Describing motion

Speed

Speed

Measuring speed

Recall what we did in measuring **density**, what do you think we need to measure in order to get the **speed** of an object?

Measuring speed

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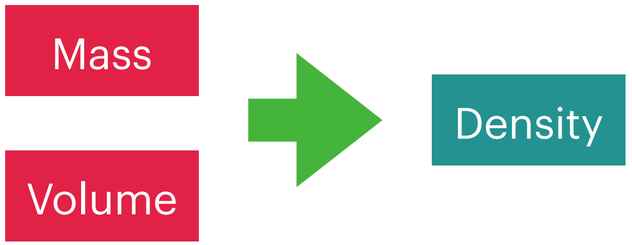

Measuring speed

Recall what we did in measuring density, what do you think we need to measure in order to get the speed of an object?

Speed

- **average** speed vs **instantaneous** speed

- Calculating **speed**:

Speed

- **average** speed vs **instantaneous** speed
- Calculating **speed**: $speed = \frac{distance}{time}$

$$v = \frac{s}{t} = \frac{\Delta s}{\Delta t} \xrightarrow{\text{rearrange}} t = \frac{s}{v}$$

$$s = vt$$

Attention: s stands for distance!!

- Unit:

Distance is not displacement!!

Speed

average speed vs **instantaneous** speed

Calculating **speed**: $speed = \frac{distance}{time}$

$$v = \frac{s}{t} = \frac{\Delta s}{\Delta t} \xrightarrow{\text{rearrange}} t = \frac{s}{v} \qquad s = vt$$

Attention: s stands for distance!!

Unit: m/s

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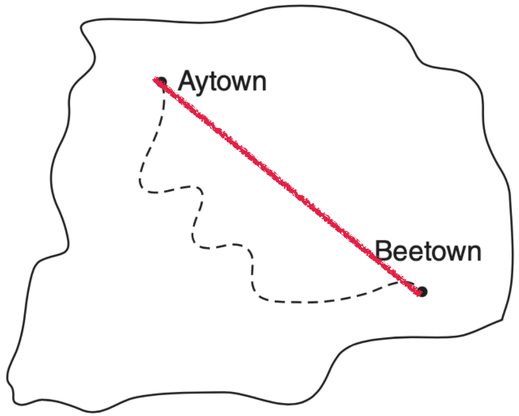

Speed vs velocity

Speed : only magnitude, ***scalar*** quantity

e.g. An aircraft has a **speed** of 200m/s.

Velocity: magnitude + direction, ***vector*** quantity

e.g. The aircraft has a **velocity** of 200m/s due north.

Scalar vs vector

Scalar : only magnitude, e.g. temperature

Vector: magnitude + direction, e.g. weight

Exercise 2.e

Which of the following physical quantities are scalars? Which are vectors?

distance, speed, time, mass, energy, force, weight, velocity, acceleration, momentum, electric field strength, gravitational field strength

Vector addition

Exercise 2.f

An aircraft is flying **due north** with a **velocity** of 200 m/s. A side wind of velocity 50 m/s is blowing due east. What is the aircraft's **resultant velocity** (give the magnitude and direction)?

Vector addition

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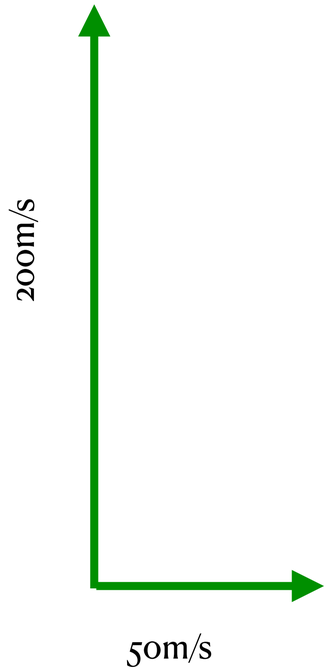

Vector addition

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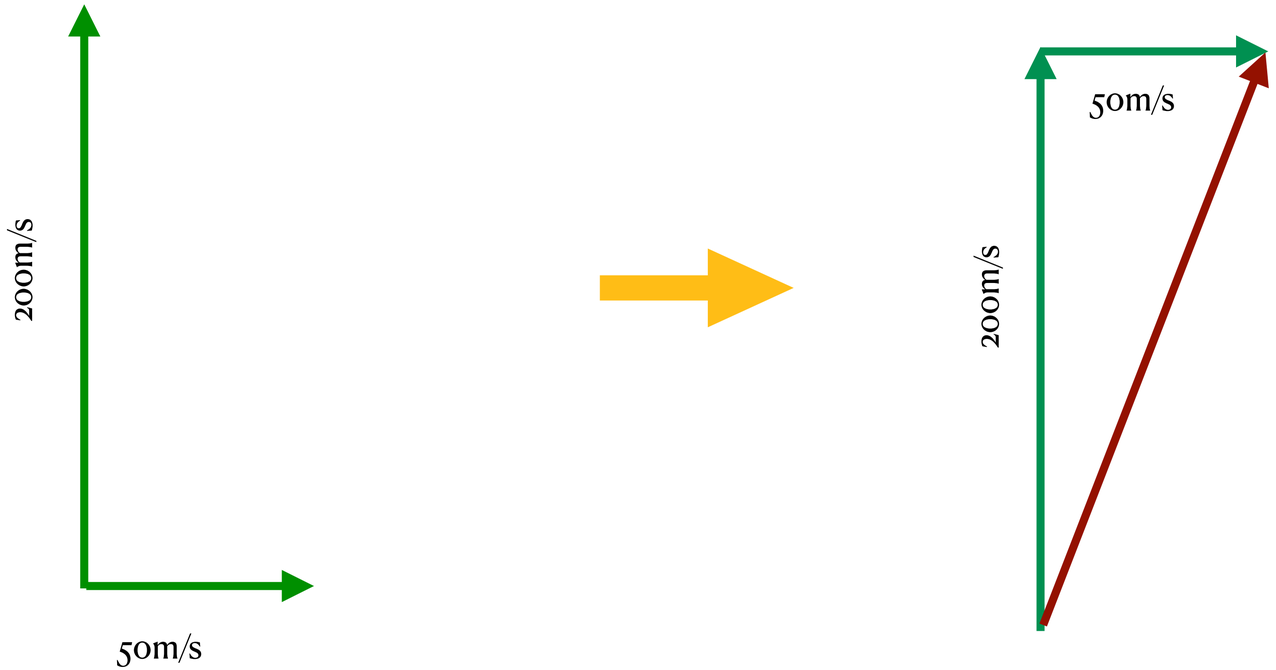
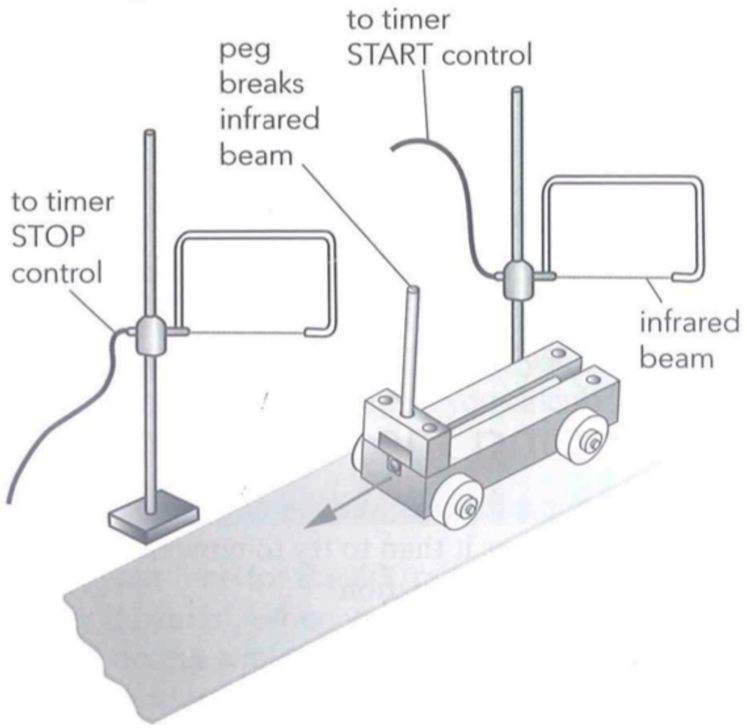
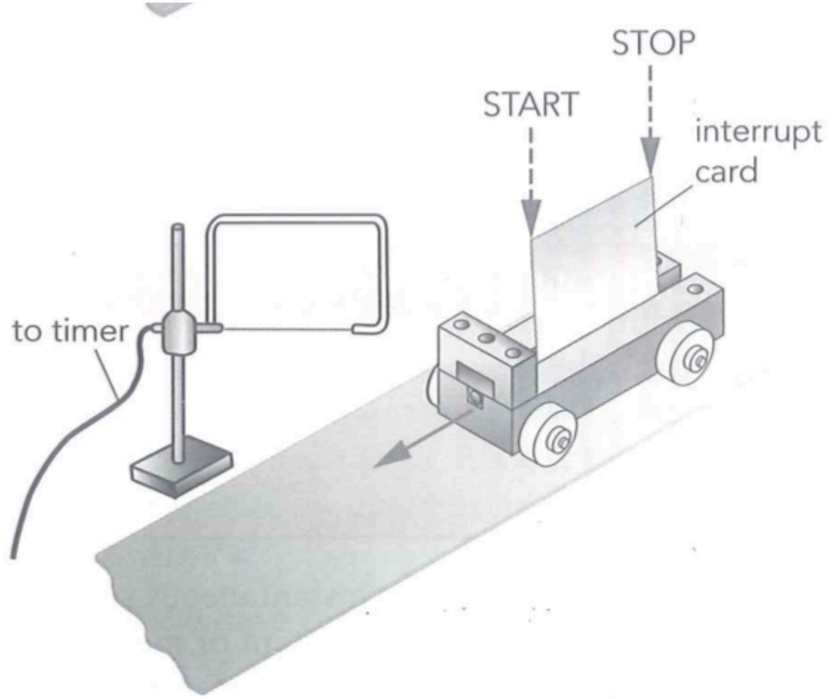


