Unit 2.2
constant acceleration

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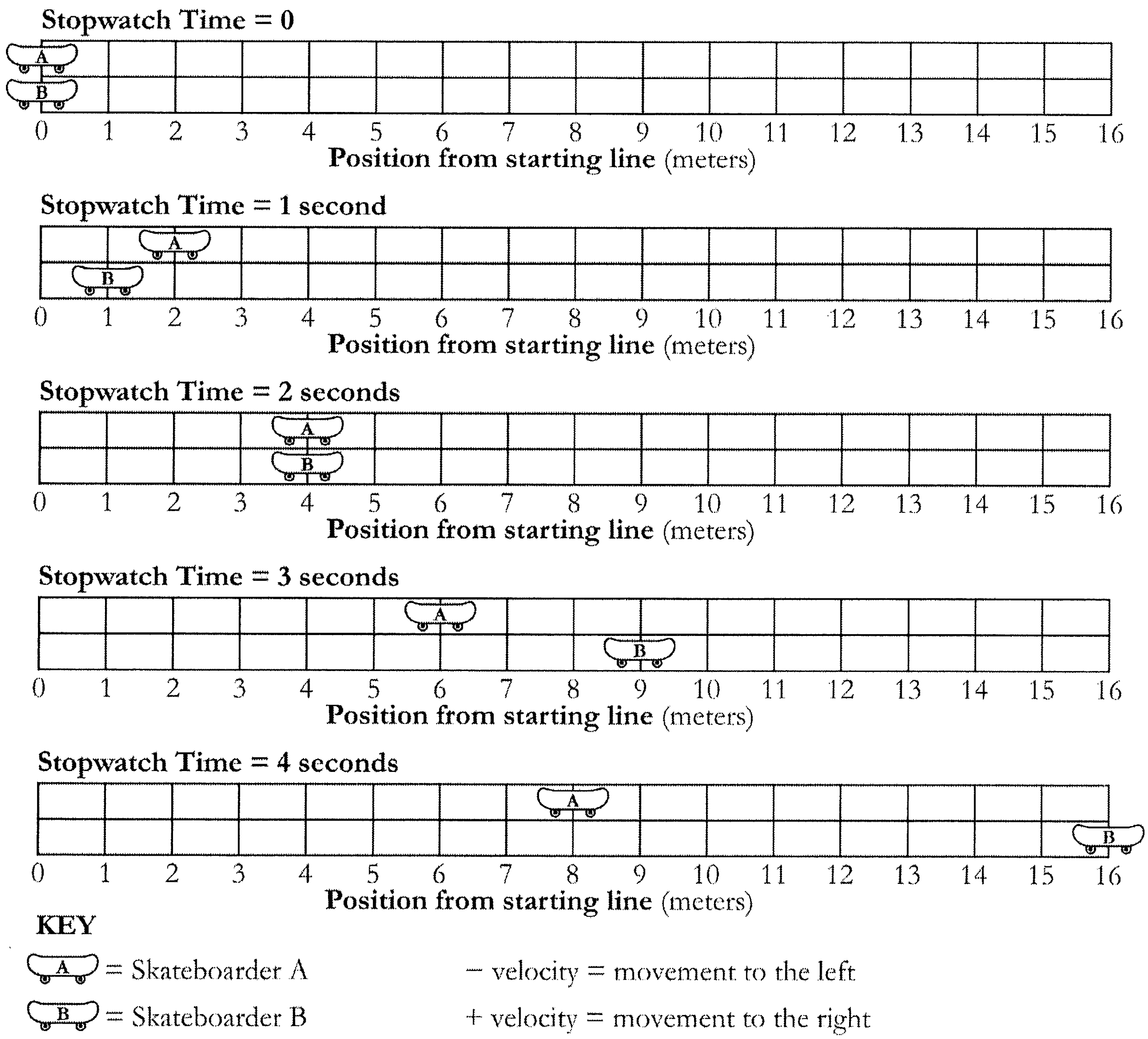
What's Happening When Velocity Changes?

Why?

We have all traveled in vehicles as they speed up, slow down, or travel steadily along a road. In this activity we will explore the ways a physicist thinks about, analyzes, and represents these types of motion.

As you work through the following questions, be sure to follow your team role(s).

