"Dissemination of Education for Knowledge, Science and Culture"
-Shikshanmaharshi Dr. Bapuji Salunkhe

Shri Swami Vivekanand Shikshan Sanstha, Kolhapur

Vivekanand College, Kolhapur (Autonomous)

Department of Physics

M.Sc. Part- I

Electrodynamics

Surprise Test

Date : 23/04/2022 | **Total Marks: 20**
Day: - Saturday | **Time :- 2pm to 3pm**

Instructions:-

1) All questions are compulsory.
2) Figures to the right indicate full marks.
3) Use of log table and calculator is allowed.

Q. 1) Select most correct alternative. **(05)**

i) Displacement current is.........

a) D b) J c) $\partial D/\partial t$ d) $\partial J/\partial t$

ii) The second Maxwell's equation is.....

a) $\nabla.\bar{B} = 0$ b) $\nabla.\bar{B} = \rho$ c) $\nabla.\bar{B} = \sigma$ d) $\nabla.\bar{B} = E$

iii) Energy density in electric field is given as ......

a) $u_e = \frac{1}{2}\mu_0 H^2$ b) $u_e = \frac{1}{2}\epsilon_0 E^2$
c) $u_e = \frac{1}{2}\mu_0 H$ d) $u_e = \frac{1}{2}\mu_0 B^2$

iv) The relation between magnetic flux density and vector potential is......

a) B = Curl(A) b) A = Curl(B) c) B = Div(A) d) A = Div(B)

v) Choose the correct alternative

a) $B = \mu H$; $D = \epsilon E$ b) $D = \mu E$; $B = \epsilon H$
c) $D = \mu H$; $B = \epsilon E$ d) $B = \mu \epsilon H$; $D = \mu\epsilon E$

Q. 2 Write a short note on Lorentz Gauge. **(05)**

Q. 3 Derive the relation for Poynting vector. **(10)**

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Vivekanand College, Kolhapur (Autonomous)
Department of Physics
M.Sc. Part- I
Electrodynamics
Surprise Test
Attendance Sheet

Date : 23/04/2022

Roll. No.	Name of Candidate	Sign
1601	Chougule Shraddha S.	Chougule.
1603	Dayama Abhishek Ashok	Dayama
1604	Gaikwad Aishwarya Suryakant	Gaikwad
1605	Gaikwad Divya Ramesh	Divya
1606	Gawade Sayali Shantaram	SGawade
1608	Hirave Pravin Prakash	Phirave
1607	Nikhil Sandeep Jadhav	NJadhav
1609	Jamadar Wahida S.	wahida
1611	Kakade Seema Vishnu	[illegible]
1615	Kandekar Pooja Sanjay	PKandekar
1617	Khokhar Sarej R	Saroj
1618	Khot priyanka Balaso	PKhot
1623	Sammed Rajendra Latthe	Latthe
1627	Akansha Bhimrao Patil	PatilA
1628	Rajay Jayawant Patil	PPatil
1629	Patil sanjayita Sanjay	Sanjay
1630	Patil Shrutika Jaysingh	SJP.
1631	Rohan Raju Sonkamble	RRS
1632	Sayyad Afsaba J	ASJ

Teacher Incharge........ ShindeAV
(Mr. A.V. Shinde)

Head of the
Department of Physics
Vivekanand College, Kolhapur

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Vivekanand College, Kolhapur (Autonomous)

Department of Physics

M.Sc. Part- I

Electrodynamics

Surprise Test

Result

Date : 23/04/2022

Roll. No.	Marks	Roll. No.	Marks
1601	13	1625	—
1602	-	1626	-
1603	04	1627	05
1604	17	1628	06
1605	09	1629	10
1606	11	1630	11
1607	—	1631	11
1608	08	1632	09
1609	09		
1610	—		
1611	16		
1612	—		
1613	—		
1614	—		
1615	16		
1616	—		
1617	11		
1618	13		
1619	—		
1620	—		
1621	—		
1622	—		
1623	05		
1624	0-		

Teacher Incharge........ShindeAV.................
(Mr. A.V. Shinde)

Head of the
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Vivekanand College, Kolhapur

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- शिक्षणमहर्षी डॉ. बापूजी साळुंखे

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VIVEKANAND COLLEGE, KOLHAPUR (AUTONOMOUS)

SUPPLIMENT 7/20

Signature of Supervisor	
Subject :	Electrodynamics
Test / Tutorial No. :	
Div. :	

Suppliment No. :

Roll No. : 1604

Class : M.Sc. Ist [Sem IInd]

Que-1 Select correct alternatives.

