Chapter Four: Motion

- 4.1 Speed and Velocity
- 4.2 Graphs of Motion
- 4.3 Acceleration

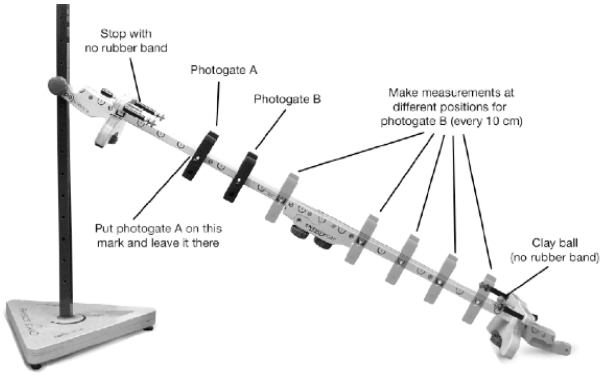
Section 4.3 Learning Goals

- Define acceleration.
- Determine acceleration by mathematical and graphical means.
- Explain the role of acceleration in describing curved motion and objects in free fall.

Investigation 4B

Acceleration

- **Key Question:**
  What is acceleration?



4.3 Acceleration

- Acceleration is the rate at which your speed (or velocity) changes.
- If your speed increases by 1 meter per second (m/s) each second, then your acceleration is 1 m/s per second.

Time (s)	Speed (m/s)
1	1
2	2
3	3
4	4
5	5

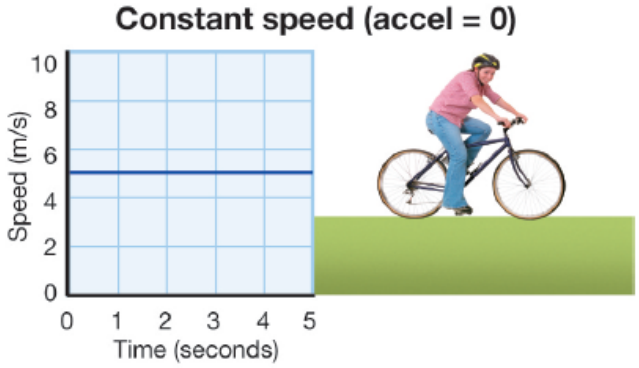
Acceleration = 1 m/s each second

Time (s)	Speed (m/s)
1	2
2	4
3	6
4	8
5	10

Acceleration = 2 m/s each second

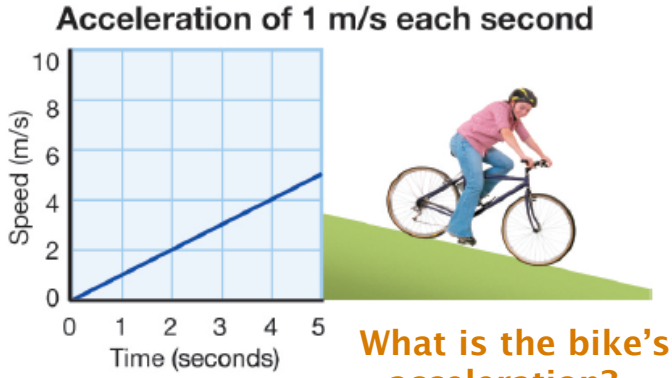
4.3 Acceleration

- There is zero acceleration at constant speed because the speed does not change.



4.3 Acceleration

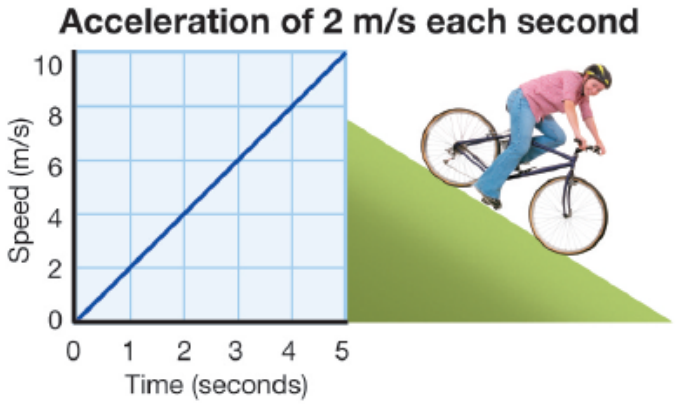
- Acceleration is easy to spot on a speed vs. time graph.



