2020/TDC (CBCS)/ODD/SEM/
PHSDSE-502T (A/B)/158

TDC (CBCS) Odd Semester Exam., 2020
held in March, 2021

PHYSICS

(5th Semester)

Course No. : PHSDSE-502T

Full Marks : 70
Pass Marks : 28

Time : 3 hours

The figures in the margin indicate full marks for the questions

Candidates have to answer *either* Option—A *or* Option—B

OPTION—A

Course No. : PHSDSE-502T (A)

(Nuclear and Particle Physics)

SECTION—A

Answer any *twenty* of the following questions : 1×20=20

1. What is the rest mass of a proton?

2. What is an alpha particle?

3. At what value of mass number A, the binding energy per nucleon is maximum?

4. Nuclear radius is measured in which unit?

5. Write the expression for nuclear charge density $\rho(r)$ that fits with the scattering data.

6. Express the nuclear radius in terms of mass number.

7. What is the value of nuclear spin for even Z and even N nuclei?

8. What is the value of electric dipole moment of a nucleus in its ground state?

9. "The density of nuclear matter depends on its volume." State True or False.

10. Name a parameter of a nucleus that is analogous to the heat energy within a liquid drop.

11. Write the energy term that appears in Bethe-Weizsäcker formula due to a force similar to surface tension in liquid.

12. Whether asymmetry in the numbers of neutrons and protons increases or decreases the binding energy of nucleus?

13. Write the magic numbers.

14. What is the exchange particle for nuclear force?

15. A component of nuclear force has directional dependence. What is this component called?

16. The attractive force exerted by a nucleon remains active only in its close vicinity. What is the name of this property?

17. How is β-particle different from an α-particle?

18. Does the energy of α-particles of various isotopes increase or decrease with increasing mass number?

19. Name the law connecting the range of α-particles in air and the disintegration constant of the α-emitter.

20. Name the instrument that is used to measure the energy of α-particle.

21. Write the reaction showing negatron mode of β-emission from a neutron.

22. After the emission of a positron will the atomic no. of the nucleus increase or decrease?

23. Is gamma ray spectrum continuous or discrete?

24. Sometimes the transition of a nucleus excited to the ground state is associated with the ejection of an orbital electron. What is this electron called?

25. For a given dielectric medium, what is the threshold velocity of a charged particle below which no Cherenkov radiation emitted?

26. What is the minimum energy of photon at which pair production is possible?

27. In Compton effect, whether the energy of photon increases or decreases after scattering by an electron?

28. In an ionization chamber, in which region the recombination is maximum?

29. What is the name of the avalanche of electrons that occurs in a proportional counter?

30. What is the approximate collection time of electrons by the anode in the GM counter?

31. Name the gaseous compound that is used in Van de Graaff accelerator to prevent breakdown.

32. In cyclotron, whether the maximum energy of ion depends on the alternating voltage or frequency of the alternating potential?

33. Among the fundamental forces, which one is weakest?

34. Strong interaction is mediated by which particle?

35. What are particles with half integral spins called?

36. Write the lepton numbers of electron and positron.

37. Which conservation law is applicable only in strong interaction?

38. Name the class of particles that is produced in strong interaction but decays only through weak interaction.

39. What is the operation that changes the sign of the charge of a particle without affecting other properties?

40. What are the electric charges of up and down quarks?

SECTION—B

Answer any *five* of the following questions : 2×5=10

41. Which experiment is termed as foundation stone of Nuclear Physics?

42. Why are the most stable nuclei found in the region near $A = 60$?

43. What is the evidence that nucleons in a nucleus are arranged in well-ordered shells?

44. State the basic assumption of shell model.

45. Name the effect that allows α-particles to escape from nucleus through potential barrier.

46. β-decays of three different modes are observed. What are these?

