9.1 Describing Acceleration

- An object travelling with uniform motion has equal displacements in equal time intervals.
- Not all objects exhibit uniform motion.
- It is important to be able to analyze situations where the motion is not uniform.
- An object travelling with non-uniform motion will:
  - have different displacements during equal time intervals
  - take different amounts of time to travel equal displacements
  - have a continuously changing velocity

As she slides, the velocity of the baseball player is continually changing, therefore her motion is non-uniform.

See page 383

Positive and Negative Changes in Velocity

- A change in velocity ($\Delta\vec{v}$) occurs when the speed of an object changes and/or its direction of motion changes.
- A change in velocity can be calculated by:

$$\Delta\vec{v} = \vec{v}_{\mathbf{f}} - \vec{v}_{\mathbf{i}}$$

  - If the change in velocity is the same sign (+, -) as the initial velocity, the speed of the object is increasing.
  - If the change in velocity is the opposite sign (+, -) of the initial velocity, the speed of the object is decreasing.
  - If the change in velocity is zero, the object is travelling with uniform motion.

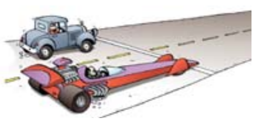
If forward is designated positive, this dragster's change in velocity is positive.

If forward is designated positive, this landing shuttle has a negative change in velocity.

See page 382

Acceleration

- Acceleration (*a*) is the rate of change in velocity.
  - This change in velocity can be due to a change in speed and/pr a change in direction.
- Two objects with the same change in velocity can have different accelerations.
  - This is because acceleration describes the rate at which the change in velocity occurs.



Suppose both of these vehicles, starting from rest, speed up to 60 km/h. They will have the same change in velocity, but, since the dragster can get to 60 km/h faster than the old car, the dragster will have a greater acceleration.

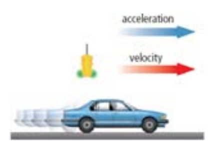
See page 384

Positive and Negative Acceleration

- The direction of the acceleration is the same as the direction of the change in velocity.
- Acceleration that is opposite the direction of motion is sometimes called deceleration.

Examples of acceleration:

1. A car speeding up in the forward direction
   - If we designate the forward direction as positive (+), then the change in velocity is positive (+), therefore the acceleration is positive (+).



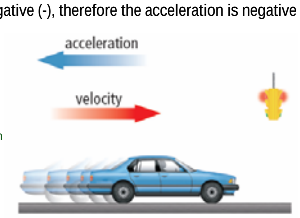
Acceleration is positive in this example

See pages 385 - 386

Positive and Negative Acceleration

Examples of acceleration:

2. A car slowing down in the forward direction.
   - If we designate the forward direction as positive (+), then the change in velocity is negative (-), therefore the acceleration is negative (-).



Acceleration is negative in this example

See pages 385 - 386

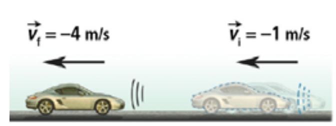
Positive and Negative Acceleration

Examples of acceleration:

3. A car speeding up in the backward direction.
   - If we designate the backward direction as negative (-) then the change in velocity is negative (-).

$$\Delta\vec{v} = \vec{v}_f - \vec{v}_i = (-4\,\text{m/s}) - (-1\,\text{m/s}) = -3\,\text{m/s} = 3\,\text{m/s backwards}$$

   - This means that the acceleration is negative (-) even though the car is increasing its speed. Remember positive (+) and negative (-) refer to directions.



A car speeds up in the backward direction.

See pages 385 - 386

Positive and Negative Acceleration

Examples of acceleration:

4. A car slowing down in the backward direction.
   - If we designate the backward direction as negative (-) then the change in velocity is positive (+).

$$\Delta\vec{v} = \vec{v}_f - \vec{v}_i = (-1\text{ m/s}) - (-4\text{ m/s}) = +3\text{m/s} = 3\text{m/s forward}$$

   - This means that the acceleration is positive (+) even though the car is decreasing its speed. Remember positive (+) and negative (-) refer to directions.

A car slows down in the backward direction.

Take the Section 9.1 Quiz

See pages 385 - 386

9.2 Calculating Acceleration

- The acceleration of an object depends on the change in velocity and the time required to change the velocity.
- When stopping a moving object, the relationship between time and acceleration is:
  - Increasing the stopping time decreases the acceleration.
  - Decreasing the stopping time increases the acceleration.

