Notes – Dynamics (Forces)

- Forces are simply defined as a push or a pull. An example would be when you hang your jacket on a hook the jacket pulls down on the hook and the hook pushes back up with an equal amount of force to hold the jacket in place.

- All forces are vectors. That is, they have magnitude and direction.

- Some basic forces are forces like gravitational force, the electromagnetic force or the strong and weak nuclear forces. The electromagnetic force is the force that gives their material their strength, flex, bend, or shatter. It is caused by the interaction of electric charges at the atomic level. The nuclear forces are forces working on atoms that hold the nucleus together. It is much stronger than the others but only works over distances the size of atoms.

- Newton's first law deals with forces. He said that *an object with no net force acting on it remains at rest or moves with constant velocity in a straight line.*

- Objects have many forces acting on them. The overall force of these individual forces put together is what governs where and how fast an object moves.

- To help understand forces we assign forces to the right a positive and forces to the left a negative sign. To solve for the net force, one combines all forces to the right and then combines all forces to the left (negative sign) and adds them all together.

- Newton's second law also deals with forces. He said that *the acceleration of an object is directly proportional to the net force on it and inversely proportional to its mass*. This law can be more easily summarised to $\vec{a} = \frac{\vec{F}_{net}}{m}$ or $\vec{F}_{net} = m\vec{a}$

- Basically, if a net force acts on an object it will accelerate, and the larger the mass the smaller the acceleration.

- The unit of force is called the newton (N). A newton is the force required to accelerate one kilogram at a rate of $+1.0\frac{m}{s^2}$.

- Ex. – What net force is required to accelerate a $1500\ kg$ race car at $+3.00\frac{m}{s^2}$?

Answer - Given Need

- Ex. – An artillery shell has a mass of $55\ kg$. The shell is fired from a large gun, leaving the barrel with a velocity of $+770\frac{m}{s}$. The gun barrel is $1.5\ m$ long. Assume the acceleration is constant in the barrel. What is the force on the shell while it is in the gun?

Answer - Given Need

- Newton's Third law also deals with forces. He said that *when one object exerts a force on a second object, the second object exerts a force equal in magnitude and opposite in direction.* This law can be more easily summarised to if you push a bowling ball with a force of $+50.\ N$ the bowling ball pushes back with a force of $-50.\ N$. These two forces are often called action-reaction forces.

- Friction is a force that opposes the motion of two objects touching. This force comes into play in discovering movement of objects.

- Friction is the force that makes it hard to start a box you are pushing on to move. Because the box is not moving before you push on it this force of friction is called static friction. If you push hard enough to overcome this force the box will move. Once the box starts moving the force against the movement is still friction but now it is called sliding friction. Sliding friction is LESS than static friction. This is why a car will stop sooner if it is NOT skidding.

- Friction can be calculated by knowing two items. The force of friction is dependent on the material of the two substances (μ) and the normal force ($\vec{F}_n$). The normal force is the force pushing two objects together, like the floor is pushing back against your feet right now.

- So the force of friction is $\vec{F}_f = \mu\vec{F}_n$. You will often find that $\vec{F}_n$ is simply the force of gravity pushing the two objects together.

- Ex. – A smooth wooden block is placed on a smooth wooden tabletop. You find that you must exert a force of $+14.0\ N$ to keep the $40.0\ N$ block moving at a constant velocity. What is the coefficient of sliding friction between the wooden block and table?

*** TIP*** → ALWAYS draw a sketch of the object with each of the forces on an object drawn as arrows and labelled.

Answer - Given Need

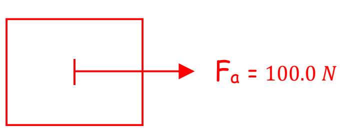
- Ex. – If a $-20.0\ N$ brick is placed on the block in the example above, what force will be required to keep the block and brick moving at a constant speed?

Answer –

- From the example above, one should see that if forces are balanced then there is no acceleration. An object will only speed up when the net overall force isn't balanced. That is if I pull harder than friction can pull back than the object will accelerate in the direction I am pulling.

- Ex. – In figure 1 a $10.0\ kg$ block rests on a frictionless, horizontal surface. A $+100.0\ N$ force is exerted horizontally on the mass. The resulting acceleration is

Figure 1



- In figure 2 the same block is now resting on a rough surface, causing friction to oppose motion. The friction force is $-20.0\ N$. The friction force is negative as the force is opposing the positive force. The NET FORCE is solved using the pulling force along with the force resisting it (friction). In essence we are adding ALL horizontal forces to get the net horizontal force.

Figure 2

-Ex. – A spring scale hangs from the ceiling of an elevator. It supports a package that weighs 25 N. What upward force does the scale exert when the elevator is NOT moving?

Answer -

- What force must the scale exert when the elevator and object accelerate upward at +1.5 m/s^2?

Answer –

- Gravity is one of the most well-known forces as we feel it all the time.

- Weight ($\vec{W}$) is the strength of the gravitational force from the earth pulling down on a mass. The more massive the larger the gravitational force pulling on the object.

