Chapter 2. Describing motion (kinematics)

Contents:

New word list:

1.2 Motion

Core

1 Define speed as distance travelled per unit time; recall and use the equation

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

2 Define velocity as speed in a given direction

3 Recall and use the equation

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

4 Sketch, plot and interpret distance–time and speed–time graphs

5 Determine, qualitatively, from given data or the shape of a distance–time graph or speed–time graph when an object is:

(a) at rest
(b) moving with constant speed
(c) accelerating
(d) decelerating

6 Calculate speed from the gradient of a straight-line section of a distance–time graph

7 Calculate the area under a speed–time graph to determine the distance travelled for motion with constant speed or constant acceleration

8 State that the acceleration of free fall g for an object near to the surface of the Earth is approximately constant and is approximately $9.8\,\text{m/s}^2$

Supplement

9 Define acceleration as change in velocity per unit time; recall and use the equation

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

10 Determine from given data or the shape of a speed–time graph when an object is moving with:

(a) constant acceleration
(b) changing acceleration

11 Calculate acceleration from the gradient of a speed–time graph

12 Know that a deceleration is a negative acceleration and use this in calculations

13 Describe the motion of objects falling in a uniform gravitational field with and without air/liquid resistance (including reference to terminal velocity)

2.1 Understanding speed

2.1.1 speed

What is motion? What is speed?

speed: average speed vs instantaneous speed

Calculating speed:

unit of speed:

rearranging the equation:

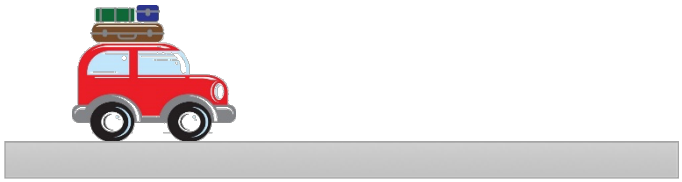
speed vs velocity:

Estimate speed (m/s)

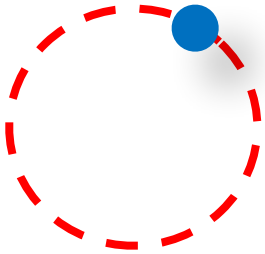
walking	1.5
plane	250
sound (in air)	340
light (in vacuum)	3.00×10^8

Uniform motion: A body that travels with constant or uniform speed.

uniform **linear** motion:



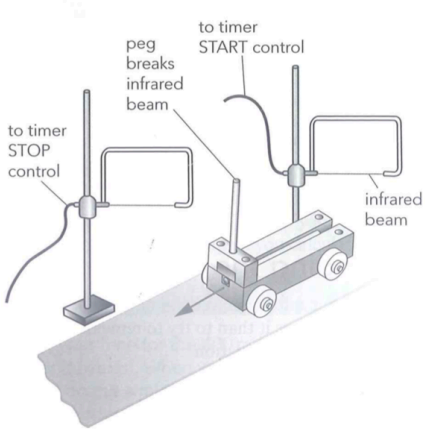
uniform **circular** motion:



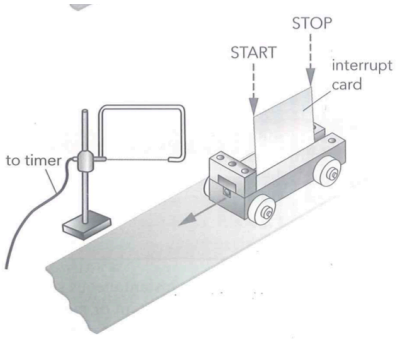
2.1.3 Experiment: determine speed in the laboratory

Two sets:

1. Using a peg + two light gates

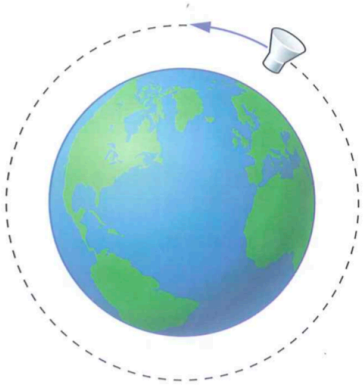


2. Using a interrupt card + a light gate



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?



