[This question paper contains 4 printed pages.]

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

I

Sr. No. of Question Paper : 1403

Unique Paper Code : 222211103

Name of the Paper : Waves and Oscillation

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

Semester : I

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 No. **1** is compulsory.

1. Attempt any **five** questions.

   (a) The displacement y of a particle executing periodic motion is given by,



P.T.O.

$$y = 4\cos^2\left(\frac{1}{2}t\right)\sin(1000\,t)$$

Show that this expression may be a result of the superposition of three independent harmonic motions.

(b) Explain the conditions for obtaining a straight line as a Lissajous figure on an oscilloscope.

(c) A particle of mass 3 moves along the axis attracted toward origin by a force whose magnitude is numerically equal to 12x. The particle is also subjected to a damping force whose magnitude is numerically equal to 12 times the instantaneous speed. If it is initially at rest at x = 10, find the position and the velocity of the particle at any time.

(d) Explain qualitatively the normal coordinates and normal modes of a coupled oscillatory system.

(e) Distinguish between stationary and progressive waves.

(f) Find the quality factor Q for the damped oscillations of an object with a frequency of 1 Hz, and whose amplitude of vibration gets halved in 5 s.

(3×5=15)

2. (a) A uniform spring of spring constant K and a finite mass 'ms' is loaded with a mass 'M'. If 'ms' is not negligible compared to 'M', show that the period of oscillations of mass spring system is,

$$T = 2\pi\sqrt{\frac{M+\frac{m_s}{3}}{K}}.$$

(b) Two vibrations at right angles to each other are described by the equations $x = 10\cos(5\pi t)$, $y = 10\cos(10\pi t - \pi/4)$. Draw graphically the Lissajous figure of the resulting motion. (10,5)

3. (a) Two collinear simple harmonic motions of nearly equal frequencies and different amplitude are superimposed on each other. Find out resultant equation and explain the formation of beats.

(b) An alternating emf of peak-to-peak value 40 volts is applied across the series combination of an inductor of inductance 100 mH, capacitor of capacitance 1pf and resistance 100 Ω. Determine resonance frequency, quality factor and bandwidth. (10,5)

4. (a) Show that for a forced and damped harmonic oscillator in steady state, the average power is equal to the average power dissipated by system.

(b) Two identical masses of mass 'M' are connected with three identical springs of same spring constant 'K' and placed on a smooth surface as shown in Fig. 1. Find out the normal mode frequencies and corresponding configuration/shapes. (10,5)

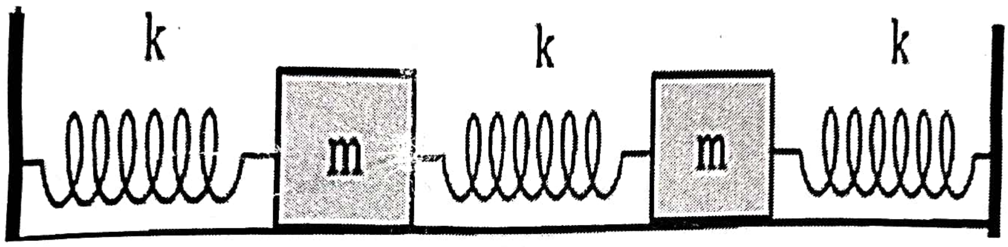



Fig. 1

5. (a) Find the expression for the normal mode of vibration and displacement for a string fixed at both the ends having tension T and mass per unit length $\mu$.

(b) A string of length l = 0.5 m and mass per unit length 0.01 kg/m has a fundamental frequency of 250 Hz. What is the tension in the string? (10,5)

(2)

[This question paper contains 8 printed pages.]

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

Sr. No. of Question Paper : 1085 I

Unique Paper Code : 2222012301

Name of the Paper : Mathematical Physics – III

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

Semester : III

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. All questions carry equal marks.

4. Question number 1 is compulsory.

5. The principal branch of argument of complex number is to be taken as $0 \leq \theta \leq 2\pi$.



P.T.O.

5. Use the following definition for the Fourier transform of f(x) :

$$\mathcal{F}[f(x)] = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(x)\, e^{-ikx}\, dx$$

6. Use the following definition for the Fourier sine transform of f(x) :

$$\mathcal{F}_s[f(x)] = \sqrt{\frac{2}{\pi}} \int_{0}^{\infty} f(x) \sin(kx)\, dx$$

7. Use the following definition for the Fourier cosine transform of f(x) :

$$\mathcal{F}_c[f(x)] = \sqrt{\frac{2}{\pi}} \int_{0}^{\infty} f(x) \cos(kx)\, dx$$

8. Use the following definition for the convolution of two functions f(x) and g(x) :

$$(f * g)(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} f(y)\, g(x-y)\, dy$$

9. Some useful formulae are given at the end.

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

(a) Obtain all the roots of the equation :

$$z^3 - i = 0;\ i = \sqrt{-1}$$

(b) Show that $tanh^{-1}(z) = \frac{1}{2} ln \frac{1+z}{1-z}$

(c) In the finite z-plane, determine and classify the singularities of the function:

$$f(z) = tan^{-1}(z^2 + 4z + 5)$$

(d) Solve $\frac{1}{2\pi i} \oint_C \frac{e^z\, dz}{z-1}$; C is $|z - 1| = 2$ .

(e) Find the residue at $z = 0$ for $f(z) = \frac{\cosh(z)}{z^3}$.



P.T.O.

(f) If $\mathcal{F}^{-1}[F(k)] = f(x)$, show that

$$\mathcal{F}^{-1}[F(k-a)] = e^{iax} f(x); a > 0.$$

(g) General solution of 1-d wave equation is given as:

$$y(x,t) = \sum_{n=1}^{\infty} c_n \sin\left(\frac{n\pi x}{L}\right) \cos\left(\frac{n\pi t}{L}\right)$$

If $0 \le x \le L$ and $y(x, 0) = x$, determine $c_n$.

2. (a) If $z = 4e^{i\pi/3}$, evaluate $|e^{iz}|$. (4)

(b) Given $\tan(x + iy) = u + iv$, show that

$$u = \frac{\sin(2x)}{\cos(2x) + \cosh(2y)}$$

and $$v = \frac{\sinh(2y)}{\cos(2x) + \cosh(2y)}$$ (6)

(c) Prove that the function $u(x, y) = 2x(1 - y)$ is harmonic and hence find $v(x, y)$ such that $f(z) = u + iv$ is analytic. Also, express $f(z)$ in terms of $z$, where $z = x + iy$. (8)

3. (a) State and verify Cauchy's theorem for the function:

$$f(z) = 3z + 2i$$

and $C$ is a triangle with vertices $1 + i, -1 \pm i$. (8)

(b) Solve the integral

$$\oint_C \frac{z^2\,dz}{(z^2 + 9)(z^2 + 4)^2};\ C \text{ is } |z| = 1$$ (5)

(c) Expand

$$f(z) = \frac{z}{(z + 1)(z - 2)}$$

in a Laurent series valid for the annular domain $0 < |z - 2| < 3$. (5)

4. Using residue theorem and suitable contour, solve any two real integrals : (2×9=18)

(a) $\int_0^\infty \frac{x^2}{x^4+1} dx$

(b) $\int_0^{2\pi} \frac{d\theta}{\cos\theta + 2\sin\theta + 3}$

(c) $\int_0^\infty \frac{x \sin 2x}{x^2+9} dx$

5. (a) Find $\mathcal{F}^{-1}\left(\frac{1}{k^2 - 4k + 29}\right)$. (8)

(b) Show that $\mathcal{F}_c\left(\frac{1}{\sqrt{x}}\right) = \frac{1}{\sqrt{k}}$. (5)

(c) Obtain the function $q(x)$, if $\mathcal{F}_s[q(x)] = e^{-2k}$. (5)

6. (a) Using the method of separation of variables, find the solution of the following partial differential equation :

$$4\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y} = 3u$$

such that $u(0, y) = 3e^{-y}$. (4)

(b) Solve one-dimensional heat equation:

$$\frac{\partial u}{\partial t} = 9\,\frac{\partial^2 u}{\partial x^2} \qquad (0 \le x \le L).$$

such that $u(0, t) = 0,\ u(L, t) = 0$

and $u(x, 0) = x(L - x)$ (14)

**Some useful formulae:**

1. $\int_0^{\infty} x^n \exp(-ax^m)\, dx = \frac{1}{m\, a^{(n+1)/m}}\, \Gamma\left(\frac{n+1}{m}\right);$

$n > -1;\ a, m > 0$

2. $\Gamma\left(\frac{1}{2}\right) = \sqrt{\pi}$

3. $\mathcal{F}^{-1}\left(\frac{1}{k^2 + a^2}\right) = \frac{\sqrt{2\pi}}{2a} e^{-a|x|}; \ a > 0$

4. $\mathcal{F}^{-1}[a\,g(k) + b\,h(k)] = a\,\mathcal{F}^{-1}[g(k)] + b\,\mathcal{F}^{-1}[h(k)]$
(a and b are constants)

(9)

[This question paper contains 2 printed pages.]

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

I

Sr. No. of Question Paper : 1142

Unique Paper Code : 2222012302

Name of the Paper : Thermal Physics

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

Semester : III

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 total of five questions out of which Question 1 is compulsory.
3. Use of non-programmable scientific calculator is permissible.
4. Some useful constants are given at the end.