Model 1 – Two skateboarders on a track



Use the information in Model 1 to answer questions 1 – 10.
Reach agreement with your team before writing down your consensus answers.

1. Which skateboarders are located at the starting line at Stopwatch Time = 0?

   a. Skateboarder A   b. Skateboarder B   c. Both skateboarders

2. **Highlight** skateboard A in one color wherever you see it in Model 1. **Highlight** skateboard B in a different color.

3. Look carefully at the positions of the two skateboarders as time passes. Circle the direction that the skateboarders are moving.

   ← Moving to the left   Moving to the right →   You can't tell.

4. Based on the data shown in Model 1, complete the data table below.

Stopwatch Time (seconds)	**Position of Skateboard A** (meters from starting line)	**Position of Skateboard B** (meters from starting line)
0	0	
1		
2	4	4
3		
4		16

STOP Send a spy to check your team's answer to question 4 with another team before you continue.

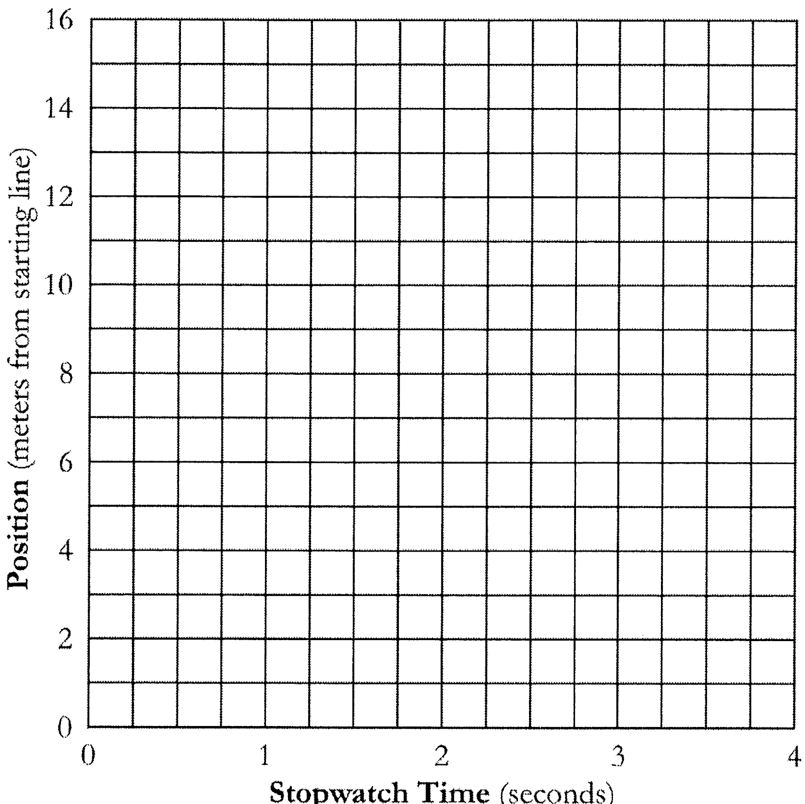
5. Create a **position vs. stopwatch time graph** from the data in Model 1. Your data table in question 4 will be helpful.

a. **Draw** and **label** a line or smooth curve to show **Skateboarder A's** data.

b. **Draw** and **label** a line or smooth curve to show **Skateboarder B's** data.

c. **Highlight** each line or smooth curve to match the colors you used in Model 1.

Position vs. Stopwatch Time



KEY

○ = Skateboarder A

□ = Skateboarder B

STOP Send spies to check your team's graph with two other teams before you continue.

6. Look closely at the graph in question 5.

a. At stopwatch time = 2 seconds, what is the position of Skateboarder A?

b. At stopwatch time = 3 seconds, what is the position of Skateboarder B?

Read This!

We recall that physicists calculate the **velocity** of a moving object by using this formula:

$$\text{Velocity} = \frac{\textbf{displacement}}{\textbf{time interval}} \quad \text{or} \quad \mathbf{v} = \frac{\Delta s}{\Delta t}$$

Remember that **displacement** (**Δs**) = (end position) – (start position) of the object.

7. Look closely at your team's **graph** in question 5. Focus on each skateboarder's position at the start and end **of each one-second interval**. Use this information to complete the data table below. Position is reported as meters from starting line.

