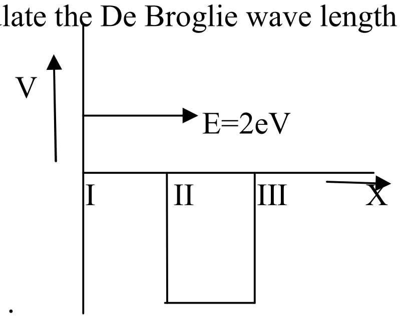
Delhi Institute for Administrative Services
India's Leading Institute for Civil Services Examination

CIVIL SERVICES EXAMINATION (MAINS) 2018
PHYSICS PAPER - II:QUANTUM MECHANICS
TUTORIAL SHEET: 1
Foundations of Quantum Mechanics

1. How Davisson - Germer electron diffraction experiment confirms the de -Broglie hypothesis of matter wave?**(1995)**
2. Using Heisenberg uncertainty principle, find the ground state energy and Bohr radius of hydrogen atom.**(1997)**
3. Using the uncertainty principle $\Delta x \Delta p \sim \frac{\hbar}{2}$, estimate the minimum energy of a particle in a simple harmonic potential $U = \frac{1}{2}kx^2$ **(1999)**
4. Find the de - Broglie wavelength associated with an electron of energy (i) 10 eV and (ii) 10 MeV **(1999)**
5. The momentum of an electron is 600 KeV/c. Determine its de Broglie wavelength and the phase and group velocities of its de Broglie waves.**(2000)**
6. A 200 eV increase in the energy of an electron changes its De Broglie wave length by a factor of two. Calculate the initial De Broglie wave length of the electron.**(2002)**
7. (i) Explain what do you understand by Heisenberg's uncertainty principle. Using this Principle, determine the energy of the ground state of a one dimensional simple harmonic Oscillator.
   (ii) An electron having an energy 2 eV is traveling in the region where V(x) varies as shown below:
   Calculate the De Broglie wave length of the electron in region I, II and III. **(2003)**



8. (i) If x and P_x are two conjugate variables, show that
   $$(\Delta x)(\Delta P_x) \geq |<[x,P_x]>/2i|$$
   (ii) An electron has a speed of 4×10^5 m/s, accurate to 0.01%. With what fundamental Accuracy can we locate the position of electron? **(2004)**

9. Calculate the wave length of neutrons at a temperature of 20º C.**(2004)**

10. Calculate the de Broglie wavelength of an electron moving with a kinetic energy of 1MeV.**(2005)**

11. Calculate the de Broglie wavelength of a thermal neutron at $27^0 C$ temperature. **(2006)**

12. (i) State and explain Heisenberg's uncertainty principle. Experimental data reveal that no electron in an atom has energy greater than 4 MeV. Assuming that the radius of a nucleus is 10^{-14} m, show using Heisenberg's uncertainty principle that an electron cannot exist inside the nucleus.
(ii) Calculate the de Broglie wavelength of thermal neutrons at 300 K. **(2007)**

13. Derive Bohr's angular momentum quantization condition in Bohr's atomic model from the concept of de Broglie waves. **(2010)**

14. Calculate the wavelength of De Broglie waves associated with electrons accelerated through a P.D. of 200 Volts. **(2011)**

15. Estimate the size of the hydrogen atom and the ground state energy from the uncertainly principle. **(2011)**

16. Use the uncertainly principle to estimate the ground state energy of a linear harmonic oscillator **(2012)**

17. In a series of experiments on the determination of the mass of a certain elementary particle, the results showed a variation of _+ (plus-minus) 20 m(e), where m(e) is the electron mass. Estimate the lifetime of the particle. **(2013)**

18. Find the deBroglie wave length of (i) a neutron (ii) and electron moving with kinetic energy of 500 eV .(1 eV = 1.602 x 10 ^-19 J) **(2014)**

19. The mean life of Lambda particle is 2.6 x 10^-10 s. What will be the uncertainty in the Determination of its mass in eV?**(2014)**

20. Find the energy, momentum and wavelength of photon emitted by a hydrogen atom making a direct transition from an excited state with n=10 to the ground state. Also find the recoil speed of the hydrogen atom in this process. **(2016)**

21. An electron is confined to move between two rigid walls separated by 10^{-9} m. Compute the de Broglie wavelengths representing the first three allowed energy states of the electron and the corresponding energies. **(2016)**

22. A typical atomic radius is about 5 x 10^{-15} m and the energy of β-particle emitted from a nucleus is at most of the order of 1 MeV. Prove on the basis of uncertainty principle that the electrons are not present in nuclei. **(2016)**

23. Using uncertainty principle, calculate the size and energy of the ground state hydrogen atom. **(2016)**

TUTORIAL SHEET: 2
Schrodinger's Wave equation and applications

1. Write down Schrodinger's equation in one dimension and explain the significance of the eigen values and eigen functions of this equation.
Solve the Schrodinger's equation if the potential function V is given as

$V(x) = V_o$ (a constant) for $|x| < \frac{a}{2}$.

a. $= 0$ for $|x| > \frac{a}{2}$

State the boundary conditions you use along with their justification. (In the solution consider particles incident from one side only). If the total energy $E < V_o$, show that there is an important difference with classical mechanics. Explain, with the help of the uncertainty principle that $E < V_o$ does not mean that kinetic energy is negative. **(1989)**

2. Set up Schrodinger's equation for a one-dimensional harmonic Oscillator. Assuming that the solution is of the form $\psi = Ae^{-\alpha x^2} f(x)$, where f (x) is a polynomial in x, find the energy Eigen values and the ground state Eigen function. Comment on the relation between the ground state energy and Heisenberg's uncertainty principle. **(1990)**

3. Set up Schrodinger's equation for a free particle confined in a cubical box and find the energy eigen values. What form will Pauli principle take for elections in such a box? Deduce the zero point energy if the length of the box be 10^{-10} metre and there be 10 electrons in it. (The coulomb interaction may be disregarded).**(1991)**

4. Using Schrodinger's equation show that a free particle in a box can have only discrete energy values. **(1992)**

5. Find the energy Eigen values of a one-dimensional harmonic oscillator whose Hamiltonian is given by $H = \frac{P^2}{2m} + \frac{1}{2}kx^2$ **(1994)**

6. An election is confined in a one - dimensional box of 1 A^o width. Draw the energy level diagram up to three energy states and also draw the corresponding normalized Eigen functions. Derive the expressions for Eigen functions and Eigen values used in the calculations. Show that Eigen functions are orthogonal. **(1995)**

7. An electron moving with energy E encounters one dimensional potential step as given below:

$V(x) = 0 \qquad x < 0$

$V(x) = V_0 \qquad x > 0$

(a) Suppose the election has the energy $E > V_0$ and is incident from -x direction, find the normalized wave function so it corresponds to unit incident flux.

(b) Solve the above problem for the case $E < V_0$ and discuss the significance of the result with the help of a suitable example. **(1996)**

8. Write down the time independent Schrodinger equation for the x < 0 and x > 0 in case of a step potential $V(x) = 0 \quad x < 0$
$= V_0 \quad x \geq 0$
Discuss the solutions thus obtained for the case $E > V_o$. Obtain the following relations

$$|R|^2 = \left(\frac{1-\mu}{1+\mu}\right)^2 \text{ and } \frac{K}{K_0}|T|^2 = \mu\left(\frac{2}{1+\mu}\right)^2$$

Where $\mu = \sqrt{1-\frac{V_0}{E}}$, R and T are reflection and transmission coefficients respectively.

