Duration: 3 hours **Total Marks 100**

Section I

Instructions for the Candidates:

1. **Attempt all 40 questions.**
2. Each question carries one mark.
3. Max marks for this section is: 40.
4. There is only **one** correct answer and **no** negative marking.
5. Please write the question number and your answer (alphabet only) next to it (For example: Q1. --- b)

Q1. In mechanics the action is

a. Σ **q.p**
b. Σ **q + p**
c. Σ **q − p**
d. $\Sigma \mathbf{q^2 . p^2}$

Q.2. The contact transformation are the transformations of

a. Phase space
b. configuration space
c. both a & b
d. point sapce

Q.3. If $\epsilon = 0$, then the shape of the orbit formed will be

a. Ellipse
b. Circle
c. Hyperbola
d. Parabola

Q.4. In equations of motion q_j =

a. $\partial H / \partial P_j$
b. $-\partial H / \partial q_j$
c. $\partial H / \partial q_j$
d. $\partial H / \partial P_j$

Q.5 If a physical quantity grows at the rate of 10% per second over the previous value then percentage change at the end of two seconds is

a. 20%
b. 19%

c. 21%
d. None

Q.6 If **A** = 1/3 i + μ j + 1/3 k is unit vector the value of μ is--------.

a. 7/9
b. 2/3
c. 49/81
d. None

Q.7 If $\int f(x)\,dx = 1/4 \tan^4 x$ then f(x) is ----------

a. $\tan^2 x \sec^2 x$
b. $\tan^2 x \sec^3 x$
c. $\tan^3 x \sec^3 x$
d. None

Q.8 If **A**= x i+ y^2 j+ z^3 k.... is **A**

a. Solenoid
b. Irrotational
c. Solenoid as well as Irrotational
d. None

Q.9. For narrow wavepacket of a particle
a. wavelength is short
b. b) position can be determined more accurately
c. momentum can be determined more accurately
d. energy can be determined more accurately

Q.10. From quantum theory of observation and measurement if a system is in a certain state for time Δt, the energy of the system in that state is uncertain by atleast
a. ħ/Δt
b. ħ/t
c. ħΔt
d. Δt/ħ

Q.11. If ϕ_1 and ϕ_2 are orthonormal functions then the value of n which normalizes the function f=n(ϕ_1 + 2iϕ_2) is
a. (1+2i)
b. 1/(1+2i)
c. c) 1/5
d. $(1/5)^{1/2}$

Q.12. The Clebsch-Gordan coefficient for $j_1=j_2=1/2$ corrsponding to j=1 yields states

a. $\phi(1,1), \phi(1,0), \phi(1,-1)$
b. $\phi(1,1), \phi(0,0), \phi(1,0)$
c. $\phi(-1,1), \phi(0,0), \phi(-1,-1)$
d. None of the above

Q.13. If a charged particle of mass 6.66×10^{-27} kg at rest is released in a uniform magnetic field of strength 10^4 N/C, travels a distance of 2.00 cm between two charged plates in 2.84×10^{-7} s. Then the charge on the particle is

a. 3.29×10^{-19} C
b. 2.12×10^{-19} C
c. 6.00×10^{-19} C
d. None

Q.14. The charge density which produces the electric field

$$\boldsymbol{E} = g(\boldsymbol{i}x + \boldsymbol{j}y + \boldsymbol{k}z)$$

a. $9g\varepsilon_0$
b. $g\varepsilon_0$
c. $3g\varepsilon_0$
d. None

Q.15. Electric field is an example of

a. Scalar Function
b. Vector Function
c. Delta Function
d. None

Q.16. A lossy dielectric has $\mu_r = 1, \varepsilon_r = 10$ and $\sigma = 20$ nS/m. An electric field E= 200 sin ωt a_z (V/m) exists in the dielectric. The conduction current density and displacement current density for this dielectric will be equal at frequency equal to

a. 36Hz
b. 360Hz
c. 3600Hz
d. 36KHz

Q.17 The root-mean square of a particle of mass m in the kinetic theory is

a. $(kT/m)^{1/2}$
b. $(3/2\ kT/m)^{1/2}$
c. $(2\ kT/m)^{1/2}$
d. $(3\ kT/m)^{1/2}$

Q.18 Suppose the temparature of the sun goes down by a factor of two, then the total power emitted by the sun will go down by a factor of

a. 2
b. 4
c. 8
d. 16.

Q.19 The 3s orbital of the hydrogen atom has ------- nodes.

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

Q.20 The ground state energy of positronium (bound positron and electron) is

a. -2 Ryd.
b. -0.5 ryd.
c. -1 Ryd.
d. None of the above.

