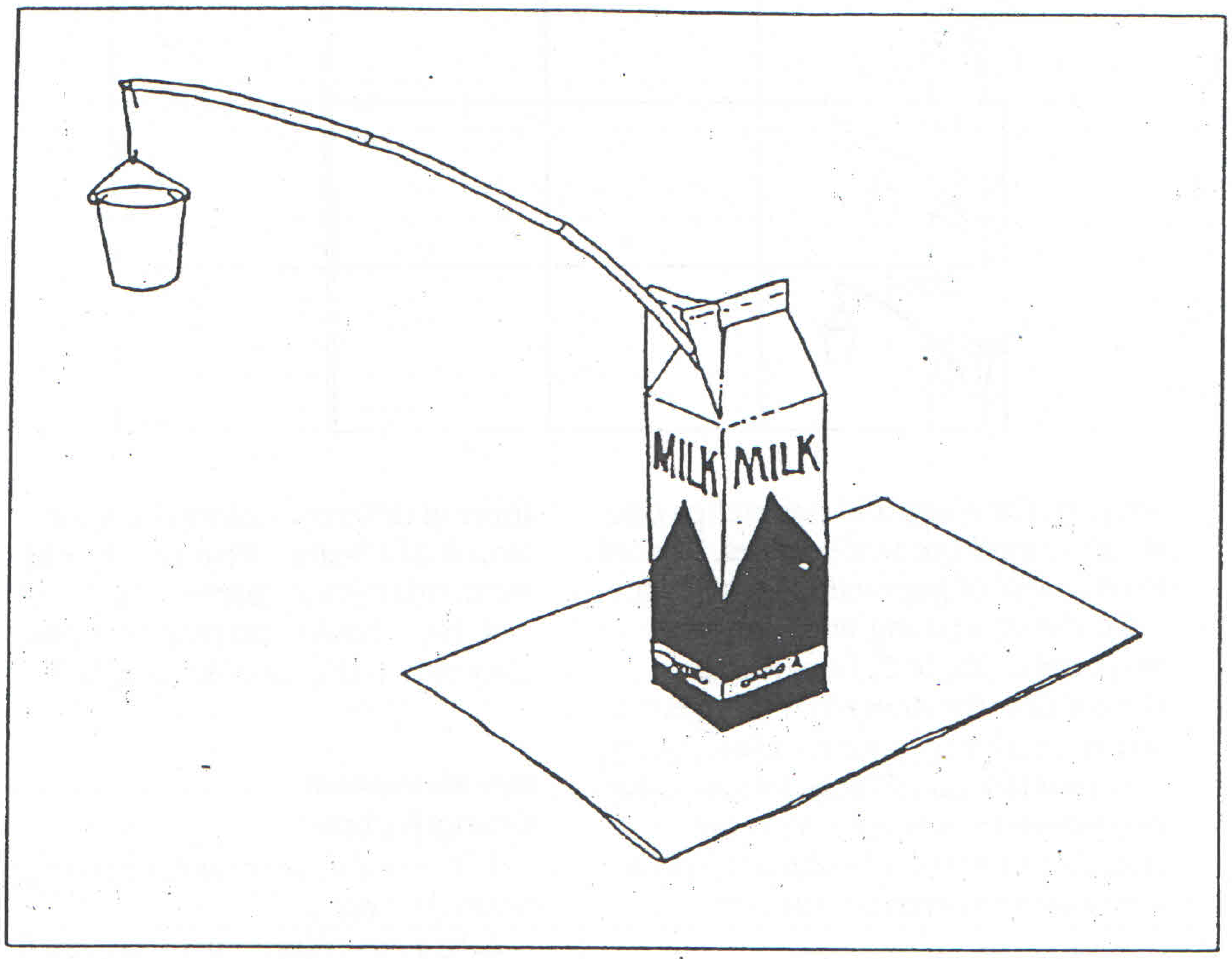
HOW MUCH FORCE CAN BE PUT ON LIBERTY'S ARM?