47. In photoelectric emission, why the emission of *k*-shell electrons is most probable?

48. Why is cyclotron not used to accelerate electrons?

49. Name four types of hyperons. Are they heavier or lighter than nucleons?

50. Name six types of quarks. Which one is the heaviest and which one is the lightest?

SECTION—C

Answer *any* **five** questions

51. Draw the curve for binding energy per nucleon against mass number. Discuss the characteristics of this curve in detail. 8

52. *(a)* For angular momentum quantum number *I*, what is the value of angular momentum? How is *I* oriented in space with respect to a given axis? 1+3=4

    (b) What is nuclear parity? What would be the parity of even-even nuclei and odd *A* nuclei? 4

53. Write the semiempirical mass formula explaining various terms. 8

54. *(a)* Write four points of resemblance between an atomic nucleus and a liquid drop. 6

    (b) What are the salient features of nuclear force? 2

55. *(a)* What were the problems related to β-emission that led to the neutrino hypothesis? How is the hypothesis solved the problems? 4

    (b) Write nuclear reactions showing β^- and β^+ decay. 1

    (c) Write in brief about electron-capture process. 3

56. *(a)* Explain elastic and inelastic processes with examples. 4

(b) Write in brief about conservation of parity and angular momentum in nuclear reaction. 4

57. What is Cherenkov radiation? Explain its formation. Write some of its features. 2+4+2=8

58. Discuss in detail the working of a cyclotron. 8

59. *(a)* Elaborate the law of conservation of charge in reactions involving elementary particles. 4

(b) Discuss conservation of parity in elementary particle reactions. 4

60. *(a)* Name different types of quarks. How much electric charge each of them carry? 3

(b) What are the fundamental interactions in nature? Compare their relative strengths. Write the names of their field particles. 5

OPTION—B

Course No. : PHSDSE–502T (B)

(Advanced Mathematical Physics)

SECTION—A

Answer any *twenty* of the following questions : 1×20=20

1. Define vector space.

2. What is basis in vector space?

3. Explain isomorphism of vector space.

4. What is zero transformation?

5. Define identity operator.

6. What do you mean by co-domain of a linear transformation?

7. Define subspace.

8. What is dimension of a vector space?

9. Define orthogonal matrix.

10. What is trace of a matrix?

11. Define eigenvalue of a matrix.

12. What is diagonalization of matrix?

13. What do you mean by characteristic polynomial?

14. Define the functions of a matrix.

15. What is unitary matrix?

16. State Cayley-Hamilton theorem.

17. Define group.

18. What do you mean by subgroup?

19. Define cyclic group.

20. What do yo mean by coset of a group?

21. What is meant by reducible representation of a group?

22. What is Abelian group?

23. Define isomorphism between two groups.

24. What is group multiplication table?

25. What do you mean by associated tensors?

26. What is tensor of order zero?

27. State the fundamental properties of tensor.

28. Define isotropic tensor.

29. What is divergence of vector point function?

30. Evaluate $\delta_q^p A_s^{qr}$.

31. Define curl of tensor field.

32. What are vector identities?

33. Define metric tensor.

34. What is Minkowski space?

35. Define covariant vectors.

36. What is contravariant tensor?

37. What do you mean by Kronecker delta?

38. Define mixed tensor.

39. Define anti-symmetric tensor.

40. Prove that $\delta_{ii} = 3$.

SECTION—B

Answer any *five* of the following questions : 2×5=10

41. The intersection of any two subspaces of a vector space is a subspace of the same. Prove it.

42. Prove that identity operator is a linear operator.

43. Show that the products of orthogonal matrices are also orthogonal.

44. Find the trace of the matrix

$$\begin{bmatrix} 2 & 1 & -1 \\ 0 & 3 & -2 \\ 2 & 4 & -3 \end{bmatrix}$$

45. Show that $(1, i, -1, -i)$ forms a group under multiplication.

46. Show that the four matrices

$$E = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}, \ A = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}, \ B = \begin{bmatrix} -1 & 0 \\ 0 & -1 \end{bmatrix}, \ C = \begin{bmatrix} 0 & -1 \\ 1 & 0 \end{bmatrix}$$

form a group under matrix multiplication.

47. Prove that $A_{\mu\nu}B^{\mu}C^{\nu}$ is an invariant, if B^{μ} and C^{ν} are contravariant vectors, and $A_{\mu\nu}$ is a covariant tensor.

