Chhatrapati Shahu Ji Maharaj
University, Kanpur

Answer Script Details
Barcode 6434653

Roll No. 24077000697
Total Mark 63/75.00
Exam MASTER OF SCIENCE _ODD EXAM-DEC-24
Subject B010703T - ELECTROMAGNETIC THEORY

Question wise Mark Summary

Q.No	Mark	Q.No	Mark	Q.No	Mark	Q.No	Mark
1A	5/5	8A	NA/7				
1B	5/5	8B	NA/7				
1C	4/5	9A	NA/5				
1D	4/5	9B	NA/5				
1E	5/5	9C	NA/5				
1F	5/5						
1G	4/5						
1H	4/5						
1I	4/5						
2	NA/15						
3	NA/15						
4	11/15						
5A	NA/5						
5B	NA/5						
5C	NA/5						
6	12/15						
7	NA/15						

Chhatrapati Shahu Ji Maharaj University
Kanpur, Uttar Pradesh

PART-II

Date of Exam: 24/01/25 Shift: I Room No.: 24
Paper Code: B010703T Subject: E.M. THEORY Year/Sem: I/I
Name of Candidate: FARHEEN RAHMAN
Roll No.: 24077000697

Signature of Candidate | Signature of Invigilator | COE Facsimile

MARKS OBTAINED

Q.	1	2	3	4	5	6	7	8	9	10
(a)										
(b)										
(c)										
(d)										
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(f)										
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(h)										
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Total										

Total Marks in Figures | Max. Marks

Total Marks in Words

Paper Code: B010703T

Signature of Evaluator

Course: M.Sc.
Session: 2024-25 Year/Semester: I/I
Subject Name: ELECTROMAGNETIC THEORY
Medium: English ● Hindi ○

Paper Code: B010703T

Exam Date: 24012025

Name of Candidate: FARHEEN RAHMAN

Father's Name: HABIB UR RAHMAN

महाविद्यालय का कोड College Code: KN04

परीक्षा केंद्र का कोड Exam Centre Code: KN04

परीक्षा का प्रकार Type of Exam
संस्थागत Regular ● | भूतपूर्व परीक्षार्थी Ex-Student ○
व्यक्तिगत Private ○ | बैक पेपर परीक्षा Back Paper Exam ○

ANSWER BOOKLET NO. 6434653

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नामांकन संख्या Enrollement Number: CSJMA24000130954

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पेपर कोड Paper Code: B010703T

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नोट- 1. परीक्षार्थी को निर्देशित किया जाता है कि आवरण पत्र के पृष्ठ भाग पर अंकित सभी निर्देशों को सावधानी पूर्वक पढ़ें।
2. खाका में भरी जाने वाली प्रविष्टियाँ बायीं तरफ से शुरू की जायें। 3. गोलों को काले या नीले बॉलपेन से भरा जायें।

INSTRUCTION TO THE CANDIDATE FOR FILLING PART-I

1. Read the instructions carefully given on the answer script and admit card.
2. Write Date of Exam, Shift, Paper Code & Name of Subject Correctly.
3. Write Name & Roll No. Correctly.
4. Write Semester & Branch Correctly.

INSTRUCTION TO THE CANDIDATE FOR FILLING PART-III

1. Use blue or black ball point pen for writing alphabets & numerals in ☐ boxes.
2. Carefully study the example before you start marking.
3. As shown in the example below, blacken thecircles completely.

Correct Method	Incorrect Method
① ● ③ ④	✓ ✗ ◉ ◐

4. Make no Stray marks o n this sheet.

5. DO NOT WRITE OR MARK ON THE BAR CODE.

IN ORDER TO AVOD UFM (UNFAIR MEANS) :

1. The Roll No. and Answer Book no. found elsewhere or any other symbol found in the answer book will be treated as unfair means.
2. Any tempering of Bar Code and Booklet no shall be treated as Unfair Means.
3. Do Not bring the materials like slip of paper/mobile/digital diaries/ study material/ revision notes in examination hall. Possession of the mobiles/ digital diaries/electronic/digital/ watch and any other electronic gadget except memory less scientific calculator shall be considered as UFM case.
4. Do not keep or paste currency note in answer script it shall be consider as UFM.