1.) Displacement Current is denoted by -
c.) $\partial \vec{D} / \partial t$

2.) Second Maxwell's eq^n is -
b.) $\nabla \cdot \vec{B} = 0$

3.) Energy density in electric field is given as,
d.) $\frac{1}{2} \varepsilon_0^2 E^2$

4.) The relation b/w mag. flux density & vector Potential -

5.) Choose correct alternative.
c.) $B = \mu H$.

Ques Write short note of on Lorentz's Gauge.

Ans:-

Lorentz's Gauge:- we know that, in electromagfield there are scaler and vector potential equation given by maxwell's.

Scaler :- $$-\frac{\rho}{\varepsilon} = \nabla^2\phi + \frac{\partial}{\partial t}\left(\nabla\vec{A} + \mu\varepsilon\frac{\partial\phi}{\partial t}\right) - \mu\varepsilon\frac{\partial^2\phi}{\partial t^2}$$

Vector :- $$-\mu J = \nabla^2\vec{A} - \nabla\left(\nabla\vec{A} + \mu\varepsilon\frac{\partial\phi}{\partial t}\right) - \mu\varepsilon\frac{\partial^2\vec{A}}{\partial t}$$ — ①

Now,

from the lorentz's condition -

$$\left[\nabla\vec{A} + \mu\varepsilon\frac{\partial\phi}{\partial t}\right] = 0$$

hence, eq^n ① becomes,

$$-\frac{\rho}{\varepsilon} = \nabla^2\phi - \mu\varepsilon\frac{\partial^2\phi}{\partial t^2}$$
$$-\mu J = \nabla^2\vec{A} - \mu\varepsilon\frac{\partial^2\vec{A}}{\partial t^2}$$ — ②

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further simplifing -

$$-\frac{\rho}{\varepsilon} = \left[\nabla^2 - \mu\varepsilon\frac{\partial^2}{\partial t^2}\right]\phi$$
$$-\mu J = \left[\nabla^2 - \mu\varepsilon\frac{\partial^2}{\partial t^2}\right]\vec{A}$$ — ③

from the Phase velocity of electromagnetic field,

$$v = \frac{1}{\sqrt{\mu\varepsilon}}$$

$$\Rightarrow \mu\varepsilon = \frac{1}{v^2}$$

putting the value of $\mu\varepsilon$ in the above eq^n -

$\therefore \quad -\frac{\rho}{\varepsilon} = \left[\nabla^2 - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right]\phi$

$-\mu J = \left[\nabla^2 - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right]\vec{A}$ ——— (4)

Here we are consider —

$$\left[\nabla^2 - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right] = \Box^2$$ — D'Alembratian operator.

$$= \left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right]$$

Now from; eqn (4) becomes as —

$\therefore$

$-\frac{\rho}{\varepsilon} = \Box^2\phi$

$-\mu J = \Box^2\vec{A}$ ——— (5)

So, above equation shows coupled differential equation of vector potential $\vec{A}$ + scaler ϕ. Now we are introducing new scaler 'λ'.