Experiment: determine speed in the laboratory





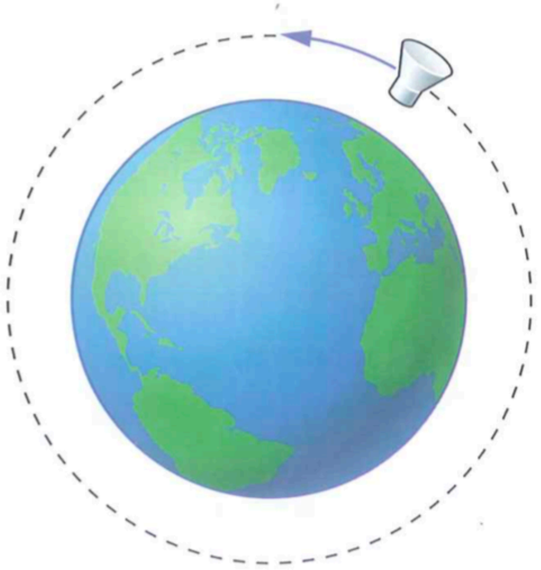
1. Using a peg + two **light gates**

2. Using a **interrupt card** + a light gate

Exercise

Exercise 2.a

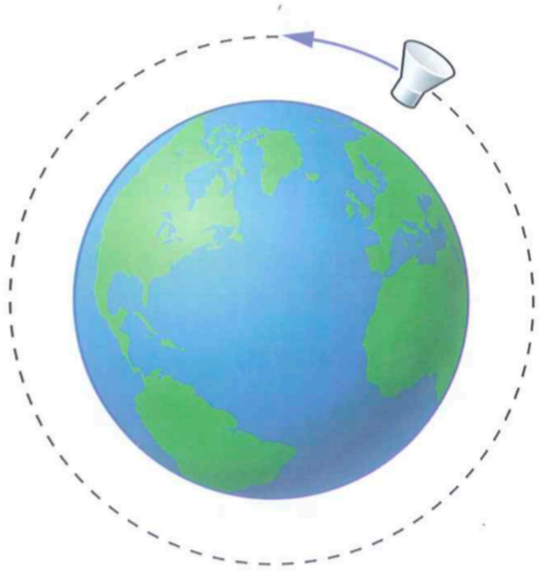
A spacecraft is orbiting the Earth at a **steady speed** of 8km/s. How long does it take to complete a single orbit?



Exercise

Exercise 2.a

A spacecraft is orbiting the Earth at a **steady speed** of 8km/s. How long does it take to complete a single orbit?



step 1.

speed $v = 8.0\ km/s$, distance $40000\ km$

time $t = ?$

step 2.

$$t = \frac{s}{v} = \frac{40000\ km}{8.0\ km/s} = 5000\ s$$

Check if units match!!

Exercise

Exercise 2.b

A car travels 600km in 5.5 hours, what is the speed of the car in **km/h and m/s**?

Exercise

Exercise 2.b

A car travels 600km in 5.5 hours, what is the speed of the car in **km/h and m/s**?

step 1.

distance $s = 600\ km$, time $t = 5.5\ h$

speed $v = ?$

step 2.

$$v = \frac{s}{t} = \frac{600\ km}{5.5\ h} \approx 109.09\ km/h$$

$$1\ km/h = \frac{1\ km}{1\ h} = \frac{1 \times 10^3\ m}{3600\ s} \approx 0.28 m/s$$

$$109.09\ km/s = 109.09 \times 1\ km/h = 109.09 \times 0.28\ m/s = 30.55\ m/s$$

Exercise

Exercise 2.c

Calculate how long does it takes for sunlight to reach us from the Sun? The Sun is about 144 million km away and the speed of light is around $3 \times 10^8 \ m/s$

step 1.

step 2.

Exercise

Exercise 2.c

Calculate how long does it takes for sunlight to reach us from the Sun? The Sun is about 144 million km away and the speed of light is around $3 \times 10^8\ m/s$

step 1.

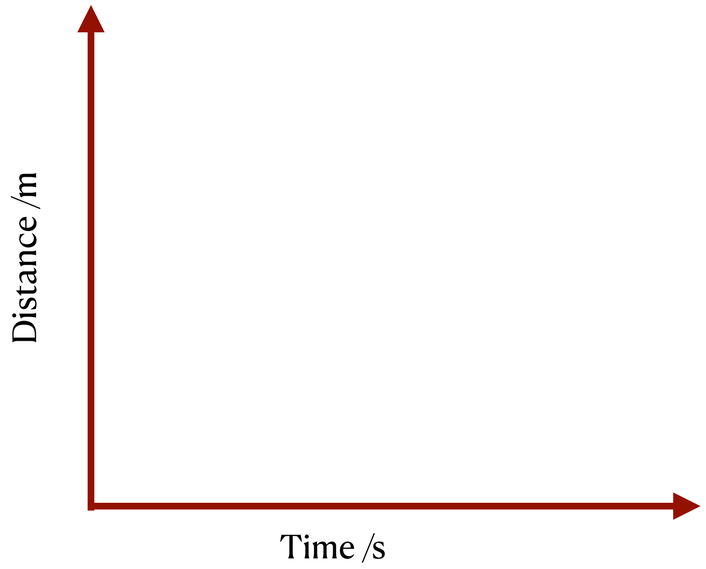
distance $s = 1.44 \times 10^8\ km = 1.44 \times 10^{11}\ m$, speed $v = 3 \times 10^8\ m/s$

time $t = ?$

step 2.

$$t = \frac{s}{v} = \frac{1.44 \times 10^{11}\ m}{3 \times 10^8\ m/s} = 480\ s = 8\ min$$

Distance-time graphs

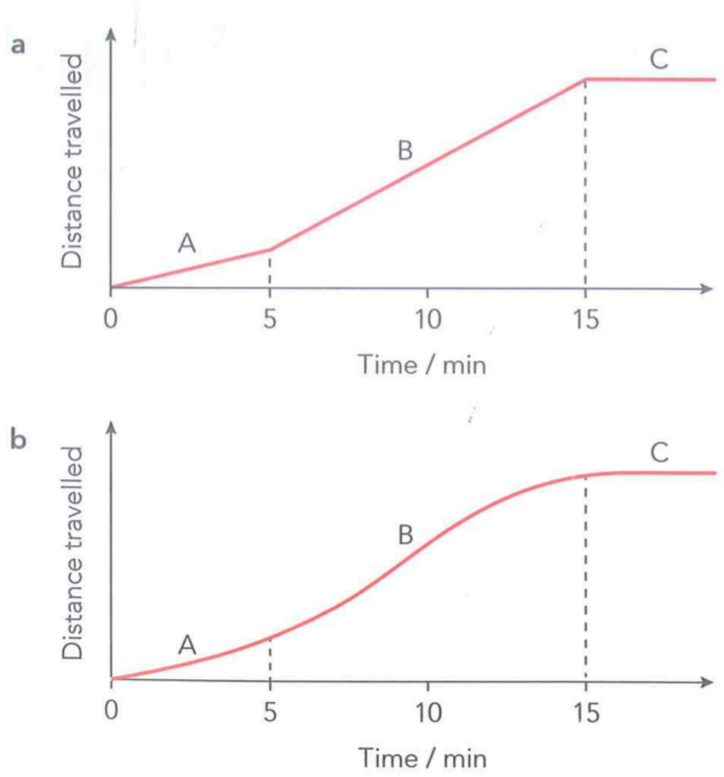


Can you draw the distance-time graph of a coach according to the description below:

"The coach drove away from the bus stop. It travels at a steady speed along the main road, leaving town. After five minutes, it reached the highway, where it was able to speed up. After ten minutes, it was forced to stop because of traffic."