Other symbols have their usual meanings. Plot the behaviorof $|R|^2$ and $\frac{K}{K_0}|T|^2$ with μ**(1997)**

9. An infinite square well potential is

$$V(x) = 0 \qquad -\frac{a}{2} < x < \frac{a}{2}$$
$$= \infty \qquad \frac{a}{2} < x < -\frac{a}{2}$$

Solve the time independent Schrodinger's equation and find the closed form expressions for the eigen - values and eigen functions of such a potential. Give a schematic representation of the first three energy levels and corresponding wave functions and probability distribution functions. Show that the zero-point energy is in accord with the uncertainty principle. **(1998)**

10. For a particle confined in a one - dimensional potential well of length L the wave function is $\psi(x) = C\, \text{Sin}\left(\frac{\pi x}{L}\right) \quad 0 < x < L$ and $\psi(x) = 0$, outside
Calculate the expectation values of xand p. **(1999)**

11. A 500 μA beam of electrons of kinetic energy 1.5eV enter a region with a sharply defined boundary in which their energy is reduced to 1.0eV by a difference of potential. Determine the reflected and transmitted currents. Derive the formulae used.**(2000)**

12. A particle is in a quantum system with a parabolic potential well.
(i) Using appropriate method find the ground state energy.
(ii) Obtain an expression for the ground state. **(2001)**

13. (i) Write down the matrix representation of the energy operator of a linear oscillator.
(ii) A linear oscillator is prepared in the state given by:
$\psi(x) = 1/\sqrt{5}\ \{\psi_0(x) + \sqrt{2}\,\psi_1(x) + \sqrt{2}\,\psi_2(x)\}$.
Evaluate the energy of the oscillator in this state. **(2001)**

14. The wave function of a particle is
$\psi(x) = A \exp(-x^2/a^2 + ikx)$.
Find the expectation values of position (x) and momentum (p) for the particle. **(2002)**

15. Solve the one dimensional Schrodinger wave equation with potential :

$$V(x) = \begin{cases} 0 & \text{for } x < -a \\ V & \text{for } -a < x < a \\ 0 & \text{for } x > a \end{cases}$$ **(2002)**

16. Distinguish between a classical and a quantum mechanical harmonic oscillator. Explain the existence of zero point energy. **(2002)**

17. Show that the motion of a classical particle is analogous to the motion of a wave packet, which can be constructed by superposition of a large number of plane waves. Construct such wave packet and derive an expression for its group velocity. **(2000)**

18. A particle of mass m, with energy E such that $-V_o < E < 0$, is trapped in a potential well as shown below:

(i) Write time independent Schrodinger equation in regions

(a) $0 < x < a$ and (b) $x > a$

(ii) Obtain an expression from which the energy eigen values can be determined.

(iii)Show that for at least one bound state to exist $a^2 V_o \geq h^2 \pi^2 / 8m$. **(2003)**

19. Consider a particle in a one – dimensional box of length a in a quantum state at t = 0, given by $\Psi(q,0) = \begin{cases} A; 0 < q, a \\ 0; otherwise \end{cases}$ Where A = a real constant. Write the expression for $\psi(q,t)$ Obtain the value of A and expansion coefficient of the total wave function.**(2004)**

20. The ground state wave function of a linear simple harmonic oscillator is $\psi = a\exp\left(-\frac{\alpha^2 x^2}{2}\right)$

Calculate the constant A and the average values of x^2 and x. Given that $\int_0^\infty e^{-x^2} = \frac{\pi}{2}^{1/2}$ **(2005)**

21. Consider a particle of mass m in an infinite one dimensional potential well of width a. the particle is found in the state given by $\psi(x) = c\left[\sin\frac{\pi x}{a} + \frac{1}{2}\sin\frac{2\pi x}{a}\right]$ Calculate c.If a measurement of energy is made, what are the possible results and what are the probabilities for each one of them? **(2005)**

22. (a) Distinguish between potential well and potential barrier. Give their illustrations. Considering one dimensional potential step, prove that sum of the reflection and transmission coefficients is unity.

(b) Prove that $\frac{d}{dt}\langle x\rangle = \frac{1}{m}\langle p_x\rangle$

Define all the terms of this relation and give its physical interpretation. **(2006)**

23. Solve the Schrodinger equation for a linear harmonic oscillator; Obtain the eigenvalues and the corresponding eigen functions. **(2007)**

24. A one – dimensional potential barrier is represented by the function $V(x) = 0$ for $x < 0 = V_0$ for $x > 0$ where V_0 is positive. Find the transmission coefficient for particles of mass m incident from the left on the barrier. **(2007)**

25. Show that the probability of transmission across the step barrier represented by the potential $V(x) = \{$ 0 for x < 0is $T = \frac{4k_1k_2}{(k_1+k_2)^2}$ where k_1 and k_2 are wave numbers in regions x < 0 and x >0.

(2008)

26. An electron is moving freely in a one dimensional infinite potential box with walls at x = 0 and $x = a$. If the electron is initially in the ground state of the box and if suddenly the wall at $x = a$ is moved $x = 4a$, calculate the probability of finding the particle in the ground state of the new box. **(2008)**

27. The Hamiltonian of a particle moving along the x-axis is given by $\hat{H} = -\alpha \frac{d^2}{dx^2} + 16\alpha \hat{x}^2$,

Where α is a real and positive constant having dimensions of energy.

i. If $\psi(x) = Ae^{-2x^2}$, find the normalization constant A. Check whether ψ is an eigen function of $\hat{H}$. If yes, find the corresponding eigen value.

ii. Calculate the probability of finding the particle anywhere along the negative x-axis.

iii. Find the eigen value of $\hat{H}$ corresponding to the eigen function $\phi(x) = x\psi(x)$, where $\psi(x)$ is the same as in part (i).

iv. Are the wave functions $\psi(x)$ and $\phi(x)$ orthogonal? **(2008)**

28. Show that the time-dependent part of all the solutions of the Schrodinger equation in one-dimension has the structure $\phi(t) = \exp(-iEt/\hbar)$, provided the potential is not an explicit function of time. **(2009)**

29. Consider a positron in a box. If the energy released is 60 eV when it jumps from the third excited state to the ground state, show that the width of the potential is nearly 0.3 nm. **(2009)**

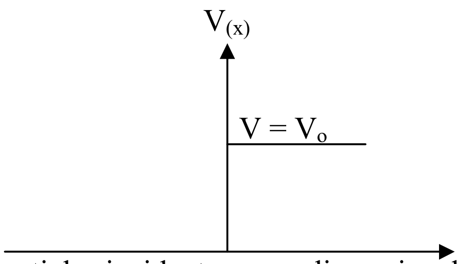
30. Obtain an expression for the probability current for the plane wave $\psi(x,t) = \exp[i(kx - \omega t)]$. Interpret your result. **(2010)**

31. A system is described by the Hamiltonian operator, $H = -\frac{d^2}{dx^2} + x^2$ Show that the function A x $\exp\left(-\frac{x^2}{2}\right)$ is an eigen function of H. Determine the eigen values of H. **(2011)**

32. Solve the Schrodinger equation for a particle of mass m in an infinite rectangular well defined by $V_{(x)} = 0 \; 0 \le x \le L = \infty \; x < 0, x > L$ Obtain the normalized eigen functions and the corresponding eigen values. **(2011)**

33. Normalize the wave function $\psi(x) = e^{-|x|} \sin \alpha x$ **(2011)**

34. (a)



Consider a beam of particles incident on one-dimensional step function potential with energy $E > V_o$as shown in the above figure. Solve the Schrodinger equation and obrain expressions for the reflection and transmission coefficients.

(b) What are the limits of the reflection coefficient for $E \rightarrow V_o$ and $E \rightarrow \infty$?

(c)Discuss the cases $0 < E < V_o$and $E < 0$. **(2013)**

35. Obtain the time independent Schrödinger equation for a particle. Hence deduce the time independent Schrödinger equation. **(2014)**

36. Solve the Schrödinger equation for a particle of mass m confined in one dimensional potential well of the form:V=0 , when 0≤x≤L=infinity , when x<0 , x>L. Obtain the discreet energy values and the normalized eigen functions. **(2014)**

37. An electron is moving in a one dimensional box of infinite height and width 1 A (Angstrom). Find the minimum energy of electron. **(2014)**

38. Normalized wave function of a particle is given: $\psi (x) = A \exp (-x^2 / a^2 + ikx)$.Find the expectation value of position.**(2015)**

39. Solve the Schrodinger equation for a step potential and calculate the transmission and reflection coefficient for the case when the kinetic energy of the particle E_0 is greater than the potential energy V (i.e., $E_0 > V$). **(2016)**

TUTORIAL SHEET: 3
Quantum Mechanics-II

1. (i) Find the eigen states of angular moments vector's component L_z of a spherically symmetric system.
(ii) Write down any two properties of Pauli spin matrices, after defining them through suitable expression. **(2001)**

2. Write down the eigen value and spin state of an electron for the spin operator S.
(i) Show that the spin states of electron are orthogonal to each other.
(ii) State the spin angular momentum commutation relations
(iii) Give the explicit forms of all the Pauli spin matrices.**(2001)**

3. (i) Express the Cartesian components of the angular momentum L in operator form. Show that $[L^2, L_z]=0$. What is the significance of this commutation relation?
(ii) Show that the Pauli matrices anti-commute. **(2003)**

4. Show that the radial probability density for the ground state of the hydrogen atom has a maximum at r = a. The ground state wave function of the hydrogen atom is given by $\Psi(r) = 1/\sqrt{\pi}\ a^{3/2}\ \ e^{-r/a}$, where the Bohr radius. **(2003)**

5. N number of non-interacting electrons are confined in a cube of volume L^3. Obtain an expression for the Fermi energy. **(2003)**

