SLE123 Physics for the Life Sciences

Week 1

Movement and force

DEAKIN COLLEGE

in association with

DEAKIN UNIVERSITY

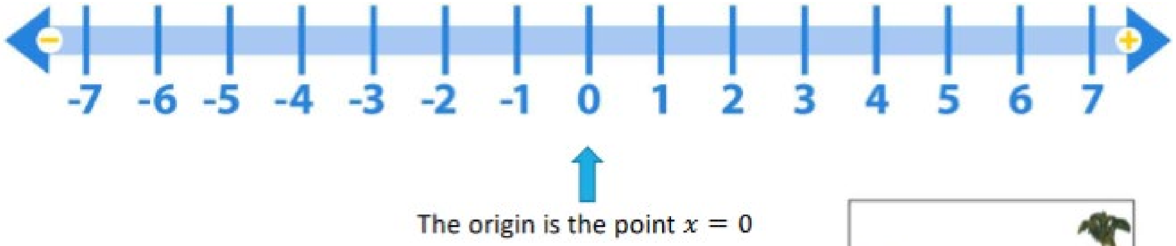
Topic 1: Movement and Force

Representing Motion

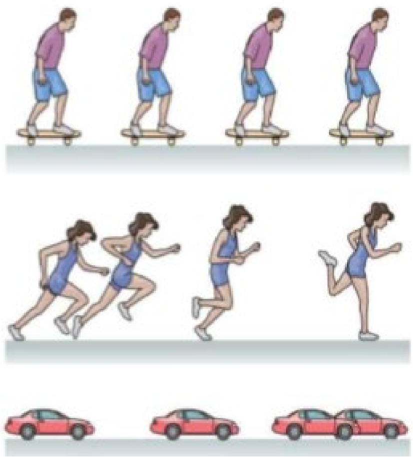
- Position & time
- Displacement & distance
- Velocity & speed
- Acceleration

1.1. Position & time

- When an object moves, its **position** changes
- To measure movement in a straight line, it often makes sense to use a special kind of number line called an x-axis



- In order to quantify motion,
- we'll need to consider changes
- in **time**.



1.2. Distance & Displacement

Distance

- the length of a path between two points
- (Distance is a scalar**:** a quantity represented by a number only**)**

Displacement

- the length and direction of a path between two points
- (Displacement is a vector: a quantity represented by a number and a direction)

Example 1

- A lecturer takes 3 steps left, then 5 steps right (assume 1 step=1 m).

(a) What is the **distance** travelled?

(b) What is its **displacement** at the end of the journey?

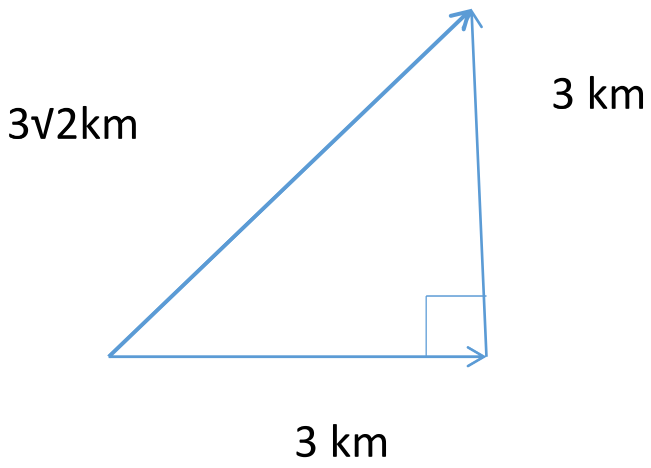
Example 2

- A bird flies 3km east then 3 km north.

(a) What is the **distance** it travelled?

(b) What is its **displacement** at the end of the journey

Displacement is a vector



Displacement Vectors

- A *displacement vector* starts at an object's initial position and ends at its final position. It doesn't matter what the object did in between these two positions.

- In motion diagrams, the displacement vectors span successive particle positions.

Checking Understanding

Maria is at position x = 23 m. She then undergoes a displacement Δx = –50 m. What is her final position?

