Purdue University Department of Physics

Physics 22000

General Physics

Lecture 2 – Motion in One Dimension

Fall 2016 Semester

Prof. Matthew Jones

A Few General Announcements

- You will need a *Modified* MasteringPhysics access code (ISBN 9780321918444).
- This has been modified so that it works with Blackboard.
- If you connect to the Pearson web site from the link provided on Blackboard, then it knows all about the course.
- We will start with a brief presentation showing how easy it is to get set up!

SUPPLEMENTAL INSTRUCTION

Free Study Sessions!

Rachel Hoagburg

Come to SI for more help in **PHYS 220**

Tuesday and Thursday	7:30-8:30PM Shreve C113

Office Hour

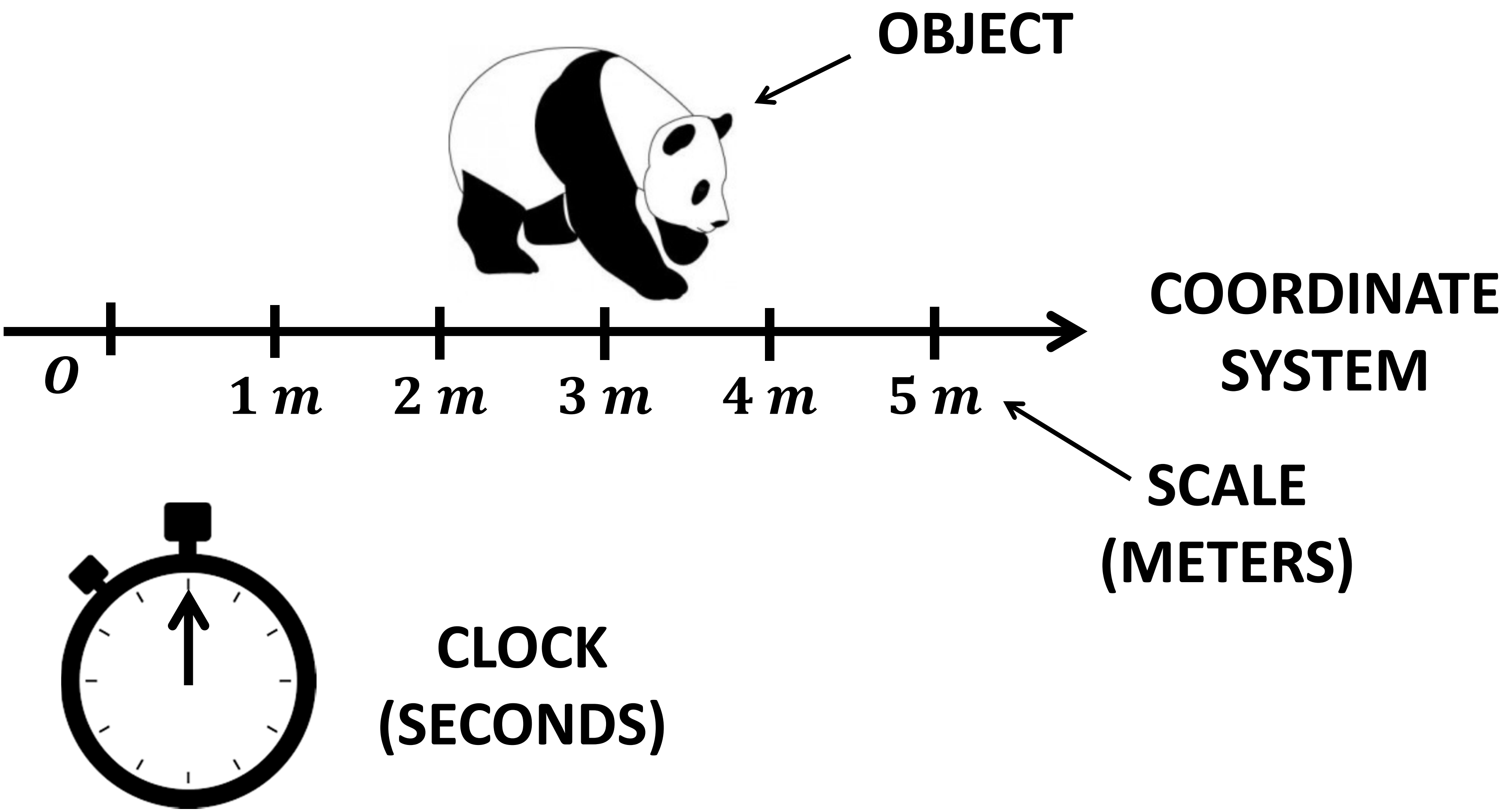
Tuesday 1:30-2:30 4th floor of Krach

For other SI-linked courses and schedules, visit purdue.edu/si or purdue.edu/boilerguide

Motion in One Dimension

- In order to describe motion of an object we need to specify both the object and a reference frame.
- The reference frame contains the observer as well as
  - A coordinate system, defining an axis along which we can make measurements
  - A scale, for measuring the position of the object
  - A clock for measuring time

Motion in One Dimension

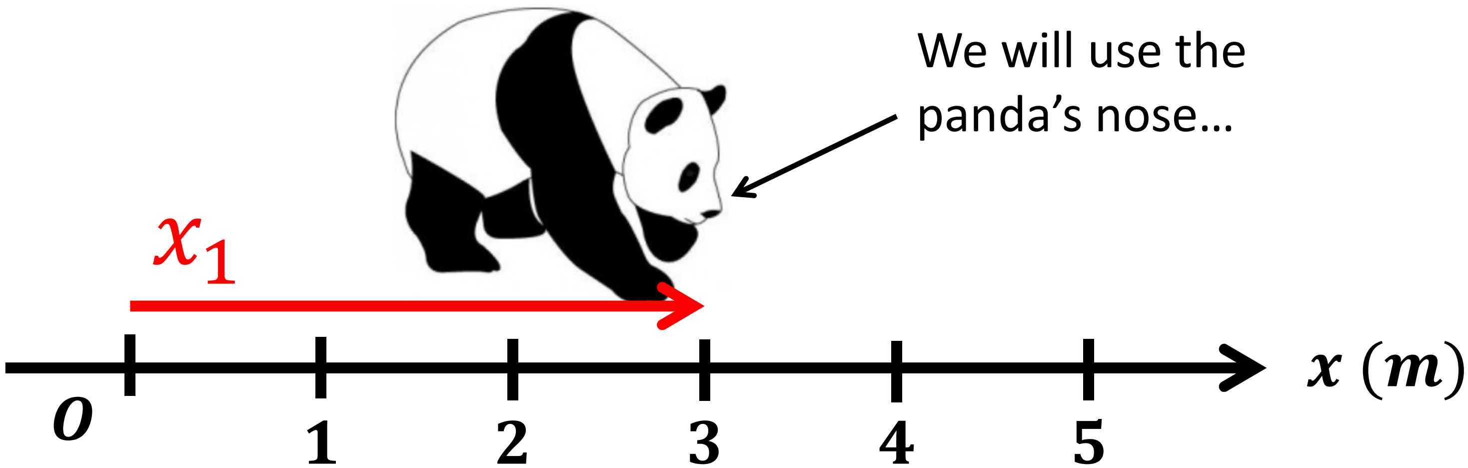


Position, displacement, etc…

- **Position** is an object's location with respect to a particular coordinate system.
- **Displacement** is a vector that starts from an object's initial position and ends at its final position.
- **Distance** is the magnitude (length) of the displacement vector.
- **Path length** is how far the object moved as it traveled from its initial position to its final position.
  - Imagine laying a string along the path the object took. The length of the string is the path length.

