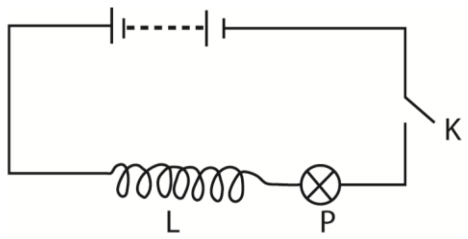
Induced e.m.f, $E = 2\pi f\mu AB\sin 2\pi ft$
Maximum e.m.f, $E_0 = 2\pi f\mu AB$
Maximum e.m.f thus increases with increase in

- Frequency or angular velocity
- Number of turns of the coil
- Magnetic flux density

(ii) Explain the structural modification needed to convert an a.c. generator into a d.c. generator.

The slip rings are replaced by commutators and the brushes are arranged so that the changeover of contacts occur over each half a cycle

(c) An iron-cored coil having a low resistance and high inductance is connected in series with a filament lamp, P. the coil and lamp are connected across a d.c. supply as shown in the figure below



Explain what is observed when switch K is closed and then opened. (04marks)

When K is closed bulb P lights dimly and increases to full brightness. This is because when K is closed and current begins to flow, back e.m.f is induced in the coil which opposes the flow of current in the circuit. Gradually the back e.m.f reduces to zero because current reaches maximum (and the change in induced magnetic field reduce to zero) and brightness increases.

When K is closed, bulb goes off since current is cut off.

(d) An alternating voltage $V = V_0\cos\omega t$ is connected across an inductor of inductance L.
(i) Derive the expression for the reactance of the inductor, X_L. (04marks)

$V = V_0\cos\omega t$

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

Since the inductor is a coil of zero resistance (for finite current) $V = -E$

$V_0\cos\omega t = L\frac{dI}{dt}$

$dI = \frac{V_0}{L}\cos\omega t \, . \, dt$

$\int dt = \frac{V_0}{L}\int cos\omega t.dt$

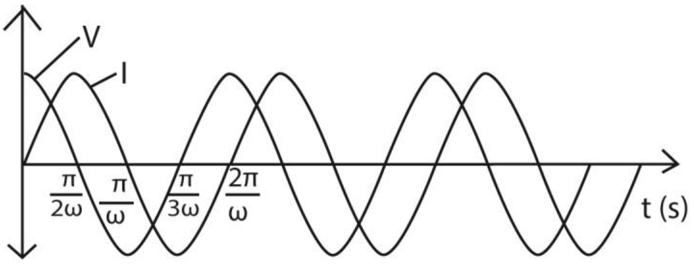
I $=\frac{V_0}{L} sin\omega t$

But I0 = $\frac{V_0}{\omega L}$

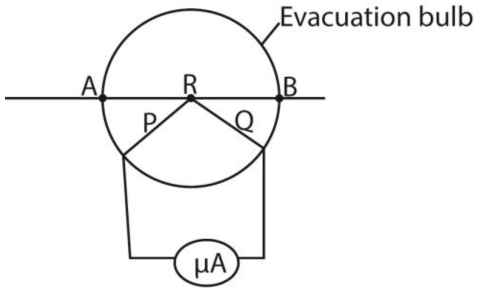
I = I_0sinωt

$X_L = \frac{V_0}{I_0} = \frac{V_0}{V_0/_{\omega L}}$ =ωL

(ii) Sketch using the same axes the variation of applied voltage and current through the inductor with time. (02marks)



(e) Describe how a thermocouple ammeter is used to measure an alternating current. (03marks)



P and Q are dissimilar wires

Current to be measured is passed through the wire AB and heats the junction R of the thermocouple.

The thermoelectric effect generated at R causes a direct current to flow through the micrometer calibrated to measure the r.m.s value of current.

SECTION D

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8. (a)(i) State the law of conservation of current at a junction in an electric circuit. (01marks)

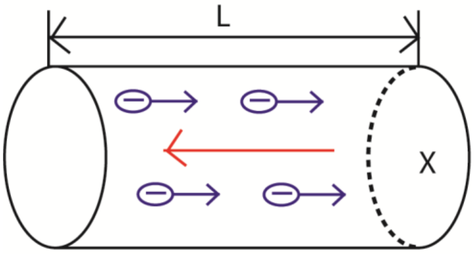
Law of conservation of current at a point/junction states that the total current flowing through a junction is equal to the total current flowing out of a junction.

