[This question paper contains 4 printed pages.]

Your Roll No................

Sr. No. of Question Paper : 5826 **J**

Unique Paper Code : 2222011203

Name of the Paper : Electrical Circuits Analysis

Name of the Course : **B.Sc. (Hons.) Physics- NEP: UGCF-2022**

Semester : II

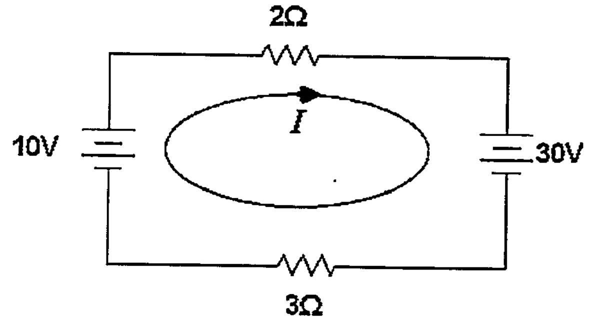
Duration : 2 Hours Maximum Marks : 60

<u>Instructions for Candidates</u>

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. **All** questions carry equal marks.
3. Ques. No. **1** is compulsory and attempt any **three** from the remaining **four** questions.
4. Use of non-programmable scientific calculator is allowed.

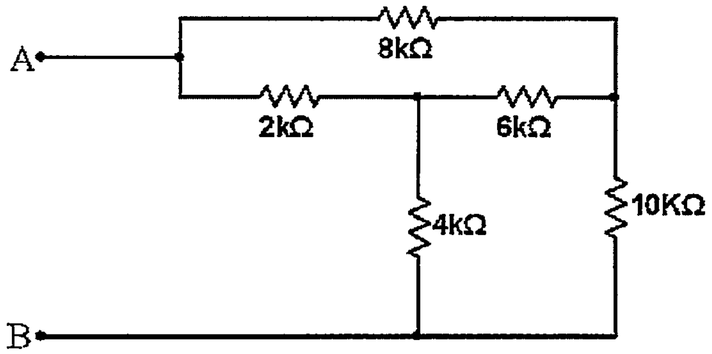
1. Attempt any **five** of the following : (5×3=15)

   (a) For the given circuit determine the power dissipated in the resistors :



P.T.O.

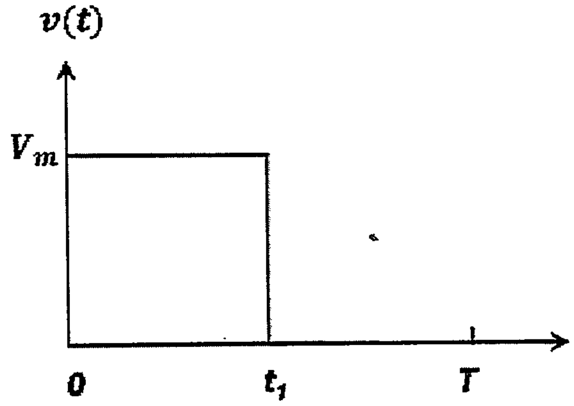
(b) Find the equivalent resistance of the following circuit using Star-Delta transformations:



(c) Define inductive reactance. Write it's S.I. units. Plot a graph showing variation of resistance and inductive reactance with change in the frequency of the ac source.

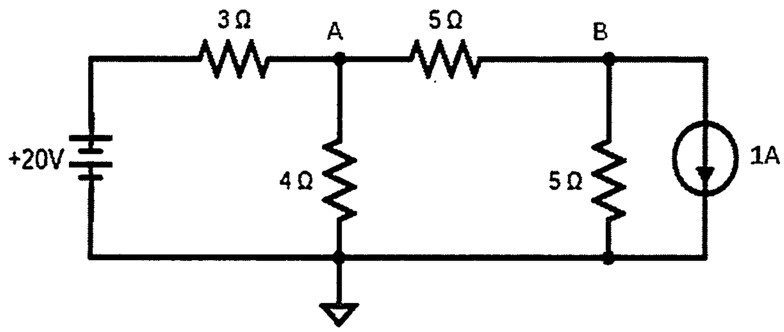
(d) Prove that an ideal capacitor does not dissipate power in an ac circuit.

(e) Find the form factor for the periodic wave shown below with time period T :



(f) A series RC circuit with R = 5 kΩ and C = 20 μF has a constant voltage source of 100 V applied at t = 0. Obtain the value of voltage across the capacitor and the resistor for t > 0 if there is no initial charge on the capacitor.

2. (a) Calculate the direction and magnitude of the current through the 5 Ω resistor between points A and B in the given circuit by Nodal analysis method. (7)



(b) A coil with a self-inductance of 2.4 H and resistance 12 Ω is suddenly switched across a 120 V DC supply of negligible internal resistance. Determine the time constant of the coil, the instantaneous value of the current after 0.1 second, the final steady value of the current and the time taken for the current to reach 5 A. (8)

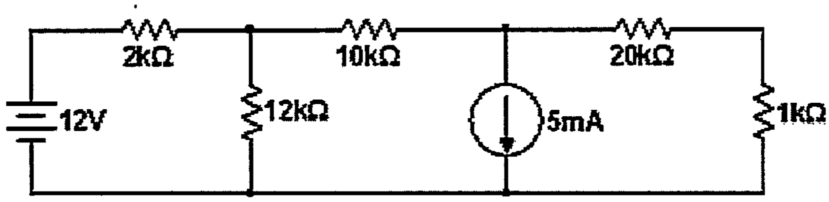
3. (a) In a parallel LCR circuit, the inductance of 0.1 H having a Quality factor of 5 is in parallel with a capacitor. Determine the value of capacitance and coil resistance at resonant frequency of 500 Hz. (7)

(b) In a series RL circuit containing pure resistance and pure inductance, the current and the voltage are expressed as :

$$i(t) = 5\sin(314t + 2\pi/3) \text{ and } v(t) = 15\sin(314t + 5\pi/6)$$

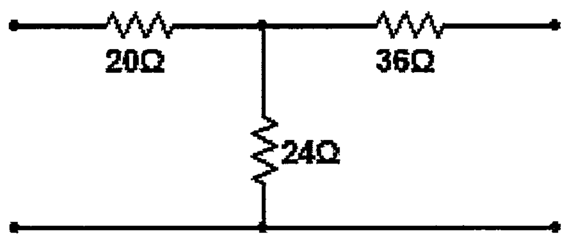
Determine the values of impedance, resistance, inductance and average power drawn by the circuit. (8)

4. (a) Find the Norton equivalent circuit for the given circuit and calculate the load voltage across 1 kΩ resistance. (7)

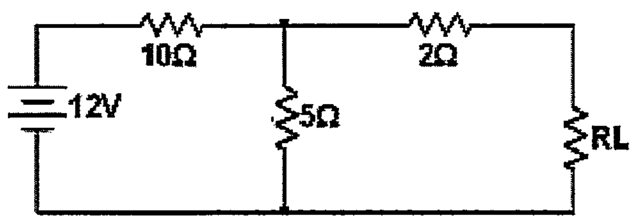


(b) Explain Millman's and Tellegen's theorem for the ac circuits. (8)

5. (a) Find the Y-parameters for the following T-network : (7)



(b) According to Maximum Power Transfer theorem, what should be the value of load resistance R_L to obtain maximum power from the 12 V battery shown in the following circuit? What is the value of this power? (8)



SL.No of QP: 1283

Unique Paper Code	:	**32221201**
Name of the Paper	:	**Electricity and Magnetism**
Name of the Course	:	**B. Sc. Hons.–(Physics)_Core (Repeat Paper)**
Semester	:	**II**
Duration	:	**3 hours**
Max. Marks	:	**75 marks**

(Write your Roll number on the top immediately upon receipt of this question paper.)
Attempt FIVE questions in all. Question No. 1 is compulsory.
All questions carry equal marks

[1]

a) Can the following be a possible electrostatic field?

$$\boldsymbol{E} = 2xy\,\boldsymbol{i} + 3y\,\boldsymbol{j} - 9xz\,\boldsymbol{k}$$

b) An electric dipole is placed in a non-uniform electric field. Calculate the force acting on it.

c) Prove that $\vec{\nabla}.\vec{B} = 0$ and explain its physical significance.

d) State and prove first Uniqueness theorem.

e) Prove reciprocity theorem for mutual inductance (i.e. M_{12}=M_{21}).

(5x3=15)

[2] a) State and prove Gauss's theorem in electrostatics. Show that $\vec{\nabla}.\vec{E} = \frac{\rho}{\varepsilon_o}$.

b) A thick spherical shell carries a charge density $\rho = \frac{k}{r^2}$. The inner and outer radii of the spherical shell are a and b respectively. Find the electric field in the regions (i) $r < a$ (ii) $a < r < b$ and (iii) r > b. **(7, 8)**

[3] a) Derive an expression for potential and electric field at a point (r,θ) due to an electric dipole.

b) Using the method of images, determine the position and magnitude of the image charge of a point charge q placed in front of an earthed conducting sphere of radius R at a distance d from its center. **(7, 8)**

[4] a) What is meant by the polarization of a dielectric? Show that the polarization of a dielectric medium gives rise to a volume charge density $\rho_P = \vec{\nabla}.\vec{P}$ and surface charge density σ_P= $\vec{P}.n$^.

b) A capacitor is composed of n plates each having an area A and separated by d. The two end plates are connected to a battery having potential V. What charge is stored on plates? What is its capacitance? **(7, 8)**

[5] a) State Biot-Savart's law. Derive an expression for the magnetic field at a point due an infinitely long straight current carrying conductor using Biot-Savart's law.

b) Prove that the magnetic vector potential due to current carrying conductor having volume V and bounded by surface S

$$\vec{A}(\vec{r}) = \frac{\mu_0}{4\pi}\iiint_V \frac{\vec{J}(\vec{r'})}{R}dv'$$

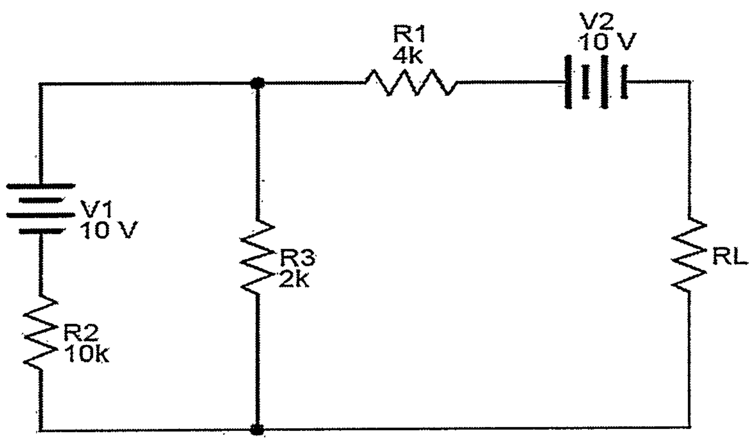
where $\vec{r'}$ is the position vector of source, $\vec{r}$ is the position vector of the observation point and $\vec{R} = \vec{r} - \vec{r'}$. **(7,8)**

[6] a) How did Maxwell modify Ampere's circuital law to make it consistent with continuity equation. Find the displacement current density in a material having $\varepsilon_r = 25$ and electric field $\boldsymbol{E} = 5 \times 10^{-6} \sin(9 \times 10^9 t)$ V/m.

b) Define mutual inductance between two coils. Show that $M = k\sqrt{L_1 L_2}$, where L_1 and L_2 are self-inductance of the two coils and parameter $k = \sqrt{k_1 k_2}$, where k_1 and k_2 are geometric factors of flux linkages between two coils. **(7, 8)**

[7] a) A series LCR circuit has $R = 10\Omega$, $L = 0.35H$ and $V = 100 \cos \pi t$. Find the value of C for resonance. Also determine the voltage across C. Plot the variation of quality factor with resistance for a series LCR circuit.

b) State maximum power transfer theorem. Draw Thevenin equivalent circuit for the following circuit and hence find the value of R_L for which the power transfer is maximum.