Distance-time graphs

"The coach drove away from the bus stop. It travels at a steady speed along the main road, leaving town. After five minutes, it reached the highway, where it was able to speed up. After them minutes, it was forced to stop because of traffic."

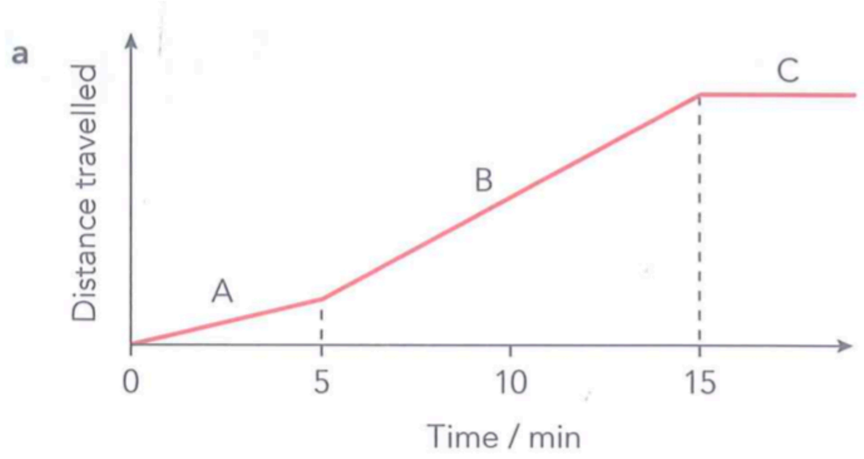


Distance-time graphs

slope:

larger slope:

slope = 0:

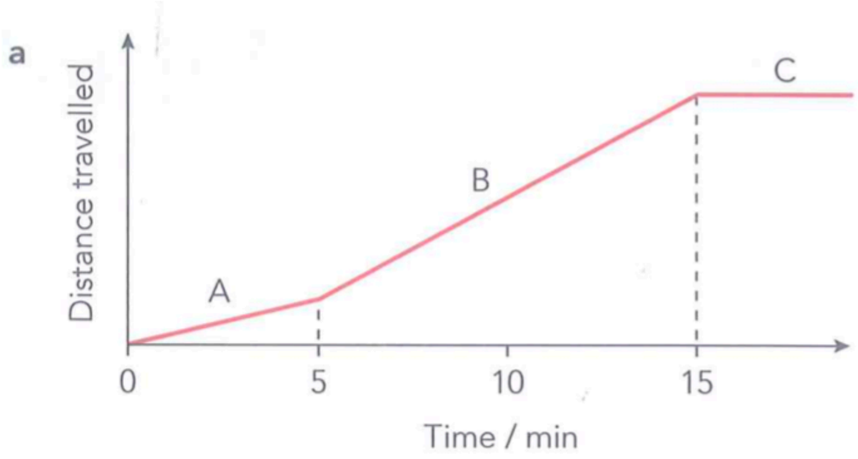


Distance-time graphs

slope: speed

larger Slope: larger speed/faster

slope = 0: not moving



Distance-time graphs

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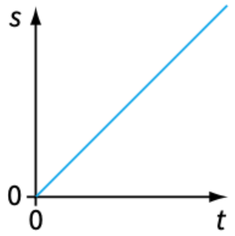
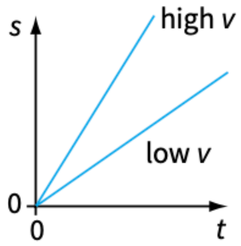
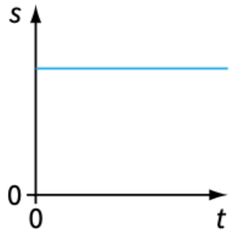
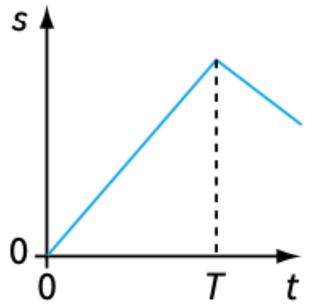
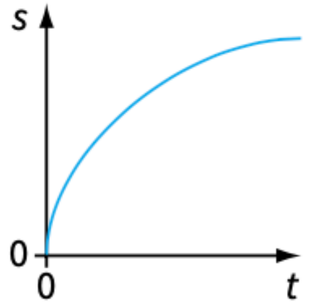








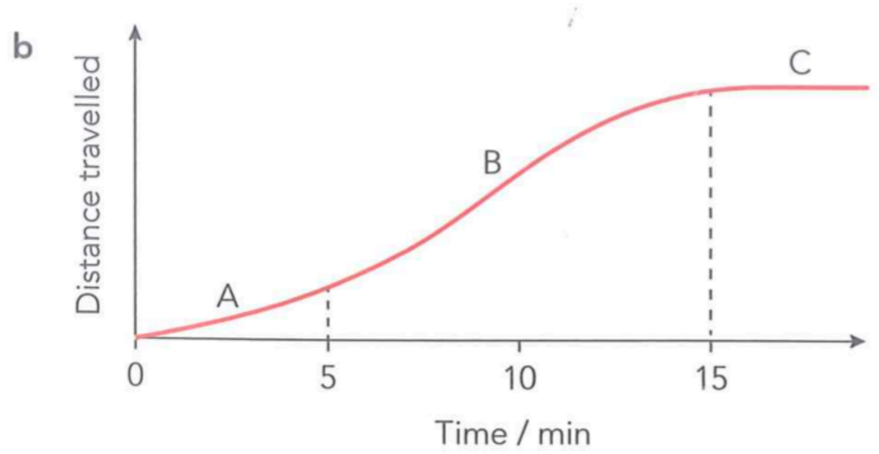


Distance-time graphs

slope: speed

larger Slope: larger speed/faster

slope = 0: not moving



How does the speed change from 5min to 10min?

Exercise

Exercise 2.d

The following figure shows the distance-time graph for a woman running a mountain marathon.

A. How **far** did she travel?

B. What was her **average speed** in **km/h**?

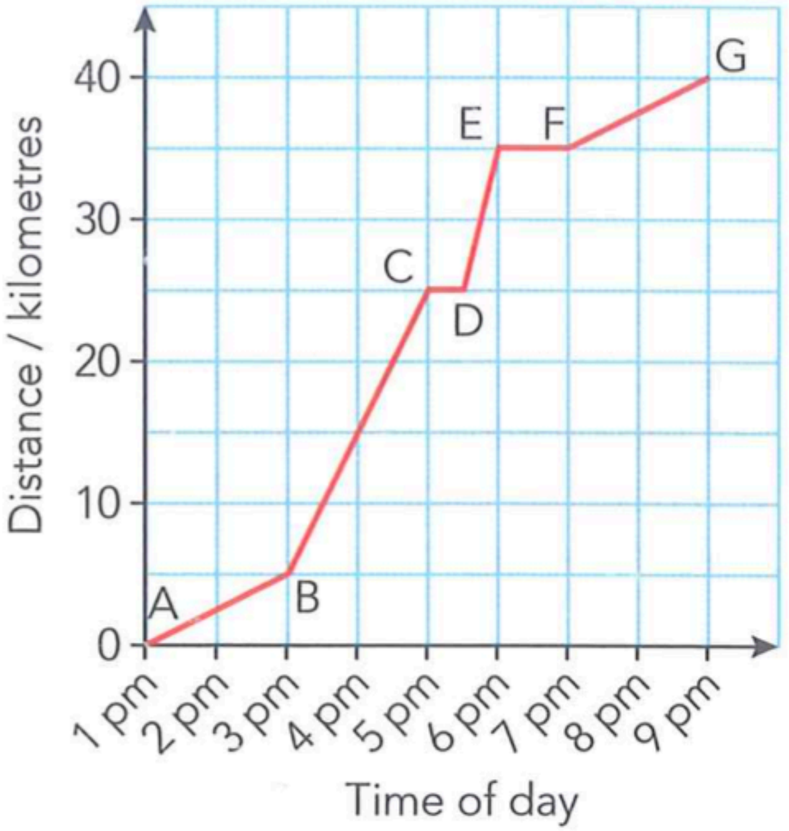
C. How many **stops** did she make?

