**Experiment and game set-up and instructions**

1. **Silly-Putty**

This is an activity to get students thinking about states of matter and behaviour of materials on different timescales. It is very flexible in terms of location and could be done at desks or in a hall.

**Equipment:** Enough silly-putty for each student to have a ~2cm diameter sphere, tray or wooden board, and stack of books (or retort stand, boss-head, and clamp)

*Notes:* Silly putty can be made from PVA glue, contact lens solution (make sure it has boric acid and sodium borate listed in the ingredients), bicarbonate of soda, and optional food colouring. Instructions to make silly putty are given in set up below.

**Total time:** 5 min for set-up, ~ 3 min for experiment

**Set up:** Make the silly putty (on day of the workshop). Amounts given for 30 students:

1. Pour 18 floz (530ml) PVA glue into a bowl.
2. Mix 1½ tsp (7.5ml) of bicarbonate of soda into the glue.
3. (Optionally) mix in any food colouring desired.
4. Mix 4½ tbsp (67.5ml) of contact lens solution into the glue.
5. Stir together as the glue forms a putty.
6. Once it all comes together, knead it for a few minutes until it's smooth.
7. Remove the putty from the bowl and store in a plastic, airtight container (e.g. Ziplock bag, Tupperware) until needed.

Set up sloping board as shown in figure 1. Form ~2cm diameter balls of silly-putty so that there's enough for each student to have one, and either place on desks, or on a tray which students can collect them from. If it has been left to sit, the putty may need a little kneading before it can be made into balls.

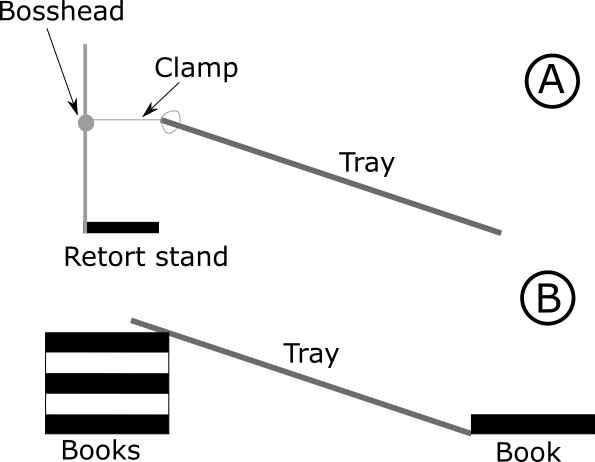


Figure 1 - Two possible set-ups of the sloping board

**Running the experiment:**

*Part one:* Students collect their silly putty and have a play with it, seeing how it behaves on different timescales. This is guided by the question: "Have a play with the silly putty and then talk in groups about its material properties. How does it behave on different timescales? Is it a solid, a fluid or something else?" displayed on the board or power-point.

Collect some feedback on what they observed, and then place a large piece of silly-putty at the top of the slope. Leave this for an hour or more until part two.

Collect in silly-putty when finished with the first bit of the experiment, but if you have enough putty then students can be allowed to take a bit home with them at the end of the workshop (especially if you're not allowed to re-use putty for hygiene reasons).

*Part two:* Come back to the silly putty which was left on the tray and discuss how it has flowed down the slope.

1. **Convection**

This is a standard convection tank demonstration. In a school it might be easiest to follow the details of however the school usually does this experiment because the details are not really important. If this is being done elsewhere, there is no 'standard' convection experiment at the school, or for any other reason you can follow the below instructions. This is designed to be carried out by the class leader and observed and discussed by the students.

**Equipment:** Convection or fish tank (a large plastic or glass tank), tap water, two flat-topped and insulated bowls, ice, boiling water, red and blue food colouring

**Total time:** 5 min for set-up, ~ 3 min for experiment

A close up of a logo

Description automatically generated**Set up:** Directly prior to the start of the workshop, fill one insulated bowl with ice and the other with boiling water. Place the tank so that it is resting on the two bowls, with one supporting either end of the tank (see figure 2). Fill the tank with tap water and leave.

**Running the experiment:** Gather around the tank. Put about 5 drops of red food colouring into the side over the boiling water, and about 5 drops of blue food colouring into the side over the ice. Watch the convection; discuss the movement of water seen, and the reasons behind it.

Figure 2 – Set up for convection tank experiment

1. **Seismic tomography**

This is an activity to explain how seismic tomography works using first arrival times. Students act as seismic rays and receivers in order to work out which colour is 'fast' and which is 'slow'. It is designed to be done outdoors, or in a large indoor space such as a hall. This activity is for 16 students at a time, so with a class of 30 you might want to do it twice, so everyone gets a go.

