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The Inclined Plane

Alrighty….
As usual we can't just jump into a new section without at least a touch of discussion…..so here it is.

It all started way back in the 15^{th} century with this dude named Sir Isaac Newton. Newton spent his free time chilling with apples and whipping up this niffy work called "The Principia." In it, Newton came up with three killer laws that cleverly describe the motion of an object. The three laws are:

First Law
An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

Second law
The rate of change of the momentum of a body is directly proportional to the net force acting on it, and the direction of the change in momentum takes place in the direction of the net force.

Third law
To every action (force applied) there is an equal but opposite reaction (equal force applied in the opposite direction).

Cool!
Okay, let's check em' out.
I suppose this would be a good time to start with a definition.

Definition: Force

In physics, force is that which changes or tends to change the state of rest or motion of a body.

The standard unit for force is newton (N). A newton is a derived standard unit. This means that the SI unit of newton is composed of two or more standard units. 1N = 1 kg x 1m/s2.

Alright, now that that is done, let's check out that first law.

"An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force."

Well, duh! If I see a rock sitting on the ground, I certainly don't expect it to just take off and start bouncing around! Of course an object at rest tends to stay at rest….That part is easy. Just look at my son in the morning before school, he is clearly an object at rest wanting to stay at rest. Now, what about the object in motion?? So if I push a book across the floor, why does it stop. Newton's first law tends to make me think that it should just keep on sliding. Hmmmmmm. I'll bet there are forces that act upon the sliding book that make it slow down….Perhaps friction?!?!

Well, let's move on….The second law:

"The rate of change of the momentum of a body is directly proportional to the net force acting on it, and the direction of the change in momentum takes place in the direction of the net force."

Whoo hoo! This is the one baby! This here is the law that will consume the rest of your class…maybe even two! Let's look at this law in terms of…………

Next page please.

An equation!

In terms of an equation, the net force is equal to the product of the object's mass and its acceleration.

Net force = mass x acceleration or $f_{net} = m * a$

The standard unit for mass is kg.
The standard unit for acceleration is m/s2.
The standard unit for force is newton (N).
1N = 1 kg x 1m/s2.

For those of you hung up on the British system of measure, the standard unit is the pound (lb).

What is that you say? The pound!

Yes, the pound! Let's think about it. We have already stated that the acceleration due to gravity is $9.8 m/sec^2$. Which, by the way, is about $37 feet/sec^2$. So…….When I stand on the scale in my bathroom, I am not really measuring my mass. I am really measuring a force. Here is the next strange twist in thought. I am really measuring the amount of force imparted on me by the bathroom scale to keep me from accelerating toward the center of the earth. See the spring inside the scale is pushing up at me with the same force that I am pushing down on the scale……Cool huh?

The third law:

"To every action (force applied) there is an equal but opposite reaction (equal force applied in the opposite direction)."

Ya' know, let's leave that one for now. I don't want to let the cat out of the bag about smashing stuff together just yet.

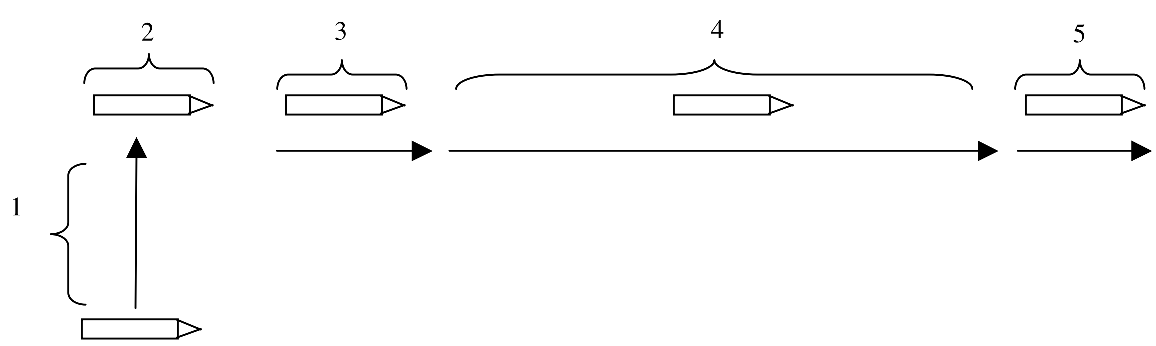
We still have one more thingy to talk about.

