

## Ice power

### Freezing water in a syringe to measure the expansion

Most pupils are aware that water expands when it freezes, but by how much? Demonstrate as follows. Fill a 10ml or 20ml syringe with cold water, sealing the nozzle end (with Blu Tac™ or clay). The result is clearer if the water is coloured slightly with food colouring, as shown in the photographs. Measure the length of the water column in millimetres. Place it in a freezer in between lessons. Measure the length of the ice column in millimetres, and calculate the percentage expansion as water turned to ice as  $(\text{length of ice} - \text{length of water}) / (\text{length of water}) \times 100\%$ .



The syringe filled to the 9 ml mark with water.



The syringe after freezing  
(Photos: Peter Kennett)

Show pupils photographs of “frost damage”, but point out that it is the successive freezing and thawing that eventually weathers rocks down, rather than one single episode of freezing.



The effects of freeze/thaw weathering in a porous limestone  
(Photo: Peter Kennett)



Rocks shattered by freeze-thaw weathering on Glyder Fawr, Wales,  
(Photo: P007204, BGS. Contains public sector information licensed under the Open Government Licence v2.0)

Ask pupils where on Earth freeze-thaw weathering is likely to be most active:

- beneath polar ice sheets;
- on mountain tops;
- in cold arid deserts;
- in hot arid deserts.

(A. On mountain tops where there is frequent freezing and thawing; under polar ice sheets it is frozen most of the time, in cold arid deserts there is not enough water, as also in hot deserts, where it usually does not become cold enough either).

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## The back up

**Title:** Ice power

**Subtitle:** Freezing water in a syringe to measure the expansion

**Topic:** A simple demonstration, using a 10 or 20 ml syringe, of the power of water to expand when it freezes.

**Age range of pupils:** 10 – 16 years

**Time needed to complete activity:** A few minutes to set up in one lesson and a few minutes to investigate the outcome in the next lesson.

**Pupil learning outcomes:** Pupils can:

- make an accurate estimate of the percentage expansion of water when it freezes;
- apply their lab observations to natural occurrences of freeze/thaw weathering.

**Context:** This activity may be used in either science or geography lessons on weathering. It can also be used in discussions of molecular theory and changes of state. For the most accurate measurements use pure (distilled or de-ionised) water at as near to 4°C as possible.

**Following up the activity:** Pupils could:

- look for evidence of freeze/thaw damage after a few frosty nights near their homes;
- measure the density of ice, compared to that of water (Weigh the syringe empty and weigh again with the water in it, to find the mass of water alone; weigh it again with the ice (it should be the same). Density = mass/volume in g per ml (cc). The volume will be different after the water has turned to ice and expanded.
- calculate what percentage of an iceberg lies below the water surface taking the average relative density of seawater as 1.025. (See Underlying Principles for the calculation)

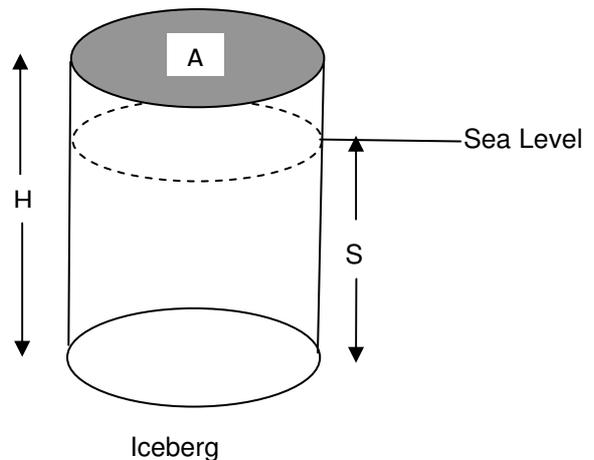


Icebergs near the Antarctic Peninsula (Photo: Peter Kennett)

**Underlying principles:**

- Water is one of very few liquids which expand, rather than contract, on freezing.
- Pupils are likely to find that water expands by about 9% on freezing, using the simple method described.
- Water is the only non-metallic substance on Earth whose density in solid form is less than its density in liquid form (*Wikipedia*).
- Ice made from pure water at 0°C has a relative density of 0.917. This is less dense than pure liquid water, which has a maximum density at 4°C defined as relative density = 1.000. Thus between 0° and 4°C water is about 8.3% denser than ice.
- The volume of water is equal to the area of the tube of the syringe (A) x the length of the water column ( $A = \pi r^2$  where r is the radius, ie half the diameter). The volume of ice is equal to A x the length of the ice column. The expansion is equal to the difference between the measurements, and the coefficient of expansion is the expansion divided by the original length.

- If the water is measured above or below 4°C the expansion on change of state will be slightly under-estimated.
- Iceberg problem – calculate it as a vertical cylinder.



The total mass of the iceberg is height (H) x area (A) x density =  $H \times A \times 0.917$

By Archimedes' Principle the mass of seawater displaced by the submerged part of the iceberg is equal to the mass of the iceberg.

The mass of seawater displaced by the submerged part is submerged length (S) x area (A) x density =  $S \times A \times 1.025$

$H \times A \times 0.917 = S \times A \times 1.025$  giving  $S/H = 0.917/1.025 = 0.898$ : i.e. 89.8% of the iceberg is submerged (nine tenths)

**Thinking skill development:**

Thought processes of construction are involved when observing the outcomes of the demonstration. Bridging skills are needed to relate the observations to the real world.

**Resource list:**

- 10 or 20 ml syringe
- Blu tak™, clay, Plasticine™ or similar substance to block the nozzle of the syringe
- pure (distilled or de-ionised) water (optional)
- access to a freezer or freezer compartment of a fridge

**Useful links:** Earthlearningidea Weathering-rocks breaking up and breaking down - matching pictures and descriptions of weathered rocks with the processes of weathering that formed them.

**Source:** Written by Peter Kennett of the Earthlearningidea Team, with acknowledgements to Martin Devon for assistance with the iceberg calculations. The original idea was published by P. Williams in *Geology Teaching* 9.1, March 1984.

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