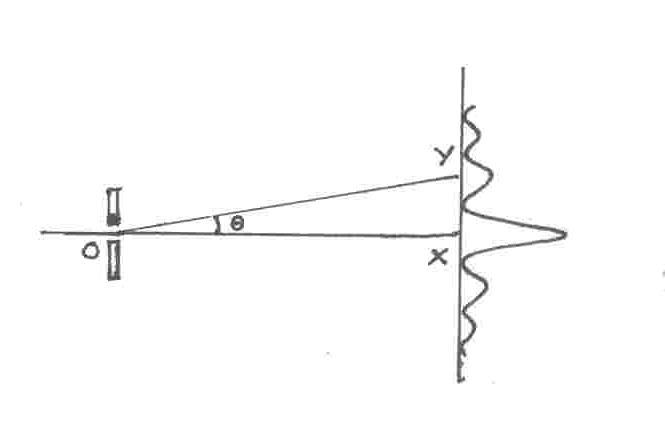
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| **UNIT – 1** |
| **QUANTUM PHYSICS** |
| **Unit-01/Lecture-01** |
| **Concept of matter waves**  Louis de Broglie made the suggestion that particles of matter, like electrons, might possess wave properties and hence exhibit dual nature. His hypothesis was based on the following arguments:  The Planck’s theory of radiation suggests that energy  is quantized and is given by  E = h (1)  where  is the frequency associated with the radiation.  Einstein’s mass-energy relation states that  E = mc2 (2)  Combining the two equations, it can be written as  E = h = mc2  Hence, the momentum associated with the photon is given by  P = mc = h/c = h/  Extending this to particles, he suggested that any particle having a momentum p is associated with a wave of wavelength given by   |  |  | | --- | --- | |  = h/p | (3) |   This is called **de** **Broglie’s hypothesis** of matter waves and  is called the de Broglie wavelength.  In case of charged particles like electrons, a beam of high energy particles can be obtained by accelerating them in an electric field. For example, an electron starting from rest when accelerated with a potential difference V, the kinetic energy acquired by the electron is given by  (1/2)mv2 = eV  where v is the velocity of the electron. The momentum may be calculated as  p = mv = (2meV)1/2  Using the de Broglie equation, the wavelength associated with the accelerated electron can be calculated as   |  |  | | --- | --- | |  = h/p = h/(2meV)1/2 | (4) |   This equation suggests that, at a given speed, the de Broglie wavelength associated with the particle varies inversely as the mass of the particle.  **Definitions [Rgpv June 2011, Dec 2011 (7)]**  **Wave Packet**  A **wave packet** consisting of waves of slightly differing wavelengths may represent the moving particle. Superposition of these waves constituting the wave packet results in the net amplitude being modified, thereby defining the shape of the wave group.  **Phase velocity**  The velocity of a individual wave of a wave packet is known as Phase velocity.  **Group velocity**  Group velocity is the velocity with which the wave packet travels.  **Q. Derive the formula of Phase velocity and Group velocity and also find relation between them?**   |  |  | | --- | --- | | A wave is represented by the formula |  | | y = A cos (t – kx) | (1) |   where y is the displacement at any instant t, A is the amplitude of vibration,  is the angular frequency equal to 2 and k is the wave vector, equal to (2/). The phase velocity of such a wave is the velocity with which a particular phase point of the wave travels.   |  |  |  | | --- | --- | --- | | This corresponds to the phase being constant. | |  | | i.e., (t – kx) = constant | |  | | or | x = constant + t/k |  | | Phase velocity vp = dx/dt = /k | |  | |  | = 2/(2/) =  | (2) |   vp is called the ‘wave velocity’ or **‘phase velocity’.**   |  |  | | --- | --- | | For group velocity, consider the combination of two waves represented by the formula |  | |  |  |   y1 = A cos (t-kx)  y2 = A cos {(+)t – (k+k)x}  The resultant displacement is given by   * 1. = y1 + y2 * 2A cos {(++)t–(k+k+k)x} cos (t-kx)  |  |  | | --- | --- | | 2 | 2 | |  2A cos(t–kx).cos(t/2-kx/2) | (3) |   The velocity of the resultant wave is given by the speed with which a reference point, say the maximum amplitude point, moves. Taking the amplitude of the resultant wave as constant,  2A cos(t/2-kx/2) = constant  or (t/2-kx/2) = constant  or x = constant + (t/k)  Group velocity vg = dx/dt = (/k) (4)  Instead of two discrete values for  and k,  if the group of waves has a continuous spread from  to (+) and k to (k+k), then, the group velocity is given by   |  |  | | --- | --- | | vg = d | (5) | | dk |  |   It can be shown that the group velocity of the wave packet is equal to the velocity of the particle with which the wave packet is associated.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTIONS | Year | Marks | | Q.1 | What is eave packet? Define group velocity and phase velocity. Derive an expression for the de Broglie wavelength associated with an electron accelerated by the electric potential V. | Dec 2011 | 14 | | Q.2 | Derive an expression for the group velocity and phase velocity. Also find relation between them. | June 2011 | 14 | |

