Chapter 2: Describing Motion

2.1 Measuring Speed

1. To calculate speed, we need to first measure
    a. Distance travelled between 2 points
    b. Time taken to travel between these 2 points

2. Definition:

Speed	The distance travelled by an object per unit time
Average Speed	The speed calculated from total distance travelled divided by total time taken

3. Formula for speed (can be used to derive another formulas):

$$speed = \frac{distance}{time}$$

4. SI Unit for speed

Quantity	SI Unit	Other units
Distance	Metre, m	Kilometre, km
Time	Second, s	Hour, h
Speed	Metre per second, m/s	Kilometre per hour, km/h

Worked Example 1:

A runner finished a 1200-meter segment of a race in 30 seconds. What was his average speed?

Worked Example 2:

A submarine is traveling at a constant speed of 20 km/h. How long will it take to cover a distance of 300 km?

Worked Example 3:

A train covers a distance of 600 km in 9000 seconds. What is the speed of the train in km/h and m/s?

Distance-time graph

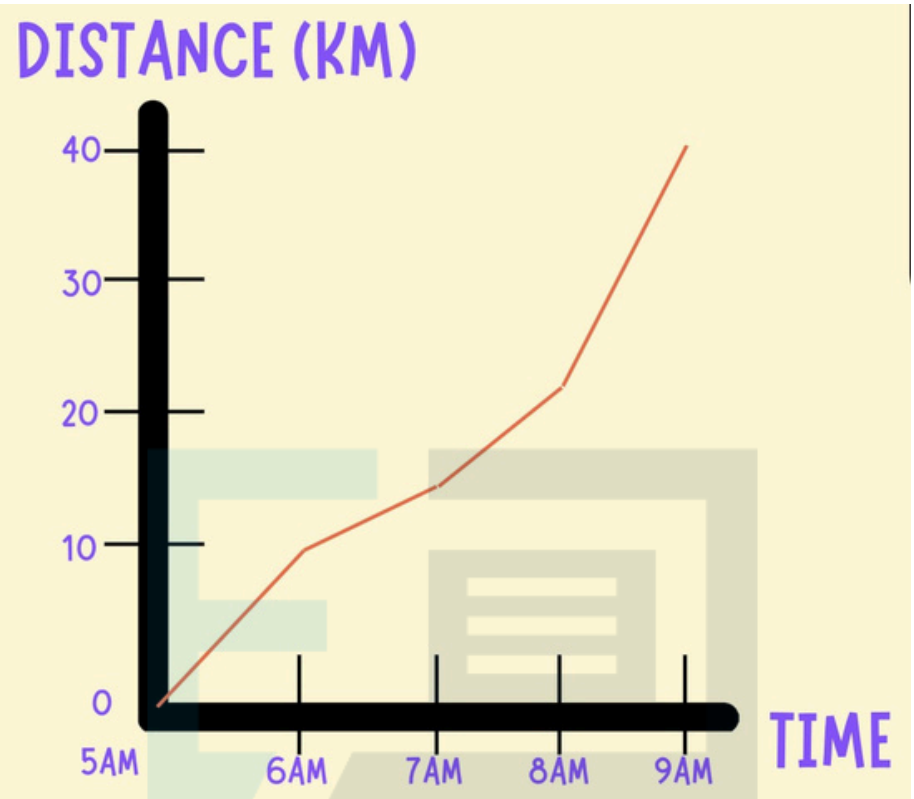
How does it look like?

Calculating speed from a distance-time graph

*Speed = Gradient of the distance time graph

- Quick tips: The gradient of the graph indicates the object's speed.
- The steeper the gradient, the faster the movement.
- When the slope is horizontal, it means the slope is zero.

Worked Example 4



The figure above shows the distance-time graph for a train.

Answer the following questions:

1. How far did the marathoner run?

2. What was the Marathoner's average speed in km/h?

3. Have the marathoner ever stopped?

4. When was the marathoner highest speed?

2.2 Measuring Acceleration

Discuss: What does it mean (in regards to acceleration) when a car company says that their car can goes from "0 – 100km/h in 2s"?
Answer:

Difference between speed and velocity:

- Both velocity and speed quantify how fast an object is moving, but velocity also requires specifying the direction.
- For example, an aircraft may have a speed of 300 m/s and a velocity of 300 m/s heading north.
- Speed is a scalar quantity, whereas velocity is a vector quantity.

Acceleration

1. Acceleration is the rate of change of an object's velocity (speed).

Calculating acceleration

1. To calculate acceleration, we need
   - Change in velocity
   - Time taken

2. Formula of acceleration

$$a = \frac{v - u}{t}$$

3. Important symbols

u	Initial Speed
v	Final Speed

4. Unit for acceleration

m/s2

Worked Example 8

A car accelerates from 20 m/s to 80 m/s in 10 seconds. What is its acceleration?

