Reg. No. :.................

Entrance Examination for Ph.D Admission in Physics, February 2020

University of Calicut

Department of Physics

Maximum Marks: 100 Duration: 2 hours.

Part A

Answer All Questions. Each question carries 2 marks. Circle the most appropriate choice **in the given answer sheet**.

1. If the Lagrangian, L, does not depend on a certain coordinate, q_k, then $\frac{d}{dt}\frac{\partial L}{\partial \dot{q}_k} = \frac{\partial L}{\partial q_k} = 0$. In this case, we say
   A. q_k is a cyclic coordinate B. q_k is a non-cyclic coordinate C. $\frac{\partial L}{\partial \dot{q}_k}$ is not conserved D. None of the above

2. The unstable fixed point of a unperturbed pendulum may be stabilised provided the oscillations are:
   A. slow enough B. very slow C. fast enough D. none

3. Which components of momentum P and angular momentum L are conserved in motion in the field of an infinite homogeneous plane (if the plane is the xy plane).
   A. P_x, P_y B. Py, L_z C. None D. P_x, P_y, L_z

4. In a medium showing anomalous dispersion
   A. $\frac{du_p}{d\omega} = 0$ B. $\frac{du_p}{d\omega} < 0$ C. $\frac{du_p}{d\omega} > 0$ D. $\frac{du_g}{d\omega} < 0$

5. If $\vec{E}(\vec{r}, t)$ and $\vec{B}(\vec{r}, t)$ denotes electric and magnetic fields, obeying Maxwell's equations, then under Lorentz transformation from one inertial frame to another, the quantity which remains invariant is
   A. $\varepsilon_0 E^2 + \frac{B^2}{\mu_0}$ B. $\varepsilon_0 E^2 - \frac{B^2}{\mu_0}$ C. $\vec{E} \times \vec{B}$ D. $(\vec{E} \times \vec{B}) \times (\vec{E} \times \vec{B})$

6. A zener diode with $V_z = 6.8$ V is connected with a series impedance of 1 kΩ resistance is connected to a voltage source of $15V$. Current through the diode is
   A. 6.8 A B. 6.8 mA C. 8.2 A D. 8.2 mA

7. The the output voltage from a 5 bit ladder D/A converter that has a digital input 11000 with a reference voltage of $5V$ is
   A. 5 V B. 3.75 V C. 2.5 V D. 1.25 V

8. Input side of a typical Op-Amp is
   A. Dual input balanced output differential amplifier B. Dual input un-balanced output differential amplifier C. Emitter Follower D. Class A amplifier

9. The ground state energy of 13 electrons in a 3 dimensional box of size 'a' is
A. $9\frac{\pi^2\hbar^2}{2ma^2}$ B. $56\frac{\pi^2\hbar^2}{2ma^2}$ C. $64\frac{\pi^2\hbar^2}{2ma^2}$ D. $84\frac{\pi^2\hbar^2}{2ma^2}$

10. If $\hat{a}$ and $\hat{a}^\dagger$ are the rising and lowering operators of a linear harmonic oscillator, $\langle(\hat{a}^\dagger + \hat{a})^2\rangle$ is
A. n B. n+1 C. 2n+1 D. 2n

11. The degeneracy of n-th state of a 2D isotropic oscillator is
A. n B. n(n-1) C. n^2 D. n+1

12. The Legendre polynomial $P_n(x)$ has
A. n zeroes between -1 and 1 B. n zeroes between 0 and 1 C. n zeroes with only one between -1 and 1 D. n zeroes with only one between 0 and 1

13. The probabilities of a problem being solved by two students are 1/3 and 1/4. The probability of the problem being solved is
A. 1/2 B. 1/3 C. 1/4 D. 1/5

14. According to Liouville's theorem, the total rate of change of density function in the vicinity of any selected phase point of a system moving through the phase space is
A. 1 B. 0 C. ∞ D. None of these

