S–5/PHSH/05/16

TDP (Honours) 5th Semester Exam., 2016

PHYSICS

(Honours)

FIFTH PAPER

Full Marks : 80

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer **eight** questions, taking **two** from each Unit

UNIT—I

1. (a) Using the generating function of Legendre's polynomial, establish the relation

$$x P_n(x) = \left(\frac{n+1}{2n+1}\right) P_{n+1}(x) + \frac{n}{2n+1} P_{n-1}(x)$$

(b) Establish the relation

$$P_n(x) = \frac{1}{n!\,2^n} \frac{d^n}{dx^n}(x^2-1)^n$$

(c) Define single-valued and multi-valued complex functions with examples.

3+4+3=10

(Turn Over)

1

2. (a) Express $f(x) = x^3 + x^2 - 3x + 2$ in a series of Laguerre polynomials.

(b) State and prove Cauchy-Riemann equations.

(c) Find $L\{f(t)\}$, where $f(t) = \cos at$, where a is a constant. 3+4+3=10

3. (a) Define branch point, branch cut, Riemann's sheet and Riemann's surface in connection with the complex function $f(z) = z^{\frac{1}{3}}$.

(b) If $L\{f(t)\} = F(s)$, then find the Laplace transform of $\frac{1}{t} f(t)$.

(c) Show that

$$L\left[\int_0^t f(t)\,dt\right] = \frac{1}{s} F(s) \qquad 3+3+4=10$$

UNIT—II

4. (a) Give the quantum theory of normal Zeeman effect and hence derive an expression for the Zeeman shift. Draw the energy level and spectral lines appear in normal Zeeman effect.

(b) Find out different states in j-j coupling scheme for a two-electron atom. Given $l_1 = 1$ and $l_2 = 2$.

(c) What is spin-orbit coupling? (4+2)+2+2=10

5. (a) Explain the significance of Stern-Gerlach experiment.

(b) Why is the ground state of an atom always singlet?

(c) Explain the origin of intrinsic magnetic moment of an atom.

(d) What is meant by metastable state? Give an example. 2+2+3+(2+1)=10

6. (a) Explain the working of a He-Ne LASER.

(b) Define numerical aperture and acceptance angle in an optical fibre. Derive an expression for the numerical aperture.

(c) If the energy of the incident photon is 1·22 MeV and that of scattered one is 0·511 MeV, what is the scattering angle of the photon? 4+(2+2)+2=10

UNIT—III

7. (a) Draw a neat circuit diagram of a bridge rectifier.

(b) Draw a self-bias circuit and explain how the bias curve is used to the Q-point of the circuit.

(c) Draw the small-signal low-frequency hybrid parameter equivalent circuit of a CE amplifier and derive expressions for current gain. 2+(2+2)+(2+2)=10

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8. (a) Define JFET parameters and establish a relation between them.

(b) The a.c. drain resistance of JFET is 30 kΩ and transconductance is 3 mA/V. Find the amplification factor of the JFET.

(c) Find the relation between open-loop gain and closed-loop gain in a negative feedback amplifier. (3+2)+2+3=10

9. (a) Show that frequency of a normally incident radio wave that can be reflected from an ionospheric layer of electron density N is given by $f = 9\sqrt{N}$. Hence explain critical frequency of the layer.

(b) Draw the block diagram of a radio transmitter.

(c) In a differential amplifier with two inputs, the output is 2·01 mV when the inputs are 110 μV and 90 μV but the output is 2 mV when inputs are 10 μV and −10 μV. Find the CMRR of the amplifier. (4+1)+2+3=10

UNIT—IV

10. (a) A linear harmonic oscillator moves with a constant energy along X-axis. What will be the phase trajectory?

(b) Two particles are to be distributed in an energy level, which is 3-fold degenerate. Find the possible microstates if the particles are (i) distinguishable, (ii) indistinguishable bosons and (iii) indistinguishable fermions.

(c) Establish Boltzmann relation between the thermodynamic probability and entropy.

