UG

USE BLACK BALL POINT PEN ONLY

ವಿಶ್ವೇಶ್ವರಯ್ಯ ತಾಂತ್ರಿಕ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಬೆಳಗಾವಿ

VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI

Session	Morning ◯ Afternoon ●
Subject	Electromagnetic Waves
Date	010321
Semester	5

Script No. U200521820

Subject Code: 18EC55

University Seat Number: 1RN18EC160

I abide by the rules and regulations of the University. I have written USN, Subject code and darkened the appropriate bubbles correctly.

SUMUKHA M

Name and Signature of the Candidate

I have verified the data filled by the candidate of this booklet & found correct

Room Superintendent's Signature

# of Graph Sheets / Drawing Sheets Enclosed

INSTRUCTIONS TO CANDIDATE

1. This form will be scanned by Computer. This Answer Book must contain 44 Pages.
2. Fill / Darken this form with BLACK INK BALL POINT PEN only.
3. Please darken the appropriate circles for USN, Date, Session and Questions answered.
4. Wrong darkening or double circle darkening will be treated as invalid and will lead to delay in processing of results.
5. The Candidate should follow instructions carefully. The candidate is responsible for any lapses in following the instructions.

INSTRUCTIONS TO THE ROOM SUPERINTENDENT

1. The Room Superintendent shall check that the USN and Signature of the candidate are filled correctly in appropriate boxes of the answer booklet before signing on the facing sheet.
2. If any discrepancy is found in the answer script like loose threading, less number of pages, wrong darkening of bubbles of USN/ Subject code should be entered in Form B against USN of candidate.
3. Corrections to mistakes in bubbling of USN or Subject code can be made using Whitener.

To be signed by the Chief Superintendent if student is booked under MPC	

INSTRUCTIONS TO CANDIDATES

1. **Only a single answer book will be issued. No additional Answer Books are permitted.**
2. **The candidate should write his / her seat number and give other information like examination, semester subject, subject code etc., against the space provided on the title page of the answer book.**
3. Revealing your identity in any other place of the answer booklet will be treated as Malpractice.
4. The question numbers should be written in the margin provided for the purpose.
5. The candidate shall **write answers on both the sides of pages** of the answer book. All **rough work** must be done in the **space provided** at the **end of the answer book.** Answers must be written using **black ball point pen only**. If there is **a change in pen,** the same shall be **attested** by the **Room Superintendent on the form B.**
6. **Answer book should be handed over personally to Room Superintendent before leaving the examination hall.**
7. No candidate shall be permitted to go to toilet during the period of examination.
8. The candidate should not take any books / notes, log table, scribbling pads, Cell phones, programmable calculators or any kind of reference material into the examination hall. The candidate should make sure that he / she has no unauthorized book or paper in the examination hall with him / her or in his / her desk. He / She should have only articles permitted like Identity Card, Hall Ticket / Admission Ticket. The Candidate should not write anything on the Admission Ticket or Identity Card or Calculator.
9. **All the Candidates should take possession of their seats 30 minutes before the commencement of the examination.** A warning bell will be given 10 minutes before the commencement of the examination. another bell be given at the beginning of the examination when question papers will be distributed and the candidate should start writing the answers. **No candidate shall be admitted after 30 minutes of the commencement of the examination and shall be allowed to leave the examination hall before 45 minutes of the commencement of the examination. No candidate should leave his / her seat during last 10 minutes.** Warning bell be given 10 minutes before the closing time and final bell is given at the end of the examination. Then all the candidates should stop writing or revising the answers and should handover the answer book to the Room Superintendent.
10. **The candidates should see that, the Room Superintendent has appended his / her signature at the specified space on the answer book, before he / she hands over the Answer Book to the Room Superintendent.**
11. Smoking and taking tea or coffee or cold drink in the examination hall is strictly prohibited. However, drinking water will be supplied on request.
12. **The Candidate should check the Answer Script for any discrepancy in threading, incorrect number of pages, missing of barcode etc. and should bring the same to the notice of Room Supervisor.**
13. **Any Candidate appearing for the UG / PG examination is liable to be charged with committing malpractice in the following cases :**
    a) **Bringing** in the examination hall or being found in possession of portions of a book, manuscript, Programmable Calculator or any other **material or matter,** which is **not permissible to be brought in to the examination hall.**
    b) **Having any written matter on scribbling pad, Question Paper, Admission Ticket, Calculator, any part of the body. Kerchief, Clothes, Socks, Instrument Box, Identity Card, Scales etc.**
    c) **Copying** from the material or matter or answer of another candidate or similar aid or assistance is rendered to another candidate within the Examination Hall.
    d) **Communicating** with any candidate or any other person inside or outside the examination hall with a view to take assistance or aid to write answers in the examination.
    e) **Making any request of representation or offers any threat for inducement or inducing to bribery to Room Superintendent. or and any other official or officer of the University / College for favours** in the examination hall or to the Examiner in the answer script.
    f) **Smugglig out or smuggling in or tearing off of the answer script sheets or supplementary sheets or inserting** papers written outside the examination hall into the answer book or **running away along with answer script from the examination hall or premises.**
    g) **Impersonating** or allowing any other person to impersonate to answer in his / her place in the examination hall.
    h) **Supply of copying material** inside or from outside the examination hall.
    i) **Bringing mobile phone** to the examination hall.
    j) **Unruly behavior** inside or near the examination hall.

PUNISHABLE

REMEMBER : YOUR FUTURE IS BRIGHT. DON'T SPOIL IT.