(ii) Explain why current from a battery is greater when bulbs are connected in parallel than when they are in series across a battery. (03marks)

The effective resistance across the bulbs is smaller when the bulbs are in parallel than when they are in series. Since the current is a ratio of p.d to resistance the current is higher when the bulbs are connected in parallel than when connected in series.

(b) A conductor of length L and cross sectional area A has n free electrons per unit volume. The average drift velocity of the electrons is v and each electron carries charge e.

Derive an expression for the current which flows (03marks)



Number of free electrons in section of the wire = nAL

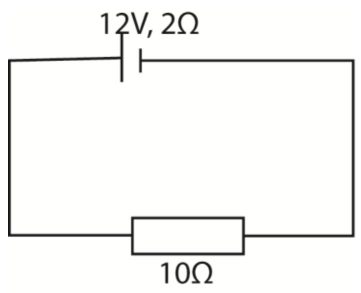
Total charge Q in the section is given by Q = nALe

Time taken for all electrons to flow through X, t = $\frac{L}{v}$

But current I = $\frac{Q}{t} = \frac{nALe}{L/v}$ = nAve

(c) A battery with an e.m.f of 12V and internal resistance 2Ω is connected to a wire of resistance 10Ω.

(i) Calculate the p.d across the wire. (02marks)

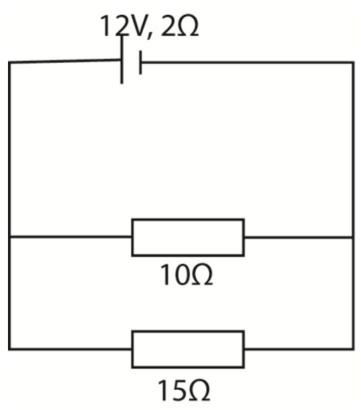


Total resistance in series = 10 +2 = 12Ω

But Current I = $\frac{V}{R} = \frac{12}{12} = 1A$

p.d across 10Ω resistor = IR = 1 x 10 = 12V

(ii) What is the p.d across the wire become if a 15Ω resistor is connected parallel to it? (03marks)



Combined resistance for 10Ω and 15Ω in parallel = $\frac{15 \, x \, 10}{15+10}$ = 6Ω

Total resistance in the circuit = 6 +2 = 8Ω

Current I = $\frac{V}{R} = \frac{12}{8}$ = 1.5A

p.d across the parallel resistors = IR = 1.5 x 6 = 9V

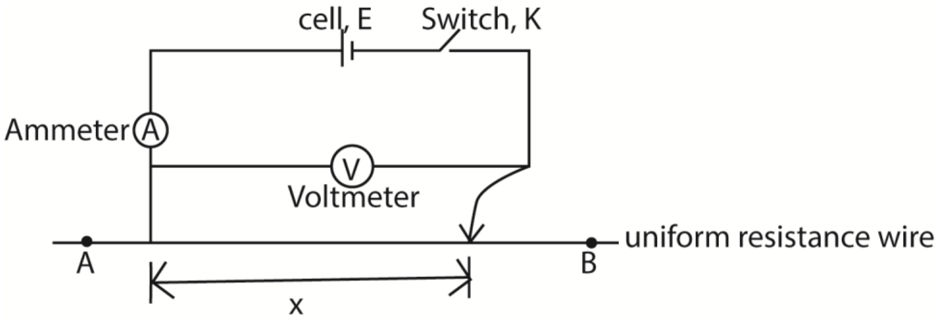
Hence, the p.d across 10Ωresistor = 9V

(d)(i) Define electrical resistivity and state its units (02marks)

Electrical resistivity of a material is the resistance is the resistance across 1m cube of the material

Units is Ohm-meter (Ωm)

(ii) Describe an experiment to determine the resistivity of the material of a wire using an ammeter, meter rule and voltmeter