अनुचित साधन से बचने हेतु :

1. उत्तर पुस्तिका के निर्देशित स्थान को छोड़कर अनुक्रमांक एवं उत्तरपुस्तिका का क्रमांक कहीं और न लिखे तथा कोई भी चिन्ह न बनायें क्योंकि यह अनुचित साधन प्रयोग की श्रेणी में आता है।
2. उत्तर पुस्तिका के बारकोड अथवा उत्तर पुस्तिका संख्या पर छेड़ छाड़ करने पर अनुचित साधन प्रयोग माना जायेगा।
3. परीक्षा कक्ष में निम्न वस्तुएं साथ न लायें, जैसे लिखे हुए कागज के टुकड़ें, मोबाईल, डिजिटल डायरी, डिजिटल वॉच, कॉपी, पुस्तक यह सभी वस्तुएं जो अनुचित साधन के अन्तर्गत आती है। केवल संबंधित प्रश्नपत्र में ही मेमोरी लेस साइंटिफिक कैल्कुलेटर ले जाने की अनुमति होगी।
4. उत्तर पुस्तिकाओं में रुपये न रखें न ही उत्तर पुस्तिका में चिपकायें। ऐसा करना अनुचित साधन प्रयोग की श्रेणी में आता है।

परीक्षार्थियों के लिये निर्देश

1. प्रवेश पत्र एवं उत्तर पुस्तिका पर दिये गये निर्देशों को ध्यान से पढ़ें।
2. कवर पृष्ठ के दूसरी तरफ कुछ न लिखें।
3. उत्तर पुस्तिका के पृष्ठों पर दोनों तरफ लिखें।
4. प्रश्न पत्र पर अपने अनुक्रमांक के अतिरिक्त कुछ न लिखें।
5. प्रश्न पत्र कोड एवं प्रश्न पत्र ID सावधानी पूर्वक लिखें।
6. अपनी स्थिति स्पष्ट लिखें।
7. उत्तर पुस्तिका के पृष्ठों की संख्या देखें। अगर उत्तर पुस्तिका में पृष्ठ (1-24) से कम है या फटे हुए है, तो परी शुरू होने के पूर्व दूसरी उत्तर पुस्तिका ले लें।
8. प्रश्नपत्र को देख , यदि प्रश्नपत्र के विषय कोड, विषय का नाम तथा प्रश्न में कोई त्रुटि है तो उसको परीक्षा होने के 30 मिनट के अन्दर कक्ष निरीक्षक को तत्काल सूचित करें, उसके बाद विश्वविद्यालय द्वारा कोई का नहीं की जायेगी।
9. प्रश्नों के उत्तर लिखने के लिये पेंसिल का प्रयोग न करें।
10. बी कॉपी या अतिरिक्त पन्ना नहीं दिया जायेगा।

INSTRUCTION TO THE CANDIDATE

1. Read the instructions carefully given on the Question Paper, Admit Card & Answer Script.
2. Do not write anything on back side of the cover page.
3. Write on both sides of pages of answer book.
4. Do not write anything on question paper except Roll Number.
5. Write Paper Code & Question Paper Id carefully.
6. CHECK the number of pages (1-24) or any other kind of damage in your answer script, if found than change the answer script immediately before the commencement of examination.
7. CHECK the Question Paper for any kind of discrepancy e.g. Subject Code, Su Name, and Question of the Question Paper during first THIRTY MINUTES of t commencement of the exam, so that it can be corrected in TIME. After that no corrections shall be entertained by the university.
8. Do not use pencil for answering the question.
9. Write status correctly e.g. those appearing in carry over papers should fill in statu as Carry Over. Those appearing as Ex- Students should fill in status as ex.
10. No supplementary answer book & graph paper will be provided.

INSTRUCTION TO THE CANDIDATE FOR FILLING PART-IV

1. Use blue or black ball point pen for writing alphabets & numerals in ☐ Boxes.
2. Use blue or black ball point pen for filling the circles.

	1	8	1	5	4	3	2	1	6	9
0	0	0	0	0	0	0	0	0	0	0
1	●	1	●	1	1	1	1	●	1	1
2	2	2	2	2	2	2	●	2	2	2
3	3	3	3	3	3	●	3	3	3	3
4	4	4	4	4	●	4	4	4	4	4
5	5	5	5	●	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	●	6
7	7	7	7	7	7	7	7	7	7	7
8	8	●	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9	●

Note- If your Roll No. is of 10 digits. Please leave first three columns .

