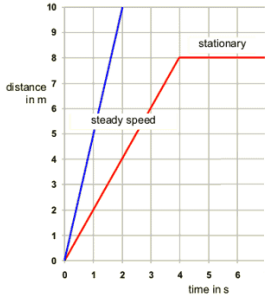
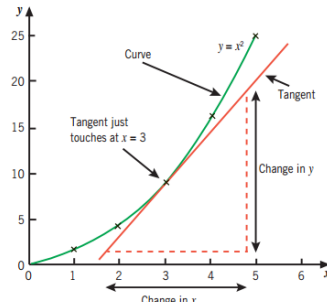


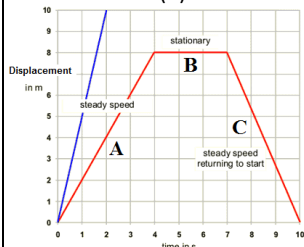
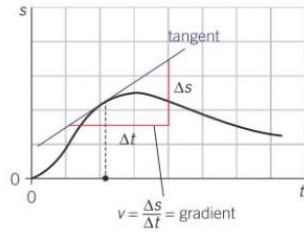
## 1. Distance and speed

<b>Average speed</b>	<p>The rate of change in distance calculated over a complete journey.</p> $\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$ $v = \frac{\Delta x}{\Delta t}$ <p><math>v</math> – average speed (<math>\text{m s}^{-1}</math>)  <math>\Delta x</math> – distance travelled (m)  <math>\Delta t</math> – time (s)</p>
<b>Distance</b>	Distance is a scalar quantity that refers to "how much ground an object has covered" during its motion, measured in m.
<b>Time</b>	Measured in seconds, s.
<b>Delta <math>\Delta</math></b>	Is a shorthand for <i>change in</i> .
<b>Distance-time graph constant speed</b>	<ul style="list-style-type: none"> <li>Stationary object is represented by a horizontal line</li> <li>An object moving at a constant speed is represented by a straight, sloping line.</li> </ul>  <p>The gradient of the graph represents the speed.</p>
<b>Constant speed</b>	Motion in which the distance travelled per unit time stays the same, measured in m/s.

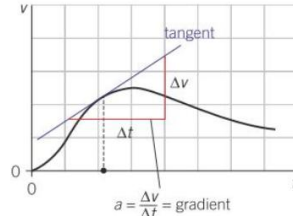


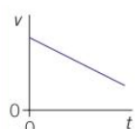
<b>Gradient</b>	In a graph, the change in the vertical axis quantity divided by the corresponding change in the horizontal axis quantity.
<b>Instantaneous speed</b>	The speed at the moment it is measured – speed over an infinitesimal interval of time. The greater the gradient, the greater the instantaneous speed.
<b>Distance-time graph varying speed</b>	<p>The gradient of the tangent to the graph represents the instantaneous speed.</p>  <p>When you calculate the gradient, make sure the triangle that you draw on the graph is large enough to provide an accurate answer.</p>

## 2. Displacement and velocity

<b>Average velocity</b>	<p>The change in displacement for a journey divided by the time taken.</p> $\text{average velocity} = \frac{\text{change in displacement}}{\text{time taken}}$ $v = \frac{\Delta s}{\Delta t}$ <p><math>v</math> – average velocity (m/s)  <math>\Delta s</math> – change in displacement (m)  <math>\Delta t</math> – time taken (s)</p>
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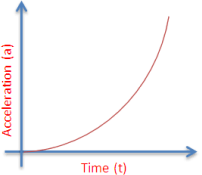
<b>Displacement</b>	<p>The distance travelled in a particular direction – it is a vector with magnitude and a direction, measured in m.</p>
<b>Displacement-time graph</b>	<ul style="list-style-type: none"> <li>Stationary object is represented by a horizontal line. (B)</li> <li>An object moving at a constant speed is represented by a straight, sloping line. <ul style="list-style-type: none"> <li>Positive slope – the object is moving away from the starting position. (A)</li> <li>Negative slope – the object is returning back. (C)</li> </ul> </li> </ul>   <p>Velocity can be determined from the gradient of the displacement-time graph.</p>

## 3. Acceleration

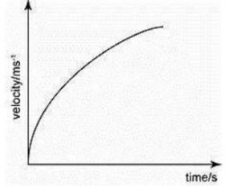
<b>Acceleration</b>	<p>The rate of change of velocity, a vector quantity.</p> $a = \frac{\Delta v}{\Delta t}$ <p><math>a</math> – acceleration (<math>\text{m s}^{-2}</math>)  <math>\Delta v</math> – change in velocity (<math>\text{m s}^{-1}</math>)  <math>\Delta t</math> – time taken (s)</p>
<b>Velocity-time graphs</b>	<p>acceleration = gradient of velocity-time graph</p> 
<b>Constant acceleration (uniform acceleration)</b>	<p>A straight line of constant, positive gradient: constant acceleration.</p> 
<b>Zero acceleration</b>	<p>A straight line of zero gradient: constant velocity or zero acceleration.</p> 
<b>Constant deceleration (uniform deceleration)</b>	<p>A straight line of constant negative gradient: constant deceleration.</p> 

Non-uniform acceleration

A curve with changing gradient: acceleration is changing.



