Circus Activity: Brickquake

Topic addressed:
Energy dissipation in an earthquake and the unpredictability of earthquakes.

Physics GCE AS and A Level specification references:

AQA A	3.2.3	Waves. Progressive waves. Oscillation of the particles of the medium
AQA B	3.1.1	Module 1, The World of Music. A, What is music? Types of wave: longitudinal and transverse waves…
EDEXCEL Concept-Led Approach	2.3	Waves. 28 understand and use the terms amplitude, frequency, period, speed and wavelength.
EDEXCEL Context-Led Approach	8.3	The Sound of Music (MUS) 28 understand and use the terms amplitude, frequency, period, speed and wavelength.
OCR A	G482	Module 4: 2.4 Waves. 2.4.1 Wave motion. (a) describe and distinguish between progressive longitudinal and transverse waves
OCR B	G492	Module UP 1: Waves and quantum behaviour 1. Knowledge and understanding of phenomena, concepts and relationships by describing and explaining cases of: (i) production of standing waves by waves travelling in opposite directions
International Baccalaureate (IB)	4.4 4.4.1 4.4.2 4.4.3	Wave characteristics Describe a wave pulse and a continuous progressive (travelling) wave. State that progressive (travelling) waves transfer energy. Describe and give examples of transverse and of longitudinal waves.
CCEA	2.1 2.1.1 2.1.2	Waves demonstrate a knowledge and understanding of the terms 'transverse wave' and 'longitudinal wave'; be able to categorise waves as transverse or longitudinal;
WJEC	PH2.1	WAVES (a) understand that a progressive wave transfers energy or information from a source to a detector without any transfer of matter; (b) distinguish between transverse and longitudinal waves; (d) explain the terms displacement, amplitude, wavelength, frequency, period and velocity of a wave;
SQA Higher	3.1	Waves 3 State that the energy of a wave depends on its amplitude.
SQA Advanced Higher	3.1	Waves 1 State that in wave motion energy is transferred with no net mass transport

Student practical or teacher demonstration:
Teacher demonstration mainly, or could be student practical, dependent on numbers and resources.

Time needed to complete the activity:
20 minutes.

Preparation and set-up time:
20 minutes.

Resource list:
- 4 clean house bricks
- string, about 3 m long
- elastic 'bungee' about 40 cm long
- a range of Newton meters (e.g. up to 50N)
- laser pointer
- a shallow tray containing water
- a winding mechanism (e.g. pulley block) clamped to the table with a G-clamp (optional)
- slinky spring (optional)
- sticky tape (optional)

Notes:
Safety? Position the audience to one side so that they are out of the way of the laser beam.
This activity is best done on a free standing table rather than a fixed bench.

Ideas for introducing/leading into the activity:
The effect of earthquakes may have a worldwide impact (e.g. 2004 Boxing Day tsunami) but what is the underlying physics? This activity simulates earthquake movements and illustrates that energy is transferred.

Brief activity outline:
As the Earth's plates move, friction 'sticks' them together at the edges and they bend slightly under pressure. Eventually the pressure is so great that a break occurs and the rock springs back elastically, causing an earthquake.

The brick 'earthquake' shows that energy is dissipated with a jog motion. By repeating the experiment, the distribution of jog distance and maximum force applied immediately prior to failure can be found.

If the distance moved by the brick each time it slips is recorded, a histogram can be plotted to show frequency for each size of slippage. An approximation of the relative energy released can be calculated using the equation: Force x Distance = Energy Transferred. This can be compared with a histogram showing the frequency of different magnitude earthquakes.

A tray of water and a slinky spring can detect the waves generated by the 'earthquake'.

Description of activity in detail:

Brickquake, pulled by hand
(©ESEU)

Brickquake pulled by a winding mechanism
(©ESEU)

The bricks are set up with two in line and the third one on top of the rear brick, just overlapping the gap. Its edge is marked on the lower brick, so that the distance moved can be measured. String is tied round this brick. The other end of the string is tied to a bungee which is connected in turn to a Newton meter and winding mechanism as in the diagram (if you have no winding mechanism, the Newton meter can just be pulled by hand, in as controlled a manner as possible).
The two lower bricks must be held firmly by blocks, clamps, or your hand.
A tray of water is put next to the lower bricks. A laser pointer is pointed at a shallow angle to the water surface so that the beam is reflected on to a screen or the ceiling and will make ripples in the water easier to see. A slinky spring can be fastened with tape under the table hanging down until it reaches the floor (optional).
The string is wound onto the winder, or pulled by hand. The measurement on the Newton meter is noted at the moment the brick moves. The distance moved by the brick is measured in metres.
When the brick moves, any motion of the water surface and slinky spring are noted.

