3/12/19 M

This question paper contains 4+2 printed pages]

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

S. No. of Question Paper : **7483**

Unique Paper Code : **32221301** **J**

Name of the Paper : **Mathematical Physics-II**

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

Semester : **III**

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

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

Section-A

1\. (*a*) Write a general expression for the Fourier series of a function $f(x)$, such that $f(x) = f(x + 2L)$, $-L < x < L$. Which terms will be missing if $f(x)$ is an even function ? Justify mathematically. 6

Or

Evaluate $\int_{-L}^{L} \cos \frac{p\pi x}{L} \cos \frac{q\pi x}{L}\, dx$ for : 6

(*i*) $p = q \neq 0$

(*ii*) $p \neq q$.

(*b*) Plot the periodic function defined by : 2,6,4

$$f(x) = -\pi, \quad -\pi < x < 0$$

$$f(x) = x, \quad 0 < x < \pi$$

Find the Fourier series of this function and hence prove that :

$$\frac{\pi^2}{8} = \frac{1}{1^2} + \frac{1}{3^2} + \frac{1}{5^2} + \ldots$$

(*c*) What is the period of sin *nx* and that of tan *x*. 2

Or

If $f(t + T) = f(t)$, then show that :

$$\int_a^b f(t)dt = \int_{a+T}^{b+T} f(t)dt.$$

Section-B

2\. (*a*) Classify the point $x = 0$ as a regular or irregular singular point for the differential equation : 3

$$x^2 \frac{d^2y}{d^2x} + \sin x \frac{dy}{dx} + e^{-x} y = 0.$$

(*b*) Solve the following differential equation about $x = 0$, using Frobenius method : 12

$$x\frac{d^2y}{dx^2}+2\frac{dy}{dx}+xy=0.$$

Or

$$x^2\frac{d^2y}{dx^2}+x\frac{dy}{dx}+\left[x^2-\frac{1}{4}\right]y=0$$

3. Attempt any *two* parts : 2×7.5=15

(*a*) Prove that :

$$J_n(x)=\frac{1}{\pi}\int_0^{\pi}\cos(n\theta-x\sin\theta)d\theta,\ n=0,1,2\ldots$$

(*b*) Expand $f(x) = x^2 - 3x + 2$ in a series of the from $\sum_{k=0}^{\infty} A_k P_k(x)$, using $P_0(x) = 1$, $P_1(x) = x$, $P_2(x)=\frac{3x^2-1}{2}$

(*c*) Using the generating function for Bessel's Polynomials or otherwise, prove that :

$$xJ'_n(x)=-nJ_n(x)+xJ_{n-1}(x)$$

(*d*) Obtain an expression for $P_4(x)$ using appropriate formula.

Section-C

4. Attempt any *one* part : 1×5=5

(*a*) Evaluate :

$$\int_0^1 \frac{dx}{\sqrt{-\ln x}}$$

(*b*) Evaluate :

$$\int_0^a y^4 (a^2 - y^2)^{1/2} dy$$

(*c*) Prove that :

$$\int_0^\infty \frac{x^{m-1}}{(a+bx)^{m+n}} dx = \frac{1}{a^n b^m} \beta(m, n).$$

Section-D

5. (*a*) The solutions to 2-D wave equation are obtained as trigonometric functions as well as in terms of Bessel functions. Explain how trigonometric cosine function is different from the Bessel Function of Order Zero. Compare them in terms of :

(*i*) Periodicity

(*ii*) Amplitude

(*iii*) Zeros.

Indicate differences using a plot. 5

Or

Using the method of separation of variables, solve : 5

$$\frac{\partial u}{\partial y} = 2\frac{\partial^2 u}{\partial x^2}; \quad 0 < x < 3, \quad y > 0$$

Given $u(0, y) = u(3, y) = 0$, and $u(x, 0) = 5 \sin 4\pi x - 3 \sin 8 \pi x$.

(*b*) Find the steady state temperature, $u(x, y)$ of a rectangular plate $(0 < x < 1; 0 < y < 2)$ subject to the boundary conditions : $u(x, 0) = 0$, $u(0, y) = 0$, $u(1, y) = 0$, and $u(x, 2) = x$. 10

Or

Using the method of separation of variables, solve 1-D wave equation :

$$\frac{\partial^2 y}{\partial t^2} = c^2 \frac{\partial^2 y}{\partial x^2}$$

Subject to conditions $y(0, t) = 0$, $y(L, t) = 0$ and

$$y(x,0) = \begin{cases} x, & 0 < x < \frac{L}{2} \\ L - x, & \frac{L}{2} \le x \le L \end{cases}, \; y_t(x,0) = 0$$

where $y_t = \dfrac{\partial y}{\partial t}$. 10

(c) Show that $u(x, t) = e^{-8t} \sin 2x$ is a solution to $\dfrac{\partial u}{\partial t} = 2\dfrac{\partial^2 u}{\partial x^2}$ with the conditions $u(0, t) = u(\pi, t) = 0$, $u(x, 0) = \sin 2x$.

Or

Using the method of separation of variables, prove that the general solution of $\dfrac{\partial f}{\partial t} = 4\dfrac{\partial f}{\partial x}$ is given by :

$$f(x,t) = Ae^{k\left[\left(\frac{x}{4}\right)+t\right]}$$

where A and k are some constants 5

This question paper contains 8 printed pages]

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

S. No. of Question Paper : **7482**

Unique Paper Code : **32221102-OC** **J**

Name of the Paper : **Mechanics**

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

Semester : **I**

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.

Use of non-programmable scientific calculator is allowed.

1. Attempt any *five* of the following questions :

(*i*) Show that in the absence of external forces, the velocity of the centre of mass remains constant.

(*ii*) A body of radius R and mass m is rolling horizontally without slipping with speed v. It then rolls up a hill to a maximum height h. If $h = 3v^2/4g$, what is the moment of inertia of the body ?

P.T.O.

(*iii*) Show that a two body problem involving central force can always be reduced to a form of a one-body problem.