A hydrogen atom is in the following state $\Psi_{nlm}(r,0) = \frac{1}{\sqrt{14}}\ [2\ \Psi_{100}(r) - 3\Psi_{200}(r) + \Psi_{322}(r)]$
(i) What is the probability of finding the system in the state 200?
(ii) What are H and L_z? **(2004)**

6. Show that for the ground state of hydrogen atom the mean value of r is 3/2 a_o, where a_o is Bohr radius. **(2004)**

7. Solve the eigen value equation$L^2 Y(\theta,\Phi) = \lambda h^2\ Y(\theta,\Phi)$And obtain the eigen value of L^2. **(2004)**

8. Write the commutation relations for the position variable x and the momentum component p_x, p_y and p_z. Explain the physical significance of these relations. **(2005)**

9. The wave function of a particle confined in a cube of volume L^3 is given by

$$\psi(x,y,z) = \left(\frac{2}{L}\right)^{3/2} \sin\frac{\pi x}{L}\sin\frac{\pi x}{L}\sin\frac{\pi z}{L}$$

Calculate the average values of p_x and $p^2{}_x$ in the region 0<x<L. **(2005)**

10. Set up the time-independent Schrodinger equation for an electron moving in a Coulomb field, $V(r) = -\frac{Ze^2}{4\pi\varepsilon_0 r}$, in polar coordinates. Solve the radial equation to get the energy eigen values. **(2005)**

11. Explain how the problem of the hydrogen atom could be solved using Schrodinger equation. Also derive an expression for its energy eigenvalue and discuss the associated bound states of this case. **(2006)**

12. (i) Define angular momentum. Express it in operator form and show that $\vec{L}\times\vec{L} = i\hbar\vec{L}$ Explain the physical significance of this relation. **(2007)**

(ii) Let Ylm be an eigenstate of L^2 and L_z with eigenvalues $l(l+1)\hbar^2$ and $m\hbar$, respectively. Show that $\phi = (L_x + iL_y)Y_{lm}$ is likewise an eigenstate of L^2 and L_z and determine the eigenvalues.

13. Determine the discrete energy levels and the corresponding eigenfunctions for a particle in an infinitely deep potential well inside a cube of dimension L, i.e. assume $V(x,y,z) = 0$ for 0< x< L; 0< y < L; 0< z< L = ∞ elsewhere **(2007)**

14. In the free electron theory of metals, a conductor is regarded as consisting of free electrons in a three dimensional box. Using the results of Q(14), obtain an expression for the density of states. **(2007)**

15. An electron is in the spin state $\chi = A\begin{pmatrix} 3i \\ 4 \end{pmatrix}$ Determine the normalization constant A. Find the expectation value of the spin operator $\hat{S}_x$ and also the uncertainty in the value of S_x in this state.
(2008)

16. Write (do not derive) the formula for the energy levels of a particle in a three dimensional cubical boxof side L. How many electrons can occupy the level having energy $66\hbar^2/8mL^2$? **(2008)**

17. Write the commutation relations of angular momentum operator $\hat{L}_x, \hat{L}_y$ and $\hat{L}_z$ and calculate the commutators $\left[\hat{L}_+, \hat{L}_z\right]$ and $\left[\hat{L}_-, \hat{L}_z\right]$.Show that $\hat{L}_+ |l,m> = \sqrt{l(l+1) - m(m+1)}|l,m+1>$,

Where $|l,m>$ is the state with definite values for L^2 and L_z. **(2008)**

18. (i) The quantum mechanical probability distribution function of an electron in the ground state of the hydrogen atom is $P(r) = Nr^2\exp(-2br)$. Using the result $\int_0^\infty P(r)dr = 1$, deduce that N is proportional to b^3.

(ii) Prove that the value of 40 $k_B T$ at T = 300 K is nearly 1 eV. Hence determine the Fermi temperature of metal whose Fermi energy is 9.4 eV.

(iii) Show that the Fermi velocity is related to the Fermi energy of electrons through the Relation
$\frac{V_F}{C} = 1\cdot 98\left(\frac{E_F}{1MeV}\right)^{1/2}$ **(2009)**

19. Prove that the most probable distance of an electron from the proton (in the hydrogen atom) is the Bohr radius of the hydrogen atom. Consider only the ground state.**(2009)**

20. (i) Consider a particle in a three-dimensional box. Derive an expression for g(E), the density of states.

(ii) Show that $\frac{g(p)}{g(E)} = \frac{dE}{dp}$, where g(p) is the density of states in the momentum space. Deduce that g(p) is proportional to p^2 for a free non-relativistic particle.**(2009)**

21. Show that the Pauli Spin Matrices obey the following relation:

i. $Tr(\sigma_x) = Tr(\sigma_y)$

ii. $\det(\sigma_y) = \det(\sigma_z)$

iii. The eigenvalues of σ_z and σ_x are the same.

iv. Write down the y-component of the spin angular momentum matrix corresponding to an antineutrino.**(2009)**

22. Show that the Pauli spin matrices satisfy the following:

$$\sigma_x^2 = \sigma_y^2 = \sigma_z^2 = 1$$

$$\sigma_x\sigma_y = -\sigma_y\sigma_x = i\sigma_z$$

$$\sigma_y\sigma_z = -\sigma_z\sigma_y = i\sigma_x$$

$$\sigma_z\sigma_x = -\sigma_x\sigma_z = i\sigma_y$$ **(2010)**

23. The normalized wave function for the electron in hydrogen atom for the ground state is

$\psi(r) = \left(\pi a_0^3\right)^{-1/2} \exp\left(-\frac{r}{a_0}\right)$ Where a_0 is the radius of the first Bohr orbit. Show that the most probable position of the electron is a_0 **(2010)**

24. Let $\vec{\sigma}$ be the vector operator with component equal to pauli spin matrices $\sigma_x, \sigma_y, \sigma_z$ if $\vec{a} \cdot \vec{b}$ are vectors in 3D space, prove the identity $(\vec{\sigma}.\vec{\alpha})(\vec{\sigma}.\vec{b}) = \vec{\alpha}.\vec{b} + i\vec{\sigma}.(\vec{\alpha} \times \vec{b})$. **(2011)**

25. For hydrogen atom, ground state is $\psi_{(x)} = \frac{1}{\left([\pi\alpha_0^2]\right)^{\frac{1}{2}}} e^{-\frac{r}{\alpha_0}}$ Calculate $\langle r \rangle$ and $\langle \frac{1}{r} \rangle$. **(2011)**

26. Show (i) Sin $(\sigma_x \phi) = \sigma_x \sin \phi$ **(2011)**

(ii) Cos $(\sigma_1 z \phi) = \cos \phi$ **(2012)**

27. What is the degree of degeneracy of the energy – eigen Values. What happened if the spin of the electron is taken into account? **(2012)**

28. Solve the radial part of the time independent Schrodinger Equation for a hydrogen atom. Obtain its expression for energy Eigen values. **(2012)**

29. Using the definition $\vec{L} = r \times p$ of the orbital angular momentum operator , evaluate [L(x) , L(y)] **(2013)**

30. The normalized wave function for the electron for the electron in the ground state of the hydrogen atom is given by $\Psi(r) = \frac{1}{\sqrt{\pi a_0^3}} e^{\frac{r}{a0}}$ **(2013)**

31. If x and p are the position and momentum operators, prove the commutation relation $[p^2, x] = -2ihp$ **(2014)**

32. Write down Pauli spin matrices . Express J(x) , J(y) and J(z) in terms of Pauli spin matrices . **(2014)**

33. Using the commutation relations
[x, p(x)] = [y, p(y)] = [z,p(z)]=ih
Deduce the commutation relation between the components of angular momentum operator L .
[L(x), L(y)]=ihL(z)
[L(y), L(z)]= ihL(x) and
[L(z),L(x)]=ihL(y) **(2014)**

34. Solve the Schrodinger equation for a particle in a three dimensional rectangular potential barrier. Explain the terms degenerate and non-degenerate states in this context. **(2015)**

35. A particle trapped in an infinitely deep square well of width a has a wave function $\psi = \left(\frac{2}{\pi}\right)^{\frac{1}{2}} \sin\left(\frac{\pi x}{a}\right)$. The walls are suddenly separated by infinite distance. Find the probability of the particle having momentum between p and $p + dp$ **(2015)**

36. Write down the matrix representation of the three Pauli matrices σ_x, σ_y and σ_z. Prove that these matrices satisfy the following identities:

- **i.** $[\sigma_x, \sigma_y] = 2\, i\, \sigma_z$
- **ii.** $[\sigma^2 . \sigma_x] = 0$
- **iii.** $(\sigma .A) (\sigma .B) = A .B + i\, \sigma .(A \times B)$
  If A and B commute with Pauli matrices. **(2016)**

