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OUR EXISTENCE

Sub zero

This resource explains how an indigenous population has created an engineering solution to the problems they encounter in extreme cold, including building safe shelters and keeping warm.



SUB ZERO

TEMPERATURE

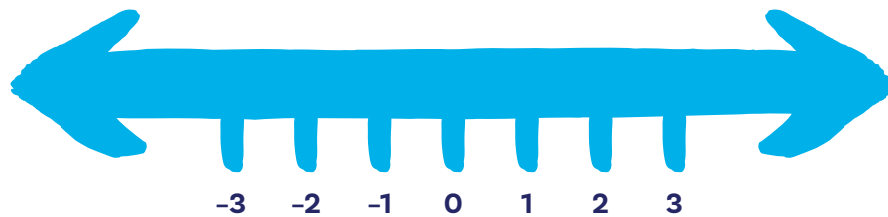
Temperature is a measure of how hot or cold an object is.

There are several temperature scales: degrees Celsius (°C), Fahrenheit (F), and Kelvin (K) are the most widely used scales for temperature.

NEGATIVE NUMBERS

A positive number is any number above zero. Positive numbers are written with no sign in front of them and they are counted up from zero to the right on a number line.

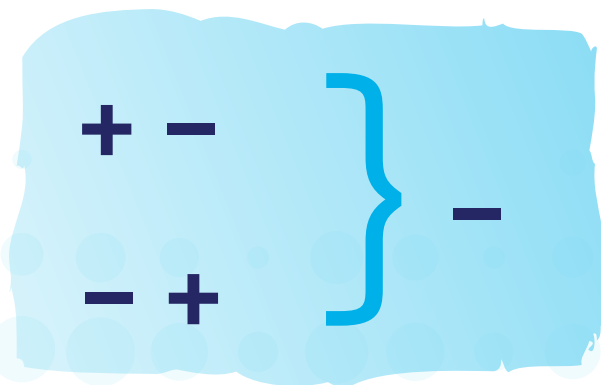
Any number below zero is a negative number. Negative numbers are written with a '-' sign in front of them and are counted down from zero to the left on a number line.



Activity 1

There are rules to use when adding, subtracting, multiplying and dividing positive and negative numbers.

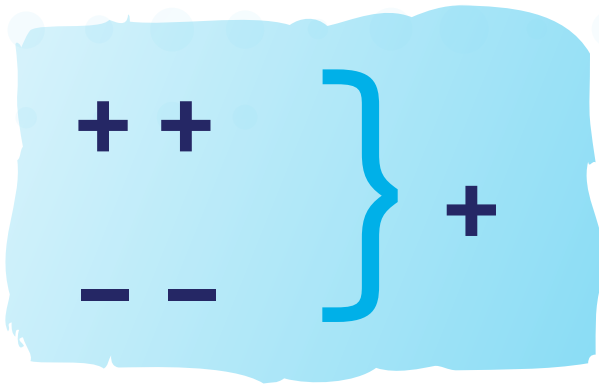
The rules for addition and subtraction are if two different signs appear next to each other, then the signs can be replaced with a subtract sign, for example:



■ $3 + -7 = 3 - 7 = -4$

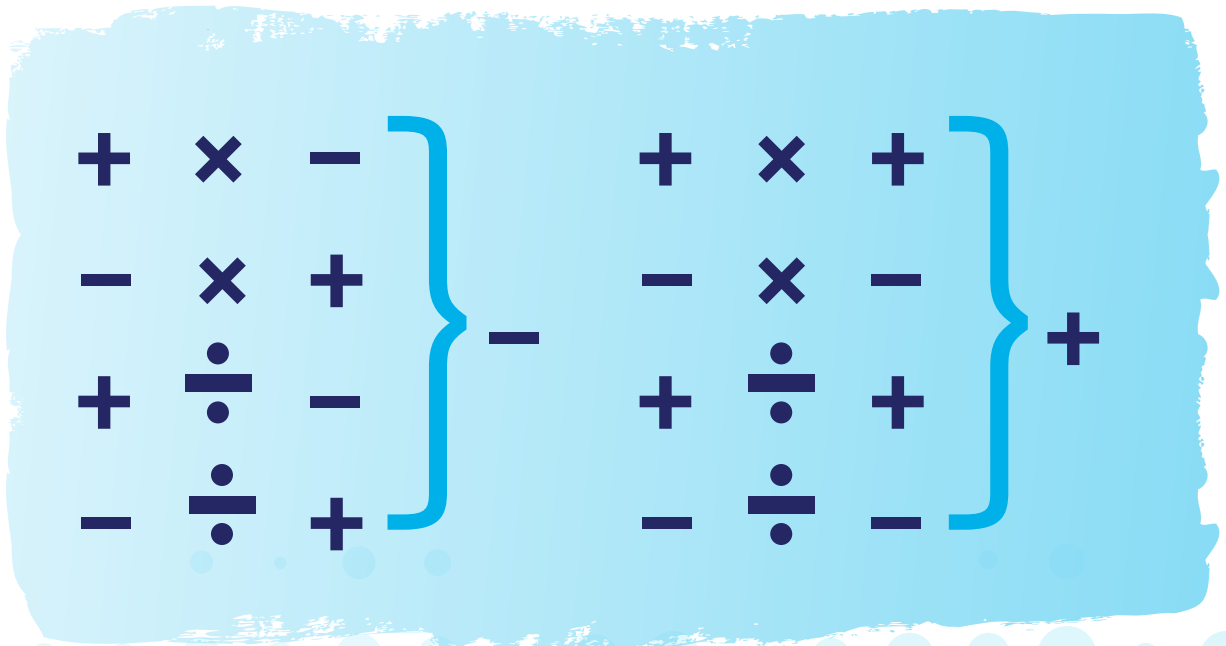


However when two of the same signs appear next to each other then they can be replaced with an addition sign, for example:



■ $3 - - 7 = 3 + 7 = 10$

The rule for multiplying and dividing is very similar. When the signs are different the answer is negative and when the signs are the same the answer is positive.



For example:

■ $3 \times 7 = 21$

■ $- 3 \times -7 = 21$

■ $3 \times - 7 = -21$

■ $-3 \times 7 = -21$

Complete the table by converting the following temperatures from Celsius to Fahrenheit.

$$F = \frac{9}{5} \times ^\circ\text{C} + 32$$

F	°C
	-50
	-30
	-10
	10
	30
	50

- Use this data to plot a conversion graph with Fahrenheit on the y axis and Celsius on the x axis.
- Use the graph to work out the gradient and intercept of the line.
- How does this relate to the equation?

Hint

To work out the gradient of a straight line graph, pick two points along the line and draw a right-angled triangle with the graph line as hypotenuse. Then use the scale on each axis to find the triangle's vertical length and horizontal length. The gradient can be calculated using **vertical length ÷ horizontal length**.

The intercept is the point at which the line crosses the y axis.

STRETCH AND CHALLENGE 1

Plot the following points on a separate graph.

Use this to work out the equation for converting Fahrenheit to Celsius.

F	°C
-50	-45.6
-30	-34.3
-10	-23.3
10	-12.2
30	-1.1
50	10

Check your equation by rearranging the equation below.

$$F = \frac{9}{5} \times ^\circ\text{C} + 32$$

Hint

The equation for a straight line graph is:

$$y = mx + c$$

Think about which unit should be on the x and y axis.



INUIT ENGINEERING

Igloos are built with the optimal ratio between height and diameter to give the structure strength. The catenoid shape of the igloo eliminates tension on the structure that would otherwise cause the igloo to bulge or collapse inwards. The structure can also withstand excessive snowstorms.

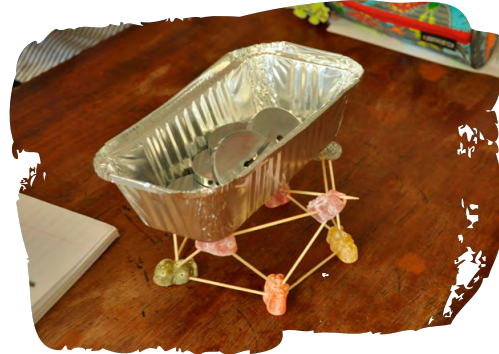
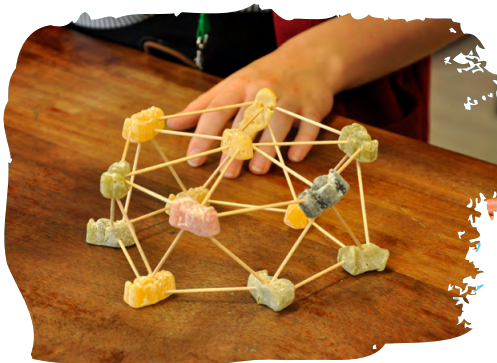
The material used to build an igloo, snow, also helps insulate the building. Little pockets of air are trapped in the snow, reducing the transfer of heat through the walls. On the outside of an igloo, temperatures can be as low as -45°C , but on the inside the temperature may range from -7°C to 16°C when warmed by body heat alone. Inuits also use animal skins to line the floor as further insulation and blubber lamps for light and further heat.



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Activity 2

In small groups, build an igloo structure from toothpicks and jelly sweets.



