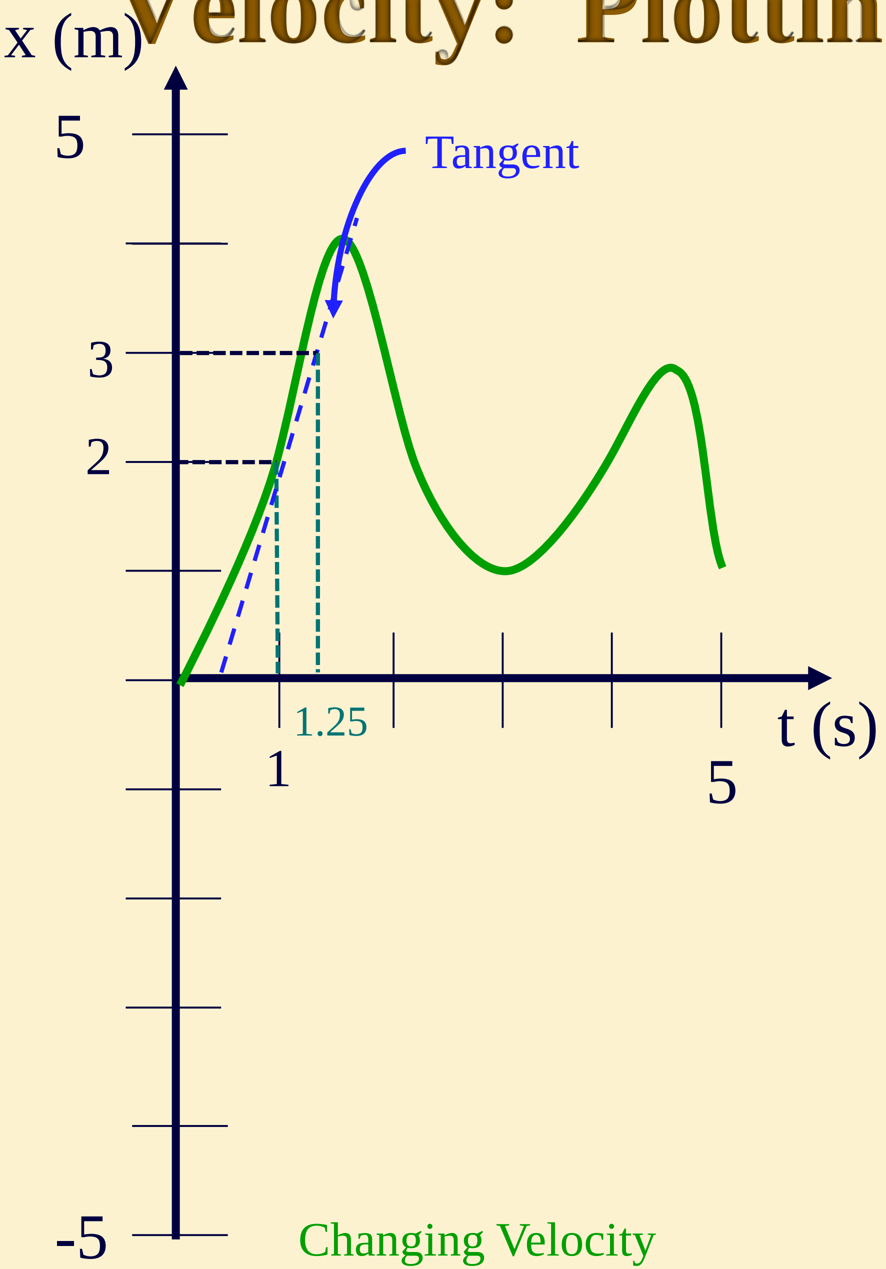
Physics 101 Lecture 2
Kinematics: Motion in 1-Dimension

Kinematics: Velocity

- ➔ Velocity: the rate of change of position
  - » $v = \Delta x / \Delta t.$
  - » average
  - » instantaneous

Velocity: Plotting Position and Time



- Instantaneous Velocity:

  the slope of *tangent* line *at any point* on a position-time graph

- Example:

  What is the *instantaneous velocity*:

  $x = 2$ m and $t = 1$ s?

