

Civil Engineering in Portsmouth 2006

Isambard Kingdom Brunel was involved in some of the most ambitious civil engineering projects the United Kingdom has ever seen. From the awe inspiring Clifton Suspension Bridge to the 80 mile atmospheric railway between Exeter and Teignmouth.

One of the things that gave Brunel the confidence to attempt such incredible feats was his knowledge of the properties of the materials he worked with. Wrought and cast iron were the building blocks of the age and steam power was the driving force. Brunel knew exactly what could and could not be achieved with them and he used this knowledge brilliantly.

Today's civil engineers have many more materials to work with a much wider range of properties. This means that the structures they can build today would have been unimaginable in Brunel's time.

Portsmouth's Spinnaker Tower is a fantastic example of just what can be achieved with modern materials. The tower stands on the waterfront in Gunwharf Quays and weighs in at over 30 000 tonnes. As a result it needs some pretty substantial foundations. These take the form of 84 reinforced concrete piles. The longest of which sinks 50 m into the ground - that's as deep as Nelson's Column is high!

The Tower is built mainly from concrete and steel. In fact, enough concrete was used to fill five and a half Olympic sized swimming pools.

The highest viewing point is from the Crow's Nest at 110 m above the ground. From here you can see nearly 40 km on a clear day. Even Brunel would have been impressed with that.



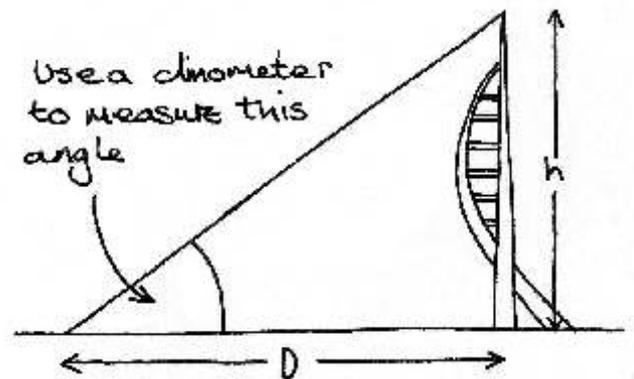
Portsmouth's eye-catching 170 m Spinnaker Tower.
Image courtesy of Heritage Projects (Portsmouth) Ltd



Measure the height of the Spinnaker Tower

No, you won't be needing climbing gear and an extra long tape measure. There is a much easier (and safer) way of doing this but first of all we need to make ourselves a simple surveying instrument called a clinometer.

Clinometers are used for measuring vertical angles. Once we know our distance from an object and the angle that a line drawn from the top of the object back to us makes with the ground we can work out how tall it is.



This is what you will need to make your clinometer:

- A transparent plastic 180° protractor
- About 30 cm of fishing line or cotton
- Two pieces of 3 cm by 1 cm wood, one about 15 cm long and the other about 20 cm long
- A plastic shaving mirror
- A wire coat hanger
- A nut and bolt (about 3 cm long) and two washers
- A large nut to use as a weight
- A paper clip
- Two round headed pins
- An electric drill
- A hot glue gun
- Side cutting pliers
- Metal file
- A pencil and 30 cm ruler

You may need an adult to help with drilling the holes.

Making the clinometer is quite simple and this is how you do it:

Step 1

Drill a small hole through the cross hair of the protractor (about 1 mm if possible) and bend the paper clip to make a wire 'eye' about 3 mm across.

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Measure the height of the Spinnaker Tower