15. The average energy in the relativistic regime for an ideal gas obeying Fermi-Dirac statistics at 0 K, in units of Fermi level energy is
A. 2/5 B. 3/5 C. 1/4 D. 3/4

16. Consider a system of ideal gas obeying Bose Einstein statistics. For the system an energy state with degeneracy 4 is having 3 particles occupied. The number of ways of selecting the particles in the energy state will be
A. 1 B. 10 C. 20 D. ∞

17. Spin and parity of ^{7}Li nucleus is
A. $\left(\frac{1}{2}\right)^+$ B. $\left(\frac{1}{2}\right)^-$ C. $\left(\frac{3}{2}\right)^+$ D. $\left(\frac{3}{2}\right)^-$

18. Life time of gamma decay is related to
A. Energy difference between the transition levels B. spin states of the respective levels C. mass number of the nucleus D. difference between the proton number and neutron number of the nucleus

19. According to the quark constitution Σ^0 has the following structure
A. uds B. udd C. uss D. uud

20. The wavelength of X-ray that can be used for crystal structure studies is
A. 10 Å B. 1.54 Å C. 12.54 Å D. 80Å

21. Cockcroft-Walton accelerator is also called
A. Cascade accelerator B. Tandem accelerator C. LINAC D. None of these

22. The law which states the ratio of the thermal conductivity to the electrical conductivity is directly proportional to the temperature is
A. Clausius-Mossotti equation B. Debye equation C. Einstein's equation
D. Wiedmann-Franz equation

23. A laser beam emerging from a laser tube operating at 600 nm has a cross-sectional diameter of 2 mm. The diameter of the beam at a distance of 1 km is approximately
A. 120 cm B. 60 cm C. 120 μm D. 60 μm

24. The Landé g-factor for the $^3P_1$ level of an atom is
A. 9/2 B. 7/2 C. 5/2 D. 3/2

25. The total radiated power from a dipole antenna varies as
A. ω^2 B. ω^3 C. ω^4 D. ω^5

Part B

Answer any 10 questions. Each question carries 5 marks.

1. The Zeeman pattern of a line consists of 9 equidistant components. The upper state term is $^2P_{3/2}$. Determine the lower state term using a schematic diagram.

2. Calculate the energy, momentum and wavelength of a photon emitted from a hydrogen atom by the transition of the electron from n=2 to n=1 state. (Ionization potential = 13.6 eV.)

3. Explain the working of Van de Graff accelerator.

4. Write short note on the quantum theory of paramagnetism.

5. Briefly explain the anti-ferromagnetic order.

6. Show that all the existing baryons can be expressed in terms of three fundamental quarks.

7. State the two essential differences between scattering by neutron-proton system and proton-proton system.

8. Evaluate the Helmholtz free energy and entropy for a 3D harmonic osscilator system with the degeneracy $g_n = (n+1)(n+2)/2$.

9. Obtain the Heisenberg uncertainty relationship from the general uncertainty relationship.

10. Design a first order low pass Butterworth filter for a cutoff frequency of 1 kHz. Modify the circuit to a second order filter with the same cutoff frequency.

11. With a suitable example how analog computer can be constructed to perform the solution of second order differential equation using operational amplifiers.

12. Write down the wave equation for the electromagnetic wave through a lossy medium. Explain the nature of the solution. What will be the solution if the medium is a perfect conductor?

13. Show directly that the transformation $Q = \log(\frac{1}{q}\sin p), P = q\cot p$ is canonical.

14. Obtain Fourier series expansion for the function $f(x) = x^3$, for $0 < x < 2\pi$.

15. Show that the eigen values of a Hermitian operator are real, and the corresponding eigen vectors are orthogonal.

Answer-sheet for Part-A **Reg. No. :..................**

Entrance Examination for Ph.D Admission in Physics, February 2020
Department of Physics, University of Calicut

