SCHOOLS
Advancing Science & Engineering through Laboratory Learning

SAMPLE ANSWERS

Materials Testing: Plastics

Introduction

Plastics are everywhere. They have an extraordinary range of uses, from soft drink bottles and packaging to car panels and building materials. The plastic that is used for an object has been selected because of its properties including its strength, its flexibility, its durability and its cost.

Supermarket bags are extremely convenient but also environmentally damaging. Researchers and industry continue to search for cost-effective environmentally friendly biodegradable plastics. To replace traditional supermarket bags, the new bioplastics must be as strong and resilient as the plastics used currently. Just how strong will these new plastics need to be to match the plastics used in the current supermarket bags? Are the biodegradable and recyclable bags being used as good as the traditional bags?

Key ideas

Force - a push or a pull.

Strength - can be thought about in many ways. In this activity, strength will be measured either as the **load** required to stretch and break a piece of material, or the **puncture force** to push an object into or through that material.

Load – A downwards force that is being applied to an object.

Puncture force is the force required to push an object into or through a material.

Fair test - When testing different materials all the variables except the one being tested need to be kept the same.

Variable - Something that can change.

Independent variable - Variable that is deliberately changed.

Controlled variables - Variables that are kept constant.

Dependent variable - Variable that changes in response to changes in the independent variable and that is observed or measured.

Equipment and materials

- Different plastic bags (3)
- Retort stand and clamp arm
- Paper clips or wire to make hook from which to suspend weights
- Scissors
- Sticky tape
- Icy pole sticks
- Bamboo skewers
- Weights
- Ruler (and/or measuring tape)
- Rubber bands
- One beaker or cup (approx. 8-10 cm diameter)
- Safety glasses/goggles

Part 1: Strength

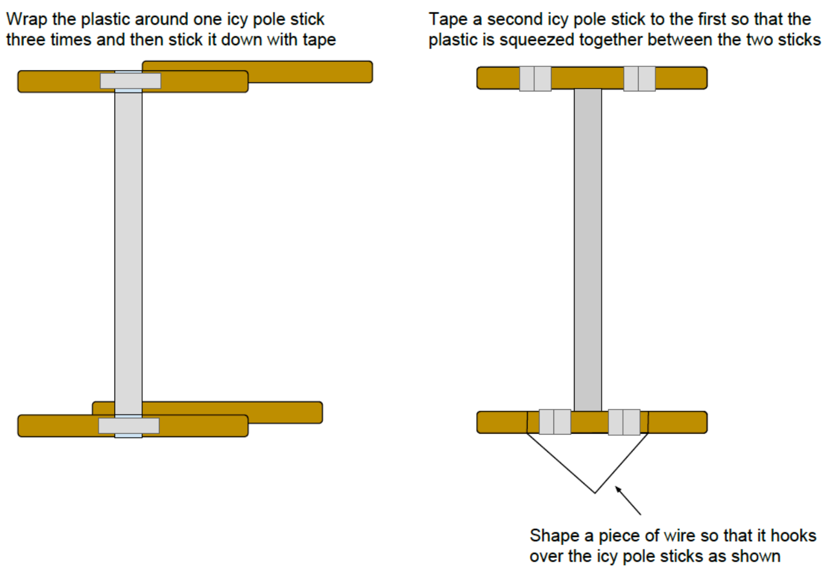
In this activity, you will work out just how strong the plastic is in different supermarket bags. The principles in the testing procedure you will use are the same as those used by materials scientists in their labs.

