Forces, Blocks and Tackles

If you think a 'block and tackle' is something that happens on a rugby pitch then think again.

Marc Brunel (1769 to 1849)

Although *HMS Warrior* was a hi tech triumph of her age, with the very latest steam engine propulsion, she would have been unable to go anywhere without blocks and tackles. These simple devices were supposedly invented by Archimedes over 2000 years ago for lifting and pulling heavy loads.

The block and tackle is a system of two or more pulleys with a rope or cable threaded between them. The most common arrangement is to have a set of fixed pulleys or 'sheaves' all mounted on a single axle, and another set left to move. Each set is called a 'block' and the whole assembly, with the rope, is called the 'tackle'.

A system of blocks and tackles allowed sailors to lift sails which could weigh well over a ton when wet.

The larger naval ships of the nineteenth century needed lots of sail area to provide the thrust to push them along. The bigger the sails, the heavier they were and the more blocks and tackles were needed to handle them.

In her heyday *HMS Warrior* carried around about 70 tons of rigging and sails and a third rate ship of the line with 75 guns needed about 1,400 pulley blocks.

A pulley block used to move one of the *Warrior's* 68 pounder muzzle-loading guns

Where did all these pulley blocks come from?

Up until October 1803 all the blocks used by the Royal Navy were made by hand and between 1797 and 1801 the Admiralty purchased an amazing 100,000 blocks per year. The vast majority of these were made by the Southampton based company William Taylor & Sons. They developed such a monopoly of the blockmaking contracts for Portsmouth and the other Royal Dockyards that people started to complain and the Admiralty started to look for other sources.

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The time was now ripe for Marc Brunel, Isambard's father, who had a cunning scheme for turning the oval blocks on a circular lathe. With persistence Brunel eventually got the backing of the First Lord of the Admiralty and took out patents in 1801 for machines which would effectively mass produce the blocks that the Navy needed.

Brunel received £1,000 (an extraordinary amount of money at that time) from the Navy Board for his designs and a set of beautiful working models. These models are now in the National Maritime Museum, Greenwich.

It took him several years to complete and install the highly complicated machines. The main difficulty was that they needed to be made from cast iron and English cast iron of the day was considered too brittle (English wrought iron was even rejected for Government contracts such as anchors).

The block that Brunel's machines were designed to produce needed several types of wood (including lignum vitae, the densest wood there is), iron, bronze and rope; all requiring hand-finishing and assembly. They were therefore very complex and expensive to produce by traditional methods.

Lignum Vitae
'The Wood of Life'

Production in Brunel's Blockmills began in October 1803 and by 1808 some 45 machines had been completed. At the peak of production, the machines were able to turn out 140,000 blocks in a year easily enough to meet the demands of the expanding Navy.

Because Brunel's technology was new, there were problems to overcome. It was difficult at first to find enough craftsmen willing to learn the new techniques, and this limited production output. However, the Blockmills were a profitable venture, paying for themselves in just three years. They were also the world's first mass production factory - a century before Henry Ford. Not only that, they were still in full use until the late 1960's.

The original large corner saw and scoring machine were still in use in 1968 and in a century and a half no substitute had been found for the swinging-arm circular saw used for cutting the lignum vitae! The small cornering saw was also still in use in the 1960s. All these machines were driven by overhead shafts and belts, which were tensioned by an ingenious system of jockey pulleys and weights.

Although steam did eventually give way to electrical power at the Blockmills, incredibly, none of Brunel's machines ever wore out.

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Now how exactly does a set of ropes and pulleys help you lift a heavy weight?

Diagram 1

Imagine that you have a 1000 newton weight hanging on a rope as in diagram 1, to the left. Now imagine you want to hang this weight 20 metres up in the air. To do this you will need to pull upwards on the rope with a force of 1000 newtons and you will have to pull 20 metres of rope to do it.

If you have a pulley set up as in diagram 2 you still have to pull with a force of 1000 newtons and you still have to pull 20 metres of rope. The only thing that has changed is the direction in which you need to pull.

