BIRLA INSTITUTE OF TECHNOLOGY, MESRA, RANCHI
(END SEMESTER EXAMINATION)

CLASS: IMSc **SEMESTER : II**
BRANCH: MATHS & COMPUTING **SESSION : SP/2024**

SUBJECT: PH109 PHYSICS-I

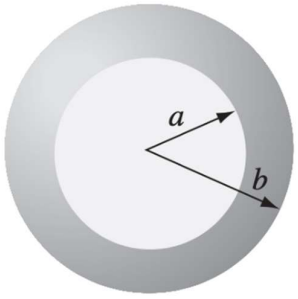
TIME: 3 Hours **FULL MARKS: 50**

INSTRUCTIONS:
1. The question paper contains 5 questions each of 10 marks and total 50 marks.
2. Attempt all questions.
3. The missing data, if any, may be assumed suitably.
4. Before attempting the question paper, be sure that you have got the correct question paper.
5. Tables/Data hand book/Graph paper etc. to be supplied to the candidates in the examination hall.

Useful Constants: Permittivity of free space (ε_0) = 8.85 x 10^{-12} C^2/Nm^2, Permeability of free space $\mu_0 = 4\pi$ x 10^{-7} Tm/A

			CO	BL
Q.1(a)	Define Gauss law of electrostatics. A thick spherical shell of inner radius a and outer radius b (See Fig below) carries volume charge density ρ given by:	[5]	1	1,5

$$\rho = k/r^2 \quad (a \leq r \leq b)\text{, where k is a constant}$$



Use Gauss law to determine the electric field vector in the three regions:
(i) r < a
(ii) a < r < b
(iii) r > b

Q.1(b)	Derive the expression for the energy density of the electric field due to a volume charge distribution (ρ). Apply it to find the total energy (in Joules) stored in a volume of space where an Electric field is present given by:	[5]	1	2,3

$$\vec{E} = (3x + 5z)\hat{z}\ \ Volt/m$$

and the volume is defined by: 0 < x < 1, 0 < y < 2 and 0 < z < 3.

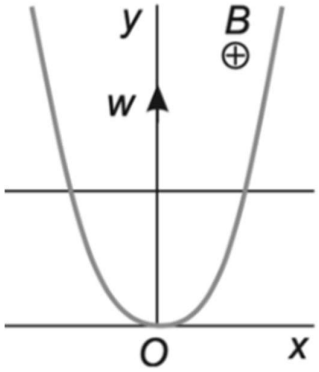
Q.2(a)	Show that Maxwell's equation in vacuum predict that electric and magnetic fields satisfy the wave equation. A plane electromagnetic wave in free space has electric field component given by:	[5]	2	

$$\vec{E} = 100e^{i(0.866y + 0.5z)}\hat{x}\ \ Volt/m$$

Determine the following for the wave:
(i) Angular Frequency (ω) and wavelength (λ)
(ii) Magnetic Field ($\vec{H}$)
(iii) Poynting vector ($\vec{s}$)
(iv) Energy density (u_{EM}) and momentum density ($\vec{g}$).

PTO

Q.2(b) Define Faraday's law of electro-magnetism. A wire bent as a parabola $y = bx^2$ (where b is a constant) is located in a unform magnetic field $\vec{B}$, which is perpendicular to the XY plane and pointing into this page. At the moment t = 0, a metal rod starts sliding translationally from the parabola apex with a constant acceleration $\vec{w}$. Determine the induced e.m.f in the loop thus formed as a function of y. [5] 2 1,5



Q.3(a) Define atomic mass unit (a.m.u). What is its value in Kg ? A nucleus with mass number A = 235 splits into two nuclei whose mass numbers are in the ratio 1:2. What is the ratio of their radii ? [5] 3 1,2

Q.3(b) Derive the semi-empirical mass formula for the binding energy of a nucleus of mass number A and atomic number Z using liquid drop model. Explain each term appearing in this formula along with the corrections that were applied to it later. [5] 3 1,2

Q.4(a) Define Brewster's angle. What is its value for a glass slab (n_2 = 1.5) immersed in water (n_1 = 1.33) in degrees ? Show that at this angle the reflected and refracted rays are perpendicular to each other. [5] 4 2

Q.4(b) What do you understand by interference ? What are the main methods of observing interference in lab ? A narrow slit (in air) on an opaque screen is illuminated by laser of wavelength 1152.2 nm. It is found that the center of the 10^{th} dark fringe in the Fraunhofer pattern lies at an angle of 6.2 degrees off the central axis. What is the slit width ? At what angle will the 10^{th} dark fringe appear if the entire setup is immersed in water (n = 1.33) instead of air (n = 1.0002) ? [5] 4 1,2

Q.5(a) What is an "inertial frame" ? Derive the Lorentz transformations connecting two inertial frames. [5] 5 1,5

Q.5(b) Define "proper length" and "proper time" in the context of special relativity. A cosmic ray particle (proper mean life time, τ = 1 micro-sec) is created in the upper atmosphere and travels at 0.9c, calculate the distance it travels before decay for the following two cases: [5] 5 1,2

(i) as measured by an observer on Earth

(ii) as measured in the rest frame of the particle.

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