1. Attempt any six (18)

   (a) How does Zeroth law of thermodynamics lead to concept of temperature ?

   (b) How does the first-order differ from the second-order phase transitions?

   (c) Show that $\left(\frac{\partial U}{\partial V}\right)_T = 0$ for an ideal gas.

   (d) Explain the need for the second law of thermodynamics when the energy conservation law exists.

   (e) Can the change in entropy be a negative quantity? Support your answer.

   (f) Calculate the root mean square speed of oxygen molecules at 300K. Take mass of oxygen molecule as $5.31\times10^{-26}$ kg.

   (g) Discuss the limitations of van der Waal's equation of state.

2. (a) What is Adiabatic Lapse Rate ? Derive an expression for the rate of change of temperature with height during the adiabatic gas expansion. How does the presence of water vapour in air affect this process? (6)

   (b) One mole of an ideal gas ($\gamma$ = 1.4) initially kept at 27° C is adiabatically compressed so that its pressure becomes 10 times its original value. Calculate its temperature after compression and work done on the gas. (6)

   (c) Show that the 100% efficiency of a reversible Carnot's heat engine violates laws of thermodynamics. (6)

3. (a) If two Carnot engines A and B are operated in series such that engine A absorbs heat at temperature $T_1$ and rejects heat to the sink at temperature

$T_2$ while engine B absorbs half of the heat rejected by engine A and rejects heat to the sink at temperature $T_3$. If the work done in both cases is equal, show that $T_3 = 3T_2 - 2T_1$. (6)

(b) The heat capacity of a given crystal of mass m at very low temperature varies like $T^3$. Calculate the entropy of the crystal as a function of temperature. (6)

(c) Show that transfer of heat from a body at higher temperature to a body at lower temperature or vice versa leads to increase of entropy of the interacting system. (6)

4. (a) Using Maxwell's equation to prove (any two) : (2*6)

(i) $C_P - C_V = \dfrac{T\alpha^2 v}{\beta_T}$

(ii) Ratio of isentropic to isochoric pressure coefficients of expansion is $\gamma/(\gamma-1)$

(iii) $T\,dS = C_p\,dT - T\,V\,\alpha\,dP$

Where, S stands for entropy, $C_v$ and $C_p$ specific heat at constant volume and pressure, respectively. $\alpha$ is the coefficient of volume expansion and $\beta_T$ is the isothermal compressibility.

(b) Use the path-independent nature of thermodynamic potentials to obtain and derive corresponding Maxwell's thermodynamic relations. (6)

5. (a) Show using Clausius-Clapeyron's latent heat equation that substances which expands on melting have their melting point raised by the increasing pressure, whereas those that contract on melting get their melting points lowered by the increase of pressure. (6)

(b) Draw the pressure-volume isotherms obtained by Andrew's experiments on $CO_2$. Discuss the deviations observed from expected ideal gas behavior. (6)

(c) How can van der Waals's equation of state can explain Andrew's experiment results ? (6)

6. (a) Obtain the coefficient of thermal conductivity (K) of a gas. Discuss the effect of temperature and molecular diameter on ?. (7+5)

(b) Calculate the mean free path of the molecules of a gas of diameter 3 angstrom at STP. How does the mean free path change if the temperature is reduced to half of its original value and pressure is doubled. (6)

**Some useful constants**

Boltzmann constant $1.38\times10^{-23}$ J/K, Gas constant 8.31 J/mole-K Avagadro's number $6.02\times10^{23}$ mol$^{-1}$ or $6.02\times10^{26}$ kmol$^{-1}$, 1 amu = $1.67\times10^{-27}$ kg The symbols like U, V, T, p, $\gamma$ stand for standard notations. (6)

(2,000)

(2)

1162

Serial Number of Question Paper :

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

| | | |
|---|---|---|
| Name of the Department | : | Physics |
| Unique Paper Code | : | 2222012303 |
| Name of the Paper | : | Light and Matter |
| Name of the Course | : | B.Sc. Hons. –(Physics) NEP: UGCF-2022 |
| Semester | : | III-Semester |
| Duration | : | 2Hours |
| Maximum Marks | : | 60 |

**Instruction for candidates** :

1. (Write your Roll No. on the top immediately on receipt of this question paper)
2. Attempt only four (4) questions.
3. Question No. 1 is compulsory.
4. Use of non-programmable scientific calculator is allowed.

1. Attempt any five questions. 5 x 3 =15

(i) What is Compton effect? Write the expression for the Compton wavelength of scattering particle.

(ii) What are the conditions for observing sustained interference pattern?

(iii) Distinguish between Haidinger and Fizeau fringes. What kind of fringes are seen in a Newton's rings setup?

(iv) An exceedingly thin film appears to be perfectly black when seen by reflected light. Why?

(v) Distinguish between Fresnel and Fraunhoffer class of diffraction. The diffraction of star light in a telescope is an example of what kind of diffraction?

(vi) Compare the double slit diffraction pattern observed in reality with the theory of Young's double slit experiment in terms of slit width and slit spacing.

2. (a) What is Photoelectric Effect? What are the observations that cannot be explained by the wave theory of light? How did Einstein explain photoelectric effect?

(b) Show that the group velocity of De-Broglie waves associated with a moving particle is equal to the particle velocity.

(c) Ultraviolet light of wavelength 3000 Å is falling on a surface whose work function is 2.28 eV. What is the maximum possible speed of the emitted electrons in m/s?

5+5+5=15

3. (a) Derive an expression for the diameter of the $n^{th}$ bright ring in Newton's rings apparatus.

(b) Explain how the refractive index of a liquid can be determined by Newton's rings method.

(c) In a Newton's rings experiment, the diameter of $15^{th}$ ring was found to be 0.59 cm and that of the $5^{th}$ ring was 0.336 cm. If the radius of plano-convex lens is 100 cm, calculate the wavelength of the light used. 6+4+5=15

4. (a) Derive an expression for the focal length of a zone plate.

(b) Explain multiple focii of a zone plate.

(c) The diameter of the first ring of a zone plate is 1.2 mm. If a plane wave of wavelength 6000Å is incident on the plate normally, where should the screen be placed so that the light is focused to the brightest point?

8+4+3=15

5. (a) Derive the intensity distribution formula for Fraunhoffer diffraction by a grating of N slits given below.

$$I = I_0 \frac{\sin^2\alpha}{\alpha^2}\frac{\sin^2(N\gamma)}{\sin^2\gamma} \qquad \frac{\pi a \sin\theta}{\lambda} = \alpha \qquad \frac{\pi d \sin\theta}{\lambda} = \gamma$$

Here the grating element d=a+b and other symbols have their usual meaning.

(b) How many orders will be visible if the light of wavelength 5000 Å is normally incident on a grating having 2620 lines per inch.(1 inch = 2.54 cm).

(c) Discuss the concept of missing orders. What orders will be missing if b = a.

7+3+5=15

(5)

**SL No of QP : 6307**

Name of the Course: B.Sc. Physical Sciences - Core - CBCS

Semester: III

Name of the Paper: Thermal Physics and Statistical Mechanics

Unique Paper Code: 42224303

Duration: 3 Hours

Maximum Marks: 75

Instruction for candidates

Attempt any *five* questions in all. Question No.1 is compulsory. All questions carry equal marks.

1. Attempt any *five* of the following: 5x3 = 15

(a) Write the Zeroth law of thermodynamics and give its physical significance.
(b) Derive an expression for work done during an adiabatic process.
(c) At what temperature, pressure remaining constant, will the rms velocity of hydrogen gas be double of its value at NTP?
(d) Derive any one of the TdS equations.
(e) Using the first law of thermodynamics, establish $C_V - C_P = R/J$.
(f) Distinguish M-B, B-E and F-D statistics in tabular form.

2 (a) Describe the construction and working of Carnot's reversible heat engine and find an expression for its efficiency.

(b) The efficiency of Carnot engine is $^1/_6$. On reducing the temperature of the sink by 60 °C, The efficiency increases to $^1/_3$. Find the temperatures of the hot and cold reservoirs between which the cycle is working. 10,5

3. (a) What are the limitations of first law of thermodynamics? Give Kelvin-Planck and Clausius statements of the second law of thermodynamics and show the equivalence of the two statements.

(b) Find the total change in entropy upon the conversion of 10 g of ice at −20 °C into steam at 100 °C. Given: specific heat of ice = 0.5 *cal/g/K*, latent heat of ice = 80 *cal/g*, latent heat of steam = 539 *cal/g*.

10,5

4. (a) Define the four thermodynamic potentials. Derive Maxwell's four thermodynamic relations by using them.

(b) Using suitable thermodynamic relations, derive the two energy equations.

10,5

5 (a) Derive Maxwell's distribution law of molecular velocities. Hence derive the probability of finding the number of molecules having velocity between $v$ and $v + dv$.

(b) Prove that the root mean square speed of the gas molecule obtained on the basis of Maxwell's distribution law is $\sqrt{\frac{3kT}{m}}$ .

10,5

6. (a) Give a brief account of quantum theory of radiation. Based on this theory, derive the Planck's law of black body radiation.

(b) Show that Wein's law and Rayleigh Jean's law are special cases of Planck's law.

10,5

7. (a) Beginning with basic assumptions, derive an expression for the Bose- Einstein distribution function.