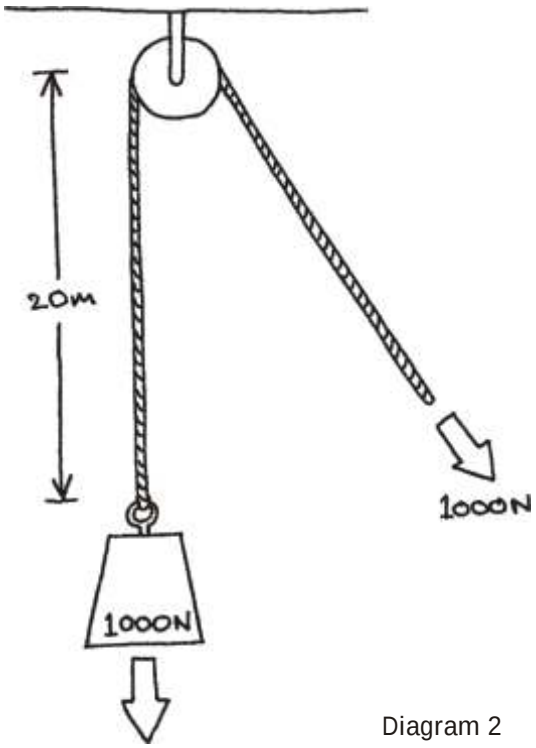

Diagram 2

The arrangement shown in diagram 3 on the next page shows how adding an extra pulley can reduce the amount of force you need to pull on the rope with by a half. Instead of pulling with 1000 newtons you only have to pull with 500 newtons because the weight is shared equally between the pulleys and the ceiling exerts the other 500 newtons of force. However, there is a trade off. If you want to exert half the force you have to pull twice as much rope through. So to lift your weight you now have to pull 40 metres of rope through.

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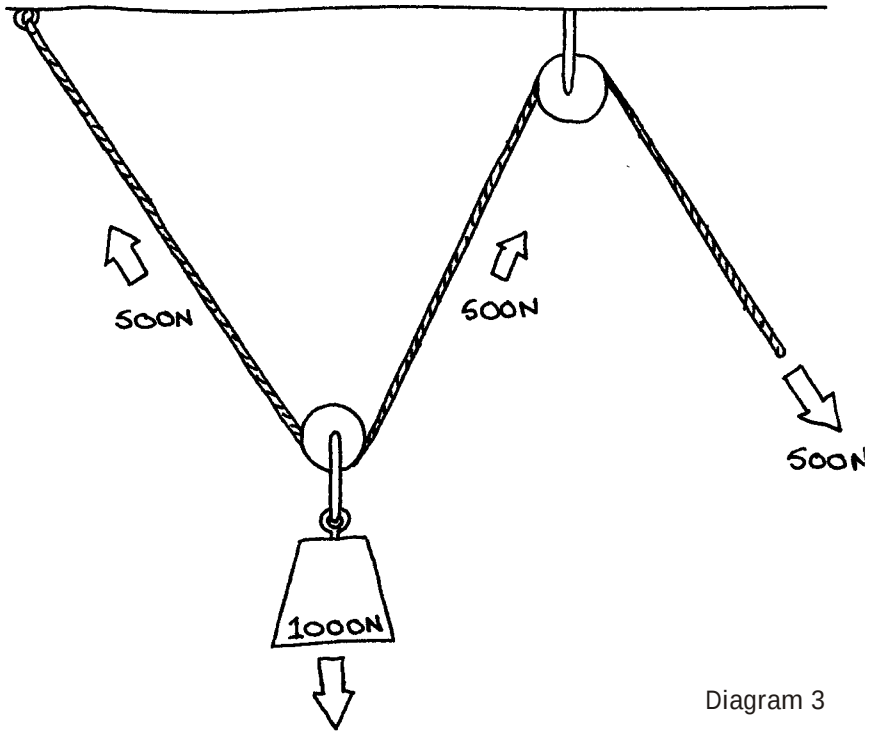

Diagram 3

Diagram 4 adds another pulley and so halves the force you need to apply again. This means now you only have to pull with 250 newtons force to lift the 1000 newton weight.

But that extra pulley again doubles the amount of rope you have to pull through, making it 80 metres.

A block and tackle can contain as many pulleys as you like but at some point friction in the pulley shafts will add so much resistance it will out weigh the benefit.