A. –27 m

B. –50 m

C. 23 m

D. 73 m

Problem task 4

- Calculate distance and displacement (Q4)

1.3. Speed & Velocity

Velocity

- is the **change in position** divided by the **change in time**.
- is a **vector** with a magnitude and direction
- $\mathbf{v}=\Delta \mathbf{x}/ \Delta t$

Speed

- Is the **magnitude** of the velocity
- Is a **scalar**, and does not have direction
- $v=\Delta x/ \Delta t$

Velocity

In other words

Velocity=displacement/time

v=**d**/t

(assuming initial velocity is zero)

Back to basics-Example 3

In example 1, if the lecturer took 2 seconds to move left (3 steps) and 5 seconds to move right (5 steps)(1 step=1m)

1. What was his/her average speed

   For the total journey

2. What was the average velocity

   For the total journey

Example 4

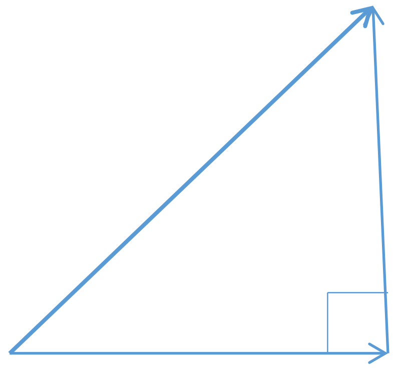
In example 2, if the bird took 3 hours to complete the journey

1. What was his/her average speed?
2. What was the average velocity

   For the total journey?

Velocity is a vector

(assume trip takes a total time of 3 hrs)



v=d/t
=3√2km/3
=√2km/hr NE

Average Speed

The Average speed is

$$\text{Average Speed} = \frac{\text{total distance covered}}{\text{time interval}}$$

If the average speed is known then the distance travelled can be calculated

Total distance = average speed x time

The average speed from Burwood Campus to the Geelong Campus is 75 km/hr and the journey takes 1hr and 20min.

What is the distance between the Burwood and Geelong Campuses ?

1.5. Average velocity

$$v_{av}=\text{displacement}/\text{time}$$

$$\mathbf{v}_{av}=\mathbf{d}/t$$

Problem task 5

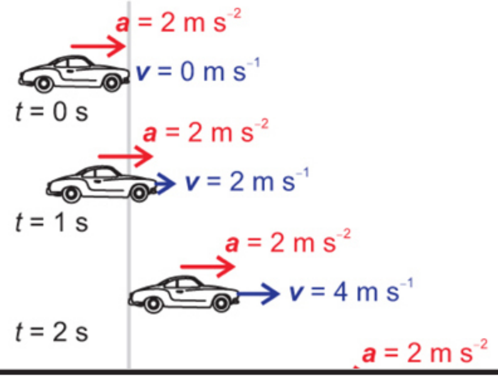
Measurement of speed & velocity (Q5)

1.4. Acceleration

Acceleration

- is the **change in velocity** divided by the **change in time**.
- is a **vector** with a magnitude and direction
- $\mathbf{a}=\Delta \mathbf{v}/ \Delta t$

Case1: starting from rest (u=0)



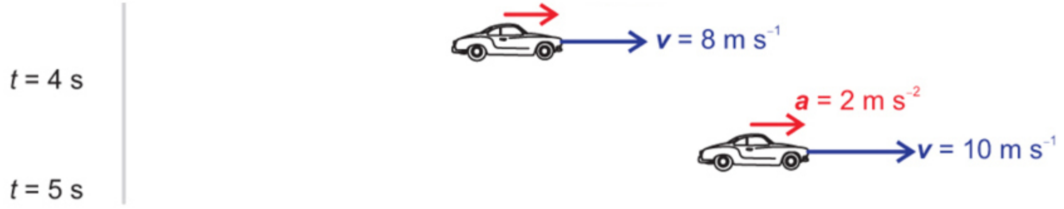


Figure 1.3

A car accelerating at 2 m s^{-2} for 5 s.

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- v=at

- v=velocity
- a=acceleration
- t=time

- (assuming initial velocity is zero)

- In the previous example, find v at t=4 sec, and a=2 m/sec^2

Exercise

1. A sprinter starts from rest and accelerates at 5 m/sec^2

How fast is he/she running

- after 2 seconds?
- After 5 seconds?

