Impact vibrations and seismics

FizziQ activity · Middle school · 35 min

Scan to open in FizziQ

Dropping balls from varying heights, middle school students use the smartphone accelerometer as a seismograph in FizziQ to study impact energy and seismic waves.

Learning objectives

- Use the smartphone accelerometer as a seismograph to detect vibrations from ball impacts
- Investigate how the amplitude of the detected vibrations depends on the drop height and mass of the ball
- Verify the relationship between gravitational potential energy (mgh) and the intensity of the impact signal
- Study how vibration amplitude decreases with distance from the impact point
- Understand the principles of seismic wave propagation through solid materials

Instruments and sensors

Accelerometer (Z-axis, used as a portable seismograph) · Accelerometer

Materials

- Smartphone with the FizziQ application
- Balls of different masses and sizes
- Surfaces of different compositions (wood, metal, sand, etc.)
- Ruler or tape measure to measure the height of fall
- Salad bowl filled with sand
- Note: the protocol remains adaptable to any comparable acceleration/vibration data acquisition tool.

Protocol

1. Open FizziQ and select the Accelerometer sensor. Choose the Z-axis (vertical) component and set the sampling rate to the maximum available for best time resolution.
2. Place the smartphone flat on a hard, smooth surface (a table or hard floor). This surface will transmit the impact vibrations to the sensor.
3. Choose a starting ball (e.g., a marble or small metal ball). Hold it at a height of 20 cm directly above a spot on the surface, about 30 cm from the smartphone.
4. Start recording in FizziQ, then drop the ball onto the surface. Let it bounce and settle, then stop recording.
5. Examine the accelerometer graph. You should see a sharp spike at the moment of impact, followed by smaller oscillations.
6. Measure the peak amplitude of the impact spike (the maximum acceleration value).
7. Repeat the drop from the same height three times and calculate the average peak amplitude for reproducibility.
8. Now repeat the experiment from heights of 10 cm, 30 cm, 40 cm, and 50 cm, recording the peak amplitude for each height.
9. Plot a graph of peak amplitude versus drop height. The amplitude should increase with height.
10. Next, keep the drop height constant at 30 cm and use balls of different masses (marble, rubber ball, steel ball). Record the peak amplitude for each.
11. Finally, investigate distance dependence: drop the same ball from the same height but place the smartphone at distances of 10 cm, 20 cm, 40 cm, and 60 cm from the impact point. Record the amplitude at each distance.

12. Plot the amplitude versus distance graph. The amplitude should decrease with distance, approximately following an inverse relationship.

Expected results

Impact amplitudes typically range from 0.05 to 2 m/s^2 depending on the ball mass, drop height, and distance. The amplitude should increase roughly as the square root of the drop height (since impact velocity $v = \sqrt{2gh}$ and the impulse is proportional to v). Heavier balls produce larger amplitudes at the same height. The distance dependence should show a clear decrease, roughly following a $1/r$ or $1/r^2$ law depending on the surface material and wave type. Hard surfaces (metal, stone) transmit vibrations more efficiently than soft ones (wood, carpet). Students should observe that each impact produces a brief, sharp spike followed by damped oscillations as the surface vibrates freely. The reproducibility between identical drops should be within ±20%, reflecting variations in the exact impact location and angle.

Questions

- How does the potential energy of the ball relate to the amplitude of the seismic wave detected?
- Why does the vibration amplitude decrease with distance from the impact point?
- What fraction of the ball's kinetic energy is converted into seismic waves? Where does the rest go?
- How does the surface material affect the propagation of impact waves?
- What is the difference between P-waves and S-waves in seismology, and which type is your smartphone detecting?
- How do real seismographs work, and how are they similar to and different from a smartphone accelerometer?

Going further

- Compare different surface materials (wood table, metal sheet, stone floor, sand) to investigate how the medium affects wave transmission
- Use a bowl of sand as the impact surface and measure how crater size relates to drop height and ball mass
- Place the smartphone on the surface at various angles relative to the impact point to investigate directional wave propagation
- Record impacts from two balls dropped simultaneously at different distances and analyze the arrival time difference to calculate wave speed
- Simulate earthquake early warning by measuring the time delay between the impact and the arrival of vibrations at the smartphone