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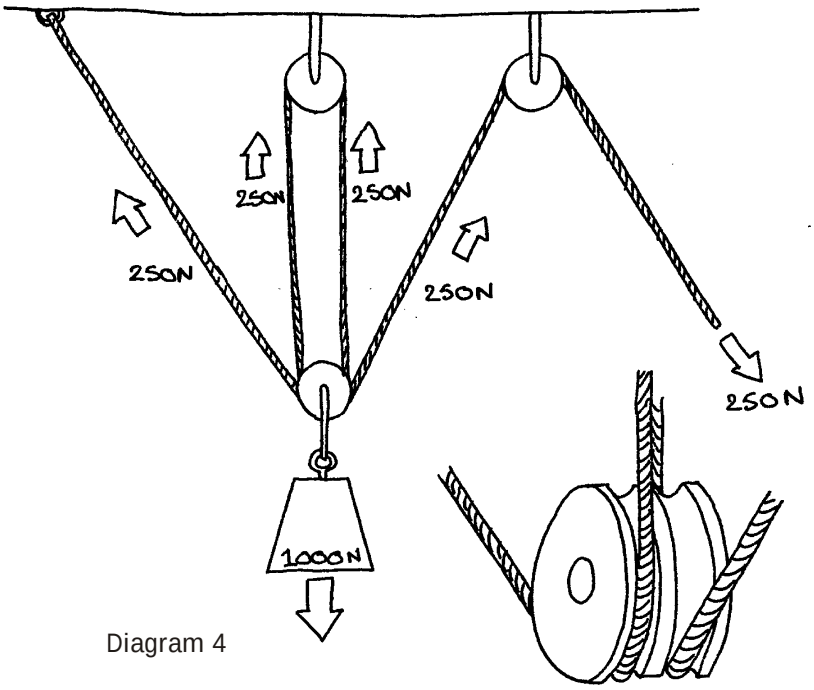
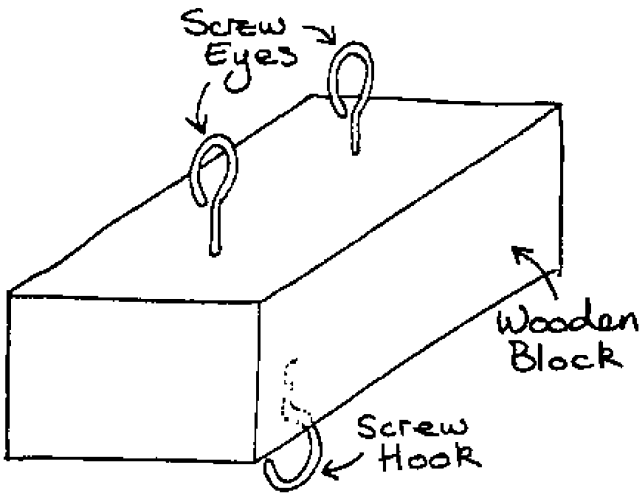


Diagram 4

Now Make Your Own Block and Tackle



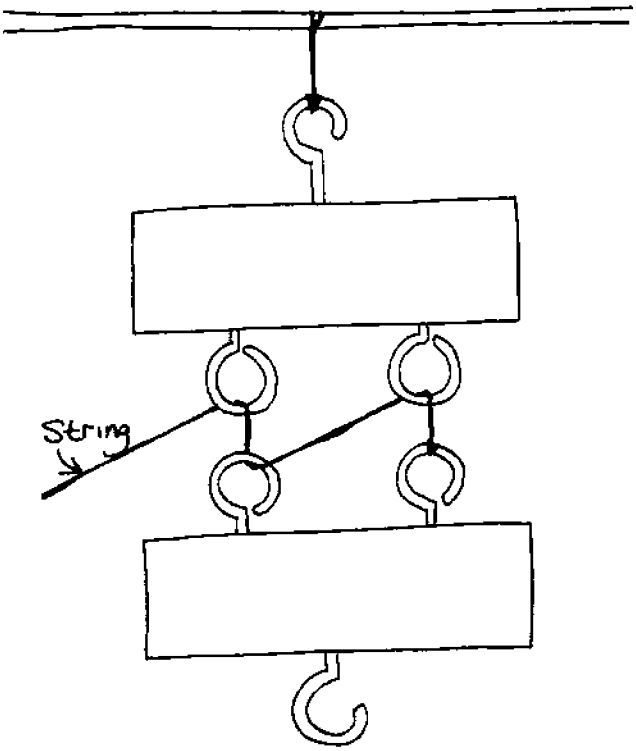
Now you know something about blocks and tackles its time to have a go at making your own.

A very simple way of making a block and tackle is shown in the diagrams on this page.

Just find two blocks of wood. The size doesn't really matter as long as the screw eyes and hooks you have are to the rough scale shown in the diagrams.

Make small pilot holes to start screwing in the eyes and hooks. You can do this with a small drill, a gimlet or a nail.

Arrange your blocks as in the diagram to the right. Tie them to a supporting bar and just add a weight.



To test your block and tackle add a known weight to the bottom block and attach a small spring balance to the free end of the string. Pulling on the spring balance should lift your weight and give you a reading of the force needed to lift it.

Take a range of readings with different weights and see by what factor your block and tackle reduces the force you have to apply to lift the weight. Remember that there will be a lot more friction in this system than in one made with pulley wheels.

Why not have a go at making a similar set up but with three screw eyes per block?