What is the bike's acceleration?

4.3 Acceleration

- If the hill is steeper, the acceleration is greater.



4.3 Acceleration

- Speed and acceleration are not the same thing.
- You can be moving (constant speed), but have no acceleration (think cruise control).

4.3 Acceleration

- Acceleration describes how quickly speed changes.
- Acceleration is the change in speed divided by the change in time.

ACCELERATION

$$\text{Acceleration } (\text{m/s}^2) \quad a = \frac{\text{Change in speed } (\text{m/s})}{\text{Time } (\text{s})} = \frac{v_{finish} - v_{start}}{t}$$

Solving Problems: Acceleration

ACCELERATION

Acceleration (m/s^2) $a = \dfrac{v_{finish} - v_{start}}{t}$

Change in speed (m/s)

Time (s)

4.3 Speed and acceleration

- An acceleration of 20 km/h/s means that the speed increases by 20 km/h each second.
- The units for time in acceleration are often expressed as "seconds squared" and written as s^2.

Can you convert this rate to m/s^2 using conversion factors?

Sports car

Speed goes from
0 to 100 km/h in 5 seconds

$$\text{Acceleration} = \frac{\text{Change in speed}}{\text{Time}}$$

$$= \frac{60 \text{ mph}}{5 \text{ seconds}}$$

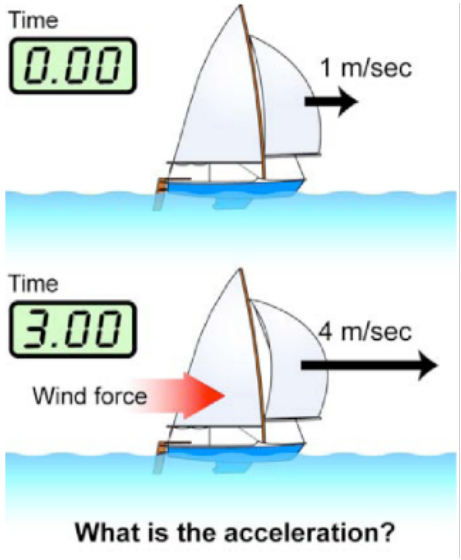
$$= \frac{100 \text{ km/h} - 0 \text{ km/h}}{5 \text{ s}}$$

$$= 20 \text{ km/h per second}$$

= 20 km/h/s

Solving Problems

- A sailboat moves at 1 m/s.
- A strong wind increases its speed to 4 m/s in 3 s.
- Calculate acceleration.



What is the acceleration?

Solving Problems

1. **Looking for:**
   - …acceleration of sailboat
2. **Given:**
   - …v_1 = 1 m/s; v_2 = 4 m/s; time = 3 s
3. **Relationships:**
   - $a = v_2 - v_1/t$
4. **Solution:**
   - $a = (4 \text{ m/s} - 1 \text{ m/s})/ 3 \text{ s}$ **= 1 m/s²**

4.3 Acceleration on motion graphs

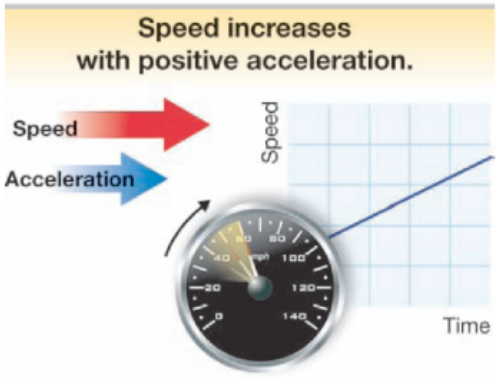
- The word “acceleration” is used for any change in speed, up or down.
- Acceleration can be positive or negative.

Speeding up

Slowing down

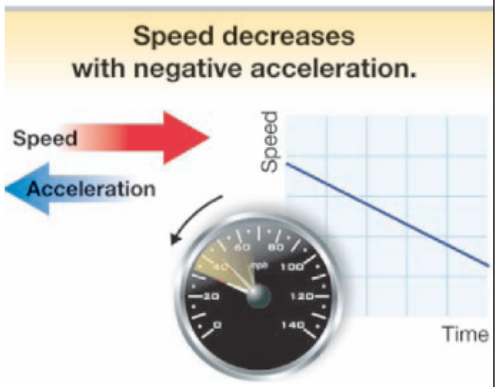
4.3 Acceleration on speed-time graphs

- Positive acceleration adds more speed each second.
- Things get faster.
- Speed increases over time.



