A-LEVEL PHYSICS • EXERCISE SHEET

3.2 Non-uniform motion

Name: _____ Class: _____ Date: _____ **Total: 13 marks**

Objective

Build the skills to answer exam questions on **non-uniform motion** —friction and drag, falling through air, and terminal velocity.

You must be able to:

- describe **friction** 摩擦力 and **drag** 阻力 (drag grows with speed)
- explain the motion of an object falling through air
- explain **terminal velocity** 收尾速度 and the energy transfer

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

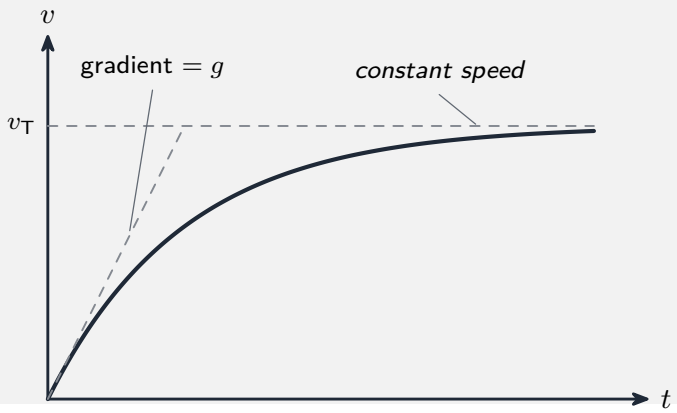
■ Drag increases with speed

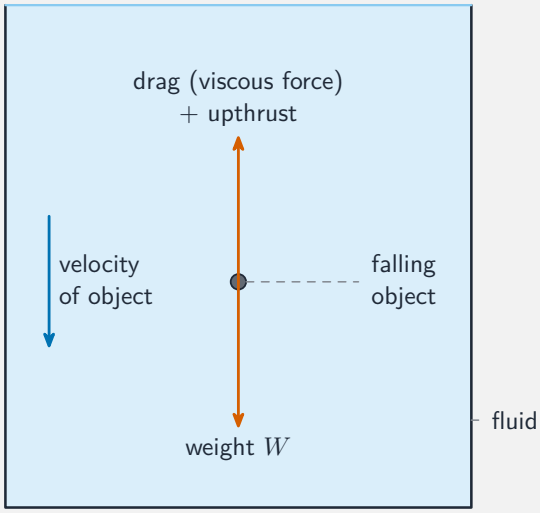
A **drag** (viscous) force from a fluid opposes motion. A simple model: **drag is zero at zero speed and grows as the speed grows**.

■ Falling through air → terminal velocity

An object dropped from rest:

1. at first only **weight** acts → it accelerates at g;
2. as it speeds up, **drag grows**, so the resultant force and the acceleration **shrink**;
3. when **drag** = **weight**, the resultant force is zero → constant speed, the **terminal velocity**.





Forces on a falling object reaching terminal velocity

Energy at terminal velocity

At terminal velocity the kinetic energy is **constant**, so the lost **gravitational potential energy** is transferred to **thermal energy of the air** —**not** to extra KE of the faller.

A **heavier** (or denser) object reaches a **higher** terminal velocity —it needs more speed (more drag) to balance its larger weight. Opening a **parachute** suddenly increases the drag, so drag exceeds weight and the diver **decelerates** to a new, much **lower** terminal velocity.

2 Practice

Now apply the methods above.

2.1 State what happens to the **drag force** on an object as its speed increases. [1]

2.2 State the condition (in terms of forces) for an object to move at **terminal velocity**. [1]

2.3 State the acceleration of an object **just after** it is released and begins to fall through air. [1]

2.4 State the main energy transfer for a parachutist falling at **terminal velocity**. [1]

3 Exam-style questions

3.1 A parachutist falls at constant (terminal) velocity. Which statement is **not** correct? [1]

- **A** Gravitational PE is converted to kinetic energy of the air.
- **B** Gravitational PE is converted to kinetic energy of the parachutist.
- **C** Gravitational PE is converted to thermal energy of the air.
- **D** The resultant force on the parachutist is zero.

3.2 Describe and explain the motion of an object dropped from rest and falling through air, until it reaches terminal velocity. [4]

3.3 A skydiver is falling at terminal velocity. State the **resultant force** on her and explain why her velocity stays **constant**. [2]

3.4 Sketch a **velocity–time graph** for an object falling from rest through air, labelling the terminal velocity. [2]

3.5 A skydiver falling at terminal velocity opens her parachute.

(a) State what happens to her velocity **just after** the parachute opens. [1]

(b) Explain, in terms of **forces**, why she settles to a new **lower** terminal velocity. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **3.2 Non-uniform motion** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/11 J25 —Q20 (terminal velocity and forces)
- 9702/21 N25 —Q2 (motion with drag)
- 9702/23 J25 —Q3 (falling in a fluid)
- 9702/11 N25 —Q8 (terminal velocity)

Solutions

2.1 It **increases** as the speed increases (zero at zero speed).

2.2 The **drag (resistive) force equals the weight**, so the **resultant force is zero**.

2.3 g (about 9.81 m s^{-2}) —the maximum acceleration, since drag is still zero.

2.4 Gravitational potential energy → **thermal energy of the air**.

3.1 B —at terminal velocity the KE of the parachutist is constant, so PE is **not** converted to her KE.

3.2 Just after release only weight acts, so acceleration = g; as speed rises, drag increases, so the resultant force and acceleration **decrease**; when drag = weight the resultant force is zero and the speed is constant —terminal velocity.

3.3 The resultant force is **zero**; with no resultant force there is no acceleration, so the velocity stays constant (Newton's first law).

3.4 Curve from the origin rising with an initial gradient (steepest at the start), bending and **flattening** to a horizontal line at the terminal velocity (labelled).

3.5 (a) Her velocity **decreases** (she decelerates). (b) The parachute greatly increases the **drag**, so drag now exceeds weight and the resultant force is **upward**; as she slows, the drag falls until **drag = weight** again, giving a new, lower terminal velocity.