(d) What is the physical significance of partition function? 2+3+3+2=10

11. (a) Establish the Fermi-Dirac distribution function.

(b) Sketch the FD distribution function for $T = 0$ K and $T > 0$ K

(c) Compare M-B, B-E and F-D statistics. 5+2+3=10

3

12. *(a)* For a cubical, three-dimensional infinite well, what is the density of states in the momentum interval between p and $+dp$?

(b) Show that the average kinetic energy per particle for a Fermi gas of N particles at $T=0K$ is $\bar{\varepsilon}=\frac{3}{5}\varepsilon_{f0}$

where $\varepsilon_{f0}=\frac{h^2}{8m}\left(\frac{3N}{\pi V}\right)^{\frac{2}{3}}$ is the Fermi energy at $T=0K$.

(c) Derive Richardson-Dushman thermionic emission equation. 2+3+5=10

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4

S–5/PHSH/05/17

TDP (Honours) 5th Semester Exam., 2017

PHYSICS

(Honours)

FIFTH PAPER

Full Marks : 80

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer **eight** questions, taking **two** from each Unit

UNIT—I

1. *(a)* Establish the relation

$$g(x,\ t) = e^{2xt-t^2} = \sum_{n=0}^{\infty} \frac{t^n}{n!} H_n(x)$$

where symbols have their usual meanings.

(b) Establish the relation

$$H_n'(x) = 2nH_{n-1}(x)$$

(c) If $L[f(t)] = F(s)$ then show that

$$\left[\int_0^t f(t)\,dt = \frac{1}{s}F(s)\right]$$

4+3+3=10

2. *(a)* Show that

$$\int_{-1}^{1} P_n(x) P_m(x) dx = 0$$

if $m = n$.

(b) Prove that $u = e^{-x}(x\sin y - y\cos y)$ is harmonic.

(c) Define singularity and pole at any point. What is isolated singularity? 3+3+(2+2)=10

3. *(a)* What are single-valued and multi-valued functions? Give example. What is Riemann surface?

(b) Construct an analytic function $f(z) = u + iv$ whose real part is $e^x \cos y$.

(c) State and prove Cauchy-Riemann equations in polar form. (2+2)+3+3=10

UNIT—II

4. *(a)* Why is a homogeneous field not used in Stern-Gerlach experiment?

(b) Explain *L-S* coupling and *j-j* coupling schemes.

(c) Show that the Compton's shift depends only on the angle of scattering but is independent of wavelength of the incident beam and also the nature of the scatterer. 2+(2+2)+4=10

5. *(a)* Why is the translational energy of a molecule not quantized?

(b) The moment of inertia of a rigid diatomic molecule *A* is 6 times that of another rigid diatomic molecule *B*. If the rotational energies of the two molecules are equal, calculate the corresponding values of the rotational quantum numbers J_A and J_B.

(c) What is the value of the g-factor for an atom with a single optical electron in $d_{3/2}$ level?

(d) Explain with diagram 'time dispersion' in optical fiber transmission. 2+3+2+3=10

6. *(a)* Calculate the wavelength of the normal Zeeman triplet of a spectral line 500 nm placed in a magnetic field of 20 Tesla. Given that e/m of the electron is $1 \cdot 76 \times 10^{11}$ C/kg.

(b) Discuss briefly about three level and four level laser systems.

(c) How is population inversion achieved in a semiconductor laser? 3+(2+2)+3=10

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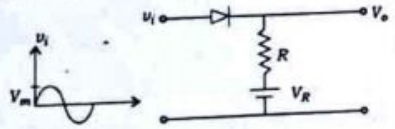
UNIT—III

7. (a) Draw a diode clamping circuit which clamps the positive peaks of the input signal at a negative voltage $-V$. Discuss the working of the circuit and hence draw the output waveform.

(b) What is the practical importance of a clamping circuit?

(c) Draw the output of the circuit given below : (2+3+1)+2+2=10



8. (a) What is slew rate? How does it limit the high-frequency operation of an OP-AMP?

