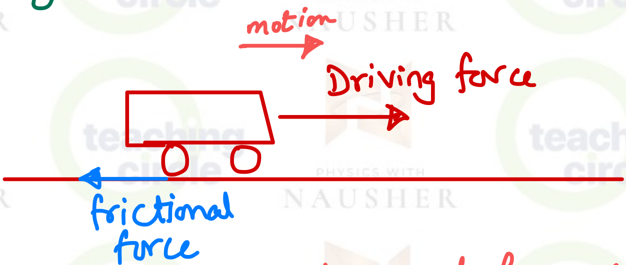
Drag Force and Air Resistance

- Drag forces are forces acting in opposite direction to an object moving through a fluid.
- Examples of drag forces are friction and air resistance.

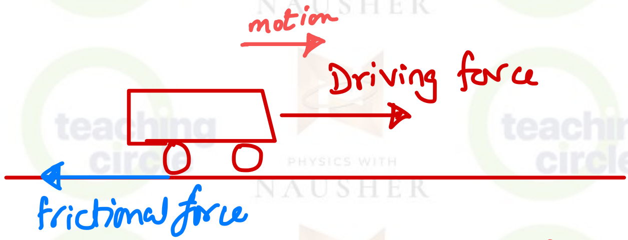
- Drag force ∝ speed of object

Hence drag force is significant at high speeds.

Example:

① 

- Driving force > frictional force, car accelarates
- resultant force is in the direction of motion of car.
- Hence speed of the car increases.

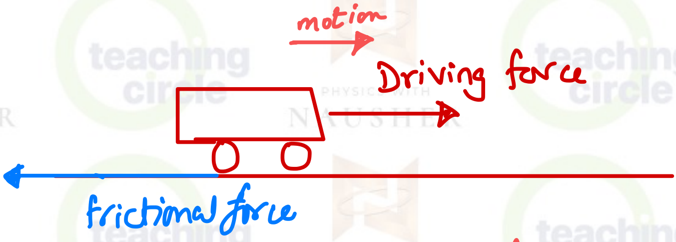
② 

- Driving force = frictional force, what happens?

A. car accelarates and speed increases

B. car decelerates and speed decreases

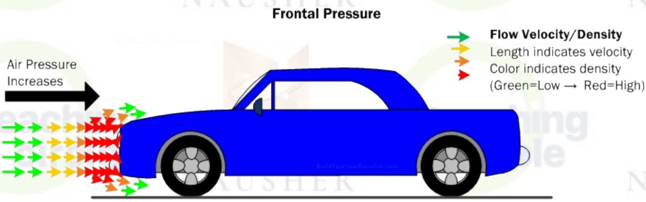
C. car continues to move with constant speed.



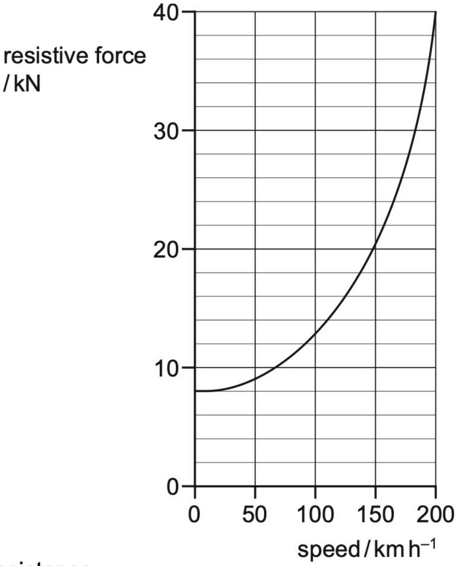
- Driving force < friction force e.g car is braking
- resultant force is in the opposite direction to motion
- car slows down.

Air Resistance

- Air resistance is an example of drag force.
- As an object moves, it experiences air resistance in the opposite direction.
- Air resistance depends on the shape and the speed at which the object moves.



