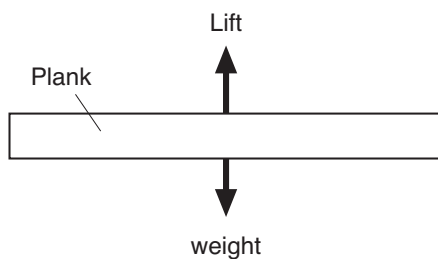


# MEASURING AND IMPROVING STABILITY IN STRUCTURES

Every year people are injured by objects such as unstable filing cabinets which topple over. Objects should be designed to be stable so that when they are tilted or pushed they will not spill over or topple.

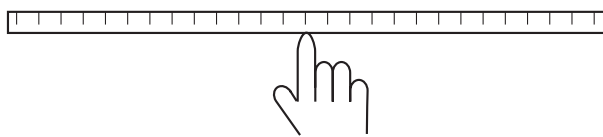
## THE SCIENCE OF STABILITY

Before considering stability it is important that the term **centre of gravity** (centre of mass) is fully understood. Why is it easier to lift a long heavy plank at the centre rather than near the ends? Although the force of gravity acts on the whole plank, the weight of the plank seems to be concentrated at its centre. This point is known as the centre of gravity. Lift the plank at its centre of gravity and it will balance. Lift it at any other point and you will need to overcome the turning effect.

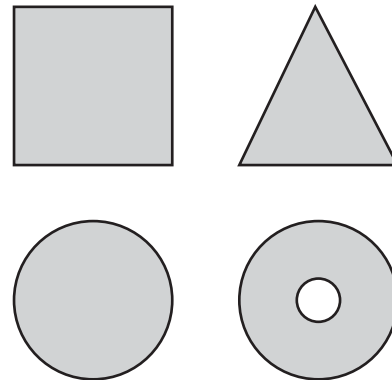


**The centre of gravity is the point through which all of the weight of the object or structure seems to act.**

It is fairly easy to find the centre of gravity of an object such as a metre rule by moving it until it balances on the end of a finger. It will be somewhere near the 50 cm mark. It becomes more difficult with irregular shaped objects.

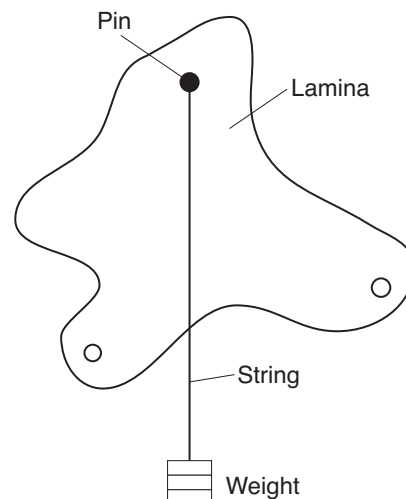


Try to work out where the centre of gravity is on the shapes below.



## FINDING THE CENTRE OF GRAVITY OF AN IRREGULAR SHAPE

Cut out an irregular shape from a flat piece of card (lamina). Pierce three holes at different points around the edge. Insert a pin through one of the holes and let the card hang freely. Attach a plumbline to the same pin and mark the position of the plumbline. The centre of gravity is somewhere on this line since the card hangs with its centre of gravity vertically below the pivot pin. Repeat with the other two holes. The centre of gravity of the lamina is the point at which the lines cross.



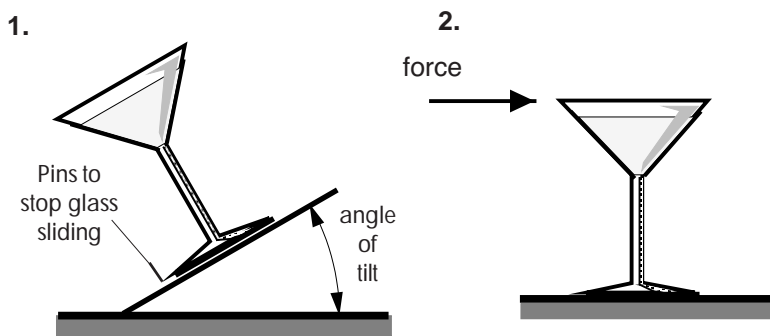
### MEASURING STABILITY

We need to measure a structure's stability so that:

- We can improve its stability.
- We can give a guarantee of stability.

You can measure the stability of a structure in at least two ways:

1. Place the structure on a surface such as a table. Tilt the table until the structure is about to topple. Measure the angle of tilt.
2. Apply a force to a point in the structure, for example, at a certain height above its base. When the structure is just about to topple, record the force.



