## Activity description

This is a practical activity in which students investigate the relationship between the normal contact force and limiting friction. They should discover that friction is a variable force and its maximum value is proportional to the normal contact force.

### Suitability and Time

Level 3 (Advanced); 1–2 hours

### Resources

Student information sheet, worksheet
*Optional*: slideshow

### Equipment

books
wooden block(s)
masses and mass hanger
pulley and clamp (or an elastoscale)
graph paper

### Health & Safety note

Carry out your own risk assessment and take suitable precautions. Do not rely on what is said here.

### Key mathematical language

Friction, equilibrium, limiting friction, normal contact force, horizontal, proportional, gradient, coefficient of friction

## Notes on the activity

*The information sheet contains information that students will discover in their investigation. It should only be given to students after they have completed the main part of the worksheet.*

The slideshow can be used to aid class discussion both before and after the investigation. Slides 1–4 provide an introduction. Slides 5–8 concern the investigation that students will carry out – whilst discussing these you can add more advice if necessary. Slides 9 and 10 can be used after students have completed the activity, to aid class discussion about the main points given in the information sheet. Slide 11 contains some questions to help students think about where friction is useful in real contexts.

Question 1 on the worksheet asks students to suggest factors that they think will influence a friction force and to investigate their ideas. Depending on the time available, this could be integrated into the initial discussion of the

activity, or form a more significant part of the investigation.

Once students have produced their straight-line graphs of $F_{MAX}$ against $N$, they could use the graphs to predict and test the force required to cause a block of a given mass to slide on the table (not suggested on the Worksheet).

The model $F \leq \mu N$ and various properties of the friction force are discussed in the information sheet. The idea of the coefficient of friction could be introduced by asking students to find the gradient of their graphs.

Two graphs are discussed in this activity: $F_{MAX}$ against $N$, and $F_{MAX}$ against the force, $P$, which causes the body to slide. It might be necessary to emphasise the differences between these two, especially as the students' graphs for $F_{MAX}$ against $N$ were obtained by measuring $P$.

## During the activity

Students could work in pairs or small groups.

## Points for discussion

How do we use friction in our everyday lives?

When might we want to decrease the friction force?

What factors affect the friction force? Is friction a constant force?

How can students ensure that their experiments are as consistent as possible?

Why is it important to make sure that the force that is trying to move the block is applied horizontally? Although students are not expected to be able to resolve forces, some might appreciate that if the force is applied at an angle to the horizontal, it will reduce the normal reaction and hence $F_{MAX}$.

What is represented by the gradient of the graph of $F_{MAX}$ against $N$?

## Extensions

If you can provide several blocks made of different materials and several different horizontal surfaces, students could also be asked to carry out experiments to find estimates for the value of $\mu$ for different combinations of surfaces. It would be useful to use blocks that have the same mass, perhaps 1 kilogram.

Typical values for the coefficient of friction, $\mu$, are 0.3 for wood on wood, 0.6 for steel on steel, and 1.0 for rubber on concrete. If the two surfaces in contact are perfectly smooth, there is no friction force and $\mu$ = 0.

### Acknowledgement

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