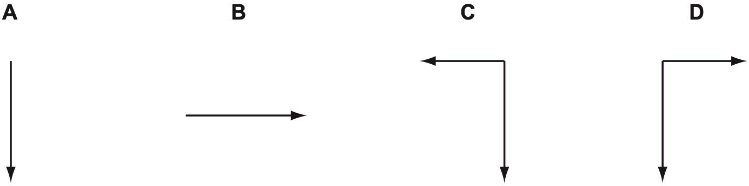
The graph shows how the total resistive force acting on a train varies with its speed.
Part of this force is due to wheel friction, which is constant. The rest is due to wind resistance.



What is the ratio $\frac{\text{wind resistance}}{\text{wheel friction}}$ at a speed of 200 km h^{-1}?

A 4 **B** 5 **C** 8 **D** 10

An object in air is thrown upwards and towards the left.
Which diagram shows the force(s) acting on the body when it is at its highest point?



Terminal velocity

- For a body in free fall with no air resistance effects (for example on the moon), the only force acting on it is the weight.
- Therefore body accelerates downwards with acceleration of free fall.
- There is no normal force because the object isn't in contact with the surface

- $F_{res} = mg$

Resultant force is the same as the weight of the object, hence in free fall resultant force is equal to the weight.

Note:
Always draw free-body diagrams and label the forces.

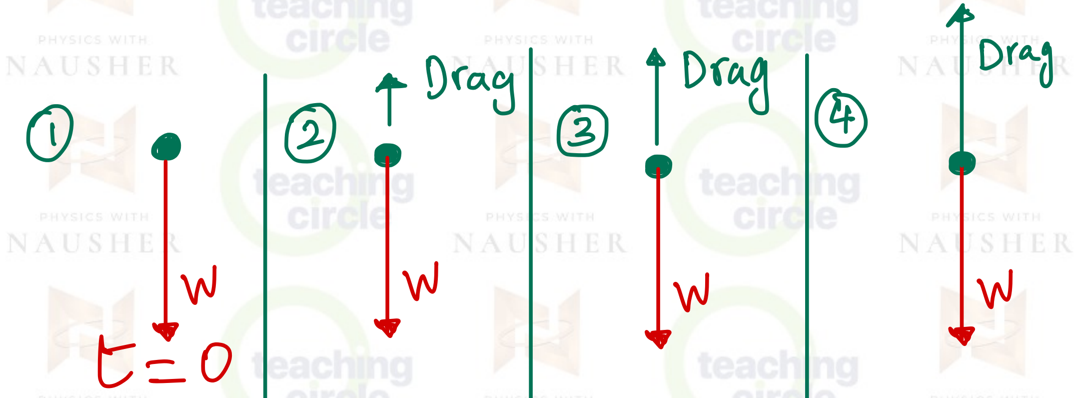
For a body **falling** with air resistance,
↳ What will be the direction of motion?

- Weight is greater than air resistance
  Hence F_{res} is in the direction of motion

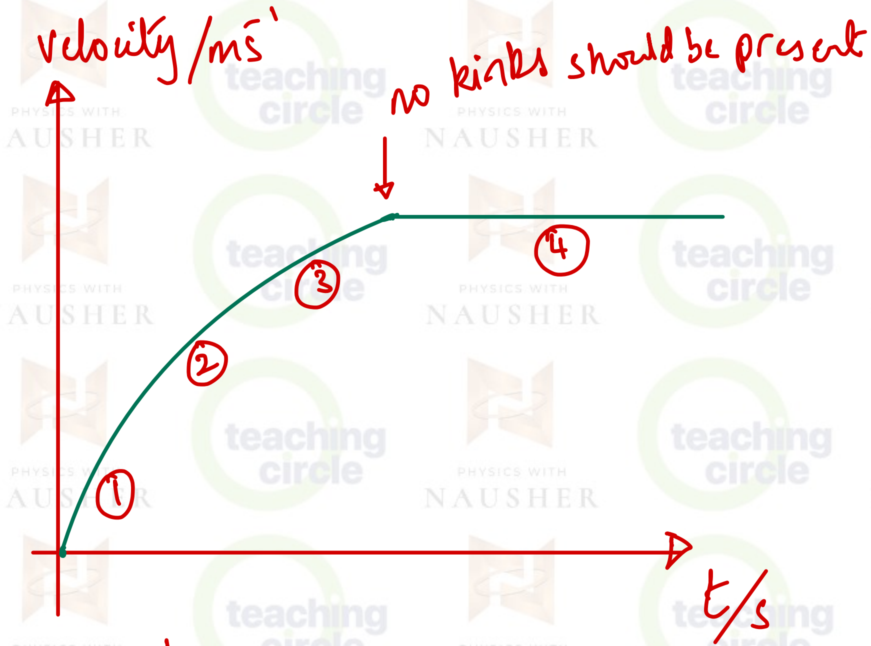
- The body accelarates according to $F \propto a$.
- As velocity increases, the drag force increases.
- The resultant force decreases, hence accelaration decreases