(*iv*) A particle of mass m moving along a path given by $\vec{r} = a\cos\omega t\,\hat{i} + b\sin\omega t\,\hat{j}$. Calculate the angular momentum about the origin.

(*v*) Find the centre of mass of a thin rod of length l whose density varies with distance x from one end as : $\rho = \rho_0 x^2/l^2$ where ρ_0 is a constant.

(*vi*) A 6000 kg rocket is set for vertical firing. If the gas exhaust speed is 1000 m/s, how much gas must be ejected each second to supply the thrust needed to overcome the weight of the rocket ?

(*vii*) Show that $\Delta s^2 = c^2\Delta t^2 - \Delta x^2 - \Delta y^2 - \Delta z^2$ is a Lorentz invariant.

(*viii*) Two spaceships approach each other, each moving with the same speed as measured by a stationary observer on the Earth. Their relative speed is $0.7c$. Determine the velocities of each spaceship as measured by the stationary observer on Earth. 5×3=15

2\. (*a*) A particle is projected from the top of a tower of height h with a velocity u at an angle α to the horizontal. Show that its range on a plane through the point of projection inclined at an angle θ below the horizontal through the point of projection is given by :

$$R = \frac{2u^2 \cos\alpha}{\cos^2\theta} \sin(\alpha + \theta)$$ 7

(*b*) A particle of mass m moves under a conservative force with potential energy $V(x) = cx/(x^2 + a^2)$, where c and a are positive constants. Find the position of stable equilibrium and the period of small oscillations about it. 5

(*c*) Show that inertial mass and gravitational mass are proportional to each other. 3

P.T.O.

3. (*a*) A particle of mass m_1 moving with velocity v_1 collides elastically with a particle of mass m_2 at rest in the laboratory frame. The scattering angle of mass m_1 as measured in laboratory frame is ϕ and the scattering angle of it as measured in C. M. frame is θ. Discuss the behavior of particle of mass m_1, giving proper geometric construction, when : 6

(*i*) $m_1 = m_2$

(*ii*) $m_1 >> m_2$

(*iii*) $m_1 << m_2$.

(*b*) Object A with mass m_1 is initially moving with a speed $v_{1i} = 3.0$ m/s and collides elastically with object B that has the same mass, $m_2 = m_1$ and is initially at rest. After the collision, object A moves with an unknown speed v_{1f} at an angle $\theta_{1f} = 30°$ with respect to its initial direction of motion and object B moves with an unknown speed v_{2f} at an unknown angle θ_{2f} w.r.t the initial direction of motion of m_1. Find the final speeds of each of the objects and the angle θ_{2f} 9

4. (*a*) Discuss the energy diagram for the planetary motion for all possible values of energy. 5

(*b*) Consider the motion of a particle of mass m under the influence of a force $\vec{F} = -k\vec{r}$, where k is a positive constant and $\vec{r}$ is the position vector of the particle :

(*i*) Prove that the motion of the particle lies in a plane.

(*ii*) Find the position of the particle as function of time, assuming that at $t = 0$, $x = a$, $y = 0$ and the velocity components $v_x = 0$, $v_y = v$.

(*iii*) Show that the orbit is an ellipse.

(*iv*) Find the period of motion of the particle.

(*v*) Does the motion of the particle obey Kepler's laws of planetary motion ? 7

(c) Prove that the angular momentum is conserved under the action of a central force. 3

5. (a) Establish the equation of motion of a damped harmonic oscillator explaining each term clearly. Solve the same for lightly damped case. 7

(b) Show that the average kinetic energy of a particle performing simple harmonic motion is equal to its average potential energy. 5

(c) The quality factor Q of a tuning fork is 5.0×10^4. Calculate the time-interval after which its energy becomes (1/10)th of its initial value. The frequency of the fork is 300 s^{-1}. (take $\log_e 10 = 2.3$) 3

6. (a) Consider the earth to be a sphere of radius R having angular speed ω. Prove that :

(i) The effective value of 'g' at latitude λ is given by $g_{eff} = g_0[1 - (2x - x^2) \cos^2 \lambda\ 1]^{1/2}$ where g_0 is the true acceleration due to gravity and $x = \omega^2 R/g_0$.

(ii) If $x << 1$; then $g_{eff} = g_0 - \omega^2 R \cos^2 \lambda$. 7,2 (*b*) Consider a body dropped from a height of 10 m, at a latitude of 30° N. Find, approximately, the horizontal deflection due to the Coriolis effect when it reaches the ground. Neglect air resistance. 3

(*c*) Calculate the fictitious force and the total force acting on a body of mass 5 kg relative to a frame moving with a downward acceleration of 2 m/s^2. 3

7. (*a*) Discuss how the null result of the Michelson-Morley experiment was explained. 5

(*b*) State the postulates of Einstein's special theory of relativity. Derive the Lorentz space-time transformation equations. Show that for the values of $v<<c$, Lorentz transformations reduces to the Galilean transformations. 8

(*c*) Explain space-like and time-like intervals. 2

8. (*a*) Why is classical expression for the kinetic energy not applicable in relativistic region ? Prove that relativistic kinetic energy is given by the relation $E_k = (m - m_0)c^2$. Also show that if $v << c$, it leads to the classical expression for kinetic energy. 8

(*b*) Two light sources A and B situated 10 meters apart flash light signals at an interval of one nanosecond. At what time interval will an observer travelling at a speed of $0.9c$ along the direction AB sees the two events ? 5

(*c*) What is a massless particle ? Give *two* examples. 2

7/12/19 M

[This question paper contains 4 printed pages]

Your Roll No. : ....

Sl. No. of Q. Paper : **8599** **J**

Unique Paper Code : 32221101

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

Name of the Paper : Mathematical Physics-I

Semester : I

Time : 3 Hours ***Maximum Marks : 75***

Instructions for Candidates :

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

(b) Question **NO. 1** is compulsory.

(c) Attempt **four** more questions out of the rest.

(d) Non-programmable calculators are allowed.

1. Do any **five** of the following : 5×3=15

(a) Determine the linear independence/linear dependence of e^x, xe^x, x^2e^x.