Step 2

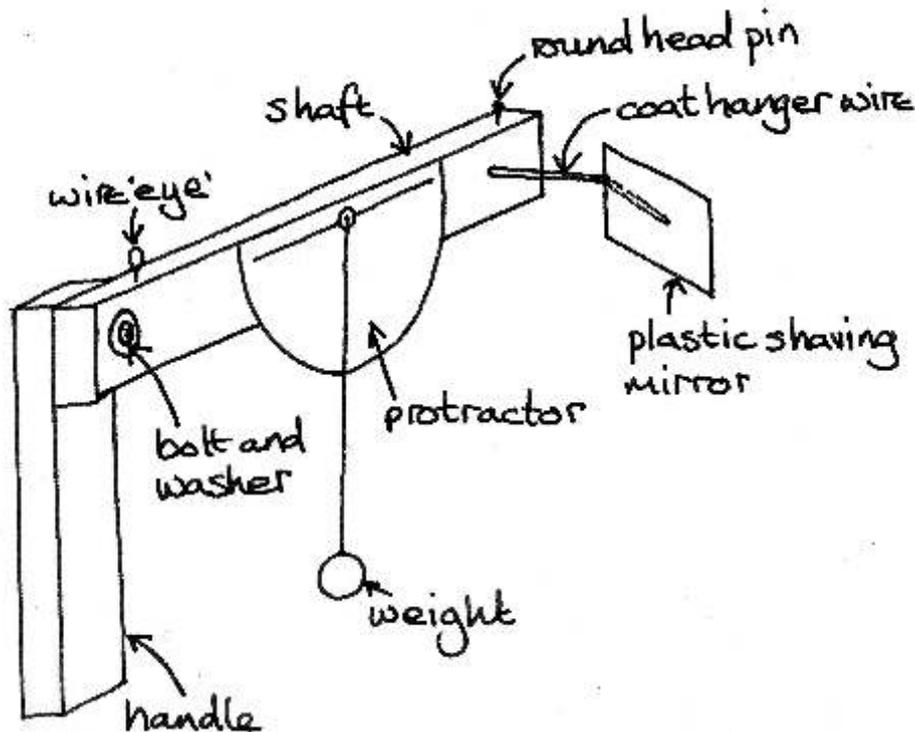
Drill holes for the bolt which will connect the handle and shaft. This hole will need to pass through the ends of both pieces of wood and you will need to be careful about making sure both holes line up. Drill a 1.5 mm hole for the coat hanger wire which will support the plastic shaving mirror.

Step 3

Use the hot glue gun to fix the protractor to the shaft. It is important that the flat edge of the protractor lines up as exactly as possible with the flat edge of the shaft. Once the glue has set, push one of your round head pins through the hole you drilled in the protractor. It is important that this pin is as close to the centre point of the cross hairs as possible.

Step 4

Connect the shaft and handle with the bolt. Make sure there is a washer on each end of the bolt. The bolt should be done up tightly, but the shaft and handle should still be moveable.



Step 5

Use the side cutting pliers to snip off about 20 cm of coat hanger wire. Push one end of this into the hole at the end of the shaft. Use the hot glue gun to fix the shaving mirror to the other end of the wire.

Be careful to file down and sharp edges on the wire.

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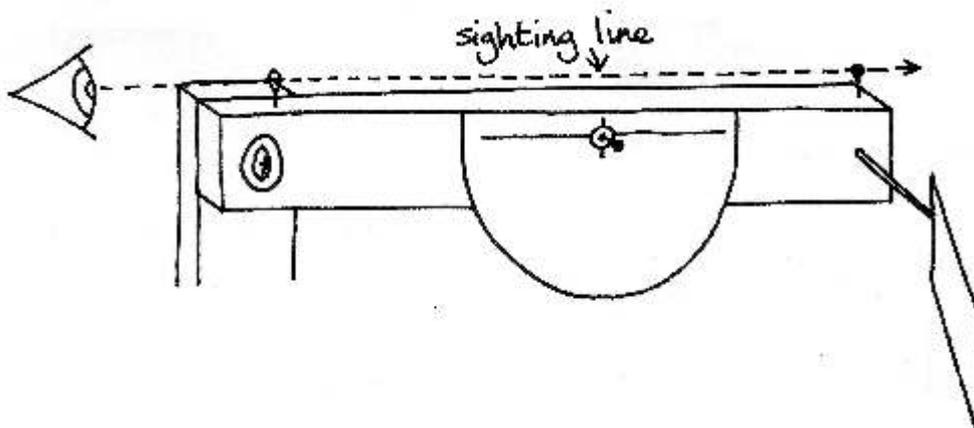


Measure the height of the Spinnaker Tower

Step 6

Draw a line down the centre of the top of the shaft. Push the wire eye you made from the paper clip into the wood about 2 cm from the handle end. Make sure it is on the centre line. You may need to drill a small hole for this and secure the eye in place with a blob of hot glue.