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| **Unit-01/Lecture-02** |
| **Relation between phase velocity and group** **velocity: [Rgpv June 2013(7)]**  The mathematical relation for phase velocity given by  vp = /k or  = k.vp  The group velocity vg is given by  vg = d = d(k.vp) dk dk   * vp + k.dvp dk * vp + (2/). dvp   d(2/)   |  |  |  |  |  | | --- | --- | --- | --- | --- | | = vp | + (2/).(-2/2).dvp | | |  | |  |  |  | d |  | | = vp | - . dvp | | | (6) | |  |  |  |  |  | |  |  | d | |  |   In the above expression, if (dvp/d) = 0, i.e., if the phase velocity does not depend on wavelength, then the group velocity and phase velocity are equal. Such a medium is called a non-dispersive medium. In a dispersive medium, (dvp/d) is positive and hence the group velocity is less than the phase velocity.  **Relation between group velocity and particle** **velocity (Velocity of de Broglie waves):**  The phase velocity of waves depends on the wavelength. This is responsible for the well known phenomenon of dispersion. In the case of light waves in vacuum, the phase velocity is same for all wavelengths.   |  |  |  | | --- | --- | --- | | In the case of de Broglie waves, we have, | |  | |  = 2 = 2mc2/h = | 2m0c2 | (1) | |  | h(1-v2/c2)1/2 |  |   and k = 2/ = 2mv/h = 2m0v (2)  h(1-v2/c2)1/2  The group velocity of de Broglie waves is given by  Vg = d/dk = d/dv  dk/dv   |  |  |  | | --- | --- | --- | | d/dv = (2m0c2/h).d(1-v2/c2)1/2 | = 2m0v | (3) | | dv | h(1-v2/c2)3/2 |  | | dk/dv = \_\_\_\_2m0\_\_\_\_\_ |  | (4) | | h(1-v2/c2)3/2 |  |  |   From equations 3 and 4 we get,  vg = v  Thus, the group velocity associated with de Broglie waves is just equal to the velocity with which the particle is moving. If we try to calculate the phase velocity,   |  |  | | --- | --- | | Vp= /k = c2/v = c2/vg | (5) |   Since the group velocity or the particle velocity is always less than c, the phase velocity of de Broglie waves turn out to be greater than c.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTIONS | Year | Marks | | Q.1 | Define group velocity and phase velocity. Prove that for a relativistic particle and non- relativistic particle, phase velocity is not equal to particle velocity. | June 2013 | 7 | |  |  |  |  | |  |  |  |  | |

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| **Unit-01/Lecture-03** |
| **Heisenberg Uncertainty Principle[ Rgpv Dec 2012(7)]**  This equation states that the product of uncertainty ∆x in the position of an object at some instant and the uncertainty in the momentum ∆p in the x-direction at the same instant is equal to or greater than ħ/2.   |  |  |  | | --- | --- | --- | | x. p  | ħ | (1) | |  | 2 |  |   Another form of uncertainty principle relates energy and time. In the atomic process, if energy E is emitted as an electromagnetic wave during an interval of time ∆t, then, the uncertainty ∆E in the measured value of E depends on the duration of the time interval ∆t according to the equation,  E. t ≥ ħ/2 (2)   |  |  | | --- | --- | | Consider the combination of two waves represented by the formula |  | |  |  |   y1 = A cos (t-kx)  y2 = A cos {(+)t – (k+k)x}  The resultant displacement is given by   * 1. = y1 + y2   = 2A cos {(++)t–(k+k+k)x} cos (t-kx)   |  |  | | --- | --- | | 2 | 2 | |  2A cos(t–kx).cos(t/2-kx/2) | (3) |   The velocity of the resultant wave is given by the speed with which a reference point, say the maximum amplitude point, moves. Taking the amplitude of the resultant wave as constant,  2A cos(t/2-kx/2) = constant  or (t/2-kx/2) = constant  for maximum amplitude cos(t/2-kx/2)=0  Thus,  (t/2-kx/2)= nπ/2.  Let the displacement of two successive nodes be x1 and x2, then  (t/2-kx1/2)= π/2  (t/2-kx2/2)= 3π/2  On solving, we get  k(x2-x1)= π   x= π/k, where k=2 π/   x=  =h/2p   x.p= h/2  Or  x.p≈ h  This is the required principle.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTIONS | Year | Marks | | Q.1 | **Explain the concept of wave packet and give the mathematical proof of Heisenberg’s uncertainty principle?** | Dec 2012 | 7 | |

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| **Unit-01/Lecture-04** |