If an object or structure is in equilibrium (balance) the equilibrium is:

- Stable** if the object or structure will return to its original position after being moved slightly to one side.
- Neutral** if the object or structure is still in equilibrium after being moved slightly to one side.
- Unstable** if after a slight movement to one side the object or structure falls and keeps falling.

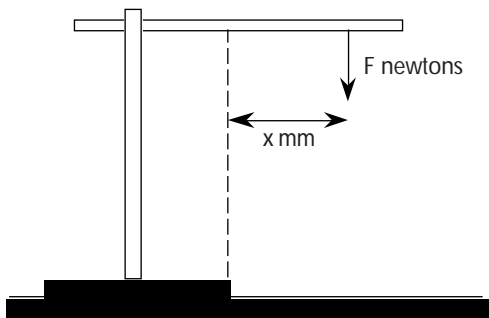
INVESTIGATING TOPPLING

Investigate how the force required to topple the structure varies with its distance from the edge of the base.

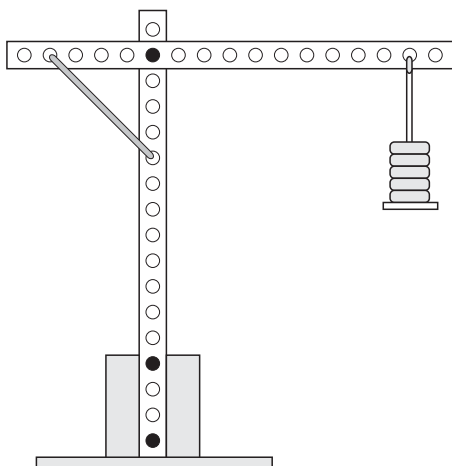
1. Clamp a rod in a stand. Add loads to the end of the rod until the structure topples. Measure and record the horizontal distance between the base and the load. Note how the load that causes the structure to topple varies with the distance.

Change the point at which the rod is clamped in the stand and note how the toppling load varies with distance.

Change the angle of the rod. Does the angle make a difference to the force required to topple the structure?



2. Using the Structures Research Frame, add loads to the end of the arm. Measure and record the horizontal distance between the base and the load. Note how the load that causes the Research Frame to topple varies with the distance.



Change the point at which the arm is secured to the tower and note how the toppling load varies with the distance.

Change the angle of the arm by securing the tie rod to a different hole on the tower. Does the angle make a difference to the force required to topple the structure?

**Practical hints:**

- Collect about ten sets of data.
- Use a wide range of loads.
- Make a note of the data you collect in a table. The results can be displayed in a graph.

Make a note of the data you collect in a table.

INVESTIGATING THE MODEL FOR THE TOPPLING FORCE

You can use a spreadsheet to help predict  $F$  when you know  $x$ . Use the helpsheets on the following pages if necessary.

Use your spreadsheet to predict the following.

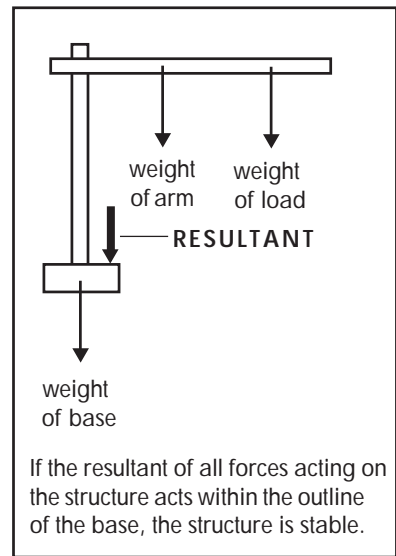
- How far from the edge of the base can a load of 6 newtons be applied if the structure is to be just on the point of toppling?
- If a load is applied 200 mm from the edge of the base and the structure is just about to topple, what is the load?
- Test your predictions in practice.

QUALITY CONTROL AND STABILITY

You can increase the stability of your structure by putting masses into its base or by widening the base and measuring the load required to topple it. For a structure to be stable, the resultant of all forces acting on it must pass through the base.

In designing a structure, it will be impossible to give stability in all situations. You will be unable to guarantee to people using the structure that it will NEVER topple, but you will be able to give them safe limits for forces that may be applied or for angles at which they may tilt the structure.

It is usually a good idea to guarantee your structure only to limits of which you are very confident. You should ensure that these limits will meet most of your possible customers' requirements.



