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ANSWER BOOK

Drag and terminal speed

Mechanics · Year 12

AQA 3.4.1.4 · CIE 3.2.1, 3.2.2, 3.2.3 · OCR A 3.2.2(a), 3.2.2(b), 3.2.2(c), 3.2.2(d)(i)

18 questions · 56 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Air resistance (drag) on the cyclist and bicycle (1); friction (rolling resistance) at the tyres or in the bearings (1). Each acts in the direction opposite to the motion (1). [3]

A2 The constant maximum speed reached by a falling object when the resultant force on it is zero (1), so the drag, plus any upthrust, balances its weight and it stops accelerating (1). [2]

A3 Drag increases as speed increases (1); at the speeds studied it rises roughly with the square of the speed (1). [2]

A4 The component of the force exerted by a fluid on an object moving through it that acts perpendicular to the direction of flow. (1) [1]

A5 The driving force equals the total resistive force (1); the resultant force is therefore zero, so the acceleration is zero. (1) [2]

A6 Similarity: both are resistive forces that oppose (relative) motion (1). Difference: drag increases with speed, whereas friction between solid surfaces does not depend on speed (or: drag requires motion through a fluid). (1) [2]

SECTION B · Standard

B1 Drag = 750 N (1) [3]
Acting upwards (1)
At terminal speed the resultant force is zero, so the upward drag exactly balances the downward weight (1)

B2 At terminal speed: weight = upthrust + drag (1) [4]
Drag = 0.30 - 0.05 (1)
Drag = 0.25 N (1)
The three forces balance, giving zero resultant force and therefore zero acceleration (1)

B3 The curve starts steep, with acceleration ≈ g (1), and its gradient decreases as drag grows with speed (1), levelling off to a horizontal line at the terminal speed where acceleration is zero (1). [3]

B4 Weight = mg = $6.5 \times 10^{-5} \times 9.81 = 6.4 \times 10^{-4}$ N (1). Resultant = $6.4 \times 10^{-4} - 4.2 \times 10^{-4}$ = 2.2×10^{-4} N downwards (1). a = F/m = 3.3 m s^{-2}. (1) [3]

B5 Spread out, the skydiver presents a larger area to the air, so at any given speed the drag is larger (1). The weight is unchanged, so the drag grows to equal the weight at a lower speed (1); at that speed the resultant force is zero, so the constant (terminal) speed reached is lower. (1) [3]

B6 (a) At top speed the driving force equals the resistive force, 2000 N (1); P = Fv, so v = P/F = 90 000/2000 = 45 m s^{-1} (1). (b) At any higher speed the drag would exceed the greatest driving force the engine can supply (1), so the resultant force would act backwards and the car would decelerate back to the top speed. (1) [4]

SECTION C · Stretch

C1 Opening the parachute sharply increases the drag (1), so drag now exceeds weight and the resultant force acts upwards (1): the parachutist decelerates. As speed falls, drag falls (1), until drag again equals weight at a new, lower terminal speed (1). [4]

C2 Drag ∝ v^2 (1) [3]
Doubling the speed multiplies drag by 4: D = 20 × $(10/5.0)^2$ (1)
D = 80 N (1)

C3 Terminal speed is reached when drag equals weight (1). A heavier skydiver has a larger weight, so a larger drag is needed to balance it (1); with the same shape they must fall faster to generate that drag (1). [3]

C4 At the landing (terminal) speed, drag = weight (1): $24v^2 = 850$, so v = √(850/24) (1) = 6.0 m s^{-1} (1). This exceeds the 5.5 m s^{-1} limit, so the canopy is not suitable. (1) [4]

C5 At terminal speed the drag equals the weight: 92 × 9.81 = 903 N (1). At half the terminal speed the drag is a quarter of this: 903/4 = 226 N (1). Resultant = 903 - 226 = 677 N downwards (1), so a = 677/92 = 7.4 m s^{-2}. (1) [4]

C6 At the start the speed is low, so drag is small and the resultant force is almost the whole driving force: the acceleration is greatest here (1). As the speed rises the drag increases (1), so the resultant force, and therefore the acceleration, decreases (1). Maximum speed is reached when the drag (plus other resistance) has grown to equal the driving force: the resultant is zero and the velocity is constant (1). When she stops pedalling, only the resistive forces act, so there is a resultant force backwards and she decelerates (1). As the speed falls the drag falls, so the deceleration itself becomes smaller and the velocity dies away gradually. (1) [6]