SM 213   Physics 1
Term 1 - 2023

Quiz 2

Marks : 10   Time : 30 Minutes

This Paper has two sections.
Section 1 : Multiple Choice Questions : **0.5 Positive Marks** each for **Correct Answer** and **0.25 Negative Marks** for each **Wrong Answer** (15 X 0.5 = 7.5)
Section 2: Fill in the Blanks : Each Question carries 0**.5 Mark** (5 X 0.5 =2.5)

Section 1

1) Do not take $\hat{r}, \hat{\theta}$ and $\hat{\phi}$ outside an integral because :

(A) these unit vectors are functions of position (B) these unit vectors are continuous (C) these unit vectors are discontinuous (D) these unit vectors are independent

2) Gauss law is always true but not useful because :

(A) symmetry is crucial for applying it (B) ρ has to be uniform otherwise it is difficult to apply it
(C) **E** has to be in the same direction as ***da*** otherwise |E| cannot be pulled out of the integral
(D) All of the above

3) It takes ———————————— to determine V

(A) One differential equation (B) Two differential equations (C) Three differential equations (D) Cannot determine with this information

4) $E^{\perp}_{above} - E^{\perp}_{below}$ =

(A) $-\dfrac{\sigma}{\epsilon_0}$ (B) $\dfrac{\sigma}{\epsilon_0}$ (C) 0 (D) $\dfrac{\sigma}{\epsilon_0}\hat{n}$

5) The electrical energy is stored :

(A) in the charge (for the purpose of electrostatics) (B) in the field (in the context of radiation theory) (C) Cannot decide (D) Both A and B

6) Magnetostatics implies :

(A) constant electric fields due to steady charges (B) constant magnetic fields due to steady currents (C) both A and B (D) None

7) $\nabla \,.\, \mathbf{B} =$

(A) 0 at all scales (B) may not be zero at nanoscale but at other scales it is zero (C) is zero at nano scales too (D) cannot decide until we know what is B

8) Ampere's law in its original form cannot handle ————————- type of current configuration :

(A) Infinite planes and straight lines (B) Infinite solenoids (C) Toroids (D) fluctuating electric fields over time

9) Magnetostatic scalar potential :

(A) exists but rarely used (B) does not exist (C) you cannot define such a quantity (D) Have no clue

10) Check the nature of the below statements : (i) It takes energy to setup magnetic fields although magnetic fields do no work (ii) Creation of B-field requires changing the field and changing B-field creates E-field and this E-field can do work (iii) There is no E-field in the beginning of creation of a B-field and in the end too it is not present.

(A) (i) is true all others false. (B) (ii) is true and all others false (C) (iii) is true and rest false (D) all are true

11) $B^{\perp}_{above} - B^{\perp}_{below} =$

(A) $\mu_0 K$ (B) - $\mu_0 K$ (C) 0 (D) $\mu_0(\mathbf{K} \times \hat{n})$

(12) Maxwell's equations are manifestation of

(A) Conservation of linear momentum (B) Conservation of Energy (C) Conservation of Angular momentum (D) they do not conserve any laws

(13) Electrical Generators exploit the idea of

(A) Back EMF (B) Motional EMF (C) Lenz's Law (D) Self Inductance

(14) The magnetic field at a distance s from a long straight wire carrying a steady current I is :

(A) $\frac{\mu_0 I}{2\pi s}$ (B) $-\frac{\mu_0 I}{2\pi s}$ (C) $\frac{\mu_0 I}{4\pi s}$ (D) $-\frac{\mu_0 I}{4\pi s}$

(15) $\delta(kx) =$ **(k is any non zero constant)**

(A) $\frac{1}{|k|}\delta(x)$ (B) $k\,\delta(x)$ (C) $-k\,\delta(x)$ (D) $|k|\,\delta(x)$

Section 2

1) **If ∇T = 0 at a point (x,y,z), where T is a vector function and if dT =0 for small displacements about this point then the point is called ——————————-**

2) $\nabla(\nabla \cdot v)$ **where v is a vector field, is called ——————————**

3) **The divergence of** $\frac{\hat{r}}{r^2}$ **_____________________**

4) **Equation for Electrostatic Pressure is ________**

5) **———————- is an earthed metal screen surrounding a piece of equipment to exclude electrostatic and electromagnetic influences.**

6) **_______________ , ____________________ and __________________ are the geometrical quantities in Electromagnetics.**

7) **The two normal derivatives present in Electrostatics and magnetostatics respectively are ___________ and ————————-**

8) **Modified Ampere's Law is ____________________**

9) **Faraday's law interms of EMF is ——————**

10) **The practical quantities D and H are related to E and B as ————— and ————-.**

SM 213 Physics 1

Term 1 - 2023

End Term

Marks : 25 Time : 120 Minutes

This Paper has three sections.