Q. Nos.

SEMI-LOG PAPER (5 CYCLES X 1/10")

05

Subject: Electromagnetic Waves

Subject Code: 18EC55

Q. Nos.

Questions Answered
(darken the circles for answered questions)

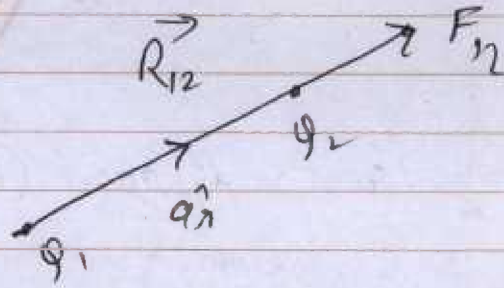
1	a	b	c	d	e
2	●	●	●	d	e
3	a	b	c	d	e
4	●	●	●	d	e
5	a	b	c	d	e
6	●	●	●	d	e
7	a	b	c	d	e
8	●	●	●	d	e
9	●	●	●	d	e
10	a	b	c	d	e

START ANSWERS FROM HERE

2. a. Expression for electric field intensity 'E' due to infinite sheet of charge density ρ_S c/m^2.

* Coloumb's law states that the force of attraction between two point charges is directly proportional to the product of the point charges and inversely proportional to the square of distance between them.

$$\vec{F} \propto \frac{Q_1 Q_2}{|\vec{R}|^2} \hat{a}_r$$



$$\vec{F} = k \frac{Q_1 Q_2}{|\vec{R}|^2} \hat{a}_r$$

$$= \frac{1}{4\pi\varepsilon_0} \frac{Q_1 Q_2}{|\vec{R}|^2} \hat{a}_r$$

$$\vec{F_{12}} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 |\vec{R_2} - \vec{R_1}|^2} \hat{a}_r = \frac{Q_1 Q_2}{4\pi\varepsilon_0 |\vec{R_2} - \vec{R_1}|^2} \frac{\hat{A_R}}{|\vec{R_2} - \vec{R_1}|}$$

$$\boxed{\vec{F} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} \hat{a}_r} \; N \text{ --- } (1)$$

Q. Nos.

* Electric field intensity is defined as the force per unit charge.
Consider a charge Q_1 placed in an electric field. Consider another point charge Q_2

* When Q_2 is brought near Q_1, a force is experienced by Q_1.
Also when Q_1 is moved around Q_2, Q_1 experiences a force.

* This force of attraction when a charge in an electric field is introduced to a point charge Q_2 per unit charge (Q_2) is called as the electric field intensity.

$$\vec{E} = \frac{\vec{F}}{Q} \quad \begin{array}{l} \text{- force} \\ \text{- charge.} \end{array} \quad -(2)$$

From equation (1)

$$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2} \hat{a}_r$$

suppose Q_1 is placed in an electric field and Q_2 be the externally introduced charge.

$$\therefore \frac{F}{Q_2} = \frac{Q_1}{4\pi\varepsilon_0 r^2} \hat{a}_r$$

From (2) $\quad \frac{F}{Q_2} = \vec{E}$

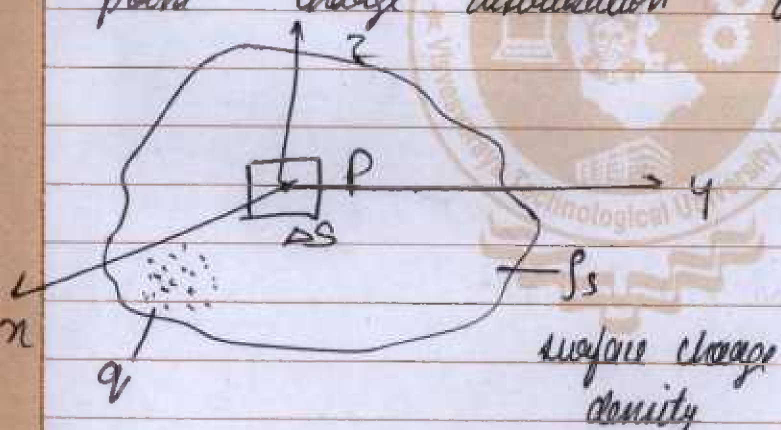
$$\Rightarrow \vec{E} = \frac{F}{Q_2} = \frac{Q_1}{4\pi\varepsilon_0 r^2}\hat{a}_r$$

$$\Rightarrow \boxed{\vec{E} = \frac{Q_1}{4\pi\varepsilon_0 r^2}\hat{a}_r} \text{ N/C or V/m} \quad — (3)$$

Considering vector notation,

$$\boxed{\vec{E} = \frac{Q}{4\pi\varepsilon_0 |r_2 - r_1|^2} \frac{\vec{R}_2 - \vec{R}_1}{|r_2 - r_1|}} \text{ N/C or V/m.}$$

* Now Consider a sheet of charge with uniform point charge distribution as shown.



* Let surface charge density be ρ_s.
* Consider an elemental point P on the surface.

Let its area be ΔS (elemental area.