Paper Code

B01070 3T

Section - A

Short Answer type Questions

Answer : 1 (a)

Maxwell's equation in Vaccum

Maxwell's given the following four equation for the vaccume

Condition for vaccum → When electromagnetic field travels in vaccum then

Charge density $\rho = 0$

Current density $J = 0$

Relative permeability $\mu = \mu_r$

Relative permeability $\varepsilon = \varepsilon_0$

Maxwell's Ist equation → $\vec{\nabla} \cdot \vec{E} = \rho / \varepsilon_0$

$\therefore \rho = 0$

$\Rightarrow \boxed{\vec{\nabla} \cdot \vec{E} = 0}$

2nd maxwell's equation → $\boxed{\vec{\nabla} \cdot \vec{B} = 0}$

3rd Maxwell's equation → $\vec{\nabla} \times \vec{E} = -\mu \frac{d\vec{H}}{dt}$

$\mu = \mu_0 \mu_r \quad \therefore \mu_0 = 1$

$$\boxed{\vec{\nabla} \times \vec{E} = -\mu \frac{dH}{dt}}$$

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8	0	1	0	7	0	3	T

Forth Maxwell's equation → $\vec{\nabla} \times \vec{H} = \vec{J} + \varepsilon_0 \frac{d\vec{E}}{dt}$

$\therefore J = 0$

$$\vec{\nabla} \times \vec{H} = \varepsilon_0 \frac{d\vec{E}}{dt} \quad \text{or}$$

$$\vec{\nabla} \times \vec{H} = \frac{d\vec{D}}{dt}$$

Maxwell's equation in matter

Ist Maxwell's equation → $\vec{\nabla} \cdot \vec{E} = \frac{\rho_b}{\varepsilon_0}$

$$\boxed{\vec{\nabla} \cdot \vec{E} = \rho_b}$$

IInd Maxwell's equation → $\boxed{\vec{\nabla} \cdot \vec{B} = 0}$

3rd Maxwell's equation →

$$\boxed{\vec{\nabla} \times \vec{E} = -\mu \frac{d\vec{H}}{dt}}$$

IV Maxwell's equation →

$$\boxed{\vec{\nabla} \times \vec{H} = J_b + \frac{d\vec{D}}{dt}}$$

where

J_b = Bound density due to bound charge

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Answer : 1(b)

Displacement current → Displacement current is defined as, " A current generated due to accelerated charge particle which imposed to vary electric field and changing magnetic flux, is known as 'displacement current'.

It is represented by 'i_d' where subscript d shows displacement.

The related density in displacement current is called 'Displacement current density' which represent by 'J_D'

According to maxwell's,

$$i_d = \varepsilon_0 \frac{d\phi}{dt} \quad -①$$

$\therefore$ flux $\phi = EA$

A = area

$$i_d = \frac{\varepsilon_0 d EA}{dt}$$

$$\frac{i_d}{A} = \varepsilon_0 \frac{dE}{dt} \quad -②$$

and we know $J = \frac{i_d}{A}$ $-③$

then equation ② becomes

$$J = \varepsilon_0 \frac{dE}{dt}$$

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and $i_d = \varepsilon_0 \frac{d\phi}{dt}$

This is the required displacement current

and displacement current density J_D

$$J_D = \frac{d\vec{D}}{dt}$$

$$J_D = \varepsilon_0 E \omega$$

This is the related density known as displacement current density.

Answer : 1(c)

Poynting Theorem :- The Poynting theorem is work energy theorem which states that, " Change in the work done of particles of system by electro-magnetic force at instant time is equivalent to the decrease in change in electromagnetic energy with energy released througout the surface." is known as poynting theorem.

$$-\vec{J}\cdot\vec{E} = \frac{d}{dt}U_{em} + \vec{\nabla}\cdot\vec{S}$$

where,

$\vec{J}\cdot\vec{E} \rightarrow$ is total energy per unit volume supplied to the system

$\frac{d}{dt}U_{em} \rightarrow$ is changing electromagnetic energy in electromagnetic fields.

