→ Remember to write Physics, especially true in Paper II

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CIVIL SERVICES EXAMINATION (MAINS) 2012

PHYSICS PAPER - II: QUANTUM MECHANICS

TUTORIAL SHEET: 1

Foundations of Quantum Mechanics

1. What are de-Broglie waves? State the uncertainty principle and explain its relation with deBroglie waves by considering a free particle . (1991)

2. Using de-Broglie's relation, deduce an expression for energy values of a particle enclosed in one-dimensional box. 'Free elections' in a long - chain molecule may be treated as particles in one - dimensional box. For a long - chain molecule of length 60 A^0, deduce the lowest three energy state values in eV units. (1993)

3. Using Heisenberg's uncertainty principle, calculate the mass of meson being exchanged between nucleons inside the nucleus, taking the range of nucleon force as 1.7 F. Distinguish between pion and muon? (1995)

4. Describe how Davisson - Germer electron diffraction experiment confirms the de -Broglie hypothesis of matter wave? (1995)

5. Using Heisenberg uncertainty principle, find the ground state energy and Bohr radius of hydrogen atom. (1997)

6. 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)

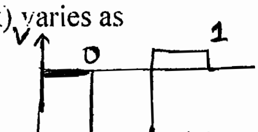
7. Find the de - Broglie wavelength associated with an electron of energy (i) 10 eV and (ii) 10 MeV. (1999)

8. 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)

9. 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)

10. (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)]

Copy 11. (i) If x and P_x are two conjugate variables, show that

$$(\Delta x)(\Delta P_x) \geq \left| \langle [x, P_x] \rangle / 2i \right|$$

(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)

12. Calculate the wave length of neutrons at a temperature of 20° C. (2004)

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

⊛ जो भी non-standard term 'question' में use की है, उसे define करो !!

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14. Calculate the de Broglie wavelength of a thermal neutron at 27^0C temperature.

(2006)

15. (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)

16. Derive Bohr's angular momentum quantization condition in Bohr's atomic model from the concept of de Broglie waves.

(2010)

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

$$V(x) = V_0 \text{ (a constant) for } |x| < \frac{a}{2}.$$

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

State the boundary conditions you use along with their justification. (In the solution consider particles incident from one side only). If the total energy $E < V_0$, show that there is an important difference with classical mechanics. Explain, with the help of the uncertainty principle that $E < V_0$ 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). here we have no option but to do by differential eqn. method (1991)

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

1-d box / 3-d Box depend on marks

5. Find the energy Eigen values of a one-dimensional harmonic oscillator whose Hamiltonian is given by

$$H = \frac{P^2}{2m} + \frac{1}{2}kx^2 \qquad (1994)$$

6. An election is confined in a one - dimensional box of 1 A° width. Draw the energy level diagram upto 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 behaviour of $|R|^2$ and $\frac{K}{K_0}|T|^2$ with μ. (1997)

9. An infinite square well potential is

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

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) (60)

10. For a particle confined in a one - dimensional potential well of length L the wave function is $\psi(x) = C \operatorname{Sin}\left(\frac{\pi x}{L}\right)$ $0 < x < L$ and $\psi(x) = 0$, outside. Calculate the expectation values of x and 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. Here we have a choice b/w
ii) Obtain an expression for the ground state. ① differential eqn method (2001)
② advanced method

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 :

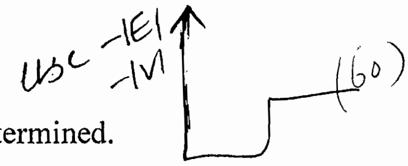
$$V(x) = \begin{cases} 0 & \text{for } x < -a \\ V & \text{for } -a < x < a \\ 0 & \text{for } x > a \end{cases}$$

(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

$$a^2 V_o \geq \hbar^2 \pi^2 / 8m .$$

(2003)

19. Consider a particle in a one – dimensional box of length a in a quantum state at t = 0, given by

$$\Psi(q,0) = \begin{cases} A; 0 < q < a \\ 0; \textit{otherwise} \end{cases}$$

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 wavefunction 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

$$\int_0^\infty e^{-x^2} = \frac{\pi^{1/2}}{2}$$

(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

$$\psi(x) = c\left[\sin\frac{\pi x}{a} + \frac{1}{2}\sin\frac{2\pi x}{a}\right] \text{Calculate c.}$$

(ii) If a measurement of energy is made, what are the possible results and what are the probabilities for each one of them? (2005)

2 number

18 marks

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.

