Kinematics

The branch of mechanics that studies the motion of a body without caring about what caused the motion.

Some Physics Quantities

Vector - quantity with both magnitude (size) & direction

Scalar - quantity with magnitude only

Vectors:

- Displacement
- Velocity
- Acceleration
- Momentum
- Force

Scalars:

- Distance
- Speed
- Time
- Mass
- Energy

Mass vs. Weight

Mass

- Scalar (no direction)
- Measures the amount of matter in an object

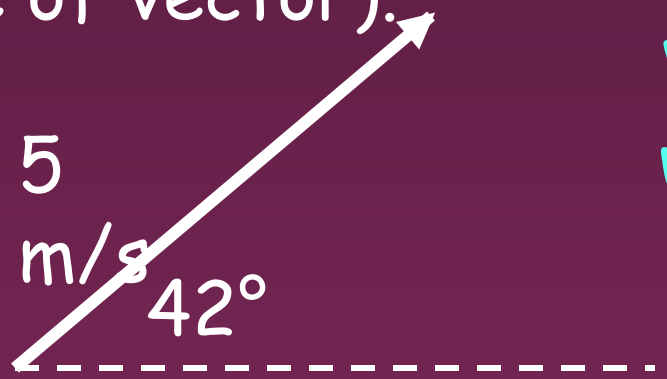
Weight

- Vector (points toward center of Earth)
- Force of gravity on an object

On the moon, your mass would be the same, but the magnitude of your weight would be less.

Vectors

- The length of the arrow represents the magnitude (how far, how fast, how strong, etc, depending on the type of vector).



- The arrow points in the directions of the force, motion, displacement, etc. It is often specified by an angle.

Vectors are represented with arrows

Units

Units are not the same as quantities!

Quantity . . . Unit (symbol)

- Displacement & Distance . . . meter (m)
- Time . . . second (s)
- Velocity & Speed . . . (m/s)
- Acceleration . . . (m/s^2)
- Mass . . . kilogram (kg)
- Momentum . . . ($kg \cdot m/s$)
- Force . . .Newton (N)
- Energy . . . Joule (J)

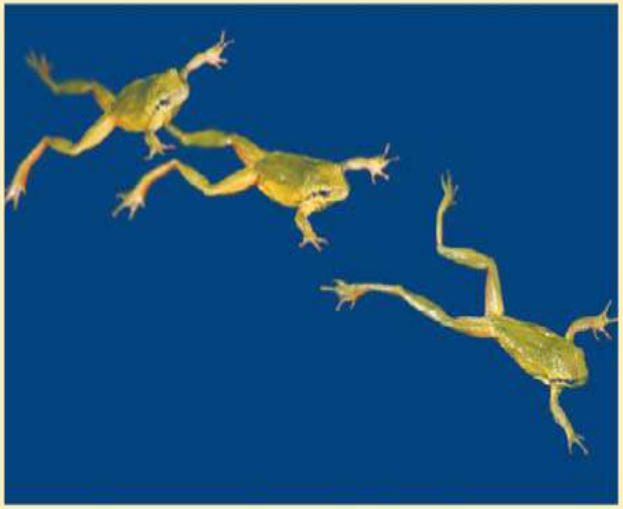
Kinematics definitions

- Kinematics – branch of physics; study of motion
- Position (x) – where you are located
- Distance (d) – how far you have traveled, regardless of direction
- Displacement (Δx) – where you are in relation to where you started

REPRESENTING MOTION

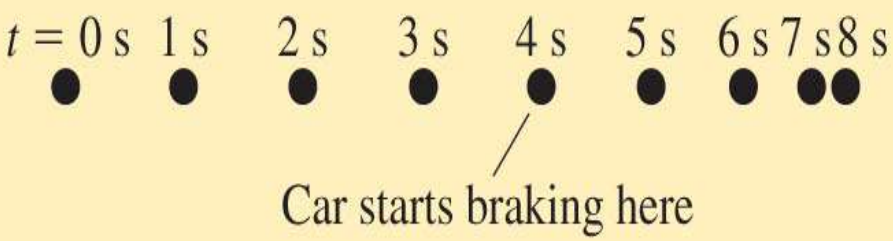
Describing Motion

Pictures like the one at right give us valuable clues about motion.



This picture shows successive images of a frog jumping. The images of the frog are getting farther apart, so the frog must be speeding up.

You will learn to make much simpler pictures to describe the key features of motion.

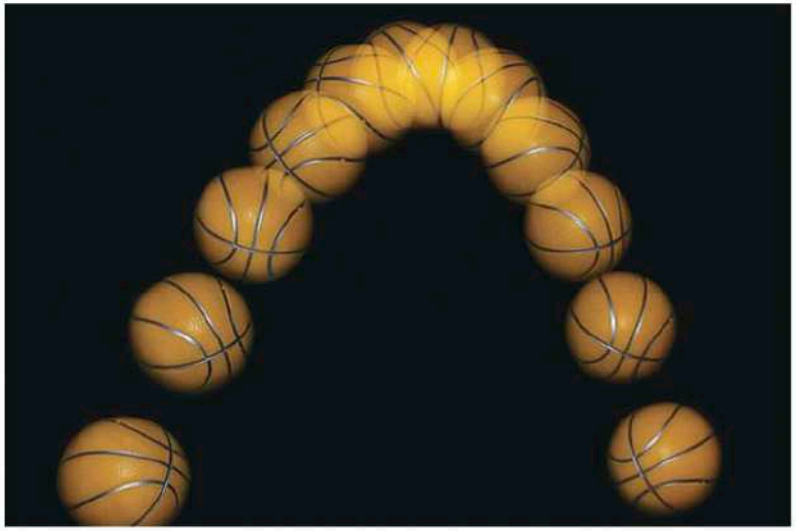


This diagram tells us everything we need to know about the motion of a car.

Four Types of Motion We'll Study

Straight-line motion

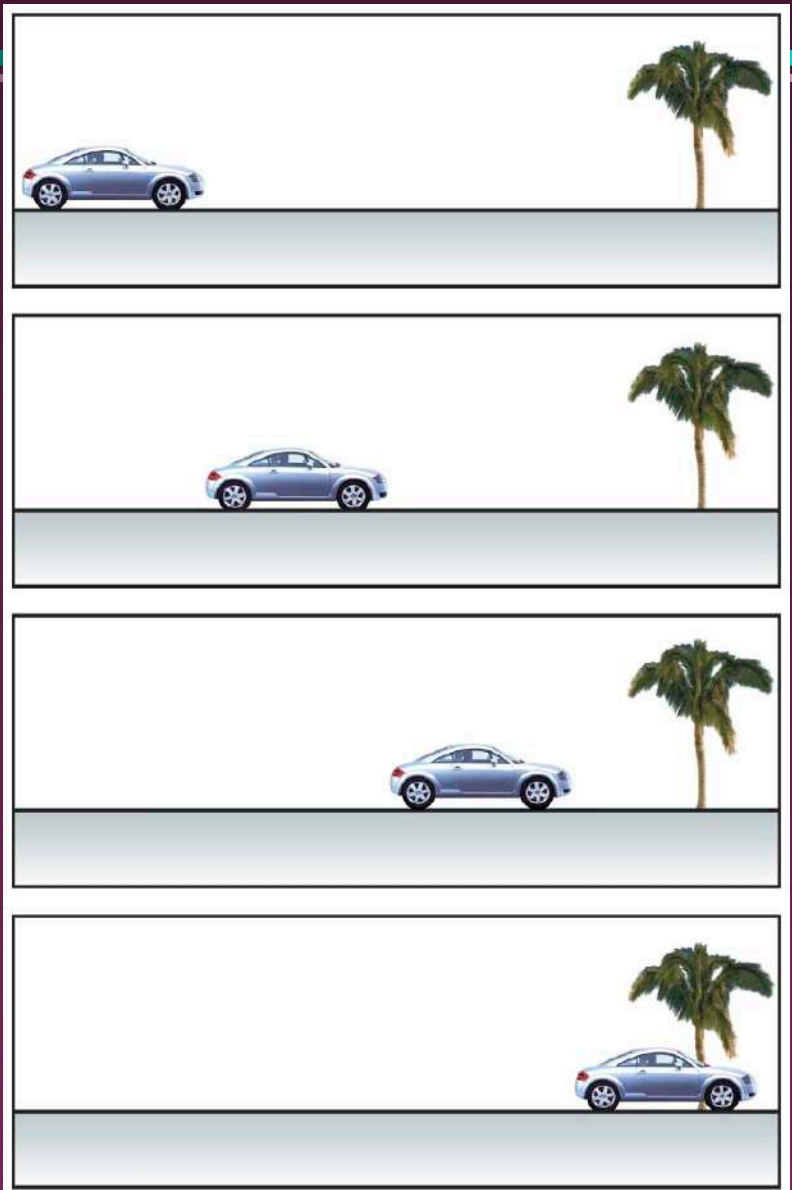
Circular motion

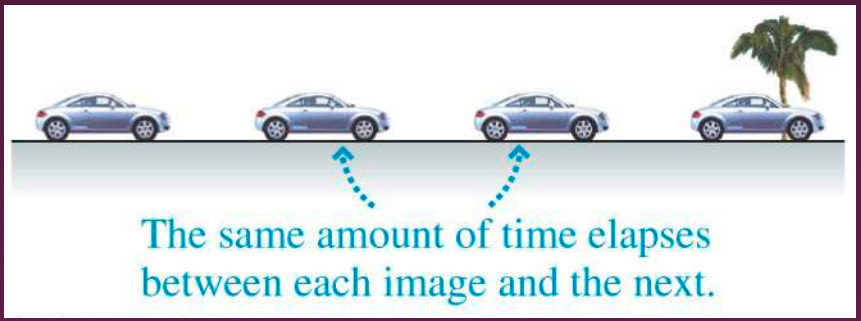


Projectile motion

Rotational motion

Making a Motion Diagram



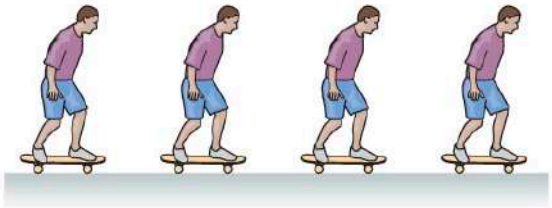


Examples of Motion Diagrams

Examples of motion diagrams

An object that occupies only a *single position* in a motion diagram is *at rest.*

A stationary ball on the ground.



Images that are *equally spaced* indicate an object moving with *constant speed.*

A skateboarder rolling down the sidewalk.

An *increasing distance* between the images shows that the object is *speeding up.*

A sprinter starting the 100-meter dash.

