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 (m/s^2). An acceleration of 3 m/s^2 means that each second the velocity changes by 3 m/s.

$$\text{acceleration (m/s}^2) = \text{change in velocity (m/s)} / \text{time taken (s)}$$
$$a = (v - u)/t$$

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 m/s. It accelerates at 2.5 m/s^2. How fast is it going 5.5 s later?

Change in velocity $= a \times t = 2.5$ m/s$^2 \times 5.5$ s $= 13.75$ m/s
New velocity $= 3.0 + 13.75 =$ 17 m/s (2sf)

Example 2 – A car at 31 m/s stops in 6.8 s. Calculate the deceleration.

Acceleration = $(v - u)/t = \ (0$ m/s $- 31$ m/s$)/(6.8$ s$) =$
$(-31$ m/s$)/\ (6.8$ s$) = -4.56$ m/s^2 so deceleration = 4.6 m/s^2 (2sf)
Here the velocity change is negative as the final velocity (0 m/s) is lower than the starting velocity (31 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.

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/s²)	**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^2, 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 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 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 (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 mph from rest in a time of 9.0 seconds. Calculate its average acceleration in m/s^2. [Note: 1 mph $=$ 0.45 m/s]

11.9 Calculate the change of speed of a train which accelerates for 9.0 seconds at a rate of 1.2 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 mph to 70 mph in 5.0 s. [Note: 1 mph $= 0.45$ m/s.] Calculate the acceleration in:

(a) miles per hour per second and;

(b) metres per second per second.