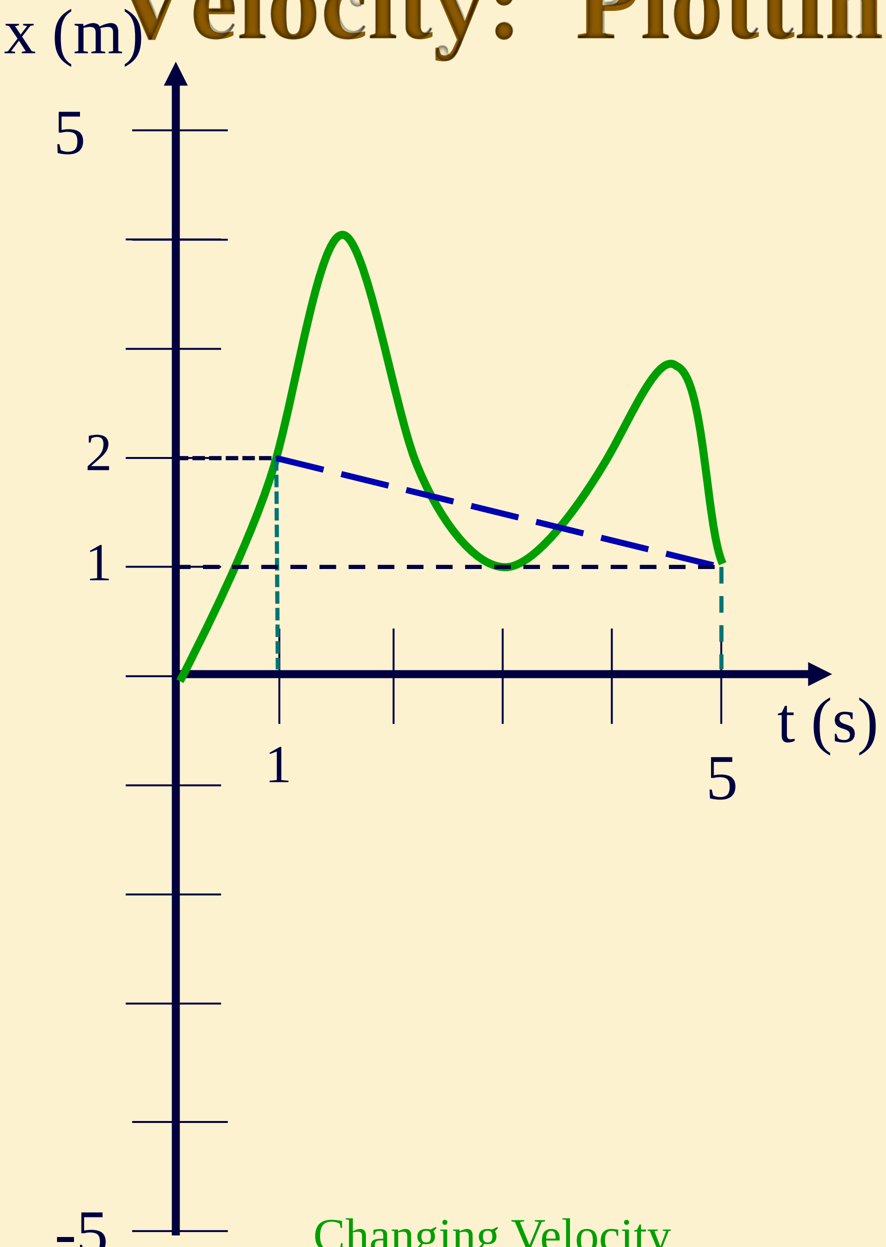
- $v = \Delta x_{\text{tan}} / \Delta t_{\text{tan}}$

  ➔ $\Delta x_{\text{tan}} = (3 - 2)\ \text{m}$

  ➔ $\Delta t_{\text{tan}} = (1.25 - 1)\ \text{s}$

  ➔ $v = \dfrac{1\ \text{m}}{0.25\ \text{s}} = 4\ \text{m/s}$

Velocity: Plotting Position and Time



- Example:

  What is the *average velocity* between :

  $t = 1$ s and $t = 5$ s?

- $\Delta v = \Delta x / \Delta t$
  - ➔ $\Delta x = (1 - 2)$ m
  - ➔ $\Delta t = (5 - 1)$ s
  - ➔ $v = \frac{-1\text{ m}}{4\text{ s}} = -0.25\,\frac{\text{m}}{\text{s}}$
  - ➔ What does "–" mean?

Changing Velocity

Velocity Clicker Question

If the average velocity of a car during a trip along a straight road is positive, is it possible for the instantaneous velocity at some time during the trip to be negative?

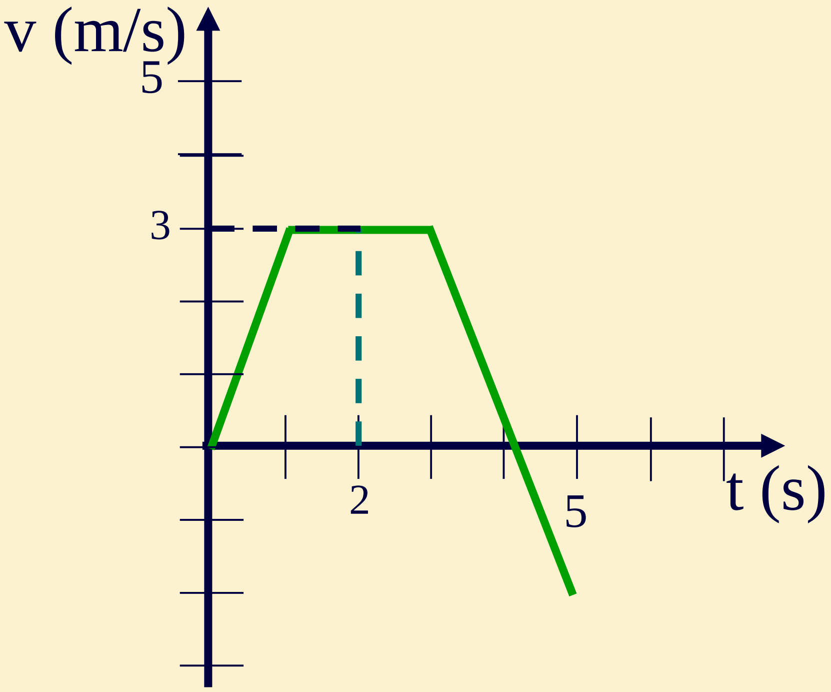
A - Yes

B - No

Kinematics: Acceleration

- Acceleration: the rate of change of velocity
  - $a = \Delta v / \Delta t$
  - average
  - instantaneous

Acceleration: Plotting Velocity and Time



- Slope:

  Instantaneous acceleration:

  $$a = \left(\frac{\Delta v}{\Delta t}\right) \textit{for small } \Delta t$$

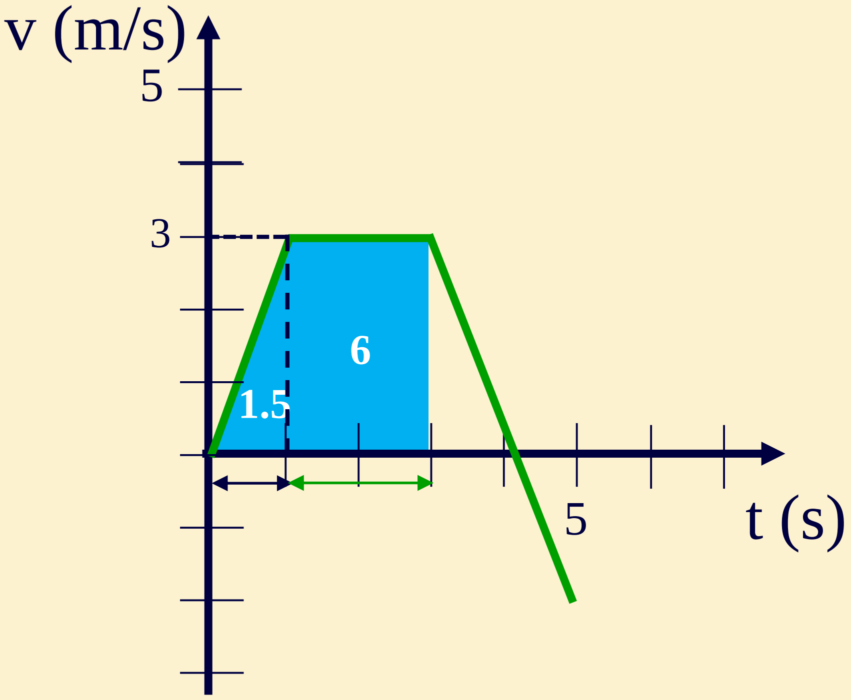
- Example:

  Velocity at $t = 2$

  ➔ $v(2) = 3\ \text{m/s}$

What's acceleration at t=2?

Acceleration: Plotting Velocity and Time



- Area:
  Displacement: $\Delta x = v\Delta t$
- Example:

  Find the *displacement* between:

  $t = 0$ s and $t = 3$ s

  ➔ $t = 0$ s to $t = 1$ s

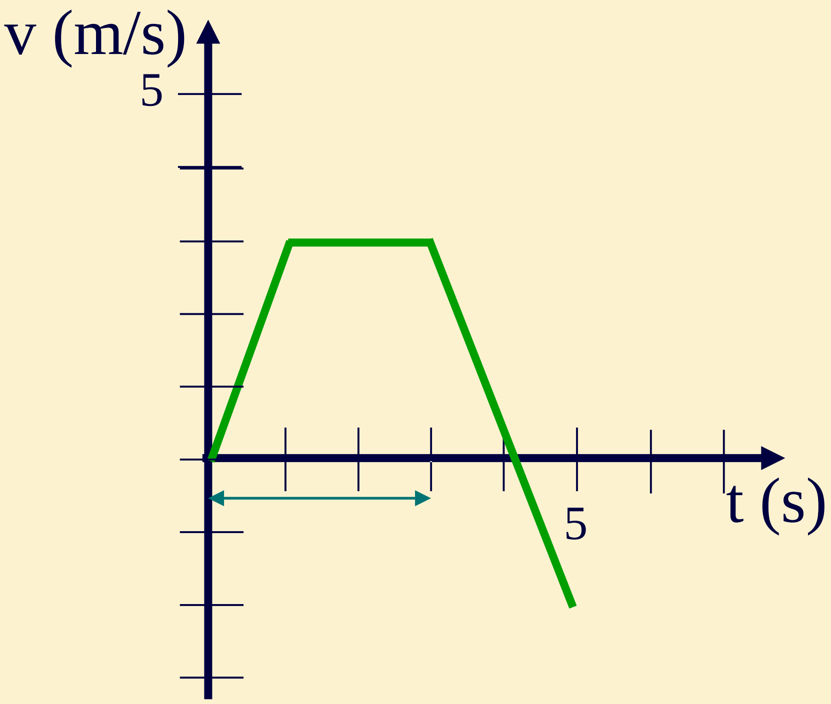
  » $\Delta x_1 = \frac{1}{2}\left(3\,\frac{\mathrm{m}}{\mathrm{s}}\right)(1\ \mathrm{s}) = 1.5\ \mathrm{m}$

  ➔ $t = 1$ s to $t = 3$ s

  » $\Delta x_2 = \left(3\,\frac{\mathrm{m}}{\mathrm{s}}\right)(3\ - 1\ \mathrm{s}) = 6\ \mathrm{m}$

  ➔ $\Delta x = \Delta x_1 + \Delta x_2 = 7.5\ \mathrm{m}$

Acceleration: Plotting Velocity and Time



- Average Velocity:

$$\Delta v = \Delta x / \Delta t$$

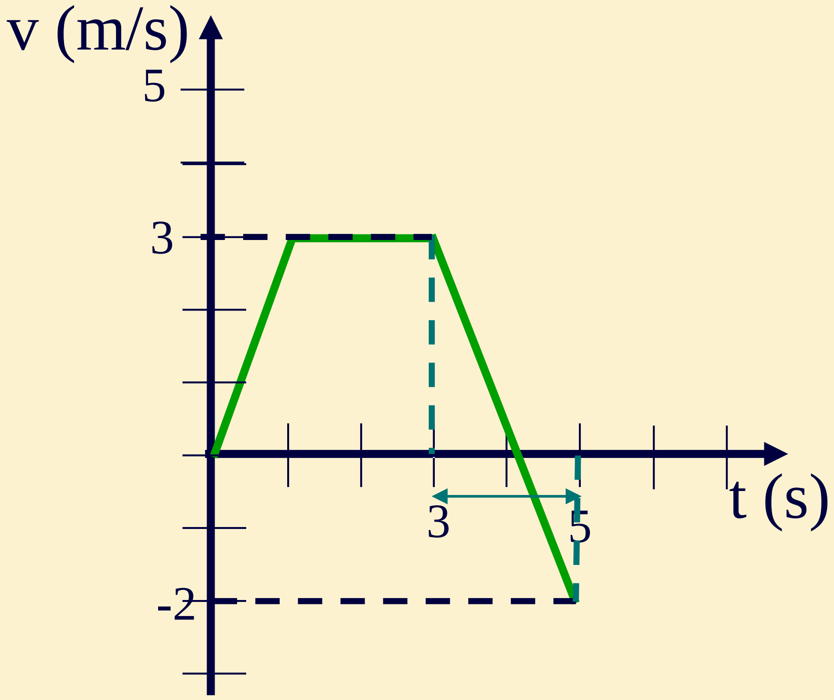
- Example:

Average velocity between $t = 0$ s and $t = 3$ s

➔ $\Delta x = 7.5$ m, $\Delta t = 3$ s

➔ $\Delta v = \frac{7.5}{3}\frac{\text{m}}{\text{s}} = 2.5$ m/s

Acceleration: Plotting Velocity and Time



- <u>Average Acceleration</u>:
  $$\Delta a = \Delta v / \Delta t$$
- Example:

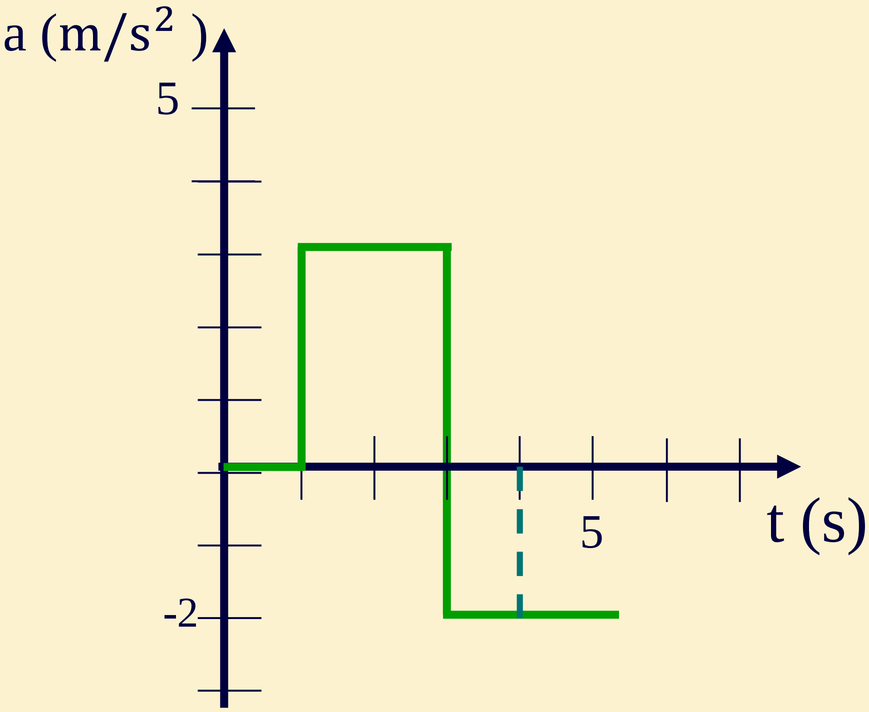
  Average acceleration between $t = 3$ s and $t = 5$ s

  ➔ $\Delta v = (-2 - 3)\frac{\text{m}}{\text{s}} = -5\,\frac{\text{m}}{\text{s}}$

  ➔ $\Delta t = (5 - 3)\text{s} = 2\text{ s}$

  ➔ $\Delta a = -\frac{5\frac{\text{m}}{\text{s}}}{2\text{ s}} = -2.5\text{ m/s}^2$

Graphical Representation of Acceleration: Plotting Acceleration and Time



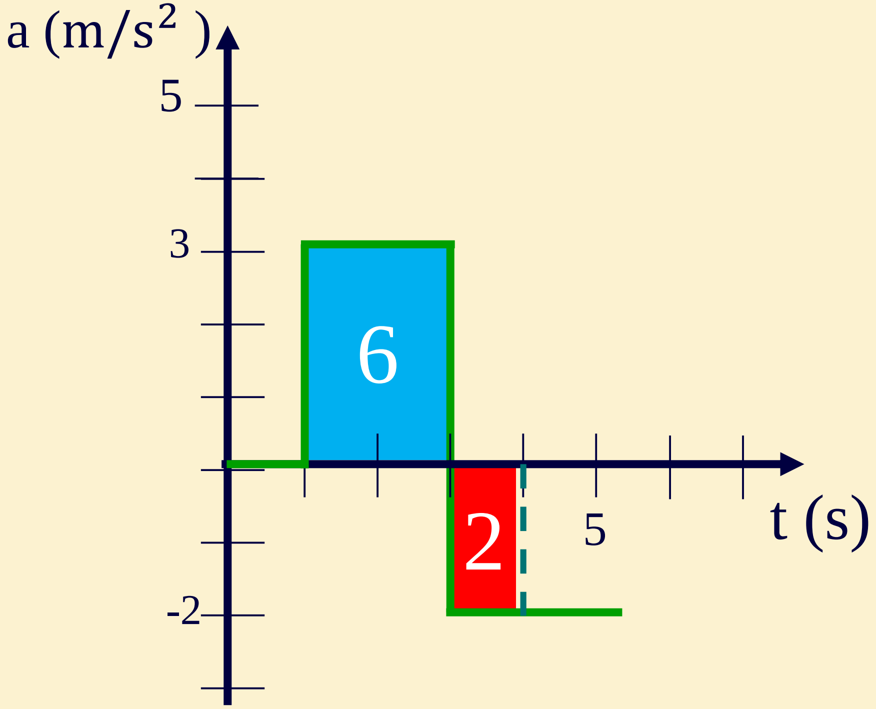
- Slope:

  $a = \Delta v / \Delta t$

- Example: Acceleration at $t = 4$ s:

  ➔ $a(4\text{ s}) = -2\,\frac{m}{s^2}$

Acceleration: Plotting Velocity and Time



- Area:

$$\Delta v = a\,\Delta t$$

- Example: Change in velocity between $t = 1$ s and $t = 4$ s
  - ➔ $t = 1\text{ s to } t = 3\text{ s}$
    - » $\Delta v_1 = \left(3\,\frac{\text{m}}{\text{s}^2}\right)(2\text{ s}) = 6\text{ m/s}$
  - ➔ $t = 3\text{ s to } t = 4\text{ s}$
    - » $\Delta v_2 = \left(-2\,\frac{\text{m}}{\text{s}^2}\right)(1\text{ s}) = -2\text{ m/s}$
  - ➔ $\Delta v = \Delta v_1 + \Delta v_2 = 4\text{ m/s}$

Acceleration Clicker Qs

Is it possible for an object to have a positive velocity at the same time as it has a negative acceleration?