Optional: A fourth brick can be added to the top of the apparatus and the experiment repeated to find out how the results differ.

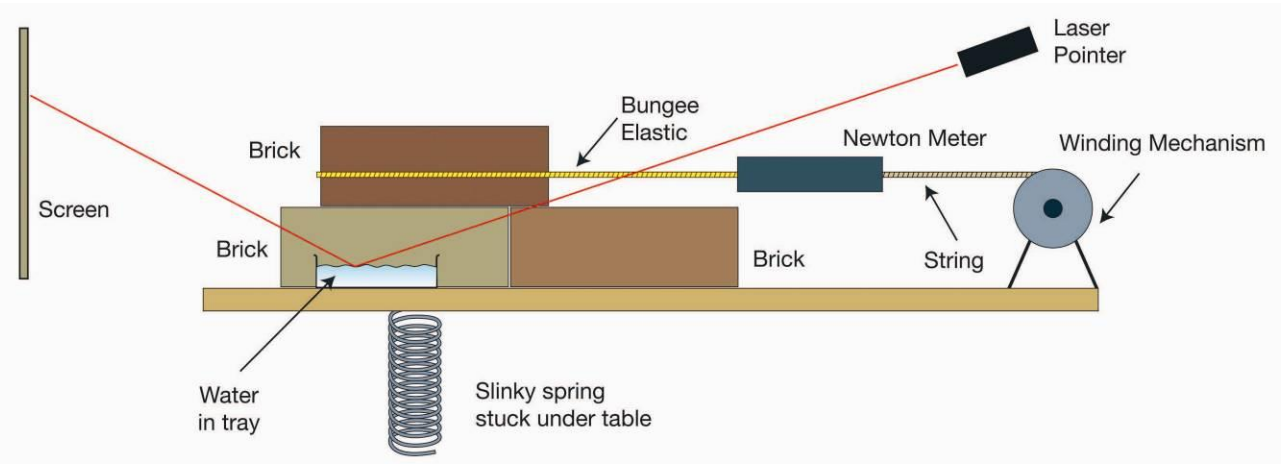

Diagram of apparatus for Brickquake (©ESEU)

Results expected:
Surface waves will be seen in the tray at the side. Body waves (P- and S-waves) will be seen in the slinky spring.
The brick will move smoothly once started or in discrete jogs. The chart below gives some actual results from the above activity and illustrates that although it may be possible to forecast an "earthquake" it is not possible to predict the energy released.

Distance moved Meters (m)	Force Newtons (N)	Relative Energy transferred Joules (J)
0.02	15	0.30
0.075	45	3.375
0.035	35	1.225
0.04	25	1.00

Earthquakes generate three sorts of waves, two sorts of body waves (that pass through bodies – S- and P-waves) and also surface waves. The S-waves are transverse waves (shear, shake or secondary waves (secondary because they arrive after P-waves)). The P-waves are the longitudinal body waves (primary, push-pull, pressure). Surface waves are caused when P- and S-waves interact with the surface, and cause the most damage in earthquakes.

The magnification of the effect of the seismic waves by the laser pen reflecting off the water surface is a mechanism similar to that used in early seismometers to magnify shock wave traces.

Student learning outcomes:
Students can describe how "earthquake" ruptures transfer energy to the surroundings in all dimensions.

Students can plot histograms of maximum force and slippage size and relate to different magnitudes of earthquakes. Students will be able to explain how difficult it is to predict exactly when an earthquake will occur and how big it will be.

Ideas for following up the activity:
Carry out a web search into the frequency of earthquakes in known earthquake areas, e.g.
http://tsunami.geo.ed.ac.uk/local-bin/quakes/mapscript/home.pl

Extension ideas for more able or faster students:
Investigate variations using more bricks in different arrangements e.g. piled on each other to discover the effect of increased vertical pressure. This relates to earthquakes generated at different depths within the crust.

Other variables can be changed, such as variations to the surface on which the bricks move.

Underlying principles:
Explain that this represents two vast rock masses which will come under tensile or shear stress until they start to slide over or past each other. This is what happens in an earthquake. The 'earthquake' initiates forced oscillations of both P- (longitudinal) and S- (transverse) waves.

Possible misconceptions:
Seismic waves only move in one direction and are of one type – this activity demonstrates that two different types of seismic waves are produced by one earthquake.

Source of activity:
Based on the ESEU Brick Earthquake from 'Prediction of Earthquakes' in the ESEU workshop publication '*The Earth and Plate Tectonics'*.