D. The rules said she had to stop for half an hour for food. When did she take the break?

E. Later she stopped to help an injured runner. When did this happen?

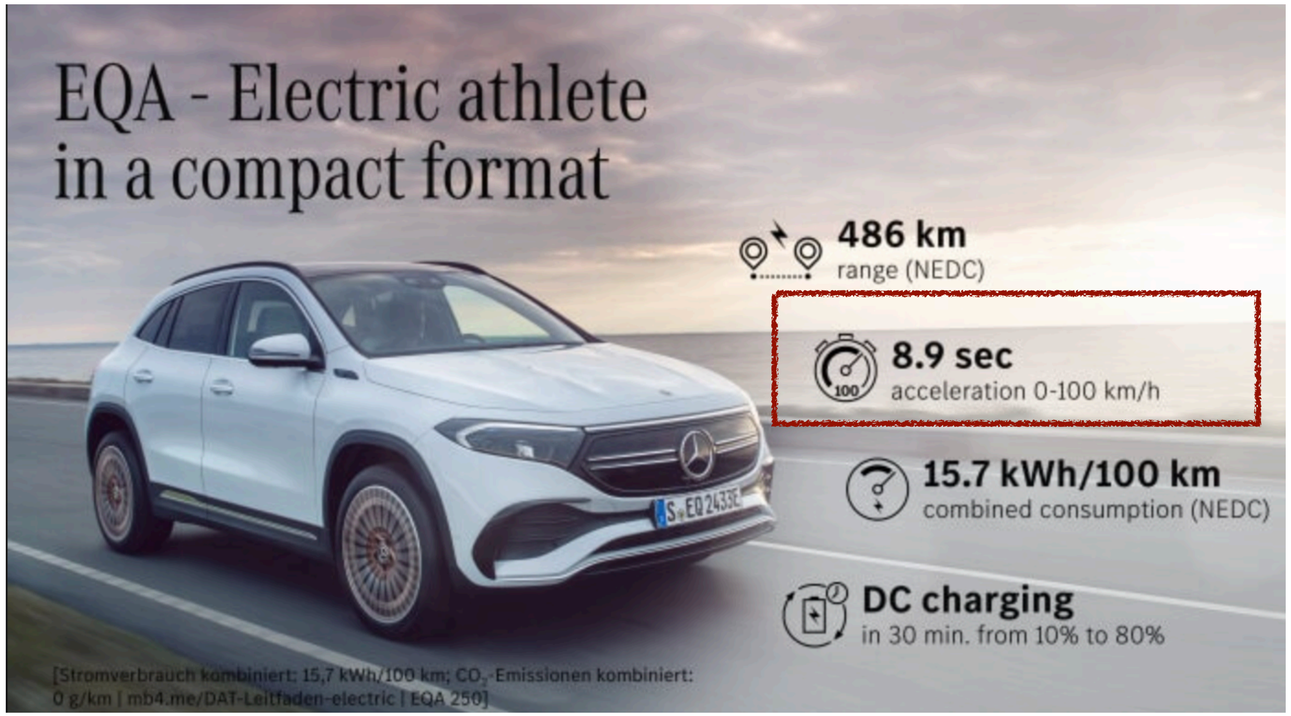
F. What would her average speed have been if she had not stopped at all?

G. What was her **highest speed** and over what section did this happen?



Understanding acceleration

Understanding acceleration



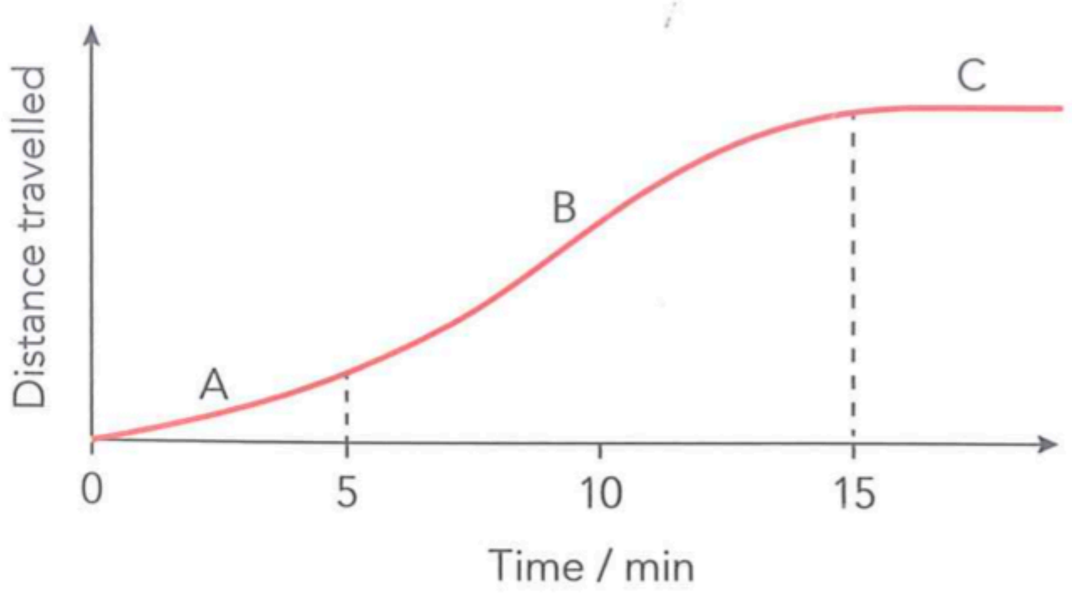
What information do you get from this car advert?

Understanding acceleration

In straight line movement :

acceleration: speed increases

deceleration: speed decreases



Calculating acceleration

Acceleration:

$$acceleration = \frac{change\ in\ velocity}{time\ taken}$$

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

v: final velocity
u: initial velocity

Calculating acceleration

Acceleration:

$$acceleration = \frac{change\ in\ velocity}{time\ taken} \qquad a = \frac{\Delta v}{\Delta t} = \frac{v - u}{\Delta t}$$

v: final velocity
u: initial velocity

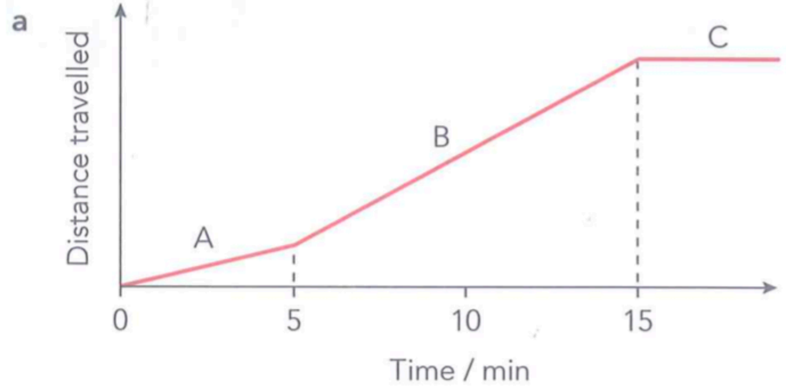
Unit: m/s^2

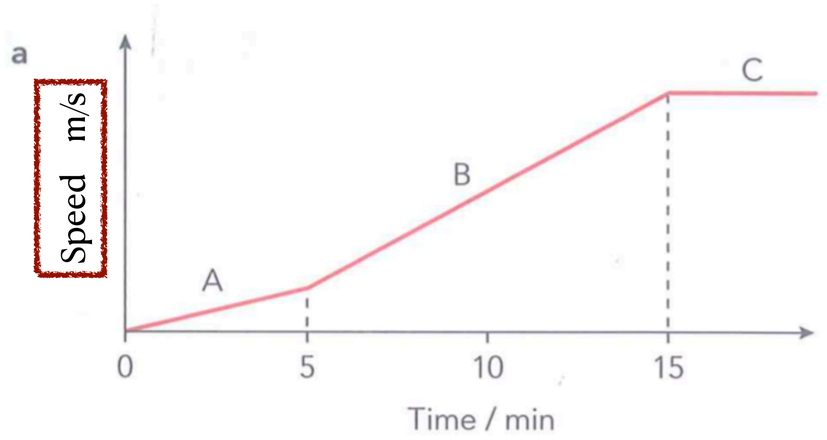
Is acceleration a scalar or a vector?