Position

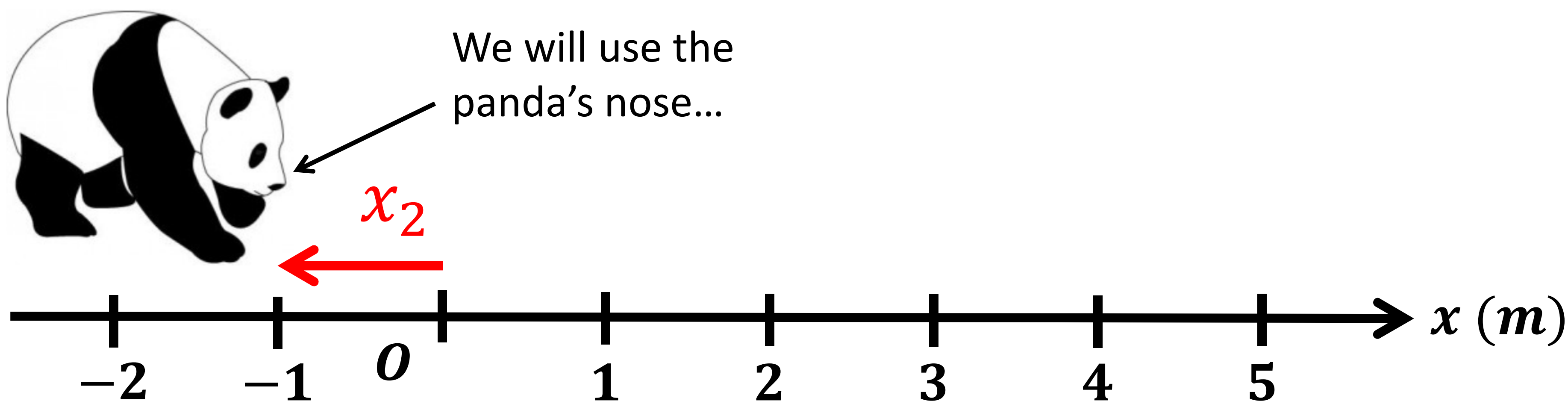
- We need to pick a point on the object
  - The position measured from the origin of the coordinate system to this point.



The panda's position is $x_1 = +3\ m$.

Position

- Position can be positive or negative.

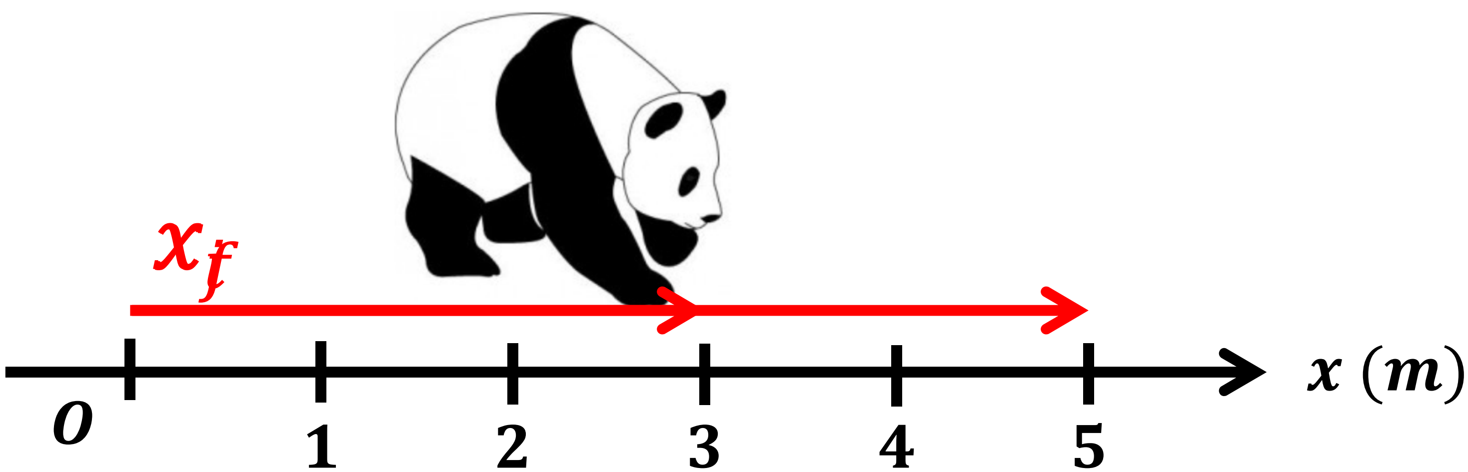


The panda's position is $x_2 = -1\ m$.

Displacement

- Displacement is the change in position:

$$d_x = x_f - x_i$$

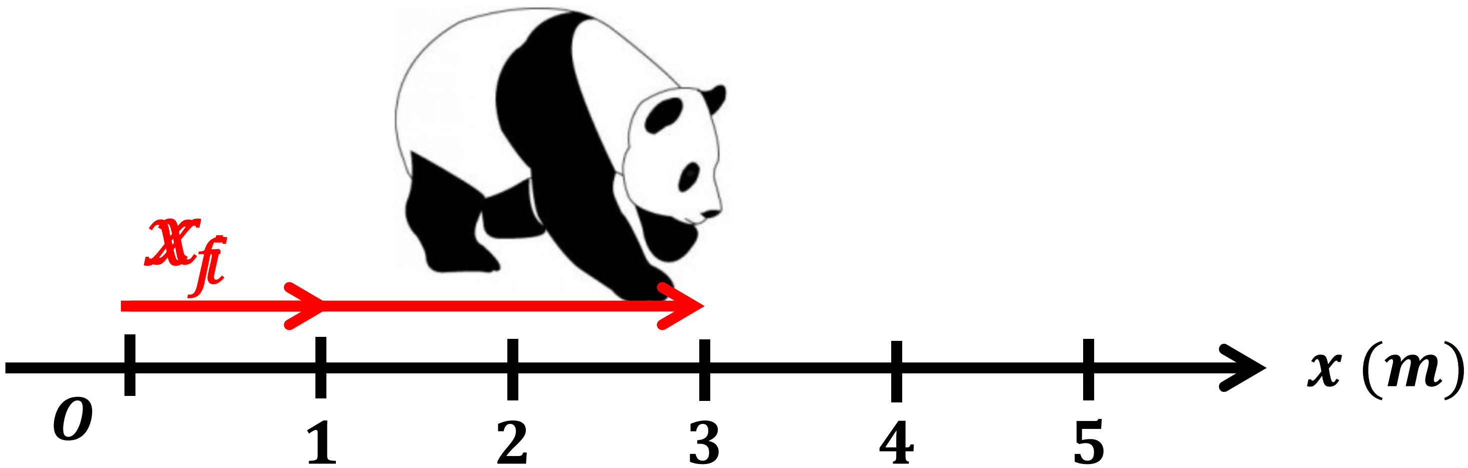


The panda's initial position is $x_i = +3\ m$.
The panda's final position is $x_f = +5\ m$.
The panda's final displacement is $d_x = +2\ m$.

Displacement

- Displacement can be positive or negative

$$d_x = x_f - x_i$$



The panda’s initial position is $x_i = +3\ m$.

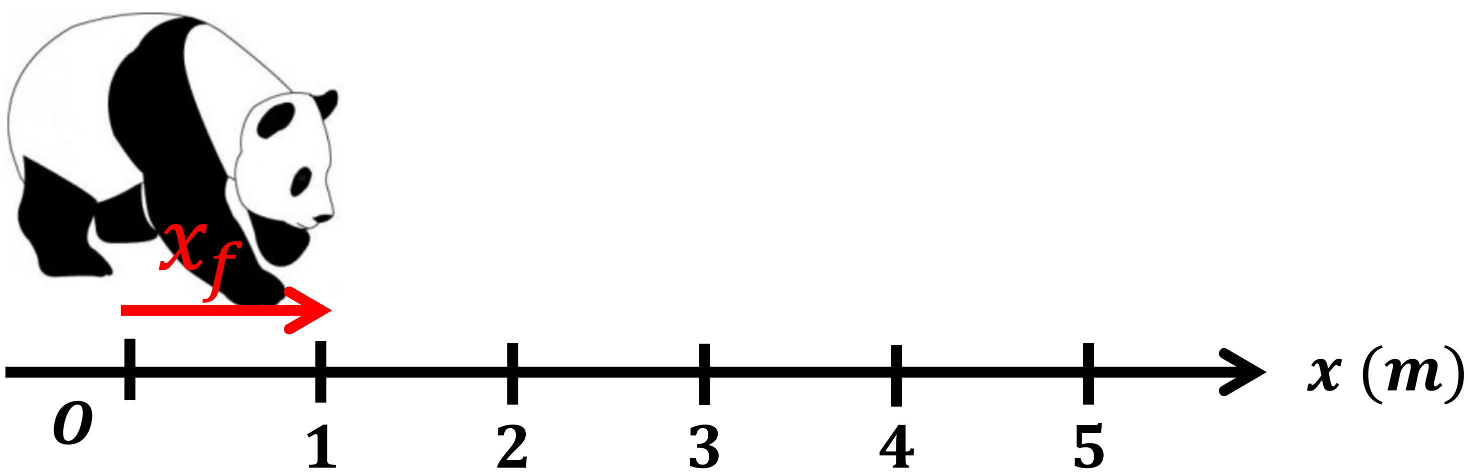
The panda’s final position is $x_f = +1\ m$.