(20) (2006)

(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)

Correspondence principle

23 Solve the Schrodinger equation for a linear harmonic oscillator; Obtain the eigenvalues and the corresponding eigenfunctions. (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 for the one dimensional wave function

$$\psi(x) = \begin{cases} \frac{1}{\sqrt{2a}}, |x| < a \\ 0, |x| > a. \end{cases}$$

Where a is a real constant, the $\boxed{\text{rms uncertainty}}$ in momentum is infinite. (2008)

26. Show that the probability of transmission across the step barrier represented by the potential

$V(x) = \begin{cases} 0, \text{ when } x < 0 \\ V_0 \text{ when } x > 0 \end{cases}$ where k_1 and k_2 are wave numbers I n regions x <0 and x >0 respectively.

To Prove $T = 4k_1k_2/(k_1+k_2)^2$

(2008)

27. 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)

28. 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)

29. 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 isa not an explicit function of time. (2009)

30. 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)

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

(2010)

32. A system is described by the Hamiltonian operator,

$$H = -\frac{d^2}{dx^2} + x^2$$

Show that the function Ax $\exp\left(-\frac{x^2}{2}\right)$ is an eigen function of H. Determine the eigen values of H.

(2010)

$$\boxed{H\psi = \frac{i\hbar\partial\psi}{\partial t}}$$

time dependent form of Schrodinger's eqn

→ remember $\left(\frac{\hbar}{2}\right)$ for S matrix
and $\hbar$ for $\sqrt{(l-m)(l+m+1)}\,\hbar$ formulae

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 $\Psi(r) = 1/\sqrt{\pi}\ a^{3/2}\quad e^{-r/a}$, 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)

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

(2004)

7. 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)

8. 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)

9. 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)

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

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

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

$\Psi_{n,l,m}$, P_l^m, Y_l^m

$[X]^* = (X^T)$ and conjugate of all elements

11. 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.

12. (a) 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)

13. (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.
(2007)

14. 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)

15. 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 (a), obtain an expression for the density of states. (2007)

16. 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)

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

18. 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

$$\hat{L}_+ |l, m> = \hbar\sqrt{l(l+1) - m(m+1)}\,|l, m+1>,$$

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

(2008)

19. (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_BT 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

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Relation $\frac{V_F}{C} = 1\cdot 98\left(\frac{E_F}{1MeV}\right)^{1/2}$

(2009)

20. 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)

21.(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)

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

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

(ii) $\det(\sigma_y) = \det(\sigma_z)$ $|A - \lambda I| = 0$

(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)

23. 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)

24. 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)

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ATOMIC PHYSICS
TUTORIAL SHEET: 4

1. What did the Stern - Gerlach experiment establishes? Explain your answer. Would the experiment succeed if it were performed with a beam of free electrons? (1989)
2. What is meant by L - S coupling? Deduce the spectral terms, which can arise from 3p4p electron configuration. Would all these terms exist in $3p^2$ configuration? Write expressions for the square of angular momentum for L = 2 and also for the component of angular momentum for mj = 2 as given by quantum mechanics. (1989)
3. What are the transitions leading to the emission of the D lines of sodium? Deduce the expression for the Lande splitting factor 'g' and calculate its values for the states involved in the emission of D lines? Hence find the change of energies of these levels when a sodium source is placed in a magnetic field, which is not too high. (1990)
4. Give the quantum numbers of the states whose energy difference accounts for the two D - lines of sodium. Find the energy difference for D_1 and D_2 lines in electron volts. (Wavelength separation = 6A°, Mean wavelength = 5893 A°) (1991)
5. What is the value of the spin of the electron and the corresponding magnetic moment? Can these be considered as arising from the classical case of rotation of a finite rigid charged body about its axis? Give reasons for your answer. (1991)
6. Derive an expression for the magnetic moment of an electron in an atom taking into account electron spin. Explain anomalous Zeeman effect by considering the above magnetic moment. (1992)
7. Draw energy diagram for transverse Zeeman effect for D line of Sodium $3^2P_{3/2} \rightarrow 3^2S_{1/2}$ (1992)
8. What values of J quantum number many be observed in normal atoms of alkalis and alkaline earths? Which of the spectral lines in alkaline earths would show normal Zeeman effect and why? (1993)
9. What are the term symbols of two equivalent p electrons? Write down the term symbols in ascending order of energies. (1995)
10. What is space quantisation? Discuss the Stern-Gerlach experiment establishing the space quantisation. (1995)
11. Taking only the spin motion of electron, proton and neutron and assuming them as point particles, obtain their magnetic moments. How far the values thus obtained agree with experimental values? If not, why? (1996)