(b) Derive the relation S = k log$W$ where S represents entropy, $W$ is thermodynamic probability and k is Boltzmann constant.

10,5

(6)

1066

**Name of Course** : **B.Sc. Hons. (Physics)_NEP:UGCF-2022**
**Semester** : **V**
**Name of the Paper** : **Electromagnetic Theory**
**Unique Paper Code** : **2222013501**
**Duration: 3 Hours**

**Maximum Marks: 90**

*(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 **five**.
Use of non-programmable calculator is allowed.

**1.** Attempt any 6 parts of the following: **6×3=18**

**(i)** Show that the time average Poynting vector for time varying fields is given by:

$$\langle \vec{S} \rangle = \frac{1}{2} Re\,(\vec{E} \times \vec{H}^*)$$

**(ii)** The electric field intensity for an electromagnetic wave is expressed as

$$\vec{E} = 120 \sin(10^{11}\, t)\, \hat{\imath}\; V/m$$

Calculate the magnitude of displacement current density and the conduction current density. Given: $\sigma$ =8.0 S/m and $\varepsilon_r$=1.

**(iii)** A light beam is incident from denser medium ($n_1$=2.0) on a rarer medium ($n_2$=1). Plot the reflection coefficients for the parallel and perpendicular components as a function of the angle of incidence.

**(iv)** What will be the minimum thickness of a calcite plate that would convert a plane polarized light of wavelength 8000 Å into circularly polarized light? (Given: $n_o$=1.5533 and $n_e$=1.5443).

**(v)** Show that if the electric field of the incident wave lies in the plane of incidence, the electric fields of the reflected and transmitted waves will also lie in the plane of incidence.

**(vi)** The refractive indices of quartz for right-handed and left-handed circularly polarized light of wavelength 7000 Å are 1.65207 and 1.65201 respectively. Calculate the rotation of plane of polarization of light produced by a plate of thickness 0.9 mm.

**(vii)** Show that a beam of plane polarized light may be regarded as composed of two equal and opposite circularly polarized light.

**2. (a)** State and establish Poynting's theorem for electromagnetic fields. Compare it with the equation of continuity and give an interpretation of the Poynting vector. **(10)**

**(b)** What are electromagnetic potentials? Discuss their non-uniqueness and hence explain the significance of gauge transformation. **(8)**

**3. (a)** Starting from Maxwell's equations in an isotropic, homogeneous dielectric material, show that electromagnetic waves are transverse in nature. Calculate the time average of momentum density stored in these fields. (12)

(b) Calculate the intrinsic impedance and wave velocity for a conducting medium with $\sigma$= 60 MS/m and $\mu_r$=1, at frequency of 120 MHz. (6)

4.(a) Derive Fresnel's relation for reflection and transmission of plane electromagnetic waves at an interface between two dielectric media when an electric vector of the incident wave is perpendicular to the plane of incidence. (10)

(b) A uniform plane wave is incident on planar boundary separating regions 1 and 2, with $\sigma_1=\sigma_2=0$ and $\mu_{r1}=\mu_{r2}=1$. Find the ratio of $\varepsilon_{r2}/\varepsilon_{r1}$, if 20 % of the incident wave energy is (a) reflected and (b) transmitted. (Assume normal incidence). (8)

5.(a) Distinguish between positive and negative crystals in terms of double refraction. How are these crystals used to make quarter wave plates? Explain how the quarter wave plate is used in producing elliptically and circularly polarized light. (12)

(b) Show that in an electrically anisotropic dielectric medium, the permittivity tensor is symmetric in nature. (6)

6. (a) Derive wave equation for $\vec{E}$ of electromagnetic wave in a symmetric planar dielectric wave guide with refractive index profile as:

$n = n_1$ , $-d/2 < x < d/2$

$n = n_2$ , $-d/2 > x > d/2$

($n_2 < n_1$) where d is the width of the guide.

Using the boundary conditions, obtain the eigenvalue equation for symmetric TE modes. (12)

(b) Find the state of polarization of electromagnetic wave having electric field vector: (6)

$$\vec{E} = 2\cos(\omega t - kz)\,\hat{\imath} - 2\cos\left(\omega t - kz - \frac{\pi}{2}\right)\hat{\jmath}$$

**Physical Constants :**

$\varepsilon_0 = 8.85\times10^{-12}$ Farad/m, $\mu_0 = 4\pi\times10^{-7}$ Henry/m

$c = 3\times10^8$ m/s, $m_e = 9.11\times10^{-31}$ kg

(7)

[This question paper contains 4 printed pages.]

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

**Sr. No. of Question Paper : 1104** **I**

Unique Paper Code : 2222013502

Name of the Paper : Quantum Mechanics – I

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

Semester : V

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 only **five (5)** questions.

3. Question No. **1** is compulsory.

4. **All** questions carry equal marks.

5. Use of non-programmable scientific calculator is allowed.



P.T.O.

1. Attempt any six : (6×3=18)

(i) Write the conditions required for physical acceptability of wave function.

(ii) What are stationary states? Why are they called so?

(iii) Let $\psi_0(x)$ and $\psi_2(x)$ are the ground state and second excited state energy eigen-functions of a particle moving in a harmonic oscillator potential with frequency ω. At t = 0, the wavefunction of the particle is

$\psi(x,0)=\frac{1}{\sqrt{3}}\psi_0(x)+\psi_2(x)$. Find $\psi(x, t)$ for $t \neq 0$.

(iv) List the four quantum numbers needed to describe an atomic electron? What is their physical significance?

(v) For 6g state of hydrogen atom, what are the values of quantum number n, l, $m_l$ and energy of the state?

(vi) Compute the commutator $[x\ p^2]$.

(vii) Show that (a) $[\hat{L}_x\ \hat{x}]=0$ (b) $[\hat{L}_x\ \hat{y}]=i\hbar\hat{z}$

2\. (i) Solve the Schrodinger equation for a particle having energy $E < V_0$ for a square well potential of finite depth $V_0$. Discuss the graphical representation of the transcendental equations.

(ii) Obtain the mathematical form of position operator in momentum space. (15,3)

3\. The potential energy of a simple harmonic oscillator of mass m, oscillating with angular frequency ω is $V(x) = \frac{1}{2} m\omega^2 x^2$.

(i) Write the time independent Schrodinger equation. Using the time independent schrodinger equation, evaluate the energy for the eigenstate

$\psi_0(\alpha x) = \sqrt{\frac{\alpha}{\pi^{1/2}}} e^{-\alpha^2 x^2}; \alpha = \sqrt{\frac{m\omega}{\hbar}}$, where ω is the angular frequency of the oscillator.

(ii) Find $\langle p \rangle$ for $\psi_0$.

(iii) If the harmonic oscillator is in the ground state at t=0, what will be the wavefunction at $t = \frac{\pi}{2\omega}$. (18)

4. Write the Schrodinger equation for a 3D hydrogen atom in spherical polar coordinates. Derive three separate equations for r, θ, ϕ using the method of separation of variables. Solve the equation for θ to obtain the normalized eigenfunctions. (18)

5. (i) What is spin angular momentum? Discuss the experimental observations which could not be accounted for without introducing the spin angular momentum.

(ii) What are Pauli Spin matrices. For $s = \frac{1}{2}$, obtain the matrix form of $S_z$.

(iii) What is total angular momentum? After defining ladder operator $J_+$ and $J_-$ obtain (a) $[\hat{J}_+ \ \hat{J}_-]$ (b) $[\hat{J}_+ \ \hat{J}_z]$. (6+6+6)

6. (i) Find $\langle r \rangle$ and $\langle r^2 \rangle$ for an electron in the ground state of the hydrogen atom? Express the answer in terms of Bohr radius.

(ii) At a given instant of time, a system is in the state $Y(\theta,\phi) = \sqrt{\frac{3}{4\pi}} \sin\theta \sin\phi$. Determine the expectation values of $L_z$ and $L^2$. (9,9)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 1123 I

Unique Paper Code : 2222013503

Name of the Paper : Digital Electronics

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

Semester : V

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. **All** questions carry equal marks.

1. Attempt any **Six** parts (all parts carry equal marks) (3×6=18)

(a) Write three differences between synchronous and asynchronous counters.



P.T.O.

(b) What are Passive and Active components in electronics? Explain giving appropriate examples.

(c) Why JK Master-Slave flip flop is preferred over level triggered JK latch?

(d) Explain the role of control voltage (pin 5) and reset (pin 4) in IC 555 timer.

(e) Subtract $(32)_{10}$ from $(12)_{10}$ using 2's complement method in 8-bit representation.

(f) Draw the circuit of a 5-bit even parity generator. Use the binary number 1100 and 0111 to generate the output.

(g) Realize a 2-input OR gate using diodes and resistors and briefly explain its working.

2. (a) A four variable truth table has high output when at least two input variables are in the high state. Draw the truth table and derive the minimized expression using Boolean algebra. Realize the logic circuit using 2-input NAND gates only.

