12 Gravity

Newton's Law of Gravity

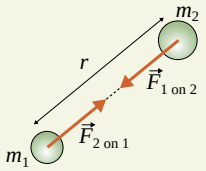
Every object in the universe attracts every other object with a *gravitational force*

$$F_{1 \text{ on } 2} = F_{2 \text{ on } 1} = \frac{Gm_1m_2}{r^2},$$

where

$$G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$$

is called the *gravitational constant*.



Surface Gravity

The free fall acceleration of an object at the surface of a planet of mass M is

$$g = \frac{GM}{r^2},$$

where r is measured from the centre of the planet.

Gravitational Potential Energy

The gravitational potential energy of a system of two objects is given by

$$U_G = -\frac{Gm_1m_2}{r}.$$

Notes:

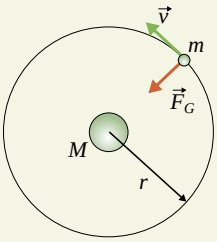
- This looks a bit like the force law, but it has a minus sign (see below) and only r on the bottom.
- The zero point is defined in this case to be when the two objects are separated by infinity (so $U_G = 0$ when $r = \infty$).
- Only when the height above the surface of a planet is much less than the radius of the planet, $y \ll R$, does this reduce to the more familiar

$$U_G = mgy.$$

Circular Orbits

If a satellite of mass m orbits a planet of mass M in a circular orbit of radius r, Newton's second law says the speed of the satellite is

$$v = \sqrt{\frac{GM}{r}}.$$



Kepler's Third Law

The *period* of an orbit is related to its radius by

$$T^2 = \left(\frac{4\pi^2}{GM}\right) r^3.$$

This is called *Kepler's third law*.