1 - Yes

2 - No

If the velocity of some object is not zero, can its acceleration ever be zero ?

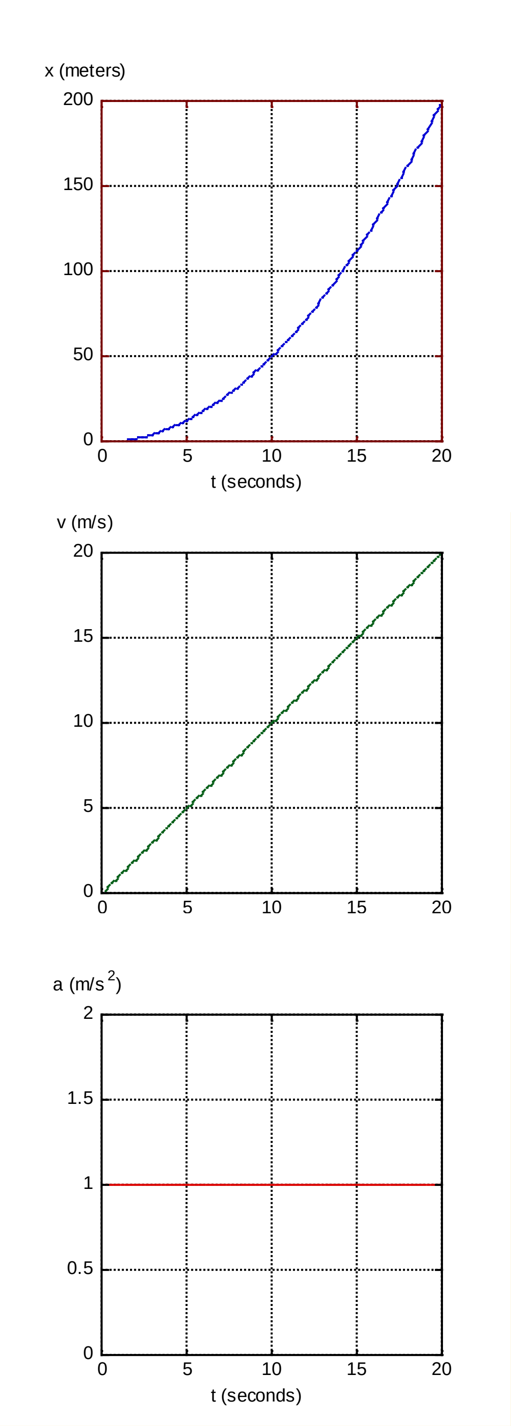
1 - Yes

2 - No

Equations for Constant Acceleration

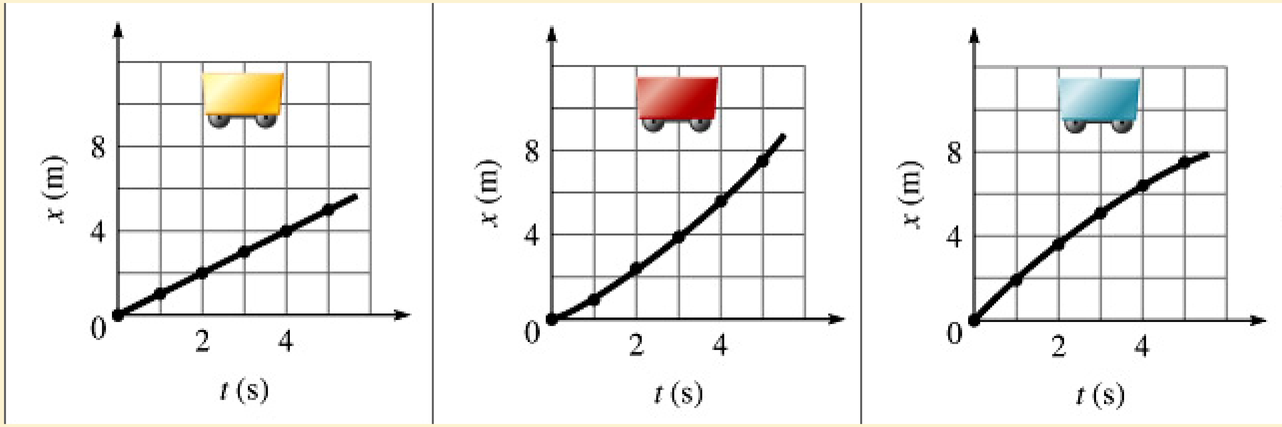
- $x = x_0 + v_0 t + \frac{1}{2} a t^2$
- $v = v_0 + at$
- $v^2 = {v_0}^2 + 2a(x - x_0)$

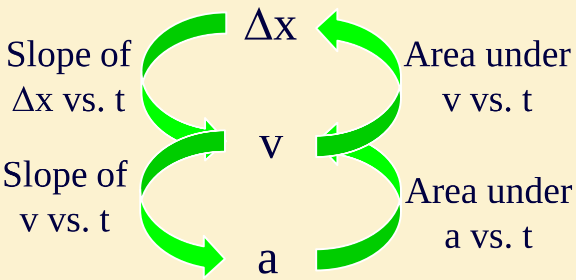
Use these equations to predict the future path and speed of an object under constant acceleration!