The panda’s final displacement is $d_x = -2\ m$.

Distance

- Distance is the magnitude of the displacement

$$d = |x_f - x_i| \text{ (always positive)}$$



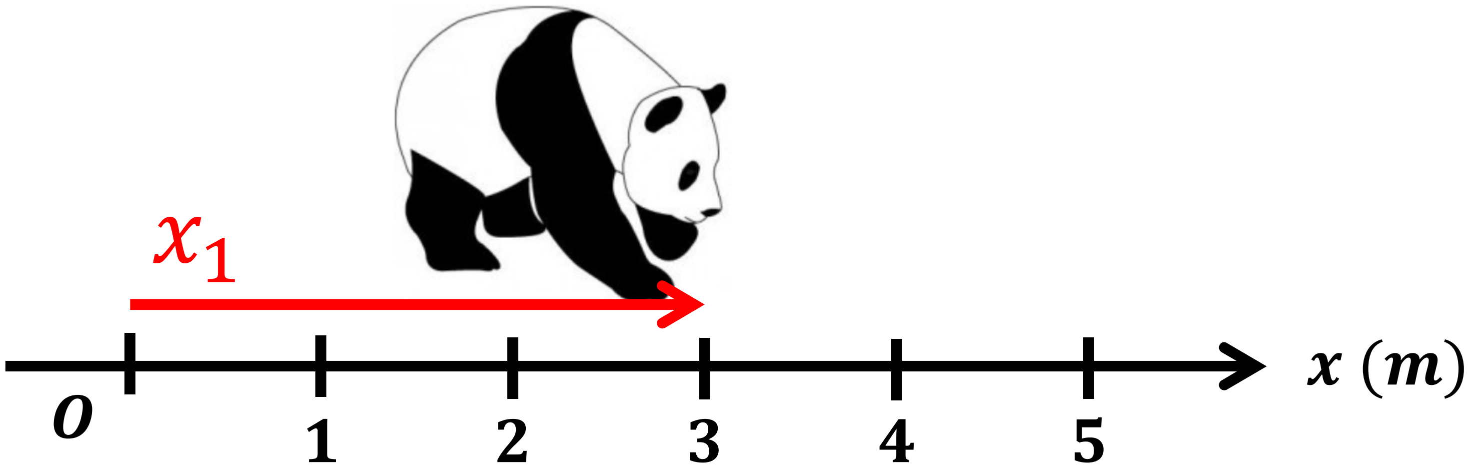
The panda's initial position is $x_i = +3\ m$.

The panda's final position is $x_f = +1\ m$.

The panda moved a <u>distance</u> of 2 m.

Path Length

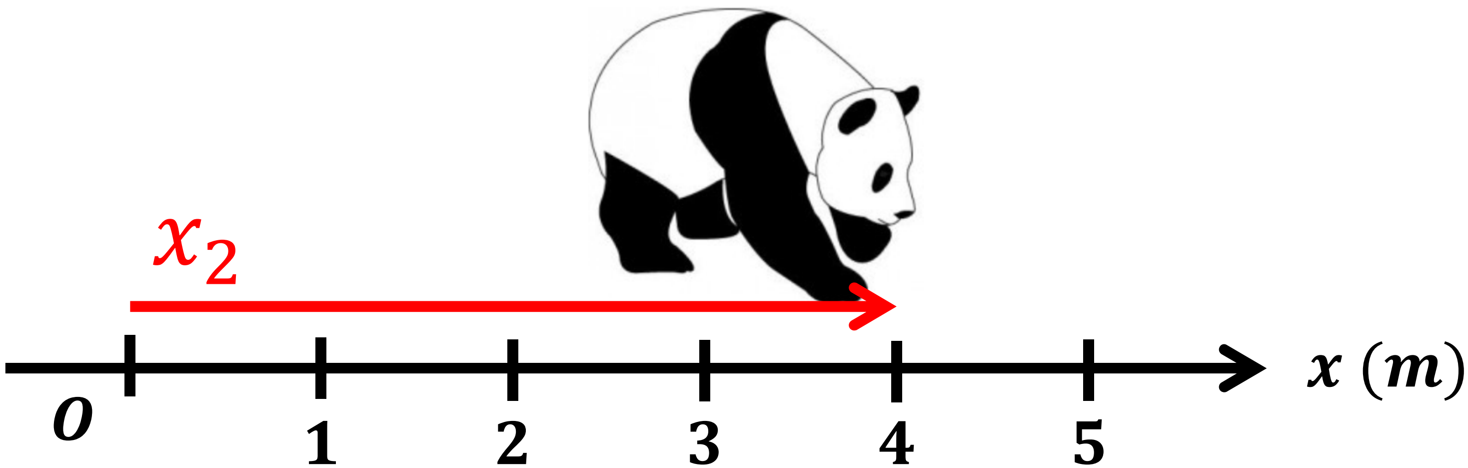
- The total distance traveled (always positive).



$$x_1 = +3\ m.$$

Path Length

- The total distance traveled (always positive).

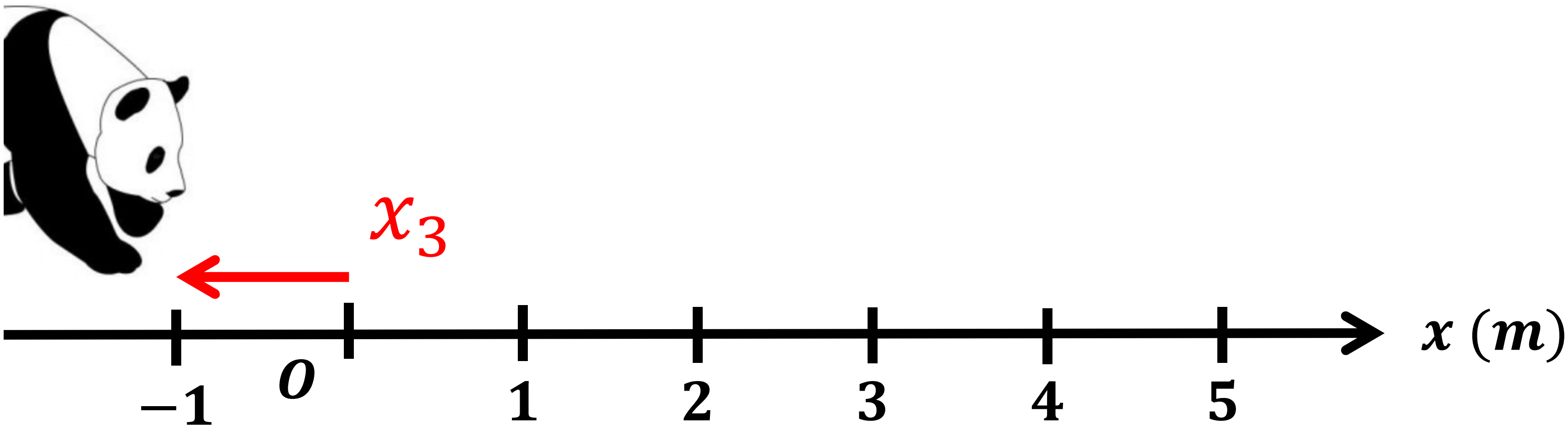


$$x_1 = +3\,m$$

$$x_2 = +4\,m \qquad d_{12} = x_2 - x_1 = 1\,m$$

Path Length

- The total distance traveled (always positive).



