PHYS I

Chapter 1:

Introduction to Physics

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Significant Figures & Scientific Notation

I. **Significant Digits:** Physics is rooted in experiment, and experimental measurements have limited precision. We communicate the extent of a measurement's precision by the number of significant digits used to represent the measurement. Below are some useful rules for determining how many significant digits there are in a number.

a. For numbers without a decimal, any zeroes to the right of the last nonzero integer are not significant.

How many significant figures are in 130500?
$1305\cancel{00} \Longrightarrow$ 4 significant digits

b. For numbers with a decimal, any zeroes to the left of the first nonzero integer are not significant.

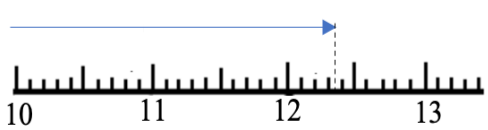
How many significant figures are in 0.0056078?
$\cancel{0.00}56078 \Longrightarrow$ 5 significant digits

Example: Determine the number of significant digits for the following values.

0.02	1030	0.00629000	880,000
________	__________	____________	___________

II. **Significant Figures in the Lab:** When creating lab reports, to communicate the precision of a given measurement correctly, we only include the significant digits that we are confident in. It is standard practice also to include an additional digit beyond those with confidence, which acts as an extension to the lab equipment's precision resulting from the experimentalist's ability to approximate.

a. For example, suppose that after calculating the length of an arrow we determine it to be 0.12345678 meters long. If we used a meter stick to measure lengths for the calculation, then the number in our calculator suggests a greater degree of precision than we actually have, because the smallest measurement a meter stick can make is in millimeters. Therefore, we would report the arrow's length as 0.1234 m, indicating that the "confidence level" is 4 significant digits.



(Finest division is in mm)

III. Significant Figures and Math: For math operations, make sure that you don't round to significant figures until after you've performed the operation. Also, be aware that multiplication/division has a different rule than addition/subtraction.

a. For multiplication and division, the result must contain the same number of sig figs as the value in the operation with the fewest sig figs.
b. For addition and subtraction, the result must contain the same number of decimal places as the value in the operation with the fewest decimal places.
c. NOTE: When doing long calculations, DO NOT round numbers until you get to the final answer. Carry all numbers out at least 3 decimal places to avoid rounding errors.

Example: Report the solution to the following problems, rounded to the appropriate number of significant figures.

1. (2.3004560) X (20.3) = _______________
2. (123.2987) + (2.31556) = _________________
3. (400.6778) ÷ (5.778) = _______________
4. (567.889) + (577.23) – (4.89999) = _________________

IV. A number is written in **scientific notation** when in the form $a \times 10^n$ where $1 \leq |a| < 10$ and n is an integer. Scientific notation is used to make very large or very small numbers with lots of zeros, like 18,300,000,000, more compact by writing them as a product of a power of 10.

a. Problem-solving process:
   i. Move the decimal of your number so that it has a value between 1 and 10.
   ii. Multiply the value you are left with by 10^n, where n is the number of times you moved the decimal. If the decimal had to be moved to the left, make n positive and make n negative if the decimal had to be moved to the right.

Example: Write the following numbers in scientific notation.

1. 2000.0 ⇒ ________________
2. 0.000807 ⇒ _________________
3. 0.00000783 ⇒ ________________
4. 931.4 ⇒ __________________

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Unit Conversion

I. **SI Units:** Often when working problems, you will have to convert to SI (International System) units. It is helpful to convert all numerical quantities to SI units before you start each problem.

a. Here are the SI units for a few dimensions that you will see in your first physics problems.

Mass, m ⇒ Kilograms (kg) Time, t ⇒ Seconds (s) Length, x ⇒ Meters (m)

b. $1 \text{ kilogram} = 1{,}000 \text{ grams}$, where the "gram" is the base unit (NOT the SI unit) for mass. There are many other prefixes used to denote multiples of a given SI base unit. The following table provides a few of the most important ones:

Name	**Symbol**	**Multiplication Factor**
kilo	k	10^3
mega	M	10^6
giga	G	10^9
tera	T	10^{12}

deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}

Example: Convert the following quantities.

1. 81 grams to kilograms
2. 13 days to seconds
3. 1 cubic centimeter (1 cm^3) to 1 cubic meter (1 m^3)
4. 1200 cm/min to m/s
5. 0.5 in/month to ft/year

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Dimensions, Dimensional Consistency, & Manipulating Physics Equations

I. **Dimensions:** Only variables with the same dimensions can be added, subtracted, or compared.
   a. It makes sense to compare 5 inches to 3 meters (comparing two variables with length dimensions), but it does not make sense to compare 15 seconds to 20 kilograms (comparing a variable with time dimension to a variable with mass dimension).

II. **Forming new dimensions:** ALL dimensions can be multiplied together and raised to an integer following the regular rules of algebra to form new dimensions.
   a. For example, $\mathrm{time}^{-1} = 1/\mathrm{time}$ means *something* per amount of time, so we can identify this dimension as a rate.
   b. $\mathrm{length} \cdot \mathrm{time}^{-1} = \mathrm{length}/\mathrm{time}$ means a *length* per amount of time, so we identify this dimension as speed.
   c. Here are some common dimensions that can be formed with the basic dimensions you already know:

Quantity	**Dimension**
Area	Length^2
Volume	Length^3

Velocity	Length/Time
Acceleration	Length/Time^2
Energy	Mass*Length^2/Time^2

III. **Dimensional consistency:** Physics equations contain variables on either side of an "equal" sign, which means that the left and right sides must be equal. This means:
   a. Both sides of an equation must have the same dimension.
   b. Any terms that are being added or subtracted from each other on either side must have the same dimension.
   c. <u>Note</u>: any equation that is not dimensionally consistent must be wrong!

