PHYSICS (H) ***Summer Assignment***

Welcome to Physics (H) - Syracuse University Project Advance (SUPA).

The honors-level physics course is a calculus-based course which includes the major areas of study of mechanics, electricity-magnetism, and modern physics. A co-requisite of calculus is a requirement. Students need to have a proficiency in algebra. The calculus portion of the course will be on calculus applications. Any needed calculus techniques will be taught during the course. Students will have the opportunity to register with Syracuse University for the first semester of the course (mechanics) and receive 4 S.U. credits. Tuition is $115 per credit.

Since we have so much to cover during the year, the preliminary unit, Introduction to Physics, will be covered through your summer assignment. You should find most of the material to be a review of topics covered in prior science and math courses. The material is fairly easy and straightforward; the goal is to achieve mastery of the basic concepts and skills needed throughout the course. There is also a practice quiz, along with solutions, which you can use to check your level of understanding.

During the first few days of class, there will be an opportunity to ask questions about things you did not understand. I will also be available after school. The assignment will be collected on the first day of class. You will be evaluated on the completeness and quality of your assignment (a project grade). The assignment will be returned to you on the following day along with a solution key. This will give you the opportunity to check through your answers and to ask about anything you did not understand. A double-value quiz on this material (similar to the practice quiz) will be given during the first two weeks of school.

Carefully read each of the following seven sections and then on separate paper answer the questions and problems which follow each section. Show work for all problems. Neat handwritten work is fine (not necessary to type.)

Materials you will need for the <u>start</u> of the course include:

- a notebook (your choice of type); you will need this every day
- a <u>bound</u> composition book (not a spiral notebook) to be used as a lab notebook
- a calculator (scientific calculator or a graphing calculator); you will need this every day
- a protractor and a ruler; these can be left at home

If you have any questions concerning this assignment, please contact Mr. Rogers (E-mail: rrogers@vtsd.com Phone: (973) 764-2960)

Join the Physics Remind
Text @vtsupaphys to 81010

PHYSICS

CONVERSION FACTORS

Time
1 day = 1.44×10^3 min = 8.64×10^4 s
1 yr = 8.76×10^3 hr = 5.26×10^5 min
= 3.156×10^7 s

Length
1 m = 100 cm = 39.37 in = 3.28 ft
1 cm = 10 mm = 0.394 in
1 km = 10^3 m = 0.621 mi
1 ft = 12 in = 0.305 m = 30.5 cm
1 in = 0.0833 ft = 2.54 cm = 0.0254 m
1 mi = 5280 ft = 1.61 km
1 fermi = 10^{-15} m
1 angstrom = 10^{-10} m
1 light-year (ly) = 9.46×10^{15} m
1 parsec = 3.26 ly = 3.09×10^{16} m

Area
1 m^2 = 10^4 cm^2 = 1.55×10^3 in^2 = 10.76 ft^2
1 cm^2 = 10^{-4} m^2 = 0.155 in^2
1 ft^2 = 144 in^2 = 9.29×10^{-2} m^2 = 929 cm^2

Volume
1 m^3 = 10^3 liters (L) = 10^6 cm^3 = 35.3 ft^3
= 6.10×10^4 in^3
1 ft^3 = 1728 in^3 = 2.83×10^{-2} m^3 = 28.3 L
1 L = 10^3 cm^3 = 10^{-3} m^3 = 54.6 in^3
1 gallon = 4 qt = 231 in^3 = 3.78 L

Velocity
1 m/s = 3.28 ft/s = 2.24 mi/h = 3.60 km/hr
1 ft/s = 0.305 m/s = 0.682 mi/hr = 1.10 km/hr
1 km/hr = 0.278 m/s = 0.913 ft/s = 0.621 mi/h
1 mi/hr = 1.47 ft/s = 0.447 m/s = 1.609 km/h

Mass
1 kg = 10^3 g = 0.0685 slugs
1 slug = 14.6 kg
1 atomic mass unit (u) = 1.6605×10^{-27} kg
= 1.49×10^{-10} J = 931.5 MeV

Mass-Weight (on surface of Earth)
1 kg = 2.2046 lb = 9.81 N
1 slug = 32.2 lb = 143.3 N
1 lb = 0.454 kg = 454 g = 3.11×10^{-2} slug
1 N = 0.102 kg = 6.98×10^{-3} slug

Force
1 newton (N) = 0.225 lb = 3.60 oz = 10^5 dyne
1 lb = 16 oz = 4.45 N

Energy and Work
1 J = 10^7 ergs = 0.738 ft·lb
1 ft·lb = 1.36 J
1 kcal = 4.186×10^3 J
1 cal = 4.186 J
1 eV = 1.602×10^{-19} J

Power
1 watt (W) = 1 J/s = 0.738 ft·lb/s
1 horse power = 550 ft·lb/s = 746 W

Pressure
1 pascal (Pa) = 1 N/m^2 = 2.09×10^{-2} lb/ft^2
= 1.45×10^{-4} lb/in^2
1 lb/in^2 = 144 lb/ft^2 = 6.90×10^3 N/m^2
1 atmosphere (atm) = 1.013×10^5 N/m^2
= 14.7 lb/in^2 = 760 torr

TABLE 10-1
Densities of Substances†

Substance	Density, ρ (kg/m^3)
Solids	
Aluminum	2.70×10^3
Iron and steel	7.8×10^3
Copper	8.9×10^3
Lead	11.3×10^3
Gold	19.3×10^3
Concrete	2.3×10^3
Granite	2.7×10^3
Wood (typical)	$0.3\text{–}0.9 \times 10^3$
Glass, common	$2.4\text{–}2.8 \times 10^3$
Ice	0.917×10^3
Bone	$1.7\text{–}2.0 \times 10^3$
Liquids	
Water (4° C)	1.00×10^3
Blood, plasma	1.03×10^3
Blood, whole	1.05×10^3
Sea water	1.025×10^3
Mercury	13.6×10^3
Alcohol, ethyl	0.79×10^3
Gasoline	0.68×10^3
Gases	
Air	1.29
Helium	0.179
Carbon dioxide	1.98
Water (steam) (100° C)	0.598

†Densities are given at 0°C and 1 atm pressure unless otherwise specified.