(b) Discuss the operation of a triangular wave generator using an OP-AMP. Also calculate the period of triangular wave generator. (2+2)+(4+2)=10

9. (a) On which factors does the selection of Q-point depend in a transistor amplifier?

(b) What is the necessity for biasing of a transistor?

(Continued)

(c) Draw the output characteristics of a transistor in CB mode and explain different operating regions.

(d) What is early effect? 2+2+4+2=10

UNIT—IV

10. (a) What is Stirling's approximation?

(b) Three distinguishable particles have total energy of 9 units. But the particles are restricted to energy levels from 0 to 4. Calculate the number of micro-states and macrostates.

(c) Show that if f is the FD distribution function, $\frac{-\partial f}{\partial E}$ is a maximum at the Fermi level.

(d) Sketch the FD distribution function for $T = 0K$ and $T > 0K$. 2+3+3+2=10

11. (a) What is the significance of partition function in statistical physics?

(b) A system has two energy levels of energy 0 and 100 K_B with degeneracy of 2 and 3 respectively. Determine the partition function and average energy at a temperature of 100 K.

(c) What are Bosons and Fermions? Give examples. 3+3+(2+2)=10

(Turn Over)

7

12. *(a)* Deduce Maxwell-Boltzmann distribution law for non-interacting particles.

(b) What is ensemble?

(c) A system of N distinguishable particles each of which can be in one of the two energy levels 0 and ε, has a total energy $n\varepsilon$, where n is an integer. Find the entropy of the system. 5+2+3=10

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S–5/PHSH/05/18

TDP (Honours) 5th Semester Exam., 2018

PHYSICS

(Honours)

FIFTH PAPER

Full Marks : 80

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer **eight** questions, taking **two** from each Unit

UNIT—I

1. *(a)* Solve $\frac{\partial^2 \psi}{\partial x^2} + \frac{\partial^2 \psi}{\partial y^2} = 0$ which satisfies the condition $\psi(0, y) = \psi(l, y) = \psi(x, 0) = 0$ and $\psi(x, a) = \sin \frac{n\pi x}{l}$.

(b) Prove by Laplace transform that

$$\int_0^\infty te^{-2t} \sin t \, dt = \frac{4}{25}$$

(c) Plot the variation of $P_1(x)$ and $P_2(x)$ as a function of x. 5+3+2=10

2. *(a)* Generating function of the Legendre polynomial $P_n(x)$ is given by

$$g(x, t) = (1 - 2xt + t^2)^{-1/2} = \sum_{n=0}^{\infty} P_n(x) t^n$$

From this, prove the recurrence relation

$$(2n+1)xP_n(x) = (n+1)P_{n+1}(x) + nP_{n-1}(x)$$

(b) Prove the following recurrence relation in case of Hermite polynomial :

$$H_{n+1}(x) = 2xH_n(x) - 2nH_{n-1}(x)$$

(c) Find the Laplace transform of the function $[2e^{-3x}\cos 5x]$. 4+4+2=10

3. *(a)* What are essential singularities and removable singularities?

(b) What are meant by branch cut and branch point?

(c) Write Cauchy-Riemann equations. An analytic function $f(z)$ has its real part, $e^{-x}(x\cos y + y\sin y)$ and $f(0) = 1$. Then show that $f(z) = 1 + ze^{-z}$.

(1+1)+(1½+1½)+(1+4)=10

(Continued)

UNIT—II

4. *(a)* Show that in Bohr's theory, if we assume the mass of the nucleus (M) is finite in comparison with mass of the electron (m), then Rydberg constant becomes

$$R_M = \frac{R_\infty}{1 + \frac{m}{M}}$$

Here R_∞ is the Rydberg constant for an infinitely heavy nucleus.

(b) Write the basic two ideas on which Bohr-Sommerfeld model has been formulated.

(c) In Stern-Gerlach experiment, why should we use a beam of neutral atoms but not ions?

