

Drag forces and terminal velocity with calculus

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

Name: _____ Date: _____ Class: _____ Mark: ____ / 20

This test covers resistive forces, terminal speed, the exponential and tanh solutions, and energy at terminal speed. Use $g = 9.81 \text{ m/s}^2$. Show every substitution and give final numerical answers with units. Calculators are allowed; the time limit is 45 minutes.

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

Time: 45 minutes · 8 questions · Total: 20 marks · Calculator allowed

Question 1 Terminal velocity (2 marks)

- Define terminal velocity. (1 mark)
- State the net force on the object at terminal velocity. (1 mark)

Question 2 Linear drag calculation (3 marks)

A ball of mass 0.30 kg falls through oil with $F = bv$ and $b = 0.60 \text{ kg/s}$.

- Calculate the terminal speed. (1 mark)
- Calculate τ . (1 mark)
- Calculate the speed 1.0 s after release from rest. (1 mark)

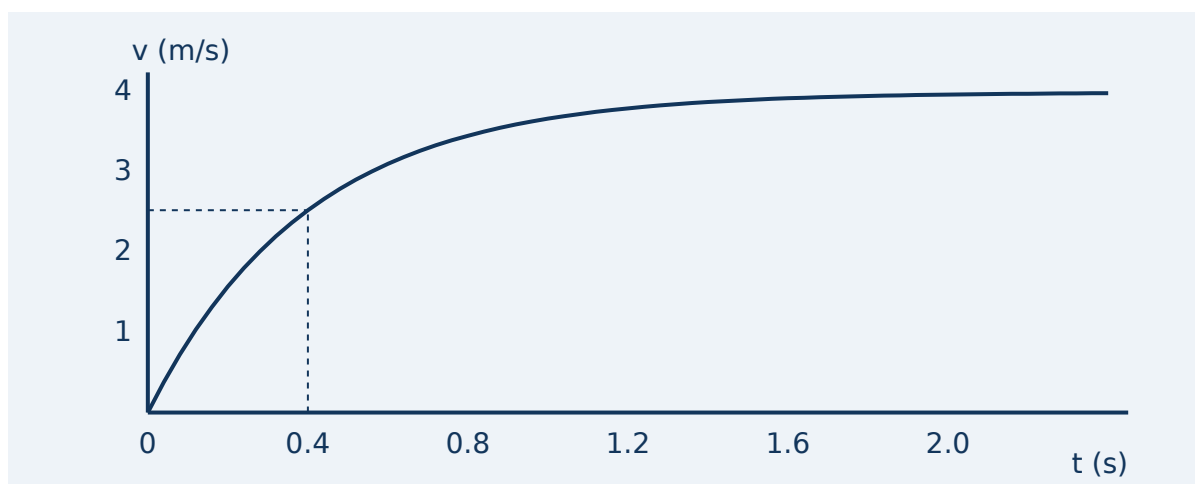
Question 3 Acceleration (2 marks)

For the ball in the previous question:

- Differentiate $v = v_t(1 - e^{-t/\tau})$ to show that $a = g e^{-t/\tau}$. (1 mark)
- State the acceleration at $t = 0$. (1 mark)

Question 4 Graph (3 marks)

The graph shows the speed of a 0.25 kg bead falling in oil.



Speed of a bead in oil.

- State the terminal speed. (1 mark)
- Use the drag law $F = bv$ to calculate b . (1 mark)
- Estimate τ and check that it agrees with m/b . (1 mark)

Question 5 Parachutist (3 marks)

A parachutist and equipment have mass 65 kg, with $F = cv^2$.

- With $c = 0.22$ kg/m before the canopy opens, calculate the terminal speed. (1 mark)
- After opening, $c = 20$ kg/m. Calculate the new terminal speed. (2 marks)

Question 6 Heavier object (2 marks)

Explain, using the force balance, why a heavier object of the same shape has a larger terminal speed. (2 marks)

Question 7 Boat (3 marks)

A 250 kg boat moves at 5.0 m/s when its engine stops. Drag is $F = bv$ with $b = 40$ kg/s.

- Calculate the time constant. (1 mark)
- Calculate the time for the speed to fall to 1.0 m/s. (2 marks)

Question 8 Energy (2 marks)

The 0.30 kg ball from question 2 moves at its terminal speed.

- Calculate the power delivered to the oil by drag. (1 mark)
- State where this energy comes from. (1 mark)