- The setup is shown above
- Various values of x, V and V are obtained and tabulated including values of R= $\frac{V}{I}$
- A graph of R against x is plotted and slope s is obtained
- Given that the diameter of the wire is d; the resistivity of the wire, ρ is given by
  ρ = $s\left(\frac{\pi d^2}{4}\right)$

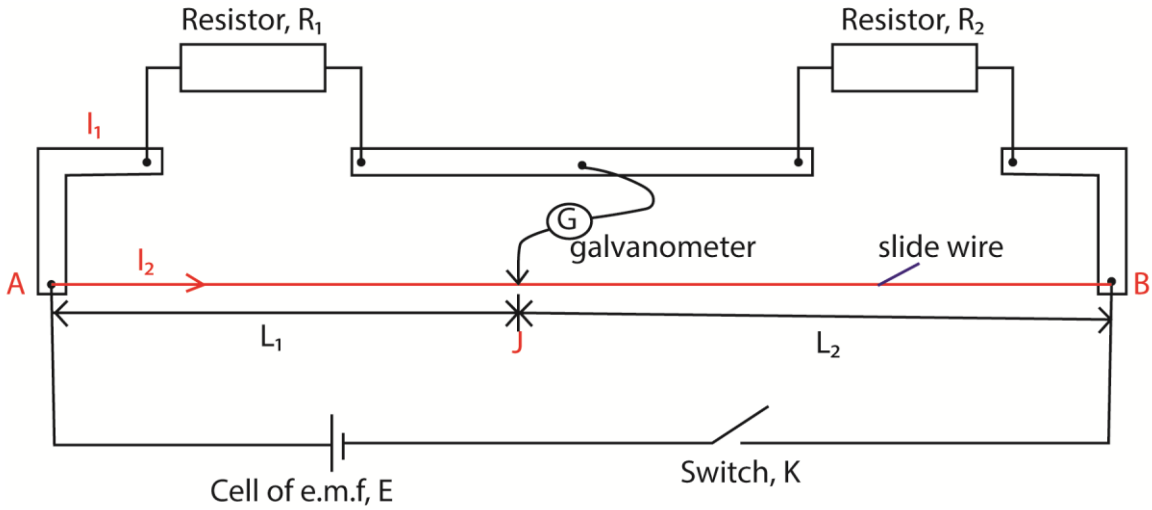
9. (a) (i) Define temperature coefficient of resistance and state its units. (02marks)

The temperature coefficient of resistance is the fractional change in resistance at 00C for very degree Celsius rise in temperature.
Units is K^{-1}

(ii)Explain why temperature coefficient of resistance is positive for metals. (03marks)

The resistance of a metal increases with increase in temperature because when the temperature increases, the atoms of the metal vibrate with higher amplitude reducing the mean free path for conduction of electrons.
The charge flow per second (or current) is reduced. This implies that resistance has increased. Hence fractional change in temperature is positive.

(b) (i) Derive the conditions for balance of meter bridge. (05marks)



- The setup is as shown above, J is the balancing point.
- At balance the current through R_1 = current through R_2 and current through AJ = current through JB

- ∴ p.d across R_1 = p.d across AJ
- $I_1R_1 = I_2R_{AJ}$
- If r is the resistance per meter of wire AB,
- Then, $I_1R_1 = I_2rL_1$ .... (i)
- P.d across R_2 = p.d across JB
- $I_1R_2 = I_2R_{JB}$
- Then, $I_1R_2 = I_2rL_2$ .... (ii)
- Dividing (i) by (ii)
- $\frac{R_1}{R_2} = \frac{L_1}{L_2}$

(ii) Explain why the meter bridge is unsuitable for comparison of low resistances. (02marks)

When the resistances are very low, the resistance of the connecting wire or the resistance of end error become significant.