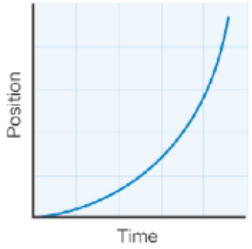
4.3 Acceleration on speed-time graphs

- Negative acceleration subtracts some speed each second.
- Things get slower.
- People sometimes use the word deceleration to describe slowing down.



4.3 Acceleration on position-time graphs

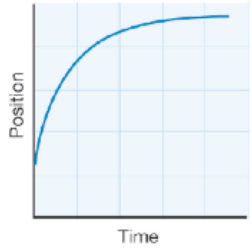
Speeding up



- The position vs. time graph is a curve when there is acceleration.
- The car covers more distance each second, so the position vs. time graph gets steeper each second.

4.3 Acceleration on position-time graphs

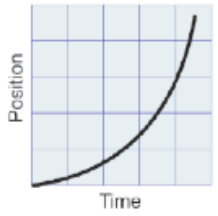
Slowing down



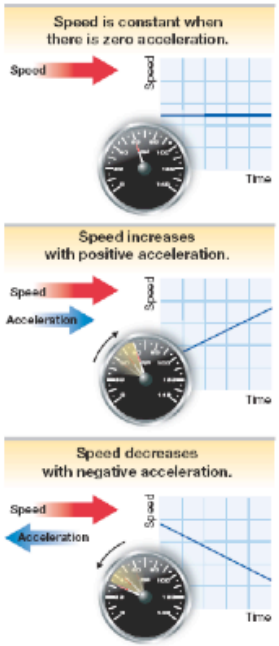
- When a car is slowing down, the speed decreases so the car covers less distance each second.
- The position vs. time graph gets shallower with time.

Acceleration on Motion Graphs

Speeding up

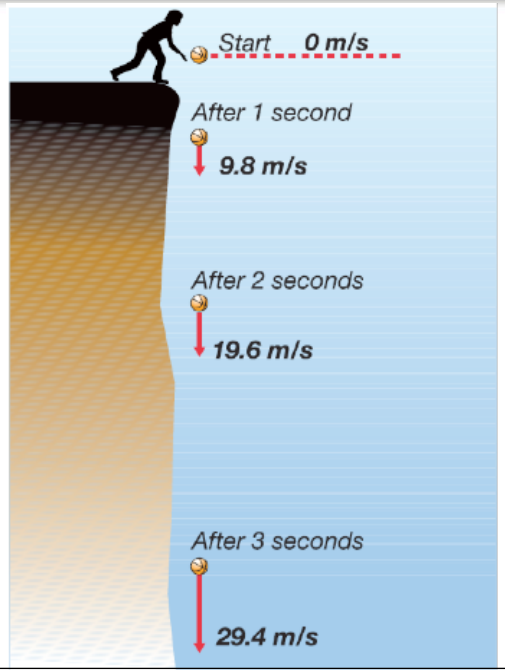


Slowing down

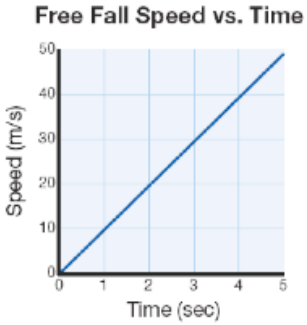


4.3 Free fall

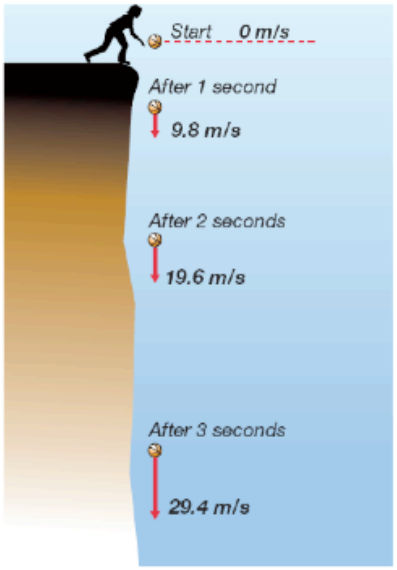
- An object is in free fall if it is accelerating due to the force of gravity and no other forces are acting on it.