Case2: already moving at t=0 (u<>0)

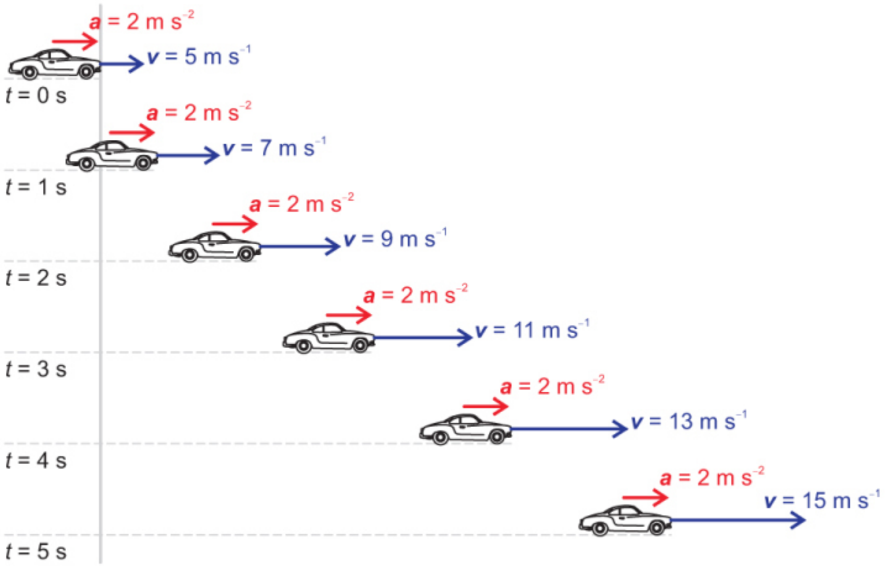

Figure 1.4

A car accelerates from an initial velocity of 5 m s^{-1} with a constant acceleration of 2 m s^{-2}.

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$\mathbf{v}=\mathbf{u}+\mathbf{a}t$

v=velocity

u=initial velocity

a=accleration

t=time

In the previous example, find v at t=4 sec, and a=2 m/sec^2 with u= 5 m/sec

Problem task 6

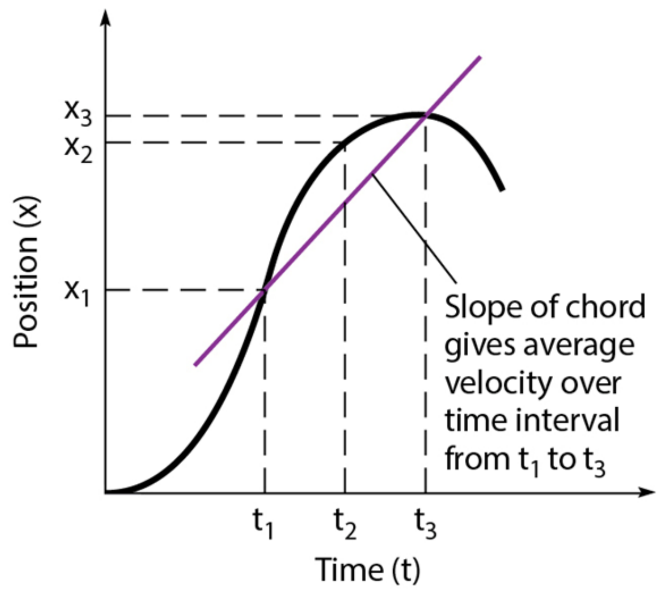
- Calculations involving acceleration (Q6,Q7)

Think – Pair – Share Activity

- A gazelle can reach a speed of 13 m/s in 3.0 s.
- A lion can reach a speed of 34.2 km/h in 1.0 s.
- A trout can reach a speed of 2.8 m/s in 0.12 s.
- Which animal has the largest acceleration?

Graphical Relationships: Average Velocity

On a graph of position versus time, the average velocity is represented by the slope of a chord.



(a)

Average velocity

$$v_{\text{av},x} = \frac{x_3 - x_1}{t_3 - t_1}$$

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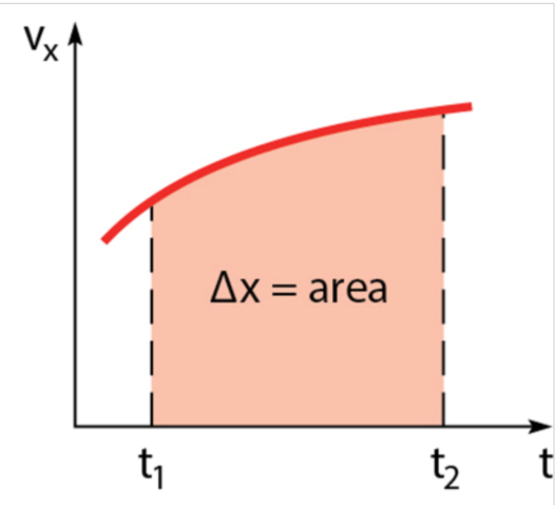
Graphical Relationships: Displacement

The (signed) area under a velocity versus time graph (between the curve and the horizontal time axis) gives the displacement in a given interval of time.



