Physics 4A
Chapter 1: Concepts of Motion

"Anyone who has never made a mistake has never tried anything new." – Albert Einstein

"Experience is the name that everyone gives to his mistakes." – Oscar Wilde

"The only real mistake is the one from which we learn nothing." – John Powell

"An expert is a person who has made all the mistakes that can be made in a very narrow field."
Niels Bohr

Reading: pages 1 – 27

Outline:

⇒ motion diagrams
    the particle model
⇒ position, time, and displacement
⇒ scalars and vectors
⇒ velocity and acceleration
⇒ one-dimensional motion
    position-time graphs
⇒ solving problems in physics
⇒ units and significant figures
    scientific notation / powers of ten (read on your own and included below)
    significant figures (read on your own and included below)
    prefixes
    unit conversion

Mathematical Skills

Powers of 10 arithmetic.

Powers of ten arithmetic is handled automatically by your calculator. Nevertheless you should have some facility with the process. It will help you check on the result your calculator displays and thus see if you keyed the numbers in correctly. In many cases you can estimate an answer by approximating the input numbers to the nearest power of ten and carrying out the calculation in your head.

When you multiply two numbers expressed as powers of ten, multiply the numbers in front of the tens, then multiply the tens themselves. This last operation is carried out by adding the powers. Thus, $(1.6\times10^3) \times (2.2\times10^2) = (1.6\times2.2)\times(10^3\times10^2) = 3.5\times10^5$ and $(1.6\times10^3)\times(2.2\times10^{-2}) = (1.6\times2.2) \times (10^3\times10^{-2}) = 3.5\times10 = 35$.

When you divide two numbers, divide the numbers in front of the tens, then divide the tens. The last operation is carried out by subtracting the power in the denominator from the power in the numerator. Thus, $(1.6\times10^3)/(2.2\times10^2) = (1.6/2.2)\times(10^3/10^2) = 0.73\times10 = 7.3$ and $(1.6\times10^3)/(2.2\times10^{-2}) = (1.6/2.2)\times(10^3/10^{-2}) = 0.73\times10^5 = 7.3\times10^4$.

When you add or subtract two numbers, first convert them so the powers of ten are the same, then add or subtract the numbers in front of the tens and multiply the result by 10 to the common power. Thus, $1.6\times10^3 + 2.2\times10^2 = 1.6\times10^3 + 0.22\times10^3 = 1.8\times10^3$.

This means you must know how to write the same number with different powers of ten. Remember that multiplication by 10 is equivalent to moving the decimal point one digit to the right and division by 10 is equivalent to moving the decimal point one digit to the left. Thus, $1.6\times10^3 = 16\times10^2 = 0.16\times10^4$. In the first case we multiplied 1.6 by 10 and divided 10^3 by 10. In the second we divided 1.6 by 10 and multiplied 10^3 by 10.

You should be able to verify the following:

$512\times10^2 = 5.12\times10^4$

$0.00512 = 5.12\times10^{-3}$

$(3.4\times10^2)\times (2.0\times10^4) = 6.8\times10^6$

$(3.4\times10^2)/(2.0\times10^4) = 1.7\times10^{-2}$

$(3.4\times10^4) + (2.0\times10^3) = (3.4\times10^4) + (0.20\times10^4) = 3.6\times10^4$

Significant digits.

Always express your answers to problems using the proper number of significant digits. Some students unthinkingly copy all 8 or 10 digits displayed by their calculators, thus demonstrating a lack of understanding. A calculated value cannot be more precise than the data that went into the calculation. Here is what you must remember about significant digits:

a. Leading zeros are not counted as significant. Thus, 0.00034 has two significant digits.
b. Following zeros after the decimal point count. Thus, 0.000340 has three significant digits.
c. Following zeros before the decimal point may or may not be significant. Thus, 500 might contain one, two, or three significant digits. Use powers of ten notation to avoid ambiguities: 5.0×10^2, for example, unambiguously contains two significant digits.
d. When two numbers are added or subtracted, the number of significant digits in the result is obtained by locating the position (relative to the decimal point) of the least significant digit in the numbers that are added or subtracted. The least significant digit of the result is at the same position.
e. When two numbers are multiplied or divided, the number of significant digits in the result is the same as the least number of significant digits in the numbers that are multiplied or divided.

Geometry.