(7, 8)

Useful Constants

$\epsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$

$\mu_0 = 4\pi \times 10^{-7} NA^{-2}$

SL No of QP : 2630

Unique Paper Code : 42221201

Name of the Paper: : Electricity, Magnetism and EMT

Name of Course : B.Sc. Prog.–CBCS_Core

Semester : II

Duration : 3 Hours Maximum Marks: 75

Instructions for Candidates

1. Write your Roll no. on the top immediately on receipt of this question paper.
2. Attempt **Five** questions in all.
3. Question No. **1** is compulsory. Attempt four questions from the rest of the paper.
4. Use of non-programmable calculator is allowed.

1. Attempt any **five** of the following: (5 x 3 =15)

   (a) Given a vector $\vec{r} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$. Show that $\oiint_S \vec{r}.d\vec{S} = 3V$, where V is volume enclosed by surface S.

   (b) Prove that the electric field at any point can be expressed as the negative gradient of potential at that point.

   (c) Two concentric spheres of diameters 10 cm and 12 cm where medium between the spheres is air and the outer sphere is earthed make a spherical capacitor. Find the charge on the inner sphere if the potential difference between the spheres is 10,000 volt.

   (d) Differentiate between diamagnetic and paramagnetic material (mention any two points). Give one example of each.

   (e) In a coil an emf of 6 V is induced when the current in the coil changes at the rate of 100 Amp per second. Find coefficient of self-inductance of the coil.

   (f) What is Lenz's law? Show that it is in accordance with the law of conservation of energy.

   (g) How does the electric field produced by the varying magnetic field differ from the electric field of stationary charges?

2. (a) Find the directional derivative of $\phi = 4xz^3 - 3x^2y^2z$ at (2, -1, 2) in the direction $2\hat{\imath} - 3\hat{\jmath} + 6\hat{k}$. (5)

   (b) Prove that $\nabla^2 r^n = n(n+1)r^{n-2}$ where n is constant. (5)

   (c) Given $\vec{A} = (3x^2 + 6y)\hat{\imath} - 14yz\hat{\jmath} + 20xz^2\hat{k}$. Evaluate the line integral from (0, 0, 0) to (1, 1, 1) along the following paths c: $x = t,\ y = t^2,\ z = t^3$. (5)

3. (a) Using Gauss's theorem, find an expression for the electric field due to an infinite line charge of uniform charge density λ at a perpendicular distance 'a' from it. (5)

   (b) Derive expressions for the electric potential due to a uniformly charged spherical shell at points inside and outside the shell. Show that the electric potential due to the shell at any point inside is equal to the value of the potential on its surface. (7)

(c) Show that the potential function $V = a(x^2 + y^2 + z^2)^{1/2}$ does not satisfy Laplace's equation. (3)

4. (a) What do you understand by polarization of a dielectric? Define three electric vectors $\vec{D}$, $\vec{E}$ and $\vec{P}$. Establish the relation between them. (7)
   (b) How does the capacitance of a parallel plate capacitor change when a dielectric slab of dielectric constant K is inserted between the plates and it completely fills the space between the plates? (4)
   (c) A parallel plate capacitor with plate area 1 m^2 is completely filled with a dielectric material of dielectric constant 5. The capacitor is charged to a potential of 200 volt. If the distance between the plates is 0.01 cm, find the energy stored in the capacitor. (4)

5. (a) Starting from Biot Savart's law, derive an expression for the magnetic vector potential at a distance $\vec{r}$ from the current element. (5)
   (b) Derive an expression for magnetic field of a small current loop. (5)
   (c) Using Biot Savart's law calculate the magnetic field due to a finite current element. (5)

6. (a) Explain Faraday's law and Lenz's law of Electromagnetic induction. (4)
   (b) Define coefficient of self-inductance. Derive an expression for self-inductance of a solenoid. (2+3=5)
   (c) A solenoid of 80 cm length has 550 turns and 2 cm diameter. Calculate:
      (i) the self-inductance of the solenoid.
      (ii) the magnetic flux linked with coil when the current in the solenoid is 2 A.
      (iii) the rate of change of current in the solenoid that will produce a self-induced emf of 0.3 volts. (6)

7. (a) Write Maxwell's equations for electromagnetic field in integral and differential form in free space. Obtain the wave equations for the electric and magnetic field vectors in vacuum. (7)
   (b) An electromagnetic wave propagates along the x direction, the magnetic field oscillates at a frequency of 10^{10} Hz and has an amplitude of 10^{-5} T, acting along the y-direction. Write down the expression of the electric field and compute the wavelength of the wave. (4)
   (c) Derive the equation of continuity using Maxwell's equation and give its significance. (4)

Physical Constants:

$\varepsilon_0 = 8.854 \times 10^{-12}$ C/N-m^2:

$\mu_0 = 4\pi \times 10^{-7}$ Wb/A-m;

$c = 3 \times 10^8$ m/s.

$e = 1.6 \times 10^{-19}$ m/s

[This question paper contains 2 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5401 **J**

Unique Paper Code : 2224001201

Name of the Paper : Electricity and Magnetism

Name of the Course : **B.Sc. Hons.–(Physics)_NEP: UGCF-2022**

Semester : II – (GE Paper)

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Question **1** is compulsory.
3. **Four** questions to be attempted from Q. No. **2** to **6**.

1. Attempt any **six** questions :

   (i) What do you understand by Line and Surface integral in electrostatics.

   (ii) What is Dielectric constant. Explain its significance in a Parallel plate capacitor.

   (iii) Explain the Divergence and Curl in magnetism.

   (iv) Define magnetic permeability, susceptibility and magnetization.

   (v) What is Lenz law. How it is related to the conservation of energy in electrostatics?

   (vi) Explain Kirchoff voltage law.

   (vii) State and explain Norton theorem. (6×3=18)

2. (i) State and explain the Gauss law of Electrostatics. Use this law to derive the expression for electric field strength due to an uniformly charged thin spherical shell when the point under consideration is (a) inside the shell and (b) outside the shell

   (ii) Define Electric field (E), Electric displacement vector (D) and Polarization (P). Derive the expression $P = \varepsilon_0 E (K-1)$, where ε_0 is permittivity of free space and K is dielectric constant.

   (iii) If two point conductors containing charges of 10 nC and 20 nC are placed 20 cm apart, find the electric field at the midpoint between the two charges. (8+7+3)

P.T.O.

3. (i) Explain Biot Savart law. Obtain expression for magnetic field due to current in a long straight wire.

(ii) With the help of Ampere circuital law, derive an expression for the magnetic field due to a long solenoid.

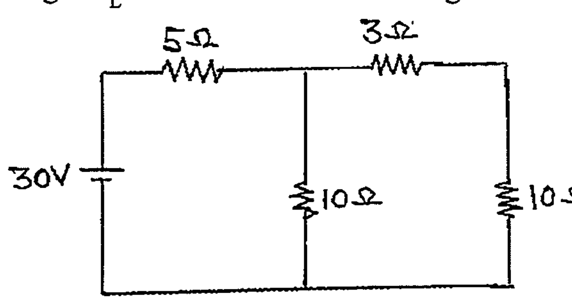
(iii) If area of each plate of a parallel plate capacitor is 8×10^{-2} m^2 and are separated by a distance 2 mm apart, find the capacitance if the gap between the plate is filled with a medium of dielectric constant 5. (8+7+3)

4. (i) Define Self and Mutual induction. Find the equivalent inductance of two inductances L1 and L2 connected in series.

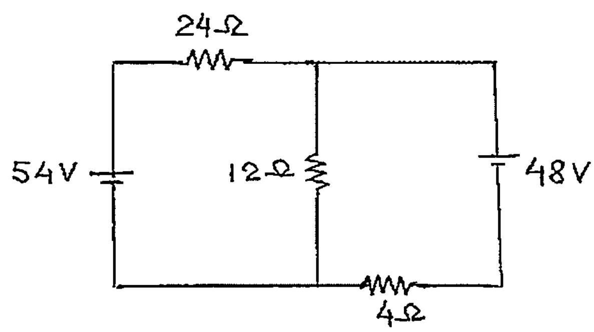
(ii) Solve Maxwell equations to show that the electromagnetic waves are transverse in nature and travels with a speed of light in which electric and magnetic vectors are mutually perpendicular.

(iii) A primary coil of 500 turns and a secondary coil of 40 turns are wound on an iron ring of mean radius of 10 cm and radius of the circular cross-sectional area of 2 cm. If the relative permeability of iron is 800, calculate the mutual inductance of the combined coils. (7+7+4)

5. (i) State and explain Thevenin theorem. Use this theorem to find the current flowing through R_L = 10 Ω in the network given below.



(ii) State and prove Superposition theorem. Find the current flowing through 12 Ω resistance using the Superposition theorem. (9+9)



6. Answer any **three** of the following questions :

(a) Explain Ampere's circuital law with one application.

(b) Differentiate between dia-, para- and ferro-magnetism.

(c) Discuss Faraday's laws of electromagnetic induction.

(d) State and prove Maximum power transfer theorem. (6+6+6)

(300)

[This question paper contains 4 printed pages.]

Your Roll No...............

Sr. No. of Question Paper	**:**	**5806**	**J**
Unique Paper Code	:	2222011202	
Name of the Paper	:	Electricity and Magnetism	
Name of the Course	:	**B.Sc. Hons. (Physics) NEP: UGCF-2022**	
Semester	:	II	

Duration : 3 Hours | Maximum Marks : 90

<u>Instructions for Candidates</u>

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **five** questions in all, including Question No. **1** which is compulsory.
3. **All** questions carry equal marks.

1. Answer **any 6** of the following : (6×3=18)

   (a) Find V_{ab} in an electric field $\vec{E} = 2\hat{i} + 3\hat{j} + 4\hat{k}$ N/C where $\vec{r}_a = \hat{i} - 2\hat{j} + \hat{k}$ m and $\vec{r}_b = 2\hat{i} + \hat{j} - 2\hat{k}$ m.

   (b) State the Second uniqueness theorem.

   (c) What is the work required to bring a charge q from infinity to a distance d above a grounded conducting plane?

