Entrance Examination for M. Sc. in PHYSICS

Dibrugarh University

Model Question Paper

Please read the following instructions carefully before answering the questions.

1. This booklet contains *50 (fifty)* multiple choice questions.

2. Each question has *4 (four)* options as answers, *only 1 (one)* of them is correct.

3. A candidate should choose the option he/she thinks to be the correct one by giving a ✓ sign below the chosen option on the question paper itself.

4. A candidate should choose *only 1 (one)* of the options against a particular question as his/her answer. More than one answers against one question will automatically be treated as an incorrect answer.

5. For each correct answer, a candidate will be awarded *2 (two)* marks. Each incorrect answer will result in a deduction of *1 (one)* mark. If no answer is provided, *0 (zero)* mark will be awarded.

6. Spaces for rough work have been provided at the end of the booklet itself. No additional papers will be provided for the same.

7. Total duration of the examination : *2 Hours.*

Name of the candidate :

Signature of the candidate :

Roll number :

Signature of the invigilator :

1. The wavefunction of a one dimensional quantum mechanical system, $\Psi(x)$ has the dimension of

(A) $[L]^{-1}$

(B) $[L]$

(C) $\Psi(x)$ is dimensionless.

(D) $[L]^{-1/2}$

. . . .

2. The Fourier transform of a function $f(x)$ is defined as

$$F(k) = \int_{-\infty}^{\infty} f(x)\, e^{ikx} dx$$

Suppose, $f(x) = \delta(x-a) + \delta(x+a)$. Then, $F(k)$ is given by

(A) 0 **(B)** $2\, Sin\,(ka)$

(C) $Sin\,(ka) + Cos\,(ka)$ **(D)** $2\, Cos\,(ka)$

. . . .

3. Consider the Legendre polynomial, $P_{2n+1}(x)$ of order $(2n+1)$, where n can take semi-positive integer values . Then, the integral,

$$I = \int_{-1}^{1} P_{2n+1}(x)\, dx$$

, is equal to

(A) $\frac{2}{4n+3}$ **(B)** $\sqrt{\frac{2}{4n+3}}$

(C) 0 **(D)** $\sqrt{\frac{2}{2n+1}}$

. . . .

4. Consider a 2×2 matrix A such that $\mathrm{Tr}[A] = 0$ and $\mathrm{Tr}[A^2] = 2$. Then $\mathrm{Tr}[A^3]$ is equal to

(A) 0 **(B)** 4

(C) 3 **(D)** 1

5. The value of the complex integral

$$I = \oint \frac{z}{z-2} dz$$

evaluated over a circle of unit radius, is

(A) πi **(B)** $2\pi i$

(C) 0 **(D)** $4\pi i$

. . . .

6. A person walks along a one dimensional line where he can walk either in the forward direction or in the backward direction with equal probabilities. In each step he covers a distance of 10 cm. Suppose, he completes a four-step walk. The probability that his displacement is zero after these four steps is

(A) $\frac{1}{2}$ **(B)** $\frac{3}{8}$

(C) $\frac{1}{4}$ **(D)** $\frac{1}{8}$

. . . .

7. Which of the following is the solution to the differential equation :

$$\frac{d^2y}{dx^2} - 3\frac{dy}{dx} + 2y = 2e^{-x}$$

(A) $y = c_1 e^{x} + c_2 e^{2x} + \frac{1}{6} e^{-x}$

(B) $y = c_1 e^{x} + \frac{1}{6} e^{-x}$

(C) $y = c_1 e^{x} + c_2 e^{-2x} + \frac{1}{6} e^{-x}$

(D) $y = c_1 e^{2x} + \frac{1}{6} e^{-x}$

. . . .

8. During a motion, the average speed of an object is recorded to be 5 ms^{-1}. Which of the following vectors in units of ms^{-1} can't physically represent the average velocity of the object ?

(A) $5\hat{i}$ **(B)** $3\hat{i} + 4\hat{j} - \hat{k}$

(C) 0 **(D)** $2\hat{i} + \hat{j} + 4\hat{k}$

9. A ball is thrown with initial velocity v_0 at an angle θ with respect to the horizontal line. Keeping v_0 fixed, the ball is repeatedly thrown at different angles by varying θ. The maximum height reached by the ball, h and the horizontal range R for each of these angles is noted down. Now, if R is plotted against the corresponding h, the graph will take the shape of

(A) A hyperbola **(B)** An ellipse

(C) A straight line **(D)** A parabola

. . . .

10. Let us consider three solid discs, each with radius R and mass m. The mass per unit area of these discs are given by $\sigma_1(r) = k_1/r$, $\sigma_2(r) = k_2$ and $\sigma_3(r) = k_3 r$ respectively. Here, r is the radial distance from the centre of the disc and k_1, k_2, k_3 are three positive constants. Which of these discs is the easiest to rotate about an axis passing through the centre of the disc and perpendicular to its plane ?