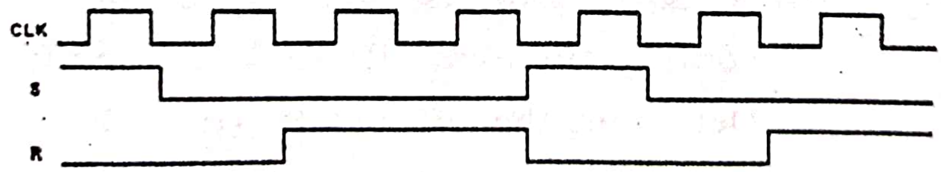
(b) Determine the minimized Boolean expression for the function: $F(A,B,C,D) = \sum m(0,8,9,10) + d(1,2,7)$ using K-map method and design the logic circuit using basic gates. (10,8)

3. (a) Implement and explain the working of a 4-bit binary addition and subtraction circuit that utilizes 2's

complement method for subtracting two numbers. Suppose the above circuit is used to subtract two binary numbers and generate carry 0 output and a sum output of 11001100. Explain how this circuit can be used to get the final answer.

(b) Implement a 16:1 Multiplexer using two 8:1 Multiplexers and explain briefly it's working. (Use only the simple block diagram of 8:1 multiplexer to implement the above). (10,8)

4. (a) Explain the working of a positive level triggered SR flip flop with the help of a circuit diagram and truth table. Explain why for S=1 and R=1 the Q output is unpredictable and lead to race condition. Draw the output waveform for the following conditions:




(b) Using the method of excitation table design the circuit of a JK flip flop using SR flip flop. Use block diagram of SR flip to draw the final circuit. (10,8)



P.T.O.

5. (a) Design a synchronous self-correcting MOD-6 count down counter using the method of excitation table. Use negative edge triggered JK flip flop to design the counter. The initial state of the counter is 000.

(b) Explain the difference between Serial-in-serial-out (SISO) and Serial-in-parallel-out (SIPO) shift registers? Explain the working of a 4-bit SISO shift register with suitable waveform, if the binary number $1100_2$ has to be shifted from the LSB side? (10,8)

6. (a) Draw circuit diagram of a monostable multivibrator using IC 555 timer and explain it's working. Derive the expression for pulse width during which it is in unstable state.

(b) IC 555 Timer is used to design a monostable configuration with R = 3.3 MΩ and C = 0.22 μF. Determine the pulse width (time for which output is high) of the output wave. Draw the waveforms across capacitor and at the output if the time period of the applied trigger input is half the above calculated pulse width. (10,8)

(9)

[This question paper contains 4 printed pages.]

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

I

Sr. No. of Question Paper : 5888

Unique Paper Code : 32221502

Name of the Paper : Solid State Physics

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

Semester : V (Reappear Paper)

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. **All** questions carry equal marks.

4. Question No. **1** is compulsory.

5. Attempt **four** questions from the remaining questions.



P.T.O.

1. Attempt any **five** parts.

(a) Write three points of difference between crystalline and amorphous solids. (3)

(b) Prove that for a SC lattice, $d_{100} : d_{110} : d_{111} = \sqrt{6} : \sqrt{3} : \sqrt{2}$; where 'd' represents interplanar distance in a crystal. (3)

(c) Calculate the Debye vibrational frequency of diamond. Assume the Debye temperature of diamond is 2230 K.

Given Plank's constant (h) = $6.6\times10^{-34}$ J-s and Boltzmann's constant ($k_B$) = $1.38\times10^{-23}$ J/K.

(3)

(d) Distinguish between conductors, semiconductors, and insulators on the basis of the band theory of solids, with suitable energy band diagrams. (3)

(e) State the difference between Diamagnetism, Paramagnetism and Ferromagnetism. (3)

(f) Define $1^{st}$ order and $2^{nd}$ order phase transitions with examples (3)

(g) Differentiate between Type I and Type II superconductors with the help of diagram. (3)

2. (a) Prove that the reciprocal lattice vector $G_{hkl}$ is perpendicular to the crystal plane (h, k, l) and that the inter planar spacing is

$$d_{hkl} = \frac{2\pi}{\left|\vec{G}_{hkl}\right|}$$

(b) Prove that reciprocal lattice of a FCC lattice is a BCC lattice. Name a lattice which is self-reciprocal.

(c) Determine Miller indices of a plane that makes intercepts of 2 Å, 3 Å and 4 Å on axes of an orthorhombic crystal with a : b : c = 4 : 3 : 2. (7,5,3)

3. (a) Derive Laue's Equations to describe the scattering of x-rays by crystal.

(b) A superconductor metal has a critical temperature of 3.7 K at zero magnetic field and a critical field of 0.0306 Tesla at 0K. Find the value of critical field at 2K. (10,5)

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

(b) Calculate the number of optical and acoustical phonon branches in a NaCl crystal containing two atoms per primitive unit cell. (10,5)

5. (a) Write down the basic assumptions of Drude's model for describing electron motion in metals. Obtain the expression for the Hall coefficient in a metal and explain the information it provides.

(b) The energy dispersion relation for an electron in a one-dimensional crystal with a lattice constant 'a' is given by $E(k) = \alpha - \beta \cos ka$, where $\alpha$ and $\beta$ are constants, and k is the wave vector. Find the effective mass ($m^*$) of the electron at the center of the first Brillouin zone (k=0). (10,5)

6. (a) Derive the expression for the magnetic susceptibility of a Diamagnetic material using Classical Langevin's theory.

(b) Show that the area of the B-H curve gives the Hysteresis energy loss. (9, 6)

7. (a) Explain the various sources of polarizability?

(b) Find the expression for the total polarizability of solids. (6,9)

(10)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 5977 **I**

Unique Paper Code : 32227502

Name of the Paper : Advanced Mathematical Physics – I

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

Semester : V

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. All questions carry equal marks.
4. Non-programmable Scientific calculator is allowed.

1. (a) Determine whether the set of real numbers equipped with the binary operation * defined by

$$a * b = a^b$$

forms a group or not. (5)



P.T.O.

(b) Let T be the linear transformation on $\mathfrak{R}^2$ defined by

$$T(x, y) = (2x + 3y,\ 2x - 5y)$$

and $S_1$ and $S_2$ be two bases of $\mathfrak{R}^2$ given by

$$S_1 = \{(1,0), (1,1)\},\ S_2 = \{(1,2), (2,1)\}$$

Find the matrix representation of T w.r.t. bases $S_1$ and $S_2$. (10)

2. (a) If H is a Hermitian matrix and I is the unit matrix of the same order as H, determine whether $A = (I - iH)(I + iH)^{-1}$ is a Unitary imatrix or not. (5)

(b) Given that eigenvalue of square matrix A is $\lambda$, prove that eigenvalue of matrix adj(A) is $\frac{|A|}{\lambda}$. (5)

(c) Find the values of x and y such that given matrix B is orthogonal :

$$B = \frac{1}{6}\begin{bmatrix} 1 & \sqrt{10} & x \\ -5 & \sqrt{10} & y \\ \sqrt{10} & 4 & \sqrt{10} \end{bmatrix}$$ (5)

3. (a) Find the eigenvalues and eigenvectors of the matrix C,

$$C = \frac{1}{6}\begin{bmatrix} 1 & 0 & 0 \\ 1 & 2 & 0 \\ -3 & 5 & 2 \end{bmatrix}$$

Can C be diagonalised or not? Give reason(s). (10)

(b) State Cayley-Hamilton theorem. Verify it for the matrix F and hence find $F^{-1}$, where

$$F = \begin{bmatrix} 2 & -1 \\ 3 & -1 \end{bmatrix}.$$ (5)

4. (a) Find $e^R$ for the matrix R, where

$$R = \frac{1}{2}\begin{bmatrix} 3 & 1 \\ 1 & 3 \end{bmatrix}$$ (7)

(b) Solve the coupled differential equations

$$\dot{y} = -y + 4y$$
$$\dot{z} = 3y - 2z$$

where, y(0) = 3, z(0) = 4 (8)

5. (a) Show that

$$\epsilon_{ijk}\,\epsilon_{kpq} = \delta_{ip}\,\delta_{jq} - \delta_{iq}\,\delta_{jp}$$

and hence prove that

$$\epsilon_{ijk}\,\epsilon_{ijk} = 6$$

(8)

(b) If $S = \begin{bmatrix} x_2^2 & x_1 x_2 \\ -x_1 x_2 & x_1^2 \end{bmatrix}$,

determine whether or not S is a Cartesian tensor of rank 2 in 2-dimension. (7)

6. Using tensors, prove the following :

(a) $\vec{A} \times (\vec{B} \times \vec{C}) = \vec{B}(\vec{A} \bullet \vec{C}) - \vec{C}(\vec{A} \bullet \vec{B})$ (7)

(b) $\vec{\nabla} \times (\vec{f} \times \vec{g}) = (\vec{g} \bullet \vec{\nabla})\vec{f} - (\vec{f} \bullet \vec{\nabla})\vec{g} + \vec{f}(\vec{\nabla} \bullet \vec{g}) - \vec{g}(\vec{\nabla} \bullet \vec{f})$ (8)

7. (a) Prove that divergence of a vector field transforms like a tensor of rank 2. (5)

(b) Obtain an expression for Moment of Inertia tensor. Also, prove that it is symmetric tensor of rank 2. (10)

8. (a) A covariant tensor has components ($xy$, $2y - z^2$, $xz$). Find its covariant components in spherical co-ordinates. (10)

(b) Find $g_{ij}$ and $g$ corresponding to $ds^2 = 5(dx^1)^2 + 3(dx^2)^2 + 4(dx^3)^2 - 6\, dx^1 dx^2 + 4\, dx^2 dx^3$. (5)

1249

Roll No. ..............................

