

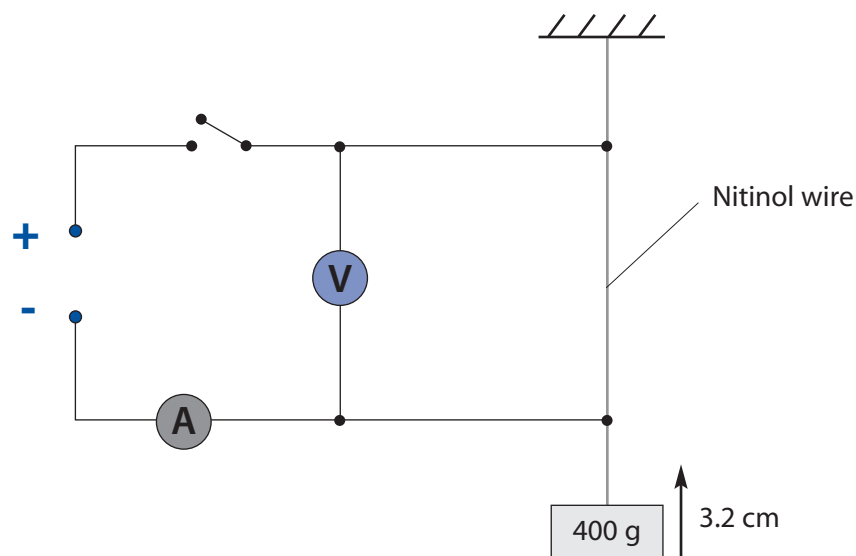
**How efficient?**

Nitinol wire (*muscle wire*) is a special alloy of nickel and titanium which suddenly shrinks by about 5% when its temperature reaches about 70 °C. If it is heated by an electrical current, it is able to transform electrical energy into mechanical work. You are going to investigate the efficiency of this process.

**In your book or file**

Write the heading "Muscle wire efficiency".

Copy the diagram.



Copy and complete these calculations. Choose from:

0.032 • 0.38 • 0.13 • 2.1 • 4.0 • 5.2 • 5.5 • 11

*When the switch is closed, the ammeter and voltmeter read 0.38 A and 5.5 V respectively.*

*The electrical power delivered to the Nitinol wire is: \_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ W.*

*The switch is closed for 5.2 s, so the total electrical energy delivered to the wire is:*

\_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ J.

*During that time the 4.0 N load (400 g mass) rises by 3.2 cm.*

*So, the useful work done on the load by the wire is:*

\_\_\_\_\_ x \_\_\_\_\_ = \_\_\_\_\_ J.

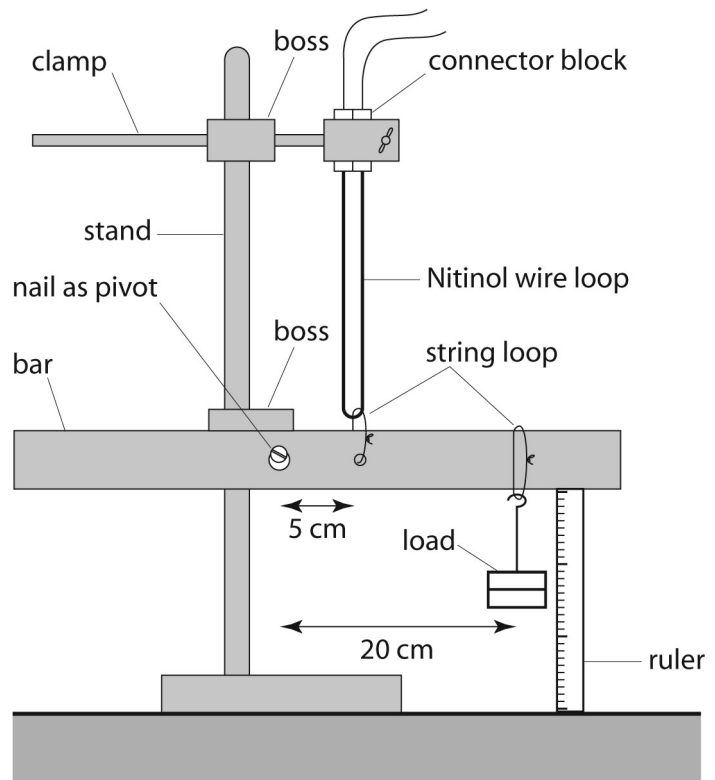
*The efficiency is therefore \_\_\_\_\_ = 0.012 or 1.2 %*

Copy this results table.

force / N	distance / m	work out $E_{out}$ / J	current / A	voltage / V	power / W	time / s	energy input $E_{in}$ / J	efficiency / %
6								
5								
4								
3								
2								
1								

### You will need

- stand
- two bosses and one clamp
- 30 cm loop of Nitinol wire in numbered plastic bag
- two string loops
- 50 cm wooden bar
- 150 mm steel nail
- 6 V battery
- push switch
- ammeter (0 - 1 A)
- voltmeter (0 - 10 V)
- five 4 mm leads
- six 100 g slotted masses
- 50 cm ruler
- stopwatch

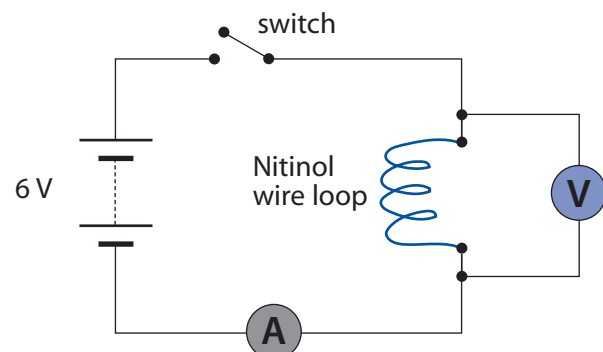


### Health and safety

Warning: the muscle wire will get hot. Remember, a risk assessment must be carried out before you start.

