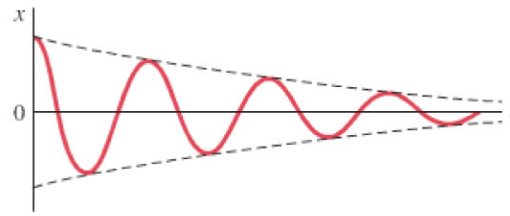

FIGURE 11–14 Damped harmonic motion.

11–5 Damped Harmonic Motion

The amplitude of any real oscillating spring or swinging pendulum will slowly decrease in time until the oscillations stop altogether. Figure 11–14 shows a typical graph of the displacement as a function of time. This is called **damped harmonic motion**. The damping† is generally due to the resistance of air and to internal friction within the oscillating system. The energy that is dissipated to thermal energy results in a decreased amplitude of oscillation.

Since natural oscillating systems are damped in general, why do we even talk about (undamped) simple harmonic motion? The answer is that SHM is much easier to deal with mathematically. And if the damping is not large, the oscillations can be thought of as simple harmonic motion on which the damping is superposed. The decrease in amplitude shown by the dashed curves in Fig. 11–14 represents the damping. Although frictional damping does alter the frequency of vibration, the effect is usually small unless the damping is large; thus Eqs. 11–7 can still be used in most cases.

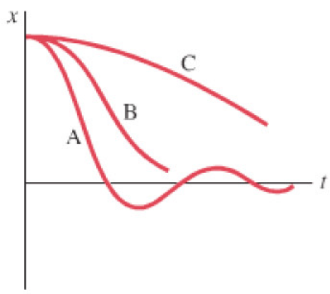

FIGURE 11–15 Graphs that represent (A) underdamped, (B) critically damped, and (C) overdamped oscillatory motion.

Sometimes the damping is so large, however, that the motion no longer resembles simple harmonic motion. Three common cases of heavily damped systems are shown in Fig. 11–15. Curve A represents an **underdamped** situation, in which the system makes several swings before coming to rest, and corresponds to a more heavily damped version of Fig. 11–14. Curve C represents the **overdamped** situation, for which the damping is so large that it takes a long time to reach equilibrium. Curve B represents **critical damping**: in this case equilibrium is reached in the shortest time. These terms all derive from the use of practical damped systems such as door-closing mechanisms and shock absorbers in a car (Fig. 11–16). Such devices are usually designed to give critical damping. But as they wear out, underdamping occurs: a door slams or a car bounces up and down several times each time it hits a bump.

PHYSICS APPLIED
Shock absorbers and building dampers

In many systems, the oscillatory motion is what counts, as in clocks and watches, and damping needs to be minimized. In other systems, oscillations are the problem, such as a car's springs, so a proper amount of damping (i.e., critical) is desired. Well-designed damping is needed for all kinds of applications. Large buildings, especially in California, are now built (or retrofitted) with huge dampers to reduce earthquake damage (Fig. 11–17).

† To "damp" means to diminish, restrain, or extinguish, as to "dampen one's spirits."

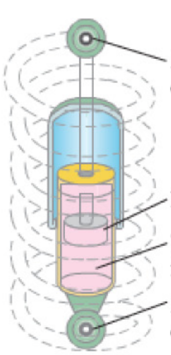

FIGURE 11–16 Automobile spring and shock absorber to provide damping so that a car won't bounce up and down so much.

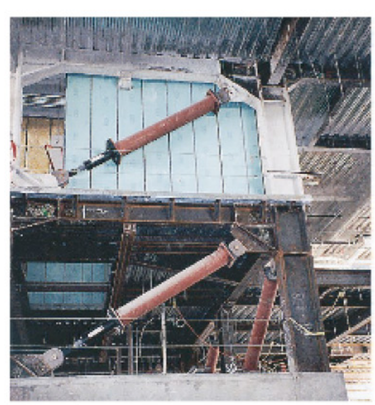

FIGURE 11–17 These huge dampers placed in a building look a lot like huge automobile shock absorbers, and they serve a similar purpose—to reduce the amplitude and the acceleration of movement when the shock of an earthquake hits.