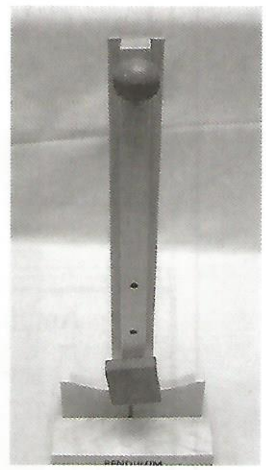
S103

TEACHER
GUIDE

THE PENDULUM

CRUSADER
EDUCATION

Overview



The Crusader Education Pendulum is crafted from durable hardwood to provide a long-lasting piece of laboratory equipment that lets students explore the basic concept of this classic piece of scientific apparatus. Experiments with the pendulum show the key fact about this device: that the time for the swing does not depend on the size of the swing. This is the basis of the pendulum's use for the first accurate clock. This Teacher Guide will explain the history and uses of this particular simple device, plus suggestions for experiments for students to do with the equipment.

The Pendulum: Basic Timekeeping

The simple machines and other devices that are part of the Crusader Education collection generally have two basic goals: to convert one form of motion or energy into another, or to amplify a force or a motion. The pendulum is different. It isn't a simple machine, but it is a simple device that was at the heart of the first devices that were able to accurately measure small intervals of time. Quantifying time was one of the key elements behind the development of modern science. So the pendulum is a device whose study—and whose understanding—is central to the understanding of modern science. Even today, clocks such as the one at left rely on a pendulum to provide the "beat." Other timekeeping devices, such as wristwatches, use the oscillation of wheels on springs, or quartz crystals. But at their heart all timekeeping devices rely on the idea of what we call simple harmonic oscillation. The first simple harmonic oscillator was the pendulum.

The Pendulum in History

The first serious study of the pendulum was done by Galileo. Legend has it that he was attending a service in the cathedral in Pisa, and noted the swing of a chandelier disturbed by a breeze. Using his pulse for timing, he noted that the time for one swing (which we call the period) did not change even as the swing became smaller and smaller.

In fact, this is the key feature of pendulums: to a good approximation, the time for one swing of a pendulum does not depend on the size of the swing. The time of one swing of a pendulum only depends on the length of the pendulum and the strength of gravity.

Christiaan Huygens, a Dutch scientist, worked out the mathematical relationship for the period of a pendulum. For a pendulum swinging back and forth at reasonably small angles, the period looks like this:

$$\text{Period} = \frac{1}{2\pi}\sqrt{\frac{l}{g}}$$

T is the period, in seconds; l is the length, in meters; g is the value of the acceleration of gravity, in m/s2. g has a value of approximately 10 meters per second per second—on earth! On other planets, gravity has a different value. (The 10 meters per second per second means this: if you drop an object, after one second, it will be falling at a speed of 10 meters per second. After two seconds, it will be falling at 20 meters per second. The speed increases by 10 meters per second, per second!)

Given the period of the swing of a pendulum is fixed by its physical properties, it is not surprising that the first very accurate clocks were pendulum clocks. What is surprising is that Galileo didn't think to develop a pendulum clock until the very end of his life! One of Galileo's biggest problems in the study of mechanics was devising an accurate way to measure time, but he never built a pendulum clock to help him do this. He continued to use his pulse, musical beats, and times based on water clocks.

Now, though, all clocks are based on the oscillations of pendulums and other systems that share the property of the pendulum that the period of oscillation depends only on physical properties of the system. The watch I am wearing on my wrist is controlled by the oscillation of a quartz crystal, whose period of oscillation is determined by the properties of quartz and the size of the crystal.

Here is one thing to note: the period of the pendulum depends only on the length and the acceleration of gravity. So you can time the motion of a pendulum to measure gravity—and in fact it is just this sort of measurement that is used to make highly accurate measurements of the earth's gravitational field. The earth's gravity does vary from place to place. In Colorado, where this document is being written, gravity is a bit weaker than it is elsewhere in the United States. Colorado is the highest of the states, and so is a bit farther away from the center of the earth—and so has gravity that is just a bit weaker!

Physics Principles: Timing

As we noted, the most important property of a pendulum is the fact that the period of its swing does not change with the size of the swing. Let's look at this in more detail:

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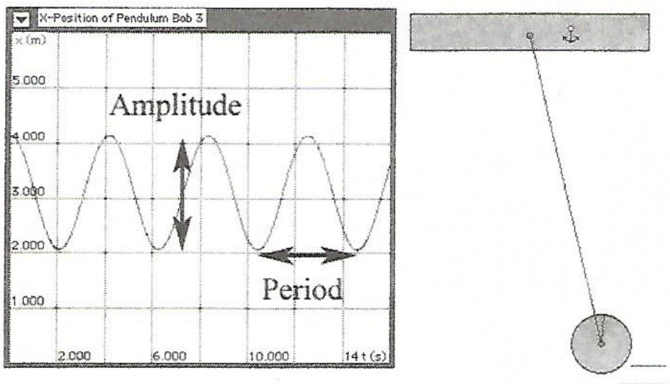
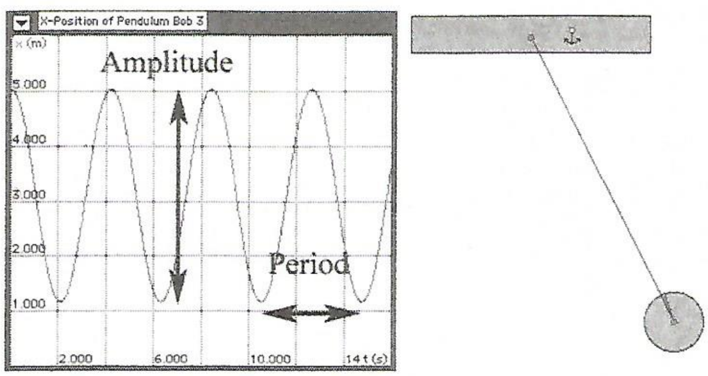
<tr><td>
</td><td>When you swing a pendulum, there are two key measurements that define the swing: the amplitude (a measure of how big the swing is) and the period (a measure of how long the swing takes.) In this case (a simulation of a very long pendulum!)
the period is just over four seconds.</td></tr>
<tr><td>
</td><td>If we take the same pendulum, but give it a bigger swing, we can see that the amplitude of the swing is larger: the pendulum swings farther. But the time for each swing—the period—stays exactly the same, just over four seconds for one swing.</td></tr>
</table>

As we noted, the period of the swing is given by the following equation:

$$\text{Period} = \frac{1}{2\pi}\sqrt{\frac{1}{g}}$$

What do we use for the length of the pendulum? For a pendulum like the one above, which looks like a big mass at the end of a string, we use the distance from the attachment point to the center of the mass on the end of the string. For a pendulum consisting of a rod, like the Crusader Education pendulum, it's a bit more complicated: the mass is spread out over the length of the pendulum. This kind of pendulum is known as a physical pendulum. The length is (more or less) the distance from the pivot point to the center of mass of the pendulum. Moving the center of mass down will increase the period, as we will see.

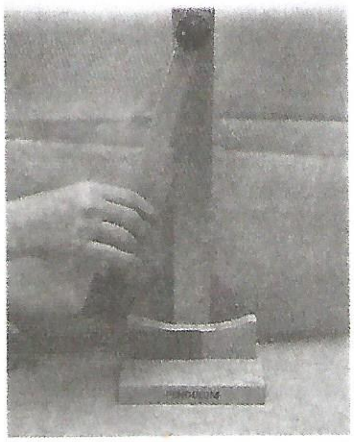
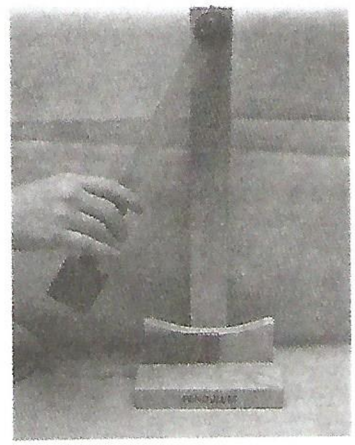
Energy

Next, let's look at energy. You can think of a pendulum as a repetitive energy exchange device. When you raise the pendulum up, you give it potential energy. When you let it swing, this energy changes to kinetic energy. When it swings up to the other side, this energy is converted back to potential energy. If no energy is lost, the pendulum must swing to a height every bit as high as it started from—one of the things about pendulums realized by Galileo and others that were crucial in the development of an understanding of energy. As the pendulum swings, it converts energy back and forth from potential to kinetic to potential, over and over.

Experiments

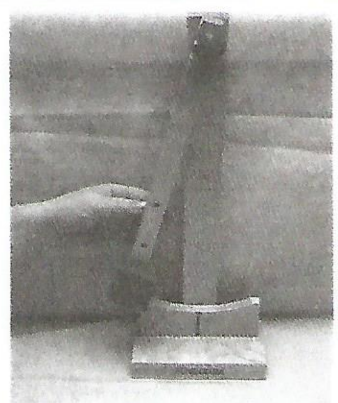
Timing the Swing

As we said, the key fact about pendulums is that the time of the swing doesn't depend on the size of the swing! Let's test this principle out. The best way to do this as a lab exercise would be to let students measure the period of the pendulum as a function of the size of the swing and discover this key property of the pendulum for themselves!