Nuclear Physics

12. Explain the fine structure of Hα line of H-atom arising due to LS coupling. (1996)
13. Derive an expression for Lande's g-factor for LS coupled state (1997)

Same

14. Draw the energy level diagram and show the allowed transitions for Zeeman pattern for $n_l=3_1 \rightarrow 2_0$ transition line of a hydrogen atom placed in a uniform magnetic field of 1 K Tesla. Calculate the doublet splitting (1997)

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15.) The atomic number of Na is 11.

(i) Write down the electronic configuration for the ground state of the Na atom.

(ii) Give the standard spectroscopic notation for the ground state.

(iii) The lowest frequency in the absorption spectrum of Na is a doublet. What are the spectroscopic designations of the pair of energy levels to which the atom is excited as a result of this absorption process?

(iv) What is the mechanism responsible for the splitting between the pairs of energy level? (1998)

16. Draw the energy level diagram showing the Zeeman splitting of $^2P_{\frac{1}{2},\frac{3}{2}}$ and $^2S_{\frac{1}{2}}$ levels in a weak magnetic field. Give the selection rules and the resulting transitions between the sublevels. Does the magnetic interaction lift the degeneracy of the level only partially or wholly? (1998)

17. What is spin-orbit coupling? Considering the Sodium doublet (5890 A° and 5896 A°), Calculate the effective magnetic field experienced by the electron in the 3p state. 18.41 T (1999)

18. Describe the Stern-Gerlach experiment and discuss its significance. (2000)

Determine all the term symbols of p^2 equivalent electrons and arrange these states in increasing order of energy. Justify your answer. (2000)

19. 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)

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

21.

(2001)

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

24. Obtain the energy states for He atom for n = 1 , 2, 3 levels (n is principal quantum number). Banwell
Draw the energy level diagram. Does L-S coupling scheme hold good in Hg atom which like He has 2 optical electrons (6S)? Comment. NO, J-J (2001)

25. What is the lowest non –zero angular momentum for an elementary particle? Name at least three elementary particles having such an angular momentum. (2002)

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

27. 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)

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

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

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

31. What is Zeeman effect? How can it be understood on a quantum mechanical basis? Obtain an expression for Zeeman shift. $\Delta\lambda$ (2004)

32. 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)

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

34. 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 field and why? (2005)

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

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

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

38. Explain normal and anomalous Zeeman effect. Obtain expression for Zeeman splitting of an alkali metal spectral line, and illustrate with an example. 39 (2008)

39. For transition to the ground state what is the longest wavelength that can be emitted by hydrogen 40 (2008)

40. 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)

41. $2^2S_{1/2}$ level in H atom is ~~1058~~ 1058 MHz above the $2^2P_{1/2}$ level 42
(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)

42. (i) Establish that
$hc = 1240 eV.nm$ 42
$= 1240$ MeV. Fm
(ii) The energy levels of a hydrogen atom are given by
$E_n = (-1/n^2).Ryd.$
Where, 1 Ryd = hcR.
Show that , $R = 1\cdot097\times10^7 m^{-1}$ .What exactly is R? (2009)

43. (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. (2009)

(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 (2010)

44. 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)

45. 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)

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[PHYSICS PAPER- II: MOLECULAR PHYSICS
TUTORIAL SHEET: 5

1. What are anti - Stokes lines? Do they occur in both Raman and Compton Scatterings? Explain how they arise and how temperature affects their intensities?
(1990)

2. Raman effect differs from Rayleigh scattering. Explain. Explain qualitatively how Raman lines originate. What is the difference between Raman Scattering and Compton Scattering?
(1992)

3. A sample shows a Raman line at 4200 A° with incident radiation having $\lambda = 4400$ A°. Where will the other corresponding Raman line fall with the same exciting radiation? Will that line be stronger or weaker than the line at 4200 A°, and why?
(1993)

4. Give the salient features of electronic band spectra of diatomic molecules in emission. Why would absorption spectrum of Iodine (I_2) vapour has longest wavelength band at λ_0, initial band separation $\Delta\lambda o$, and the bands converge at wavelength λ_∞? Relate this data broadly to the concerned parameter of I_2 molecule.
(1993)