$\vec{\nabla}\cdot\vec{S} \rightarrow$ is the energy released througout the surface

Application $\rightarrow$ Poynting theorem is basically work-energy theorem in which we can find the workdone by electromagnetic fields on charge 'q' at an instant of time dt.

$$\frac{dW}{dt} = -\frac{d}{dt}U_{em} + \vec{\nabla}\cdot\vec{S}$$

Answer : 1 (d)

Boundary condition $\rightarrow$

1) $D_{1n} - D_{2n} = \sigma$

a) Normal component of electric displacement vector is not continuous

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while which difference of them is equal to the surface charge density.

b) Electric displacement vector are 'normal' to the interface.

2) $B_{1n} - B_{2n} = 0$

a) Normal component of magnetic induction B is contineous.

b) Magnetic induction is normal to the interface.

3) $E_{1t} - E_{2t} = 0$

a) Tangential component of electric field vector is contineous.

b) Tangential component of electric field vector is perpendicular to the interface.

4) $H_{1t} - H_{2t} = J_{s\perp}$

a) Tangential component of Magnetic field strength is not contineous.

b) Difference of tangential component of magnetic field strength is equal to the current density.

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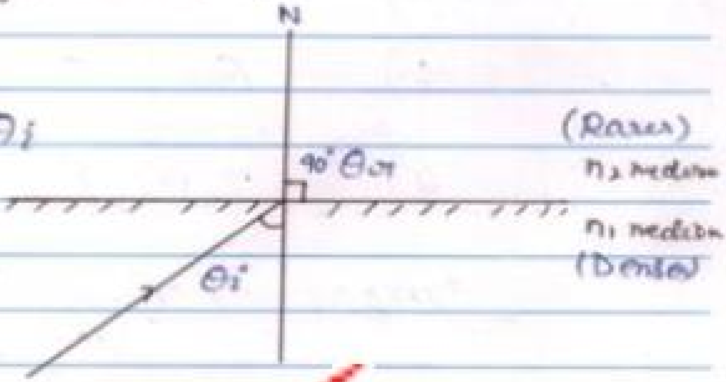
7

Answer: 1(e)

Total Internal Reflection →

The angle at which angle of incidence is θ_i when angle of refraction goes to 90° is called 'critical angle θ_c'



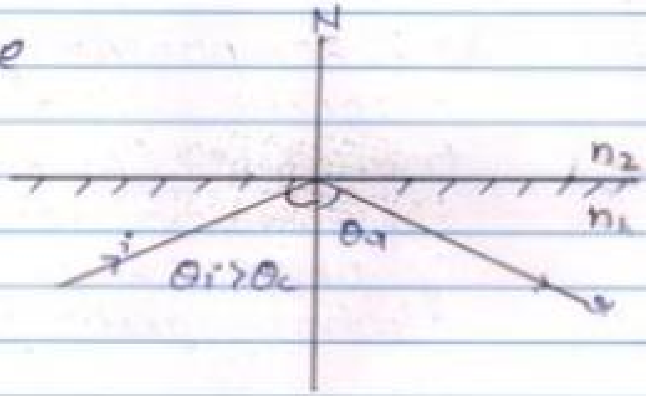
by snell's law, $\frac{\sin\theta_i}{\sin\theta_r} = \frac{n_2}{n_1} = \sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$

$$\frac{\sin\theta_c}{\sin 90°} = \frac{n_2}{n_1} = \sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$$

$$\boxed{\theta_c = \sin^{-1}\sqrt{\frac{\varepsilon_2}{\varepsilon_1}}}$$

Total internal reflection is defined as

"when angle of incidence is greater than the critical angle then ray is reflected back in its first medium". this pheno-menon is called "Total internal reflection".



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Condition for total internal reflection →

1) $\theta_i > \theta_c$

2) $n_1 > n_2$

Importance → This phenomenon is play the most important role in the nature like scattering refractive index, [illegible] fibre etc.

