# BEAMS AND BOX SECTIONS

## OBJECTIVE:

You will understand and demonstrate how beams and box sections are used in construction to support a load above an opening.

## INTRODUCTION:

Beams are horizontal cross-members designed to support loads in buildings and other constructions.

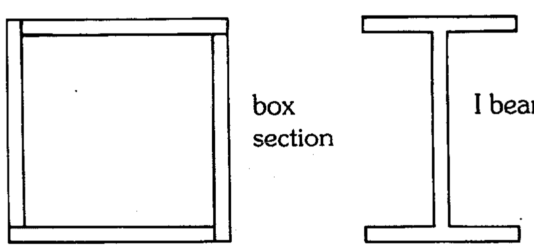
Cave paintings dating from the Upper Paleolithic or Old Stone Age period suggest that wooden beams might have been used in constructing huts as long as 15–20,000 years ago. Wooden beams have been found in Turkey supporting the flat roofs of mud-walled houses dating from around 4000–3000 BC. Massive stone beams were used above the burial chambers in Egyptian pyramids from around 2500 BC, while metal reinforcements are found supporting stone beams in the Parthenon in Athens, built around 440 BC. Since the nineteenth century, concrete, steel, and light alloy have increasingly been used as the structural material in beams.

Wherever beams are used, key considerations are keeping costs down and construction lightweight, while maximizing the load-bearing properties of the beam. With the development of rolled and welded steel by the 1880s, variously shaped cross-sections of beam could be manufactured that much improved load-bearing properties. Box-section and I-shaped steel beams came into use and were incorporated in bridges and large steel-frame structures such as the Eiffel Tower, completed in 1889.

The stiffness of a simple beam (and its ability to carry a load) is proportional to its breadth multiplied by the cube of its depth; in other words, if it is deep and narrow it resists loads better than if it is broad and shallow. Both box sections and I beams rely partly on this principle. In addition, they have right angles where horizontal and vertical components join, and these resist bending and buckling (see figure 1).

In this investigation, you will be comparing the load-bearing properties of a box section with that of a simple beam.

Figure 1




## TIME NEEDED:

30 minutes for construction
30 minutes for testing

## MATERIALS:

- 3 pieces of medium-weight cardboard, 37.5 cm x 20 cm
- pencil
- metric ruler
- scissors
- 10 25g (1-oz.) weights
- 10 50g (2-oz.) weights
- 3 67.5cm lengths of masking tape
- enough books to produce two equal stacks at least 12.5 cm high
- graph paper

## *Safety Precautions*

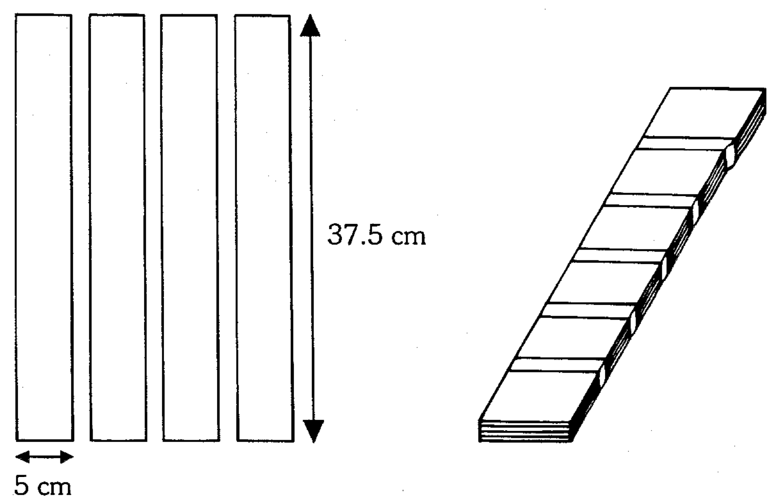
Please read and copy the safety precautions at the beginning of this book.

# PROCEDURE:

1. Make a simple beam (A) by cutting one sheet of cardboard into four 37.5 cm x 5 cm lengths. Stack and tape the pieces together, using one of the 67.5cm strips of tape, cut up into several smaller pieces (see figure 2).

