A1

Saturday, August 03, 2024 11:36 AM

DUE: 8:30am on Tue 13-Aug-2024, I.e beginning of the lecture.
Assignment covers topics in Chapter-7 of Atkins11e

A. Answer the following problems:
   1. A sodium lamp emits yellow light (550nm). Calculate the energy of a photon and number of photons in a 1 W sodium vapor lamp (assume 50% efficiency).
   2. The work function of metallic cesium is 2.14 eV. Calculate the kinetic energy and the speed of the ejected electron by light of wavelength (a) 700nm and (b) 300nm
   3. To what speed must a proton be accelerated from rest for it to have a de Broglie length of 100pm. What is the accelerating potential needed?
B. Answer the following problems:
   1. What is the probability of finding a particle in the middle of the box (in a small range dx). How is the correspondence principle applicable to this specific problem?
   2. Ground state wavefunction of hydrogen atom is given by $exp\left(-\frac{r}{a}\right)$ where a=53 pm and r is the distance from the nucleus. (a) calculate the probability that electron will be found within a sphere of 1.0 pm centered on the nucleus.
C. Answer the following problems:
   1. For a free particle, find expectation value of momentum and show the calculation to check de Broglie's relation between momentum and wavelength
   2. For the particle in the 1-d box in the quantum state n, show the calculation to check Heisenberg's uncertainty relation between uncertainties in position and momentum
   3. For the particle in the 1-d box, the system is so prepared that It is in superposition of $n = 1$ and $n = 2$ states. Write down the wavefunction of the system, and demonstrate that it satisfies Schrodinger equation
   4. Evaluate the commutators for a 1-d system: (a) $[x, p]$, (b) $[H, p]$ (c) $[H, x]$. Here, H is the Hamiltonian; x and p are the usual variables
D. Answer the following problems:
   1. Do a complete calculation for the tunneling particle to calculate transmission and reflection coefficient. Comment on various factors of the problem that effect the transmission coefficient
   2. A nitrogen molecule is confined in a cubic box of volume $1.0 \quad m^3$. (a) Assuming that the molecule has an energy equal to $\frac{3}{2}k_B T$ at $T = 300 \quad K$, what is the value of $n = \left(n_x^2 + n_y^2 + n_z^2\right)^{½}$ for this molecule? (b) For this value of n, what is the energy separation between n and $n + 1$ energy levels? (c) What is the de Broglie wavelength of the molecule?
E. Answer the following problems:
   1. For the 1-d Simple Harmonic Oscillator, consider large n wavefunctions. Compare and contrast with classical mechanical harmonic oscillator.
   2. If the vibration of a diatomic A-B is modelled using a harmonic oscillator, the vibrational frequency is given by $\omega = \sqrt{\left\{\frac{k_f}{\mu}\right\}}$ where k_f is the force constant of the bond, and $\mu = \frac{m_A m_B}{m_A + m_B}$ is the effective mass. When isotopic substitution is made, the spring constant can be assumed to be unchanged. If the vibrational frequency of $^1H^{35}Cl$ is $5.63 \times 10^{14} s^{-1}$, find the vibrational frequency of (a) $^1H^{37}Cl$ and (b) $^2H^{35}Cl$.
   3. Calculate the average kinetic energy and average potential energy of ideal harmonic

oscillator in quantum state n.

F. Anwer the following problems:

1. The rotation of a molecule can be represented by the motion of a particle moving over the surface of a sphere. Calculate the magnitude of its angular momentum when $l = 1$ and the possible components of the angular momentum along the z-axis. Express your results as multiples of h.
2. The moment of inertia of a methane molecule (CH_4) is $5.27 \times 10^{-47} kg \cdot m^{-2}$; what is the minimum energy needed for it to start rotating? What is the angular momentum in this minimum energy state? For the same molecule, if it is in its first excited state, what is the degeneracy?
3. Find the operator for x-component of the angular momentum $\hat{l}_x$. Generalize for y-component $\hat{l}_y$, and z-component $\hat{l}_z$. Also find the commutator $\left[\hat{l}_x, \quad \hat{l}_y\right]$ in terms of h and $\hat{l}_z$; without calculations, generalize for other circular permutations.

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