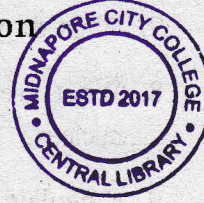# 2023

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 :

$$2\times10=20$$

1. Find the density of C_6^{12} nucleus.

2. Calculate the binding energy for the deuteron in *MeV*, given $M_n = 1.675 \times 10^{-27}$ kg, $M_p = 1.67 \times 10^{-27}$ kg, $M_D = 3.343 \times 10^{-27}$ kg, $C = 3 \times 10^8$ m/s.

3. Which experimental fact indicates saturation of nuclear force ?

4. Write down the asymmetry term in the Bethe-Weizsäcker semi-empirical formula for nuclear binding energy.

5. Using the extreme single particle shell model, determine the ground-state spin-parity of Mg_{12}^{25} nucleus.

P.T.O.

6. Indicate the processes by which Gamma rays are absorbed in matter.

7. What do you mean by "Parity Violation"?

8. What are the Bohr's hypothesis about a compound nucleus?

9. Calculate the threshold energy required to initiate the reaction $P^{31}(n, p)Si^{31}$. Given, $m_n = 1.00898u$, $m_p = 1.008144\ u$, $M_p = 30.9836u$, $M_{Si} = 30.98515\ u$.

10. Explain the term 'dead time' of a GM counter.

11. Identify the unknown particle in the reactions given below, using the conservation laws.

    (i) $\mu^- + p \rightarrow n^1 + (\ )$

    (ii) $\pi^- + p \rightarrow K^0 + (\ )$

12. Write down the quark composition of proton and π^+.

13. Why does a free neutron not decay into an electron and a positron?

14. What are leptons? How many leptons are there?

15. 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 :

$5 \times 4 = 20$

16. What do you mean by the quenching of GM counter. Why is it essential? How is it achieved internally?

17. Find the Q-value of the nuclear reaction $X(x,y)Y$ in terms of mass and kinetic energy of the incident, product particles and residual nucleus, if the product nucleus emitted with angle 90° w.r.t. the direction of the incident particle.

18. Rn^{222}_{86} decays to Po^{218}_{84} by emitting an α - particle. If the parent nucleus is at rest before decay, calculate the velocity of the emitted α - particle. Given, $M_{Rn} = 222.01753\ u$, $M_{Po} = 218.008930\ u$ and $M_{\alpha} = 4.002603u$.

19. Show that in the β-decay —

$$X^A_Z \rightarrow Y^A_{Z+1} + \beta^- + \bar{\gamma}_e,$$ the kinetic energy of recoil E_y of the product nucleus Y is related to the β-disintegration energy Q by the relation,

$$E_y = \left(\frac{Q + 2m_0 c^2}{2M_y c^2} \right) T_{max},$$ where, T_{max} is the maximum kinetic energy of the emitted β-particle and m_0 and M_y are the masses of β and Y respectively.
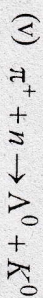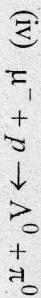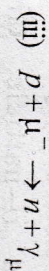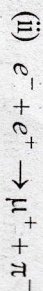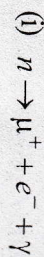
P.T.O.

20. Find the minimum kinetic energy in the laboratory system that a neutron must have in order to initiate the reaction :

$$n_0^1 + O_8^{16} + 2.20 MeV \rightarrow C_6^{13} + He_2^4.$$

Given, $M_n = 1.008665u$, $M_0 = 15.994915u$, $M_C = 13.003355u$, $M_{He} = 4.002603u$.

21. State with reasons whether the following reactions are allowed or forbidden :

(i) $n \rightarrow \mu^+ + e^- + \gamma$

(ii) $e^- + e^+ \rightarrow \mu^+ + \pi^-$

(iii) $p + \mu^- \rightarrow n + \gamma_\mu$

(iv) $\mu^- + p \rightarrow \Lambda^0 + \pi^0$

(v) $\pi^+ + n \rightarrow \Lambda^0 + K^0$

Group - C

Answer any *two* of the following questions :

$$10 \times 2 = 20$$

22. (a) Explain the principle of operation of a cyclotron.

(b) A cyclotron has an oscillator frequency of 12×10^6 MHz and Dee radius of 21 inches. Calculate the magnetic induction (B) needed to accelerate deuterons. Given, $e = 1.6 \times 10^{-19}$ coulomb, $M_d = 3.3 \times 10^{-27}$ kg.

(c) Show that the radius of curvature of the path of the particle inside a cyclotron is proportional to $\sqrt{n}$, where n is the number of times the particles has been accelerated across the space between the Dees.

$$3+3+4$$

23. (a) Obtain the expression for the binding energy of a nucleus based on the liquid drop model. State the semi-empirical mass formula of Bethe-Weizsacker.