   (d) At the boundary of two dielectric materials, material 1 has $\epsilon_1 = 2\epsilon_0$, and material 2 has $\epsilon_2 = 4\epsilon_0$. If $e_1^{\perp} = 6$ V/m, what is $\epsilon_2^{\perp}$, assuming no free surface charge?

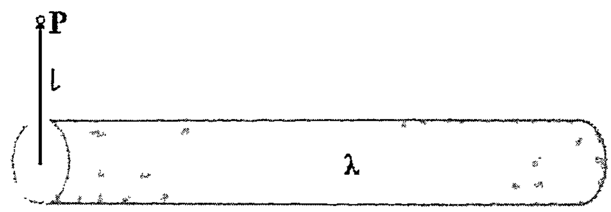
   (e) A solenoid of length 0.5 m and 1000 turns per meter carries a current of 2 A. Find the magnetic field inside the solenoid.

P.T.O.

(f) A material placed in a field H = 800 A/m shows a M = –0.08 A/m. Find its magnetic susceptibility χ_m. What type of material is it?

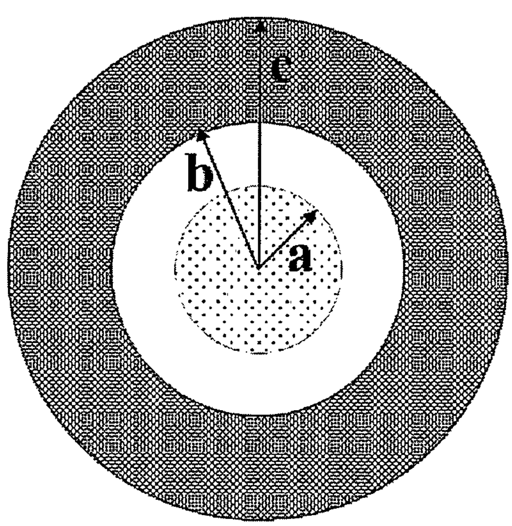
(g) A cylindrical conductor of uniform cross section, has a voltage drop of 2.0 V along its 100 m length and a current density of 5.0×10^5 A/m². What is the conductivity of the material in the conductor?

2. (a) A half-infinite line has linear charge density λ. Find the electric field at a point that is "even" with the end, a distance l from it, as shown in Figure. (8)



(b) Prove that electrostatic field is negative of gradient of electrostatic potential. (2)

(c) State Ampere's law. The coaxial line shown in Figure below carries the same current i up the inside conductor of radius a and down the outer conductor of inner radius b & outer radius c.



Find the magnetic field at all distances r from the center of the conductor. (8)

3. (a) Let a charge q be distributed over a sphere of radius R with a constant volume charge density ρ, and thus for $r > R$ the charge density is zero. Applying the Laplace's or Poisson equations, find the electrostatic potential inside $r < R$ and outside $r > R$ the sphere. (8)

(b) For the above system, find the electrostatic field on the surface of the sphere. (2)

(c) What do you understand by magnetization and magnetic polarization of the material? Derive expressions for differential and integral form of Ampere's law in the presence of magnetized materials. (8)

4. (a) A point charge q is situated a distance a from the centre of a grounded conducting sphere of radius R. Applying the method of images, find the electrostatic potential at any point outside the sphere. (8)

(b) The electric field in a region is given by $\vec{E} = x\hat{i}$. Find the total flux passing through a cube bounded by the surfaces, $x = 1$, $x = 2$, $y = 0$, $y = 1$, $z = 0$ and $z = 1$. (2)

(c) Write down the four fundamental Maxwell equations in the differential form along with their explanations. Also, comment on their significance. (8)

5. (a) A sphere of radius R carries a polarization $\vec{P}(\vec{r}) = k\vec{r}$, where k is a constant and $\vec{r}$ is the vector from the center. (a) Calculate the bound charges σ_b and ρ_b. (b) Find the field inside and outside the sphere. (8)

(b) Show that the potential is constant inside an enclosure completely surrounded by conducting material, provided there is no charge within the enclosure. (2)

(c) A tightly wound cylindrical coil of wire, of radius a and n turns per unit length, is usually called a solenoid. Use Biot Savart law to find the magnetic field at the point on its axis if the wire carries a current I. Consider the turns to be essentially circular and solenoid to be infinite in both directions. (8)

6. (a) Find the magnetic field $\vec{B}$ and hence the vector potential $\overline{A}$ at a distance r from a long straight wire carrying a current I. (8)

(b) A point charge q is located d distance above an infinite grounded conducting plane. Find the direction of the electric field at the point P directly above the charge, at a height 2d from the plane. (2)

(c) State the Gauss Law in integral and differential form. Suppose the electric field in some region is found to be $\vec{E} = kr^3\hat{r}$, in spherical coordinates (k is some constant). (a) Find the charge density ρ. (b) Find the total charge contained in a sphere of radius R, centered at the origin. (8)

[This question paper contains 2 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5786 **J**

Unique Paper Code : 2222011201

Name of the Paper : Mathematical Physics II

Name of the Course : **B.Sc. (H) Physics (UGCF) – DSC-4**

Semester : II

Duration : 2 Hours Maximum Marks : 60

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **Four** questions in all.
3. Question number **1** is compulsory. Attempt any **three** questions from the rest.
4. **All** questions carry equal marks.
5. Use of calculator not allowed.
6. Some useful formulae are given at the end.

1. Attempt **all** questions. **All** questions carry equal marks. (3×5=15)

(a) Represent the vector $\vec{A} = z\hat{i} - 2x\hat{j} + y\hat{k}$ in cylindrical coordinates.

(b) What is the period of following functions :

(i) $\tan(x)$ (ii) $\cos(nx)$, $n \in I$

(c) Evaluate (i) $\int [P_4(x)]^2 \, dx$ (ii) $\int P_1(x) P_4(x) dx$

(d) Determine whether or not it is possible to solve the following differential equation using Frobenius method about x = 0:

$$x(1-x)\frac{d^2y}{dx^2} + (1-x)\frac{dy}{dx} - y = 0$$

(e) Evaluate the following integral using Gamma function

$$\int_0^\infty x^3 \, e^{-2x} \, dx$$

2. Consider the following function :

$$f(x) \begin{array}{l} = 0 \text{ for } -5 < x < 0 \\ = 3 \text{ for } \;\; 0 < x < 5 \end{array}$$

(a) Plot the above function f(x).

(b) Find the Fourier Series expansion of the above function. (5,10)

P.T.O.

3. (a) Using Gamma and Beta functions prove :

$$\int \frac{x^2}{\sqrt{2-x}} dx = \frac{64\sqrt{z}}{15}$$

(b) Prove that for the Orthogonal Curvilinear Coordinates (u_1, u_2, u_3)

$$\vec{\nabla}F = \frac{\hat{e}_1}{h_1}\frac{\partial F}{\partial u_1} + \frac{\hat{e}_2}{h_2}\frac{\partial F}{\partial u_2} + \frac{\hat{e}_3}{h_3}\frac{\partial F}{\partial u_3}$$

where F is a scalar field, h_i are scale factors and $\hat{e}_1$ represents unit vector in the increasing i direction. Further derive the expression of the gradient of F in spherical coordinate system. (5,10)

4. Consider the Differential Equation : (5,10)

$$2x^2y''(x) + 3xy'(x) - (x^2 + 1)y(x) = 0$$

(a) Identify and name the nature of all the real singularities (both finite and infinite) of above differential equation.

(b) Solve the above differential equation around x = 0 by Frobenius Method.

5. (a) Expand the function $f(x) = 7x^4 - 3x + 1$ in terms of Legendre Polynomials in the interval [−1, 1].

(b) Starting from Generating function of Legendre Polynomails derive the following recurrence relation of Legendre Polynomials

$$P_n(x) = P'_{n+1}(x) - 2xP'_n(x) + P'_{n-1}(x)$$ (10,5)

Some useful formulae :

Legendre Polynomails :

$$P_0(x) = 1, P_1(x) = x, P_2(x) = \frac{1}{2}(3x^2 - 1)$$

$$P_3(x) = \frac{1}{2}(5x^3 - 3x), P_4(x) = \frac{1}{8}(35x^4 - 30x^2 + 3)$$

Generating Function of Legendre Polynomails :

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

(2000)

[This question paper contains 2 printed pages.]

Your Roll No...............

J

Sr. No. of Question Paper : 5676

Unique Paper Code : 2222012403

Name of the Paper : Analog Electronics

Name of the Course : **B.Sc. Hons. – (Physics)_NEP: UGCF-2022**

Semester : IV

Duration : 2 Hours

Maximum Marks : 60

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt any **Four** questions in all. Question No. **1** is compulsory.
3. Simple non-programmable calculators are allowed.

1. Attempt **any five** parts. (3×5=15)

 (a) Explain the working principle of a photodiode. Also Draw I-V characteristics.

 (b) Draw the I-V characteristics of a Zener diode and explain its use as a voltage regulator.

 (c) A diode is used in a half-wave rectifier. If the peak input voltage is 12 V, calculate the average output voltage (assume ideal diode).

 (d) Why is voltage divider bias preferred over fixed bias in amplifier circuits?

 (e) A transistor has $\beta = 120$ and base current = 30 μA. Find the collector current.

 (f) Define the slew rate of an op-amp. If an op-amp has a slew rate of 0.5 V/μs, how much time will it take to swing from 0 to 3 V?

 (g) State any three differences between an ideal op-amp and a practical op-amp.

2. (10+5)

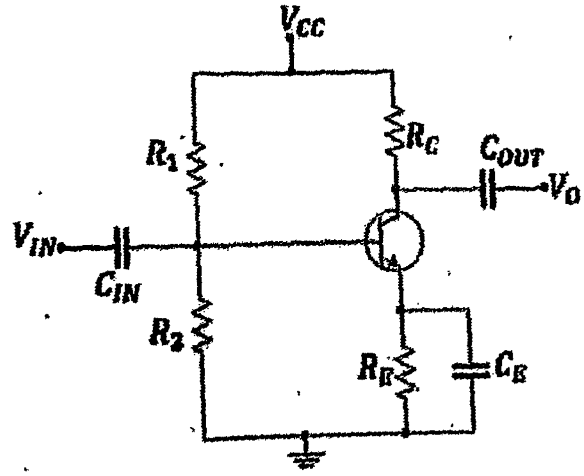
 (a) Explain the construction and working of a full-wave bridge rectifier. Derive expressions for average output voltage and ripple factor.

(b) A Zener diode voltage regulator circuit is connected with 15 V input and a 9 V Zener. Calculate the current through Zener if the load draws 10 mA and the series resistance is 100 Ω. Also draw the proper circuit diagram of a Zener diode voltage regulator.

3. (10+5)

(a) Explain the input and output I-V characteristics of a transistor in CE configuration. Describe the active, cut-off, and saturation regions.

(b) In the voltage divider bias circuit, $R_1 = 33\ k\Omega$, $R_2 = 10\ k\Omega$, $R_C = 2\ k\Omega$, $R_E = 1\ k\Omega$, $V_{CC} = 15$ V, and $\beta = 100$. Calculate the base voltage V_B, emitter voltage V_E, and collector current Ic. Assume $V_{BE} = 0.7$ V, $C_{in} = C_{out} = 10\ \mu A$ and $C_E = 50\ \mu A$.