SI Derived Units and Their Abbreviations

Quantity	Unit	Abbreviation	In Terms of Base Units†
Force	newton	N	$kg \cdot m/s^2$
Energy and work	joule	J	$kg \cdot m^2/s^2$
Power	watt	W	$kg \cdot m^2/s^3$
Pressure	pascal	Pa	$kg/(m \cdot s^2)$
Frequency	hertz	Hz	s^{-1}
Electric charge	coulomb	C	$A \cdot s$
Electric potential	volt	V	$kg \cdot m^2/(A \cdot s^3)$
Electric resistance	ohm	Ω	$kg \cdot m^2/(A^2 \cdot s^3)$
Capacitance	farad	F	$A^2 \cdot s^4/(kg \cdot m^2)$
Magnetic field	tesla	T	$kg/(A \cdot s^2)$
Magnetic flux	weber	Wb	$kg \cdot m^2/(A \cdot s^2)$
Inductance	henry	H	$kg \cdot m^2/(s^2 \cdot A^2)$

†kg = kilogram (mass), m = meter (length), s = second (time), A = ampere (electric current).

Metric (SI) Multipliers

Prefix	Abbreviation	Value
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^9
mega	M	10^6
kilo	k	10^3
hecto	h	10^2
deka	da	10^1
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

I. Scientific Method

Observation and careful experimentation and measurement are one side of the scientific process. The other side is the invention or creation of *theories* to explain and order the observations. Theories are never derived directly from observations. They are inspirations that come from the minds of human beings. For example, the idea that matter is made up of atoms (the atomic theory) was certainly not arrived at because someone observed atoms. Rather, the idea sprang from creative minds. The theory of relativity, the electromagnetic theory of light, and Newton's law of universal gravitation were likewise the result of human imagination.

In usage outside of science, the word "theory" is often used as a synonym for a "hunch" or a "conjecture." So someone may say, "I have a theory about why this works" meaning they have an untested hypothesis. Or a well-established scientific theory such as the theory of evolution will be downplayed with the remark "it's only a theory." This reflects a misunderstanding of the word "theory" in science. For science, a theory is a synthesis of a large collection of information including well-tested guesses. It provides a useful explanation of phenomenon and allows testable predictions to be made.

The great theories of science may be compared, as creative achievements, with great works of art or literature. But how does science differ from these other creative activities? One important difference is that science requires *testing* of its ideas or theories to see if their predictions are borne out by experiment.

Although the testing of theories can be considered to distinguish science from other creative fields, it should not be assumed that a theory is "proved" by testing. First of all, no measuring instrument is perfect, so exact confirmation cannot be possible. Furthermore, it is not possible to test a theory for every possible set of circumstances. Hence a theory can never be absolutely "proved." In fact, theories themselves are generally not perfect—a theory rarely agrees with experiment exactly, within experimental error, in every single case in which it is tested. Indeed, the history of science tells us that long-held theories are sometimes replaced by new ones. The process of one theory replacing another is an important subject in the philosophy of science.

When scientists are trying to understand a particular set of phenomena, they often make use of a **model**. A model, in the scientific sense, is a kind of analogy or mental image of the phenomena in terms of something we are familiar with. One example is the wave model of light. We cannot see waves of light as we can water waves. But it is valuable to think of light as if it were made up of waves, because experiments indicate that light behaves in many respects as water waves do.

The purpose of a model is to give us an approximate mental or visual picture—something to hold onto—when we cannot see what actually is happening. Models often give us a deeper understanding: the analogy to a known system (for instance, water waves in the above example) can suggest new experiments to perform and can provide ideas about what other related phenomena might occur.

You may wonder what the difference is between a theory and a model. Sometimes the words are used interchangeably. Usually, however, a model is relatively simple and provides a structural similarity to the phenomena being studied, whereas a **theory** is broader, more detailed, and can give quantitatively testable predictions, often with great precision. Sometimes, as a model is developed and modified and corresponds more closely to experiment over a wide range of phenomena, it may come to be referred to as a theory. The atomic theory is an example, as is the wave theory of light.

Models can be very helpful, and they often lead to important theories. But it is important not to confuse a model, or a theory, with the real system or the phenomena themselves.

Problems & Questions

1. In science, what is meant by a "theory"?
2. How does the use of the term "theory" in science differ from the use of "theory" in common language?
3. Why can't a scientific theory be "proved"?
4. What is meant by a "model"?
5. What is the fundamental difference between science and the arts?

II Measurement and Uncertainty

In the quest to understand the world around us, scientists seek to find relationships among the various physical quantities they observe and measure.

We may ask, for example, in what way does the magnitude of a force on an object affect the object's speed or acceleration? Or by how much does the pressure of gas in a closed container (such as a tire) change if the temperature is raised or lowered? Scientists normally try to express such relationships quantitatively, in terms of equations whose symbols represent the quantities involved. To determine (or confirm) the form of a relationship, careful experimental measurements are required, although creative thinking also plays a role.

Accurate measurements are an important part of physics. But no measurement is absolutely precise. There is an uncertainty associated with every measurement. Uncertainty arises from different sources. Among the most important, other than blunders, are the limited accuracy of every measuring instrument and the inability to read an instrument beyond some fraction of the smallest division shown. For example, if you were to use a centimeter ruler to measure the width of a board the result

1

could be claimed to be accurate to about 0.1 cm, the smallest division on the ruler. The reason is that it is difficult for the observer to interpolate between the smallest divisions, and the ruler itself may not have been manufactured or calibrated to an accuracy very much better than this.