2.2.1 Speed-time graph

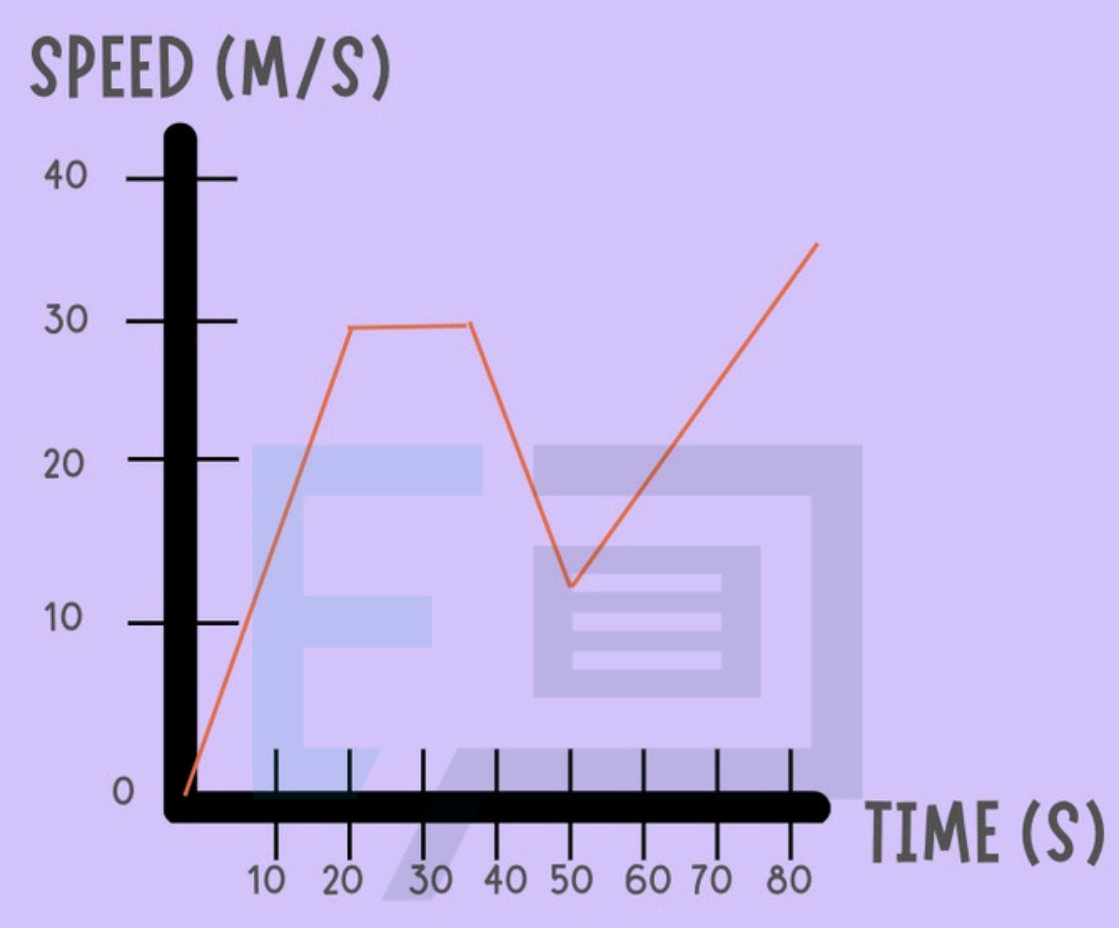
A speed-time graph shows how the object's speed changes as it moves.

Distance-time graph	Speed-time graph

*Always check the graph labels

Analysing a **SPEED-TIME GRAPH**

Worked Example 5:



Name the sections that represent:

a. Steady speed
b. Speeding up
c. Being stationary
d. Slowing down

2.2.2 Using a speed-time graph to deduce distance travelled

Formula to calculate distance from a speed time graph

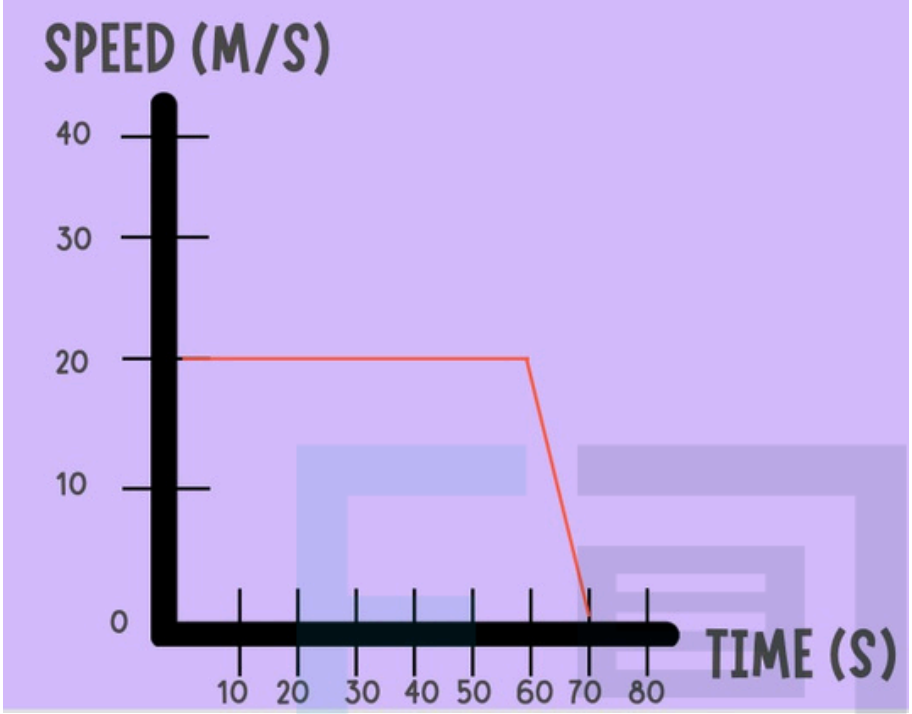
Distance =

Area of a rectangle =

Area of a triangle =

Worked Example 6

Using the speed-time graph, calculate the distance travelled by the object.



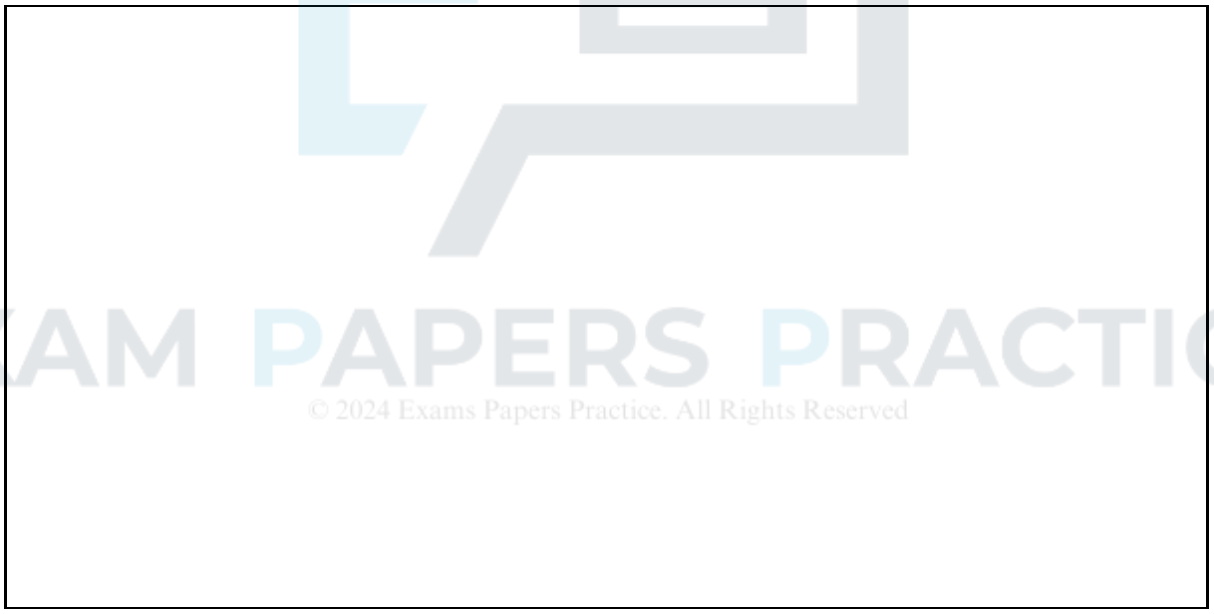
2.2.4 Calculating acceleration from a speed-time graph

We can find the acceleration of an object by calculating the gradient of its speed-time graph.

Worked Example 9 - Calculating acceleration from a speed-time graph

A roller coaster starts at rest and gradually accelerates up a steep incline. It then reaches its maximum speed at the peak before descending rapidly. The table below shows its speed changes. Draw a speed-time graph to represent this data.