You should be familiar with the following geometric concepts:

a. The circumference of a rectangle is given by $2(a + b)$, where a and b are the lengths of its sides.
b. The area of a rectangle is given by ab.
c. The area of a triangle is given by $\frac{1}{2} lh$, where l is the length of one side and h is the length of the perpendicular line from that side to the vertex opposite that side (the altitude).
d. The volume of a rectangular solid is given by abc, where a, b, and c are the lengths of its sides. The volume of a cube is given by a^3, where a is the length of one of its sides.
e. The circumference of a circle is given by $2\pi r$, where r is its radius. The value of π is about 3.14159.
f. The area of a circle is πr^2.
g. The surface area of a sphere is given by $4\pi r^2$.
h. The volume of a sphere is given by $4/3\pi r^3$.
i. The area of the curved surface of a right circular cylinder is the product of the circumference of an end and the cylinder length: $2\pi rl$. The ends are circles and each has an area of πr^2.
j. The volume of a right circular cylinder is the product of the area of an end and the length: $\pi r^2 l$.

Carefully note that all circumferences have units of length, all areas have units of length squared, and all volumes have units of length cubed.

General Problem-Solving Techniques from Halliday, Resnick, and Walker

1. Read the problem carefully and all the way through.

2. Reread the problem one sentence at a time and draw a sketch or diagram to help you visualize what is happening.

3. Write down and organize the given information. Some of the information can be written in labels on the diagram. Be sure that the labels are unambiguous. Identify in the diagram the object, the position, the instant of time, or the time interval to which the quantity applies. Sometimes information might be usefully written in a table beside the diagram. Look at the wording of the problem again for information that is implied or stated indirectly.

4. Identify the goal of the problem. What quantities need to be found?

5. If possible, make an estimate to determine the order of magnitude of the answer. This estimate is useful as a check on the final result to see if it is reasonable.

6. Think about how to get from the given information to the final desired information. Do not rush this step. Which principles of physics can be applied to the problem? Which will help get to the solution? How are the known and unknown quantities related? Are all of the known quantities relevant, or might some of them not affect the answer? Which equations are relevant and may lead to the solution to the problem? This step requires skills developed only with much practice in problem solving.

7. Frequently, the solution involves more than one step. Intermediate quantities might have to be found first and then used to find the final answer. Try to map out a path from the given information to the solution. Whenever possible, a good strategy is to divide a complex problem into several simpler subproblems.

8. Perform algebraic manipulations with algebraic symbols (letters) as far as possible. Substituting the numbers in too early has a way of hiding mistakes.

9. Finally, if the problem requires a numerical answer, substitute the known numerical quantities, *with their units,* into the appropriate equation. Leaving out the units is a common source of error. Writing the units shows when a unit conversion needs to be done-and also may help identify an algebra mistake.

10. Once the solution is found, don't be in a hurry to move on. Check the answer is it reasonable? Try to think of other ways to solve the same problem. Many problems can be solved in several different ways. Besides providing a check on the answer, finding more than one method of solution deepens our understanding of the principles of physics and develops problem-solving skills that will help solve other problems.

GENERAL STRATEGY

Problem Solving

MODEL Make simplifying assumptions.

VISUALIZE Use:

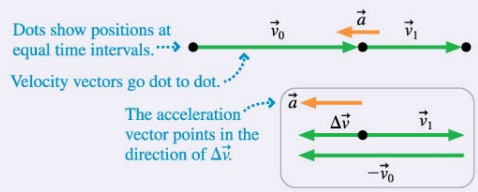
- **Pictorial representation**
- **Graphical representation**

SOLVE Use a **mathematical representation** to find numerical answers.

ASSESS Does the answer have the proper units and correct significant figures? Does it make sense?

Motion Diagrams

- Help visualize motion.
- Provide a tool for finding acceleration vectors.



► These are the *average* velocity and acceleration vectors.

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IMPORTANT CONCEPTS

The **particle model** represents a moving object as if all its mass were concentrated at a single point.

Position locates an object with respect to a chosen coordinate system. Change in position is called **displacement.**

Velocity is the rate of change of the position vector $\vec{r}$.

Acceleration is the rate of change of the velocity vector $\vec{v}$.

An object has an acceleration if it

- Changes speed and/or
- Changes direction.

Pictorial Representation

❶ Draw a motion diagram.

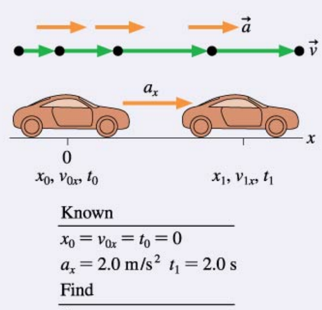
❷ Establish coordinates.

❸ Sketch the situation.

❹ Define symbols.

❺ List knowns.

