

2022

5th Semester Examination

PHYSICS (Honours)

Paper : DSE 2-T

[CBCS]

Full Marks : 60

Time : Three Hours

*The figures in the margin indicate full marks.
Candidates are required to give their answers
in their own words as far as practicable.*

[Nuclear and Particle Physics]

Group - A

Answer any **ten** of the following questions : $10 \times 2 = 20$

1. (a) Calculate binding fraction for ^{16}O . Given $M(^1\text{H}) = 1.007825 \text{ u}$, $M(^1_0\text{n}) = 1.008655 \text{ u}$, $M(^{16}\text{O}) = 15.994915 \text{ u}$, and $1 \text{ u} = 931.5 \text{ MeV}$.
- (b) A 5 MV Van'de Graaff generator is equipped to accelerate protons, deuterons and α -particles. What are the maximum energies of the various particles available from the accelerator?
- (c) Show that the mass difference of two mirror nuclei of odd A and with N and Z differing by one unit is given by : $M_p - M_n + a_c A^{\frac{2}{3}}$.

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[Nuclear and Particle Physics]

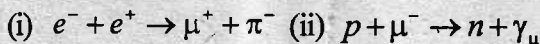
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- (d) Predict the state of energy level of unpaired odd nucleon and spins and parities of the following nuclei from the single particle shell model of ${}^{33}_{16}\text{S}$.
- (e) The masses of the different nuclei taking part in ${}^7\text{Li}_3(p, n){}^6\text{Li}_3$ reaction in u are follows :
 $M({}^7\text{Li}_3) = 7.01822$, $M({}^1\text{H}_1) = 1.00814$, $M({}^4\text{He}_4) = 4.00260$ and mass of the product nucleus = 7.01915. Calculate the Q-value of this reaction in MeV.
- (f) What is exoergic reaction? Give an example.
- (g) What do you mean by 'dead time' and 'recovery time' of a GM counter?
- (h) What are the predictions of nuclear shell model?
- (i) Write down Bohr's independence hypothesis on compound nuclear reaction mechanism.
- (j) A cyclotron has a magnetic field of 1.5 Wb/m². The extraction radius is 0.5m. Calculate the frequency of RF oscillator necessary for accelerating deuterons.
- (k) Using Gell-Mann-Nishijima relation, show that strangeness quantum number of Σ -particles is -1.
- (l) Explain parity violation in weak interaction or in Beta decay.
- (m) State with reasons whether the following reactions are allowed or forbidden.



- (n) What are Lepton and Baryon quantum numbers?
- (o) A π^+ meson of rest mass $273 m_e$ decays from rest to emit a μ^+ meson of rest mass $207 m_e$ with an average kinetic energy 4.2 MeV and a μ^- -neutrino. Calculate the energy of the μ^- -neutrino.

Group - B

Answer any *four* of the following questions : $5 \times 4 = 20$

2. What is scintillation detector? Write down the uses and limitations of the detector. 1+2+2
3. Derive an expression for the Coulomb energy of a nucleus A_ZX in terms of A and Z. Give any two achievements of liquid drop model. 3+2
4. Find the density of ${}^{12}_6C$ nucleus. Comment on the following properties of ${}^{208}_{82}Pb$ nucleus (i) Charge (ii) Spin (iii) Size. 2+1+1+1
5. (a) What are the different modes of radioactive decays? 2
(b) Explain internal conversion process. 3
6. (a) Find the lowest values of the kinetic energy of an electron and a proton causing the emergence of Cherenkov's radiation in a medium with refractive index $n = 1.60$. 3
(b) Calculate Compton shift in wavelength when scattering angle is 180° . 2

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7. What are colour quarks? Why was it necessary to introduce an additional property designated as colour to quarks and antiquarks? 2+3