(A) The first disc

(B) The second disc

(C) The third disc

(D) Each disc can be rotated with equal ease.

. . . .

11. Let R be the radius of earth and the the acceleration due to gravity on its surface be g_0. The approximate height at which the acceleration due to gravity(g) will be one tenth of g_0 is

(A) $\sqrt{10}R$ **(B)** $\frac{9}{20}R$

(C) $9R$ **(D)** $\frac{9}{10}R$

12. The canonical momenta p_x and p_y of a two dimensional classical system are given by, $p_x = m\dot{y}$ and $p_y = m\dot{x}$ respectively. The Lagrangian of the system can be written as

(A) $L = m\dot{x}\dot{y}$

(B) $L = m\dot{x}\dot{y} - k(x^2 + y^2)$

(C) $L = m\dot{x}\dot{y} - bxy$

(D) All of (A), (B), (C)

. . . .

13. The Lagrangian of a particle moving in one dimension, in suitable units, is given by

$$L = 2q\dot{q} - V(q)$$

The Hamiltonian, H, of the particle is

(A) $H = V(q)$ **(B)** $H = 2q\dot{q} + V(q)$

(C) $H = q\dot{q} - V(q)$ **(D)** H is not defined.

. . . .

14. The Hamiltonian of a one dimensional simple harmonic oscillator is given by

$$H = \frac{p^2}{2m} + \frac{1}{2}m\omega^2 x^2$$

The phase space volume, V of the system is independent of which of the following quantities ?

(A) Mass, m

(B) Total Energy, E

(C) Angular frequency, ω

(D) All of (A), (B), (C)

15. Two charges Q_1 and Q_2 with masses m_1 and m_2 respectively are moving under the influence of identical potentials. If the charges have the same de Broglie wavelength and $Q_1 : Q_2 = 1 : 4$, then $m_1 : m_2$ is equal to

(A) $1 : 4$ **(B)** $2 : 1$

(C) $4 : 1$ **(D)** $1 : 2$

. . . .

16. In a photo-electric setup with threshold frequency f_0, the stopping potential is given by V_0 when the frequency of the incident light is 3 times the threshold frequency. If frequency of the incident light is increased to 5 times the threshold frequency, the stopping potential will be given by,

(A) $2V_0$ **(B)** $\frac{5}{3}V_0$

(C) V_0 **(D)** $\frac{3}{5}V_0$

. . . .

17. The wave number of maximum radiation for a black body kept at temperature T is k_m. If the temperature is halved, then, k_m

(A) Gets doubled

(B) Remains unchanged

(C) Gets quadrupled

(D) None of (A), (B) and (C)

. . . .

18. Which of the following one dimensional wavefunctions can't be normalized ?

(A) $\psi(x) = 0$

(B) $\psi(x) = Ax$

(C) $\psi(x) = A\exp(-bx)$

(D) All of (A), (B) and (C)

19. The ground state wavefunction of a particle confined in a one dimensional infinite well potential from $x = 0$ to $x = a$ is given by

$$\psi(x) = \sqrt{\frac{2}{a}} Sin\left(\frac{\pi x}{a}\right)$$

The uncertainty in momentum, Δp, of the particle is

(A) $\Delta p = 0$ **(B)** $\Delta p = \pi\hbar/a$

(C) $\Delta p = -\pi\hbar/a$ **(D)** $\Delta p = a/\pi\hbar$

. . . .

20. The quantum mechanical Hamiltonian of a particle of mass m under the influence of a two dimensional harmonic oscillator is given by

$$H = \frac{p_x^2}{2m} + \frac{p_y^2}{2m} + \frac{1}{2}m\omega^2 x^2 + 2m\omega^2 y^2$$

The ground state energy of the particle is

(A) $\hbar\omega$ **(B)** $\frac{3}{2}\hbar\omega$

(C) $2\hbar\omega$ **(D)** $\frac{1}{2}\hbar\omega$

. . . .

21. The Hamiltonian of a two state quantum system operates on the wavefunctions Ψ_1 and Ψ_2 as : $H\Psi_1 = a\Psi_2$ and $H\Psi_2 = b\Psi_1$. The energy eigenvalues of the system are

(A) a, b **(B)** ab, ab

(C) $\sqrt{ab}$, $-\sqrt{ab}$ **(D)** a^2, b^2

. . . .

22. What do we quantize in quantum mechanics ?

(A) Position **(B)** Conjugate momentum

(C) Energy **(D)** All of (A), (B), (C)

23. In Bohr's model, the ground state kinetic energy possessed by the hydrogen atom electron is

(A) 13.6 eV **(B)** -13.6 eV

(C) 0 eV **(D)** 6.8 eV

. . . .