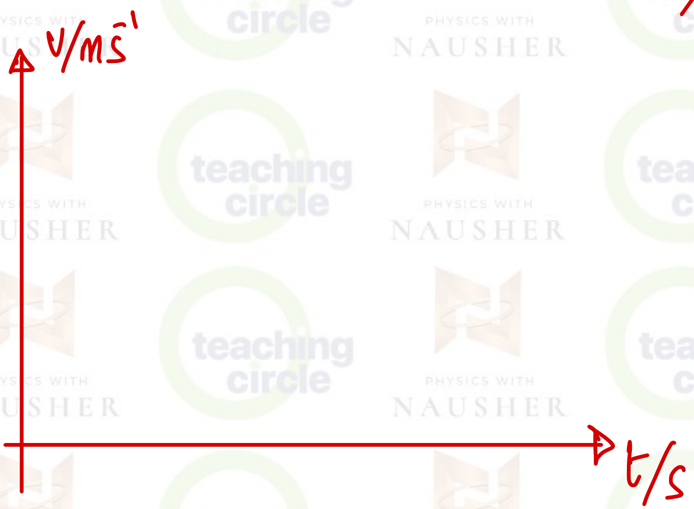
- When drag force becomes equal to the weight of the object, the resultant force is zero.
- The body falls at a constant velocity called terminal velocity.
- Terminal velocity is the maximum velocity a body can reach.

Timeline



1	2	3	4
object is just dropped	speed of object increases	speed of object increases more, drag increases more.	object reaches a velocity where Weight = Drag
a = max	a = decrease	a = decreases further	a = 0
F_{res} = Weight	$F_{res} = W - D$	$F_{res} = W - D$	$F_{res} = W - D$
$W > D$	$W > D$	$W > D$	$W = D$
e.g 10N > 0N	10N > 2N	10N > 6N	10N = 10N
Direction of motion	Direction of motion	Direction of motion	Direction of motion



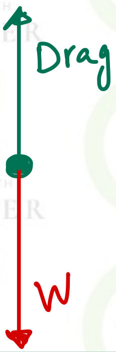


gradient of v-t = accelaration.

accelaration decreases to zero.

If the parachutist opens parachute.

4



object reaches a velocity where Weight = Drag

$a = 0$

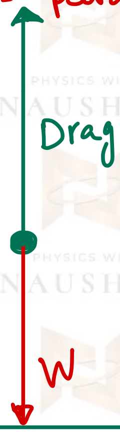
$F_{res} = W - D$

$W = D$

$10N = 10N$

Direction of motion

5



objects velocity decreases

Drag > Weight

$a = -ve$

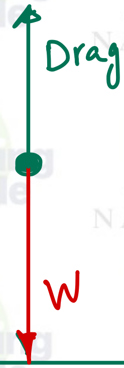
$F_{res} = W - D$

$W < D$

$10N < 15N$

Direction of motion

6



objects velocity continues to fall.