4. (10+5)

(a) Explain the construction and working of RC phase shift oscillator. Derive the condition for sustained oscillation and expression for its frequency.

(b) A Hartley oscillator operates at a frequency of 1 MHz. The capacitor in the tank circuit is 200 pF, and the mutual inductance is 0.002 mH. If both the inductors in the circuit are of same value, calculate the value of L.

5. (10+5)

(a) Draw the circuit diagram of a basic integrator using an operational amplifier and derive the expression for its output voltage. Draw the circuit of a practical integrator and explain the need for modifications over the basic integrator.

(b) A zero-crossing detector is used to process a sinusoidal input signal with a peak-to-peak voltage of 5 V and a frequency of 60 Hz. What will be the period of the output waveform generated by the detector. If the output of the op-amp swings from –5 V to +5 V and the slew rate of the op-amp is 0.5 V/μs, estimate the minimum time the op-amp takes to complete this transition.

1287

Roll No. ....

Name of the Department	:	Department of Physics and Astrophysics
Name of Course	:	B.Sc. Hons.–(Physics)_Core –
Semester	:	IV - Semester
Name of the Paper:	:	Analog Systems and Applications
Unique Paper Code	:	32221403
Question paper Set number	:	
Duration	:	3 hours
Max. Marks	:	75 marks

Instructions for Candidates:

(a) Write your Roll No. on the top immediately on receipt of this question paper.
(b) Attempt any Five questions in all. Question No.1 is compulsory.
(c) Non-programmable calculators are allowed.

(Given: $\varepsilon_o = 8.85 \times 10^{-12}\ F/m$; $k = 1.38 \times 10^{-23}\ J/K$; $q = 1.6 \times 10^{-19}$C)

1. Attempt any *FIVE* of the following:

(3 X 5=15)

a) A germanium diode has a reverse saturation current of 10μA at room temperature (300K). Determine the saturation current at 500K.
b) The resistivity of an intrinsic germanium at 300 K is 50 Ωcm. Find the intrinsic carrier concentration of the semiconductor if the electron and hole mobilities respectively are: $\mu_n = 3900\ cm^2/volt.sec$ and $\mu_p = 1900\ cm^2/volt.sec$.
c) Define the term β_{dc} for a transistor. How is it related to α_{dc}?
d) Mention the characteristics of an ideal and practical Op-Amp.
e) Define the following specifications for a D/A converter.
   (i) Resolution
   (ii) Settling Time
f) List the two types of feedbacks. Which one is used in linear applications like amplification?

2.

a) Define depletion region and barrier height for a p-n junction diode. Show that the width of the depletion region for a step junction p-n diode in thermal equilibrium is given by

$$W = \sqrt{\frac{2\varepsilon V_0 (N_A + N_D)}{q\, N_A N_D}}$$

where the symbols have their usual meanings.

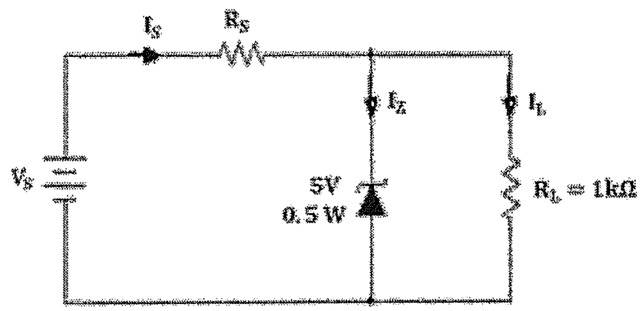
b) A germanium p-n step junction has donor density $N_d = 10^{17} cm^{-3}$ on n-side and acceptor density $N_a = 10^{15} cm^{-3}$ on p-side. Calculate the built-in potential at the junction if intrinsic carrier density $n_i = 10^{13} cm^{-3}$. Assume $\frac{kT}{q} = 26mV$.

(10,5)

3.

a) Explain the working of a full wave bridge rectifier using suitable diagrams and obtain expressions for its ripple factor and rectification efficiency.

b) For the given Zener regulator circuit, find the range over which the supply voltage V_S can be varied without the loss of regulation. The Zener diode has the specifications $V_Z = 5V$, $P_Z = 0.5W$ and $I_{Zmin} = 5mA$. The value of $R_L = 1K\Omega$ and $R_S = 100\Omega$

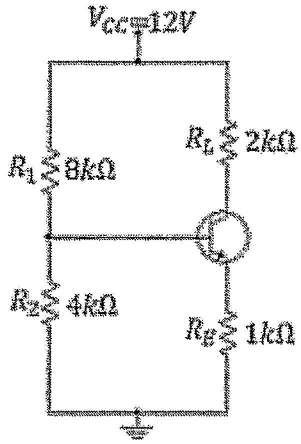


(10,5)

4.

a) Draw the circuit to study the *I-V* characteristics of the transistor in common base configuration. Sketch its input and output characteristics. Also indicate the active, saturation and cut off regions.

b) The voltage divider bias circuit given below uses a silicon transistor Calculate its operating point and draw the D.C. load line. Given $V_{BE} = 0.7\ V$.



(8,7)

5.

a) Obtain the expression for stability factor $S_{I_{CO}}$ for a voltage divider bias configuration.

b) Draw the circuit diagram of an RC coupled CE amplifier. Explain the role of all components in the circuit. Draw the AC equivalent circuit in low, mid and high frequency range and state the associated assumptions for each frequency range.

(7, 8)

6.

a) Derive the relation between A_f(gain with feedback) and A (gain of internal amplifier) for an amplifier with negative feedback with feedback factor B.

b) Give the circuit diagram of Hartley oscillator and derive the expression for frequency of oscillations.

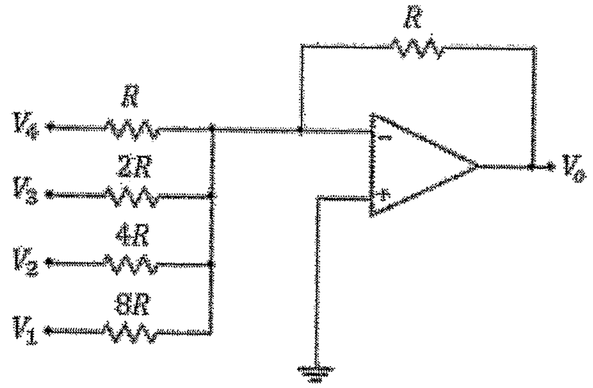
(5,10)

7.

a) Explain the concept of virtual ground in an Op-Amp?

b) Draw the circuit diagram for an ideal differentiator using Op-Amp and hence derive the expression for the output signal. .

c) Derive the expression for the output V_o for the op-amp circuit given below.



(3,6,6)

This question paper contains 2 printed pages. Your Roll No. ....

Sl. No. of Ques. Paper: 1285

Unique Paper Code : 32221401

Name of the Paper : Mathematical Physics-III

Name of the Course : B. Sc. (Hons.) Physics (CBCS-LOCF)

Semester : IV

Duration : 3 hours Maximum Marks : 75

Instructions for students:

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt *five* questions in all including **Q. No. 1** which is compulsory.
3. Use of Non-programmable scientific calculator is allowed.

1. Attempt **ALL** the questions: (5 × 3 = 15)

 (a) Find the polar form of the complex number $z = 2 + i$.

 (b) Determine and classify all the singularities of the function: $\cot\frac{1}{z}$

 (c) Solve : $z^4 + 1 = 0$.

 (d) If Fourier transform of $f(x)$ is $F(k)$, find Fourier transform of $f'(x)$.

 (e) Show that the Dirac δ-function can be expressed as $\delta(x) = \lim\limits_{b\to\infty} \frac{\sin bx}{\pi x}$

2. (a) Prove the identity: (8)

$$\cos^4\theta = \frac{1}{8}\cos 4\theta + \frac{1}{2}\cos 2\theta + \frac{3}{8}$$

 (b) Evaluate $\int_C \bar{z}\,dz$ from $z = 0$ to $z = 4 + 2i$ along the curve C given by $z = t^2 + it$.

(7)

3. (a) Evaluate the following integral using Cauchy's integral theorem (8)

$$\oint_C \frac{e^{zt}}{(z^2+1)^2}\,dz,$$

 if C is the circle $|z| = 3$

 (b) Expand $f(z) = \frac{1}{z+1}$ in Taylor series about $z = 1$ (7)

4. Using contour integration, prove any *two* of the following integrals: (7.5 × 2 =15)

 (i) $$\int_0^\infty \frac{1}{x^4+1}\,dx = \frac{\pi}{2\sqrt{2}}$$

 (ii) $$\int_0^\pi \frac{a\,d\theta}{a^2+\sin^2\theta}\,dx = \frac{\pi}{\sqrt{a^2+1}};\ a > 0$$

(iii) $\int_0^\infty \frac{\cos \pi x}{x^2+1} dx = \frac{\pi}{2} e^{-\pi}$

5. (a) Find Fourier sine transform of $f(x) = xe^{-x^2/2}$ (8)

   (b) Prove that the Fourier transform of a odd function is an odd function. (7)

6. (a) Using the convolution theorem, find inverse Laplace transform of the function:

$$\frac{1}{s^2(s-a)}$$ (8)

   (b) Using Laplace transform, evalutate: $\int_0^\infty \frac{e^{-t} - e^{-3t}}{t} dt$ (7)

7. (a) Solve the following differential equation using the method of Laplace transforms

$$y'' - 4y' + 4y = 0$$

with $y(0) = 0$, $y'(0) = 3$ (8)

   (b) State and prove the convolution theorem for Fourier transform. (7)

[This question paper contains 2 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5537 **J**

Unique Paper Code : 2222012401

Name of the Paper : Modern Physics (DSC)

Name of the Course : **B.Sc. (Hons.) Physics – NEP UGCF-2022**

Semester : IV

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Question No. 1 is compulsory.
3. Attempt any four from the remaining five questions.
4. All questions carry equal marks.
5. Use of non-programmable calculators is allowed.

1. Attempt any **six** of the following questions: (6×3=18)

   (a) In the Compton scattering experiment, radiation scattered at each angle generally consists of two distinct wavelengths. Briefly discuss the origins of these wavelengths?

   (b) If the uncertainty in a photon's wavelength is one part in a million, determine the uncertainty in its position if the photon's wavelength is 500 nm.

   (c) Evaluate the commutator (i) $[\hat{x}, \hat{p}_x]$, (ii) $[\hat{x}, \hat{p}_y]$, and (iii) $[\hat{x}, \hat{p}_x{}^2]$

   (d) A particle of kinetic energy 8.5 eV is incident on a potential step of height 4.5 eV. Calculate the reflection coefficient.

   (e) Explain the terms (i) induced absorption (ii) spontaneous emission, and (ii) stimulated emission.

   (f) State Moseley's law and discuss its significance.

   (g) Calculate the radius of ^{235}U. What would be the mass of 1 mm^3 of nuclear matter? Given: $1u = 1.66 \times 10^{17}$ kg/m^3.

