Pulley Power

Discussion:

What is a pulley? A pulley is a wheel. It uses rope that goes around the wheel. The rope is attached to an object. The other end of the rope has a force applied such as a push or a pull. Like other simple machines, pulleys make lifting things easier.

Where have you seen pulleys being used? Maybe you have seen them on flagpoles, window blinds, cranes, boats, rock climbing gear, clothes lines, or gym training equipment.

A pulley would be one of the most common simple machines that you would find on a sailboat. Often they are called blocks.

Why do boats have pulleys? What job do they do? Pulleys help make heavy loads easier to pull, such as pulling in the sail. They help control the power of the wind without needing to use engines, batteries or petrol.

Pulleys redirect force.

On a halyard, which is the rope that pulls the sail up, a pulley is used to change the direction of the force. When you pull the halyard down the sail goes up.

Pulley Power

Activity: Have a go with pulley systems
Time: 30 mins

Materials:
- Pulley frame
- Spring scales
- Rope
- Pulleys
- Weights

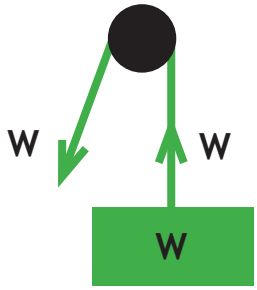
Procedure:
A fixed pulley is used to change the direction of force needed to do the work. To hoist up a load with a pulley and rope, force is exerted downward on the rope. It is easier to pull down using your own weight than to pull upwards.

Using the pulley frame, build a system that will lift a weight using one fixed pulley. What do you notice about the force you are exerting compared to just lifting the weight with your hands.

Now connect another pulley to make a combined pulley system. Predict how heavy the weight will be to lift. Adding the second pulley means that it requires only half the force otherwise needed to lift up the load. You may use the pulley system diagram cards to help you or come up with your own systems.

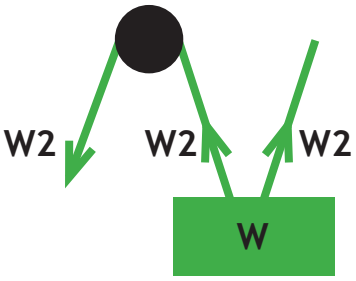
Experiment to see what happens if you add a third and forth pulley. Using several pulleys reduces the force required to lift an object.

Calculate the mechanical advantage of using two and three pulleys using the spring scales. How can pulleys make our lives easier?



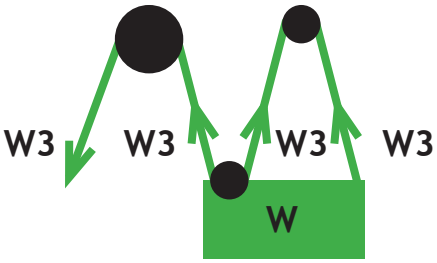
1 to 1

The force in the rope is equal to the weight being lifted



2 to 1

The force in the rope is half the weight being lifted



3 to 1

The force in the rope is a third the weight being lifted

Knot Knowhow

Discussion:

Knots have been used for hundreds of years. What do you need knots for, in your everyday life?

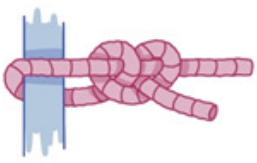
Every sailor needs to know a variety of knots for rigging their sails, to tie objects down and to tie their boat up to the dock when they get back from a day out. When you are rigging up the Optimist see if you can identify the different knots used.

Below are some of the most common knots used by sailors and a description of what they could be used for. It takes practice to tie them quickly!

Reef Knot: (or Square Knot)
Many sailors use a reef knot when tying two ropes together, but these often come loose when not under load, so shouldn't be used when safety is critical. It is the first knot we learn when tying our shoelaces.

Figure of Eight:
The figure of eight knot is a type of stopper knot. It is often used to stop the end of a rope coming out of a pulley.

Bowline:
The most commonly used knot on a sailboat. This knot puts a non-slipping loop at the end of a line. It becomes more secure under pressure, but it is still easy to untie.