Answer : 1(f)

TM Mode	TE Mode
1) It is transverse magnetic mode	It is transverse electric mode.
2) Z component of magnetic field is transverse (or ⊥) to the net direction of propagation of electromagnetic wave. i.e, $H_z = 0$	Z component of electric field is transverse (or ⊥) to the net direction of propagation of electromagnetic waves. i.e, $E_z = 0$
3) TM mode	TE mode satisfies

satisfied for circular and rectangular wave guide.	circular and rectangular waveguide.
4) fields components are	fields components are
$E_x = -\frac{j\beta}{h^2}\frac{\partial E_z}{\partial x}$	$E_x = -\frac{j\beta}{h^2}\times 0 - \frac{j\omega\mu}{h^2}\frac{\partial H_z}{\partial y}$
$E_y = -\frac{j\beta}{h^2}\frac{\partial E_z}{\partial y}$	$E_y = +\frac{j\omega\mu}{h^2}\frac{\partial H_z}{\partial x}$
$H_x = \frac{j\varepsilon\omega}{h^2}\frac{\partial E_z}{\partial y}$	$H_x = -\frac{j\beta}{h^2}\frac{\partial H_z}{\partial x}$
$H_y = -\frac{j\varepsilon\omega}{h^2}\frac{\partial E_z}{\partial x}$	$H_y = -\frac{j\beta}{h^2}\frac{\partial H_z}{\partial y}$

Answer (g)

Dielectric materials → Dielectric material are those whose properties are different in different medium.

$$\varepsilon_r(\omega) = \chi_e(\omega)$$

$\varepsilon_r(\omega)$ = dielectric

$\chi_e(\omega)$ = Susceptibility

The electromagnetic field are different

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in this material and change current density and charge density etc properties in the all direction.

Answer (h)

Cut Off frequency → The cut off frequency is the minimum frequency 'f_c' at which signal pass through the waveguide.

$$f_c = \frac{1}{2\pi\sqrt{\mu\varepsilon}}\sqrt{\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2} \quad -①$$

Where,

μ = permeability of dielectric medium in wave guide

ε = permittivity of medium

f_c = cut off frequency

m = Half cycle in electric field

n = half cycle in magnetic field

a = Bigger dimension of wave guide

b = Smaller dimension of

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waveguide

Power × Area = Power average.

$$P_{avg} = \frac{E_{0x}^2}{2\eta} \vec{S}$$ —③

η = intrinsic material

eq. ② write as $P_{avg} = \frac{E_{0x}^2}{2\eta} ab$

which relates to the cut off frequency components a & b.

Case - I $f > f_c$

f = Incident signal (input signal) frequency
f_c = Cut off frequency

then wave propagate in waveguide

Case - II $f = f_c$ no propagation.

Case - III $f < f_c$ wave signal never be propagate in the waveguide.

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Answer-(2)

Cavity Resonator → If the cylindrical waveguide has the finite length. and conductor of waveguide is purily conductor and the hollow of waveguide in vaccume then this is called the 'cavity resonator' has higher frequency

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Type of Cavity Resonator

1. Regulated cavity resonator
2. Unragulated Cavity resnator
3. Inductance cavity resonator
4. Capacitive cavity resonator
5. Waveguide cavity resonator

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Section - B

Long Answers type Qutions-

Gauge → The gauge is the transformation of field components and electromagnetic potential.

Gauge Transformation → If we transform the electromagnetic potential (known as vector potential '$\vec{A}$' and scalar potential 'ϕ') is such a way that electric field and magnetic fields remains invarient are unchanged then this transformation is called Gauge transformation.

Invarience of Gauge Transformation.

Let transforms scalar potential

$$\phi' = \phi + \beta \quad -①$$

and vector potential

$$A \rightarrow A' = A + \alpha \quad -②$$

then we know that

$$\vec{B} = \vec{\nabla} \times \vec{A}$$

$$\vec{E} = -\frac{\partial \vec{A}}{\partial t} - \nabla\phi$$

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$$B' = B$$

$$\nabla \times A' = \nabla \times A$$

$$\nabla \times (A + \alpha) = \nabla \times A$$

$$\nabla \times A + \nabla \times \alpha = \nabla \times A$$

$$\nabla \times \alpha = 0$$

we know

curl of gradient of scalar is zero

$$\boxed{\alpha = \nabla \lambda} \quad -③$$

and

$$E' = E'$$

$$-\frac{\partial A'}{\partial t} - \nabla \phi' = -\frac{\partial A}{\partial t} - \nabla \phi$$

we get

$$\boxed{\beta = -\frac{\partial \lambda}{\partial t}} \quad -④$$

put in eq. ① & ②

$$\boxed{\phi \rightarrow \phi' = \phi - \frac{\partial \lambda}{\partial t}}$$

$$\boxed{A \rightarrow A' = A + \nabla \lambda}$$

} Gauge transformation eqn

These eqn are guage transformation eqn

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For B → Invarience of Gauge for magnetic field