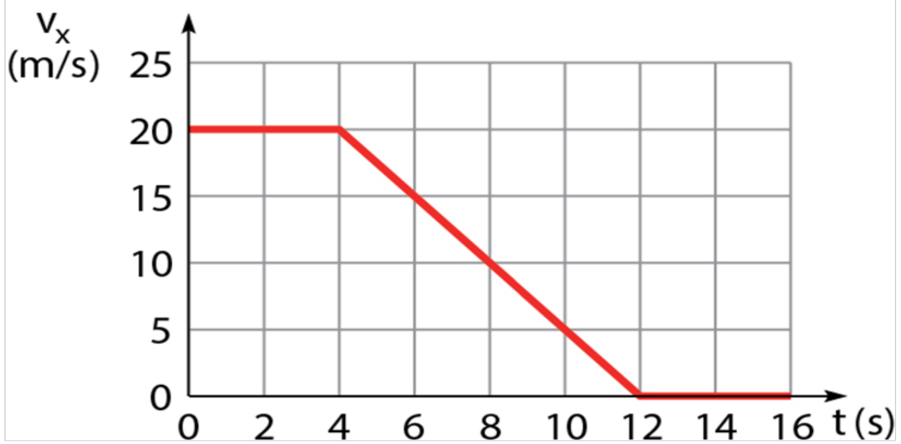
(c)

If the velocity is positive (above the horizontal axis), the area is positive.

If the velocity is negative (below the horizontal axis), the area is negative.

Example: Chapter 2 Problem 10

Speedometer readings are obtained and graphed as a car skids to a stop along a straight-line path. How far does the car move between t = 0 and t = 16 seconds?



Since there is not a reversal of direction, the (positive) area between the curve and the time axis will represent the distance traveled.

Example: Chapter 2 Problem 10 continued

The rectangular portion has an area

$$\text{length} \times \text{width} = (20\ \text{m/s})(4\ \text{s}) = 80\ \text{m}.$$

The triangular portion has an area

$$\frac{1}{2}\text{base} \times \text{height} = \frac{1}{2}(8\ \text{s})(20\ \text{m/s}) = 80\ \text{m}.$$

The total area is 160 m, the distance traveled by the car.

Problem task 7

- Velocity-time graphs (Q9)

The Direction of Acceleration

The acceleration has the same direction as the *change* in velocity.

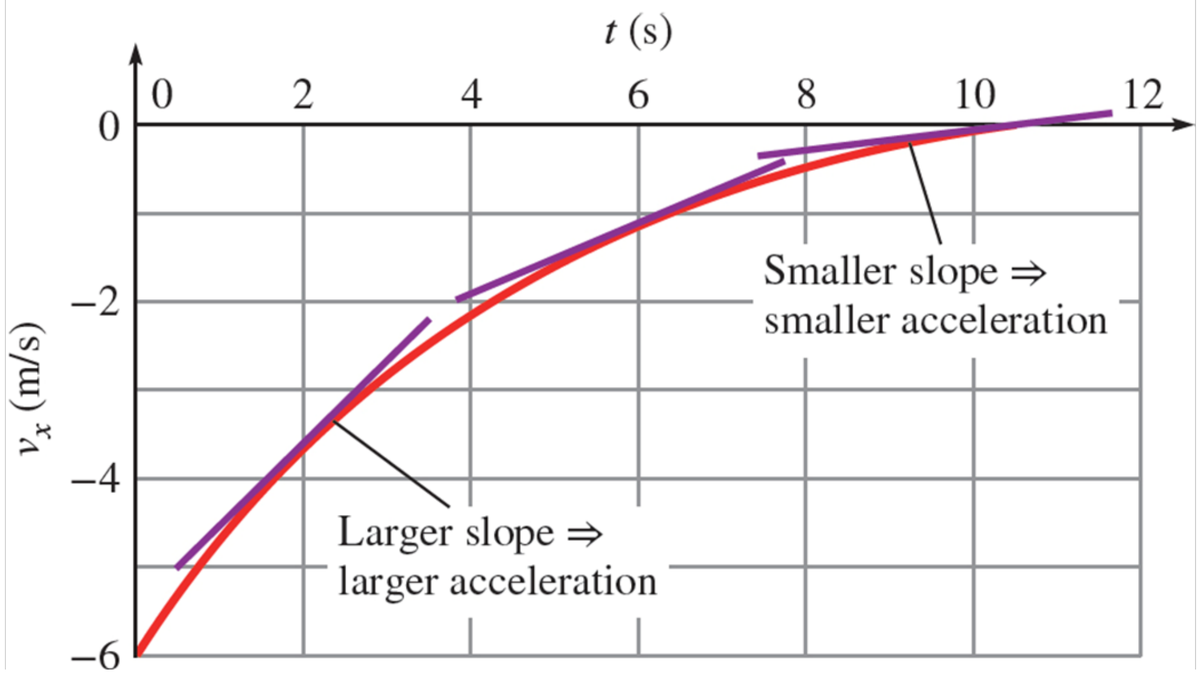
When the acceleration and velocity are in the **same direction**, the object is **speeding up**.