When giving the result of a measurement, it is also important to state the precision, or **estimated uncertainty**, in the measurement. For example, the width of a board might be written as 5.2 ± 0.1 cm. The ± 0.1 cm ("plus or minus 0.1 cm") represents the estimated uncertainty in the measurement, so that the actual width most likely lies between 5.1 and 5.3 cm. The **percent uncertainty** is simply the ratio of the uncertainty to the measured value, multiplied by 100. For example, if the measurement is 5.2 and the uncertainty about 0.1 cm, the percent uncertainty is

$$\frac{0.1}{5.2} \times 100 = 2\%.$$

Often the uncertainty in a measured value is not specified explicitly. In such cases, the uncertainty is generally assumed to be one or two units (or even three) in the last digit specified. For example, if a length is given as 5.2 cm, the uncertainty is assumed to be about 0.1 cm (or perhaps 0.2 cm). It is important in this case that you do not write 5.20 cm, for this implies an uncertainty on the order of 0.01 cm; it assumes that the length is probably between 5.19 cm and 5.21 cm, when actually you believe it is between 5.1 and 5.3 cm.

The number of reliably known digits in a number is called the number of **significant figures.** Thus there are four significant figures in the number 23.21 and two in the number 0.062 cm (the zeros in the latter are merely "place holders" that show where the decimal point goes). The number of significant figures may not always be clear. Take, for example, the number 80. Are there one or two significant figures? If we say it is *about* 80 km between two cities, there is only one significant figure (the 8) since the zero is merely a place holder. If it is 80 km within an accuracy of 1 or 2 km, then the 80 has two significant figures. If it is precisely 80 km measured to within ± 0.1 km, then we write 80.0 km.

A problem may arise in determining if zeros in a measurement are a part of the measurement (significant) or are just place holders (not significant). It is important to understand that the number of significant figures is determined by how a measurement was made (i.e., by the measuring instrument). The number of significant figures is not determined by a rule. A rule merely provides a convenient way for the person recording the measurement to indicate to others how significant figures the measurement has.

For example, consider the length of track used for a one-hundred-meter race. How many significant figures does the one-hundred-meter measurement have? The answer depends on how the track was measured in laying out the start and finish lines. We would expect the measurement error to be much less than 1 meter, probably closer to a few cm. Therefore, the one-hundred-meter measurement is correct to at least three significant figures, possibly four or five significant figures. When we write the measurement, we may write 100. m or 100.0 m to convey the level of precision. But even if we were to express the measurement as 100 m, it still has at least three significant figures because that was the way it was measured. Again, it is the measurement process that determines the number of significant figures, not a rule.

If we do not have any information on how a measurement was made, then we might not be able to say how many significant figures the measurement has. For example, if a distance is given as 5000 m without any background information, then the number of significant figures for the measurement is unknown. It has at least one significant figure, but it might have two, three, four, or more significant figures, depending on how the measurement was made. The convention has been to assume the fewest number of significant figures for the ambiguous case, but a better practice is to always be clear on the number of significant figures by the way the measurement is written. We should write 5×10^3 m for one significant figure, 5.0×10^3 m for two significant figures, and so on.

When making measurements, or when doing calculations, you should avoid the temptation to keep more digits in the final answer than is justified. For example, to calculate the area of a rectangle 11.3 cm by 6.8 cm, the result of multiplication would be 76.84 cm^2. But this answer is clearly not accurate to 0.01 cm^2, since (using the outer limits of the assumed uncertainty for each measurement) the result could be between $11.2 \times 6.7 = 75.04\ cm^2$ and $11.4 \times 6.9 = 78.66\ cm^2$. At best, we can quote the answer as 77 cm^2, which implies an uncertainty of about 1 or 2 cm^2. The other two digits (in the number 76.84 cm^2) must be dropped since they are not significant. As a general rule, *the final result of a multiplication or division should have only as many digits as the number with the least number of significant figures used in the calculation.* In our example, 6.8 cm has the least number of significant figures, namely two. Thus the result 76.84 cm^2 needs to be rounded off to 77 cm^2.

When adding or subtracting measured values, the final result can be no more precise than the least precise number used. Precision is indicated by the number of decimal places, not the number of significant figures. If adding 2.3 cm and 10.4 cm, since both values are correct to the nearest tenth, the sum is 12.7 cm, correct to the nearest tenth. Note that this is not the same result you would get if you followed the significant figures conventions for multiplication and division. For the sum of 2.3 cm and 10.418 cm, the result is still 12.7 cm, correct to the nearest tenth. You can add the values first and then round, or round first and then add.

Keep in mind when you use a calculator that all the digits it produces may not be significant. When you divide 2.0 by 3.0, the proper answer is 0.67, and not 0.66666666. Digits should not be quoted (or written down) in a result, unless they are truly significant figures. However, to obtain the most accurate result, it is good practice to keep an extra significant figure or two throughout a calculation, and round off only in the final result. Note also that calculators sometimes give too few significant figures. For example, when you multiply 2.5×3.2, a calculator may give the answer as simply 8. But the answer is good to two significant figures, so the proper answer is 8.0.

If a constant is used in an expression, that constant is not a measured value and thus does not enter into consideration for the number of significant figures. For example, in the formula for the perimeter of a rectangle ($P = 2L + 2W$), the "2" is a constant so the number of significant figures is determined by the measured "L" and "W" values.

Problems & Questions

6. What is the percent uncertainty in the measurement 2.26 ± 0.25 m?
7. What, approximately, is the percent uncertainty for the measurement 1.67?
8. How many significant figures do each of the following numbers have:
   (a) 142 (b) 81.60 (c) 7.63 (d) 0.03 (e) 0.0086 (f) 3236 (g) 8700
9. A land deed lists the dimensions of a lot as 80 ft wide by 100 ft. deep. To how many significant figures is the measurement of the depth of the lot? Explain.
10. Multiply 2.079×10^2 m by 0.072×10^{-1} m, taking into account significant figures.
11. (a) Add 7.2×10^3 s + 8.3×10^4 s + 0.09×10^6 s, taking into account significant figures.
    (b) Add 3.2 cm + 14.16 cm, taking into account significant figures.
12. Express the following sum with the correct number of significant figures:
    1.00 m + 142.5 cm + 1.24×10^5 μm.
13. The age of the universe is thought to be somewhere around 10 billion years. Assuming one significant figure, write this in powers of ten in (*a*) years; (*b*) seconds.