Skateboarder A

Time Interval	Position at start of time interval	Position at end of time interval	Δs (meters)
0 – 1			
1 – 2	2	4	+2
2 – 3			
3 – 4			

Skateboarder B

Time Interval	Position at start of time interval	Position at end of time interval	Δs (meters)
0 – 1			
1 – 2	1	4	+3
2 – 3			
3 – 4			

For Skateboarder A:

a. Is **Δs** the **same** during every time interval?

b. Is **velocity** the **same** during every time interval?

c. Circle the word that best describes the velocity as time intervals pass.

Decreasing   Steady   Increasing

For Skateboarder B:

a. Is **Δs** the **same** during every time interval?

b. Is **velocity** the **same** during every time interval?

c. Circle the word that best describes the velocity as time intervals pass.

Decreasing   Steady   Increasing

STOP Check your team's answer to question 7 with your teacher before you continue.

8. Draw a line to connect each skateboarder to the statement that best describes their motion.

Skateboarder A…	… moves slower and slower as each second passes.
Skateboarder B…	… moves the same velocity as each second passes.
	… moves faster and faster as each second passes.

Read This!

Physicists use the term **acceleration** to describe the kind of motion that Skateboarder B experienced.

9. Write a one sentence definition. This is a first draft. You will be revising it later.

***Acceleration** is…*

Check your team's answer to question 9 with your teacher before you continue.

10. Imagine you are driving a car. You watch the **speedometer values** (miles per hour). Your friend takes a photo of the speedometer value every second for five seconds. Circle the set of photos you expect when your car is **accelerating**.

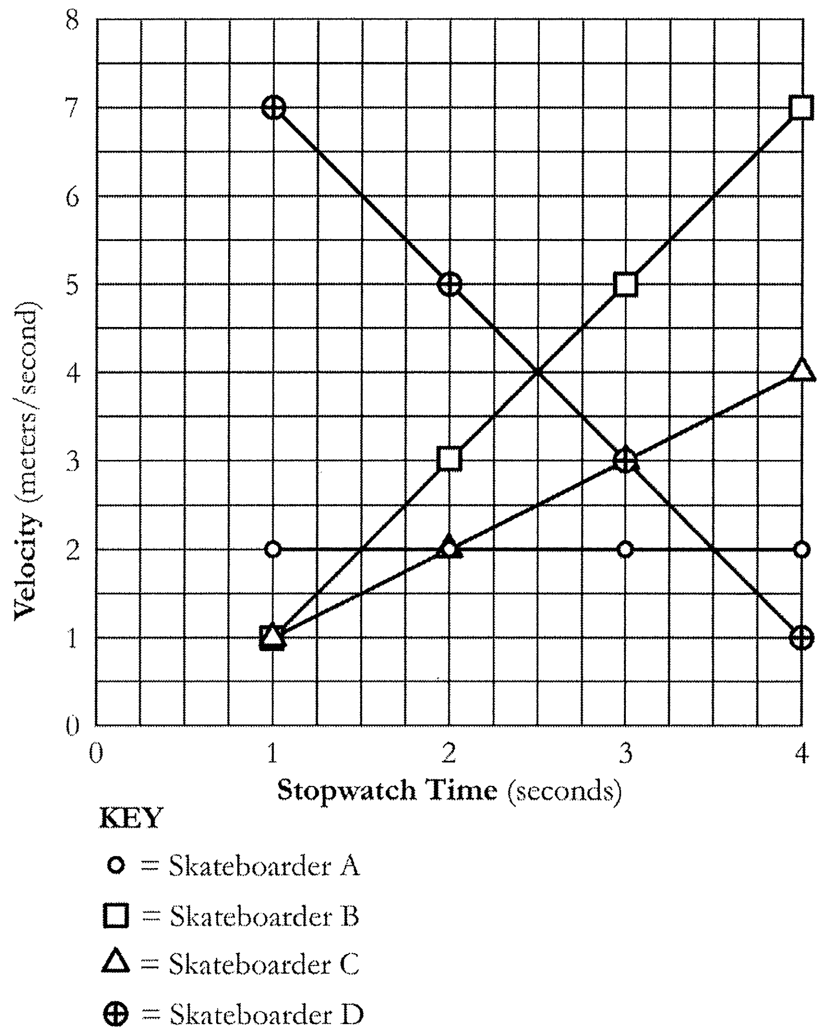
65 → 64 → 63 → 62 → 61

23 → 24 → 25 → 26 → 27

35 → 35 → 35 → 35 → 35

Model 2 – Interpreting velocity vs. stopwatch time graphs

Velocity vs. Stopwatch Time



Use the information in Model 2 to answer questions 11 – 18.
Reach agreement with your team before writing down your consensus answers.

