Physics 20 Lesson 1 Average Speed

I. Pearson text book reference

For all of the lessons there will be references made to the Physics text by Pearson. The Pearson text book was designed specifically for the Alberta physics curriculum. It is an excellent resource and should be referred to often by you the student. For this lesson refer to page 6.

II. Introduction to Physics 20

The majority of Physics 20 involves the classic work that every physicist has been trained in since the time of Galileo, namely the study of motion. You will learn that physics involves two basic ideas:

1. The ability to describe the physical universe using numbers and equations. (Of course, word descriptions are also used, but the **language** of physics is mathematics.)
2. The physical universe can be understood in terms of some simple laws or principles from which all kinds of phenomena can be described, predicted and understood.

There are three branches of the study of motion:

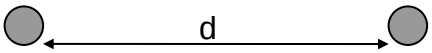
Kinematics is the branch of physics that deals with the *description* of the motion of objects without referring to any forces or agents which may cause the motion.

Dynamics is the branch of physics which attempts to explain the *causes* for the motion that kinematics describes.

Energetics is the branch of physics that deals with the transformation of one kind of energy into another form of energy.

III. Position, Distance and Time

Distance – is the linear space between two points.



The symbol for distance is (d) and the units are: m, cm, km, mm, light years, etc. The standard unit for distance is the meter (m).

Position – for an accurate description of any motion it is necessary to know where an object is relative to a point of reference. For example, 17th avenue is 1 block away from the front doors of Ernest Manning High School. In this case the **reference point** is the front doors of EMHS. Motion or a change in position is always measured relative to some reference point which is referred to as the **origin**. (See Pearson pages 13 and 14 for a discussion on **frames of reference**.)

Time – is the interval between two events. The symbol for time is (t) and the units are: s (seconds), min (minutes), h (hours), a (years). The standard unit for time is the second (s).

IV. Speed

There are two basic types of motion:

Uniform motion – motion which involves constant speed or constant velocity.
Non-uniform motion – motion which involves a change in speed or velocity.

Speed (v) is defined as the rate at which an object is moving.

$$\text{speed} = \frac{\text{change in distance}}{\text{change in time}}$$

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

where v – speed (m/s, cm/s, km/h, etc.)
Δd – change in distance (m, cm, mm, km, etc.)
Δt – change in time (s, min, h, a, etc.)

There are three ways that the term “speed” is used:

Uniform Speed

Uniform speed refers to speed that remains unchanged and constant.

Average Speed

While variations in the actual speed may occur, we can calculate an average speed for the time interval.

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}}$$

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

Instantaneous Speed

Instantaneous speed is the speed of an object at a given *instant* in time.

Example 1

An object travels 510 km in 4.0 h. What was the average speed of the object?

$\Delta d = 510$ km
$\Delta t = 4.0$ h
$v_{ave} = ?$

$$v_{ave} = \frac{\Delta d}{\Delta t} = \frac{510\,km}{4.0\,h} = \textbf{127.5 km/h}$$

Example 2

An object travels 6.5 km in 31 minutes. What was the average speed in m/s?

$\Delta d = 6.5$ km $= 6500$ m
$\Delta t = 31$ min $= 31 \times 60 = 1860$ s
$v_{ave} = ?$

$$v_{ave} = \frac{\Delta d}{\Delta t} = \frac{6500\,m}{1860\,s} = \textbf{3.4 m/s}$$

for conversions remember

1 hour = 60 minutes = 3600 seconds

1 minute = 60 seconds

You may be asked to solve for variables other than average speed. Such questions will involve manipulating formulas.

Example 3

An object travelling at 60 km/h will travel how far in a 20 minute time interval?

$v_{ave} = 60$ km/h
$\Delta t = 20$ min$= 20/60 = 0.33$ h
$\Delta d = ?$

$$v_{ave} = \frac{\Delta d}{\Delta t}$$ (manipulate the formula)

$\Delta d = v_{ave}\,\Delta t = 60$ km/h $\times$ 0.33 h $=$ **20 km**

Example 4

How much time is required for an object travelling at 50 m/s to travel a distance of 6.0 km?

$v_{ave} = 50$ m/s
$\Delta d = 6.0$ km $= 6.0 \times 1000 = 6000$ m
$\Delta t = ?$

$$v_{ave} = \frac{\Delta d}{\Delta t}$$ (manipulate the formula)

$$\Delta t = \frac{\Delta d}{v_{ave}} = \frac{6000\,m}{50\,m/s} = \textbf{1.2 x } \mathbf{10^2}\textbf{ s}$$

Example 5

Convert 40.0 km/h into m/s.

