**Describing Motion and Calculating Acceleration**

We’ve already learned how to calculate average speed using the formula:

v av = d

 t

We can also use graphs to tell us information about an object’s motion. For now, we will just look at graphs for uniform motion (constant speed)

Distance versus Time Graphs (d vs. t)

* The independent variable is **time**
* The dependent variable is **distance**
* To find the **speed** of an object you must calculate the **slope** of the line on the distance versus time graph
* The steeper the slope, the **faster** the object
* When an object is stopped, the slope of the d vs. t graph is **zero.**

Example 1: The distance versus time graph below shows the motion of a car driving down the TCH. Find the car’s speed.



**Speed versus Time Graphs (v vs. t)**

* The independent variable is **time.**
* The dependent variable is **velocity**.
* The **area** under a speed versus time graph gives total distance traveled.

Example 2: The speed versus time graph below indicates the motion of a motorcycle. How far does the motorcycle travel in 3.0 h?



We can also use graphs to compare the motion of two different objects.

Example 3: Find the speed of each runner.



Example 4: The graph below represents the uniform motion of 2 cars: A and B

**Graph of distance vs. time for two cars**

Use the Graph of distance vs. time for two cars to answer the following questions:

(a) Make a qualitative observation to determine which car is moving faster. Explain.

(b) Determine, quantitatively, which car is moving faster. Show workings.

(c) What has happened to car B after 1.5 hours? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(d) What is the speed of Car B at 2.00 hours? \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

(e) Using the slopes calculated in question # 2, draw a speed-time graph for both cars.



 *Position-Time Graphs*: These graphs will represent displacement. The label on the y-axis will include the direction. The slope can be used to calculate velocity.

**Automobile Trip**

20

16

12

8

4

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| **Displacement****(m)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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 0 2 4 6 8 10 12 14 16 18 20 20

**Time (s)**

**Section A: (0 to 6 s)**

v = d2 – d1 = 12m [N] – 0 m [N] = 2 m/s [N]

 t2 – t1 6s – 0s

**Section B: (6 to 10 s)** The slope is zero so the car has stopped.

**Section C: (10 to 14 s)**

v = d2 – d1 = 2m [S] – 12 m [S] = **-** 3 m/s [S]

 t2 – t1 14s – 10s

**Section D: (14 to 15 s)** The slope is zero so the car has stopped.

**Section E: (15 to 20 s)**

v = d2 – d1 = 20m [N] – 2 m [N] = 3.6 m/s [N]

 t2 – t1 20s – 15s

The slopes (or velocity) from the displacement-time graph can be plotted on a velocity-time graph.

**Automobile Trip**

8

4

0

-4

-8

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| **Velocity****(m/s)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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 0 2 4 6 8 10 12 14 16 18 20 20

**Time (s)**

**Acceleration**

**Textbook Reference**: Section 10.3 and Section 12.5

*Uniform Motion:* This occurs when an object travels at a constant speed. If an object is traveling with uniform motion, its average speed andits instantaneous speed are equal.

*Non-Uniform Motion:* An object travels at different speeds at different times. In this case, the instantaneous speed varied with time. For example, you may speed up to pass a car, or in other words, you are accelerating.

*Acceleration*: The rate of change of speed or velocity. It is calculated by the ratio of the speed (velocity) to the time interval during which the change had occurred.

If the ratio of v is constant, than the acceleration is constant.

 t

If the acceleration varies over time, it is described as average acceleration.

v

Acceleration (a) = v2 – v1 or

 t2 – t1

t

v

Acceleration (a) = v2 – v1 or

 t2 – t1

t

If you recall the velocity-time graph, the slope of a line is the acceleration.

# Velocity-Time

**C**

Line A is shows acceleration.

Line B shows a constant velocity.

Line C shows deceleration.

**B**

**A**

**Velocity**

**Time**

Acceleration Problems

1. If a skier has a change in speed of 3.8 m/s in 1.5 s, what is her acceleration?

a = v = 3.8 m/s = 2.5 m/s2

 t 1.5 s

1. A car with an initial speed of 12 m/s accelerates at 0.62 m/s2  for 15 s. What is the final speed of the car?

a = v = v2 – v1

 t t

Rearrange the formula.

v2 – v1 = a t

v2  = v1 + a t

v2 = 12 m/s + (0.62 m/s2)(15 s) = 21.3 m/s or 21m/s

1. A plane starts from rest and accelerates to a final velocity of 270 km/h[E] in a time of 32 s. What is the airplane’s acceleration?

a = v = v2 – v1 = 270 km/h[E] – 0 = 270 km/h[E] = 75 m/s[E] = 2.3 m/s2

 t t2 – t1  32 s 32 s 32s

Remember: To convert km/ h to m/s, you must divide by 3.6.

 To convert m/ s to km/h, you must multiply by 3.6.

Exercises:

1. A skier is moving at 1.8 m/s (down) near the top of a hill. 4.2 s later she is traveling at 8.3 m/s (down). What is her average acceleration?
2. A jet plane accelerates from rest to 750 km/h in 2.2 min. What is its average acceleration?

1. A skateboarder, traveling at a constant speed, approaches a ramp and accelerates at 0.75 m/s2 for 4.0 s to a final speed of 6.0 m/s. What was the skateboarder’s initial speed?
2. An air puck on an air table is attached to a spring. The puck is fired across the table at an initial velocity of 0.45 m/s [right] and the spring accelerates the air puck at an average acceleration of 1.0 m/s2 [left]. What is the velocity of the air puck after 0.60 s?
3. A person throws a ball straight up from the ground. The ball leaves the person’s hand at an initial velocity of 10.0 m/s [up]. The acceleration of the ball is 9.81 m/s2 [down]. How long does it take the ball to reach a velocity of 10.0 m/s [down]?