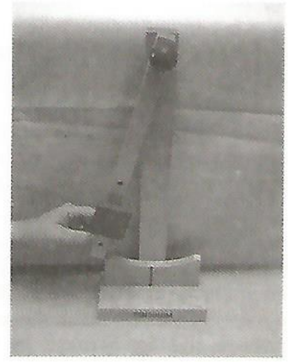
Step 1: Put the pendulum mass in the lowest hole. Pull the pendulum a measured distance to the side, and release it. Measure the period of the swing. (Hint: you will get better accuracy with this measurement if you let the pendulum complete several swings, and then divide to get the period for one swing. For example: measure the time for 5 swings, and then divide by 5.)	Step 2: Now, pull the pendulum twice as far to the side, so the amplitude of the swing is twice as large. Let the pendulum go, and measure the period of the swing. Again, you should measure the swing for several periods, and divide to get the period for one swing. Do you get the same period as you did in Step 1? In fact, you may get a different value, due to measurement error. But the values will be close!
	

Different Lengths

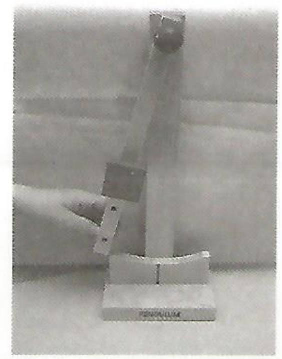
The period of a pendulum does depend on the length, though! You can show this by adjusting the position of the mass. There are three holes that the mass can go in; measuring the period for the mass in each position in turn is instructive.

Step 1: Put the mass in the top hole, and pull the pendulum a fixed distance to the side. Pulling the stick to the edge of the base support is an easy distance to measure. The exact distance the stick is pulled to the side isn't crucial; what is important is that the next measurement can be made with the pendulum pulled to the side by the same amount! Let the pendulum go, and measure the period as before.	

Step 2: Next, predict: if you move the mass to the middle hole, how will this change the period? Move the mass, pull the pendulum to the side by the same amount as before, and let it go. Does the period vary as you predicted?



Step 3: Finally, predict what will happen if the mass is put in the top hole. How will the period vary? Pull to the side by the same amount, and measure as before.



Extensions

Once your students have fully explored the pendulum system, there are some nice extensions you might have them think about.

Pendulums in Your Body: Your Legs!

When you walk, jog or run, your legs move back and forth like pendulums. This has an interesting consequence: the number of steps you take per second depends on the length of your legs, but not much else! If you measure the numbers of steps you take in one minute when you walk slowly, and then measure the number of steps you take in one minute when you walk more quickly, you will find that the number is about the same. Your legs are pendulums—and the time for one stride doesn't depend much on how big the stride is! (Note: there is some dependence, as your legs don't swing freely; your muscles apply forces.) Length does make a big difference though...

Different Length Legs, Different Length Pendulums

People have legs of very different lengths. Since our legs work like pendulums, this means that different people will have a very different stride period: the time it takes to take one step. People with long legs like the father in this picture have a long stride period. People with very short legs, like the little girl, will have a very short stride period. When you watch little children walk, you see that they move their legs back and forth very often. This is not because they are trying to move them this fast, it's just a natural result of the physics of pendulums! The next time you have a chance to watch a crowd of people walk by, take notice of their stride period: how often they take steps!

Pendulums at the Playground: The Swings

The swings at the playground are, of course, pendulums. And they will work just like pendulums do: the time for one swing doesn't depend on the weight of the person swinging, or how big the swing: it just depends on the length of the swing and the acceleration of gravity. You can try this and see. It makes a great lab exercise to have students take measurements of the period of a swing as a function of the mass of the person in the swing and how big the swing. You can essentially demonstrate the same experiments described earlier, but in a bigger way!

This guide written and illustrated by Brian Jones,
Little Shop of Physics, Colorado State University

S 103

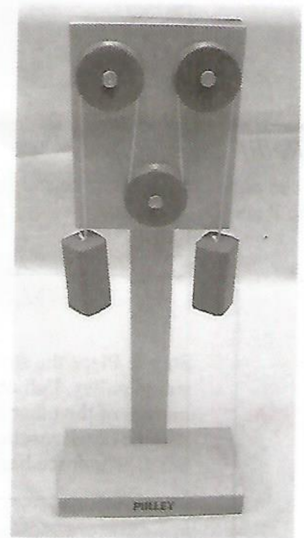
TEACHER GUIDE

THE PULLEY

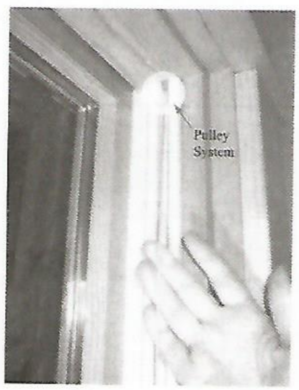
CRUSADER EDUCATION

Overview

The Crusader Education Pulley is crafted from durable hardwood to provide a long-lasting piece of laboratory equipment that lets students explore the basic concept of this simple machine. This Teacher Guide will explain the history and uses of the pulley, plus suggestions for experiments for students to do with the equipment.