5. Give the theory of vibration - rotation spectra of diatomic molecules. Explain the nature of P, Q, R branches.
(1994)

6. Discuss the gross and fine structure of electronic band spectra of a diatomic molecule.
(1994)

7. Explain the origin of anti-stokes lines in Raman Spectra?
(1995)

8. Calculate the bond length and force constant of the bond of $^{12}C\ ^{16}O$ molecule, given $0 \rightarrow 1$ rotational ~~rational~~ line in V = 0 state is at 115.3 GH_Z and the wavelength of the vibrational frequency is 14.7 μm.
[vibration-rotation]
(1996)

9. Write in brief the differences between the IR active and Raman active bands.
(1997)

10. Calculate the force constant for the coupling between H and Cl given that the fundamental frequency of $H^1\ cl^{35}$ molecule is 8.7×10^{13} H_Z. Assuming the force constant of $H^2\ cl^{35}$ to be the same as that of $H^1\ cl^{35}$. Calculate the vibration frequency of $H^2\ cl^{35}$.
(1998)

11. (i) State and explain Frank – Condon principle.
(ii) In three separate pairs of electronic states (one ground and another upper excited) of the diatomic molecules, the average distances are:
(i) equal (ii) Slightly greater and (iii) appreciably greater.
In accordance with Frank-Condon principle, obtain most favourable transitions. State vibrational levels in each of the three situations.
Illustrate the transitions in all the aforesaid situations by drawing suitable energy level diagrams.
(2001)

F : 19 masses
Cl : 35 in amu
Br : 80
I : 127

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12. Write an expression for the energy of a diatomic molecule executing both rotation and vibration in a given electronic state. Explain the observed spectra giving a schematic diagram. What are O, P, Q, R and S branches ? (2007)

13. Why does a spinning nucleus precess in a magnetic field ? Explain the underlying principle of nuclear magnetic resonance (NMR) spectroscopy. (2007)

14. (a) (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 querries).

(iii) In CO molecule $J=0 \rightarrow J=1$ line occurs at frequency 1.153×10^{11} Hz. Calculate the moment of inertia of CO molecule.

(b) (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? Symmetric Molecules

(iv) A Raman Stoke's line is observed at 552 nm. When a sample is excited by Hg green line of wave length 546 nm. Calculate the wave length of anti-stoke's line do $\left(\frac{1}{\lambda}\right)$ (2001)

15. (i) A sample is irradiated by a 5000 A° radiation to give a Raman line at 5050.5 A°. Calculate the Raman frequency. do $\left(\frac{1}{\lambda}\right)$

(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)

16. (i) Calculate the moment of inertia of Hcl molecule from the expression
$= 20.68(J+1)$
where $J = 0,1,2,....$ (2002)

17. 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)

18. Explain the nature, origin and significance of 21 cm Hydrogen line.

(2002)

19. Calculate the change in rotational constant Bo when deuterium is substituted for hydrogen in a hydrogen molecule. (2002)

20. (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)

21. 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? Rot. Vib-Rot. elec.

22. 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.

in MHz (2003)

$(\mu_z)_{proton} = 2.793\ \mu_N$ (copy)
This is standard value

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23. 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)

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

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

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

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

28. The constants B and γ_0 for a KCl molecule have values $1{\cdot}43 \times 10^{-5}$ eV and $8{\cdot}4 \times 10^{12}$ s^{-1} respectively. Determine the number of rotational levels between the vibrational levels v =0 and v = 1. (2005)

Raman

29. 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)

30. 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? Symmetric Molecules, Coloured Salt Solution } analysis (2005)

31. 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, HCl and HI molecules are 4141·3 cm^{-1}, 2988·9 cm^{-1} and 2309·5 cm^{-1} respectively. Compare the force constants of these three molecules. (2005)

32. (i) State and explain Franck – Condon Principle. (2007)

(ii) In three separate pairs of electronic states (one ground and another upper state) of diatomic molecules, the average internuclear 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)

33. 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)

34. 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)

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

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

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

38. 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)

39. (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 $J = O \rightarrow J = 1$ line occurs at a frequency $1 \cdot 153 \times 10^{11}$ Hz. Calculate the moment of inertia of CO molecule.
(2010)

40. 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)

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

42. 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)

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TUTORIAL SHEET: 6
NUCLEAR PHYSICS