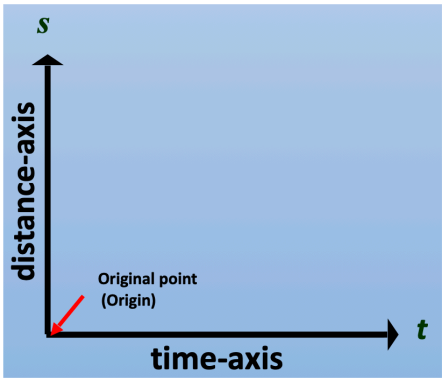
Exercise 2.b

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

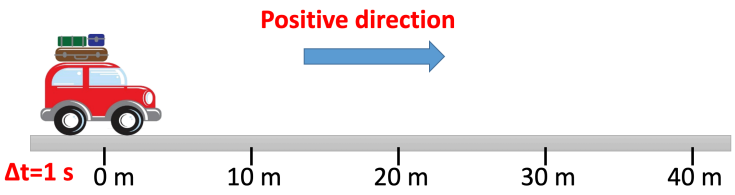
Exercise 2.c

I went for a walk one day. I walked 6km at 6 km/h and then 10 km at 5 km/h in the same direction. Determine the average speed for the entire journey.

2.2 Distance-time graphs: to visually describe how object moves



Can you draw a distance-time graph representing the motion of following car? What can you say about its motion? Relating the motion and graph, what conclusion can you draw about distance-time graph?

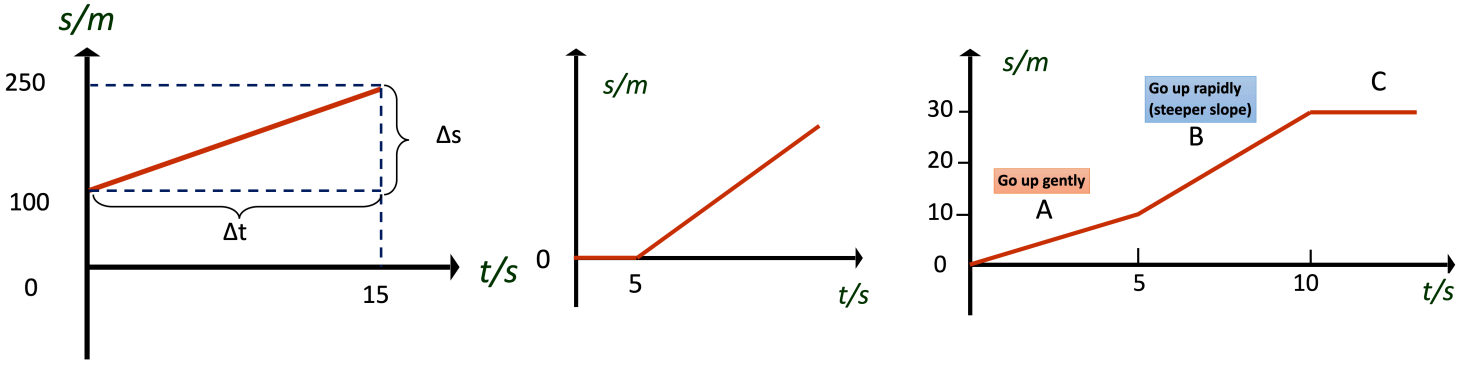


Slope/gradient of distance-time graph:

Larger Slope:

Slope = 0/horizontal line:

Can you describe the motions represented by the following graphs?



Exercise 2.d

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

How far did she travel?

What was her average speed in km/h?

How many stops did she make?

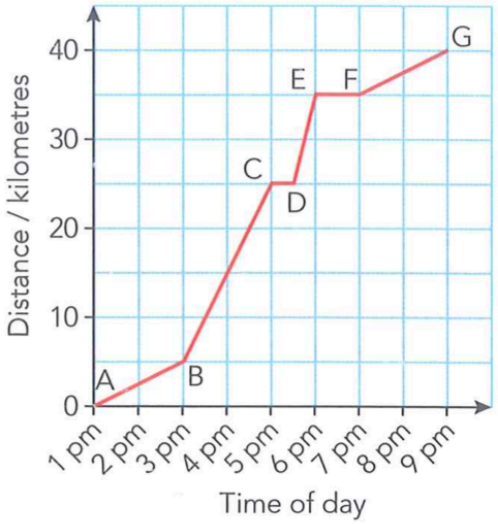
The rules said she had to stop for half an hour for food. When did she take the break?

