

(3 Hours)

[Total Marks : 100

Section I

N. B. 1) ATTEMPT ALL QUESTIONS

2) EACH QUESTION CARRIES ONE MARK (Max Marks for this section: 40)

3) There is only ONE correct answer and NO negative marking

4) Please write the question number and your answer (alphabet only) next to it (example: 1 b)

Question I :

(40 marks)

1. The effective Bohr radius of He^+ (singly ionized He atom) is ----- .
 - a. $2a_0$
 - b. $a_0/2$
 - c. a_0
 - d. none of the above.

2. The ground state energy of He^+ (singly ionized He atom) is ----- .
 - a. -2 Ryd.
 - b. -0.5 Ryd.
 - c. -1 Ryd.
 - d. -4 Ryd.

3. For a system of bosons, the mean occupation number for energy $\epsilon = \mu$, the chemical potential, is
 - a. 1
 - b. 0
 - c. ∞
 - d. $1/2$.

4. The 3d orbital of the hydrogen atom has ----- nodes.

- a. 0
- b. 1
- c. 2
- d. 3.

5. The Madelung constant for a line of ions of charge q and $-q$ alternately separated by a uniform distance R is

- a. 0
- b. $\ln 2$
- c. $2 \ln 2$
- d. ∞ .

6. The ground state of Eu^{+3} ion (configuration $4f^6$) is

- a. 7F_0
- b. 7F_6
- c. 1S_0
- d. 1F_3 .

7. For the hydrogen atom, the degeneracy of the shell with eigenvalue $E_n = -1/n^2 \text{ Ryd.}$, where n is principal quantum number, is

- a. $2n+1$
- b. $2l+1$
- c. n^2
- d. $n(n-1)/2$.

8. For angular momentum operators L^2 and L_i , $i = x, y, z$, the commutator $[L^2, L_x] = \dots\dots\dots$

- a. 0.
- b. $i\hbar L_y$
- c. $i\hbar L_y L_z$
- d. $i\hbar L_z$.

A linear harmonic oscillator is initially in the superposition state

$$\Psi(x, t=0) = A [2 \phi_0(x) + \phi_1(x)]$$

where $\phi_n(r)$ are the steady-state solutions of the harmonic oscillator with energy eigenvalues $E_n = (n + 1/2) \hbar \omega$, $n = 0, 1, 2, \dots$

9. In an energy measurement, what is the probability of getting a value greater than E_1 ?
- 1
 - 0
 - 0.4
 - none of the above .
10. The expectation value of the energy of the system in this state is $\langle E \rangle = \dots\dots\dots$
- $\hbar\omega$
 - $2\hbar\omega$
 - $5/6\hbar\omega$
 - $0.7\hbar\omega$.
11. A current amplifier is characterized by
- low input impedance and high output impedance
 - high input impedance and low output impedance
 - low input impedance and low output impedance
 - high input impedance and high output impedance
12. The avalanche effect is observed in a diode when
- majority carriers have enough energy to dislodge valence electrons
 - heavily doped diode is forwards biased
 - reverse voltage exceeds the breakdown voltage
 - the forward voltage exceeds the breakdown voltage
13. An ideal voltage source of 12 V provides a current 240 mA to a load. If the load impedance is doubled, the new load current becomes:
- 120 mA
 - 240 mA
 - 480 mA
 - 60 mA
14. The decimal equivalent of the binary number 10101 is
- 31
 - 21
 - 41
 - 11
15. Which of the following is used as a passive component in electronic circuits ?
- resistor
 - Transistor
 - Vacuum triode
 - Tunnel diode

16. The calibration signal, usually available from a CRO is of the :

- a) sine-wave voltage
- b) square-wave voltage
- c) saw-tooth wave voltage
- d) dc voltage

17. The basic memory element in a digital circuit

- a) Consists of a AND gate
- b) consists of a NOR gate
- c) Consists of a NAND gate
- d) is a FLIP-FLOP

18. Which of the following is NOT responsible for electrical conduction in a discharge tube ?

- a) Positive ions
- b) electrons
- c) protons
- d) negative ions

19. In which of the following will the wavelength corresponding to transition from $n=2$ to $n=1$ be minimum?

- a) Hydrogen atom
- b) deuterium atom
- c) singly ionized He
- d) doubly ionized Li

20. The possible values of the total angular momentum J resulting from the addition of two angular momenta $J = 1$ and $J = 2$ are given by:

- a) 1,3
- b) 1, 2, 4
- c) 0,1,2
- d) 1,2,3

21. In Raman Scattering, the energy separation between two consecutive Stokes lines depends on :
- Intensity of incident light
 - wavelength of the incident light
 - energy separation between the vibrational levels in the excited state
 - energy separation between the vibrational levels in the ground state
22. Which of the following is NOT magnetically ordered :-
- Paramagnet
 - Ferromagnet
 - Anti ferro magnet
 - Ferrite
23. A p-type semiconductor is
- Uncharged
 - Positively charged
 - Negatively charged
 - Uncharged at 0 K but positively charged at higher temperatures
24. Diffusion current in a p-n junction is greater in magnitude than the drift current :
- If the junction is forward biased
 - If the junction is reversed biased
 - Always - irrespective of biasing
 - Never - irrespective of biasing
25. Einstein's theory concludes that at lower temperatures, the specific heat of a solid
- Drops linearly with increase in temperature
 - Drops exponentially with decrease in temperature
 - Drops linearly with decrease of temperature
 - Drops exponentially with increase in temperature
26. A particle moves around the sun in an elliptical orbit with semi-major axis a and time period T . T is proportional to
- a^2
 - $a^{\frac{1}{2}}$
 - $a^{\frac{3}{2}}$
 - a^3

