Newton's Law
of
Universal Gravitation

(Why are we attracted to that big bright object in the sky)

Newton's Big Idea

- Newton developed the idea that two bodies exert a force on each other over a distance.
  - Specifically, sun and earth
- He concluded that the force of gravity decreases with the square of the distance, r.

$$F \propto \frac{1}{r^2}$$

- Newton realized that the force of gravity depended not only on distance, but also on the mass of the objects.

$$F \propto \frac{m_{earth} m_{other\,body}}{r^2}$$

- He proposed that if this is true between the Earth and some object, why not between any two objects.

Newton's Law of Universal Gravitation

- Every particle in the universe attracts every other particle with a force that is proportional to their masses and inversely proportional to the square of the distance between them. This force acts along the line joining the two particles.

$$\boxed{F = G\frac{m_1 m_2}{r^2}}$$

G is the universal gravitational constant, 6.67×10^{-11} Nm^2kg^{-2}

Example 1

- What is the force acting on a 2000 kg spacecraft when it orbits the Earth at a distance of twice the Earth's radius?
  - – Radius of Earth = 6380 km
  - – Mass of Earth = 5.98×10^{24} kg

F=4900 N

Example 2

- A 50 kg person and a 75 kg person are sitting on a bench so that their centers are 50 cm apart. What is the magnitude of the gravitational force each exerts on each other?

F=1×10^{-6} N

Gravitational Field Strength

- We can use Newton's Law of Universal gravitation to calculate the gravitational field strength (also called gravitational acceleration), g.
- Consider an object with mass, *M*, sitting on Earth.

$$F = G\frac{m_1 m_2}{r^2} \qquad F = ma$$

$$F = G\frac{Mm_{earth}}{r^2} \qquad F = Mg$$

$$G\frac{Mm_{earth}}{r^2} = Mg$$

$$g = G\frac{m_{earth}}{r^2}$$

We can calculate the gravitational field strength for any object using this method.

Example

- Mt. Everest is 8848 m above sea level. Determine the value of g at the top of the mountain.
  - Radius of Earth = 6380 km
  - Mass of Earth = 5.98×10^{24} kg

$g = 9.77\ Nkg^{-1}$ (or ms^{-2})