* Now, total ~~tent~~ the surface charge density is equal to integral of the ρ_s.

$$\Rightarrow \int_S \rho_s . ds \quad — (A)$$

Q. Nos.

* $Q_1 = \int_s \rho_s \, d\vec{s}$ — (B)

Using (B) in equation (3)

$$\boxed{\vec{E} = \frac{\rho_s}{4\pi\varepsilon_0 \rho} \hat{a_r}} \quad V/m$$

$$\varepsilon_0 = 8.854 \times 10^{-12}$$

$$F = \frac{Q_1 Q_2}{\varepsilon_r r^2} \times 9 \times 10^9 \qquad \left[\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \ N/m \right.$$

$$\boxed{\vec{E} = \frac{\rho_s}{2\pi\varepsilon_0 \rho}} \quad V/m$$

2. b. Q_1 at $y = 7$

$20\, pC/m^2 = 20 \times 10^{-9} \ C/m^2$

Q_2 at $y = 3$

$-8\, pC/m^2 = -8 \times 10^{-9} \ C/m^2$

$Q_3 = 6\, PC/m^2 = -6 \times 10^{-9} \ C/m^2$

at $y = -1$

$Q_4 = -18 \times 10^{-9} \ C/m^2$

at $y = -4$

$$\vec{E} = \frac{\rho_s}{2\pi\varepsilon_0 \rho}$$

$$\vec{E} = \frac{Q_1}{4\pi\varepsilon_0 R^2} \hat{a_r} \quad V/m \qquad \vec{E} = \frac{\rho_s}{4\pi\varepsilon_0 \rho}$$

i) $P_A\ (2, 6, -4)$

For Q_1

$= 2a\hat{x} + (-a\hat{y}) - 4a\hat{z}$; magnitude $= \sqrt{21}$

$\rho_s = 20 \times 10^{-9}$

$$E = \frac{20 \times 10^{-9}}{4\pi\varepsilon_0 \sqrt{21}} \cdot (2a\hat{x} + a\hat{y} - 4a\hat{z})$$

$$= 39.22\,(2a\hat{x} + a\hat{y} - 4a\hat{z})$$

$$= \boxed{78.44a\hat{x} + 39.22a\hat{y} - 156.89a\hat{z}}$$

$$\frac{20 \times 10^{-9}}{2\pi\varepsilon_0 \sqrt{21}} (2a\hat{x} + a\hat{y} - 4a\hat{z}) = \cancel{78.44\,a_x}$$

$$156.88a\hat{x} + 78.44a\hat{y} - 627.52\,a\hat{z}$$

For $Q_2 = ?$

$2a\hat{x} + 3a\hat{y} - 4a\hat{z}$ $\quad \rho_s = -8 \times 10^{-9}\ c/m^2$

$$E = \frac{-8 \times 10^{-9}}{4\pi\varepsilon_0 \times \sqrt{29}} (2a\hat{x} + 3a\hat{y} - 4a\hat{z})$$

$$= -26.70a\hat{x} - 40.05a\hat{y} - 53.40a\hat{z}$$

For $Q_3 = ?$

$2a\hat{x} + 7a\hat{y} + 4a\hat{z}$ $\quad \sqrt{69}$ $\quad \rho_s = 6 \times 10^{-9}\ c/m^2$

$$E = \frac{6 \times 10^{-9}}{4\pi\varepsilon_0 \sqrt{69}} (2a\hat{x} + 7a\hat{y} - 4a\hat{z})$$

$$12.98a\hat{x} + 45.44a\hat{y} - 25.96a\hat{z}$$

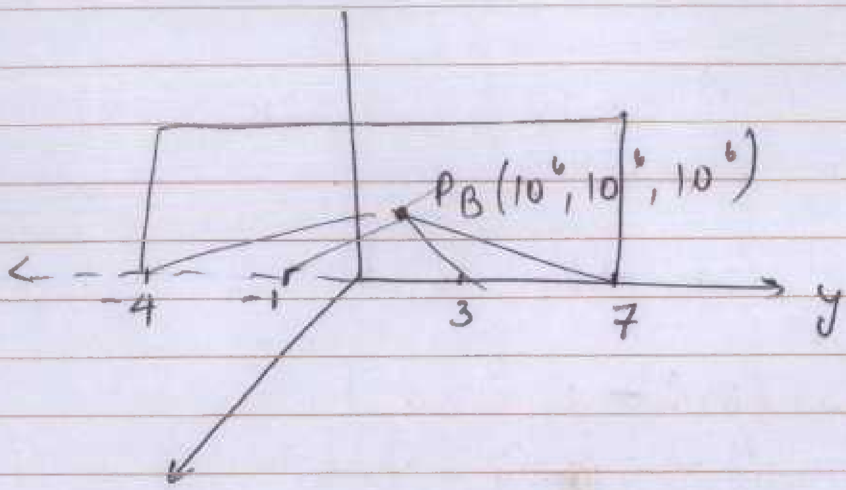
$Q_4 = ?$

$2a\hat{x} + 10a\hat{y} - 4a\hat{z}$ $\quad$ Mag $= \sqrt{120}$ $\quad \rho_s = -18 \times 10^{-9} c/m^2$

$$E = \frac{-18 \times 10^{-9}}{4\pi\varepsilon_0 \sqrt{120}} (2a\hat{x} + 10a\hat{y} - 4a\hat{z}) = -29.5a\hat{x} - 147.68a\hat{y} + 59.070a\hat{z}$$

Q. Nos.

(ii) $P_B(10^6, 10^6, 10^6)$



$$\vec{E} = \frac{Q}{4\pi\epsilon_0 R^2} \hat{a_R} \quad V/m$$

$$\vec{E} = \frac{20\times10^{-9}}{4\pi\epsilon_0 R^2} + \frac{-8\times10^{-9}}{4\pi\epsilon_0 R^2} + \frac{6\times10^{-9}}{4\pi\epsilon_0 R^2} - \frac{4\times10^{-9}}{4\pi\epsilon_0 R^2}$$

2. c. To find outward flux ψ.

cube of length 2 m.