Q.21. For a linear diatomic molecule, the time scales of rotation, vibration and electronic excitation are related as follows

a. $t_{elec} \ll t_{vib} \ll t_{rot}$
b. $t_{rot} \sim t_{elec} \sim t_{vib}$
c. $t_{elec} \ll t_{rot} \ll t_{vib}$
d. $t_{vib} \gg t_{elec} \sim t_{rot}$

Q.22. Consider an atom with a doubly degenerate state Ψ_1 and Ψ_2 having the same eigenvalue E. Then the wave function $\alpha\Psi_1 + \beta\Psi_2$ where α, β are constants has the average energy

a. $(\alpha + \beta)E$
b. $(\alpha - \beta)E$
c. $\alpha\beta E$
d. E

Q.23. A diffraction grating has 6000 lines per cm. The diffracted second order spectral line is observed at 50°. The wavelength of light is

a. 5393 Å
b. 2783 Å
c. 6384 Å
d. 3800 Å

Q.24. The wavelength corresponding to a typical pure rotational transition in a water molecule is in the

a. infrared region
b. microwave region
c. ultraviolet region
d. X-ray region

Q.25. The drift velocity of electrons, in silicon

a. is proportional to the electric field for all values of electric field
b. is independent of the electric field
c. increases at low values of electric field and decreases at high values of electric field exhibiting negative differential resistance.
d. increases linearly with electric field at low values of electric field and gradually saturates at higher values of electric field.

Q.26. A silicon sample A is doped with 10^{18} atoms/cm^3 of boron. Another sample B of identical dimensions is doped with 10^{18} atoms/cm^3 of phosphorous. The ratio of electron to hole mobility is 3. The ratio of conductivity of the sample A to B is

a. 3
b. 1/3
c. 2/3
d. 3/2

Q.27. Silicon is doped with boron to a concentration of $4x10^{17}$atoms/cm^3. Assuming the intrinsic carrier concentration of silicon to be 1.5 x 10^{10} cm^{-3} and the value of KT/q to be 25 mV at 300 °K. Compared to undoped silicon, the Fermi level of doped silicon

a. Goes down by 0.13 eV
b. Goes up by 0.13 eV
c. Goes down by 0.427 eV
d. Goes up by 0.427 eV

Q.28. What is an energy gap?

a. the energy equal to the energy acquired by an electron passing a 1 V electric field
b. an energy level at which an electron can exist
c. the space between two orbital shells
d. the energy band in which electrons can move freely

Q:29 Slew rate of an ideal Opamp

a. Infinite
b. Very high
c. Low
d. Very low

Q.30 In the differential circuit, which of the following terminals are connected together?

a. Bases
b. Collector
c. One base to another collector
d. Emitters

Q.31 In a 8085 microprocessor system with memory mapped I/O --

a. I/O devices have 8 bit addresses
b. I/O devices are accessed using IN and OUT instructions
c. arithmetic and logic operation can be directly performed with I/O data
d. none

Q.32. In order to startup, a feedback oscillator requires--

a. Negative feedback less than one
b. Positive feedback greater than one
c. Unity feedback equal to one
d. No feedback

Q.33. The dominant interactions underlying the following processes

A. $K^- + p \rightarrow \Sigma^- + \pi^+$, B. $\mu^- + \mu + \rightarrow K^- + K^+$, C. $\Sigma^+ \rightarrow p + \pi^0$ are

a. A: strong, B: electromagnetic and; C: weak
b. A: strong, B: weak and; C: weak
c. A: weak, B: electromagnetic and; C: strong
d. A: weak, B: electromagnetic and; C: weak

Q.34. The intrinsic electric dipole moment of a nucleus ${}^{A}X_{Z}$

a. increases with Z, but is independent of A

b. decreases with Z, but is independent of A

c. is always zero

d. increases with Z and A

Q.35. The recently-discovered Higgs boson at the LHC experiment has a decay mode into a photon and a Z boson. If the rest masses of the Higgs and Z boson are 125 GeV/c^2 and 90 GeV/c^2 respectively, and the decaying Higgs particle is at rest, the energy of the photon will approximately be

a. 353 GeV

b. 35 GeV

c. 30 GeV

d. 15 GeV

Q.36. In a classical model, a scalar (spin-0) meson consists of a quark and an antiquark bound by a potential

$$V(r) = ar + b/r$$

where $a = 200$MeV fm^{-1} and $b = 100$ MeV fm. If the masses of the quark and antiquark are negligible, the mass of the meson can be estimated as approximately

a. 141 MeV/c^2

b. 283 MeV/c^2

c. 353 MeV/c^2

d. 425 MeV/c^2

Q.37. In diamond the co-ordination number of C-atoms is ____ and its unit cell has ____ C-atoms.