III Units, Standards, and the SI System

The measurement of any quantity is made relative to a particular standard or **unit**, and this unit must be specified along with the numerical value of the quantity. For example, we can measure length in units such as inches, feet, or miles, or in the metric system in centimeters, meters, or kilometers. To specify that the length of a particular object is 18.6 is meaningless. The unit *must* be given; for clearly, 18.6 meters is very different from 18.6 inches or 18.6 millimeters.

The first real international standard was the **meter** (abbreviated m) established as the standard of **length** by the French Academy of Sciences in the 1790s. In a spirit of rationality, the standard meter was originally chosen to be one ten-millionth of the distance from the Earth's equator to either pole,† and a platinum rod to represent this length was made. (This turns out to be, very roughly, the distance from the tip of your nose to the tip of your longest finger, with arm and hand stretched out horizontally.) In 1889, the meter was defined more precisely as the distance between two finely engraved marks on a particular bar of platinum–iridium alloy. In 1960, to provide greater precision and reproducibility, the meter was redefined as 1,650,763.73 wavelengths of a particular orange light emitted by

†Modern measurements of the Earth's circumference reveal that the intended length is off by about one-fiftieth of 1 percent. Not bad!

the gas krypton 86. In 1983 the meter was again redefined, this time in terms of the speed of light (whose best measured value in terms of the older definition of the meter was 299,792,458 m/s, with an uncertainty of 1 m/s). The new definition reads: "The meter is the length of path traveled by light in vacuum during a time interval of 1/299,792,458 of a second."†

British units of length (inch, foot, mile) are now defined in terms of the meter. The inch (in.) is defined as precisely 2.54 centimeters (cm; 1 cm = 0.01 m). Other conversion factors are given in the table on the inside of the front cover of this book. [see attached reference pages.]

The standard unit of **time** is the **second** (s). For many years, the second was defined as 1/86,400 of a mean solar day. The standard second is now defined more precisely in terms of the frequency of radiation emitted by cesium atoms when they pass between two particular states. Specifically, one second is defined as the time required for 9,192,631,770 periods of this radiation. There are, of course, precisely 60 s in one minute (min) and 60 minutes in one hour (h). Note that these two factors of 60 (as well as the 2.54 cm per inch) are definitions and hence have an indefinite number of significant figures.

The standard unit of **mass** is the **kilogram** (kg). The standard mass is a particular platinum–iridium cylinder, kept at the International Bureau of Weights and Measures near Paris, France, whose mass is defined as exactly 1 kg. [For practical purposes, 1 kg weighs about 2.2 pounds.]

When dealing with atoms and molecules, the **unified atomic mass unit** (u) is usually used. In terms of the kilogram

$$1\ \text{u} = 1.6605 \times 10^{-27}\ \text{kg}.$$

The definitions of other standard units for other quantities will be given as we encounter them in later chapters.

In the metric system, the larger and smaller units are defined in multiples of 10 from the standard unit, and this makes calculation particularly easy. Thus 1 kilometer (km) is 1000 m, 1 centimeter is $\frac{1}{100}$ m, 1 millimeter (mm) is $\frac{1}{1000}$ m or $\frac{1}{10}$ cm, and so on. The prefixes "centi-," "kilo-," and others are listed on reference sheet and can be applied not only to units of length, but to units of volume, mass, or any other metric unit. For example, a centiliter (cL) is $\frac{1}{100}$ liter (L) and a kilogram (kg) is 1000 grams (g).

When dealing with the laws and equations of physics it is very important to use a consistent set of units. Several systems of units have been in use over the years. Today the most important is the **Système International** (French for International System), which is abbreviated SI. In SI units, the standard of length is the meter, the standard for time is the second, and the standard for mass is the kilogram. This system used to be called the MKS (meter-kilogram-second) system.

In addition to the meter, kilogram, and second, the other base units in SI are: mole (mol) for an amount, Ampere (A) for electric current, Kelvin (K) for temperature, and candela (cd) for light intensity. Every physical quantity can be expressed in combinations of these seven base units. Certain combinations are used so frequently that special derived units are defined. For example, the SI unit for force is the newton, which is defined as kg·m/s^2. Some of the other commonly used SI derived units are shown in the table included on your Reference Sheet. Note that these use the three units of the original MKS (meter-kilogram-second) system plus Ampere for electricity and magnetism.

A second metric system is the **cgs system,** in which the centimeter, gram, and second are the standard units of length, mass, and time, as abbreviated in the title. The **British engineering system** takes as its standards the foot for length, the pound for force, and the second for time.

SI units are the principal ones used today in scientific work. We will therefore use SI units almost exclusively in this book, although we will give the cgs and British units for various quantities when introduced.

To determine the definition of a derived unit in another system, substitute the base units of that system into the SI definition of the derived unit. For example, the cgs unit for force is the dyne. Using the SI force unit (Newton) definition (kg·m/s^2) and making the appropriate substitutions, the dyne is defined as g·cm/s^2.

In doing any calculations, it is important that all the measurements are expressed in units that are within the same system. In chemistry, you often used the cgs system because length and mass measurements are generally smaller than those measurements in physics. For physics, we will nearly always be using SI units. So even if a length is measured in centimeters and a mass is measured in grams, convert these to meters and kilograms, respectively, before doing any calculations. And always be sure to include the units with any reported result.

14. Write out the following numbers in full with a decimal point and correct number of zeros: (a) 8.69×10^4; (b) 7.1×10^3; (c) 6.6×10^{-1}; (d) 8.76×10^2; (e) 8.62×10^{-5}.
15. Write the following numbers in powers of ten notation: (a) 1,156,000 (b) 218 (c) 0.0068 (d) 27.635 (e) 0.21 (f) 22
16. Write the following as full (decimal) numbers with standard (no prefix) units: (a) 86.6 mm; (b) 35 μV; (c) 860 mg; (d) 600 picoseconds; (e) 12.5 femtometers; (f) 250 gigavolts.
17. Express the following using metric prefixes: (a) 10^6 volts; (b) 10^{-6} meters; (c) 5×10^3 days; (d) 8×10^2 bucks; (e) 8×10^{-9} pieces.
18. What are the base units for length, mass, and time in SI?
19. In the cgs system, the derived unit for energy and work is the erg. Express the erg in terms of its base cgs units. [See reference sheet for the base units of derived SI units and make appropriate substitutions.]