Science Themes
forces
lever arms

Science Skills
observing
measuring deflections
comparing lever arms

Time Frame
one class period

Materials
- ☐ *plastic drinking straws*
- ☐ *paper milk carton*
- ☐ *piece of cardboard (approx. 8" x 10")*
- ☐ *small paper cup (3 oz., bathroom size)*
- ☐ *paperclips*
- ☐ *hand punch*
- ☐ *glue*
- ☐ *meterstick or yardstick (for measuring deflections)*

Introduction

If you lift a five-pound bag of sugar to the top shelf of a kitchen cupboard, you readily notice the force on your arm. Likewise, in a windy rainstorm, you can feel your umbrella push and pull on your arm and shoulder. Face into the wind and you feel a hard push. Face away from the wind and you feel a strong pull.

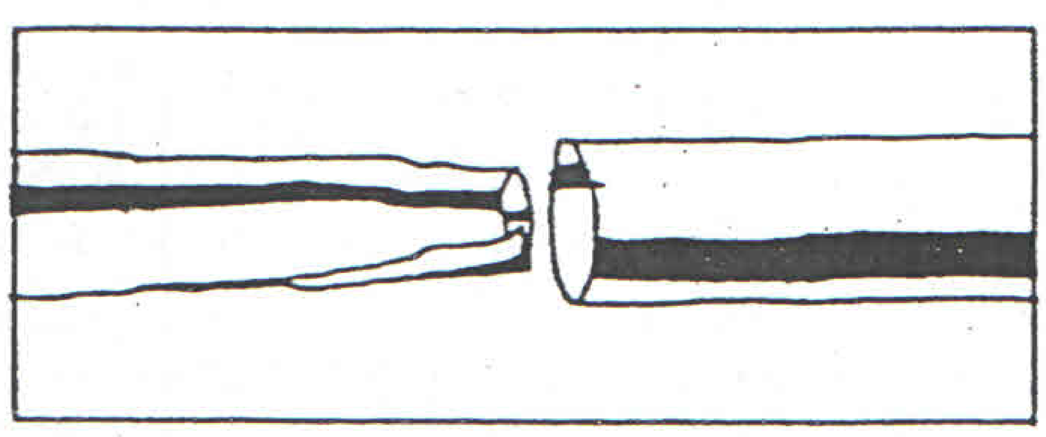
Consider the Statue of Liberty and her outstretched arm holding the torch high into the sky. If people were to stand on the balcony of the torch, how would Liberty's arm react to the weight? How many people could the arm hold before breaking? What happens during a strong wind? Will Liberty's arm bend?

In this activity you investigate how much force can be applied to a beam, like Liberty's arm, without breaking it. Does the length of the beam make a difference in how much of a load it can support? Does where the load is applied make a difference?

Getting Started

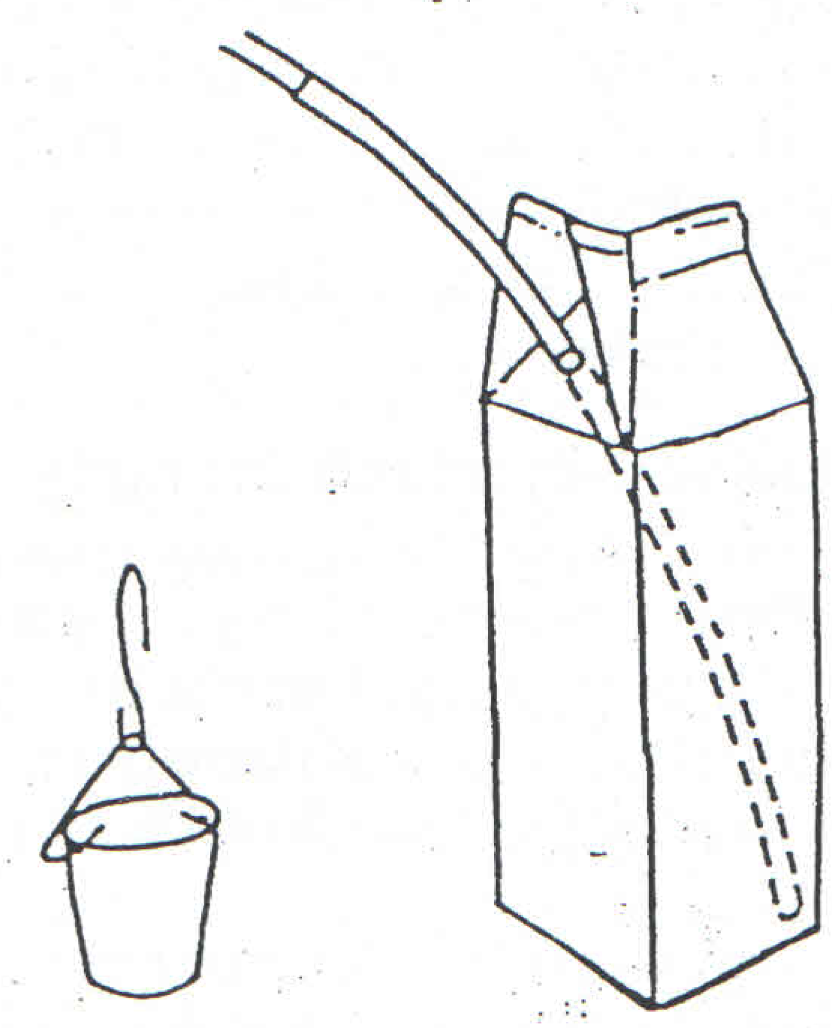
The beams used in this activity are simple tubes of different lengths assembled from plastic drinking straws. You'll want to test these tubes arranged vertically like the arm of the Statue of Liberty.

