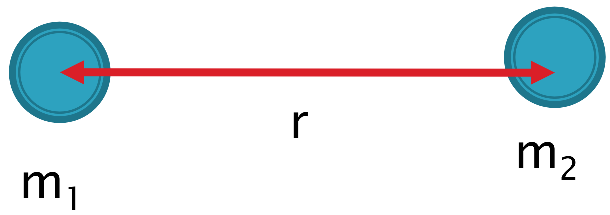
Newton's Law of Universal Gravitation

Newton recognized that two objects with mass will attract each other:



- The force of attraction depends on the masses of the objects and the distance (radius) between them

→ If the masses increase then the force increases $\Rightarrow$ $F \propto m_1 m_2$

→ If the radius increases then the force decreases $\Rightarrow$ $F \propto \dfrac{1}{r^2}$

Gravity is Proportional to Mass

- Assume that the force of gravity between two objects is 100N.

$$F \propto m_1 m_2$$

1. What is the new force if the mass of object #1 is doubled?

2. What is the new force if the mass of object #2 is reduced by half (divided by two)?

Gravity is Inversely Proportional to Distance

- Assume that the force of gravity between two objects is 100N.

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

1. What is the new force if the distance between the objects is doubled?

2. What is the new force if the distance between the objects is reduced by half (divided by two)?

Newton's Law of Universal Gravitation

$$F_G = \frac{Gm_1 m_2}{r^2}$$

Where: m_1 and m_2 are mass in kg

r is the distance between the objects in meters

G is the Universal Gravitational Constant:

$$G = 6.67 \times 10^{-11}\ Nm^2/kg^2$$

Example 1:

Two students, of mass 64 kg and 72 kg are sitting so that they are separated by a distance of 2.8 m. Find the magnitude of the gravitational force between them.

m_1=64 kg

m_1=72 kg

r=2.8 m

G=6.67 x 10^{-11} Nm^2/kg^2

$$F_G = \frac{Gm_1 m_2}{r^2}$$

$$= \frac{(6.67 \text{ x } 10^{-11})(64)(72)}{(2.8)^2}$$

$$= 3.92 \; x \; 10^{-8} N$$

Ans: 3.9 x 10 $^{-8}$ N

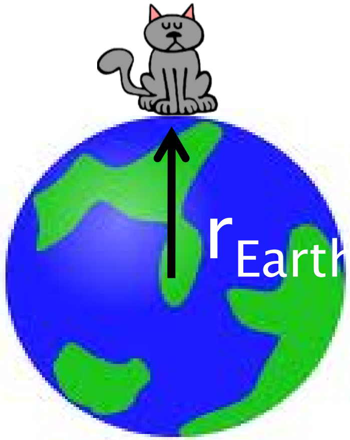
Example 2a:

A cat of mass 5Kg is sitting on the surface of the Earth.
Use $F_g = mg$ to find the force of gravity on the cat.

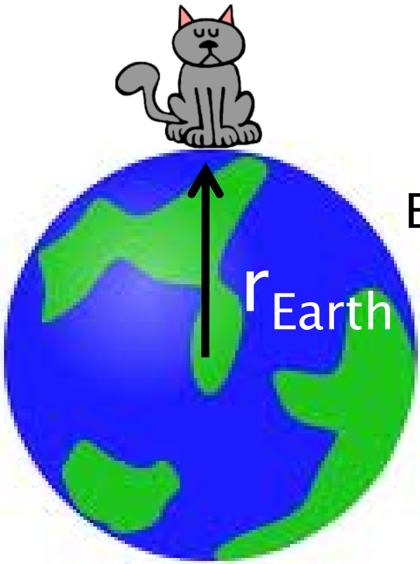
Example 2b:

Use Newton's Law of Universal Gravitation to find the force of gravity on the same cat. Assume the following values for the mass and radius of Earth.

Mass of Earth: 5.97×10^{24} kg   Radius of Earth= 6.37×10^{6} m



We can use both expressions for gravitational force to find the force of gravity on an object (a cat for example) on the surface of the Earth:



Cat mass $= m$

Earth mass $= M_{Earth}$

Radius between cat and Earth $= r_{Earth}$

$$F_g = mg$$	$$F_G = \frac{G m_E m}{{r_{Earth}}^2}$$

But both of these expressions must be the SAME!!

$$F_g = F_G$$

$$\cancel{m}g = \frac{G m_E \cancel{m}}{{r_{Earth}}^2}$$

The mass of the object cancels!!

So this gives us an expression for calculating the gravitational field strength of the Earth !!!!

$$g = \frac{G m_E}{{r_{Earth}}^2}$$

Example: $M_E = 5.97 \times 10^{24}$ kg, $r_E = 6.37 \times 10^6$ m

Calculate the value of g for the Earth.

Example 3a:

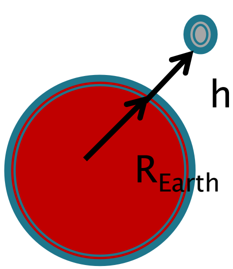
What is the gravitational force on a 520 kg rocket which is in orbit at a distance of 7.37×10^{6} m from the ***centre*** of the Earth?

Mass of Earth: 5.97×10^{24} kg   Radius of Earth= 6.37×10^{6} m

Example 3b:

What is the gravitational force on a 520 kg rocket which is in orbit at a distance of 1.00×10^{6} m ***above the surface*** of the Earth?

Mass of Earth: 5.97×10^{24} kg   Radius of Earth= 6.37×10^{6} m



Ans: 3.81×10^{3} N

Classwork:

Read Section 4.2 pages109-113

Read Section 4.3 pages115-118

Complete Worksheet