'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL

B.Sc. Honours 6th Semester Examination, 2023

DSE-P4-PHYSICS

Time Allotted: 2 Hours | Full Marks: 60

The figures in the margin indicate full marks.

The question paper contains DSE-4A and DSE-4B.
Candidates are required to answer any *one* section from the *two* sections and they should mention it clearly on the Answer Book.

DSE-4A

NUCLEAR AND PARTICLE PHYSICS

GROUP-A

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

   (a) Show that the electric dipole moment of a nucleus in its ground state vanishes. 3

   (b) Show that the nuclear density is almost same for all the nuclei. 3

   (c) Show that the photoelectric effect cannot take place with a free electron. 3

   (d) What are the difficulties associated with the continuous β-ray spectrum? 3

   (e) Why the Bethe-Bloch formula of interaction of charged particles with matter does not apply to the electrons? 3

   (f) Check if the following reactions are allowed or not. Give brief explanation. 3

   (i) $\pi^- + n \rightarrow \Sigma^- + \mathrm{K}^\circ$

   (ii) $\Sigma^\circ \rightarrow \mathrm{K}^+ + \pi^-$

   (iii) $\pi^+ \rightarrow \mu^+ + \upsilon_\mu$

GROUP-B

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

2. Derive an expression for the Q-value of a nuclear reaction. Show that a threshold of energy is needed for an endoergic reaction. 4+2

3. (a) Why ${}^{1}_{1}\mathrm{H}$ or ${}^{2}_{1}\mathrm{H}$ radioactivity is not possible while α-radioactivity is observed in nature? 3

   (b) The mean range of ${}^{210}\mathrm{Po}$ α-particles ($E_\alpha = 5.3$ MeV) in air at STP is 0.03842 mm. Find out its range in Aluminium ($A = 27$, $\rho = 2700$ kg/m^3). 3

4. On the basis of the semi-empirical mass formula of Weizsäcker, obtain an expression for the binding energy and mass of a nucleus in its ground state. 6

5. (a) Differentiate between a GM counter and an ionisation chamber. 3

   (b) Why a GM counter is not quite suitable for the detection of gamma rays? 3

6. (a) Derive an expression for the maximum kinetic energy of a particle accelerated by a cyclotron. 4

(b) A proton synchrotron accelerates protons to 15×10^3 MeV. The magnetic field strength is 1.5 T. What is the radius of the proton's orbit? 2

7. (a) If the maximum energy of the recoil electron is 1 MeV in a Compton scattering experiment, what is the energy of the scattered photon? 3

(b) ^{7}Li ($z = 3$) and ^{7}Be ($z = 4$) have the atomic masses 7.016005 u and 7.016929 u, respectively. Which of them will show β-activity and of what type? Calculate the Q-value for the β-emission. 1+1+1

GROUP-C

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

8. (a) What are the similarities between a liquid drop and a nucleus? 2

(b) Explain all the terms that appear in the Bethe-Weizsäcker semi-empirical formula for the nuclear binding energy. 4

(c) Apply the semi-empirical mass formula for the prediction of nuclear stability against β-decay. 4

(d) Predict the ground state spin and parity of a $^{17}_{8}$O nucleus on the basis of the single particle shell model. 2

9. (a) Briefly describe the electron scattering experiment performed by R. Hofstadter, for the estimation of nuclear charge distribution. Further discuss the Fermi distribution for the nuclear charge density. 4+2

(b) How did Rutherford estimate the nuclear radius from his scattering experiment? 3

(c) Find out the distance of closest approach of 1 MeV protons incident on gold (z = 79) nuclei. 3

10. (a) Discuss Gamow's theory of emission of α-particles from a radioactive substance and show that it leads to the Geiger-Nuttal Law. 5+1

(b) Why internal conversion is preffered over γ-emission by some excited nuclei? 2

(c) What is a neutrino? Explain qualitatively how the neutrino hypothesis solves the apparent breakdown of conservation of angular momentum and energy in β-decay. 1+3

11. (a) Explain the action of Van-de-Graff generator by drawing a neat sketch of the machine. 5

(b) What do you mean by resonant states? 2

(c) Write down the composition of a proton in terms of quarks. 1

(d) Discuss the evidence of the existence of gluons. 4

DSE-4B

CLASSICAL DYNAMICS

GROUP-A

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

(a) Define the gyroradius and the gyrofrequency for a charged particle moving in a uniform magnetic field. Estimate the gyrofrequency of an electron moving perpendicular to a magnetic field of 1 Gauss. Given $m_e = 9.1 \times 10^{-31}$kg and $q_e = 1.6 \times 10^{-19}$ C. 1+2

(b) Show that the Lagrangian of a two body system under a central force can be simplified to a one body system represented by the reduced mass. 3