A *decreasing distance* between the images shows that the object is *slowing down.*

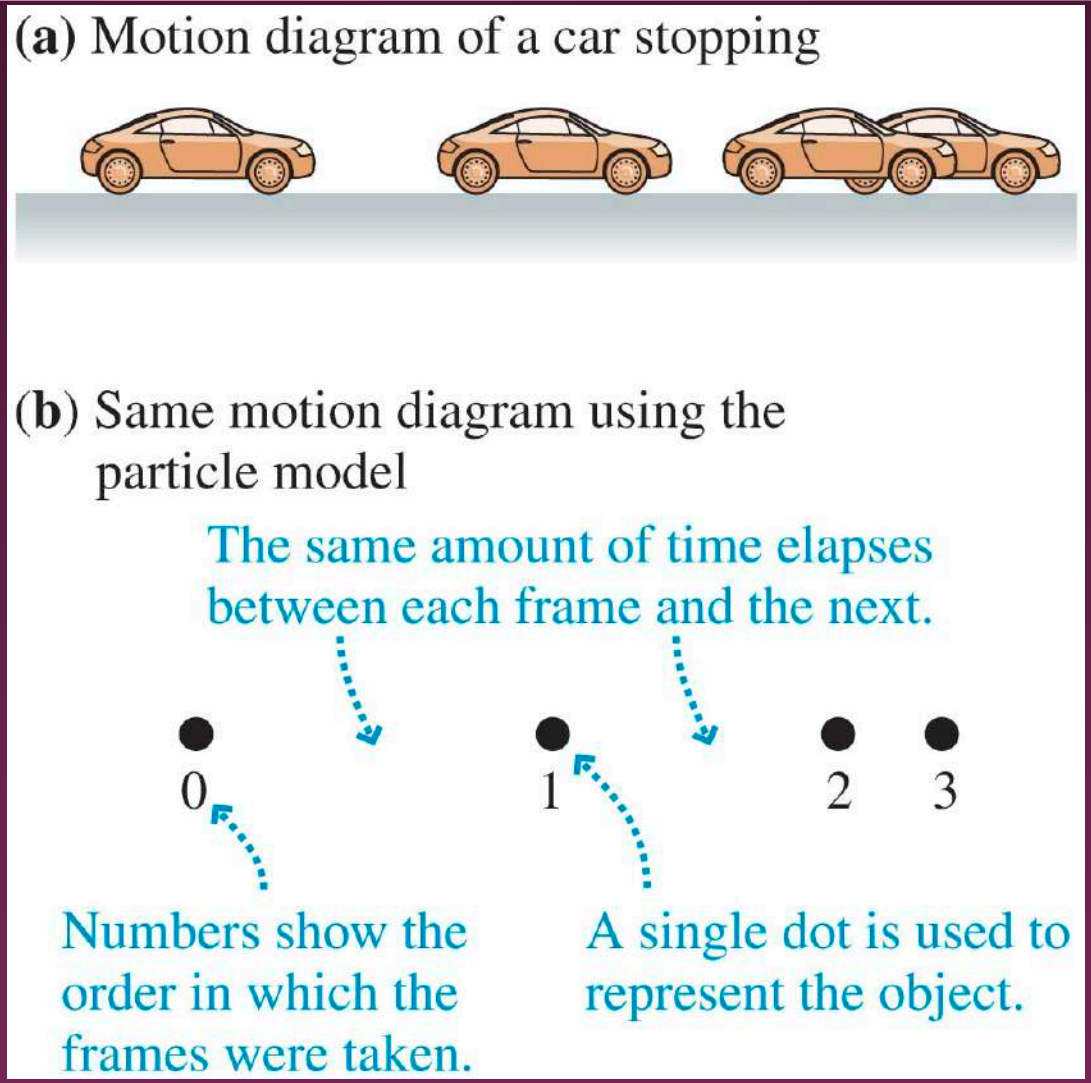
A car stopping for a red light.

A more complex motion diagram shows changes in speed and direction.

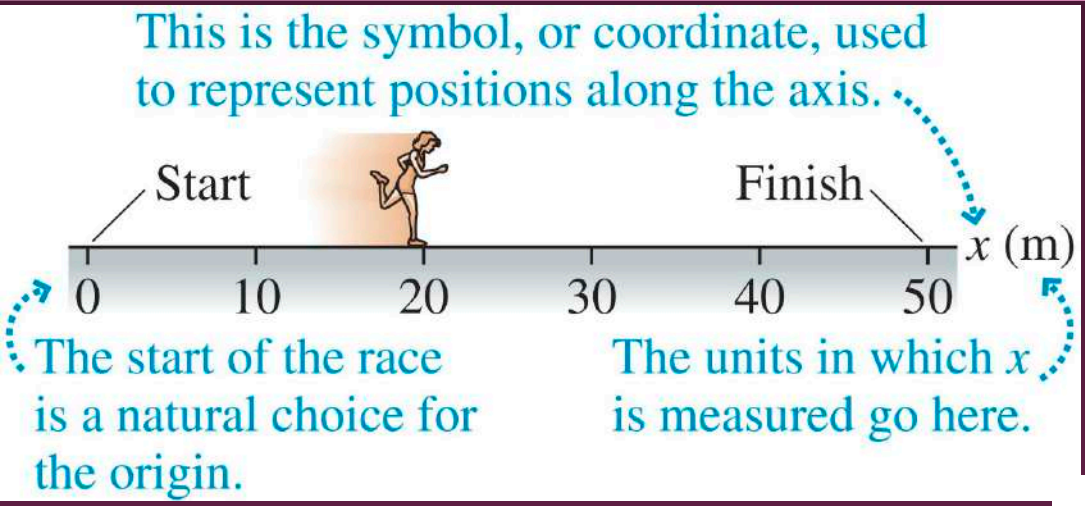
A basketball free throw.

The Particle Model

A simplifying *model* in which we treat the object as if all its mass were concentrated at a single point. This model helps us concentrate on the *overall* motion of the object.

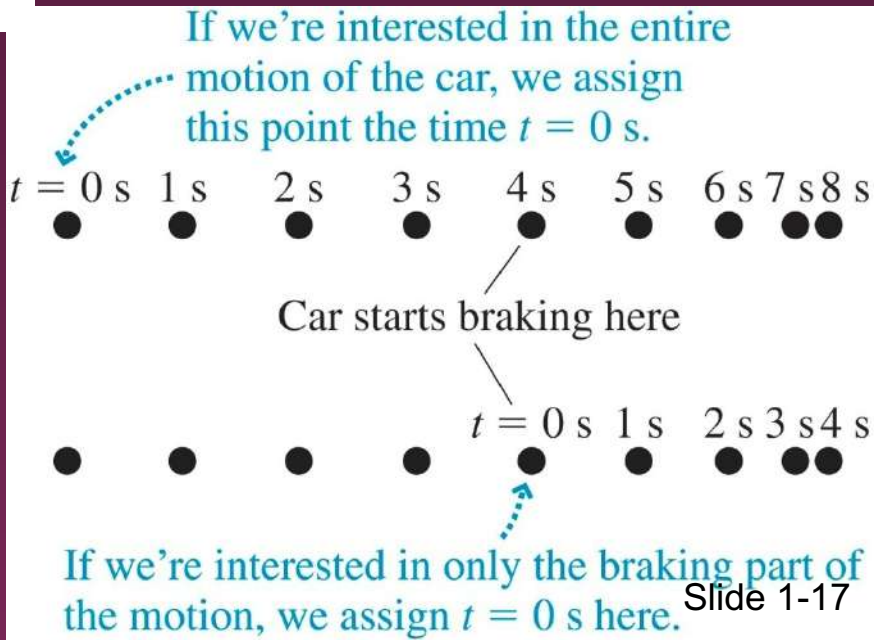


Position and Time



The position of an object is located along a *coordinate system.*

At each time *t*, the object is at some particular position. We are free to choose the origin of time (i.e., when *t* = 0).



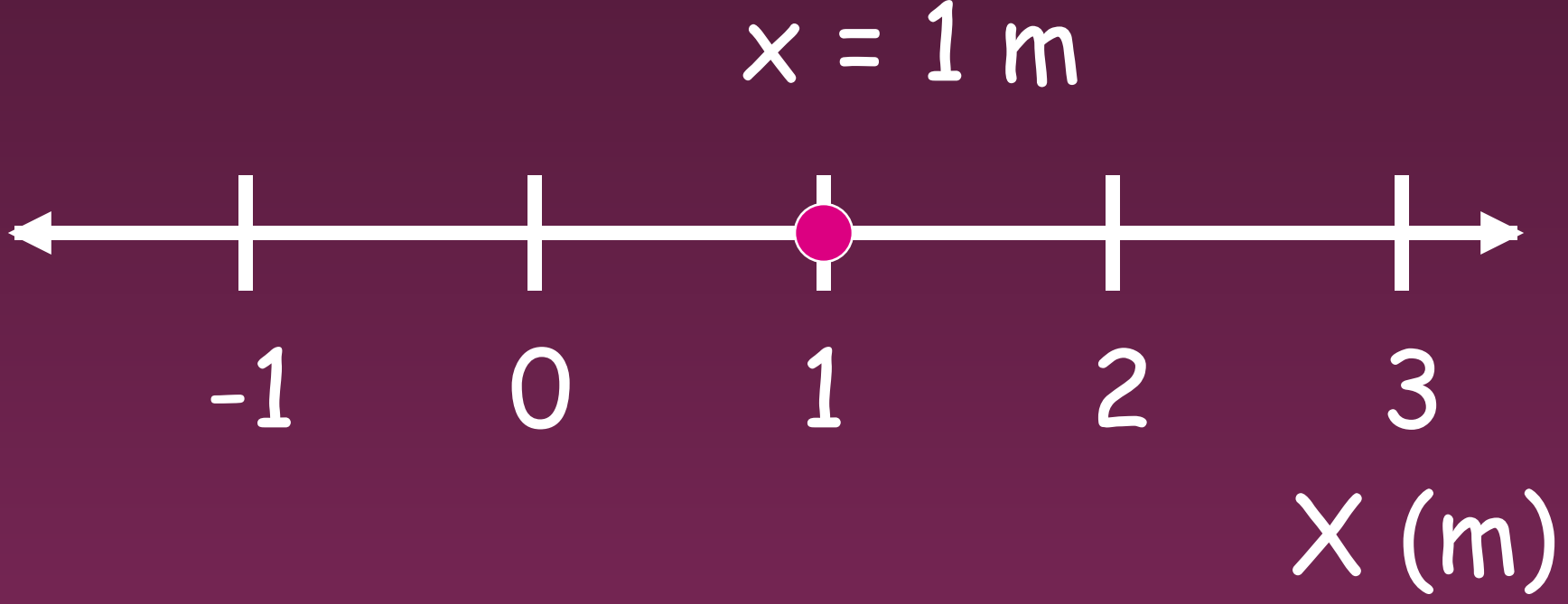
Particle

- Has position and mass.
- Has NO size or volume.
- Located at *one point* in space.