Group - C

Answer any *two* of the following questions : $10 \times 2 = 20$

8. (a) What is meant by isospin? Give the value of the isospin and the z component of the isospin for (i) pions and (ii) nucleons. 3
- (b) For heavy α -emitters show that the kinetic energy of α -particle is nearly equal to α -disintegration energy. 2
- (c) Write down Nordheim's rules to determine the ground-state spin-parity of an odd-odd nuclei. Find the ground-state spin-parity of ^{42}K nucleus. 3+2
9. (a) Why are the most stable nuclei found in the region near $A = 60$? Find the energy release, if two ^2H nuclei fuse together to form ^4He nucleus. The binding energy per nucleon of H and He is 1.1 MeV and 7.0 MeV respectively. 2+3
- (b) What are magic number? What is the evidence for shell structure of the nucleus? Sketching the main assumption, explain the shell model of the nucleus. 1+2=2
10. (a) Discuss the energy spectrum curve from β -decay of a radioactive nuclide. Show that the law of

conservation of energy and momentum are not obeyed in β -decay. 4+2

- (b) The beam of a fixed frequency cyclotron has a maximum radius of 1 m. The magnetic field induction is 1.5 tesla. Find the energy of α -particles accelerated by the accelerator. 4

11. (a) Show that the Q-value of nuclear reaction is :

$$Q = K_y \left(1 + \frac{m_y}{M_y} \right) - K_x \left(1 - \frac{m_x}{M_y} \right) - \frac{2}{M_y} \sqrt{m_x m_y k_x k_y} \cos \theta$$

where, m_x : mass of incident particle, m_y : mass of product particle, M_x : mass of target nucleus, M_y : mass of product nucleus. Other symbols have usual meanings. 5

- (b) Explain the difference between ionization chamber, proportional counter and Geiger Muller Counter. 3
- (c) Write down and explain the semi-empirical mass formula. 2

OR

[Astronomy and Astrophysics]

Group - A

1. Answer any *ten* of the following questions : $10 \times 2 = 20$

- (a) With the help of a suitable diagram illustrate the nautical triangle for deriving transformations between the horizontal and equatorial frames.
- (b) Write down the Kepler's second and third law of planetary motion.
- (c) What can we learn from H-R diagram?
- (d) What do you mean by red and blue shift of spectral lines?
- (e) Suppose the rotation curve of the Milky Way is flat out to $2R_0$. What mass does that imply out to that distance?
- (f) What do you mean by luminosity and brightness?
- (g) Name the different types of detectors used in Astronomical telescopes. Among them, which one is the most important at the present time?
- (h) What are white dwarfs?
- (i) How helium is generated inside the star?

- (j) Distinguish between stars of population - I and II.
Where are they found in the galaxy.
- (k) If the magnitudes of the components of a binary star are 1 and 2, find the total magnitude.
- (l) What are red giant stars?
- (m) What are solar flares?
- (n) The distance of a star is $r = 100$ pc and its apparent magnitude $m = 6$. What is its absolute magnitude?
- (o) Calculate the frequency of highest intensity radiation whose temperature is (i) 2400 K and (ii) 800 K, respectively.

Group - B

Answer any **four** of the following questions : $5 \times 4 = 20$

2. What is Celestial sphere? Draw the celestial sphere and indicate the direction of the celestial pole at the latitude $\phi = 45^\circ$ in the Horizontal system. Also indicate the zenith, the nadir, the meridian and the horizon in the same diagram. What do you mean by the zenith distance? 2
3. Discuss in brief about different stellar nucleosynthesis processes.

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4. What is horizon system and Equatorial system related with astronomical coordinate system?
5. Explain the nebular model of the origin of the solar system, mentioning the two main difficulty of this model. What was the reason for its revival in the 1940s?
6. Write a short note on Milky way.
7. Show schematic diagram of the solar atmosphere. Write some salient features of Mars. What are protostars?

2+2+1

Group - C

Answer any *two* of the following questions : $10 \times 2 = 20$

8. (a) Discuss about solar corona.
(b) Calculate the temperature at which a particle will has the sufficient energy to ionize a hydrogen atom.
(c) The distance between the components of the binary star ξ Herculis is $1.38''$. What should the diameter of a telescope be to be able resolve the binary? If the focal length of the objective is 80 cm, what should the focal length of the eyepiece be to resolve the components, when the resolution of the eye is $2''$? Assume that $\lambda = 550 \text{ nm}$. $3+3+(2+2)$
9. (a) Discuss in brief about the necessity and effectiveness of space telescope.