The Pulley: A Simple Machine



A simple machine will allow you to, by using muscle power alone, perform tasks that would be otherwise quite difficult. For instance, you can use an inclined plane (a ramp) to raise a weight much greater than that which you can lift. A pulley does this in a very simple way: it lets you change the direction of an applied force.

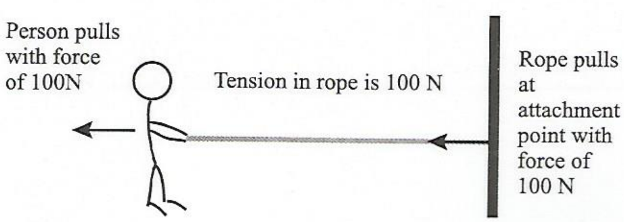
You quite possibly have pulleys in your house that you use regularly! Sash windows are often raised with the assistance of a pulley system. Raising a window sash can take a great deal of force. But a close view of this window reveals a cord that goes over a pulley that is attached to a weight inside the window frame. A downward force of gravity on this weight is transferred, via the pulley and the cord, to an upward force on the window sash, making the raising of the sash an easy matter! The pulley hasn't done any work, but it makes a job that would otherwise be quite difficult very simple.

The Pulley in History

Archytas of Tarentum is thought to be the inventor of the pulley as well as being the first to double the cube and to solve other important problems in mathematics. He is also thought to be the first person to invent a flying machine; his "pigeon", a mechanical device, is thought to have flown using some sort of jet propulsion!

It is likely that the basic concept behind the pulley, has been around since long before Archytas! If you throw a rope over a tree branch to lift a weight, you are using the tree branch to change the direction of the applied force, just as the pulley does. This sort of approach has been used for millennia. But the pulley adds a wheel to the system, allowing the rope to slide freely, with very little reduction in force. And once it was developed, it became ubiquitous in mechanical devices and in theoretical problems in mechanics.

Physics Principles



There are two basic concepts we need in order to understand the operation of a pulley: tension and force. Tension is a force, but a special kind of force, so we will measure tension with the same units as we use for force.

There are many units of force we could use, but we will use the metric unit of force, the newton (N), named after Isaac Newton. One pound (the pound is the unit of force in the British system of units) is equal to about 5 newtons.

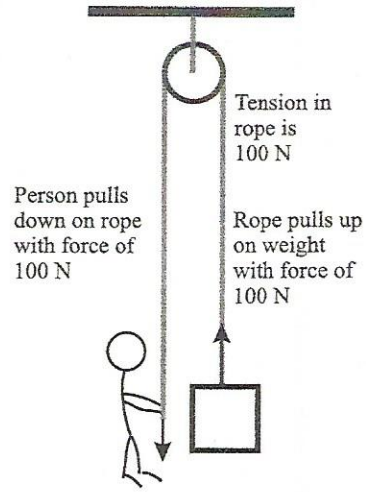
When you pull on a rope, you make a certain tension in the rope. If you tie the end of the rope to something else, the rope makes a force on what you tie the rope to.

Suppose you pull on the end of a rope with a force of 100 newtons (N), which is about 20 pounds. This gives the rope a tension of 100 N, which means that whatever you tie the rope to will experience a force of 100 N as well!

Now, let's add a pulley to the system. The pulley won't amplify the force. But it will redirect the force, so that it can be applied in another direction.

When you lift a load with a pulley, the rope goes over the pulley as shown. This redirects the rope, and so redirects the force as well. The person is pulling down on the rope, but the rope which has been redirected by the pulley will pull up on the load.

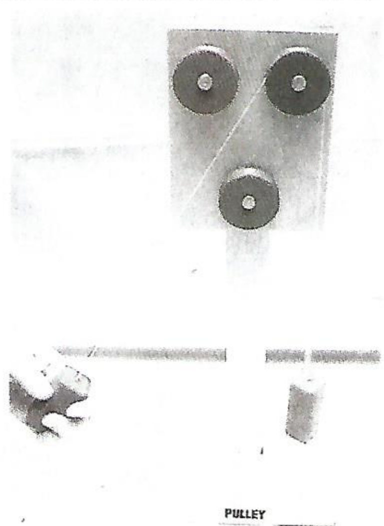
And that's it: that's why you use the pulley! In fact, most pulleys are used just like this, and for a very simple reason: it is easier to pull down (when you can use your weight to help!) than to pull up. So you redirect the force, which allows you to apply a downward force and turn it into an upward force on the weight you are trying to lift. Of course, pulleys can redirect force in other ways as well, and multiple pulleys will let you move the force to another position.