Half Hitches:
This is a perfect knot to use to tie a rope tightly around an object.

Knot Knowhow

Activity: Practice tying knots
Time: 20 to 30 mins

Materials:
- Ropes
- Knot example board

Procedure:
Check out the knots example board and the card showing you how to tie the different knots. Now have a go! Once you have mastered one, move onto the next. You can use this video to help you tie the four knots.
https://www.maritimemuseum.co.nz/know-your-knots

Extra:

Have races with each other tying the various knots. Try tying them behind your back or play this fun game.

Monkeys Tails: (A reef knot is used)

Materials:
- 20 pieces of rope.

How to play:

Divide the class into two teams. Hide all but two pieces of rope. Each team chooses a "monkey", who is given one of the extra pieces of rope for their tail. At a given signal, all players except the "monkeys" run to find the hidden ropes. As students find the rope they take it to their "monkey" and tie it with a reef knot to the last piece of rope that the "monkey" holds as their tail. The team with the longest tail of ropes wins.



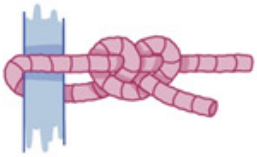
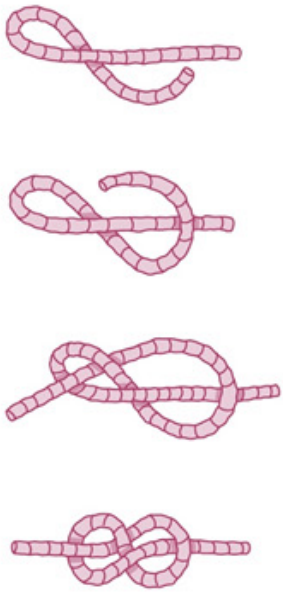



Figure of eight



To tie:

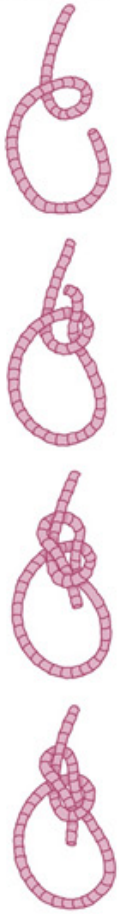
Make a loop with the end.

Put the end through the loop. over the top of the standing part.

Pull both ends to tighten.

It should look like an ‘8’.

Bowline



To tie:

Make a loop and put the tag end through the loop.

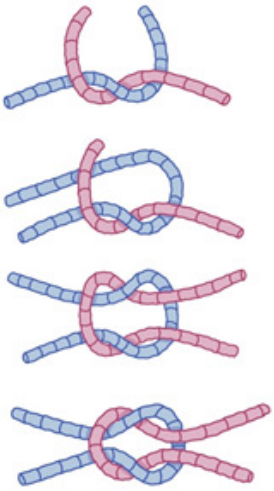
Pass it behind the standing end and through the same loop.

Hold the loop and tag end and pull to tighten.

There is a well-known ‘story’ to help you tie the bow-line:

The loop is a rabbit hole, the standing part is the tree and the tag end is the rabbit.
The rabbit comes up the hole, goes around the back of the tree, then jumps back into the hole.

Reef Knot



To tie:

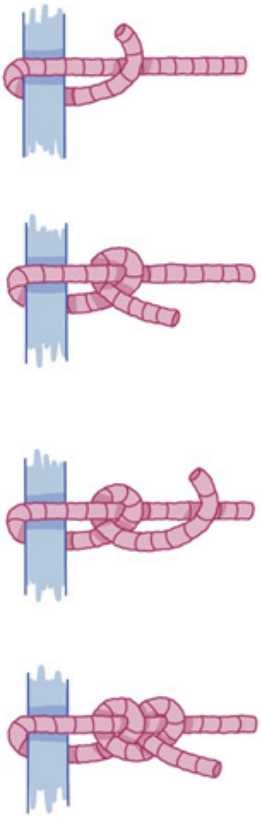
Take a rope in each hand.