(d) In the ground state of a sodium atom, the quantum numbers of the valance electron are

$$n = 3,\ l = 0,\ j = \frac{1}{2}$$

Write the spectroscopic designation of this state. 4+2+2+2=10

5. *(a)* Explain the reason why normal Zeeman effect occurs only in atoms with even number of electrons.

(Turn Over)

10

(b) Show the anomalous Zeeman transitions for Na-D lines.

(c) The ground state of chlorine atom is $2p_{3/2}$. Find out the magnetic dipole moment of a chlorine atom in its ground state.

(d) A photon of energy 0·9 MeV is scattered through 120° by a free electron. Calculate the energy of the scattered photon. 2+3+2+3=10

6. (a) What is meant by 'population inversion'? Does population inversion violate Maxwell-Boltzmann distribution law? Why is population inversion not possible where only two atomic levels are present?

(b) What are meant by the terms 'acceptance angle' and 'numerical aperture' of an optical fibre? What is the necessity of repeaters in an optical fibre link? (2+1+2)+(1½+1½+2)=10

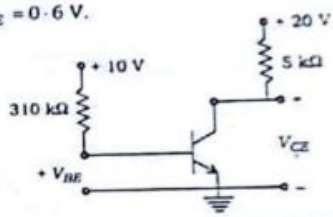
UNIT—III

7. (a) What is the function of clipping circuit? Draw the circuit diagram of a diode clipper that limits the positive peak of the input voltage.

(b) What are the factors that affect the bias stability of a transistor? Draw the circuit diagram of a self-bias *n-p-n* transistor in common-emitter configuration and explain how it improves the stability.

(c) What is early effect?

(d) A transistor is operating in the CE mode. Calculate V_{CE}, if $\beta = 125$, $V_{BE} = 0·6$ V.



2+(1+3)+2+2=10

8. (a) Mention two differences between bipolar junction transistor (BJT) and field effect transistor (FET).

(b) Define pinch-off voltage of an FET. Draw the circuit of an *n*-channel FET for studying the drain characteristic curves with proper biasing. Sketch the static drain characteristic curve and indicate the location of the pinch-off voltage on the drain characteristics.

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(c) A common source FET amplifier uses a load resistance $R_L = 300$ kΩ. If the a.c. drain resistance and the trans-conductance of the FET are 120 kΩ and 0·16 mA/V respectively, then find the magnitude of the voltage gain of this amplifier. 2+(2+1+2+1)+2=10

9. (a) Explain with diagram how an OP-AMP can be used as an integrator.

(b) What is meant by 'input offset current' of a practical OP-AMP?

(c) What is Barkhausen criterion for oscillator?

(d) Draw a block diagram which will self-explain the principle of radio trans-mission and reception. 3+2+2+3=10

UNIT—IV

10. (a) What is meant by phase space? Write the relation between the entropy and the probability of state.

(b) What is the difference between a priori probability and thermodynamic probability?

(c) What are the limitations of Maxwell-Boltzmann (MB) statistics?

(d) Five identifiable (i.e., distinguishable) particles are distributed in three non-degenerate states with energies 0, E and $2E$. Now determine the most probable distribution for a total energy $3E$. (1+1)+2+2+4=10

11. (a) What is the significance of 'partition function' in statistical physics?

(b) Using Maxwell-Boltzmann (MB) distribution function, obtain the law of equipartition of energy for a system of ideal gas particles.

(c) The first vibrational energy of a diatomic molecule is 600 cm^{-1} above the ground state. Calculate the relative population of molecules in these two levels at $T = 400$ K. Given Boltzmann constant = $1{\cdot}38 \times 10^{-16}$ cgs unit.

(d) Name the statistics obeyed by neutron, π-meson, muon and neutrino. 2+4+2+2=10

12. (a) Sketch the FD distribution function at the absolute zero temperature and at a finite non-zero temperature.

(b) Write two differences between FD and BE statistics.

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(c) What are meant by 'Fermi energy' and 'Fermi temperature'?