27. A particle of mass m is constrained to move on a plane curve

$$xy = C (C > 0)$$

under gravity (y -axis is vertical). The Lagrangian of the particle is given by

a) $\frac{1}{2}m\dot{x}^2 \left(1 + \frac{C^2}{x^4}\right) + \frac{mgC}{x}$

b) $\frac{1}{2}m\dot{x}^2 \left(1 + \frac{C^2}{x^4}\right) - \frac{mgC}{x}$

c) $\frac{1}{2}m\dot{x}^2 \left(1 + \frac{C^2}{x^2}\right) + \frac{mgC}{x}$

d) $\frac{1}{2}m\dot{x}^2 \left(1 + \frac{C^2}{x^2}\right) - \frac{mgC}{x}$

28. The Lagrangian of a particle moving in a plane under the influence of a central potential is given

by $L = \frac{1}{2}m(\dot{r}^2 + r^2\dot{\theta}^2) - V(r)$. The generalized momenta corresponding to r and θ are given

by

a) $m\dot{r}$ and $mr^2\dot{\theta}$

b) $m\dot{r}$ and $mr\dot{\theta}$

c) $m\dot{r}^2$ and $mr^2\dot{\theta}$

d) $m\dot{r}^2$ and $mr^2\dot{\theta}$

29. The residue of the function

$$f(z) = \frac{z}{(2z+1)(5-z)} \text{ at } z = -\frac{1}{2} \text{ is}$$

a) $\frac{1}{11}$

b) $-\frac{1}{11}$

c) $\frac{1}{22}$

d) $-\frac{1}{22}$

30. The eigenvalues of the matrix $\begin{bmatrix} 1 & i \\ -i & 1 \end{bmatrix}$ are

- a) +1 and -1
- b) 0 and +1
- c) 0 and +2
- d) -1 and 0

31. The k^{th} Fourier component of $f(x) = \delta(x)$ is

- a) 1
- b) 0
- c) $(2\pi)^{-1/2}$
- d) $(2\pi)^{-3/2}$

32. The solution of the system of differential equations

$$\frac{dy}{dx} = y - z \quad \text{and} \quad \frac{dz}{dx} = -4y + z$$

is given by (for A and B arbitrary constants)

- a) $y(x) = Ae^{3x} + Be^{-x}, z(x) = 2Ae^{3x} - 2Be^{-x}$
- b) $y(x) = Ae^{3x} + Be^{-x}, z(x) = 2Ae^{2x} + 2Be^{-x}$
- c) $y(x) = Ae^{3x} + Be^{-x}, z(x) = 2Ae^{2x} - 2Be^{-x}$
- d) $y(x) = Ae^{3x} + Be^{-x}, z(x) = -2Ae^{2x} - 2Be^{-x}$

33. Given that the binding energies of ${}^2\text{H}$, ${}^4\text{He}$ and ${}^6\text{Li}$ are B_2, B_4 and B_6 respectively, the Q value of the reaction ${}^2\text{H} + {}^6\text{Li} \rightarrow 2{}^4\text{He}$ is

- a) $2B_2 + 6B_6 - 8B_4$
- b) $B_2 + B_6 - 2B_4$
- c) $2B_4 - B_2 - B_6$
- d) $8B_4 - 6B_6 - 2B_2$

34. Which of the following statements is incorrect for the nuclear force between two nucleons:

- a) it is charge independent
- b) it is spin independent
- c) it is velocity dependent
- d) it has a non central component

35. The quark structure of Δ^{++} is

- a) uuu
- b) udu
- c) sss
- d) ddd

36. If the nuclear radius of ^{27}Al is 3.6 Fermi, the approximate nuclear radius of ^{64}Cu in Fermi is

- a) 4.8
- b) 3.6
- c) 2.4
- d) 1.2

37. The electromagnetic field due to a point charge must be described by Lienard Weichert potentials when

- a) the point charged is highly accelerated
- b) the electric and magnetic fields are not perpendicular
- c) the point charge is moving with velocity close to light
- d) the calculation is done for the radiation zone, i.e. far away from charge

38. The behavior of Lorentz force law

$$\frac{d\vec{p}}{dt} = q(\vec{E} + \vec{v} \times \vec{B})$$

under transformations of space inversion (P) and time reversal (T) is as follows:

- a) Invariant under both P and T
- b) Invariant under P but not under T
- c) Invariant under T but not under P
- d) Neither invariant under P nor under T

39. The vector potential \vec{A} corresponding to a constant magnetic field B in the z direction is

- a) $\frac{B}{2}(\hat{i}x - \hat{j}y)$
- b) $\frac{B}{2}(\hat{j}x - \hat{i}y)$
- c) $-Bz\hat{k}$
- d) $B(\hat{j}x - \hat{i}y)$

40. In an electromagnetic field, which one of the following remains invariant under Lorntz transformations :

- a) $\vec{E} \times \vec{B}$
- b) $E^2 - c^2B^2$
- c) B^2
- d) E^2

