

Drag forces and terminal velocity with calculus

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

Model answers use the sample data above. Your own values will differ a little, but the graph should still be a straight line through the origin with c near a few times 10^{-3} kg/m for cases of this size.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:M Unit 2

Question 1 Speeds and squares

$v = 1.49, 2.13, 2.63, 3.03, 3.33$ m/s and $v^2 = 2.23, 4.54, 6.92, 9.18, 11.09$ m²/s² for $n = 1$ to 5. Result: **v^2 rises from 2.2 to 11.1 m²/s².**

Question 2 Graph

The points lie on a straight line through the origin. Using $m = 4.00$ g = 4.00×10^{-3} kg:
gradient = $11.09 / (4.00 \times 10^{-3}) = \mathbf{2.8 \times 10^3 \text{ m}^2\text{s}^{-2}\text{kg}^{-1}}$.

Question 3 Drag constant

Gradient = g/c , so $c = 9.81 / (2.8 \times 10^3) = \mathbf{3.5 \times 10^{-3} \text{ kg/m}}$.

Question 4 Why the last metre?

The cases start from rest and accelerate before reaching terminal speed. Timing only the last metre, after 1.5 m of fall, means v is close to v_t , so the speed is nearly **constant** over the timed section.

Question 5 Uncertainty

Percentage uncertainty in $t = 0.02/0.30 = 6.7\%$, so in v it is **6.7%**. Squaring doubles the percentage, so the uncertainty in v^2 is **13%**.

Question 6 Conclusion

$v^2 \propto m$, so $v_t \propto \sqrt{m}$. This agrees with **quadratic drag**, $v_t = \sqrt{(mg/c)}$, and rules out linear drag, which would give $v \propto m$.

Question 7 Improvements

Use a longer drop so terminal speed is surely reached, and film at a higher frame rate to cut the timing uncertainty. Averaging more repeats also helps. **Longer drop, faster video.**