<u>Example:</u> What are the correct units of a, b, and c so that the following equation is dimensionally consistent?

$$v = at^3 + bx^2 + cxt^2$$

What are the SI units of the following variables?

v = ___________ t = ___________ x = ____________

Now find SI units for a, b, and c:

a = ___________ b = ___________ c = ____________

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Example: Which of the following equations are dimensionally consistent?

1. $t = \frac{2a}{v}$
2. $v^2 = ax$
3. $v = at$
4. $x = \frac{v}{a}$
5. $3t = \left(\frac{x}{a}\right)^{\frac{1}{2}}$
6. $v = \frac{at^2}{4}$

IV. Equations: Given a physics equation, we can use the rules of algebra to solve for any variable of interest.

Example: Use algebra to solve this equation for time, t.

$$v_{\mathrm{f}} = v_0 + at$$

Example: Solve for final position, x_{f}.

$$v = \frac{(x_{\mathrm{f}} - x_0)}{(t_{\mathrm{f}} - t_0)}$$

Example: Solve for acceleration, a.

$$y_{\mathrm{f}} = y_0 + v_0 t + \frac{1}{2} a t^2$$

Example: Solve for initial velocity, v_0.

$$v_{\mathrm{f}}^2 = v_0^2 + 2a(x_{\mathrm{f}} - x_0)$$

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Scalars and Vectors

I. Describing Physical Factors: In physics, we study physical factors like temperature, position, velocity, and height. One way we classify these factors is by deciding whether or not it makes sense to assign them a certain direction in space. For instance, does it make sense to assign a direction to a temperature reading, like 32°C? No! However, it does make sense to assign a direction to the speed a car is traveling. We use the terms scalar and vector to make this distinction.

- **a.** A **Scalar** is a quantity with a magnitude with no standard direction. Scalars are always expressed as positive values. Examples of scalars are temperature, color, and mass.
- **b.** A **Vector** is a quantity with a magnitude and direction in space. Vectors can be expressed as negative or positive depending on your coordinate system. Examples of vectors are displacement, velocity, and acceleration.
- **c.** **Note**: Speed and velocity are easy to confuse. Speed is simply how fast the object is moving; if you're in a car, your speed is shown on your speedometer. An object's velocity is its speed value with a direction attached to it. So, your speed is 65 mph, but your velocity is 65 mph, travelling north.

Example: Determine whether a vector or a scalar quantity would best describe the following physical factors.

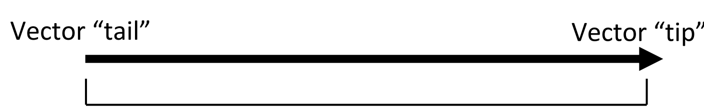
1. The speed limit on a highway
2. The amount of matter in a star
3. The change in position of an ant on a picnic blanket.
4. The change in position of the hands of a clock.

II. Describing Scalars: Because scalar quantities do not have a direction, describing them only requires you to specify the magnitude of the quantity.

- **a.** For example, you only need a number and a unit to communicate temperature, as in "the temperature of the oven is **204°C**", and to communicate mass, as in "my cat has a mass of **6.8 kg**".

III. Describing Vectors: In order to describe a vector quantity correctly, we need some method to communicate both the magnitude and the unique direction of the quantity.

- **a.** To visualize vector quantities, we usually imagine them as **arrows** with lengths determined by the **magnitude** of the vector quantity (a greater magnitude corresponds to a greater length) and direction determined by the **direction** of the vector.



This length represents the vector's **magnitude**.

b. For example, if a car is driving northeast at 5 m/s, we could use the arrow below to represent the car's velocity. Here we let 1 cm be equivalent to 1 m/s, so the arrow should be drawn 5 cm long (**magnitude**) and based on the compass provided, the arrow is pointing northeast (**direction**).

c. We specify that a variable is a vector by putting a small "half arrow" above it. For example, since velocity is a vector, its symbol is $\vec{v}$.

V. Vector Notation: Although arrows are great at helping us visualize vectors, it would get too complicated to draw vector quantities as arrows when carrying out calculations. So, we need to come up with a more convenient, coordinate-based system for representing vectors.

a. <u>For now</u>, we are only going to consider one-dimensional motion, that is, motion that takes place along a straight line. Here is the problem-solving process for 1D motion:

i. Draw a coordinate axis (typically a dotted line) parallel to the 1D motion. If the motion is horizontal, this axis is usually called the **x-axis**. If the motion is vertical, this axis is usually called the **y-axis**.

ii. Define one end of the axis as positive and the other as negative. Typically, we set the left side of the x-axis as negative and the right as positive, and the top of the y-axis as positive and the bottom as negative. However, as long as you are consistent, you can flip these.

iii. The vector can then be represented as a magnitude paired with a sign (**+, -**). We write the vector as a positive quantity if it points toward the positive end of the coordinate axis, and as a negative quantity if it points toward the negative end of the coordinate axis.