$B' = B$

$\nabla \times A' = (\nabla \times A) = B$

$\nabla \times (A + \nabla\lambda) = (\nabla \times A) = B$

$\nabla \times A + \nabla \times \nabla\lambda = (\nabla \times A) = B$

$B + 0 = B$

$$\boxed{B' = B'} \quad -⑤$$

magnetic field is invarient in guge transfomation. proved

Invarient of Gauge for electric field

for E →

$E' = E$

$E' = -\frac{\partial A}{\partial t} - \nabla\phi$

$E' = -\frac{\partial}{\partial t}(A' - \nabla\lambda) - \nabla(\phi' + \frac{\partial\lambda}{\partial t})$

$E' = -\frac{\partial A'}{\partial t} + \frac{\partial \nabla\lambda}{\partial t} - \nabla\phi' - \nabla\frac{\partial\lambda}{\partial t}$

$\therefore E' = -\frac{\partial A'}{\partial t} - \nabla\phi'$

$$\boxed{E' = E'} \quad -⑥ \text{ proved}$$

eqn ⑤ and ⑥ shows that em field are invarient under guge transfomation.

" The invarience of em field under guge transfomation is known 'Gauge Invarience'."

Do Not Write anything in this Portion

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Type of Gauge

1) Lorentz Gauge →

maxwell equation in terms of scalar ϕ and vector A potential are

$$\nabla^2 A - \mu\epsilon\frac{\partial^2 A}{\partial t^2} - \nabla\left(\nabla\cdot A + \mu\epsilon\frac{\partial \phi}{\partial t}\right) = -\mu J \quad -①$$

$$\nabla^2 \phi - \mu\epsilon\frac{\partial^2 \phi}{\partial t^2} + \frac{\partial}{\partial t}\left(\nabla\cdot A + \mu\epsilon\frac{\partial \phi}{\partial t}\right) = -e/\epsilon \quad -②$$

these equation are coupled it vanishes if:

Lorentz condition applying.

$$\nabla\cdot A + \mu\epsilon\frac{\partial \phi}{\partial t} = 0$$

we get

$$\nabla^2 A - \mu\epsilon\frac{\partial^2 A}{\partial t^2} = -\mu J \quad -③$$

$$\nabla^2 \phi - \mu\epsilon\frac{\partial^2 \phi}{\partial t^2} = -e/\epsilon \quad -④$$

Use D Alembert operator

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$$\Box = \nabla^2 - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}$$

we get

$$\left.\begin{aligned} \Box A &= -\mu J \\ \Box \phi &= -\rho/\epsilon \end{aligned}\right\} - (5)$$

These eq^n similar as poisson equation

Lorentz condition is invarient under gauge transfomation →

gauge transfomation,

$$\phi \to \phi' = \phi - \frac{\partial \lambda}{\partial t}$$

$$A \to A' = A + \nabla\lambda$$

this is apply on Lorentx condition

$$\nabla \cdot A + \mu\epsilon\frac{\partial \phi}{\partial t} = 0$$

we get

$$\Box \lambda = 0 \quad - (6)$$

If eq^n (6) satisfied by Lorentx then Lorentx is invavent under guge transfomation

Do Not Write anything in this Portion

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2) Coulomb Gauge →

This guge shows that,

"Scalar potential is just instantaneous to the electrostatic potential."

for static med condition

Coulomb condition $\nabla \cdot A = 0$

then

we get the solution of ϕ & A

$$A(r,t) = \frac{\mu}{4\pi} \int \frac{J'(r',t)\, dv'}{|r - r'|}$$

and

$$\phi(r,t) = \frac{1}{4\pi\epsilon} \int \frac{\rho(r',t)\, dv'}{|r - r'|}$$

which show scalar potential is electrostatic potential

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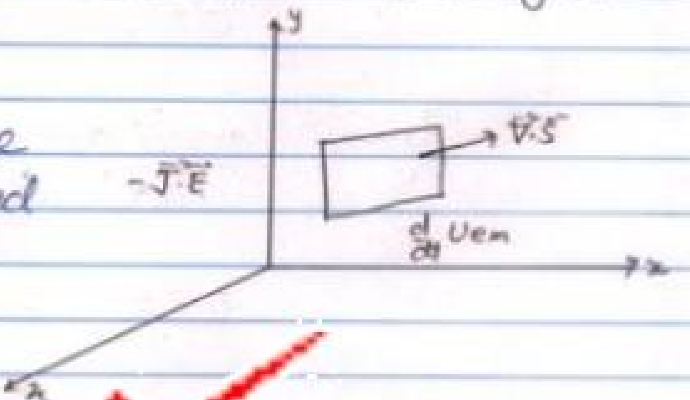
Section : C