(d) Calculate the Fermi energy at 0 K of sodium containing one free electron per atom. The density and atomic weight of sodium are $9 \cdot 7 \times 10^2$ kg/m^3 and 23 respectively. (1+1)+2+(1½+1½)+3=10

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S–5/PHSH/05/19

TDP (Honours) 5th Semester Exam., 2019

PHYSICS

(Honours)

FIFTH PAPER

Full Marks : 80

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer **eight** questions, taking **two** from each Unit

UNIT—I

1. *(a)* The motion of transverse vibration of a string is characterized by the equation, $\frac{\partial^2\psi}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2\psi}{\partial t^2}$. Now the boundary conditions are given by $\psi(0, t) = 0 = \psi(L, t)$, $\left.\frac{\partial\psi}{\partial t}\right|_{t=0} = 0$ and $\psi(X, 0) = Y$. Then show that the general solution of this periodic motion is given by $\psi(X, t) = \sum_{n=1}^{\infty} Y_n \sin\left(\frac{n\pi x}{L}\right)\cos\left(\frac{n\pi ct}{L}\right)$.

(b) Prove by Laplace transform that

$$\int_0^{\infty} te^{-2t}\sin t\,dt = \frac{4}{25}$$ 7+3=10

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2. (a) What is meant by the terms 'singular points' and 'isolated singularities'?

(b) Show that the function, $f(z) = e^{-\frac{1}{z}}$ is an analytic function of z.

(c) In polar coordinates, show that the Cauchy-Riemann equations become $\frac{\partial U}{\partial r} = \frac{1}{r}\frac{\partial V}{\partial \theta}$ and $\frac{\partial V}{\partial r} = -\frac{1}{r}\frac{\partial U}{\partial \theta}$. 2+3+5=10

3. (a) From the generating function of the Legendre polynomials $P_n(X)$,

$$g(x, t) = (1 - 2xt + t^2)^{-\frac{1}{2}} = \sum_{n=0}^{\infty} P_n(x)\, t^n$$

show that $xP_n'(X) - P_{n-1}'(X) = nP_n(X)$.

(b) Prove the following recurrence relation in case of Hermite polynomial :

$$H_n'(X) = 2xH_n(X) - H_{n+1}(X)$$ 5+5=10

UNIT—II

4. (a) Name the two distinct features that characterize the vector atom model. What is meant by Larmor precession? Define Larmor frequency.

(b) In a Stern-Gerlach experiment, a beam of silver atoms with velocity v enters in an inhomogeneous magnetic field of gradient $(\partial B / \partial Z)$ and length L. After emerging from the magnetic field, they travel a distance b before reaching the screen. Find an expression of the magnitude of splitting.

(c) The calcium line $\lambda = 422{\cdot}67$ nm exhibits normal Zeeman splitting in a uniform magnetic field of 1 tesla. Find the wavelengths of the triplets of Zeeman pattern. (1+1+1)+4+3=10

5. (a) H_2 and O_2 molecules do not show vibrational spectra. What is the reason?

(b) Why does a diatomic molecule not rotate in the ground state?

(c) In the case of Compton scattering, prove that Compton shift is given by

$$\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$ 2+2+6=10

6. (a) In what respect He-Ne laser is superior to Ruby laser?

(b) What are meant by core, cladding of an optical fibre?

(c) Mention three differences between step-index and graded-index optical fibres. 3+4+3=10

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UNIT—III

7. (a) Draw the circuit diagram of a bridge rectifier with transformer and load.

(b) Draw the circuit of an *n-p-n* transistor in CE mode. Sketch its output characteristic curve and indicate the active, cutoff and saturation region.

(c) Draw a 'fixed bias' circuit using *n-p-n* transistor. Find an expression of 'stability factor' of this circuit. What are the main disadvantages of this circuit? 1+(1+2+1)+(1+2+2)=10

8. (a) What are 'load line' and 'Q-point' of a transistor amplifier?

