



'समानो मन्त्रः समितिः समानी'

UNIVERSITY OF NORTH BENGAL
B.Sc. Honours 6th Semester Examination, 2022

DSE-P3-PHYSICS

Time Allotted: 2 Hours

Full Marks: 60

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

The question paper DSE3 contains DSE-3A, DSE-3B and DSE-3C.

Candidates are required to answer any *one* section from the *three* sections and they should mention it clearly on the Answer Book. Candidates should also ensure that the chosen section in the paper DSE3 is different from the chosen section in the paper DSE4.

DSE-3A

NUCLEAR AND PARTICLE PHYSICS

GROUP-A

1. Answer any **four** questions from the following: 3×4 = 12
 - (a) Explain the term mass defect, packing fraction and binding energy of nuclei. 3
 - (b) Why electron cannot exist as an integral part of the nucleus? 3
 - (c) Show that the frequency of revolution of the ion in a cyclotron is independent of its speed and the radius of the path. 3
 - (d) Give at least three evidences in favour of the shell model of the nucleus. 3
 - (e) On what factors does the stability of a nucleus depend? 3
 - (f) Check if the following reactions are allowed or forbidden: 3
 - (i) $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$
 - (ii) $\mu^- \rightarrow e^- + \nu_e + \bar{\nu}_e$
 - (iii) $\pi^+ + n \rightarrow k^+ + k^0$.

GROUP-B

Answer any *four* questions from the following

6×4 = 24

2. (a) Calculate the Q -value for the reaction- ${}^3\text{H}(d, n){}^4\text{He}$. Give an expression for the neutron energy for this reaction in terms of the deuteron energy, Kx and angle θ . 2+3
- (b) Explain differential cross-section of a nuclear reaction. 1

3. (a) Explain pair-production. Show that the threshold energy for the pair production is equal to $2m_e c^2$, where $m_e c^2$ = rest mass energy of electron. 1+3
 (b) What is meant by 'dead-time' of a GM-counter? 2
4. (a) What do you mean by resonance reaction? 1
 (b) With the help of a diagram explain the principle of action of linear accelerator. What is the main advantage of this type of accelerator? 4+1
5. Use semi-empirical mass formula to predict the more stable nuclei between ${}^7_3\text{Li}$ and ${}^8_3\text{Li}$. ($a_c = 0.71$ MeV, $a_n = 22.7$ MeV). Using energetics of β -decay find conditions of β^+ disintegration and electron capture. 3+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 and the magnetic field strength is 1.5 T. What is the proton orbit radius? 2
7. (a) Explain with the help of energy level diagram the fine structure of α -spectrum. 4
 (b) Assuming that $1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$ and the radius of a nucleus to be given by $R = r_0 A^{1/3}$, where $r_0 = 1.2 \times 10^{-15} \text{ m}$. Calculate the density of nuclear matter. 2

GROUP-C

Answer any two questions from the following

12×2 = 24

8. (a) Discuss the nature of β -ray spectrum. Explain the role of neutrino hypothesis in understanding the spectrum. 4+3
 (b) What are the properties of neutrino? 2
 (c) What is Kurie plot? 1
 (d) Why pair production cannot occur in vacuum? 2
9. (a) Describe the liquid drop model of the nucleus. Point out the usefulness and limitations of this model in understanding the nuclear phenomenon. 3+3
 (b) Predict the ground state spins and the parities of ${}^{27}_{13}\text{Al}$ and ${}^{41}_{18}\text{Ar}$. 2
 (c) Comment on whether the following reactions are exothermic or endothermic. 4
 (i) ${}^3_1\text{H} + {}^2_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0n$
 (ii) ${}^4_2\text{He} + {}^{14}_7\text{N} \rightarrow {}^{17}_8\text{O} + {}^1_1\text{H}$
- Given $M({}^3_1\text{H}) = 3.0169982$, $M({}^2_1\text{H}) = 2.0147361$, $M({}^4_2\text{He}) = 4.0038727$,
 $M({}^1_0n) = 1.0089832$, $M({}^{14}_7\text{N}) = 14.003074$, $M({}^{17}_8\text{O}) = 16.999133$ and
 $M({}^1_1\text{H}) = 1.007825$. (All in unified atomic mass unit).

- 10.(a) Give the constructional details and the working of a synchrotron. 3½ + 3½
- (b) What is the energy to which protons can be accelerated in a cyclotron with a dee diameter of 2 m and a magnetic field of flux density 0.72 Wb/m²? Mass of proton = 1.67 × 10⁻²⁷ kg. 3
- (c) Find the distance of closest approach of 1 MeV proton incident on gold nuclei. 2
- 11.(a) What are ‘baryon and lepton number’? Show, with examples, that in any nuclear reaction, they are conserved. 3+3
- (b) What do you mean by resonant states? Give examples of baryonic and mesonic resonances. 1+1
- (c) What do you mean by quarks? 2
- (d) Give the quark model of (i) meson and (ii) proton. 2

DSE-3B

ASTROPHYSICS AND ASTRONOMY

GROUP-A

1. Answer any **four** questions from the following: 3×4 = 12
- (a) Define parsec. 3
- (b) What do you mean by Galaxy Morphology? 3
- (c) What is luminosity of a star? 3
- (d) The temperature of chromosphere and corona is very high in comparison to that of photosphere. Why photosphere is the brightest of the three? 3
- (e) What is equation of time? Briefly explain it. 3
- (f) Describe the differences between Newton’s and Einstein’s Gravitational theory. 3

