Name: Answers

Gravitational Force

Gravitational Force is the force of attraction between two objects. This force is proportional to the objects' mass and inversely proportional to the square of the distance between them. This distance is measured **center-to-center.**

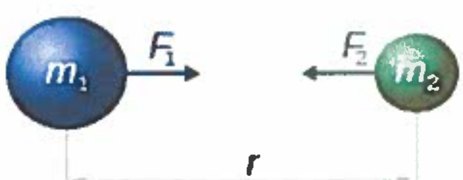
- Gravitational force is a field force = it acts at distance
- Gravitational force is always directed towards the center of the object (ex.of Earth)
- The further away from the center, the weaker the attractive pull of gravity
- Every object that has mass is surrounded by a **gravitational field**. Gravitational field is space in which other objects with mass experience the force of gravity.
- $\vec{F_g} = mg$ where g is the acceleration due to gravity in m/s^2 and m is the mass of the object

Weight ≠ Mass

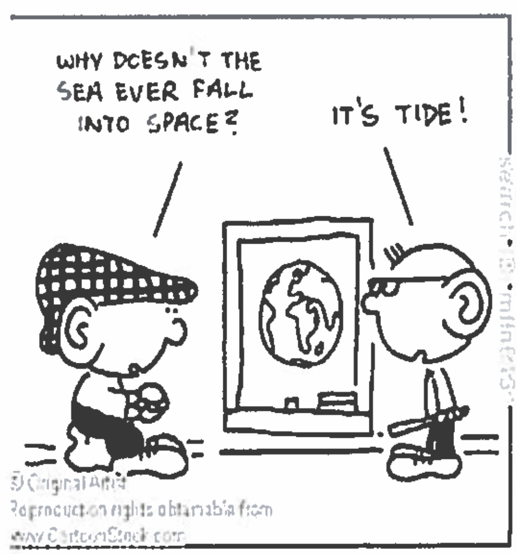
- Weight = is given in Newtons and it describes how much the attractive force of gravity affects the object's mass
- Mass = is given in kilograms and it describes how much matter an object consists of

For example: A 60-kg astronaut will always have the mass of 60 kg no matter where in space she is. However, her weight will change depending on her distance from the Earth or other objects with strong gravitational field. When she is in weightless space her mass is still 60 kg, however she does not experience any forces of gravity, thus her weight is zero.

- **Weight = mg**



$$F_1 = F_2 = G\frac{m_1 \times m_2}{r^2}$$



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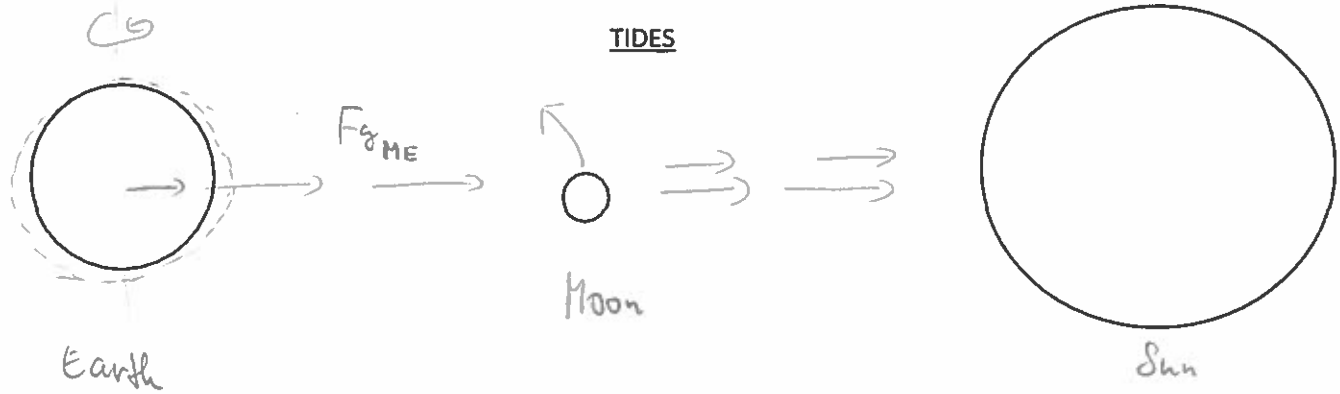


Newton's Law of Universal Gravitation

$F = \frac{G\, m_1\, m_2}{r^2}$, where G is the universal gravitational constant $6.67 \times 10^{-11}\ N \cdot m^2 \cdot kg^{-2}$

m_1 and m_2 is the mass of the object 1 and object 2, r is the distances between the centers of the two objects.

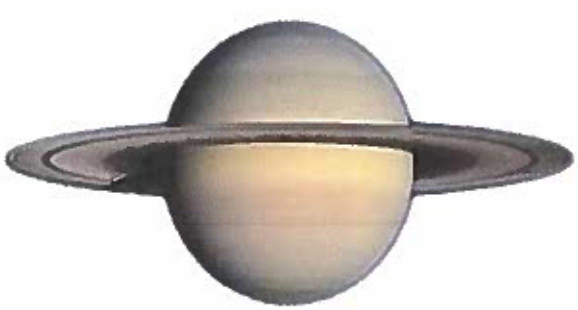
- The gravitational field at any point P in space is defined as the gravitational force felt by a unit mass placed at P.
- The strength of the gravitational field at any point P in space is the magnitude of the gravitational force felt by a unit mass placed at P.

