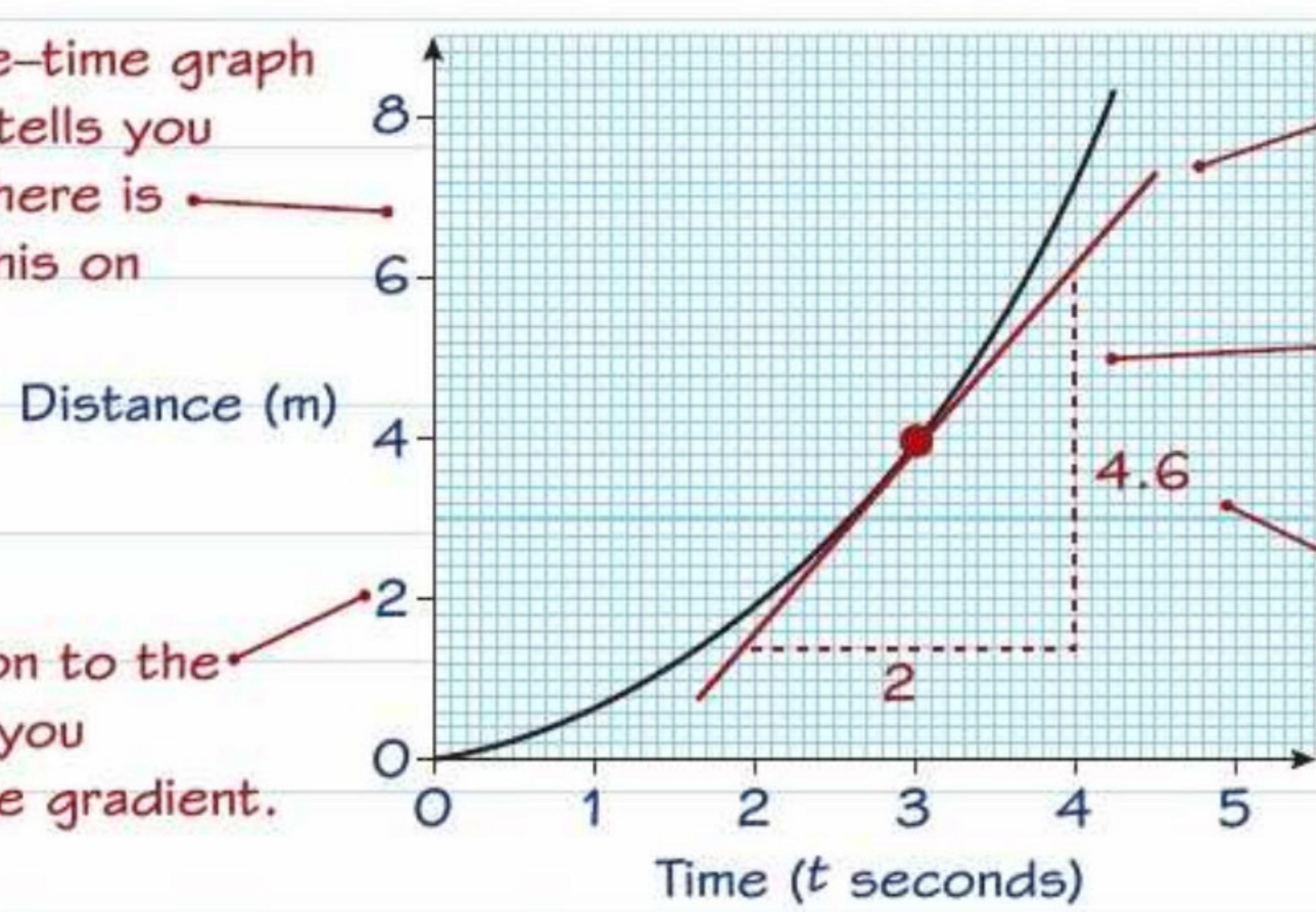


Gradients of curves

You can estimate the gradient of a curve at a given point by drawing a **tangent** to the curve at that point. This distance-time graph shows a runner accelerating at the start of a race.

On a distance-time graph the gradient tells you the speed. There is more about this on page 30.

Pay attention to the scale when you calculate the gradient.



This straight line is the **tangent** to the curve at $t = 3$.

Draw a large triangle to make your estimate as accurate as possible.