2. (a) Draw the experimental setup for studying photoelectric effect. What are the main features of the observations? Discuss how classical wave theory fails and how Einstein's quantum theory of light successfully explains the phenomenon. (10)

(b) Determine the wavelength of the incident photon in Compton scattering if the maximum energy imparted to the electron is 50 keV? (8)

3. (a) Obtain the time-dependent Schrodinger equation in one dimension and discuss the statistical interpretation of wave function. (10)

(b) A particle is described by the wave function

$$\psi(x) = 0 \qquad x < 0$$
$$= \sqrt{2}e^{-x/L} \qquad x \geq 0$$

where L=2 nm. Calculate the probability of finding the particle in the region $x \geq 1$ nm. (8)

4. (a) Sketch the first three wave functions and corresponding probability densities for a particle confined in a one-dimensional box of length L. What are the energy eigenvalues corresponding to these wave functions? Discuss the differences between the classical and quantum mechanical descriptions of such a particle. (10)

(b) A particle of kinetic energy 2.5 eV is incident on a potential step of height 4.0 eV. Calculate the penetration depth of the particle into the classically forbidden region. (8)

5. (a) On what condition does the quantum physics yield the same results as classical physics according to Bohr correspondence principle. Discuss the validity of the principle on the basis of classical and quantum pictures of the Bohr model for hydrogen atom. (10)

(b) Calculate the ratio of Einstein's A and B coefficients, and the ratio of probabilities of spontaneous and stimulated emission for a system in thermal equilibrium at room temperature (T = 300 K) for transition that occur in the visible region ($h\nu$ = 2 eV). Given: $k_B = 1.38\times10^{-23}$ J/K. (8)

6 (a) Discuss the various contributions to the binding energy of a nucleus of atomic number Z and mass number A, and obtain the Weizsaecker semi-empirical mass formula. (10)

(b) Calculate the binding energy of α-particle and express it in MeV and joules. Given:

m_p = 1.00758 amu, m_n = 1.00897 amu and m_{He} = 4.0028 amu. (4)

(c) Calculate the distance in free space over which the intensity of a 2 eV neutron beam be reduced by a factor of one-half? Given: Mass of neutron = 1.67×10^{-27} kg, Decay constant for a free neutron = 1.14×10^{-3} s^{-1}. (4)

[This question paper contains 4 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5597 **J**

Unique Paper Code : 2222012402

Name of the Paper : Solid State Physics

Name of the Course : **B.Sc. Hons.-(Physics)_NEP:UGCF-2022**

Semester : IV

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt any five questions in total. Question No. 1 is compulsory.
3. All questions carry equal marks.
4. Use of non-programmable scientific calculators is permitted.

1. Attempt any **six** of the following: (3 x 6 = 18)

(a) Draw (221) and (110) planes in a cubic crystal. Also, show [111] direction in a cubic unit cell.

(b) An X-ray beam of wavelength 1.54 Å is diffracted from the (100) planes of a solid with a cubic lattice of lattice constant 3.05 Å. Find the Bragg's angle at which the first-order diffraction occurs.

(c) Hall coefficient of a specimen of a strong n-type silicon is 3.66×10^{-4} m^3C^{-1}. The resistivity of the specimen is 8.93×10^{-3} m. Find the mobility and density of the charge carriers.

(d) Calculate Einstein's frequency for copper (Cu) metal that has an Einstein's température θ_E=230° K.

(e) Discuss various sources of polarizability in a dielectric.

(f) Explain the B-H curve of a ferromagnetic material.

(g) Explain Meissner's effect in the superconductor.

2. (a) Explain Ewald's construction and derive Bragg's law $2\vec{K}.\vec{G} + G^2 = 0$ for X-ray diffraction in a reciprocal lattice, where the symbols have their usual meanings. (12)

(b) Calculate the packing fraction for face-centered cubic (FCC) crystal. (6)

3. (a) For the Kroning-Penney model of electron behaviour in solids, derive the relation $P\frac{sin(\alpha a)}{\alpha a} + cos(\alpha a) = cos(ka)$ where P is proportional to the barrier strength (height and width) between adjacent lattice atoms, a is the lattice constant, k is the wavenumber, and $\alpha = \sqrt{\frac{2mE}{\hbar^2}}$.. Sketch the general behaviour of this relation as a function of αa clearly indicating the value of ?$\alpha a = 0$

and the limiting case $\alpha a \to \infty$. By considering the above condition clearly indicate on your sketch the ranges of αa that correspond to allowed energy bands. (12)

(b) Show that in the limit of $P \to \infty$ the relation leads to discrete allowed energy given by $E_n = \frac{n^2\hbar^2\pi^2}{2ma^2}$. (6)

4. (a) Derive an expression for the lattice specific heat of a solid based on the Debye model and demonstrate that it varies as T^3 at low temperatures. (12)

(b) Calculate the number of optical and acoustical phonon branches for a NaCl crystal, containing two atoms per primitive unit cell. (6)

5. (a) Describe the Langevin theory of para-magnetism and explain Weiss modification in this theory assuming the existence of an internal molecular field. (12)

(b) A paramagnetic salt contains 10^{28} ions/m^3, each with magnetic moment 9.27 x 10^{-24} A-m^2. Calculate paramagnetic susceptibility produced in a uniform magnetic field H = 10^6 A/m at 300° K. (6)

6. (a) Define the term "Local electric field" at an atom. Deduce Lorentz relation for E_{Loc} inside a dielectric. (12)

(b) Draw a typical P-E hysteresis curve for a ferroelectric material and give one example. (6)

Charge of an electron = 1.602×10^{-19} C

Planck's Constant = 6.62×10^{-34} J-s

Boltzmann Constant = 1.38×10^{-23} J/K

$\mu_0 = 4\pi \times 10^{-7}$ Kg m s^{-2} A^{-2}

2631

Name of the paper	:	Waves and Optics
Name of the course	:	B.Sc. Prog physics CBCS_LOCF/
Unique Paper code	:	42224412
Semester	:	IV
Duration	:	3 hours
Maximum Marks	:	75

Instruction for candidates

Write your Roll number on the top immediately on receipt of this question paper

Attempt any FIVE questions. Q1 is compulsory.

All questions carry equal marks

Q1. Answer any **five** questions

a) What is linearity and superposition principle?

b) Explain the role of compensating plate in Michelson interferometer.

c) Explain the factors that affect the quality of sound.

d) What are coherent sources? Give examples.

e) Write differences between Fresnel's and Fraunhofer's class of diffraction of light.

f) Define nodes and antinodes for a stationary wave.

g) Distinguish between polarized and unpolarized light. [3x5]

Q2.

a) Two collinear SHMs acting simultaneously on a particle are given by

$x_1 = a_1 \sin(\omega t)$

$x_2 = a_2 \sin(\omega t + \phi)$

where a_1 and a_2 are the amplitudes of x_1 and x_2, ϕ is the phase difference between the two waves.

Find the resultant motion of the particle in terms of a_1, a_2 and ϕ.

b) What are Lissajous figures? Give their applications.

[10, 5]

Q3

a) What are half period zones? Describe the factors on which the amplitude due to a zone depends.

b) Using principle of reversibility, show that there is a phase change of π when light waves are reflected from the surface of denser medium. [8, 7]

Q4.

a) Derive an expression for the focal length of zone plate. Explain how it acts like a convergent lens having multiple foci.

b) Discuss the essential conditions for obtaining a sustained interference pattern. [10, 5]

Q5

a) Explain the formation of interference fringes by Fresnel's Biprism when a monochromatic source of light is used. Derive the expression for fringe width.

b) Two narrow parallel slits 0.5×10^{-3} m apart are illuminated by a monochromatic light of wavelength 5890 Å. Calculate the width of fringes which are obtained on a screen distant 0.5 m from the slits. [10,5]

Q6

a) What are Newton's rings? How they are constructed. Show that in reflected light diameters of bright rings are proportional to square root of odd natural numbers and diameters of dark rings are proportional to square root of natural numbers.

b) Explain the phase velocity and group velocity. [12, 3]

Q7

a) Describe Fraunhofer diffraction by a single slit using a well labelled diagram. Also draw the intensity diagram.

b) What is a plane polarised light. Discuss the method for the production of plane polarised light. [9,6]

[This question paper contains 4 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5557 **J**

Unique Paper Code : 2222013602

Name of the Paper : DSC Atomic, Molecular and Nuclear Physics

Name of the Course : **B.Sc. (Hons.) Physics_ NEP: UGCF-2022**

Semester : VI

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt **FIVE** questions in all
3. **Question No. 1 is compulsory**
4. Attempt **four** questions from the rest of the paper
5. Use of non-programmable scientific calculator is allowed.

1. Attempt any **six** questions from the following: **(6 x 3 = 18)**

a) Briefly explain the modes of relaxation of an excited atomic state.

b) The effective potential (in arbitrary units) when solving a one-electron atom problem is

$$V_{\{eff\}}(r) = -\frac{2}{r} + \frac{l(l+1)}{r^2}$$

Plot $V_{\{eff\}}$ Vs r for hydrogen atom for $l = 0$ and $l = 1$.

c) What is the consequence of breaking of the Born-Oppenheimer approximation on the ro-vibrational spectrum of a diatomic molecule?

d) Show that the Darwin term results in a shift of 0.7305 cm^{-1} for $S_{1/2}$ state in H atom. Given 1 eV = 8065.54 cm^{-1}; $\alpha^2 \approx (1/137)^2 = 1/18769$; Rydberg constant = 1.097×10^5 cm^{-1}.

e) Differentiate between σ and π bonds.

f) State the Geiger-Nuttal law and represent it graphically.

g) What conclusions can be drawn from Weisskopf estimates about transition probabilities in terms of multipole order and the type of radiation?

