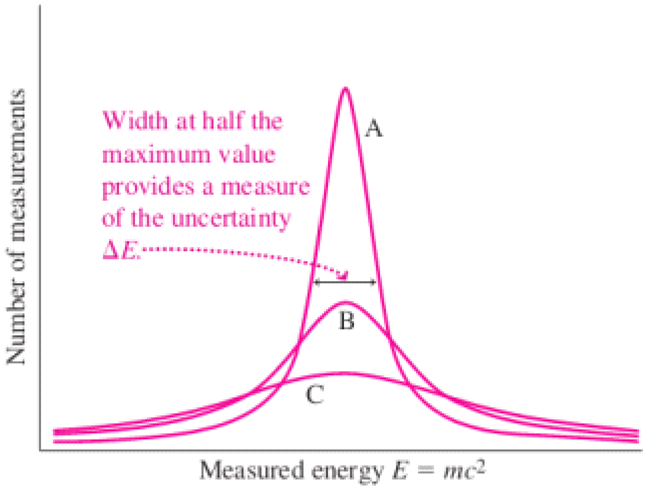
Section Fourteen Quantum Physics

Part One

Particle physicists use the energy–time uncertainty relation to estimate the lifetimes of unstable particles produced in high-energy particle accelerators. Some particles have lifetimes of and shorter—impossible to measure directly. However, physicists can measure particle masses, and they do so for many instances of the same particle to get a distribution of masses. By Einstein's that corresponds to a distribution of energies (Fig. 14.1). Measuring the distribution's width at half its peak (see Fig. 14.1) gives an estimate of the energy uncertainty, and the particle's lifetime.




1. Which of the curves in Fig. 14.1 represents the particle with the shortest lifetime?

a. A

b. B

c. C

d. You can't tell from the graph.

2. An energy uncertainty of 1 MeV corresponds to a particle life-time closest to

a. $10^{-34}$ s

b. $10^{-21}$ s

c. $10^{-9}$ s

d. 1 μs

3. The converse approach is used for particles with longer lifetimes: Direct measurement of the lifetime yields, through energy–time uncertainty, a range of expected values for particle energies or masses. The longer the lifetime,

a. the wider the mass range and the narrower the energy range.

b. the wider the mass and energy ranges.

c. the narrower the mass range and the wider the energy range.

d. the narrower the mass and energy ranges.

4. For a particle with lifetime, the corresponding mass range is closest to

a. $10^{-44}$ u

b. $10^{-27}$ u

c. $10^{-17}$ u

d. 1 u

Quantum dots , or qdots, are nanoscale crystals of semiconductor material that trap electrons in a potential well closely resembling the three-dimensional square well discussed in Section 35.4. Physicists, materials scientists, and semiconductor engineers have been studying qdots for their potential to miniaturize electronic components. More recently, qdots have been used in biology and medicine to "tag" individual molecules, helping scientists follow cellular processes. Qdots also facilitate high-resolution imaging within the cell, and they show promise for medical diagnostics and targeting tumors for the delivery of anticancer agents. In the bio-medical context, qdots work as replacements for traditional fluorescent dyes. Illuminating qdots promotes their electrons to higher energy levels; as they drop back, they emit photons of precise wave-length. A dot's size and structure determine this wavelength.

5. If a qdot's size is decreased, what happens to the wavelength of the photon emitted in a transition from the dot's first excited state
to the ground state?

a. The wavelength increases.
b. The wavelength decreases.
c. The wavelength is unchanged.

6. If the dot behaves as a perfectly cubical 3-D square well, the first excited state is

a. nondegenerate.
b. twofold degenerate.
c. threefold degenerate.
d. You can't tell without knowing the energy.

7. If the dot behaves as a perfectly cubical 3-D square well, the ground state is

a. nondegenerate.
b. twofold degenerate.
c. threefold degenerate.
d. You can't tell without knowing the energy.

8. If all three sides of a qdot are halved, its ground-state energy

a. is halved.
b. drops to one-fourth its original value.
c. doubles.
d. quadruples.

Part two

1 Chlorophyll is a photosynthetic molecule common in green plants. On a per-unit-wavelength basis, its ability to absorb visible light has two peaks, at 430 nm and 662 nm. (a) Find the corresponding photon energies. (b) Use these peak wavelengths to explain why plants are green.

2. (a) If the work function for a certain metal is 1.8 eV, what is the stopping potential for electrons ejected from the metal when light of wavelength 400 nm shines on the metal?(b) What is the maximum speed of the ejected electrons?

3 Find the kinetic energy of an initially stationary electron after a 0.10-nm X-ray photon scatters from it at 90 degrees

4. An electron drops from the n=7 to the level of n=6 an infinite square well 1.5 nm wide. Find (a) the energy and (b) the wavelength of the photon emitted.

5. A group of hydrogen atoms is in the same excited state, and pho-tons with at least 1. 5-eV energy are required to ionize these atoms. What's the quantum number n for the initial excited state?