Circus Activity: Brickquake

Participant Sheet

Topic addressed:
This activity investigates the energy dissipation in an earthquake and the unpredictability of earthquakes.

As the Earth's plates move, friction 'sticks' them together at the edges and they bend slightly under pressure. Eventually the pressure is so great that a break occurs and the rock springs back, causing an earthquake.

The brick earthquake shows that energy is dissipated with a jog motion. By repeating the experiment the distribution of jog distance and maximum force applied immediately prior to failure can be found. A tray of water and a slinky spring detect the waves generated by the 'earthquake'.

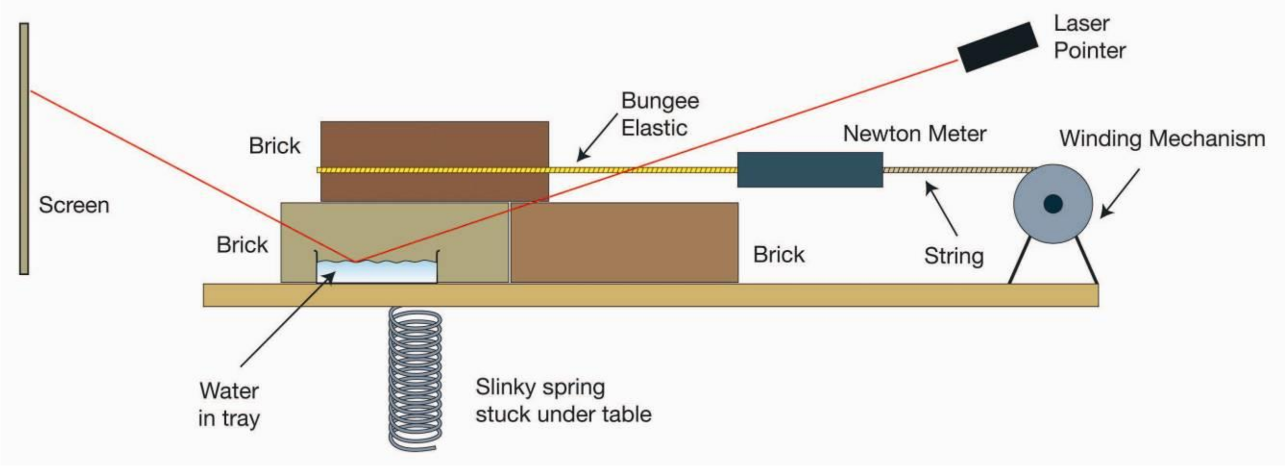

Diagram of brickquake apparatus (©ESEU)

Description of activity in detail:
- The bricks are set up with two in line and the third one on top of the rear brick, just overlapping the gap. Its edge is marked on the lower brick, so that the distance moved can be measured.
- String is tied round the top brick.
- The other end of the string is tied to a bungee which is connected in turn to a Newton meter and winding mechanism as in the diagram (if you have no winding mechanism, the Newton meter can just be pulled by hand, in as controlled a manner as possible).
- The two lower bricks must be held firmly by blocks, clamps, or your hand.
- Mark the position of the front face of the top brick on the lower brick.
- A tray of water is put next to the lower bricks.
- A laser pointer is pointed at a shallow angle to the water surface in the tray so that the beam is reflected on to a screen or the ceiling and will make ripples in the water easier to see. **Take care that the beam is not directed towards people.**
- A slinky spring is fastened with tape under the table, hanging down until it reaches the floor (optional).

1. Wind the string in slowly or pull it by hand and watch what happens to the water surface and the slinky spring at the moment the brick starts to move.
    - What sort of waves do you see?
    - Which direction is the energy moving in?

2. Wind the string in slowly and record the reading on the Newton meter at the moment the brick moves. Measure the distance moved by the brick. An approximation of the relative energy released can be calculated using the equation:
   Force x Distance = Energy Transferred.
   Repeat this at least 10 times recording your results in a table.
   Plot a histogram to show frequency for each amount of energy released.

Watching a laser beam on the ceiling (©ESEU)

Extension activities:

Carry out a web search into the frequency of earthquakes in known earthquake areas and compare it with your histogram
e.g. http://tsunami.geo.ed.ac.uk/local-bin/quakes/mapscript/home.pl

Investigate variations using the bricks in different arrangements e.g. piled on each other to discover the effect of increased vertical pressure. This relates to earthquakes generated at different depths within the crust.
Other variables can be changed, such as variations to the surface on which the bricks move.