(b) Determine the order, degree and linearity of the following differential equation.

$$\frac{d^3y}{dx^3} + x^2\left(\frac{d^2y}{dx^2}\right)^2 = 0$$

(c) Find the are of the triangle having vertices at P (1,3,2), Q (2,-1,1) and (-1,2,3).

(d) Let $\vec{A}$ be a constant vector. Prove that $\vec{\nabla}\left(\vec{r}.\vec{A}\right) = \vec{A}$

P.T.O.

(e) Find the acute angle between the surfaces $xy^2z-3x-z^2=0$ and $3x^2-y^2+2z=1$ at the point $(1,-2,1)$

(f) A random variable X has probability density function

$$f(x) = \frac{1}{\sqrt{2\pi}} e^{-(x-5)^2/2}$$

$-\infty < x < \infty$

Find the mean

2. (a) Solve the simultaneous differential equations given below.

$$\frac{dy}{dt} = y \quad , \qquad \frac{dx}{dt} = 2y + x$$

(b) Two independent random variables X and Y have probability density functions $f(x) = e^{-x}$ and $g(y) = 2e^{-2y}$ respectively. What is the probability that X and Y lie in the intervals $1 < x \leq 2$ and $0 < y \leq 1$

The time rate of change of the temperature of a body at an instant t is proportional to the temperature difference between the body and its surrounding medium at that instant.

(c) Box A contains 8 items out of which 3 are defective. Box B contains 5 items out of which 2 are defective. An item is drawn randomly from each box. 5+5+5

(i) What is the probability that both the items are non-defective ?

(ii) What is the probability that only one item is defective ?

(iii) What is the probability that the defective item came from box A ?

3. Solve the following differential equations.

(a) $y'' + y = \sec x$ 8

(b) $(z + ye^{xy})dx + (xe^{xy} - 2y)dy = 0$ 7

4. (b) Solve the initial value problem. 8

(i) $y'' + 4y' + 8y = \sin x$

(ii) $y(0) = 1$, $y'(0) = 0$

(b) A metal bar at a temperature 100^0 F is placed in a room at a constant temperature of 0^0F. After 20 minutes the temperature of the bar is 50^0 F. Find : 7

(i) The time it will take the bar to reach a temperature of 25^0 F

(ii) Temperature of the bar after 10 minutes

5. (a) If v denotes the region inside the semicircular cylinder

$0 \leq x \leq \sqrt{a^2 - y^2} \quad 0 \leq z \leq 2a$

Evaluate $\iiint_v x\,dv$ 7

(b) 17 8

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

(b) Find the value of $\nabla^2(\ln r)$

(c) Prove that : 5

$$\iiint \frac{dv}{r^2} = \oiint_S \frac{\bar{r}.\hat{n}}{r^2}\, ds$$

Where v is the volume of region enclosed by surface

7. (a) Suppose $\vec{A} = (2y+3)\hat{i} + xz\hat{j} + (yz - x)\hat{k}$

Evaluate $\int_c \vec{A}.d\bar{r}$ along the following paths : 9

(i) $x = 2t^2$, $y = t$, $z = t^3$ from $t = 0$ to $t = 1$

(ii) The straight line from (0,0,0) to (0,0,1) then to (0,1,1) and then to (2,1,1)

(iii) The straight line joining (0,0,0) and (2,1,1)

(b) Evaluate $\iint \vec{A}.\hat{n}\, dS$

where $\vec{A} = z\hat{i} + x\hat{j} - 3y^2z\hat{k}$ and S is the Surface of the cylinder $x^2+y^2=16$ included in the first octant between $z = 0$ to $z = 5$ 6

This question paper contains 8+2 printed pages]

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

13/12/19 M

S. No. of Question Paper : **8619**

Unique Paper Code : **32221102** **J**

Name of the Paper : **Mechanics**

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

Semester : **I**

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

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

Question No. **1** is compulsory and carriers **19** marks.

Answer any *four* of the remaining six, each carrying **14** marks, attempting any *two* parts out of three from each question.

1. Attempt all parts of this question :

(*i*) Calculate the percentage contraction of a rod moving with a velocity 0.8c in a direction inclined at 45° to its own length. 3

(*ii*) A particle slides back and forth on a frictionless track whose height as a function of horizontal position x is given by $y = ax^2$, where $a = 0.92\ m^{-1}$. If the particle's maximum speed is 8.5 m/s, find the turning points of its motion. 3

P.T.O.

(*iii*) A space traveller weighs 80 kg on earth. Find the weight of the traveller on another planet whose radius is twice that of the earth and whose mass is 3 times that of the earth. 3

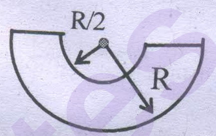
(*iv*) A rigid body is rotating about its axis of symmetry, its moment of inertia about the axis of rotation being 1 kg m^2 and its rate of rotation 2 rev/s. What is its angular momentum about the given axis ? What additional work will have to be done to double its rate of rotation ? 3

(*v*) A particle, moving in a straight line with S.H.M. of period $2\pi/\omega$ about a fixed point O, has a velocity $\sqrt{3}b\omega$ when at a distance b from O. Calculate its amplitude and the time it takes to cover the rest of its distance. 3

(*vi*) A 4800 kg elephant is standing at one end of a 15000 kg rail car, which is at rest all by itself, on a frictionless horizontal track. The elephant walks 19 m towards the other end of the car. How far does the car move ? 4

2. (i) (a) Find the location of the center of mass of a solid hemisphere of uniform density and radius R.

