57.14: The Rings of Saturn

If you look at the planet Saturn through a telescope (Fig. $57.14.1$), you'll see it surrounded by a prominent set of rings. Although the rings look solid, they are actually composed of a vast number of chunks of ice or icecovered rock, ranging in size from small grains to chunks the size of buildings. It was shown by the Scottish physicist James Clerk Maxwell (following Laplace) that Saturn's rings cannot be solid. For one thing, if the rings were solid, Maxwell showed that their orbit would be unstable and they would eventually crash onto Saturn's surface.

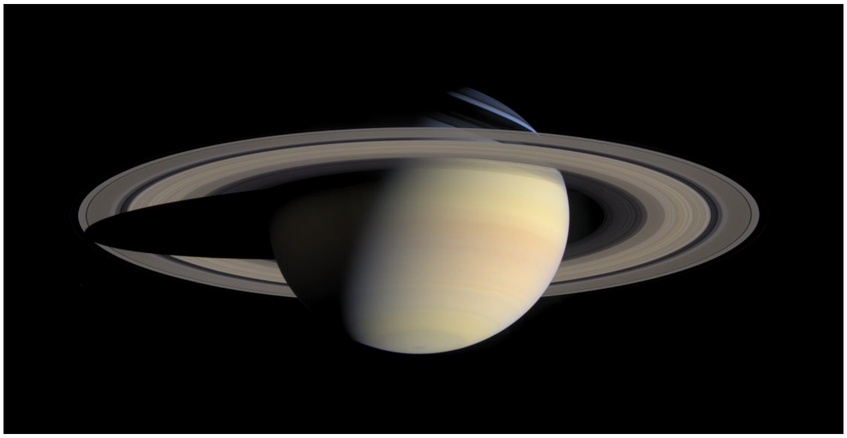

Figure $57.14.1$: Saturn and its rings, as seen by the Cassini spacecraft. (Credit: NASA.)

For another thing, tidal forces would tear the rings apart. According to the vis viva equation (Eq. 57.10.6), for a circular orbit, the velocity v of a body in orbit decreases with increasing distance from the planet by $v \propto r^{-1/2}$. But if the rings were solid, they would rotate as a solid body, obeying $v = r\omega$, so $v \propto r$ - the velocity would increase with increasing distance. The orbital velocity can't both increase and decrease with distance, so the result would be a large stress on the rings that would tear them apart.

In general, it has been shown that no body that is held together by gravity can avoid being torn apart if it orbits a planet with an orbital radius inside the so-called Roche limit, which is given by

$$r = 2.44 R_p \sqrt[3]{\frac{\rho_p}{\rho_b}} \tag{57.14.1}$$

where R_p is the radius of the planet, ρ_p is its density, and ρ_b is the density of the orbiting body.

The rings of Saturn are also extremely thin-maybe only 100 yards or so thick. Why are Saturn's rings so thin? It has to do with the ring particles colliding with each other. Ring particles that are high above or below the rings are in a highly inclined orbit, and have more energy than ring particles that are closer to the ring plane. When those particles collide with other particles, some of their energy is lost, so causing them to move to lower-energy orbits closer to the ring plane. Over time, the ring particles (especially the larger ones) tend to flatten themselves into a thin plane, as we see today. This is the general picture, but the details are still being worked out.