| **Applications of uncertainty principle: [Rgpv June 2013(7)]**  (a). The uncertainty principle has far reaching implications. In fact, it has been very useful in explaining many observations which cannot be explained otherwise. A few of the applications of the uncertainty principle are worth mentioning  We have the following ‘Thought experiment’ to illustrate the uncertainty principle. Imagine an electron being observed using a microscope.  The process of observation involves a photon of wavelength  incident on the electron and getting scattered into the microscope. The event may be considered as a two-body problem in which a photon interacts with an electron. The change in the velocity of the photon during the interaction may be anything between zero (for grazing angle of incidence) and 2c (for head-on collision and reflection). The average change in the momentum of the photon may be written as equal to (h/c) or (h/).This difference in momentum is carried by the recoiling electron which was initially at rest. The change or uncertainty in the momentum of the electron may thus be written as (h/). At the same time, the position of the electron can be determined to an accuracy limited by the resolving power of the microscope, which is of the order of . Hence, the product of the uncertainties in position and momentum is of the order of h. This argument implies that the uncertainty is associated with the measuring process. The illustration only estimates the accuracy of measurement, the uncertainty being inherent in the nature of the moving particles involved.    **b). Diffraction of a beam of electrons**: Diffraction ofa beam of electrons at a slit is the effect of uncertainty principle. As the slit is made narrower,  Thereby reducing the uncertainty in the position of the electrons in the beam, the beam spreads even more indicating a larger uncertainty in its velocity or momentum.  Figure (2) shows the diffraction of an electron beam by a narrow slit of width ∆x. The beam travelling along OX is diffracted along OY through an angle θ. Due to the wave nature of the electron, we observe Fraunhoffer diffraction on the screen placed along XY. The accuracy with which the position of the electron is known is ∆x since it is uncertain from which place in the slit the electron passes. According to the theory of diffraction, we have   = x.sin  or ∆x = / sin   Further, the initial momentum of the electron along XY was zero and after diffraction, the momentum of the electron is p. sin θ where p is the momentum of the electron along the incidence direction. Hence, the change in momentum of the electron along XY is p. sin θ or (h/). Sin. Assuming the change in the momentum as representative of the uncertainty in momentum, we get   |  |  |  |  | | --- | --- | --- | --- | | x. px =  | | | .h.sin  = h | |  |  |  |  | |  | sin  | |  |   **(c). Electron cannot reside in nucleus**: In beta decay, electrons areemitted from the nucleus of the radioactive element. Assuming the diameter of the nucleus to represent the uncertainty in the position of electron inside the nucleus, the uncertainty in the momentum can be calculated as follows:  Radius of the nucleus = r = 5 x 10-15 m  x = 2r = 10-14 m.  p = h/2x = 6.62x10-34/(2x3.14x10-14) = 1.055x10-20 kg m s-1  Assuming that the electron was at rest before its emission, the change in momentum can be taken as equal to its momentum. This magnitude of change in momentum indicates large velocity for the electron. Hence, the energy of the emitted electron will be   1. = pc = 1.055x10-20 x 3x108 = 3.165 x 10-12 J    * 19.8 MeV.   This indicates that the electrons inside the nucleus must have kinetic energy of 19.8 MeV. But the electrons emitted during beta decay have kinetic energy of the order of 1 MeV. This indicates that electrons do not exist in the nucleus of the atom but are ‘manufactured’ by the nucleus at the time of decay. |



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| S.NO | RGPV QUESTIONS | Year | Marks |
| Q.1 | State Heisenberg’s uncertainty principle and derive it from hypothetical gamma ray microscope? | June 2013 | 7 |

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| **Unit-01/Lecture-05** |