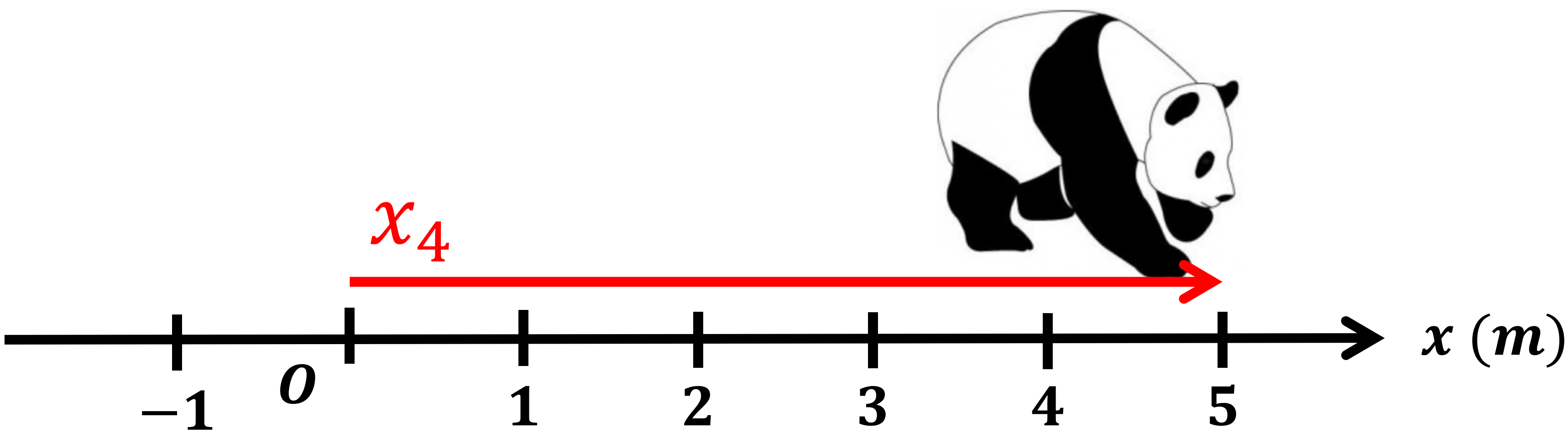
$$x_1 = +3\ m$$

$$x_2 = +4\ m \qquad d_{12} = x_2 - x_1 = 1\ m$$

$$x_3 = -1\ m \qquad d_{23} = x_3 - x_2 = (-1m) - (4\ m) = -5\ m$$

Path Length

- The total distance traveled (always positive).



$$x_1 = +3\ m$$

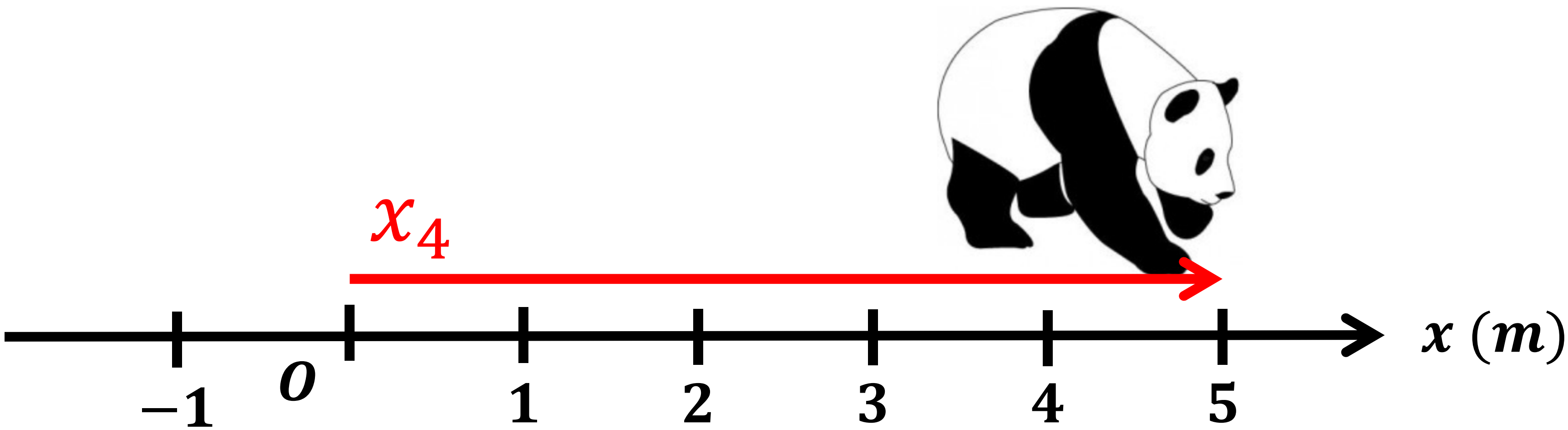
$$x_2 = +4\ m \qquad d_{12} = x_2 - x_1 = 1\ m$$

$$x_3 = -1\ m \qquad d_{23} = x_3 - x_2 = (-1m) - (4\ m) = -5\ m$$

$$x_4 = +5\ m \qquad d_{34} = x_4 - x_3 = (5\ m) - (-1\ m) = 6\ m$$

Path Length

- The total distance traveled (always positive).



$$x_1 = +3\ m$$

$$x_2 = +4\ m \qquad d_{12} = x_2 - x_1 = 1\ m$$

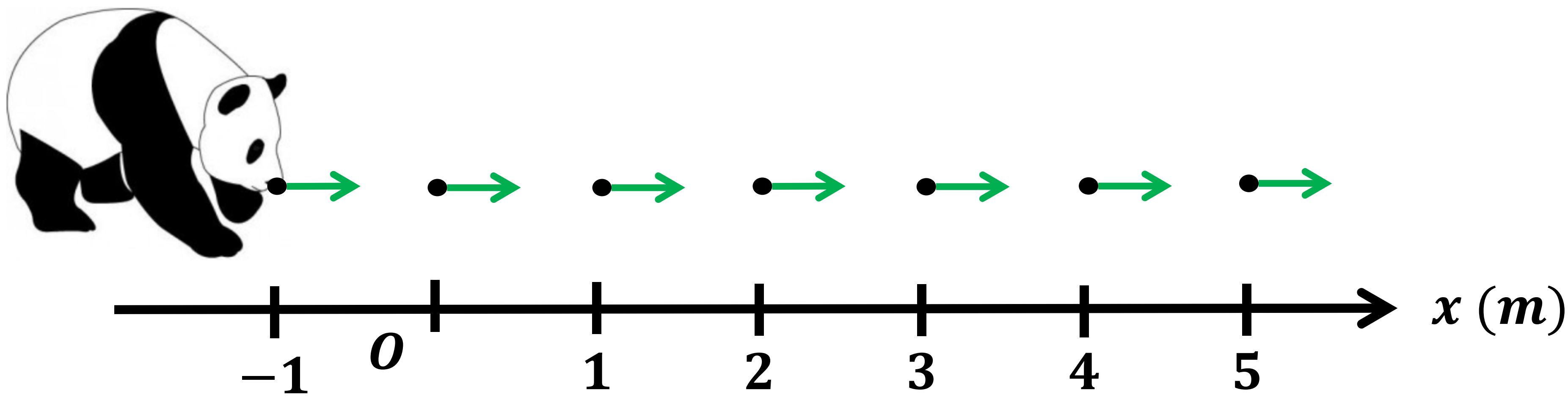
$$x_3 = -1\ m \qquad d_{23} = x_3 - x_2 = (-1m) - (4\ m) = -5\ m$$