37. Calculate the density of states for an electron moving freely inside a metal with the help of quantum mechanical Schrodinger's equation for free particle in a box. **(2016)**

ATOMIC PHYSICS
TUTORIAL SHEET: 4

1. What is Lamb shift? Explain it by illustrating through a suitable energy level diagram. Has Lamb shift been observed in any atom other than hydrogen? **(2001)**

2. Give briefly an account on the important historical developments to establish the concept of electron spin. **(2001)**

3. On the basis of vector atom model, discuss briefly the L-S and J-J coupling schemes. **(2001)**

4. Write down expressions for spin angular momentum, orbital angular momentum and total angular momentum under L-S coupling scheme. **(2001)**

5. Write the spectral symbol of the term with
   S = 1/2 ,J = 5/2 and g = 6/7 **(2002)**

6. Derive an expression for the spin-orbit interaction energy in one electron system. Calculate the energy separation between the levels $^2P_{1/2}$ and $^2P_{3/2}$. **(2002)**

7. Write the electronic configuration of mercury (Z=80) .Obtain the spectral term for the normal and the first excited configuration on the atom. **(2002)**

8. Calculate the Larmor frequency of a spin ½ particle in a magnetic field B. **(2003)**

9. Define the gyromagnetic ratio and obtain an expression for the Lande 'g' factor. What is the importance of 'g' in spectroscopy? **(2003)**

10. What is Zeeman Effect? How can it be understood on a quantum mechanical basis? Obtain an expression for Zeeman shift. **(2004)**

11. Calculate the Zeeman shift observed in the normal Zeeman Effect when a spectral line a wave length 5000 A° is subjected to the magnetic field of 0.4 wb/m^2. **(2004)**

12. What are the term symbols for atoms with the following S & L quantum numbers. S=1/2 and L=3? **(2004)**

13. How many lines occur in the multiplet arising from $^2P_{3/2} \rightarrow {}^2S_{1/2}$ and $^2P_{1/2} \rightarrow {}^2S_{1/2}$ transitions of alkali metal atoms placed in a weak magnetic fields why? **(2005)**

14. Describe Stern-Gerlach experiment and discuss its implications. **(2005)**

15. What is Lamb shift? Has it been observed in any atom other than hydrogen? **(2007)**

16. Describe Stern- Gerlach experiment. Explain how it demonstrates the discrete nature of the magnetic moment of an atom. **(2007)**

17. Explain normal and anomalous Zeeman Effect. Obtain expression for Zeeman splitting of an alkali metal spectral line, and illustrate with an example. **(2008)**

18. For transition to the ground state what is the longest wavelength that can be emitted by hydrogen **(2008)**

19. What was the aim of Stern – Gerlach experiment? Why were silver atoms chosen instead of electrons in the experiment? What was the outcome of the experiment?**(2009)**

20. $2^2 S_{1/2}$ level in H atom is 1058 MHz above the $2^2 P_{1/2}$ level
(i) What is this known as?
(ii) Express the above frequency in cm^{-1}.
(iii) Calculate the energy difference between the above two levels in eV. **(2009)**

21. (i) Establish that $hc = 1240 eV.nm$ = 1240 MeV. Fm
(ii) The energy levels of a hydrogen atom are given by $E_n = (-1/n^2).Ryd$.
Where1 Ryd = hcR.Show that $R = 1 \cdot 097 \times 10^7 m^{-1}$ What exactly is R? **(2009)**

22. (i) Find the ground state total orbital (L) and total spin (S) quantum numbers for nitrogen.
(ii) Find the L and S values of the two "first excited states" of helium atom.
(b).(i) Explain spin-orbit coupling of an atomic electron.
(ii). Show that the 2p state in the H atom splits up into two substates due to spin-orbit coupling.
(iii) Calculate the energy of separation in eV, resulting from the spin-orbit coupling when the magnetic field experienced by the electron is 0.4 T. **(2009)**

23. What is Zeeman Effect? How it can be understood on quantum mechanical basis? Obtain an expression for Zeeman splitting of atomic energy levels in a magnetic field B. Explain the magnetic splitting of sodium D-lines.**(2010)**

24. What is spin-orbit interaction?Calculate the energy shift due to spin-orbit interaction term in H-like system. Discuss the significance of this shift in relation to the fine structure of hydrogen spectral lines **(2010)**

25. Discuss the fine structure of hydrogen atom spectrum. Draw the compound doublet spectrum arising as a result between 2 p and 2d levels. **(2011)**

26. What do you mean by term symbols? Obtain term symbols for the following sets of values of S andL:
(i) S= $\frac{1}{2}, L = 2$ $(ii) S = 1, L = 1$ $(iii) S = \frac{3}{2}, L = 1$ **(2011)**

27. Show that $^2S_{\frac{1}{2}}, {}^2P_{\frac{1}{2}}, {}^2P_{\frac{3}{2}}$ levels of sodium spectrum are split in the ratio of 3 : 1 : 2 due to anomalous Zeeman Effect. **(2011)**

28. Sodium doublets are produced by transitions $3^2P_{\frac{1}{2}} \rightarrow 3^2S_{\frac{1}{2}} (D_1)$ and $3^2P_{\frac{3}{2}} \rightarrow 3^2S_{\frac{1}{2}} (D_2.)$ Calculate the Lande's g- factors for these levels. **(2012)**

29. Discuss the fine structure of sodium D line. Draw D_1 and D_2 lines due to the transitions between ^{2}P and ^{2}S levels. **(2013)**

30. A sample of certain element is placed in a magnetic field of flux density 0.3 tesla. How far apart is the Zeemen component of a spectral line of wavelength 4500 A?
Given: e/m = 1.76×10^{11} c/kg, c = $3.0 \times 10^{8} ms^{-1}$. **(2014)**

31. Obtain an expression for the normal Zeeman shift. Illustrate the Zeeman splitting of spectral lines of H atom and the allowed transitions for the l = 1 and l = 2 states. **(2014)**

32. What is Zeeman Effect? How can it be understood on the basis of quantum mechanics? **(2015)**

33. Obtain Zeeman splitting for sodium D-lines. **(2015)**

34. Find the magnetic moment of an atom in $3P_2$ state, assuming that LS coupling holds for this case. **(2015)**

35. In the Stern-Gerlach experiment using Ag atoms, the oven temperature is 1000 K, l ≈ 25 cm and $\frac{\partial B_z}{\partial z} \simeq 10^{+3}$ Tesla/m. Calculate the separation of the two components. **(2016)**

36. Describe Stern-Gerlach experiment. Discuss how it has explained space quantization and electron spin. Find the value of angle between the spin angular momentum S and its z-component of an electron moving along the external magnetic field B. **(2016)**

37. The series limit wavelength of Balmer series in hydrogen spectrum is experimentally found to be 3646 A. Find the wavelength of the first line of this series. **(2016)**

38. Compute the allowed spectral terms for two non-equivalent p-electrons of the basis of Pauli's exclusion principle. **(2016)**

39. Explain in detail L-S coupling and j-j coupling schemes. **(2016)**

40. What is Lamb shift? What is its significance in determining the fine structure of H_α Balmer line in hydrogen atom? **(2016)**

PHYSICS PAPER- II: MOLECULAR PHYSICS

TUTORIAL SHEET: 5

1. i. Discuss qualitatively the occurrence of rotational energy levels of diatomic molecule. Write down the selection rule.

ii. Is it possible to obtain pure rotational spectra of H2, HF, O2 and No molecules? Can one obtain pure rotational spectra in emission? Comment. (On both of the above mentioned queries).

iii. In CO molecule $J=0 \rightarrow J=1$ line occurs at frequency 1.153×101^{11} Hz. Calculate the moment of inertia of CO molecule.

i. What is Raman Effect? How does it differ from Rayleigh scattering? Write down its important applications.

ii. Explain Raman Effect with the aid of quantum mechanical theory.

iii. Why is Raman Effect considered complimentary to infrared absorption spectra?

iv. A Raman Stoke's line is observed at 552 nm. When a sample is excited by Hg green line of wave length546 nm. Calculate the wave length of anti-stoke's line **(2001)**

2. (i) A sample is irradiated by a 5000 A^o radiation to give a Raman line at 5050.5 A^o. Calculate the Raman frequency.

ii. Explain, both red and violet degraded bands have been observed in electronic band systems, but rotation-vibration spectra show bands degraded to red only.**(2002)**