| **Compton Effect {Rgpv June 2012(7), Dec 2013 (7)]**  He discovered that “when a beam of monochromatic radiation (X-ray) of sharply defined frequency were incident on a material of low atomic number (like carbon), the ray suffered a change of frequency on scattering”. The scattered beam contains two wavelengths. In addition to the expected incident wavelength, there exists a line of longer wavelength. The change of wavelength is due to the loss of energy of the incident rays. This phenomenon is known as **Compton Effect**.  [http://upload.wikimedia.org/wikipedia/commons/thumb/e/e3/Compton-scattering.svg/259px-Compton-scattering.svg.png](http://en.wikipedia.org/wiki/File:Compton-scattering.svg)  Let a photon of energy collides with an electron at rest. During the collision it gives a small fraction of energy to the frequency of electron. The electron gains kinetic energy and recoils.   * **Before collision**  1. Energy of incident photon =  1. Momentum of incident photon=  1. Rest mass of free electron= 2. Momentum of rest electron=0  * After collision  1. Energy of scattered photon =  1. Momentum of scattered photon=  1. Energy of electron= 2. Momentum of recoil electron=mv   Where   * Energy of system before collision=  * Energy of system after collision=  * Momentum before collision= momentum after collision   Where, *h* is [Planck's constant](http://en.wikipedia.org/wiki/Planck%27s_constant).  Before the scattering event, the electron is treated as sufficiently close to being at rest that its total energy consists entirely of the mass-energy equivalence of its rest mass m:    Squaring and adding above eqs.  According to the principle of conservation of energy,  From relativistic mechanics,  On comparing above eq. ,we get    Dividing the above eq. by , we get  ∆ λ is known as **Compton shift.**  **Different cases**   * **If** =0o, then ∆ λ=0. * **If** =90o, then ∆ λ==0.0242 Ao. This constant value is called **Compton wavelength**. * **If** =180o, then ∆ λ==0.0484 Ao. This is the maximum wavelength. |

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| S.NO | RGPV QUESTIONS | Year | Marks |
| Q.1 | What is Compton effect? Explaining the Compton expression, discuss the various possibilities of X-ray scattering? | June 2012 | 14 |
| Q.2 | An X ray photon of Wavelength 0.4Ao is scattered through an angle of 45o by a loosely bound electron. Find the wavelength of the scattered photon. | DEC 2013 | 7 |

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| **UNIT 1/LECTURE 6** |
| **Characteristics of wave function: [RGPV June 2013 (7)]**  Waves in general are associated with quantities that vary periodically. For example, water waves involve the periodic variation of the height of the water surface at a point. Similarly, sound waves are associated with periodic variations of the pressure.    In the case of matter waves, the quantity that varies periodically is called **‘wave function’**. The wave function, represented by ψ, associated with matter waves has no direct physical significance. It is not an observable quantity. But the value of the wave function is related to the probability of finding the body at a given place at a given time. The square of the absolute magnitude of the wave function of a body evaluated at a particular time at a particular place is proportional to the probability of finding the body at that place at that instant.  The wave functions are usually complex. The probability in such a case is taken as , i.e. the product of the wave function with its complex conjugate. Since the probability of finding the body somewhere is finite, we have the total probability over all space equal to certainty.   |  |  | | --- | --- | | i.e. dV = 1 | (1) |   Equation (1) is called the normalization condition and a wave function that obeys the equation is said to be **normalized**. Further,  must be single valued since the probability can have only one value at a particular place and time. Since the probability can have any value between zero and one, the wave function must be continuous. Momentum being related to the space derivatives of the wave function, the partial derivatives ∂/∂x, ∂/∂y and ∂/∂z must also be continuous and single valued everywhere. Thus, the important characteristics of wave function are as follows:   1.  