Inclined Planes- Worksheet

1. Turn on the air pump then lift the air track up from one side by using the handle beside the device or by using your hands. The photo-gate is a device that measure the time the cart takes to pass the gate. Turn the photo-gate on and allow the cart to slide on the inclined plane. Raise the inclined plane in successive step and record the time registered by the photo-gate at each step for each angle of inclination. What do you notice in the time readings while changing the angle of inclination of the track?

2. Conclude from your previous answer what has happened to the motion of the cart when sliding on the air track?

3. What are the physical quantities that will change every time you increase the tilt of the air track? How can you measure them? If you cannot measure these quantities directly, what other alternative methods can you use for measurements? [Think of a mathematical method knowing that the system resembles a triangle]

4. How can you calculate the acceleration of the cart using the devices in front of you and the laws of motion in one dimension which you have previously learned? Show your work. ($v^2=v_o^2+2\ a\ \Delta x$)

5. After defining the physical quantities that are changing from step 3, collect the data that links these quantities together and tabulate your results. What is the independent and dependant variable?

6. Draw a graph of your tabulated results and calculate the slope of the straight line. If the graph does not show a straight line how can you redefine one of the quantities to correct for this.

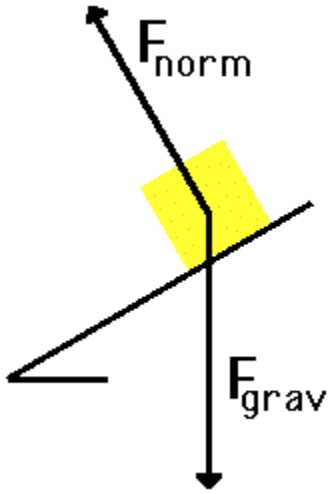
7. Use the previous graph to conclude an equation for this experiment.

8. Calculate the acceleration of the cart by using the previous equation at three different angles (more than 90°, less than 90° and the last one at $\theta = 90^{\circ}$) what is the highest acceleration the cart can obtain? Why? What this case called in physics?

9. Turn the air bump off. Now lift the air track and notice what happen to the cart. Why? Use Newton's second law to write an equation for the acceleration of cart when the air bump is off. Compare between this equation and the one in question (7). What the extra term in the last equation refer to?

Inclined Planes

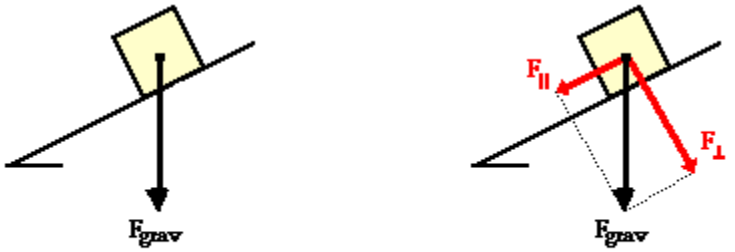
An object placed on a *tilted surface* will often slide down the surface. The rate at which the object slides down the surface is dependent upon how *tilted* the surface is; the greater the *tilt* of the surface, the faster the rate at which the object will slide down it. In physics, a *tilted surface* is called an inclined plane. Objects are known to accelerate down inclined planes because of an unbalanced force. To understand this type of motion, it is important to analyze the forces acting upon an object on an inclined plane. The diagram at the right depicts the two forces acting upon a crate that is positioned on an inclined plane (assumed to be friction-free). As shown in the diagram, there are always at least two forces acting upon any object that is positioned on an inclined plane - the force of gravity and the normal force. The force of gravity (also known as weight) acts in a downward direction; yet the normal force acts in a direction perpendicular to the surface (in fact, *normal* means "perpendicular").



The first peculiarity of inclined plane problems is that the normal force is not directed in the direction opposite the direction of the force of gravity. But this is only because the object is no longer on horizontal surfaces. The truth about normal forces is not that they are always upwards, but rather that they are always directed perpendicular to the surface that the object is on.

Normal forces are always directed perpendicular to the surface.