- (b) What is stellar parallax?
- (c) Write down the parameter used to express the frequency of sunspots, explaining the symbols. What do you mean by solar limb darkening?
- (d) The apparent magnitude of full moon is 12.5 and that of Venus at its brightest is 4.0. Which is brighter and how much? $3+2+3+2$
10. (a) How do we determine cosmic abundances?
- (b) On the basis of relative number of atoms of hydrogen and helium of the universe, calculate the fractional mass of the matter in the universe contributed by hydrogen and helium.
- (c) What is the basis of the Harvard classification of stellar spectra? Draw and explain the HR diagram. How do we interpret this diagram? What do you mean by 'Main Sequence' on this diagram? $3+2+(1+2+1+1)$
11. (a) Which one is the lightest planet in solar family? Write in brief about origin of solar family.
- (b) An astronomical object named Cygnus X-1 which is a strong x-ray source is found to radiate like a blackbody with peak wavelength at 1.45 nm. Calculate its temperature. Assume the constant of

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Wien's displacement law is equal to 2.9×10^{-3} mK.

(c) Classify luminosity of the stars.

(d) What direct information do we get from the rotation curves of galaxies? $(1+3)+2+2+2$

(11)

OR

[Physics of Earth]

Group - A

Answer any *ten* questions : $10 \times 2 = 20$

1. Which are the Jovian planets in our solar system?
2. What are the two chief processes of energy generation in stars?
3. What are sources of earth's internal thermal energy?
4. Why moon has no atmosphere?
5. The wavelength of UV radiation detected in solar radiation in the upper atmosphere of earth is 282 nm and the power of radiation is found 11 Wm^{-2} . Find the surface temperature of sun. (Stefan constant = $5.7 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$).
6. Discuss two important geological evidences in favour of continental plate motion.
7. What is Cryosphere?
8. Define the term "Albedo" with example.
9. Write the names and characteristics of the clouds formed in the upper part of troposphere?
10. What are greenhouse gases? Draw the variation in concentration of greenhouse gases in the atmosphere of Antarctica for the last 300 years.

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11. Define the geological time scale of mesozoic era.
12. What is the application of Richter scale?
13. Define the factors which influence ocean currents.
14. Why do the comets have a long tail like structure?
15. What is solar flare?

Group - B

Answer any *four* questions : $5 \times 4 = 20$

1. What is cosmic microwave background radiation? Discuss the significance of the temperature associated with the radiation spectrum? 3+2
2. What are the cosmic rays? Define the hard component and soft component of cosmic ray flux measured in laboratory. 2+3
3. What are different types of plate motion? Discuss the mechanism of production of the San Andreas fault. 2+3
4. Discuss the principles of uniformitarianism and catastrophism. 5
5. Discuss the most accepted hypothesis on the origin of earth magnetic field. 5
6. Draw and explain the predicted variation of carbon-dioxide concentration in earth atmosphere in billion years from present time. 5

Group - C

Answer any *two* questions : $10 \times 2 = 20$

1. (a) Write a brief note on Cuiper belt? What are dwarf planets? 3+2
(b) Discuss about the formation of Van Allen radiation belt. 5
2. (a) What are different types of seismic waves? Discuss how internal structure of earth can be revealed by the reflection and refraction of seismic waves. 2+4
(b) What is a time-travel curve? Discuss it's importance. 2+2
3. (a) What are the differences between an RNA and an DNA molecule? What geological evidence would lead us to conclude that an RNA world came before proteins or DNA? 3+3
(b) Discuss the salient features of mitosis and meiosis. 4
4. (a) What is magnetic reversal of earth? What is the origin of sea floor magnetism? 3+3
(b) Discuss how a volcanic Island transforms into a seamount. 4

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OR

[Advanced Mathematical Physics-II]**Group - A**Answer any *ten* questions : $10 \times 2 = 20$

1. A biased six-sided die has probabilities $\frac{1}{2}p, p, p, p, p, 2p$ of showing 1, 2, 3, 4, 5, 6 respectively. Calculate p .
2. If a group is defined as $a * b = a + b - 1$, then find the inverse of the group.
3. A bag contains seven red balls and three white balls. Three balls are drawn at random and not replaced. Find the probability function for the number of red balls drawn.
4. Let $\phi : (G, o) \rightarrow (G^*, *)$ be a homomorphism. Then prove that ϕ is one-to-one if $\ker \phi = \{e_G\}$.
5. Given $P(A) = 1/2, P(B) = 1/3, P(AB) = 1/4$. Find $P(A/B)$ and $P(A+B)$.
6. If two representations ρ and ρ' have same character, then show that they are isomorphic.
7. The overall percentage of failures in an examination is 20%. If 6 candidates appear in the examination, what is the probability that at least 5 passes?

