a WOW Lab BLUEPRINT

Pulleys and Mechanical Advantage

Additional Information

Pulleys have been used for over 2000 years to achieve mechanical advantage. The Greek philosopher Archimedes is said to have moved a giant warship full of cargo and passengers using only pulleys and his own strength. Mechanical advantage is the ratio between the output and input forces in a system of simple machines. For example, system A in **figure 1** has a mechanical advantage of one since the output force is equal to the input force. On the other hand, system B in **figure 1** has a mechanical advantage of two because in an ideal frictionless system, the output force will be twice the input force. System A is called a fixed pulley and it simply changes the direction of the force. System B is called a movable pulley and it is used to multiply the input force by distributing the load equally on each side of the pulley. This gain in output force does, however, come at a cost. In order to move the load a given distance, the force in system B must be applied over twice the distance of system A, meaning that the work applied will remain independent of the simple machine system.

System C in **figure 1** also has a mechanical advantage of two because the added pulley is a fixed pulley. If another movable pulley was added, the mechanical advantage would increase. It may seem that we could continue adding pulleys indefinitely and achieve infinite output forces. While this is true in an ideal frictionless world, in reality, friction plays a huge role in the efficiency of the system. In each pulley, there will be friction in the axle that will cause some of the input force to be converted to heat. Thus, a balance between the mechanical advantage and the loss of energy due to friction must be found. One way of improving mechanical advantage without adding many more pulleys is to use a compound pulley system where a second simple system is used to apply a force to the first, thus multiplying the mechanical advantages.

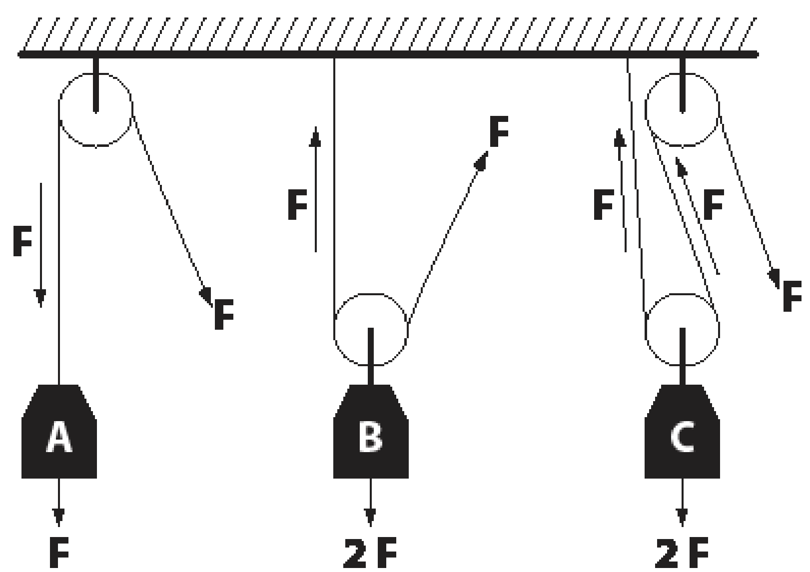

Figure 1

For example, system D in **figure 2** has a mechanical advantage of six (2 x 3) while using only four pulleys, whereas an extrapolation of system C would use five pulleys to achieve the same mechanical advantage.

Further advantage can be gained if the force is being applied by the load itself. In other words, if a person were to lift himself or herself using a pulley system, it would have the same effect as adding another movable pulley (system E in **figure 2**) but without the loss due to friction. This document explains how to demonstrate the concepts of mechanical advantage in an effective and exciting manner in the classroom.

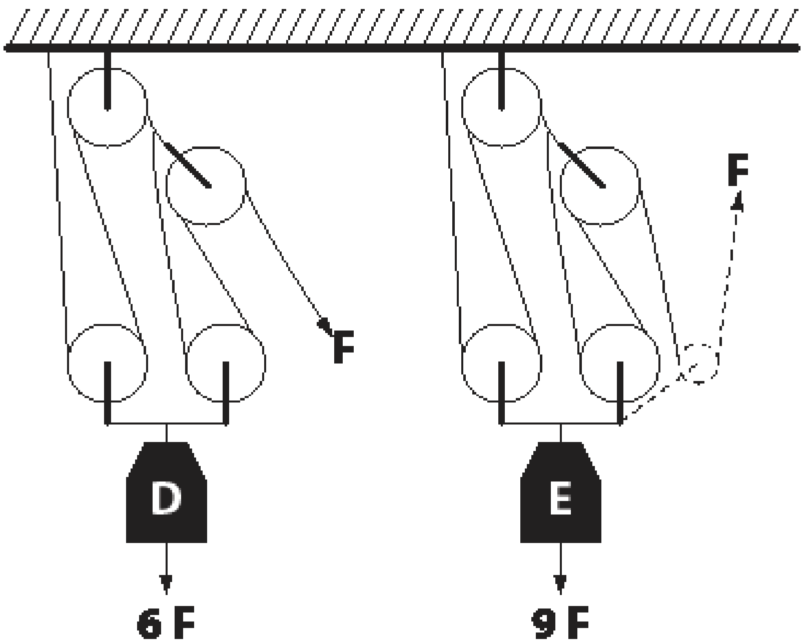

Figure 2

The following document provides instructions on how to tie all of the knots needed to set up the pulley. For easy reference, the pages where each knot can be found are provided below:

The Fisherman's Knot

This knot is usually tied around another knot, but in this instance it is tied around the thumb.

Step 1

Place the rope in the palm of your hand, so that the end of the rope is facing towards the thumb.

Figure 3

Step 2

Wrap your fingers around the rope to form a fist, with the end of the rope pointing out of the top (**Figure 3**).

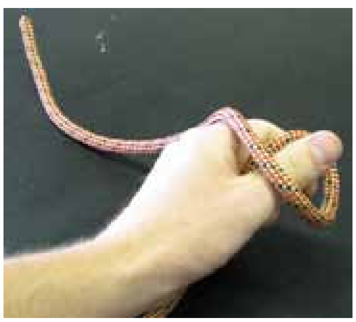

Figure 4

Step 3

Coil the free end of the rope around your thumb and the fixed strand of the rope (**Figure 4**).

Figure 5

Step 4

Coil the free end of the rope around your thumb a second time, ensuring that it is below the first loop (closer to your hand). The start of the second loop should cross over the fixed strand of rope (**Figure 5**).

Step 5

Tuck the free end of rope inside the two loops (**figures 6** and **7**) and pull both ends of rope.

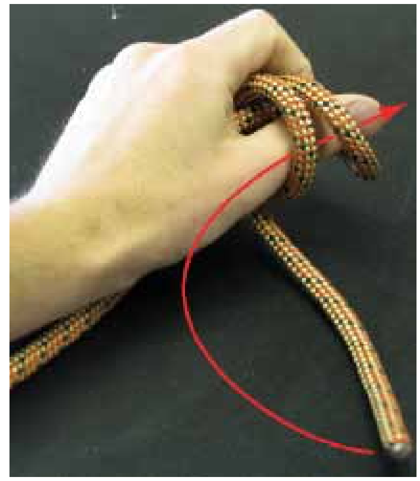
Figure 6


Figure 7

Step 6

The finished knot should resemble the knot in **figure 8**.


Figure 8

The Double Figure-Eight

Step 1

Form a loop in the rope, as shown in **figure 9**.

Figure 9

Step 2

Fold the end of the loop over the static ends of the rope (**Figure 10**).

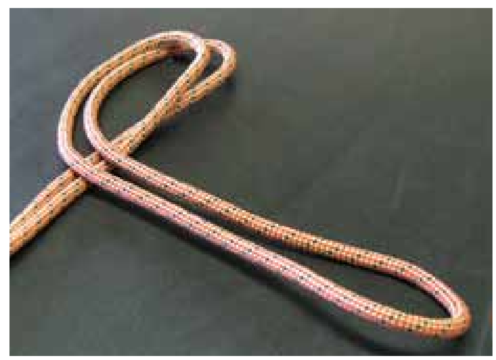

Figure 10

Step 3

Fold the end of the loop under the static ends of the rope and pass it through the loop that was formed in Step 2 (**Figure 11**).

Step 4

Pull the end of the loop and the static ends of the rope (**Figure 12**).

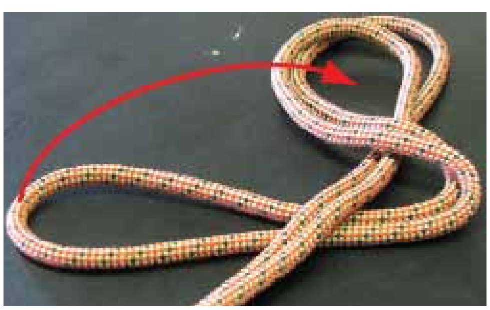

Figure 11

Figure 12

The Alpine Butterfly Knot

Step 1

Wrap the rope around the palm of your hand, so that both ends are near your fingertips and are pointing downwards (**Figure 13**).

Figure 13

Step 2

Complete the turn, ending it near the fingertips so that the end of the rope is pointing upwards (**Figure 14**).

Figure 14

Step 3

Do another half turn with the rope, this time crossing over the first turn on the back of your hand so that the ends of the rope are closest to your thumb, with both pointing downwards. See **figure 15** for a front and back view.