# TECHNOLOGY STUDY FILE 7

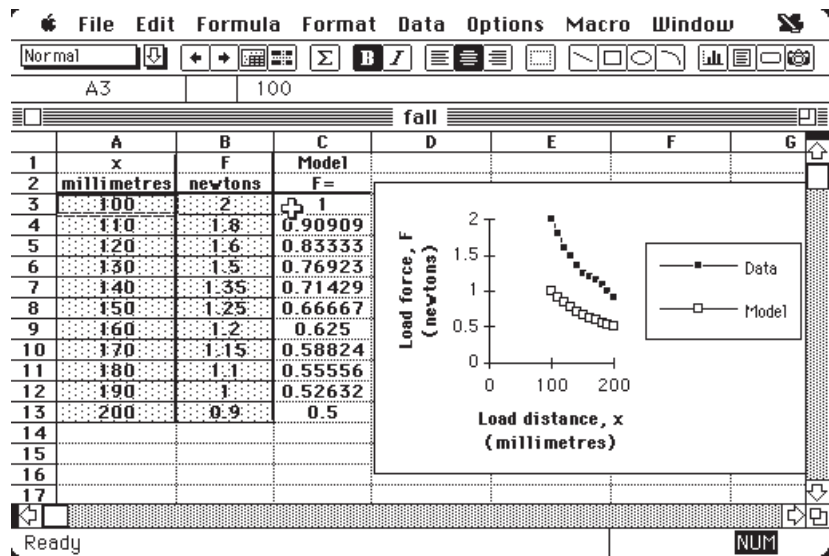
## COMPUTER HELPSHEET

Using a spreadsheet, enter your data for x into column A.

Enter your data for F into column B.

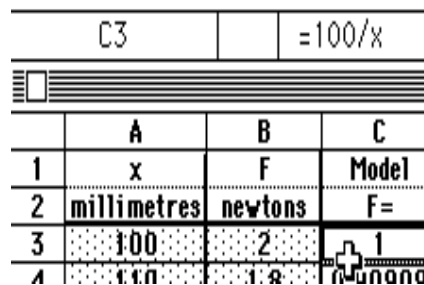
Enter a formula into column C such as  $F=100/x$ .

Your spreadsheet will look something like this:



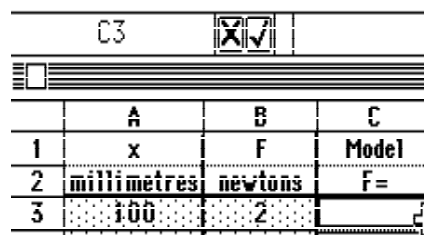
## INVESTIGATING THE MODEL

Click on cell C3.



The model in column C is  $F=100/x$ .

Delete the formula in the input strip by pressing the <delete> key.



TECHNOLOGY STUDY FILE 7

Type in a new model.  
Try '=150/x'.

C3			=150/x
	A	B	C
1	x	F	Model
2	millimetres	newtons	F=
3	100	2	=150/x

A new prediction appears in cell C3.

Press <return>.

C4			=100/x
	A	B	C
1	x	F	Model
2	millimetres	newtons	F=
3	100	2	1.5
4	110	1.8	0.90909

Notice that the predictions in cells C4-C13 do not change.

Copy your model into all of column C.

Click on cell C3. Keep the mouse button pressed down and drag down so that cells C3 to C13 are highlighted.

C3			=150/x
	A	B	C
1	x	F	Model
2	millimetres	newtons	F=
3	100	2	1.5
4	110	1.8	0.90909
5	120	1.6	0.83333
6	130	1.5	0.76923
7	140	1.35	0.71429
8	150	1.25	0.66667
9	160	1.2	0.625
10	170	1.15	0.58824
11	180	1.1	0.55556
12	190	1	0.52632
13	200	0.9	0.5

Click on **Edit** on the menu bar. Select **Fill Down** from the **Edit** menu.

Try altering your model in column C so your predictions are as close as possible to the data in column B. Use your graph to help you.

	A	B	C
1	x	F	Model
2	millimetres	newtons	F=
3	100	2	1.5
4	110	1.8	1.36364
5	120	1.6	1.25
6	130	1.5	1.15385
7	140	1.35	1.07143
8	150	1.25	1
9	160	1.2	0.9375
10	170	1.15	0.86957
11	180	1.1	0.83333
12	190	1	0.78947
13	200	0.9	0.75

New predictions appear in cells C3 to C13.