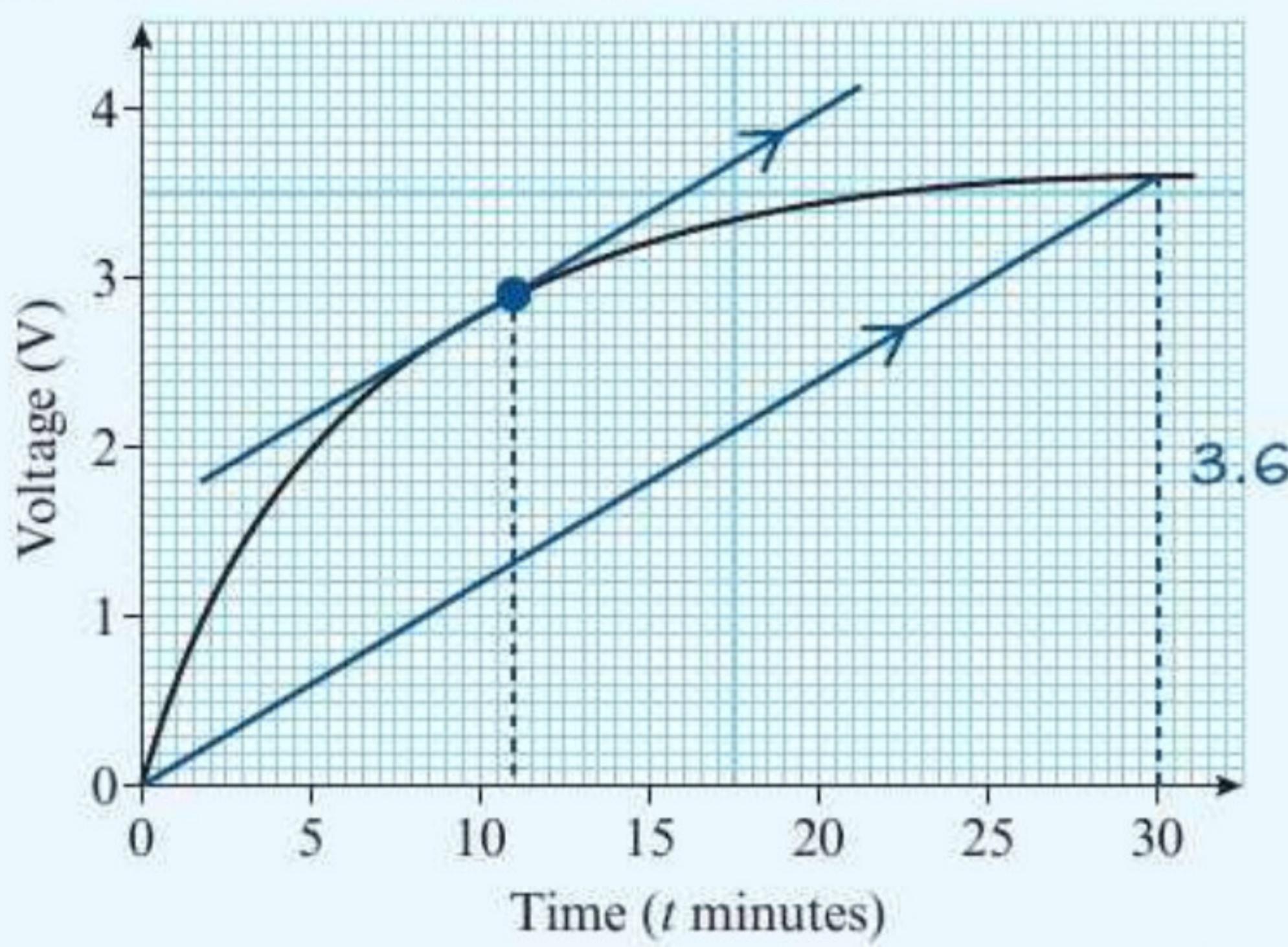
$$\frac{4.6}{2} = 2.3$$

so after 3 seconds the runner was travelling at approximately 2.3 m/s.

Worked example

Target grade 9

This graph shows the voltage across a phone battery as it charges from empty.



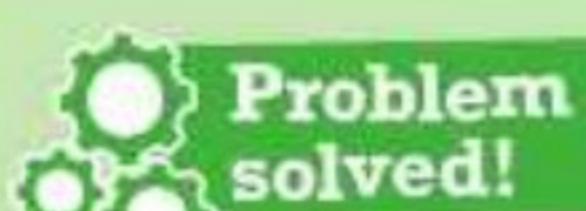
(a) Work out the average rate of increase of voltage between $t = 0$ and $t = 30$. (2 marks)

$$\frac{3.6}{30} = 0.12 \text{ V/min}$$

Amir wants to stop charging his phone when the rate of increase of voltage drops to this average level.

(b) After how long should Amir stop charging his phone? You must show how you got your answer. (2 marks)

11 minutes



(a) To work out the average rate of change between $t = 0$ and $t = 30$ draw a straight line between these points on the graph and find its gradient. This is the same as working out $\frac{\text{Change in voltage}}{\text{Change in time}}$

(b) You need to find the point **on the curve** with the same gradient. That means you need to find a **tangent** to the curve that is parallel to the first line. Slide a transparent ruler across the graph until it just touches the curve. You can show how you got your answer by drawing the tangent to the curve at this point.

Examiners' report

Read scales carefully. On the horizontal axis 10 small squares represents 5 minutes, so 1 small square represents 0.5 minutes.

Real students have struggled with questions like this in recent exams – **be prepared!**



Now try this

Target grade 9

A container is filling with water. This graph shows the depth of water in the container.

(a) Work out the average rate of increase of depth between $t = 0$ and $t = 40$.
 (b) Use the graph to estimate the rate of increase of depth of water at $t = 10$.

(2 marks)

(2 marks)