$D = 5x^2 a_x + 10z\, a_z \quad C/m^2$

We know flux $\psi = \oint_S \vec{D}\cdot\vec{ds} \quad C$

$\psi = \oint_S \vec{D}\cdot\vec{ds} = Q$

$$= \int_0^2\int_0^2\int_0^2 5x^2 a_x + 10z\, a_z \; dx\,dy\,dz$$

$\quad x \;\; y \;\; z$

$$\int_0^2\int_0^2 \left.\frac{5x^3}{3}\right]_0^2 + \left.10zx\right]_0^2 \, dy\, dz$$

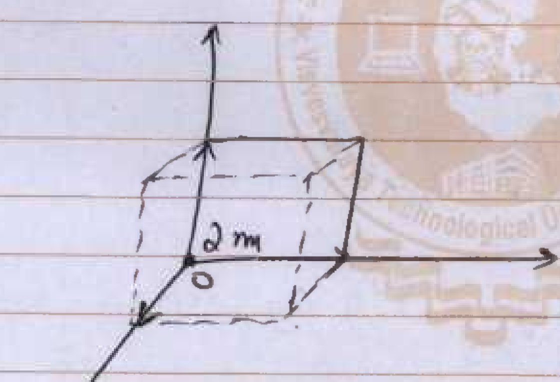
$$\int_0^2\int_0^2 \frac{40}{3} + 20z \; dy\, dz$$

$$\int_0^2 \left.\frac{40}{3}y\right]_0^2 + \left.20yz\right]_0^2 \; dz$$

$$= \int_0^2 80/3 + 40z \; dz$$

$$\left.\frac{80}{3}z + \frac{40z^2}{2}\right]_0^2$$

$$\frac{160}{3} + 80 = 133.33\ C = \psi$$



$$\psi = \oint_s \vec{D}\cdot\vec{ds} = q \qquad \text{also} \qquad q = \int_{vol} \rho_v \, dv$$

$$\oint_s \vec{D}\cdot\vec{ds} = \int_{vol} \rho_v \, dv = \int_{vol} \nabla\cdot\vec{D} \; dv$$

$$q = \int_{vol} \nabla\cdot\vec{D} \; dv$$

$$= \frac{\delta D_x}{\delta x} + \frac{\delta D_y}{\delta y} + \frac{\delta D_z}{\delta z}$$

Q. Nos.

$\Rightarrow \quad 10x\,a_x + 10 = \nabla \cdot \vec{B}$

$\int_{vol} 10x\,a_x + 10 \; dv$

$vol = 6a^2 = 24$

$= \int_0^{24} 10x\,a_x + 10 \; dx$

$\frac{10x^2}{2} + 10x \Big]_0^{24}$

$2880 + 240 = 3120\,C$

4. a. $q = 5\mu C = 5 \times 10^{-6}\,C$

From origin to $P(2, -1, 4)$

$E = 2xyz\,a_x + 2x^2 a_y + x^2 y\,a_z \quad V/m$

work $w = -Q \int_{initial}^{final} \vec{E} \cdot dL$ joules

$$\boxed{w = -q \int_B^A \vec{E} \cdot dL \text{ joule}}$$

$(0,0,0)$ to $(2,0,0) = 2\hat{a}_x + 0\hat{a}_y + 0\hat{a}_z$

$-5 \times 10^{-6} \int_0^2 \int_0 \int_0 4xyz \; dx\,dy\,dz$

$-5\times10^{-6} \int_B^A (2xyz\,a_x + x^2 2a_y + x^2 y\,a_z)(2\hat{a}_x - \hat{a}_y + 4\hat{a}_z)$

$$\cancel{\frac{4x^2yz}{2}} = \cancel{2x^2yz\Big]_0^0} - \int 4xyz - 2x^2 + 4x^2y \quad dx\, dy\, dz$$

4. b. $E = ?$ $\quad P(3, 60°, 25°)$ $\quad r \quad \theta \quad \phi$

$$V = \frac{60 \sin\theta}{r^2} \, V$$

From Potential gradient, we know,

$$\boxed{\vec{E} = -\nabla V}$$

$$\Rightarrow E = -\left[\frac{1}{\rho}\frac{\delta V}{\delta r} + \frac{1}{\rho^2}\frac{\delta V}{\delta \theta} + \frac{1}{r\sin\theta}\frac{\delta V}{\delta \phi} \right]$$

$$= -\frac{1}{3}\left[-\frac{60 \sin\theta}{r}\right] - \frac{1}{3^2}\left[\frac{-60\cos\theta}{r^2}\right] - \frac{1}{3\sin\theta} \frac{60 \sin\theta}{r^2}$$

$$= \frac{\cancel{60}^{30} \sin\theta}{\cancel{3}\rho} + \frac{60\cos\theta}{9\rho^2} - \frac{60 \sin\theta}{3 \sin\theta (9)}$$

$$r^{-2} = \frac{r^{-2+1}}{-2+1} \quad \frac{r^{-1}}{-1}$$

$$\frac{20\sin\theta}{\rho} + \frac{6.66\cos\theta}{\rho^2} - 2.22$$

$r = 3$

$\theta = 60°$

$\phi = 25°$

$$E = \frac{20\sin\theta \, \hat{a_x}}{\rho} + \frac{6.66\cos\theta \, \hat{a_y}}{\rho^2} - 2.22 \, \hat{a_z}$$