Here,

$\vec{A}' = \vec{A} + \nabla\lambda \Rightarrow \vec{A} = \vec{A}' - \nabla\lambda$

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

from the Lorentz's condition —

$\left[\nabla\vec{A} + \mu\varepsilon\frac{\partial\phi}{\partial t}\right] = 0$ --- [from old Lorentz's condn]

Now putting the values of $\vec{A}$ + ϕ

$\left[\nabla\vec{A} + \mu\varepsilon\frac{\partial\phi}{\partial t}\right] = 0$

$\left[\nabla(\vec{A}' - \nabla\lambda) + \mu\varepsilon\frac{\partial}{\partial t}\left(\phi' + \frac{\partial\lambda}{\partial t}\right)\right] = 0$

$\nabla\vec{A}' - \nabla^2\lambda + \mu\varepsilon\frac{\partial}{\partial t}\phi' + \mu\varepsilon\frac{\partial\lambda}{\partial t} = 0$

$$\nabla\vec{A}' + \mu\varepsilon \frac{\partial \phi'}{\partial t} = \nabla^2 \lambda - \mu\varepsilon \frac{\partial \lambda}{\partial t}$$

$$\nabla\vec{A}' + \mu\varepsilon \frac{\partial \phi'}{\partial t} = \left(\nabla^2 - \mu\varepsilon \frac{\partial}{\partial t}\right)\lambda \quad \text{--- (6)}$$

Phase velocity, we know it

$$v = \frac{1}{\sqrt{\mu\varepsilon}} \Rightarrow \mu\varepsilon = \frac{1}{v^2}$$

from eq^n (6)

$$\nabla\vec{A}' + \mu\varepsilon \frac{\partial \phi'}{\partial t} = \left[\nabla^2 - \frac{1}{v^2}\frac{\partial}{\partial t}\right]\lambda \quad \text{--- (7)}$$

Hence,

$$\left[\nabla^2 - \frac{1}{v^2}\frac{\partial}{\partial t}\right] = \Box^2$$

Now eq^n (7) is becomes,

$$\nabla\vec{A}' + \mu\varepsilon \frac{\partial \phi}{\partial t} = \Box^2 \lambda$$

from the Lorentz's condition

$$\boxed{\Box^2 \lambda = 0}$$

∴ In the electromagnetic field new vector potential $\vec{A}'$ and scaler ϕ' are

and transformation of $\vec{A} \rightarrow \vec{A}'$ and $\phi \rightarrow \phi'$ shows Lorentz's gauge transformation.

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VIVEKANAND COLLEGE, KOLHAPUR (AUTONOMOUS)

SUPPLIMENT

16/20

Signature of Supervisor	

Suppliment No. :

Roll No. : 1611

Class : MSC – I (physics)

Subject : Electrodynamics

Test / Tutorial No. :

Div. :

Q.1

1) a) $\vec{B}$

2) b) $\nabla \cdot \vec{B} = 0$

3) b) $\frac{1}{2} \epsilon_0 \vec{E}^2$

4) a) $\cancel{\nabla \times}$ $B = \nabla \times A$

5) c) $B = \mu H$

Q.2 Poynting vector

the wordone is defined as

$dW = \vec{F} \cdot \vec{dl}$ .... ①

where $\vec{F}$ is lorentz force acting on charg q

$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$

and $\vec{dl}$ is small displacement

$\vec{v} = \frac{\vec{dl}}{dt}$

$\therefore \vec{dl} = \vec{v} \cdot dt$

eq^n ① becomes

$dW = q(\vec{E} + \vec{v} \times \vec{B}) \cdot \vec{v} \cdot \vec{dt}$

$= q(\vec{E} \cdot \vec{v}) \vec{dt} + q(\vec{v} \times \vec{v} \cdot \vec{B}) dt$

$dW = q(\vec{E} \cdot \vec{v}) \vec{dt}$

$\frac{dW}{dt} = q(\vec{E} \cdot \vec{v})$ .... ②

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we know that charge q is defined as,

$q = \int \rho \, dV$ $\qquad \rho = \frac{dq}{dV}$

eq^n ② becomes $\qquad dq = \rho \, dV$.