IV. Converting Units

Any quantity we measure, such as a length, a speed, or an electric current, consists of a number *and* a unit. Often we are given a quantity in one set of units, but we want it expressed in another set of units. For example, suppose we measure that a table is 21.5 inches wide, and we want to express this in centimeters. We must use a **conversion factor** which in this case is

$$1 \text{ in.} = 2.54 \text{ cm}$$

or, written another way,

$$1 = 2.54 \text{ cm/in.}$$

Since multiplying by one does not change anything, the width of our table, in cm, is

$$21.5 \text{ inches} = (21.5 \text{ in.}) \times \left(2.54 \frac{\text{cm}}{\text{in.}}\right) = 54.6 \text{ cm}$$

Note how the units (inches in this case) cancelled out. A table containing many unit conversions is found inside the front cover of this book. (See reference sheet.)

TABLE 1–4
Metric (SI) Prefixes

Prefix	Abbreviation	Value
exa	E	10^{18}
peta	P	10^{15}
tera	T	10^{12}
giga	G	10^{9}
mega	M	10^{6}
kilo	k	10^{3}
hecto	h	10^{2}
deka	da	10^{1}
deci	d	10^{-1}
centi	c	10^{-2}
milli	m	10^{-3}
micro†	μ	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

† μ is the Greek letter "mu."

EXAMPLE 1–2 **The 100-m dash.** What is the length of the 100-m dash expressed in yards?

SOLUTION Let us assume the distance is accurately known to four significant figures, 100.0 m. One yard (yd) is precisely 3 feet (36 inches), so we can write

$$1 \text{ yd} = 3 \text{ ft} = 36 \text{ in.} = (36 \text{ in.})\left(2.540 \frac{\text{cm}}{\text{in.}}\right) = 91.44 \text{ cm}$$

or,

$$1 \text{ yd} = 0.9144 \text{ m},$$

since 1 m = 100 cm. We can rewrite this result as

$$1 \text{ m} = \frac{1 \text{ yd}}{0.9144} = 1.094 \text{ yd}.$$

Then

$$100 \text{ m} = (100 \text{ m})\left(1.094 \frac{\text{yd}}{\text{m}}\right) = 109.4 \text{ yd},$$

so a 100-m dash is 9.4 yards longer than a 100-yard dash.

Your reference sheets include conversions for area and volume. Note that in making metric conversions for area, the conversion is made for each of the two linear dimensions contained in an area. For example, when converting from m^2 to cm^2, the conversion from m to cm which involves two decimal places is done for both the length and the width. Therefore, the conversion involves 2 + 2 or four decimal places and we fine $1\ m^2 = 10^4\ cm^2$. Likewise, a volume conversion involves a conversion for three linear dimensions. So the conversion from m^3 to cm^3 requires 2+2+2 or six decimal places ($1\ m^3 = 10^6\ cm^3$).

When using a reference sheet, you can form a conversion factor by choosing any two quantities on the same line and forming a ratio. Using the factor-label method allows you to easily decide on which quantity is the numerator and which is the denominator for the conversion factor. Also note that the reference sheets include combined units such as velocity (speed).

Problems & Questions

20. The area of a surface is 200. cm^2 . Express this area in: (a) m^2 ; (b) mm^2
21. The volume of an object is 1000 m^3. Express this volume in: (a) cm^3; (b) ft^3; (c) in^3.
22. The volume of an object is 500 cm^3. Express this volume in: (a) m^3; (b) km^3; (c) in^3.
23. The mass of a nickel (5¢ piece) is approximately 5 grams. Express this mass in: (a) kg; (b) slugs; (c) atomic mass units.
24. One atmosphere of pressure is defined as 760 mm of mercury (Hg) [also called torr]. If the barometric pressure reads 30.2 inches of Hg, express this pressure in: (a) cm of Hg; (b) atmospheres; (c) hectoPascals (hPa).

V. DENSITY

The **density**, ρ, of an object (ρ is the lowercase Greek letter "rho") is defined as its mass per unit volume:

$$\rho = \frac{m}{V}, \tag{10-1}$$

where m is the mass of the object and V its volume. Density is a characteristic property of any pure substance. Objects made of a given pure substance, such as pure gold, can have any size or mass, but the density will be the same for each. (Sometimes we will find Eq. 10–1 useful for writing the mass of an object as $m = \rho V$, and the weight of an object, mg, as $\rho V g$.)

The SI unit for density is kg/m^3. Sometimes densities are given in g/cm^3. Note that since $1\ kg/m^3 = 1000\ g/(100\ cm)^3 = 10^{-3} g/cm^3$, then a density given in g/cm^3 must be multiplied by 1000 to give the result in kg/m^3. Thus the density of aluminum is $\rho = 2.70\ g/cm^3$, which is equal to $2700\ kg/m^3$. The densities of a variety of substances are given in Table 10–1. The table specifies temperature and pressure because they affect the density of substances (although the effect is slight for liquids and solids).

Problems & Questions

25. The density of air at 0°C and 1 atmosphere of pressure (STP) is 1.29×10^{-3} g/cm^3. Express this density in kg/m^3. What is the specific gravity of air at STP?
26. What is the specific gravity of mercury?
27. A sample of an alloy has a specific gravity of 6.4. What is the density of the metal expressed in g/cm^3 and kg/m^3?