2. a) Calculate the change in energy due to spin orbit interaction responsible for the fine structure of hydrogenic atoms.

b) The D_1 line of Sodium is due to the transition $^2P_{1/2} \rightarrow {}^2S_{1/2}$. Draw and discuss the shifts in the spectral line caused by a strong magnetic field. What is the name of this effect?

c) For the hydrogen atom at the $n = 2$ energy level, demonstrate that the spin-orbit interaction causes no energy shift for $S_{1/2}$ state. **(9+6+3)**

3. a) State the differences between the spectra of rigid rotator and non-rigid rotator. Support with a diagram.

b) What are the dipole selection rules for one-electron atoms?

c) A free neutron decays into a proton by the emission of β^- particles of maximum kinetic energy 0.782 MeV. Find the mass of proton and hydrogen atom. Given the rest mass of electron = 0.0005486 u, rest mass of neutron = 1.008665 u. **(6+6+6)**

4. a) Derive the following expression for the wave number for energy level(s) (cm^{-1}) in case of Raman spectra $\bar{\vartheta} = (\overline{\vartheta_0} \pm B(4J+6)\ )$ cm^{-1} where $\bar{\vartheta}$ and $\overline{\vartheta_0}$ are the wave numbers of energy levels of Raman Spectra and the exciting lines respectively, B is the rotational constant and J is the rotational quantum number. What do the positive and negative signs in the above equation, refer to?

b) The first rotational absorption of $^{12}C^{16}O$ occurs at 3.84235 cm^{-1} while that of $^{13}C^{16}O$ is at 3.67337 cm^{-1}. Find the atomic weight of ^{13}C. Given mass of ^{16}O =16.00 u and mass of ^{12}C = 12.00 u.

c) State the Franck-Condon principle. Draw electronic transitions illustrating the principle. **(9+6+3)**

5.a) A radioactive substance A with decay constant λ_A transforms into another radioactive substance B with decay constant λ_B which further decays into a stable end- product C $(A \rightarrow B \rightarrow C)$. Assume at $t = 0$ only substance A with N_{A0} atoms is present. The number of atoms of substances A and B present at any instant t are $N_A(t)$ and $N_B(t)$ respectively. Discuss the equilibrium conditions for (i) longer lived parent nucleus compared to the daughter nucleus (ii) longer lived daughter nucleus than the parent nucleus. In each case represent graphically the variation of activity with time.

b) Using the nuclear Shell model, explain how does the spin orbit interaction explain the existence of magic number 28. Why are the low-lying excited states assigned $(1/2)^+$ and $(1/2)^-$? **(6+12)**

6.a) Explain the fine structure splitting of spectral lines in H-atom due to the transition from the first excited state to the ground state. Identify the allowed transitions according to the selection rules. Why does each line from the first excited state to the ground state, split into a doublet in the fine structure of the hydrogen atom?

b) Show that the laws of conservation of energy and angular momentum are not violated if a neutrino or an anti-neutrino is emitted in beta decay.

c) Explain the origin of P and R branches in the vibration rotation spectra of diatomic molecules. **(6+6+6)**

Useful information:

$$\langle 1/r \rangle = \frac{Z}{n^2 a_0} \; ; \langle \frac{1}{r^2} \rangle = \frac{Z^2}{\left(l+\frac{1}{2}\right) n^3 {a_0}^2} \; ; \langle \frac{1}{r^3} \rangle = \frac{Z^3}{l\left(l+\frac{1}{2}\right)(l+1) n^3 {a_0}^3}$$

a_0 is the Bohr radius

Z is the nuclear charge, l is the orbital quantum number

n is the principal quantum number

1304

[This question paper contains .... printed pages]

Your Roll No. ....

S.No. of Question Paper :

Unique Paper Code : 32227626

Name of the Paper : DSE Classical Dynamics

Name of the Course : B. Sc. (Hons) Physics CBCS-LOCF

Semester : VI

Duration: **3 Hours** Maximum Marks: **75**

(Write your Roll No on the top immediately on receipt of this paper.)
Question No. 1 which is compulsory.
Attempt any *four* questions from the remaining.

Q1) Attempt all of the following [3×5 = 15]

a) The Lagrangian L of a particle with mass m moving in one dimension is given by

$$L(x,\dot{x},t) = \frac{1}{2}m\dot{x}^2 + \alpha\left(\frac{1}{2}x^2 + tx\dot{x}\right) - \frac{1}{2}kx^2$$

where α and k are constants. Find the equation of motion of this particle.

b) Determine the Hamiltonian of a free particle in (i) cylindrical coordinate system and (ii) spherical polar system.

c) Let $A^{\mu} = (9,4,6,6)$ be a four-vector. Determine whether this four-vector is time-like, space-like or light like vector.

d) In an inertial frame S, a car is travelling in the xy-plane with constant speed of $u = 0.5c$ along a line which makes 45^0 with the x-axis. Find the components of its four-velocity.

e) A particle moves along the x-axis under the influence of a force with potential $V(x) = 2(x^4 - x^2)$. Determine the positions of stable and unstable equilibria.

Q2)

a) Using Hamilton's principle, derive the Euler-Lagrange equation for a system with N degrees of freedom. [8]

b) Let $L_1(q,\dot{q})$ and $L_2(q,\dot{q})$ be two Lagrangian which are related like this:

$$L_2(q,\dot{q}) = L_1(q,\dot{q}) + \frac{d}{dt}[f(q,t)]$$

where $\dot{q} = \frac{dq}{dt}$ and $f(q,t)$ arbitrary function of the generalized coordinate q and time t. Using the Euler-Lagrangian equation, show that both these Lagrangian leads to the same equation of motion. [7]

Q3)

a) A simple pendulum of mass m and length L is attached to another mass M at the point of support. Mass M can move in a horizontal line lying in the plane in which mass m moves. Assume that there is no friction in the movement of mass m and M. Find the Lagrangian and the corresponding equations of motion. Identify cyclic coordinates and the corresponding conserved conjugate momentum. [8]

b) If the Lagrangian of the system does not explicitly depend on time, then prove that the Hamiltonian is conserved. [7]

Q4)

a) Two identical simple pendulums of length l and point mass m are coupled by a massless spring of constant k. The unstretched length of the spring is equal to the distance between the two supports of the pendulums. Write the Lagrangian of the system in appropriate generalized coordinates. Find the normal coordinates and normal frequencies of small oscillations about the equilibrium. [8]

b) A particle moving along the x-axis under the influence of force with potential $V(x) = bx^2 + \frac{a}{x^4}$ where a and b are positive constants. Determine the frequency of oscillation about the stable equilibrium point under small oscillations. [7]

Q5)

a) Starting from the displacement 4-vector, determine the components of (i) 4-velocity η^μ and (ii) the 4-acceleration a^μ. Using this determine the value of $\eta^\mu\eta_\mu$ and $a^\mu a_\mu$. [8]

b) In an inertial frame S, the space-time coordinates of event A are $(t_A, x_A, 0, 0)$ and coordinates of event B are $(t_B, x_B, 0, 0)$. Assuming the invariant space-time interval between them is space-like show that there exists an inertial frame S' in which the two events are simultaneous. Find the velocity of frame S' with respect to S. [7]

Q6)

a) For a particle with rest mass m, how is four-moment p^μ defined? If $\vec{u}$ is a 3-velocity vector of the particle, derive the components of the four-momentum p^μ and prove that $E^2 + p^2c^2 = m^2c^4$ where the symbols have their usual meaning. [8]

b) In an inertial frame S two particles with four-momentum p_1^μ and p_2^μ collide with each other. After getting scattered the resulting particles have four-momentum p_3^μ and p_4^μ. If the total 4-momentum is conserved in the inertial frame S, using the Lorentz transformation, show that it is also conserved in inertial frame S'. Consider the frame S' to be moving along x-axis with respect frame S with constant velocity v. [7]

Q7)

a) What is Reynolds number? Discuss its significance with respect to flow of fluids. Water is observed to flow through a capillary of diameter $1.0\ mm$ with a speed of $3\ m/s$. Viscosity of water in CGS units is 0.018 at $0°C$, 0.008 at $30°C$ 30◦C and 0.004 at $70°C$. Calculate the Reynolds number and test at which of these three temperatures is the flow likely to be streamlined. Assume that for Reynolds number R < 2200 flow is steady. [8]

b) Derive the continuity equation in 3-dimensions for incompressible fluid. [7]

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Roll. No. ....

Name of the Course : B.Sc. Hons.–(Physics)- CBCS_Core

Semester : VI - Semester
Name of Paper : Electromagnetic Theory
Unique Paper Code : 32221601
Duration : 3 Hours Maximum Marks : 75

Instructions for Candidates:
(Write your Roll No. on the top immediately on receipt of this question paper)
Question No.1 is compulsory. Answer any four of the remaining six.
Use of non-programmable scientific calculator is allowed.

Q1. Attempt any five parts of this question - **(5x3=15)**

(a) The E-field in free space $\tilde{E}$ = 50cos (10^8t+kx) $\hat{\jmath}$. Find the direction of propagation, the magnitude of propagation vector and time it takes to travel a distance $\lambda/2$.

(b) If the frequency of a plane EM wave is 8×10^9 Hz and it propagates through a non-magnetic conductor with conductivity $\sigma=5.8\times10^7$ S/m, find the skin depth of the conductor.

(c) A sugar solution in a tube of length 20 cm produces optical rotation of 13°. The solution is diluted to 1/3 of its previous concentration. Find optical rotation produced by 30 cm long tube containing the diluted solution.

(d) In a material for which σ = 5.0 mho/m, ϵ_r = 1 and $|\vec{E}|$ = 250 sin10t (V/m). Find $\vec{J_c}$ and $\vec{J_d}$ and frequency at which they have equal magnitude.

(e) Derive the equation of continuity using Maxwell's equations.

(f) For the glass-air interface calculate Reflection and Transmission coefficients (for normal incidence at interface between two linear dielectric media). Given η_{air} = 1, η_{glass} = 1.5.

Q2. (a). State and establish the Poynting theorem for conservation of energy for electromagnetic fields. Explain the physical significance of each term in the equation. **(10)**

(b) In a non-magnetic medium $\vec{E} = 4sin\ (2\pi \times 10^7 t - 0.8x)$ $\hat{a}_z$V/m. Find the (i) velocity of propagation of EM waves through this medium, (ii) ϵ_r , (iii) intrinsic impedance η and (iv) the average power carried by EM wave. (Take μ_r= 1) **(5)**

Q3. (a) Derive Fresnel's relations for reflection and refraction of plane EM waves at an interface between two dielectric media when the electric field vector of the incident wave is perpendicular to the plane of incidence. **(10)**

(b) The average density of electrons in an ionosphere is $9 \times 10^9/\text{m}^3$. Calculate the plasma frequency and the phase velocity of the plane EM wave of frequency 200 MHz propagating through the ionosphere. **(5)**

Q4. (a) A plane EM wave propagating in a conducting medium is characterized by the parameters ∈, μ and σ. Show that the propagation constant is complex in this case. Discuss the propagation of EM waves in a good and bad conductor. Here ∈, μ and σ are respectively permittivity, permeability and conductivity of the medium. **(10)**

(b) Calculate the Reflection coefficient (for normal incidence) for light at an Air to Silver interface at optical frequency $\omega = 4 \times 10^{15}$ rad/s. [given $\mu_1 = \mu_2 = \mu_0$, $\epsilon_1 = \epsilon_0$, $\sigma = 6 \times .10^7 (\Omega.m)^{-1}$]. **(5)**

Q5. (a) Show that in an anisotropic dielectric medium Electric field, Magnetic field and the Poynting vector on one hand and the Electric displacement, the Magnetic field and the wave normal on the other hand form orthogonal triplets. **(10)**

(b) Find out the thickness of a Calcite QWP (Quarter Wave Plate) having its optic axis Parallel to the surface so that it can introduce a phase difference of $\pi/2$ between ordinary and extra-ordinary components at wavelength λ_0 = 5893A°. (given $\eta_0 = 1.65836$, $\eta_e = 1.48641$). **(5)**

Q6. (a) Starting from Maxwell's equations derive the wave equations for propagation of an electromagnetic wave in an inhomogeneous non-magnetic medium. Solve the appropriate wave equation for the TE modes in a step index symmetric planar dielectric wave guide. **(10)**

(b) For a typical step-index (multimode) fiber with $\eta_1 = 1.45$ and Δ=0.01. Find the numerical aperture (NA) of the optical fiber. (Here Δ is a parameter given by $\Delta = \frac{\eta_1^2 - \eta_2^2}{2\eta_1^2}$ with $\eta_2 < \eta_1$ and η_1 , η_2 being the refractive index of core and cladding respectively). **(5)**

Q. 7(a) State Biot's laws for rotatory polarization. Using the Fresnel's theory of optical rotation, obtain the formula for the angle of rotation of plane of vibration. **(7)**

(b) A beam of light is passed through a polarizer. If the polarizer is rotated with the beam as an axis, the intensity I of the emergent beam does not vary. What are the possible states of polarization of the incident beam? How to ascertain its state of polarization with the help of the given polarizer and a quarter wave plate? **(3)**

(c) Discuss the State of Polarization (SOP) when the x and y components of the Electric fields are given by the following equations.