48. If A^{ji} and A_{ij} are the reciprocal symmetric tensors and x_i is the component of a covariant tensor of rank one, then show that

$$A_{ij}x^i x^j = A^{ij}x_i x_j$$

where $x^i = A^{i\alpha}x_\alpha$.

49. Show that the transformations of tensors form a group.

50. Show that δ^i_j is a mixed tensor of rank two.

SECTION—C

Answer *any* **five** questions

51. (a) Show that the set

$$S = \{(1, 0, 0), (1, 1, 0), (1, 1, 1), (0, 1, 0)\}$$

is not a basis set. 3

(b) If $S = \{\alpha_1, \alpha_2, \alpha_3\}$ is a basis of the vector space $V(F)$, then show that every element α of V can be uniquely expressed as a linear combination of elements of S. 5

52. The standard basis for a 2×2 matrix

$$B=\left\{\begin{bmatrix}1 & 0\\0 & 0\end{bmatrix},\begin{bmatrix}0 & 0\\1 & 0\end{bmatrix},\begin{bmatrix}0 & 1\\0 & 0\end{bmatrix},\begin{bmatrix}0 & 0\\0 & 1\end{bmatrix}\right\}$$

and the basis $A=\left\{\begin{bmatrix}1 & 0\\0 & 0\end{bmatrix},\begin{bmatrix}2 & 0\\-1 & 0\end{bmatrix},\begin{bmatrix}0 & 1\\0 & 1\end{bmatrix},\begin{bmatrix}-3 & 0\\0 & 2\end{bmatrix}\right\}$

(a) Find the transition matrix from A to B.

(b) Find the matrix that has coordinate vector $[V]_A=(-8, 3, 5, -2)$. 4+4=8

53. *(a)* Find the characteristic equation of the following matrix and verify the Cayley-Hamilton theorem : 5

$$\begin{bmatrix}1 & 2 & 3\\2 & -1 & 4\\3 & 1 & 1\end{bmatrix}$$

(b) Diagonalize the given matrix

$$\begin{bmatrix}\cos\theta & -\sin\theta & 0\\\sin\theta & \cos\theta & 0\\0 & 0 & 1\end{bmatrix}$$ 3

54. *(a)* Prove that a matrix and its transpose have the same characteristic roots. 3

(b) Show that the equations

$$-2x+y+z=a,\ x-2y+z=b,\ x+y-2z=c$$

have no solution unless $a+b+c=0$. In which case they have infinitely many solutions? Find these solutions when $a=1$, $b=1$ and $c=-2$. 5

55. *(a)* Find the normal (invariant) subgroup and factor (quotient) group of D_3 group. 5

(b) Prove that the covering operations of an equilateral triangle form a group homomorphic onto the group of elements (1, −1). 3

56. *(a)* Show that any representation by matrices with non-vanishing determinants is equivalent to a representation by unitary matrices through a similarity transformation. 5

(b) Show that three cube roots of unity form an Abelian group under multiplication. 3

57. *(a)* Show that any tensor of rank 2 can be expressed as a sum of symmetric and anti-symmetric tensor, both of rank 2. 3

(b) Show that the array

$$T=\begin{pmatrix}-xy & -y^2\\x^2 & xy\end{pmatrix}$$

is a second rank tensor while the array $\begin{pmatrix}-xy & -y^2\\x^2 & -xy\end{pmatrix}$ is not a tensor. 5

58. *(a)* Prove that an anti-symmetric tensor of the second-order can be associated with a vector in three dimensions. 3

(b) State and prove quotient law of tensors. 5

59. *(a)* Show that Kronecker delta is an invariant mixed tensor of rank 2. 3

(b) A covariant tensor has components xy, $2y-z^2$, xz in rectangular coordinates. Find its covariant components in spherical coordinates. 5

60. *(a)* If A^{μ} is an arbitrary contravariant vector and $C_{\mu\nu}A^{\mu}A^{\nu}$ is an invariant, then show that $(C_{\mu\nu}+C_{\nu\mu})$ is a covariant tensor of second order. 5

(b) Show that the expression $A(i, j, k)$ is a tensor, if its inner product with an arbitrary tensor B_k^{ji} is a tensor. 3

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