Work

Define: Work

In physics, work is defined as a force acting upon an object to cause a displacement.
Work = Force * Distance
Work is expressed in Newton Meters Nm.
Work can also be described in Joule (J)
1J = 1Nm

What the heck is work? Well, let me tell ya. In physics, there ain't no work being done unless some force has moved something some distance. In other words, reading this is NOT work. Picking up this paper IS work. Pushing your hand straight down on the top of the table is NOT work (unless the table moves). Picking your pencil off the table IS work. Work needs both a force and a distance. Here is a stranger one to think about. Let's say I **1)** pick a pencil off the floor and **2)** hold it 1m off the ground. I then **3)** accelerate to 1m/sec and **4)** carry the pencil at 1m/sec for 10meters. After 10 meters **5)** I slow down to a stop. Let's diagram it here:



Would it surprise you that both step 2 and 4 did not require any work? Here is why. Step one required a force to accelerate the pencil off the floor and move it against gravity to a height of 1m. Step three required a force to accelerate the pencil from a horizontal speed of 0m/sec to a speed of 1m/sec. Step 5 required a force to slow the pencil to 0m/sec from a speed of 1m/sec. Hmmmmm. In step 2 the pencil is not moving…OK, no distance. I get that. But what about step 4? The pencil is moving right? Well, to understand this we need to revisit Newton's first law.
"An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force."
So, since the speed is constant, we need to assume that the net force is 0 (remember, net force requires and acceleration). Since the force causing the constant horizontal speed is 0 then Work = Force * Distance would have a 0 in the Force part of the equation. Multiplying something time nothing gives you nothing. Thus Work equals zero.

Gosh I love this stuff.

The Lab:

Okay, what ya need:

1 Inclined plane — 1 Heavy metal car
1 Niffy spring scale — 1 Meter Stick

1)
Create a table like this in your lab book. You will likely need a whole page and many more rows than the 3 shown here.

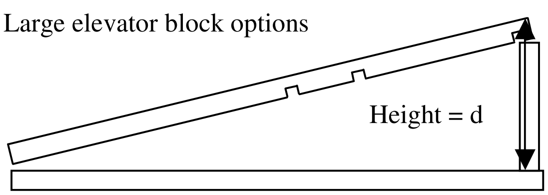
Weight in Newtons (N)	Height of ramp in meters (m) d	Calculated Work W = f * d	Measure force to roll cart up the ramp (N)	Measured length of the ramp in meters (m)	Measured Work W = f * d

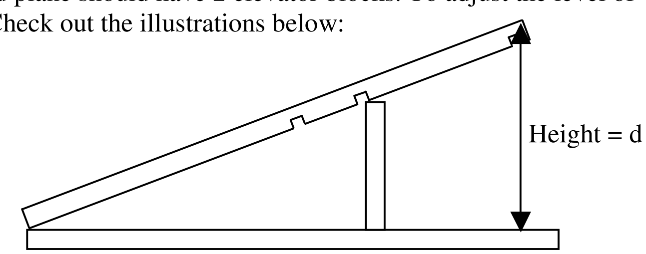
2)
Let's find out how many newtons (N) of force the spring in the balance imparts on the car to keep it from accelerating. In other words….hook it up and weigh it. Fill this data into the first column of your table.