Figure 2

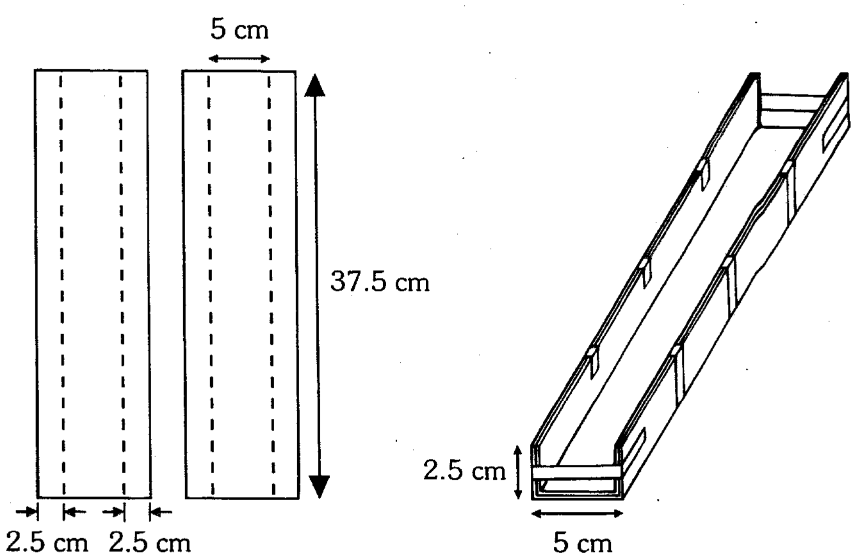
A




2. Make an open box section beam (B) by cutting one sheet of cardboard into two 37.5 cm x 10 cm lengths. Measure and mark fold lines 2.5 cm in from either long edge on both. Use the blunt side of the scissors blade to score along these lines. Bend the two sheets into shape along these fold lines and secure them together using another 67.5cm piece of tape (see figure 3).

Figure 3

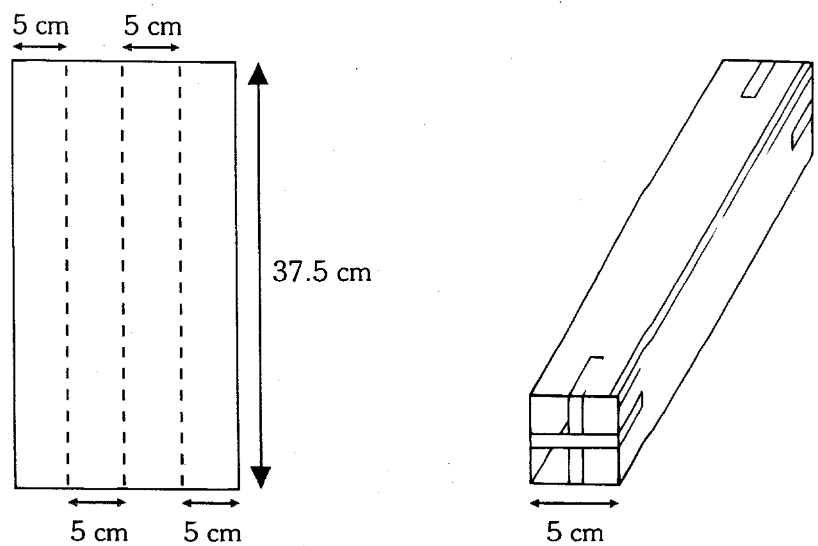
B




3. Make a box section beam (C) by marking, scoring, and folding one sheet of cardboard into a 37.5 cm x 5 cm x 5 cm open-ended box. Secure the folded box using the last 67.5cm piece of tape (see figure 4).

