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**3 (Sem-3/CBCS) PHY HC 1**

**2021**

**(Held in 2022)**

**PHYSICS**

**(Honours)**

Paper : PHY-HC-3016

**(Mathematical Physics-II)**

Full Marks : 60

Time : Three hours

**The figures in the margin indicate full marks for the questions.**

1. Answer the following questions : (each question carries **one** mark)  $1 \times 7 = 7$

(a) Show that  $P_n(-x) = (-1)^n P_n(x)$ .

(b)  $L_1(x) - L_0(x) = ?$

Contd.

(c) Express the one-dimensional heat flow equation.

(d)  $\int_0^{\infty} e^{-x} x^{2n-1} dx = ?$

(e)  $\beta\left(\frac{1}{2}, \frac{1}{2}\right) = ?$

(f) Square matrix = Symmetric matrix + ?

(g) If,  $\mu^{-1} M \mu = M'$ , then show that  
 $\text{Tr } M = \text{Tr } M'$ .

2. Answer the following questions : (each question carries **2** marks)  $2 \times 4 = 8$

(a) Show that  $x=0$  is a regular singular point for the following differential equation :

$$2x^2 \frac{d^2 y}{dx^2} + 3x \frac{dy}{dx} + (x^2 - 4)y = 0$$



- (b) Can we express the one-dimensional Schrödinger's equation

$$-\frac{\hbar^2}{2m} \frac{\partial^2 \psi(x, t)}{\partial x^2} + V\psi(x, t) = i\hbar \frac{\partial \psi}{\partial t}(x, t)$$

in terms of space dependent and time independent equations if  $V$  is a function of both  $x$  and  $t$ ? Explain.

- (c) Show that  $\beta(l, m) = \beta(m, l)$ .

- (d) Show that the matrix

$$\sigma_2 = \begin{pmatrix} 0 & -i \\ i & 0 \end{pmatrix}$$

$$\sigma_2' = \begin{bmatrix} 0 & -i \\ i & 0 \end{bmatrix}$$

is Hermitian as well as unitary.

3. Answer **any three** questions from the following : (each question carries **5** marks)

$$5 \times 3 = 15$$

- (a) By the separation of variable method, solve the  $t$ -dependent part of the following equation :

$$\frac{\partial u}{\partial t} = c^2 \frac{\partial^2 u}{\partial x^2}$$

(b) If  $\begin{pmatrix} x \\ y \end{pmatrix}$  transforms to  $\begin{pmatrix} x' \\ y' \end{pmatrix}$  in the

way —

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} \text{ then}$$

show that  $x'^2 + y'^2 = x^2 + y^2$ .

Verify that the transformation matrix is orthogonal. 2+3=5

(c) How many real numbers are required to express a general complex matrix of dimension  $2 \times 2$ ? Show that a  $2 \times 2$  Hermitian matrix of dimension  $2 \times 2$  carries four real numbers. Also, show that a skew-Hermitian matrix of dimension  $2 \times 2$  carries only the real numbers. 1+2+2=5

(d) Find the Fourier's series representing  $f(x) = x$ ,  $0 < x < 2\pi$ , and sketch its graph from  $x = -4\pi$  to  $x = +4\pi$ .

3+2=5



(e) Show that

$$L'_n(x) - n L'_{n-1}(x) + n L_{n-1}(x) = 0. \quad 5$$

4. If,  $y = \sum_{k=0}^{\infty} a_k x^{m+k}$  happens to be the power

series solution of the equation,

$$2x(1-x) \frac{d^2 y}{dx^2} + (1-x) \frac{dy}{dx} + 3y = 0, \text{ then show}$$

$$\text{that } a_{k+1} = \frac{-2m - 2k + 3}{2m + 2k + 1} \quad 10$$

**Or**

Show the following :

$$4+3+3=10$$

$$(1) \quad (n+1) P_{n+1} = (2n+1) x P_n - n P_{n-1}$$

$$(2) \quad n P_n = x P'_n - P'_{n-1}$$

$$(3) \quad P'_{n+1} - P'_{n-1} = (2n+1) P_n$$

5. Solve the equation

$$\frac{\partial^2 \psi}{\partial x \partial t} = e^{-t} \cos x$$

given that,  $\psi(t=0) = 0$  and  $\left. \frac{\partial \psi}{\partial t} \right|_{x=0} = 0$

10

**Or**

Consider a vibrating string of length  $l$  fixed at both ends, given that

$$y(0, t) = 0, \quad y(l, t) = 0$$

$$y(x, 0) = f(x), \quad \frac{\partial y}{\partial t}(x, 0) = 0; \quad 0 < x < l$$

Solve completely the equation of vibrating string

$$\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2}. \quad 10$$

6. If  $A = \begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 1 \end{pmatrix}$ , obtain  $A^{-1}$ .

From the matrix equation

$$\begin{pmatrix} 2 & 1 \\ 3 & 2 \end{pmatrix} \begin{pmatrix} a & b \\ c & d \end{pmatrix} \begin{pmatrix} -3 & 2 \\ 5 & -3 \end{pmatrix} = \begin{pmatrix} -2 & 4 \\ 3 & -1 \end{pmatrix},$$

obtain,  $a, b, c, d$ .

4+6=10

**Or**

Obtain the eigenvalues and eigenvectors of the matrix

$$M = \begin{pmatrix} 2 & -i \\ i & 2 \end{pmatrix}$$

and hence diagonalize the same. 4+6=10

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