Name of the Department : Department of Physics and Astrophysics

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

Name of the Paper : Communication Systems (**DSE paper**)

Semester : V- Semester

Unique Paper Code : 2223010015

Question paper Set number : Set I

Duration : 2 hours

Maximum Marks : 60 Marks

**Instructions for Candidates:**

*(a) Write your Roll No. on the top immediately on receipt of this question paper.*
*(b) Attempt **FOUR** questions in all. Question number one is compulsory.*
*(c) Non-programmable scientific calculator is allowed.*

**Q1** Attempt any five parts from this question. All questions carry same marks (3x5=15)

(a) State the difference between analog and digital modulation. Give one example of each.

(b) Determine the percent power saving when the carrier wave and one of the sidebands is suppressed in an AM wave modulated to a depth of 50%.

(c) Explain the need for modulation in communication?

(d) Draw PPM and PWM wave forms for a sinusoidal modulating signal.

(e) Why is the uplink frequency kept higher than the downlink frequency in satellite communication?

(f) What information is contained in the SIM number?

**Q2**

(a) Define Amplitude Modulation (AM) and write mathematical expressions for AM. The output signal from an AM modulator is.

$$V_{AM}(t) = 5\cos(1800\pi t) + 20\sin(2000\pi t) - 5\cos(2200\pi t)$$

Determine the following.

(i) Frequency and amplitude of modulating signal
(ii) Frequency and amplitude of carrier signal
(iii) Modulation index.

(iv) Ratio of the power in the sidebands to the power in the carrier. (7)

(b) Define the two types of angle modulation. (2)

(c) A single tone modulating signal cos $(15\pi 10^3 t)$ frequency modulates a carrier of 10 MHz and produces a frequency deviation of 75 KHz. Find the modulation index and phase deviation produced in FM wave. If another modulating signal produces a modulation index of 100 while maintaining the same deviation, find the frequency and amplitude of the modulating signal. Assume $k_f$=$15KHz/volt$. (6)

Q3

(a) State and prove sampling theorem. Calculate the Nyquist rate and sampling frequency for analog signal is expressed by the equation (7)

$$x(t) = 5\cos(100\pi t) + 10\sin(500\pi t) - 8\cos(300\pi t)$$

(b) What is Pulse Amplitude Modulation (PAM)? Draw the circuit of a Pulse Amplitude modulator and explain its working. List the disadvantages of PAM. (8)

Q4

(a) Sketch ASK, FSK and BPSK waveforms for the sequence: 1011011010. (3)

(b) Describe in detail the three basic operations involved in Pulse Code Modulation. (6)

(c) Distinguish between Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM). (6)

Q5

(a) Draw and explain the block diagram of transponder in a communication satellite. What are the advantages of a geostationary satellite? (8)

(b) Why is mobile phone called a cellphone? Explain the concept of cell sectoring and cell splitting in mobile communication? (7)

(2)

[This question paper contains 4 printed pages.]

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

**Sr. No. of Question Paper : 5979** **I**

Unique Paper Code : 32227504

Name of the Paper : Nuclear and Particle Physics

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

Semester : V

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. Use of Scientific Calculator is allowed.

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

   (i) Show that the nuclear density is independent of the mass number A. How can it be concluded that nuclear density is very high?

P.T.O.

(ii) What are the nuclear magic numbers? State the two basic assumptions of nuclear shell model.

(iii) A certain radioactive element disintegrates for an interval of time equals to its mean life. What is the remaining fraction that does not disintegrate?

(iv) Compare the photoelectric effect and Compton scattering in terms of the interactions between the incident photons and the target matters.

(v) What are the advantages offered by the semiconductor detectors over gas filled or scintillation detectors?

(vi) Why are the cyclotrons cannot be used to accelerate electrons? For a cyclotron, the r.f. potential applied across the dees is 20 KV and magnetic field of 1.10 T. If the maximum kinetic energy acquired by the protons is 4.56 MeV, then find radius of the dees.

(vii) Find the strangeness and hypercharge of a neutral elementary particle whose isotopic spin projection is ½ and baryon number is +1.

2. (a) Discuss Rutherford's $\alpha$-scattering experiment for the estimation of the nuclear size. Using the presently accepted empirical nuclear radius formula, determine the ratio of the nuclear radii of ${}^{4}_{2}H$ and ${}^{238}_{92}U$. (3+2=5)

(b) Define the binding energy (BE) and average binding energy (BE/A) of a nucleon. Draw the average binding energy versus mass number curve. Write the main features of this curve.

(4+2+4=10)

3. (a) Explain the concept of nuclear force. Why is the surface term more significant for the lighter nuclei in the liquid drop model? (3+2=5)

(b) Write the semi-empirical binding-energy formula and obtain the expression of the atomic number $Z_0$, the most stable isobar for a given mass number A. Identify the most stable isobar from the given isobars: $^6He_2$, $^6Be_4$ and $^6Li_3$.

(Given, $a_3 = 0.7053$MeV, $a_4 = 23.702$ MeV)

(2+7+1=10)

4. (a) Establish the relation between the mass of the parent atom and the mass of the daughter atom for the spontaneous positron emission. State the three differences of the electron capture from positron emission. (2+3=5)

(b) Explain how the alpha decay process is a quantum phenomenon. Write the decay equation of $^{222}_{86}Rn$ to $^{2218}_{84}Po$ with the emission of a-particle. Calculate the Q value of the decay and the kinetic energy of the $\alpha$-particle in MeV. (4+1+5=10)

5. (a) Why are the deuterons and neutrons used as bombarding agents in nuclear reactions? Write one each of deuteron induced and neutron induced nuclear reaction. (3+2=5)

(b) What is the significance of nuclear reaction cross section? The cross-section and the number of atoms per cubic meter of $Cd^{113}$ for capturing thermal neutrons are $2\times10^{-24}$ $m^2$ and $5.58\times10^{27}$ atoms/$m^3$. What thickness of $Cd^{113}$ is needed to absorb 99% of the incident beam of thermal neutrons? Is $Cd^{113}$ an efficient absorber of thermal neutrons? (3+6+1=10)

6. (a) How are the elementary particles divided into two main categories? Distinguish between baryons and mesons. (1+4=5)

(b) Give the qualitative description of Quark model of elementary particles. Write down the quark contents of protons, neutrons and pions. (5+5=10)

**Useful data:**

$r_0$ = 1.4fm, mass of the proton = $1.67\times10^{-27}$kg, M($^4_2$He) = 4.0028amu, M($^{222}_{86}$Rn) = 222.017531amu and M($^{218}_{84}$Po) = 218.008930amu

(200)

(13)

[This question paper contains 2 printed pages.]

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

I

**Sr. No. of Question Paper : 1566**

Unique Paper Code : 2222511101

Name of the Paper : Mechanics

Name of the Course : **B.Sc. Prog.**

Semester : I

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 **one** is Compulsory.

---

1. Attempt any **five** :

(a) What is the velocity of n-mesons whose observed mean life is $2.5\times10^{-7}$ sec. The proper mean life of these $\pi$-mesons is $2.5\times10^{-8}$ sec.

(b) Find the value of a if the vector force field $F = (y^2z^3-\alpha xz^2)\, i + 2xyz^3 j + (3xy^2z^2 - 6x^2z)\, k$ is conservative.

(c) Write the formula for Lorentz and inverse Lorentz transformations.

(d) State the law of gravitational attraction and hence define the gravitational constant G. Also write its dimensions.

(e) A light and heavy body has equal kinetic energies of translation. Which one has the larger momentum?

(f) State Newton's Laws of motion. Show that Newton's first law of motion is a special case of second law. (5×3=15)



P.T.O.

2. (a) Prove that $\nabla^2 (\ln r) = 0$. (8)

   (b) Solve : $(D^2+4)y = \sin 3x$. (7)

3. (a) What are central forces? Show that angular momentum of particle moving under the influence of central forces is always conserved. (8)

   (b) A neutron moving with a velocity of 106 m/s collides with a deutron at rest. After collision, the combined mass (titron) moves with a certain velocity. Calculate the velocity, if the mass of neutron is $1.67\times10^{-27}$ kg and the mass of the deutron is $3.34\times10^{-27}$ kg. (7)

4. (a) Derive a general differential equation of motion of a simple harmonic oscillator and obtain its solution. (8)

   (b) State Kepler's laws of planetary motion. Show that areal velocity of a planet around the sun is constant. (7)

5. (a) Describe Michelson-Morley experiment with suitable mathematical expression. (10)

   (b) Atomic particles in the form of a beam have a velocity of 95% speed of light. What is their relativistic mass compared with their rest mass? (5)

(14)

1478

**Name of the Department: Physics**

Unique Paper Code: 2222512301

Name of the Paper: Heat & Thermodynamics

Name of the Course: **B.Sc. (Prog.) Physical Science—NEP-UGCF**

Semester: III

Duration: 2 hours

Maximum Marks: 60

**Instructions for Candidates**

1. Write your Roll No. on the top immediately on the receipt of this question paper.
2. Question no. **1** is compulsory.
3. Attempt any **Four** questions including Question no. 1.
4. All questions carry equal marks.
5. Use of non-programmable scientific calculators is allowed.