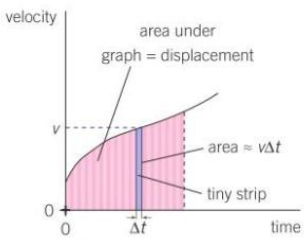
Non-uniform deceleration



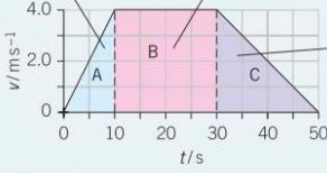
4. More on velocity – time graphs

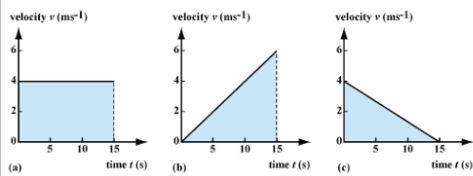
Calculating displacement t for non-uniform acceleration

The area under velocity-time graph is equal to displacement.

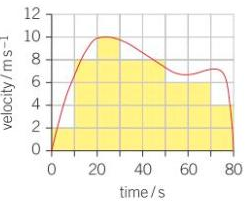


Calculating displacement t for uniform acceleration





Calculating displacement t under a non-linear velocity-time graph



For non-linear velocity-time graphs, you can determine the area under the graph by counting squares.

5. Equations of motion

suvat

s – displacement/distance travelled  
u – initial velocity  
v – final velocity  
a – acceleration  
t – time taken for the change in velocity

Equation without s

$$v = u + at$$

Equation without v

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

Equation without a

$$s = \frac{1}{2}(u + v)t$$

Equation without t

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

6. Car stopping distances

Stopping distance

The total distance travelled from the time when a driver first sees a reason to stop to the time when the vehicle stops, the sum of the thinking distance and the braking distance.

Thinking distance

The distance travelled by a vehicle from when the driver first perceives a need to stop to when the brakes are applied.

Thinking distance = speed x reaction time

Distance is directly proportional to time.

Braking distance

Distance travelled by a vehicle from the time the brakes are applied until the vehicle stops.

Distance is directly proportional to the initial speed squared.

If you double your initial velocity, it is going to take four times the distance to brake.

Reaction time

Reaction time is the amount of time it takes to respond to a stimulus.

Factors affecting braking distance

- The type of braking system,
- Brake pad material,
- Brake alignment,
- Tyre pressures,
- Tyre tread and grip,
- Vehicle weight,
- Suspension system,
- The co-efficient of friction of the road surface,
- Wind speed,
- Slope of road,
- Surface smoothness
- The braking technique applied by the driver.

Factors affecting thinking distance

- Speed
- Distractions, e.g. mobile phones
- Alcohol
- Drugs
- Tiredness
- Visibility

Factors affecting thinking and braking distance

- speed

Speed / mph	20	30	40	50	60	70
Speed / m s <sup>-1</sup>	8.9	13.4	17.8	22.2	26.7	31.1
Thinking distance / m	6	9	12	15	18	21
Braking distance / m	6	14	24	38	55	75
Stopping distance / m	12	23	36	53	73	96

Thinking, braking, and overall stopping distances according to the Highway code.

7. Free fall and g

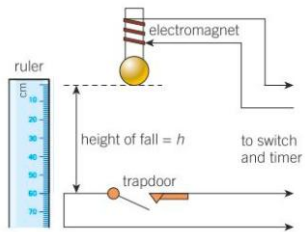
Free fall


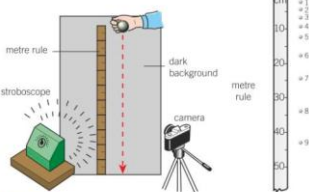
The motion of an object accelerating under gravity with no other force acting on it.

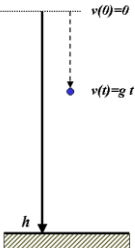
Acceleration of free fall

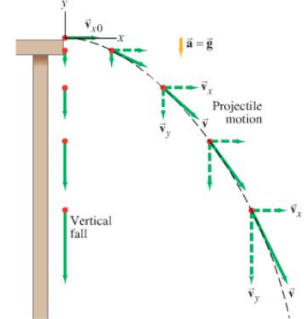
The rate of change of velocity of an object falling in a gravitational field, symbol *g*, measured in m s<sup>-2</sup>.