3. Calculate the moment of inertia of HCl molecule from the expression= 20.68(J+1) cm where J = 0,1,2,…. **(2002)**

4. A diatomic gas is found to have a number of absorption bands in the ultraviolet region. Each band is observed to have a fine structure. How can the observed spectrum be explained and analysed?**(2002)**

5. Explain the nature, origin and significance of 21 cm Hydrogen line. **(2002)**

6. Calculate the change in rotational constant Bυ when deuterium is substituted for hydrogen in a hydrogen molecule. **(2002)**

7. (i) What are the typical energies (ev) of the radiations, required to excite (i) electronic transitions (ii) vibrational transitions and (iii) rotational transitions in a molecule?
(ii) The rotational spectrum of HI consist of equidistant lines with a separation of 12.8 cm^{-1}. Calculate the (a) M.I. and (b) bond length of HI molecule. **(2003)**

8. Discuss the salient features of O, P,Q,R and S branches of electronic spectrum of diatomic molecules. Which spectrum contains only branches, both branches and bands, branches and progressions? **(2003)**

9. Show that a spinning nucleus processes in a magnetic field. Explain the underlying principle of NMR spectroscopy. The magnetic moment of a proton is 2.793 μn Calculate the radio frequency at which nuclear magnetic resonance occurs in watr kept in a magnetic field of 1.5 T. **(2003)**

10. Water vapor shows Infrared absorption bands at 1595 cm^{-1}, at 3652 cm^{1} and at 3756 cm^{-1}. If the Raman spectrum is observed with the Argon ion laser 514.5 nm, at what wavelength would you expect to find the Raman - stokes lines? **(2004)**

11. High resolution laser spectroscopy can resolve lines that cannot be resolved by conventional spectroscopy. Justify this statement. **(2004)**

12. Briefly describe rotational fine structure of electronic spectra of diatomic molecules.**(2004)**

13. What are the selection rules for rotational spectra? Draw a neat diagram to show the allowed rotational transitions.**(2004)**

14. Explain the molecular phenomenon of spontaneous emission between two electronic states of the same multiplicity and differentiate it from that of different multiplicity. **(2005)**

15. The constants B and V_0 for a KCI molecule have values 143 $\times 10^{-5}$ eV and 84 $\times 10^{12}$ s^{-1} respectively. Determine the number of rotational levels between the vibrational levels v =0 and v = 1. **(2005)**

16. How can the pure rotation spectrum of H_2 molecule be observed? If the bond length of H_2 molecule is 0.07417 nm. What would be the spacing of lines in its spectrum?**(2005)**

17. Differentiate between Rayleigh and Raman scatterings. Why is Raman scattering considered to be a breakthrough in molecular spectroscopy? What are the advantages of using laser light in Raman spectroscopy?**(2005)**

18. Obtain an expression for the vibration-rotation energy levels of a diatomic molecule in a given electronic state.The wave numbers of the vibrational transitions occurring in HF, HCI and HI molecules are34143 cm^{-1}, 29889 $cm^{-1}$and 23095 cm^{-1} respectively. Compare the force constants of these three molecules. **(2006)**

19. (i) State and explain Franck – Condon Principle.
(ii) In three separate pairs of electronic states (one ground and another upper state) of diatomic molecules, the average inter nuclear distances are-
(i) equal;
(ii) slightly greater;
(iii) appreciably greater.
In accordance with Franck- Condon principle, obtain most favourable transitions from the ground state vibrational levels in each of the above situations.
Illustrate the transitions by drawing suitable energy – level diagrams. **(2007)**

20. Draw the potential energy of a diatomic molecule as a function of inter atomic distance. Mark the vibrational and rotational energy levels. Explain the selection rule for transitition between vibrational states. **(2008)**

21. Assume a diatomic molecule consisting of two atoms of masses m_1 and m_2, separated by a distance $\vec{r}$. Write down the Hamiltonian operator for the molecule. Determine the rotational energy levels of the molecule, **(2008)**

22. Write full form of acronyms EPR and NMR. Give underlying principle of EPR. **(2008)**

23. Explain fluorescence and phosphorescence in electronically excited molecules.**(2009)**

24. Discuss the vibrational spectra of a diatomic molecule treating it as a harmonic oscillator as well as an anharmonic oscillator and compare them.**(2009)**

25. Explain Born – Oppenheimer approximation. Discuss the intensity distribution in the vibrational electronic spectra of a diatomic molecule on the basis of Franck – Condon principle.**(2009)**

26. Calculate, giving necessary steps, the radio frequency at which nuclear magnetic resonance occurs in water kept in a uniform magnetic field of $2 \cdot 4T$. The magnetic moment of proton is $2 \cdot 793 \mu N$.
(2010)

27. (i) Discuss occurrence of rotational energy levels of a diatomic molecule and show that the pure rotation spectrum of such a molecule consists of a series of equally spaced lines separated by a constant wave number difference 2B. Write down the selection rules.
(ii) Is it possible to obtain pure rotational spectra of H_2, HF, O_2 and NO molecules?
(iii)In CO molecule J = O →J = 1 line occurs at a frequency $1 \cdot 153 \times 10^{11}$ Hz. Calculate the moment of inertia of CO molecule. **(2010)**

28. What is Raman Effect? How does it differ from Rayleigh scattering? Explain Raman Effect on the basis of quantum mechanical theory.How is Raman Effect experimentally studied? What are the advantages of using laser sources in the study of Raman Effect?**(2010)**

29. State and explain Franck-Condon principle. Discuss its applications in molecular spectroscopy. **(2010)**

30. On the basis of inertia I_A. I_B and I_C each about X, Y and Z axes respectively, how can you classify molecules? **(2011)**

31. (a) (i)Treating a diatomic molecule as a simple oscillator, obtain its energy (vibrational) levels.
(ii)The observed vibrational frequency of the Co molecule is 6.42 $\times$ 10^{13} Hz. What is the effective force constant of the molecule? (C= $12u, O = 16u$)
(b) (i) Discuss pure rotational spectra of linear molecules
(ii) What is Lamb shift? **(2011)**

32. Why should rotational Raman spectrum show a separation of the first Raman line from the exciting line as 6B cm^{-1}. While the separation between successive lines is equal to 4B cm^{-1}. when B is the rotational constant ? **(2012)**

33. What will happen to the energy level of an unpaired electron when subjected to an external magnetic field? Find the condition for electron spin resonance. **(2013)**

34. (a) With proper selection rules, construct the energy level diagram and allowed transitions for ESR spectrum of hydrogen atom. (b) Why are Raman active vibrations and infrared vibrations in CO_2molecule complementary to each other? (c) In a Raman spectrum of linear triatomic molecule, the first three lines are 4.86, 8.14 and 11.36cm^{-1}. Calculate the rotational constant, B and the moment of inertia of the molecule. (Given h = 6.626 x 10^{-27}J.s, C = 3.0 x 10^{10}cm/sec.)**(2013)**

35. Discuss the vibrational spectra of a diatomic molecule treating it as an anharmonic oscillator. **(2014)**

36. Explain how the nuclear spin I depends on the mass number A and atomic number Z of atoms.**(2014)**

37. (i) Obtain an expression for the resonance condition in NMR.
(ii)Explain the relaxation processes in NMR spectroscopy. **(2014)**

38. Establish that: $hc = 1240\ MeV.\ fm$ **(2015)**

39. Hydrogen molecule is diatomic. Obtain the rotational energy levels of this molecule. Write down the selection rules. Obtain the smallest energy required to excite the lowest rotational mode. **(2015)**

40. The observed vibrational frequency of CO molecule is $6.42 \times 10^{13}\ Hz$. What is the effective force constant of the molecule? **(2015)**

TUTORIAL SHEET: 6
NUCLEAR PHYSICS

1. Explain why a neutral particle such as neutron possesses a finite value of magnetic moment, and how it is determined? **(2002)**

2. Write down the configuration of ^{7}Li, ^{13}C and ^{25}Mg.in the ground state of the nuclear shell model. **(2002)**

3. Explain how neutrino was discovered from the β -decay of radioactive nuclei. **(2002)**

4. Explain shell model of the nucleus. Give evidence for nuclear shell structure. What are the limitations of the shell model? **(2002)**

5. Sketch carefully the binding energy per nucleon curve for stable nuclei. Explain its salient features. On the basis of this curve explain why fusion is possible only for low mass nuclei, whereas fission takes place in heavy nuclei. **(2003)**

6. List some of the important properties of deuteron and show that it is a loosely bound system and has only one bound state. **(2003)**

7. Distinguish between a nuclear reaction and decay. Which conservation laws are obeyed in nuclear reactions? Explain the significance of Q value.Calculate the Q value for the following nuclear reaction$_1{}^2$H + $_1{}^2$H = $_2{}^3$He + n **(2003)**

8. Calculate the fission rate of ^{235}U. required to produce 4 watts and the amount fissioning of 1kg of ^{235}U . (Assuming energy released per fission of ^{235}U is 200 Mev).**(2004)**

9. Calculate Binding energy per nucleon of $^4{}_2$He and $^{16}{}_8$O.**(2004)**

10. Write down the Bethe-Weizsacker formula. Explain various terms of the formula.**(2004)**

11. Explain how energy is released in stars.**(2004)**

12. Describe in detail one experiment for detection of Neutrino. **(2004)**

13. What is the difference between neutrino and antineutrino? How is helicity of neutrino determined? **(2004)**

14. (a) Write the Weizacker mass formula and explain the significance of various terms.
(b) Determine the amount of $^{210}_{84}\rho_0$ necessary to provide a source of $^{210}_{84}\rho_0$ α-particles of strength 5 mC$_1$. The half-life of is 138 days. **(2005)**

15. Describe how parity violation was experimentally detected in $^{60}C_O$ β-decay. How was the observed asymmetry in the distribution of emitted electrons explained?

