TAP 205- 2: Distance, time and speed calculations

Try these calculations

Graph paper is needed for some. These questions are all based on the connection between speed, distance and time. Answer in the spaces provided:

Hints

In these questions it is useful to remember that:

– if an object is accelerating steadily from rest its average speed is half the maximum speed

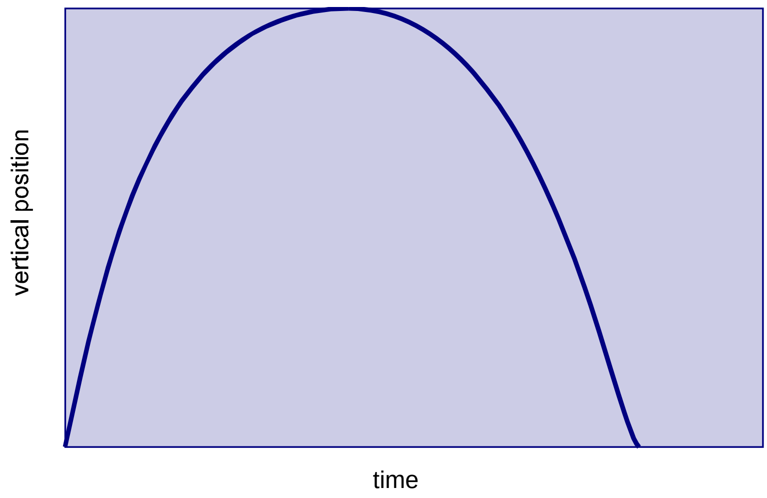
– and that distance travelled = average speed time

1. You are watching a batsman hit a cricket ball. If 0.375 s passes between the time you see him strike the ball and the time you hear the sound of this, how far from the batsman are you sitting? The speed of sound in air is 340 m s^{-1}. (The speed of light is nearly a million times bigger than this, so you see the bat hit the ball more or less at the instant it occurs.)

2. A girl diving from a 15 m platform wishes to know how fast she enters the water. She is in the air for 1.75 s and dives from rest (with an initial speed of zero). What can you tell her about her entry speed?

3. An experiment performed on the Moon finds that a feather falls 20.75 m from rest in 5 s. What is its speed as it hits the Moon's surface?

4. The sketch graph shown represents the variation in vertical height with time for a ball thrown upwards and returning to the thrower.



From this graph sketch a velocity–time graph.

5. In a Tour de France time trial a cyclist is able to reach a top speed of 100 km h^{-1} by starting from rest and pedalling flat out for a distance of 3 km. If the rate at which the cyclist's speed changes is uniform, how long will this take?

6. You are travelling in a car moving at 50 km h^{-1} (just over the 30 mph speed limit). What is this speed in m s^{-1}? You have to brake so the car comes to rest uniformly in 1.4 s, how far will you travel? A cat runs out in front of your car and your reaction time is 0.6 s. What is the total distance the car will travel before stopping?

7. A steam traction engine speeds up uniformly from rest to 4 m s^{-1} in 20 s. It then travels at a steady speed for 440 m and finally comes to rest uniformly in 10 s having travelled 500 m in total. Draw a speed–time graph for its motion showing key values of speed and time. What is the total time for the journey? What is the average speed for the whole journey?

8. A tennis ball is dropped from a height of 2 m above a hard level floor, and falls to the floor in 0.63 s. It rebounds to a height of 1.5 m, rising to a maximum height 1.18 s after it was released. Draw a speed–time graph indicating speed and time at key points of the motion.

Practical advice

These questions are mostly revision from pre-16 level. They do address application of distance, time and speed measurements in a variety of contexts, and force students to think carefully about interpreting and using graphs of motion.

Social and human context

Sports provide many examples of coordinated and relative motion.

Answers and worked solutions

1.

$$\text{Speed} = \frac{\text{distance}}{\text{time}} \Rightarrow \text{distance} = \text{speed} \times \text{time} = 340\ \text{m s}^{-1} \times 0.375\ \text{s} = 127.5\ \text{m}$$

= 128 m to 3sf

2. When you have read chapter 9 you will be able to do this calculation using ideas about acceleration. There is a simpler way: the girl's average speed is

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{15\,\text{m}}{1.75\,\text{s}} = 8.57\ \text{m s}^{-1}.$$

As she dives from rest, her final speed must be twice this average (if we assume that she accelerates uniformly). So, her speed on entry is

$$\text{maximum speed} = 2 \times 8.57\ \text{m s}^{-1} = 17.14\ \text{m s}^{-1} \approx 17.1\,\text{m s}^{-1}.$$

=17 ms^{-1} to 2sf

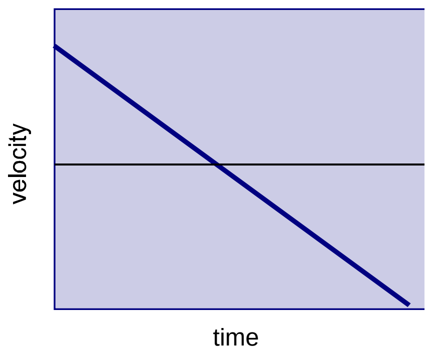
3. The solution to this problem is similar to that for question 2. Find the average speed and then double it. The average speed is

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{20.75\,\text{m}}{5\ \text{s}} = 4.15\ \text{m s}^{-1}.$$

Hence:

$$\text{maximum speed} = 2 \times 4.15\ \text{m s}^{-1} = 8.30\ \text{m s}^{-1}.$$

4. The velocity is calculated from the gradient of the distance–time graph. At first the graph rises, implying a positive gradient, which gradually decreases to zero, implying a speed of zero. The gradient then becomes negative and gradually steeper, showing an increasing negative velocity.