(b) State the Geiger-Nuttall law. What is meant by fine structure in α-ray spectrum? $(4+2)+(2+2)$

24. 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. Show how neutrino hypothesis explains this discrepancy. What is Kurie plot.

$$3+2+3+2$$

25. (a) Show that spin-orbit interaction force between nucleus overcomes the limitations of single particle shell model.

(b) Discuss the success and limitations of the single particle shell model.

(c) Find the total angular momentum and parity for the ground state of S_{16}^{33} nucleus using the shell model,

$$5+3+2$$

P.T.O.

(6)

OR

[Astronomy and Astrophysics]

Group - A

Answer any *ten* questions : 2×10=20

1. Why emission spectra of different elements are different?

2. Why is an iron core unable to support a star?

3. What are solar prominences?

4. Which type of electromagnetic radiation can reach the earth surface without absorption in the atmosphere?

5. A star is plotted exactly in the middle of a H-R diagram. What is the colour of the star?

6. What are terrestrial planets and jovian planets?

7. What do you mean by constellations? Give examples.

8. What is the nearest galaxy beyond Milky Way?

9. Why reflecting telescopes are better than refracting telescopes?

10. What is fusion reaction?

11. Which one is the lightest planet in solar family?

12. Which elements are most abundant in the universe?

13. What is resolving power of a telescope?

14. Define parsec.

15. What causes tides or tidal bulge on the earth?

(7)

Group - B

Answer any *four* questions : 5×4=20

16. How solar wind is formed? Discuss the relation between the luminosity, temperature and radius of a star. What is neutron star? 2+2+1

17. What is Schwarzchild radius of a black hole? Determine the Schwarzchild radius of the Sun. Explain the result. 2+2+1

18. Discuss in brief about magnifying power and light gathering power of telescope. What is Ryleigh criteria? What are popular techniques to measure the position of heavenly bodies? 2+2+1

19. Write down the importance of emission and absorption spectra in the field of astronomy. How spectral analysis helps to determine surface temperature of a star? What is blue shift? 2+2+1

20. What do you mean by 'dark matter'? Explain its neccessity from the rotation curve of a galaxy. 2+3

21. Discuss about indirect method to measure stellar radius. The luminosity of a star is 40 times than that of the Sun and its temperature is twice as much. Determine the radius of the star. 3+2

P.T.O.

(8)

Group - C

Answer any *two* questions.   10×2=20

22. What causes some ordinary stars to become giant whereas others to become dwarfs? Discuss about Jeans criteria. Calculate the energy of the electromagnetic radiation whose wavelength is 20cm. What is stellar parallax? 3+3+2+2

23. What do you mean by vernal equinox and autumnal equinox? How these are related to positional astronomy? Determine the declination (δ) of — (i) celestial north pole (ii) celestial south pole (iii) zenith. Discuss about different types of galaxies. 2+2+3+3

24. Determine the temperature at which a particle will have sufficient energy to ionize a hydrogen atom. Discuss in brief about nebula. Calculate the total angular momentum of the Sun-Jupiter system if Jupiter has a circular orbit of radius 5.2 AU, and its orbital period is 11.86 year. Assume that the Sun only interacts with Jupiter. 3+3+4

25. What are extrasolar planets? Discuss H-R diagram related with stellar spectra. Write a short note on various nucleosynthesis process occurring inside the stars. 2+3+5

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(9)

OR

[Physics of Earth]

Group - A

Answer any *ten* questions :   2×10=20

1. Define the inflation period during the evolution of universe.

2. What do you mean by chromatic aberration?

3. What is the solar corona?

4. What is hydrosphere?

5. Define the epicenter of earthquake?

6. If the Earth's axis was exactly normal to the Earth's orbital plane, how would the sun appear from the north pole?

7. What is called a seamount?

8. What are the renewable and non-renewable mineral resources?

9. Which gases in the earth atmosphere are essential for the synthesis of amino acid?

10. What are the sources of internal heat of the earth?

11. Name three gases which are abundant in the Venus atmosphere.

12. What are the Van Allen belts?

13. What are the causes of toxic rain?

P.T.O.
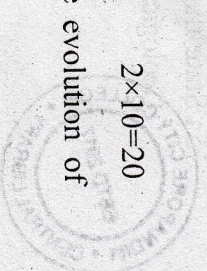
14. What proportion of the Earth's free water is useful for drinking and irrigation? Why is the proportion so small?

15. State the principle of orthogonal horizontality for the geological age determination.

Group - B

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

16. (i) Describe the difference between porosity and permeability.

    (ii) Discuss three reasons why ground water is a particularly valuable source.   2+3

17. (i) Discuss the relation of seasonal variation with the eccentricity of earth orbit and inclination of earth rotation axis.