1. Explaining the physical meaning of each term, write semi-empirical mass formula for a nucleus. Find the value of atomic number of most stable nucleus for a given mass number A. (60 marks) (1997)
2. Explain the phenomenon of nuclear fission and obtain the expression for fissionability parameter. Show that the critical value of the fissionability parameter is 50. (1997)
3. What is the basis of thermonuclear fusion? Estimate the order of temperature required for promoting the fusion reaction of lighter nuclei. Calculate the Q - value of the proton - proton cycle.
$4\,{}^{1}_{1}H \rightarrow {}^{4}_{2}He + 2\,{}^{0}_{+1}e + Q$ (1998)
4. Discuss one experimental method for the determination of energies of β - particles emitted radioactive isotopes. Draw a diagram of typical β - ray spectrum. (1999)
5. Write down Weizsaker formula for the binding energy of a nucleus. Explain the significance of each term. Derive an expression for the atomic number Z of the most stable nucleus for a given mass number A. Determine the atomic number Z of the stable nucleus having A=64. (1999)
6. Using the uncertainty principle, show that the electrons cannot exist inside the nucleus. How does then one account of the beta decay of a nucleus? (2000)
7. How do you explain the continuous spectrum in beta decay of radioactive nuclei? (2000)
8. A nuclear reactor has an output power of 1 MW with a thermal efficiency of 30%. How much uranium per day is consumed to run this reactor, if the average energy released per fission of ^{235}U is 200 MeV, and the uranium is enriched to 2% ^{235}U? (2000)
9. Describe important experimental facts that led Pauli to postulate the existence of neutrino particle. (2001)
10. Discuss briefly the concepts of fission barrier, excitation energy and activation energy on the basis of liquid drop model. Why ^{235}U is fissionable by thermal neutrons while ^{238}U is not? (2001)
11. Classify the Indian power reactors into BWR, PHWR and FBR varieties, explaining the acronyms, type of fuel used and location for each variety. (2001)
12. A nuclear reactor operates at a power level of 10 M W. What will be the flux of neutrons required to maintain this power level? Given that a free neutron has an average lifetime ~~of~~ 10^{-3} second before its capture in a uranium nucleus and energy released per fission is 200 MeV. (2001)
13. Describe briefly the various cycles for energy production in stars, relating them to the life history ~~of a~~ star." Fusion reactors operate in the core of stars but have not become a reality on earth as yet". Comment on the statement. (2001

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

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

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

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

18. 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)

19. List some of the important properties of deuteron and show that it is a loosely bound system and has only one bound state. (30) (2003)

20. 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
$${}_1^2H + {}_1^2H \rightarrow {}_2^3He + n$$ (2003)

21. 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)

22. Calculate Binding energy per nucleon of ${}^4_2He$ and ${}^{16}_8O$. (2004)

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

24. Explain how energy is released in stars. (2004)

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

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

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

28. Describe how parity violation was experimentally detected in ^{60}Co β-decay. How was the observed asymmetry in the distribution of emitted electrons explained? (2005)

1 Ci = 1 Curie = 3.7×10^{10} Bq
1 Bq = 1 Becquerel = 1 decay/second

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

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

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

Given

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

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

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

31. 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 parties agree with those predicted on the basis of the shell model ? (2007)

32(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 ? (2007)

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

33. 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)

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

35. 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)

36. 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)

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

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

39. A star converts all its hydrogen to helium, achieving 100% helium. It then converts the helium to carbon via the reaction

$$^{4}_{2}He + ^{4}_{2}He + ^{4}_{2}He \rightarrow ^{12}_{6}C + 7\cdot 27MeV$$

The mass of the star is $5\cdot 0\times 10^{32}$ kg and it generates energy at the rate of 5×10^{30} W. How long will it take to convert all Helium atoms to carbon at this rate?

(2010)

40. 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)

41. 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)

42. Explain parity violation in β-decay. Describe how parity violation was experimentally detected in the decay of ^{60}Co.