(b) Mass in the shape of a hemisphere of radius R/2 is removed from the hemisphere in part (a), as shown in the figure. Where is the center of mass of the remaining mass ? 4+3



(ii) Two particles having masses m_1 and m_2 move so that their relative velocity is v and the velocity of their centre of mass is v_{cm}. Prove that the total kinetic energy of the system is $(Mv_{cm}^2 + \mu v^2)/2$, where M is the total mass and μ is the reduced mass of the system. 7

(iii) An empty freight car of mass 500 kg starts from rest under an applied force of 100 N. At the same time sand begins to run into the car at a steady rate of

20 kg/s from a hopper at rest on the track. Find the speed of the car when 100 kg of sand has been transferred. 7

3. (*i*) Obtain an expression for the moment of inertia of a solid cylinder about an axis through its centre and perpendicular to its axis of cylindrical symmetry. 7

(*ii*) A ring of mass 0.3 kg and radius 0.1 m and a solid cylinder of mass 0.4 kg and of the same radius are given the same kinetic energy and released simultaneously on a flat horizontal surface such that they begin to roll as soon as released towards a wall which is at the same distance from the ring and the cylinder. Assuming that the rolling friction in both cases is negligible, find out which object reaches the wall first ? 7

(*iii*) A uniform rod of mass M and length L lies on a smooth horizontal plane. A particle of mass m moving at a speed v perpendicular to the length of the rod strikes it a distance L/4 from the centre and stops after the collision. Find :

(*a*) The velocity of the centre of the rod.

(*b*) The angular velocity of the rod about its centre just after collision. 4+3

4. (*i*) Derive the expression for the gravitational potential due to a spherical shell of radius R and mass M at a point outside the shell and also at a point inside the shell. Give its graphical representation. 7

(*ii*) A bead of mass m slides without friction on a smooth rod along the x-axis. The rod is equidistant between two spheres of mass M. The spheres are located at $x = 0$, $y = \pm a$ and attract the bead gravitationally :

(*a*) Find the potential energy of the bead.

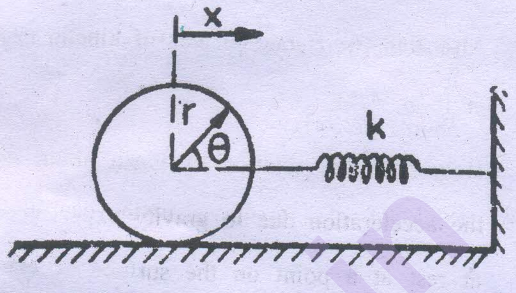
(*b*) The bead is released at $x = 3a$ with velocity v_0 towards the origin. Find the speed as it passes the origin.

(*c*) Find the frequency of small oscillations of the bead about the origin. 3+2+2

(*iii*) A particle of mass m moves in the central force field with the force function $f(r) = -Kr$, with $K > 0$. Find the effective potential energy and hence show that all the orbits are bounded. Find the radius and period of circular orbits, if any. 7

5. (*i*) What do you understand by 'logarithmic decrement', 'relaxation time' and 'quality factor' of a weakly damped harmonic oscillator ? Show that the average energy of a weakly damped harmonic oscillator decays exponentially with time. 3+4

(*ii*) A circular solid cylinder of radius r and mass m is connected to a spring of spring constant k as shown in the figure below.



Determine the frequency of horizontal oscillations of the system if the cylinder :

(*a*) Slips on the surface without rolling.

(*b*) Rolls on the surface without slipping.

Neglect friction. 3+4

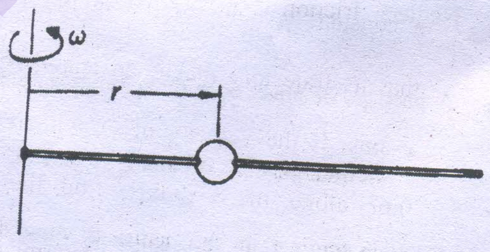
(*iii*) A particle of mass m with velocity v_0 collides elastically with another particle of mass M at rest, and is scattered through angle θ in the centre of mass frame. Show that the final velocity of mass m in the laboratory frame is :

$$v_f = \left(\frac{v_0}{m+M}\right)(m^2 + M^2 + 2mM\cos\theta)^{1/2}$$

Also find the fractional loss of kinetic energy of mass m if $m = M$. 7

6. (i) How does the rotation of Earth about its axis affect the acceleration due to gravity experienced by a body at rest at a point on the surface of earth ? Support your answer with a suitable derivation and diagram. 7

(ii) A bead of mass 'm' slides without friction on a rigid wire rotating at constant angular speed ω as shown in the figure. Find an expression for the force exerted by the wire on the bead that is initially at rest at a distance r_0 from the axis. 7



(*iii*) The space and time coordinates of two events as measured in frame S are :

Event 1 : $x_1 = x_0,\ t_1 = x_0/c,\ y_1 = z_1 = 0,$

Event 2 : $x_2 = 2x_0,\ t_2 = x_0/c,\ y_2 = z_2 = 0.$

Find the velocity of another frame S' in which the second event occurs by time $x_0/2c$ before the first event. 7

7. (*i*) Derive the expression for relativistic Doppler's effect. 7

(*ii*) A particle with a rest mass m_0 and kinetic energy $3m_0c^2$ makes a completely inelastic collision with a stationary particle of rest mass $2m_0$, without any radiation loss and the two particles forming a composite particle. What is the rest mass of the composite particle and its speed ? 7

(*iii*) (*a*) Suppose that a particle moves relative to O' with a constant velocity of $c/2$ in the $x'y'$-plane such that its trajectory makes an angle of 60° with the x'-axis. If the velocity of O' with respect to O is $0.6c$ along the x-x'-axis, find the equations of motion of the particle as determined by O.

P.T.O.

(*b*) Define proper time. What is time dilation ? With what velocity should a rocket move so that as observed from Earth every year spent on the rocket corresponds to 4 years on Earth ? 4+3

[This question paper contains 8 printed pages.]

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

Sr. No. of Question Paper : 7484A **J**

Unique Paper Code : 32221302

Name of the Paper : Thermal Physics

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

Semester : III

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. Answer any **four** of the remaining **six**, attempting any **two** parts from each question.