$a > 0 => acceleration$ $a < 0 => deceleration$

Speed-time graphs

Recap information we get from **distance-time graphs**, what information do you expect to get from **speed-time graphs**?

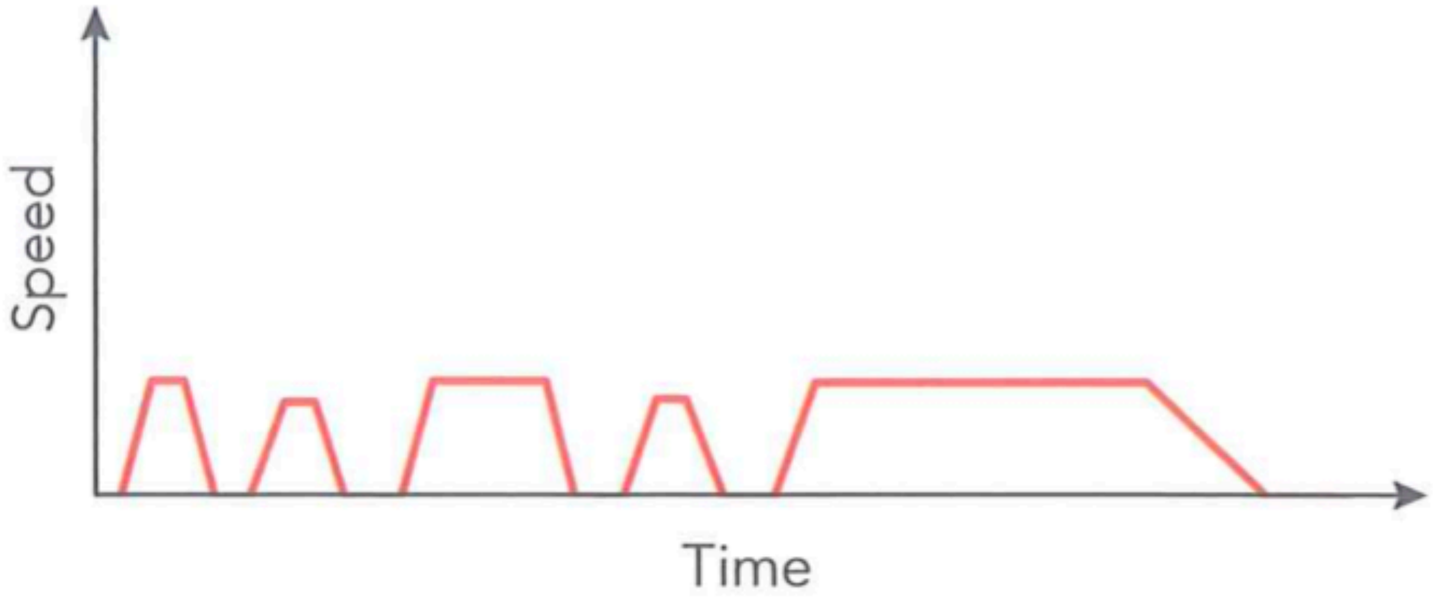




Speed-time graphs

The following speed-time graph shows a bus's speed change over a time period.

What information can you get from it?



Speed-time graphs summary

Slope:

Larger slope:

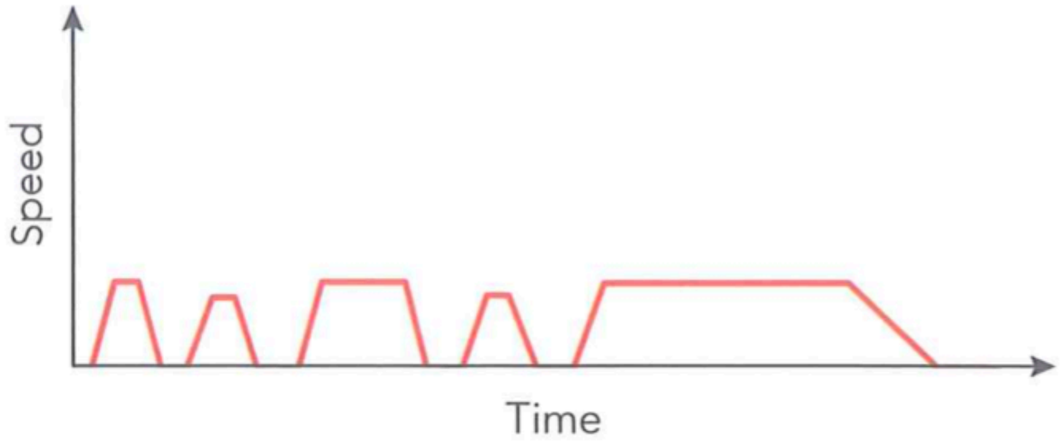
Positive slope:

Negative slope:

Slope =0 (a horizontal graph):

Straight line:

Curved line:



Speed-time graphs summary

Slope: magnitude of acceleration

Larger slope: larger acceleration

Positive slope: accelerating

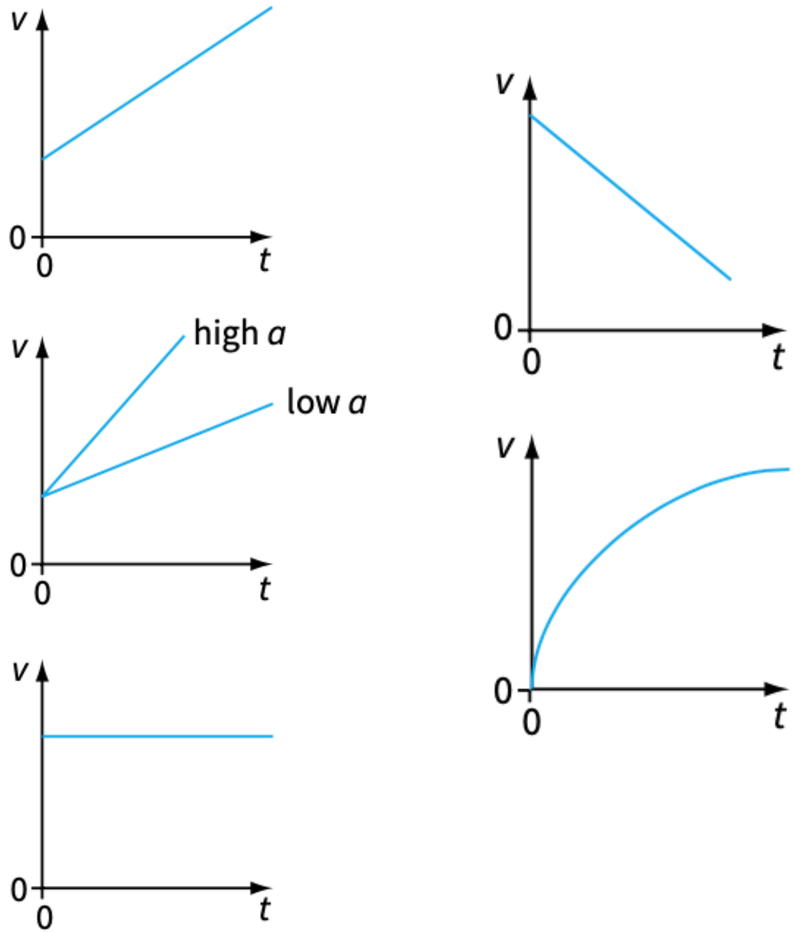
Negative slope: decelerating

Slope =0 (a horizontal graph): a = 0,

constant speed(including stationary)

Straight line: constant acceleration

Curved line: changing acceleration



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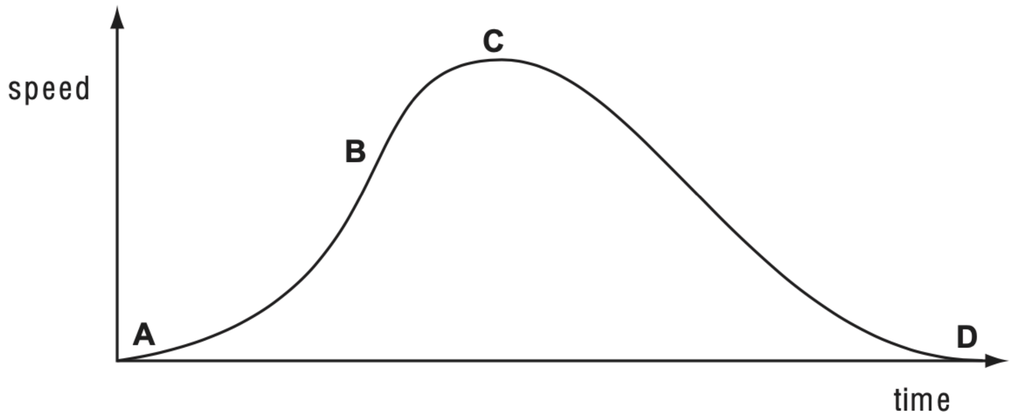


largest speed?