VI Relationships, Proportionality, and Equations

One of the important aspects of physics is the search for relationships between different quantities—that is, determining how one quantity affects another. For example, how does temperature affect the air pressure in a tire? Or how does the net force on an object affect its acceleration? Sometimes a given quantity is affected by two or more quantities; for instance, the acceleration of an object is related to both its mass and the applied force. If it is suspected that a relationship exists between two or more quantities, one can try to determine the precise nature of this relationship. This is done by varying one of the quantities and measuring how the other varies as a result. If it is likely that a particular quantity will be affected by more than one factor or quantity, only one of the latter is varied at a time, while the others are held constant.†

As a simple example, the ancients found that if one circle has twice the diameter of a second circle, the first also has twice the circumference. If the diameter is three times as large, the circumference is also three times as large. In other words, an increase in the diameter results in a proportional increase in the circumference. We say that the circumference is *directly proportional to* the diameter. This can be written in symbols as $C \propto D$, where "$\propto$" means "is proportional to," and C and D refer to the circumference and diameter of a circle, respectively. The next step is to change this proportionality to an equation, which will make it possible to link the two quantities numerically. This merely entails inserting a proportionality constant, which in many cases is determined by measurement. (In some cases it can be chosen arbitrarily, if it involves only the definition of a new unit.) The ancients found that the ratio of the circumference to the diameter of any circle was 3.1416 (to keep only the first few decimal places). This number is designated by the Greek letter π. It is the constant of proportionality for the relationship $C \propto D$, and to obtain an equation we insert it into the proportion and change the $\propto$ to $=$. Thus, $C = \pi D$.

Other kinds of proportionality occur as well. For example, the area of a circle is proportional to the *square* of its radius. That is, if the radius is doubled, the area becomes four times as large; and so on. In this case we can write $A \propto r^2$, where A stands for the area and r for the radius of the circle.

Sometimes two quantities are related in such a way that an increase in one leads to a proportional *decrease* in the other. This is called *inverse proportion*. For example, the time required to travel a given distance is in-

†When one quantity affects another, we often use the expression "is a function of" to indicate this dependence; for example, we say that the pressure in a tire is a function of the temperature.

versely proportional to the speed of travel. The greater the speed, the less time it takes. We can write this inverse proportion as: time $\propto$ 1/speed. The larger the denominator of a fraction, the smaller the fraction is as a whole. For example, $\frac{1}{4}$ is smaller than $\frac{1}{2}$. Thus, if the speed is doubled, the time is halved, which is what we want to express by this inverse proportionality relationship.

Whatever kind of proportion is found to hold, it can be changed to an equality by insertion of the proper proportionality constant. Quantitative statements or predictions about the physical world can then be made with the equation.

If the equation involves a variable in the denominator which is squared, this is referred as an *inverse square* relationship. For example, the equation for gravitational force is: $F = Gm_1m_2/r^2$ where G is a constant, m_1 and m_2 are the two masses, and r is the distance between the masses (center-to-center).. Consider this equation being used to calculate the gravitational force on a given mass located on the surface of a planet. What would happen to this force if the planet's radius were twice as large, but the mass was the same? According to the equation, F varies inversely with r squared, so twice r gives a force 1/4 as large. If the radius is tripled, the force becomes 1/9 as large.

At times we may consider the effect of changing more than one variable. For example, what if the planet had twice the radius and three times the mass? Using a mass and the radius we get $3/2^2 = 3/4$, so the force is 3/4 as large.

Problems & Questions

28. If an increase in temperature caused an object to increase its volume by 50%, what would be the change in the object's density?

29. A hypothetical planet has a mass four times that of Earth and a radius three times that of Earth. How does your weight (gravitational force) on this planet compare to your weight on Earth?

30. The formula for kinetic energy is: $KE = 0.5mv^2$; where m = mass and v = speed.
(a) Two identical cars are traveling down a road. Car B is traveling at twice the speed of Car A. How do their kinetic energies compare?
(b) A truck and a car are traveling down a road at the same speed. The truck has twice the mass of the car. How do their kinetic energies compare?
(c) The truck is now traveling at twice the speed of the car. Now how do their kinetic energies compare?

31. The formula for centripetal acceleration is: $a = v^2/r$; where v = speed and r = radius.
(a) Two identical cars are traveling around a curve. Car B has twice the speed as Car A. Compare their centripetal accelerations.
(b) Car A and Car B travel at the same speed but around two different curves. The curve for Car B has twice the radius as for Car A. Compare their centripetal accelerations.
(c) A car and a truck travel around the same curve at the same speed. The truck has twice the mass as the car. Compare their centripetal accelerations.

VII

DIMENSIONAL ANALYSIS

When we speak of the *dimensions* of a quantity, we are referring to the type of units that must be used. The dimensions of area, for example, are always length squared (abbreviated $[L^2]$, using square brackets) and the units can be square meters, square feet, and so on. Velocity, on the other hand, can be measured in units of km/h, m/s, and mi/h, but the dimensions are always a length $[L]$ divided by a time $[T]$, that is, $[L/T]$. The formula for a quantity may be different in different cases, but the dimensions remain the same. For example, the area of a triangle of base b and height h is $A = \frac{1}{2}bh$, whereas the area of a circle of radius r is $A = \pi r^2$. The formulas are different in the two cases, but the dimensions in both cases are the same: $[L^2]$.

When we specify the dimensions of a quantity, we usually do so in terms of basic quantities such as length $[L]$, time $[T]$, mass $[M]$, and electric current $[I]$. Thus, force, which by Newton's second law has the same units as mass $[M]$ times acceleration $[L/T^2]$, has dimensions of $[ML/T^2]$.

Dimensions can be used as a help in working out relationships, and such a procedure is referred to as *dimensional analysis*. One useful technique is the use of dimensions to check a relationship for correctness. Two simple rules apply here. First, we can add or subtract quantities only if they have the same dimensions (we do not add centimeters and pounds); second, the quantities on each side of an equals sign must have the same dimensions.

For example, suppose that you derived the equation $v = v_0 + \frac{1}{2}at^2$, where v is the speed of an object after a time t, when it starts with an initial speed v_0 and undergoes an acceleration a. Let us do a dimensional check to see if this equation can be correct. We write a dimensional equation as follows, remembering that the dimensions of speed are $[L/T]$ and of acceleration are $[L/T^2]$:

$$\left[\frac{L}{T}\right] \stackrel{?}{=} \left[\frac{L}{T}\right] + \left[\frac{L}{T^2}\right][T^2]$$

$$\stackrel{?}{=} \left[\frac{L}{T}\right] + [L].$$

The dimensions are incorrect: on the right side, we have the sum of two quantities whose dimensions are not the same. Thus, we conclude that an error was made in the derivation of the original equation.

