'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 5th Semester Examination, 2023

DSE-P1-PHYSICS

Time Allotted: 2 Hours | Full Marks: 40

The figures in the margin indicate full marks.

The question paper contains paper DSE-1A and DSE-1B.
The candidates are required to answer any *one* from *two* sections.
Candidates should mention it clearly on the Answer Book.

DSE-1A

ADVANCED MATHEMATICAL PHYSICS-I

GROUP-A

1. Answer any ***five*** questions from the following: 1×5 = 5

   (a) Define covariant tensor of rank 2.

   (b) Find the Laplace transform of $t^3\delta(t-6)$.

   (c) Are the vectors $X_1=(1,0,0)$, $X_2=(0,1,0)$ and $X_3=(0,0,1)$ linearly dependent?

   (d) $A=\begin{pmatrix}1\\0\end{pmatrix}$ and $B=\begin{pmatrix}0\\-1\end{pmatrix}$ represents basis of a 2-D vector space. Find out the inner product of A and B.

   (e) Find the norm of the vector $X=(3,\ 4,\ 12,\ 13)$.

   (f) Simplify the relation: $\varepsilon_{ijk}\ \varepsilon_{klm}$

   (g) Find $L^{-1}\left[\dfrac{s+2}{(s+2)^2-25}\right]$.

   (h) Write matrix representation of δ_{ij} in 2D.

GROUP-B

Answer any *three* questions from the following 5×3 = 15

2. Prove that if $\langle u,v\rangle$ is the Euclidian inner product on R^n and if A is an $n\times n$ matrix, then $\langle u,\ Av\rangle=\langle A^Tu,v\rangle$. 5

3. If $ds^2=g_{ij}dx^idx^j$ is invariant, show that g_{ij} is a symmetric covariant tensor of rank 2. 5

4. From the set of vectors (1, 0, 1), (0, 0, 1) and (1, 1, 0), construct a set of orthonormal vectors using Gram-Schmidt's orthogonalisation method. 5

5. (a) Find the inverse Laplace transform of $\cot^{-1}(1+s)$. 2

(b) If T_{ijk} is a tensor of rank 3, prove that $\dfrac{\partial T_{ijk}}{\partial x^m}$ is a tensor of rank 4. 3

6. (a) Suppose that $u, v \in V$ and $\| u \| \leq 1$ and $\| v \| \leq 1$. Prove that 3

$$\sqrt{1-\| u \|^2} \cdot \sqrt{1-\| v \|^2} \leq 1-|\langle u, v \rangle|$$

(b) Prove that the Cartesian tensor $A_{ijkl} = \partial_{ij}\partial_{kl}$ is an isotropic tensor. 2

GROUP-C

Answer any *two* questions from the following 10×2 = 20

7. (a) Solve the following equation by the Laplace transform method: 5

$$y'' + 2y' + 2y = 5\sin x \quad , \quad \text{given} \quad y(0) = y'(0) = 0$$

(b) Apply the convolution theorem to obtain the function whose transform is $\dfrac{1}{(p^2+a^2)^2}$, where a is arbitrary constant. 5

8. (a) Let the vector space P_2 have the inner product $\langle p(x), q(x) \rangle = \int_0^1 p(x)\,q(x)\,dx$. 7

Apply the Gram-Schmidt procedure to transform the standard basis $1, x, x^2$ to an orthogonal basis.

(b) Show that the transformation by unitary operator preserves the inner product of two vectors. 3

9. (a) Define Gradient of a vector field. 2

(b) Show that, in general co-ordinates, the quantities $\dfrac{\partial v^i}{\partial u^j}$ do not form the components of a tensor. 3

(c) Find out the covariant and contravariant metric tensor for polar co-ordinate system. Hence find the expression of area element and distance between two points in polar co-ordinate system. 3+2

10.(a) A vector is defined in the Cartesian co-ordinate system as $\vec{A} = 2\hat{i} + \hat{j}$. A new co-ordinate system is formed using the basis vectors $\vec{e}_1 = \hat{i} + 2\hat{j}$ and $\vec{e}_2 = -\hat{i} - \hat{j}$. Find the dual basis vectors and the contravariant components A^1 and A^2 of A in this new system. 6

(b) Four particles of equal mass m are placed on the vertices of a square of side $2a$ centered at the origin. Their co-ordinates are generally given by $(\pm a, \pm a, 0)$. Construct the moment of inertia tensor for the entire system and use it to obtain the principal moments of inertia. 4

DSE-1B

NANO-MATERIALS AND APPLICATIONS

GROUP-A

1. Answer any ***five*** questions from the following: 1×5 = 5

   (a) What do you mean by 1-D nanomaterials?

   (b) What is a carbon nanotube emitter?

   (c) Filters used in XRD may eliminate which line?

   (d) What is electron confinement?

   (e) What do you mean by "bottom up approach" in thin film fabrication?

   (f) What experiment is performed to understand the surface roughness of a nanomaterial?

   (g) What do you mean by indirect band-gap?

GROUP-B

Answer any *three* questions from the following 5×3 = 15

2. A particle of mass 'm' is confined in a 1-D box of length 'a' having potential 'V'. The potential value is zero outside the box. Show that the allowed energy levels are quantized. How does it relevant to nanoparticles? 3+2

3. Explain the procedure of fabricating structured thin film using photolithography. 5

4. What kind of Lasers are used in Pulsed Laser Deposition (PLD)? Write down the advantages and disadvantages of PLD technique. 1+2+2

5. How does the scanning tunneling microscope works? Discuss it briefly. Write down its usefulness in the field of nanomaterials. 3+2

6. Write on the specific features of quantum dot lasers. 5

GROUP-C

Answer any *two* questions from the following 10×2 = 20

7. (a) What do you mean by charging effects in nanomaterials? How can it be removed during optical measurements? 2+2

   (b) What is luminescence? Write down its few applications. 2+2

   (c) Define excitons and plasmons. 2

8. (a) Write down the basic differences between MBE and PLD. 4

   (b) Classify different CVD techniques. How does it advantageous over PVD technique. 4+2

9. (a) Write down the differences between magnetic storage device and electronic storage device. Write down the limitations of magnetic storage devices. 4+2

   (b) Why does the nanostructures are preferred in modern devices? 2

   (c) What is hoping conductivity? 2

10. (a) What is CNT? Write down the different properties of CNTs? 2+2

   (b) Define dielectric constant of a nanostructure. 3

   (c) X-rays of wavelength 0.71 Å are reflected from the (110) plane of a NaCl crystal of lattice constant $a = 2.82$ Å. Calculate the corresponding glancing angle for 2nd order reflection. 3

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