Make a long beam with four soda straws. Squeeze one end of a straw and insert it inside a second straw. And so on, until the beam is four straw segments long.



One way of aligning a tube like Liberty's arm is to stick it through a hole in the top of a milk carton as shown. Use a hand-punch to make the hole.

Stick the long beam into this hole so that it extends upward like the arm of the Statue of Liberty.



The lightweight milk carton needs to be anchored to the floor or a table top. Putting something heavy inside the milk carton is one way. Another is to attach the milk carton to a wider piece of cardboard. Gluing the bottom of the carton to the cardboard works well.

A weight holder can be made from a small paper cup (3-ounce, bathroom size cup). Make two holes opposite each other just beneath the top of the cup, and attach a bent paperclip as shown. A second paperclip can attach this handle to the straw tube.

At three positions along the beam, attach paperclips as shown. The paperclips will allow you to hang a weight at different positions along the beam.

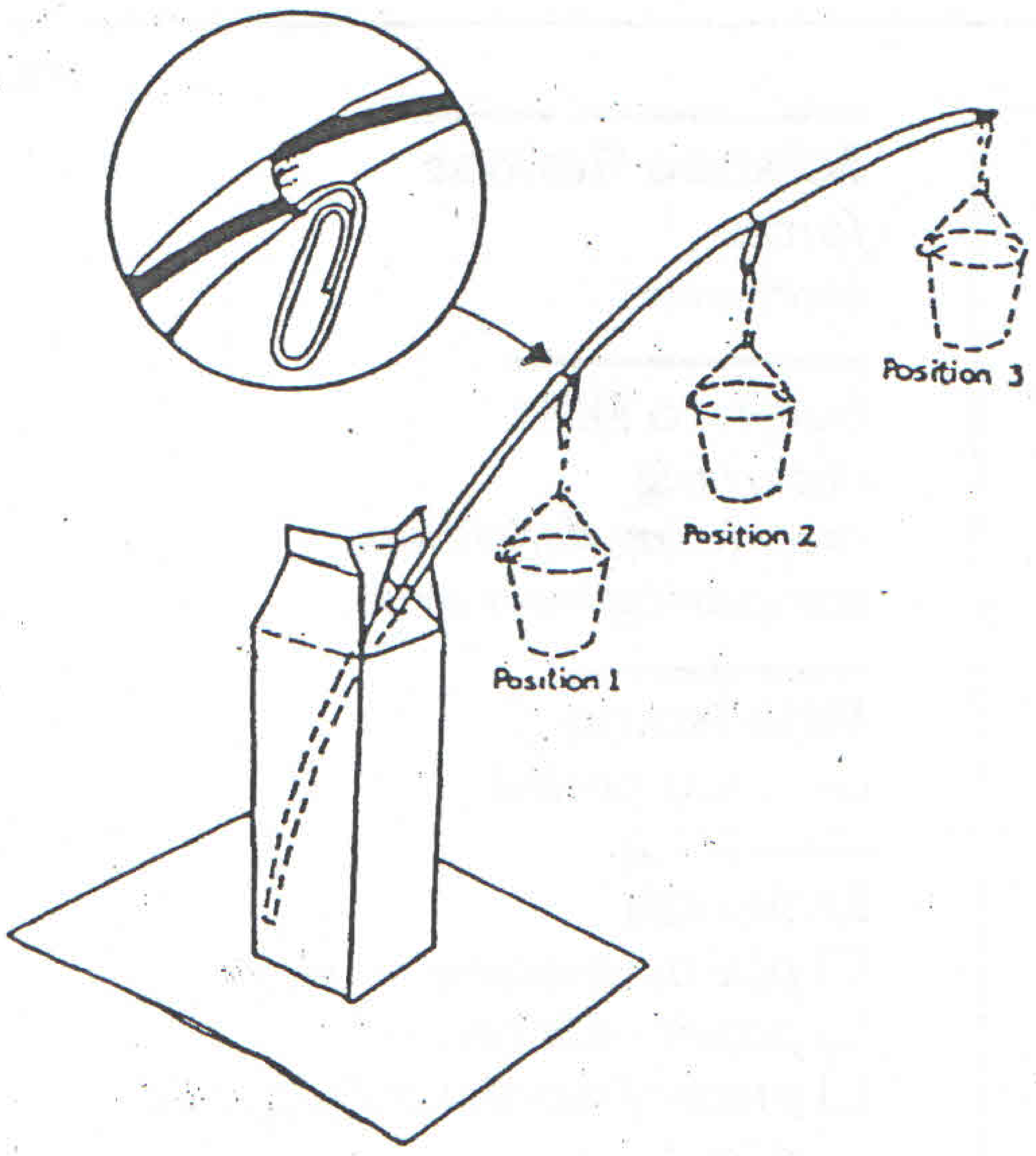
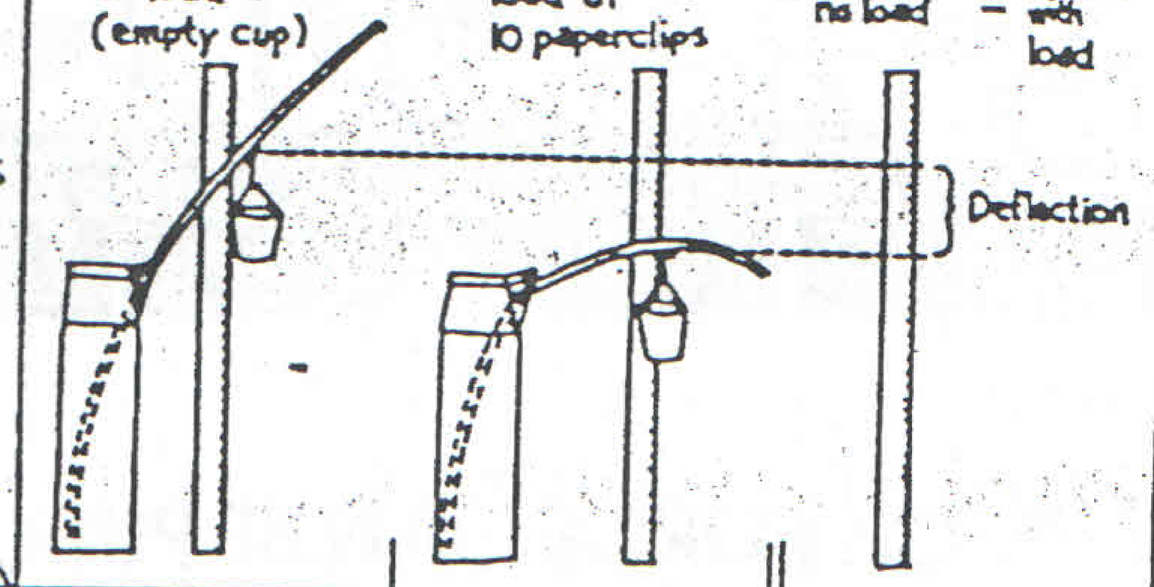


Table 1—How Much Does the Arm Bend?