1. Attempt **all** parts.

(a) Which of the two, an isothermal or an adiabatic, has greater slope? Prove mathematically. (2)

(b) A Carnot's engine whose sink is at 27°C has an efficiency of 50%. By how much the temperature of the source be changed to decrease its efficiency to 40%? (2)

(c) One kilogram of water is heated from 0°C to 100°C and converted into steam at the same temperature. Calculate the increase in entropy. Given that specific heat of water is $4.18 \times 10^3\, Jkg^{-1}K^{-1}$ and latent heat of vaporisation is $2.24 \times 10^6\, Jkg^{-1}$. (3)

(d) Using Carnot's cycle derive Clausius-Clapeyron latent heat equation. (4)

(e) A substance has volume expansivity = 2bT/V and isothermal compressibility = a/V, where 'a' and 'b' are constants. Find the equation of state. (3)

(f) Define Boyle Temperature. Give relation between Boyle temperature, Temperature of inversion and Critical temperature. (2)

(g) What is Brownian motion? Give its characteristics. (3)

2. (a) (i) State first law of thermodynamics. What are its physical significance and limitations? Write first law of thermodynamics for an adiabatic, isobaric and isochoric processes. (4)

(ii) Derive the work done by an ideal gas in expanding adiabatically from initial state (P_i, V_i, T_i) to the final state (P_f, V_f, T_f}). (3)

(b) Using first law of thermodynamics, prove that

(i) $$\left(\frac{\partial U}{\partial P}\right)_V = \frac{C_V K_T}{\beta}$$

(ii) $$\left(\frac{\partial U}{\partial V}\right)_P = \frac{C_P}{\beta V} - P$$

Where β and K_T are volume expansion coefficient and isothermal compressibility respectively. (3.5,3.5)

(c) Find ΔW and ΔU for an iron cube of side 6 cm as it is heated from 20°C to 300°C. For iron $C = 0.11$ cal/g°C and volume coefficient of expansion is $\beta = 3.6 \times 10^{-5}\,{}^\circ C^{-1}$. Given, Mass of the cube is 1700 gm. (7)

P.T.O.

3. (a) What are reversible and irreversible processes? Give one example of each. Prove that if Kelvin-Planck statement of second law is violated then Clausius statement is also violated. (7)

(b) If, two Carnot engines R and S are operated in series such as engine R absorbs heat at temperature T_1 and rejects heat to the sink at temperature T_2, while Engine S absorbs half of the heat rejected by engine R and rejects heat to the sink at temperature T_3. If the work done in both the cases is equal, show that $T_2 = (T_3 + 2T_1)/3$. (7)

(c) (i) A refrigerator freezes 6 kg of water at 0°C into ice in a time interval of 20 min. Assume that room temp, is 25°C, calculate the power needed to accomplish it.

(ii) If coefficient of performance of a refrigerator is 5 and operates at the room temperature 27°C, find the temperature inside the refrigerator. (3.5,3.5)

4. (a) Define entropy. What is principle of increase of entropy? Find increase in entropy for reversible and irreversible processes. (7)

(b) If two bodies have equal mass *m* and heat capacity c, are kept at different temperatures T_1 and T_2 respectively, taking $T_1>T_2$ and the first body as source of heat for reversible engine and the second as sink, find out the maximum work done. (7)

(c) (i) The temperature variation of C_P is given by the relation $C_P = 0.4\ T - 0.05\ T^2 - 0.25$, in the temperature range 50 K to 100 K in cal/K. If 4 moles of the substance is heated from 50 K to 100 K, calculate the change in entropy.

(ii) An ideal gas is confined to a cylinder by a piston. The piston is slowly pushed such that the gas temperature remains at 20°C. During compression, 730 J of work is done on the gas. Find the entropy change of the gas. (3.5,3.5)

5. (a) What are thermodynamic potentials? Why are they so called? Give relations for them. Write physical significance of Gibb's free energy. (7)

(b) Apply Maxwell's relation to prove that the difference of isothermal compressibility and adiabatic compressibility is equal to $TV\beta^2/C_P$.

(c) Minute droplets of water are slowly pushed out of an atomizer into air. The average radius of the droplets is 10^{-4} cm. If 1 kg of water is atomized isothermally at 25°C, calculate the amount of heat transferred. The specific volume of water at 25°C is 1.00187×10^{-3} m^3kg^-1 and the rate of change of surface tension of water with temperature is -0.152×10^{-3} $Nm^{-1}K^{-1}$. (7)

6. (a) Define mean free path (λ) of molecules of a gas.

Derive the expression $\lambda = \frac{3}{4\pi\sigma^2 n}$. Where σ is the diameter of the gas molecules and n is the no. of molecules per unit volume. (Assuming that all molecules move with the same velocity i.e. the average velocity of the gas. (7)

(b) (i) Plot Maxwell distribution function for molecular speeds at temperatures T_1, T_2 and T_3 such as $T_1 < T_2 < T_3$. Write the necessary inference from these curves.

(ii) Calculate the value of v_x for which the probability of a molecule having x-velocity falls to half of its maximum value. (3,4)

(c) (i) Calculate the probability that the speed of oxygen molecule lies between 109.5 and 110.5 metre/sec at 300 K.

(ii) Hydrogen and Nitrogen are maintained under identical conditions of temperature and pressure. Calculate the ratio of their coefficients of viscosity if the diameters of these molecules are 2.5×10^{-10} m and 3.5×10^{-10} m respectively. (4,3)

7. (a) Discuss Joule-Thomson porous plug experiment. Obtain equation for Joule-Thomson co-efficient. (7)

(b) What are the limitations of Van der waal's equation of state. Draw and discuss similarities and dis-similarities of theoretical and experimental curves for CO_2 gas. (7)

(c) The Van der Waal's constant for Hydrogen are $a = 0.247$ *atm.* litre^{2}mol^{-2} and $b = 2.65 \times 10^{-2}$ *litre/mol*. Calculate

(i) The temperature of inversion

(ii) Joule Thomson coefficient for 2 atm fall of pressure, initial temp, being 100 K. Given $R = {}^{224}/_{273}$ atoms litre/mol/K. (7)

This question paper contains 8 printed pages]

16/12/19 M

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

S. No. of Question Paper : **7485-A**

Unique Paper Code : **32221303** **J**

Name of the Paper : **Digital Systems and Applications**

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

Semester : **III**

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

(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,

attempting any *two* parts from each question.