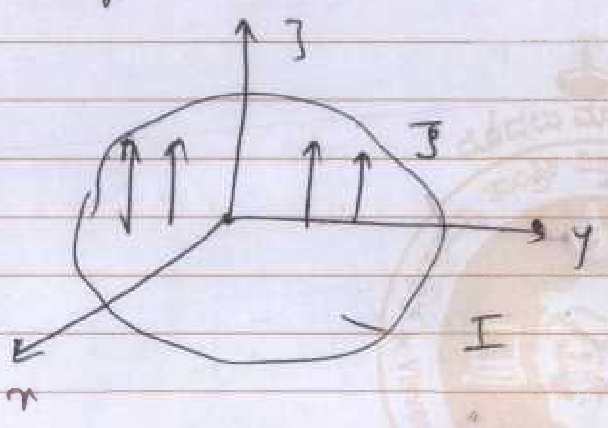
Q. Nos.

4. C. Equation of Continuity :

Consider current $I = \oint_S \vec{J} \cdot \vec{dS}$. —(1)

where $\vec{J}$ = current density.

Consider a closed surface S with current charge density J.



J is ~~moved~~ moving out of the the surface

Let I be total current enclosed within the closed gaussian surface

J is shown with upper arrows. Meaning : it is leaving the surface.

Let Q_i be the charges.

$\therefore \quad I = \frac{\Delta Q_i}{\Delta t}$ = the charges moving out of the surface.

From (1)

$$\therefore \quad I = \oint_S \vec{J} \cdot \vec{ds} = \frac{\Delta Q_i}{\Delta t} \quad \text{—(2)}$$

$$I = \oint_S \vec{J} \cdot \vec{ds} = \frac{d}{dt} \frac{Q_i}{t} \quad \text{—(3)}$$

Q. Nos.

From divergence theorem,

$$\oint_S \vec{J} \cdot \vec{ds} = \int_{vol} \rho_v \, dv$$

but $\rho_v = \nabla \cdot \vec{D}$

$$Q_1 = \oint_S \vec{J} \cdot \vec{ds} = \int_{vol} \nabla \cdot \vec{D} \, dv \quad \text{--- (4)}$$

From (3) & (4)

$$\therefore \oint_S \vec{J} \cdot \vec{ds} = \frac{d}{dt}\left[\int_{vol} \nabla \cdot \vec{D} \, ds\right]$$

taking the differential inside the volume integral on RHS,

$$\oint_S \vec{J} \cdot \vec{ds} = \int_{vol} \frac{\delta}{\delta t} \nabla \cdot \vec{D} \, ds$$

For an elementary charge (potential,

$$\vec{J} \cdot \nabla \Delta V = \frac{\delta}{\delta t} \nabla \cdot B \cdot \Delta V$$

$$\Rightarrow \boxed{\vec{J} = \frac{\delta}{\delta t} \nabla \cdot \vec{D}}$$

but $\phi = \cancel{\int_{vol} \rho_v} \, dv \quad \lim_{\Delta V \to 0} \oint \frac{\nabla \cdot \vec{D}}{\Delta V} = \rho_v$

(by divergence theorem)

$$\Rightarrow \boxed{\vec{J} = -\frac{\delta}{\delta t} \rho_v}$$

Q. Nos.

$J = -10^6 z^{1.5} a_z \quad A/m^2$

$0 \leq \rho \leq 20\,\mu m$

$z = 0.1\,m$

$I = \oint_s \vec{J} \cdot ds$

$= \int_0^{0.1} -10^6 z^{1.5} a_z (20 \times 10^{-6})\, ds$

$= 20 \times 10^{-6} \times 10^6 \int_0^{0.1} z^{1.5} a_z$

$= 20 \int_0^{0.1} z^{1.5} a_z$

$20 \left. \frac{z^{2.5}}{2.5} \right]_0^{0.1} = 8 z^{2.5} \Big]_0^{0.1}$

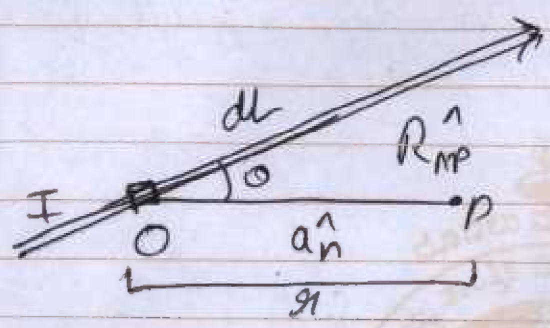
$= \underline{\underline{0.094}}$ Ampere.

$I = \int_0^{20\mu} -10^6 z^{1.5} a_z\, dz$ (0.1)

$-10^7 \times \left. \frac{\cancel{z}^{2.5}}{2.5} \right]_0^{20\mu} = 1.788 \times 10^{-19}$ A

6. a. Biot Savart's law.

Consider an infinitely moving current (linear). As shown.
Consider any point P at at distance of AP (R_{AP}) from the current.



r – distance of dl from P.

$\sin = \sin\theta$

Idl – current element

Position vector $\hat{a_n}$

Consider a small element (current element) dL.

Let the angle made by the direction of the moving current element and point P be $\sin\theta$.

Let the current element be IdL.

Magnetic field intensity is denoted by H.

