Spring constant: $k = 4\pi^2 m/T^2$

FizziQ activity · High school · 30 min

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A smartphone hung from a spring oscillates while FizziQ's accelerometer records the motion; students measure the period and compute the stiffness $k = 4\pi^2 m/T^2$.

Learning objectives

- Measure the oscillation period of a spring-mass system with the accelerometer
- Calculate the spring constant from the period and mass
- Verify experimentally that the period is independent of amplitude
- Compare the dynamic method (oscillation) with the static method (extension under load)
- Use the autocorrelation function for precise period measurement

Instruments and sensors

Accelerometer (linear acceleration) · Accelerometer

Materials

- Smartphone or tablet with FizziQ
- A spring (laboratory spring or Slinky)
- A rigid support (door handle, curtain rod, lab stand)
- Optional: additional known masses
- Note: the protocol remains adaptable to any comparable acceleration data acquisition tool.

Protocol

1. Build a support for your smartphone: take a cardboard roll (toilet paper type), cut two slits at each end, and slide the phone in. Attach a hook or loop of string at the top.
2. Weigh your smartphone (with its case and support) using a balance. Note this mass m in kilograms.
3. Open FizziQ and select the Accelerometer instrument (linear acceleration, without gravity).
4. Hang the spring from a solid support (door handle, curtain rod, lab stand). Suspend the phone in its holder from the bottom of the spring.
5. Gently pull the phone downward (a few centimeters is enough) then release. Be careful not to pull too far — the phone must not fall!
6. Start recording in FizziQ while the system oscillates. Record at least 10 complete oscillations.
7. Stop recording and observe the acceleration versus time graph. You should see a clean sinusoidal oscillation with slowly decreasing amplitude.
8. Measure the period T by counting the number of peaks over a given time interval, or use the FizziQ autocorrelation function for higher precision.
9. Calculate the spring constant with the formula: $k = (2\pi/T)^2 \times m$. Compare with the manufacturer's value for the spring if available.
10. Repeat the experiment by adding an extra mass (for example, a small book attached to the phone). The period should increase. Recalculate k and verify consistency.

Expected results

The acceleration graph shows a regular sinusoidal oscillation with slowly decreasing amplitude due to damping. The period T is constant (independent of amplitude, as long as oscillations remain small). Typical values: for a standard lab spring with k = 10-50 N/m and a smartphone of 0.2 kg, T ≈ 0.4-0.9 s. The calculated k should agree with the static method within 5-10%.

Questions

- Why does the oscillation period not depend on the amplitude?
- What happens if you pull the spring very far: does the period change? Why?
- How does adding mass to the system affect the period?
- Why is the autocorrelation method more precise than counting peaks?
- How does damping affect the measured period?
- What are the advantages of the dynamic method over the static method for measuring k?

Going further

- Plot T^2 versus m for several masses and verify linearity; the slope gives k
- Compare the spring constant obtained with the static method (measure extension under known weight)
- Test whether two identical springs in parallel give double the stiffness
- Investigate the effect of large amplitudes on the period (non-linear regime)
- Use the frequency spectrum (FFT) to determine the oscillation frequency with high precision