Merry waves – all year round
Modelling how the energy of seismic waves is transmitted

Hang a series of the plastic balls often used for Christmas decorations on a clothes hanger, as in the photo below. It is best to do this with one piece of string, as this makes it easier to align the balls. Place a ruler through the string to line up the balls in a horizontal row.

Aligning balls in a "Christmas style" wave transmission model with the aid of a ruler.

Photo: Pepe Sellés-Martínez.

Lift the first ball up to the left and let it drop to hit the row – most of the balls will not be displaced, but the final ball will jump away from the row, showing how energy has been transmitted along the row. This shows how the energy from seismic P-waves (longitudinal waves) is transmitted through a system without displacement of matter along the way.

The model can also be used to show the effects of S-waves (transverse waves), since the balls are not joined together and therefore model fluids (where molecules are also not linked together). Lift the first ball up towards you, (at right angles to the line of balls), then let it drop to hit the next ball in the row from the side. Since pressure acts at an angle to the row, it is not transmitted along the row, showing that S-waves are not transmitted by liquids and gases.

It is useful to set up this demonstration with pupils as follows.

Before the demonstration, ask your pupils:

- Which sorts of waves are generated by earthquakes?
  A. Surface waves and body waves.
- What are the differences between surface and body waves?
  A. Surface waves move over the surface of the Earth following an earthquake; P-and S- body waves are transmitted through the Earth.
- What type of force is associated with the transmission of P-waves and in which direction does it act? The same for S-waves?
  A. P-waves are transmitted by compression acting in the direction of transmission and S-waves by shear acting transversely to the direction of transmission.
- Have they seen any models of P- and S-wave transmission?
  A. They may have seen other models of P- and S-wave transmission.
- Which aspects of P- and S-wave transmission do these models reproduce well, and which do they reproduce less well?
  A. The models usually show how waves are transmitted by interactions between molecules, but not how the energy is transmitted.
- How could a model be made to illustrate both wave transmission and energy transmission?
  A. They may describe a 'Newton's Cradle'-like model, as above.

Before using the model, ask:

- What will happen when the left hand ball is: a) lifted sideways and dropped, and b) lifted forwards and dropped to hit the row?
- Why have you made these predictions?

After demonstrating the model, ask:

- Why did the model behave as you saw?
- How is it possible for the last ball to move, whilst the others remain still?
- Why did the ball falling sideways not cause movement of the ball at the other end of the row?
- What would be the effect if some sand were to be put into the balls?

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The back up

Title: Merry waves – all year round

Subtitle: Modelling how the energy of seismic waves is transmitted

Topic: A demonstration of how the vibration of particles by the propagation of pressure waves does not cause noticeable displacement of mass.

Age range of pupils: 12 – 18 years

Time needed to complete activity: A few minutes to discuss and demonstrate the model; longer to assemble it from scratch.

Pupil learning outcomes: Pupils can:

- describe how energy is transmitted in the form of waves;
- note that there is no macroscopic displacement of mass involved in the process;
- explain how P and S waves move though the Earth's interior;
- explain how a tsunami wave propagates though a mass of water.

Context:
Pupils can find it difficult to visualise how energy can be transferred through a material as a wave without noticeable displacement of mass. Many people also think that all waves involve movement of mass – thinking, for example, that the movement of a tsunami wave across the ocean involves movement of masses of water sideways, in the same way as they have seen waves moving across a beach.

Such misconceptions may be related to some models used to show propagation of seismic waves. For example, models using ropes and springs clearly show backwards and forwards movement (for P-waves) or sideways movement (for S-waves) of the mass of material, whereas they are actually modelling the movement of molecules, not the whole mass of the material. This distinction is often not stressed to pupils.

This model has therefore been devised to show how energy is transmitted by P-waves (and not transmitted by S-waves).

Following up the activity:
Test out the effect of adding some sand to each ball, as suggested in the questions to pupils on page 1.

Ask pupils how the model relates to the transmission of tsunami waves, to help them to understand that in tsunami waves too, the wave is transmitted but the water molecules are not greatly displaced by the moving wave.

Try Earthlearningidea activities “Waves in the Earth 1, The slinky simulation” and “Waves in the Earth 2, Human Molecules” showing the propagation of seismic waves, but be wary of the issues described above.

Underlying principles:
- In a solid the atoms are arranged in fixed positions relative to other atoms.
- At the micro-level, P-waves (longitudinal waves) are transmitted by distortion and recovery of the bonds between atoms (inter-atomic bonds).
- At the macro-level, P-waves are transmitted by impact followed by elastic deformation and recovery.
- The model indicates that it is possible for energy to be transmitted from one side to the other of a system without significant displacement of the intermediate components. As the balls are not fixed relative to each other, it is a better model of macro behaviour than micro behaviour.
- Note that there is a slight movement of intermediate balls. This means energy transmission is not perfect and a very small amount is lost at each junction because the balls are not perfectly elastic. Taking the junction between balls as equivalent to faults in the Earth, it is the small energy lost which can be detected by seismographs; if there were no energy lost, the passage of P-waves would not be detected.
- Adding a little sand inside the balls produces greater movement of the intermediate balls, hence less movement of the final ball. The impact on a ball displaces some sand and that movement is not recovered, hence more energy remains in the ball with sand and its movement is increased.

Thinking skills development:
Pupils establish a pattern of the behaviour of molecules when struck by a body wave. Applying the demonstration to the real situation demands bridging skills.

Resources list:
- 7 plastic balls of the kind used for Christmas trees
- a clothes hanger
- about 3m of string
- a 50cm long ruler

Assembling the device.

Photo: Pepe Sellés-Martínez.

Useful links:
http://www.sep.org.uk/publications.asp#waves (Science Enhancement Programme) for a booklet giving simple activities for classroom use, mostly involving inexpensive equipment.
www.bgs.ac.uk/schoolseismology for details of the School Seismology Project, with links to real-time world data on earthquakes.

Source: Pepe Sellés-Martínez, a special production for ELI of Aulagea, Buenos Aires, Argentina.