1. Attempt any **5** of the following. Each part carries equal marks.
   a. Give the significance of T-S diagram of a Carnot's cycle.
   b. Define and obtain the expression for mean free path of a molecule of gas.
   c. Deduce Clausius Clapeyron latent heat equation from Maxwell's thermodynamic relation.
   d. Define entropy of a system with its physical significance.
   e. Derive Rayleigh Jeans law from Planck's law of black body radiation.
   f. Define Microstate and Microstate for a thermodynamic system.

(5×3 = 15)

2. (a) Describe the construction of Carnot Engine. Obtain the expression of efficiency of Carnot engine in terms of temperature of source and sink. (10)

   (b) A Carnot's engine whose low temperature reservoir is at 7°C has an efficiency of 50%. It is desired to increase the efficiency to 70%. By how many degrees should the temperature of high-temperature reservoir be increased. (5)

[This question paper contains 4 printed pages.]

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

Sr. No. of Question Paper : 6463 I

Unique Paper Code : 42354302

Name of the Paper : Algebra

Name of the Course : B.Sc. (Prog.) Physical Sciences/Mathematical Sciences

Semester : III DSC

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. This question paper has **six** questions in all.

3. Attempt any **two** parts from each question.

4. **All** questions are compulsory.

1. (a) Let $G = \left\{\begin{bmatrix} a & a \\ a & a \end{bmatrix} \middle| a \in \mathbb{R},\ a \neq 0\right\}$. Show that G is an abelian group under matrix multiplication. (6)

P.T.O.

(b) Describe the symmetries of an equilateral triangle and write the complete multiplication table for $D_3$. (6)

(c) Find orders of each of the elements of U(10). Show that it is cyclic and find all its generators. (6)

2. (a) State and prove Lagrange's theorem. Give statement of Fermat's little Theorem. (6.5)

(b) Prove that intersection of two subgroups is a subgroup. Is the union of two subgroups a subgroup? Justify your answer. (6.5)

(c) Define center of a group. Prove that center of a group G is a subgroup of G. (6.5)

3. (a) Find the order of each of the following permutations : (6)

(i) (124)(357)

(ii) $\begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 2 & 1 & 5 & 4 & 6 & 3 \end{bmatrix}$

(b) Let H be a subgroup of group G, and let a and b belong to G. Prove that aH = H if and only if $a \in H$. (6)

(c) Define a normal subgroup. Let

$H = \left\{\begin{bmatrix} a & b \\ 0 & d \end{bmatrix} : a, b, d \in \mathbb{R}, ad \neq 0\right\}$. Is H a normal subgroup of GL(2, $\mathbb{R}$)? Justify. (6)

4. (a) Let R be a ring with unity 1 and a is an element of R such that $a^2 = 1$. Let S = {ara: r ∈ R}. Prove that S is a subring of R. Does S contain 1? (6.5)

(b) Show that $\mathbb{R} \oplus \mathbb{R}$ is not an Integral Domain. (6.5)

(c) Let S = {a + ib: a, d ∈ $\mathbb{Z}$, b is even}. Show that S is not an ideal of $\mathbb{Z}[i]$. (6.5)

5. (a) Determine whether or not the set

$S = \left\{\begin{bmatrix} 2 & 1 \\ 1 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 1 \\ 1 & 2 \end{bmatrix}, \begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}\right\}$ is linearly independent over $Z_5$. (6)

(b) Find a basis and dimension for the subspace W of $\mathbb{R}^3$ defined by W = {(a, b, c) ∈ $\mathbb{R}^3$ | 2a – 3b + c = 0}. (6)

(c) Which of the following is a subspace of $\mathbb{R}^3$? Justify. (6)

(i) $W_1 = \{(a, b, c) \in \mathbb{R}^3 \mid a + b = c\}$

(ii) $W_2 = \{(a, b, c) \in \mathbb{R}^3 \mid a^2 + b^2 = c^2\}$.

6. (a) Define a linear transformation. Determine whether $T: \mathbb{R}^2 \to \mathbb{R}^2$ given by

$T([a, b]) = [2a - 3b, 3a + 4b]$ is a linear transformation or not. (6.5)

(b) Let $T: \mathbb{R}^3 \to \mathbb{R}^2$ be a linear transformation such that $T([1, -1, 0]) = [2,1]$, $T([0,1,-1]) = [-1,3]$ and $T([0,1,0]) = [0,1]$. Find $T([a, b, c])$ for any $[a, b, c] \in \mathbb{R}^3$. (6.5)

(c) Let $T: \mathbb{R}^3 \to \mathbb{R}^3$ be the linear transformation given by $T([a, b, c]) = [a, 0, a - b + c]$. Find a basis for ker(T) and a basis for range(T). Also, verify the rank-nullity theorem. (6.5)

(200

(16)

**Name of course: B.Sc. Prog. (Physics)_NEP:UGCF-2022**
**Scheme/Mode of examinations: V - Semester**
**Name of the paper: Elements of Modern Physics (DSC paper)**
**Unique paper code/subject code: 2222513501**
**Maximum Marks: 60**
**Duration: 2 hours**
SL. No of Q.: 1468

Attempt *four* questions in all. Q1 is compulsory. All questions carry equal marks. Use of non-programmable scientific calculator is allowed. You may use the values of physical constants provided in the end.

**Q1** Answer any **five** of the following:

(i) What is Compton wavelength? Obtain its value.

(ii) Define work function of a metal. Radiation of wavelength 5400 Å falls on a metal plate with work function 1.9 eV. Find the kinetic energy of emitted photoelectrons and their stopping potential.

(iii) Which law explains the continuous spectrum emitted by a Blackbody? Write its expression. Draw the energy distribution curve between wavelength ($\lambda$) and energy density ($E_\lambda d\lambda$) at two different temperatures.

(iv) Evaluate the commutator of position and momentum operators.

(v) Define mass defect and binding energy. Draw the graph between Binding energy per nucleon and atomic mass number.

(vi) State Moseley's law and write its significance. [5x3]

**Q2** (a) State Heisenberg uncertainty principle and derive it for position and momentum, using the concept of matter wave packet. An electron moves with a speed of 300 m/s with an accuracy of 0.01%. Find the accuracy with which position of electron can be located.

(b) Describe gamma ray microscope thought experiment to validate Uncertainty principle. [9,6]

**Q3** (a) The wave function for a free particle is given by

$$\psi(x,t) = A\exp[-i/\hbar(Et - px)],$$

where symbols have their usual meanings. Obtain momentum (p), energy (E) and Hamiltonian (H) operators based on this wave function and hence obtain one- dimensional time dependent Schrodinger equation. [9]

(b) What is Normalized wave function? Obtain the normalisation constant for wave function ($\Psi$) of a particle confined to a box of width L. Given

$\Psi_n = A \sin(n\pi x/L)$ and $0 < x < L$ [6]

**Q4** (a) Explain how Sommerfield theory could overcome the limitations of Bohr's atomic theory. [7]

(b) Write a relation between wavelength and Rydberg Constant (R) for hydrogen spectra and hence find and name the series whose wavelength lies in the visible region of electromagnetic spectrum. Also find the shortest and longest wavelengths of this series. [5]

(c) State Bohr's correspondence principle. [3]

**Q5** (a) Describe in detail the construction and working principle of Van de Graaff generator using a well labelled diagram [7]

(b) Obtain semi-empirical mass formula to calculate the binding energy of a nucleus. Describe all the five terms used in the formula. [8]

**Useful physical constants**
**$h = 6.62 \times 10^{-34}$ Js,**
**Rest mass of electron, $m_e = 9.1 \times 10^{-31}$ kg**
**$c = 3 \times 10^8$ m/s**
**Rydberg's constant (R) = $1.097 \times 10^7$ $m^{-1}$**

This question paper contains 3 printed pages]

Roll No. | | | | | | | | | | | |

S. No. of Question Paper : **6344**

Unique Paper Code : **42357501**

Name of the Paper : **Differential Equations**

Name of the Course : **B.Sc. (Prog.) Physical Sciences/Mathematical Sciences**

Type of the Paper : **DSE**

Semester : **V**

Duration : **3 Hours** Maximum Marks : 7:

*(Write your Roll No. on the top immediately on receipt of this question paper.)*

Attempt any *two* parts from each question.

Use of simple calculator is allowed.

1. (*a*) Determine the constant A such that the equation :

$$(x^2 + 3xy)dx + (Ax^2 + 4y)dy = 0$$

is exact. Solve the resulting exact equation.

(*b*) Solve the differential equation $\frac{dy}{dx} - \frac{y}{x} = -\frac{y^2}{x}$.

(*c*) Solve the differential equation $(1 - x^2)\frac{dy}{dx} + xy = xy^2$. 6+6

2. (*a*) Find the orthogonal trajectories of the family of curves $y = ax^n$, $a$ being the parameter.

P.T.O.

(*b*) Prove that if $f_1(x)$ and $f_2(x)$ are two solutions of $a_0(x)\frac{d^2y}{dx^2} + a_1(x)\frac{dy}{dx} + a_2(x)y = 0$, then $c_1f_1(x) + c_2f_2(x)$ is also a solution of this equation, where $c_1$ and $c_2$ being arbitrary constants.

(*c*) If $y = x$ is a solution of the equation :

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

find a linearly independent solution by reducing the order. Write the general solution.

