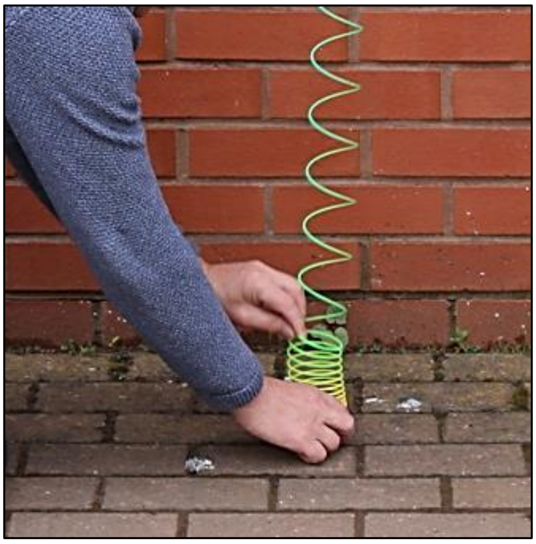
The slinky seismic waves demo
Using slinkies to show how earthquakes produce P-, S- and surface waves

Slinky demo 1
Ask a person to hold one end of a slinky in the air, as shown in the photo.

Then, while you are holding the other end on the ground with one hand, pull the lower coils of the slinky out and down, and then let go, to produce a 'shaking slinky' earthquake. This shows how an earthquake caused by sudden fault movement at a focus deep underground, reaches the Earth's surface at the epicentre.

Slinky demo 2
Explain that, although it was hard to see in the first demo, the 'earthquake' actually produced two sorts of earthquake waves. Show how one sort of wave was formed by pulling the slinky down only. Then let go.



This generates P-waves – the coils bounce up and down (the coils move together in compression, and then move apart in rarefaction as the wave passes) as the shock waves travel up to the 'surface' (and then bounce back again).

Slinky demo 3
Show how the second sort of waves is produced by pulling the slinky out to the side before letting go. This time the slinky shakes sideways as S-waves are produced. The coils shake from side to side as these transverse waves pass through.

Slinky demo 1 repeated
Repeat the first demonstration to show how one 'release' of the slinky produces both P- and S-waves.

Slinky demo 4
Ask two people to hold a second slinky in the air, as in the photo. Bend a paperclip into a hook and attach the second slinky, so that it hangs down. Produce an 'earthquake' by pulling the slinky out and down, as in demo 1. This time, when you release the slinky, the P- and S-waves travel up to the 'surface' slinky at the top, which then bounces up and down in 'surface waves'.

This shows how the shock waves from the focus of an earthquake travel to the surface as P- and S-waves, making the surface move up and down in surface waves. It is the surface waves which cause the most damage in earthquakes. In strong earthquakes, you can see surface waves as the ground moves up and down, destroying buildings, roads and railways and causing injury and death.

The back up

Title: The slinky seismic waves demo

Subtitle: Using slinkies to show how earthquakes produce P-, S- and surface waves

Topic: Two slinky springs used to show how one earthquake produces P-, S- and surface waves.

Age range of pupils: 7 years upwards

Time needed to complete activity: 10 minutes

Pupil learning outcomes: Pupils can:
- describe seismic waves and their movement using correct terminology;
- describe how seismic waves are linked to energy release through earthquakes
- explain how one earthquake can produce P-, S- and surface waves.

Context:
It can be difficult to understand how one sudden movement along a fault plane at the underground focus of an earthquake can cause three different sorts of earthquake waves with different properties. These are:

<table>
<tr><th>Wave type</th><th>Meaning</th><th>Other names</th><th>Features</th></tr>
<tr><td rowspan="2">P-wave</td><td rowspan="2">fastest wave – so arrives first, called primary</td><td>longitudinal – travel by vibration along the material</td><td rowspan="2">travel through solids and fluids (liquids and gases)</td></tr>
<tr><td>push/ pull wave, comPressional wave</td></tr>
<tr><td rowspan="2">S-wave</td><td rowspan="2">slower wave, so arrives second, called secondary</td><td>transverse – travel by lateral movement</td><td rowspan="2">travel through solids only</td></tr>
<tr><td>shake wave, shear wave, sideways wave, slow wave</td></tr>
<tr><td>Surface wave</td><td>movement of the Earth's surface only</td><td>Love waves and Rayleigh waves</td><td>surface movement only</td></tr>
</table>

Note that people often think incorrectly that seismic wave velocity increases because of the increase in density of the medium it travels through. Seismic velocity often does increase as density does, but not BECAUSE of the increase in density. The increase in velocity is because rigidity and incompressibility of the medium increase at faster rates than density.

Following up the activity:
Jean-Luc Berenguer, who devised this activity uses the Japanese mythological explanation of earthquakes as part of his story.

He explains how, before anybody knew the cause of earthquakes, the Japanese believed they were caused by a catfish called Namazu who lived deep in the mud under Japan. He was guarded by the god Kashima, but when Kashima let his guard down, Namazu thrashed about causing earthquakes. The picture shows people being angry with Namazu for causing a big earthquake – but this might cause him to squirm again, causing aftershocks.

The painting of Namazu is in the public domain because it is more than 70 years old.

Jean-Luc crouches on the ground at the bottom of the slinky and explains that Namazu is getting more and more stressed and the god is losing attention, as he pulls the slinky out and down further and further, finally Namazu thrashes – he releases the slinky, and earthquake waves hit the surface.

Underlying principles:
- Wave motion involves the molecule-by molecule movement of the medium through which the wave is being transmitted.
- P-waves travel faster than S-waves.
- P wave velocity is directly proportional to the rigidity of the medium and its resistance to compression (its incompressibility). It is inversely proportional to its density.
- S wave velocity is directly proportional to the rigidity of the medium, and inversely proportional to its density.
- People often think that seismic wave velocity increases with the density of the medium it travels through – it often does, but not because of the increase in density but because rigidity and incompressibility increase at faster rates than density.
- Since fluids (liquids and gases) have no rigidity, they cannot transmit S-waves.
- Surface waves are the wave movement of the Earth's surface, produced as P- and S-waves reach the surface.

Thinking skill development:
Bridging skills are needed to relate the slinky movement to real-world shock wave transmission, triggered by earthquakes. The movement of the horizontal slinky relates to the movement of the ground, damaging buildings and other constructions (S-waves induce shearing in buildings).

Resource list:
- two slinky springs (plastic or metal)
- a metal paperclip

Useful links:
EduMed Observatory (http://edumed.unice.fr/en/) data and didactic resources to teach seismology at school.
The School Seismology Project at: http://www.bgs.ac.uk/schoolseismology with links to real time world data on earthquakes.
The Earthlearningideas, 'Waves in the Earth 1 – the slinky simulation' at https://www.earthlearningidea.com/PDF/76_Slinkies.pdf and Waves in the Earth 2 – human molecules at https://www.earthlearningidea.com/PDF/77_Human_molecules.pdf

Source: Activity devised by Jean-Luc Berenguer, science teacher (Biology and Geology), and project leader for EduMed Observatory (University Côte d'Azur - Géoazur), France.
Thanks to David Bailey for the photos and to Dan Boatright and Nick Sampson for being worthy slinky holders.