$\frac{dW}{dt} = \int \rho (\vec{E} \cdot \vec{v}) \, dV$ $\qquad q = \int \rho \, dV$

but current density $\vec{J} = \rho \cdot \vec{v}$

$\frac{dW}{dt} = \int \vec{J} \cdot \vec{E} \cdot dV$

$\frac{dW}{dt} = \int \vec{E} \cdot \vec{J} \, dV$ .... ③

above eq^n ③ shows that, the total work done per unit time is dot product of integration of electric field $\vec{E}$ & current density $\vec{J}$ over the volume v.

we know that Maxwells four eq^{n}s are

i) $\nabla \vec{E} \,/\, \nabla \vec{D} = 0$ ii) $\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$

iii) $\nabla \vec{B} = 0$ iv) $\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

Maxwells fourth eq^{n}s is

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

$$\therefore \vec{J} = \nabla \times \vec{H} - \frac{\partial \vec{D}}{\partial t}$$

premultiplying by $\vec{E}$ we get

$$\vec{E} \cdot \vec{J} = \vec{E}(\nabla \times \vec{H}) - \vec{E} \cdot \frac{\partial \vec{D}}{\partial t} \quad \ldots\ldots (4)$$

$$\therefore \nabla(\vec{E} \times \vec{H}) = \vec{H}(\nabla \times \vec{E}) - \vec{E}(\nabla \times \vec{H})$$

$$\therefore \vec{E}(\nabla \times \vec{H}) = \vec{H}(\nabla \times \vec{E}) - \nabla(\vec{E} \times \vec{H})$$

$$\therefore \vec{E}(\nabla \times \vec{H}) = -\vec{H} \frac{\partial \vec{B}}{\partial t} - \nabla(\vec{E} \times \vec{H})$$

eq^n (4) becomes

$$\vec{E} \cdot \vec{J} = -\vec{H} \frac{\partial \vec{B}}{\partial t} - \vec{E} \cdot \frac{\partial \vec{D}}{\partial t} - \nabla(\vec{E} \times \vec{H}) \quad \ldots (5)$$

Here we take partial derivatives of

$$\frac{\partial}{\partial t}(\vec{H} \cdot \vec{B}) = \vec{H} \cdot \frac{\partial \vec{B}}{\partial t} + \vec{B} \cdot \frac{\partial \vec{H}}{\partial t}$$

$$= \mu_0 \vec{H} \frac{\partial \vec{H}}{\partial t} + \mu_0 \vec{H} \frac{\partial \vec{H}}{\partial t}$$

$$\frac{\partial}{\partial t}(\vec{H} \cdot \vec{B}) = 2 \mu_0 \vec{H} \frac{\partial \vec{H}}{\partial t}$$

$$\mu_0 \vec{H} \cdot \frac{\partial \vec{H}}{\partial t} = \frac{1}{2} \frac{\partial}{\partial t} (\vec{B} \cdot \vec{H})$$

$$\frac{\cancel{\mu_0}}{\cancel{\mu_0}} \vec{H} \cdot \frac{\partial \vec{B}}{\partial t} = \frac{1}{2} \frac{\partial (\vec{B} \cdot \vec{H})}{\partial t}$$

$$\vec{H} \cdot \frac{\partial \vec{B}}{\partial t} = \frac{\partial}{\partial t} \left(\frac{1}{2} \mu_0 \vec{H}^2\right)$$

current density in

$$\vec{H} \cdot \frac{\partial \vec{B}}{\partial t} = \frac{\partial}{\partial} U_m \Rightarrow \text{magnetic field } \cancel{\text{in}} \quad \cdots \text{ ⑥}$$

where $U_m = \frac{\partial}{\partial t}\left(\frac{1}{2} \mu_0 \vec{H}^2\right)$

$$\therefore \frac{\partial}{\partial t}(\vec{E} \cdot \vec{D}) = \vec{E} \cdot \frac{\partial \vec{D}}{\partial t} + \vec{D} \cdot \frac{\partial \vec{E}}{\partial t}$$

$$= \varepsilon_0 \vec{E} \cdot \frac{\partial \vec{E}}{\partial t} + \varepsilon_0 \vec{E} \cdot \frac{\partial \vec{E}}{\partial t}$$

$$\frac{\partial}{\partial t}(\vec{E} \cdot \vec{D}) = 2 \varepsilon_0 \vec{E} \cdot \frac{\partial \vec{E}}{\partial t}$$

