2015

PHYSICS

[**Honours**]

PAPER – IV

Full Marks : 90

Time : 4 hours

The figures in the right hand margin indicate marks

Candidates are required to give their answers in their own words as far as practicable

Illustrate the answers wherever necessary

GROUP – A

Answer any **two** questions : 15 × 2

1. (*a*) Consider kinetic energy of the system in terms of generalized coordinates and also assume that the potential energy depends on generalized coordinates only. Show that

$$p_k = \frac{\partial L}{\partial \dot{q}_k},$$

where L is the Lagrangian of the system. 3

(*b*) What is a cyclic coordinate ? What do you do with this ? Explain with an example. 3

(*c*) Calculate the frequencies of vibration of a double pendulum formed by two equal masses and equal lengths of strings. Use Lagrange's equations. 6

(*d*) Consider the harmonic oscillator problem with $H = p^2/2m + kq^2/2$ and a generating function $F_1 = 1/2\sqrt{km}\, q^2 \cot Q$. Obtain the transformed Hamiltonian. 3

2. (*a*) How do you predict the stability of nuclei against β^- decay using mass parabola ? 3

(*b*) Compare a fixed frequency cyclotron with a betatron. 4

(*c*) Mention and explain one evidence for the supposition that β^- decay accompany neutrino. 3

(*d*) Briefly discuss the Gamo's theory of α-decay. Why the α spectrum is discrete ? 4 + 1

3. (*a*) Write down the partition function for a canonical system. How do you calculate the average energy of such a system in thermal equilibrium in terms of partition function ? If the system consists of atomic oscillators having energies $\epsilon_n = nh\nu$, $n = 0, 1, 2, 3 \ldots \infty$, find out the average energy. Comment on the formula that you obtain ; State a model in which you can apply this. 1+2+4+1

(*b*) Two classical particles have energy states $E = 0, \epsilon, 2\epsilon$ with degeneracies 1, 2, 4 respectively. Find the average energy of the system. 3

(*c*) Make a rough plot of energy distribution functions at two different temperatures for a gas of particles obeying MB statistics and that obeying FD statistics. Indicate which curves correspond to higher temp. in two cases. 4

4. (*a*) Discuss the role played by an optical resonator in laser. Find out the expression for frequency separation between two consecutive modes. Calculate the number of

modes in the wavelength range 2 nm centered about the wavelength 50 nm. The length of the optical resonator is 30 cm. 2 + 4 + 2

(*b*) Explain with necessary diagram, the step-index and graded-index optical fibres. In what respect do they differ ? 3 + 1

(*c*) Show that for a diatomic molecule, the frequency of lines in the rotational spectrum tends to the classical rotational frequencies for the transition between states J and $J+1$, for large values of J. 3

GROUP – B

Answer any **five** questions : 8 × 5

5. (*a*) Show that Lagrange's equations are unchanged if the Lagrangian is multiplied by a scalar constant is added to it. 2

(*b*) For what value of α and β, the transformation $Q = q^{\alpha}\cos\beta p$ and $P = q^{\alpha}\sin\beta p$ is canonical ? 3

(*Continued*)

(*c*) Find the eigen frequencies and the normal coordinates of a vibrating system characterised by a Lagrangian for three degrees of freedom as given by 3

$$L = \frac{1}{2}\left(\dot{\eta}_1^2 + \dot{\eta}_2^2 + \dot{\eta}_3^2\right) - \alpha^2\left(\eta_1^2 + \eta_2^2 + \eta_3^2\right) - \eta_1\eta_2.$$

6. (*a*) Find the S, L and J values that correspond to each of the following states : $^1S_0$, $^3P_2$, $^3D_{3/2}$, $^5F_5$, $^6H_{5/2}$. 5

(*b*) State precisely the conditions and schemes for *LS* and *jj* couplings. 3

7. (*a*) Obtain an expression for the energy levels of a diatomic molecules where the mass of one atom is twice that of the other. 5