(2010)

Hafnium, Tantalum } Nuclear Isomerism

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TUTORIAL SHEET: 7
PARTICLE PHYSICS

1. Discuss briefly the three types of interactions between the elementary particles and explain the relative strength of the various kinds of interactions between elementary particles. (1988)

2. Write an essay on elementary particles with the following points:
(i) Types of particles (ii) Quantum numbers
(iii) Conservation laws (iv) Type of interactions. (1993)

3. What are weak interactions? Mention the various processes in which the weak interactions play a dominant role. β decay, Decay of strange Particles (1993)

4. What are the conservation laws of elementary particles? How are these applied to Leptons and Baryons? (1994)

5. Explain parity violation in β-decay. (1994)

6. What is helicity of a neutrino? How is it measured? (1994)

7. State conservation laws obeyed by strong and weak interactions? (1995)

8. Define parity for a quantum - mechanical system. Describe an appropriate experiment proving the parity violation in weak interaction. How can the parity violation in weak interaction be understood? Explain. (1996)

9. Mention the conservation laws violated in the following elementary particle reactions:
(i) $\bar{\mu} \to \bar{e} + \nu e$ (ii) $n \to p + \bar{e}$
(iii) $K \to \pi^0 + \pi^0$ (iv) $e^+ + e^- \to \gamma$

10. In nature, we have basically four kind of forces in the following order of increasing interaction strength:-
(i) Gravitational (ii) Weak
(iii) Electro Magnetic (iv) Nuclear or strong.
Comment on their spatial dependence and give their relative strengths in terms of dimensionless coupling constants. (1998)

11. The following reactions do not take place: -
(i) $n \to p + e^- + \bar{\nu}_e$
(ii) $p \to \pi^0 + e^- + \nu_e$ Explain the reasons in terms of conservation laws. (1999)

12. Which of the following reactions are allowed? What are the conservation laws violated by the rest? Classify the particles (fermions/bosons, mesons/baryons, leptons/hadrons) involved and the type of interactions in the case of the allowed ones.
(i) $\Sigma^\circ \to \pi^+ + \pi^-$ (ii) $\pi^- + p \to n + \pi^\circ$
(iii) $\pi^+ + p \to \pi^+ + p + \pi^- + \pi^0$ (iv) $\pi^\circ \to \gamma + \gamma$ (2000)

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

14. 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)

15. Distinguish between Hadrons and Leptons. (IFS, 2001, IAS 2002)

16. Discuss Gellmann-Nishijima classification of elementary particles. (IFS, 2001)

17. What are quarks? List the various types of them. Give the concept of coloured quarks. (IFS, 2002)

18. Which of the fundamental interactions is present in the following nuclear process? Use the conservation laws to arrive at the conclusion.

$$\Sigma^\circ \to \lambda^\circ + \gamma \quad (\text{lifetime} \le 10^{-14}\ \text{s})$$ (IFS ,2002)

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

20. Distinguish between particle and antiparticle. How antiparticle were discovered? (IAS, 2002)

21. Mention the conservation laws for strong, electromagnetic and weak interactions. (IAS, 2002)

22. 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)

23. State the conservation law which is violated in each of the following processes:

(i) $n \to p + \bar{e} + \gamma$ (ii) $\pi^- + p \to k^+ + k^-$
(iii) $\pi^- + p \to \Sigma^+ + k^-$ (iv) $\Sigma + k \to p + p$ (2003)

24. Which of the following reactions are allowed and forbidden under the conservation of strangeness, baryon number and change conservation?

(i) $\pi^+ + n \to \lambda^\circ + k^+$ (ii) $\pi^+ + n \to k^\circ + k^+$
(iii) $\pi + p \to \lambda^\circ + k^+$ (iv) $\pi + p \to \pi^\circ + \lambda^\circ$ (2004)

25 State the quantum numbers I_z, Y and S for the separate uds quarks and antiquarks. What combination of these leads to the formation of (i) proton and (ii) neutron? (2005)

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

27. 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)

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

29. Give the hypercharge and isospin of the quarks and antiquarks. What are the quark contents of the mesons: $\pi^+, \pi^0, \pi^-, K^-, K^0, K^-$ and η? (2008)

30. 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 leptoquark?

(2009)

31. 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)

32. State the quantum number I_z, Y and S for the uds quarks and antiquarks. Which combination of these leads to the formation of (i) proton and (ii) neutron?