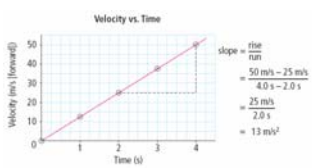
Airbags cause the person to slow down in a longer period of time compared to hitting a solid object, such as the dashboard. This increased time results in a smaller deceleration.

See page 392

Velocity-Time Graphs

- The motion of an object with uniform motion can be represented by a position-time graph.
- The motion of an object with a changing velocity can be represented by a velocity-time graph.
- The slope of a velocity-time graph is average acceleration.
- Acceleration is measured in m/s^2.

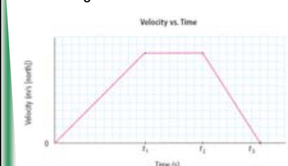
The slope of a velocity-time graph is the average acceleration of the object.



See pages 393 - 394

Determining Motion from a Velocity-Time Graph

- A velocity-time graph can be analyzed to describe the motion of an object.
  - Positive slope (positive acceleration) – object's velocity is increasing in the positive direction
  - Zero slope (zero acceleration) – object's velocity is constant
  - Negative slope (negative acceleration) – object's velocity is decreasing in the positive direction or the object's velocity is increasing in the negative direction



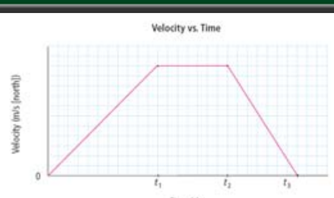
State during which time interval:

a) the acceleration was zero.
b) the acceleration was negative.
c) the acceleration was positive.
d) the object was increasing its velocity north.
e) the object was decreasing its velocity north.
f) the object was moving at a constant velocity north.

Answers are on the next slide

See pages 394 - 395

Determining Motion from a Velocity-Time Graph



State during which time interval:

a) the acceleration was zero. (t_1 to t_2)
b) the acceleration was negative. (t_2 to t_3)
c) the acceleration was positive. (0 to t_1)
d) the object was increasing it's velocity north. (0 to t_1)
e) the object was decreasing it's velocity north. (t_2 to t_3)
f) the object was moving at a constant velocity north. (t_1 to t_2)

See pages 394 - 395

Calculating Acceleration

- The relationship of acceleration, change in velocity, and time interval is given by the equation:

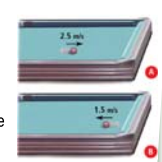
$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$$

Example:

- A pool ball travelling at 2.5 m/s towards the cushion bounces off at 1.5 m/s. If the ball was in contact with the cushion for 0.20 s, what is the ball's acceleration? (Assume towards the cushion is the positive direction.)

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} \text{ where } \Delta\vec{v} = \vec{v}_f - \vec{v}_i$$
$$= \frac{-1.5\text{ m/s} - 2.5\text{ m/s}}{0.20\text{ s}}$$
$$= \frac{-4.0\text{ m/s}}{0.20\text{ s}}$$
$$= -20\text{ m/s}^2$$

The acceleration is 20 m/s^2 away from the cushion.



The ball's velocity changes from 2.5 m/s toward the cushion (A) to 1.5 m/s away from the cushion (B).

See pages 396 - 397

Calculating Acceleration

- The relationship of change in velocity, acceleration, and time interval is given by the equation:

$$\Delta\vec{v} = (\vec{a})(\Delta t)$$

Example:

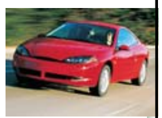
- A car accelerates from rest at 3.0 m/s^2 forward for 5.0 s. What is the velocity of the car at the end of 5.0 s?

$$\Delta\vec{v} = (\vec{a})(\Delta t)$$
$$= (3.0\,\text{m/s}^2)(5.0\,\text{s})$$
$$= 15\,\text{m/s}$$

The car's change in velocity is 15 m/s forward, therefore

$$\Delta\vec{v} = \vec{v}_f - \vec{v}_i$$
$$15\,\text{m/s} = \vec{v}_f - 0$$
$$\vec{v}_f = 15\,\text{m/s}$$

The car's velocity after 5.0 s is 15 m/s forward.



The car accelerates from rest for 5.0 s.