(*b*) How many modes of vibration are there in a H_2O molecule ? 1

(*c*) H_2, CO_2, CH_4 – all these molecules do not show rorational spectra. Why ? 2

8. (*a*) What is intrinsic and extrinsic attenuation of optical energy in optical fibre ? The fibre loss in 30 km long fibre is 0·8 dB/km. This optical fibre is used in a communication link. Compute the output power when the input power is 200 μW. 2 + 2

(*b*) What do you mean by 'dead time' in GM counter ? A GM counter has a deadtime of 400 μ*s*. What are the true counting rates when the observed rates are 10 per minute ? 2 + 2

9. (*a*) Which of the following reactions are allowed or forbidden and why ? 4

(*i*) $n \rightarrow p + e^-$

(*ii*) $n \rightarrow \pi^+ + e^- + \overline{\nu_e}$

(*iii*) $\pi^- + p \rightarrow \pi^0 + n$

(*iv*) $\pi^+ \rightarrow \mu^+ + \nu_\mu$

(*b*) How do the cross-sections for the neutron and proton induced nuclear reations vary with energy ? Explain. 4

10. (*a*) Give the explanation of anomalous Zeeman effect on the basis of quantum mechanical theory. 6

(*b*) The Zeeman components of 500 nm spectral line are 0·0116 nm apart when the magnetic field is 1·00 Tesla. Find the ratio e/m for the electron from this data. 2

11. (*a*) Outline the major evidences in favour of the nuclear shell model. 4

(*b*) In what way a scintillation counter is superior to a G.M. counter ? 2

(*c*) Explain pair creation. 2

12. (*a*) What are four different types of interactions ? Explain any one of them with illustration. 4

(*b*) Find the maximum kinetic energy of the electron emitted in the β- decay of free neutron. The neutron-proton mass difference is 1.30 MeV and $m_e = 0.51$ MeV. 2

(*c*) Why must the quarks in a hadron have different colour degrees of freedom. 2

GROUP – C

Answer any **five** questions : 4×5

13. A system has 5 different macrostates under which there are 6, 20, 42, 12 and 2- microstates. Energy, E for the system has values 4, 4, 2, 6 and 10 units respectively for 5 macrostates. Find the relative probabilities for each of the microstates and calculate $\langle E \rangle$ and $\langle E^2 \rangle$. 4

14. If F and G are two functions of canonical variables. Prove that the Poisson bracket between the two is invariant under canonical transformation. 4

15. Describe briefly the working of a semiconductor laser for obtaining green light. What are the semiconductor materials to be used for such lasers ? 3 + 1

16. (*a*) Explain the concepts of positron emission and electron capture. 2

(*Continued*)

(*b*) An electron of rest mass m_0 moves in a plane perpendicular to a uniform magnetic field B along a circular orbit of radius 30 meters. Total energy of the electron $\epsilon = 2{\cdot}5 \times 10^9$ eV. Allowing for relativistic kinematics ($E >> m_0c^2$). Compute B. 2

17. (*a*) Give the variation of cosmic ray intensity with latitude and explain the cause. 3

(*b*) What do you know about strong and weak interactions ? 1

18. Why is $^{235}_{92}U$ fissionable by slow neutrons whereas $^{238}_{92}U$ is not. 4

19. Explain the meaning of iso-spin and strangeness. 2 + 2

20. Considering M-B distribution for occupation index in an energy level, find out the continuous energy distribution law for an ideal gas of N-molecules. 4

5. Use origin software to draw a mean graph with given set of data with proper label and scale

5+2

6. Write a program to find the roots of a quadratic equation: $ax^2 + bx + c = 0$ and verify it for given values of a, b and c.

3+4

7. Write down a program to find the area of a circle, given by the equation : $x^2 + y^2 = a^2$ and verify it for given value of a.

3+4