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## 11 Acceleration

Acceleration means that there is a change of velocity – a change of speed or a change of direction of motion.

This could mean

- **speeding up**
  - when the acceleration is in the same direction as the motion
- **slowing down (also called deceleration)**
  - here the acceleration is in the opposite direction to the motion
- **changing direction (a centripetal acceleration)**
  - here the acceleration is at right angles to the motion

We measure acceleration in **metres per second squared ( $\text{m/s}^2$ )**. An acceleration of  $3 \text{ m/s}^2$  means that each second the velocity changes by  **$3 \text{ m/s}$** .

acceleration ( $\text{m/s}^2$ ) = change in velocity ( $\text{m/s}$ ) / time taken ( $\text{s}$ )

$$a = (v - u) / t$$

When the velocity changes we use  $u$  for the velocity at the start, and  $v$  for the velocity at the end.

Example 1 – A car is travelling at  $3.0 \text{ m/s}$ . It accelerates at  $2.5 \text{ m/s}^2$ . How fast is it going  $5.5 \text{ s}$  later?

Change in velocity =  $a \times t = 2.5 \text{ m/s}^2 \times 5.5 \text{ s} = 13.75 \text{ m/s}$

New velocity =  $3.0 + 13.75 = 17 \text{ m/s}$  (2sf)

Example 2 – A car at  $31 \text{ m/s}$  stops in  $6.8 \text{ s}$ . Calculate the deceleration.

Acceleration =  $(v - u) / t = (0 \text{ m/s} - 31 \text{ m/s}) / (6.8 \text{ s}) =$

$(-31 \text{ m/s}) / (6.8 \text{ s}) = -4.56 \text{ m/s}^2$  so deceleration =  $4.6 \text{ m/s}^2$  (2sf)

Here the velocity change is negative as the final velocity ( $0 \text{ m/s}$ ) is lower than the starting velocity ( $31 \text{ m/s}$ ), thus is a deceleration.

**Example 3** – A car starts from rest. It accelerates backwards until it is reversing at 4.0 m/s. This takes 5.0 s. Calculate the acceleration.

$$\text{Acceleration} = (v - u)/t = (-4.0 \text{ m/s})/(5.0 \text{ s}) = -0.80 \text{ m/s}^2.$$

The change in velocity is negative as the final velocity (−4.0 m/s) is lower than the starting velocity (0 m/s). However, although the acceleration is negative, this is not a deceleration as the car is speeding up (backwards).

**11.1** Complete the table with the correct values. Each row represents a separate situation.

Acceleration (m/s <sup>2</sup> )	Velocity (m/s) after ... s						
	0.0	1.0	2.0	3.0	4.0	5.0	6.0
3.0	0.0	3.0	(a)	9.0	(b)	(c)	18
5.0	0.0			(d)		(e)	(f)
7.0	3.0			(g)	(h)		(i)
−25.0	30.0			(j)	(k)		(l)
(m)	10.5		13.5		(n)		
(o)	45		36		27		(p)

**11.2** In Q11.1(d), what would the velocity be 15 s after the start if the acceleration were maintained?

**11.3** In Q11.1(o), at what time does the vehicle come to a stop?

**11.4** A tennis ball is thrown in the air upwards at 15 m/s. If it is accelerating downwards at 10 m/s<sup>2</sup>, what will its velocity be 2.0 s after it is thrown? (Remember to say how fast it is going and also which way.)

**11.5** A rollercoaster speeds up from rest to 100 mph (45 m/s) in 1.2 s.

(a) Calculate the acceleration.

(b) The rollercoaster car then travels vertically upwards, and decelerates at  $10 \text{ m/s}^2$ . How much time passes before it is stationary (for a moment)?

- 11.6 A car starts from rest and reaches a speed of  $40 \text{ m/s}$  in a time of  $8.0$  seconds. Calculate its average acceleration.
- 11.7 Complete the table with the correct values. Each row represents a separate situation.

Starting velocity (m/s)	Final velocity (m/s)	Time taken (s)	Acceleration ( $\text{m/s}^2$ )
0.0	(a)	8.5	3.5
4.5	35	8.5	(b)
26	0.0	(c)	$-6.7$
(d)	5.0	1.2	$-1.5$
0.0	(e)	300	31

- 11.8 A certain make of car can reach  $60 \text{ mph}$  from rest in a time of  $9.0$  seconds. Calculate its average acceleration in  $\text{m/s}^2$ . [Note:  $1 \text{ mph} = 0.45 \text{ m/s}$ ]
- 11.9 Calculate the change of speed of a train which accelerates for  $9.0$  seconds at a rate of  $1.2 \text{ m/s}^2$  in a straight line.
- 11.10 In overtaking a lorry on a straight section of road, a driver increases speed from  $50 \text{ mph}$  to  $70 \text{ mph}$  in  $5.0 \text{ s}$ . [Note:  $1 \text{ mph} = 0.45 \text{ m/s}$ .] Calculate the acceleration in:
- (a) miles per hour per second and;
- (b) metres per second per second.