'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 5th Semester Examination, 2021

DSE-P1-PHYSICS

The figures in the margin indicate full marks.
All symbols are of usual significance.

Candidates should also ensure that the chosen section in the paper DSE-1 is different from the chosen section in the paper DSE-2.

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

DSE-1A

NANO-MATERIALS AND APPLICATIONS

Time Allotted: 2 Hours **Full Marks: 40**

GROUP-A

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

(a) What is the size range of nanomaterials? 1

(b) What do you mean by quasi-particles? 1

(c) What is thermionic emission? 1

(d) How many dimensions do the nanotubes have on the nanoscale? 1

(e) Filters used in XRD may eliminate which line? 1

(f) Selection of deposition process depends on which factor? 1

(g) Which deposition process is used when a film needs to be deposited on both sides of the wafer? 1

(h) What is double quantum dot? 1

GROUP-B

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

2. Explain with suitable examples specific surface area of Nanoparticles and their special applications. 5

3. (a) Distinguish between top-down approach and bottom-up approach for the fabrication of nanomaterials. 2

(b) Explain chemical vapour deposition (CVD) technique. 3

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

5. If a quantum box is very small such that there are not any confined levels in the box, then under what condition there will be at least one bound level? 5

6. Explain the conditions for blockade. 5

GROUP-C

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

7. (a) What is NEMS? 3
   (b) Explain the application of nanostructured thin films for photonic device. 5
   (c) Define magnetic quantum well. 2

8. What is XRD? Discuss its instrumentation and application briefly. 2+8

9. (a) Solve the Schrödinger equation in order to describe the wave function and energy levels for two dimensional quantum wells. 8
   (b) What are the properties of CNTs? 2

10. Make short notes on: 5+5
   (a) Scanning Tunneling Microscopy
   (b) Atomic Force Microscopy.

DSE-1B

ADVANCED MATHEMATICAL PHYSICS-I

Time Allotted: 2 Hours **Full Marks: 40**

GROUP-A

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

   (a) If $F_1(s)=\frac{1}{s+2}$ and $F_2(s)=\frac{1}{s+3}$, find the inverse Laplace transform of 1

   $F(s)=F_1(s)F_2(s)$.

   (b) Calculate the direct Laplace transformation of an arbitrary constant a. 1

   (c) Let $S=\{(-1,\,0,\,1),(2,\,1,\,4)\}$. Find the value of x for which $(3x+2,\,3,\,10)$ belongs to the linear span of S. 1

   (d) Define infinite dimensional vector space. 1

   (e) If T is a 5^{th} rank Cartesian tensor and U is a 2^{nd} rank Cartesian tensor, then what is the rank of $T_{ijklm}U_{lm}$? 1

   (f) Write the matrix representation of δ_{ij} in 2D. 1

   (g) What is an isotropic / invariant tensor? Give an example. 1

(h) Find the orthogonal pair in $\mathbb{R}^2$ with respect to the inner product defined as $(x,\, y) = 3x_1y_1 + 2x_2y_2$, where $x = \begin{pmatrix} x_1 \\ x_2 \end{pmatrix} \in \mathbb{R}^2$ and $y = \begin{pmatrix} y_1 \\ y_2 \end{pmatrix} \in \mathbb{R}^2$. 1

GROUP-B

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

2. Express the following in terms of unit step functions and obtain Laplace Transformation: 5

$$f(t) = \begin{cases} 4 \; ; & 0 < t < 1 \\ -2 \; ; & 0 < t < 3 \\ 5 \; ; & t > 3 \end{cases} .$$

3. Find the inverse Laplace Transform of 3+2

(a) $\dfrac{s+4}{s(s-1)(s^2+4)}$

(b) $\cot^{-1}(1+s)$.

4. (a) Prove that the vectors (1, 1, 0), (1, 2, 3) and (2, –1, 5) form a basis for $\mathbb{R}^3$. 2

(b) Suppose $u, v \in V$ and $\| u \| \le 1$ and $\| v \| \le 1$. 3

Prove that $\sqrt{1 - \| u \|^2} \cdot \sqrt{1 - \| v \|^2} \le 1 - |\langle u,\, v \rangle|$.

5. Show that the matrix $[g^{ij}]$ is the inverse of the matrix $[g_{ij}]$, where g is the metric tensor. Hence calculate the contravariant components g^{ij} of the metric tensor in cylindrical polar coordinates. 1+4

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

(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

$$y'' + 2y' + 2y = 5\sin x$$

given $y(0) = y'(0) = 0$

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

8. Find the inverse Laplace transformation of $\frac{1}{2}\log\left\{\frac{s^2+b^2}{(s-a)^2}\right\}$. 10

9. (a) If v_i are the components of a first order Cartesian tensor, show that $\nabla\cdot\vec{v}$ is a zero order tensor. 3

(b) Show that the T_{ij} given by 7

$$T=[T_{ij}]=\begin{pmatrix} x_2^2 & -x_1x_2 \\ -x_1x_2 & x_1^2 \end{pmatrix}$$

are the components of a second rank tensor.