The value for *g* varies depending upon factors including altitude, latitude, and the geology of an area.

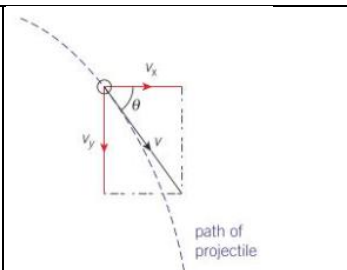
<b>Determining g</b>	<p>The basic idea behind determining g in the laboratory is to drop a heavy ball over a known distance and time its descent.</p> <p>Methods for measuring g are:</p> <ul style="list-style-type: none"> <li>- electromagnet and trapdoor</li> <li>- light gates</li> <li>- taking pictures</li> </ul>
<b>Electromagnet and trapdoor</b>	<ul style="list-style-type: none"> <li>- An electromagnet holds a small steel ball above a trapdoor</li> <li>- When the current is switched off, a timer is triggered, the electromagnet demagnetises, and the ball falls.</li> <li>- When it hits the trapdoor, the electrical contact is broken and the timer stops.</li> </ul>  <p>The value for g is calculated from the height from the fall and the time taken. Negative side – tiny delays into the timing.</p>
<b>Light gate</b>	<p>A light gate usually consists of two light beams, one above the other, with detectors connected to a timer.</p>

<b>Taking pictures</b>	<p><b>Camera</b> in rapid-fire repeating mode</p>  <p>▲ <b>Figure 3</b> The photos are taken at regular intervals and the distance between each image of the ball increases as it falls vertically towards the ground, showing that it is accelerating</p> <p>A <b>stroboscope</b> illuminates the scene with rapid flashes.</p>  <p>▲ <b>Figure 4</b> Determining g using a camera and stroboscope</p> <p>The camera shutter is held open, producing a photograph with multiple images of the falling ball.</p>
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8. Projectile motion	
<b>Free fall</b>	<p>A free falling object is an object that is falling under the sole influence of gravity.</p> <ul style="list-style-type: none"> <li>- Free-falling objects do not encounter air resistance.</li> <li>- All free-falling objects (on Earth) accelerate downwards at a rate of <math>9.8 \text{ m s}^{-2}</math>.</li> </ul>  $h = \frac{1}{2}gt^2$ $v^2 = 2gh$ $v = gt$ <p>h – height (m) a = g – gravitational field strength (<math>\text{m s}^{-2}</math>) t – time (s) v – vertical velocity (<math>\text{m s}^{-1}</math>)</p>
<b>Vertical motion – upward</b>	<ul style="list-style-type: none"> <li>- An object that is thrown vertically upwards decelerates under the earth's gravity. Its speed decreases until it attains a maximum height, where the velocity is zero.</li> <li>- Then it is accelerated uniformly downwards under gravity. When it returns to the point of projection, it has the same speed as that at the instant of projection.</li> <li>- no air resistance</li> <li>- suvat equations</li> </ul>

<b>Horizontal projectile motion</b>	<ul style="list-style-type: none"> <li>- The motion in two dimensions x and y.</li> <li>- The motion can be looked at as two components of the motion separately: horizontal (x-axis) and vertical (y-axis).</li> </ul>  <ul style="list-style-type: none"> <li>- Assuming no air resistance.</li> <li>- An object projected horizontally will reach the ground in the same time as an object dropped vertically, from the same height.</li> <li>- The vertical displacement and time of flight can be calculated using equations of motion.</li> </ul>
<b>Horizontal projectile motion – horizontal component</b>	<ul style="list-style-type: none"> <li>- Horizontal velocity remains constant.</li> <li>- Horizontal acceleration is equal to zero.</li> <li>- The horizontal velocity is unaffected by the fall.</li> </ul>
<b>Horizontal projectile motion – vertical component</b>	<ul style="list-style-type: none"> <li>- The vertical velocity changes due to acceleration of free fall.</li> </ul>

## Horizontal projectile motion – velocity $v$



$$\text{Actual velocity } v = \sqrt{v_x^2 + v_y^2}$$

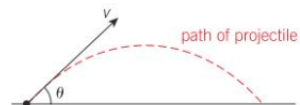
$v_x$  – vertical component

$v_y$  – horizontal component

$$\theta = \tan^{-1} \left( \frac{v_y}{v_x} \right)$$

## Projectile motion

- Projectile fired at an angle  $\theta$  to the horizontal.



- The motion can be analysed in terms of the independence of motion in the horizontal and vertical directions.

- The horizontal component of the velocity is

$$v_x = v \times \cos \theta$$

- The vertical component of the velocity is

$$v_y = v \times \sin \theta$$