6+6

3. (*a*) Solve the initial value problem :

$$\frac{d^3y}{dx^3} - 5\frac{d^2y}{dx^2} + 7\frac{dy}{dx} - 3y = 0, \; y(0) = 1, \; y'(0) = 0, \; y''(0) = -5.$$

(*b*) Use the method of variation of parameters to solve the equation :

$$\frac{d^2y}{dx^2} - 2\frac{dy}{dx} = e^x \sin x.$$

(*c*) Find the general solution of $(2x+1)(x+1)\frac{d^2y}{dx^2} + 2x\frac{dy}{dx} - 2y = (2x+1)^2$, given that $y = x$ and $y = (x+1)^{-1}$ are linearly independent solutions of the corresponding homogenous equation.

6+6

4. (*a*) Find the general solution of the equation $x^2\frac{d^2y}{dx^2} - 2x\frac{dy}{dx} + 2y = x^3$.

[This question paper contains 8 printed pages.]

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

Sr. No. of Question Paper : 6345 I

Unique Paper Code : 42357502

Name of the Paper : Mechanics and Discrete Mathematics (DSE)

Name of the Course : **B. Sc. (Prog.) Physical Sciences/ Mathematical Sciences**

Semester : V

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 all questions by selecting two parts from each question.

3. Parts of question to be attempted together.

4. Use of Calculator not allowed.

P.T.O.

[This question paper contains 8 printed pages.]

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

**Sr. No. of Question Paper : 6345** **I**

Unique Paper Code : 42357502

Name of the Paper : Mechanics and Discrete Mathematics (DSE)

Name of the Course : **B. Sc. (Prog.) Physical Sciences/ Mathematical Sciences**

Semester : V

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 all questions by selecting two parts from each question.

3. Parts of question to be attempted together.

4. Use of Calculator not allowed.

P.T.O.

1. (a) Three forces of equal magnitude $P$ act on a particle such that their directions are parallel to the sides $BC$, $CA$ and $AB$ of a triangle $ABC$. Show that the magnitude of their resultant $R$ is

$$R = P(3 - 2\cos A - 2\cos B - 2\cos C)^{1/2}.$$

(7.5)

(b) Find the centre of gravity of a sector of a circle subtending an angle $2\alpha$ at the centre. (7.5)

(c) Two light rings can slide on a rough horizontal rod. The rings are connected by a light inextensible string of length a, to the mid-point of which is attached a weight $W$. Show that the greatest distance between the rings, consistent with the equilibrium of the system is $\frac{\mu a}{\sqrt{1+\mu^2}}$, where $\mu$ is the coefficient of friction between either ring and the rod. (7.5)

2. (a) A particle travels along a straight line with constant acceleration 'a'. Prove that, $v = u+at$, $s = ut+\frac{1}{2}at^2$ and $v^2 = u^2 + 2as$, where s is the

distance covered from the instant $t = 0$, $u$ is the initial velocity and v is the final velocity (7.5)

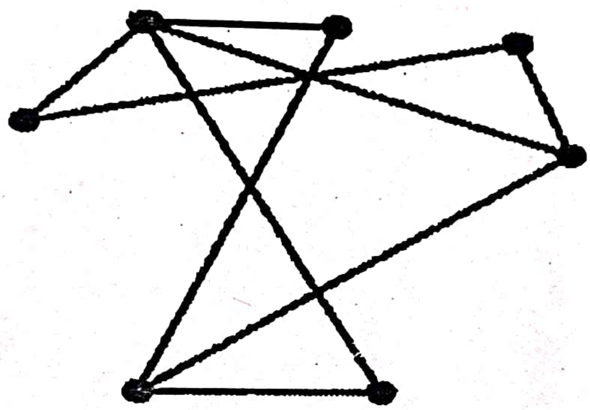
(b) A uniform bar $AB$, 10 feet long is hinged at B and is supported in a vertical plane by a light string $AC$ 10 feet above $B$. If $AB$ weighs 20 lbs and $AC = 15$ feet, find the tension in $AC$ and the reaction at $B$. (7.5)

(c) A light ladder is supported on a rough floor and leans against a smooth wall. How far up the ladder can a man climb without slipping taking place? (7.5)

3\. (a) (i) The speed of a particle moving along $x$-axis is given by $v^2 = 16 - x^2$. Prove that the motion is simple harmonic and find its amplitude. (4)

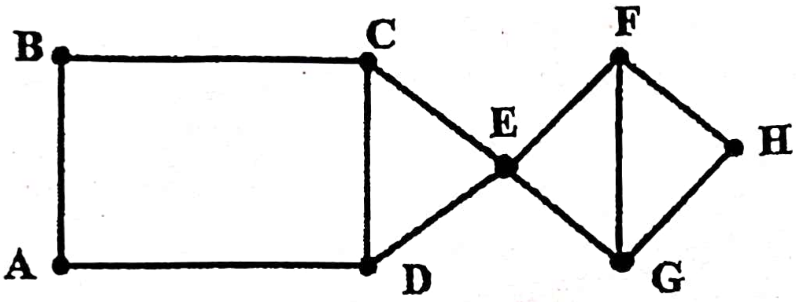
(ii) A point moving in a straight line with SHM has velocities $v_1$ and $v_2$ when its distance from the centre are $x_1$ and $x_2$ respectively. Show that the period of motion is $2\pi\sqrt{\frac{x_2^2-x_1^2}{v_2^2-v_1^2}}$. (3.5)

(b) Define a bipartite graph and a complete bipartite graph? Determine whether the graph given below is bipartite. Give the bipartition sets or explain why the graph is not bipartite.



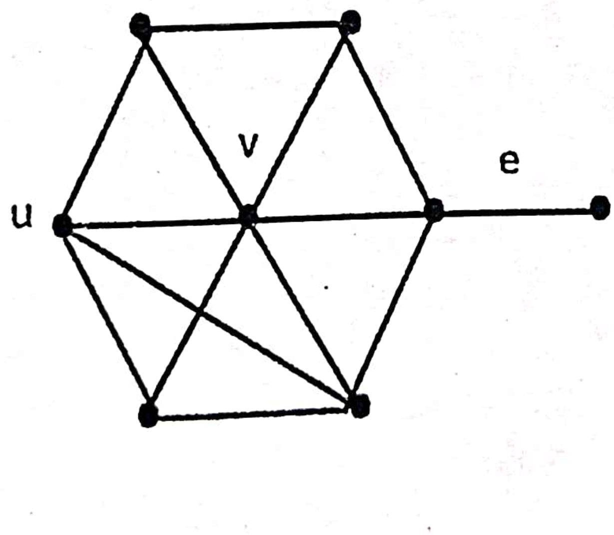
If bipartite then determine whether it is complete bipartite. (7.5)

(c) Define vertex connectivity $K(G)$ and edge connectivity $\lambda G$). Find $\kappa(G)$ and $\lambda(G)$ for the following graph and hence verify the relation $\kappa(G) \leq \lambda(G)$.




(7.5)

4. (a) (i) Define sub-graph of a graph. Draw pictures of the sub-graphs of G\{e}, G\{v} and G\{u} of the following graph G.

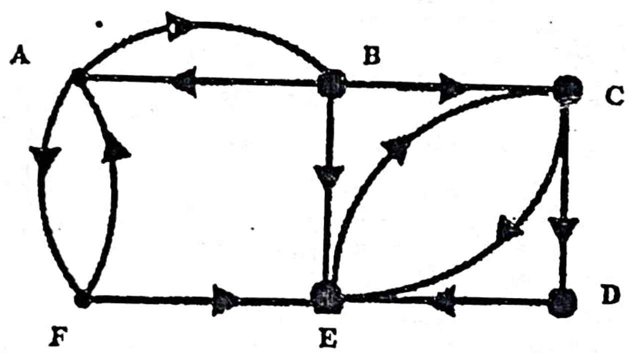



(4.5)

P.T.O.

(ii) Define a complete graph. Does there exists a graph G with 32 edges and 14 vertices; each of degree 6 or 7? Justify your answer. (3)

(b) Define strongly connected and weakly connected graph. Determine whether the following graph is strongly connected and if not, whether it is weakly connected. Justify your answer.




(7.5)

(c) Define degree of a vertex. Draw the following graphs:

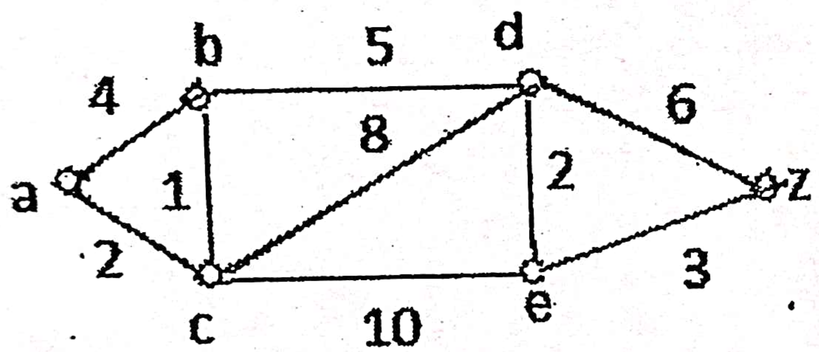
(i) $K_6$

(ii) $K_{2,5}$

(iii) $W_5$

Also find degree of each vertex. (7.5)

5. (a) Use Dijkstra's algorithm to find the length of a shortest path between a and z in the following weighted graph.