Position

- Location of a particle in space.
- One dimension (x)
- Two dimensions (x,y)
- Three dimensions (x,y,z)

1-Dimensional Coordinates

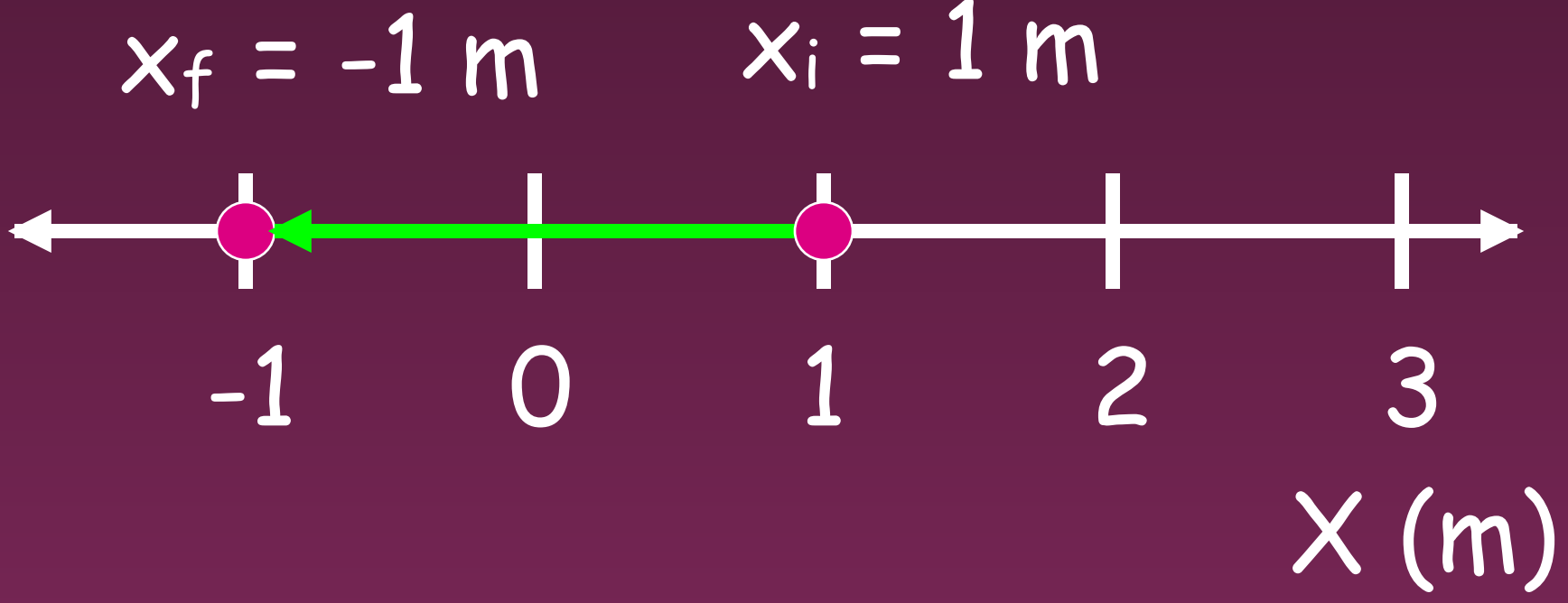


Distance

- The total length of the path traveled by an object.
- Does not depend upon direction.
- "How far have you walked?"

1-Dimensional Coordinates

Distance moved by particle is 2 meters.



Displacement

- The change in position of an object.
- Depends only on the initial and final positions, not on path.
- Includes direction.
- "How far are you from home?"

Displacement

- Represented by Δx.
- $\Delta x = x_2 - x_1$

  where

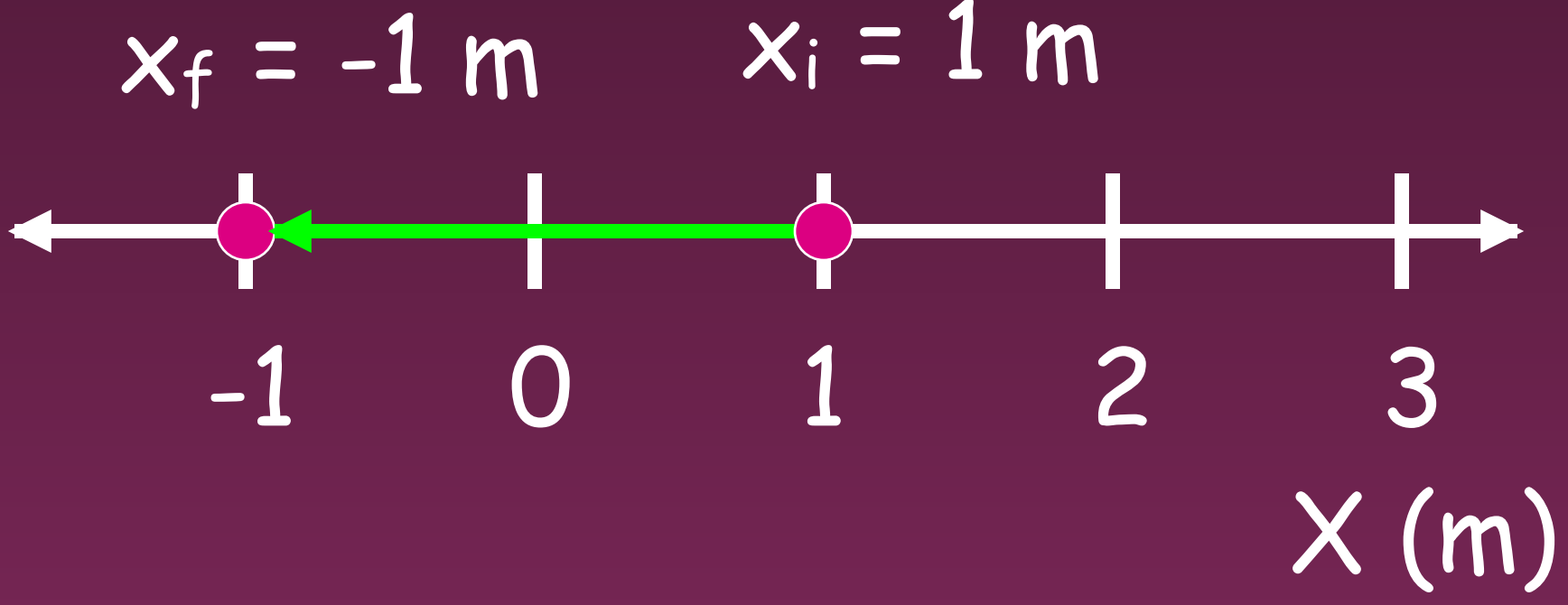
  x_2 = final position

  x_1= initial position

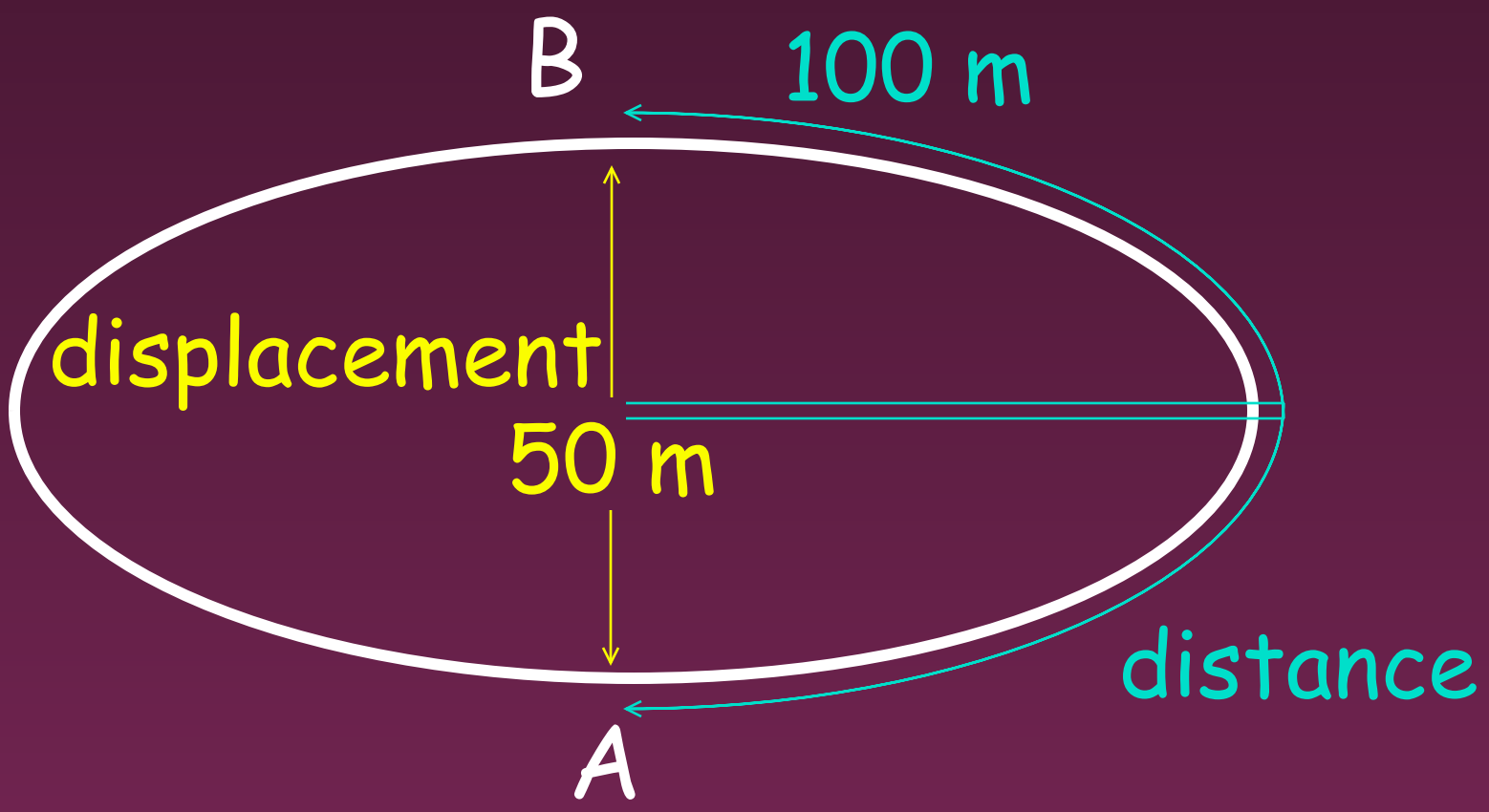
1-Dimensional Coordinates

Distance moved by particle is 2 meters.