1. Attempt *all* parts of this question :

(*i*) Why two state operations is preferred for designing digital circuits ? Name *two* devices that you see around which exhibit two states. 3

(*ii*) Draw the circuit of a NOT gate using transistor and explain its working. 3

(*iii*) What do you understand by an instruction cycle and a machine cycle in 8085 microprocessor ? 3

(*iv*) Apply the duality theorem to the following expression : 2

(*a*) A(B + C) = AB + AC

(*b*) $A + \bar{A}B = A + B$

(*v*) Subtract 11001101 from 10110101 using 2's complement method. 3

(*vi*) What is the role of control voltage pin in IC 555 timer ? 2

(*vii*) Draw block diagram of a RAM chip and explain the role of each pin. 3

2. (*i*) (*a*) What do you understand by Digital and Linear ICs ? Give *two* examples of each. 4

(*b*) In an oscilloscope, a 100 V signal produces a deflection of 2 cm corresponding to a certain setting of vertical gain control. If another voltage produces 7.3 cm deflection for the same setting of the vertical gain control, what is the value of the voltage ? 3

(*ii*) Perform the following conversions :

(*a*) $(198.25)_{10}$ into Binary number and Hexadecimal number. 4

(*b*) $(324.24)_{10}$ into Octal number. 3

(*iii*) A three variable truth table produce logic 1 output when the number of 1s in the input variables is even. Generate the Truth Table for the problem considering the output as don't care for the terms for which the decimal equivalent of the input variables is 0, 1 and 2. Determine the simplest SOP equation for this truth table using K-Map method and design the logic circuit for the function using NAND gates and XOR gates only. 7

3\. (*i*) (*a*) Draw truth table and block diagram of a full subtractor circuit using half subtractors. 4

(*b*) The SUB input control signal of a full adder/subtractor circuit is connected to the output of a 4-input XOR gate. Tabulate the combinations of the XOR gate input variable for which the adder/ subtractor circuit perform the task of (*i*) Addition and (*ii*) Subtraction. 3

(*ii*) Design an encoder which generates the following truth table : 7

Input	Output
Y_1	A B C
0	0 0 0
3	0 0 1
1	0 1 0
7	0 1 1
2	1 0 0
6	1 0 1
5	1 1 0
4	1 1 1

(*iii*) Design a 4-bit serial-in-parallel-out shift right register using negative edge triggered D flip-flops. Display the timing diagram to store 4-bit binary number $(1101)_2$ assuming the register is initially all clear. How many number of clock pulses are required to store the number ? 7

4. (*i*) Draw the circuit of a clocked SR latch using NAND gates and explain its working. Why the S = 1 and R = 1 is called the forbidden condition ? 7

(*ii*) (*a*) Draw circuit diagram of a JK latch (using NAND gates) and discuss its truth table. 4

(*b*) Mention the methods by which the race around condition is avoided in JK latch. 3

(*iii*) Design a MOD-8 asynchronous down counter using negative edge triggered JK flip-flops. Draw the timing diagram of the counter assuming the initial state as 0000 and that the propagation delay of each flip-flop is 10 ns. The time period of the input clock pulse is 100 ns. 7

P.T.O.

5. (*i*) An instruction (MOV C, A) with the hex code 4F H is stored in the memory location 2006 H. Discuss the steps taken by the microprocessor in order to execute this instruction. What would be the content of the program counter (PC) register after the execution of this instruction ? 7

(*ii*) Explain with a timing diagram the following operation : 7

Memory Location	M/Code	Mnemonic
2000	06	MVI B, 52H
2001	52	

(*iii*) A memory bank uses a 16-line address bus and 8-line data bus. The first 32 KB of the memory is allocated to two ROM's of 16 KB each, and the remaining space to the RAM's of 8KB each. Write down the initial and final addresses of each chip in the entire memory map. 7

6\. (*i*) (*a*) What are flags ? If the accumulator contains 0BH and register C contain 05H, which flags are affected when CMP C is executed. 3

(*b*) If the clock frequency of a microprocessor is 5MHz, how much time is required to execute an instruction of 7 T states ? 4

(*ii*) What are the various general purpose registers present in microprocessor 8085 and explain their function ? What is the role of program counter (PC) and stack pointer (SP) registers ? 7

(*iii*) Write an assembly language program to subtract 5DH from FCH stored in memory locations 2006H and 2007H, respectively using indirect addressing mode. The difference is to be stored in the memory location 2008H and borrow in 2009H. 7

7. (*i*) Design an astable multivibrator circuit using IC 555 timer with the following specifications. The time period of the output waveform is 100 ms and duty cycle is 80%. Draw the output waveform and the voltage across the capacitor. 7

(*ii*) (*a*) Give the truth table of XOR and XNOR gates and explain their working as odd and even parity detectors. 4

(*b*) Discuss and explain the principle of error detection using parity method. What is the limitation of this method ? 3

(*iii*) A 5 MHz and 10 MHz square wave signal is fed to the J and K inputs of a JK flip-flop. Draw the timing diagram for the output Q assuming that the flip-flop is active all the time and is initially clear. 7

2/12/19 M

[This question paper contains 8 printed pages.]

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

Sr. No. of Question Paper : 7486A **J**

Unique Paper Code : 32221501

Name of the Paper : Quantum Mechanics and Applications

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

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 **Q.1** and all its parts are compulsory.

3. Attempt any **four** questions from the rest. Also, attempt any **two** parts out of **three** from each question.

4. Non-programmable calculators are allowed.

1. (a) Normalize the wave function, $\Psi(x) = e^{-|x|/a}$.
(3)

P.T.O.