Section 1 : Multiple Choice Questions : **0.5 Positive Marks** each for **Correct Answer** and **0.25 Negative Marks** for each **Wrong Answer** (10 X 0.5 = 5)
Section 2: Short questions. Each question carries **2 mark**s Answer All (5 X 2 =10)
Section 3: Long questions. Each question carries **5 marks.** Answer All (2 X5 = 10). There is internal choice in this section but you should answer One choice fully. If you answer from both the choices partially, you will get the least marks after correction from your answers.

Section 1

1) The biggest embarrassment for Electromagnetic theory is :

(A) The energy of a point charge is infinite (B) The energy equation has two equations (C) The superposition principle is not valid for electrostatic energy (D) what embarrassment ??? !!!!

2) $\mathbf{A}_{dip}(r) =$

(A) $\frac{\mu_0}{4\pi}\frac{\mathbf{m}\times\hat{r}}{r^2}$ (B) $-\frac{\mu_0}{4\pi}\frac{\mathbf{m}\times\hat{r}}{r^2}$ (C) $\frac{\mu_0}{4\pi}\frac{\mathbf{m}\,.\,\hat{r}}{r^2}$ (D) $-\frac{\mu_0}{4\pi}\frac{\mathbf{m}\,.\,\hat{r}}{r^2}$

3) Helmholtz theorems talk about ———(i) ———- and ———(ii)——— creating —————(iii) ——— and ——iv——— respectively

(A) (i) rotational fields (ii) Solenoidal fields (iii) Scalar potential (iv) Vector potential
(B) (i) irrotational fields (ii) Solenoidal fields (iii) Scalar potential (iv) Vector potential
(C) (i) rotational fields (ii) non-Solenoidal fields (iii) Vector potential (iv) scalar potential
(D) (i) irrotational fields (ii) non-Solenoidal fields (iii) vector potential (iv) scalar potential

4) Is E = y $\hat{x}$ an Electrostatic field? The Reason is ————-

(A) Yes, because $\nabla\times E = 0$ (B) No, because $\nabla\times E \neq 0$ (C) Yes, because $\nabla\times E \neq 0$ (D) No because $\nabla\times E = 0$

5) Faraday-induced electric fields are determined by ———(i) —— in exactly same way as magetostatic fields are determined by —(ii)—————-

(A) (i) $\frac{\partial\mathbf{B}}{\partial t}$ (ii) $\mu_0\mathbf{J}$ (B) (i) - $\frac{\partial\mathbf{B}}{\partial t}$ (ii) - $\mu_0\mathbf{J}$ (C) (i) - $\frac{\partial\mathbf{B}}{\partial t}$ (ii) $\mu_0\mathbf{J}$ (D) (i) $\frac{\partial\mathbf{B}}{\partial t}$ (ii) - $\mu_0\mathbf{J}$

6) I have created two hypothetical states 2 and 1/6 and say they are entangled and now are on either side of a communication channel. I have created an algorithm that if I want to transport a state '3 ' from one end to other, I do an operation (2*3 = 6) and send the answer to the other side of the channel and there on the other side they would multiply (1/6) with (18) which would effectively transmit 3. In this logic if I have to transmit a (1/2), the operation on the other side of the channel is :

(A) multiplication with 1/2 (B) multiplication with 1/6. (C) multiplication with 6 (D) multiplication with 3

7) Values of spin are ± 1/2. The reason for this is :

(A) there are two kinds of spins up and down that's why (B) while all other physical properties have 2π periodicity, spin has 4π periodicity (C) there are two ways electrons can orient towards a magnetic field that's why (D) because of Pauli's exclusion principle

8) Momentum and Energy operator are respectively :

(A) $\frac{\hbar}{i}\frac{\partial}{\partial x}$ and $i\hbar\frac{\partial}{\partial t}$ (B) - $\frac{\hbar}{i}\frac{\partial}{\partial x}$ and - $i\hbar\frac{\partial}{\partial t}$ (C) $i\hbar\frac{\partial}{\partial t}$ and $\frac{\hbar}{i}\frac{\partial}{\partial x}$ (D) - $i\hbar\frac{\partial}{\partial t}$ and - $\frac{\hbar}{i}\frac{\partial}{\partial x}$

9) ____(i) __ exceeds the velocity of light while ____(ii)_________ is less than the velocity of light.