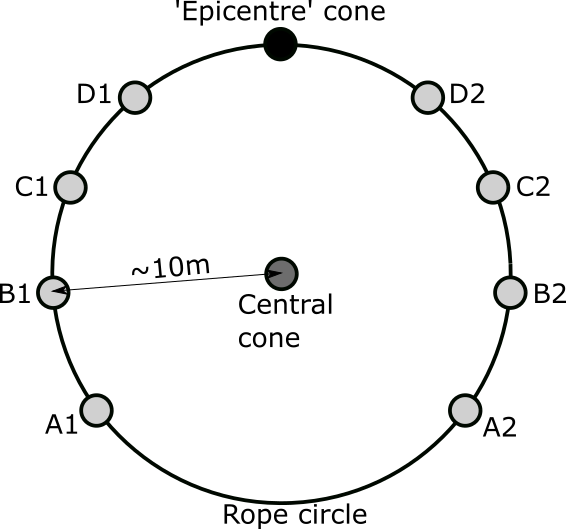


Figure 3- Set-up for tomography activity

**Equipment:** 60m of rope, 8 stopwatches, 8 mini whiteboards, PE cones of 3 colours e.g. (8 blue, 1 red, and 1 yellow), mats of two colours

*Notes:* The rope can be replaced by another way of marking a circle, or dispensed with entirely. The mats can be substituted for anything which are safe for students to run on and can be used to delineate two distinct areas.

**Total time:** 3 min for set-up, ~ 10-15 min for experiment

**Set up:** Set up as shown in figure 3, placing the [blue] cones at positions A1-D2, [red] cone in the centre and [yellow] cone at the 'epicentre'. This part of set-up could be done before the workshop, but could also be used as an opportunity to discuss seismometer arrays and explain what all the bits in this model are representing.

**In-workshop set up:**

Show the students the two velocity-anomaly mats and explain that these will represent patches in the mantle where seismic waves move faster or slower than usual. Tell them which colour means faster seismic wave speed and which slower (ideally, this should be red for slow speeds and blue for fast). Explain that you will secretly place these mats in the Earth, and it will be their job to work out where.

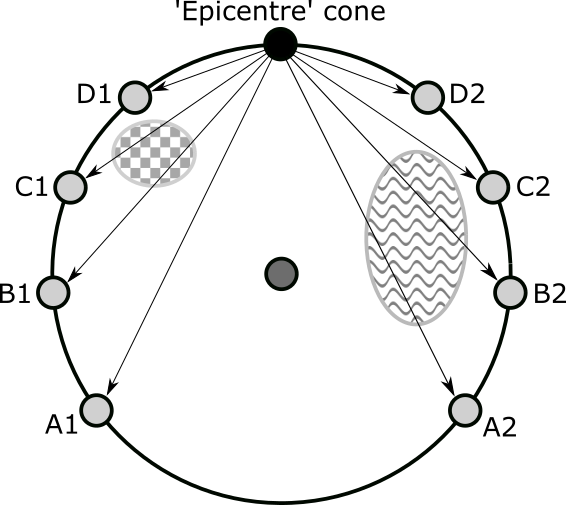


Figure 4 - Showing paths of the 8 seismic rays on the overall set-up

Give stopwatches, mini whiteboards, and pens to 8 students and get them to stand at cones A1-D2, facing away from the circle. They are representing the seismometers/receivers.

Choose another 8 students to be the seismic rays. They will each walk from epicentre to one of the receivers. When they get to the fast patch they should run across it, when they get to the slow patch they should walk very slowly across it – the rest of the time they should try to walk at the same speed (decide this with them before starting e.g. 1 long step per second.)

**Running the experiment:** Once everyone is in place:

1. Tell the receivers to start recording. Receivers start their stopwatches simultaneously.

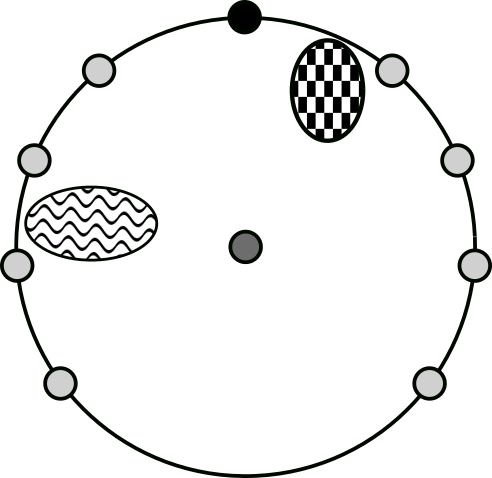
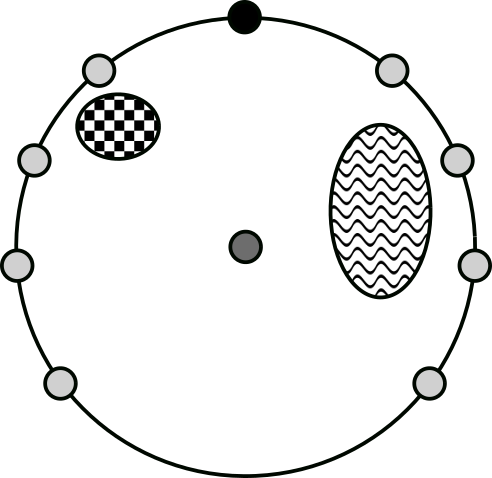