Figure 4

C

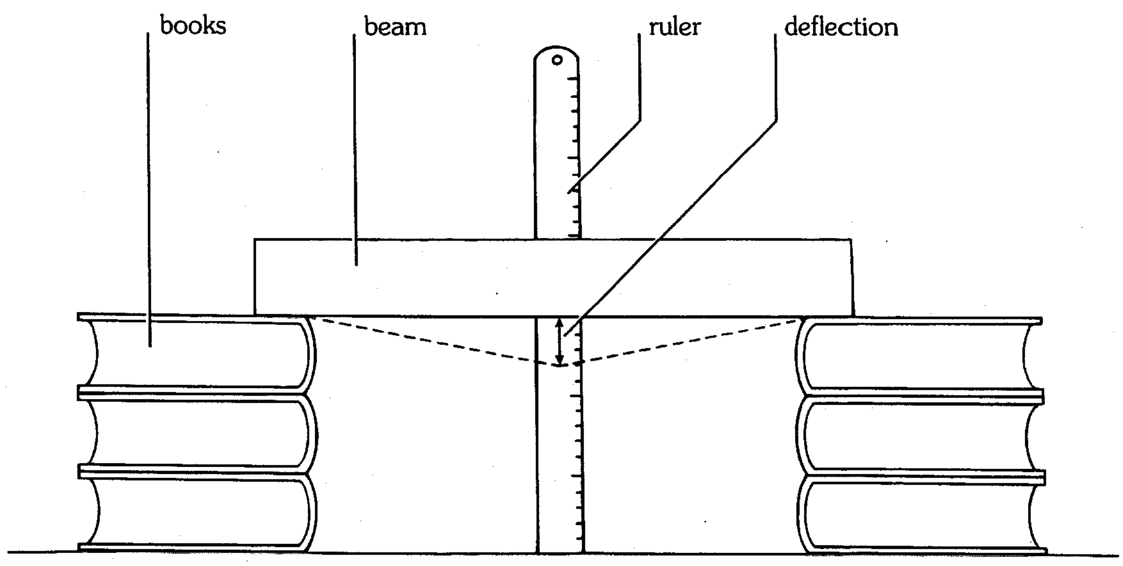



4. You are now ready to test the beams. Arrange two stacks of books the same height, at least 12.5 cm high and 30 cm apart.

5. Place beam A across the gap between the two stacks of books, centered on the stacks.

6. Using a ruler, measure the deflection of the underside of the beam from the horizontal. For example, if the stacks are 15 cm high, and the center of the beam is 12 cm above the table, then the deflection is 3 cm (see figure 5). (Note: The deflection will be very small or nonexistent at the start.)

Figure 5




7. Place a 25g weight precisely in the middle of the beam and measure the deflection again. Repeat this, adding a 25g weight each time. Record the deflection for each weight in the Data Table in the column marked Beam A. If the overall weight reaches 250 g, begin adding 50g weights each time. Continue adding weights until the beam collapses or bends sufficiently to touch the table.

8. Repeat steps 5–7 for beams B and C, recording the deflection in the Data Table under columns Beam B and Beam C respectively.

# DATA TABLE

| Load (g) | Deflection (mm) | | |
|---|---|---|---|
| | Beam A | Beam B | Beam C |
| 0 | | | |
| 25 | | | |
| 50 | | | |
| 75 | | | |
| 100 | | | |
| 125 | | | |
| 150 | | | |
| 175 | | | |
| 200 | | | |
| 225 | | | |
| 250 | | | |
| 300 | | | |
| 350 | | | |
| 400 | | | |
| 450 | | | |
| 500 | | | |
| 550 | | | |
| 600 | | | |

## ANALYSIS:

1. On a single sheet of graph paper, plot curves for deflection against load for each of the three beams.
2. Which beam best resisted the load (that is, which took more weights before collapsing or touching the table)?
3. Why were the same amounts of cardboard and tape used in constructing each beam?
4. What was the purpose of the tape used at the ends of beams B and C?
5. Suggest a way in which beams B and C could be made stronger with minimal use of extra cardboard and tape.
6. Do some research. Give three reasons why one beam resisted loads better than the other two.

## OUR FINDINGS:

Click on above link to see what we found.

# SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

# GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES