Name: ____________________

Period: ____________________

# Gravity

**3.6**

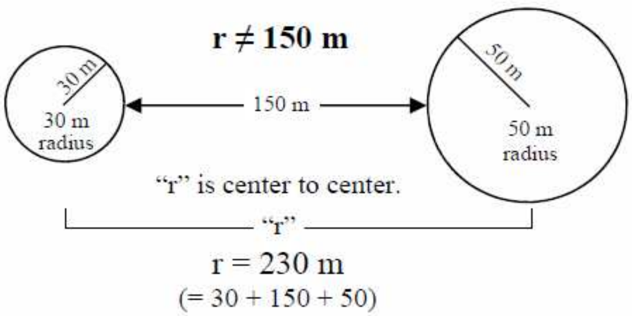
Gravity is a force that pulls ***all*** masses toward each other. Nothing that we know of can block gravity. The person sitting next to you, a mountain, even objects at the opposite ends of the universe attract each other. The reason you don't notice the force of gravity of anything other than the earth is that their gravitational forces are so small in comparison.

## Newton's Law of Universal Gravitation

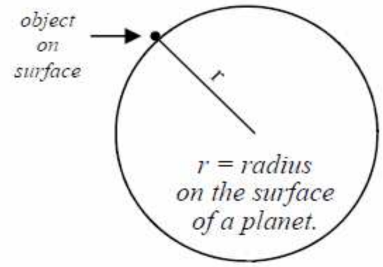
$$F_g = G\frac{m_1 m_2}{r^2}$$

- Force of Gravity (*in N*) → $F_g$
- Mass of Object 1 (*in kg*) → $m_1$
- Mass of Object 2 (*in kg*) → $m_2$
- Gravitational Constant $= 6.673\times10^{-11}\ Nm^2/kg^2$ → $G$
- Distance ***between the centers*** of $m_1$ and $m_2$ (*in m*) → $r$

## "r" is from the **Centers** of the Two Masses



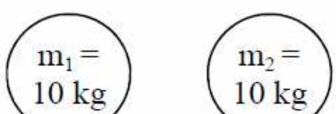

We use "r" instead of "d" because Newton first determined the force of gravity from the earth. "r" was the distance to the center of the earth, the earth's "radius". For an object touching the earth, the distance between them is zero, but "r" is not.




"r" = radius of the planet because the size of the object is negligible (it can be ignored) in comparison to the radius of the planet.

## The Force of Gravity Increases with Mass

The force of gravity is *directionally proportional* to mass: as the mass increases, the force of gravity increases

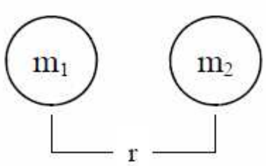



Doubling the mass doubles the force of gravity between them.

**Twice as much force.**

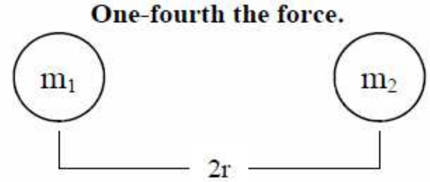

## The Force of Gravity Decrease with Distance

The force of gravity is *indirectionally proportional* to the square of the distance: as the distance decreases, the force of gravity decreases quickly.




Doubling the distance reduces the force by a factor of four.

**One-fourth the force.**




**Calculator Help:** Use EXP or EE for scientific notation: $3.3 \times 10^7$ is: 3.35E7

**Example**: Find the weight of a 20 kg object on the surface of Mars.
$r_{Mars} = 3.39\text{x}10^6$ m
$m_{mars} = 6.4\text{x}10^{23}$ kg

***Solution***: *The weight of the object is the force of gravity between the object and Mars.*

Variables:
$G = 6.673 \text{ x } 10^{-11}$
$m_1 = 20$ kg
$m_2 = 6.4 \text{ x } 10^{23}$ kg
$r = 3.39 \text{ x } 10^6$ m
*(the radius of the object is negligible to the radius of Mars, so you can ignore it.)*

$$F_g = G\frac{m_1 m_2}{r^2}$$
$$= 6.673\times10^{-11}\frac{(20)(6.4\times10^{23})}{(3.39\times10^6)^2}$$
$$= 6.673\times10^{-11}\frac{1.28\times10^{25}}{1.15\times10^{13}}$$
$$= 6.673\times10^{-11}(1.11\times10^{12})$$
$$= 7.43\times10^1$$
$$= 74.3\text{N}$$

*On the earth a 20 kg object would weigh 196 N ($F_w = mg$, where $g = 9.8\ m/s^2$). The object is much lighter on Mars.*

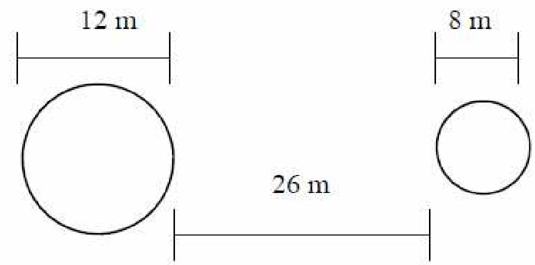
1. Does gravity increase or decrease with greater distance?

2. Does gravity increase or decrease with greater mass?

3. If one of the masses is tripled, how does the gravity change?

4. If the distance between the masses is doubled, how does the gravity change?

5. What does the "r" in the equation mean?




6. To find the gravitational force between the two objects at the right, r = ?

7. A $6.5\times10^{12}$ kg object is $3.2\times10^{4}$m away from a 3,800 kg object. Calculate the force of gravity between them.

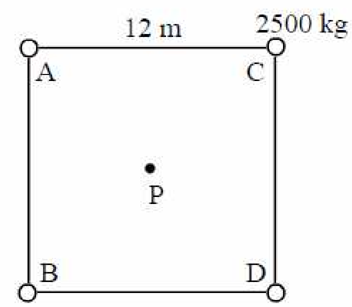
8. A 35 kg object is on the surface of Venus. Venus has a mass of $4.87\times10^{24}$ kg and a radius of $6.05\times10^{6}$ m.
   A. What is the weight of the object on the earth (*use g = 9.8 m/s²*)?

   B. What is the mass of the object on the earth?

   C. What is mass of the object on Venus?

   D. What is weight of the object on Venus?

9. Four identical 2500 kg objects are at the corners of a square with 12 m sides.

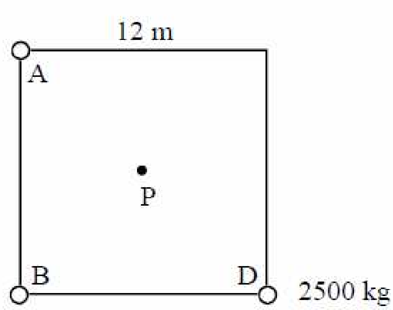



   A. What is the distance between A and B?

   B. Calculate the force of gravity between A and B.

   C. Calculate the force of gravity between B and D.

   E. A 25 kg object is then placed at the center of the square (point P). Remembering that force is a vector, calculate the net force on the object at point P.




10. Object C is then removed, as is the object at point P.
    A. Draw (with arrows) and label the gravitational forces on Object B, due to objects A and D.

    B. Calculate the net gravitational force on Object B.

    The 25 kg object is placed back at point P.
    C. Calculate the distance between each corner and point P.

    D. Calculate the new gravitational force on the object at point P.