(a) Differentiate between K-capture and inverse β-decay.
(b) Explain what is internal conversion and how it differs from β-decay. **(2005)**

16. Calculate the spin and parities of the ground states of ${}_{2}^{4}$He and ${}_{30}^{67}$Zn nuclei.**(2005)**

17. Calculate the Q – value of the reaction : ${}_{4}^{9}Be\left({}_{2}^{4}He, n\right){}_{6}^{12}C$

Given

Mass $\left({}^{9}Be\right) = 9.012183u$

Mass $\left({}^{4}He\right) = 4.002603u$

Mass $\left({}^{12}C\right) = 12.000u$ **(2007)**

18. Write down the nucleonic configuration of ${}^{7}Li, {}^{12}C, {}^{17}O$ and ${}^{27}Al$ In the ground state of the nuclear shell model and hence calculate the corresponding ground state angular momenta and parties. How do the observed ground state angular momenta and parities agree with those predicted on the basis of the shell model? **(2007)**

19. (i)Write down the Bethe –Weizsacker semi- empirical mass formula for a nucleus. Explain the significance of each term occurring in it. Discuss the stability of a nucleus against β- decay. What is the effect of pairing term on stability?

(ii)What are mirror nuclei? How does the charge independence of nuclear force emerge from this concept? **(2007)**

20. What is β- decay? Give three examples of β- decay of nuclei. Explain how neutrino hypothesis helped in explaining conservation of energy- momentum and angular momentum What is Kurie plot? How can one use Kurie plot to set limits on mass of the neutrino? **(2008)**

21. What is nuclear isomerism? Give two examples and explain how this can be understood from single particle shell model. **(2008)**

22. Write down the Yukawa potential and derive an expression for the mass of π-meson in terms of range of nuclear force. What part of the Nucleon – Nucleon interaction is explained by this potential? **(2009)**

23. What is the simplest two-nucleon bound system? How does its study help in obtaining information about nuclear forces? Indicate clearly how the non-central forces can be explained by the observed magnetic moment of this system.**(2009)**

24. Compare the methods of electron scattering and neutron scattering experiments to obtain information about nuclear size. **(2009)**

25. Calculate the packing fraction and the binding energy per nucleon for ${}_{8}^{16}O$ and ${}_{38}^{87}Sr$ nuclei.**(2010)**

26. A star converts all its hydrogen to helium, achieving 100% helium. It then converts the helium to carbon via the reaction ${}_{2}^{4}He + {}_{2}^{4}He + {}_{2}^{4}He \rightarrow {}_{6}^{12}C + 7\cdot 27MeV$ The mass of the star is $5\cdot 0\times 10^{32}$ kg and it generates energy at the rate of 5×10^{30} kg. How long will it take to convert all Helium to carbon at this rate?**(2010)**

27. What are magic numbers? Discuss shell structure of a nucleus. How is this model able to explain various properties of nuclei? Discuss the limitations of this model.**(2010)**

28. Predict from the single particle shell model the shell configuration, ground state spin and parity for the following nuclei: $^{13}_{7}N$; $^{17}_{8}O$ **(2010)**

29. Explain parity violation in β-decay. Describe how parity violation was experimentally detected in the decay of ^{60}Co. **(2010)**

30. Find the total kinetic energy of electron and antielectron neutrino emitted in beta decay of free neutron. (The neutron-proton mass difference is 1.30 Mev and mass of electron is 0.51 Mev) **(2010)**

31. What are chain reactions? What do you mean by critical size of the core in which chain reaction takes place? What is critical mass? **(2010)**

32. ^{235}U yields two fragments of A = 95 and A = 140. Obtain the energy distribution of the fission products. Assume that the two fragments are ejected with equal and opposite momentum. **(2010)**

33. Show that nucleus is a quantum system. **(2011)**

34. (a) (i) What is the importance of study of deuteron ? Obtain the solution of Schrodinger equation for ground state of deuteron and show that deuteron is a loosely bound system.
(ii) What do you mean by non- central forces?
(b) (i) What are chain reactions? What do you mean by critical size of the core in which chain reactions take place? What is critical mass?
(ii) $U\ 235\ yields$ fragments of A= 95 and A= 140. Obtain the energy distribution of the fission products. Assume that the two fragments are ejected with equal and opposite moments.
(2011)

35. (a) Write down the Bethe- Weizsacker Semi-empirical mass formula for a nucleus. Explain the significance of each term. Discuss the stability of a nucleus against $\beta-decay.What$ is the effect of pairing term on stability?
(b) What are mirror nuclei? How does the charge independence of nuclear force emerges from this concept? **(2012)**

36. Calculate the recoil energy of $^{57}_{26}Fe$ nucleus when it emits a gamma photon of energy 14 KeV. **(2012)**

37. Calculate the Q-value of the reaction: $^{9}_{4}Be\left(^{4}_{2}He,n\right)^{12}_{6}C$

Given:

Mass$\left(^{9}_{4}Be\right) = 9.01283\ u$

Mass $\left({}^{4}_{2}He\right) = 4.002603\ u$
Mass $\left({}^{12}_{6}C\right) = 12.000\ u$
Mass $(n) = 1.0086652\ u$**(2013)**

38. Write down the nucleonic configuration of, ^{7}Li, ^{12}C, ^{17}O, and ^{27}Al in the ground state of the nuclear shell model and hence calculate the corresponding ground state angular momenta and parities. How do the observed ground state angular momenta and parities agree with those predicted on the basis of shell model? **(2013)**

39. What is the role of neutrino in the weak interaction of radioactive nuclides? Explain the experimental detection of neutrino. **(2013)**

40. Explain parity violation in β-decay. Describe how parity violation was experimentally detected in the decay of ^{60}Co. Mention any other decay process in which the parity violation has been demonstrated. **(2013)**

41. Explain why stable light nuclei have equal number of protons and neutrons whereas heavy nuclei have excess of neutron. **(2014)**

42. What are the magic numbers in nuclei? List the experimental evidences indicating their existence. **(2014)**

43. It is possible to estimate the nuclear radius from the study of alpha decay? Explain how. **(2014)**

44. State the basic assumption of single particle shell model. How do the centrifugal and spin-orbit terms remove the degeneracy of a three-dimensional spherical harmonic oscillator? **(2016)**

45. Predict the spin and parity of ground states of the following nuclei on the basis of shell model:

(i) $8^{O^{15}}$
(ii) $8^{O^{16}}$
(iii)$17^{Cl^{33}}$ **(2016)**

46. Explain why the deuteron has no excited state. **(2016)**

TUTORIAL SHEET: 7
PARTICLE PHYSICS

1. Illustrate with any five examples that production of strange particles conserves strangeness, parity and isotopic spin while their decay violates all these quantities. **(2001)**

2. Discuss the significance of Gellmann-Nishijima relation in strange particle production and decay. Give-examples in support of your answer. Obtain quark quantum numbers using the modified relation for quarks. **(2001)**

3. Which conservation laws are obeyed in nuclear reactions? Explain the significance of Q value of a nuclear reaction. **(2002)**

4. Distinguish between particle and antiparticle. How antiparticle were discovered?**(2002)**

5. Mention the conservation laws for strong, electromagnetic and weak interactions.**(2002)**

6. Give the characteristic properties of strange particles which distinguish them from non strange ones. Write the Gellmann – Nishijima relation and show how it is used for the classification of elementary particles. **(2003)**

7. State the conservation law which is violated in each of the following processes:
(i) $n = p + \bar{e} + r$ (ii) $\pi^- + p = k^+ + k^-$
(iii) $\pi^- + p = \Sigma^+ + k^-$ (iv) $\Sigma + k = p + p$ **(2003)**