8. If G is a finite abelian group, then show that every irreducible representation of G is one dimensional.
9. Distinguish between the function and functional.
10. Can you explain physically why a straight line joining the two points in Brachistochrone problem cannot be the curve?
11. Prove that the intersection of two normal subgroups of a group G is normal in G .
12. If the function F and G are constants of motion, then show that the Poisson bracket of F and G must be a constant of motion.
13. Check whether the transformation $Q = p$ and $P = -q$ is canonically conjugate or not?
14. Find the probability of drawing two aces at random from a pack of cards (i) when the first card drawn is replaced at random into the pack before the second card is drawn, and (ii) when the first card is put aside after being drawn.
15. For a rigid body consisting of N particles, how many generalised coordinates need to be specified?

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Group - B

Answer any **four** questions : 5×4=20

1. (a) The random variable X is distributed as $X \sim \text{Bin}(3, \frac{1}{2})$. Evaluate the probability function $f(x)$ using the binomial recurrence formula.
- (b) Write down the Poisson distribution function and hence calculate moment generating function, mean and variance. 2+(1+2)
2. A radioactive substance decays with a fairly long half life time. We observe such a system for an interval of time which is very small compared to the half life time. Show that the probability of getting n counts during an interval of time ' t ' is given by

$$P_n(t) = \frac{(\mu t)^n}{n!} e^{-\mu t},$$

where μ = probability of one particle emitted per unit time. What is the identity of the above probability distribution? 4+1

3. State the Hamilton's principle and derive Lagrange's equation of motion from it. Discuss how the result modified for non-conservative forces. 1+3+1
4. Prove that G of order m is isomorphic to a subgroup of S_m . 5

5. Find under what conditions $Q = \frac{\alpha p}{x}$ and $P = \beta x^2$, where α, β are constants, represents a canonical transformation for a system of one degree of freedom, and obtain a suitable generating function. Apply the transformation to the solution of the harmonic oscillator. 5
6. Determine the character table for D_3 . 5

Group - C

Answer any *two* questions : 10×2=20

1. (a) The duration (in minutes) of a telephone call made from a public call-box is a random variable T . The probability density function of T is

$$0; \quad t < 0$$

$$f(t) = \frac{1}{2}; \quad 0 \leq t < 1$$

$$ke^{-2t}; \quad t \geq 1$$

where k is a constant. To pay for the call, 20 paise has to be inserted at the beginning, and a further 20 paise after each subsequent half-minute. Determine by how much the average cost of a call exceeds the cost of a call of average length charged at 40 paise per minute. 6

- (b) Calculate the inertia tensor for a system of four point masses given as 1g, 2g, 3g and 4g located at the points (1, 0, 0), (1, 1, 0), (1, 1, 1) and (1, 1, -1), respectively. 4

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2. (a) Show that the geodesics of a spherical surface are all great circles.
- (b) What is Poisson bracket? Show that for a dynamical system, the Poisson bracket of its Hamiltonian with any integral of motion vanishes.
- (c) What is canonical transformation and what do you mean by canonical coordinates? $5+(1+2)+(1+1)$
3. (a) State and prove Schur's lemma.
- (b) Show that the order of any group is a multiple of the order of any of its subgroups.
- (c) Prove that every cyclic group is abelian. $(1+3)+4+2$
4. (a) Show that while the generating function $F = \sum q_k P_k$ generates the identity transformation, the generating function $F = \sum q_k Q_k$ generates the exchange transformation.
- (b) The transformation equation between two sets of coordinates are :

$$P = 2(1 + q^{1/2} \cos p) q^{1/2} \sin p$$

$$Q = \log(1 + q^{1/2} \cos p)$$

Show that the transformation is canonical.

- (c) Consider four-element Abelian group consisting of the set $\{1, i, -1, -i\}$ under ordinary multiplication. Choose the basis vector as $(1, i)^T$. Find the two dimensional representative matrices corresponding to each elements. Show that the representative matrices have the same multiplication properties as the elements of the group. 2+4+4
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