Experiments

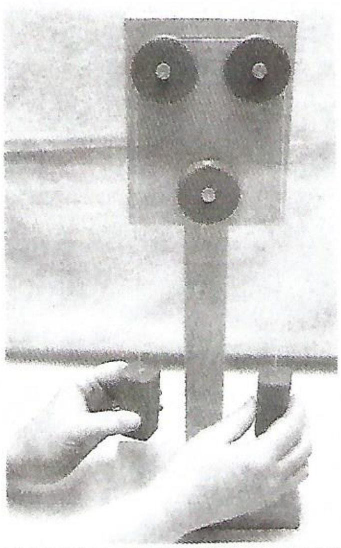
Redirecting Force

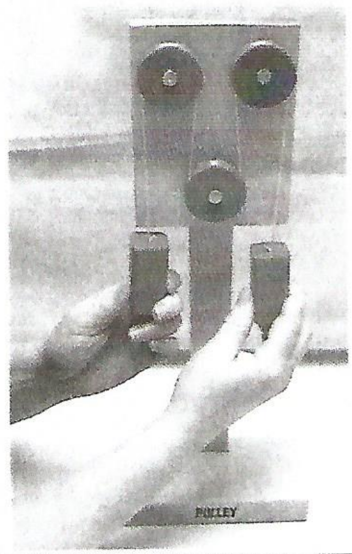
The pulley system is quite sturdy, so the best way to have students explore it is to have them apply forces to it and feel the result. Sensing the force directly is a nice way to have students learn what the pulley does.

Step 1: Place the string between the two blocks over a single pulley. Pull down on one block, and note the motion of the other block. Pulling in any direction on the one block results in an upward force on the other block. The force has been redirected.	

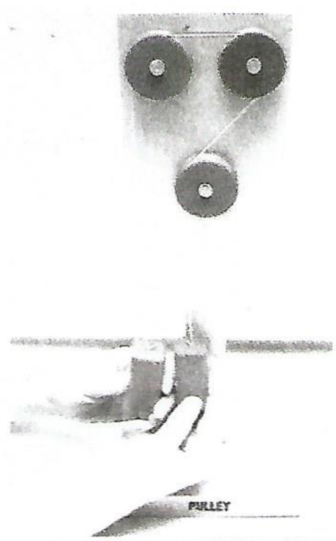
Step 2: Now, place the string over the two topmost pulleys, so that the string goes up from one block, over the top of the pulleys, and down to the other block. Pull down on one side, and hold the block on the other side in place. You can tell that the force pulling up on this block is equal to the force with which you are pulling down on the first block.

Step 3: Now string the cord over all three pulleys as shown. Pull down on one block and note the upward force on the other. Again, the forces are equal though the force has changed from down to up to down to up! Each pulley changes the direction of the force but not the magnitude.



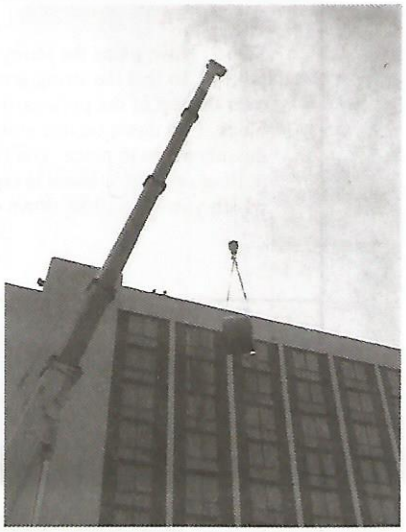


Step 4: Finally, look at other ways that you can loop the cord, and look at the forces involved. This is one of the more enjoyable ways to use the device; it's easy and fun to think of different ways to string the cord!



Extensions

Once your students have fully explored the pulley system, there are some nice extensions you might have them think about.



Other Pulley Systems: The Elevator

Elevators, particularly older ones, tend to be suspended from a cable that goes over a pulley and attaches to a counterweight. This means less work moving the elevator up and down; the downward force on the counterweight is converted to an upward force on the elevator. This tends to balance the weight of the elevator and make it easier to move up and down.

Other Pulley Systems: The Flagpole

Raising a flag on a pole is a job most easily accomplished with a pulley. A pulley sits at the top of the flagpole. A rope goes over the pulley, and comes back down, where it is attached to the flag. A downward pull on the rope is turned into an upward pull on the flag, bringing it to the top of the pole.

Other Pulley Systems: The Crane

A crane likely has a pulley at the top of the boom. The pulley changes the direction of the force in the cable. This is important, as it allows the motor that drives the cable to be down on the ground rather than at the top of the pulley!

Other Pulley Systems: ?

If you look for pulleys, you will see them in many places, in obvious places like garage doors and hoists, but also in places like bicycles (the gear shift cables may well go over a pulley) or even electronic equipment! (Dials may well turn cords that go over pulleys to turn other dials.)