Acceleration

Exercise 2.g

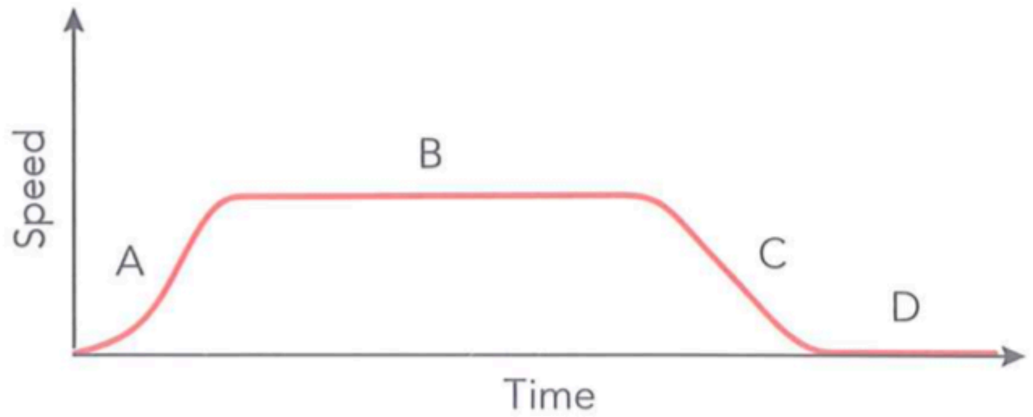
Look at the following speed-time graph of a train during part of its journey. Describe the motion of the train in **each phase**, namely A, B, C, D.

Phase A:

Phase B:

Phase C:

Phase D:



Acceleration

Exercise 2.g

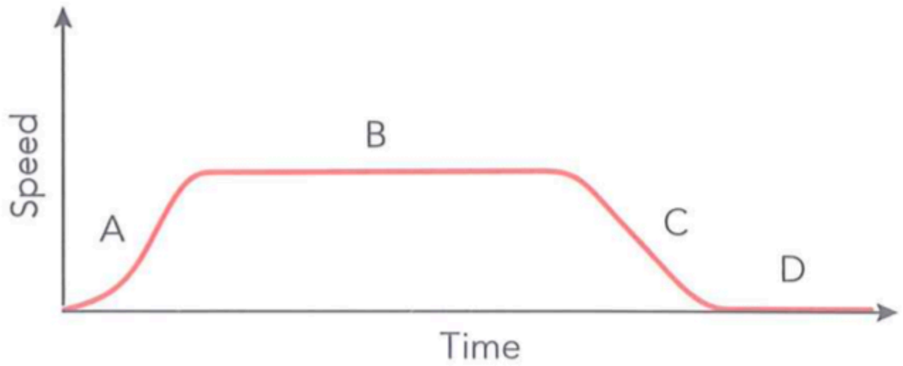
Look at the following speed-time graph of a train during part of its journey. Describe the motion of the train in **each phase**, namely A, B, C, D.

Phase A: sloping upwards/positive slope, speed increases => **accelerating**

Phase B: horizontal/slope = 0, speed is constant => **traveling at steady speed**

Phase C: sloping downwards/negative slope, speed decreases => **decelerating**

Phase D: horizontal/slope = 0 and speed =0 =>**not moving/stationary**

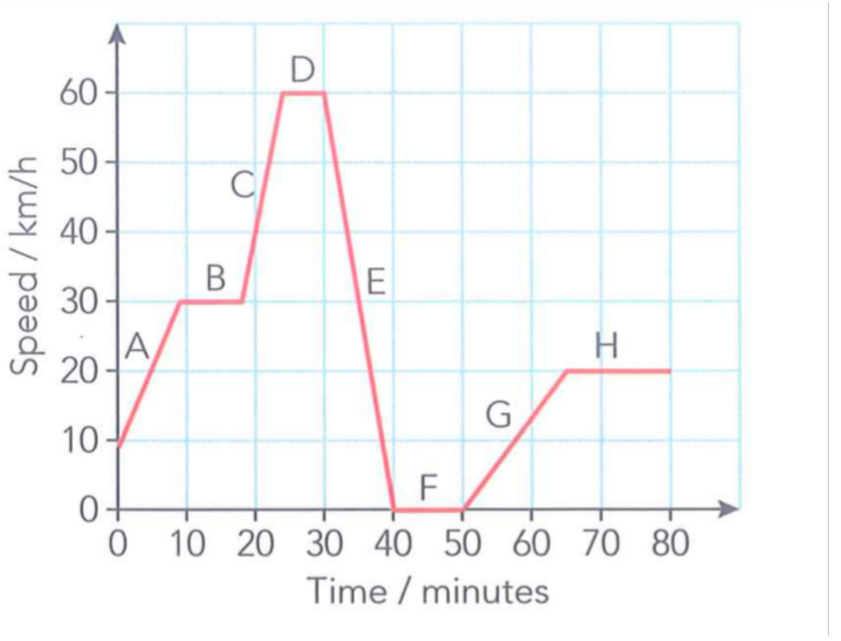


Acceleration

Exercise 2.h

Look at the speed-time graph on the right. Name the sections that represent:

- steady speed
- speeding up (accelerating)
- being stationary
- slowing down (decelerating)



Acceleration

Exercise 2.i

During an aircraft's landing, its speed changes from 300m/s to 50m/s in 80s. What is its **acceleration**?

Acceleration

Exercise 2.i

During an aircraft's landing, its speed changes from 300m/s to 50m/s in 80s. What is its **acceleration**?

step 1.

final speed $v = 50\ m/s$, initial speed $u = 300\ m/s$

Acceleration $a = ?$

Negative acceleration means deceleration!!

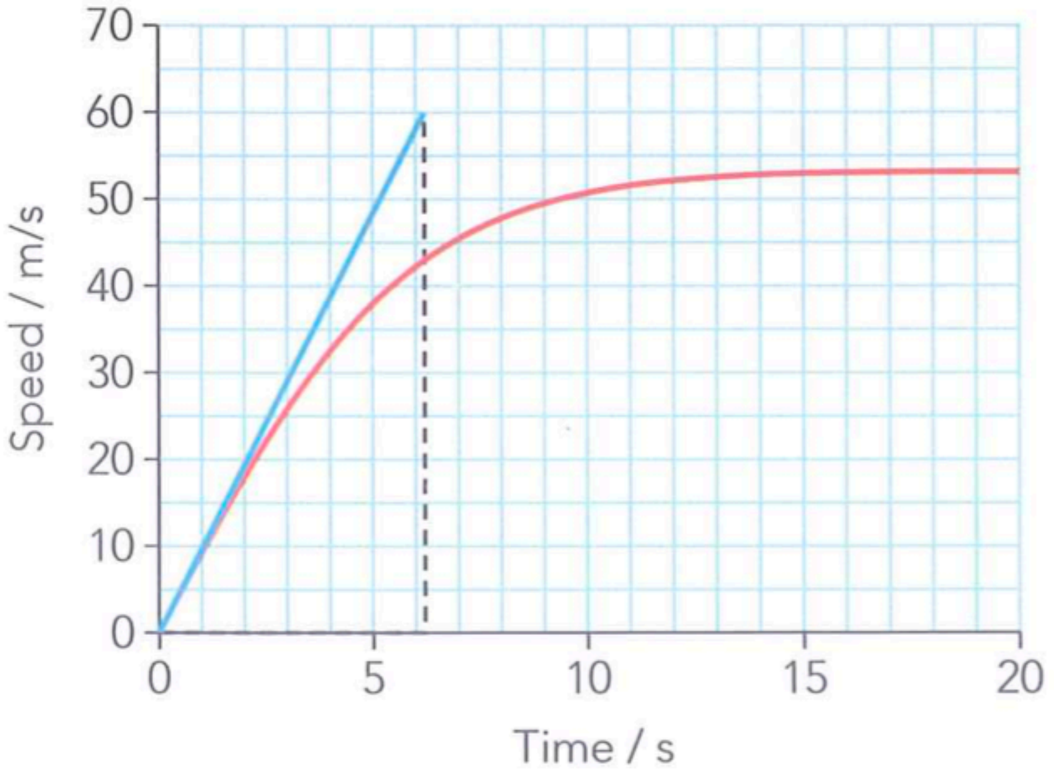
step 2.

