Physics 2A
Chapter 1: Representing 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 2 - 24

Outline:

⇒ introduction to motion
- motion diagrams
- the particle model
- position and coordinate systems

⇒ velocity
⇒ significant figures (read on your own - covered in PLC #2 and included below)
⇒ scientific notation (read on your own and covered below)
⇒ units (SI)
- base and derived units
- prefixes
- converting units

⇒ estimation (read on your own)
⇒ vectors
- introduction to vectors
- vector addition
- vectors and trigonometry
- velocity vectors

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
$(1.6\times10^3) \times (2.2\times10^{-2}) = (1.6\times2.2) \times (10^3\times10^{-2}) = 3.5 \times 10 = 35$.

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, $(1.6\times10^3) / (2.2\times10^2) = (1.6/2.2) \times (10^3/10^2) = 0.73 \times 10 = 7.3$ and $(1.6\times10^3)/ (2.2\times10^{-2}) = (1.6/2.2) \times (10^3/10^{-2}) = 0.73 \times 10^5 = 7.3\times10^4$.

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.

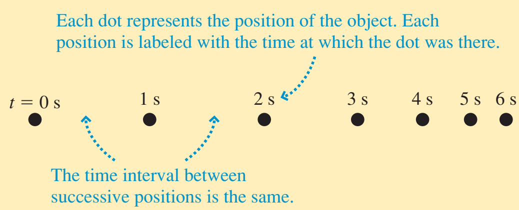
SUMMARY

The goals of Chapter 1 have been to introduce the fundamental concepts of motion and to review the related basic mathematical principles.

IMPORTANT CONCEPTS

Motion Diagrams

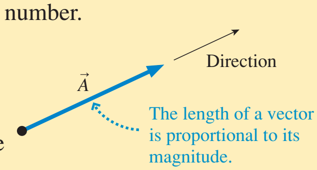
The **particle model** represents a moving object as if all its mass were concentrated at a single point. Using this model, we can represent motion with a **motion diagram,** where dots indicate the object's positions at successive times. In a motion diagram, the time interval between successive dots is always the same.



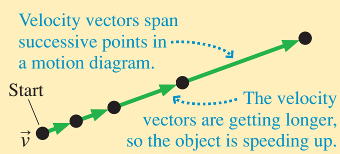
Scalars and Vectors

Scalar quantities have only a magnitude and can be represented by a single number. Temperature, time, and mass are scalars.

A **vector** is a quantity described by both a magnitude and a direction. Velocity and displacement are vectors.

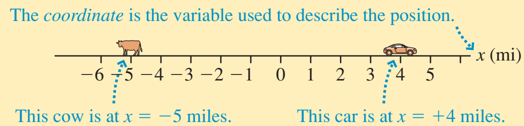


Velocity vectors can be drawn on a motion diagram by connecting successive points with a vector.



Describing Motion

Position locates an object with respect to a chosen coordinate system. It is described by a **coordinate.**



A change in position is called a **displacement.** For motion along a line, a displacement is a signed quantity. The displacement from x_i to x_f is $\Delta x = x_f - x_i$.

Time is measured from a particular instant to which we assign $t = 0$. A **time interval** is the elapsed time between two specific instants t_i and t_f. It is given by $\Delta t = t_f - t_i$.

Velocity is the ratio of the displacement of an object to the time interval during which this displacement occurs:

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

Units

Every measurement of a quantity must include a **unit.**

The standard system of units used in science is the **SI system.** Common SI units include:

- Length: meters (m)
- Time: seconds (s)
- Mass: kilograms (kg)

APPLICATIONS

Working with Numbers

In **scientific notation,** a number is expressed as a decimal number between 1 and 10 multiplied by a power of ten. In scientific notation, the diameter of the earth is 1.27×10^7 m.

A **prefix** can be used before a unit to indicate a multiple of 10 or 1/10. Thus we can write the diameter of the earth as 12,700 km, where the k in km denotes 1000.