Push a round headed pin into the shaft at the opposite end to the handle. Make sure it is on the centre line and try to also make sure that the round head of the pin is at the same height above the shaft as the eye. This wire eye and round headed pin will form your sighting line.



Step 7

Tie one end of your fishing line onto the round headed pin sticking out of the protractor. Onto the other end of the fishing line tie a heavy nut. This should keep the

fishing line taught and make sure that any wind doesn't blow it around. You might also want to run a permanent black marker along the fishing line to make it a bit more visible.

Step 8

Grip the handle of the clinometer and hold it up to your eye. Practice sighting along the shaft using the wire eye and round head pin. With your free hand adjust the position of the shaving mirror so that you can see where the fishing line lays against the protractor and take a reading without moving the clinometer. This will take some practice as you will be taking the readings from a mirror so all the numbers will be backwards.

You are now ready to go and use your clinometer.

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Measure the height of the Spinnaker Tower

Using Your Clinometer

Your clinometer can be used to measure the height of anything as long as you know how far away you are from the base of it.

To measure the height of the Spinnaker Tower we have chosen a location on the deck of *HMS Warrior 1860*. The position we have chosen is just in front of the fore mast. The picture below shows exactly where you will need to stand.

Face the tower and hold your clinometer up to your eye. Adjust the angle of the shaft until the tip of the tower lines up with the round head pin and the wire eye on your clinometer.

Without moving the clinometer, look into the mirror and read off the angle that the fishing line makes with the protractor. Remember that this will need some practice as the numbers on the protractor will appear back wards in the mirror.



Use your clinometer here!

Take three or four different readings and average them to reduce your errors. The other thing to bear in mind with the protractor is that the numbers that you read off are not the angle that the clinometer shaft is making with the ground. Instead they are the angle the shaft is making with the vertical. To convert them, simply subtract the angle you have read from 90° . This will give you the shaft angle with the vertical.

You will probably have two scales on the protractor, you can use either but if you get a negative answer when subtracting your angle from 90° , just ignore the minus sign.

Once you have your angle its just some simple trigonometry.

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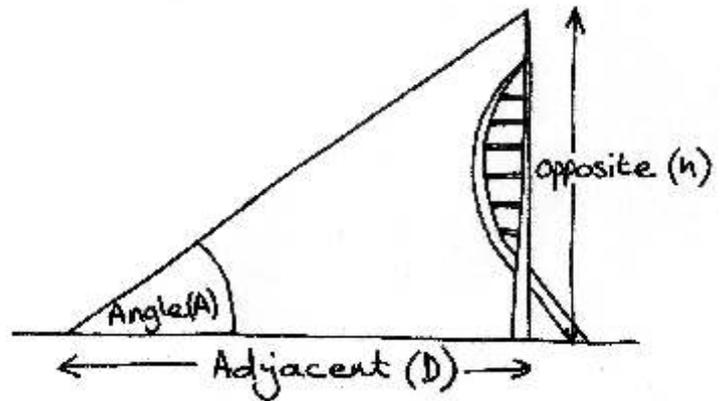
Measure the height of the Spinnaker Tower

The Maths Bit

The straight line distance from the point on the *Warrior's* deck to the base of the tower is 330 metres. Using our knowledge of trigonometry we know that the tan of an angle is the length of the side of the triangle opposite that angle divided by the length of the side adjacent to that angle.

Your clinometer gives you angle A , you know distance D so its quite simple to find height, h using the formula

$$\text{Tan}(A) = \frac{\text{Opposite}(h)}{\text{Adjacent}(D)}$$



Just rearrange the equation and find a calculator that will give you the tan of your angle and hey presto you have the answer.

You can check your answer below, but no cheating.

You don't have to go on board the *Warrior* to measure the height of the Spinnaker Tower. Use a map to choose a spot and simply work out the distance between that spot and the base of the tower. You just need to make sure that the spot you choose is on about the same level as the base of the tower.

Answer

The Spinnaker Tower is 170 metres tall - how close did you get?