When the acceleration and velocity are in **opposite directions**, the object is **slowing down**.

Example: A car is driving east and slowing down. The acceleration is west.

Graphical Relationships: Acceleration

The acceleration a_x is the slope on a graph of $v_x(t)$ and the change in velocity Δv_x is the area under the graph of $a_x(t)$.



Example: Chapter 2 Problem 36

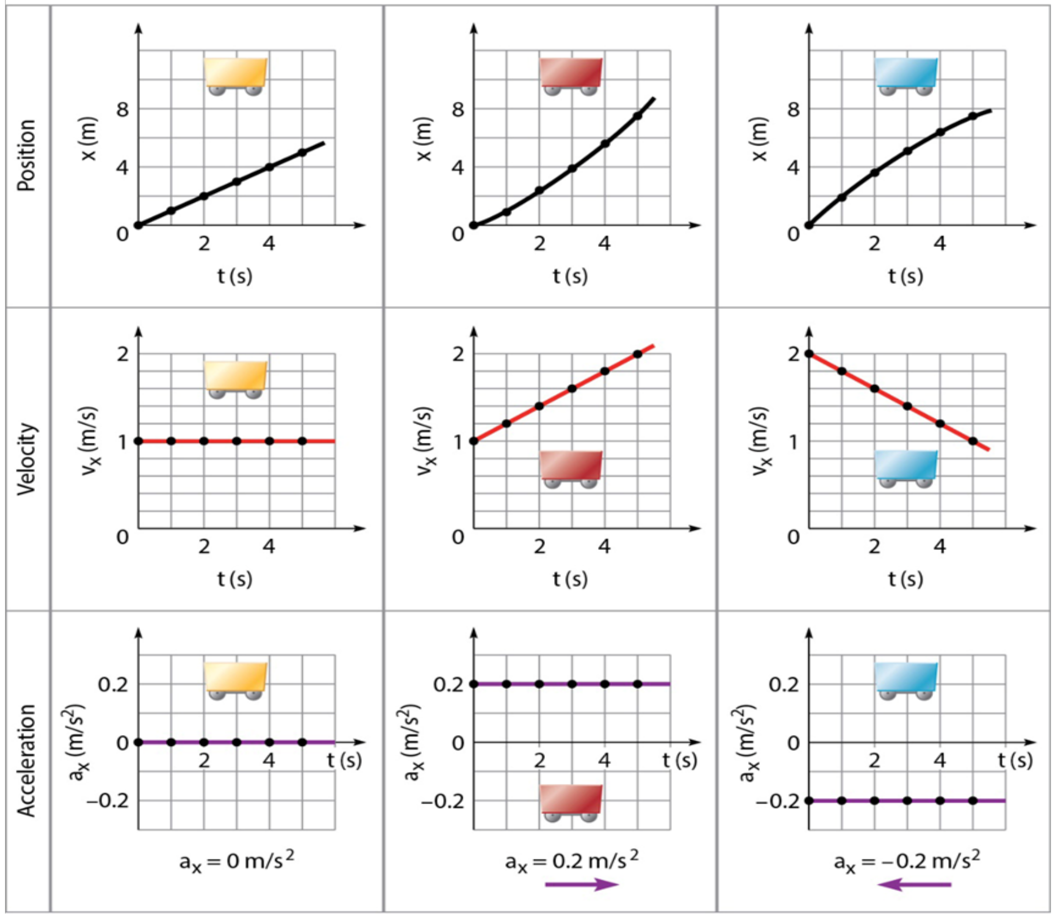
The graph shows speedometer readings as a car skids to a stop on a straight roadway. What is the magnitude of the acceleration at *t* = 7.0 s?