8. Which of the following reactions are allowed and forbidden under the conservation of strangeness, baryon number and change conservation?
(i) $\pi^+ + n = \lambda^o + k^+$ (ii) $\pi^+ + n = k^o + k^+$
(iii) $\pi + p = \lambda^o + k^+$ (iv) $\pi + p = \pi^o + \lambda^o$ **(2004)**

9. State the quantum numbers I_z, Y and S for the u d and s quarks and antiquarks. What combination of these leads to the formation of (i) proton and (ii) neutron? **(2005)**

10. What are the basic interactions in nature? Give one example for each. Compare their relative strengths and ranges. **(2005)**

11. Give some characteristic properties of strange particles which distinguish them from non – strange ones. Write the GellMann-Nishijima relation. How is it used for the classification of elementary particles? **(2007)**

12. Explain lepton number conservation and why it is necessary to distinguish between different types of neutrinos? **(2008)**

13. Give the hypercharge and iso spin of the quarks and antiquarks. What are the quark contents of themesons: $\pi^+, \pi^0, \pi^-, K^-, K^0, K^-$ and η? **(2008)**

14. At what energies do we anticipate the unification of strong and electroweak interactions? What will happen to coupling constants of these interactions in this situation? How does unification indicate the decay of proton and existence of lepto quark?**(2009)**

15. What are the field quanta of weak and electromagnetic interactions? Show that weak interaction is a short range force while electromagnetic interaction is a long range one.**(2009)**

16. State the quantum number I_z, Y and S for the u d s quarks and anti quarks. Which combination of these leads to the formation of (i) proton and (ii) neutron? **(2010)**

17. Expain conservation of Baryon Number . Comment on the stability of proton. **(2010)**

18. Which of the following reactions are permitted or forbidden by various conservation laws ?
(i) $K^- + P \rightarrow \lambda^0 + \pi^0$
(ii) $K^- + n \rightarrow \Sigma^+ + \pi^0$
(iii) $\pi^- + P \rightarrow K^- + \Sigma^+$
(iv) $\pi^+ + n \rightarrow K^- + n^0$
(v) $\pi^- + P \rightarrow \lambda^0 + K^0$
(vi) $\pi^- + P \rightarrow K^- + \Sigma^-$ **(2012)**

19. State the quantum l_z, Y and S for the u d s quarks and antiquarks. Which combination of these leads to the formation of (i) proton and (ii) neutron? **(2013)**

20. In the following reaction indicate with an explanation, whether they proceed by strong, electromagnetic or weak interaction or they are forbidden:
(i) $x^+ \rightarrow \mu^+ + v_\mu$
(ii) $p \rightarrow n + e^+ + v_e$
(iii) $p + \pi^- \rightarrow K^+ + \Sigma^-$ **(2013)**

21. (i) What are salient features of nuclear forces?
(ii) Discuss Yukawa's theory of nuclear forces. **(2014)**

22. (i) How does liquid drop model explain fission?
(ii) What are the limitations of shell model? **(2014)**

23. Describe grand unification theories (GUT). **(2015)**

24. How many types of neutrinos exist? How do they differ in their masses? **(2015)**

25. (i) $\Omega^- \rightarrow \wedge^0 + K^-$
(ii) $\wedge^0 \rightarrow p + \pi^-$
(iii) $K^- \rightarrow \mu^- + \upsilon_\mu$ **(2015)**

26. State the quantum numbers I_z, Y and S for uds quarks and antiquarks. Which combination of these leads to the formation of a (i) proton and (ii) neutron? **(2015)**

27. What are elementary particles and how are they classified? Describe in brief the different types of interactions that can occur between the elementary particles. **(2016)**

28. Explain the various leptonic family members. What is leptonic number conservation? Based on this conservation law, state whether the following reaction are possible or not:

(i) $x^- \rightarrow \mu^- + \mu_\tau$
(ii) $n \rightarrow P^+ + e^- + V_e$**(2016)**

29. Write down the quark structure of the following hadrons:$\Delta^{++}, \Omega^-, \Sigma^-$ *and* Λ^o
Write down the following decays in terms of quarks:

i. $n \rightarrow P^+ + e^- + V_e$
ii. $\Delta^+ \rightarrow \pi^+ + n$
iii. $\Sigma^+ \rightarrow P^+ + \pi^o$**(2016)**

30. Explain unification of electromagnetic and weak interactions. What is Z^o-boson? What is its relevance in electroweak unification? **(2016)**

STATE PHYSICS: TUTORIAL SHEET

SUPERCONDUCTIVITY: 8

1. What is Meissner effect? Superconducting tin has a critical temperature of 3.7K in zero magnetic field and critical field at 0K is 306 gauss. Determine the critical field at 2K. **(1999)**

2. Explain why superconductors are perfect diamagnets.

3. Describe Josephson junction and the effect. How is it exploited in the formation of a SQUID? Write down the applications of a SQUID? **(2001)**

4. Give a qualitative account of BCS theory of superconductivity.**(2001)**

5. Explain Meissner effect and Josepheson effect. Describe their applications in the field of superconductivity. **(2002)**

6. What are high temperature superconductors? Give two examples indicating their transition temperature. Differentiate between the conventional and high temperature superconductivity. **(2003)**

7. What is a Josephson junction? Discuss DC and AC Josephson effects and obtain the relation $\upsilon=2eV/h$, where symbols have their usual meanings. **(2003)**

8. What is Josephson Effect? Discuss briefly DC and AC effects. Give some practical applications of Josephson junctions. **(2007)**

9. Distinguish between 'soft' and 'hard' superconductors. Explain how penetration depth varies with magnetic field strength and temperature.**(2008)**

10. A type-II superconducting material with superconducting transition temperature T_c is placed in a magnetic field. What is the material state (normal or superconducting or mixed) for

(i) $T < T_c; H > H_{C_2}$ (ii) $T > T_c; H < H_{C_1}$

(iii) $T < T_c; H_{C_1} < H < H_{C_2}$ (v) $T > T_c; H > H_{C_2}$ **(2009)**

11. Describe the characteristic properties of a superconductor. Derive London equation for a superconductor and hence explain Meissner effect. **(2010)**

12. What is Josephson tunneling? Distinguish between a.c. and d.c. Josephson effects.**(2010)**

13. Describe the Characteristics properties of a superconductor. Derive London equation for a super conductor and hence explain Meissner effect. **(2011)**

14. Explain the variation of Magnetisation of Type I and Type II superconductors as a function of applied magnetic field **(2012)**

15. Cooled to 4 K and then magnetic field is applied. With schematic diagrams, explain path of magnetic field lines in all these situations: **(2013)**

16. Lead in the superconducting state has critical temperature of 6.2 K at zero magnetic field and a critical field of 0.064 Mam^{-1} at 0 K. Determine the critical field at 4 K. **(2014)**

17. Distinguish between a superconductor and perfect conductor. Explain what is a Cooper pair. **(2015)**

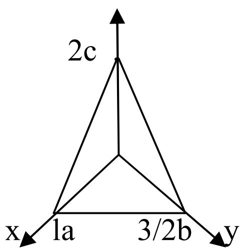
18. With the help of a schematic diagram, show how entropy and specific heat vary with temperature for a superconductor. **(2016)**

TUTORIAL SHEET: 9

Crystal Structure & its Determination

1. Obtain reciprocal lattice to normal BCC lattice. **(2001)**
2. Determine the reciprocal lattice vectors of an fcc lattice. **(2005)**
3. Show that the reciprocal lattice of a hexagonal lattice is a hexagonal lattice with a rotation of axes **(2009)**
4. Derive Bragg diffraction condition in vectorial form using incident and diffracted wave vectors and reciprocal lattice vector. **(2010)**

5. An electron beam of 4 Kev is diffracted through a Bragg angle of 16^o for the first maxima. If the energy is increased to 16 keV, find the corresponding Bragg angle for diffraction. **(2010)**

6. 

