

3.6 Particle in a Box

27. Obtain an expression for the energy levels (in MeV) of a neutron confined to a one-dimensional box 1.00×10^{-14} m wide. What is the neutron's minimum energy? (The diameter of an atomic nucleus is of this order of magnitude.)
28. The lowest energy possible for a certain particle trapped in a certain box is 1.00 eV. (a) What are the next two higher energies the particle can have? (b) If the particle is an electron, how wide is the box?
29. A proton in a one-dimensional box has an energy of 400 keV in its first excited state. How wide is the box?

3.7 Uncertainty Principle I

3.8 Uncertainty Principle II

3.9 Applying the Uncertainty Principle

30. Discuss the prohibition of $E = 0$ for a particle trapped in a box L wide in terms of the uncertainty principle. How does the minimum momentum of such a particle compare with the momentum uncertainty required by the uncertainty principle if we take $\Delta x = L$?
31. The atoms in a solid possess a certain minimum **zero-point energy** even at 0 K, while no such restriction holds for the molecules in an ideal gas. Use the uncertainty principle to explain these statements.
32. Compare the uncertainties in the velocities of an electron and a proton confined in a 1.00-nm box.
33. The position and momentum of a 1.00-keV electron are simultaneously determined. If its position is located to within 0.100 nm, what is the percentage of uncertainty in its momentum?
34. (a) How much time is needed to measure the kinetic energy of an electron whose speed is 10.0 m/s with an uncertainty of no more than 0.100 percent? How far will the electron have traveled in this period of time? (b) Make the same calculations

for a 1.00-g insect whose speed is the same. What do these sets of figures indicate?

35. How accurately can the position of a proton with $v \ll c$ be determined without giving it more than 1.00 keV of kinetic energy?
36. (a) Find the magnitude of the momentum of a particle in a box in its n th state. (b) The minimum change in the particle's momentum that a measurement can cause corresponds to a change of ± 1 in the quantum number n . If $\Delta x = L$, show that $\Delta p \Delta x \geq \hbar/2$.
37. A marine radar operating at a frequency of 9400 MHz emits groups of electromagnetic waves 0.0800 μ s in duration. The time needed for the reflections of these groups to return indicates the distance to a target. (a) Find the length of each group and the number of waves it contains. (b) What is the approximate minimum bandwidth (that is, spread of frequencies) the radar receiver must be able to process?
38. An unstable elementary particle called the eta meson has a rest mass of 549 MeV/c² and a mean lifetime of 7.00×10^{-19} s. What is the uncertainty in its rest mass?
39. The frequency of oscillation of a harmonic oscillator of mass m and spring constant C is $\nu = \sqrt{C/m}/2\pi$. The energy of the oscillator is $E = p^2/2m + Cx^2/2$, where p is its momentum when its displacement from the equilibrium position is x . In classical physics the minimum energy of the oscillator is $E_{\min} = 0$. Use the uncertainty principle to find an expression for E in terms of x only and show that the minimum energy is actually $E_{\min} = h\nu/2$ by setting $dE/dx = 0$ and solving for E_{\min} .
40. (a) Verify that the uncertainty principle can be expressed in the form $\Delta L \Delta \theta \geq \hbar/2$, where ΔL is the uncertainty in the angular momentum of a particle and $\Delta \theta$ is the uncertainty in its angular position. (Hint: Consider a particle of mass m moving in a circle of radius r at the speed v , for which $L = mvr$.) (b) At what uncertainty in L will the angular position of a particle become completely indeterminate?

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