    (ii) When is summer solstice in northern hemisphere?   4+1

18. (i) What is caldera?

    (ii) Explain how granitic magma forms ash flow tuffs and calderas.   2+3

19. (i) What is half-life of radio isotopes?

    (ii) Briefly discuss about the basis of radiometric dating.   1+4

20. (i) What are sources of tectonic stress?

    (ii) Discuss about different kinds of plate interactions.   2+3

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21. (i) What are the two main factors that a planet can sustain atmosphere?

    (ii) Explain why the moon has no atmosphere.   2+3

Group - C

Answer any *two* questions :   10×2=20

22. (i) Describe the two main types of sea-floor sediment. Discuss the origin of each type.   3+2

    (ii) List three ways in which sediment can be transported by a stream. Which type of transport is independent of stream velocity?   3+2

23. (i) Briefly discuss about thermal structure of the atmosphere at various altitudes with diagram.   5

    (ii) What are cyclone and anticyclone? Discuss the Coriolis effect on the development on cyclone.   2+3

24. (i) What are chief reasons of melting of glaciers in Antarctica? Draw qualitatively the cumulative change of ice mass in Antarctica for the last 30 years.   3+2

    (ii) Differentiate between Alpine glaciers and Continental glaciers. Where are the Alpine glaciers found today?   4+1

P.T.O.

(12)

25. (i) What do you mean by weathering? Explain the differences between mechanical and chemical weathering. 2+3

(ii) What are the components of healthy soil? What is the function of each component? 2+3

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(13)

OR

[Advanced Mathematical Physics-II]

Group - A

Answer any *ten* questions : 2×10=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. Prove that every group of prime order is cyclic.

3. Suppose that a pair of fair dice are to be tossed and let the random variable X denote the sum of points. Obtain the probability distribution for X.

4. Let $\phi : (G, o) \rightarrow (G^*, *)$ be a homomorphism. Then prove that ϕ is one-to-one if ker $\phi = \{e_G\}$.

5. Define Mean, Mode and Median.

6. If two representations ρ and ρ' have same character, then show that they are isomorphic.

7. Define "Moment generating functions" for discrete and continuous distributions.

8. If G is a finite abelian group, then show that every irreducible representation of G is onedimensional.

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? P.T.O.

11. Prove that the intersection of two normal subgroups of a group G is normal in G.

12. Can the Hamilton's principle replace the Newton's laws for holomorphic systems?

13. Show that the Poisson bracket of two constants of motion is iseIf a constant of motion.

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. Show that H is Legendre transform of L.

Group - B

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

16. (a) The random variable X is distributed as $X \sim Bin\left(3, \dfrac{1}{2}\right)$. 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. $2+(1+2)$

17. Calculate the approximate Gaussian distribution function from the Poisson distribution. 5

18. State the Hamilton's principle and derive Lagrange's equation of motion from it. Discuss how the result is modified for non-conservative forces. $1+3+1$

19. Let A be a proper subset of a universal set I. Prove that the set of sets $\{\phi, A, A', I\}$ forms a commutative group under the binary composition Δ, the symmetric difference. Show that each element in the group is its own inverse. [ϕ = the null set, A' = the complement of A] $3+2$

20. The transformation equation between two sets of coordinates are —

$$P = 2\left(1 + \sqrt{q}\cos p\right)\sqrt{q}\sin p; \quad Q = \log\left(1 + \sqrt{q}\cos p\right)$$

Show that the transformation is canonical and the generating function of this transformation is $4+1$

$$F_3 = -\left(e^Q - 1\right)^2 \tan p.$$

21. Discuss harmonic oscillator as an example of canonical transformations. 5

Group - C

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

22. (a) The joint density function of two random variables X and Y is given by

$$f(x, y) = \begin{cases} \dfrac{xy}{96}, & 0 < x < 4, 1 < y < 5 \\ 0, & \text{otherwise} \end{cases}$$

Find $E(X), E(Y), E(XY)$.   P.T.O.

(b) Calculate the moment generating function for the binomial distribution and hence derive the variance.

$$(1\frac{1}{2}+1\frac{1}{2}+2)+5$$

23. (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? $5+(1+2)+(1+1)$

24. (a) State and prove Schur's lemma.

(b) Let a subgroup H of a group G is normal if and only if $aH\,a^{-1} = H$ for every a in G

(c) Prove that every cyclic group is abelian. $(1+3)+4+2$

25. (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) Determine the canonical transformations defined by the generating function $G(q,Q.t) = \frac{1}{2} m\omega q_1^2 \cot Q$, and hence obtain an expression for the displacement of a harmonic oscillator.

(c) Prove that the order of every subgroup of a finite group G is a divisor of the order of G $2+(2+2)+4$