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TUTORIAL SHEET: 8
SOLID STATE PHYSICS
SUPERCONDUCTIVITY

several like metals (Hg, Pb), alloys (Pb-Bi)
ceramics cuprates

1. What is Super conductivity? In what kinds of materials is it found to occur? Name some parameters, which characterise a super conductor. Cite any two major uses if we succeed in making Super conductors with Tc not far below atmospheric temperatures? (1990)

2. Write a short note on Super conductivity. (1992)

3. Explain the basic distinction between a perfect Conductor and a Super Conductor. (1997)

4. 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)

5. Explain why superconductors are perfect diamagnets.

6. (i) Obtain reciprocal lattice to normal BCC lattice
(ii) Describe Josephson junction and the effect. How is it exploited in the formation of a SQUID? Write down the applications of a SQUID? (2001)

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

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

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

10. 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)

11. Determine the reciprocal lattice vectors of an fcc lattice. (2005)

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

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

14. Show that the reciprocal lattice of a hexagonal lattice is a hexagonal lattice with a rotation of axes

(2009)

15. 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) $T < T_c; H > H_{C_2}$ N (ii) $T > T_c; H < H_{C_1}$. N

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

m

(2009)

16. What is Josephson tunneling? Distinguish between a.c. and d.c. Josephson effects.

(2010)

17. 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)

18. What is nearly free electron approximation? On the basis of this approximation explain the formation of energy bands in solids.

(2010)

19. 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)

20. Distinguish between classical and quantum theory of paramagnetism. Explain the paramagnetism of free electrons on the basis of F.D. distribution.

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PHYSICS PAPER – II : ELECTRONICS
TUTORIAL SHEET: 9
Band theory of solids

1. State the difference in the electronic energy states in an isolated atom and in a solid. Hence explain difference between a conductor, an insulator and an intrinsic semiconductor. What is the role of impurities in so called extrinsic semi conductors?
(1989)

2. Why do the electronic energy levels in a solid form bands? Describe in terms of the band theory the difference between a conductor, an intrinsic semi conductor and an insulator.
How do the energy levels change when some impurities are introduced in a Semi-conductor? Explain how by doping you can have both n-type and p-type semi conductors starting with pure Germanium.
The band gap in case of Germanium is about 0.8 eV at 0^0K. Neglecting the variation of band gap with temperature make a rough estimate of the temperature at which the resistance of a pure Germanium sample will be reduced to $\frac{1}{e}$ times its value at 300 K.
(1991)

3. Phosphorous is doped in a silicon wafer. The impurity concentration is 10^{13} per cm^3. If all the donors are active. Calculate its resistivity at room temperature. The mobility of electrons is 1250 cm^2/V-second
(1999)

4. Distinguish between intrinsic and extrinsic semiconductors. Explain the concept of 'hole'.
(2001)

5. Discuss the variations of free carrier concentration with temperature of intrinsic and extrinsic semiconductors.
(2002)

6. Show that the condition of periodicity of lattice leads to the Block theorem. What is a Block function? (2004)

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

8. (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)

10. 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)

11. An In As semiconductor sample is cut in the form of a small bar of size $1\cdot0$ cm $\times1\cdot0$ mm $\times2\cdot0$mm. Its lengthwise resistance is $1\cdot25\ \Omega$. A Hall field of $1\cdot7$ V/m develops when a current of $0\cdot12$ A

is passed lengthwise and a magnetic field of $0{\cdot}05T$ is applied normal to its length as shown above. Calculate the carrier density. (2005)

12. Draw the device structure of a p-n junction solar cell and explain how the light energy is converted into electrical energy. Define the 'short-circuit current', 'open-circuit voltage' and 'efficiency' of a solar cell.

(2007)

13. Silicon is the most popular semiconductor material used for the fabrication of electronic devices and integrated circuits. Why? Give at least five reasons.

(2009)

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TUTORIAL SHEET: 10
SEMI CONDUCTORS

1. What is a P-N junction? Describe with energy level diagram the formation of double layer of charges, which generates a potential difference (V) across the junction. Hence show that the capacitance of the double layer $C=KV^{-1/2}$, where K is a constant. State some practical use of this relation between C & V.
(1988)
2. What is a Zener diode? Explain what function it performs in the circuit given below as the load resistance R_L is varied. What is the purpose of introducing resistor R_2 in the circuit? (V_s and Rs represents source voltage and resistance respectively).
(1989)
3. How is a p-n junction prepared? Explain the charge and potential distributions in such a junction in open circuit. Explain how a p-n junction can be used to build a solar cell. Describe the mechanism of the increase of conductivity of Germanium by doping it with Arsenic.
(1990)
4. Explain the formation of potential barrier in an unbiased p-n junction.
(1992)
5. Show that in the non-degenerate approximation the Fermi level in a n-type semiconductor is slightly below the bottom of the conduction band and in p-type it is slightly above the top of the valence band, but in both cases it remains within the band gap.
(1993)
6. Describe and explain the theory and operation of the zener diode. Explain what is meant by
   a. Avalanche break down
   b. Zener break down
(1993)
7. How does built in potential appear across a p-n junction? Explain under what biasing conditions drift and diffusions currents respectively dominate.
(1995)
8. What is the photovoltaic mode of operation of a photodiode? Describe the construction and working of a silicon solar cell.
(1998)
9. Discuss the different breakdown mechanisms for a reverse biased Zener diode.
(2000)
10. Do these mechanisms have different temperature coefficients? Explain.
    Which one of these mechanisms shows a negative dynamic resistance? Why?
(2000)
11. A Zener diode of 1 W power has a dynamic resistance of 10 mΩ at the breakdown voltage of 3 V. What will be the fluctuations in the current through the diode if the voltage fluctuates by 100 mV? What will happen to the diode? Why?
(2000)

