15 Stopping With and Without Brakes

Formulae:

$$\text{distance travelled} = \text{average speed} \times \text{time} \qquad s = vt$$

$$\text{resultant force} = \text{mass} \times \text{acceleration} \qquad F = ma$$

$$\text{change in velocity} = \text{acceleration} \times \text{time} \qquad v - u = at$$

$$\text{kinetic energy} = \tfrac{1}{2} \times \text{mass} \times \text{speed}^2 \qquad E = \tfrac{1}{2} mv^2$$

$$\text{work done} = \text{force} \times \text{distance} \qquad W = Fs$$

Data:

To convert miles/hr to m/s, multiply by $1\,609/3\,600 = 0.447$.

With Brakes

The shortest distance taken to stop a car from the moment when the driver first notices a problem is called the stopping distance. This is made of two parts – the distance the car travels while the driver reacts and first applies the brakes (the thinking distance), and the distance the brakes take to stop the car (the braking distance).

The Highway Code estimates that a typical reaction time of a driver is two thirds of a second; and that once applied, brakes will give a car a 6.67 m/s^2 deceleration. This reaction time may seem very long - but it takes into account the fact that during a long drive a driver may not be fully alert, and that the action of moving your foot from the accelerator to the brake pedal and stamping takes longer than pressing a button with your finger.

Example 1 – Calculate the thinking distance at 30 mph.

Conversion: 30 mph $= 30 \times 0.447 = 13.4$ m/s.
Thinking distance $=$ reaction time $\times$ speed $= 0.667$ s $\times$ 13.4 m/s $=$ 8.9 m.

Example 2 – Calculate the braking distance from 30 mph.

Conversion: 30 mph $= 30 \times 0.447 =$ 13.4 m/s.
Velocity drop $=$ deceleration $\times$ braking time, so
braking time $=$ velocity reduction / deceleration $= 13.4/6.67 = 2.0$ s.
Average speed on decelerating from 13.4 m/s to 0 m/s is $(13.4 + 0)$ / 2 $= 6.7$ m/s.
Braking distance $=$ braking time $\times$ average speed $= 2.0$ s $\times$ 6.7 m/s $=$ 13.4 m.

15.1 Using the data in the examples, calculate the overall stopping distance from 30 mph (according to the Highway Code).

15.2 Using the Highway code values for reaction time and deceleration:

(a) Calculate the thinking distance at 60 mph.

(b) Calculate the braking distance at 60 mph.

(c) Use Example 1 and your answer to (a) to complete the sentence: when you double your speed, the thinking distance __________.

(d) Use Example 2 and your answer to (b) to complete the sentence: when you double your speed, the braking distance __________.

In your answer to (c), going at twice the speed, you cover twice the distance during your reaction time, as the reaction time doesn't change.
In your answer to (d), going at twice the speed, it takes you twice the time to stop. However, you are going twice as fast, leading to an overall multiplication by 4.

15.3 A car is traveling at 70 mph.

(a) Calculate the thinking distance.

(b) Calculate the braking distance.

(c) Another car is travelling at 35 mph, what is its overall stopping distance?

15.4 How much longer is the stopping distance at 35 mph compared to

30 mph? Measure out this distance. Discuss why the 30 mph speed limit is so important in built-up areas.

15.5 Here is an alternative way of calculating the braking distance from 60 mph (26.8 m/s). We are in a 700 kg car. Calculate:

(a) The kinetic energy of the car.

(b) The force needed for a 6.67 m/s^2 deceleration.

(c) The braking distance. [energy transfer $=$ force $\times$ distance]

15.6 The "two second rule": A driver waits until the vehicle in front passes a road sign and then sees if her car passes this road sign within two seconds. If it has, she is driving too close. Assume that a driver is keeping the two second rule exactly.

(a) How far will the driver be behind the vehicle in front at 30 mph?

(b) How far will the driver be behind the vehicle in front at 60 mph?

(c) By referring back to your answer to Q15.1, does a driver following the 2 second rule at 30 mph always keep at least one stopping distance behind the vehicle in front?

(d) By referring back to your answer to Q15.2, does a driver following the 2 second rule at 60 mph always keep at least one stopping distance behind the vehicle in front?

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In wet conditions, drivers should allow *at least* twice these distances.

Without Brakes

15.7 A car runs into a wall and stops in 0.30 s. It was going at 20 m/s.

(a) Calculate the deceleration.

(b) A person fixed to the car by a seatbelt has the same deceleration. They have a mass of 70 kg. Calculate the force on the person.

(c) Repeat the calculation for the force if the car took 0.90 s to stop.