If such a dimensional check does come out correct, it does not prove that the equation is correct; for example, a dimensionless numerical factor (such as $\frac{1}{2}$ or 2π) could be wrong. Thus a dimensional check can only tell you when a relationship is wrong; it cannot tell you if it is completely right.

Another use of dimensional analysis is for a quick check on an equation you are not sure about. For example, suppose that you cannot remember whether the equation for the period T of an oscillating mass m on the end of a spring with constant k is $T = 2\pi\sqrt{k/m}$ or is $T = 2\pi\sqrt{m/k}$. A dimensional check can tell you. The dimensions of k, since from Hooke's law k = force/distance, are $[ML/T^2/L] = [M/T^2]$. Thus the formula $T = 2\pi\sqrt{m/k}$ is correct:

$$[T] = \sqrt{\frac{[M]}{[M/T^2]}},$$

whereas the formula $T = 2\pi\sqrt{k/m}$ is not:

$$[T] \neq \sqrt{\frac{[M/T^2]}{[M]}}.$$

The technique of dimensional analysis can also be done by using the specific units within a given system. For physics this would be SI units. So instead of using general dimensions of L for length, M for mass, and T for time, use the specific units of meter, kilogram, and second. Applying this to the previous example ($T = 2\pi \sqrt{m/k}$), we get "$s = \sqrt{kg/(kg/s^2)}$".

A dimensional analysis can be used to determine the units for a constant in a given formula. For example, in the gravitational force equation $F = Gm_1m_2/r^2$, G is the universal gravitational constant. To determine the units for G, solve the equation for G to obtain $G = Fr^2/m_1m_2$. Using SI units, G must have units of Nm^2/kg^2. It is convenient to retain common derived units (such as N) when expressing the units.

Problems & Questions

32. What are the units for G (the universal gravitational constant) in the cgs system?
33. Use a dimensional analysis to verify that each of the following formulas are dimensionally correct. Work with basic or derived SI units.
    (A) $F = BLI$ (B) $P = Fv$ (C) $I = V/R$
    {F = force; B = magnetic field; L = length; I = current; P = power; v = speed; V = electric potential; R = electric resistance)

VIII Error and Deviation

In a laboratory experiment, the error refers to how close the experimental result is to the accepted value. The absolute error is the absolute value of the difference between the experimental (observed) value and the accepted value ($E_a = | O - A |$). To get a better indication of the size of the error, the absolute error needs to be compared to the accepted value to determine the % error (% error = $(E_a/A) \times 100\%$). Since the % error will be used quite often for lab, a convenient way to remember is: % error = difference/ accepted value.

When a series of measurements is taken, the deviation indicates the consistency of the measurements. For each measured value, the absolute deviation equals the absolute value of the difference between the measured value and the average (mean) of the measured values. These absolute deviations are then averaged to give the average absolute deviation. Finally, the average absolute deviation is compared to the average of the measured values to give the % average deviation (% avg dev = (avg dev/avg measured value) x 100%).

Problems & Questions

34. A student finds through her laboratory experiment the density of copper as 9.7 g/cm^3. The accepted value for the density of copper is 8.9 g/cm^3. Find the absolute error and the percentage error.

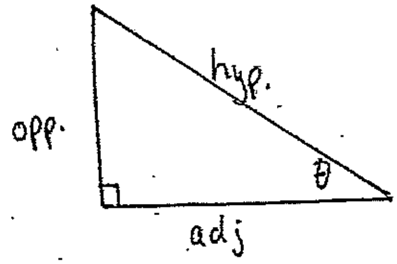
35. A student obtained the following measurements for the diameter of a wire:
    1.738 mm 1.734 mm 1.733 mm 1.735 mm
    A) Calculate the average of the measurements
    B) For each measurement, calculate the absolute deviation
    C) Calculate the average of the absolute deviations
    D) Calculate the percentage average deviation

IX Right Triangle Ratios

Sin θ = opp./hyp

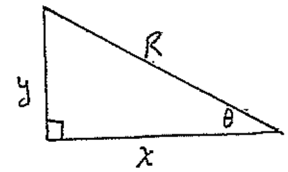
Cos θ = adj/hyp

Tan θ = opp/adj



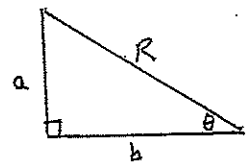
Problems

36. Given the triangle shown with side **R** and angle **θ** :



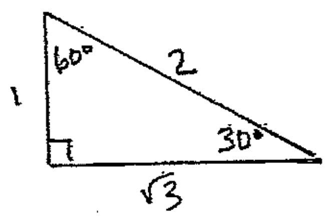
A) Write an expression for the length of side x.
B) Write an expression for the length of side y.

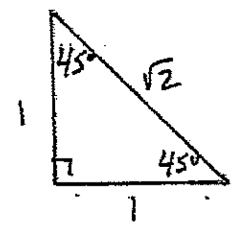
37. Given the triangle with sides **a** and **b**:



A) Write an expression for the measure of angle θ.
B) Write an expression for the length of side R.

X Special Right Triangles





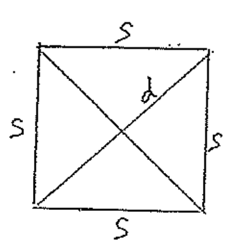
Problems

38. Complete the following table **without the use of a calculator or reference table.**

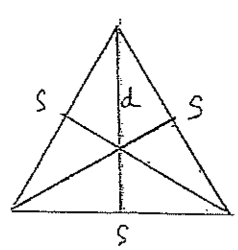
Angle	*sin*	*cos*	*tan*
30°			
45°			
60°			

39. Solve for ***d*** in each of the following figures. Answer should be in simplest radical form.

A)



B)



PHYSICS (H) Prelim. Practice Quiz Name ______________________

1. A theory is:
A) an explanation of how things work that has not been tested
B) an educated guess that has yet to be proven by experiment
C) a synthesis of a large collection of information including well-tested guesses
D) a fact which is well-established by experimentation
E) a guess that has been tested over and over again and always found to be true

2. Which of the following fields of study makes use of physics?
A) architecture B) biology C) chemistry D) earth science
E) all of the above

3. How many significant figures does the measurement 0.0230 g have?
A) 2 B) 3 C) 4 D) 5

4. The Vernon HS track is four hundred meters long. How many significant figures is this measurement?
A) 1 B) 2 C) at least 3

Use the following information for the next 2 questions:
A rectangle has a length of 6.1 cm and a width 3.374 cm.

