Short Answers Type Questions on Quanatum

1. Ψ itself has no physical meaning but a function of it represents a physically meaningful quantity. How?
   $\Psi^* \Psi = \rho$, ρ is the probability density of finding the particle.
2. $\Delta x \, \Delta p_x \geq h/(4\pi)$ is one of the uncertainty relation. What is the other one?
   $\Delta E \, \Delta t \geq h/(4\pi)$
3. In the famous Schrodinger equation $H\psi = E\psi$. What is *H*?
   The Hamiltonian, the total energy (kinetic+ potential) operator.
4. In the famous Schrodinger equation H Ψ = E Ψ; divide both sides by Ψ to get H = E. Possible?
   No, *H* is not multiplicative but differential;
5. Energy is often expressed in terms of a quantity whose SI unit is $\mathbf{m^{-1}}$. What is that quantity?
   Wave number; 1/λ
6. How does wave number (1/λ) represent energy?
   E=hν=hc/λ or, E/hc=1/λ
7. $(mc^2 = p.c) = E = (h\nu = h\, c/\lambda)$
   p.c = h c/λ; **p = h/λ ,** all in 1905; can you call it de Broglie relation?
   For light only (in 1905); de Borglie's one is a general one.
8. The first experiment that was solved by a new revolutionary theory. What is that experiment that classical science failed to explain?
   Black body radiation
9. The smallest possible value of a universal constant is named after the name of a physicist. Who is he/she?
   M. Planck; $h = 6.626 \times 10^{-34}$ J.s
10. In explaining the BBR, what new concept was introduced which has no classical analogue?
    Quantization of energy emission
11. N. Bohr, in his theory of H-atom used the new concept of *quantization. Quantization o*f what quantity?
    Angular momentum of e^-
12. In his theory of H-atom, what Bohr *could* and could *not explain* of an atom?
    IP and line spectra. Finer spectra of multi electron atom.
13. Einstein published *five* papers in the same journal, in the same year. One of those papers brought him the Nobel. On which *work* it was? In which year were they published?

1905; PEE

14. A simple looking equation brought de Broglie his Nobel prize. What is that equation and what's it all about?

    P=h/λ; wave-particle duality in general.

15. ***g = Af, A*** is operator, ***f*** is function of ***x***. If **A= exp( ) and *f(x)*= *ln x,*** then ***g*** is***?***

    $e^{\ln x}$ = P, ln P = ln x; Or, P = x

16. If *A f*(x) = $3x^2$ *f*(x) + 2x *df/dx,* where *A* is an operator and *f* is an arbitrary function. What is *A*?

    ***A* = $3x^2$. + 2x (*d/dx*) .**

17. If *A* e^x = e^x ; give *three different* operators *A.*

    ***A* → 1. d/dx d^2/dx^2**

18. What do you suppose is meant by the *zeroth* power of an operator?

    A^0 = 1. Appling *A zero* times to *f* leaves *f* unchanged.

19. Under what condition, $(A + B)^2 = A^2 + 2AB + B^2$? [*A and B* are operators].

    AB = BA

20. Under what condition, *A (B + C) = AB + AC ?* [*A, B, and C are* operators].

    They are linear operators.

    A(B+C)*f = *A(Bf + Cf) [sum rule for B & C]

    = A(Bf) + A(Cf) [A is linear]

    = (AB)f + (AC)f [product rule]

    = (AB + AC)f [sum rule for AB & AC.]

21. Complex conjugation $(f + g)^*$ is linear operation. Justify or criticize.

    Not justified. *A* is *linear* if (i) *A (f + g) = Af + Ag and (ii) A(cf) = c(Af)*

    $(f + g)^* = f^* + g^*$ *but* $(cf)^* = c^*f^* \neq c f^*$ (i) is satisfied but not (ii).