$$\therefore \frac{\cancel{\varepsilon_0}}{\cancel{\varepsilon_0}} \vec{E} \frac{\partial \vec{D}}{\partial t} = \frac{1}{2} \frac{\partial}{\partial t}(\vec{E} \cdot \varepsilon_0 \vec{E})$$

$$\vec{E} \cdot \frac{\partial \vec{D}}{\partial t} = \frac{\partial}{\partial t}\left(\frac{1}{2} \varepsilon_0 \vec{E}^2\right)$$

$$\vec{E} \cdot \frac{\partial \vec{D}}{\partial t} = U_e \quad \cdots\cdots \text{ ⑦}$$

current density in

= electric field $\cancel{\text{in}}$

where $U_e = \frac{\partial}{\partial t}\left(\frac{1}{2} \varepsilon_0 \vec{E}^2\right)$.

so eq^n ⑥ becomes

$$\vec{E} \cdot \vec{J} = -\frac{\partial}{\partial t}(U_m) - \frac{\partial}{\partial t}(U_e) - \nabla(\vec{E} \times \vec{H})$$

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VIVEKANAND COLLEGE, KOLHAPUR (AUTONOMOUS)

SUPPLIMENT

Signature of Supervisor

Suppliment No. :

Roll No. : 1601

Class : Msc I

Subject : Electrodynamics

Test / Tutorial No. :

Div. :

13/20

1) Relation for Poynting Vector:

Let us consider q charges moving in electromagnetic field with electric field $\vec{E}$ and magnetic field $\vec{B}$ with velocity $\vec{v}$. Total work done by q charges in electromagnatic field is given by

$$dW = \vec{F}\, d\vec{l}$$

Where $\vec{F}$ = lorentz force acting on q charge in electromagnatic field.

$d\vec{l}$ = Small displacement of q charge.

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We know $F = q(\vec{E} + \vec{v} \times \vec{B})$

$$d\vec{l} = v\, dt \qquad \therefore v = \frac{dl}{dt}$$

Total work done by q charge in electromagnatic field can be written as.

~~dw = q ($\vec{E} \times \vec{v}$~~

$$dW = q(\vec{E} + \vec{v} \times \vec{B})\, v\, dt$$

$$= q(\vec{E} \cdot \vec{v})\, dt + q(\vec{v} \times \vec{B} \cdot \vec{v})\, dt$$

$$= q(\vec{E} \cdot \vec{v})\, dt + q(\vec{v} \cdot \vec{v} \times \vec{B})\, dt$$

$$dW = q(\vec{E} \cdot \vec{v})\, dt + 0$$

$$\frac{dW}{dt} = q(\vec{E} \cdot \vec{v}) \quad \text{—— (1)}$$

We know that volume density of electric charge is electromagnatic field is ρ.

$$\rho = \frac{dq}{dv}$$

Total workdone by volume density is

$$q = \int \rho\, dv$$

Above eq^n becomes

$$\frac{dW}{dt} = \int \rho\, (E \cdot V)\, dv$$

let J be the velocity of volume density of electromagnatic field.

~~J~~ ~~H~~

$$\frac{dw}{dt} = \int (E \cdot J)\, dv \quad \text{--- } (2)$$

By maxwell's fourth equation

$$\nabla \times \vec{H} = \vec{J} + \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

$$J = \nabla \times \vec{H} - \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

Premultiplying by $\vec{E}$

$$\vec{E} \cdot \vec{J} = \vec{E}\,(\nabla \times \vec{H}) - E \frac{\partial \vec{D}}{\partial t} \qquad D = \varepsilon_0 E$$

$$\vec{E} \cdot \vec{J} = \vec{E}\,(\nabla \times \vec{H}) - \vec{E} \frac{\partial \vec{D}}{\partial t} \quad \text{--- } (3)$$

