# Calculating Acceleration

PowerPoint 9.2

## Velocity-Time Graphs

A ***velocity-time graph*** illustrates an object's $\Delta\vec{v}$, which is the object's $\vec{a}$.

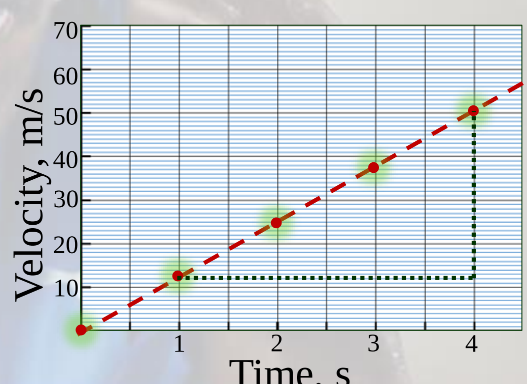
| **Time (s)** | 0.0 | 1.0 | 2.0 | 3.0 | 4.0 |
|---|---|---|---|---|---|
| **Velocity (m/s)** | 0.0 | 12.5 | 25.0 | 37.5 | 50.0 |

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

$$= \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$$

$$= \frac{50\frac{m}{s} - 12.5\frac{m}{s}}{4\ s - 1\ s} = 12.5\ \frac{m}{s^2}$$

Units for acceleration



# Velocity-Time Graphs

If $\vec{a}$ is constant, then $\Delta\vec{v}$ will be the same over identical $\Delta t$.

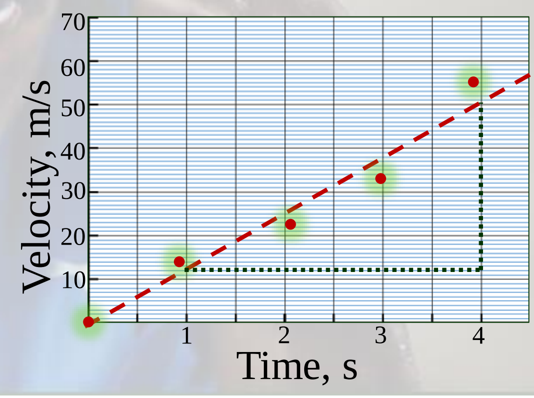
In reality, constant acceleration is rare and a best-fit line is drawn in order to determine an object's ***average acceleration***, $\vec{a}_{av}$.

- A straight line on a velocity-time graph is ***constant acceleration***.

$$\vec{a}_{av} = \frac{\Delta\vec{v}}{\Delta t}$$

$$= \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$$

$$= \frac{50\frac{m}{s} - 12.5\frac{m}{s}}{4\,s - 1\,s} = 12.5\,\frac{m}{s^2}$$




# Comparison Between Graphs

Position-Time Graphs, from 8.2

- Useful for objects at constant velocities
- $Slope = \vec{v}_{av}$


Velocity-Time Graphs

- Useful for objects whose velocity is not-constant
- Shows changes in velocity and acceleration of an object
- $Slope = \vec{a}$ or $\vec{a}_{av}$

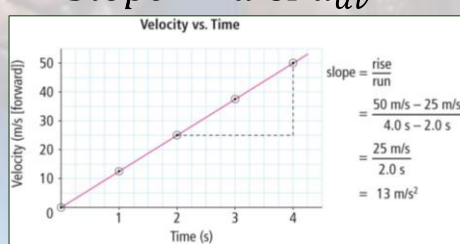



**Figure 9.11** The slope of a velocity-time graph is the average acceleration of the object.

# Determining Motion from a Velocity-Time Graph

$0\ to\ t_1$

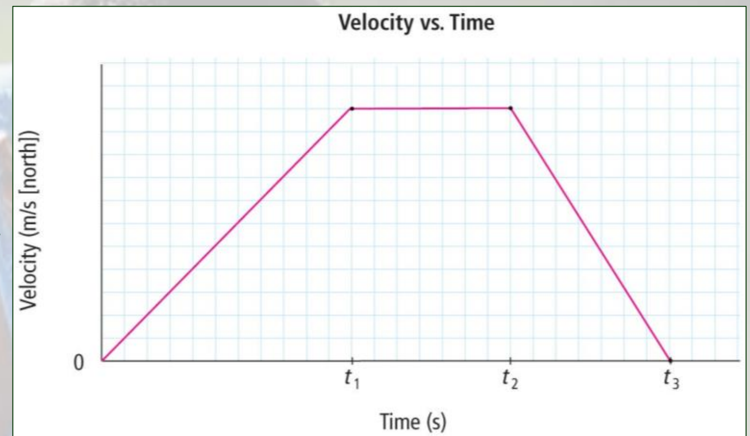
Constant positive $\vec{a}$,
in a northerly direction