1.	A.	B.	C.	D.
2.	A.	B.	C.	D.
3.	A.	B.	C.	D.
4.	A.	B.	C.	D.
5.	A.	B.	C.	D.
6.	A.	B.	C.	D.
7.	A.	B.	C.	D.
8.	A.	B.	C.	D.
9.	A.	B.	C.	D.
10.	A.	B.	C.	D.
11.	A.	B.	C.	D.
12.	A.	B.	C.	D.
13.	A.	B.	C.	D.
14.	A.	B.	C.	D.
15.	A.	B.	C.	D.
16.	A.	B.	C.	D.
17.	A.	B.	C.	D.
18.	A.	B.	C.	D.
19.	A.	B.	C.	D.
20.	A.	B.	C.	D.
21.	A.	B.	C.	D.
22.	A.	B.	C.	D.
23.	A.	B.	C.	D.
24.	A.	B.	C.	D.
25.	A.	B.	C.	D.

I. **Mathematical Methods of Physics**

Dimensional analysis; Vector algebra and vector calculus; Linear algebra, matrices, Cayley Hamilton theorem, eigenvalue problems; Linear differential equations; Special functions (Hermite, Bessel, Laguerre and Legendre); Fourier series, Fourier and Laplace transforms; Elements of complex analysis: Laurent series-poles, residues and evaluation of integrals; Elementary ideas about tensors; Introductory group theory, SU(2), O(3); Elements of computational techniques: roots of functions, interpolation, extrapolation, integration by trapezoid and Simpson's rule, solution of first order differential equations using Runge-Kutta method; Finite difference methods; Elementary probability theory, random variables, binomial, Poisson and normal distributions.

II. **Classical Mechanics**

Newton's laws; Phase space dynamics, stability analysis; Central-force motion; Two-body collisions, scattering in laboratory and centre-of-mass frames; Rigid body dynamics, moment of inertia tensor, non-inertial frames and pseudoforces; Variational principle, Lagrangian and Hamiltonian formalisms and equations of motion; Poisson brackets and canonical transformations; Symmetry, invariance and conservation laws, cyclic coordinates; Periodic motion, small oscillations and normal modes; Special theory of relativity, Lorentz transformations, relativistic kinematics and mass–energy equivalence.

III. **Electromagnetic Theory Electrostatics**

Gauss' Law and its applications; Laplace and Poisson equations, boundary value problems; Magnetostatics: Biot-Savart law, Ampere's theorem, electromagnetic induction; Maxwell's equations in free space and linear isotropic media; boundary conditions on fields at interfaces; Scalar and vector potentials; Gauge invariance; Electromagnetic waves in free space, dielectrics, and conductors; Reflection and refraction, polarization, Fresnel's Law, interference, coherence, and diffraction; Dispersion relations in plasma; Lorentz invariance of Maxwell's equations; Transmission lines and wave guides; Dynamics of charged particles in static and uniform electromagnetic fields; Radiation from moving charges, dipoles and retarded potentials.

IV. **Quantum Mechanics**

Wave-particle duality; Wave functions in coordinate and momentum representations; Commutators and Heisenberg's uncertainty principle; Matrix representation; Dirac's bra and ket notation; Schroedinger equation (time-dependent and time-independent); Eigenvalue problems such as particle-in-a-box, harmonic oscillator, etc.; Tunneling through a barrier; Motion in a central potential; Orbital angular momentum, Angular momentum algebra, spin; Addition of angular momenta; Hydrogen atom, spin-orbit coupling, fine structure; Timeindependent perturbation theory and applications; Variational method; WKB approximation; Time dependent perturbation theory and

Fermi's Golden Rule; Selection rules; Semi-classical theory of radiation; Elementary theory of scattering, phase shifts, partial waves, Born approximation; Identical particles, Pauli's exclusion principle, spin-statistics connection; Relativistic quantum mechanics: Klein Gordon and Dirac equations.