Displacement of particle is -2 meters.



Distance vs Displacement



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

Answer

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

A. –27 m

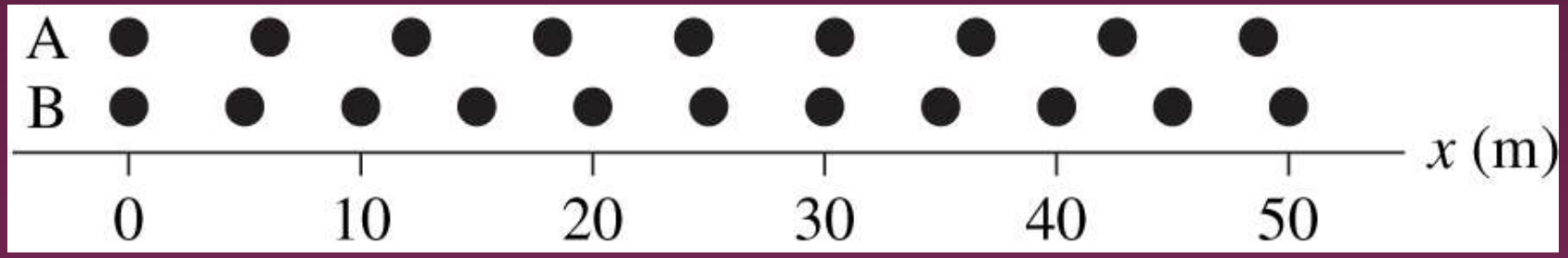
B. –50 m

C. 23 m

D. 73 m

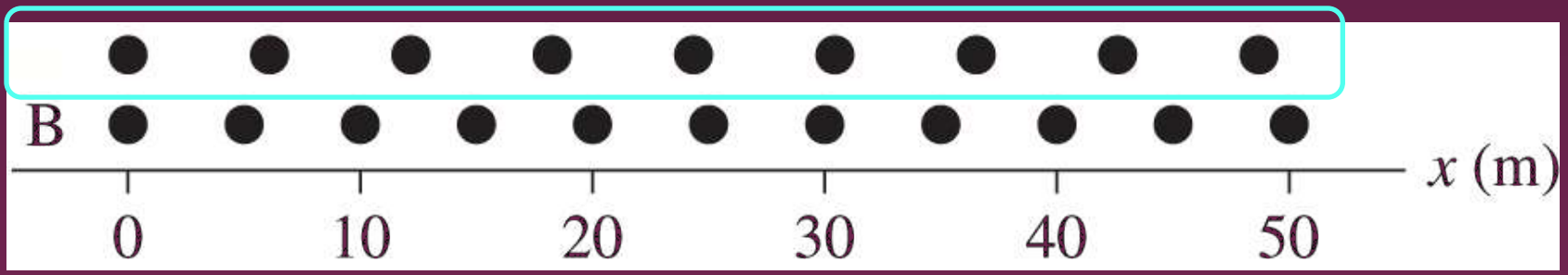
Checking Understanding

Two runners jog along a track. The positions are shown at 1 s time intervals. Which runner is moving faster?



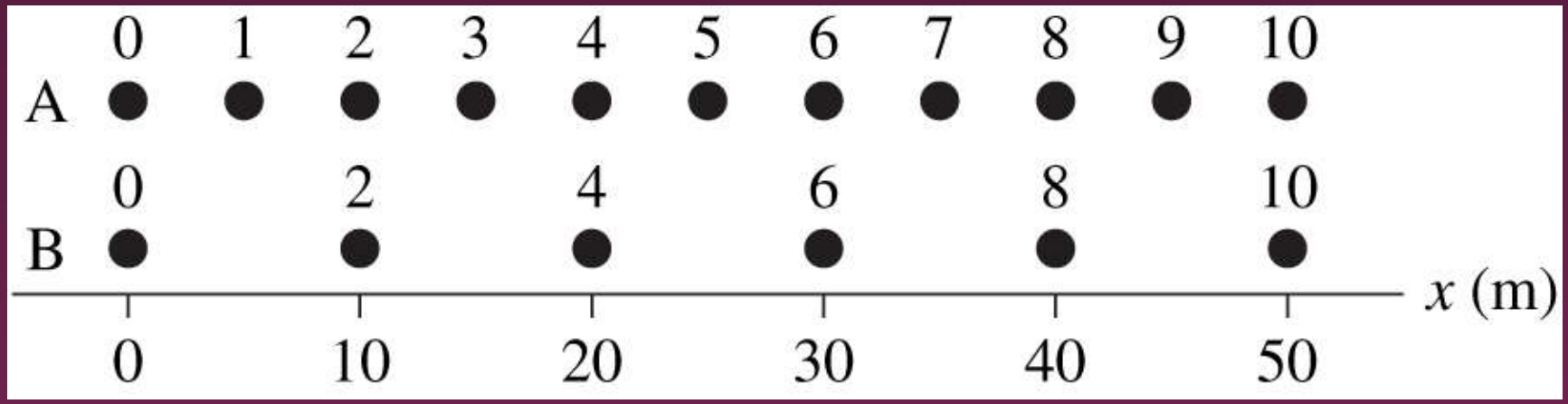
Answer

Two runners jog along a track. The positions are shown at 1 s time intervals. Which runner is moving faster?



Checking Understanding

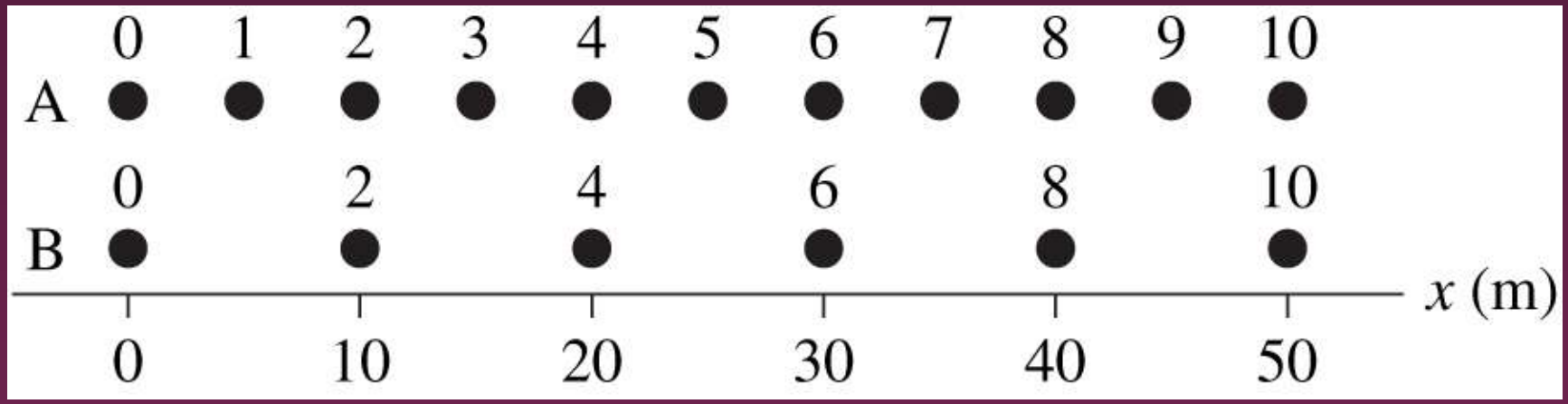
Two runners jog along a track. The times at each position are shown. Which runner is moving faster?



C. They are both moving at the same speed.

Answer

Two runners jog along a track. The times at each position are shown. Which runner is moving faster?



C. They are both moving at the same speed.

Average Speed

$$s_{ave} = \frac{d}{t}$$

Where:

s_{ave} = rate (speed)

d = distance

t = elapsed time

Average Velocity

$$v_{ave} = \frac{\Delta x}{\Delta t}$$

Where:

v_{ave} = average velocity

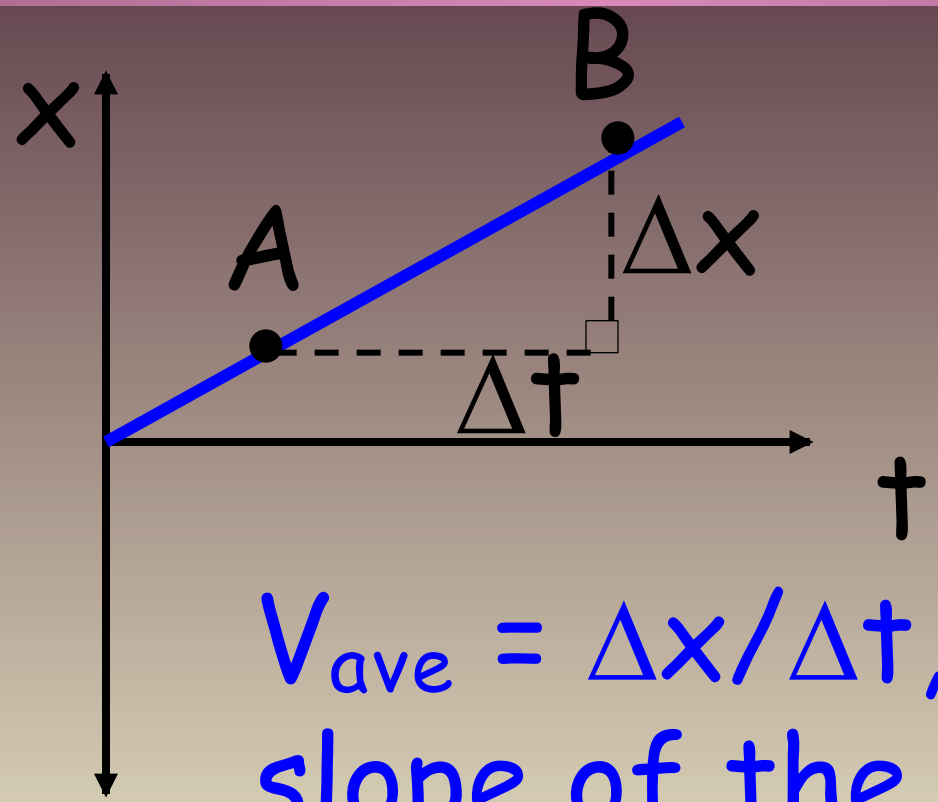
Δx = displacement $(x_2 - x_1)$

Δt = change in time $(t_2 - t_1)$

Velocity vs Speed

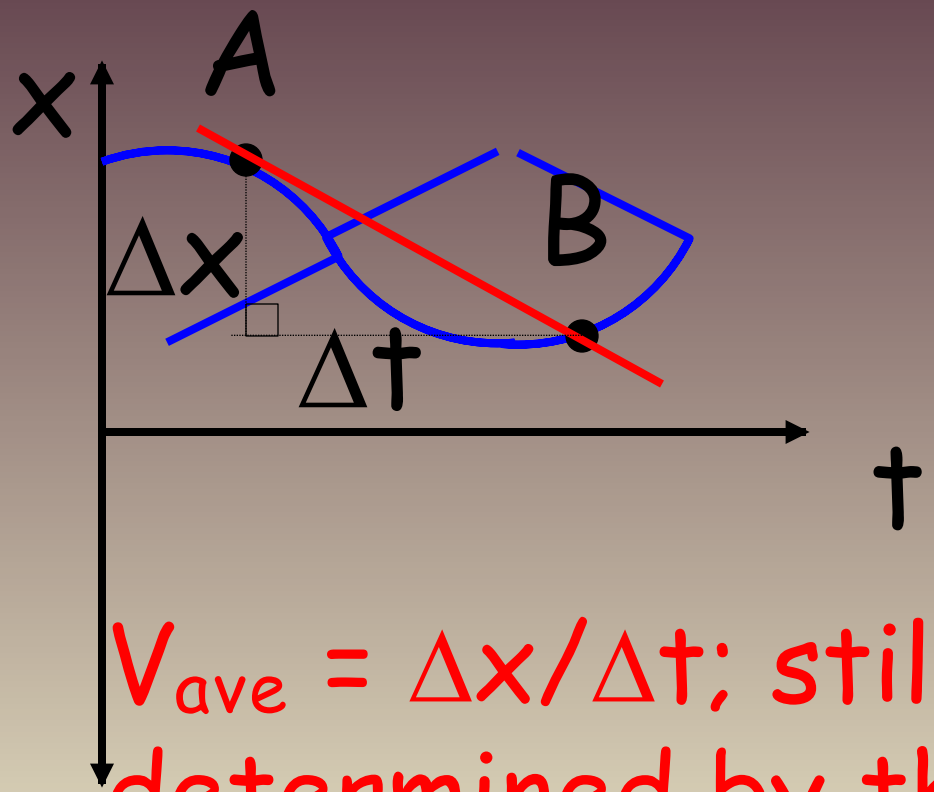
- Average speed is always positive.
- Average velocity can be positive or negative depending direction.
- Absolute value of velocity can be used for speed if the object is not changing direction.

Average Velocity



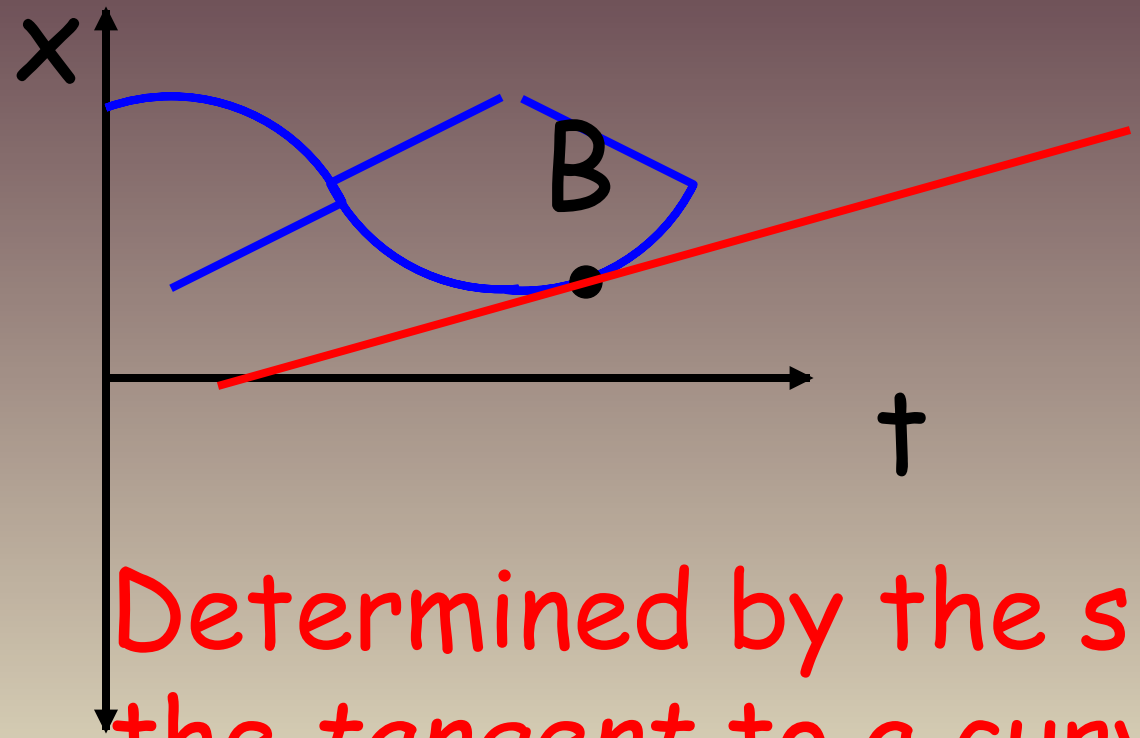
$V_{ave} = \Delta x / \Delta t$, or the slope of the line connecting A and B.

Average Velocity



$V_{ave} = \Delta x/\Delta t$; still determined by the slope of the line connecting A and B.

Instantaneous Velocity



Determined by the slope of the *tangent* to a curve at a single point.

Acceleration

- A change in velocity is called *acceleration*.
- Acceleration can be
- speeding up
- slowing down
- turning

Uniformly Accelerated Motion

- In Physics B, we will generally assume that acceleration is *constant*.
- With this assumption we are free to use this equation:

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

Units of Acceleration

The SI unit for acceleration is m/s^2.

Sign of Acceleration

Acceleration can be positive or negative.

The sign indicates direction.

General Rule

If the sign of the velocity and the sign of the acceleration is the same, the object speeds up.

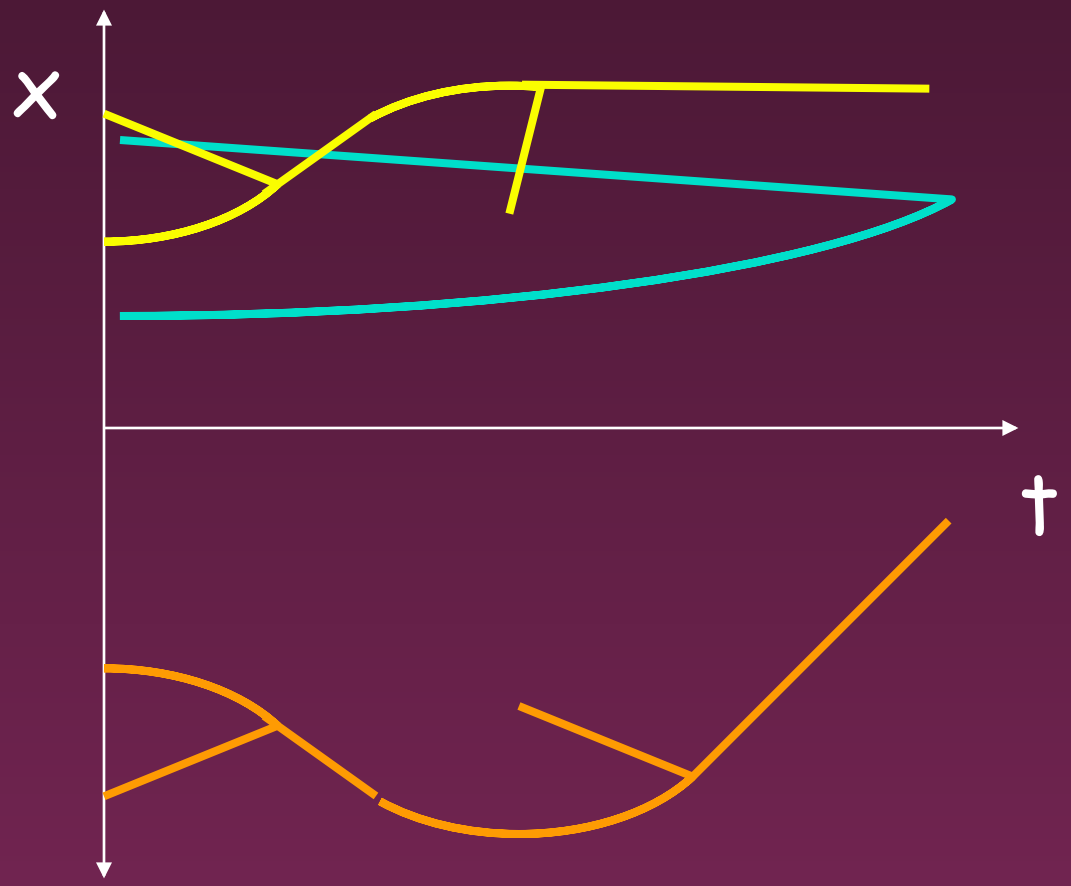
If the sign of the velocity and the sign of the acceleration are different, the object slows down.