- Use a tray to place weights on top of the igloo. Record how many weights the igloo structure can hold before collapsing.
- Now build a cube and repeat the experiment to find out how many weights a cube structure can hold.
- Which is the strongest structure?

STRETCH AND CHALLENGE 2

Use what you have learnt to design and build the strongest structure. How many weights can it hold?

Cover your structure with any material you have available. Test your structure against the elements by using a fan to simulate a strong wind and flour to act as snow in a blizzard.

DANGERS OF THE COLD

There are many dangers to being exposed to cold temperatures.

When the body is exposed to cold temperatures the blood vessels narrow and blood flow to extremities such as fingers, toes, ears and the nose is restricted. This is to keep blood flowing to vital organs. As the extremities get colder, typically when exposed to temperatures below 0.55 °C, the fluid in the tissues can freeze into crystals, which can cause cell and tissue damage. The lack of blood flow also deprives the tissue of much needed oxygen, causing further damage.

FROSTBITE

The symptoms of frostbite usually begin with affected areas turning white, feeling cold, and developing pins and needles. If left in cold temperatures, this can develop into superficial frostbite; frostbite that affects the top layers of skin and tissue. The affected parts will feel numb, and hard to the touch. When thawed the skin will blister and turn red. The skin and tissue under the blister is usually intact, however, treatment is needed to ensure there is no lasting damage. If the frostbite becomes advanced, the skin colour becomes blotchy and eventually blue. When the skin thaws from advanced frostbite, blood filled blisters can form and turn into black scabs; this is a sign of tissue death and amputation might be necessary.



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HYPOTHERMIA

Hypothermia is caused by a fall in the body's core temperature, which is 37 °C for humans. Hypothermia is triggered at 35 °C and people start to lose consciousness at approximately 32 °C. Mild or moderate hypothermia can cause shivering, pale and cold skin, and even tiredness, confusion and irrational behaviour. Severe hypothermia can cause shallow breathing, weakening pulse and unconsciousness.

KEEPING WARM

Activity 3

Disposable vs reusable hand warmers

In pairs you will investigate the following question:

Which hand warmer is better for Inuits?

To answer this question, investigate the following:

- How do you activate the hand warmers? What do you think might be happening when the hand warmer is activated?
- How hot does each hand warmer get?
- How long does each hand warmer remain hot once it has been activated?

What else do you need to consider? Try testing other aspects of the hand warmers that you think are important.

Present your findings to the rest of the group.



NOTES FOR TEACHERS

ACTIVITY 1

The following points should be plotted on a graph:

F	°C
-58	-50
-22	-30
14	-10
50	10
86	30
122	50

If students are struggling with the scale, then they should use the following scales:

For 1 mm graph paper, each 1 mm square = 1 degree for both Celsius and Fahrenheit.

For 2 mm graph paper each 2 mm square = 2 degrees for both Celsius and Fahrenheit.

It is not recommended that 1 cm square graph paper is used as the scales are not precise enough to find the intercept.

The gradient of the graph is 1.8 which is $\frac{9}{5}$ as a fraction, and the intercept is 32.

Pupils could use excel to plot their graph to check the working.

STRETCH AND CHALLENGE 1

For this graph, each 1 mm square should represent 0.5 degrees for both Celsius and Fahrenheit. If using 2 mm graph paper, each 2 mm square should represent 1 degree for both Celsius and Fahrenheit.

The equation from the graph should be: $^{\circ}\text{C} = \frac{5}{9} \times F - 17.8$

When calculating the gradient, students might keep the answer as a decimal, 0.56, which is $\frac{5}{9}$ as a fraction. Because of the scale of the graph students could find that the intercept is -17.5.

The equation can be checked by rearranging the previous equation: $F = \frac{9}{5} \times ^{\circ}\text{C} + 32$

Minus 32 from both sides: $F - 32 = \frac{9}{5} \times ^{\circ}\text{C}$

Multiply by $\frac{5}{9}$: $(F - 32) \frac{5}{9} = ^{\circ}\text{C}$

Multiply out the brackets: $\frac{5}{9} \times F - 17.8 = ^{\circ}\text{C}$

ACTIVITY 2

The easiest dome structure to build is a geodesic dome, which work as a good approximation to the igloo shape. However, if students build geodesic structures they should be made aware the igloo has a slightly different structure to avoid later confusion. You could extend this activity with a competition between the groups to see who is able to build the strongest structure.

ACTIVITY 3

Conduct a full risk assessment before this activity. Students should be aware of the risk of burning and handle hand warmers with care. You could extend this activity by making your own hand warmers. The Royal Society of Chemistry has produced an activity called 'Hand Warmers', which includes a method for making a reusable hand warmer in school. The resource can be found at <http://tinyurl.com/rschandwarm>



Royal Academy of Engineering

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