### Instructions

- 1 Use the nail and a boss to suspend the centre of the bar about 20 cm above the bench.

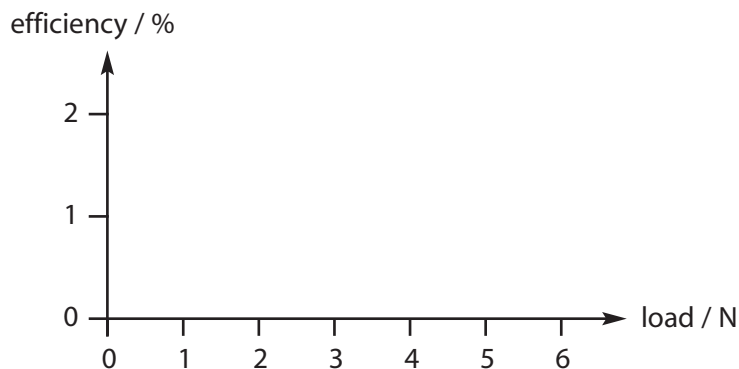


- 2 Use the other boss and clamp to hold the muscle wire 5 cm to the left of the pivot at the bar's centre, as shown above. The bar should be horizontal when the wire is taught.
- 3 Connect the switch, ammeter and loop of wire in series with the 6 V battery. If all is well, the current in the wire should be about 0.35 A when the switch is closed.
- 4 Connect the voltmeter in parallel with the loop of wire. It should read a voltage of about 5.5 V when the switch is closed.
- 5 Hang 600 g exactly 20 cm from the pivot. This provides a force of 6 N.
- 6 Hold one end of the ruler on the bench so that the scale is against the 600 g mass. This will be used to measure the vertical distance that the mass is moved by the muscle wire.
- 7 Press the switch and start the stopwatch. Stop timing when the load has stopped moving up.
- 8 Release the switch when you know:
  - the distance moved upwards by the load
  - the reading on the ammeter
  - the reading on the voltmeter.
- 9 Blow on the loop of wire to cool it down. Repeat the experiment for the other loads in the table.

### In your book or file

Do the calculations to complete the table.

Present your results as an efficiency-load graph. Remember to add a best-fit line to your graph.



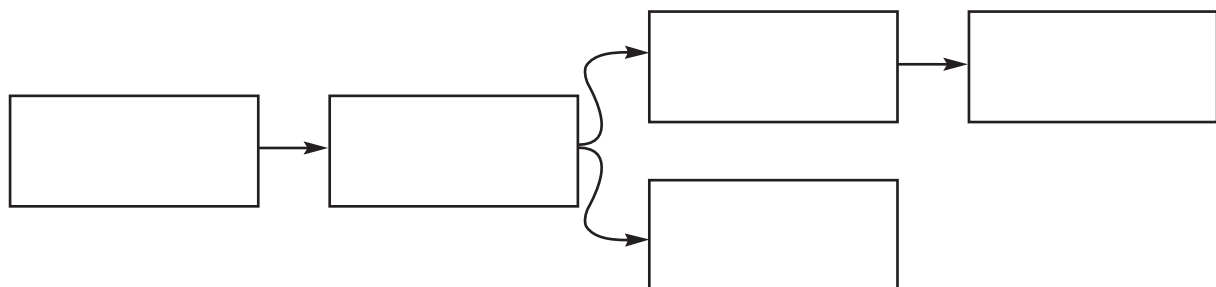
What conclusions can you draw from the graph?

Copy this flow diagram.

Complete it with the following:

*Work on the load • Heat energy in the wire • Heat energy in the room •*

*Electrical energy in the wire • Gravitational energy of the load*



A conventional electric motor can easily have an efficiency of 10%. So why would anyone use Nitinol wire instead? Here are some ideas.

*Motors produce rotary motion.*

*Nitinol wire is modern technology.*

*Nitinol wire is much lighter than a motor.*

*Nitinol wire has no moving parts to wear out.*

Write down **two** advantages and **one** disadvantage of using Nitinol wire instead of an electric motor.

## Extension

Melanie has an idea about the efficiency of muscle wire.



*"A lot of the heat energy is wasted because it is lost to the surroundings by conduction, convection and radiation. The faster you heat up the wire, the less time there is for it to escape from the wire. So more of it can be transformed into useful work by the wire."*

Test Melanie's idea by repeating one of your experiments with a 4.5 V battery instead of a 6 V one.

Write a short report on the extra experiment. It should include:

- what you did
- the results of the experiment
- how they support or disprove Melanie's theory.