24. In the hydrogen atom spectrum, which of the following spectral series falls in the visible region ?

(A) Balmer **(B)** Paschen

(C) Brackett **(D)** Lyman

. . . .

25. Consider three nuclei with mass numbers $A = 1$, 8 and 27 respectively. Their nucleon densities (number of nucleons / volume), d_1, d_2 and d_3 are in the ratio

(A) $1 : 1 : 1$ **(B)** $1 : 2 : 3$

(C) $1 : 8 : 27$ **(D)** $1 : 4 : 9$

. . . .

26. A radioactive substance X starts decaying into another substance Y at $t = 0$. After a time T, the amounts of X and Y become equal. The time after which the amount of Y will be 15 times that of X is

(A) $15T$ **(B)** $7.5T$

(C) $4T$ **(D)** $2.5T$

. . . .

27. A system of ideal gas molecules is characterized with a root mean squared speed of 1.73 m/s. If the average speed of ideal gas molecules of mass m at temperature T is given by $v_{average} = 1.6\sqrt{\frac{k_BT}{m}}$, then, the variance, σ^2 of molecular speeds of the system, in units of m^2s^{-2}, is

(A) 0.11 **(B)** 1.67

(C) 0.44 **(D)** 0.01

28. A cyclic thermodynamic process occurs in two different paths. While the first path takes the shape of a circle on the $P - V$ diagram, the second path is a square whose sides in length are equal to the radius of the circle. If the net work done by the system in the second path is W, then, the net work done in the first path is

(A) W **(B)** $W/3.14$

(C) 0 **(D)** $3.14W$

. . . .

29. Which of the following thermodynamic quantities has the same unit as entropy ?

(A) Specific Heat

(B) Helmholtz free energy

(C) Volume

(D) Entropy doesn't have a unit.

. . . .

30. When 1 gram of water freezes into ice, the change in its specific volume is approximately 0.091 cc. The pressure required to be applied to freeze 10 gram of water at -1^o C ($L = 80$ Cal.gm^{-1}) is

(A)10 atm **(B)** 1/10 atm

(C) 1 atm **(D)** 2.24 atm

. . . .

31. The number of ways in which 2 particles can be distributed in 6 states when the particles are **i)** distinguishable, **ii)** indistinguishable and obey Bose-Einstein statistics and **iii)** indistinguishable and only one particle can occupy a single state, in respective order are

(A) 36, 21, 15 **(B)** 12, 24, 24

(C) 72, 62, 62 **(D)** 12, 31, 31

32. Consider a gas of non-interacting and non-relativistic identical bosons which is confined in a wire, in a plane, and in a cube like structure of arbitrary size. The Bose-Einstein condensation can be observed in

(A) Wire only **(B)** Wire and plane

(C) Cube only **(D)** In all dimensions

. . . .

33. Three point charges of magnitude $2Q$, $-Q$ and $-Q$ are placed at the vertices of an equilateral triangle. Which of the following statements about the electrostatic field, E and the potential V at the centre of the triangle, is correct ?

(A) E is nonzero but V is zero.

(B) E is zero but V is nonzero.

(C) Both E and V are nonzero.

(D) Both E and V are zero.

. . . .

34. Again consider three point charges of magnitude $2Q$, $-Q$ and $-Q$ placed at the vertices of an equilateral triangle. The potential at a large distance r from the centre is proportional to

(A) $1/r$ **(B)** $1/r^2$

(C) r **(D)** $1/r^3$

. . . .

35. Consider a uniformly charged non-conducting sphere of radius R. The ratio of the magnitude of electric fields at $r = R/2$ and $r = R$ is (*Here, r is the radial distance from the centre of the sphere.*)

(A) $4:1$ **(B)** $1:2$

(C) 0 **(D)** $2:1$

36. An electromagnetic wave is normally incident on an air-dielectric interface. The dielectric media is isotropic and non-magnetic. The magnetic field of electromagnetic wave in the dielectric medium in units of wb/m^2 is given by

$$\vec{B} = 4\times10^8(A\hat{i}+5\hat{j})\exp\left[i(5x+4y-5\times10^8 t)\right]$$

The value of the constant A is

(A) 4 **(B)** -4 **(C)** 5 **(D)** -5

. . . .

37. An electromagnetic wave passes from glass ($\mu_{glass} = 1.5$) to water ($\mu_{water} = 1.33$). The reflection and transmission coefficients are

(A) 0.964 and 0.036 **(B)** 0.928 and 0.072

(C) 0.072 and 0.928 **(D)** 0.036 and 0.964

. . . .

38. The force per unit length between two infinitely long conducting parallel wires separated by a distance d and carrying currents I_1 and I_2 is proportional to

(A) I_1I_2/d^2

(B) I_1I_2d

(C) $I_1^2I_2^2/d$

(D) None of (A), (B) and (C)

. . . .