Place the right over the left one and under.

Then take the left one over the right one and under.

Pull the ends tight to finish.

Half Hitch



To tie:

Pass the rope around the object it is being secured to.

Then pass the end through the loop and tighten.

To tie a second half hitch, wrap the end around the standing part, through the loop and tighten.

Sink and Float

Discussion:

How does a sailboat float? A boat floats because of how it displaces water.

Floating was first recorded by a scientist named Archimedes. He discovered that when an object is placed in water it takes up space and experiences an upward force equal to the weight of the water pushed aside by the object. This is called displacement. (You could demonstrate this by putting an object in a cup of water.)

A boat will float if it displaces water equal to its own weight. There is only so much weight a boat can carry before it sinks completely. If a boat weighs less than the maximum volume of water that it could displace (push aside), it will float.

What do you wonder about when you are floating or sinking in water?
Have you noticed that you feel much lighter when you are in water? That's because your body has displaced water that is pushing back and creating buoyancy. We humans can sink, so that is why it is essential for us to wear a life jacket for all recreational activities on the water.

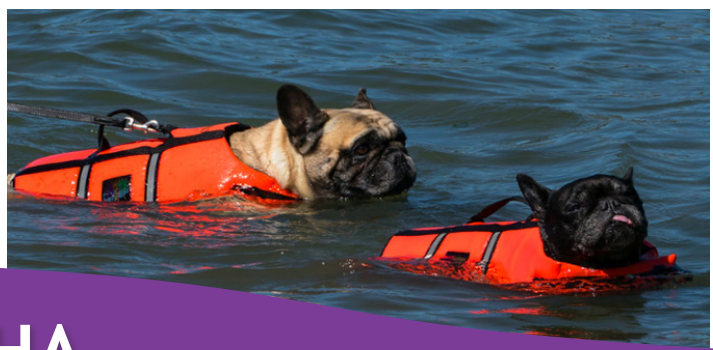
Show the students the lifejackets. Why do life jackets float? They are small compared to our size, but are filled with a very light weight material like foam, that can displace a lot of water compared to their weight, so they float.

Your body already has some buoyancy, so a life jacket doesn't need to support all of your weight. It just needs to displace enough to keep your head above the water.

There are different types of life jackets and they are designed for different activities. (Inflatable, foam buoyancy vests, collar vs no collar, crotch strap.) Show the different types from the kit. What type of life jacket have you worn? Where?

Try on the life jackets. Do they fit? It is important for your life jacket to fit properly. If it is too big, you may slip out of it. If it is too small, it may not hold you up. When you go sailing, float in your life jacket to feel its effect.

Life jackets also help your body retain heat if you fall into cold water. And, a bright coloured life jacket makes you easier to see and to find.



Sink and Float

Activity: Make a tinfoil boat and have a competition to see whose boat can carry the most weight.
Time: 30 mins

Materials:
- Tinfoil - 15cm square each
- Weights (gemstones)
- Buckets of water x 2

Procedure:
- Fill the buckets with water.
- Take one piece of tinfoil each and make a boat hull that will float and carry as much weight as possible.
- In pairs put your boats in each of the buckets.
- Make a prediction of how many stones you think the boats will carry before they will sink.
- Add a stone one at a time until your boats sink.
- Repeat with the rest of the students.

Were your predictions correct? Which boat carried the most weight? Why? How does the boat's shape and size affect how well it floats?

Hull and Sail Materials

Discussion:

What is the hull of a boat? The main part or the bottom of the boat is called the hull. Hulls come in all shapes and sizes.

What are sailboat hulls made from? Early boat hulls may have been a floating log, hollowed out in the middle. Boat designers have changed the shapes of boats over the years and also the materials that they were built from, to make them go faster.
An example of the evolution of boat hull materials is easy to see in the boats that have competed for the America's Cup.

Look at the sample hull materials from the kit.

Which do you think was the first material used to build an America's Cup boat? Put them in order of oldest to newest. Use the spring scales to compare their weights. Read more about the history of materials on the America's Cup History card to check your order is correct.