How Much Arm Bends / Where Load is Placed	Height with no load (empty cup)	Height with load of 10 paperclips	Height with no load − Height with load
Position 1 			
Position 2 			
Position 3 			

The Activity

Applying a force at difference places.

How does the tubular arm deflect when pulled downward? Does where you pull affect it? How much weight can the arm support before breaking?

With a weight of 10 paperclips in the cup, measure how much the arm bends when the weight is hung at each of the three positions. Table 1, *How Much Does the Arm Bend?*, suggests a way of organizing your measurements.

How length affects strength.

Combine straws to make beams of different length—2 straws, 3 straws, and 4 straws long. The test is to compare the strengths of these beams. How much weight can each arm support?

Start with the longest beam. Slip it through the top of the milk carton. Insert a paperclip in the top end of the straw, and attach a cup for holding weights. Carefully add paperclips one at a time until the arm buckles. Record the number of paperclips in the cup.

Do the same thing with the other two beams. Table 2, *How Much Weight Can the Arm Hold*, suggests a way of recording your measurements.

Repeat this set of measurements for two new sets of beams. You can assemble new sets of beams to replace the straw segments that buckle.

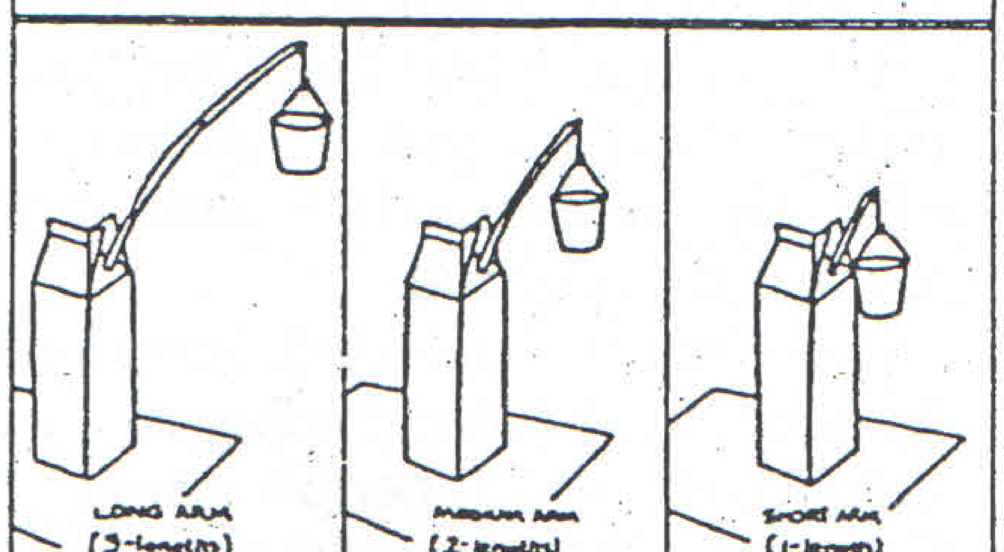
Discussion

1. From your testing of different beams, which length of beam can support the least weight?
2. If you want a small force to have its greatest effect (i.e., bend a beam the most), where on a beam would you apply the force?
3. In these tests you observed what happens when you apply the same force at different points along the length of a beam. What rule would summarize your observations?
4. How could you make the beams stronger so they would bend less?

Going Further

1. Try out your ideas for making the beams stronger.
2. In your community, can you find examples of beams attached only to the ground? Can you see them bend? Under what forces?

Table 2—How Much Weight can the Arm Hold?



	WEIGHT WHICH CAUSES ARM TO BUCKLE WHEN HUNG AT THE END OF THE ARM.		
	LONG ARM (3-lengths)	MEDIUM ARM (2-lengths)	SHORT ARM (1-length)
Thin tube made of single straws sample #1			
sample #2			
sample #3			
	MEAN:	MEAN:	MEAN:

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