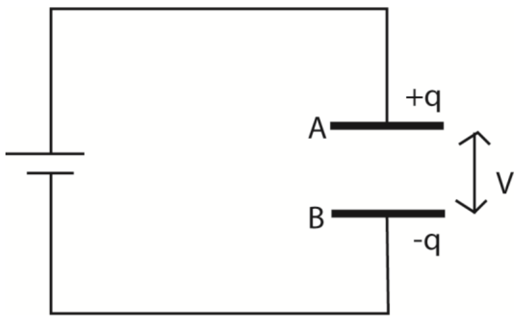
(c) A standard resistor is connected across the right hand gap of a meter bridge and a coil X across the left hand gap of meter bridge. When the coil is heated to a temperature of 40^0C, the balance length is 525mm from left-hand end of the bridge.
When the temperature of X is raised to 100^0C, the balance point is 546mm from the left end.

(i) Calculate the temperature coefficient of resistance of the coil X (06marks)

At 40^0, $\frac{X_{40}}{R} = \frac{52.5}{47.5} = 1.105$ ………… (i)
At 100^0, $\frac{X_{100}}{R} = \frac{54.6}{45.4}$ = 1.203 ………. (ii)
Hence $\frac{X_{100}}{X_{40}} = \frac{1.203}{1.105}$ = 1.089
Using $R_\theta = R_0(1 + \alpha\theta)$
$X_{100} = X_0(1 + 100\alpha)$
Also,
$X_{40} = X_0(1 + 40\alpha)$
$\frac{X_{100}}{X_{40}} = \frac{(1+100\alpha)}{(1+40\alpha)}$ = 1.089
$\alpha = 1.57\ x\ 10^{-3}K^{-1}$

(ii) Why are standard resistors made of alloys such as constantan and magnesium? (02marks)
The temperature coefficient of constantan and magnesium are small, thus, there negligible change in resistance with moderate change temperature

10. (a) Derive an expression for energy stored in a capacitor of capacitance, C, charged to voltage, V. (04marks)



When a small amount of charge δq is transferred from B to A
Total charge = q + δq
Total p.d = V + δV
Work done, δw = (V + δV)δq
∴ δw = Vδq, but q = CV
$\delta w = \frac{q}{C}\delta q$
Work done, W = $\int_0^Q \frac{q}{C}\delta q$
= $\frac{1}{2} x \frac{Q^2}{C}$
= $\frac{1}{2}CV^2$
Alternatively
δq = δ(CV) = CδV
δw = CVδV
Work done = $\int_0^V CV\delta V = \frac{1}{2}CV^2$
(b) A parallel plate capacitor with plate area of 2 x $10^{-2}m^2$ and plate separation of 5.0x 10^{-3}m is connected to a 500V supply.
(i) Calculate the energy stored in the capacitor (04marks)
Charge Q = CV but C = $\frac{\varepsilon_{0A}}{d}$
= $\frac{\varepsilon_{0A}V}{d}$
= $\frac{8.85 x 10^{-12} x 2 x 10^{-2} x 500}{5 x 10^{-3}}$
= 1.77 x 10^{-8}C
Energy stored = $\frac{1}{2}QV$
= $\frac{1}{2} x 1.77 x 10^{-8} x 500$
= 4.4 x 10^{-6}J
(ii) If the space between the plates is completely filled with oil and the total charge in the capacitor becomes 4.42 x 10^{-8}C. Find the dielectric constant of the oil (03marks)
Capacitance, C' = ε_rC, where ε_r = electric field
From Q = C'V
=> Q = $\varepsilon_r V \frac{\varepsilon_0 A}{d}$
$\varepsilon_r = \frac{Qd}{\varepsilon_0 Av} = \frac{4.42 x 10^{-8} x 5 x 10^{-3}}{8.85 x 10^{-12} x 2 x 10^{-2} x 500}$ = 2.5

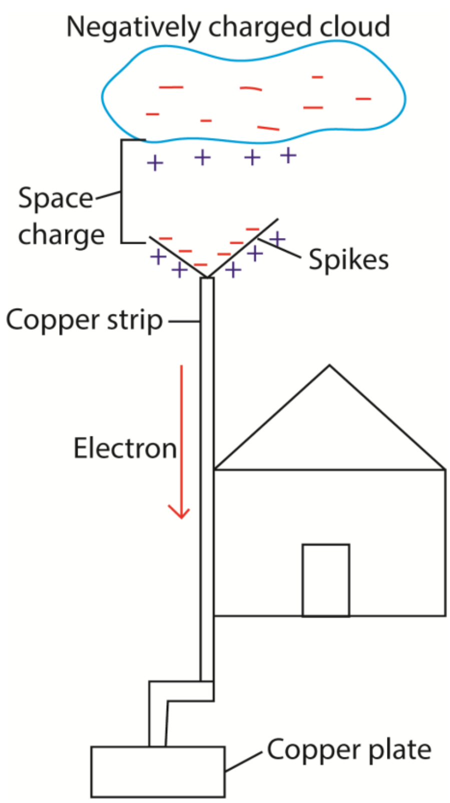
Or

Q = CV

= $4.42 \times 10^{-8} = \varepsilon r \times 3.54 \times 10^{-11} \times 500$

$$\varepsilon_r = \frac{4.42 \: x \: 10^{-8}}{3.54 \: x \: 10^{-11} x \: 500} = 2.5$$

(c) Explain how a lightning conductor may protect a building from damage by lightning. (05marks)



Action

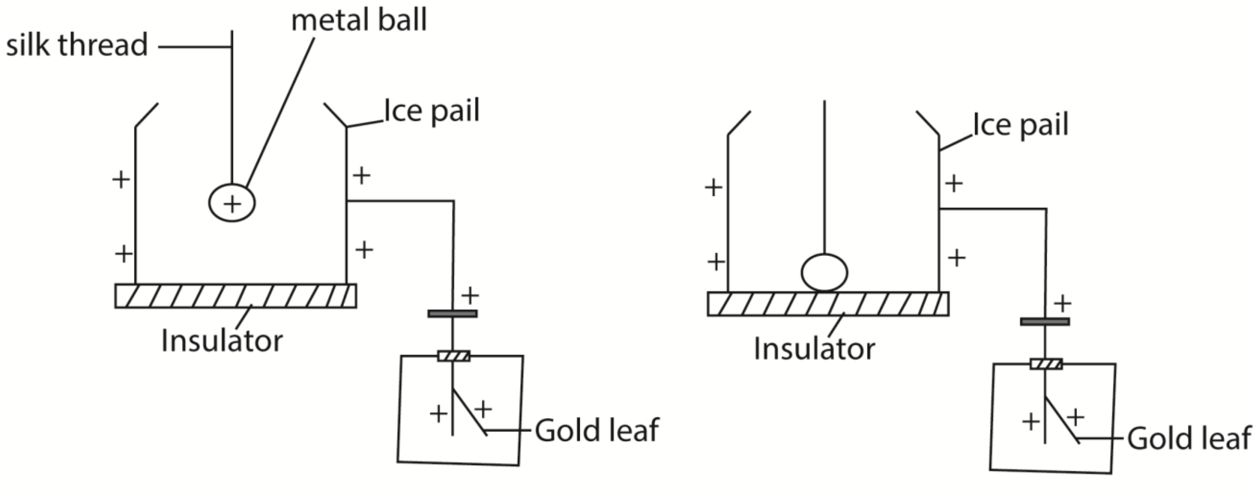
(i) When a negatively charged cloud passes over lightning conductor, it induces positive charges on the spikes by repelling electrons to the grounds through copper conductor.

(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.

(d) Describe an experiment to show that charge on a hollow conductor resides on the outer surface. (04marks)

Experiment to show that excess charge resides only on the outside of a hollow conductor.



- Ice pail is placed on an insulator and connected to a gold leaf electroscope
- A positively charged metal ball held on a long silk thread is lowered into the pail without touching the sided nor the bottom.
- Positive charges are induced on the outside of the pail and golf leaf diverges. The divergence does not change when the ball is moved about as long as it does not touch the pail.
- When the metal ball is allowed to touch the bottom, the divergence remains unchanged although it loses the charge.
- This shows that the charge induced inside the ice pail (hollow conductor) is of equal magnitude and opposite to the charge on the metal ball. Thus the total charge inside the hollow conductor is zero.
- Hence excess charge resides only on the outside of a hollow conductor.

END