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

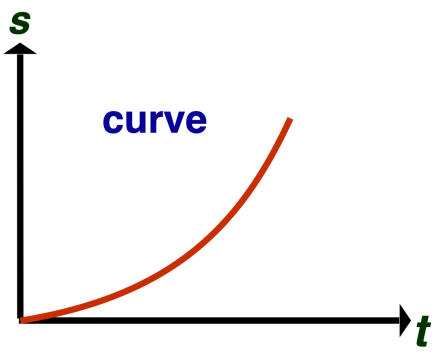
What would her average speed have been if she had not stopped at all?

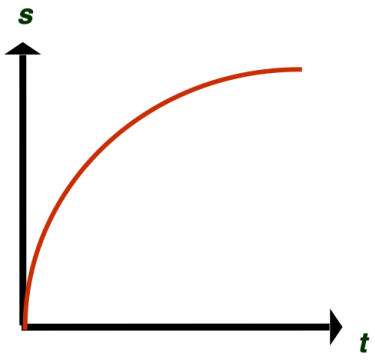
What was her highest speed and over what section

did this happen?

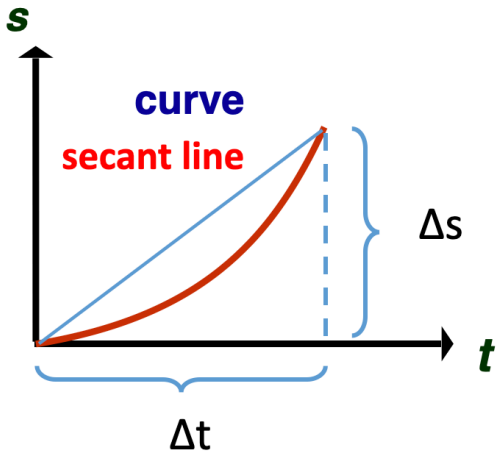


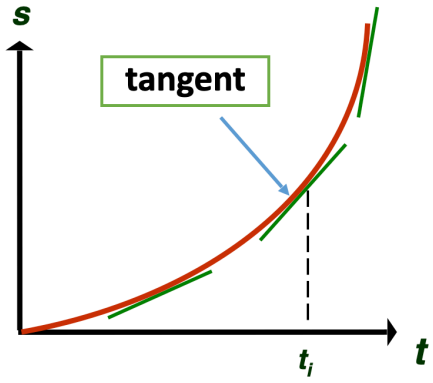
What does curved line represent in distance-time graph?





Average speed vs instantaneous speed?





Summary on distance-time graph:

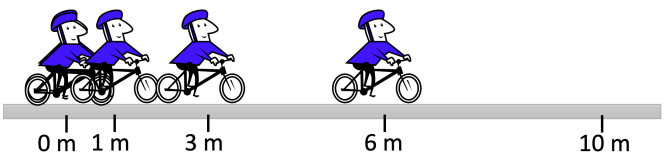
Every point on the graph shows the distance of a body at any instant of time.

the gradient of the graph is the instantaneous speed of the body.

2.3 Understanding acceleration

2.3.1

Can you draw distance-time graph of following motion? How do you describe the motion?



In straight-line motion:
Accelerate: speed increase;

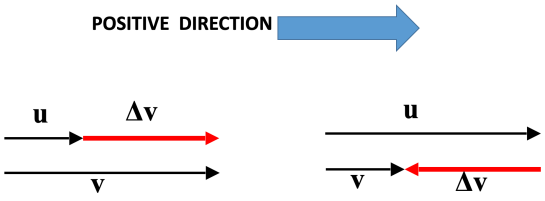
Decelerate: speed decrease

Def of acceleration:

equation:

unit of acceleration:

Is acceleration a scalar or a vector?