Velocity & Acceleration Sign Chart

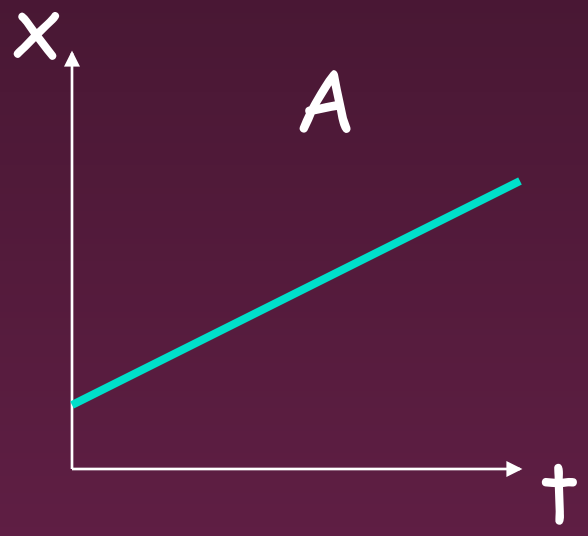
		VELOCITY	
ACCELERATION		+	-
	+	Moving forward; Speeding up	Moving backward; Slowing down
	-	Moving forward; Slowing down	Moving backward; Speeding up

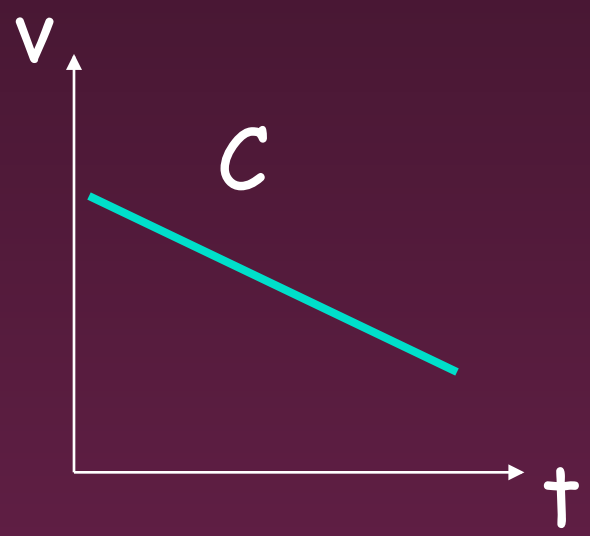
Accelerating objects…

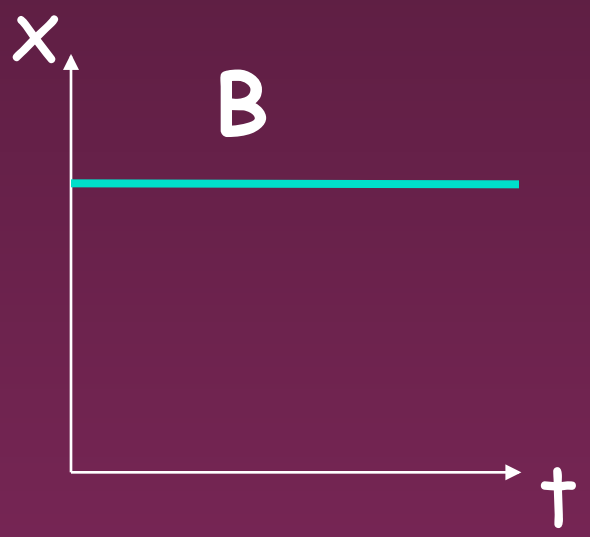
Note: each of these curves has many different slopes (many different velocities)!

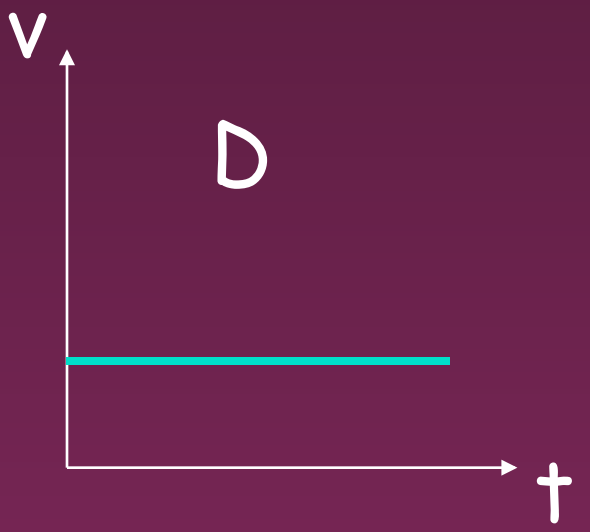


Pick the constant velocity graph(s)…

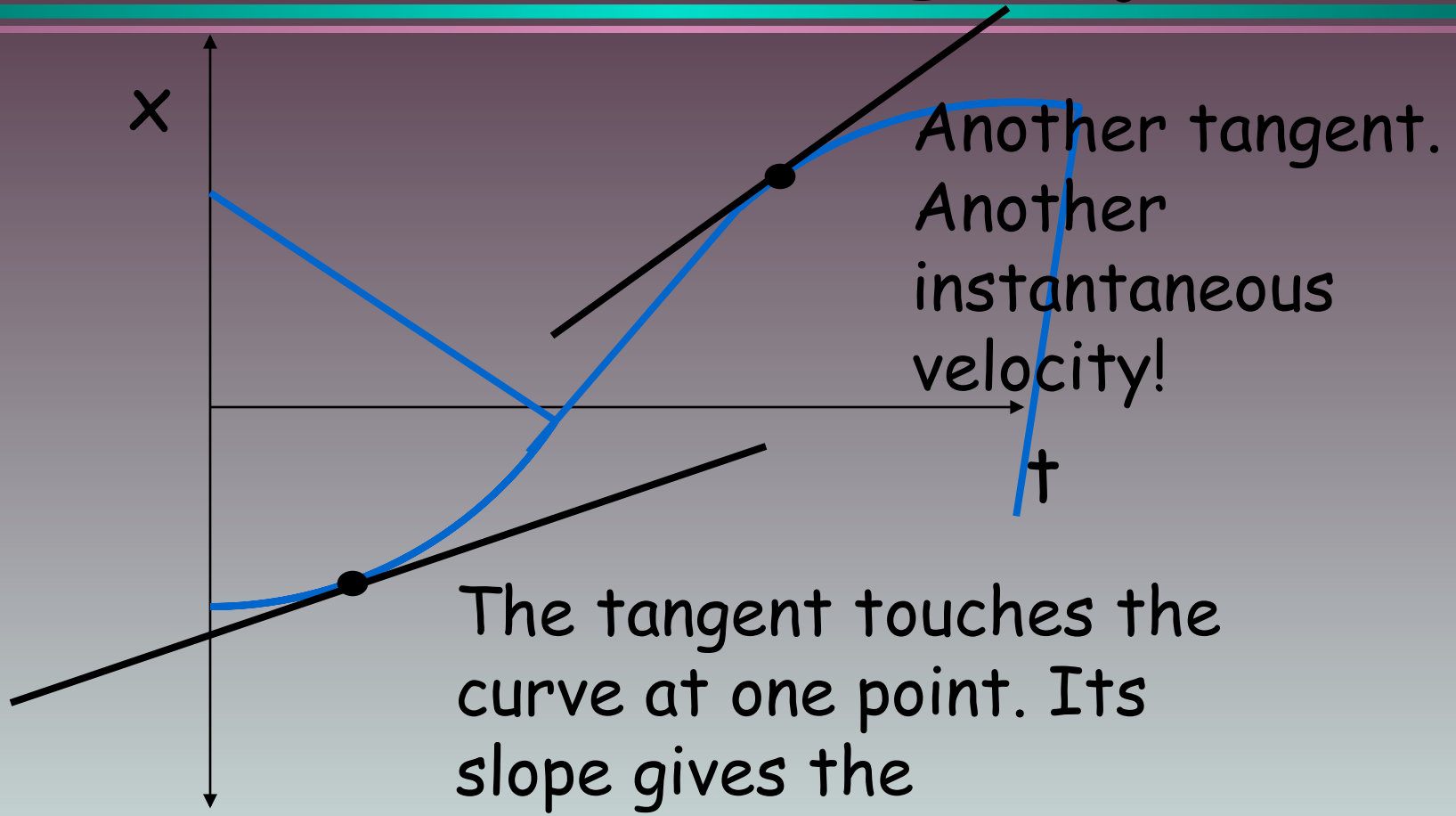








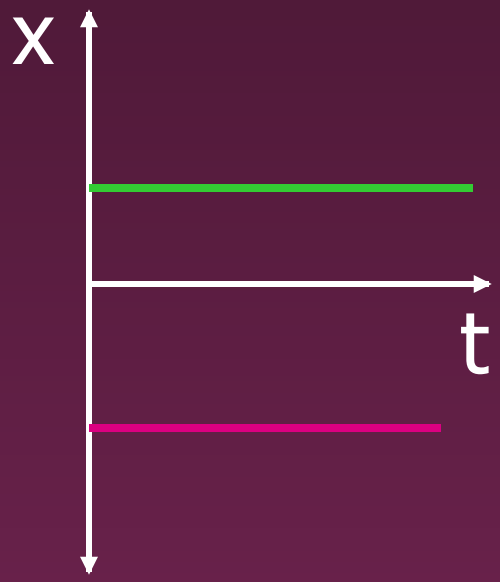
Another accelerating object.



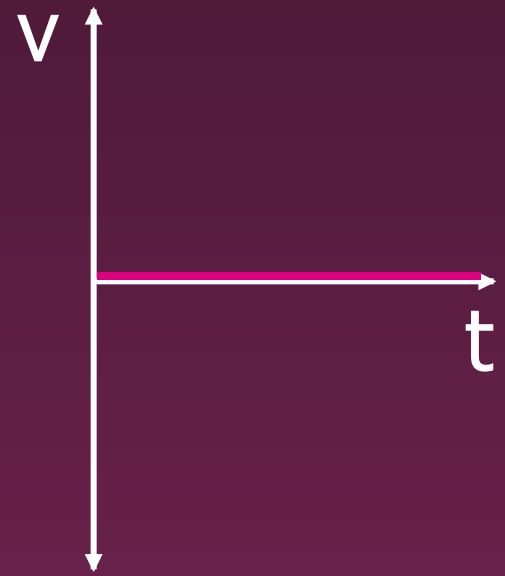
Another tangent. Another instantaneous velocity!

The tangent touches the curve at one point. Its slope gives the instantaneous velocity at that point.