$$x_4 = +5\ m \qquad d_{34} = x_4 - x_3 = (5\ m) - (-1\ m) = 6\ m$$

Total path length: $\boldsymbol{l_{14} = (1m) + (5m) + (6m) = 12\ m}$

Motion Diagrams

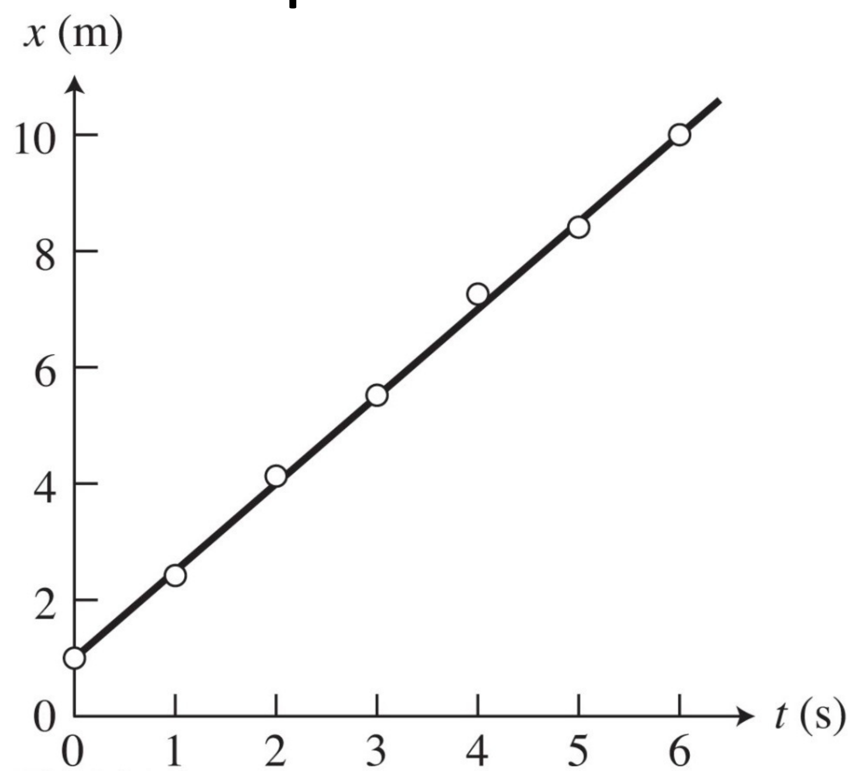
- Draw points at equally spaced time intervals.



- In this case, the speed is constant so the points are equally spaced along the x-axis.
- The velocity vectors are all the same length.

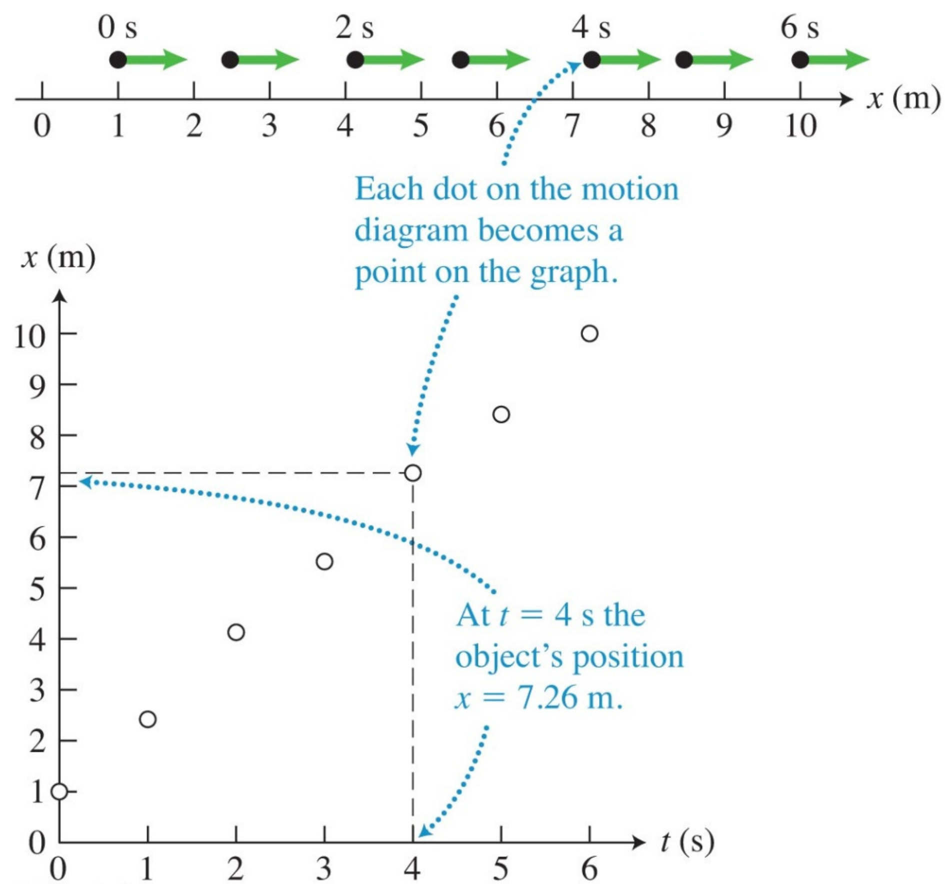
Kinematic Graphs

- Time, t, is usually the independent variable (horizontal axis)
- The position, x, is the dependent variable (vertical axis – it depends on the time, t)



Kinematic Graphs

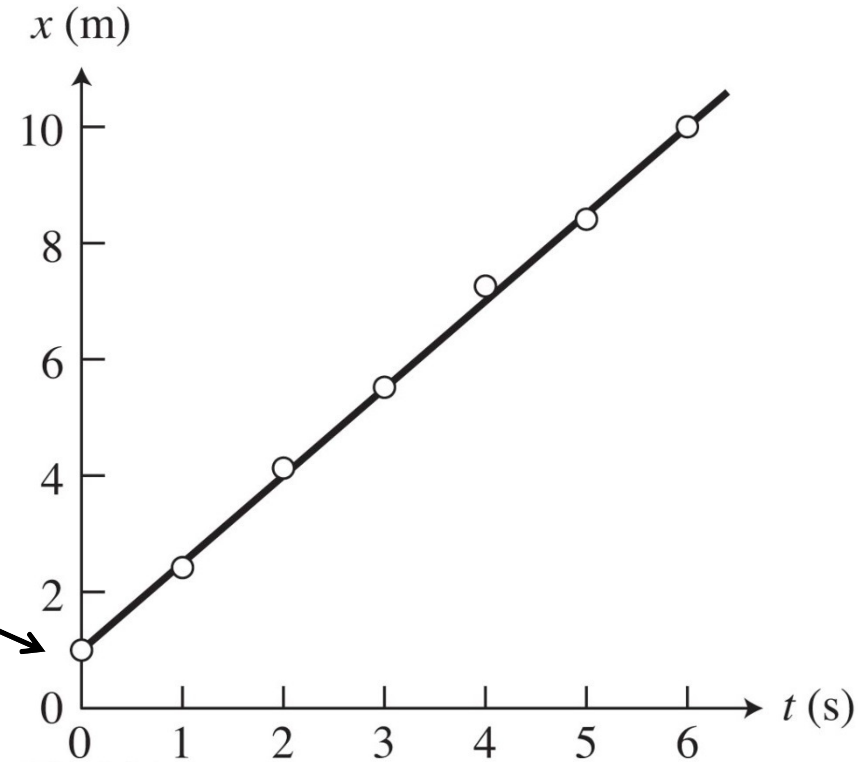
- Kinematics graphs can contain more precise information than motion diagrams.
- The position of each dot on the motion diagram corresponds to a point on the position axis.
- The graph line combines information about the position of an object and the clock reading when this position occurred.



