Chapter 3 (Wave Nature of Particle)
Worksheet

Q1. A particle of mass M at rest decays into two particles of masses m_1 and m_2, having nonzero velocities. The ratio of the de Broglie wavelengths of the particles, λ_1/λ_2, is

(a) m_1/m_2 (b) m_2/m_1 (c) 1 (d) $\sqrt{m_2}/\sqrt{m_1}$

Q2. The correct expression for the de-Broglie wavelength λ of a particle (E is the kinetic energy) is

(a) $\lambda = \dfrac{hc}{\sqrt{\left(E+2m_0c^2\right)}}$ (b) $\lambda = \dfrac{hc}{\sqrt{E\left(E+m_0c^2\right)}}$

(c) $\lambda = \dfrac{hc}{\sqrt{E\left(E+2m_0c^2\right)}}$ (d) $\lambda = \dfrac{hc}{\sqrt{\left(E+m_0c^2\right)}}$

Q3. A proton has kinetic energy E which is equal to that of a photon. The wavelength of photon is λ_2 and that of proton is λ_1. The ratio $\dfrac{\lambda_2}{\lambda_1}$ is proportional to

(a) E^2 (b) $E^{1/2}$ (c) E^{-1} (d) $E^{-1/2}$

Q4. X-ray diffraction from a crystal gives a strong peak at an angle of 120^0 from the incident beam. If spacing between the spacing between the adjacent atomic planes giving rise to this diffraction is $2\overset{0}{\mathrm{A}}$

what will be corresponding momentum of X-ray.

(a) $3.3\times10^{-24}\,kgm/\sec$ (b) $4.3\times10^{-24}\,kgm/\sec$

(c) $5.3\times10^{-24}\,kgm/\sec$ (d) $6.6\times10^{-24}\,kgm/\sec$

Q5. For relativistic particle moving with velocity v the phase velocity is given by

(a) v (b) $\dfrac{v}{2}$ (c) $\dfrac{c^2}{v}$ (d) $\dfrac{c^2}{2v}$

Q6. A particle of rest mass m_0 is moving uniformly in a straight line with relativistic velocity $0.8c$, where c is the velocity of light in vacuum . The phase velocity of the de Broglie wave associated with the particle is,

(a) c (b) $\dfrac{5}{4}c$ (c) $\dfrac{4}{5}c$ (d) $\dfrac{c}{2}$

Q7. If rest mass of particle is m_0 and de-Broglie wavelength associated with particle is λ then the phase velocity associated with the de-Broglie wave of particle is

(a) $\frac{h}{m_0\lambda}$ (b) $c\sqrt{1+\left(\frac{m_0c\lambda}{h}\right)^2}$

(c) $c\sqrt{1+\left(\frac{h}{m_0c}\right)^2}$ (d) $\left(\frac{h^2c^2}{m_0^2\lambda^2c^2h^2}\right)^{1/2}$

Q8. The frequency and wavelength of the surface tension wave in shallow water are related by $v=\sqrt{\frac{2\pi T}{\rho\lambda^3}}$ Where T is the surface tension and ρ is the density. The group velocity of such a wave is

(a) $\frac{3}{2}\sqrt{\frac{2\pi T}{\rho\lambda}}$ (b) $\frac{3}{2}\sqrt{\frac{2\pi T}{\rho\lambda^2}}$ (c) $\frac{3}{2}\sqrt{\frac{\pi T}{\rho\lambda^2}}$ (d) None of these

Q9. For a wave in a medium the angular frequency ω and the wave vector $\vec{k}$ are related by, $\omega=ck$, where and c are constants. If v_P is phase velocity and v_g is group velocity then

(a) $v_P > v_g$ (b) $v_P = v_g = \alpha c, \alpha > c$

(c) $v_P = v_g = \alpha c, \alpha < 1$ (d) $v_P = v_g = \alpha c, \alpha = 1$

Q10. The dispersion law for a certain type of wave motion is $\omega=\left(c^2k^2+m^2\right)^{\frac{1}{2}}$, where ω is the angular frequency, *k* is the magnitude of the propagation vector, and *c* and *m* are constants. The group velocity of these waves approaches

(a) infinity as $k\to0$ and zero as $k\to\infty$ (b) infinity as $k\to0$ and *c* as $k\to\infty$

