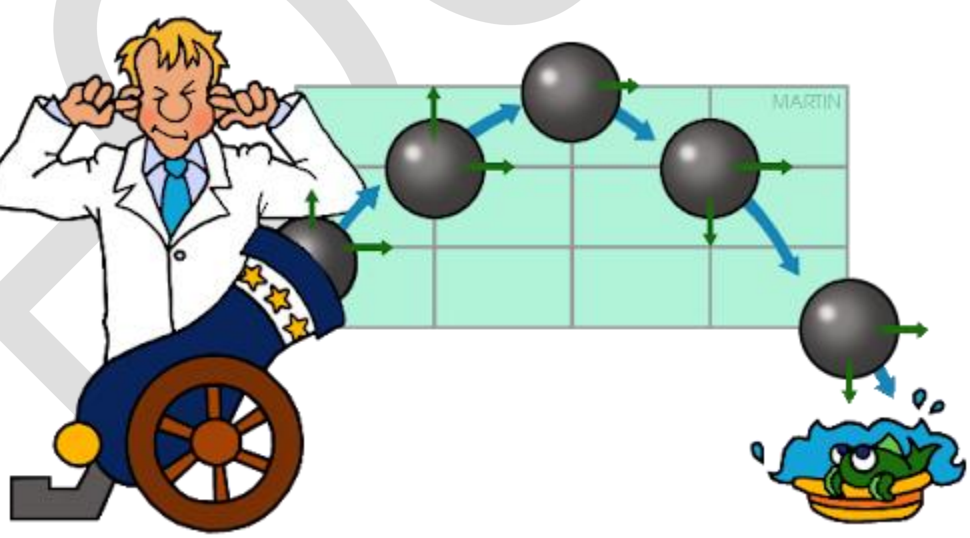
Cambridge AS Physics

(Code: 9702)

Chapter 1
Kinematics – describing motion



Speed

$$v = \frac{d}{t}$$

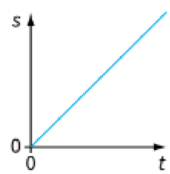
$m\,s^{-1}$	metres per second
$cm\,s^{-1}$	centimetres per second
$km\,s^{-1}$	kilometres per second
$km\,h^{-1}$ or km/h	kilometres per hour
mph	miles per hour

Quantity	Symbol for quantity	Symbol for unit
distance	*d*	m
displacement	*s*, *x*	m
time	*t*	s
speed, velocity	*v*	$m\,s^{-1}$

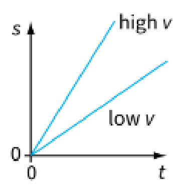
$$v = \frac{\Delta s}{\Delta t}$$

Displacement-time graph

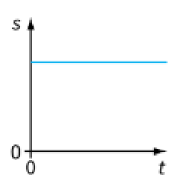
The straight line shows that the object's velocity is constant.



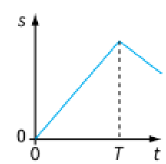
The slope shows which object is moving faster. The steeper the slope, the greater the velocity.



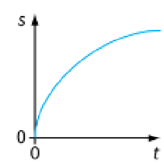
The slope of this graph is 0.
The displacement *s* is not changing.
Hence the velocity $v = 0$.
The object is stationary.



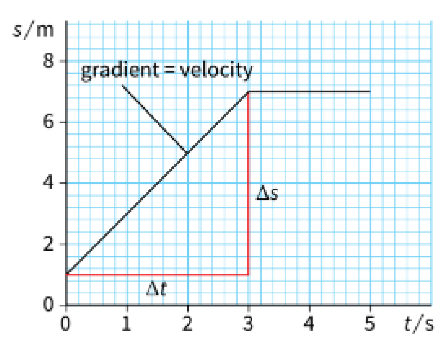
The slope of this graph suddenly becomes negative. The object is moving back the way it came.
Its velocity *v* is negative after time *T*.



This displacement–time graph is curved. The slope is changing. This means that the object's velocity is changing – this is considered in Chapter 2.



velocity = gradient of displacement–time graph



Combining displacement-time graph

A spider runs along two sides of a table (Figure 1.13). Calculate its final displacement.

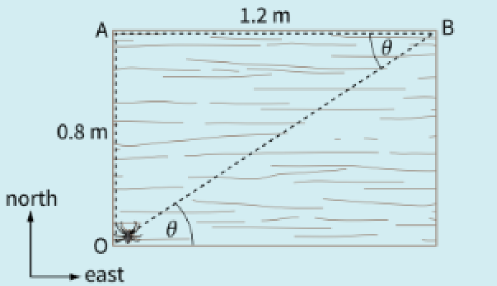


Figure 1.13 The spider runs a distance of 2.0 m, but what is its displacement?

Step 1 Because the two sections of the spider's run (OA and AB) are at right angles, we can **add** the two displacements using Pythagoras's theorem:

$$OB^2 = OA^2 + AB^2$$

$$= 0.8^2 + 1.2^2 = 2.08$$

$$OB = \sqrt{2.08} = 1.44\,\text{m} \approx 1.4\,\text{m}$$

Step 2 Displacement is a vector. We have found the **magnitude** of this vector, but now we have to find its direction. The angle θ is given by:

$$\tan\theta = \frac{\text{opp}}{\text{adj}} = \frac{0.8}{1.2}$$

$$= 0.667$$

$$\theta = \tan^{-1}(0.667)$$

$$= 33.7° \approx 34°$$

So the spider's displacement is 1.4 m at an angle of 34° north of east.

An aircraft flies 30 km due east and then 50 km north-east (Figure 1.14). Calculate the final displacement of the aircraft.

