

Space Careers Wayfinder

Engineering Solutions

Background

The physical conditions for launching and orbiting a satellite can be harsh and demanding. During launch, it must withstand extreme vibrational movement and while in orbit the satellite needs to withstand high energy radiation, exceptionally low pressures and temperature ranges from -65°C to $+125^{\circ}\text{C}$. Everything needs to be meticulously planned for the satellite while it is still on the Earth's surface because once launched into orbit, it will be extremely expensive to send something to fix the issue if that is even possible.

Space materials engineers need to ensure that materials used will withstand these difficult conditions and perform as expected. There are multiple factors that need to be assessed when considering potential materials. The table below lists just three of the properties and characteristics which have to be considered.

Malleable	The ability of a material to be beaten into a sheet or squeezed into a shape without breaking/shattering. The results of the investigation the students will conduct for this property will be qualitative (descriptive) in nature.
Ductile	The ability of a material to be stretched into a wire or to be bent. It does not have any units, but it is a ratio calculated by dividing the final length of stretching by the original length section that is being tested. The larger the ratio, the greater the ductility. The lowest ratio possible is a value of 1, where the initial and final lengths are the same. That is, where no discernible stretching occurred.
Tensile strength	Is calculated by dividing the force required to break a material by its cross-sectional area. The force of a dangling mass is equal to mass (kg) times gravity (9.81 m/s^2) and is also known as the weight, measured in Newtons (N). The cross-sectional area (m^2) is the area of a sliced cross-section cut at right angles to the long axis.

Many materials used for space craft are composed of polymers. These can include “thermal control coatings, adhesives, tapes, potting compounds, toughening/damping materials, seals, thin film substrates, thermal insulations in addition to composite structures” https://link.springer.com/chapter/10.1007/978-1-4899-0502-4_23

The Brief

Engineers need to understand the effect the wide range of temperatures are likely to have on an orbiting satellite. As well as increased exposure to radiation, temperatures will typically fall in the range between -65°C and $+125^{\circ}\text{C}$ for a satellite orbiting in Low Earth Orbit (around 2,000 km or less).

The Task

To determine the effect of temperature on the tensile strength, ductility and malleability of a material at frozen and ‘warm’ conditions.

Gummy snakes are a type of polymer made from proteins. They display similar properties to most other polymers when subjected to varying temperatures.

Your challenge is to determine the effect of temperature on the malleability, ductility and tensile strength of this polymer.

Teacher prior preparation for a class of 30

Pre-testing each of these procedures is recommended to ensure that the brand of snakes, the mass carriers and masses are appropriate to the task to determine if modifications to the method are necessary for your available resources.

- 6 sandwich sized brown paper bags
- 6 gummy snakes (‘The Natural’ brand works) placed in a straight position into the bottom of each paper bag. Total 36 frozen snakes
- tray for freezing the cold samples
- 36 room temperature snakes
- cold esky

This gives a leeway of 6 spares for cold and warm samples.

IMPORTANT Students should not eat any of the samples as they will no longer be food grade and are liable to contamination in a laboratory environment.

The six bags of samples should be placed in a freezer for at least 48h prior to the activity, **only to be taken out of the freezer and placed into the cold esky immediately before use**. These will be referred to as the ‘frozen samples’ and are at a temperature of approximately -18°C . Students will only collect these one at a time from the esky to prevent samples from warming up due to ambient room temperature.

The warm samples will be warmed by students holding the room temperature snakes in their hands for one minute, causing an estimated temperature of 25°C – 30°C .