22. *A* is *linear* if

    (i) *A (f + g) = Af + Ag and (ii) A(cf) = c(Af). Give example where (ii) is satisfied but not (i).*

    $( )^{-1}$ (*d/dx*) $( )^{-1}$

23. Give the kinetic energy operator *T* for a two particle, three dimensional system.

    $T = -(\hbar^2/2m_1)(\partial^2/\partial x_1^2+\partial^2/\partial y_1^2+\partial^2/\partial z_1^2) - (\hbar^2/2m_2)(\partial^2/\partial x_2^2 + \partial^2/\partial y_2^2 + \partial^2/\partial z_2^2)$

24. For the PIB (cubic), what is the degeneracy of the energy level with $8mL^2E/h^2 = 12$.

    Non-degenerate or g = 1

25. For the PIB (cubic), what is the degeneracy of the energy level with $8mL^2E/h^2 = 14$.

    g = 6

    1 2 3 1 3 2 2 1 3 2 3 1 3 1 2 3 2 1

26. $c_1 \Psi_{151} + c_2 \Psi_{333} + c_3 \Psi_{511}$

    This combination of the PIB stationary state wave functions is also an eigen function of PIB Hamiltonian. Justify or criticize.

    Yes. Ψ_{151} , Ψ_{333} and Ψ_{511} are degenerate states.

27. If the state function $\Psi = (2/L)^{1/2} \sin(3\pi x/L)$ for a PIB, what is the possible value that results as measurement of energy ?

    It is exactly the eigen value since Ψ is an eigen function for the PIB.

    And the measured value is $E_3 = 9h^2 /(8mL^2)$.

28. we will *not* get one of the eigen values of operator *B* when we measure the property B and the system's state function is not an eigen function of *B.* Justify or criticize.

    We will get; only we can't predict which eigen value.

29. For the **n=25** SHO wave function, the sign of **Ψ** in the right-hand classically forbidden region is opposite the sign in the left-hand classically forbidden region. Justify or criticize.

    Ψ_{25} is odd function. Ψ_0 is even, and if Ψ_n is odd, Ψ_{n+1} is even;

    Ψ does not oscillate in the forbidden regions.

30. Adding a constant *C* to the potential energy leaves the stationary state wave functions unchanged and simply adds the energy eigenvalues.

    Justify or criticize.

    Justified. $(H + C)\Psi = H\Psi + C\Psi = E\Psi + C\Psi = (E + C)\Psi$.

31. $(\Delta A)^2$ is defined as $\langle (A - \langle A\rangle)^2 \rangle$. Hence $(\Delta A)^2 = \langle A^2 \rangle - \langle A\rangle^2$

    justify or criticize.

    Justified.

    $$(A - \langle A\rangle)^2 \Psi = (A - \langle A\rangle)(A - \langle A\rangle)\Psi$$
    $$= A^2\Psi - A\langle A\rangle\Psi - \langle A\rangle A\Psi + \langle A\rangle^2\Psi$$
    $$= A^2\Psi - 2\langle A\rangle A\Psi + \langle A\rangle^2\Psi \quad \text{or,}$$
    $$\langle (A - \langle A\rangle)^2 \rangle = \langle A^2 \rangle - 2\langle A\rangle\langle A\rangle + \langle A\rangle^2 = \langle A^2 \rangle - \langle A\rangle^2$$

32. Under what condition $\langle c f | B | g\rangle = \langle f | B | c g\rangle$?

    $c = c^*$; B is linear.

33. What operator is shown to be Hermitian by the equation $\langle f|g\rangle = \langle g|f\rangle^*$?

    The operator is *multiplication by* 1.

34. If *A* and *B* are Hermitian *then* under what condition, *(AB) is Hermitian?*

    A and B would commute.

    Proof: $\langle \Psi|AB|\Psi\rangle = \langle A\Psi|B|\Psi\rangle = \langle (BA)\Psi|\Psi\rangle$; For *(AB)* to be Hermitian,

    $\langle \Psi|AB|\Psi\rangle = \langle (AB)\Psi|\Psi\rangle$; Comparing the equations, $AB = BA$

35. If *A* and *B* are Hermitian then*, is* their anticommutator [AB + BA] also Hermitian?

    Yes.

    Proof: $\langle\Psi|AB + BA|\Psi\rangle = \langle\Psi|AB|\Psi\rangle + \langle\Psi|BA|\Psi\rangle$

    $= \langle BA\Psi|\Psi\rangle + \langle (AB)\Psi|\Psi\rangle = \langle (BA + AB)\Psi|\Psi\rangle$

36. If *($x\, p_x$) Hermitian?*

    No.

Both x and p_x *are Hermitian; but they don't commute. So,* (x p_x) *is* not Hermitian.

37. If (1/2)(x p_x+ p_x x) *Hermitian?*
38. Yes.

Both x and p_x *are Hermitian, so their anticommutator* (x p_x+ p_x x) *is Hermitian.*