(i) $E_x = E_0 \cos(\omega t + kz)$

$E_y = (\frac{E_0}{\sqrt{2}}) \cos(\omega t + kz + \pi)$

(ii) $Ex = E_0 \sin(\omega t + kz)$

$Ey = E_0 \cos(\omega t + kz)$ **(5)**

Value of Constants:

ϵ_0 =8.85 □ 10^{-12} farad/m = $\frac{10^{-9}}{36\pi}$ farad/m

$\mu_0 = 4\pi$ □ 10^{-7} henry/m

$\eta_0 = 120\pi\Omega$ =377Ω

Mass of electron = 9.11 □ 10^{-31}Kg

C=3 □ 10^8 m/s

[This question paper contains 4 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5651 **J**

Unique Paper Code : 2223010023

Name of the Paper : Research Methodology

Name of the Course : **B.Sc. Hons.-(Physics)_NEP:UGCF-2022**

Semester : VI- Semester (DSE Paper)

Duration : 3 Hours Maximum Marks : 90

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Q1 is compulsory. Answer any SIX parts from Q1 and FIVE questions in ALL.
3. Use of a non-programmable calculator is allowed.
4. Attempt all the parts of questions together.
5. Z- and T- tables are permitted.

1. Attempt any six parts of the following: (3×6=18)

(a) Explain three types of biases that may occur in research.

(b) Discuss any two methods of data collection for qualitative research highlighting one of their merits.

(c) What is Source-Normalized Impact Per Paper (SNIP)? If SNIP is A/B, explain the terms A and B.

(d) Name any two databases used in Physics/Astrophysics and also mention one of their capabilities.

(e) What is gnuplot? Write a code to plot sin(x) between -5 and 5. Include a title as "Fig.1" with font size 20.

(f) A person wishes to apply for a patent. Mention any three prerequisites which should be considered before filing a patent application.

(g) Discuss any fellowship scheme for students by the Council of Scientific & Industrial Research. What is its eligibility criterion and mention one benefit it provides?

2. (a) What is the purpose of a literature review? Smita does not know how to conduct a literature review. Give three reasons why she should conduct a literature review for her research. (4)

(b) You are given the following dataset taken during an experiment in their usual units.

x	2	5	7	9	10
y	5	12	20	24	30

(i) Compute the sample means $\bar{x}$ and $\bar{y}$

(ii) Use the least square fitting (for linear regression) formulas to compute β_1 and β_0

$$\beta_1 = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sum(x_i - \bar{x})^2}$$

$$\beta_o = \bar{y} - \beta_1\bar{x}$$

(iii) Write the final linear regression equation.

(iv) The instrument should have a reading (0,0). How can this data be used to indicate that the instrument was not set properly and needed calibration? (8)

(c) What are the important requirements for using the Z-test? Use the Z-test for the following data. A school wants to compare the average test scores of male and female students:

Male: $n_1 = 50$, Mean, $\overline{X}_1 = 78$; Standard Deviation, $\sigma_1 = 10$;

Female: $n_2 = 50$, Mean, $\overline{X}_2 = 74$; Standard Deviation, $\sigma_2 = 9$. Show that we fail to reject the null hypothesis at the 1% significance level. (6)

3. (a) What are the key features of a good research problem? (5)

(b) Consider the function: $f(\theta) = (\theta - 4)^2$. . Use the gradient descent method to minimise this function starting from an initial value of $\theta_0 = 0$ .. Using a learning rate of $\beta = 0.1$, perform two iterations to obtain the updated values of θ using the rule: $5\theta_{n+1} = \theta_n - \beta \cdot \nabla f(\theta_n)$ after computing the gradient $\nabla f(\theta)$. Discuss one advantage and disadvantage of this method. (7)

(c) What is the difference between linear and multilinear regression? Explain with the help of a mathematical expression and when are these used? (6)

4. (a) A scientist is looking for a journal for the publication of their work. Below are three journals with various parameters. Based on this data, discuss five factors which will help to decide their choice to be a non-predatory journal. Which journal is likely to be a predatory journal in this list? (6)

Journal	Peer Review Time	Indexing	APC (Dollars)	Impact Factor	Editorial Board Information
X	3 Weeks	Indexed in reputed database	2000	Not Calculated	Available
Y	3 Days	Not Indexed	1500	Not Calculated	Not Available
Z	4 Weeks	Indexed in reputed database	2500	5.2	Available

(b) What is the NASA/IPAC Extragalactic database (NED)? Explain the purpose and input fields of the Coordinate Calculator in this database. (5)

(c) Explain three ways in which errors can be communicated for a published article. Describe their differences. (7)

5. (a) Discuss any four features of scientific conduct. Specify two reasons why it is needed. (6)

(b) Explain the difference between redundant and duplicate publications. What is meant by salami slicing and why should it be discouraged? (5)

(c) Mention five different types of work which can be copyrighted. Explain the concept of "fair use" in copyright law with the help of an example. (7)

6. (a) What is a trademark? Mention three different types of trademarks. What is a symbol for a registered and unregistered trademark? (6)

(b) What is a control parameter in any experiment? Why is it needed? Explain it with the help of any physics experiment. What are the objectives of background setting of an experiment? (7)

(c) What is the peer-review process? Differentiate between single-blind and double-blind peer review. (5)

[This question paper contains 2 printed pages.]

Your Roll No...............

Sr. No. of Question Paper	:	**5870**	**J**
Unique Paper Code	:	2222513601	
Name of the Paper	:	Solid State Physics (DSC paper)	
Name of the Course	:	**B.Sc. Prog. -Physical sciences with Physics_NEP: UGCF-2022**	
Semester	:	VI	

Duration : 2 Hours　　　　　　　　　　　　　　　　Maximum Marks : 60

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Answer any **four** questions. **Q1** is compulsory.
3. **All** questions carry equal marks.
4. Use of scientific calculator is allowed.

Q1 Answer any *five* questions:

(i) The primitive translation vectors of the hexagonal space lattice are
$\mathbf{a}_1 = (3^{1/2}a/2)\hat{\boldsymbol{x}}$; $\mathbf{a}_2 = (3^{1/2}a/2)\,\hat{\boldsymbol{y}}$; $\mathbf{a}_3 = c\hat{\boldsymbol{z}}$
Show that the volume of the primitive cell is $V = 3^{1/2}a^2c$

(ii) Define primitive and non-primitive unit cell of a 2D oblique lattice.

(iii) Explain the concept of local electric field in a dielectric material.

(iv) In a hexagonal plane lattice the translation vector is $\mathbf{T} = 2\mathbf{a} + 3\mathbf{b}$ where $\mathbf{a} = \mathbf{b}$ = 3 Å and angle is 120°. Determine magnitude and direction of $\mathbf{T}$.

(v) How Hall effect can be used to identify n-type and p-type semiconductors?

(vi) What are ferromagnetic domains? Give examples of ferromagnetic materials.

[5 x 3=15]

Q2

(a) Show that reciprocal of BCC lattice is a FCC lattice in real space.

(b) If $\mathbf{k}$ is the wavevector and $\mathbf{G}$ is reciprocal lattice vector, write the Bragg's condition of crystal diffraction using Ewald's construction.

(c) Copper has fcc structure and the atomic radius is 1.278 Å. Determine its density (Atomic weight of Cu = 63.54, Avogadro number = 6.023×10^{23}).

[6,6,3]

Q3

(a) Draw the labelled periodic potential diagram of a Kronig-Penney model and explain the salient features of the model. Explain conductors, semiconductors and insulators based on energy bands.

(b) Obtain the mathematical relation for effective mass of electron in solids.

(c) What is superconductivity? Give an example of a superconductor. **[6,6,3]**

Q4

(a) Explain lattice vibrations for a linear diatomic chain of atoms. Derive the dispersion relation and draw the diagram showing optical and acoustic branches.

(b) Derive Dulong and Petit's law for specific heat of solids. Explain the conditions suggested by Einstein and Debye for further improvement. **[8,7]**

Q5

(a) Derive Langevin's theory of diamagnetism and show that diamagnetic susceptibility is negative and independent of temperature.

(b) Draw B-H hysteresis loop a ferromagnetic material. Explain the B-H lopp with the help of domain theory.

(c) Define electronic, ionic and orientational dipolar polarizability for dielectric materials. **[6,6,3]**

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Name of the Department : **Physics**
Name of Course : **B.Sc. Prog.(Physics)CBCS: LOCF-Old Course**
Name of the Paper : **Solid State Physics (DSE Paper)**
Semester : **VI- Semester**
Unique Paper Code : **42227637**
Question paper Set number: Set 1

Time : 3 hour **Max Marks : 75**

Attempt Five questions in all. Q1 is compulsory.

Q1. Attempt any **five questions** from the following:

(a) Define unit cell in crystal structure? Distinguish between primitive and non-primitive unit cells.

(b) X-ray of wavelength 1.4 Å is found to be Bragg reflected in first order from the (1 1 1) plane of an fcc structure. If the lattice parameter of the crystal is 5 Å. Find the angle at which the X-ray is incident on the (111) plane of the crystal.

(c) What are phonons? Which distribution function will be followed to define the number of phonons in a solid at any given temperature? How does their numbers vary at low and high temperature as per Debye theory?

(d) Differentiate between dia-, para-, and ferromagnetic materials with examples.

(e) State Hall effect with suitable diagram. What will be the sign of Hall coefficient if the majority carriers are holes?

(f) A superconducting lead has a critical temperature of 7.26 K at zero magnetic field and a critical field of 8×10^5 A/m at 0 K. Find the critical field at 5 K.