(b) Sketch neatly the structure of an *N*-channel FET. Explain how the depletion region is formed when proper biasing is applied. Then explain what is meant by 'pinch-off voltage'.

(c) What is meant by 'virtual ground' of an OP-AMP? What is 'input offset voltage' of an OP-AMP? (1½+1½)+(1+2+1)+(2+1)=10

9. (a) Explain with diagram how an OP-AMP can be used as a differentiator.

(Continued)

(b) Explain with the help of a block diagram, the working principle of a feedback amplifier. Find out the expression for the voltage gain with feedback.

(c) What is the difference between Colpitts and Hartley oscillators? 3+(3+2)+2=10

UNIT—IV

10. (a) What is the basic difference between microcanonical and canonical ensemble?

(b) Using Maxwell-Boltzmann distribution law, show that average energy per particle is $\frac{3}{2}$ kT.

(c) In a system of 3 particles each having spin $\frac{1}{2}$ so that each spin can exists along or opposite to some direction (say *z*-direction), each particle has a magnetic moment μ along *z*-direction and $-\mu$ along opposite direction. An external magnetic field $\vec{H}$ is applied in the system.

(i) List all possible microstate and macrostate.

(ii) If the total energy of the system is known to be $+\mu H$, what are the possible states and what is the probability that the spin of the first one will be up? 2+3+(2+3)=10

(Turn Over)

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11. (a) Prove that $S = k \ln\Omega$, where the symbols have their usual meaning.

(b) Show that the thermodynamic probability Ω for an ideal gas of N molecules in volume V is of the form $\Omega \propto V^N f(E)$.

(c) Show that for high temperature and low density, both the BE and FD statistics reduce to MB statistics. 4+3+3=10

12. (a) Obtain the expression for Bose-Einstein distribution function.

(b) Name the statistics obeyed by each of the following particles :

Neutron, Photon, Proton and α-particle

(c) Calculate the Fermi energy at 0 K of solid monovalent sodium of density $\rho = 9 \cdot 7 \times 10^3$ kg.m^{-3}. Atomic weight of Na is 23. 5+2+3=10

★★★

17

S–5/PHSH/05/20

TDP (Honours) 5th Semester Exam., 2020
(Held in 2021)

PHYSICS

(Honours)

FIFTH PAPER

Full Marks : 80

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer **eight** questions, taking **two** from each Unit

UNIT—1

1. *(a)* Using the method of separation of variables, find the solution of Laplace's equation in two-dimensional polar form.

(b) What do you understand by linear property of Laplace's transformation? Using Laplace transformation show that

$$\int_0^\infty \frac{\sin t}{t}\,dt = \frac{\pi}{2}$$

5+(1+4)=10

2. (a) Write down the generating function for the polynomial solutions of Legendre differential equation. From the generating function obtain the relation

$$\frac{1-t}{(1-2tx+t^2)^{3/2}} = \sum_{n=0}^{\infty}(2n+1)P_n(x)t^n$$

(b) From the generating function of Hermite polynomials establish the recurrence relations

$$H_{n+1}(x) = 2xH_n(x) - 2nH_{n-1}(x)$$

$$H_n'(x) = 2nH_{n-1}(x) \qquad 5+5=10$$

3. (a) Consider the complex function $f(z) = z^{\frac{1}{2}}$. Write down the two branches of the multivalued function. Hence define branch point and branch cut.

(b) What is singularity of a complex function? Define with an example the removable singularities.

(c) Construct an analytic function $f(z) = u + iv$ whose real part is $e^x \cos y$.

$(2+1+1)+(1+1+1)+3=10$

UNIT—2

4. (a) With the help of suitable diagram, explain *j-j* coupling.

(b) For $l_1 = 1$ and $l_2 = 2$, find the available states under *j-j* coupling scheme for a two-electron atomic system.

(c) Give a schematic description of the Stern-Gerlach experiment and outline its major outcomes.

