



Motion along a straight line

Displacement, s
↳ distance in a given direction

$$s = vt$$

Velocity, v
↳ change of displacement per unit time

$$v = \frac{\Delta s}{\Delta t}$$

Acceleration, a
↳ change of velocity per unit time

$$a = \frac{\Delta v}{\Delta t}$$

Horizontal/vertical

When an object is projected upwards, the top point of the object's path is the point at which its velocity is 0 m s^{-1} . The path of the object after the top point is identical to the path before that point – the same values can be used, except the object is moving down instead of up!

Average speed:

the total distance travelled divided by the total time elapsed during the journey

Average velocity:

the total displacement travelled divided by the total time elapsed during the journey

Instantaneous vs average

Instantaneous speed:

the speed at a particular point in time

Instantaneous velocity:

the velocity at a particular point in time

- Velocity can be determined from the gradient of a displacement–time curve.
- Displacement can be determined from the area under a velocity–time curve.
- Acceleration can be determined from the gradient of the velocity–time curve.
- Velocity can be determined by the area under the acceleration–time curve.

Equations of motion

The following equations only hold if the object is travelling with uniform acceleration:

$$v = u + at$$

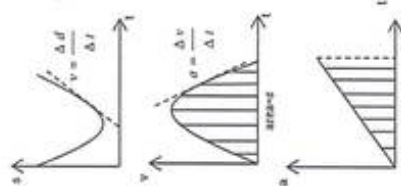
$$s = \left(\frac{u+v}{2} \right) t$$

$$s = ut + \frac{1}{2} at^2$$

$$v^2 = u^2 + 2as$$

Exam Tip!

You will be expected to be able to use the same equations when the object is in free fall and the acceleration a is equal to the acceleration due to gravity g .



Motion

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Projectile motion

Projectile:

A projectile is any object that has been propelled into the air by a force and has no means of self-propulsion i.e. only acted upon by the force of gravity.

Principles of projectile motion:

1. The acceleration of a projectile is equal to the acceleration due to gravity, g , which always acts in the downwards direction.
2. The horizontal motion of a projectile is constant, since the only force acting on a projectile is the force of gravity, which acts downwards. The acceleration due to gravity only has vertical components and, therefore, only affects the vertical motion of the projectile.
3. Vertical motion and horizontal motion of the projectile are independent of each other.

Horizontal versus vertical motion

Horizontal motion component:

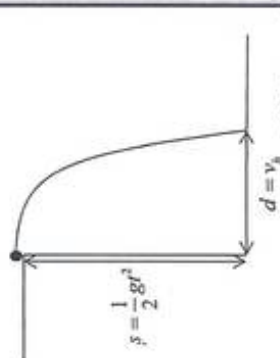
$$d = v_h t$$

- The faster an object is projected horizontally, the further it will travel in the horizontal direction.
- The time taken for an object to fall a distance s will be independent of the initial horizontal velocity.

Vertical motion component:

$$s = ut + \frac{1}{2} gt^2$$

- The velocity at which a projectile accelerates downwards due to gravity is independent of the initial horizontal velocity of the projectile.
- An object projected horizontally and an object falling vertically will fall through a distance s in the same time.



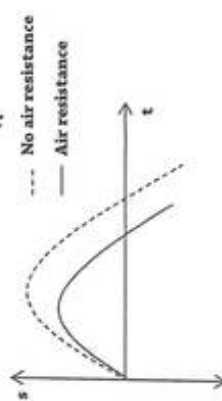
Friction: is a force that opposes the direction of motion. In the case of projectile motion, this will be referred to as the drag force due to air resistance.

Lift: is a force that acts perpendicular to oncoming flow direction of the fluid acting on the body.



Air resistance

- As an object travels through air, it experiences a drag force in the opposite direction due to the air resistance of the air it passes through.
- Air resistance increases with speed.
- It is caused by the friction between the air and the projectile's surface.
- The drag force has a horizontal component that decreases the horizontal velocity and therefore the projectile's range.
- The drag force decreases the maximum height of the projectile.
- Terminal speed is reached when the drag force is equal to the weight force.



Displacement–time graph of an object thrown from a platform with and without air resistance