Inclined plane: weight components

FizziQ activity · High school · 30 min

High school students place a smartphone on an inclined plane and verify $P_\parallel = mg \sin\theta$ and $P_\perp = mg \cos\theta$ with the FizziQ accelerometer and inclinometer.

Learning objectives

- Measure the weight components on an inclined plane with the accelerometer
- Verify the relationships $P_\parallel = mg \sin\theta$ and $P_\perp = mg \cos\theta$
- Plot and interpret force versus angle graphs
- Determine the static friction coefficient from the critical sliding angle
- Verify that the weight magnitude remains constant regardless of inclination

Instruments and sensors

Accelerometer (G-force measurement) · Inclinometer (tilt angle) · Accelerometer

Materials

- Smartphone or tablet with FizziQ
- A board or rigid book
- Supports of varying heights (books, blocks)
- Optional: tape to prevent the phone from sliding
- Note: the protocol remains adaptable to any comparable accelerometer-based measurement tool.

Protocol

1. Open FizziQ and select two instruments: the Accelerometer (G-force measurement in x, y, z) and the Inclinometer (angle).
2. Place your smartphone flat on a horizontal table. Note the G-force values in all three axes. You should read approximately 0 in x and y, and 1g in z.
3. Build an inclined plane by resting a rigid board on a support. Start with a small angle (about 10°).
4. Place the smartphone flat on the inclined plane, screen up, with the bottom edge toward the bottom of the slope.
5. Record the G-force values in all three axes along with the inclination angle. If the phone slides, use a small piece of tape to hold it.
6. Increase the plane angle in steps of about 5° (by adding books under the board). At each angle, record the forces and angle.
7. Plot the graphs: parallel component versus $\sin\theta$, and perpendicular component versus $\cos\theta$.
8. Verify that the parallel component is proportional to $\sin\theta$ and the perpendicular component is proportional to $\cos\theta$.
9. For each angle, verify that the quadratic sum of the two components gives 1g (constant weight magnitude).
10. Note the critical angle at which the phone begins to slide. This angle gives the static friction coefficient: $\mu_s = \tan\theta_c$.

Expected results

The perpendicular component decreases with angle following $\cos\theta$: it equals 1g at 0° and approaches 0 at 90°. The parallel component increases following $\sin\theta$: it equals 0 at 0° and approaches 1g at 90°. The sum of squares always gives $1g^2$. The critical sliding angle typically ranges from 15° to 35° depending on the surface, giving μ_s = 0.27 to 0.70.

Questions

- Why does the weight not change when the plane angle varies?
- How is the parallel weight component balanced when the phone does not slide?
- What happens to the normal reaction force as the angle increases?
- Why does the phone slide above a certain critical angle?
- How would you measure the kinetic friction coefficient (while the phone is sliding)?
- Can you predict the critical angle from knowledge of the surface materials?

Going further

- Compare the friction coefficients of different surfaces (wood, plastic, fabric, rubber)
- Study kinetic friction by letting the phone slide and recording the acceleration during the slide
- Verify the Pythagorean identity $\sin^2\theta + \cos^2\theta = 1$ from your data
- Investigate how the orientation of the phone on the plane affects the readings
- Use the experiment to calibrate the inclinometer against a protractor