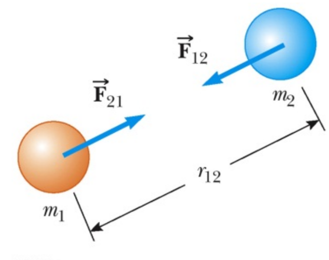
Newton's Law of Universal Gravitation – When objects are close to the surface of Earth we can find the weight of an object by using the equation weight = mass X acceleration due to gravity (w = mg). The ___________________ of an object ______________________________ the ____________________'s surface, on another planet, or in space can be found, but it cannot be found using the same equation.

- Every ___________________________ in the Universe _____________________ every _________________ _________________________ with a ____________________ that is directly ___________________________ to the product of the ____________________ and ________________________ proportional to the __________________ of the _______________________ between them.

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

- G is the constant of universal gravitational = 6.673 x 10^{-11} N m^2 /kg^2



- The force that mass 1 exerts on mass 2 is equal and opposite to the force mass 2 exerts on mass 1
- The forces form a Newton's third law action-reaction
- If the __________________ are ________________ (Earth, Sun, etc.) the distance "___" must be from the __________________ of the object, not from its surface.
- Can be used the find the force of attraction between two objects, even if they are small, because of the attraction of mass to any other mass.

Example Problem:

A satellite has a mass of 100 kg and is located at 2.0 X 10^6 m above the surface of Earth. The Earth has a mass of of M_E = 5.98 X 10^{24} kg and a radius of r_E = 6.38 X 10^6 m. (a) What is the magnitude of the gravitational force on the satellite? (b) If the mass of the satellite is doubled what is the gravitational force on the satellite? (c) If the total radius (r_E + distance above the Earth's surface) is doubled, what is the gravitational force on the satellite?

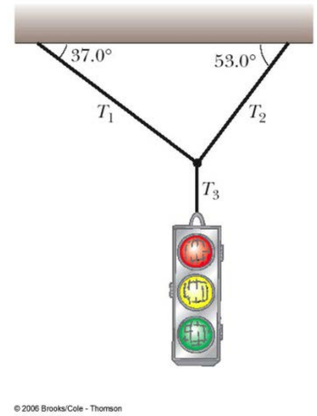
(a) Simply use the equation shown above with the m_1 as the satellite, m_2 as the mass of the Earth, and r as the total distance from the center of the Earth.

(b) If the mass of the satellite is doubled you could redo the work above or use the relationship between mass and the force of gravity. You can get the relationship from the equation.

(c)

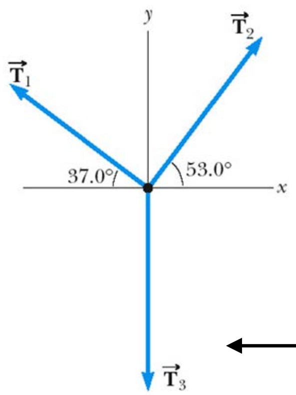
Example Problems on static equilibrium when the angles are NOT the same:

A 100.0 kg traffic light is supported as shown. Find the tension in each cable.



There are two forces acting on the traffic light, _____ and _____.

Hopefully you can see that $\boldsymbol{T_3 = F_g}$



There are three forces acting where all three cables come together. $\boldsymbol{T_1}$, $\boldsymbol{T_2}$, and $\boldsymbol{T_3}$. $\boldsymbol{T_1}$ is the tension from the left cable, $\boldsymbol{T_2}$ is the tension from the right cable, and $\boldsymbol{T_3}$ which equals the weight of the light.

1. To solve the problem, we must resolve the ________________ into their _____ **&** ______ components and then ________ up the ________________ in the _____ **&** _____ directions.
2. We know that the ___________ of these ____________________ must equal ____.
3. Let's look at the forces acting in the ***x*** direction. The only forces acting in the ***x*** direction are the two ***x*** components from the tension. The weight has no ***x*** component since its direction is straight down. The two ***x*** component forces are in opposite directions.

Now we can write out an equation for the sum of the forces in the y direction. ***Let down be negative and up be positive.***

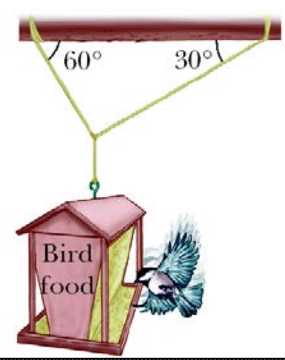
We now have two equations with two unknowns, so we have to set up a system of equations and use substitution.

Solve for T_1 in the first equation:

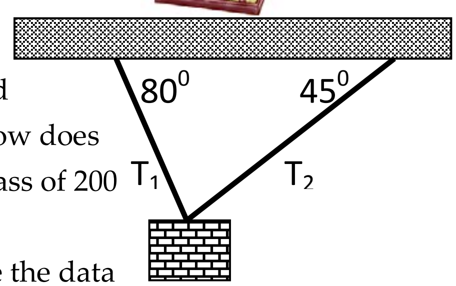
Plug this value into the second equation:

Now we can find T_1 by plugging the value of T_2 into the first equation, which we already solved for T_1.

<u>Homework Problems:</u>



1. A 150-N bird feeder is supported by three cables as shown in the diagram to the right. Find the tension in each cable.
2. Calculate the tension is each rope using the diagram to the right. The ropes have a negligible mass and the mass of the brick is 25 kg.



3. Objects with masses of 200 kg and 500 kg are separated by 0.400 m. (a) Find the gravitational force exerted on each object because of each other. (b) How does force change if the distances is cut in half? (c) How does it change if the mass of 200 kg is increased to 400 kg?
4. The average distance separating Earth and the Moon is 384,000 **<u>km</u>**. (a) Use the data shown ($M_E = 5.98 \times 10^{24}$ kg, $M_M = 7.36 \times 10^{22}$ kg, $r_E = 6.38 \times 10^6$ m, $r_M = 1.74 \times 10^6$ m) to find the net gravitational force exerted by Earth and the Moon on a 3.00×10^4 kg spaceship located halfway between them. (b) How would that force be if the mass of the ship was cut in half?