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Forces and Motion

Reading Material to Accompany Activity

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Forces and Motion Stations – **Background Information**

<u>Station 1:</u>

Newton's First Law of Motion:
'An object at rest or moving at a constant speed in a straight path continues to do so until a net force acts on it.'
Newton's Second Law of Motion—
'An object acted upon by a net force will accelerate in the direction of this force.'
Newton's Third Law of Motion—
'Forces always act in equal but opposite pairs.'

The force of the trap being sprung propels the mousetrap car by yanking the string wrapped around the axle, thus turning the axle and wheels. The car moves forward due to the friction between the wheels and the floor. If there was no friction (such as on ice or oil), the wheels would have nothing to grab onto, and the car would be no different than any other wheel-less object sliding across the surface. When the trap is sprung, the car undergoes a rapid initial acceleration, then a steady deceleration due to friction because there is no constant force to keep the car moving.

The fan car is different because it is propelled by the force of the fan blades pushing against the air, and has a constant force acting on it. It will undergo an initial acceleration, then retain a constant speed until it bumps into something or the batteries in the fan die!

Gravity, of course, is also acting on the car, and the floor is exerting a force back on the car pushing down on it (Newton's 3^{rd} law).

The speed can be determined by measuring the time it takes for the car to travel a specific distance, then dividing distance by time. Average speed can be determined by measuring the speed at different points in the car's motion: for instance, the time taken for the car to travel from 0m to 5m; from 5m to 10m; from 2m to 6m, etc.

<u>Station 2:</u>
The load force can be determined by lifting the sled-pulley straight off the floor using the spring scale. As long as nothing is added to or removed from this assembly, the load force will remain constant throughout the experiment. The load distance is the vertical distance traveled by the load. The effort force is the force measured on the spring scale as the load is lifted (when the load is lifted straight up with the spring scale, the effort force equals the load force, but when a pulley is used, the effort force is less than the load force). The effort distance is the distance moved by the student's hand pulling the spring scale to lift the load (again, when the load is lifted straight up, the effort distance equals the load distance, but when a pulley is used, the effort distance is greater than the load distance).
With each additional loop around the pulley system, the effort force to lift the load the same distance becomes less and the effort distance becomes greater. The actual mechanical advantage of a machine tells how much it reduces the amount of force

required to do work (it does not reduce the amount of work done -- work remains constant because work on the load = LF x LD, which is not changed by using a machine). Actual mechanical advantage = LF/EF.

Station 3a:

The double cone gives the illusion of rolling uphill, but in fact as it travels toward the open end of the V, it is actually falling lower toward the table. Gravity then is the force causing it to roll toward the higher end of the V. Students may measure the distance between the tabletop and the bottom of the double cone when it sits at the beginning of the ramp and at its final resting point. A cylinder would not roll up the ramp because its shape would not allow its center of gravity to drop. A sphere would roll up the ramp because it, like the double cone, would actually fall lower as the V spread apart, but it would fall through to the table before it reached the end.

Station 3b:

The center of gravity of any object will fall at the same rate, so the center of gravity of the meter stick and the steel ball fall at the same rate. However, the part of the meter stick under the steel ball must fall faster because it has farther to fall, so it falls out from under the steel ball, and at an angle to lay flat, while the steel ball drops straight down, which is into the second cup.

Station 3c:

Picture one is a bungee jumper. The only force that initially acts on both the jumper and the bungee cord is gravity. Once the bungee cord is loosely extended, its elasticity begins to counteract the force of gravity (because it is firmly attached at the top, so will not simply fall). The elastic force becomes stronger and stronger the more the cord is stretched until finally it is stronger than the force of gravity and pulls back up. It reaches a point where gravity again becomes the stronger force and the jumper falls again. The two forces alternate back and forth, eventually achieving equilibrium, and the jumper is then suspended motionless in the air.

Picture two is a skydiver. Again, the force that initially acts on the skydiver is gravity, and as the diver jumps, he begins to accelerate downward. Air resistance, however, is pushing upward on the diver, and he eventually reaches a speed where air resistance and gravity are equal, and he now falls at a constant speed. This is called *terminal velocity*. Changing body positions, which changes the amount of air resistance, also changes the terminal velocity. The skydiver can slow his fall by falling horizontally in a spread-eagle position, or speed up by pointing his body downward like an arrow. When the skydiver finally opens his parachute, the air resistance is increased considerably, slowing his terminal velocity enough that he can land safely.

Station 4:

The force required to pull the sled across the table depends on the weight of the load and the friction of the surface against the sled. On a sandpaper surface, there will be more friction; so more force is required to move the sled. When wheels are added, the frictional force is significantly reduced (after the initial force required to overcome the friction holding the load still), so less effort force is required.

When the cart is pulled up an inclined plane, the effort force (EF) is greater than when it is pulled across a flat surface, because now you are also pulling against gravity. (The EF required to pull the cart up the inclined plane is still much less than the EF required to lift the car straight up to the same height!) As the slope of the inclined plane increases, so does the force of gravity that you must overcome, and so does the effort force required to pull the cart to the same height (while the effort distance decreases).