Drag decreases

$a = 0$

$F_{res} = W - D$

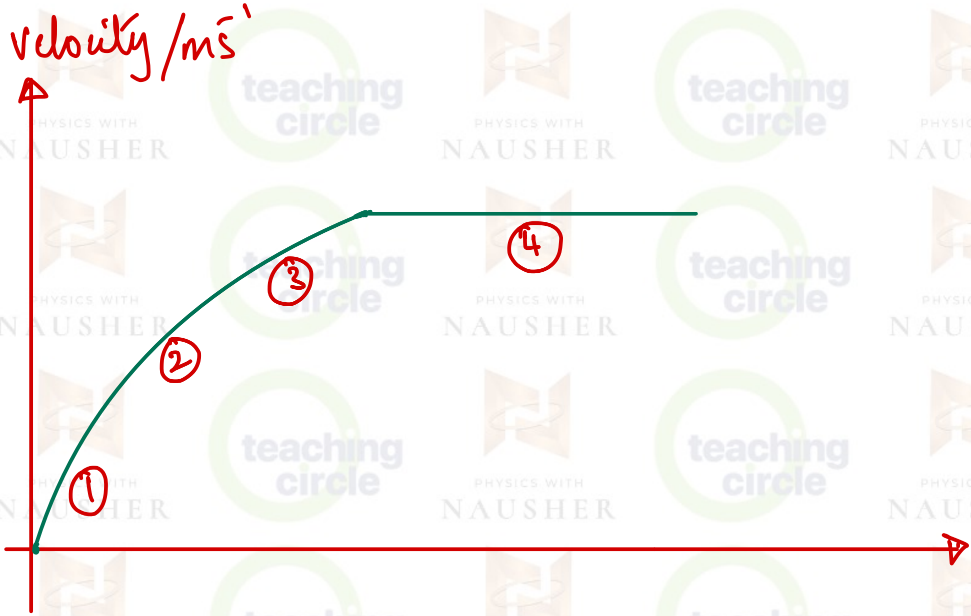
$W = D$

$10N = 10N$

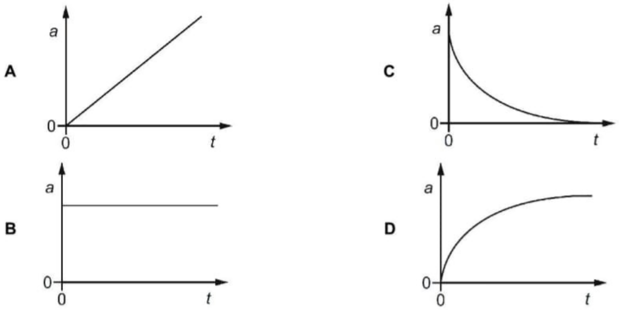
Direction of motion

Note:

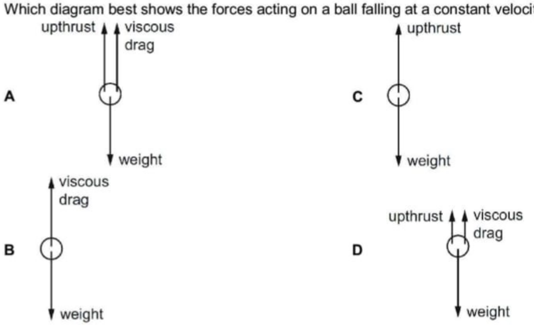
⑤ About this stage, never think the object will go backwards. Why? Relate to ____.



A beach-ball falls vertically from a high hotel window. Air resistance is **not** negligible.
Which graph shows the variation with time t of the acceleration a of the ball?



Which diagram best shows the forces acting on a ball falling at a constant velocity through a liquid?



1 The drag force F_D acting on an object falling through air is given by

$$F_D = \frac{1}{2} C\rho A v^2$$

where A is the cross-sectional area of the object,
v is the velocity of the object in the air,
ρ is the density of the air and
C is a constant called the drag coefficient.

(a) Use SI base units to show that the drag coefficient has no units.

[3]

(b) Fig. 1.1 shows a sphere falling at terminal velocity in air.

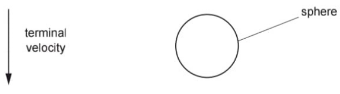


Fig. 1.1

Assume that the upthrust on the sphere is negligible.

On Fig. 1.1, draw and label arrows to show the directions of the **two** forces acting on the sphere. [2]

(c) The mass of the sphere is 49 g.

Calculate the drag force F_D acting on the sphere.

F_D = ... N [2]