Step 4

Complete the turn so that one end of the rope is pointing upwards and one is pointing downwards.

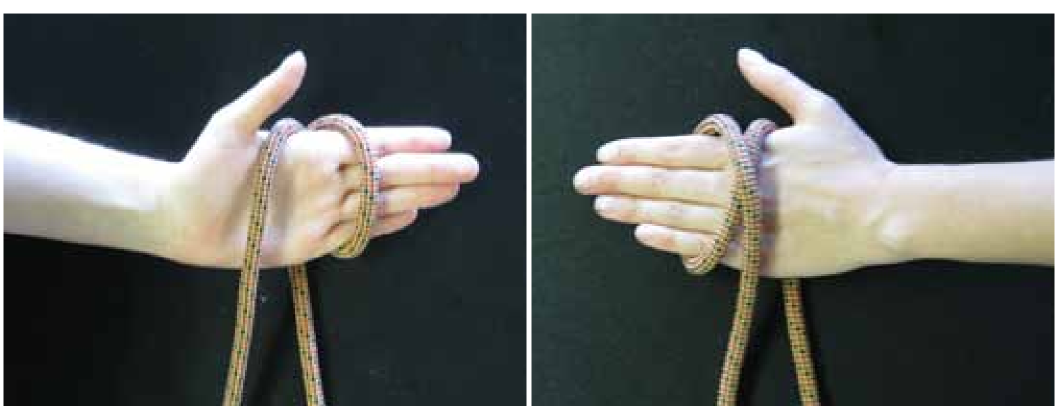

Figure 15

Step 5

Grab the turn nearest to your fingertips and pull it over the other two turns (**Figure 16**).

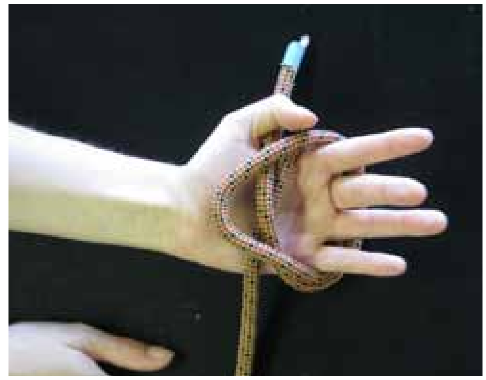

Figure 16

Step 6

Tuck the turn under the two other turns and pull it through (**Figure 17**).

Figure 17

Step 7

Tighten the knot by pulling on the loop and the two ends of the rope (**Figure 18**).

Figure 18

Step 8

Ensure that the finished knot resembles the front and back views shown in **figure 19**.

Figure 19

The Tuck Bowline

Step 1

Wrap the rope around the beam that will be supporting the pulley.

Step 2

Form a loop in the fixed end of the rope, as in **figure 20**.

Step 3

Pass the free end of the rope through the loop so that it comes out of the loop (**Figure 21**).

Step 4

Pass the free end of the rope behind the fixed end of rope that forms the bottom portion of the loop and pass it through the loop from Step 2 (**Figures 22** and **23**).


Figure 20


Figure 21


Figure 22


Figure 23

Figure 24

Step 5

Pass the end of the rope over the closest portion that is looped over the beam (**figure 24**) and tuck it back into the loop, following the portion of rope that is hanging down (**figure 25**), so that both ends are beside each other and pointing downwards.

Step 6

Pull the loop tight by pulling simultaneously on the two ends that are passed through the loop (**figure 26**) and the two ends that are around the beam.

Step 7

Ensure that the knot resembles the knot pictured in **figure 27**.

Figure 25

Figure 26

Figure 27

The Water Knot

Step 1

Form a loop in the webbing (**figure 28**) and pull the end of the webbing through the loop to form a loose overhand knot (**Figure 29**).

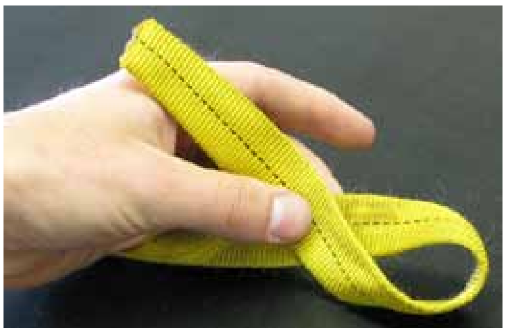

Figure 28

Figure 29

Step 2

Thread the second end of the webbing through the knot, in the opposite direction, so that it lines up beneath the other free end. In **figure 30**, the two ends of the ropes are different colours for clearer pictures.

Figure 30

Step 3

Follow the exact path of the other knot, except in the reverse direction (**Figures 31** and **32**).