Part 1: Hazards

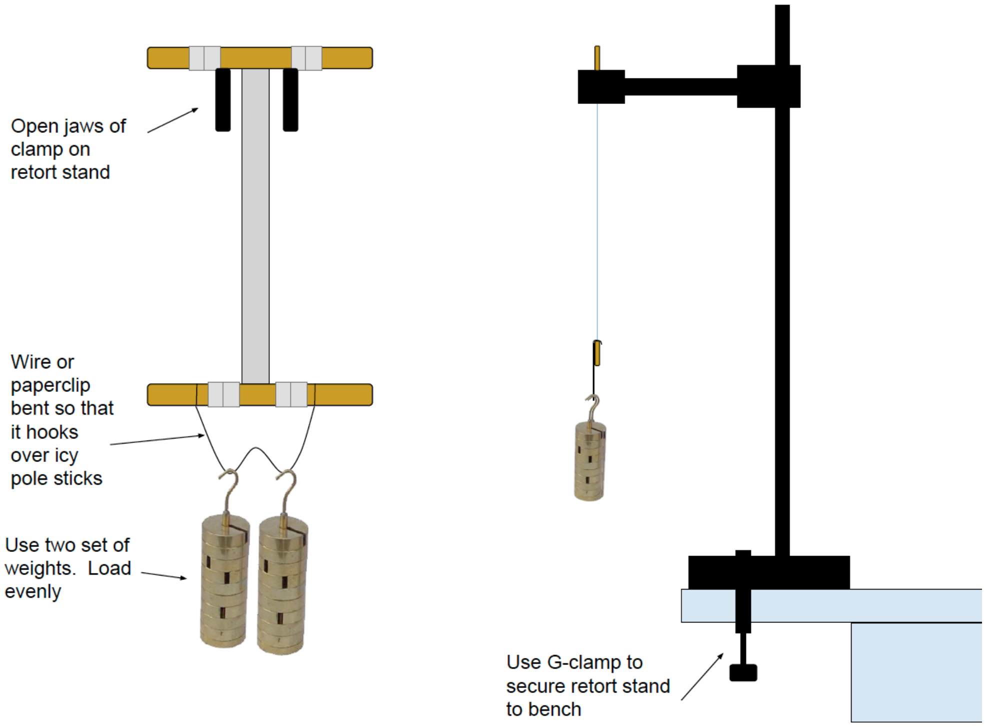
The main hazard will arise when samples of plastic give way under load. Things may fly in unpredictable directions. You must wear safety glasses/goggles, and also keep faces well away from the plastics when they are heavily loaded. Keep clear if you think the plastic is about to snap. Set up a tray with something soft in it so the weights do not crash to the floor and keep feet clear.

Part 1: Investigation Instructions

From the samples of plastic bags for testing, cut strips 30 cm long and 2 cm wide. Wind the plastic strip around the one icy pole stick as shown leaving 20 cm between the sticks. Use sticky tape to hold the plastic in place. Tape a second icy pole stick to the first one for extra support.



Suspend the top icy pole sticks from a clamp on a retort stand as shown below. Add weights to increase the load on 50 – 100 g at a time initially and 50 g at a time when you think the plastic is about to snap. Place something soft underneath the weights so that when the plastic breaks the weights do not crash to the ground. The supports on brass weights can be easily broken. Each time you add the load measure the distance between the top and bottom icy pole sticks i.e. the length of the plastic and also measure the width of the plastic at the midpoint of the length of plastic. Continue to add weights until the plastic test strip breaks.



As well as the measurements, note other observations you make while the weights are being added.

Part 1: Results

Record your results in the spaces below.

Source of plastic	
Plastic 1	A very stretchy plastic bag
Plastic 2	
Plastic 3	

<table>
<tr><th></th><th colspan="2">Plastic Bag 1</th><th colspan="2">Plastic Bag 2</th><th colspan="2">Plastic Bag 3</th></tr>
<tr><th>Load</th><th>Length</th><th>Width</th><th>Length</th><th>Width</th><th>Length</th><th>Width</th></tr>
<tr><td>0 g</td><td>27.5 cm</td><td rowspan="12" colspan="5">Most plastics would not stretch so much</td></tr>
<tr><td>100 g</td><td>28.5 cm</td></tr>
<tr><td>200 g</td><td>29.0 cm</td></tr>
<tr><td>300 g</td><td>29.0 cm</td></tr>
<tr><td>400 g</td><td>29.3 cm</td></tr>
<tr><td>500 g</td><td>125 cm</td></tr>
<tr><td>600 g</td><td>136 cm</td></tr>
<tr><td>700 g</td><td>152 cm</td></tr>
<tr><td>800 g</td><td>162 cm</td></tr>
<tr><td>900 g</td><td>179 cm</td></tr>
<tr><td>1000 g</td><td>192 cm</td></tr>
<tr><td>1100 g</td><td>failure</td></tr>
</table>

