'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 1st Semester Examination, 2021

GE1-P1-PHYSICS

Time Allotted: 2 Hours | Full Marks: 40

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

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

GE-1A

MECHANICS

GROUP-A

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

1. Define the term initial frame of reference.

2. Write down the characteristics of a conservative force.

3. What do you mean by simple harmonic motion?

4. If $\vec{A} = 2\hat{i} - 3\hat{j} + 6\hat{k}$ and $\vec{B} = a\hat{i} + \hat{j} + \hat{k}$ are perpendicular to each other, then find the value of a.

5. State Hooke's law of elasticity.

6. Show that the angular momentum of a particle moving under the action of a central force field is conserved.

7. Define modulus of rigidity.

8. Write down the conditions for over-damped, critically damped and under-damped simple harmonic motion.

GROUP-B

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

9. (a) Find out the area of a parallelogram having diagonals $\vec{A} = 3\hat{i} + \hat{j} - 2\hat{k}$ and $\vec{B} = \hat{i} - 3\hat{j} - 4\hat{k}$. 3

   (b) Determine the unit vector which is perpendicular to both the vectors $\vec{A} = \hat{i} + \hat{j} + \hat{k}$ and $\vec{B} = 2\hat{i} - \hat{j}$. 2

10. If the external torque $\tau = 0$, then show that angular momentum is conserved. Establish the relation between torque and angular acceleration. 2+3

11.(a) State Kepler's laws of planetary motion. 3

(b) Show that areal velocity of a particle moving in a central force field is always constant. 2

12. Establish the differential equation of simple harmonic motion and find out its general solution. 2+3

13.(a) Write down the postulates of Einstein's special theory of relativity. 2

(b) Derive an expression for the resultant velocity for an object moving with velocity V_1 relative to another object moving with velocity V_2. 3

GROUP-C

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

14.(a) Define Young's modulus (Y), Bulk modulus (K), Poission's ratio (σ) and hence establish the relation $Y = 3K(1+\sigma)$. 3+4

(b) Show that the value of Poission's ratio lies between -1 and $+\frac{1}{2}$. 3

15.(a) If $|\vec{A}+\vec{B}| = |\vec{A}-\vec{B}|$, then prove that $\vec{A}$ and $\vec{B}$ are perpendicular to each other. 2

(b) If $|\vec{a}| = 10$, $|\vec{b}| = 1$ and $\vec{a}\cdot\vec{b} = 8$, then find out $|\vec{a}\times\vec{b}|$. 3

(c) Find out $\vec{\nabla}\cdot\vec{A}$ and $\vec{\nabla}\times\vec{A}$ at a point (3, 1, 2), where $\vec{A} = 3\hat{i} + \hat{j} - 4\hat{k}$. 3

(d) State the work-energy theorem. 2

16. Derive the consequences of Lorentz transformation on the measurement of length and time. 5+5

17.(a) The equation of a SHM is $x = a\sin(\omega t + \phi)$. Show that the velocity (v) and acceleration (f) of a particle executing the above harmonic motion satisfies the relation; $\omega^2 - v^2 + f^2 = a^2\omega^4$. 4

(b) Derive an expression for the total energy of a harmonic oscillator. Hence, show that it is constant and is proportional to the square of the amplitude. 4+2

GE-1B

THERMAL PHYSICS AND STATISTICAL MECHANICS

GROUP-A

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

1. What do you mean by mean free path of the molecules of a gas?

2. Draw p-V indicator diagram for isobaric and isochoric processes.

3. Explain the term microstate.

4. What are the limitations of Maxwell-Boltzmann statistics?

5. What do you mean by a perfectly blackbody?

6. Consider ozone gas at room temperature and atmospheric pressure. What is the value of γ for that gas, where γ is ratio of specific heats at constant pressure and constant volume?

7. If the temperature is doubled, then by how many times the r.m.s speed of a gas is increased or decreased?

8. What is Boson? Give an example.

GROUP-B

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

9. (a) If the number of degrees of freedom per molecule of a perfect gas is 'x', then show that $\gamma = 1 + 2/x$, where $\gamma = C_P/C_V$. 3

   (b) Calculate the values of γ for monoatomic and diatomic gas. 2

10. (a) What is meant by 'internal energy' of a system? 1

    (b) Show that, $C_P = T\left(\frac{\partial V}{\partial T}\right)_P \left(\frac{\partial P}{\partial T}\right)_S$ 4

    $$C_V = -T\left(\frac{\partial P}{\partial T}\right)_V \left(\frac{\partial V}{\partial T}\right)_S .$$

11. (a) What do you mean by Fermi energy? 2

    (b) Calculate the occupation probability at $2kT$ units of energy above the Fermi energy E_F, where k = Boltzmann constant. 3

12. (a) What do you mean r.m.s. speed of gas molecules? 1

    (b) Calculate r.m.s. speed from Maxwell-Boltzmann velocity distribution law. 2

    (c) Show that r.m.s. speed is $\sqrt{3}/8$ times the speed of sound, in that medium. 2

13. (a) What is entropy of a thermo-dynamic system? 1

    (b) 100 g water at 60ºC is mixed with 30 g of water at 20ºC. Calculate the entropy change of the system. 4

GROUP-C

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

14.(a) What is the difference between a heat engine and a refrigerator? 2

(b) Prove that $\eta = \dfrac{1}{1+\omega}$, where η is the efficiency of heat engine and ω is the co-efficient of performance of refrigerator. 2

(c) "The lowering of sink temperature (T_2) is more effective in increasing the efficiency of a Carnot engine." 3

Explain the above observation.

(d) A reversible heat engine converts $1/6$ th of the heat input into work. If the temperature of the sink is reduced by 62ºC, its efficiency is doubled. Find out the temperatures of the source and the sink. 3

15.(a) Explain the ultraviolet-catastrophe in Rayleigh-Jeans spectral distribution. 2

(b) Write down Planck's law of radiation. Derive the Rayleigh-Jeans law and Wien's displacement law from Planck's law. 1+4

(c) Calculate the wavelength of light corresponding to the maximum in the spectral distribution of the sun. Assume that the sun radiates with properties of a black-body radiator at 600 K. 3

16.(a) Calculate the Fermi-Dirac distribution function from the Fermi-Dirac statistics. 5

(b) Calculate the lowest energy of a system of 10 identical particles in a cubical box of side L, using 5

(i) Boltzmann-Einstein statistics.

(ii) Fermi-Dirac statistics.

17.(a) Derive the velocity distribution function for a gaseous system that obeys the Maxwell-Boltzmann statistics. 7

(b) N particles are distributed among three energy states $E_1 = 0$, $E_2 = kT$, $E_3 = 2kT$. If the total energy of the system is $200kT$ find out the value of N. 3

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