From above eq^n ~~eq^n~~ (3) ~~becom~~

$$\vec{E} \cdot \vec{J} = -\vec{H} \frac{\partial \vec{B}}{\partial t} - \vec{E} \frac{\partial \vec{D}}{\partial t} - \nabla (\vec{E} \times \vec{H}) \quad \text{--- } (4)$$

let $\dfrac{\partial (\vec{B} \cdot \vec{H})}{\partial t} = \vec{B} \cdot \dfrac{\partial \vec{H}}{\partial t} + \vec{H} \cdot \dfrac{\partial \vec{B}}{\partial t}$ $\qquad \vec{B} = \mu_0 \vec{H}$

$$= \mu_0 \vec{H} \cdot \frac{\partial \vec{H}}{\partial t} + \mu_0 \vec{H} \frac{\partial \vec{H}}{\partial t}$$

$$\frac{\partial (\vec{B} \cdot \vec{H})}{\partial t} = 2 \mu_0 \vec{H} \frac{\partial \vec{H}}{\partial t} \qquad \vec{H} = \frac{\vec{B}}{\mu_0}$$

$$= 2 \frac{\cancel{\mu_0}}{\cancel{\mu_0}} \vec{H} \frac{\partial \vec{B}}{\partial t}$$

$$\frac{\partial(\vec{B}\cdot\vec{H})}{\partial t} = 2\vec{H}\frac{\partial\vec{B}}{\partial t}$$

$B = \mu_0 \vec{H}$

$$\vec{H}\cdot\frac{\partial\vec{B}}{\partial t} = \frac{1}{2}\frac{\partial}{\partial t}(\vec{B}\cdot\vec{H})$$

$$= \frac{1}{2}\mu_0\frac{\partial\vec{H}^2}{\partial t}$$

$$= \cancel{2F}\ \frac{\partial}{\partial t}\left(\frac{1}{2}\mu_0\vec{H}^2\right)$$

$$\vec{H}\cdot\frac{\partial\vec{B}}{\partial t} = \frac{\partial}{\partial t}(u_m) \quad \text{— (5)}$$

$\therefore \frac{1}{2}\mu_0\vec{H}^2 = u_m$ Energy density of a charge in electromagnatic field.

We know, $\frac{\partial}{\partial t}(\vec{E}\cdot\vec{D}) = \vec{E}\cdot\frac{\partial\vec{D}}{\partial t} + \vec{D}\frac{\partial\vec{E}}{\partial t}$ $\quad \vec{D} = \varepsilon_0 E$

$$= \vec{E}\varepsilon_0\frac{\partial\vec{E}}{\partial t} + \varepsilon_0\vec{E}\frac{\partial\vec{E}}{\partial t}$$

$$\frac{\partial}{\partial t}(\vec{E}\cdot\vec{D}) = 2\vec{E}\varepsilon_0\frac{\partial\vec{E}}{\partial t}$$

$$= 2\vec{E}\frac{\cancel{\varepsilon_0}}{\cancel{\varepsilon_0}}\frac{\partial\vec{D}}{\partial t}$$

$$\frac{\partial}{\partial t}(\vec{E}\cdot\vec{D}) = 2\vec{E}\frac{\partial\vec{D}}{\partial t}$$

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SUPPLIMENT

Suppliment No. :		Signature of Supervisor	
Roll No. :	1610	Subject :	Electrodynamics.
Class :	m.sc I	Test / Tutorial No. :	
		Div. :	

9/20

3. Lorentz Gauge

→ we know that scaler & vector potential is given by coupled differential.

$$\left.\begin{aligned} \frac{\rho}{\varepsilon} &= \nabla^2 \phi \left(\nabla \vec{A} - \frac{\partial^2}{\partial t^2} \right) + \mu\varepsilon \frac{\partial^2 \phi}{\partial t^2} \\ \mu J &= \nabla^2 \vec{A} - \nabla \left(\nabla \vec{A} - \frac{\partial \phi}{\partial t^2} \right) + \mu\varepsilon \frac{\partial^2 \vec{A}}{\partial t} \end{aligned}\right\} \quad \text{—} (1)$$

Lorentz condition

$$\nabla^2 \vec{A} = -\mu\varepsilon \cdot \frac{\partial^2}{\partial t^2}$$

Hence eqn (1) becomes.