Free Fall



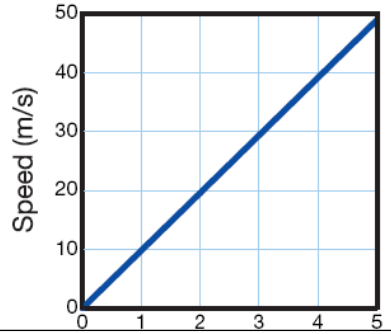
Time (sec)	Speed (m/s)
0	0
1	9.8
2	19.6
3	29.4
4	39.2
5	49.0



4.3 Free fall

- Falling objects increase their speed by 9.8 m/s every second, or 9.8 m/s^2
- The letter "g" is used for acceleration due to gravity.

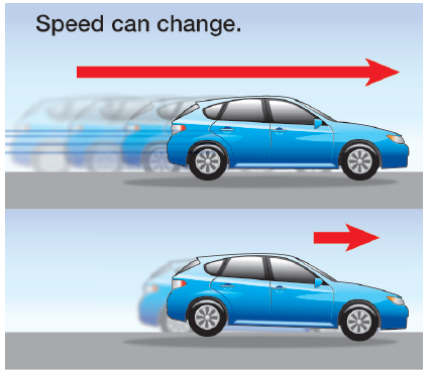
Free Fall Speed vs. Time

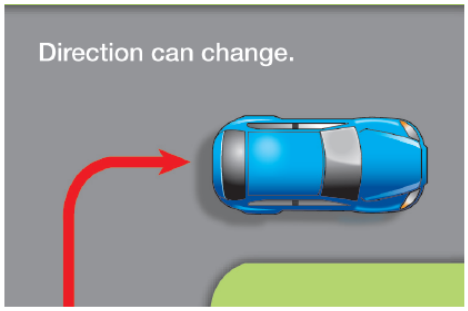


Time (sec)	Speed (m/s)
0	0
1	9.8
2	19.6
3	29.4
4	39.2
5	49.0

4.3 Acceleration and direction

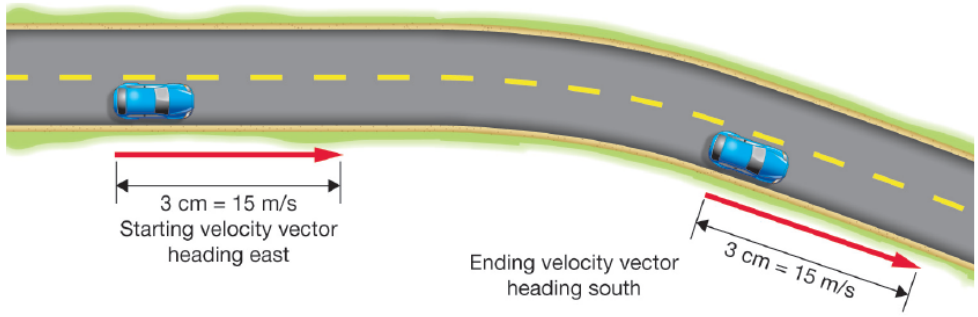
- **Acceleration occurs whenever there is a change in speed, direction, or both.**



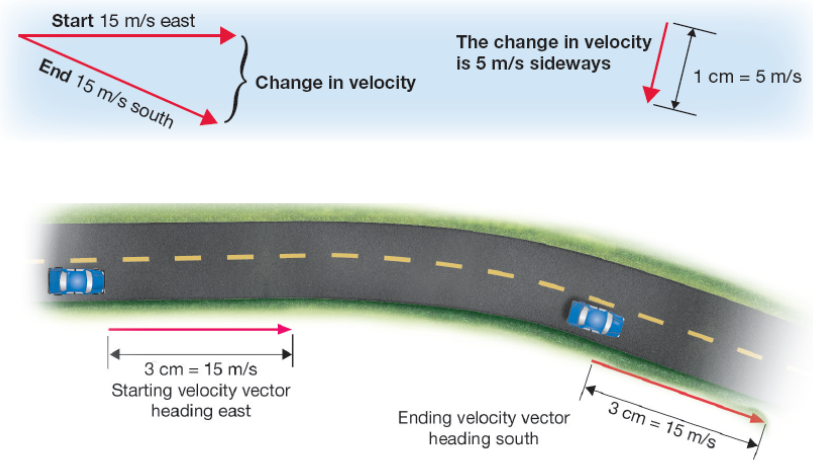


4.3 Acceleration and direction

- A car driving around a curve at a constant speed is accelerating because its direction is changing.