(b) Write the Schrodinger equation for a system of two particles of masses m_1 and m_2 carrying charges e_1 and e_2 respectively in what kind of field? (2)

(c) Given that the position and momentum operators are Hermitian, verify whether the operator $\hat{x}^2 + \hat{x}\hat{p}_x$, is Hermitian. (3)

(d) Write the values of quantum numbers n, l, s, j, m_l for the following states :

(i) $2\,{}^2S_{1/2}$ (ii) $5\,{}^2F_{5/2}$. (3)

(e) Consider the state, $\psi = \sqrt{\frac{1}{10}}\phi_1 + \sqrt{\frac{3}{5}}\phi_2 + \sqrt{\frac{3}{10}}\phi_3$, where ϕ_n are orthonormal eigenstates of an operator $\hat{A}$. Find the expectation value of the operator $\hat{A}$ in the state ϕ, if it satisfies the eigenvalue equation $\hat{A}\phi_n = (2n^2 + 1)\phi_n$. (3)

(f) Write down the wave function for a system of (i) two Bosons and (ii) two fermions indistinguishable. (2)

(g) What is the probability that an electron in the state

$$\psi_{210} = \frac{1}{\sqrt{\pi}}\left(\frac{1}{a_0^{5/2}}\right) r e^{-r/2a_0} \cos(\theta)$$ of the hydrogen atom, exists between a distance of $3a_0$ to $6a_0$ from the nucleus. (3)

2. (a) (i) Set up the time dependent Schrodinger equation and hence derive the time independent Schrodinger equation. (4)

(ii) Starting with the Schrodinger equation in one dimension and using a de Broglie plane wave as a solution, show that when V = 0 this leads to the correct nonrelativistic relationship between energy and momentum. (3)

(b) For a Gaussian wave packet

$$\left(\psi(x) = Ae^{\frac{x^2}{4\alpha^2}} e^{-i(k_0 x - w_0 t)}\right)$$

corresponding to a free particle (i) Find the probability current density and (ii) Verify the continuity equation. (4+3)

P.T.O.

(c) (i) Explain spreading of a Gaussian wave packet for a flee particle in one dimension. (5)

(ii) Calculate the fractional change in the width of the wave packet in one second if the wave packet corresponds to a particle of mass 6.644×10^{-27} Kg. The initial width being of the order of 10^{-10} m. (2)

3. (a) Write the Schrodinger equation for a linear Harmonic oscillator and solve it to obtain the energy eigen values. (7)

(b) (i) A Harmonic Oscillator has a wave function which is a superposition of the ground state and the second excited state eigenfunctions $\psi(x) = \psi_0(x) + 2\psi_2(x)$.

Find the expectation value of the energy. (3)

(ii) Using the Uncertainty Principle show that the ground state energy for a Harmonic Oscillator is non-zero. (4)

(c) (i) An electron is confined in the ground state of a one-dimensional harmonic oscillator such that $\Delta x = 10^{-10}$m. Assuming that the average

Kinetic energy is equal to the average Potential energy, find the energy in electron volts required to excite it to the first excited state. (4)

(ii) For a linear harmonic oscillator in its ground state, show that the probability of finding it beyond the classical limits is approximately 0.16. (3)

4. (a) (i) Obtain the solution for the Legendre equation

$$\left(1-\xi^2\right)\frac{d^2P(\xi)}{d\xi^2}-2\xi\frac{dP(\xi)}{d\xi}+\lambda P(\xi)=0,$$

What are the conditions that need to be imposed so that the solutions are well behaved? What do the conditions imply. (4)

(ii) Verify whether the function $Y_{1,1}(\theta,\phi)$ = $-\sqrt{\frac{3}{8\pi}}\sin\theta e^{i\phi}$ is an eigenstate of the following angular momentum operator :

$$\hat{L}_x = i\hbar\left(\sin\phi\frac{\partial}{\partial\theta}+\cot\theta\cos\phi\frac{\partial}{\partial\phi}\right)$$ (3)

(b) Calculate $\langle V(r) \rangle = -\frac{e^2}{4\pi \in_0} \left\langle \frac{1}{r} \right\rangle$ for the first excited state of the hydrogen atom with the wave function

$$\left[\psi_{210} = \frac{1}{\sqrt{\pi}} \left\{ \frac{1}{2a_0} \right\}^{5/2} re^{-r/2a_0} \cos\theta \right].$$ (7)

(c) The electron in the hydrogen atom is replaced by a muon of mass $m_\mu \approx 200m_e$, where m_e is the mass of the electron. Determine the corresponding changes in the following :

(i) The Larmor frequency and hence the Zeeman splitting for the 2p level in the presence of a magnetic field of 1 Tesla. (Ignore the electron spin)

(ii) The wavelength of the corresponding H_α line. Will it be in the visible region? (Rydberg constant R = $1.097 \times 10^7 m^{-1}$ for the hydrogen atom) (3+4)

5. (a) Consider a particle trapped inside a one dimensional finite square well. Solve time independent Schrodinger equation for the system and obtain the bound state eigenfunctions. Discuss how the energy levels are obtained graphically. (7)

(b) (i) Derive the relationship between magnetic dipole moment and orbital angular momentum of an electron revolving around a nucleus. (3)

(ii) Explain space quantization. Calculate the possible orientation of the total angular momentum vector J corresponding to $j = 3/2$ with respect to a magnetic field along the z-axis. (4)

(c) (i) What is Larmor Precession? Derive the expression for Lannor frequency. (4)

(ii) A beam of electron enters a uniform magnetic field of flux density 1.2 tesla. Calculate the energy difference between electrons whose spins are parallel and antiparallel to the field. (3)

6. (a) (i) Explain Normal Zeeman Effect. (2)

(ii) Write the term diagram for the splitting of the yellow line of sodium $(1s^2,2s^2,2p^6)3s^1$ into two components D1 and D2. (2)

(iii) In a Stern-Gerlach experiment, a beam of hydrogen atom with velocity 3×10^3 m/s, passes through an inhomogeneous magnetic field of length 50 cm and having gradient of 200 T/m perpendicular to the direction of the incident beam. Find out the transverse deflection of the atoms at the point where the beam leaves the field. (Bohr magneton 9.24×10^{-24} J/T, $M = 1.67 \times 10^{-27}$Kg). (3)

(b) (i) Write down the normal electronic configuration of Carbon atom (Z = 6) and obtain the spectral terms arising from equivalent electrons. (4)

(ii) The quantum number of two optical electrons in a two valence electron atom are

$n_1 = 6,\ l_1 = 3,\ s_1 = 1/2$

$n_2 = 5,\ l_2 = 1,\ s_2 = 1/2$

assuming j-j coupling, find the possible values of J. (3)

(c) (i) What is spin orbit coupling. Calculate the change in the energy level due to this. (5)

(ii) Write the term symbol for the ground state of the hydrogen atom in the LS coupling scheme. (2)

12/12/19 M

[This question paper contains 7 printed pages]

Your Roll No. : ....