(3×5)

Q2. (a)What do miller indices signify? Determine the Miller indices for a plane that intercepts the axes at 2a, 3b, ∞. Sketch (001) and (111) planes a cubic lattice. (2, 3, 2)

(b) Deduce Bragg's law $2\mathbf{K.G} + \mathbf{G}^2 = 0$ for X-ray diffraction by crystal using Ewald's construction. The symbols have their usual meaning. (8)

Q3. (a) Obtain the dispersion relation for a linear diatomic lattice of mass M and m, and show that the spectrum consists of two branches. (10)

(b) Discuss the behavior of the two branches when M and m are equal. (5)

Q4. (a) Discuss the experimental observations for the variation of specific heat of solids with temperature. Discuss Einstein theory of specific heat. Show by necessary derivations how far does it able to explain the experimental results. (3, 8)

(b) Taking the value of Einstein temperature θ_E =100K, estimate an order of natural frequency of vibration for a crystal. Given: $h = 6.6\times10^{-34}$ Js, $K_B = 1.38\times10^{-23}$ J/K. (4)

Q5. (a) What do you mean by polarization of a dielectric material? Find an expression for the local field that is responsible for polarizing molecules or atoms of a dielectric. (3, 8)

(b) How does total polarizability of a dielectric material depend on the frequency of an ac field. Explain with the help of proper diagram. (4)

Q6. (a) Derive an expression for the susceptibility of a paramagnetic material using classical Langevin theory. (10)

(b) Draw a typical B-H hysteresis loop for a ferromagnetic material and explain it using domain theory. Show clearly the coercive force, saturation magnetization and remanence on the curve. (5)

Q7. (a) Discuss the Kronig Penney model for the motion of electron in a one -dimensional periodic potential. Show that in the limit $P\to0$, the Kronig-Penney model reduces to the free electron energy dispersion. (8, 2)

(b) What is a super conductor? How a superconductor is different from a perfect or ideal conductor. Give its three experimental properties. (2, 3)

[This question paper contains 4 printed pages.]

Your Roll No...............

Sr. No. of Question Paper : 5577 **J**

Unique Paper Code : 2222013603

Name of the Paper : Statistical Analysis in Physics

Name of the Course : **B.Sc. (H) Physics**

Semester : VI

Duration : 2 Hours Maximum Marks : 60

Instructions for Candidates

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt four questions in all.
3. Question Number 1 is compulsory.
4. Non-programmable calculators are allowed. Use of statistical tables are allowed.

1. Attempt **any five** of the following: (3×5=15)

(a) What do we mean by Cumulative Distribution Function (CDF)? Mention a few properties of a CDF. How can we get CDF from a given probability density function?

(b) A particular study showed that 12 % of men will likely develop prostate cancer at some point in their lives. A man with prostate cancer has a 95% chance of a positive test result from a medical screening exam. A man without prostate cancer has a 6% chance of getting a false positive test result. What is the probability that a man has cancer given that he has a positive test result?

(c) State central limit theorem. Give an example of one distribution for which we cannot use this theorem.

(d) Suppose we have a 6-sided white dice and a 4-sided black dice. Each dice is fair. If X and Y are the outcomes of white and black dice respectively. Assuming each dice is fair, find the covariance of X and Y.

(e) What do you mean by joint probability distribution? Consider X and Y be two jointly continuous random variables with joint probability density function given by

$$f_{XY}(x,y) = x + Cy^2 \qquad 0 \le x \le 1, 0 \le y \le 1$$
$$= 0 \qquad \text{otherwise}$$

Find $P[0 \le x \le 1/2,\ 0 \le y \le 1/2]$.

(f) What does conjugate priors mean? If you are using bayesian linear regression to estimate the parameters and the distribution of the likelihood is binomial, what should be the conjugate prior (write expression also) so that the posterior is normalized?

2. (a) State and derive Bayes theorem. Discuss at least two advantages of using Bayes theorem for the parameter estimation. What does the denominator in Bayes theorem represent? (7)

(b) A coin has an unknown bias θ, representing the probability of landing heads. If our prior belief is that θ Beta(2, 2) and we toss the coin 5 times and observe 4 heads and 1 tail.

(a) Determine the posterior distribution of θ given this data.

(b) Compute the posterior mean.

(c) Compute the MAP estimate of θ. (8)

3. (a) Derive posterior mean for Gaussian likelihood with known variance and Gaussian prior. (7)

   (b) Normally distributed IQ scores have a mean of 100 and standard deviation of 15. Use the standard z-table to answer the following questions.

      (i) What is the probability of randomly selecting someone with an IQ score less than 80?

      (ii) What is the probability of randomly selecting someone having IQ between 95 and 100?

      (iii) What IQ score corresponds to the 90th percentile?

      (iv) The middle 30% of the IQs fall between what two values? (8)

4. (a) What do you mean by point estimation? State the properties that a good point estimate should have. Write two different methods that can be used for the point estimation. (7)

   (b) Suppose we have a factory which makes diodes. The diodes have a lifetime which is modelled by an exponential distribution with parameter λ. Suppose we check 5 diodes and find that their lifetimes are 2,3,1,3 and 4 years. What is the maximum likelihood estimate for λ.

   (Exponential distribution: $f(x|\lambda) = \lambda e^{-\lambda x}$). (8)

5. (a) What do you understand by the term "Bayes Factor"? At the ITO intersection, vehicles pass through at an average rate of 600 per hour.

      (i) Find the probability that none passes in a given minute.

      (ii) What is the expected number passing in 5 minutes? (7)

(b) Consider a crime scene. The police find that there are two different types of blood on the crime scene left by the criminals- one is type O and other type AB. We know that in the population, type O is found in 60% of the population and type AB in 1% of the population. The police arrest two people R and S. R has a blood group O. Does the data, that is two types O and AB are found on the scene, support the hypothesis that R is one of the criminals? (8)

6. (a) What do we mean by Bayesian linear regression? Discuss (in brief) the significance of using conjugate priors while estimating the posterior density function of the parameter. (7)

(b) In a bayesian linear regression, the prior (θ) follows the normal distribution with mean 0 and standard deviation 1. If the data is as follows: (Assume variance =1)

x	2	4	6	8
y	4	16	36	64

Compute the posterior distribution of the θ. (8)

1289

Sr. No. of Question Paper	:		**Set B**
Unique Paper Code	:	32221602	
Name of the Paper	:	Statistical Mechanics	
Name of the Course	:	B. Sc. (Hons) Physics (CBCS-LOCF)	
Semester	:	VI	

Duration : 3 Hours Maximum Marks : 75

Instructions for Candidates:

1. Write your Roll No. on the top immediately on receipt of this question paper.
2. Attempt *five* questions in all.
3. **Question No. 1** is compulsory.
4. **All** questions carry equal marks.
5. **Non-programmable scientific calculator** is allowed.

1. Attempt all parts. $(5 \times 3 = 15)$

(a) Electromagnetic radiation inside a cavity of volume V is in equilibrium at temperature T. If the temperature of the cavity is halved, by what factor does the pressure change?

(b) Draw the phase trajectory in phase space for a free particle (mass m) moving with energy E along x-axis in the range [0, L]. Find the total number of micro-states available to it.

(c) A system has two non-degenerate energy levels having energy gap of 0.1 eV. If the probability that the system is in the higher level is 0.25, determine its temperature.

(d) Partition function of a single particle is Z_s. Write the partition function of a system of N such particles if these particles are

(i) classical (identical and distinguishable)

(ii) classical (identical and indistinguishable)

(e) What is the difference between a degenerate gas and a degenerate energy level?

2. (a) The partition function of a system is given by the equation

$$Z = e^{bT^3V}$$

where b is some constant. Prove that

(i) mean energy, $\overline{E} = 3bVk_BT^4$

(ii) mean pressure, $\overline{P} = bk_BT^4$

(iii) entropy, $S = 4bVk_BT^3$ (4, 4, 4)

(b) The thermodynamic probability of an ideal gas increases from e^{10} to e^{1000}.

Find the change in entropy. (3)

3\. (a) Partition function of classical ideal monoatomic gas consisting of N indistinguishable particles at fixed temperature T in volume V is given as:

$$Z(N,V,T) = \frac{V^N}{N!}\left(\frac{2\pi m k_B T}{h^2}\right)^{3N/2}$$

Derive the Sackur-Tetrode equation and hence show that the entropy given by the Sackur-Tetrode equation is an extensive parameter. (6, 2)

(b) State and derive the principle of equipartition of energy using statistical method. Mention its two limitations. (5, 2)

4\. (a) Show that at transition temperature ($T = T_c$), pressure of an ideal quantum gas consisting of N particles of spin zero moving non-relativistically in 3-dimensions is given by

$$P(T_c) = 0.513\frac{N k_B T_c}{V} \quad (10)$$

(b) Consider a blackbody radiation inside a cavity maintained at absolute temperature T. Determine the number of photons per unit volume inside this cavity. (5)

5\. (a) Show that at absolute zero, the pressure of a non-relativistic gas of electrons is $p_F = \frac{2}{5}\left(\frac{N}{V}\right)\epsilon_F$. Find the pressure of the free electron gas in MKS units in a monovalent metal which has number density of free electrons $6 \times 10^{28} m^{-3}$ and $\epsilon_F = 6eV$. (5,2)

(b) At T = 0 K, maximum energy of fermions (spin = 1/2) is $\in_F(0)$ and the speed of randomly selected fermion is v. For non-relativistic case, prove that

(i) $$v_{rms} = \sqrt{\frac{6}{5m}\in_F(0)}$$

(ii) $$\frac{v_{\max}}{v_{rms}} = \sqrt{\frac{5}{3}}$$ (5, 3)

6\. (a) The entropy of a blackbody radiation is given as

$$S = \frac{4}{3}\sigma V^{1/4} E^{3/4};\quad \sigma \text{ is a constant}$$

Show that the temperature of the radiation is given by

$$T = \frac{1}{\sigma}\left(\frac{E}{V}\right)^{1/4}$$ (3)

(b) Write Planck's law of blackbody radiation in terms of frequency and hence deduce Stefan-Boltzmann law. (2, 5)

(c) A spherical blackbody of radius 5 cm is maintained at temperature 327°C. Calculate the power radiated and the wavelength at which the maximum energy is radiated? (3, 2)

7. In a hypothetical system, 4 particles are distributed over 4 degenerate energy levels $(0, \in, 2\in, 3\in)$ such that the total energy of the system is $3\in$. Degeneracies of these energy levels are respectively (5, 4, 3, 2). Find all the possible **macrostates** and their corresponding **microstates** if particles are

(a) classical (identical and distinguishable)

(b) bosons

(c) fermions (5, 5, 5)

Some useful constants and integrals:

$c = 3 \times 10^8\ \text{ms}^{-1}$,

$m_e = 9.11 \times 10^{-31}$ kg,

$b = 2898\ \mu\text{m K}$,

$\sigma = 5.67 \times 10^{-8}\ \text{Jm}^{-2}\text{s}^{-1}\text{K}^{-4}$,

$h = 6.626 \times 10^{-34}\ \text{J s} = 4.136 \times 10^{-15}$ eV s,

$k_B = 1.38 \times 10^{-23}\ \text{J/K} = 8.617 \times 10^{-5}$ eV/K,

$$\int_0^\infty \frac{x^{n-1}\,dx}{(z^{-1}e^x) - 1} = \Gamma(n)\,g_n(z);\quad g_n(1) = \zeta(n)$$

$$\int_0^\infty \frac{x^{n-1}\,dx}{(z^{-1}e^x) + 1} = \Gamma(n)\,f_n(z);\quad f_n(z) = g_n(z) - [2^{1-n} g_n(z^2)]$$

$\zeta(3/2) = 2.612$, $\zeta(5/2) = 1.341$, $f_{3/2}(1) = 0.765$,

$$\zeta(2) = \frac{\pi^2}{6},\ \zeta(4) = \frac{\pi^4}{90},\ \Gamma\left(\frac{1}{2}\right) = \sqrt{\pi}$$