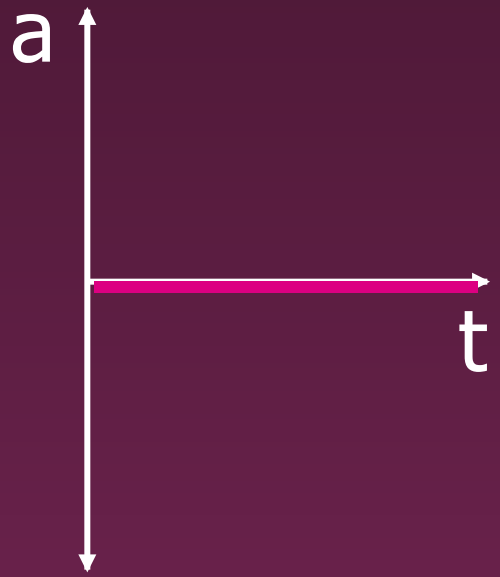
Summary: Constant position graphs



Position vs time

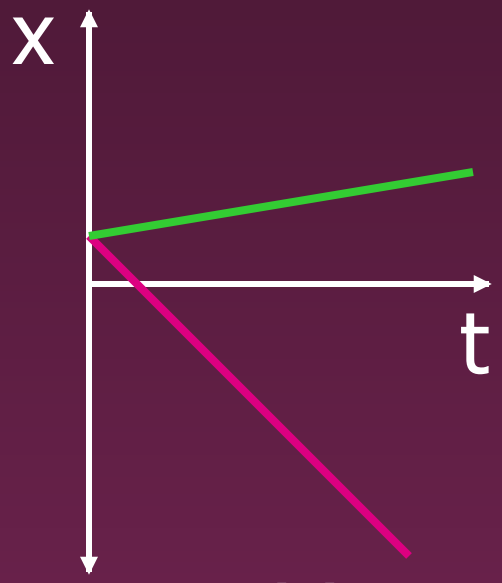


Velocity vs time

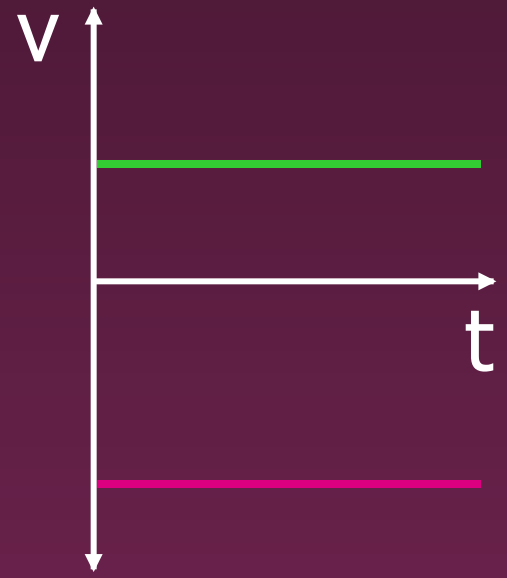


Acceleration vs time

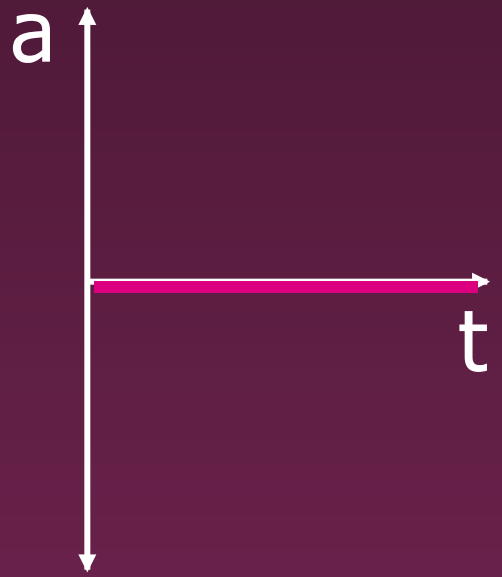
Summary: Constant velocity graphs



Position vs time

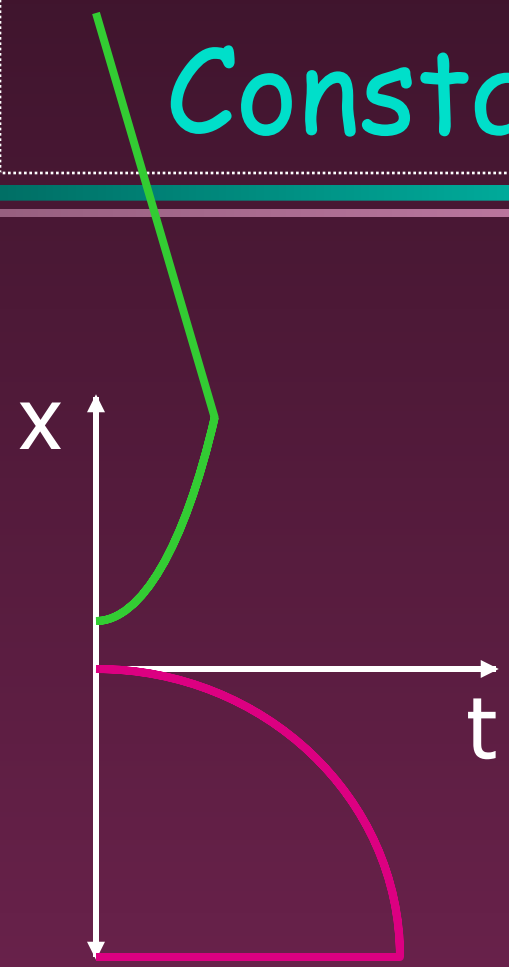


Velocity vs time

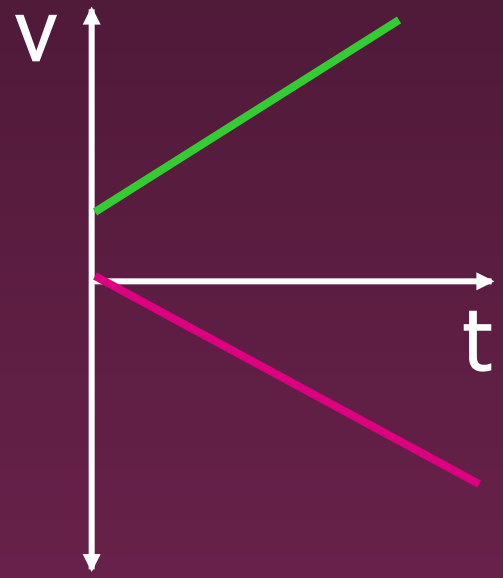


Acceleration vs time

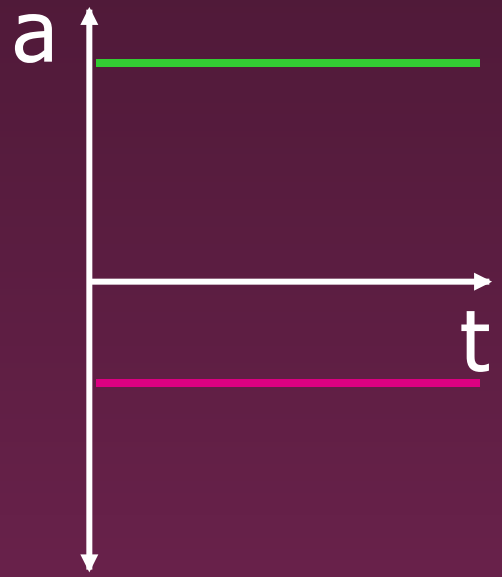
Summary: Constant acceleration graphs



Position vs time



Velocity vs time

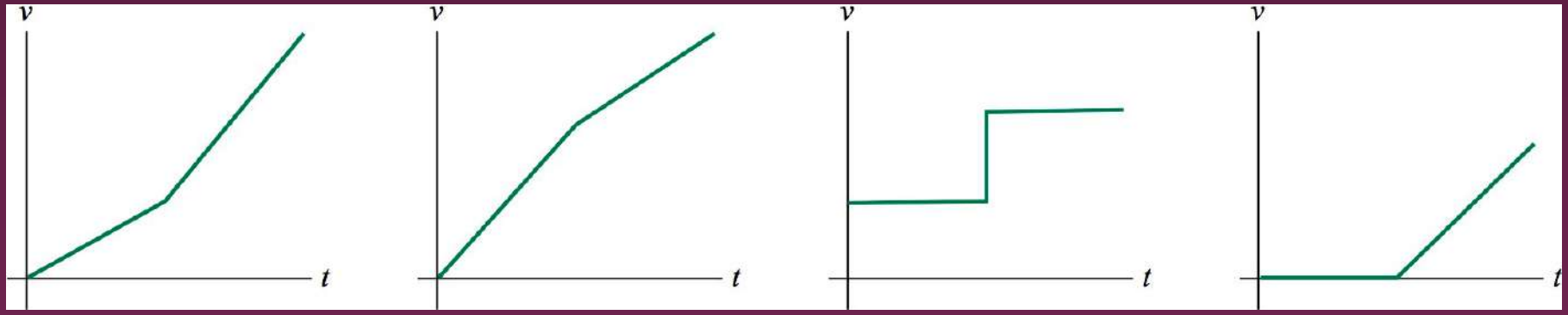


Acceleration vs time

Checking Understanding

Here is a motion diagram of a car moving along a straight stretch of road:

Which of the following velocity-versus-time graphs matches this motion diagram?

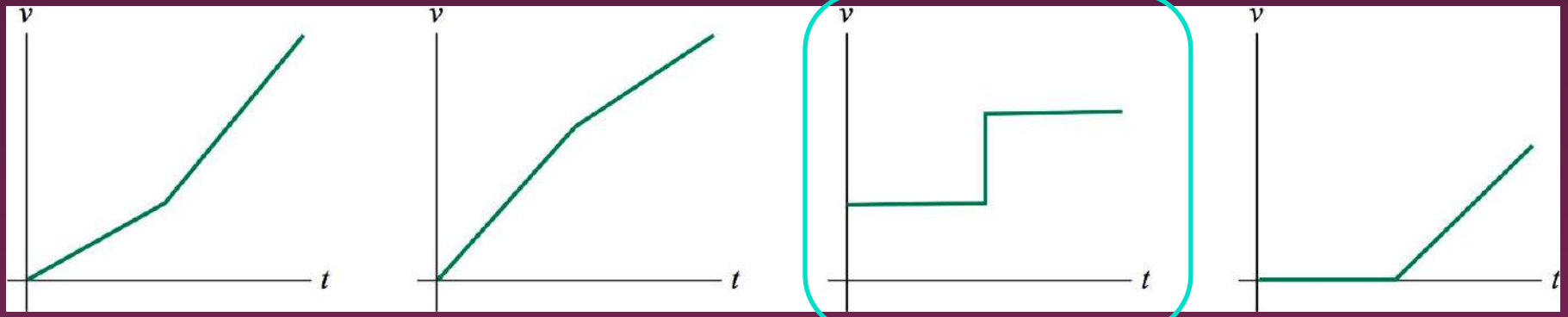


A. B. C. D.

Answer

Here is a motion diagram of a car moving along a straight stretch of road:

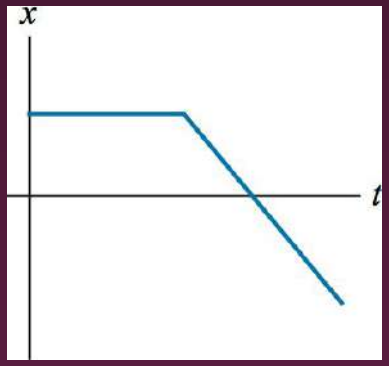
Which of the following velocity-versus-time graphs matches this motion diagram?