(A) (i) group velocity (ii) phase velocity (B) (i) phase velocity (ii) group velocity (C) (i) group velocity (ii) wave velocity (D) (i) body velocity (ii) phase velocity

10) Zero-point energy of a quantum harmonic oscillator is :

(A) $h\nu$ (B) $\frac{1}{2}h\nu$ (C) 0 (D) $\frac{3}{2}h\nu$

Section 2

1) Derive $W = \frac{1}{2}\sum_{i=1}^{n} q_i V(r_i)$ and $W = \frac{1}{2}\int \rho V d\tau$. Comment on these two equations.

2) Magnetic forces do no work. Illustrate this idea with an example of rectangular loop of wire supporting a mass m, hanging vertically in a uniform magnetic filed B. (You can make the necessary assumptions)

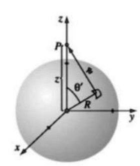
3) Start from $\nabla \times B$ and derive $\nabla^2 A = -\mu_0 J$. State the necessary assumptions made.

4) What are the differences between a particle in a infinite potential well and a finite potential well. Mention at least 3 .

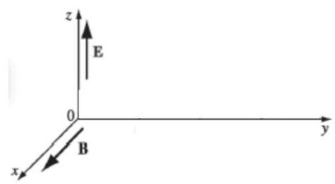
5) Use Uncertainty principle and prove the non-existence of electrons and existence of protons and neutrons in the nucleus (make relevant assumptions)

Section 3

Q1 (A)) Find the potential of a uniformly charged spherical shell of Radius R (see figure below)



(B)) If B points in the x-direction and E in the z-direction, as shown below. If a particle at rest is released from origin, what path will it follow? Derive the equation.



OR

Given E = E$_m$ $Sin(\omega t - \beta z)\mathbf{a}_y$ in free space, find D, B and H. Sketch E and H at t=0 . Show that E and H constitute a wave travelling in z-direction and verify the speed of this wave and also calculate $\frac{E}{H}$. What is this ratio?

Q2) Derive the expression for Compton scattering

OR

Explain qualitatively the solutions of Hydrogen atom in various directions. How do different quantum numbers emerge and what do they quantise. What are the constraints on the quantum numbers so that transitions between different energy levels take place.

VECTOR IDENTITIES

Triple Products

(1) $\mathbf{A} \cdot (\mathbf{B} \times \mathbf{C}) = \mathbf{B} \cdot (\mathbf{C} \times \mathbf{A}) = \mathbf{C} \cdot (\mathbf{A} \times \mathbf{B})$

(2) $\mathbf{A} \times (\mathbf{B} \times \mathbf{C}) = \mathbf{B}(\mathbf{A} \cdot \mathbf{C}) - \mathbf{C}(\mathbf{A} \cdot \mathbf{B})$

Product Rules

(3) $\nabla(fg) = f(\nabla g) + g(\nabla f)$

(4) $\nabla(\mathbf{A} \cdot \mathbf{B}) = \mathbf{A} \times (\nabla \times \mathbf{B}) + \mathbf{B} \times (\nabla \times \mathbf{A}) + (\mathbf{A} \cdot \nabla)\mathbf{B} + (\mathbf{B} \cdot \nabla)\mathbf{A}$

(5) $\nabla \cdot (f\mathbf{A}) = f(\nabla \cdot \mathbf{A}) + \mathbf{A} \cdot (\nabla f)$

(6) $\nabla \cdot (\mathbf{A} \times \mathbf{B}) = \mathbf{B} \cdot (\nabla \times \mathbf{A}) - \mathbf{A} \cdot (\nabla \times \mathbf{B})$

(7) $\nabla \times (f\mathbf{A}) = f(\nabla \times \mathbf{A}) - \mathbf{A} \times (\nabla f)$

(8) $\nabla \times (\mathbf{A} \times \mathbf{B}) = (\mathbf{B} \cdot \nabla)\mathbf{A} - (\mathbf{A} \cdot \nabla)\mathbf{B} + \mathbf{A}(\nabla \cdot \mathbf{B}) - \mathbf{B}(\nabla \cdot \mathbf{A})$

Second Derivatives

(9) $\nabla \cdot (\nabla \times \mathbf{A}) = 0$

(10) $\nabla \times (\nabla f) = 0$

(11) $\nabla \times (\nabla \times \mathbf{A}) = \nabla(\nabla \cdot \mathbf{A}) - \nabla^2\mathbf{A}$