As per the law,
Biot savart's law states that ~~the~~ when an infinitely moving current element is considered and any point is taken in to consideration, magnetic field intensity is

1) directly proportional to the current element
$d\vec{H} \propto Id\vec{L}$

(ii) magnetic field intensity is directly proportional to the sine of the angle θ made between the point OP and direction of current element

$$d\vec{H} \propto \sin\theta$$

(ii) inversely proportional to the square of the distance between them.

$$d\vec{H} \propto 1/r^2$$

Putting all the conditions we get

$$d\vec{H} \propto \frac{I d\vec{L} \sin\theta}{r^2} \hat{a}_r$$

$$dH \propto \frac{I dL \sin\theta}{r^2}$$

$$\Rightarrow d\vec{H} = \oint \frac{I dL \sin\theta}{r^2} \quad A/m.$$

$$d\vec{H} = \oint \frac{I dL \sin\theta}{r^2} \hat{a}_r \quad A/m$$

$$\vec{H} = \oint \frac{I dL}{r^2} \hat{a}_r \quad A/m \quad //$$

~~Also~~ ~~the~~ ~~magnetic~~ ~~field~~ ~~intensity~~ ~~is~~ ~~a~~

Also the line integral of magnetic field intensity in a closed surface is exactly equal to the amount of charge enclosed within the closed surface.

$$\oint H \cdot dl = I$$

When there is any Point P around an infinitely moving linear charge (current) element, P its magnetic field intensity $= H = \frac{I}{2\pi\rho}$ //

I - current

ρ - length of Point ~~ρ = length~~ P from current element.

6. b. $H = \frac{x+2y}{z^2} a_y + \frac{2}{z} a_z$ A/m

We know $\vec{H} = \oint \frac{I dl}{r^2} \hat{a_r}$ A/m

also $H = \frac{I}{2\pi\rho}$ A/m

$$J = \frac{\delta}{\delta t} - \delta v.$$

$$I = \oint_S J \cdot d\vec{S} \text{ Ampere}$$

$I = \frac{\Delta q}{\Delta t}$ - change of charge per unit time.

Q. Nos.

6. c. * Scalar magnetic potential: Scalar magnetic potential refers to the potential which has only magnitude and no direction of the magnetic properties.

Since potential is the amount of work done in moving a positive unit charge from point A to B and since it is scalar, therefore only the work done is mentioned and the coordinates or the location of the component is not mentioned.

Hence here in scalar magnetic potential we only know the magnitude i.e., the scalar component but not specification of direction of work done or direction or position of the magnetic field's presence.

As scalar magnetic potential has incomplete data it is not preferred in most of the situation or it is used only where the direction and position are already determined and only magnitude is to be found.

* Vector magnetic potential: we know potential is the amount of work done in moving a charge component from point A to point B.

Here in vector magnetic potential (V) the direction and positions vectors of the magnetic potential and the magnetic field (electric field), all of it is mentioned.

This is because it is a vector quantity. Both magnitude and direction is well known and specified.

A ~~mo~~ vector magnetic potential is a potential with full data of magnitude, intensity (magnetic intensity), current and the direction of its application and its position in the magnetic or electric field in which it is placed in.

8. a. Boundary condition between 2 magnetic medias.

From laplace equation, we know $\nabla^2 V = 0$.

Consider the boundary potential V_b.

Consider two laplace equations $\nabla^2 V_1 = 0$ and $\nabla^2 V_2 = 0$

such that $\nabla^2 V_1 - \nabla^2 V_2 = 0$

$$\nabla^2 (V_1 - V_2) = 0$$

Now boundary conditions for V_1 (V_{1b}) and V_2 (V_{2b})

Q. Nos.

Consider the vector relation,

$$\nabla \cdot V\vec{D} = V(\nabla \cdot \vec{D}) + \vec{D}(\nabla \cdot V)$$

Let $(V_1 - V_2)$ be the scalar component V

and $\nabla(V_1 - V_2)$ be the vector component $\vec{D}$

$$\therefore \nabla\left((V_1-V_2)\nabla(V_1-V_2)\right) = (V_1-V_2)\left(\nabla \cdot \nabla(V_1-V_2)\right) + \nabla(V_1-V_2)\left(\nabla \cdot (V_1-V_2)\right)$$

Integrating with respect to volume.

$$\int_{vol} \nabla\left(\nabla(V_1-V_2)(V_1-V_2)\right) dv = \int_{vol} \nabla^2 (V_1-V_2)(V_1-V_2)\, dv + \int_{vol} \nabla^2 (V_1-V_2)(V_1-V_2)\, dv$$

Applying divergence theorem to LHS using the boundary condition,

$$\cancel{\oint \nabla\left(\nabla(V_1-V_2)(V_1-V_2)\right)} \Rightarrow$$

$$= \oint (V_1-V_2)\ \nabla(V_1-V_2)$$

$$= \oint (V_{1b}-V_{2b})\ \nabla(V_{1b}-V_{2b})$$

$$\Rightarrow V_1 - V_2 \quad = LHS$$

RHS $\int_{vol} \nabla^2 (V_1 - V_2)^2 \, dv$

$$= \int_{vol} \left(\nabla (V_1 - V_2)^2\right)^2 dv$$

the integral of RHR goes to zero as shown

But $V_1 - V_2 \neq 0$

$$\therefore \quad \nabla^2 (V_1 - V_2)^2 = 0$$

$$(V_1 - V_2)^2 = 0$$

$$V_1 - V_2 = 0$$

$$\Rightarrow V_1 = V_2$$

When the orbital magnetic moment and spin magnetic moment cancell out each other the net magnetic moment is zero.
This is called diagmagnetic material.