Uniformly accelerated (linear) motion:

Calculate the acceleration of following uniformly accelerated (linear) motion:

Initial velocity u **Final velocity v**

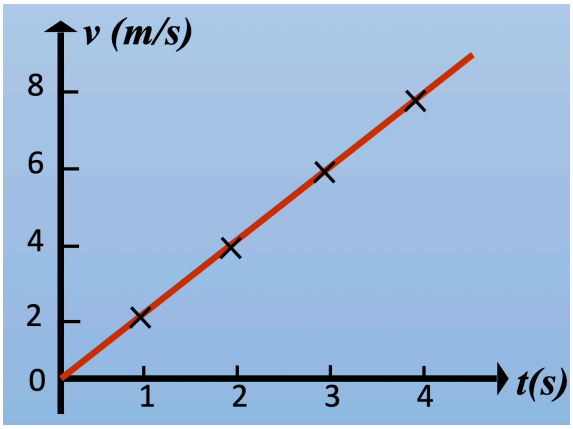
A car accelerates from rest with acceleration of 2m/s, what is its speed at 5s?

Δt=1 s **0 m/s → 2 m/s → 4 m/s → 6 m/s → 8 m/s …**

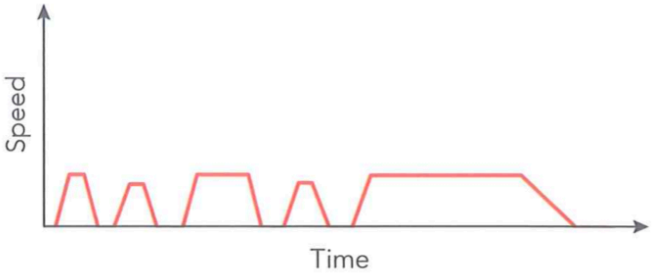
2.4 Speed-time graphs

2.4.1 Can you draw a speed-time graph of the motion above? Recap information we get from distance-time graphs, what information do you expect to get from speed-time graphs?

Attention: always check the **axes** to see labels when reading graphs!!



The following speed-time graph shows a bus's speed change over a time period. What information can you get from it?



In summary, in speed-time graphs:

Slope:

Larger slope:

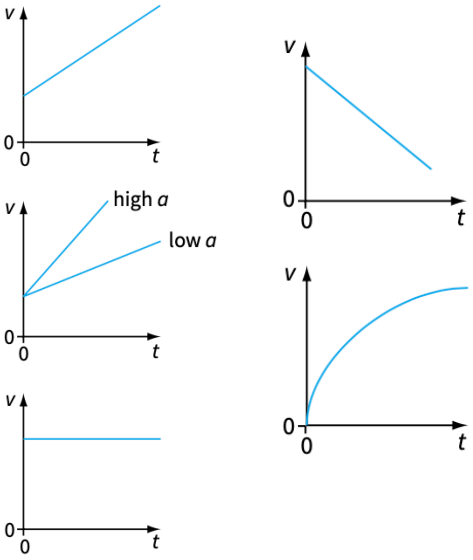
Positive slope:

Negative slope:

Slope =0 (a horizontal graph):

Straight line:

Curved line:

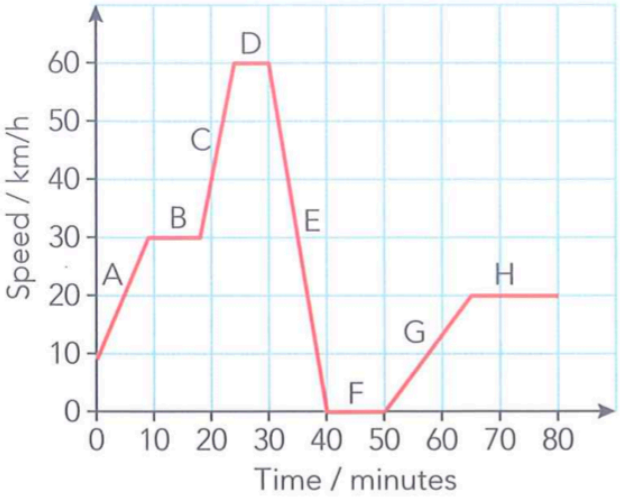


Exercise 2.h

Look at the speed-time graph on the right.