V. <u>Thermodynamic and Statistical Physics</u>

Laws of thermodynamics and their consequences; Thermodynamic potentials, Maxwell relations; Chemical potential, phase equilibria; Phase space, micro- and macrostates; Microcanonical, canonical and grand-canonical ensembles and partition functions; Free Energy and connection with thermodynamic quantities; First- and second-order phase transitions; Classical and quantum statistics, ideal Fermi and Bose gases; Principle of detailed balance; Blackbody radiation and Planck's distribution law; Bose-Einstein condensation; Random walk and Brownian motion; Introduction to nonequilibrium processes; Diffusion equation.

VI. <u>Electronics</u>

Semiconductor device physics, including diodes, junctions, transistors, field effect devices, homo and heterojunction devices, device structure, device characteristics, frequency dependence and applications; Optoelectronic devices, including solar cells, photodetectors, and LEDs; High-frequency devices, including generators and detectors; Operational amplifiers and their applications; Digital techniques and applications (registers, counters, comparators and similar circuits); A/D and D/A converters; Microprocessor and microcontroller basics.

VII. <u>Experimental Techniques and data analysis</u>

Data interpretation and analysis; Precision and accuracy, error analysis, propagation of errors, least squares fitting, linear and nonlinear curve fitting, chi-square test; Transducers (temperature, pressure/vacuum, magnetic field, vibration, optical, and particle detectors), measurement and control; Signal conditioning and recovery, impedance matching, amplification (Op-amp based, instrumentation amp, feedback), filtering and noise reduction, shielding and grounding; Fourier transforms; lock-in detector, box-car integrator, modulation techniques. Applications of the above experimental and analytical techniques to typical undergraduate and graduate level laboratory experiments.

VIII. <u>Atomic & Molecular Physics</u>

Quantum states of an electron in an atom; Electron spin; Stern-Gerlach experiment; Spectrum of Hydrogen, helium and alkali atoms; Relativistic corrections for energy levels of hydrogen; Hyperfine structure and isotopic shift; width of spectral lines; LS & JJ coupling; Zeeman, Paschen Back & Stark effect; X-ray spectroscopy; Electron spin resonance, Nuclear magnetic resonance, chemical shift; Rotational, vibrational, electronic, and Raman spectra of diatomic molecules; Frank – Condon principle and selection rules; Spontaneous and stimulated emission, Einstein A & B coefficients;

Lasers, optical pumping, population inversion, rate equation; Modes of resonators and coherence length.

IX. **Condensed Matter Physics**

Bravais lattices; Reciprocal lattice, diffraction and the structure factor; Bonding of solids; Elastic properties, phonons, lattice specific heat; Free electron theory and electronic specific heat; Response and relaxation phenomena; Drude model of electrical and thermal conductivity; Hall effect and thermoelectric power; Diamagnetism, paramagnetism, and ferromagnetism; Electron motion in a periodic potential, band theory of metals, insulators and semiconductors; Superconductivity, type – I and type - II superconductors, Josephson junctions; Defects and dislocations; Ordered phases of matter, translational and orientational order, kinds of liquid crystalline order; Conducting polymers; Quasicrystals.

X. **Nuclear and Particle Physics**

Basic nuclear properties: size, shape, charge distribution, spin and parity; Binding energy, semi-empirical mass formula; Liquid drop model; Fission and fusion; Nature of the nuclear force, form of nucleon-nucleon potential; Charge-independence and charge-symmetry of nuclear forces; Isospin; Deuteron problem; Evidence of shell structure, single- particle shell model, its validity and limitations; Rotational spectra; Elementary ideas of alpha, beta and gamma decays and their selection rules; Nuclear reactions, reaction mechanisms, compound nuclei and direct reactions; Classification of fundamental forces; Elementary particles (quarks, baryons, mesons, leptons); Spin and parity assignments, isospin, strangeness; Gell-Mann Nishijima formula; C, P, and T invariance and applications of symmetry arguments to particle reactions, parity non-conservation in weak interaction; Relativistic kinematics.