A crystal plane is shown in the above figure. Find its Miller indices and interplanar spacing. **(2013)**

7. Explain the working of SEM and TEM highlight the major differences in principles. Draw neat schematic diagrams. **(2014)**

8. What is the reciprocal lattice and why is it named so? Derive the relationships for the primitive translation vectors of the reciprocal lattice in terms of those of the direct lattice. **(2014)**

9. How does he energy gap in superconductors differ from the energy gap in insulator? How does it vary with temperature for superconductors? **(2014)**

10. Obtain Laue's equations for X-ray diffraction by crystals. Show that these are consistent with the Bragg's law. **(2016)**

11. The primitive translation vectors of a two-dimensional lattice are a = 2 i + j , b = 2 j. Determine the primitive translation vectors of its reciprocal lattice. **(2016)**

PHYSICS PAPER – II : SOLID STATE PHYSICS
TUTORIAL SHEET: 10
Band theory of solids

1. Show that the condition of periodicity of lattice leads to the Bloch's theorem. What is a Bloch function? **(2004)**

2. By drawing E vs. $\vec{k}$ curve, distinguish between metal, insulator and semiconductor. **(2004)**

3. (i) Discuss briefly the concept of effective mass in semiconductors and explain the significance of negative effective mass.
(ii) In isolated atoms, the electrons have discrete and definite energies but in solids they have bands of energies. Explain why. **(2005)**

4. Discuss the motion of an electron in one-dimensional periodic potential and show that it leads to formation of bands of allowed and forbidden states in the electron energy spectrum. How are the Insulators, semiconductors and conductors discriminated on the basis of band structure? **(2005)**

5. Explain the origin of energy band formation in solids. Show that in nearly free electron approximation, the energy band gap is 2 | V_G|, where $V_G$is Fourier transform of periodic potential seen by the valence electrons. **(2010)**

6. Explain the reduced zone scheme of plotting the energy bands in solids. On the basis of E vs k curve distinguish between conductors, semiconductors and insulators. **(2010)**

7. What is nearly free electron approximation? On the basis of this approximation explain the formation of energy bands in solids.**(2010)**

8. Starting with the expression for the density of states for electrons in a band, show that the Fermi energy of an intrinsic semiconductor is at the middle of the band gap. Use these results to estimate the electron density at 300K (Assuming $E_g = 1$ eV and the rest masses of electron and hole as m_e and m_h). **(2013)**

9. Describe the motion of an electron in one dimensional periodic potential and show that it leads to formation of bands of allowed and forbidden states in the electron energy spectrum. How are the conductors, semiconductors and insulators discriminated on the basis of band structure? **(2015)**

10. What is the difference between direct and indirect band gap semiconductors? Which one is suitable for use in solar cells? **(2016)**

TUTORIAL SHEET: 11

TRANSISTORS

1. 1. Circuit as shown in the figure. It is designed to establish the quiescent potential at V_{CE} = 12V, I_C = 1.5 mA and stability factor S ≤3. Find the values of resistors R_E, R_1 and R_2 where symbols have their usual meaning. **(2004)**

2. Explain the working of a phase-shift oscillator. Draw the circuit diagram of a phase-shift oscillator using either a transistor or an op-amp. What are the conditions which must be satisfied to achieve stable oscillations?Calculate the frequency of oscillations for $R = 1k\Omega$ and C = 01 μF.**(2007)**

3. Explain the difference between n-p-n and p-n-p transistors. Give their device structure and biasing circuits. Draw a circuit for a single-state common-emitter amplifier. **(2007)**

4. Draw the circuit diagram of a two-stage RC-coupled common emitter transistor amplifier. Show how the magnitude and phase of voltage gain vary with frequency. Define bandwidth of this amplifier. An amplifier with open loop voltage gain, $A_v = 1000 \pm 100$ is avallable. It is necessary to have an amplifier whose voltage gain varies by no more than $\pm 0 \cdot 1\%$. Find the reverse transmission factor β of the feedback network used and the gain with feedback. **(2008)**

5. A certain colpits oscillator uses a tank circuit with L=20mH; $C_1 = 200$ pf and $C_2 = 200$ pf. What is the frequency of oscillation? **(2008)**

6. (i) "Transistors are current operated devices, while vacuum tubes are voltage operated" – Explain.
(ii) Why are junction transistors called bipolar devices? **(2008)**

11. Draw the common-base amplifier circuit, using an n-p-n transistor and briefly discuss its working. **(2010)**

12. Draw and explain the collector characteristics of a bipolar junction transistor in common emitter configuration. Using the plot, explain how the transistor can be used as an ON-OFF switch. **(2013)**

13. Explain how the circuit shown above can be a source of oscillations. Use this circuit to construct a transistor oscillator and explain its working. What is the frequency of oscillations of this circuit? (2013)

14. Differentiate between n-p-n transistors. Give their device structure and biasing circuits when used as an amplifier. **(2015)**

15. Design a transistor based Colpitt oscillator which can oscillate at 9 MHz. Explain how the oscillations are created and sustained. **(2015)**

TUTORIAL SHEET: 12
Digital Electronics

1. Draw a circuit using AND, OR and NOT gates to realize the following truth table:

Input			Output
A	B	C	D
0	0	0	0
0	0	1	1
0	1	0	1
1	0	0	1
0	1	1	0
1	0	1	0
1	1	0	0
1	1	1	1

2. Define ex-OR. Give its truth table and draw the possible logic blocks.**(1996)**

3. Simplify the following logic function and draw the corresponding logic gates:
$Y = AB + B\overline{C} + \overline{A}B + \overline{A}C + \overline{B}C + \overline{A}\overline{B}\overline{C} + ABC$ **(1997)**

4. Simplify the following logic function and draw the corresponding logic diagram:-
Y = (A+B). (A+C). (B+C) **(1998)**

5. Simplify the given Booleam expression and draw the corresponding logic circuit using NAND gates $Y=(\overline{A} + B + C).(\overline{A} + \overline{B} + C)$ **(1999)**

6. (a) Combination switching circuit can perform an addition of the numbers held in two registers.
- (i) Write down the truth table for the addition of two bits.
- (ii) Write down a Boolean expression for ht necessary circuit functions.
- (iii) Arrive at the Exclusive –OR function.
- (iv) Draw the logic diagram for the circuit which performs the addition.

(b) (i) What is sequential switching circuits?
(ii) Describe a simple sequential circuit.
(iii) Describe a clocked RS Flip –Flop.
(iv) Briefly describe ROMs. **(2001)**

7. Show that a negative logic OR gate is like a positive logic AND gate.**(2002)**

8. Explain the operation of the following circuit as a gate. Draw the truth and find the operation carried out by this gate neglecting the source impedance,Junction saturation voltages and diode voltages in forward direction. Find the minimum value of h_{fe}. **(2003)**

9. (a) Give the two forms of the De Morgan's theorem.
(b) What is the principle used in 'half –adder'? Give the truth table for it. **(2004)**

10. Simplify the equation $Y = [A\overline{B}(C + BD) + \overline{AB}C]$ Using Boolean algebra. Give the logic circuit for the equation before and after the simplification.**(2007)**

11. Give the Boolean expression and the truth table for an XOR gate. Why are NAND gates called universal gates? Realise OR and XOR gates employing only NAND gates. **(2007)**

12. How can the NAND-gates be combined to perform the OR – operation?**(2008)**

13. Simplify the logical expression AB + AB + ABC using a karnaugh map. **(2010)**

14. Simpligy the logical expression (A + B) B (A + C) and draw the logical circuit to implement it. **(2010)**

15. Construct a digital circuit to add three bits A, B and C and provide their sum and carry as-outputs. Show appropriate Boolean expressions and truth table to justify the outputs. **(2013)**

16. Simplify the logical expression [AB (C + BD) + A B] C. **(2015)**

17. Why are NAND and NOR gates called universal gates? Give the logic diagram, Boolean equation and the truth table of NAND gate. **(2016)**

TUTORIAL SHEET: 13
Electronics: Miscellaneous

1. Distinguish between Einstein and Debye models of specific heats of solids. Obtain an expression for the specific heat of a solid on the basis of Debye model. Discuss the results for low and high temperature ranges. **(2010)**

2. Distinguish between classical and quantum theory of paramagnetism. Explain the paramagnetism of free electrons on the basis of F.D. distribution. **(2010)**

3. Find an expression for lattice specific heat of solids, and its low and high temperature limits. What is Debye temperature? **(2010)**

4. Find an expression for lattice specific heat of solids and its low and high temperature limits. What is Debye's temperature? **(2011)**

18. The velocity of sound in f.c.c. gold and f.c.c. copper is 2100m/s and 3800 m/s respectively. If the Debye temperature of copper is 348 K, then determine the Debye temperature of gold. Take the densities of gold and copper as 1.93 x 10^4kg/$m^3$and 0.89 x 10 ^{4} kg/m^3 respectively. **(2014)**

1. Draw the device structure of a-p-n junction solar cell and explain how light energy is converted into electrical energy. Draw and explain its I-V characteristics. **(2015)**

2. Find an expression for lattice specific heat of a solid, and its low and high temperature limits. What is Debye temperature? **(2015)**

3. Write down the salient features of the Einstein's theory of lattice heat capacity. Further write down the expression for specific heat in Einstein's theory and explain its high and low temperature limits. **(2016)**