must be finite, continuous and single valued everywhere. 2. ∂/∂x, ∂/∂y and ∂/∂z must be finite, continuous and single valued everywhere. 3.  must be normalizable.   **Physical significance of wave function:**  We have already seen that the wave function has no direct physical significance. However, it contains information about the system it represents and this can be extracted by appropriate methods. Even though the wave function itself is not directly an observable quantity, the square of the absolute value of the wave function is intimately related to the moving body and is known as the probability density. This probability density is the quantum mechanical method of finding the body at a particular position at a particular time. The wave function carries information about the particle’s wave-like behaviour. It also provides information about the momentum and energy of the particle at any instant of time.  **Schrodinger’s wave equation: [RGPV JUNE 2013, DEC 2013 (7)]**  The motion of a free particle can be described by the wave equation.   |  |  |  |  | | --- | --- | --- | --- | |  |  = A | exp{-i(t –kx)} | (1) | | But |  = 2 |  = 2 (E/h) = (E/ħ) |  | | and k = 2/ = 2 (p/h) = (p/ħ) | | |  | | where | E is | the total energy and | p is the momentum of |   the particle. Substituting in the equation (1), we get,   |  |  |  |  | | --- | --- | --- | --- | |  = A exp{-i (Et-px)} | |  | (2) | |  | ħ |  |  |      |  |  |  |  | | --- | --- | --- | --- | | Differentiating equation (2) with | | | respect to | | x twice, we get, | |  |  | | ∂2 = | -p2  or p2 = - ħ2 | . ∂2 | (3) | | ∂x2 | ħ2 | ∂x2 |  |   Differentiating equation (2) with respect to t, we get,   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | ∂ | = | - iE | .  or E  | = - ħ . ∂ | (4) | | ∂t |  | ħ |  | i ∂t |  | | The total energy of the particle can be written as | | | | | | | E | = | p2 | + U |  | (5) | |  |  | 2m |  |  |  |     Where U is the potential energy of the particle. Multiplying both sides of the equation by    |  |  | | --- | --- | | E  = p2 + U | (6) | | 2m |  |   Substituting for E and p2 from equation (1.42) and (1.43)   |  |  |  |  |  | | --- | --- | --- | --- | --- | | - ħ | ∂ | = - ħ2 | ∂2 + U | (7) | | i | ∂t | 2m | ∂x2 |  |   This is known as **Schrodinger’s time dependent equation** in one dimension.  The wave function  in equation (2) may also be written as   = A exp {-i (Et-px)} = A exp (-iEt). exp (ipx)  ħ ħ ħ   =  exp (-iEt) (8 )  ħ  where  is a position dependent function. Substituting this form of  in equation (6),   |  |  |  |  | | --- | --- | --- | --- | | E exp(-iEt) | = p2 |  exp(-iEt) + U exp(-iEt) | | | ħ | 2m | ħ | ħ |   or E exp(-iEt) = - ħ2 . ∂2 . exp(-iEt) + U exp(-iEt)  ħ 2m ∂x2 ħ ħ  or ∂2 exp(-iEt) + 2m (E-U) exp(-iEt) = 0  ∂x2 ħ ħ2 ħ   |  |  |  |  | | --- | --- | --- | --- | | or ∂2 | + 2m (E-U) | = 0 | (9) | | ∂x2 | ħ2 |  |  |   This is the Schrodinger’s wave equation in one dimension. In three dimensions, the above equation may be written as   |  |  |  |  | | --- | --- | --- | --- | | ∂2 + | ∂2 + | ∂2 + 2m(E-U) = 0 | | | ∂x2 | ∂y2 | ∂z2 | ħ2 |   or 2 + 2m(E-U) =0  ħ2  This equation is known as **the steady state or time** **independent Schrodinger wave equation** in threedimensions.   |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTION | YEAR | MARKS | | Q.1 | Discuss the concept of wave function associated with the particle. Give examples of admissible wave function. Why derivatives of wave function should be continuous everywhere? | JUNE2013 | 7 | | Q.2 | Derive Schrodinger’s time dependent equation for matter wave? | DEC 2013 | 7 | |

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| **UNIT 1/LECTURE 7** |