FUNDAMENTAL THEOREMS

Gradient Theorem : $\int_{\mathbf{a}}^{\mathbf{b}} (\nabla f) \cdot d\mathbf{l} = f(\mathbf{b}) - f(\mathbf{a})$

Divergence Theorem : $\int (\nabla \cdot \mathbf{A})\, d\tau = \oint \mathbf{A} \cdot d\mathbf{a}$

Curl Theorem : $\int (\nabla \times \mathbf{A}) \cdot d\mathbf{a} = \oint \mathbf{A} \cdot d\mathbf{l}$

FUNDAMENTAL CONSTANTS

ϵ_0	$=$	$8.85 \times 10^{-12}\,\mathrm{C^2/Nm^2}$	(permittivity of free space)
μ_0	$=$	$4\pi \times 10^{-7}\,\mathrm{N/A^2}$	(permeability of free space)
c	$=$	$3.00 \times 10^{8}\,\mathrm{m}/s$	(speed of light)
e	$=$	$1.60 \times 10^{-19}\,\mathrm{C}$	(charge of the electron)
m	$=$	$9.11 \times 10^{-31}\,\mathrm{kg}$	(mass of the electron)

rest mass of proton = 1.67 X 10 ^ (-27) kg

SPHERICAL AND CYLINDRICAL COORDINATES

Spherical

$$\begin{cases} x = r\sin\theta\cos\phi \\ y = r\sin\theta\sin\phi \\ z = r\cos\theta \end{cases} \qquad \begin{cases} \hat{\mathbf{x}} = \sin\theta\cos\phi\,\hat{\mathbf{r}} + \cos\theta\cos\phi\,\hat{\boldsymbol{\theta}} - \sin\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{y}} = \sin\theta\sin\phi\,\hat{\mathbf{r}} + \cos\theta\sin\phi\,\hat{\boldsymbol{\theta}} + \cos\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{z}} = \cos\theta\,\hat{\mathbf{r}} - \sin\theta\,\hat{\boldsymbol{\theta}} \end{cases}$$

$$\begin{cases} r = \sqrt{x^2+y^2+z^2} \\ \theta = \tan^{-1}(\sqrt{x^2+y^2}/z) \\ \phi = \tan^{-1}(y/x) \end{cases} \qquad \begin{cases} \hat{\mathbf{r}} = \sin\theta\cos\phi\,\hat{\mathbf{x}} + \sin\theta\sin\phi\,\hat{\mathbf{y}} + \cos\theta\,\hat{\mathbf{z}} \\ \hat{\boldsymbol{\theta}} = \cos\theta\cos\phi\,\hat{\mathbf{x}} + \cos\theta\sin\phi\,\hat{\mathbf{y}} - \sin\theta\,\hat{\mathbf{z}} \\ \hat{\boldsymbol{\phi}} = -\sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}} \end{cases}$$

Cylindrical

$$\begin{cases} x = s\cos\phi \\ y = s\sin\phi \\ z = z \end{cases} \qquad \begin{cases} \hat{\mathbf{x}} = \cos\phi\,\hat{\mathbf{s}} - \sin\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{y}} = \sin\phi\,\hat{\mathbf{s}} + \cos\phi\,\hat{\boldsymbol{\phi}} \\ \hat{\mathbf{z}} = \hat{\mathbf{z}} \end{cases}$$

$$\begin{cases} s = \sqrt{x^2+y^2} \\ \phi = \tan^{-1}(y/x) \\ z = z \end{cases} \qquad \begin{cases} \hat{\mathbf{s}} = \cos\phi\,\hat{\mathbf{x}} + \sin\phi\,\hat{\mathbf{y}} \\ \hat{\boldsymbol{\phi}} = -\sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}} \\ \hat{\mathbf{z}} = \hat{\mathbf{z}} \end{cases}$$