The Student Activity

Materials required for each lab group:

- 6 x gummy snakes frozen for a minimum 48 hours. Collect these one at a time only immediately prior to use to prevent them warming up
- 6 x gummy snakes at room temperature
- mass carrier (or available alternative such as small 'sandcastle' bucket with handle, sand and digital balance) and masses to allow maximum mass load capacity of at least 500g
- scissors
- 2 x medium bulldog clips
- 30 cm ruler
- approximately 4 cm x 4 cm section of sheet graph paper with mm markings
- marker pen
- calculator
- small hammer or equivalent hard mass for hitting sample
- optional - spring balance of at least up to 10N (=1 kg) maximum scale. If you have an accurate set, you can replace the use of any weight calculations and associated mass carrier and mass related equipment and use the numerical figures directly using the Newtons scale
- optional - student own phone camera if allowed in class. User must maintain dry hands and their own duty of care of their own device

The following three tests should be performed separately on both the cold and warm samples while wearing safety glasses.

Malleability – The ability to be beaten or rolled into sheets.

1. Collect the frozen sample.
2. Place it onto a solid surface like concrete
NOTE Protect any surface likely to be marked or damaged before commencing the activity.
3. While keeping all fingers away from the sample for safety, give it a tap with the hammer by allowing it to do a guided 'drop' from a height of 15 cm while holding onto the end of the handle with your other hand.
4. Write a description of what happens to the sample and dispose it into the bin.
5. Repeat steps 1 – 4.
6. Collect two 'room temperature' samples and warm these by using the warmth from your hands for one minute. **This is how you will make the *warmed* samples for all further testing.**
7. Repeat steps 2 - 4 with both warmed samples.
8. Using your understanding of the definition of malleability in the table, what can you infer about the effect of temperature on the malleability of a substance?



Photo credit:

<http://www.aluminummetals.com/products/colored-aluminum-sheet-metal-near-me-143.html>

Ductility – The ability to be drawn into a wire or to be bent.

Use the top flat surface of a table/bench, near a straight edge for easy measurements of length.

1. Collect the frozen sample.
2. Use the *force of a pressing thumb* to clamp the head of the snake near the table edge. The force need only be firm and steady, but not so hard as to decapitate the head.
3. Place a ruler along the table edge with the zero mark at the clamping point. Ignore measuring the part of the head under the thumb. Do not try to bend it to align it along the ruler. Just place it so the longest resting length is visible next to the ruler.
4. Record the length from the clamping point to the tail. This is called the resting length.
5. Using your index finger and thumb of the other hand, grab a point 2 cm from the bottom of the tail. Then slowly and gently stretch the sample along the ruler edge with group members watching the tip of the tail and *continually verbalising* the total length of the sample every half centimetre length. If possible, this could be recorded by a group member using a phone video ensuring that the sample and ruler are clearly focused. Playback would allow accurate recording of the length before breaking. If so, skip step 6.
6. Continue until it snaps and record the last said length before it snapped.
7. Calculate the ductility ratio as a single number to two decimal places, by dividing the final length recorded (before snapping) by the resting length.
8. Repeat this once more and calculate an average ratio of ductility for the frozen samples.
9. Repeat steps 2 – 8 but using the warmed samples.
10. Using your understanding of the definition of ductility in the table, what can you infer about the effect of temperature on the ductility of a substance?



Photo credit:

<https://mindsetonline.co.uk/shop/metal-wires-by-the-reel/>

Tensile strength – The ability to resist a force of stretching until breaking.

1. Collect the frozen sample.
2. Suspend the sample vertically by using your stronger hand's index finger and thumb holding the head, with the tail dangling downwards.
3. Bulldog clip the mass carrier (or bucket handle) with the bottom of the clip two centimetres from the tail of the snake. Ensure you can add masses after clipping.

Note If using the bucket and sand option, to prevent spillage and the bucket breaking, when sand is being added, a team member should have their fingers gently under and just touching the handle, ready to catch the bucket when the sample snaps. The bottom of the bucket need only be *just suspended* above the floor.

4. Gradually add masses of 25 - 50 g increments until it continues stretching of its own accord to breaking. Record the total mass the sample was able to support before breaking. If it supports more than your maximum load, then record it with a greater than (>) symbol. E.g., If your maximum load is 500g, then record as >500g and for any further calculations using this figure, use the > symbol instead of the = symbol.