When orbital magnetic moment and spin magnetic moment do not cancel each other, net magnetic moment will either allign in ~~90~~ parallel or anti symmetric.
— Ferromagnetic materials.

Q. Nos.

8. b. permittivity $= 5 \mu H/m$

$\Rightarrow 5 \times 10^{-6}$ H/m

(A) $x < 0$

20μ H/m

$= 20 \times 10^{-6}$ H/m

(B) $x > 0$

20μ H/m

$= 20 \times 10^{-6}$ H/m.

(1) $K = 150 a_y - 200 a_z$ A/m

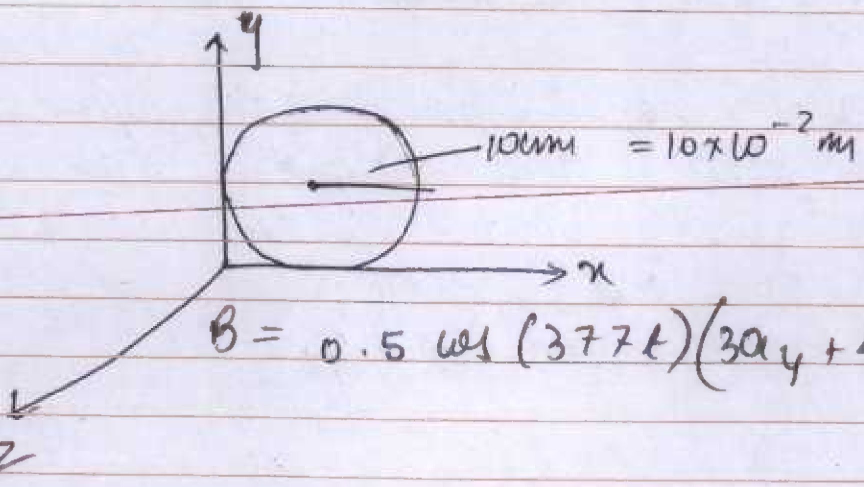
at $x = 0$

$H_A = 300 a_x - 400 a_y + 500 a_z$ A/m.

$|H_A| = \sqrt{300^2 + 400^2 + 500^2}$

(A) 707.106

8. c. radius $= 10cm = 10 \times 10^{-2}$ m



$B = 0.5 \cos(377t)(3a_y + 4a_z)$ T

Q. Nos.

area of the circular loop $= \pi r^2 = \pi(10\times10^{-2})$

$= 0.314\ m^2$

magnetic field $\times$ area

$=$

$0.157\ \cos(377t)(3a_y + 4a_z)\ T$

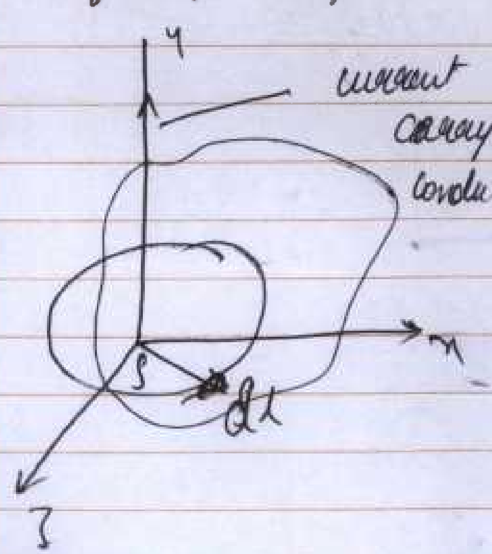
$j = \rho v \cdot v$,

$\Rightarrow v = j/\rho v$

9. a. According to ampere's law, the line integral of magnetic field intensity of a closed surface is equal to the total current enclosed within it. $\oint \vec{H}\cdot dl = I$

But Continuity equation deals with the current, and current charge density relation given by $j = -\frac{\delta}{\delta t}\rho v$

consider a current carrying conductor. (linear, infinitely long).



from figure,

$dl = \rho\, d\phi\, \hat{a_\phi}$

From magnetic field intensity for a infinitely long wire,

Q. Nos.

$$H = \frac{I}{2\pi\rho} \hat{a}_\phi$$

Now $\vec{H} \cdot dl = \frac{I \hat{a}_\phi}{2\pi\rho} \times \rho \, dl \, \hat{a}_\phi$

$$= \frac{I}{2\pi} dl$$

$$\oint_l \vec{H} \cdot dl = \int_0^{2\pi} \frac{I}{2\pi} dl$$

$$= \frac{I}{2\pi} \int_0^{2\pi} dl \Rightarrow \frac{I}{2\pi} dl \Big]_0^{2\pi}$$

$$= \frac{I}{2\pi}(2\pi) - 0 = I = \oint \vec{H} \cdot dl$$

9. b. $E = E_m \sin(\omega t - \beta z) a_y$ V/m.

$D = ?$

(i) $D = \varepsilon_0 E$

$$= 8.854 \times 10^{-12} \times E$$

$$= 8.854 \times 10^{-12} E_m \sin(\omega t - \beta z) a_y$$

$$D = \frac{Q}{4\pi r^2} \hat{a}_r$$

(ii) B = magnetic field - using biot savart's law.