Part 1: Analysis

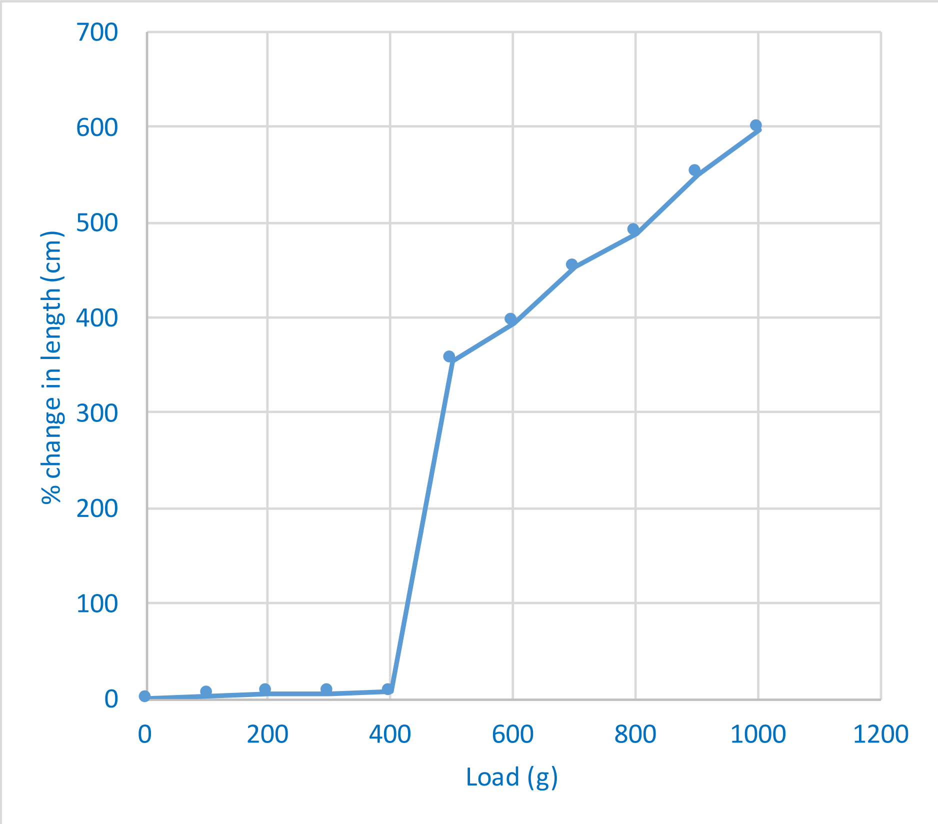
Calculate the percentage change in length versus load.

Plastic 1: percentage change in length versus load			
Load	Length	Change in length	Percentage change in length
0 g	27.5 cm		
omitted			
300 g	29.0 cm	0.0 cm	5
400 g	29.3 cm	0.3 cm	7
500 g	125 cm	95.7 cm	355
600 g	136 cm	11 cm	395
700 g	152 cm	16 cm	453
800 g	162 cm	10 cm	489
900 g	179 cm	17 cm	551
1000 g	192 cm	13 cm	598

Plastic 2: percentage change in length versus load			
Load	Length	Change in length	Percentage change in length

Plastic 3: percentage change in length versus load			
Load	Length	Change in length	Percentage change in length

Draw graphs of the change in length versus load and percentage change in length versus load. Put your different graphs on the same set of axes.



Part 1: Discussion and Conclusions

How did the plastics compare? Which one is strongest? What is the evidence?

The stronger the plastic the smaller the percentage change in length with increasing load and the greater the load/weight needed to break the plastic test strip.

How did each of the plastics behave as the load was increased? Were there differences?

Only data from a very stretchy plastic has been shown in these sample answers.