$t_1\ to\ t_2$

$\vec{a} = 0$,
travelling at a constant $\vec{v}$

$t_2\ to\ t_3$

Constant negative $\vec{a}$,
in a southerly direction




0 $t_1$ $t_2$ $t_3$

# Practice Calculating $\vec{a}$ from a Velocity-Time Graph

0 s to 2 s

$$\vec{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{\left(6\frac{m}{s}\right) - \left(12\frac{m}{s}\right)}{(2\ s) - (0\ s)} = -3\ \frac{m}{s^2}$$

2 s to 4 s

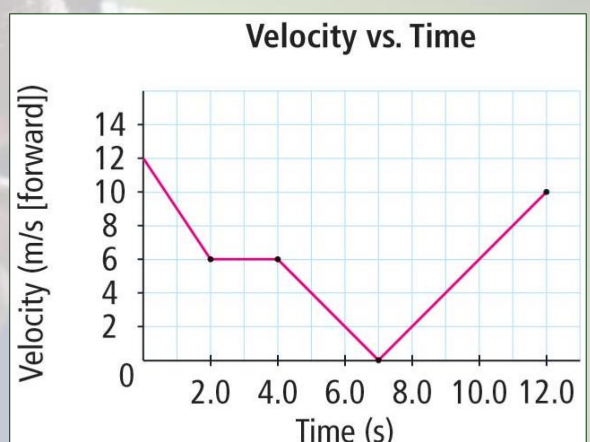
$$\vec{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{\left(6\frac{m}{s}\right) - \left(6\frac{m}{s}\right)}{(4\ s) - (2\ s)} = 0\ \frac{m}{s^2}$$

4 s to 7 s

$$\vec{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{\left(0\frac{m}{s}\right) - \left(6\frac{m}{s}\right)}{(7\ s) - (4\ s)} = -2\ \frac{m}{s^2}$$

7 s to 12 s

$$\vec{a} = \frac{v_f - v_i}{t_f - t_i} = \frac{\left(10\frac{m}{s}\right) - \left(0\frac{m}{s}\right)}{(12\ s) - (7\ s)} = 2\ \frac{m}{s^2}$$

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## Try Calculating $\vec{a}$ without a Graph

Question

The ball's velocity changes from 2.5 m/s toward the cushion to 1.5 m/s away from the cushion in a time interval of 0.20 s.

Answer

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

$$= \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i}$$

$$= \frac{\left(-1.5\frac{m}{s}\right) - \left(2.5\frac{m}{s}\right)}{0.20\ s} = -20\ \frac{m}{s^2}$$

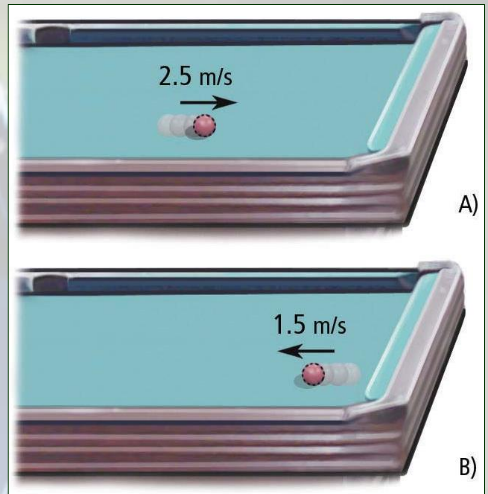



**Figure 9.13** The ball's velocity changes from 2.5 m/s toward the cushion (A) to 1.5 m/s away from the cushion (B) in a time interval of 0.20 s.

## Calculating $\Delta\vec{v}$ and $\Delta t$

The formula for $\vec{a}$ can also be rewritten to calculate $\Delta\vec{v}$ or $\Delta t$.

$$\Delta\vec{v} = \vec{a}\Delta t \quad \Leftarrow \quad \vec{a} = \frac{\Delta\vec{v}}{\Delta t} \quad \Rightarrow \quad \Delta t = \frac{\Delta\vec{v}}{\vec{a}}$$

Remembering the formula $\Delta\vec{v} = \vec{v}_f - \vec{v}_i$, one can also calculate initial and final velocity.

# Try this Practice Problem

**Question**

A motorcycle is travelling north at 11 m/s. How much time would it take for the motorcycle to increase its velocity to 26 m/s [N] if it accelerated at 3.0 m/s$^2$?

**Answer**

Be sure to write this part down.

1. Write down what you know
2. Identify what you're asked to find.
3. Find formulae which will help you find what you're looking for and that contain values that are known.

1. $\vec{a} = 3.0\ \frac{m}{s^2}$ 2. $\Delta t = ?$ 3. $\Delta t = \frac{\Delta \vec{v}}{\vec{a}} = \frac{\left(15\frac{m}{s}\right)}{3.0\ \frac{m}{s^2}} = 5\ s$

$v_i = 11\frac{m}{s}$

$v_f = 26\frac{m}{s}$

$\Delta \vec{v} = \vec{v}_f - \vec{v}_i = \left(26\frac{m}{s}\right) - \left(11\frac{m}{s}\right) = 15\frac{m}{s}$

# Try this Practice Problem

**Question**

A skier moving 6.0 m/s forward begins to slow down, accelerating at -2.0 m/s$^2$ for 1.5 s. What is the skier's velocity at the end of the 1.5 s?