Linear Motion

- A straight line graph can be described by the equation: $x(t) = kt + b$

b is the y-intercept
(value of y when t=0)



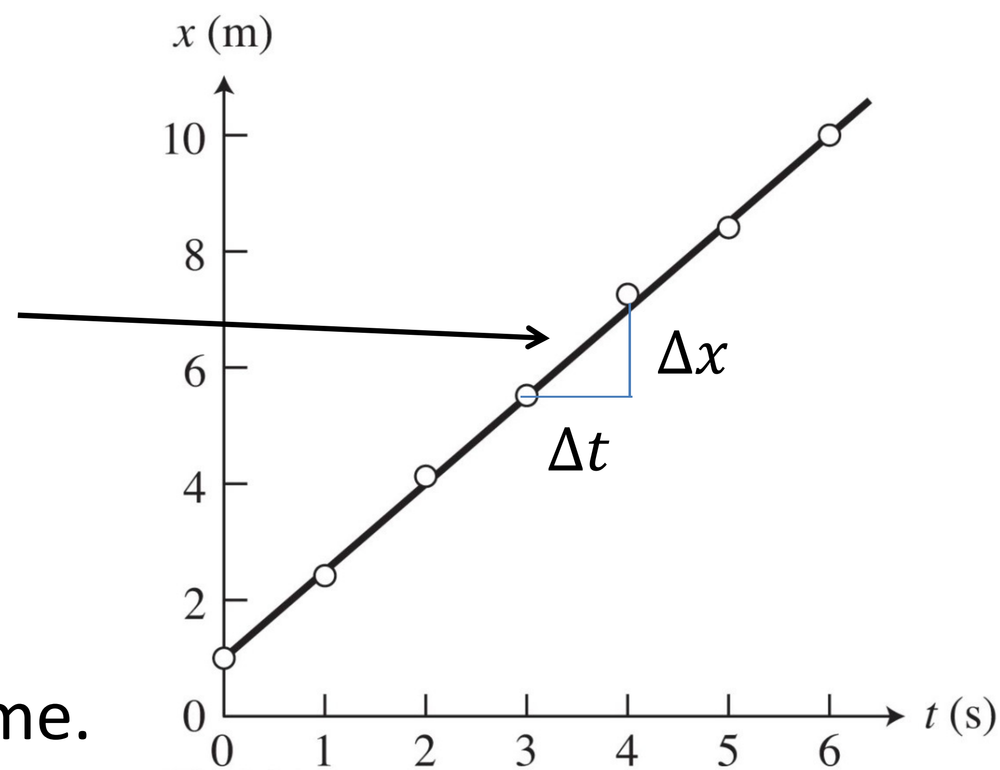
Linear Motion

- A straight line graph can be described by the equation: $x(t) = kt + b$

The slope is,

$$k = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

The slope has units m/s and indicates how the position changes with time.



Velocity and Speed

- We *define* **velocity** to be the *slope* of the position vs time graph.

$$v_x = \frac{x_2 - x_1}{t_2 - t_1} = \frac{\Delta x}{\Delta t}$$

- If the slope is positive, the object moves in the +x direction
- If the slope is negative, the object moves in the –x direction.
- Velocity has both magnitude and direction.
- The magnitude of the slope (which is always positive) is the **speed** of the object.

Constant Velocity Linear Motion

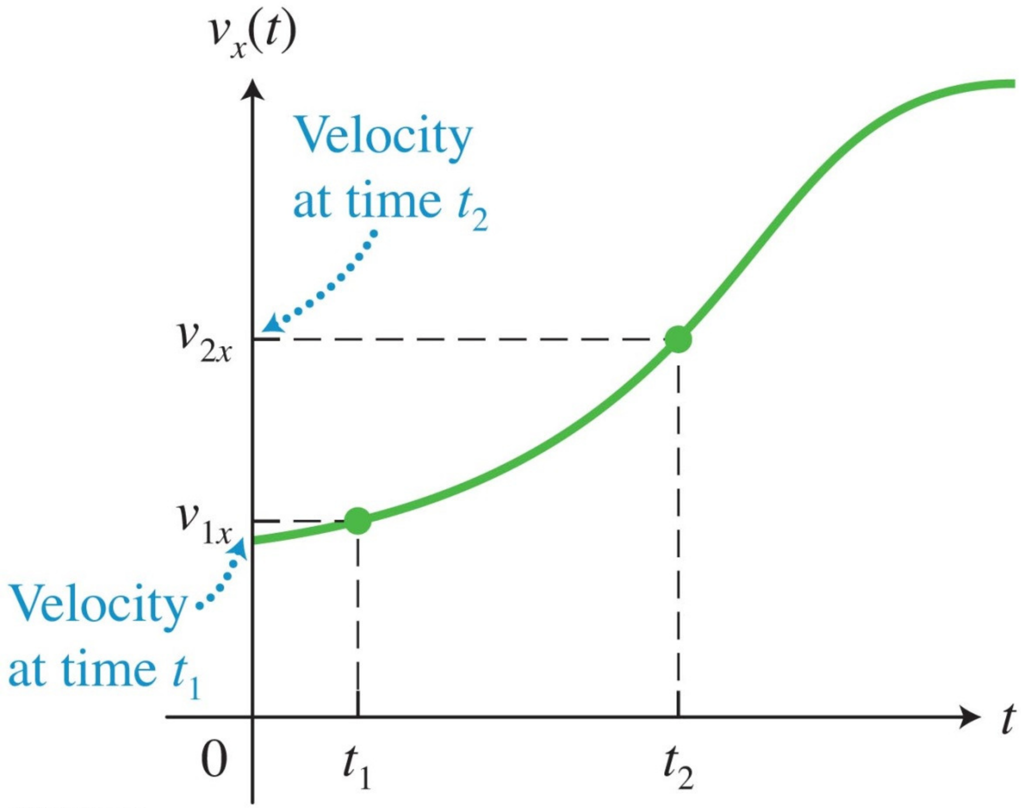
- Position equation for constant velocity linear motion:

$$x(t) = x_0 + v_x t$$

- $x(t)$ means that the position, x, is a function of the time, t.
- The initial position at $t = 0$ is x_0.
- The velocity, v_x, is the slope of the position *vs* time graph.

Graphs of Velocity

- We can also draw graphs of the velocity as a function of time:



The velocity is always positive.

The velocity is increasing with time.

A horizontal line on the v vs t graph means the velocity is constant.

Displacement from a Velocity Graph

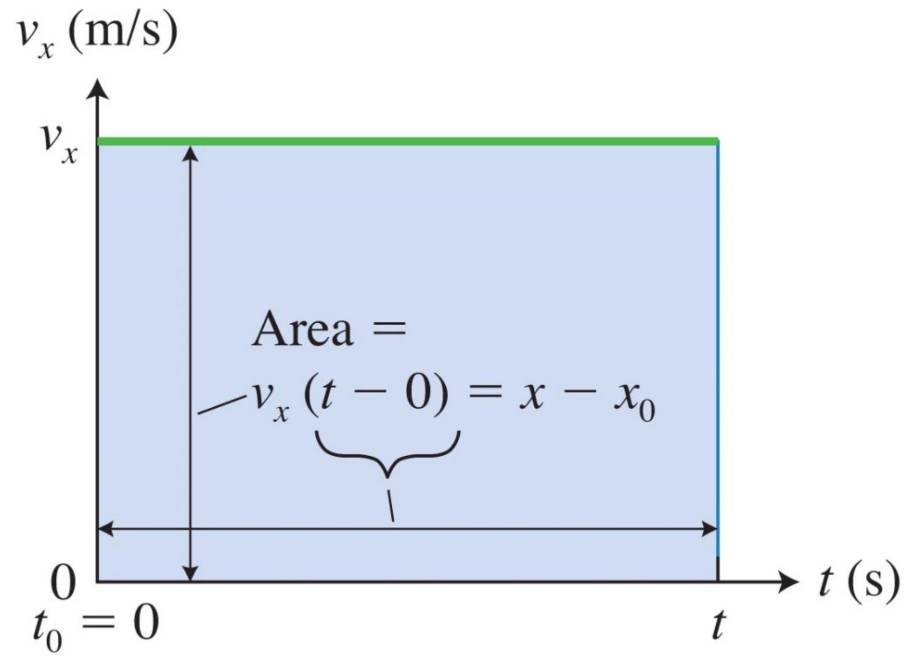
Displacement $x - x_0$ between $t_0 = 0$ and time t is the **area** between the v_x vs t curve and the t axis.

