Centripetal acceleration: spinner

FizziQ activity · High school · 35 min

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A smartphone spinning inside a salad spinner records acceleration with the FizziQ accelerometer; students verify $a = \omega^2 r$ and assess human g-force tolerance limits.

Learning objectives

- Measure the centripetal acceleration inside a rotating salad spinner using the smartphone accelerometer
- Relate the measured acceleration to the rotational speed and radius of rotation
- Compare the measured g-forces with human physiological tolerance limits
- Verify the relationship $a = \omega^2 r$ between centripetal acceleration, angular velocity, and radius
- Understand the concept of g-force and its effects on the human body

Instruments and sensors

Absolute acceleration meter · Accelerometer

Materials

- Smartphone with the FizziQ application (accelerometer sensor)
- Salad spinner
- Protection for the smartphone (soft cloth or padded case)
- Tape measure to measure the inner radius of the spinner basket
- Stopwatch (optional, to time the spinning duration)
- Note: the protocol remains adaptable to any comparable acceleration measurement tool.

Protocol

1. Measure the inner radius of the salad spinner basket using a tape measure. Record this value in meters.
2. Open FizziQ on your smartphone and select the Accelerometer sensor. Choose the absolute acceleration measurement.
3. Protect your smartphone by wrapping it in a soft cloth or placing it in a padded case. Ensure it fits securely inside the spinner basket.
4. Place the smartphone inside the salad spinner basket with the screen visible through the transparent lid (if possible). Position it so the sensitive axis is oriented radially (pointing toward the center of rotation).
5. Set the FizziQ recording frequency to the maximum available rate for best time resolution.
6. Start recording in FizziQ, then begin spinning the salad spinner steadily and as fast as possible.
7. Maintain a constant spinning speed for at least 5 seconds, then stop. Stop the FizziQ recording.
8. Examine the acceleration graph. Identify the plateau region where the spinning speed was approximately constant and read the maximum acceleration value.
9. Convert the measured acceleration to g-force units by dividing by 9.81 m/s². Record the number of g's.
10. Calculate the angular velocity ω from the measured acceleration using $\omega = \sqrt{a/r}$, where r is the basket radius.
11. Convert ω to revolutions per minute (RPM): $RPM = \omega \times 60 / (2\pi)$.
12. Compare the measured g-force with human tolerance thresholds: 2-3g (blood pooling in legs), 4-6g (risk of blackout for untrained persons), 9g+ (limit for trained fighter pilots with g-suits).
13. Discuss whether an astronaut could survive a ride in this salad spinner, and calculate how large the spinner would need to be to reach dangerous g-forces at the same rotation speed.

Expected results

Typical salad spinners can generate accelerations of 5-15 m/s² (0.5-1.5g) depending on their size and the vigor of spinning. A spinner with a 10 cm radius spun at 3 revolutions per second would produce a centripetal acceleration of about 3.6g. Students should find that the measured acceleration is well within human tolerance for brief exposure, though sustained exposure at even 2-3g would be uncomfortable. The calculation of angular velocity from the measured acceleration and radius provides a useful cross-check: if the student counts rotations during a timed interval, the independently measured RPM should approximately match the calculated value. Measurement noise and vibrations from the spinning mechanism may cause the acceleration graph to show oscillations around the mean value, typically ±10-20% of the plateau value.

Questions

- How does the centripetal acceleration change if you double the rotational speed while keeping the radius constant?
- Why do larger centrifuges produce higher g-forces at the same rotational speed?
- What physiological effects would an astronaut experience at 3g? At 6g? At 9g?
- Why do fighter pilots wear special g-suits, and how do these suits work?
- What is the difference between centripetal acceleration and centrifugal force?
- How could you modify this experiment to verify the relationship $a = \omega^2 r$ more precisely?

Going further

- Repeat the measurement with objects of different masses inside the spinner to verify that centripetal acceleration is independent of mass
- Use a timer and visual counting to independently measure the rotation speed and compare with the accelerometer-derived value
- Investigate how the acceleration changes if you modify the radius by repositioning the smartphone
- Compare a salad spinner with a manual egg beater or a record turntable
- Calculate the size of a centrifuge that would be needed to produce 6g at the rotation speed of your salad spinner