See pages 396 - 397

Calculating Acceleration

- The relationship of time interval, change in velocity, and acceleration is given by the equation:

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

Example:

- A train is travelling east at 14 m/s. How long would to increase its velocity to 22 m/s east, if it accelerated at 0.50 m/s^2 east? Assign east direction positive (+).

$$\Delta\vec{v} = \vec{v}_f - \vec{v}_i = (22\,\text{m/s}) - (14\,\text{m/s}) = 8.0\,\text{m/s}$$

To find the value of Δt:

$$\Delta t = \frac{\Delta\vec{v}}{\vec{a}}$$
$$= \frac{8.0\,\text{m/s}}{0.50\,\text{m/s}^2}$$
$$= 16\,\text{s}$$

It would take 16 s for the train to increase its velocity.

See pages 396 - 397

Calculating Acceleration

Try the following acceleration problems.

1. A truck starting from rest accelerates uniformly to 18 m/s [W] in 4.5 s. What is the truck's acceleration?
2. A toboggan moving 5.0 m/s forward decelerates backward at -0.40 m/s^2 for 10 s. What is the toboggan's velocity at the end of the 10 s?
3. How much time does it take a car travelling south at 12 m/s to increase its velocity to 26 m/s south if it accelerates at 3.5 m/s^2 south?

Answers are on the next slide.

See page 397

Calculating Acceleration (continued)

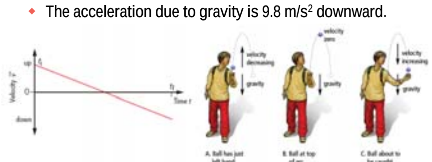
Try the following acceleration problems.

1. A truck starting from rest accelerates uniformly to 18 m/s [W] in 4.5 s. What is the truck's acceleration? (4.0 m/s^2 [W])
2. A toboggan moving 5.0 m/s forward decelerates backward at -0.40 m/s^2 for 10 s. What is the toboggan's velocity at the end of the 10 s? (1.0 m/s forward)
3. How much time does it take a car travelling south at 12 m/s to increase its velocity to 26 m/s south if it accelerates at 3.5 m/s^2 south? (4.0 s)

See page 397

Gravity and Acceleration

- Objects near the surface of Earth fall to Earth due to the force of gravity.
  - Gravity is a pulling force that acts between two or more masses.
- Air resistance is a friction-like force that opposes the motion of objects that move through the air.
- Ignoring air resistance, all objects will accelerate towards Earth at the same rate.
  - The acceleration due to gravity is 9.8 m/s^2 downward.



See pages 398 - 399

Calculating Motion Due to Gravity

- To analyze situation where objects are accelerating due to gravity, use the equations:

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} \qquad \Delta\vec{v} = (\vec{a})(\Delta t) \qquad \Delta t = \frac{\Delta\vec{v}}{\vec{a}}$$

- In these equations, the acceleration ($\vec{a}$) is 9.8 m/s^2 downward.
- Example:
  - Suppose a rock falls from the top of a cliff. What is the change in velocity of the rock after it has fallen for 1.5 s? Assign "down" as negative (-).

$$\Delta\vec{v} = (\vec{a})(\Delta t)$$
$$= (-9.8\,\text{m/s}^2)(1.5\,\text{s})$$
$$= -15\,\text{m/s}$$

Since down is negative (-), the change in the rock's velocity is 15 m/s down.

See page 400

Calculating Motion Due to Gravity

Try the following acceleration due to gravity problems.

1. What is the change in velocity of a brick that falls for 3.5 s?
2. A ball is thrown straight up into the air at 14 m/s. How long does it take for the ball to slow down to an upward velocity of 6.0 m/s?
3. A rock is thrown downwards with an initial velocity of 8.0 m/s. What is the velocity of the rock after 1.5 s?

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} \qquad \Delta\vec{v} = (\vec{a})(\Delta t) \qquad \Delta t = \frac{\Delta\vec{v}}{\vec{a}}$$

See page 400

Answers are on the next slide.

Calculating Motion Due to Gravity (continued)

Try the following acceleration due to gravity problems.

1. What is the change in velocity of a brick that falls for 3.5 s? (34 m/s downward)
2. A ball is thrown straight up into the air at 14 m/s. How long does it take for the ball to slow down to an upward velocity of 6.0 m/s? (0.82 s)
3. A rock is thrown downwards with an initial velocity of 8.0 m/s. What is the velocity of the rock after 1.5 s? (23 m/s downward)

Take the Section 9.2 Quiz

See page 400