The slope of the graph at *t* = 7.0 sec is

$$\left|a_{\text{av}}\right| = \left|\frac{\Delta v_x}{\Delta t}\right| = \left|\frac{v_2 - v_1}{t_2 - t_1}\right| = \left|\frac{(0-20)\,\text{m/s}}{(12-4)\,\text{s}}\right| = 2.5\,\text{m/s}^2$$

Graphs of x, v_x, a_x for the Three Carts

The slope of the $x(t)$ graph at any time is the velocity v_x at that time. The slope of the $v_x(t)$ graph at any time is the acceleration a_x at that time.

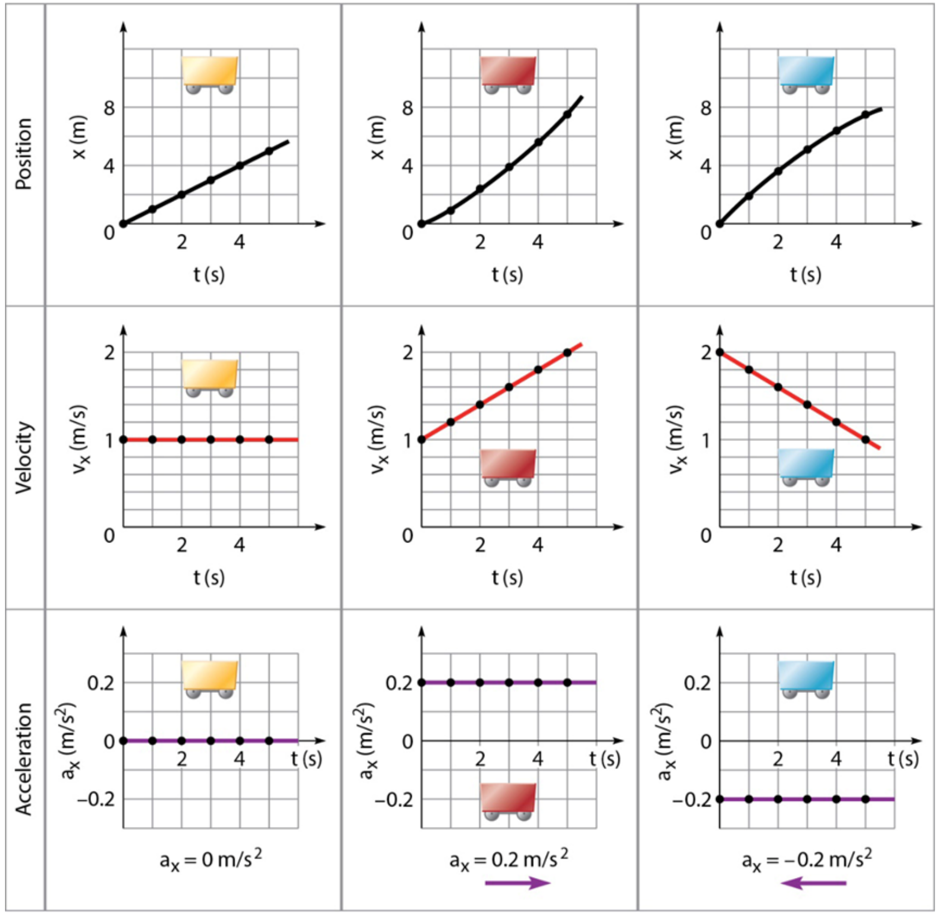


Graphs of x, v_x, a_x for the Three Carts

For each cart,
The graph of $a_x(t)$ is a constant (zero, positive, or negative).

The graphs of $v_x(t)$ are straight lines with zero, positive, or negative slope.

The graph of position $x(t)$ is a straight line with positive slope for the cart with zero acceleration. For the other two carts, the graphs of $x(t)$ are parabolas with either increasing slope (concave up) for positive acceleration or decreasing slope (concave down) for negative acceleration.



Topic Summary

- **Displacement**

$$\Delta x \equiv x_f - x_i$$

- **Velocity**

$$\text{average speed} = \frac{\text{path length}}{\text{elapsed time}}$$

$$\bar{v} \equiv \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

- **Acceleration**

$$\bar{a} \equiv \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$