- Using Newton's second law we can find weight. Force equals mass times acceleration. Acceleration at the surface of the earth from gravity is $-9.81\frac{m}{s^2}$. So, weight will be mass times 9.81.

-Gravity is ALWAYS acting on an object whether it is in the air or on the ground. Gravity is so important it has its own letter $\vec{g}$.

- Newton did a lot of his work on gravity. He proposed that as you get further from an object the gravitational force weakens. In fact, the force of gravity is equal to $\frac{1}{d^2}$. That is as you travel further from the surface the force of gravity decreases by the inverse square of the distance.

- If you are a distance of two earth radii the gravity will be $\frac{1}{4}$ not one half!!

- Newton ultimately came up with an equation relating gravity to all objects in existence. The formula is

$$\vec{F}_g = \frac{Gm_1m_2}{r^2}$$

Where G is a universal constant of value 6.67×10^{-11}, and r is radius or distance between the centers of the objects.

- This equation shows that if the mass of one object doubles, so does the force. Or as the distance doubles the force between them would be one quarter.

- Ex. – Two bowling balls each have a mass of $6.8\ kg$. They are located next to one another with their centers $21.8\ cm$ apart. What gravitational force do they exert on each other?

Answer –

- This equation for universal gravitation has large implications. With this formula we can actually mathematically show what the force of gravity ($\vec{F}_g$) on the surface of the earth is. If the force of gravity times mass is known as weight ($\vec{W}$) and weight is mass multiplied by gravity then we can combine the two equations.

- $\vec{F}_g = \frac{Gm_1m_2}{r^2}$ and $\vec{F}_g = W = m \times g$ then $\cancel{m} \times g = \frac{Gm_1\cancel{m_2}}{r^2}$ $g = \frac{Gm_1}{r^2}$

- This formula is excellent for solving for the gravitation force of any object. It is this formula that we use to solve for gravitational field strength on earth.

Earth's gravity strength at the surface - $\vec{F}_g = \frac{(6.67 \times 10^{-11})(5.98 \times 10^{24})}{(6.38 \times 10^6)^2}$ $\vec{F}_g = 9.81\ N \times kg$

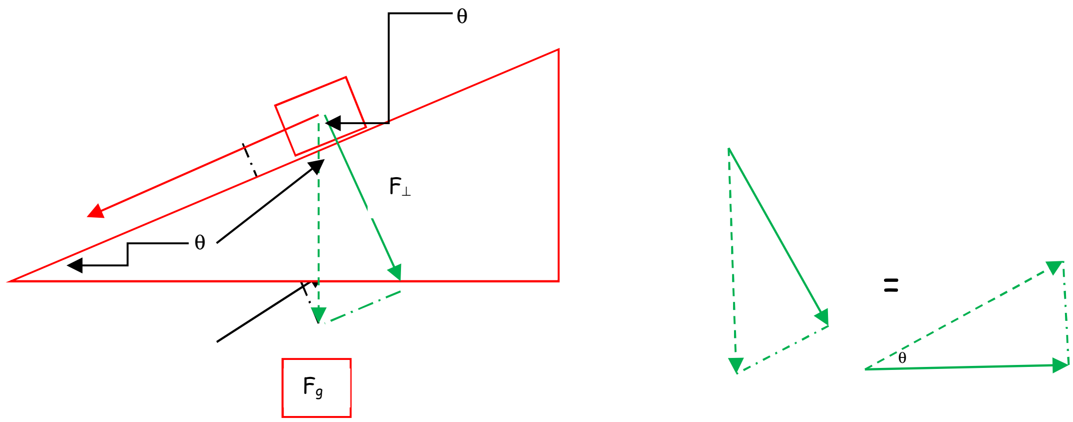
- There is another way force can be exerted. Elastic objects are objects that have special properties of their bonds between atoms. This allows them to stretch and compress without breaking. By imparting a force on the elastic object, the object will be stretched or compressed. The magnitude of this force needed can be calculated based on two items: the spring constant and the distance the object is stretched or compressed from its equilibrium state.
- The equation used is $\vec{F}_e = kx$ where k is the spring constant (value changes depending on material of spring) and x is the displacement from equilibrium.

- Ex. - How far will a spring of $k = 23 \frac{N}{cm}$ stretch when a $3.5\ kg$ mass is hung on it?

Answer – Given Need

- Forces often work on objects on a ramp. Objects on a ramp have gravity pulling down towards the center of the earth (straight down). To find out the force pulling an object down a ramp we need to break the force of gravity into components to find the component of force pulling parallel to the ramp not straight down. The force parallel is symbolized by F_{II} and the force perpendicular to the ramp is shown as $F_{\perp}$. Recalling what we learned in vectors will serve us well. Here is what a typical ramp problem breaks down to look like as components.

- Ex. –



- Ex. – Your friend is moving into a new house and has asked for your help in moving. A box weighing $57\ kg$ is resting on a ramp inclined at $30°$. Find the components of the weight parallel and perpendicular to the plane.

Answer –

- Ex. – Using the same question as above what would be the acceleration of the box if the plane is frictionless? (don't forget direction!!!!)