(c) Write down the conditions for a stable and an unstable equilibrium. For a potential given by, $V(x) = \frac{k}{2}x^2 + \frac{k^2}{x}$ where $k > 0$, find out the equilibrium values of x and determine their stability. 1+2

(d) Show that if an object is measured to be moving with a velocity $v < c$ in one inertial frame, then it will travel with a velocity $v' < c$ when measured in all other possible inertial frames. 3

(e) Show that momentum conjugate to a cyclic coordinate is conserved. In a real system give an example of such a conserved momentum. 3

(f) What is the laminar flow? How does a laminar flow gets transformed into a turbulent flow? 1+2

GROUP-B

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

2. What do you mean by the symmetry of a dynamical system? Show that the isotropy of space leads to conservation of angular momentum. 1+5

3. Write down the expression for the effective potential (V_{eff}) for the gravitational force. Plot V_{eff} versus r and mark on the diagram the energy levels for which an object moves in circular, elliptic, parabolic and hyperbolic orbits. 1+3+2

4. Using Lorentz transformation, derive and explain the length contraction and time dilation. 3+3

5. (a) Show that $\frac{d\gamma}{dt} = \frac{\gamma^3}{c^2}\vec{v}\cdot\vec{a}$, where $\vec{v}, \vec{a}$ are the 3 dimensional velocity and acceleration, respectively. 3

(b) An inertial frame A is moving along +x-axis relative to a frame S with a velocity of 3c/5. Another inertial frame B is also moving along the +x-axis relative to the frame S with a velocity of c/3. What is the velocity of frame B with respect to frame A? 3

6. Two coupled oscillators, each having the same mass m and described by the generalized coordinates x and y respectively, have the following kinetic and potential energies: 3+3

$$T = ml^2(2\dot{x}^2 - 10\dot{x}\dot{y} + 13\dot{y}^2)$$
$$V = mgl(5x^2 - 22xy + 25\dot{y}^2)$$

where l is a constant with dimension of length and g is the acceleration due to gravity. Derive the characteristic equation and find out the normal frequencies of vibration of the system.

7. A large plate moves with speed v_0 over a stationary plate on a layer of oil. If the velocity profile is that of a parabola, with the oil at the plates having the same velocity as that of the plates, what is the shear stress on the moving plate on the oil? If a linear profile is assumed, what is the shear stress on the upper plate? Given that the thickness of the oil layer is d. 3+3

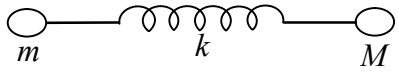
GROUP-C

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

8. (a) Differentiate between a holonomic and a scleronomic system. 2

(b) A particle of charge q, starting from rest at origin, is travelling in a uniform magnetic field given by $\vec{B} = B\hat{x}$ and a uniform electric field given by $\vec{E} = E\hat{z}$. Derive the equations of motion of the particle and show that it represents a cycloid. 10

9. An oscillating linear diatomic molecule is shown below: 5+4+3



where m, M are the masses of the atoms and k is the spring constant of the bond between them. Construct the Lagrangian of the system and derive the characteristic equation. Find out the normal frequencies of vibration and the normal modes of oscillation of the system.

10.(a) An observer B is moving with a velocity v with respect to another observer A, where $0 < v < c$. Assume that a photon is moving in the same direction as B and the observer A measures its energy as E. Show that the observer B measures the photon energy as, 4

$$E' = E\sqrt{\frac{1+\beta}{1-\beta}}, \text{ where } \beta = v/c.$$

(b) A moving source emits radiation at a frequency ω_0 and a stationary observer detects the same radiation at frequency ω. Derive the relation between ω_0 and ω. Assume that the velocity is relativistic. 3

(c) An excited nucleus with rest mass m_0 drops to a lower energy state by losing energy ε. It emits a photon and undergoes a recoil. Show that the frequency of the photon is 5

$$\upsilon = \frac{\varepsilon}{h}\left(1 - \frac{\varepsilon}{2m_0c^2}\right), \text{ where } h \text{ is the Planck's constant.}$$

11.(a) The velocity field of a fluid, in cylindrical coordinates, is given by

$$\vec{v} = A\left[1 - \left(\frac{r}{R}\right)^2 + c\ln\left(\frac{r}{R}\right)\right]\hat{z}$$

where A, c, R are positive constants.

(i) At what value of r does the fluid have maximum velocity? Find out the magnitude of the maximum velocity. 2+2

(ii) Check if the fluid is compressible and if it is irrotational. 1+3

(b) A fluid, of density 920 kg/m^3, flows through a pipe of diameter 50 mm with a flow rate of 0.15 m^3/min. The coefficient of viscosity is 56 mPa.s. Compute the Reynold's number and determine if the fluid flow is laminar or turbulent. Given that the critical Reynold's number is 2320. 4

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