1. Consider a particle in an infinite square well described initially by a wave that is a superposition of the ground and first excited states of the well:

$$\Psi(x,0) = C[\psi_1(x) + \psi(x_2)]$$

   (a) Derive the value of C by normalizing this wave, assuming ψ_1 and ψ_2 are themselves normalized. (*5 pts*)

   (b) Find $\psi(x,t)$ at any later time t. (*5 pts*)

   (c) What is the probability of finding the particle in the ground state and first excited state, respectively? (*5 pts*)

2. What are the essential points of Planck's theory of blackbody and Einstein's hypothesis on photoelectric effect? (*10 pts*) Why are they so critical to the development of quantum physics? (*5 pts*)

3. Quantum numbers, such as n, l and m_l, are used for the electron wave functions of the hydrogen atom. What are the physical meaning of these quantum numbers and how do they relate to each other? (*15 pts*)

4. What are the deficiencies of Bohr's quantum model of atom and how are they solved by later model? (*10 pts*)

5. Write the statistical distribution function for distinguishable particles, bosons, and fermions, and name one particle for each function that it follows. (*10 pts*)

6. Explain the conductivity of crystalline solids using energy band theory. (*10 pts*)

7. The energy bang gap of Si, Ge, GaAs, and GaN is 1.1 eV, 0.7 eV, 1.4 eV, and 3.4 eV, respectively. Which one is transparent to your eyes? Why? (*10 pts*)

8. The photon energy of a light-emitting diode (LED) is 2.8 eV. What color is this light-emitting diode? (*5 pts*) The output power of this light-emitting diode is measured to be 20 mW when it is biased at 20 mA. Calculate the external quantum efficiency, i.e. the percentage of injected carriers being converted to photons that are measured by the power meter. (*5 pts*) If it is not 100%, where do you think the carriers go? (*5 pts*)

Parameters that may be used:

$h = 6.626 \times 10^{-34}$ J-s

$m_e = 9.11 \times 10^{-31}$ kg

$c = 3 \times 10^8$ m/s

$e = 1.6 \times 10^{-19}$ C

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