$$a = \frac{v - u}{\Delta t} = \frac{50\ m/s - 300\ m/s}{80\ s} \approx -3.13\ m/s$$

Acceleration

Exercise 2.j

What is the skydiver's acceleration at a. 0s, b 5.5s



Finding distance travelled

Speed-time graph tells us how **speed** changes. Can we know distance from it?

Finding distance travelled

Speed-time graph tells us how speed changes. Can we know distance from it?

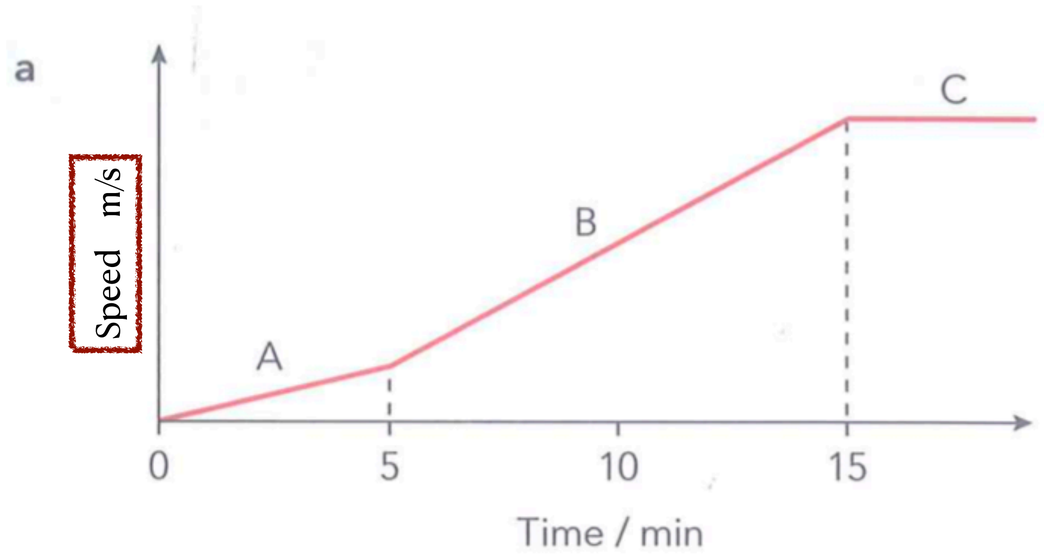
distance = area under speed-time graph

Calculating distance from speed-time graph: Straight-line graph => rectangles and triangles

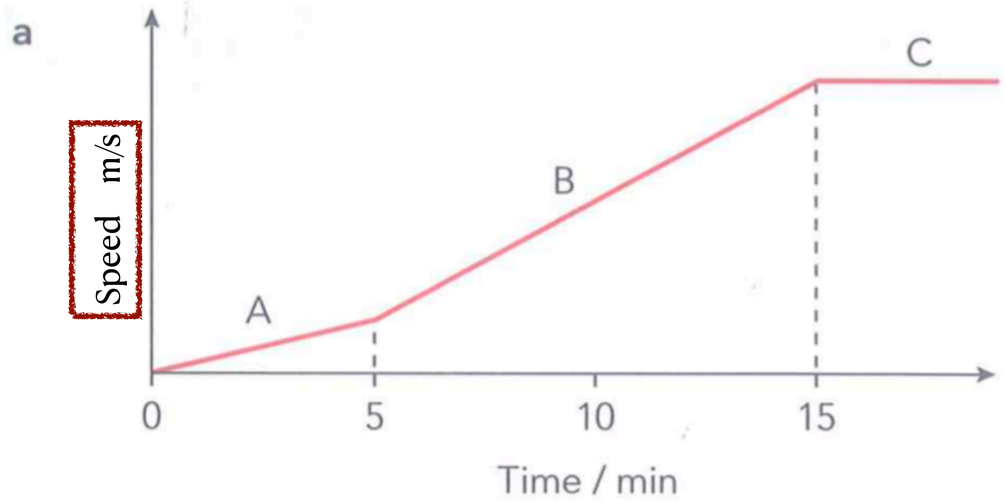
Area of rectangle = width × height

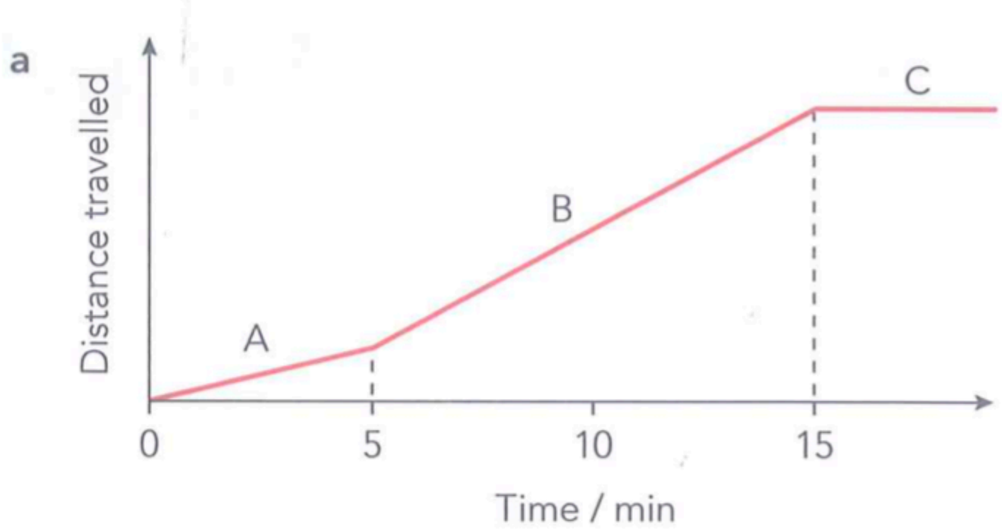
Area of triangle = $\frac{1}{2} \times base \times height$