Figure 5 - Two possible positionings for the velocity anomaly mats

1. After a second or so, silently signal to the seismic rays to start. 'Earthquake' happens, seismic rays walk across the 'Earth' to their receiver (figure 4).
2. Receivers stop their stopwatches when they are tapped on the shoulder by a seismic ray. Receivers record their times on mini whiteboards.
3. Secretly put down the two velocity-anomaly mats (shown as patterned circles in figure 5) within the 'Earth'.
4. Re-run steps 1-3 with the velocity anomalies present.
5. Receivers compare their two recorded times and work together to work-out where the two mats were placed. Seismic rays can help by re-tracing their steps (at a constant speed) so that the receivers can constrain where the anomalies where. If the students are stuck, remind them to compare their two times.
6. Receivers put the mats where they think the anomalies were, and the seismic rays tell them whether they got it right.

Repeat the experiment with the other half of the class. When you do so, use a different configuration of the two velocity anomaly mats.

1. **Seismic wave speed and temperature**

This is an activity to explain how seismic wave speed depends on temperature. It takes the form of a race between a 'hot' team and a 'cold' team. It is designed to be done outdoors, or in a large indoor space such as a hall. This activity can be adapted to work for any number of students at a time.

**Equipment:** None

**Total time:** ~ 6 min for experiment

**In-workshop set up:** Split the class into two groups. Group A should be about 1/3 bigger than group B, so with about 30 students group A should have roughly 18 students and group B should have roughly 12.

Get group A to stand in a line so that each person can just reach to tap the back of the person in front (students approximately an arms' length from one another). Now get group B to form a line parallel to this, spaced slightly wider so they cover the same distance total between the first and last person.

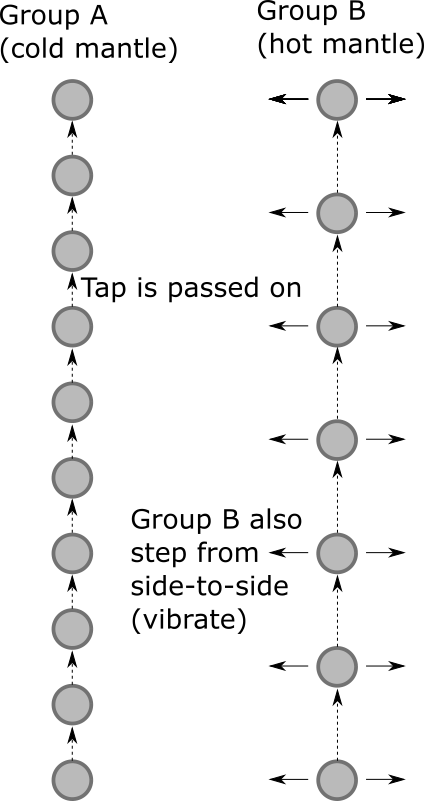


Figure 6 - Diagram of set-up and running of seismic wave-speed and temperature experiment. Grey circles represent students.

Group A represents cold mantle, and group B represents hot mantle. This is why group B are spread further apart, and also why they need to 'vibrate' (step from side-to-side) during the experiment. We are going to see which temperature seismic waves move faster through. (See figure 6 for visual explanation.)

Explain what to do when you say 'go', then start the experiment.

**Running the experiment:**

1. Signal go. The person at the end of each group goes to tap the person in front of them to start the 'wave'.
2. When each person is tapped by the person behind them, they then move forwards to tap the person in front of them.
3. The 'wave' travels through the two groups, hopefully at different speeds.
4. Discuss which 'wave' got to the front of the line first (this should be group A; cold mantle).
5. Optionally, re-shuffle the groups and repeat the experiment in the name of reproducibility.
6. **Making hotspot tracks**

This is an activity to demonstrate how hotspot tracks, such as a Hawaiian ridge, are made. This is designed to be ideally be done in a science lab with access to sinks. However, it can be adapted to be done in a hall, with tubs/buckets of water as emergency fire-extinguishers. This activity can be done with any number of students, but for larger groups additional adult supervision will be needed to ensure students are behaving safely.