We can perform a **unit conversion** to convert the diameter of the earth to a different unit, such as miles. We do so by multiplying by a conversion factor equal to 1, such as 1 = 1 mi/1.61 km.

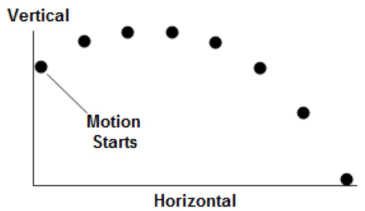
Significant figures are reliably known digits. The number of significant figures for:

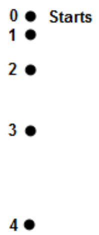
- **Multiplication, division, and powers** is set by the value with the fewest significant figures.
- **Addition and subtraction** is set by the value with the smallest number of decimal places.

An **order-of-magnitude estimate** is an estimate that has an accuracy of about one significant figure. Such estimates are usually made using rough numbers from everyday experience.

Questions and Example Problems from Chapter 1

Question 1
For each motion diagram, write a short description of the motion of an object that will match the diagram. Your descriptions should name specific objects.





Question 2
Your roommate drops a tennis ball from a third-story balcony. It hits the sidewalk and bounces as high as the second story. Draw a motion diagram, using the particle model, showing the ball's velocity vectors from the time it is released until it reaches the maximum height on its bounce.

Problem 1
Interpret the following problem by drawing a motion diagram showing the object's position and its velocity vectors. Do *not* solve this problem or do any mathematics.

A motorist is traveling at 20 *m/s.* He is 60 m from a stop light when he sees it turn yellow. His reaction time, before stepping on the brake, is 0.50 s. What steady deceleration while braking will bring him to a stop right at the light?

Problem 2
A car travels along a straight east-west road. A coordinate system is established on the road, with x increasing to the east. The car ends up 14 mi west of the intersection with Mulberry Road. If its displacement was -23 mi, how far from and on which side of Mulberry Road did it start?

Problem 3
Keira starts at position x = 23 m along a coordinate axis. She then undergoes a displacement of -45 m. What is her final position?

Problem 4
Alberta is going to have dinner at her grandmother's house, but she is running a bit behind schedule. As she gets onto the highway, she knows that she must exit the highway within 45 min if she is not going to arrive late. Her exit is 32 mi away. What is the slowest speed at which she could drive and still arrive in time? Express your answer in miles per hour.

Problem 5
It takes Harry 35 s to walk from x= - 12 m to x= - 47 m. What is his velocity?

Problem 6
In the United States, we often use miles per hour (mi/h) when discussing speed, while the SI unit of speed is m/s. What is the conversion factor for changing m/s to mi/h? If you want to make a quick approximation of the speed in mi/h given the speed in m/s, what might be the easiest conversion factor to use?

Problem 7
Convert the following to SI units: a) 8.0 in b) 66 ft/s

Problem 8

List the following three speeds in order, from smallest to largest: 1 mm per /μs, 1 km per ks, 1 cm per ms.

Problem 9

Estimate the average speed at which your fingernails grow, in both m/s and um/h. Briefly describe how you arrived at this estimate.

Problem 10

A city has streets laid out in a square grid, with each block 135 m long. If you drive north for three blocks, then west for two blocks, how far are you from your starting point?

Problem 11
A ball on a porch rolls 60 cm to the porch' s edge, drops 40 cm, continues rolling on the grass, and eventually stops 80 cm from the porch's edge. What is the magnitude of the ball 's net displacement, in centimeters?

Problem 12
What is the value of each of the angles of a right triangle whose sides are 100, 150, and 180 cm in length?

Problem 13
An ocean liner leaves New York City and travels 18.0^{o} north of east for 155 km. How far east and how far north has it gone. In other words, what are the magnitudes of the components of the ships displacement vector in the directions (a) due east and (b) due north?