Clicker Q

…interpreting graphs…





(A) (B) (C)

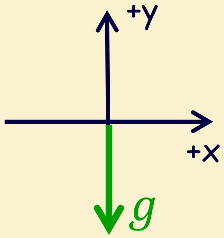
Which x vs t plot shows positive acceleration?

Kinematics: Free Fall—A Special Case

- Free Fall: An object's motion is caused by *gravity alone*
  - ➔ $a = g$, the *acceleration of gravity*
  - ➔ $g = 9.8\ \mathrm{m/s^2}$
  - ➔ The 3 kinematic equations become:
    - » $y = y_0 + v_{0y}\, t - 1/2\, gt^2$
    - » $v_y = v_{0y} - gt$
    - » $v_y{}^2 = v_{0y}{}^2 - 2g(y - y_0)$

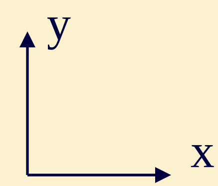
A Few Facts About *g*

- For Gravity:
  - ➔ Acceleration is $g = 9.8\ \mathrm{m/s^2}$ near the surface of the earth.
  - ➔ g **always** points downward
  - ➔ Position may be positive, zero or negative
  - ➔ Velocity may be positive, zero or negative



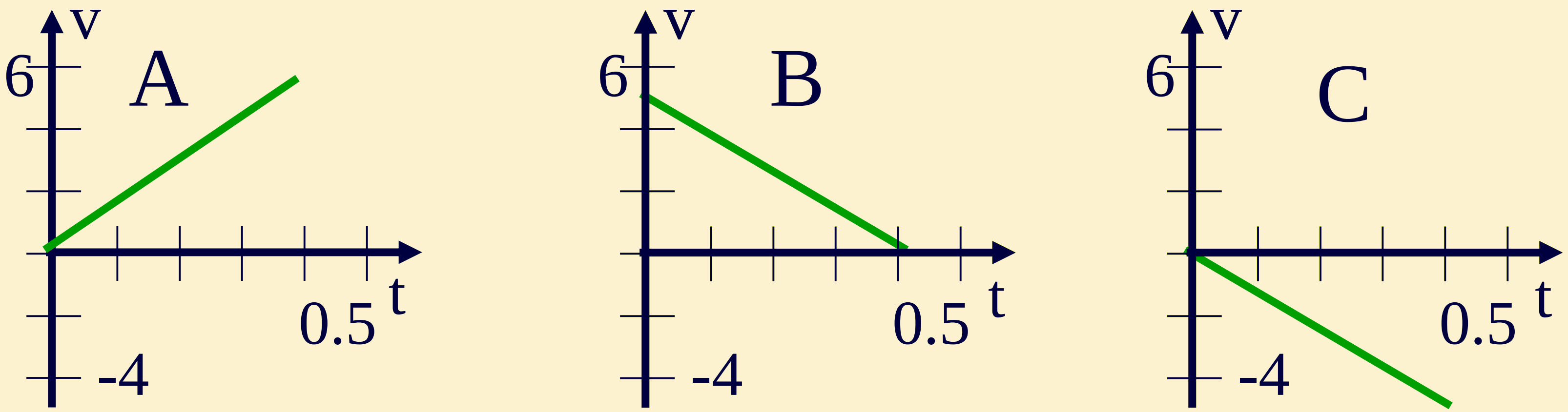
- To Calculate position or velocity as a function of *time*:
  - ➔ Position: $y = y_0 + v_{0y}t - \frac{1}{2}gt^2$
  - ➔ Velocity: $v_y = v_{0y} - gt$
- To calculate velocity as a function of *position*:
  - ➔ $v_y^2 = v_{0y}^2 - 2g(y - y_0)$

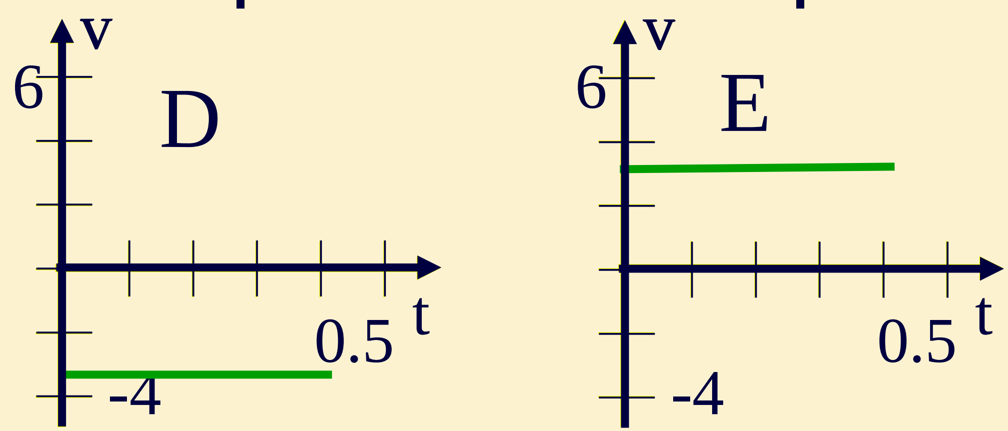
Dropped Ball Clicker Q



A ball is dropped from a height of two meters above the ground.