11. **Highlight** each line in Model 2 to match the colors you used in Model 1. Choose two new colors to **highlight** lines C and D.

12. What is the velocity for Skateboarder B at stopwatch time = 3 seconds? Include correct +/− sign and units.

STOP Check your team's answer to question 12 with your teacher before you continue.

13. Complete the data table below. Use the **Velocity** values from the graph in Model 2. One row has been completed for you.

Skateboarder	Stopwatch Time = 1 second	Stopwatch Time = 2 seconds	Stopwatch Time = 3 seconds	Stopwatch Time = 4 seconds
A ○				
B □	+1 m/sec	+3 m/sec	+5 m/sec	+7 m/sec
C △				
D ⊕				

Use your data table above to answer questions a - c.

a. Which skateboarder is **stationary** (not moving at all)?

A B C D None of them Can't tell from graph

b. Which skateboarder has a **negative velocity**?

A B C D None of them Can't tell from graph

c. Which skateboarder has the **lowest velocity** at stopwatch time = 4 sec?

A B C D None of them Can't tell from graph

STOP Check your team's answer to question 13 with your teacher before you continue.

14. Look closely at the directions of the lines for each skateboarder's data in Model 2. Draw a line to connect the beginning of each statement with the ending that makes it true.

When an object moves at the same velocity as time passes, a graph of its velocity vs. stopwatch time data…

When an object moves faster and faster as time passes, a graph of its velocity vs. stopwatch time data…

When an object moves slower and slower as time passes, a graph of its velocity vs. stopwatch time data…

… is a horizontal line.

… is a vertical line.

… is a line that slants up.

… is a line that slants down.

15. We use lots of different words to describe motion and acceleration.
Draw Xs to show which skateboarder(s) match each description.

Description of Motion	**Skateboarders** A	B	C	D	**None**
a. The skateboarder moves faster and faster as time passes.					
b. The skateboarder's velocity remains the same as time passes.					
c. As time passes, the skateboarder moves slower and slower as time passes.					
d. As time passes, the skateboarder's velocity decreases.					
e. This skateboarder is moving from right to left on the track.					
f. At Stopwatch Time = 2 seconds, these skateboarders have a velocity of+ 2 m/sec.					
g. At Stopwatch Time = 3 seconds, these skateboarders are moving at the same speed.					
h. These skateboarders are moving from left to right on the track.					
i. The skateboarder is stationary (not moving at all).					
j. The skateboarder's velocity is negative.					

STOP Check your team's answer to questions 14 and 15 with your teacher before you continue.

Read This!

When we drive a car, we use the term **acceleration** when we are leaving a stop sign. We use the term **deceleration** when we are approaching a stop sign.

16. Which skateboarder is experiencing **deceleration**? Explain your answer. Include specific details from Model 2.

17. Look back at your data table in question 13. Use that information to fill in the data table below.
Include a **positive sign** to show an **increase** in velocity as each second passes.
Include a **negative sign** to indicate a **decrease** in velocity as each second passes.
The unit **m/sec²** means "meters per second every second."

Skateboarder	Describe how much the skateboarder's velocity changes every second	Numerical change in velocity every second
A ○		
B □	Increases by 2 m/sec every second (from 1 → 3 → 5 → 7 m/sec)	+2 m/sec^2
C △		
D ⊕		

18. The numerical values you calculated in question 17 are called **acceleration**. Write a sentence to define the concept of acceleration.
***Acceleration** is…*

What I Still Wonder…

19. Write one additional question you have about velocity, acceleration, deceleration, or velocity vs. stopwatch time graphs.

Extension Questions

Read This!

Physicists usually do NOT use the term deceleration. Instead, they use the terms **positive acceleration** and **negative acceleration** to describe the direction that the accelerating force is acting on an object. What happens when the same value (magnitude) of an accelerating force acts in different directions on an object that is moving to the left or right? The ideas get complicated! Let's explore some of these situations in Model 3.

