Investigating how freezing affects materials

Installation of MIRI

Background

The James Webb Space Telescope needs to withstand the extremely cold temperature of deep space. The team working on the design of the telescope therefore selected materials to build it that would be able to withstand extremely cold temperatures. They did this by testing materials and how their properties changed when they were cryogenically frozen (taken to very low temperatures). This was to simulate the temperature that the telescope will be operating in once it is in space.

Overview

In this activity children investigate how the properties of different materials change when they are frozen. This activity may be done over two sessions. In the first session children find out about one of the problems that the design team working on the Webb Telescope had: that the space facing side of the telescope needed to withstand very cold temperatures. They think about the temperatures of some familiar things and find out how some materials change with very cold temperatures. They then plan how they might test various materials to see how freezing them affects their properties. They should decide on which materials they will test, how they will record any observations and how they will present this information back to the class. In a second lesson they test the effects of freezing on their chosen materials and report their findings.

Curriculum areas

- Materials and their properties
- Working scientifically

Investigating how freezing affects materials

Learning objectives

To explore how freezing affects the properties of materials.

To understand aspects of testing of the James Webb Space Telescope by its design team.

Big questions

What is it like in space?

Why do we want to explore space?

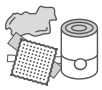
What do space engineers and designers do?

Vocabulary

Stretchy, breakable, hard, soft, strong, weak, tough, brittle, stiff, rigid, flexible, absorbent, waterproof, smooth, rough, transparent, opaque, magnetic, non-magnetic, translucent.

Resources

Trays to drop frozen materials into



A selection of materials such as: Blutack, wood, clingfilm, hard plastic, cotton, paper, card, wool, foam, cornflour, rubber, sponge, cork, leather, polystyrene etc.

Advance preparation

Print out the picture cards for use in groups or as a whole class exercise. Draw a line on the board to represent a temperature scale or thermometer, making sure there is plenty of space below 0°C.

For the second session a sample of each material chosen will need to be placed in a freezer for several hours, ideally overnight. The frozen materials should be taken out of the freezer as late as possible before being explored by the children.

Safety

Make sure children have dry hands before touching the frozen materials. Any ice forming on the surface, could stick to wet hands. Avoid using metals, as these can cause freezer burns to skin if handled at cold temperatures.

Make sure that children are wearing eye protection if dropping the frozen materials. Depending on the material used any small parts breaking off could cause injury.

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Introduction

Show children the picture of Webb (slide 2), and ask them if they know what it is? Ask them to explain their reasoning. Ask them what it is designed to do and where it will be situated? Explain that it is a space telescope that will collect infrared radiation, (heat) coming from distant stars and planets, so scientists and astronomers can find out more about how they are formed. It will orbit the Sun at a point 100 million miles away from Earth.

Show them the image of where the telescope will be in space showing them the temperature, (slide 3).

Explain that the temp on the side of the telescope facing into space is extremely cold (-220 C). Ask why think it is so cold? (It is facing away from and at a very far distance from the sun.) So the materials that the space facing part of the telescope is made of need to be able to withstand extreme cold. The materials scientists and engineers who worked on the design of the telescope tested possible materials and how they changed after extreme cold, so they know that they won't break or lose strength at these extreme temperatures.

Activity - How cold?

First ask the children what is the coldest thing they know? Ask them if they know what temperature it is? Show them the different pictures and ask them to put them in order starting with the coldest and going to the least cold. This can be done as a whole class activity or in groups.

Ask children to give reasons for their ordering. They may even provide ideas for what temperature they think the cards could be.

This activity should generate lots of discussion and if children can provide valid reasoning for their answers then there should be some variability in answers. Here are suggested answers:

- Milk in the fridge is around 3°C. This can vary between 1°C-4°C depending on how cold your fridge is.
- Slush drink is around -3°C. The sugar in the drink lowers the freezing point of the liquid.
- Hot Chocolate is around 58°C. It is often served much hotter, but this may scald your mouth.
- Temperature in a classroom is around 20°C. It should be no lower than 18°C and no higher than 24°C. Children may consider how we try to maintain a comfortable temperature in a classroom.
- A snowy day in UK is around -7°C. It can be anything below 0°C, if the temperature increases the snow will begin to melt.
- A summer's day in UK is around 26°C. This can obviously vary and can reach 32°C, but this is quite unusual.
- Ice cube is around -6°C. Home freezers will vary from -4°C to -10°C
- A cold drink straight from the fridge is around - 4°C. This like the milk will depend on the temperature of the fridge.

Show children a clip of how materials change after being cooled by liquid nitrogen, for example: https://www.youtube.com/watch?v=T8AnkEqh3ig

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Explain that Liquid Nitrogen is -196 C, ask if they think it is as cold as Webb in Deep Space? Ask them to show where it would be on the scale.

Ask them what happens to these materials after cooling? What word do we use for something that breaks easily? (brittle)

Explain that the temperature in Deep space is even colder than liquid nitrogen. It is around -2700C. The temperature of the telescope on the cold side will still be about 50 degrees above deep space temperature. What temperature will this be? Put this on the scale.

You may wish to show some or all of this short video, which explains the temperature of deep space:
https://www.youtube.com/watch?v=QC2tdZEHczk&list=PLcy1hEnsejK22GOXkFNRGzjEUwyRDuVpj&index=11

The temperature of the telescope on the cold side will still be about 50 degrees above deep space temperature. Webb is looking at objects which appear to be emitting light at temperatures as low as 100 degrees above deep space temperature. To be able to see these objects a telescope has to be made cooler than these objects but it will still be hotter than deep space.

Ask why would this be a problem if the materials used to build Webb became brittle when cooled?

Tell the children they are going to work like the materials scientists working on Webb to investigate what happens to a range of materials when they are made extremely cold. Explain that we can't use liquid nitrogen to freeze things in class, so will need to think of our own test.

Challenge the children to design an investigation to see how the properties of material change after freezing. Ask them to decide what equipment they will need, how they will carry out their tests and how they will record their results or observations and report back to the class on their findings. You can provide prompts, or use the planning grid provided, if needed.

After 10 mins ask the children to feed back their ideas of how they will investigate the change in materials after freezing. If they need any support show them the two samples of a material, one frozen and one not and ask they to describe the properties. Ask them if the properties of this material change after freezing?

Worksheets are provided for use in class, but it is more challenging for children to design their own way of recording observations/test results.

One idea to investigate would be to find out which materials become most brittle when frozen?
Put them in the freezer for a day. Children design a test - Drop test? Do they break/crack remain solid?

Further links

James Webb Space Telescope, NASA site: https://jwst.nasa.gov/index.html

James Webb Space Telescope, ESA: http://sci.esa.int/jwst/