Draw v_y vs t

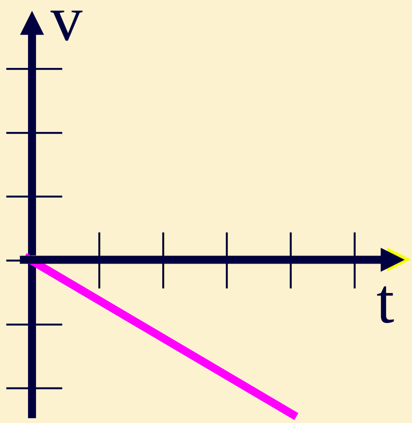




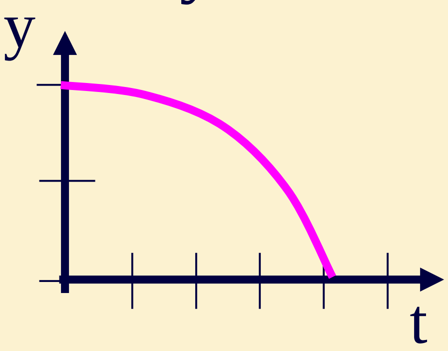
Dropped Ball: Position & acceleration

A ball is dropped from a height of two meters above the ground.

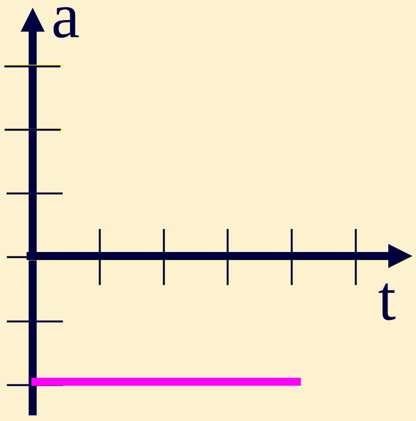
- Draw v vs t



- Draw y vs t

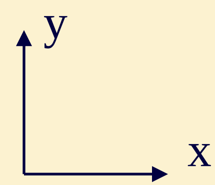


- Draw a vs t

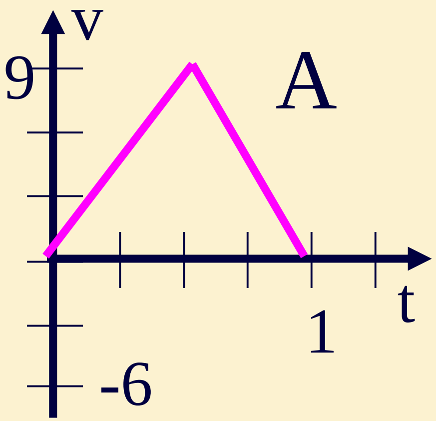


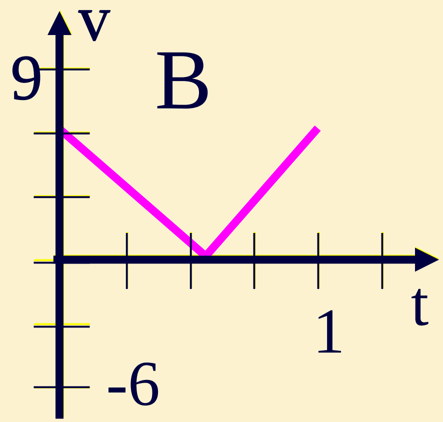
Tossed Ball Clicker Q

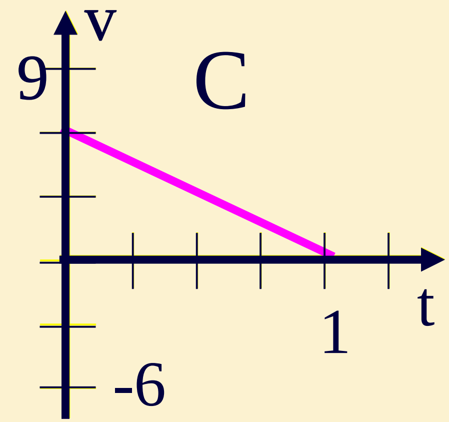
A ball is tossed from the ground up a height of two meters above the ground, and falls back down.

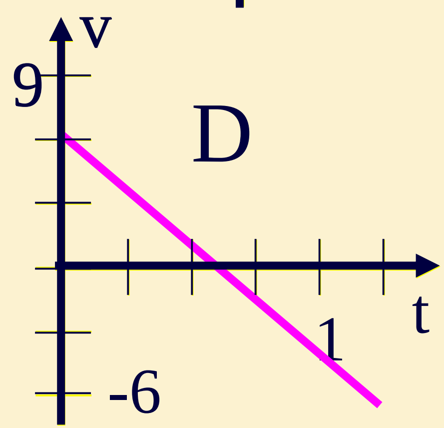


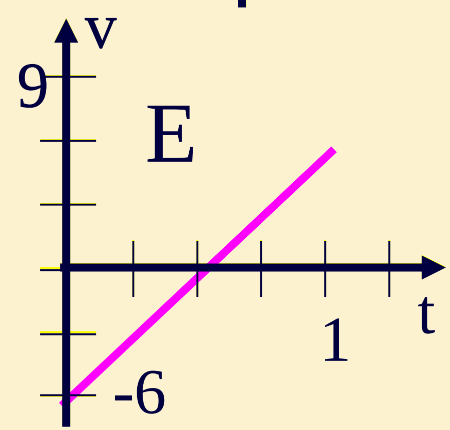
Draw v vs t







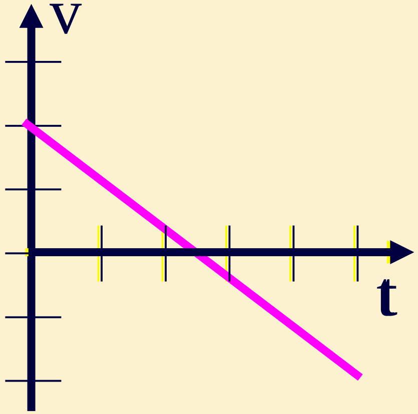




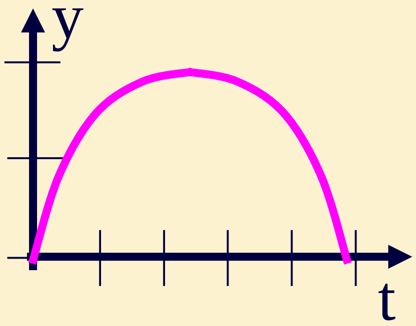
Tossed Ball, x, v, a relationships

A ball is tossed from the ground up a height of two meters above the ground. And falls back down