GROUP-B

Answer any **four** questions from the following

6×4 = 24

2. What do you mean by Galaxy? Describe Hubble’s classification of Galaxies. 2+4
3. What are the types of telescope? Explain briefly the working principle of any one of them. 2+4
4. Derive the expression of Jeans mass. What is its physical origin? 4+2
5. (a) Describe properties of Galactic Nucleus. 3
- (b) Using appropriate diagram, explain the horizontal coordinates of a star and determine these for the pole star. 3

6. Describe Hertzsprung-Russell diagram to classification of stars. The masses of four main sequence stars are $15 M_{\odot}$, $10 M_{\odot}$, $5 M_{\odot}$ and $1 M_{\odot}$. Place them correctly on the Hertzsprung-Russell diagram. 4+2
7. (a) State and explain Hubble's law related to the distance-velocity relation of galaxy. 3
 (b) Estimate the age of the universe for the value of Hubble's parameter $70 \text{ kms}^{-1}\text{Mpc}^{-1}$. 3

GROUP-C

Answer any *two* questions from the following

12×2 = 24

8. (a) Describe nature of the rotation and rotational curve of Milky way. 4+4
 (b) Describe basic structure and properties of the Milky way. 2+2
9. (a) State and explain Virial theorem to understand the presence of dark matter. 6
 (b) What is the source of solar energy? Describe it by thermo-nuclear reaction. 1+2+3
 Describe also different types of layer of sun.
- 10.(a) Describe the origin of the solar system by the Nebular model. 6
 (b) What do you mean by local and global thermodynamic equilibria? 3
 (c) Determine the size to which the Earth must shrink to that use of Einstein's theory of gravity becomes necessary. 3
- 11.(a) Discuss how you determine temperature and radius of star. 3+3
 (b) Briefly explain the different criteria to make a telescope. 6

DSE-3C

ADVANCED MATHEMATICAL PHYSICS-II

GROUP-A

1. Answer any *four* questions from the following: 3×4 = 12
- (a) Show that the inverse of each group element of a group is unique. 3
 (b) Prove that for all $x, y \in G$, $(xy)^{-1} = y^{-1}x^{-1}$. 3
 (c) Define Hamiltonian H . Give its physical significance. 1+2
 (d) Discuss the limit at which binomial distribution becomes Poisson distribution. 3
 (e) Show $[J_z, J_x] = J_y$ where $[]$ stands for Poisson bracket and J_x, J_y and J_z are the x, y and z -component of angular momentum. 3
 (f) The mean and variance of a Binomial distribution are 3 and 2. Find the probability that the variate takes values less than or equal to 2. 3

GROUP-B

Answer any four questions from the following

6×4 = 24

2. Show that homogeneity and isotropy of space leads to conservation of linear and angular momentum respectively. 3+3
3. (a) Show that a function whose Poisson bracket with Hamiltonian vanishes is a constant of motion. 3
 (b) What do you mean by Legendre dual transformation? How one can obtain Hamilton's function from Lagrange's function. 1+2
4. (a) What do you mean by representation of a group? Distinguish between reducible and irreducible representation. 2+2
 (b) Define a cyclic group. 2
5. (a) Derive the expression for mean and standard deviation of the Binomial distribution. $1\frac{1}{2}+2\frac{1}{2}$
 (b) Four bad apples are mixed accidentally with 20 good apples. Obtain the probability distribution of the number of bad apples in a draw of 2 apples at random. 2
6. (a) What do you mean by canonical transformation? Show that the transformations $P = \log(\sin p)$ and $Q = q \tan p$ are canonical. 4
 (b) State and explain Hamilton's least action principle. 2
7. A point P is chosen at random on the circumference of the circle $x^2 + y^2 = 1$. The random variable X denotes the distance of P from the point $(1, 0)$. Find the mean and variance of X . 6

GROUP-C

Answer any two questions from the following

12×2 = 24

8. (a) What is Abelian group? 2
- (b) Show that four matrices $A = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$, $B = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$, $C = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}$ and $D = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$ form an Abelian group of order four under multiplication. 4
- (c) Show that the identity element of a group is unique. 2
- (d) Write short notes on: 2+2=4
 (i) Homomorphism
 (ii) Isomorphism.

9. (a) Define the character of a representation. 2
 (b) Prove that all conjugate elements of a group have the same character. 4
 (c) State and explain Schur's lemma. 3
 (d) What do you mean by order of a group? Prove that an element of a group and its inverse have the same order. 1+2

- 10.(a) Discuss the motion of a force free symmetrical top. 4
 (b) Obtain the Euler Lagrange differential equation by variational method. 4
 (c) The Hamiltonian of a one dimensional harmonic oscillator is given by 4

$$H(q, p) = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 q^2$$

where all the symbols have their usual meanings. A canonical transformation from (q, p) to (Q, P) is performed using the following generating function:

$$F_1(q, Q) = \frac{1}{2}m\omega q^2 \cot Q$$

Find $H(Q, P)$.

- 11.(a) Define the Poisson distribution. 1
 (b) Work out the Moment Generating Function (MGF) for the distribution. 4
 (c) A biased die has probabilities $p/2, p, p, p, p, 2p$ of showing 1, 2, 3, 4, 5, 6 respectively. Find the variance of this probability distribution. 4
 (d) Calculate the mean of the probability distribution 3

$$f(x) = \frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

σ, μ are positive constants.

—x—