**Answer**

1. Write down what you know.
2. Identify what you're aske to find.
3. Find formulae which will help you find what you're looking for and that contain values that are known.

1. $\vec{a} = -2.0\ \frac{m}{s^2}$ 2. $\vec{v}_f = ?$ 3. $\Delta \vec{v} = \vec{v}_f - \vec{v}_i$ ➡ $\left(-3.0\frac{m}{s}\right) = \vec{v}_f - \left(6.0\frac{m}{s}\right)$

$\Delta t = 1.5\ s$

$\vec{v}_i = 6.0\frac{m}{s}$

$\vec{v}_f = 3.0\frac{m}{s}$

$\Delta \vec{v} = \vec{a}\Delta t = \left(-2.0\frac{m}{s^2}\right)(1.5s) = -3.0\frac{m}{s}$

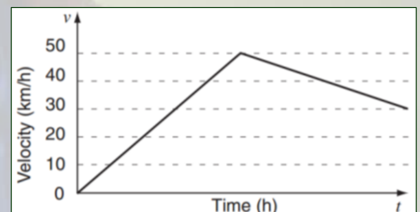
# Provincial Exam Question

Question

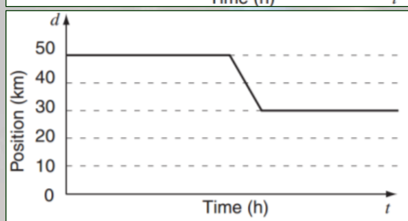
Which of the following graphs shows a car travelling at a constant velocity of +50 km h, then slowing down to +30 km has it enters a school zone?

A.

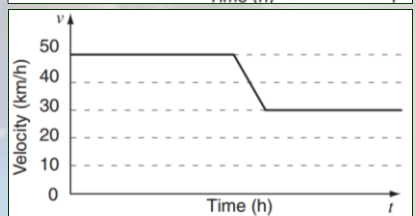

B.




C.




D.




Answer

D.

# Provincial Exam Question

Question

On the surface of the moon, the acceleration due to gravity is −1.6 m/s². If a ball is thrown upward at +20 m/s, how long does it take for the ball to reach a velocity of 0 m/s before falling back to the surface of the moon?

A. 0.08 s

B. 12.5 s

C. 20 s

D. 32 s

Answer

B. 1. $\vec{a} = -1.6\ \frac{m}{s^2}$ 2. $\Delta t = ?$ 3. $\Delta t = \frac{\Delta\vec{v}}{\vec{a}} = \frac{\left(-20\frac{m}{s}\right)}{\left(-1.6\ \frac{m}{s^2}\right)} = 12.5\ s$

$\vec{v}_i = +20\frac{m}{s}$

$\Delta\vec{v} = \vec{v}_f - \vec{v}_f = \left(0\frac{m}{s}\right) - \left(20\frac{m}{s}\right) = -20\frac{m}{s}$

$\vec{v}_f = 0\frac{m}{s}$

# Provincial Exam Question

Question

A car moving at +15 m/s pulls onto the highway and accelerates at +1.2 m/s$^2$ for 8.2 seconds. What is its final velocity?

A. +9.8 m/s
B. +16.2 m s
C. +20.7 m s
D. +24.8 m s

Answer

D.

1. $\vec{a} = +1.2\ \frac{m}{s^2}$ 2. $\vec{v}_f = ?$ 3. $\Delta\vec{v} = \vec{v}_f - \vec{v}_f$ ➡ $\left(9.84\frac{m}{s}\right) = \vec{v}_f - \left(15\frac{m}{s}\right)$

$\vec{v}_i = +15\frac{m}{s}$

$\vec{v}_f = 24.8\frac{m}{s}$

$\Delta\vec{v} = \vec{a}\Delta t = \left(1.2\ \frac{m}{s^2}\right)(8.2\ s) = 9.84\frac{m}{s}$

$\Delta t = 8.2\ s$

# Summary

***Velocity-time graphs*** allow for analysis if changes in velocity over time. The slope of the best-fit line in such a graph is an object's ***acceleration***.

With the formulae below, one can calculate the initial velocity, $\vec{v}_i$, the final velocity, $\vec{v}_f$, the time interval, $\Delta t$, and the acceleration, $\vec{a}$, of an object in motion.

$\Delta\vec{v} = \vec{v}_f - \vec{v}_i$ $\quad\Delta\vec{v} = \vec{a}\Delta t$ $\quad\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$ $\quad\Delta t = \frac{\Delta\vec{v}}{\vec{a}}$