5. The perimeter ($P = 2L + 2W$) of the rectangle written with the correct number of significant figures is:
A) 18.948 cm B) 18.95 cm C) 19.0 cm D) 19 cm E) 2×10^1 cm

6. The area ($A = LW$) of the rectangle written with the correct number of significant figures is:
A) 20.5814 cm^2 B) 20.581 cm^2 C) 20.58 cm^2 D) 20.6 cm^2 E) 21 cm^2

7. What is the per cent uncertainty in the measurement 2.58 ± 0.15 cm?
A) 2.9% B) 5.8% C) 8.7% D) 12% E) 17.2%

8. What, approximately, is the per cent uncertainty for the measurement 5.2 m?
A) 0% B) 1% C) 2% D) 3% E) 4%

9. Express 0.02 days using a metric prefix.
A) 2 centidays B) 2 decidays C) 2 hectodays D) 2 microdays E) 2 millidays

10. Write the measurement 13.5 gigameters as a full (decimal) number with standard (no prefix) units.
A) 135,000 m B) 1,350,000 m C) 13,500,000 m
D) 1,350,000,000 m E) 13,500,000,000 m

11. The volume of an object is 20 m^3. Express this value in cm^3.
A) 2×10^{-5} B) 2×10^{-1} C) 2×10^3 D) 2×10^5 E) 2×10^7

12. The standard (basic) SI unit of mass is the:
A) atomic mass unit B) gram C) kilogram D) milligram E) slug

13. Electrostatic force (F_e) given by the equation: $F_e = k\, q_1q_2/r^2$, where k is Coulomb's constant, q_1 and q_2 are electric charges, and r is the distance between the charges. What are the SI units for Coulomb's constant?
A) $m^2/(N{\cdot}C^2)$ B) $N/(m^2{\cdot}C^2)$ C) $C^2/(m^2{\cdot}N)$ D) $(N{\cdot}m^2)/C^2$ E) $(N{\cdot}C^2)/m^2$

14. The unit for energy in the International System (SI) is the Joule (J), which is defined as $kg\ m^2/s^2$. In the cgs (centimeter-gram-second) system, the unit for energy is the erg, which is defined as:
A) $cg \cdot m^2/s^2$ B) $cg \cdot cm^2/s^2$ C) $g \cdot m^2/s^2$ D) $g \cdot cm^2/s^2$

15. A 150-pound student has a weight (in metric units) of:
A) 0.0015 N B) 15.3 N C) 33.8 N D) 667 N E) 1470 N

16. Express 50. mi/h in m/s.
A) 2.2 m/s B) 22 m/s C) 45 m/s D) 49 m/s E) 110 m/s

17. The density of aluminum is 2.70 g/cm^3. Expressed in kg/m^3 the density is:
A) 0.00270 B) 0.270 C) 2.70 D) 27.0 E) 2,700

18. The specific gravity of lead is 11.3 . What is the density of lead in g/cm^3?
A) 0.0885 B) 1.13 C) 1.13×10^3 D) 11.3 E) 11.3×10^3

19. The pressure (P) of a gas at a constant volume is directly proportional to its absolute temperature (T). Which one of the following does NOT express this relationship ?
(k is a proportionality constant)
A) $P = kT$ B) $P/T = k$ C) $PT = k$ D) $T/P = k$

20. *The kinetic energy of an object is expressed by the formula:*
$KE = \frac{1}{2} mv^2$ where m = mass and v = speed.

If a moving automobile is able to double its speed, what happens to its kinetic energy?
A) it doubles B) it becomes 4 times as much
C) it becomes 1/2 as much D) it becomes 1/4 as much
E) it remains unchanged

21. Gravitational force is given by the formula: $F = Gm_1m_2/r^2$. A hypothetical planet has a mass three times that of Earth and a radius four times that of Earth. Your weight (gravitational force) on this planet would be ... of your weight on Earth.
A) 3/16 B) 9/16 C) 3/4 D) 4/3 E) 16/3

22. A student performs an experiment to measure the index of refraction of water. She experimentally determines the value to be 1.41. The accepted value is 1.33. Her percent error is:
A) 0.08% B) 5.7% C) 6.0% D) 94% E) 106%

Use the information given below to answer the next 2 questions.

A student took the following 5 measurements for the diameter of a cylinder.

diameter (cm)

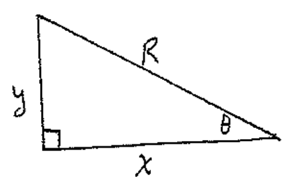
3.5
3.1
3.0
3.3
3.6

23. The average absolute deviation (in cm) for these measurements is:
A) 0.1 B) 0.2 C) 0.3 D) 0.4 E) 0.5

24. The percent average deviation is:
A) 2% B) 3% C) 4% D) 5% E) 6%

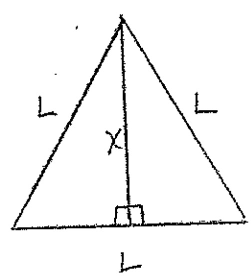
All of the following should be solved without the use of a calculator or a reference table.

25. Given the triangle with side y and angle θ. Determine the length R.



A) $y \cos \theta$ B) $y/\cos \theta$ C) $y \sin \theta$ D) $y/ \sin \theta$ E) $(\sin \theta)/y$

26. Given the equilateral triangle with side L. Determine the length x.



A) $L/2$ B) $2L$ C) $L\sqrt{3}$ D) $\frac{1}{2} L\sqrt{3}$ E) $L\sqrt{3}/3$

27. A square has a side L. Determine the length of the diagonal of the square.

A) $\frac{1}{2} L$ B) L C) $2L$ D) $L\sqrt{2}$ E) $\frac{1}{2} L\sqrt{2}$