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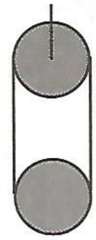


CRUSADER EDUCATION

THE BLOCK AND TACKLE

Overview

The Crusader Education Block & Tackle is crafted from durable hardwood to provide a long-lasting piece of laboratory equipment that lets students explore the basic concept of this compound machine. Students lift masses directly or by use of the pulley system, and note directly the savings in force this device provides. This Teacher Guide will explain the history and uses of this particular compound machine, plus suggestions for experiments for students to do with the equipment.

The Block & Tackle: A Compound Machine

A pulley is a simple machine. A block and tackle is made up of multiple pulleys it is a compound machine. Most simple (and compound) machines have one basic goal: to allow you to perform a task using less force than you would otherwise need. In the case of the block and tackle, the most common use is this: a block and tackle is used to lift a large weight with less force than would normally be required.

The block and tackle is really a system of pulleys. For 2400 years, since the development of the pulley by Archytas Of Tarentum, this system of pulleys has been the best way to lift or move large loads using muscle power.
But such systems of pulleys are used even when a motor or engine is providing the necessary force. In the picture at left, a crane lifts a load onto the roof of a building. The hook that attaches to the weight is connected to a pulley system. The cable that runs the pulley system is driven by a motor on the crane. The force that the cable must apply is only one half the weight of the load. This is a significant savings. This allows the crane to lift as much as 240 tons, much more than it could otherwise raise.

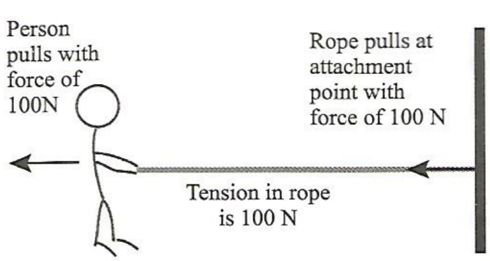
The Block & Tackle in History

Archytas of Tarentum is thought to be the inventor of the pulley, which forms the core of the block and tackle. He is also thought to be the first person to invent a flying machine; his "pigeon", a mechanical device, is thought to have flown using some sort of jet propulsion!
After the development of the pulley came the development of lifting systems based on it, specifically the block and tackle. The "block" is a collection of multiple pulleys housed in a single block; the "tackle" is everything else required to make the system run. In the Crusader Education device, there is a block at the top and one at the bottom in this case, a real block of wood with two pulleys inset.

Galileo was the first to make a detailed study of the principles of the block and tackle, and he did so by considering the basic principles we will outline below. The key is this: the amount of energy needed to lift a load can't be changed, but the force can. There is a tradeoff between force and distance. You can lift a load over a short distance with a large force, or, in the case of the block and tackle, do the work over a large distance with a smaller force. You can't reduce both the force and the distance! As Galileo put it, "...machines are useful for maneuvering great loads without dividing them, because there is often much time but little force..but he who would shorten the time and use only a little force will deceive himself."[1]

Physics Principles

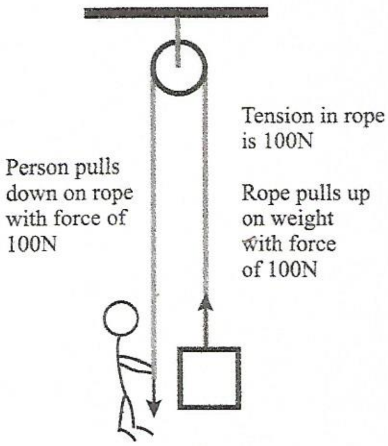
There are three basic concepts we need to understand for the operation of a block and tackle: tension, work and force. Let's take a look at tension and force first. There are many units of force we could use, but we will use the metric unit of force, the newton (N), named after Isaac Newton.
When you pull on a rope, you make a certain tension in the rope. If you tie the end of the rope to something else, the rope makes a force on what you tie the rope to.

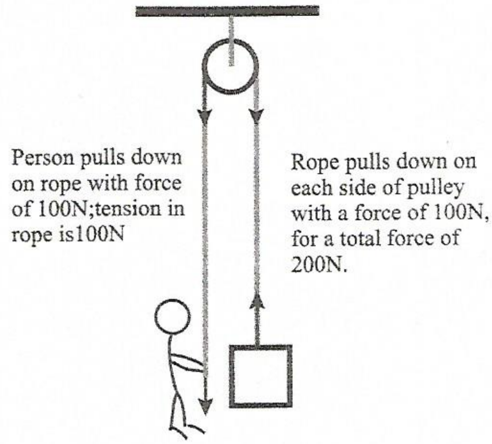


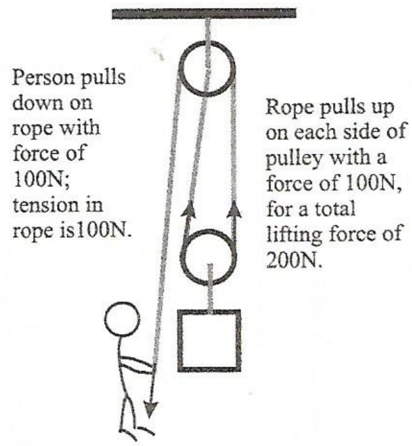
Suppose you pull on the end of a rope with a force of 100 newtons (N), which is about 20 pounds. This gives the rope a tension of 100 N, which means that whatever you tie the rope to will experience a force of 100 N as well!