Area is width times height

$$v_x(t - t_0)$$

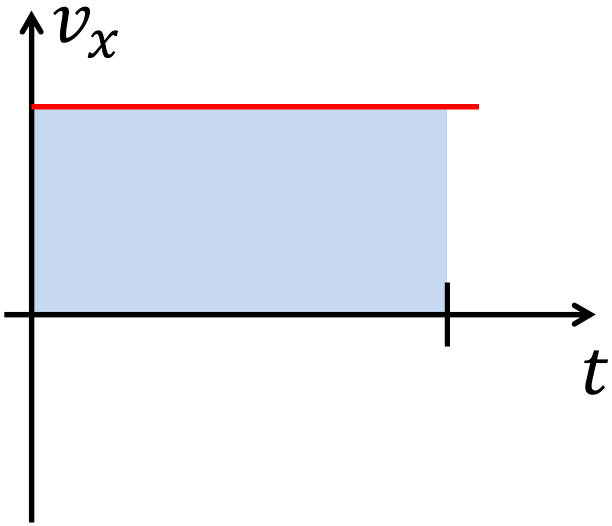
Since $v_x = \frac{x - x_0}{t - t_0}$,

$$(x - x_0) = v_x(t - t_0)$$

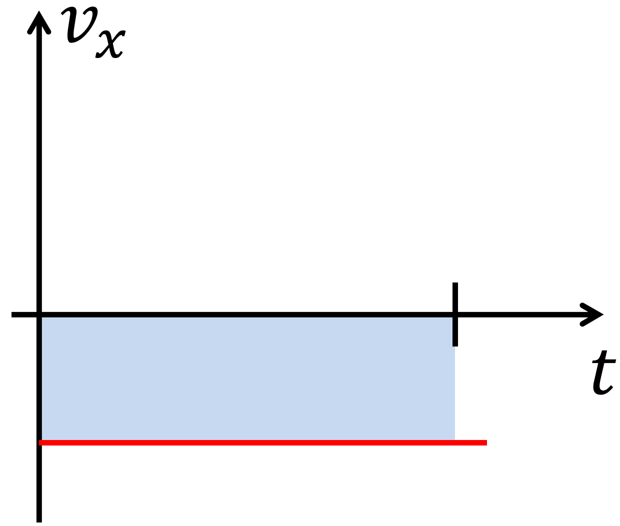


An object's displacement $x - x_0$ between $t_0 = 0$ and time t is the area between the v_x-versus-t curve and the t axis.

Displacement from a Velocity Graph



Velocity is always positive so the displacement is positive



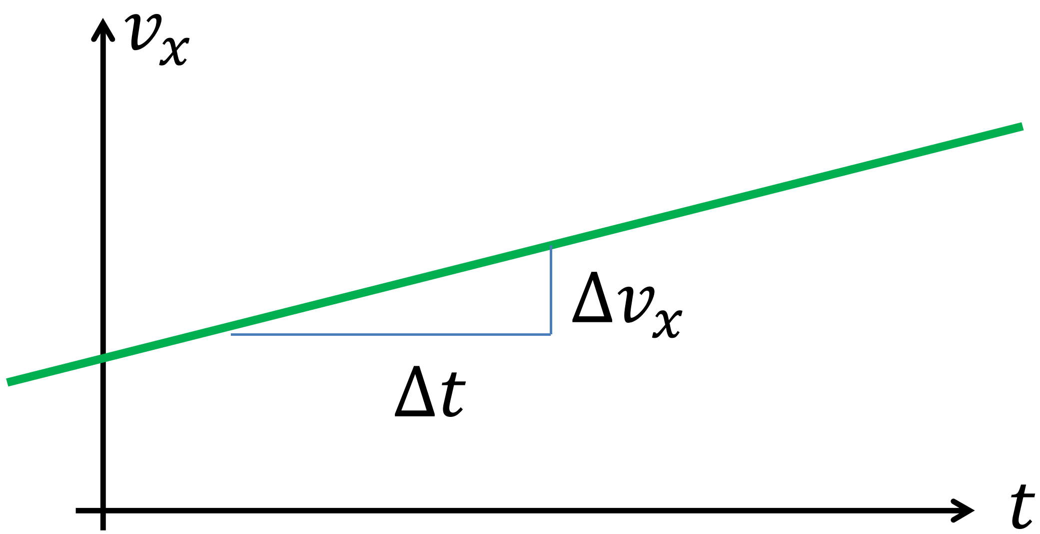
Velocity is always negative so the displacement is negative

When Velocity is Not Constant

- On a velocity vs time graph, the velocity will be a horizontal, straight line only when it is constant.
- The ***instantaneous velocity*** is the velocity of an object at a particular time.
- The ***average velocity*** is the ratio of the change in position and the time interval over which the change occurred.
- For motion with a constant velocity, these are the same. If the velocity is changing, they are not.

Acceleration

- The simplest type of linear motion with a changing velocity occurs when the velocity changes at a constant rate
- It increases or decreases by the same amount, Δv_x, in each equal time interval, Δt.



The velocity is in the positive direction and increases with a constant rate.

Finding Acceleration from a v vs t Graph

- Acceleration is the slope of the velocity vs time graph:

$$a_x = \frac{v_{2x} - v_{1x}}{t_2 - t_1} = \frac{\Delta v_x}{\Delta t}$$

- A larger slope means that the velocity is increasing at a faster rate.
- Velocity has *magnitude* and *direction*… therefore, acceleration has *both magnitude and direction* (it's a vector).
- The ***average acceleration*** of an object during a time interval Δt is

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1} = \frac{\Delta \vec{v}}{\Delta t}$$

When is Acceleration Negative

- Acceleration can be positive or negative
- If an object is moving in the +x direction, and it is slowing down, then the slope of the $v\ vs\ t$ graph is negative.
- **An object can have negative acceleration and still speed up!**
  - Consider an object moving in the –x direction. Its velocity is *always negative*, but is increasing in magnitude.

