Quantum Mechanics (Part-1) : PHL502/PH502
Time : 1 hour 15 min

Name:

ID:

- **No mobile, No calculator.**
- **Don't forget to write your names and ID in your question paper.**
- **Put a circle or tick on the right answer on this question paper. However, you can use rough papers (if required), which are not to be submitted. Submit your question paper to the TAs, as your answers are there.**
- **It is recommended to make a copy of your answers with you (either in a paper or in your brain if it is reliable ☺) so that you can cross verify your marks when I reveal the answer keys after the exam.**

Values of some universal constants (if required)
Planck constant $h = 6.62 \times 10^{-34}\ m^2Kg/s$, speed of light $c = 3 \times 10^8\ m/s$
electron mass $m_e = 9.1 \times 10^{-31}\ Kg$, proton mass $m_p = 1.6 \times 10^{-27}\ Kg$,
Length scales $1\ fm = 10^{-5}\mathring{A} = 10^{-6}nm = 10^{-15}m$
$1eV = 1.6 \times 10^{-19}$ Jule, Boltzmann constant $K = 1.38 \times 10^{-23}\ m^2Kg/s^2/^0K$

1. Light is a wave. Which phenomenon supports this fact?
(a) Black body radiation
(b) Interference
(c) Photoelectric effect
(d) Compton scattering
(e) none of the above

2. If the work function of a material is Φ, then the photoelectric effect can not be seen for incident light with frequency $\nu = f\frac{\Phi}{h}$, where
(a)$f = 10$
(b)$f \gg 1$
(c)$f = 0.5$
(d)$f > 1$
(e) none of the above

3. In the photo-electric effect, stopping potentials are the same for incident light with
(a) different frequencies but the same intensities
(b) different intensities and different frequencies
(c) different intensities but the same frequencies
(d) same intensities but different wavelengths
(e) none of the above

4. Spectral energy density E_λ of black body radiation depends on the wavelength λ as
(a) an increasing function
(b) a decreasing function
(c) a decreasing first and then increasing function
(d) a increasing first and then decreasing function
(e) none of the above

5. Based on the calculation Compton wavelength of electron $\lambda_c = \frac{h}{mc}$ in meter, which rays will be the best to show the Compton effect?
(a) Radio wave ($\lambda > 10^{-3}$ m)
(b) Microwave ($\lambda = 10^{-3} - 10^{-6}$ m)
(c) Ultra-violet ray ($\lambda = 10^{-7} - 10^{-9}$ m)
(d) X-ray ($\lambda = 10^{-9} - 10^{-12}$ m).
(e) none of the above

6. Matter-wave of the electron, accelerated by 10^2 order voltage, is basically
(a) Radio Wave
(b) visible Ray
(c) X-Ray
(d) sound wave
(e) none of the above

7. Light can be considered as motions of billions of particles (called photons) with speed c. Which phenomenon is most suitable for supporting this fact?
(a) Reflection
(b) Interference
(c) Photoelectric effect
(d) refraction
(e) none of the above

8. Ratio between Compton wavelength and de-Broglie wavelength of electron with mass m and velocity $v(<< c)$ is
(a) hc/mv
(b) v/c
(c) c/v
(d) hv/mc
(e) none of the above

9. Compton wavelength and de-Broglie wavelength of an electron can be the same when
(a) electron is at rest
(b) electron move with non-relativistic speed

(c) electron's velocity reaches the speed of light i.e., $v = c$
(d) electron move with relativistic speed $v = c/\sqrt{2}$
(e) none of the above

10. The recoil momentum of an atom is p_A when it emits an infrared photon of wavelength 1500 nm, and it is p_B when it emits a photon of visible wavelength 500 nm. What is the ratio p_A/p_B?
(a) $1:3$
(b) $1:5$
(c) $3:1$
(d) $5:1$
(e) none of the above

11. Using Schrodinger equation $\frac{-\hbar^2}{2m}\frac{\partial^2\psi}{\partial x^2} + V\psi = E\psi$, solve 1D potential box problem, whose $V(x) = 0$, (for $0 < x < a$) and ∞ elsewhere. When we put boundary conditions $\psi(x = 0) = \psi(x = a) = 0$ on the guess wave-function $\psi = A\ Sin(kx) + B\ Cos(kx)$ with $k = \sqrt{2mE}/\hbar$, then we will get
(a) $\psi_n = B\ Cos(k_n x)$ with $k_n = n\pi/a$
(b) $\psi_n = A\ Cos(k_n x)$ with $k_n = n\pi/a$
(c) $\psi_n = B\ Sin(k_n x)$ with $k_n = n\pi/a$
(d) $\psi_n = A\ Sin(k_n x)$ with $k_n = n\pi/a$
(e) none of the above.

12. After putting normalization condition $\int |\psi_n|^2 dx = 1$ on the wave function of the earlier question, we can find the unknown constant as
(a) $\sqrt{\frac{2}{a}}$
(b) $\sqrt{\frac{1}{a}}$
(c) $\frac{2}{a}$
(d) $\frac{1}{a}$
(e) none of the above.

13. For 1D potential problem (above mentioned) energy and momentum of $n = 4$ state is a and b times larger than those of $n = 3$ state. The values of a, b are
(a) $a = \frac{4}{3}$, $b = \frac{16}{9}$
(b) $a = \frac{16}{9}$, $b = \frac{4}{3}$
(c) $a = 16$, $b = 4$
(d) $a = \frac{16\hbar^2}{9L^2}$, $b = \frac{4\hbar}{3L}$
(e) none of the above.

14. Which statement is true for classical but not true for quantum harmonic oscillator?
(a) Total energy will be discrete,
(b) Total energy will be continuous,
(c) Total energy changes with the frequency of the oscillator,
(d) Total energy is independent of x (position).
(e) none of the above.

15. Similarity between wave equation for Light/Sound and matter-wave is both have

(a) single time derivative
(b) double time derivative
(c) single space derivative
(d) double space derivative
(e) none of the above.

16. The degeneracy of the state having energy $\frac{14h^2}{8mL^2}$ for a particle in a 3D-cubic box of length L is
(a) 5
(b) 6
(c) 7
(d) 8
(e) none of the above.

17. The zero point energy of the harmonic oscillator E is
(a) zero
(b) $\frac{1}{2}\hbar\omega$
(c) $\frac{3}{2}\hbar\omega$
(d) $\frac{5}{2}\hbar\omega$
(e) none of the above.

18. For which of the following quantum mechanical models are the energy levels equally spaced?
(a) H-atom
(b) particle in a box
(c) 1-D harmonic oscillator
(d) none of the above
(e) none of the above.

19. Which of the following is not the characteristics of Planck's black body radiation distribution.
(a) As temperature increases, the peak of the curve shift towards higher wavelength
(b) As temperature increases, the peak of the curve shift towards lower wavelength
(c) Total emissive power is proportional to T^4
(d) At a given wavelength, as temperature increases, emissive power also increases
(e) none of the above.

20. Compton shift $\delta\lambda$ and Compton wavelength λ_c are equal if the angle of scattering is,
(a) $\theta = 0$
(b) $\theta = 90^0$
(c) $\theta = 180^0$
(d) $\theta = 360^0$
(e) none of the above.