'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 5th Semester Examination, 2022

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: $1\times5 = 5$

(a) Find the Laplace transform of the periodic function $f(t) = e^t$, for $0 < t < 2\pi$.

(b) Define unit step function.

(c) Why the familiar Kronecker delta δ_{kl} is called an isotropic tensor?

(d) Show that a second rank contravariant symmetric tensor remains symmetric under a general coordinate transformation.

(e) Explain why the set of all 2×2 singular matrices over the field of real numbers is not a subspace of all 2×2 matrices over the same field.

(f) Find the matrix of the linear transformation T: $\mathbb{R}^2 \to \mathbb{R}^2$ such that

$$T\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} x-y \\ 2x+y \end{pmatrix} \text{ relative to the basis } \left\{\begin{pmatrix} 1 \\ 0 \end{pmatrix}, \begin{pmatrix} 0 \\ 1 \end{pmatrix}\right\}.$$

(g) Verify that (–2, 1, 3, 0), (0, –3, 1, –6), (–2, –4, 0, 2) is an orthogonal set of vectors in $\mathbb{R}^4$.

(h) Give an example of a dual tensor.

GROUP-B

Answer any *three* questions from the following $5\times3 = 15$

2. Find the inverse Laplace transform of the function $f(s) = \dfrac{s+1}{s^2 - 5s + 6}$. 5

3. Show that the set of vectors {(0, 1, –1), (1, 1, 0), (1, 0, 2)} constitutes a basis of a vector space over a field and hence find the coordinates of the vector (1, 0, –1) with respect to this basis. $2\frac{1}{2}+2\frac{1}{2}$

4. Using the properties of the Levi-Civita tensor ϵ_{ijk} show that 2+3

(a) $\vec{A}\cdot(\vec{A}\times\vec{B})=0$

(b) $\vec{\nabla}\times(\vec{\nabla}\times\vec{A})=\vec{\nabla}(\vec{\nabla}\cdot\vec{A})-\nabla^2\vec{A}$

5. Find g^{ij} and $g=\det(g^{ij})$ corresponding to the metric tensor 5

$$ds^2 = 5(dx^1)^2 + 3(dx^2)^2 + 4(dx^3)^2 - 6dx^1dx^2 + 4dx^2dx^3$$

6. Let V be an inner product space and v_1, v_2, v_3 be vectors in V with $\langle v_1, v_2\rangle = 3$, $\langle v_2, v_3\rangle = -2$, $\langle v_1, v_3\rangle = 1$ and $\langle v_1, v_1\rangle = 1$. Calculate 3+2

(a) $\langle v_1, 2v_2+3v_3\rangle$ and $\langle 2v_1 - v_2, v_1+v_3\rangle$

(b) $\| v_2 \|$ if $\langle v_2, v_1+v_2\rangle = 13$.

GROUP-C

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

7. Solve the following initial value problem by Laplace transform: 10

$$\frac{d^2y}{dt^2} - y = t, \text{ given both } y=1 \text{ and } \frac{dy}{dt}=1 \text{ at } t=0.$$

8. Let S denotes the family of vectors in $\mathbb{R}^3$ corresponding to the points on the plane $2x-y+z=0$. Find: 5+5

(a) an orthonormal basis $\{u_1, u_2\}$ for S.

(b) u_3 such that $\{u_1, u_2, u_3\}$ is an orthonormal basis for $\mathbb{R}^3$.

9. (a) Show that in case of Cartesian tensor, both the contravariant and covariant components of vector are identical. 5

(b) If A^i and B_i are any two vectors, one contravariant and the other covariant, then show that sum of A^iB_i are the components of a mixed tensor of rank two. 5

10.(a) If $\{u_1, ..., u_n\}$ be an orthonormal family of vectors in an inner product space V, prove that $\| u_1 + \cdots + u_n \| = \sqrt{n}$. 5

(b) Using Cauchy-Schwarz inequality show that if $a_1, a_2, \cdots, a_n$ are positive real numbers, then $(a_1+a_2+\cdots+a_n)\left(\frac{1}{a_1}+\frac{1}{a_2}+\cdots+\frac{1}{a_n}\right) \geq n^2$. 5

DSE-1B

NANO-MATERIALS AND APPLICATIONS

GROUP-A

1. Answer any ***five*** questions from the following: $1\times5 = 5$

(a) What is the range of dimension of nanoparticles?

(b) What is a quantum dot laser?

(c) What will be the density of states of infinitely deep potential well of width 1 nm corresponding to energy 3 eV?

(d) State the basic difference between SEM and STM.

(e) What do you mean by quasi particles?

(f) What is meant by Coulomb blockade?

(g) Mention the basic principle of MEMS.

(h) Distinguish between exciton and polaron.

GROUP-B

Answer any *three* questions from the following $5\times3 = 15$

2. (a) Define specific surface area of nanoparticles. Explain with examples. $1\frac{1}{2}+1\frac{1}{2}$

(b) Use Scherrer equation to calculate the size of nanocrystalline, when diffraction peak is observed at 30° having FWHM = 0.8 using radiation of wavelength 0.154 nm. (Scherrer constant = 0.9). 2

3. Explain how oxide nanoparticles can be obtained by sol-gel method. What is the limitation for this method in this regard? 4+1

4. Explain in detail molecular beam epitaxy (MBE) in nanomaterial synthesis. 5

5. Define band gap. Explain in detail why are the direct band gap materials preferred over indirect band gap materials for optoelectronic device application. 1+4

6. List out the applications of nanomaterials in electronics. 5

GROUP-C

Answer any *two* questions from the following $10\times2 = 20$

7. Write short notes on the following: 5+5

(a) Ball milling

(b) Gas phase deposition.

8. (a) What is CNT? Discuss its applications. 2+2

   (b) What do you mean by nanowires? 2

   (c) Briefly explain vacuum based deposition process. Write its limitations. 2+2

9. Compare SEM and TEM for the study of thin film. Also state the effectivity of the techniques to study the distribution of nanoparticles. 5+5

10. What is called bottom up approach? Discuss different types of bottom up approaches for the preparation of nanoparticles. 2+8

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