much less than the speed of light, Eq. 26–4 gives the classical momentum, $p = m_0 v$.

We have written m_0 rather than m because Eq. 26–4 suggests to some physicists a relativistic interpretation of mass. Namely, that an object at rest has a **rest mass** m_0, but that its mass can increase with speed according to the formula

$$m_{\text{rel}} = \frac{m_0}{\sqrt{1 - v^2/c^2}} = \gamma m_0, \qquad \textbf{(26–5)}$$

Mass increase formula

where m_{rel} is called the **relativistic mass**. But be careful *not* to think a mass acquires more particles or more molecules as its speed becomes very large. It doesn't. In fact, many physicists believe an object has only one mass (its rest mass), and that it is only the momentum that increases with speed, a relativistic effect that everyone agrees to. [We use subscripts on m (m_0 and m_{rel}) to avoid any misunderstanding. If you see m without a subscript, you can feel pretty confident that it means rest mass.]

Relativistic momentum has been tested many times on tiny elementary particles (such as muons), and it has been found to increase in accord with Eq. 26–4.

EXAMPLE 26–7 **Momentum of moving electron.** Compare the momentum of an electron when it has a speed of (*a*) 4.00×10^7 m/s in the CRT of a television set, and (*b*) $0.98c$ in an accelerator used for cancer therapy.

APPROACH We use Eq. 26–4 for the momentum of a moving electron.

SOLUTION (*a*) At $v = 4.00 \times 10^7$ m/s, the electron's momentum is

$$p = \frac{m_0 v}{\sqrt{1 - \dfrac{v^2}{c^2}}} = \frac{m_0 v}{\sqrt{1 - \dfrac{(4.00 \times 10^7 \text{ m/s})^2}{(3.00 \times 10^8 \text{ m/s})^2}}} = 1.01 m_0 v.$$

The factor $\gamma = 1/\sqrt{1 - v^2/c^2} \approx 1.01$, so the momentum is only about 1% greater than the classical value. (If we put in the rest mass of an electron, $m_0 = 9.11 \times 10^{-31}$ kg, the momentum is $p = 1.01 m_0 v = 3.68 \times 10^{-23}$ kg·m/s.) (*b*) With $v = 0.98c$, the momentum is

$$p = \frac{m_0 v}{\sqrt{1 - \dfrac{v^2}{c^2}}} = \frac{m_0 v}{\sqrt{1 - \dfrac{(0.98c)^2}{c^2}}} = \frac{m_0 v}{\sqrt{1 - (0.98)^2}} = 5.0 m_0 v.$$

An electron traveling at 98% the speed of light has $\gamma = 5.0$ and a momentum 5.0 times its classical value.

26–8 The Ultimate Speed

A basic result of the special theory of relativity is that the speed of an object cannot equal or exceed the speed of light. That the speed of light is a natural speed limit in the universe can be seen from any of Eqs. 26–1, 26–3, or 26–4. It is perhaps easiest to see from Eq. 26–4: as an object is accelerated to greater and greater speeds, its momentum becomes larger and larger. Indeed, if v were to equal c, the denominator in this equation would be zero (in the other equations too), and the momentum would become infinite. To accelerate an object up to $v = c$ would thus require infinite energy, and so is not possible.