(The difficulty in this conversion is that two factors are being changed at the same time. The method shown below uses unit analysis to eliminate the original units and replacing them with the desired unit.)

$$\frac{40.0\ \cancel{km}}{1\ \cancel{h}} \times \frac{1000\ m}{1\ \cancel{km}} \times \frac{1\ \cancel{h}}{3600\ s} = \mathbf{11.1\ m/s}$$

(A far simpler way to convert km/h to m/s or m/s to km/h is to remember the number **3.6** which comes from 3600/1000. To convert km/h to m/s divide by 3.6. To convert from m/s to km/h multiply by 3.6)

Example 6

An airplane travels 1800 km at a speed of 1000 km/h. It then encounters a headwind that slows the plane to 850 km/h for the next 2300 km. What was the plane's average speed?

(Some people may feel inclined to just average 850 km/h and 1000 km/h directly. However, since the speeds apply to different distances and times, they cannot be averaged directly.)

For average speed we need the total time and the total distance:

$$\Delta t_1 = \frac{\Delta d}{v_{ave}} = \frac{1800 km}{1000 km/h} = 1.8\ h \qquad \Delta t_1 = \frac{\Delta d}{v_{ave}} = \frac{2300 km}{850 km/h} = 2.71\ h$$

$\Delta t = 1.8\ h + 2.71\ h = 4.51 h$

$\Delta d = 1800\ km + 2300\ km = 4100\ km$

$$v_{ave} = \frac{\Delta d}{\Delta t} = \frac{4100 km}{4.51 h} = \mathbf{910\ km/h}$$

V. More difficult problems

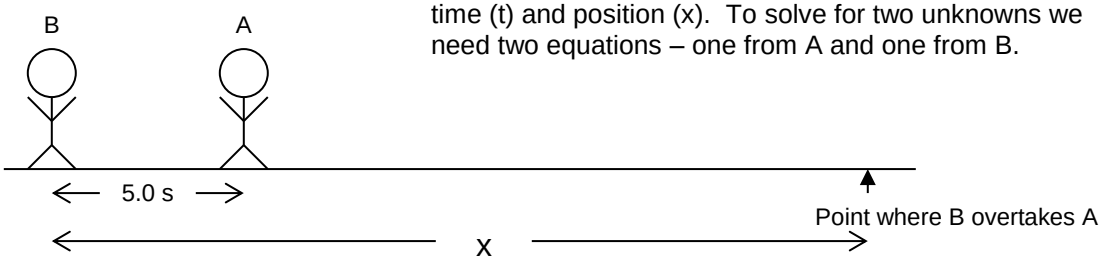
Some problems are not easy, in fact they can be quite difficult. In the following example there are two unknowns that must be solved for. One equation is sufficient to calculate one unknown. For two unknowns, two equations are required.

Example 7

Two roller bladers, A and B, are having a race. B gives A a head start of 5.0 s. Each roller blader moves with a constant speed in the same direction. If A travels at 5.0 m/s and B travels at 7.5 m/s:

a. How long will it take for B to catch A?
b. At what position will B catch up with A?

To solve this problem we need to first recognise that there are two unknowns to solve for at the same time: time (t) and position (x). To solve for two unknowns we need two equations – one from A and one from B.



Both A and B will skate a distance x from the origin.

If we call the time that A travels t

$\Delta t_A = t$

then roller blader B will be moving for 5.0 s less. Therefore,

$\Delta t_B = t - 5.0$

For roller blader A:

$$v_A = \frac{\Delta d_A}{\Delta t_A}$$

$$5.0\,\text{m/s} = \frac{x}{t}$$

$x = 5.0\,t$ (1^{st} equation)

For roller blader B:

$$v_B = \frac{\Delta d_B}{\Delta t_B}$$

$$7.5\,\text{m/s} = \frac{x}{t-5}$$

$x = 7.5\,(t - 5)$ (2^{nd} equation)

To solve the equations we combine them by substituting equation 1 into equation 2.

$5.0\,t = 7.5\,(t - 5)$
$5.0\,t = 7.5\,t - 37.5$
$-2.5\,t = -37.5$

$$t = \frac{-37.5}{-2.5}$$

$t =$ **15 s**

To calculate the position we substitute t = 15 s into either equation 1 or 2.