If you use a pulley to change the direction of the rope, you can change the direction of the applied force as well.
The pulley can do more than this, as we will see. Since the rope applies a force wherever it touches, you can use a pulley to multiply an applied force. Let's see how this all works.

1René Dugas, A History of Mechanics, ,Editions du Griffon (1955)





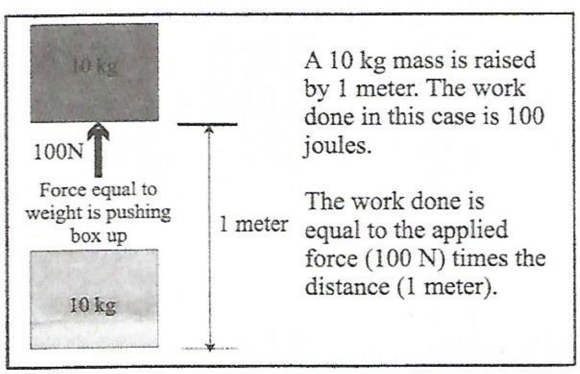


When you lift a load with a pulley, the rope goes over the pulley as shown. This redirects the rope, and so redirects the force as well. The person is pulling down on the rope, but the rope, which has been redirected by the pulley, will pull up on the load.

Something else happens as well. The tension in the rope is 100 N, as noted. Since the rope touches at two points on the pulley, it makes force at two points. Each point of contact gives a force of 100 N, for a total force on the pulley of 200 N. This makes sense, really: the person is pulling down on the rope with a force of 100 N, and the box is pulling down on the rope with a force of 100 N, so something should be pulling up on the rope with a force of 200 N! But the key thing for us to note is this: each point of contact with the rope gives a force of 100 N, so by making the rope go over the pulley, we have doubled the force.

We can use this force doubling to lift a weight if we make a pulley arrangement as above. The rope goes up, over the top pulley, down and around the bottom pulley, and then back up, where we show it attaching to the axle of the top pulley. A weight is hung from the bottom pulley. Now the person pulls down on the rope with a force of 100 N. The rope will have a tension of 100 N. But there will be a lifting force of 200 N on the bottom pulley, as shown. The person can lift twice as much weight as they otherwise could by using this pulley arrangement! Of course, we could imagine using multple pulleys: each pulley adds more force. The Crusader Education pulley has two pulleys and an attachment point on the bottom, for a lifting force of five times the pulling force!

Here's one more example: the crane that we saw before has a pulley at the end with two points of contact with the rope. This means that the lifting force will be twice the force in the cable. There is another good reason to make a crane like this: stability. Since there are two places where the cable touches, it will lift the load with less twisting.



Now, let's look at *energy*. You can use the pulley to reduce the force necssary to lift the load, but there must be a tradeoff somewhere... or else, as Galileo has told us, we are deceiving ourselves! The tradeoff is this: if we use less force to lift a load, we must exert this force through a greater distance. The key here is energy, or work. Work is done by forces; the work done by a force is defined as the force times the distance over which the force acts. Whenever you change energy from one form into another, we say you are doing work. When you raise an object up, you increase its potential energy. This means you have done work. In this case, you are doing work because you must push up on the box with a force equal to the force with which gravity is pulling down on it. It is this force that you apply that does the work. Here's a specific example: if you take a box that has a mass of 10 kilograms (about 22 pounds) and raise it by a distance of 1 meter (just over one yard), you do an amount of work that is equal to approximately 100 joules. A joule (the symbol for a joule is J; we write 100 joules as "100 J") is a unit of energy or a unit of work.

The details look like this:

Weight of box = mass x gravity = (10 kg) x (10 m/s2) = 100 N

By "gravity" we mean a number that represents the strength of gravity. Technically, it is the acceleration of gravity. We use the symbol "g" to represent it, and it has a value of approximately 10 meters per second per second on earth! On other planets, gravity has a different value. (The 10 meters per second per second means this: if you drop an object, after one second, it will be falling at a speed of 10 meters per second. After two seconds, it will be falling at 20 meters per second. The speed increases by 10 meters per second, per second!)