Poynting Theorem → This theorem is work enegy theorem that states, " The total work done of (charge particle q is done by the electromagnetic force at instante of time dt, is equavalent to the decrease in enesy stored in the electromagnetic field and enesy releesed througout the surface."

Proof → suppose some current and charge distribution in system at time t then how much work done is done



by the p charge particle by electromagnetic field at instant of time 't'.

The Lorentz force

$$F = q(E + v \times B) \cdot v\,dt$$

we know $\rho dv = q$

at work done $\frac{dw}{dt}$ is the total power w t per unit time per unit area

$$\frac{dW}{dt} = -\int (E \cdot J)\, d\tau$$

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$$\frac{dW}{dt} = -J \cdot E \quad -①$$

The energy is

$$U_e = \frac{1}{2}\varepsilon_0 E^2$$

$$U_m = \frac{1}{2}\mu_0 H^2$$

$$\frac{d}{dt} U_{em} = \frac{d}{dt}\int \frac{1}{2}(B \cdot H + E \cdot D) \quad -②$$

by curl of maxwell ③ equation and ④ equation we get

$$\nabla^2 E = \mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2} \quad -③$$

$$\nabla^2 H = \mu_0 \varepsilon_0 \frac{\partial^2 H}{\partial t^2} \quad -④$$

when we subtract these equation by multiple ∇

$$\nabla \cdot (\nabla \times E) - \nabla \cdot (\nabla \times H) = \frac{d}{dt}\left(\frac{1}{2}\mu_0 H^2 + \varepsilon_0 E^2\right) + J \cdot E \quad -⑤$$

$$-\vec{\nabla} \cdot \vec{S} = \frac{d}{dt}\left(\frac{1}{2} B \cdot H + D \cdot E\right) + J \cdot E$$

we get that $S = E \times H$ put after

we transfom eq^n as.

$$\vec{\nabla}\cdot\vec{S} + \frac{d}{dt}\left(\frac{1}{2} D\cdot E + B\cdot H\right) = +J\cdot E \quad (6)$$

using equation ①

$$\frac{dW}{dt} = -J\cdot E$$

$$\vec{\nabla}\cdot\vec{S} + \frac{d}{dt}\left(\frac{1}{2} D\cdot E + B\cdot H\right) = -\frac{dW}{dt} \quad (7)$$

on the integration both side we get

$$-\int J\cdot E\, dV = \frac{d}{dt}\int \frac{1}{2}(D\cdot E + B\cdot H)\, dV + \int \vec{\nabla}\cdot\vec{S}\, dV \quad (8)$$

or

$$-\int J\cdot E\, dV = \int \frac{d}{dt} U_{em} dV + \int \vec{\nabla}\cdot\vec{S}\, dV \quad (9)$$

This is the integral for of poynting theorem

equation ⑨ becomes write as

$$-J\cdot E = \frac{d}{dt} U_{em} + \vec{\nabla}\cdot\vec{S} \quad (10)$$

This is the differential form of

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poynting theorem.

Application →

* poynting theorem says that, " power per unit volume supplied to the system is $-J \cdot E$

* and energy is stored in the electro magnetic field is $\frac{dU_{em}}{dt}$

* lastly the energy which are througout the surface is $\nabla \cdot \vec{S}$

* This theorem is very useful in conservation theorem and work energy principle.

* widely used to finding the total workdone done by the system in instant time.

* This provides the conservation laws of momentum ; energy and work done principle and so on. .

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$P_{avg} = \frac{E_0 h}{2\eta} s = P_b$

$\nabla \times H = J_c + \frac{\partial D}{\partial t}$

$\nabla \times E = -\mu_0 \frac{dH}{dt}$