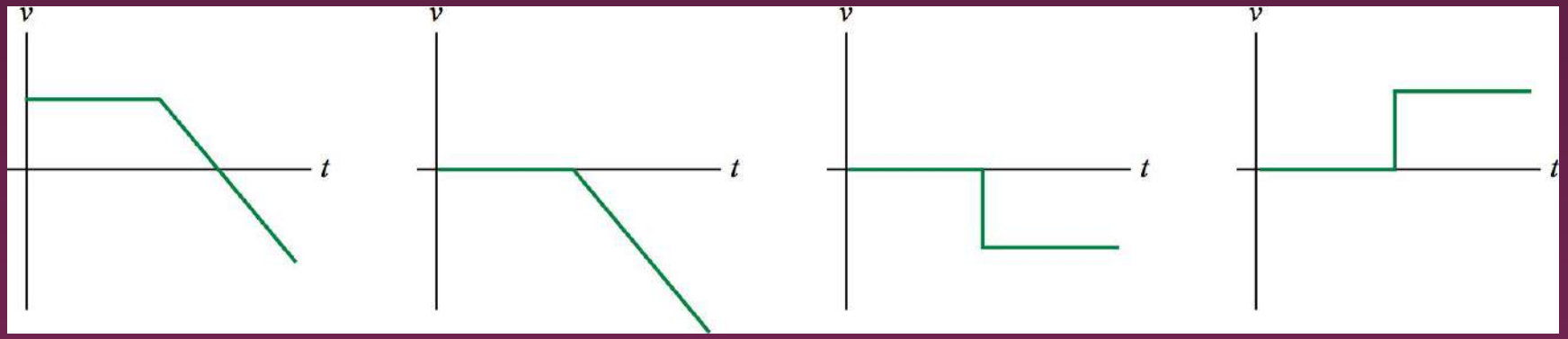
A. B. C. D.

Checking Understanding

A graph of position versus time for a basketball player moving down the court appears like so:



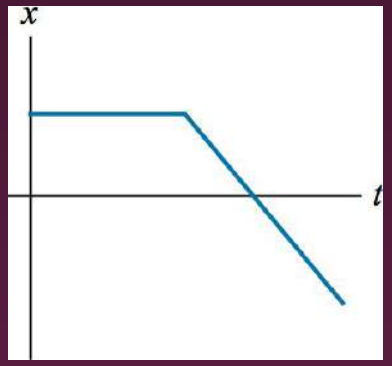
Which of the following velocity graphs matches the above position graph?



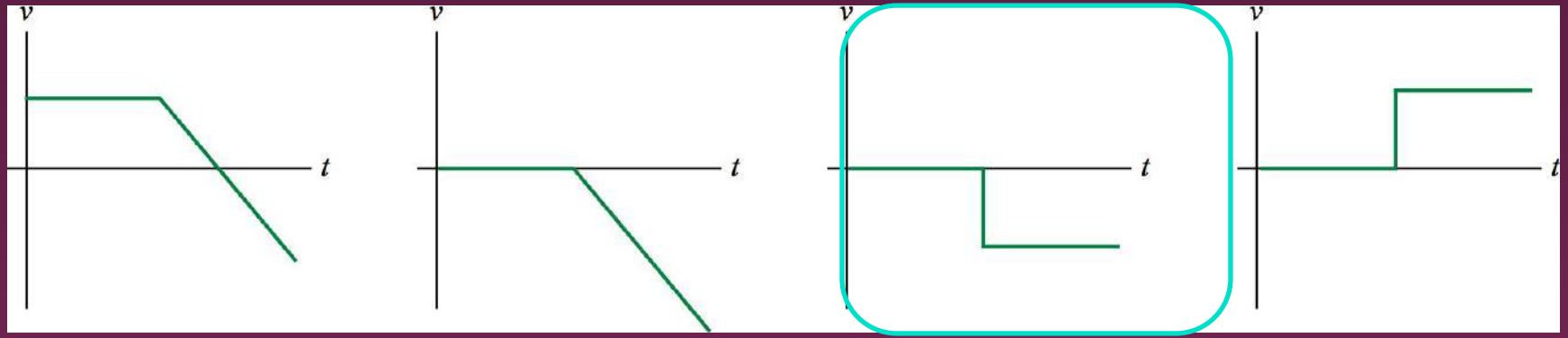
A. B. C. D.

Answer

A graph of position versus time for a basketball player moving down the court appears like so:



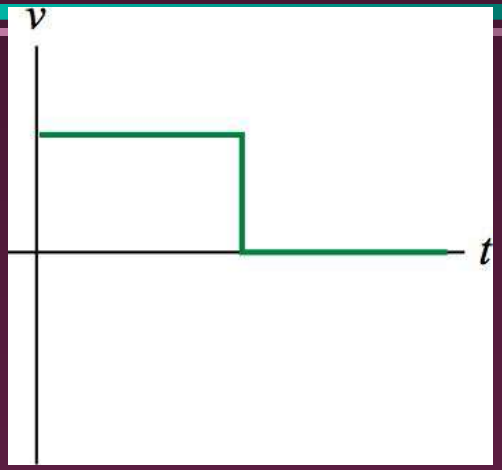
Which of the following velocity graphs matches the above position graph?



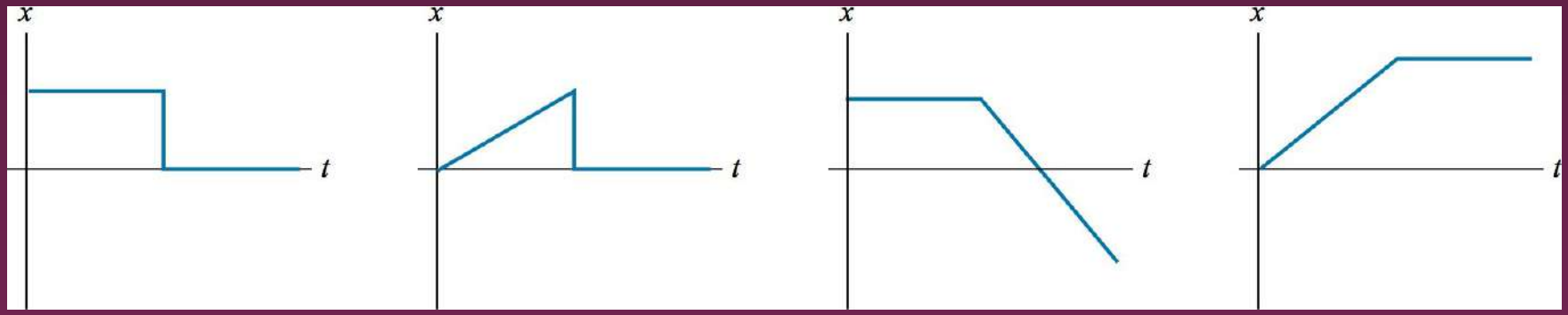
A. B. C. D.

Checking Understanding

A graph of velocity versus time for a hockey puck shot into a goal appears like so:



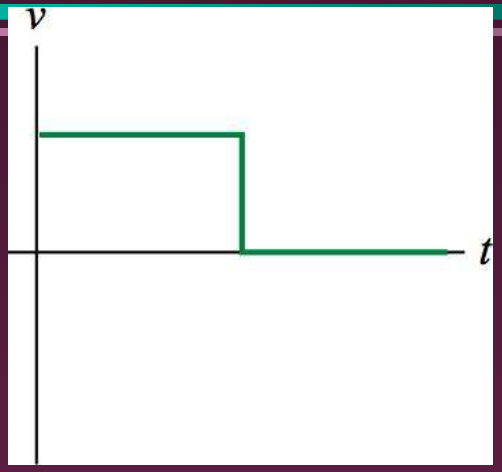
Which of the following position graphs matches the above velocity graph?



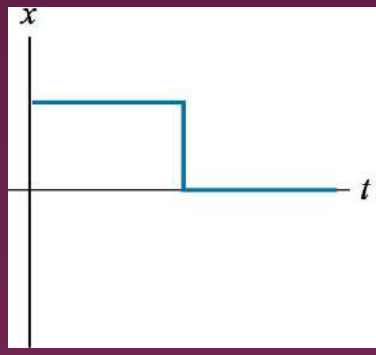
A. B. C. D.

Answer

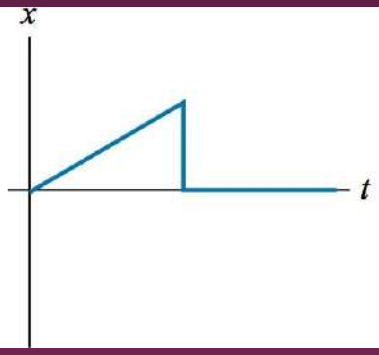
A graph of velocity versus time for a hockey puck shot into a goal appears like so:



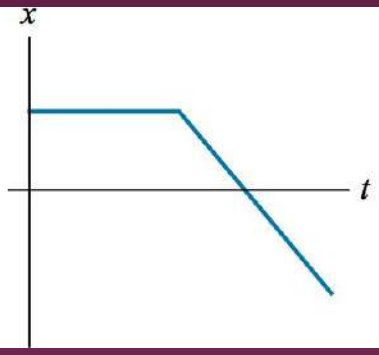
Which of the following position graphs matches the above velocity graph?



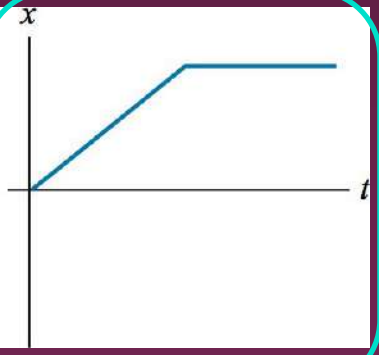
A.



B.



C.



D.

Summary

$$v = v_0 + at$$

$$x = x_0 + v_0 t + 1/2\, at^2$$

$$v^2 = v_0^2 + 2a(\Delta x)$$

Free Fall

- Occurs when an object falls unimpeded.
- Gravity accelerates the object toward the earth.

Acceleration due to gravity

- $g = 9.8\ m/s^2$ downward.
- $a = -g$ if up is positive.
- acceleration is down when ball is thrown up EVERYWHERE in the balls flight.

Summary

$$v = v_0 - gt$$

$$x = x_0 + v_0 t - 1/2\, gt^2$$

$$v^2 = v_0^2 - 2g(\Delta x)$$

Symmetry

- When something is thrown upward and returns to the thrower, this is very symmetric.
- The object spends half its time traveling up; half traveling down.
- Velocity when it returns to the ground is the opposite of the velocity it was thrown upward with.
- Acceleration is $-9.8\ m/s^2$ everywhere!