Using this force we compute the following for the work done:

Work done = force x distance = (100 N) x (1 meter) = 100 J

Now, suppose we use a device like the Crusader Education Block and Tackle device to lift this object. A look at the block and tackle verifies that the rope touches the bottom block in 5 places. This means that lifting a 100 N weight will take the following rope tension:

Rope Tension = (Lifting Force) / (Points of Contact)

Rope Tension = (100 N) / (5 points) = 20 N

So we can lift the weight with only 1/5 of the force! So where is the tradeoff? Here's the key:

When using the block and tackle, the work is still the same, but the work is done over a longer distance.

If you lift at 100 N weight a distance of 1 m with a block and tackle, you will find that you need to pull the rope a total distance of 5 m! The work you do is:

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The work you do is:

$$\text{Work done} = \text{force} \times \text{distance} = (20\ \text{N}) \times (5\ \text{meters}) = 100\ \text{J}$$

The net result?

The work done is the same but it was done with less force.

And that's it: that's why you use the block and tackle. You do the same work, but over a longer distance. And so you need less force!

Experiments

Feeling the Force

One of the best things about this block and tackle system is that it is sturdy enough to lift a pretty decent load, so that students can feel the force reduction for themselves!

Step 1: Pick a weight that can be easily placed on the block, and have students lift it to get a good feeling for the weight. We chose two cans for our weight; this was a good choice as the two cans balanced nicely in the second part of the experiment.

Step 2: Now have students lift the weight using the block and tackle. They should easily be able to tell that the force necessary to lift the weight is much less. In principle, the force necessary to lift the weight should be 1/5 of the force to lift the weight directly, but there are limiting factors: you must also lift the weight of the block, and there is some friction in the pulleys which produces some loss.

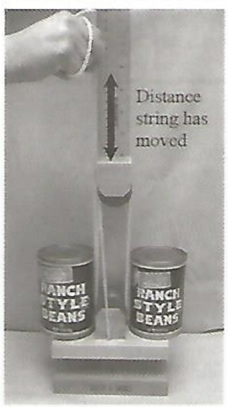
Here are some questions to ask your students about this exercise:

1. In Step 2, there was less force required to lift the weight using the block and tackle. In principle, what reduction in force is possible using this device? (In fact, as noted, it should be 1/5, but it will be more than this.)

2. Less force is used in Step 2, but something else changes as well! What can you say about the distance the rope was pulled compared to the distance that the weight was raised? (The rope must be pulled a much greater distance than the distance the mass is raised.)

Different Distances

As we have noted, when you raise an object with a block and tackle, the rope is pulled a much greater distance than the object is raised. It is instructive to measure this.

Step 1: Place a mass on the block so that it can be lifted. Lift the block a small amount off the base, and note its position using a ruler. Adjust your fingers on the rope so that your fingers sit right at the top of the device.	Step 2: Next, pull the rope to raise the block by a few centimeters. Measure the new position of the block. Notice how far the block moved upward.
	
Step 3: Finally, measure how far the rope moved during the lifting operation. Compare the distance the rope moved to the distance the block moved.	Here are some questions to ask your students about this exercise:
	1. The rope moves much more than the block. Explain why this must be true when the concept of work is considered. (The force is less, so the distance must be greater.) 2. In principle, you found that the force necessary to raise the weight is 1/5 of the weight itself. Given this, what should be the relationship of the distance the weight is raised and the distance the rope is pulled? Is this what you observed? (Since the force is 1/5, the distance must be 5 times as large. In fact, a careful measurement will give this result.)

Extensions

Once your students have fully explored the block and tackle system, there are some nice extensions you might have them think about.

Other Pulley Systems: The Elevator

There is one place where pulleys are used that you might not think about because you can't see the pulleys! Elevators are generally raised by a pulley system that is run by a motor at the top of the shaft. Here are a few questions:

1. Using a pulley system in an elevator means that less force can be used to raise the elevator. But there is another good reason for using a pulley system on the elevator: safety! Can you think why using a pulley system might make the elevator more safe? (Since the cable is part of a pulley system, it can have less tension than the weight of the car. Since the cable is under less tension, it will be less prone to breaking.)

2. Elevators that go in very tall shafts don't generally use pulleys. For instance, the elevators in the mine shafts in the Soudan Mine in northern Minnesota lower cars nearly half a mile into the ground on a single cable, with no pulley. Suppose the designers of this elevator had chosen to use a pulley that cut the force necessary to raise the cars by 1/4.

   Can you see a drawback to this? (The big problem is pretty clear: the cable would need to be nearly 2 miles long in order to run this elevator! The elevator drops the 1/2 mile into the shaft in 2 minutes. If the designers had used a pulley system like the one noted, the 2 mile cable would need to be spinning off the motor at a rate of 2 miles in 2 minutes or 60 miles per hour!)

Past and Present

- See if you can find examples of pulley systems being used in historical situations. Where might you expect to see pulleys being used?
- Can you think of places where pulleys might be used currently?

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