

Motion with derivatives and integrals

AP Physics C (Mechanics and E&M, calculus-based) · Lab

Name: _____ Date: _____ Class: _____

How does the acceleration of a falling object change as it speeds up? You will extract velocity and acceleration from position data of a falling coffee filter stack and relate the changes to air resistance.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:M Unit 1

Aim

Use video measurements of a falling stack of coffee filters to find velocity and acceleration from position data, and show how the acceleration falls as air resistance grows.

Equipment

- four nested basket coffee filters
- vertical metre rule fixed to a wall
- phone with a slow-motion video mode (at least 120 frames per second) on a stand
- stable step stool or tall ladder, used safely
- video player that can step frame by frame

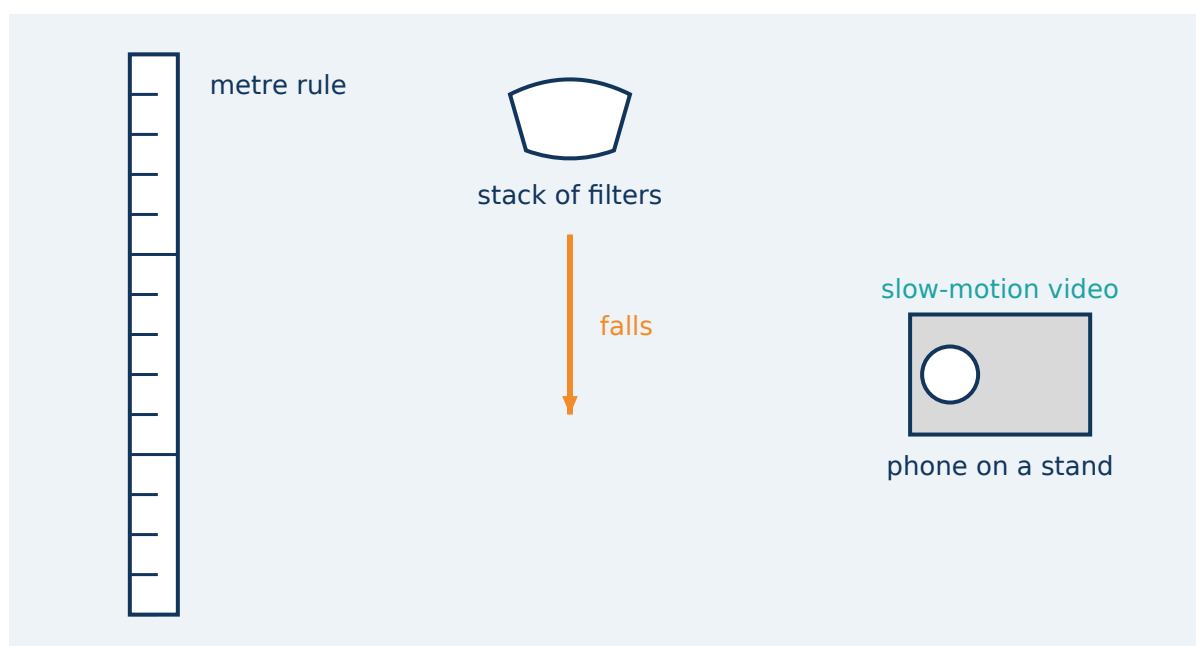
Safety

Safety

Do not stand on a chair. Use a stable step stool with a helper, or drop from a high shelf by hand. Keep the floor clear of tripping hazards and wipe up any dust.

Method

1. Fix the rule vertically and place the phone 1.5 m away, level with the middle of the rule.
2. Release the filters from rest next to the top of the rule while filming.
3. Step through the video and, for times 0.00, 0.05, 0.10 ... 0.50 s after release, record how far the bottom of the stack has fallen.
4. Repeat three times and use the average position at each time.



Lab set-up: the video is stepped through frame by frame to read the position against time.

Results

Sample measurements by Wanjiru in Nairobi:

t (s)	0.0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5
distance fallen y (m)	0.000	0.015	0.053	0.105	0.165	0.229	0.297	0.367	0.438	0.509	0.581

Analysis questions

Question 1 Average velocities

Calculate the average velocity in each 0.05 s interval and assign it to the midpoint time.

Question 2 Velocity-time graph

Plot these velocities against the midpoint times and draw a smooth curve.

Question 3 Acceleration at the start and end

Estimate the acceleration for the first two intervals and for the last two intervals.

Question 4 Terminal velocity

Estimate the terminal velocity from the graph.

Question 5 Check by integration

Add the average velocities $\times 0.05$ s over the whole fall and compare with the measured distance fallen at 0.50 s.

Question 6 Explain the shape

Explain why the acceleration decreases with time, using forces.

Question 7 Uncertainty

Identify the main source of uncertainty in y and suggest one improvement.