| **APPLICATIONS OF SCHRODINGER’S EQUATION: [RGPV Dec2013 (7)]**  **Case of a free particle:**  A free particle is defined as one which is not acted upon by any external force that modifies its motion. Hence, the potential energy U in the Schrodinger’s equation is a constant and does not depend on position or time. For convenience, the potential energy may be assumed to be zero. Then, the Schrodinger’s equation for the particle becomes   |  |  |  |  | | --- | --- | --- | --- | | ∂2 | + 2m E | = 0 | (10) | | ∂x2 | ħ2 |  |  |   Where E is the total energy of the particle which is purely kinetic. This is of the form,  ∂2 + k2 = 0  ∂x2  Where k2 = 2mE/ħ2. The solution of this equation may be written as   = A cos kx + B sin kx  Solving for the constants A and B pose some difficulties because we cannot apply any boundary conditions on the wave function as it represents a single wave which is not localized and not normalizable. Since the solution has not imposed any restriction on the value of k, the free particle is permitted to have any value of energy given by the equation,  E = ħ2k2/2m  Since the total energy is purely kinetic, the momentum of the particle would be p = ħk or h/. This is just what we would expect, since we have constructed the Schrodinger equation to yield the solution for the free particle corresponding to a de Broglie wave.    **Particle in a one dimensional potential box:**  The simplest problem for which Schrodinger’s time independent equation can be applied and solved is the case of a particle trapped in a box with impenetrable walls.  Consider a particle of mass m and energy E travelling along x-axis inside a box of width L. The particle is thus restricted to move inside the box by reflections at x=0 and x=L (Fig. 1).  The particle does not lose any energy when it collides with the walls and hence the total energy of the particle remains constant. The potential energy of the particle is considered to be zero inside the box and Infinite outside. Since the total energy of the particle cannot be infinite, it is restricted to move within the box. The example is an oversimplified case of an electron acted upon by the electrostatic potential of the ion cores in a crystal lattice. Since the particle cannot exist outside the box,  ψ = 0 for x ≤ 0 and x ≥ L (1)  We have to evaluate the wave function inside the box.  The Schrodinger’s equation (1.48) becomes   |  |  |  |  | | --- | --- | --- | --- | | ∂2 | + 2m E = | 0 for 0 < x < L | (2) | | ∂x2 | ħ2 |  |  |  |  |  |  |  | | --- | --- | --- | --- | |  = | A sin (2mE)1/2 | x + B cos (2mE )1/2 x | (3) | |  | ħ2 | ħ2 |  |   where A and B are constants.  Applying the boundary condition that ψ=0 at x = 0, equation 3 becomes  A sin 0 + B cos 0 = 0 or B = 0.  Again, we have ψ = 0 at x = L. Then,  A.sin(2mE)1/2.L=0  ħ2  If A = 0, the wave function will become zero irrespective of the value of x. Hence, A cannot be zero.  Therefore, sin(2mE)1/2.L=0   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | |  | | | ħ2 | |  | | or (2mE)1/2L=n | | | Where n=1,2,3 .. | | (4) | | ħ2 | | |  | |  | | From | | (4), the energy eigen values may be written as | | | | | | | En = | | n22 ħ2 | Where n = 1,2,3,… … | | (5) | | |   2mL2  From this equation, we infer that the energy of the particle is discrete as n can have integer values. In other words, the energy is quantized. We also note that n cannot be zero because in that case, the wave function as well as the probability of finding the particle becomes zero for all values of x. Hence, n = 0 is forbidden. The lowest energy the particle can possess is corresponding to n = 1 and is equal to  E1 = π2ħ2 2mL2  This is called ‘ground state energy’ or ‘zero point energy’. The higher excited states will have energies like 4E1, 9E1, 16E1, etc. This indicates that the energy levels are not equally spaced.  The wave functions or the Eigen functions are given by   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | n | = A. Sin | | 2mEn1/2 | x |  | |  |  |  | ħ2 |  |  | | or n | = | A. Sin | n x |  | (6) | |  |  |  | L |  |  | | Applying the normalization condition, | | | | |  | | i.e.  A2 | | Sin2 nx . dx | | = 1 | (7) | |  |  | L |  |  |  |   Since the wave function is non-vanishing only for   |  |  |  |  | | --- | --- | --- | --- | | 0 < x < L, it can be shown that | | |  | |  Sin2 nx | dx | = (L ) | (8) | | L |  | 2 |  | | Substituting in equation (8), we have | | |  | | A2 (L ) = 1 | or | A = ( 2 )1/2 | (9) | | 2 |  | L |  |   The eigen function or wave functions in equation (9) becomes   |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | n | = ( | 2 )½ | sin | (2mEn)½ x |  | | n | = ( | 2 )½ | sin | nx | |  |  | L |  | L |     Fig. (2) shows the variation of the wave function inside the box for different values of n and Fig.