What do you wonder about sails? Why were sails invented? Pacific voyagers used wind to sail their waka to Aotearoa. I wonder what material they used. Raupo - a reed, or flax were used back then, but the materials used have changed dramatically over the years.

Look at the sample sailcloth materials from the kit.

The early European ships of the 19th century used a cotton canvas sail cloth. This was used for over 200 years and it wasn't until the 1950s that synthetic materials like polyester and nylon became available. The sails were therefore lighter and lasted longer. In the 1980s, Kevlar, which was also used in the manufacture of tyre and bullet proof vests, became common in sails. These were very strong and light, but were expensive compared to polyester. Now racing sails are built from carbon fibre. They are even stronger and lighter than sails built in the past.

Early sails were a crab claw shape or they were square, but the problem with that was that the only direction they could go was downwind - with the wind behind them. They needed to use oars and paddles to go against the wind - upwind. What shape are sails today? As technology improved, sails began to be cut differently, into the more familiar triangular shape we see today.

Hull and Sail Materials

Activity: Calculate the area and perimeter of a sail.
Time: 30 mins

You are going to calculate the area and the perimeter of a sail. This is one way you can use maths in other parts of your life.
The area is the size of a surface - the amount of space inside the boundary of a flat two dimensional object, such as a sail.
The perimeter is the length of the outline of a shape, such as the outline of a sail.
What are some of the reasons you may want to calculate the area of a sail? To order new sails for a boat, or to compare the size with other sails. What would be some benefits of reducing the sail area? When there is too much wind for the sailor or boat to handle.

Materials:
- Sail from the kit
- Tape measure
- Paper and pens
- Chalk

Procedure:
- Roll out the sail and talk about the different parts of a sail.
- Foot, head, luff, leech, tack and clew.
- In pairs, use a tape measure to measure the perimeter of the sail. Measure the luff, leech and foot and add them together.
- Luff + Leech + Foot = Perimeter
- Now measure the area of the sail.
- ½ Base (Foot) x Height (Luff) = Area

How does the size of the sail affect the boat's speed?
What could you do to depower the sail?

Extra: Measure out the size of a Super Yacht sail or an America's Cup sail
Time: 15 mins

Go outside to a large concrete area or on the beach and measure out the size of an America's Cup sail - approximately 26 meters in length (luff). Use the tape measures, or measure in steps. Draw it on the concrete with chalk. An average adult step is 70 cm, so the length of an America's Cup sail would be approximately 37 adult steps. In groups, measure the perimeter and area of the sail. Super yacht sails are around 65 meters in luff and 18 meters along the foot. A Sunburst, two person dinghy sail is 4.5 in luff and 2.4 in foot. Measure these out and draw with the chalk and compare with the America's Cup sail.

Hull and Sail Materials

America's Cup History of Hull Materials - 1851 to 2021

The first America's Cup was held way back in **1851**. The hull of the winner, called America, was built from **oak** and other types of **wood**. At the time, this was modern and lightweight.

For the next 80 years competing boats were all built from wood, but methods improved and the boats were built lighter.

In the **1930s** there was a major technology jump and boats were being built from **steel**. What do you think was the advantage of steel? The hulls were much thinner and stronger and so the techniques used for boat building changed.

From the **1950** through to the **1980s** America's Cup boats were built from **aluminium**. This meant the hull was a lot lighter. Feel the difference between the steel and aluminium from the kit.

In **1987** the NZ Challenge built their boats using fibreglass, which was controversial at the time, because no one had done it before.

In the 1**990s carbon fibre** was introduced. While these hulls were very light, they required 20 tons of lead on the bottom of the keel to keep them upright.

The boats that will compete in the **2021** America's Cup regatta, are built using a **carbon Nomex sandwich**, which is as light and as strong as materials have ever been. It is this advancement which allows the boats to be light enough to be lifted out of the water on aerofoils. Previously boats were too heavy and were stuck in the water, but now a 25 meter long boat can lift up on foils and travel at many times the speed of the wind largely due to advances in boat construction.