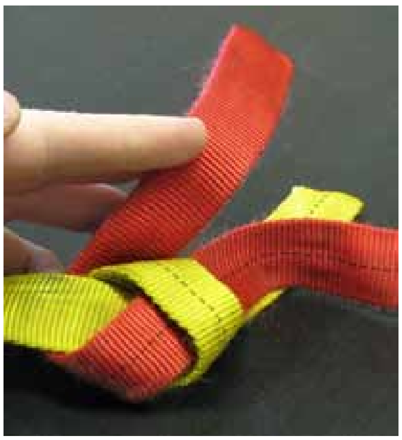

Figure 31

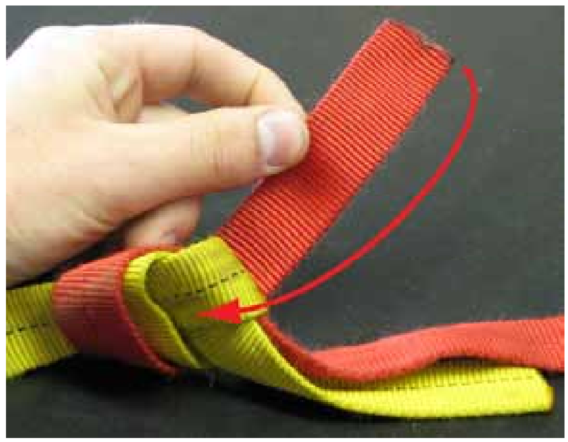

Figure 32

Step 4

Pull the knot tight (**Figure 33**).

Figure 33

The Girth Hitch

Step 1

Tie the piece of webbing into a loop using a water knot (**Figure 34, Step 1**).

Step 2

Wrap the loop around your anchor (**Figure 34, Step 2**).

Step 3

Pass one end of the loop through the other end and pull it tight (**Figure 34, Step 3**).

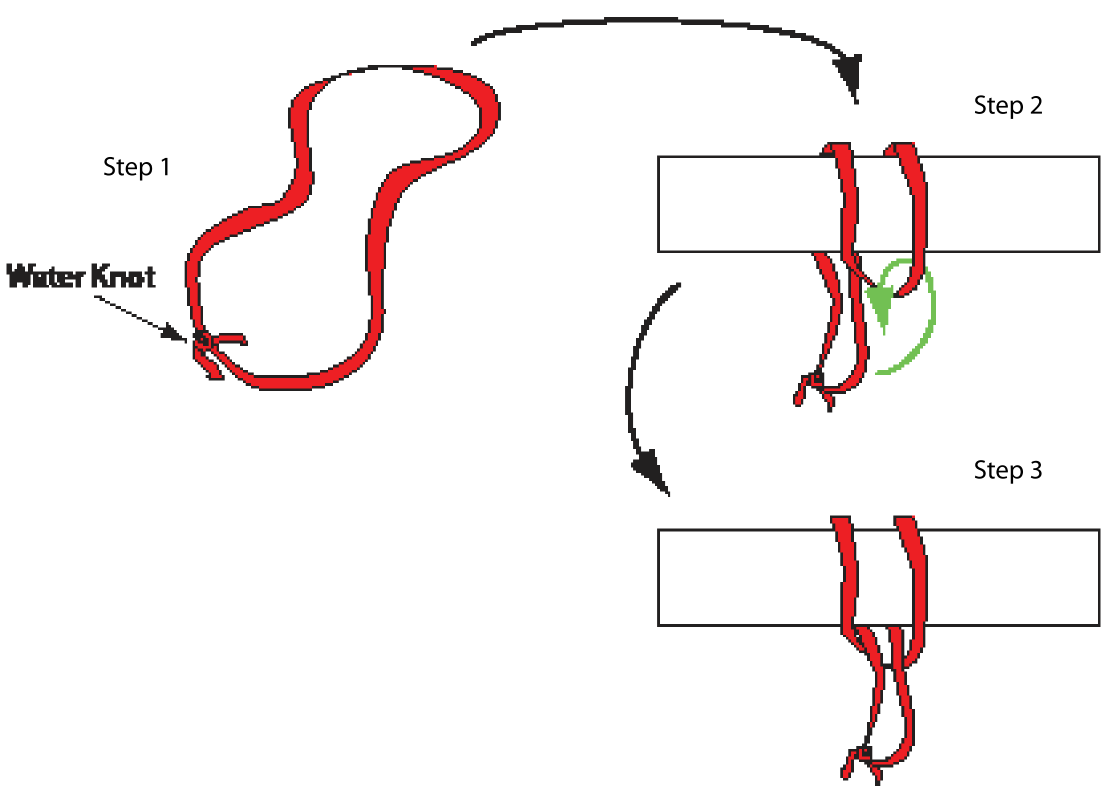

Figure 34