$x = 5.0\,t$
$x = 5.0\,(15\text{ s})$
$x =$ **75 m**

To summarise, B will catch A 10 s after A started at a distance of 75 m from the origin.

VI. Practice Problems

1. If an object can travel at 30 m/s, how long will it take for the object to travel 700 cm? (0.23 s)

2. You run 100 m at a speed of 5.0 m/s and then you walk 100 m at a speed of 1.0 m/s. What was your average speed? (1.67 m/s)

*3. Bill is 35.0 m away from Tom. Both men walk in the same direction. Bill walks at 1.65 m/s and Tom walks at 1.85 m/s. From where they began, how far does Tom walk before he catches up with Bill? How long does it take for Tom to catch Bill? (324 m, 175 s)

VII. Hand-In Assignment

Format for solving problems:

- Solutions are written on a separate sheet of paper.
- List the data or provide a diagram.
- Write the appropriate equation.
- Plug-in the numbers with the correct units.
- The answer must have the correct unit attached to it.

1. What distance does a car travel in 75 minutes if it travels with an average speed of 75 km/h during this time? (94 km)
2. A bean plant grows at 3.858×10^{-5} cm/s. How much will it grow in three days? (10.00 cm)
3. If light travels at 3.0×10^{8} m/s, how long will it take for light to travel from the sun to the Earth which is a distance of 1.5×10^{8} km away? (500 s)
4. A man walks 200 m at a speed of 1.5 m/s and then he runs the remaining 300 m at 3.0 m/s to a store. How long does it take him to travel the total distance? What is his average speed for the journey? (2.3×10^{2} s, 2.1 m/s)
5. A man walks for 25 s at a speed of 1.5 m/s and then runs for 40 s at 3.0 m/s. How far does the man travel? What was his average speed? (157.5 m, 2.4 m/s)
6. A rhinoceros sees a group of American tourists 700 m away. The tourists are wearing fake safari hats. The rhinoceros hates fake safari hats. The rhinoceros rambles toward them for 500 m at a speed of 2.5 m/s and then charges for 200 m at a speed of 6.5 m/s. If the tourists need to get into their safari jeep to escape the rhinoceros, how long do they have to make it to safety? What was the rhinoceros' average speed? (2.3×10^{2} s, 3.0 m/s)
7. A turtle and a hare enter a race. How far apart will the two be after 4.5 min if the turtle has a top cruising speed of 0.25 m/s and the hare blazes along at 5.0 m/s? (1.3 km)
8. Jake the snake can slither at 125 cm/s and Mack the rat can run at 200 cm/s. If they start at the same point, how far apart will they be after 5.0 s if they both run in the same direction? (375 cm)
9. If Jake the snake's tail is 345 cm from a hole and he slithers under stress at 150 cm/s, can Mickey the mongoose catch him before he escapes? Mickey can move at 450 cm/s and he starts at 10.8 m from the hole. (he escapes)
10. Jack the jaguar can run for only 1.0 min at 13.0 m/s before he has to stop to rest, while Zeke the zebra can gallop at 7.25 m/s for 5.0 min. How long does Zeke actually have to run for to elude Jack? Can Jack catch Zeke for lunch if they are initially 350 m apart? Why is this scenario very unlikely in the real world? (Zeke escapes)
11. Mr. Licht is standing 50 m from a large bell. With his mighty throwing arm, Mr. Licht throws a rock at the bell and he hears the sound of the bell 4.5 s later. If the speed of sound is 330 m/s, what was the speed of the rock in the air? (11.5 m/s)

*12. A British Concorde (BC) and a French Concorde (FC) flew in opposite directions around the earth (40 000 km). The BC covered half of its flight distance at a supersonic speed of 2500 km/h and the other half at a subsonic speed of 1000 km/h. The FC spent half of its flight time at 2500 km/h and the other half at 1000 km/h. Which Concorde completed the trip first, and by how many hours did it beat the other? (5.14 h)

*13. Two trains, one starting in Calgary and the other in Edmonton, travel toward one another. The Edmonton train travels at 120 km/h toward Calgary, while the Calgary train travels at 140 km/h toward Edmonton. If the trains begin at the same time and Edmonton and Calgary are 285 km apart, how far from Calgary will the trains pass each other? (153 km)