a. 4; 8

b. 4; 6

c. 6; 4

d. 4; 4

Q.38. Mobility of electrons is

a. electric field per unit flow of electrons

b. reciprocal of conductivity

c. average electron drift velocity per unit field

d. reciprocal of drift velocity

Q.39. Some polar crystals produce small electric current on heating. This phenomenon is called

a. piezoelectricity
b. pyroelectricity
c. ferroelectricity
d. antiferroelectricity

Q.40. The transition temperature T_c and critical field H_c in superconductors are related by

a. $H_c = H_0(1 - T_c)$
b. $H_c = H_0(1 + T_c)$
c. $H_c = H_0[1 - (T/T_c)^2]$
d. $H_c = H_0[1 + (T_c/T)^2]$

Where H_0 is the field in superconducting state at 0 K.

Section II

(Max. Marks: 30)

Attempt any THREE out of Six

All Questions carry EQUAL (10m) marks

Q.1.a. The nature of the orbit is determined by the value of its eccentricity $\epsilon = \sqrt{[1 + (2EL^2/\mu k^2)]}$. Discuss the various shapes of orbits formed depending upon the value of eccentricity. (5m)

Q1.b. What are the main features of the motion of a particle under the action of central force?. Show that the area swept per unit time i.e. dA/dt remains constant in such a motion. (5m)

Q.2.a. If $\sigma_1, \sigma_2, \sigma_3$ are Pauli's Matrices show that $\sigma_1^2 = \sigma_2^2 = \sigma_3^2 = I$; I Unit Matrix. (5m)

Q.2.b. Write the differential equation of damped harmonic oscillator and discuss its solution for critically damped case. (5m)

Q.3. Prove that $[J^2, J_-] = 0$ and $[J^2, J_+] = 0$ (10m)

Q.4. Give the neat diagram and describe the Four Point Probe method of resistivity measurement of semiconductors. Discuss its salient features. (10m)

Determine the resistivity of an n-type silicon sample doped with 5×10^{16} phosphor atoms / cm^3 at 300 K. [Given constants: electronic charge (q) = 1.6×10^{-19} C, electron mobility (μ_n) = 1350 cm^2/ V. s.]

Q.5 Consider an ideal gas of N particles obeying classical statistics. The energy of a particle has the extreme relativistic form, $\varepsilon = pc$, where p is the magnitude of the momentum and c is the speed of light. For the thermodynamics: (10m)

(i) Calculate the canonical partition function.
(ii) Find the Helmholtz free energy and the energy of the system.
(iii) From this obtain the pressure, the enthalpy and the specific heat C_v.

Q.6. Consider a one-electron atom placed in a constant magnetic field $\vec{B} = B_z\hat{z}$. The field is suffciently weak, so that it acts only as a minor correction to the spin-orbit interaction term $\vec{L}\cdot\vec{S}$ in the hydrogen atom fine structure Hamiltonian. By treating the magnetic field interaction as a perturbation, obtain the correction to the fine structure energy levels. (10m)

Show that the degeneracy in the one-electron energy levels is completely removed. Also comment on Lande's g-factor.

You may need the identity:

$$\langle jm|(\vec{V}\cdot\vec{J})\vec{J}|jm\rangle = j(j+1)\hbar^2\langle jm|\vec{V}|jm\rangle$$

for any vector operator $\vec{V}$.

Section III
(Max Marks 30)

Attempt any TWO out of four Questions

All Questions carry EQUAL (15m) marks

Q.1 Find a magnetic field a distance 's' from a long straight wire carrying a steady current I. (15m)

Q.2 Discuss the Fermi's theory of beta decay in detail. Derive the Q-value for the three types of beta decay processes? (15m)

Q.3.a. With respect to crystals, state what do you understand by the terms: primitive cell, unit cell, crystal lattice, basis, packing factor and co-ordination number. Briefly describe the classification of crystals in the Bravais lattice system. (9m)

Q.3.b. The density of silver is 10.5×10^3 kg/m^3. The atomic weight of silver is 107.9. Assuming that each silver atom provides one conduction electron, calculate the density of electrons. The conductivity of silver at 20°C is $6.8\times10^7\ \Omega^{-1}$ m. Calculate the mobility of electrons in silver. Applying the classical theory, estimate the electron (6m)

collision time and the corresponding mean free path.

Q.4 a. Explain the General and Special functions of General Purpose Registers in 8086 processor. (7m)

Q.4b. What is meant by addressing mode? Explain the 8086 addressing modes for control transfer instructions (8m)

**********END**********