5. The top speed of the cyclist is 100 km h^{-1}. If the cyclist accelerates uniformly from rest, the average speed must be half this, i.e. 50 km h^{-1}. To find the time taken to travel 3 km at this speed:

$$\text{speed} = \frac{\text{distance}}{\text{time}} \Rightarrow \text{time} = \frac{\text{distance}}{\text{speed}} = \frac{3\text{ km}}{50\text{ km h}^{-1}} = 0.06\text{ h} = 216\text{ s}$$

6. To convert 50 km h^{-1} to m s^{-1}:

50 km h^{-1} = 50 km h^{-1} x 1000 m km^{-1} / 3600 s h^{-1} = 13.8 m s^{-1}.

The average speed of the car is half the maximum, or 6.9 m s^{-1}. Then:

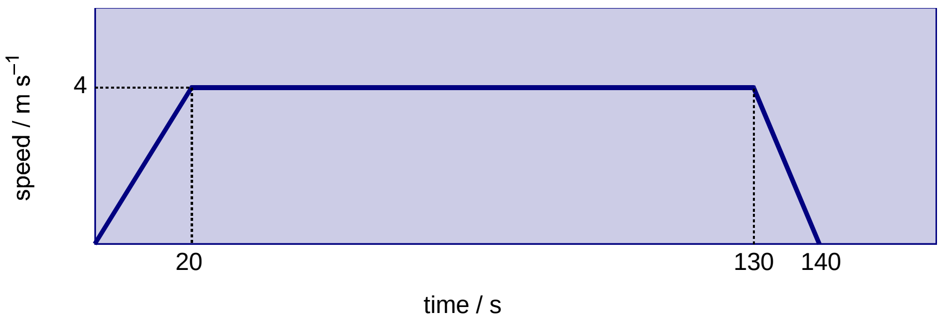
distance = speed x time = 6.9 m s^{-1} x 1.4 s = 9.7 m

When the cat runs out, you first move for 0.6 s at the maximum speed of 13.8 m s^{-1}. Hence, the additional 'thinking distance' travelled is

distance = speed   time = 13.8 m s^{-1} x 0.6 s = 8.3 m

Thus, the total distance travelled is 8.3 m + 9.7 m = 18 m.

7.



The engine travels 440 m at 4 m s^{-1}.

time = distance / speed = 440 m / 4 m s^{-1} = 110 s

Distance travelled = area under the speed-time graph.

total distance = (1/2 x 20 x 4) + (110 x 4) + (1/2 x 10 x 4) = 500 m

The total time for the journey is then 20 s + 110 s + 10 s = 140 s. The average speed is then

$$\text{Average speed} = \frac{\text{distance}}{\text{time}} = \frac{500\text{ m}}{140\text{ s}} = 3.57\text{ m s}^{-1}$$

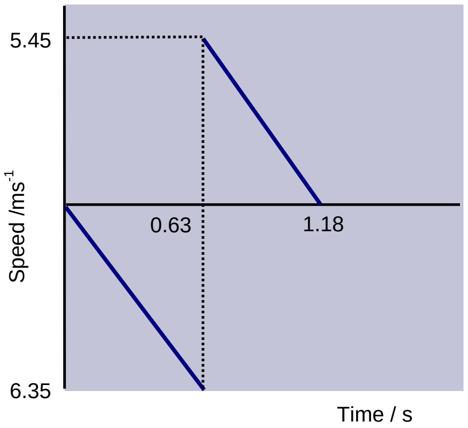
8. The ball falls to the floor in 0.63 s. Its average speed during the fall is

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{2\text{ m}}{0.63\text{ s}} = 3.17\text{ m s}^{-1}.$$

Its maximum speed (the speed with which it hits the floor) is then 2 x 3.17 m s^{-1} = 6.35 m s^{-1}. On the rebound, the average speed is

$$\text{average speed} = \frac{\text{distance}}{\text{time}} = \frac{1.5\text{ m}}{0.55\text{ s}} = 2.73\text{ m s}^{-1}.$$

The time in this equation is calculated from 1.18 s – 0.63 s = 0.55 s. The maximum speed on the rebound must then be 2 x 2.73 m s^{-1} = 5.45 m s^{-1}.



External references

This activity is taken from Advancing Physics Chapter 8, 20S