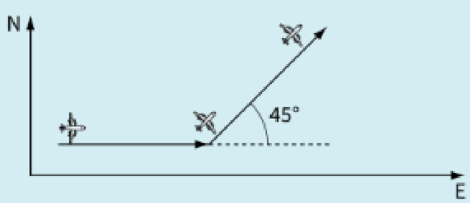


Figure 1.14 What is the aircraft's final displacement?

Here, the two displacements are not at 90° to one another, so we can't use Pythagoras's theorem. We can solve this problem by making a scale drawing, and measuring the final displacement. (However, you could solve the same problem using trigonometry.)

Step 1 Choose a suitable scale. Your diagram should be reasonably large; in this case, a scale of 1 cm to represent 5 km is reasonable.

Step 2 Draw a line to represent the first vector. North is at the top of the page. The line is 6 cm long, towards the east (right).

Step 3 Draw a line to represent the second vector, starting at the end of the first vector. The line is 10 cm long, and at an angle of 45° (Figure 1.15).

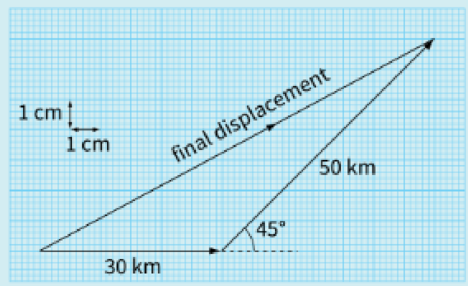


Figure 1.15 Scale drawing for Worked example 4. Using graph paper can help you to show the vectors in the correct directions.

Step 4 To find the final displacement, join the start to the finish. You have created a **vector triangle**. Measure this displacement vector, and use the scale to convert back to kilometres:

length of vector = 14.8 cm

final displacement = 14.8 × 5 = 74 km

Step 5 Measure the angle of the final displacement vector:

angle = 28° N of E

Therefore the aircraft's final displacement is 74 km at 28° north of east.

Combining velocities

An aircraft is flying due north with a velocity of $200\,m\,s^{-1}$. A side wind of velocity $50\,m\,s^{-1}$ is blowing due east. What is the aircraft's resultant velocity (give the magnitude and direction)?

Here, the two velocities are at 90°. A sketch diagram and Pythagoras's theorem are enough to solve the problem.

Step 1 Draw a sketch of the situation – this is shown in Figure 1.16a.

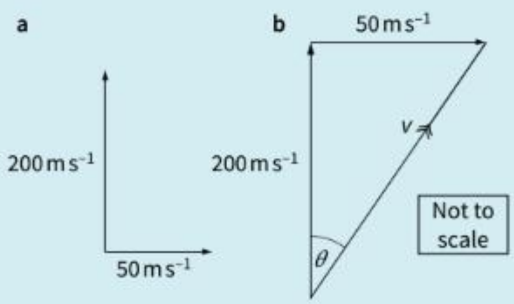


Figure 1.16 Finding the resultant of two velocities – for Worked example 5.

Step 2 Now sketch a vector triangle. Remember that the second vector starts where the first one ends. This is shown in Figure 1.16b.

Step 3 Join the start and end points to complete the triangle.

Step 4 Calculate the magnitude of the resultant vector v (the hypotenuse of the right-angled triangle).

$$v^2 = 200^2 + 50^2 = 40\,000 + 2500 = 42\,500$$

$$v = \sqrt{42\,500} \approx 206\,m\,s^{-1}$$

Step 5 Calculate the angle θ:

$$\tan\theta = \frac{50}{200}$$

$$= 0.25$$

$$\theta = \tan^{-1}(0.25) \approx 14°$$

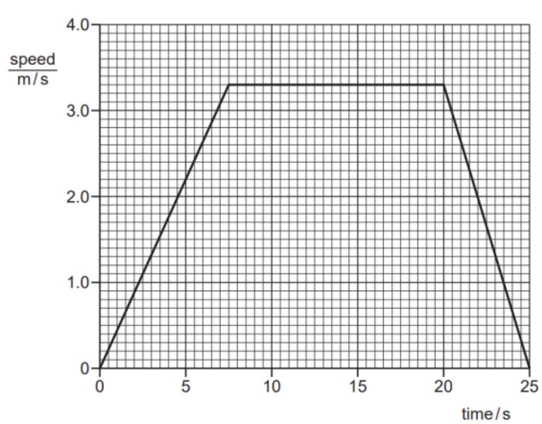
So the aircraft's resultant velocity is $206\,m\,s^{-1}$ at 14° east of north.

EXCERSISE

1.

a. A bus travels at a constant speed. It stops for a short time and then travels at a higher constant speed.
Draw a distance-time graph for this bus journey

b. A lift (elevator) starts from rest at the ground floor of a building. The speed-time graph for the motion of the lift to the top floor of the building. Use the graph to determine the distance from the ground floor to the top floor of the building.



2. Figs. 1.1 and 1.2 show speed-time graphs for two objects, each moving in a straight line.

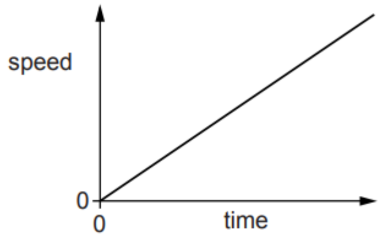


Fig. 1.1

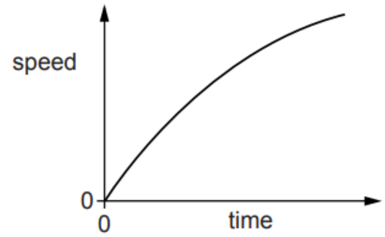


Fig. 1.2

i. Describe the motion of the object shown by the graph in Fig. 1.1.

ii. Describe the motion of the object shown by the graph in Fig. 1.2.