(d) When a beam of monochromatic X-rays is scattered by a light element, such as carbon, show that the wavelength shift depends on the angle of scattering but independent of the wavelength of the incident beam and the nature of the scatterer. 2+2+3+3=10

5. (a) What is nuclear magnetic resonance (NMR)?

(b) Calculate the Lande g-factors for sodium D-lines. Find out the $(m_j g)$ values for D_1 and D_2 lines.

3. What is basic requirement that a molecule can show rotational spectra? Explain why does a hetero-nuclear molecule show rotational spectra but homonuclear molecule does not.

4. Why is the ground state always singlet?

2+4+2+2=10

5. (a) What is meant by stimulated emission?

(b) With the help of an energy level diagram, explain the working of a three-level laser system.

(c) What is optical resonator?

(d) In a step index fibre, the refractive indices of the core and cladding are respectively 1·43 and 1·40. Find the propagation angle, the numerical aperture and acceptance angle.

2+3+2+3=10

UNIT—3

7. (a) What is clamper? Draw a circuit diagram for positive clamper with diode and explain its function.

(b) A transistor having $\alpha = 0.975$ and a reverse saturation current $I_{co} = 10\ \mu A$, is operated in CE configuration. If the base current is 250 μA, calculate the emitter current and collector current.

(c) What are the advantages of negative feedback in a transistor amplifier?

(2+3)+3+2=10

8. (a) What do you mean by hybrid parameters?

(b) Draw the equivalent hybrid parameter model for a low frequency small signal transistor amplifier and calculate the forward current gain and input impedance.

(c) Define common mode rejection ratio and slew rate.

(d) Draw the circuit diagram of a square wave generator. 2+(1+3)+(1+1)+2=10

9. (a) Draw the circuit diagram for a triangular wave generator using OPAMP.

(b) What is virtual ground? Draw a circuit diagram of a non-inverting OPAMP and find its voltage gain.

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(c) Derive the secant law that relates between maximum frequencies of a wave reflected for a given angle of incidence for ionospheric propagation of radio waves. 2+(1+3)+4=10

UNIT—4

10. (a) Mention the differences between MB, FD and BE statistics.

(b) Show that the minimum value of a cell in phase space is of the order $\left(\frac{h^3}{8}\right)$, where $h = \frac{h}{2\pi}$.

(c) An electron gas obeys the MB statistics. Calculate the average thermal energy (in eV) of an electron in the system at room temperature of 300 K. 3+3+4=10

11. (a) State the principle of equal a priori probability.

(b) What is Stirling approximation?

(c) Define thermodynamic probability.

(Continued)

(d) An excited state of an atom is 1·38 eV above the ground state. Calculate the number of atoms in this excited state relative to the ground state at 16000 K. The Boltzmann constant

$K_B = 1{\cdot}38 \times 10^{-23}$ joule/K

2+2+2+4=10

12. (a) Find out the expression for Fermi-Dirac distribution function.

(b) State third law of thermodynamics. Explain its significance.

(c) A system has two energy levels in thermal equilibrium with a heat reservoir at 600 K. The energy difference between two levels is 0·1 eV. Which ensemble is applicable for this system? Find the probability that the system is in higher energy level. 5+2+3=10

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21

S–5/PHSH/05/21

TDP (Honours) 5th Semester Exam., 2021
(Held in 2022)

PHYSICS

(Honours)

FIFTH PAPER

Full Marks : 80

Time : 3 hours

The figures in the margin indicate full marks for the questions

Answer **eight** questions, taking **two** from each Unit

UNIT—I

1. *(a)* If $P_n(x)$ be the Legendre polynomial, then find the value of $P_n'(1)$.