Most plastics would have similar features on the graph: flat region, sharp rise, followed by steady increase until it breaks. For most plastics some of these regions (usually the sharp rise) is very small and might not be easily observable.

Represent what you think is happening at the particle (molecular) level as the plastic is stretched and eventually breaks. Represent the elastic phase, the plastic phase and the point of failure.

There are some good pictures at the website, *The Hand Book on Mechanical Maintenance*, compiled by: K P Shah, <http://practicalmaintenance.net/?p=1135>

Are there variables you have not controlled in your tests? How might these variables affect your conclusions?

Possible variables not controlled are thickness of plastic samples and time weights are left suspended from plastic before measurement is taken. In a well-designed experiment, all variables except the independent variable (the different plastic bags) should be kept the same to ensure any changes observed in the dependent variable are due to the plastic itself and not the thickness of the sample or time weight is left hanging from the plastic.

Identify two improvements to the method to ensure it is a well-controlled experiment.

- Plastic samples to be same thickness to start off with.
- All three plastic samples to be tested at the same time after weight has been added.

Suppose you had to increase the strength of the handles of the plastic bag — what could you do? Describe a test you could do to gain evidence for your proposal.

We could add more than one layer of plastic when making the handle.

Repeat the experiment varying the number of pieces of plastic suspended between the icy pole sticks. This will be the Independent Variable. Could start off using a greater load and determine the number of 50-100g weights/load needed to break the test strip.

Part 2: Cutting and tearing

Not only are items purchased from the supermarket heavy requiring supermarket bags to be strong but they also often come in packages with sharp edges and corners. Bags may be punctured or cut and eventually tear.

In this activity, you use the materials and your own improved version of the suggested testing technique provided to compare the resistance of the bags to puncturing.

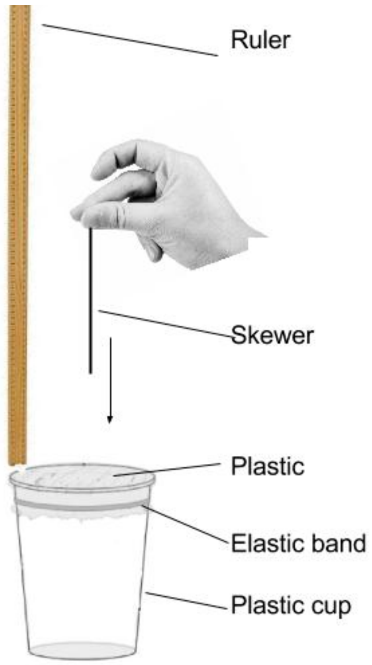
Part 2: Hazards

There are hazards in this activity from sharp objects. Care should be used with scissors to keep fingers clear while cutting. Both scissors and the bamboo skewers are sharp and care that they are not poked into skin or eyes. Wear eye protection.

Part 2: Investigation Instructions

From the samples of plastic bags for testing, cut 15 cm squares – big enough to be stretched over the beaker/cup and held in place with a rubber band.

Stretch a sheet of plastic bag over the top of a plastic cup or beaker and secure it with a rubber band as shown. Drop a bamboo skewer, point down, onto the stretched plastic, from different heights.



Part 2: Preliminary Observations and Results

What do you observe when you drop a bamboo skewer, point down, from a height of about 1 cm above the plastic bag onto the plastic?

Bamboo skewer rebounds like a ball bouncing on the ground and the plastic stretches slightly as the skewer hits it.

Repeat this from 20 cm above the stretched plastic bag. What do you observe this time?

Skewer pierces/punctures the plastic and does not rebound off it, but stays embedded within the plastic.

Using this technique compare three different plastic bags for their resistance to puncturing. What needs to be done to ensure that the tests are fair?

There are many possibilities. Just some include:

- Same type, size and opening diameter plastic cup/beaker used for each plastic sample.
- Each plastic sample should be stretched and secured the same way over the plastic cup/beaker.
- Skewer released the same way from fingers with no force exerted on skewer by fingers.
- Measurement of height of skewer from cup/beaker taken the same way.