Name the sections that represent:

a. steady speed
b. speeding up (accelerating)
c. being stationary
d. slowing down (decelerating)

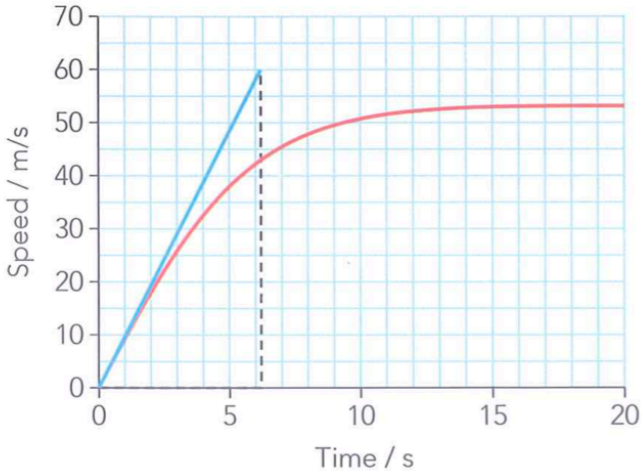


Exercise 2.i

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

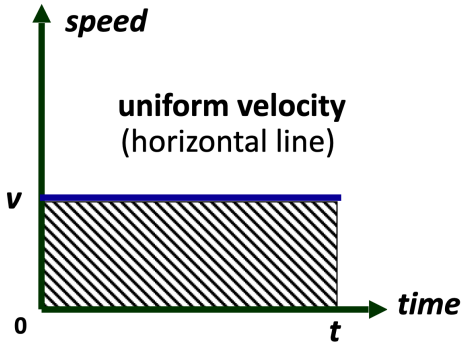
Exercise 2.j

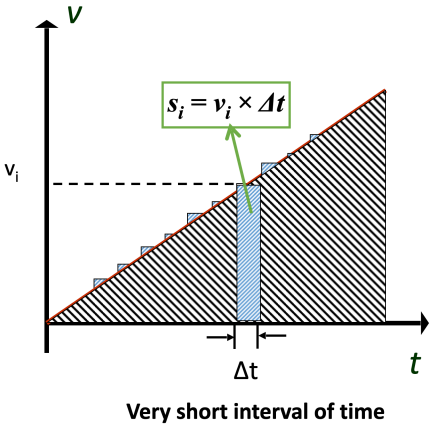
What is the skydiver's acceleration at a. 0s, b 5.5s



2.4.2 Finding distance travelled

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





Very short interval of time

distance =

Calculating distance from speed-time graph(calculating area):

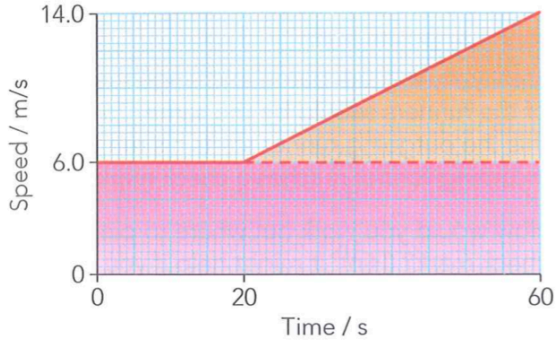
Straight-line graph can be broken down into rectangles and triangles

Area of rectangle =

Area of triangle =

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.

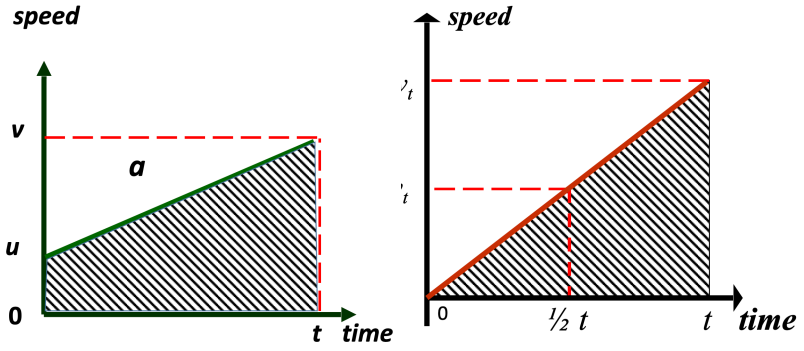


Exercise 2.l

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

2.4.3 Equation of motions for uniformly accelerated linear motion $a = constant$

Average velocity:



2.4.4 Falling

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

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

$a = g = 9.8\,m/s^2$

(near surface)

Falling with resistance:

Resistance change —> acceleration change

Projectile:

Horizontally/X direction: uniform speed

Vertically/Y direction: free fall