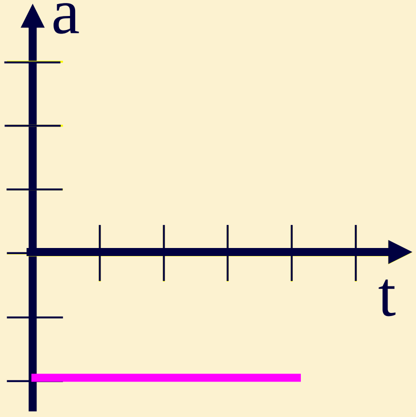
- Draw v vs t



- Draw y vs t



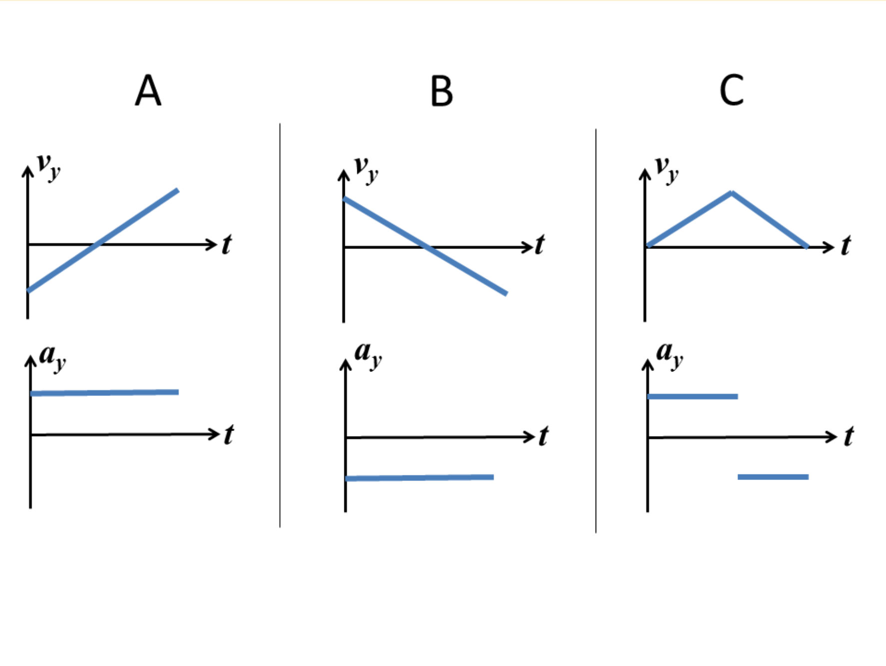
- Draw a vs t



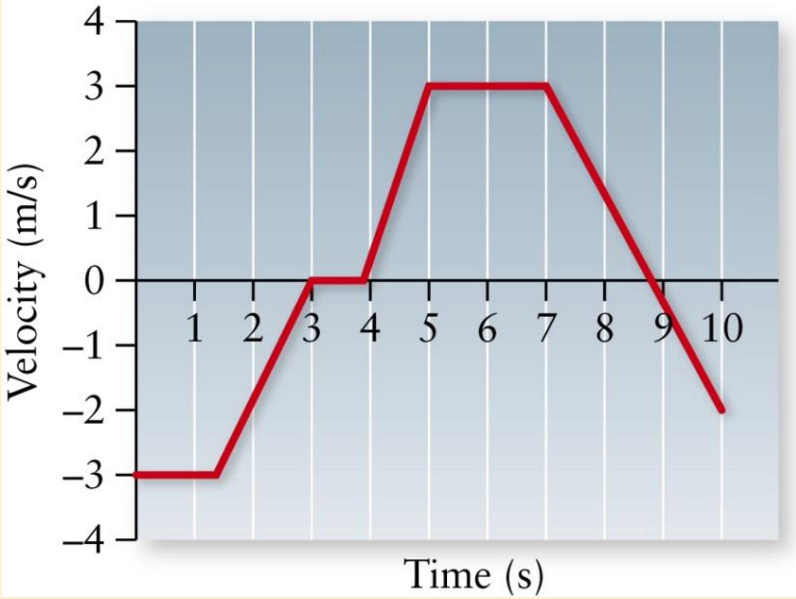
Checkpoint 1: Look familiar?

A fox locates its prey, usually a mouse, under the snow by slight sounds the rodents make. The fox then leaps straight into the air and burrows its nose into the snow to catch its next meal.

1) Which of the three pairs of graphs represent the free fall motion of the fox? Assume the +y direction is pointed upward.



Checkpoint 2



The figure graphs the x component of the velocity of a car traveling in a straight line. During what intervals of time is car slowing down?

1) Interval 1: From t = 0 s to about t = 1.3 s
2) Interval 2: From about t = 1.3 to t = 3 s
3) Interval 3: From t = 3 s to t = 4 s
4) Interval 4: From t = 4 s to t = 5 s
5) Interval 5: From t = 5 s to t = 7 s
6) Interval 6: From t = 7 s to about t = 8.7 s
7) Interval 7: From about t = 8.7 s to t = 10 s

A) Intervals 1, 3 and 5
B) Intervals 2, 4, 6 and 7
C) Intervals 2 and 4
D) Intervals 6 and 7
E) Intervals 2 and 6

Summary of Concepts

- Kinematic Quantities:
  - ➔ Position & Displacement
  - ➔ Velocity & Speed
  - ➔ Acceleration
- Free Fall
  - ➔ $y = y_0 + v_{0y} t - 1/2\, gt^2$
  - ➔ $v_y = v_{0y} - gt$
  - ➔ $v_y{}^2 = v_{0y}{}^2 - 2g(y - y_0)$