Part 2: Planning More Detailed Investigation(s)

Your task is to use the preliminary investigation above to work out which of the plastics has the greatest resistance to puncture with the skewer. Work with your partner or your group to decide which variables you will keep the same (controlled variables) which variable/s you will change (independent variable) and which variable you will measure (dependent variable).

Controlled variables

These are essentially many of the variables in the previous box:

- Same type, size and opening diameter plastic cup/beaker used for each plastic sample.
- Each plastic sample should be stretched and secured the same way over the plastic cup/beaker.
- Skewer released the same way from fingers with no force exerted on skewer by fingers.
- Measurement of height of skewer from cup/beaker taken the same way.

Independent variable

For each plastic:

- height from which skewer is dropped.

Once the tests are completed, we can compare the results, but the choice of plastic is not considered to be an independent variable.

Dependent variable(s)

For each plastic:

The observation of whether skewer punctures the plastic and potentially the depth of penetration.

Record your testing procedure. How many tests will you do on each plastic?

This could be a picture similar to the one a few pages back, but with more labels and annotations.

Other students might have a dot-point procedure.

Since the puncture hole (damage to the plastic) is very localised, it is possible to repeat the test for each plastic several times.

To paraphrase Ian Fleming's James Bond novel *Goldfinger*:

> *Once is an accident. Twice is a coincidence. Three times is much more certain.*

Scientists and engineers normally repeat a test at least three times.

Part 2: More Observations and Results

Record your results. What units will you be using?

Units would most probably be centimetres (cm) or perhaps millimetres (mm) or metres (m).

Part 2: Analysis

Summarise your results in a form that visually displays the differences in resistance to puncturing.

The test(s) on each plastic yields a single average number. Hence the result for each plastic could be plotted on a number line.

If we put a series of number lines side by side in a vertical format, we get a bar graph to show:

Horizontal axis: average various plastic samples as separate "entries"

Vertical axis: average dropping height of skewer (cm) that causes plastic to puncture

There are other possibilities.

Why did you choose to use this particular representation? Hint: what are the advantages of using this way of visually summarising your results?

- Using some kind of graph or pictorial representation makes it easy to compare sets of data between different groups at a glance.
- clarify trends better than do tables.

Part 2: Discussion and Conclusions

How did the plastics compare? Which one is strongest? What is the evidence?

Strongest plastic will be the one that has the skewer largest dropping height need to puncture it.

Do you think your results are reliable when making a judgement about which plastic bag will resist cutting by sharp objects? What are the strengths and weaknesses of the testing procedure you used?

Reliability is the degree to which an assessment tool produces stable and consistent results. Repeating an experiment reduces the effect of errors and hence increases the reliability of an experiment. Ensuring experiment is well controlled also assists here.

Strengths: Well controlled experiment with only one variable.

Weakness: Could question if a skewer is a good **model** of a sharp object that could pierce a plastic bag. Could test a variety of sharp objects and could test force applied by sharp object rather than dropping height.

Are there variables you have not controlled in your tests? How might these variables affect your conclusions?

Depends on experimental design. The purpose of a controlled experiment is to ensure any changes measured/observed (piercing height) are due to independent variable (different plastic sample) and no other uncontrolled variable. To be able to attribute all changes to independent variable being tested.

Identify two improvements to the method to ensure it is a well-controlled experiment.

Part 3: Reflections

What other investigations could you undertake with the plastics and equipment used?

Part 4: Extensions

Stress vs strain

What extra measurements do you need Make the appropriate measurements and calculate the engineering stress and strain at different loads till failure. Design a table and record your measurements. Plot a stress vs strain curve for each plastic tested.

How do the shapes of the curves compare?

What do the shapes of the graphs suggest about the plastics used in supermarket bags?

Independent investigation

What question do you intend to investigate?

Do you have a hypothesis? Briefly state it.

Outline the procedure for conducting your test.

Record your measurements.

Present data.

Analyse your data.

What conclusions can you draw? Did the experiment produce evidence to support your hypothesis? Are there improvements you would make in your experimental method?

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