Model 3 – How positive and negative acceleration affect a car's motion

What happens to the velocity of a car as time passes?

Situation	**Initial Velocity**	**Acceleration**	**Time = 0 sec**	**Time = 1 sec**	**Time = 2 sec**	**Time = 3 sec**
Q	+3 m/sec	+1 m/sec^2	+3 m/sec	+4 m/sec	+5 m/sec	+6 m/sec
R	+3 m/sec	−1 m/sec^2	+3 m/sec	+2 m/sec	+1 m/sec	0 m/sec
S	−3 m/sec	+1 m/sec^2	−3 m/sec	−2 m/sec	−1 m/sec	0 m/sec
T	−3 m/sec	−1 m/sec^2	−3 m/sec	−4 m/sec	−5 m/sec	−6 m/sec

KEY

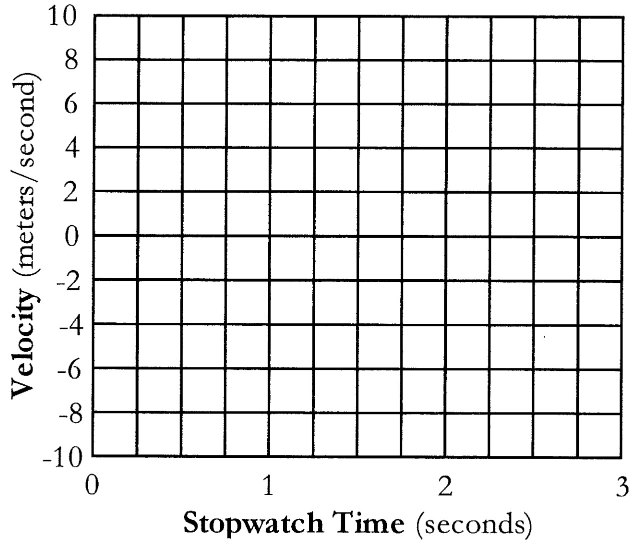
– velocity = movement to the left

+ velocity = movement to the right

Use the information in Model 3 to answer questions 20 – 22.
Reach agreement with your team before writing down your consensus answers.

20. **Graph** the data in Model 3.
Label each line as Situation Q, R, S, or T.

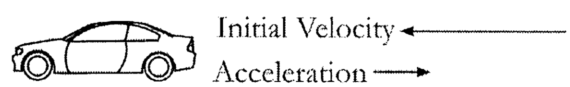
Velocity vs. Stopwatch Time



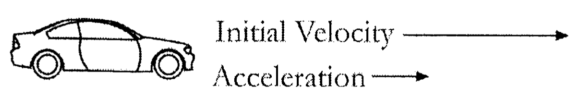
Send spies to check your team's graph lines and labels with two other teams before you continue.

21. Draw lines to **match** the car's motion diagram to the situations in Model 3.

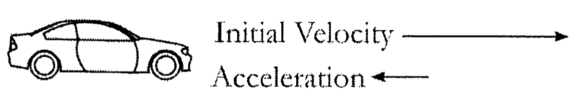
Q



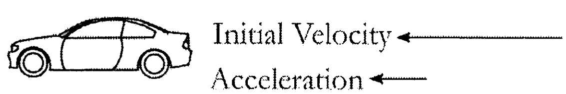
R



S



T



22. **Describe** the motion of the car in each situation in Model 3. This takes careful, slow thinking and reasoning. One description has been completed for you. Underline the similar phrases in each of your answers.

Q	
R	The car starts at an initial velocity of +3 m/sec. This means it is moving to the right at a speed of 3 m/sec. Its acceleration is −1 m/sec^2. This means that each second its velocity decreases by 1 m/sec. The car's speed decreases from 3 → 2 →1 until it reaches 0 m/sec.
S	
T	

23. Discuss with your team. **Draw arrows** (vectors) to show reasonable initial velocity and acceleration values. You do NOT need to include numbers. Just include length and direction.

A moving train applies its brakes	Initial Velocity Acceleration
A train is traveling **steadily**	Initial Velocity Acceleration
A stopped train **starts moving**	Initial Velocity Acceleration

24. Describe how the motion of an object changes when…

a. its initial velocity and its acceleration both have the same signs (both + or both −)

b. its initial velocity and its acceleration have different signs (one + and one −)