(c) zero as $k\to0$ and infinity as $k\to\infty$ (d) zero as $k\to0$ and *c* as $k\to\infty$

Q11. A particle of rest mass m_0 is moving uniformly in a straight line with relativistic velocity βc, where *c* is the velocity of light in vacuum and $0<\beta<1$. The phase velocity of the de Broglie wave associated with the particle is

(a) βc (b) $\frac{c}{\beta}$ (c) c (d) $\frac{c}{\beta^2}$

Q12. In case of photon which one of the following is correct if v_g is group velocity and v_p is phase velocity

(a) $v_p \neq v_g$ (b) $\left(v_p=v_g\right)>c$ (c) $\left(v_p=v_g\right)=c$ (d) $\left(v_p=v_g\right)<c$

MSQ (Multiple Select Questions)

Q13. If particle of rest mass m_0 is moving with kinetic energy $2m_0c^2$ then which is correct statement?

(a) The speed of particle is $\frac{2\sqrt{2}}{3}c$

(b) Total energy is given by $3m_0c^2$

(c) The de Broglie wave length associate with particle is $\frac{3h}{2\sqrt{2}m_0c}$

(d) The de Broglie wave length associate with particle is $\frac{h}{2\sqrt{2}m_0c}$

Q14. An electron is in a box $0.10\,nm$ across, which is the order of magnitude of atomic dimensions. Which on of following is correct?

(a) According to de Broglie hypothesis lowest value of energy is fixed .

(b) According to de-Broglie hypothesis that energy is discrete .

(c) According to de –Broglie hypothesis the momentum is discrete.

(d) The lowest value of energy is $38eV$

Q15. Which is correct for Davisson-Germer experiment?

(a) The experiment proves wave nature of electrons.

(b) The experiment can be verified by condition achieved by Bragg's diffraction

(c) The angle between incoming and reflected wave for which intensity is maximum is ϕ then Bragg's angle is also ϕ

(d) The angle between incoming and reflected wave for which intensity is maximum is ϕ then Bragg's angle is $\frac{\phi}{2}$

Q16. If Davisson and Germer had used V volts to accelerate their electron beam instead of 54 volts,

(a) If de-Broglie wave length associated to electron is $0.123\,nm$ the value of V is $100V$.

(b) At scattering angle measured in experiment $\phi = 42.52^0$ would they have found a peak in the distribution of scattered electrons (the intensity)

(c) At scattering angle measured in experiment $\phi = 95^0$ would they have found a peak in the distribution of scattered electrons (the intensity)

(d) for Bragg's diffracting $d\sin\theta = \lambda$ $\theta = 42.52^0$ where d is inter planner distance .

Q17. The relation between angular frequency ω and wave number k for a elastic wave in crystal is $\omega^2 = \alpha k^2 + \beta k^3$. Which of the following is correct?

(a) The phase velocity is $\sqrt{\alpha + \beta k}$

(b) The group velocity is $\dfrac{2\alpha + 3\beta k}{(4\alpha + 4\beta k)^{1/2}}$

(c) if v_p is phase velocity and v_g is group velocity then $v_g.v_p = \alpha + 1.5\beta k$

(d) The wave number $k_0 = 0$ for which the phase velocity equals the group velocity .

Q18. Which of the following is correct?

(a) The phase velocity is equivalent to velocity of particle

(b) The group velocity is equivalent to velocity of particle

(c) Group velocity may be more than speed of light

(d) Phase velocity may be more than speed of light

Q19. If a relativistic free particle moving with speed v the which one of following is correct

(a) Group velocity is equal to v (b) Phase velocity is equal to v

(c) Group velocity is equal to $\dfrac{c^2}{v}$ (d) Phase velocity is equal to $\dfrac{c^2}{v}$

NAT (Numerical Answer Type Questions)

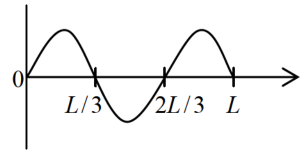
Q20. The de-Broglie wavelengths of a proton and an α- particle are equal. The ratio of their velocities is_________