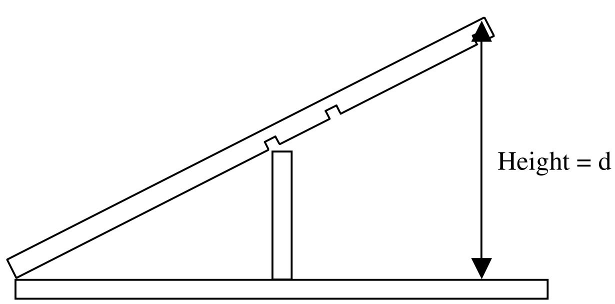
Record the data in your lab book!

3)
Now we need to set up out inclined plane. Each inclined plane should have 2 elevator blocks. To adjust the level of incline, simply lock the block into a slot on the plane. Check out the illustrations below:

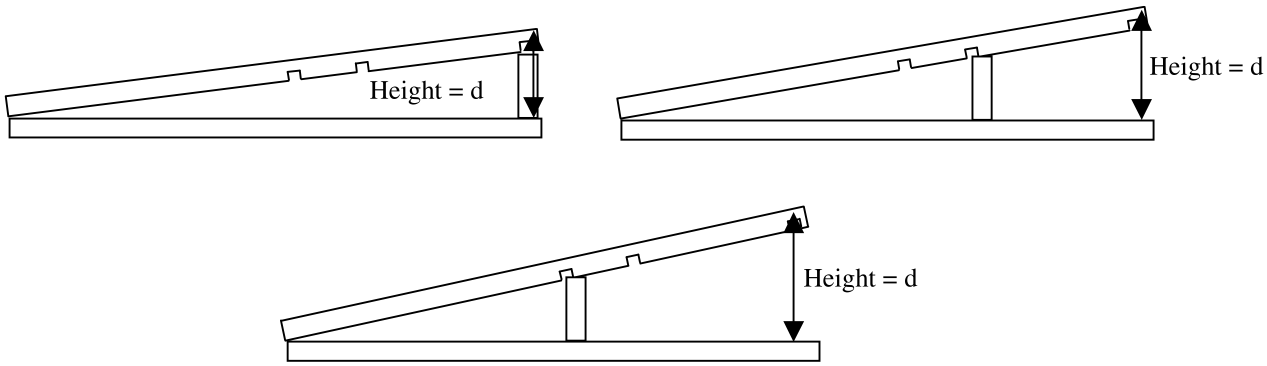
Large elevator block options







Small elevator block options.



Your job here is simple. Set up the ramp in all 6 positions shown above. In each case, measure the hieght (h) and record it in the second column of your table. Next record the work needed to move the cart up the ramp by simply appling the Work formula:

Work = Force * Distance

So, If the cart weighs 2N and the height of the ramp is 20cm (or0.20meter) The amount of work required to move the cart is:

Work = 2N * 0.20m
Work = 0.4Nm
This data goes in column 3 of your table

Once you have an idea of the amount of work required to lift the cart up to the ramp level, next check the force required to actually move the cart up the ramp. To do this, simply connect the cart to the spring scale and gently pull the cart up the ramp. While the cart is slowly moving up the ramp, read the value in Newtons that the scale is diplaying. Be as carefull as you can to pull the cart up the ramp at a uniform speed. Nice and slow.

Repeat this reading for each ramp height at least 3 times to get an average value. Record this data in the 4th column

Record the data in your lab book!

4)

Now let's check out your work.

In theory, the amount of work required to simply lift the cart straight up should be equal to the amount of work required to push the cart up the ramp. The difference is the total distance the cart moves. In the case of the ramp, the cart has to travel the whole length of the ramp. That is likely a lot further than the distance required to lift it straight up.

So here is what you do. Measure the length of the ramp (column 5 of your table) and multiply it by the force required to pull the cart up the ramp. For example, if the height of the ramp is 0.20m and the cart weighs 2N the amount of work required to move the cart up the ramp should be 0.4Nm. If the ramp is 0.5m long, I should get about 0.8N of force to pull the cart up.

Well, don't just sit there…..get started!