(b) Using the generating function of the Legendre polynomials, show that

$$P_n(-x) = (-1)^n P_n(x)$$

(c) For the Legendre polynomials, prove that

$$\int_{-1}^{+1} P_l(x) P_m(x)\, dx = 0 \quad (l \neq m)$$

2+3+5=10

2. *(a)* Write down the Laguerre differential equation. For the Laguerre polynomial, establish the recurrence relation

$$L_{n+1} + (x - 2n - 1)L_n + n^2 L_{n-1} = 0$$

(b) Solve the Laplace's equation $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$, subject to the following conditions :

$$u(0, y) = u(l, y) = u(x, 0) = 0 \text{ and}$$
$$u(x, a) = \sin\left(\frac{n\pi x}{l}\right)$$

(1+4)+5=10

3. *(a)* Write down the necessary and sufficient conditions for a function $f(z)$ of the complex variable z to be analytic, where $z = x + iy$. Examine whether $\sin z$ is an analytic function of z.

(b) Define Laplace transform. Use Laplace transform to evaluate *(i)* $\mathscr{L}(\cos at)$ and *(ii)* $\mathscr{L}(t^2 \cos at)$.

(2+2)+(1+2+3)=10

UNIT—II

4. *(a)* Why is a homogeneous field not used in the Stern-Gerlach experiment?

(b) Explain the *L-S* coupling scheme for the addition of angular momenta.

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(c) For the d-electron of the hydrogen atom, calculate the values of L, S and J, and determine the possible angles between L and S.

(d) Give the quantum theory of normal Zeeman effect. 2+2+3+3=10

5. (a) Draw the Zeeman pattern for the transition $6\,^1D_2 \rightarrow 5\,^1P_1$ of the cadmium atom.

(b) What is Lande g-factor? Evaluate the value of Lande's g-factor for the pure spin angular momentum.

(c) With an energy level diagram, explain the working of a 3-level laser system. 3+(2+2)+3=10

6. (a) Define numerical aperture. State the relation between the numerical aperture and acceptance angle.

(b) Explain why laser action is more difficult in the ultraviolet region of the electromagnetic spectrum.

(c) What is the active material in He-Ne laser? How is the population inversion achieved in this laser?

(d) How many photons are emitted each second from a 2·5 mW He-Ne laser (wavelength = 632·8 nm)?

(1+2)+2+(1+2)+2=10

UNIT—III

7. (a) Show that a transistor can be considered as a two-port network and hence define the hybrid parameters. Why are they called hybrids?

(b) Derive the small signal hybrid model of a transistor in c.c. configuration.

(2+3+2)+3=10

8. (a) Draw the circuit of a self-biased *n-p-n* transistor explaining the role of different resistances. Draw the d.c. load line of the above circuit and locate the *Q*-point on it.

(b) What is an emitter-follower circuit? Why is it so called? Mention its common use.

(3+2)+(3+1+1)=10

9. (a) What are the advantages of negative feedback? What is the criterion of oscillation in an amplifier?

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(b) Why is it advisable to have common mode rejection ratio high in a differential amplifier?

(c) Explain the action of a Hartley oscillator.

(2+1)+2+5=10

UNIT—IV

10. (a) What is phase space? Considering a one-dimensional linear harmonic oscillator, determine its trajectories in phase space.

(b) What is ensemble? Define micro-canonical ensemble.

(c) Three distinguished particles have a total energy of 9 units. But the particles are restricted to energy levels from 0 to 4. Calculate the number of microstates and macrostates. (2+2)+(2+1)+3=10

11. (a) What is partition function? Explain its importance in statistical mechanics.

(b) Consider a system of four distinguishable particles *a*, *b*, *c*, *d* and these four particles are to be distributed into two exactly identical compartments. Find the possible ways in which these particles can be distributed in two compartments.

(c) Establish Boltzmann relation between the thermodynamics probability and entropy. (2+2)+3+3=10

12. (a) Consider a thermodynamic system of n number of non-interacting particle. Find an expression for the most probable distribution of the system.

(b) What is Fermi energy? Show how Fermi distribution function varies with temperature.

(c) In a system in thermal equilibrium at absolute temperature T, two states with energy difference $4 \cdot 83 \times 10^{-19}$ Joule occur with relative probability e^2. Find the temperature of the system.

4+(1+2)+3=10

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