PHYSICS 4, CHAPTER 3
ADDITIONAL PROBLEMS

1. What is the de Broglie wavelength of an electron with a kinetic energy of 120 eV?

2. The wavelength of the yellow spectral emission line of sodium is 590 nm. At what kinetic energy would an electron have that wavelength as its de Broglie wavelength?

3. Assume that an electron is moving along an x axis and that you measure its speed to be 2.05×10^6 m/s, which can be known with a precision of 0.50%.
What is the minimum uncertainty (as allowed by the uncertainty principle in quantum theory) with which you can simultaneously measure the position of the electron along the x axis?

4. The uncertainty in the position of an electron along an x axis is given as 50 pm, which is about equal to the radius of a hydrogen atom. What is the least uncertainty in any simultaneous measurement of the momentum of this electron?

5. An electron and a 0.020 0-kg bullet each have a velocity of magnitude 500 m/s, accurate to within 0.010 0%. Within what lower limit could we determine the position of each object along the direction of the velocity?

6. A 0.500-kg block rests on the frictionless, icy surface of a frozen pond. If the location of the block is measured to a precision of 0.150 cm and its mass is known exactly, what is the minimum uncertainty in the block's speed?

7. The average lifetime of a muon is about 2 ms. Estimate the minimum uncertainty in the rest energy of a muon.

8. An electron is confined to a one-dimensional, infinitely deep potential energy well of width
L = 100 pm.
(a) What is the smallest amount of energy the electron can have?
(b) How much energy must be transferred to the electron if it is to make a quantum jump from its ground state to its second excited state?
(c) If the electron gains the energy for the jump from energy level E_1 to energy level E_3 by absorbing light, what light wavelength is required?
(d) Once the electron has been excited to the second excited state, what wavelengths of light can it emit by de-excitation?

9. A ground-state electron is trapped in the one-dimensional infinite potential well with width L = 100 pm.
(a) What is the probability that the electron can be detected in the left one-third of the well ($x_1 = 0$ to $x_2 = L/3$)?
(b) What is the probability that the electron can be detected in the middle one-third of the well (between $x_1 = L/3$ and $x_2 = 2L/3$)?

10. The ground-state energy of an electron trapped in a one dimensional infinite potential well is 2.6 eV. What will this quantity be if the width of the potential well is doubled?

11. An electron is trapped in a one-dimensional infinite potential well. For what
(a) higher quantum number and
(b) lower quantum number
is the corresponding energy difference equal to the energy of the n = 5 level?
(c) Show that no pair of adjacent levels has an energy difference equal to the energy of the n = 6 level.

12. An electron is trapped in a one-dimensional infinite potential well that is 100 pm wide; the electron is in its ground state. What is the probability that you can detect the electron in an interval of width $\Delta x = 5.0$ pm centered at x =
(a) 25 pm,
(b) 50 pm, and
(c) 90 pm?

13. (a) Use the quantum-particle-in-a-box model to calculate the first three energy levels of a neutron trapped in an atomic nucleus of diameter 20.0 fm.
(b) Explain whether the energy-level differences have a realistic order of magnitude.

14. An electron that has an energy of approximately 6 eV moves between infinitely high walls 1.00 nm apart. Find
(a) the quantum number n for the energy state the electron occupies and
(b) the precise energy of the electron.
15. An electron is contained in a one-dimensional box of length 0.100 nm.
(a) Draw an energy-level diagram for the electron for levels up to $n = 4$.
(b) Photons are emitted by the electron making downward transitions that could eventually carry it from the $n = 4$ state to the $n = 1$ state. Find the wavelengths of all such photons.
16. A ruby laser emits 694.3-nm light. Assume light of this wavelength is due to a transition of an electron in a box from its $n = 2$ state to its $n = 1$ state. Find the length of the box.
17. A laser emits light of wavelength λ. Assume this light is due to a transition of an electron in a box from its $n = 2$ state to its $n = 1$ state. Find the length of the box.
18. A particle in a one-dimensional box of length L is in its first excited state, corresponding to $n = 2$. Determine the probability of finding the particle between $x = 0$ and $x = L/4$.