❻ Identify desired unknown.



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APPLICATIONS

For **motion along a line:**

- Speeding up: $\vec{v}$ and $\vec{a}$ point in the same direction, v_x and a_x have the same sign.
- Slowing down: $\vec{v}$ and $\vec{a}$ point in opposite directions, v_x and a_x have opposite signs.
- Constant speed: $\vec{a} = \vec{0}$, $a_x = 0$.

Acceleration a_x is positive if $\vec{a}$ points right, negative if $\vec{a}$ points left. The sign of a_x does *not* imply speeding up or slowing down.

Significant figures are reliably known digits. The number of significant figures for:

- **Multiplication, division, powers** is set by the value with the fewest significant figures.
- **Addition, subtraction** is set by the value with the smallest number of decimal places.

The appropriate number of significant figures in a calculation is determined by the data provided.

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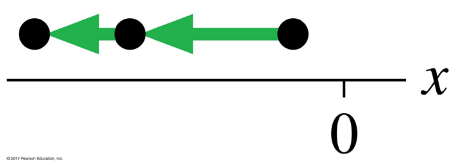
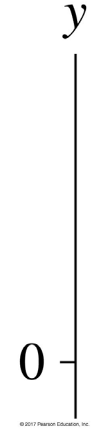
Conceptual Questions and Example Problems from Chapter 1

Conceptual Question 1.6
Determine the signs (positive, negative, or zero) of the position, velocity, and acceleration for the particle in the figure below.



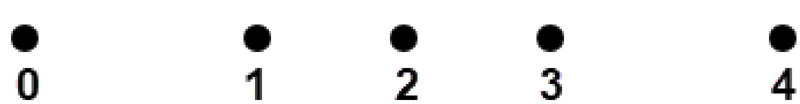
Conceptual Question 1.8
Determine the signs (positive, negative, or zero) of the position, velocity, and acceleration for the particle in the figure to the right.



Problem 1.3
You are watching a jet ski race. A racer speeds up from rest to 70 mph in just a few seconds, then continues at a constant speed. Draw a basic motion diagram of the jet ski, using images from the video, from 10 s before reaching top speed until 10 s afterward.

Problem 1.7
A softball player slides into second base. Use the particle model to draw a motion diagram showing his position and his average velocity vectors from the time he begins to slide until he reaches the base.

Problem 1.9
The figure below shows the first five points of a motion diagram. Use Tactics Box 1.3 to find the average acceleration vectors at points 1, 2, and 3. Draw the completed motion diagram showing the velocity vectors and acceleration vectors.



Problem 1.16
A roof tile falls straight down from a two-story building. It lands in a swimming pool and settles gently to the bottom. Draw a complete motion diagram of the tile.

Problem 1.25
Convert the following to SI units:

a) 75 in

b) 3.45×10^6 yr

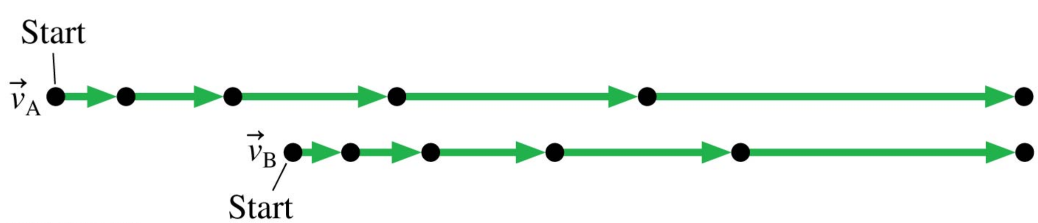
c) 62 ft/day

d) 2.2×10^4 mi^2

Problem 1.38
A speed skater moving across frictionless ice at 8.0 m/s hits a 5.0-m-wide patch of rough ice. She slows steadily, then continues on at 6.0 m/s. What is her acceleration on the rough ice? (Draw a complete pictorial representation. Do not solve these problems or do any mathematics.)

Problem 1.42
Ice hockey star Bruce Blades is 5.0 m from the blue line and gliding toward it at a speed of 4.0 m/s. You are 20 m from the blue line, directly behind Bruce. You want to pass the puck to Bruce. With what speed should you shoot the puck down the ice so that it reaches Bruce exactly as he crosses the blue line? (Draw a complete pictorial representation. Do not solve these problems or do any mathematics.)

Problem 1.52
For the motion diagram shown below, (a) Complete the motion diagram by adding acceleration vectors (b) Write a physics problem for which this is the correct motion diagram. (c) Draw a pictorial representation for your problem.



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