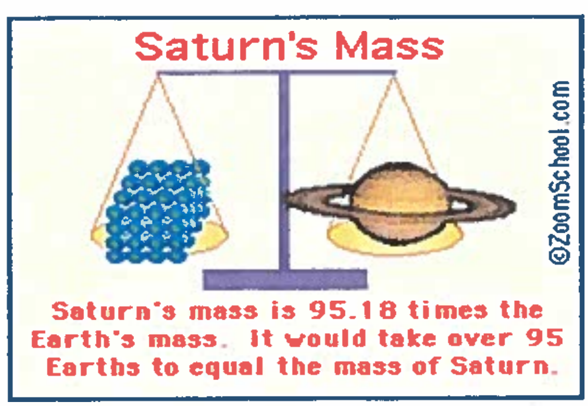
$$r = \sqrt{\frac{Gm}{g}}$$

- Gravitational Field: $g = \frac{Gm}{r^2}$ [N/kg]
- Acceleration due to gravity : $g = \frac{Gm}{r^2}$ [m/s^2]

Magnitude of the gravitational force is directly proportional to masses of the two objects

and inversely proportional to square of the center-to-center distance





1. Find the strength of gravitational field on Saturn. The mass of Saturn is approximately 5.683×10^{26}kg and its radius is 58 232 km. Assume that Saturn is a perfect sphere and its mass is distributed throughout the entire planet.

$r = 58\ 232$ km
$= 58\ 232\ 000$ m
$= 5.8232 \times 10^{7}$ m

$$g = \frac{G m_s}{r_s^2}$$

$$= \frac{(6.67 \times 10^{-11})(5.683 \times 10^{26})}{(5.8232 \times 10^{7})^2}$$

$$= 11.2\ N/kg$$

2. How does the strength of the gravitational field of Saturn compare to the strength of the gravitational field of planet Earth? ($m_E = 5.98 \times 10^{24}$kg, $r_E = 6.38 \times 10^{6}$m)

$g_E = 9.8$ N/kg

$g_S = 11.2$ N/kg

$$g = \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{(6.38 \times 10^{6})^2}$$

$g = 9.8$ N/kg

$$\frac{g_S}{g_E} = \frac{11.2}{9.8} = 1.14$$

∴ the gravitational field of Saturn is 1.14 times stronger than the gravitational field of Earth.

3. a)Newton's Law of Universal Gravitation states that all objects exert an attractive force on all other objects. Why don't you feel gravitational attraction from objects around you?

- the mass of the objects is negligible when compared to the mass of the Earth
- objects create very weak gravitational field around them, but the effects of this weak gravity often cancel out, depending on the position

$m_1 = \frac{588}{9.8} = 60 kg$

b) Provided that your weight is 588 N and you are standing 0.5 m away from a 35.0-kg bookshelf, is there a gravitational force between you and the bookshelf? If yes, find its magnitude. If not, explain why.

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

$$= \frac{(6.67\times10^{-11})(60)(35)}{(0.5)^2}$$

$$= 5.6\times10^{-7} N$$

4. a) What is the acceleration due to gravity on Saturn?

$$g = 11.2 \frac{m}{s^2}$$

b) What would be the weight of a 70-kg person on Saturn?

weight : $(70)(11.2) = 784 N$

c) How does the weight of the person on Saturn compare to the weight of the person when they are on Earth?

$W_S = 784$

$W_E = (70)(9.8) = 686$

$$\frac{W_S}{W_E} = \frac{784}{686} = 1.14$$

The weight on saturn is 1.14 greater than on Earth because

5. a) Find the gravitational force experienced by a 100-kg object that is on the Moon's surface.

(m_M=7.34x10^{22}kg, r_M=1.71x10^{6}m)

$$F_g = \frac{(6.67\times10^{-11})(7.34\times10^{22})(100)}{(1.71\times10^{6})^2}$$

$$= 169.4\ N$$

b)What is the acceleration due to gravity on the Moon?

$$g = 1.69\ \frac{m}{s^2}$$

6. What is the gravitational attraction between Moon and Earth if their surfaces are separated on average by 3.76x10^{8}m?

$$r = r_E + r_m + 3.76\times10^8$$

$$= (6.38\times10^6) + (1.71\times10^6) + (3.76\times10^8)$$

$$= 3.841\times10^8\ m$$

$$F_g = \frac{(6.67\times10^{-11})(5.98\times10^{24})(7.34\times10^{22})}{(3.841\times10^8)^2}$$

$$F_g = 1.98\times10^{20}\ N$$

7. Find the mass of an object that orbits the Earth 320 km and experiences gravitational pull of 686 N [towards the center of the Earth].

$r = r_E + 320\,000$

$r = 6.38 \times 10^6 + 320\,000$

$r = 6.7 \times 10^6$ m

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

$F_g r^2 = G m_1 m_2$

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

$m_2 = \frac{(686)(6.7 \times 10^6)^2}{(6.67 \times 10^{-11})(5.98 \times 10^{24})}$

$m_2 = \frac{3.079454 \times 10^{16}}{3.98866 \times 10^{14}}$

$m_2 \doteq 77.2$ kg