Q21. The potential energy of a particle of mass in is given by

$$V(x) = \begin{Bmatrix} E_0; & 0 \le x \le 1 \\ 0; & x > 1 \end{Bmatrix}$$

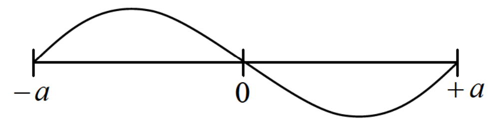
λ_1 and λ_2 are the de-Broglie wavelengths of the particle, when $0 \le x \le 1$ and $x > 1$ respectively. 'If the total energy of particle is $2E_0$, then ratio $\dfrac{\lambda_1}{\lambda_2}$ _________

Q22. A free particle of mass m is confined to a region of length L. The de Broglie wave associated with the particle is sinusoidal in nature as given in the figure. The momentum of the particle is $\dfrac{\alpha h}{L}$. Then value of α is given by_________



Q23. The de Broglie wavelength of a relativistic electron having $1\ MeV$ of energy is________$\times 10^{-12}\ m$. (Take the rest mass energy of the electron to be $0.5\ MeV$. Plank constant $= 6.63\times 10^{-34}\ Js$, speed of light $= 3\times 10^{8}\ m/s$, Electronic charge $= 1.6\times 10^{-19}\ C$)

Q24. A particle is confined in a one dimensional box with impenetrable walls at $x = \pm a$. Its energy $2\,eV$ and the corresponding de-Broglie wavelength is as shown below.

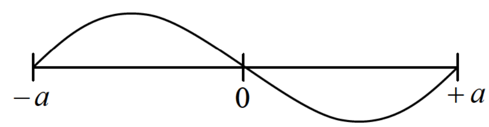


The lowest possible energy of the particle is __________ eV

Q25. A particle of mass M at rest decays into two particles of masses m_1 and m_2, having nonzero velocities. The ratio of the de Broglie wavelengths of the particles, λ_1/λ_2, is_________

Q26. $\psi(x)$ is the eigen function of a particle moving freely back and forth along the x- axis between impenetrable walls located at $x = -a$ and $x = a$ as shown in the figure . The potential energy is given by

$$V(x) = \begin{cases} 0, & |x| < a \\ \infty, & \text{otherwise} \end{cases}$$



The energy of the particle is $2\,eV$ when it is in the quantum state associated with this eigen function. When three electrons are put in the well, then the lowest possible energy is_______eV.

Q27. The de Broglie wavelength of a relativistic particle having $2MeV$ of energy is_________$\times 10^{-12} m$. (Take the rest mass energy of the particle to be $1MeV$. Plank constant$= 6.63\times 10^{-34}\ Js$, speed of light $= 3\times 10^{8} m/s$, Electronic charge $= 1.6\times 10^{-19} C$)

Q28. An electron is in a box $0.10\,nm$ across, which is the order of magnitude of atomic dimensions. According to to de-Broglie hypothesis the energy of related to first overtone _________eV

Q29. The velocity of an electron if its de Broglie wavelength is $1\,\mu m$ is ________$m/\sec$

Q30. The de Broglie wavelength λ and the kinetic energy E for a highly relativistic electron are related as $\lambda = \alpha / E$. If λ and E represent the numerical values in angstrom and kilo electron volt, The numerical value of α ____________

Q31. When an electron is accelerated through a potential difference V, its de Broglie wavelength is given by $\lambda = \dfrac{\alpha}{\sqrt{V}}$ for nonrelativistic speeds. If λ and V represent numerical values in angstrom and volt, the numerical value of α is__________

Q32. X-ray diffraction from a crystal gives a strong peak at an angle of 120^0 from the incident beam. If spacing between the spacing between the adjacent atomic planes giving rise to this diffraction is $2\overset{0}{\mathrm{A}}$. The wavelength of X-ray is given by $\alpha\times10^{-10}m$ then value of α is _______

Q33. The relativistic free particle moving with speed $v=0.5c$ then group velocity is αc the value of α is ________

Q34. The relativistic free particle moving with speed $v=0.5c$ then phase velocity is αc the value of α is _________

Q35. The relation between angular frequency ω and wave number k for given type of waves is $\omega=\left(\alpha k+\beta k^3\right)^{1/2}$. The wave number k_0 for which the phase velocity equals the group velocity is $n\sqrt{\frac{\alpha}{\beta}}$ then value of n is______________