(3) shows the probability densities of finding the particle at different places inside the box for different values of n. Thus, wave mechanics suggests that the probability of finding any particle at the lowest energy level is maximum at the centre of the box which is in agreement with the classical picture. However, the probability of finding the particle in higher energy states is predicted differently by the two formulations.     |  |  |  |  | | --- | --- | --- | --- | | S.NO | RGPV QUESTION | YEAR | MARKS | | Q.1 | Obtain an expression of energy levels for particle trapped in one dimensional square with infinitely deep potential well. | Dec2013 | 7 | |

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| **UNIT 1/LECTURE 8** |
| Q1. X-rays of wavelength 1.54 Ao are Compton scattered at an angle of 60o. Calculate the change in the wavelength.  **Solution:**  Change in wavelength =  = h (1-cos ) /moc  h (1-cos 600)/ moc   * + = 1.2 x 10-12m (Ans).   [Q2. In a Compton scattering experiment, incident photons of energy 10 KeV are scattered at 45o to the incident beam. Calculate the energy of the scattered photon.](https://www.rgpvonline.com/)  **Solution:**  Change in wavelength =  = h (1-cos ) moc  = 7.1 x 10-13m.  Wavelength of incident photon =  = hc/eE  = 1.243 x 1010m.  Wavelength of scattered photon =’=  +   = 1.25 x 1010m.  Energy of scattered photon = hc/’   * + 1.59 x 10-15 J   + 9.93 keV (Ans).   Q3.Gamma Rays of energy 0.5 MeV are scattered by electrons. What is the energy of scattered gamma rays  at a scattering angle of 30o? What is the kinetic energy of scattered electron?  **Solution:**  Wavelength of incident gamma rays =  = hc/E   * + 6.62x10-34x3x108/1.6x10-19x0.5x106 * 2.486 x 10-12m.  |  |  | | --- | --- | | Change in wavelength = |  = h (1-cos ) | |  | moc | | = | 3.24 x 10-13m. |   Wavelength of scattered photon =’=  +   2.81 x 10-12m.  Kinetic energy of the scattered electron = hc/’  = 0.442 MeV (Ans).  Q4. X-rays of wavelength 1.5 Ao are Compton scattered. At what angle will be scattered x-rays have a wavelength of 1.506 A?  **Solution:**  Change in wavelength =  = h (1-cos ) moc  cos  = (1 – m0c. /h) = (1 – 0.247) =0.753  Angle of scattering, = 41.20 (Ans).  Q5.Calculate the de Broglie wavelength associated with an electron travelling with a velocity of 105 ms-1. Assume the mass of the electron to be 9.1 x 10-31kg. and h = 6.62x10-34Js.   |  |  | | --- | --- | | **Solution:** |  | | De Broglie wavelength  = h | = 6.62 x 10-34\_\_\_\_ | | P | 9.1 x 10-31x105 |  * + = 7.27 x 10-9 m. (Ans.) |

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| **UNIT 1/LECTURE 9/ADDITIONAL TOPICS** |
| **Photoelectric effect**  The photoelectric effect occurs when matter emits electrons upon exposure to electromagnetic radiation, such as photons of light. Here's a closer look at what the photoelectric effect is and how it works.  The photoelectric effect is studied in part because it can be an introduction to wave-particle duality and quantum mechanics.  When a surface is exposed to sufficiently energetic electromagnetic energy, light will be absorbed and electrons will be emitted. The threshold frequency is different for different materials. It is visible light for alkali metals, near-ultraviolet light for other metals, and extreme-ultraviolet radiation for nonmetals. The photoelectric effect occurs with photons having energies from a few electronvolts to over 1 MeV. At the high photon energies comparable to the electron rest energy of 511 keV, Compton scattering may occur pair production may take place at energies over 1.022 MeV.  Einstein proposed that light consisted of quanta, which we call photons. He suggested that the energy in each quantum of light was equal to the frequency multiplied by a constant (Planck's constant) and that a photon with a frequency over a certain threshold would have sufficient energy to eject a single electron, producing the photoelectric effect. It turns out that light does not need to be quantized in order to explain the photoelectric effect, but some textbooks persist in saying that the photoelectric effect demonstrates the particle nature of light. |