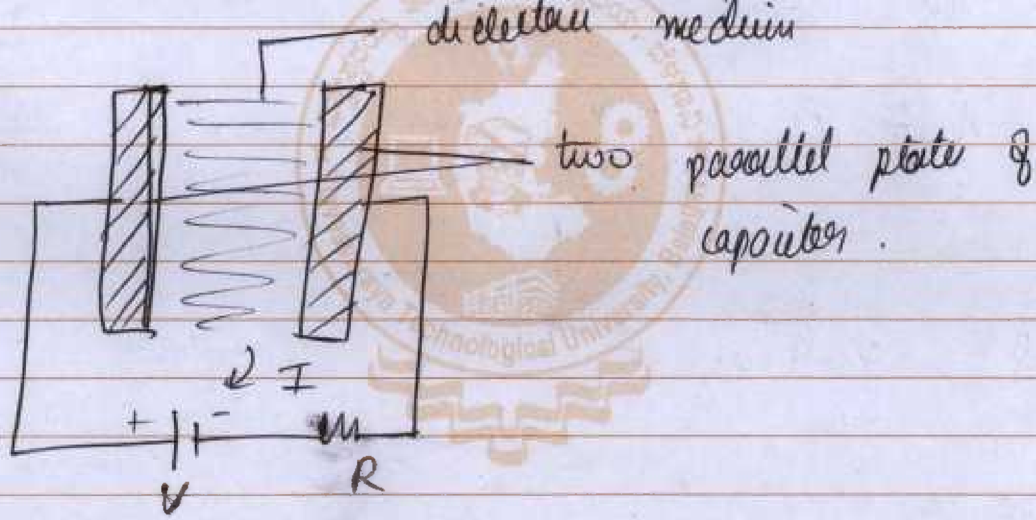
(ii) $H = ?$

from biot savart's law

$$H = \oint \frac{I\, dL \sin\theta}{4\pi r^2} \hat{a_r}$$

9. c. Consider 2 plates of a parallel plate capacitor.

It is separated by a dielectric medium M.



Output or voltage of parallel plate capacitor

$V = V_0 e^{j\omega t}$

current $I = \frac{V}{R}$

From potential, we know that

$$V = -\phi \int_A^B \vec{E} \cdot dL$$

Q. Nos.

therefore

$$I = \frac{-\phi \int_A^B \vec{E} \cdot dl}{R} \quad -(1)$$

But from Gauss laws and current density j,

$$I = \oint_s \vec{J} \cdot d\vec{s} \quad -(2)$$

using (2) in (1)

$$\oint_s \vec{J} \cdot d\vec{s} = \frac{-\phi \int_A^B \vec{E} \cdot dl}{R}$$

$$\phi = \oint_{vol} \rho_v \, dl = -\nabla V$$

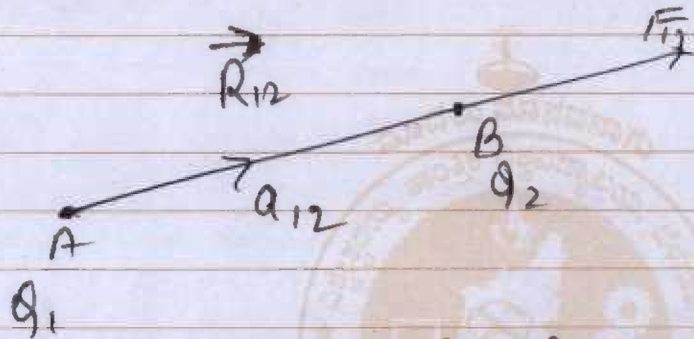
$\therefore$ Conduction current is equal to displacement current

for $V = V_0 e^{j\omega t}$

Q. Nos.

3. a. State and prove Gauss law.

~~Gauss law states the that the force of attraction between two charges is directly proportional to the product of the charges and inversely~~ proportional to the square of the distance between them.



$$F \propto \frac{Q_1 \times Q_2}{|\vec{R}_{12}|^2} \hat{a}_{12}$$

$$= \vec{F}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{Q_1 Q_2}{|\vec{R}_{12}|^2} \hat{a}_{12}$$

$$\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \Rightarrow$$

$$\vec{F}_{12} = \frac{9 \times 10^9 . Q_1 Q_2}{|\vec{R}_{12}|^2} \hat{a}_{12}$$

$$\vec{R}_{12} = \vec{R}_2 - \vec{R}_1$$

$$|\vec{R}_{12}| = |\vec{R}_2 - \vec{R}_1|$$

$$\therefore \quad \hat{a}_{12} = \frac{\vec{R}_{12}}{|\vec{R}_{12}|} = \frac{\vec{R}_2 - \vec{R}_1}{|\vec{R}_2 - \vec{R}_1|}$$

$$\therefore \vec{F_{12}} = \frac{1}{4\pi\varepsilon_0} \frac{Q_1 \cdot Q_2}{|\vec{R_2} - \vec{R_1}|^2} \cdot \frac{\vec{R_2} - \vec{R_1}}{|\vec{R_2} - \vec{R_1}|} \quad N$$

Now Gauss law : ~~that~~

$$Q = \oint_S \vec{D} \cdot \vec{ds} = \psi$$

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

Q. Nos.

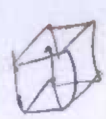
Q. Nos.

Q. Nos.

ROUGH WORK

$$E = \frac{F}{q} = \frac{q}{4\pi\varepsilon_0 r^2}\hat{a}_r$$

$$E = \frac{\rho_s}{2\pi\varepsilon_0 \rho}\hat{a}_\rho$$



$2 \quad 6a^2$

$7+1+2$
$+1$