Time / s	Speed / m/s
0	0.0
5	5.0
10	5.0
15	0.0
20	5.0
25	15.0
30	35.0



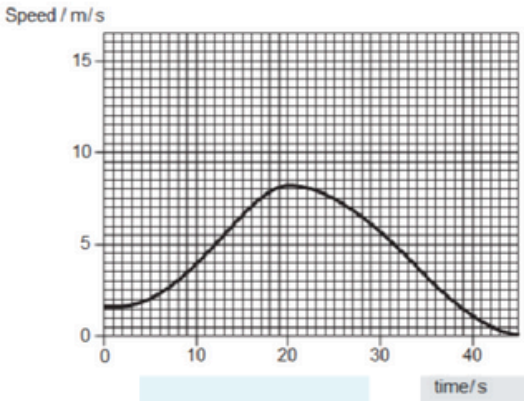
Calculating acceleration from a curve speed-time graph

- Draw a tangent at the time which acceleration needs to be found
- Calculate the gradient of the tangent

Past Year Questions

1

The graph shows the speed-time graph of a cyclist who is moving in a straight line.



What is the acceleration of the cyclist at a time of 20 seconds?

A 0.5 m/s^2

B -0.5 m/s^2

C 0 m/s^2

D 11.5 m/s^2

2

A car travels along a clear 10.0 km section of motorway in 6.0 minutes. It then drives through 3.0 km of roadworks in 3.0 minutes.

Which calculation will give the correct average speed for the journey?

A $\frac{3.0}{3.0}$ = 1.00 km/min

B $\frac{10.0}{6.0}$ = 1.67 km/min

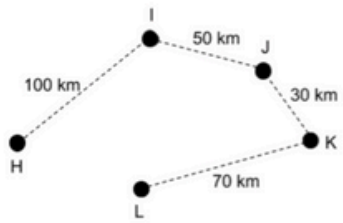
C 1.67 + 1.00 = 2.67 km/min

D $\frac{13.0}{9.0}$ = 1.44 km/min

3

A helicopter flies the route shown below.

It stops at point I for 30 minutes to pick up some cargo.



The total time the helicopter takes between taking off from **H** and landing at **L** is 4.0 hours.

Calculate the average speed of the helicopter **when it is flying.**

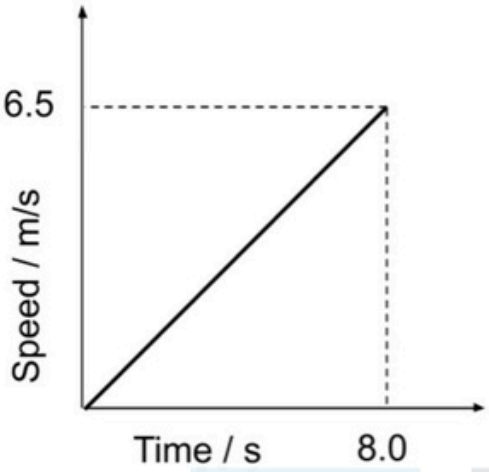
A 55.6 km/h

B 250 km/h

C 62.5 km/h

D 71.4 km/h

4 The graph shows the journey undertaken by a car.



Which equation correctly gives the distance travelled by the car?

A $\frac{6.5 \times 8.0}{2}$ = 26 m

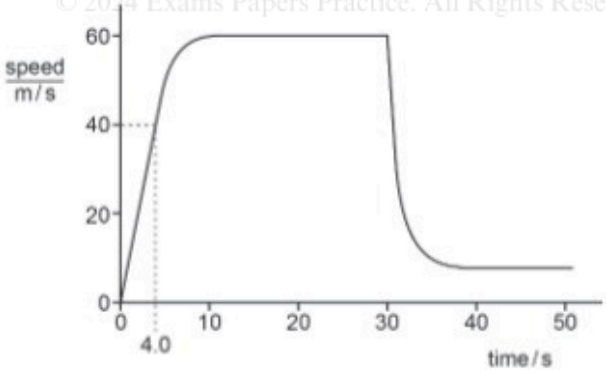
B 6.5 x 8.0 = 52 m

C $\frac{6.5}{8.0}$ = 0.81 m

D $\frac{8.0}{6.5}$ = 1.2 m

5 A sky-diver jumps out of a hot-air balloon, which is 4000 m above the ground. At time = 30 s, she opens her parachute.

The graph is the speed-time graph of her fall.



(a) Label with the letter X the point on the graph where the sky-diver opens her parachute. [1]

(b) Label with the letters Y and Z the **two** parts of the graph where the sky-diver falls at terminal velocity. [1]

[Total: 2]

6

An aeroplane lands with a speed of 62m/s, on a horizontal runway at time $t = 0$. The aeroplane decelerates uniformly as it travels along the runway in a straight line until it reaches a speed of 6.0 m/s at $t = 35$ s.

At $t = 35$ s, the aeroplane stops decelerating and moves along the runway at a constant speed of 6.0 m/s for a further 15 s.

On the diagram, sketch the shape of the graph for the distance travelled by the aeroplane along the runway between $t = 0$ and $t = 50$ s. You are **not** required to calculate distance values.