5. Calculate the weight by using the following formula

$$W = mg$$

Where

$$W = \text{weight in Newtons (N)}$$
$$m = \text{mass in kilograms (kg)}$$
$$g = \text{acceleration due to Earth's gravity}$$
$$= 9.8\text{m/s}^2$$



Photo credit:

<https://www.tec-science.com/material-science/material-testing/tensile-test/>

6. Repeat steps 1 – 5.
 7. Repeat steps 2 – 5 twice using the warmed samples.
 8. You will use the following method **once** to find the approximate cross-sectional area (m^2):
 - Use the scissors to make a sharp cut about halfway between the head and the tail of a warm snake
 - Use the marker pen to colour in the cut surface of both exposed cut ends
 - Stamp each end fully within a different 1 cm^2 box on the graph paper
 - The important part of the print is the external outline. After printing, use a pencil to shade the interior part of the shape. Hint - It may be easier to count unshaded squares and subtract from 100
 - Knowing that $1\text{ cm}^2 = 100\text{ mm}^2$, estimate the average shaded area (A) in mm^2 and then convert this to a figure in m^2 . Hint – This is an area, not a length. How many mm^2 are in 1 m^2 ?
 9. Calculate the tensile strength using the following formula
- $$F_T = W \div A$$
- Where
- $$F_T = \text{tensile strength (N/m}^2\text{)}$$
- $$W = \text{weight in Newtons (N)}$$
- $$A = \text{cross-sectional area (m}^2\text{)}$$
10. Using your understanding of the definition of tensile strength in the table, what can you infer about the effect of temperature on the tensile strength of a substance?

Make an overall summary statement of how temperature affects each of the three properties tested.

Research task

Composite materials are formed by combining two or more varied materials. Composites have a number of benefits over traditional materials.

Research composite materials used in satellites and the useful properties of each of these materials. Tabulate your findings.

Australian Curriculum

Investigate how advances in technologies enable advances in science, and how science has contributed to developments in technologies and engineering (AC9S10H02)

Plan and conduct valid, reproducible investigations to answer questions and test hypotheses, including identifying and controlling for possible sources of error and, as appropriate, developing and following risk assessments, considering ethical issues, and addressing key considerations regarding heritage sites and artefacts on Country/Place (AC9S9I02), (AC9S10I02)

Select and use equipment to generate and record data with precision to obtain useful sample sizes and replicable data, using digital tools as appropriate (AC9S9I03), (AC9S10I03)

Select and construct appropriate representations, including tables, graphs, descriptive statistics, models and mathematical relationships, to organise and process data and information (AC9S9I04), (AC9S10I04)

Analyse and connect a variety of data and information to identify and explain patterns, trends, relationships and anomalies (AC9S9I05), (AC9S10I05)

Assess the validity and reproducibility of methods and evaluate the validity of conclusions and claims, including by identifying assumptions, conflicting evidence and areas of uncertainty (AC9S9I06), (AC9S10I06)

Construct arguments based on analysis of a variety of evidence to support conclusions or evaluate claims, and consider any ethical issues and cultural protocols associated with accessing, using or citing secondary data or information (AC9S9I07), (AC9S10I07)

Write and create texts to communicate ideas, findings and arguments effectively for identified purposes and audiences, including selection of appropriate content, language and text features, using digital tools as appropriate (AC9S9I08), (AC9S10I08)

Design and Technologies

Analyse and make judgements on how the characteristics and properties of materials are combined with force, motion and energy to control engineered systems (AC9TDE10K03)

Analyse and make judgements on how characteristics and properties of materials, systems, components, tools and equipment can be combined to create designed solutions (AC9TDE10K06)

Analyse needs or opportunities for designing; develop design briefs; and investigate, analyse and select materials, systems, components, tools and equipment to create designed solutions (AC9TDE10P01)