39. Three particles A, B, and C having identical mass, m, undergo one dimensional simple harmonic motion under the influence of the potentials $V_A(x) = \frac{1}{2}kx^2$, $V_B(x) = \frac{1}{2}kx^2+V_0$ and $V_C(x) = \frac{1}{2}kx^2+\lambda x$ respectively. Here, k and λ and V_0 are positive constants. Let the angular frequencies of A, B and C be ω_A, ω_B and ω_C respectively. Then,

(A) $\omega_B > \omega_A > \omega_C$ **(B)** $\omega_B < \omega_A < \omega_C$

(C) $\omega_A > \omega_C > \omega_B$ **(D)** $\omega_A = \omega_C = \omega_B$

40. An inertial frame S_0 is at rest. Another inertial frame S_1 is moving with a uniform relativistic velocity v along the positive x-direction. A third inertial frame S_2 is moving with a uniform velocity v along the positive x-direction relative to S_1. If an observer on S_0 measures the velocity of S_2 to be c, the velocity of light, then v is equal to

(A) $c/2$ **(B)** $c/3$

(C) $c/4$ **(D)** None of (A), (B), (C)

. . . .

41. The total energy of an elementary particle of mass m is twice its rest mass energy. The relativistic speed of the particle is

(A) c **(B)** $2c/\sqrt{3}$

(C) $\sqrt{3}c/2$ **(D)** None of (A), (B), (C)

. . . .

42. In the case of a Doppler effect of sound, when the observer and the source are moving towards each other, the frequency of sound is observed to be f_1. The observer and the source exchange their speeds while crossing each other and now starts moving away from each other. The frequency of sound is now observed to be f_2. Without the Doppler effect, the frequency of the sound will be

(A) $\sqrt{f_1 f_2}$ **(B)** $\frac{1}{2}(f_1 + f_2)$

(C) $\sqrt{f_1^2 + f_2^2}$ **(D)** $\frac{1}{2}(f_1 - f_2)$

. . . .

43. The packing fraction of a bcc lattice is

(A) $\pi\sqrt{3}/8$ **(B)** $\pi\sqrt{3}/6$

(C) $\pi\sqrt{2}/6$ **(D)** None of (A), (B), (C)

44. Consider an electron in a perfectly periodic lattice, wherein the energy-wavenumber relationship in the first Brillouin zone is

$$E = \frac{\hbar^2 k^2}{5m_e}$$

The effective mass m^* for this lattice system is

(A) m_e **(B)** $\frac{5}{2}m_e$

(C) $10m_e$ **(D)** $\frac{2}{5}m_e$

. . . .

45. Monochromatic light from a helium-neon laser (632.8 nm) shines at a right angle onto the surface of a diffraction grating. The angle at which one would observe the second-order is 42.22 degrees. What is the spacing between the lines on the grating?

(A) 2.55×10^{-5} m

(B) 1.88×10^{-6} m

(C) 3.62×10^{-3} m

(D) None of (A), (B) and (C)

. . . .

46. A clock hung on a wall has marks instead of numerals on its dial. On the adjoining wall, there is a plane mirror and image of the clock in the mirror indicates the time $3:25$. Then the time in the clock is

(A) $7:40$ **(B)** $8:35$

(C) $2:40$ **(D)** $4:07$

47. A $1000\ \mu$F capacitor is charged with a 50 V source through a 2 KΩ resistance. The time taken by the capacitor to get charged 0.95 times of its full capacity ?
Useful Information: **ln(20) = 3**

(A) 6 seconds **(B)** 12 seconds

(C) 3 seconds **(D)** 9 seconds

. . . .

48. Which of the following statement about semiconductor is not true?

(A) Mobility of a semiconductor decreases with increase in temperature.

(B) A compensated semiconductor has equal numbers of donor and acceptor impurity atom.

(C) Diffusion of holes in a semiconductor is independent of the applied electric field.

(D) Electron and holes always diffuses in opposite direction to each other.

49. Which of the following statement about PN junction is true?

(A) Width of the depletion layer on either side of the junction is always equal.

(B) Zener effect usually takes place for a heavily doped PN junction.

(C) Reverse saturation current can be increased by increasing the reverse bias voltage.

(D) A photodiode is normally forward biased.

. . . .

50. In a base biased transistor circuit, $V_{CC} = 15$ V, $V_{BB} = 15$ V, $R_B = 500$ KΩ and $R_C = 3$ KΩ. If the transistor is ideal and $\beta_{dc} = 100$ then the Q point will be (where the symbols have their usual meaning)

(A) 6 V, 3 mA **(B)** 3 V, 6 mA

(C) 5 V, 5 mA **(D)** 5 V, 6 mA

. . . .

END