Sl. No. of Q. Paper : **7487-A** **J**

Unique Paper Code : 32221502

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

Name of the Paper : Solid State Physics

Semester : V

Time : 3 Hours ***Maximum Marks : 75***

Instructions for Candidates :

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

(b) Question No. **1** with all its parts is compulsory.

(c) Attempt any **four** from the remaining **six** questions.

(d) Out of three parts of question Nos. **2-7** attempt any **two** parts.

(e) Non-programmable scientific calculator is allowed.

P.T.O.

1. Attempt **all parts** of this question.

(a) Draw the lattice planes (121) and (211) in a crystal with a cubic unit cell. 2

(b) What is an essential condition for the Bragg Diffraction to occur? Determine the maximum wavelength for which Bragg Diffraction can be observed from a crystal with an atomic separation of 0.2 nm. 3

(c) What is the most important feature of dispersion curve that distinguishes diatomic lattice from a monoatomic lattice? State the reason. 2

(d) How are metals, semiconductors and insulators differentiated on the basis of band theory ? 3

(e) As number of domains in a ferromagnetic material increases, the total energy stored in the system decreases. Then why the domains with single atom do not occur preferably ? 3

(f) A superconducting lead has a critical temperature of 7.26 K at zero magnetic field and a critical field of 8 x10^5 A/m at 0 K. Find the critical field at 5 K. 3

(g) The susceptibility of a paramagnetic material is 1.2×10^{-5} at 300K. Find the susceptibility at 400K. 3

2. (a) What is the significance of reciprocal lattice as compared to normal lattice? Write the relation of the primitive translational vectors of the reciprocal lattice in terms of primitive translational vectors of the normal lattice. Prove that the reciprocal lattice vector $G = ha^* + kb^* + lc^*$ is perpendicular to the (hkl) plane. 2,2,3

(b) What is the importance of Geometrical Structure Factor in the analysis of the crystal structure? Calculate it for BCC and illustrate diagrammatically the absence of (100) reflection for a BCC lattice. 2,3,2

(c) Show that the concept of Brillouin zone (B.Z.) in crystals emerges from the interpretation of the Bragg's law $2\overline{K}.\overline{G} + G^2 = 0$. What significance one can attach to the Brillouin Zone with respect to the observations made from x-ray diffraction. 5,2

P.T.O.

3. (a) Explain quantization of lattice vibrations. Obtain dispersion relation for elastic waves in a linear monoatomic chain and show that in the short wavelength limit lattice behave as continuum and no dispersion takes place. 2,5

(b) How does Einstein assumptions lead to an improvement in the specific heat of a solid over the classical theory ? Explain its demerits. 5,2

(c) Copper has an atomic weight of 63.5, a density of 8.9×10^3 kg/m^3 and frequency of longitudinal and transverse modes are 4.76×10^3 m/s and 2.32×10^3 m/s. Estimate the specific heat of copper at 30K. 7

4. (a) Draw the potential experienced by an electron in a 1D monoatomic crystal lattice. How is this modified in Kronig Penney model? Set up the Schrodinger equation for an electron in this model and obtain the E-k relationship. 1,1,5

(b) Explain with the help of diagrams how the concept of effective mass is inherent to band theory. If energy of an electron in a crystal is given by $E = 7\hbar^2 k^2/m$. Calculate its effective mass. 4,3

(c) For an intrinsic semiconductor with gap width, $E_g = 0.7$ eV, determine the position of the Fermi level at 300 K if $m_h^* = 6m_e^*$ Also calculate the density of electrons and holes at 300K. 3,4

5. (a) Obtain an expression for diamagnetic susceptibility using Langevin's theory. What is the significance of negative susceptibility ? 6,1

(b) Ferromagnetic materials lose their magnetism on heating. Give a qualitative idea how various energies, involved in the total energy of a ferromagnet as per domain theory, contribution may get affected by the applied heat energy resulting in the density of magnetism. 7

(c) A magnetic substance has 10^{28}atom/m^3. The magnetic moment of each atom is 1.8×10^{-23}Am^2. Calculate the paramagnetic susceptibility at 300K. What would be the dipole moment of a bar of this material 0.1m along and 1sq.cm cross-section in a field of 4×10^4Am. 4,3

6. (a) Explain Polarizability of atoms and molecules. Derive Clausius –Mosotti relation between polarizability and dielectric constant of a solid. 2,5

(b) The value of dielectric constant for water is 81 at very low frequency (near to zero) and 1.8 at optical frequencies. Explain with diagram the possible reasons for this variation in the dielectric constant. 7

(c) Expand the Langevin's function for small values of the pE/kT and show that the zeroth order is absent. Explain why this makes physical sense. 7

7. (a) Explain Meissner Effect in superconductors with suitable diagram. Does it contradict Maxwell's equations? Support your answer with suitable reason. 2,1,4

(b) What do you understand by critical magnetic field of a superconductor? How is it dependent on temperature? A superconducting material has a critical temperature of 3.8 K in zero magnetic field and critical field of 0.0306 T at 0 K. Find the critical field at 2 K. 2,1,4

(c) (i) Calculate the Hall coefficient for sodium (Na) whose lattice constant is 0.428 nm. Sodium is bcc and will have two atoms per unit cell. 3

(ii) How one can show and validate the idea of the presence of electrons and holes in semiconductors using Hall effect. Explain with the help of diagram. 4

Values of Constants

$k_B = 1.3807 \times 10^{-23}\ JK^{-1}$

$N_A = 6.022 \times 10^{23}\ mol^{-1}$,

$h = 6.63 \times 10^{-34}\ Js$

$\mu_o = 4\ \pi \times 10^{-7}\ Hm^{-1}$

$\mu_B = 9.2732 \times 10^{-24}\ Am^2$

$\epsilon_o = 8.854 \times 10^{-12}\ Fm^{-1}$

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

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