Key points from Lecture 3 of ASTR 350

1. The gravitational force between a particle of mass m_1 and a particle of mass m_2 separated by a distance r is
$$F = \frac{Gm_1 m_2}{r^2}\ , \tag{1}$$
where $G = 6.67 \times 10^{-11}$ N m^2 kg^{-2} is the gravitational constant.

2. It is a universal, mutual law: all things attract all other things in this way.

3. Luckily, the gravitational field outside of a sphere (even one with a density that varies as a function of the distance from the center) is the same as if all the mass were concentrated at the center of the sphere.

4. In principle, the mass in Newton's second law $F = ma$ (the inertial mass) could be different from the mass in Newton's law of gravity. For example, it could depend on the composition of the mass. But to the (amazing!) precision that we can measure things, the inertial mass equals the gravitational mass. This is called the *weak equivalence principle*, and one consequence is that in a vacuum, all things fall in the same way.

5. In orbit, things aren't weightless; they are just freely falling as they orbit! But (and this looks ahead to general relativity), you can't locally tell the difference between freely falling reference frames and frames with no gravity at all. This is a profound principle.

6. Escape velocity (or more correctly, escape speed). A distance R from the center of a spherical object (star, planet, ...) of mass M, if something moves away with a speed
$$v_{\rm esc} = \sqrt{2GM/R} \tag{2}$$
or higher, and if we ignore air resistance etc. the object escapes to infinity. From the Earth's surface, for example (again ignoring air resistance), $v_{\rm esc} = 11.2$km s^{-1}.

7. Suppose that $v_{\rm esc} = c$, the speed of light in a vacuum. Then for mass M, $R = 2GM/c^2$. Really tiny: would be just 0.88 cm for Earth's mass.