(7.5)

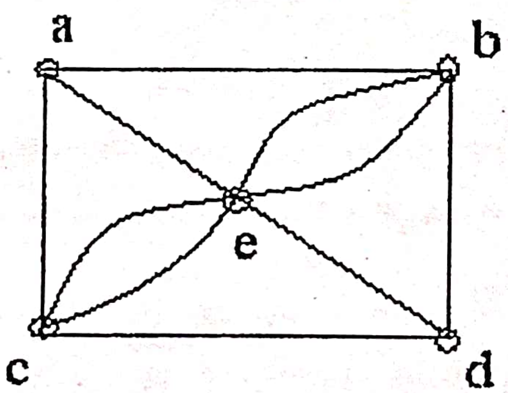
(b) (i) Define Hamiltonian Path with example. (2.5)

(ii) Define Hamiltonian Cycle with example. (2.5)

(iii) Define weighted graph with example. (2.5)

P.T.O.

(c) Determine whether the given graph has an Euler circuit. Construct such a circuit when one exists. If no Euler circuit exists, determine whether the graph has a Euler path and construct such a path if one exists.




(7.5)

(19)

This question paper contains 3 printed pages]

Roll No. [ ]

S. No. of Question Paper : 6447

Unique Paper Code : 42357501

Name of the Paper : Differential Equations

Name of the Course : B.Sc. (Prog.) Physical Sciences/Mathematical Sciences

Type of the Paper : DSE

Semester : V

Duration : 3 Hours Maximum Marks : 75

*(Write your Roll No. on the top immediately on receipt of this question paper.)*

Attempt any *two* parts from each question.

Use of simple calculator is allowed.

1. (*a*) Solve the differential equation $(x^2 + y^2)dx - 2xydy = 0$.

(*b*) Solve the differential equation $xdy + (xy + y - 1)dx = 0$.

(*c*) Solve the initial value problem $xy^2 \frac{dy}{dx} - 2y^3 = 2x^3$ when $y(1) = 1$. 6+6

2. (*a*) Find the orthogonal trajectories of the family of rectangular hyperbolas $xy = c^2$.

(*b*) Show that $e^x$ and $xe^x$ are linearly independent solutions of the differential equation $\frac{d^2y}{dx^2} - 2\frac{dy}{dx} + y = 0$ on the interval $-\infty < x < \infty$. Write the general solution. Find the particular solution for which $y(0) = 1$ and $y'(0) = 4$.

P.T.O.

(c) If $y = e^x$ is a solution of the differential equation $x\frac{d^2y}{dx^2} - (2x+1)\frac{dy}{dx} + (x+1)y = 0$, find a linearly independent solution by reducing the order. Write the general solution.

6+6

3. (a) Solve the initial value problem :

$$\frac{d^3y}{dx^3} - 2\frac{d^2y}{dx^2} + 4\frac{dy}{dx} - 8y = 0, \quad y(0) = 2, \quad y'(0) = 0, \quad y''(0) = 0.$$

(b) Use the method of variation of parameters to solve the equation :

$$\frac{d^2y}{dx^2} + 3\frac{dy}{dx} + 2y = 2e^x.$$

(c) Find the general solution of $(x^2 + 2x)\frac{d^2y}{dx^2} - 2(x+1)\frac{dy}{dx} + 2y = (x+2)^2$, given that $y = x + 1$ and $y = (x+1)^2$ are linearly independent solutions of the corresponding homogeneous equation.

6+6

4. (a) Find the general solution of the equation $2x^2\frac{d^2y}{dx^2} + 3x\frac{dy}{dx} - 3y = x^3$.

(b) Solve the following linear system of equations :

$$\frac{dx}{dt} + 2\frac{dy}{dt} - x + y = 0$$

$$2\frac{dx}{dt} + \frac{dy}{dt} + 2x + y = 3e^{-t}.$$

(c) Show that $x = 2e^{5t}$, $y = e^{5t}$ and $x = e^{-t}$, $y = -e^{-t}$ are two linearly independent solutions on every interval $a \le t \le b$ of the linear system $\frac{dx}{dt} = 3x + 4y; \frac{dy}{dt} = 2x + y$. Write the general solution.

6+

5. (a) Solve the following by the method of characteristics :

$$xu(u^2 + xy)u_x - yu(u^2 + xy)u_y = x^4.$$

(b) Use separation of variables $u(x, y) = f(x).g(y)$ to solve the following equation :

$$y^2u_x^2 + x^2u_y^2 = (xyu)^2.$$

(c) Find the partial differential equation arising from the following surface : 6.5+6.5

$$z = xy + f(x^2 + y^2).$$

6. (a) Classify the following equation and obtain the general solution by reducing it to canonical form :

$$x^2u_{xx} + 2xyu_{xy} + y^2u_{yy} + xyu_x + y^2u_y = 0.$$

(b) Reduce the following equation to canonical form :

$$y^2u_{xx} - x^2u_{yy} = 0.$$

(c) Find the solution of the following initial value system : $u_t + 3uu_x = v - x$; $v_t = cv_x$ with $u(x, 0) = x$ and $v(x, 0) = x$. 7+7

**Sr. No. of Question Paper :** 6461
**Name of the Course** : B.Sc. (Prog.) Physical Science- CBCS (DSE)
**Semester** : V
**Name of the Paper** :Elements of Modern Physics
**Unique Paper Code** :42227929
Duration :3 Hours Maximum Marks : 75

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

1. All parts are compulsory: [3x5 = 15]
(a) Explain zero-point energy with one example.
(b) Give the name of electromagnetic regions of Balmer, Lyman and Paschen Series of hydrogen spectrum.
(c) An electron has a speed of 600 m/s with an accuracy of 0.005 %. Calculate the certainty with which we can locate the position of the electron. [Given: h=6.6 x $10^{-34}$Js and m= 9.1 x $10^{-31}$ kg.]
(d) What are quantum dots? How are they related with quantum mechanics?
(e) The radius of nuclei having mass number 27 is 3.6 fermi. Calculate the radius of nuclei having mass number 216.

2. (a) Name an experiment which verifies existence of matter waves. Show that the wavelength of matter waves obtained from this experiment matches with the wavelength determined using de-Broglie hypothesis.

(b) When two ultraviolet beams of wavelengths $\lambda_1 = 80\ nm$ and $\lambda_2 = 110\ nm$ fall on a lead surface, they produce photoelectrons with maximum energies 11.39 eV and 7.15 eV, respectively. Estimate the numerical value of the Planck constant.

(c) In Compton Effect experiment, the wavelength of the X-ray scattered at an angle of 45° is 0.022 Å. Calculate the wavelength of incident X-ray.

(5, 5, 5)

3. (a) What are the shortcomings of Rutherford's atomic model and explain how Bohr's model overcomes these discrepancies.

(b) Show that the velocity of electron in first Bohr orbit is (1/137) times c, where 'c' is the velocity of the light.
(c) The wavelength of first spectral line of Balmer series of hydrogen atom is 656.3 nm. Estimate Rydberg constant and hence calculate the wavelength for the second spectral line.

(5, 5, 5)

4. (a) Write Einstein's photoelectric equation and explain why the process of photoelectric effect cannot take place with a truly free electron?

(b) Explain Heisenberg's energy-time uncertainty relation. The lifetime of an excited state of an atom is about $10^{-8}$ sec. Calculate the minimum uncertainty in the determination of the energy of the excited state.

(c) Calculate the de Broglie wavelength of an α- particle accelerated through a potential difference of 4 kV.

(5, 5, 5)

5. (a) In the double slit experiment of electrons, the diffraction pattern of only slit one opened is $\psi_I = M_I\, e^{-i(ky-\omega t)}/\sqrt{1+y^2}$ and when the only second slit is opened is $\psi_{II} = M_{II}\, e^{-i(ky+\pi y-\omega t)}/\sqrt{1+y^2}$, where $M_I$ and $M_{II}$ are the normalization constants that need to be found. Calculate the intensity detected on the screen when:

(i) both slits are open and a light source is used to determine which of the slits the electron went through, and

(ii) both the slits are open and no light source is used.

(b) If $f(x) = e^{\alpha x}$, where α is some constant, show that $f(x)$ is an eigen function of the operator $\frac{d^2}{dx^2}$. Also find the eigenvalue.

(10, 5)

6. (a) Obtain the reflection and transmission coefficients of electrons incident on a potential step when the energy of the incident particles is relatively more than the energy of the potential step.

(b) Calculate the permitted energy levels of an electron trapped in a box of 1 Å width.

(10, 5)

7. (a) Show that pair production cannot occur in empty space.

(b) Calculate the energy released in MeV for the following fusion reaction:

$${}^{2}H_{1} + {}^{2}H_{1} \rightarrow {}^{1}H_{1} + {}^{3}H_{1} + Q$$

Given: Mass of ${}^{2}H_{1}$ = 2.014102 amu,
Mass of ${}^{1}H_{1}$ = 1.007825 amu,
Mass of ${}^{3}H_{1}$ = 3.016040 amu

(c) One gram of radioactive substance disintegrates at the rate of $3.7 \times 10^{10}$ disintegrations per second. The atomic weight of the substance is 226. Calculate its mean life.

(5, 5, 5)

**Constants:**

h= $6.62 \times 10^{-34}$ J.s

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

e= $1.6 \times 10^{-19}$ C

$m_e$= $9.1 \times 10^{-31}$ kg