Finding distance travelled



Finding distance travelled

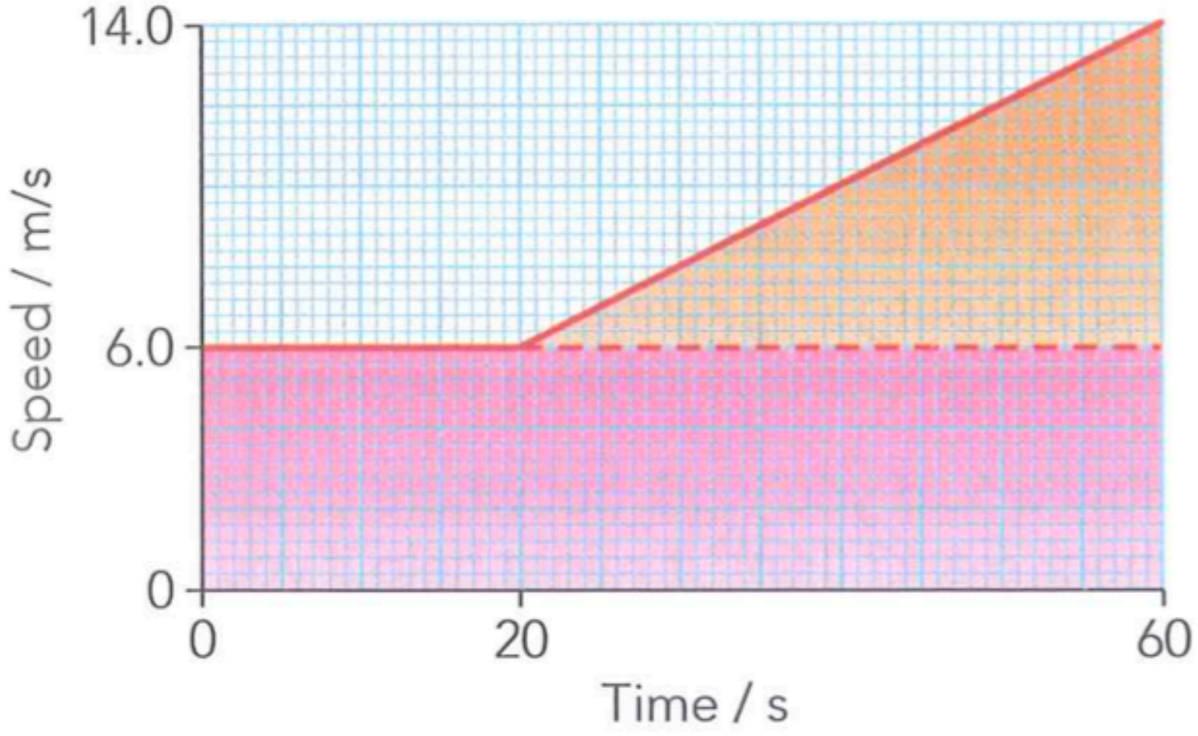




Finding distance travelled

Exercise 2.k

A train's motion can be represented by the graph below. Calculate the distance the train travels in a. 15s, b 60s.



Finding distance travelled

Exercise 2.k

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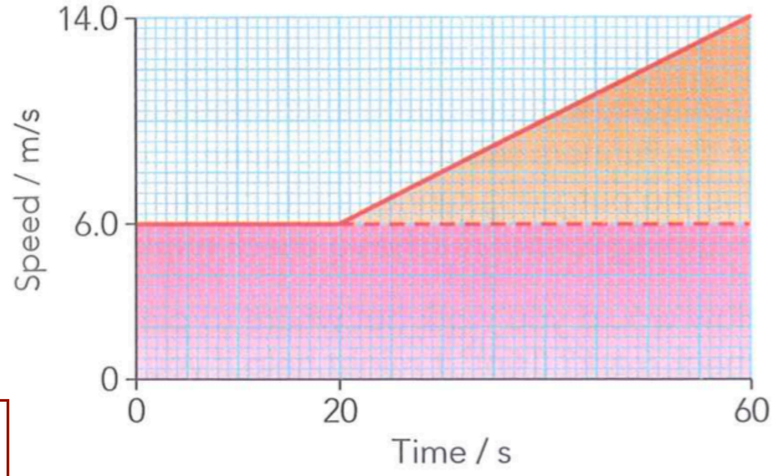


step 1. The area can be divided into a rectangle and a triangle

step 2.

Area of a triangle = $\frac{1}{2} \times base \times height = \frac{1}{2} \times 40s \times 8.0\ m/s = 160\ m$

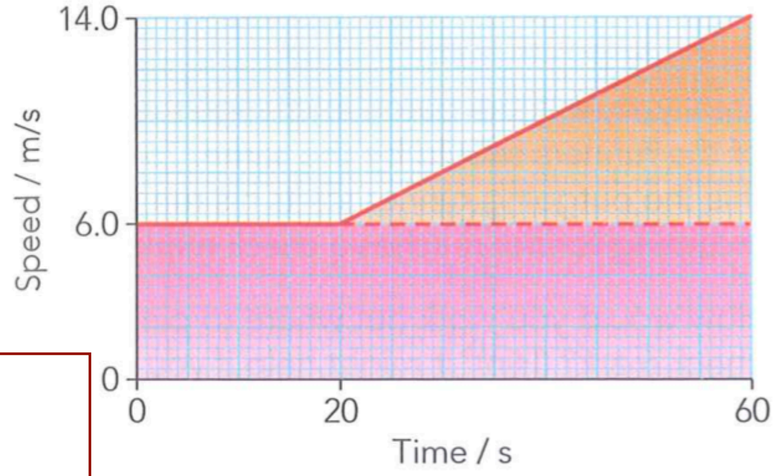
Area of a rectangle = $width \times height = 60s \times 6.0\ m/s = 360\ m$

Total distance travelled $= 360\ m + 160\ m = 520\ m$

Finding distance travelled

Exercise 2.k

A train's motion can be represented by the graph below. Calculate the distance the train travels in a. 15s, b 60s.



step 1. Distance = area under speed-time graph

step 2.

Area of a rectangle = $width \times height = 20s \times 6.0\ m/s = 120\ m$

Area of a trapezoid =

$$\frac{1}{2} \times (short\ base + long\ base) \times height = \frac{1}{2} \times (6.0 + 14.0) m/s \times 40s = 400\ m$$

Total distance travelled $= 120\ m + 400\ m = 520\ m$

Finding distance travelled

Exercise 2.I

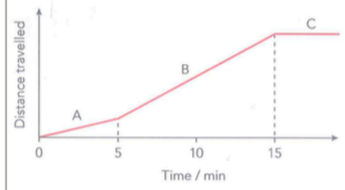
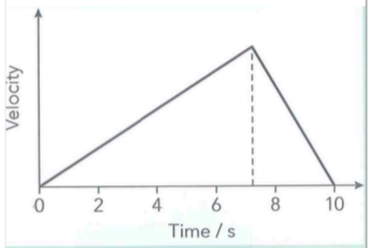
Draw a speed-time graph to show a car that accelerates uniformly from 6m/s for 5s then travels at a steady speed go 12m/s for 5s.

On your graph, shade the area that shows the distance travelled by the car in 10s.

Calculate the distance travelled in this time.

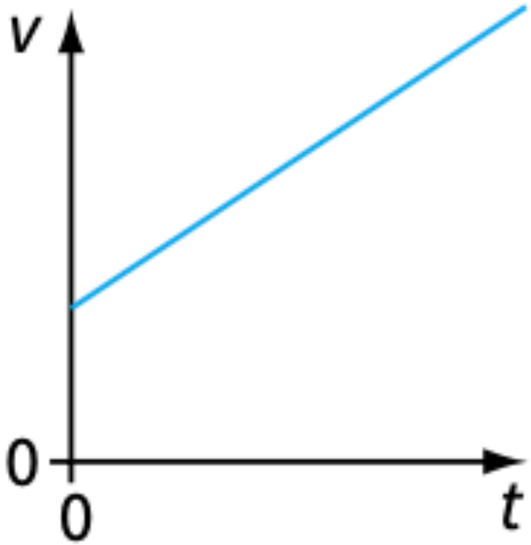
Summary

1. Scalar vs vector
2. Speed vs velocity & acceleration
3. Distance/speed-time graphs

	distance-time graph	speed-time graph
example		
distance		
speed		
acceletation		

Uniformly accelerated motion

$a = constant$



Uniformly accelerated motion

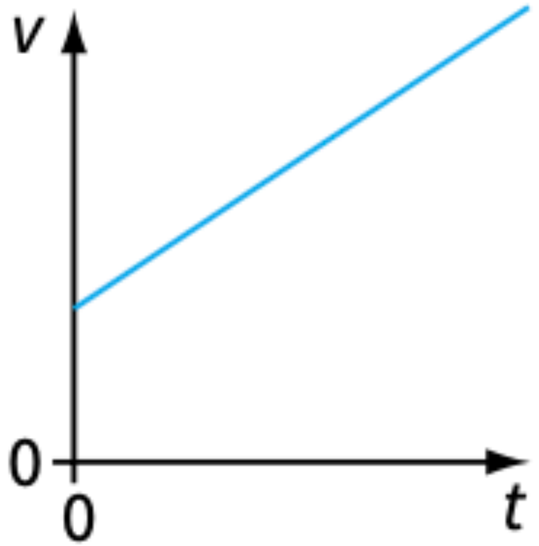
$a = constant$

$$v = u + at$$

$$s = \frac{(u+v)}{2} \times t$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$



Falling

Free fall: any motion of a body where gravity is the only force acting upon it.

$$a = g = 10 m/s^2$$ (near surface)

- distance-time graph?
- speed-time graph?
- acceleration-time graph?

Falling

Falling with resistance:

Resistance change —> acceleration change

Projectile

Horizontally/X direction: uniform speed

Vertically/Y direction: free fall