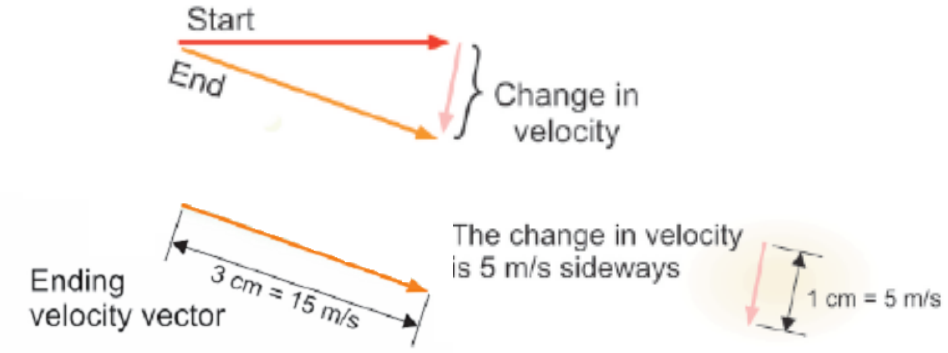


Acceleration and Direction

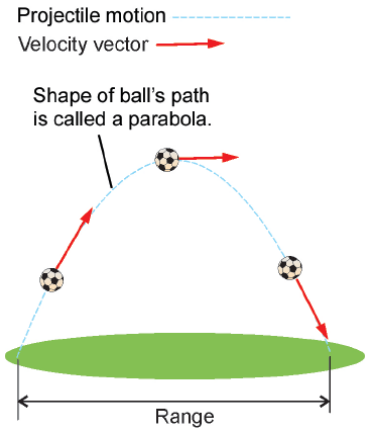


4.3 Acceleration and direction

- **Individual vectors can be drawn to scale to calculate the change in direction.**



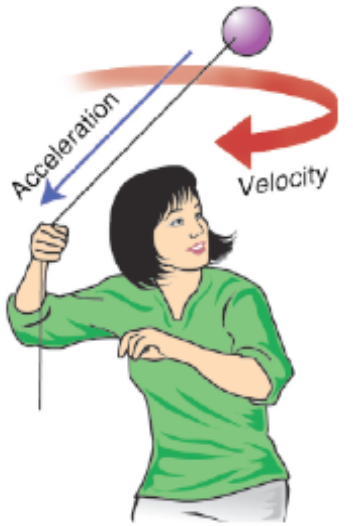
4.3 Curved motion



- A soccer ball is an example of a projectile.
- A projectile is an object moving under the influence of only gravity.
- The path of the ball makes a bowl-shaped curve called a parabola.

4.3 Curved motion

- Circular motion is another type of curved motion.
- An object in circular motion has a velocity vector that constantly changes direction.

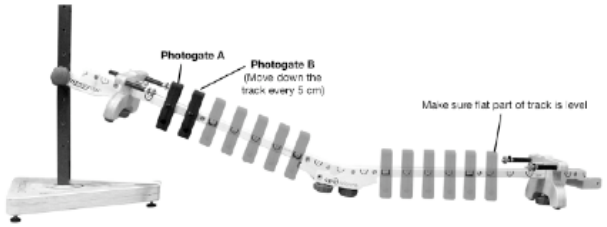


Investigation 4C

Studying Two Part Motion

- **Key Question:**

  What happens to the Energy Car as it travels down a hill and across a flat section of track?



BIOLOGY ▸▸ CONNECTION

High Tech Animal Trackers

- The more we learn about how animals interact with their environments, the better decisions we can make about how we use the oceans.
- Satellite tagging research studies have led to many new laws and guidelines governing human activities around endangered species.