10.(a) Four particles of equal mass m are placed on the vertices of a square of side $2a$ centred at the origin. Their coordinates 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

(b) A vector is defined in the Cartesian coordinate system as $\vec{A}=2\hat{i}+\hat{j}$. A new coordinate system is constructed 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

DSE-1C

CLASSICAL DYNAMICS

Time Allotted: 2 Hours **Full Marks: 60**

GROUP-A

1. Answer any ***four*** questions from the following: 3×4 = 12

(a) What do you mean by generalized coordinate? What is the advantage of using generalized coordinates? 1+2

(b) The potential energy of the particle is given by $V(x)=x^4-4x^3-8x^2+48x$. Find the points of stable and unstable equilibria. 3

(c) Explain the meaning of normal modes and principal oscillations. 3

(d) State the fundamental postulates of special theory of relativity. What is the significance of the postulates? 3

(e) Explain the meaning of pressure and density at a point inside the fluid. 3

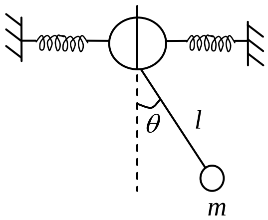
(f) What is Reynold's number? What is its importance in the study of fluid motion? 1+2

GROUP-B

Answer any *four* questions from the following 6×4 = 24

2. What is Hamilton's principle? Derive Lagrange's equation of motion from it. 2+4

3. Obtain the normal modes of small oscillation for the following dynamical system. 6



Use small angle approximation.

4. (a) Derive Poiseuille's equation in case of flow of liquid through a capillary tube. 4

(b) Write down Navier Stoke's equation for the motion of viscous fluid and explain the terms. 2

5. Discuss the four momentum and the energy-momentum dispersion relation. 6

6. (a) Show that $E^2 = p^2c^2 + m_0^2c^4$ (symbols have usual meanings) for a relativistic particle of rest mass 'm_0'. 3

(b) Determine the length and the orientation of a rod of length 10 m in a frame of reference which is moving with $0.6c$ velocity in a direction making 30° angel with the rod. 3

7. For a symmetric top, the Lagrangian is expressed as $L = \frac{1}{2}I_1(\dot{\theta}^2 + \dot{\phi}^2\sin^2\theta) + \frac{1}{2}I_3(\dot{\psi} + \dot{\phi}\cos\theta)^2 - Mgl\cos\theta$, where θ, ϕ, ψ are the variables. Obtain the Hamiltonian. What are the integrals of motion in this case? 6

GROUP-C

Answer any *two* questions from the following 12×2 = 24

8. (a) Prove that the total energy E of a particle of mass m acted on by a central force is given by, 6

$$E = \frac{L^2}{2m}\left[\left(\frac{du}{d\phi}\right)^2 + u^2\right] + V(r)$$

where $V(r)$ is the potential energy. L is the angular momentum of the particle. $u = \frac{1}{r}$, (r, ϕ) being the polar coordinates of the particles.

(b) Obtain the Lagrangian, Hamiltonian, and equations of motion for a projectile near the surface of earth. 4

(c) Water is flowing with a speed of 50 cm/s through a pipe of diameter 3 mm. Calculate Reynold's number. Is the flow streamline? Given $\eta = 1$ centipoise. 2

9. (a) Discuss the time-derivatives that usually appear in the discussion of the motion of any fluid. 8

(b) Explain the meaning of steady state and stationary state in the context of fluid dynamics. 4

10.(a) Prove that the free-dimensional volume element $dxdydz$ is not invariant under Lorentz transformation while the four dimentional volume element $dxdydzdt$ is invariant. 4

(b) A π-meson of rest mass m_π decays into a μ-meson of rest mass m_μ and a neutrino of mass m_υ. Show that the total energy of the μ-meson is $\frac{1}{2m_\pi}\left[m_\pi^2 + m_\mu^2 - m_\upsilon^2\right]c^2$. 4

(c) Obtain the relativistic energy momentum transformation relation. 4

11.(a) Determine the Lagrangian of a free particle in (i) Cartesian, (ii) Cylindrical, (iii) Spherical polar coordinates. Also find the expressions for the Hamiltonian of the corresponding systems. 3+3+3

(b) What do you mean by holonomic and scleronomic systems? Give examples. 3

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