**Equipment:** Tealight candles or other small candles (enough for at least one between two), matches, wooden splints, one hotspot printout each (on plain paper) plus spare copies, sinks/plastic tubs or buckets filled with ~5cm depth of water

**Total time:** ~ 5 min for experiment

**Set up:** Print out the hotspot printouts, fill the sinks or tubs/buckets with water

**In-workshop set up:** Hand out the printouts, tealights, and splints to the students. Explain that in this experiment the tealights represent the hotspot, and the paper represents the pacific plate. Their task is to produce a hotspot track of burns, following the Hawaiian ridge.

*Safety warnings*: \*\*do students need to wear safety goggles? YES \*\* Students with long hair must tie their hair back. Keep the paper no closer than ~2cm from the top of the flame. Keep the paper moving slowly over the tealight – when a patch begins to look black and smokes you need to move it on. If the paper sets on fire (with flames) put the sheet into the sink/tubs full of water, and get a new one.

**Running the experiment:** Use a match to light the 'master candle' at the front of the room. Students should use a splint to carry a flame over to their tealight in order to light it. Students follow instructions to produce hotspot burn tracks. Keep a careful eye on the students to ensure that they are all behaving safely.

**Discussion points:** Most students will get a series of burn 'dots' rather than a smooth line of burn. This is like real life, where we see a series of discrete volcanoes/islands along the hotspot track, rather than one long volcano.

1. **Creep**

This is an activity to explain how small motions of crystals can add up to flow in a solid over time. It takes the form of a race between two piles of e.g foam bricks. It is designed to be done outdoors, or in a large indoor space such as a hall. This activity can be adapted to work for any number of students at a time.

**Equipment:** A rope or otherwise to delineate the finish line, a large number (30-60) of similar objects e.g. foam blocks, carboard boxes, tea-lights, books. Ideally these objects are 3D, stackable, and can't roll.

**Total time:** 3 min for set-up, ~ 8 min for experiment (longer for a larger total number of objects)

**Set up:** Organise the objects into two evenly sized piles so that all objects are touching at least one another. At a distance of about 10x the length of an individual object from these piles mark a finish line (this is ~3m for objects of about 30cm length). If you have a larger number of objects, say 60 in total, you can make this distance longer (~25x the length of an individual object). The bottom line is that it has to be shorter than the total length of all the objects in one pile when lined-up touching. (See figure 7 for visual explanation.)

**In-workshop set up:** Split the students into two equal groups, each group gets a pile. Each object in the pile represents a crystal in the mantle. The challenge is to be the first group to get at least one object over the pre-defined finish line.

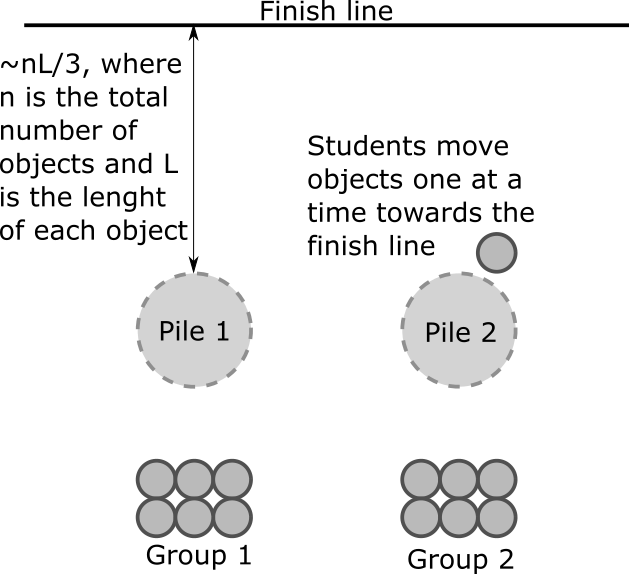


Figure 7 - Set-up for creep experiment

Rules for moving objects:

* Team members should take it in turns to move objects, so everyone gets a go.
* Only one person in the team may move an object at any time.
* Objects can only be moved a maximum of a handspan at a time.
* Every object in the pile must remain touching at least one other object in the pile.
* You may discuss strategy during the race.

**Running the experiment:** Give a count-down to go, and then let them get on with it, making sure everyone gets a go and the rules are being obeyed. Once the race is over and one team has won, discuss what happened.

**Discussion points:**

* Each movement of an object is like an individual crystal sliding past another, or dissolving and re-crystallising further on.
* These tiny movements added up to a big overall motion.
* The objects have ended up in lines parallel to the direction of motion (pictures of this in ice and peridotite in the power-point).