VECTOR DERIVATIVES

Cartesian. $d\mathbf{l} = dx\,\hat{\mathbf{x}} + dy\,\hat{\mathbf{y}} + dz\,\hat{\mathbf{z}}; \quad d\tau = dx\,dy\,dz$

$$\textit{Gradient}: \quad \nabla t = \frac{\partial t}{\partial x}\hat{\mathbf{x}} + \frac{\partial t}{\partial y}\hat{\mathbf{y}} + \frac{\partial t}{\partial z}\hat{\mathbf{z}}$$

$$\textit{Divergence}: \quad \nabla \cdot \mathbf{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$$

$$\textit{Curl}: \quad \nabla \times \mathbf{v} = \left(\frac{\partial v_z}{\partial y} - \frac{\partial v_y}{\partial z}\right)\hat{\mathbf{x}} + \left(\frac{\partial v_x}{\partial z} - \frac{\partial v_z}{\partial x}\right)\hat{\mathbf{y}} + \left(\frac{\partial v_y}{\partial x} - \frac{\partial v_x}{\partial y}\right)\hat{\mathbf{z}}$$

$$\textit{Laplacian}: \quad \nabla^2 t = \frac{\partial^2 t}{\partial x^2} + \frac{\partial^2 t}{\partial y^2} + \frac{\partial^2 t}{\partial z^2}$$

Spherical. $d\mathbf{l} = dr\,\hat{\mathbf{r}} + r\,d\theta\,\hat{\boldsymbol{\theta}} + r\sin\theta\,d\phi\,\hat{\boldsymbol{\phi}}; \quad d\tau = r^2\sin\theta\,dr\,d\theta\,d\phi$

$$\textit{Gradient}: \quad \nabla t = \frac{\partial t}{\partial r}\hat{\mathbf{r}} + \frac{1}{r}\frac{\partial t}{\partial \theta}\hat{\boldsymbol{\theta}} + \frac{1}{r\sin\theta}\frac{\partial t}{\partial \phi}\hat{\boldsymbol{\phi}}$$

$$\textit{Divergence}: \quad \nabla \cdot \mathbf{v} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 v_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial \theta}(\sin\theta\, v_\theta) + \frac{1}{r\sin\theta}\frac{\partial v_\phi}{\partial \phi}$$

$$\textit{Curl}: \quad \nabla \times \mathbf{v} = \frac{1}{r\sin\theta}\left[\frac{\partial}{\partial \theta}(\sin\theta\, v_\phi) - \frac{\partial v_\theta}{\partial \phi}\right]\hat{\mathbf{r}} + \frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial v_r}{\partial \phi} - \frac{\partial}{\partial r}(r v_\phi)\right]\hat{\boldsymbol{\theta}} + \frac{1}{r}\left[\frac{\partial}{\partial r}(r v_\theta) - \frac{\partial v_r}{\partial \theta}\right]\hat{\boldsymbol{\phi}}$$

$$\textit{Laplacian}: \quad \nabla^2 t = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial t}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial t}{\partial \theta}\right) + \frac{1}{r^2\sin^2\theta}\frac{\partial^2 t}{\partial \phi^2}$$

Cylindrical. $d\mathbf{l} = ds\,\hat{\mathbf{s}} + s\,d\phi\,\hat{\boldsymbol{\phi}} + dz\,\hat{\mathbf{z}}; \quad d\tau = s\,ds\,d\phi\,dz$

$$\textit{Gradient}: \quad \nabla t = \frac{\partial t}{\partial s}\hat{\mathbf{s}} + \frac{1}{s}\frac{\partial t}{\partial \phi}\hat{\boldsymbol{\phi}} + \frac{\partial t}{\partial z}\hat{\mathbf{z}}$$

$$\textit{Divergence}: \quad \nabla \cdot \mathbf{v} = \frac{1}{s}\frac{\partial}{\partial s}(s v_s) + \frac{1}{s}\frac{\partial v_\phi}{\partial \phi} + \frac{\partial v_z}{\partial z}$$

$$\textit{Curl}: \quad \nabla \times \mathbf{v} = \left[\frac{1}{s}\frac{\partial v_z}{\partial \phi} - \frac{\partial v_\phi}{\partial z}\right]\hat{\mathbf{s}} + \left[\frac{\partial v_s}{\partial z} - \frac{\partial v_z}{\partial s}\right]\hat{\boldsymbol{\phi}} + \frac{1}{s}\left[\frac{\partial}{\partial s}(s v_\phi) - \frac{\partial v_s}{\partial \phi}\right]\hat{\mathbf{z}}$$

$$\textit{Laplacian}: \quad \nabla^2 t = \frac{1}{s}\frac{\partial}{\partial s}\left(s\frac{\partial t}{\partial s}\right) + \frac{1}{s^2}\frac{\partial^2 t}{\partial \phi^2} + \frac{\partial^2 t}{\partial z^2}$$

Evaluator Comments

IMT2022100 0.5 -0.25 -0.25 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.25 0.25 0 0 0.25 1.25 4 9.5

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