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TUTORIAL SHEET: 11
(TRANSISTORS)

1. (a) What is the role of transistor in an amplifier?
(b) If a signal from a high impedance source is to be amplified, which configuration is preferred and why?
(c) What will happen to output voltage of an amplifier if a part of the output is returned to the input (i) in phase (ii) 180^0 out of phase?
(1992)

2. Describe the characteristics of grounded emitter transistor amplifier circuit and determine expressions for
(a) Input resistance (b) Output resistance
(c) Current gain (d) Voltage gain (d) Power gain
(1993)

3. Establish the two Barkhausen conditions for sustained sinusoidal oscillations. Sketch the circuit of Wien's bridge oscillator and explain its working.
(1995)

4. A Si BJT is connected as shown in figure. Show that it is in active region and works an amplifier. Calculate its mid frequency gain, given that BJT has h_{fe} = 100, hie = 1KΩ
hre = hoe = 0, Ico = 20 mA

5. Draw the circuit of an emitter-follower and find in voltage gain.
(1997)

6. Explain the working of N-P-N transistor. Derive expressions for the current and voltage gains.
(1998)

7. A junction diode in series with a parallel combination of a large resistor and a capacitor acts as a linear detector of amplitude-modulated waves. Explain the action. (1999)

8. Explain the effect of negative and positive voltage feedback on an amplifier characteristics.
(2002)

9. Derive the various current components in a p–n–p transistor when it is actively biased. Using Ebers –Moll model, show that for the common –emitter configuration

$$I_C = -\alpha I_E = -I_{CO}\left(e^{V_C/V_T} - 1\right)$$

Where the symbols have the usual meaning. (2003)
(2003)

10. Draw a circuit diagram of an R –C phase shift oscillator. Explain its working Derive an expression for its frequency.
(2004)

11. A transistor with β = 50, V_{BE} = 0.7V, V_{CC} = 22.5 V and R_C = 5.6 kΩ is used in biasing 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 meanings.
(2004)

12. Explain the working of a pnase-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)

13. Explain the difference between n-p-n and p-n-p transistors. Give their device structure and biasing circuits.Draw a ciecuit for a single-state common-emitter amplifier.

(2007)

14. 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)

15. 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)

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

(2008)

TUTORIAL SHEET: 12
(LOGIC GATES)

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:
$Y = AB + B\overline{C} + \overline{A}B + \overline{A}C + \overline{B}C + \overline{ABC} + ABC$

(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

$$Y = [A\overline{B}(C + BD) + \overline{ABC}]$$

Using Boolean algebra. Give the logic circuit for tht 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)

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TUTORIAL SHEET: 13
Electronics: Miscellaneous

(1) (a) FET have a unique properties make BJTs not suitable for some important applications. What are these most important FET applications?

(b) Briefly describe FETs available resistors.

(2001)

(2) (a) What are the main applications of JFET? Discuss their advantage over bipolar transistors. Explain the working of a n –channel JFET with the help of schematic diagram.

(b) Write down the characteristics of an idea operational amplifier. Explain the term virtue ground in an operational amplifier.

(2002)

(3) Calculate the gain of the following amplifier circuit:

Given that $g_m = 10$ mV/A, $r_d = 1$ MΩ and $Z_L = 10$ kΩ.

(2003)

(4) The following information is included on the data sheet for an N –channel JFET:

N –channel JFET:

$I_{DSS} = 20$ mA, $V_P = -8$V and $g_{mo} = 5000$ μs

Determine the value of drain current and Tran conductance at $V_{GC} = -4$V.