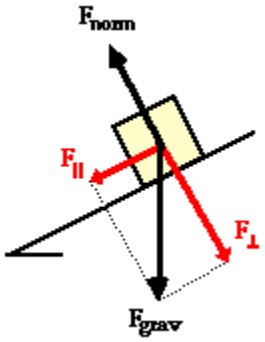
The task of determining the net force acting upon an object on an inclined plane is a difficult manner since the two (or more) forces are not directed in opposite directions. Thus, one (or more) of the forces will have to be resolved into perpendicular components so that they can be easily added to the other forces acting upon the object. Usually, any force directed at an angle to the horizontal is resolved into horizontal and vertical components. However, this is not the process that we will pursue with inclined planes. Instead, the process of analyzing the forces acting upon objects on inclined planes will involve resolving the weight vector (F_{grav}) into two perpendicular components. This is the second peculiarity of inclined plane problems. The force of gravity will be resolved into two components of force - one directed parallel to the inclined surface and the other directed perpendicular to the inclined surface. The diagram below shows how the force of gravity has been replaced by two components - a parallel and a perpendicular component of force.



The force of gravity can be resolved into two components. Together, these two components replace the affect of the force of gravity.

The perpendicular component of the force of gravity is directed opposite the normal force and as such balances the normal force. The parallel component of the force of gravity is not balanced by any other force. This object will subsequently accelerate down the inclined plane due to the presence of an unbalanced force. It is the parallel component of the force of gravity that

causes this acceleration. The parallel component of the force of gravity is the net force.



For objects on inclined planes (with no friction)

$F_{\perp} = F_{norm}$

$F_{||}$ is the net force

The task of determining the magnitude of the two components of the force of gravity is a mere manner of using the equations. The equations for the parallel and perpendicular components are:

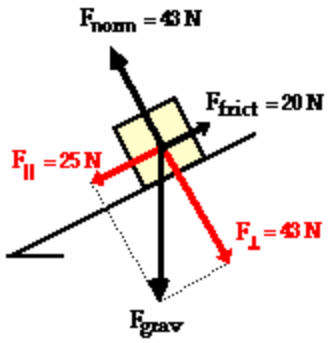
$$F_{||} = mgsin\,\theta \qquad\qquad F_{\perp} = mgcos\,\theta$$

In the absence of friction and other forces (tension, applied, etc.), the acceleration of an object on an incline is the value of the parallel component ($mg\ sin\ \theta$) divided by the mass (m). This yields the equation

$$a = gsin\,\theta$$

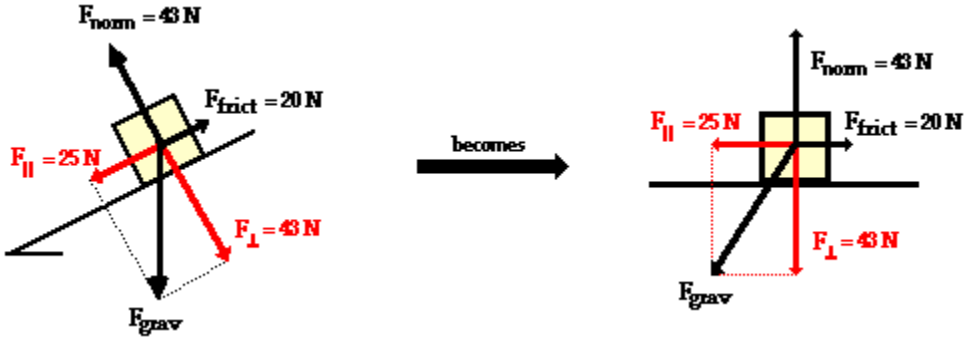
(in the absence of friction and other forces)

In the presence of friction or other forces (applied force, tensional forces, etc.), the situation is slightly more complicated. Consider the diagram shown above. The perpendicular component of force still balances the normal force since objects do not accelerate perpendicular to the incline. Yet the frictional force must also be considered when determining the net force. As in all net force problems, the net force is the vector sum of all the forces. That is, all the individual forces are added together as *vectors*. The perpendicular component and the normal force add to 0 N. The parallel component and the friction force add together to yield 5 N. The net force is 5 N, directed along the incline towards the floor.



The net force is 5 N.

The above problem (and all inclined plane problems) can be simplified through a useful trick known as "tilting the head." An inclined plane problem is in every way like any other net force problem with the sole exception that the surface has been *tilted*. Thus, to transform the problem back into the form with which you are more comfortable, merely *tilt* your head in the same direction that the incline was *tilted*. Or better yet, merely *tilt* the page of paper so that the surface no longer appears level. This is illustrated below.



Once the force of gravity has been resolved into its two components and the inclined plane has been tilted, the problem should look very familiar. Merely ignore the force of gravity (since it has been replaced by its two components) and solve for the net force and acceleration.