Determining the Change in Velocity from the Acceleration

- The slope of the velocity vs time graph is

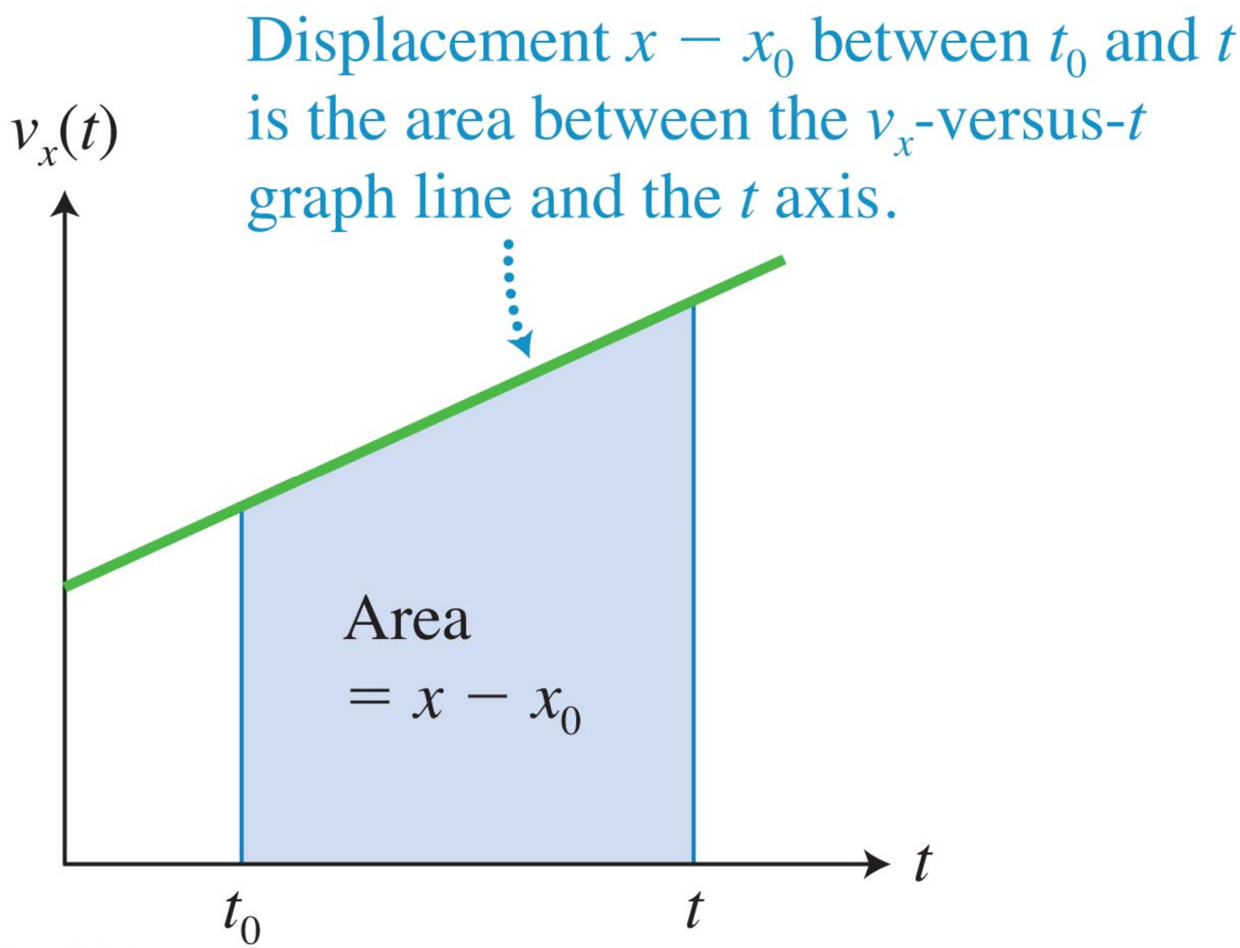
$$a_x = \frac{v_x - v_{0x}}{t - t_0}$$

- For simplicity, suppose the clock starts at $t_0 = 0$.
- Then,

$$\boldsymbol{v_x(t) = v_{0x} + a_x t}$$

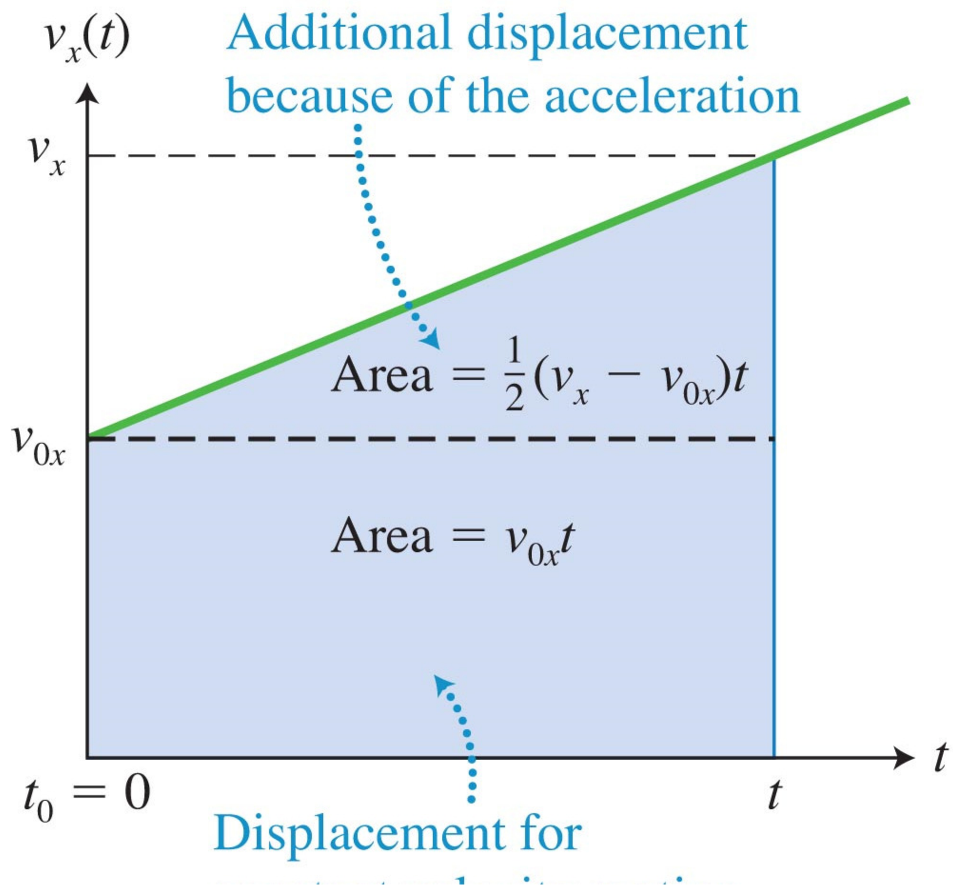
- This says that v_x is a function of time, t, and has the initial value v_{0x}.

Displacement from a Velocity vs Time Graph



Position as a Function of Time

- The equation for displacement can be found from the area under the velocity vs time graph:



Position of an Object During Linear Motion with Constant Acceleration

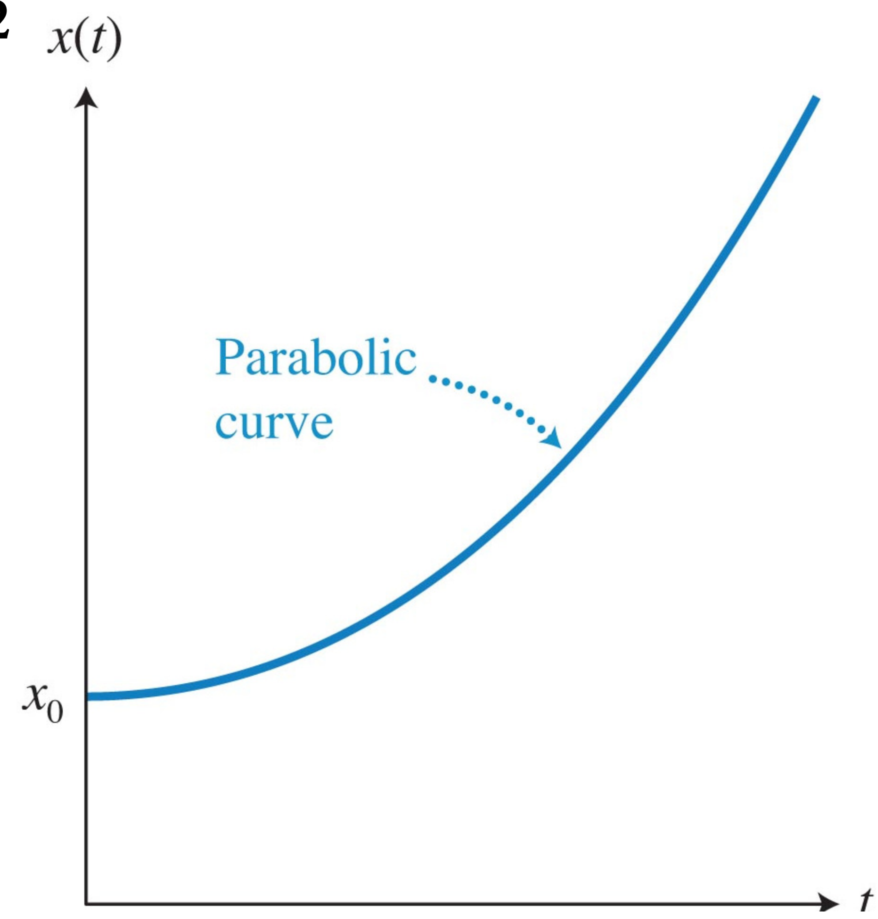
- The initial position, at time $t = 0$, is x_0.
- The initial velocity, at time $t = 0$, is v_{0x}.
- The acceleration, a_x, remains constant for all t.
- The position, as a function of time, is

$$x(t) = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$

Graph of Position vs Time for Constant Acceleration

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2$$

- Position is quadratic in time (there is a t^2 term), so the graph is parabolic.
- The slopes of the tangent lines (indicating the instantaneous velocity) are different for different times.



Three Equations of Motion

- Two equations so far:

$$\boldsymbol{x(t) = x_0 + v_{0x}t + \frac{1}{2}a_x t^2}$$

$$\boldsymbol{v_x(t) = v_{0x} + a_x t}$$

  – Solve for t using the second equation

  – Substitute this expression for t into the first equation.

- Alternate equation for linear motion with constant acceleration:

$$\boldsymbol{2\, a_x(x - x_0) = v_x^2 - v_{0x}^2}$$

- Remember that $\boldsymbol{x}$ and $\boldsymbol{v_x}$ are functions of time, t.