$$\left.\begin{aligned} \frac{\rho}{\varepsilon} &= \nabla^2 \phi + \mu\varepsilon \frac{\partial^2 \phi}{\partial t^2} \\ \frac{\mu}{J} &= \nabla^2 \vec{A} + \mu\varepsilon \frac{\partial^2 \vec{A}}{\partial t^2} \end{aligned}\right\} \quad -(2)$$

We know that ~~scaler~~ the velocity of em wave is given by

$$= \frac{1}{\sqrt{\mu\varepsilon}} = \mu\varepsilon = \frac{1}{V^2}$$

$$\left.\begin{aligned} \frac{\rho}{\varepsilon} &= \nabla^2\phi - \frac{1}{v^2}\frac{\partial^2\phi}{\partial t^2} \\ \mu J &= \nabla^2\vec{A} - \frac{1}{v^2}\frac{\partial^2\vec{A}}{\partial t^2} \end{aligned}\right\} - (3)$$

$$\left.\begin{aligned} \frac{\rho}{\varepsilon} &= \left[\nabla^2\phi - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right]\phi \\ \mu J &= \left[\nabla^2\vec{A} - \frac{1}{v^2}\frac{\partial^2}{\partial t}\right]\vec{A} \end{aligned}\right\} - (4)$$

$\frac{\rho}{\varepsilon} = \nabla^2\vec{A} - \frac{1}{v^2}\frac{\partial^2}{\partial t^2} = \Box^2$ DeAlembert's operator.

$$\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2} - \frac{1}{v^2} - \frac{\partial^2}{\partial t^2}.$$

$$\left.\begin{aligned} \frac{\rho}{\varepsilon} &= \Box^2\phi \\ \frac{\rho}{\varepsilon} &= \Box^2\vec{A} \end{aligned}\right\} - (5)$$

eq^n (5) know as coupled differential eqn for scaler & vector potential by applaying lorentz condition.

Now we will introduced scaler λ such that.

~~$\nabla^2 - \mu\varepsilon\frac{\partial^2}{\partial t^2} = 0$~~ .. old lorentz condition.

$\vec{A} = \vec{A'} + \nabla\lambda = 0$

$\phi = \phi' - \frac{\partial\lambda}{\partial t} = 0$

~~$\nabla^2 - \mu$~~ $\nabla^2\phi - \mu\varepsilon\frac{\partial^2\phi}{\partial t^2}$ ... old lorentz condition.

$$\nabla\vec{A}' - \nabla\left(\nabla^2 \lambda - \mu\varepsilon \frac{\partial^2 \lambda}{\partial t^2}\right) + \mu\varepsilon \frac{\partial^2 \lambda}{\partial t^2}$$

Now we know that velocity of em wave is give by

$$\frac{1}{\sqrt{\mu\varepsilon}} \quad = \mu\varepsilon = \frac{1}{v^2}$$

$$\nabla\vec{A}' = \left[\nabla^2 \lambda - \mu\varepsilon \frac{\partial^2}{\partial t^2}\right]\lambda$$

$$\nabla\vec{A}' + \mu\varepsilon \frac{\partial \phi}{\partial t} = \left[\nabla^2 - \frac{1}{v^2}\frac{\partial^2}{\partial t^2}\right]\lambda$$

$$\nabla^2\vec{A}' + \mu\varepsilon \frac{\partial \phi}{\partial t} \; \Box^2 \lambda$$

Let $\Box^2 \lambda = 0$

$$\boxed{\nabla\vec{A}' + \mu\varepsilon \frac{\partial \phi}{\partial t} = 0}$$

The lorentz condition Term of scaler & vector potential $\vec{A}$ to $\vec{A}'$ & statisfy scaler & vector potential ϕ to ϕ'.

Q1

1) Displacement current is denoted by $\vec{J}$

2) Third maxwell's eqn is $\nabla \cdot \vec{B} = 0$

3) energy density in electric field is given as
$1/2\, \mu_0 H^2$

4) The Relation between magnetic flux density & vector potential is $B = \nabla \times \vec{A}$

5) choose correct alternative
$B = \frac{H}{\mu}$