UNIT 3
MOTION
PHYSICS

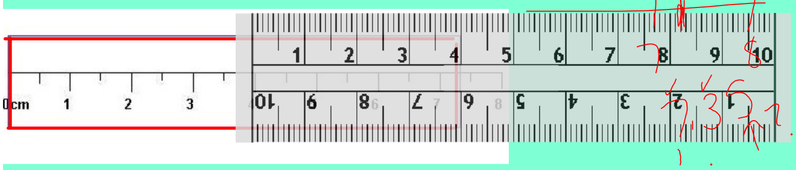
Only those who have the patience to do simple things perfectly will acquire the skill to do difficult things easily.
-- Johann von Schiller

Unit 3
MOTION

- All measurements are uncertain, but how uncertain?

- One method scientist devised to measure and communicate the certainity of a measurement is by counting significant digits.
- By international agreement, scientist count all those digits that are certain plus one digit that is uncertain.
- Certainity is measured by counting the number of certain digits plus one.
- It is important to be honest when reporting a measurement, so that it does not appear to be more accurate than the equipment used to make the measurement allows.
- We can achieve this by controlling the number of digits, or **significant figures**, used to report the measurement.

When measuring, you should be 100% certain of all the digits EXCEPT the last digit. **You always estimate the last digit.** For example, in the following diagram, we know for certain that the length of the rectangle is 7 cm. We estimate that it is another 0.3 cm, giving us a total of 7.3 cm. The last digit -- the 0.3 -- is estimated.

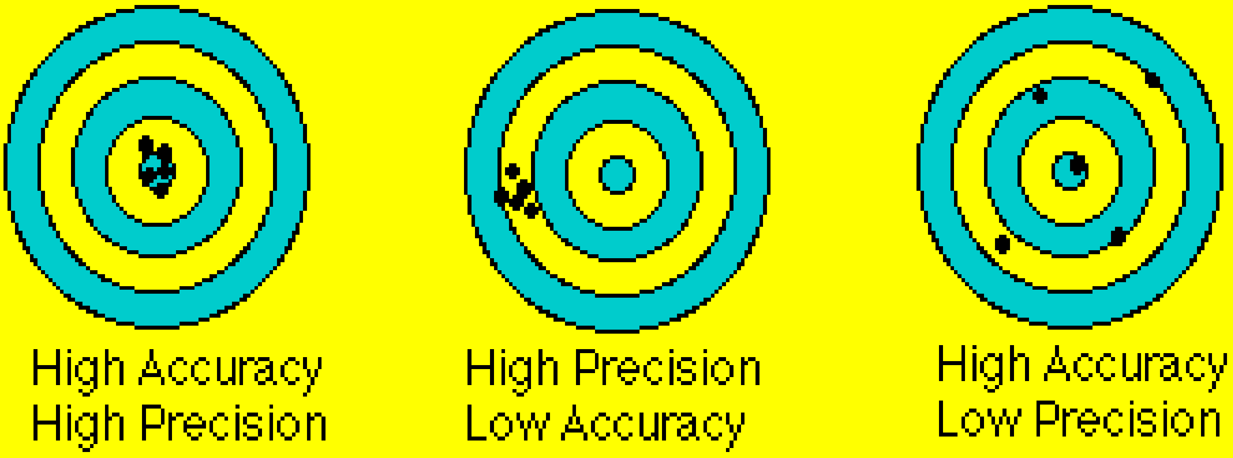


(You could also say the we know the length is 70 mm and estimate it to be about another 3 mm to give a length of 73mm)
- If you measure a line to be exactly 5 cm long, you should record it as 5.0 cm to show your confidence in the measurement.
- How a measurement is recorded indicates what tool was used to make the measurement. For example, a measurement of 23.4 cm indicates a centimetre ruler (because we estimated the 0.4 cm or 4 mm) and a measurement of 23.45 cm indicated a millimetre ruler. (Do you know why?)

We should distinguish "accurate" from "precise." Precision and accuracy are terms used to describe the quality of a measurement. Some view these terms as synonyms, but in fact they are different.

Precision indicates the degree of reproducibility of a measurement. It depends on how well you make a measurement.

Accuracy describes how close a measured value is to the true value. It depends upon the quality and calibration of the measuring device.



of significant digits.

- Calculations done on these measurements must follow the rules for significant digits. The significance of a digit has to do with whether it represents a true measurement or not.
- Any digit that is actually measured or estimated will be considered significant. Placeholders, or digits that have not been measured or estimated, are not considered significant. The rules for determining the significance of a digit will follow.

Rules For Significant Digits

Digits from 1-9 are always significant.

675 has 3 significant digits

Zeros between two other significant digits are always significant

2045 has 4 significant digits

Zeros after a decimal are significant.

231.00 has 5 significant digits
1.450 has 4 significant digits

Zeros used solely for spacing the decimal point (placeholders) are not significant. Initial zeros before a decimal are not significant

0.0981 has 3 significant digits
0.056000 has 5 significant digits

Trailing zeros before a decimal are not significant

8700 has 2 significant digits

	# of sign. digits	
543 kg		All non-zero digits are always significant
5057 L		Zeros between 2 sig. dig. are significant
5.00		additional zeros to the right of decimal and a sig. dig. are significant.
0.007		Placeholders are not sig.
20400		trailing zeros before a decimal are not significant

Base and Derived Units

You should easily be able to make statements like the following as far as the role of instruments in physics is concerned:

- thermometers are used to measure temperature
- meter sticks are used to measure distance
- microscopes and telescopes are used to see things that are very small or very far
- computers are used to collect, store and analyze data
- electric meters are used to measure current and voltage

…and so on and so on.

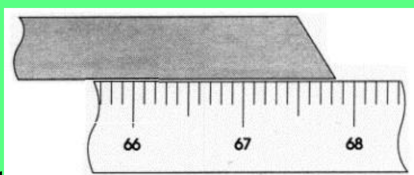
When making measurements it's important to distinguish between base units and derived units. **Base units** are units that are defined. **Derived units** are ones that we "figure out" by using base units.

Consider this: The length and width of a rectangle are measured in meters (a base unit.) The area of the rectangle, however, given in square meters or m^2, is a derived unit because it comes from an expression or relationship. In this case the relationship is:

Area = length x width
m^2 = m x m (Derived unit)
= (base unit) x (base unit)

m = base unit
m^2 = derived unit
sec = base unit
m/s = derived unit

Measurements and Significant Digits
Again!
Look at the picture below.



[redacted]

meter stick) so that we are SURE of all digits but the last one. That is, we write down all the digits that are CERTAIN, and then we ESTIMATE one (and only one) more.

Calculations and Significant Digits

The importance of using significant digits when adding, subtracting, multiplying and dividing measurements can best be demonstrated by considering a division operation as an example:

Example 1

You travel a distance of 125.2 km in a time of 2.6 hr. Assuming you didn’t speed up or slow down at any time (which of course is a bit of a silly assumption), how far did you go in one hour? If you have your calculator at hand you can easily determine the answer by dividing 2.6 into 125.2.

Solution.

[redacted]

MULTIPLYING AND DIVIDING

WHEN MULTIPLYING AND/OR DIVIDING, the number of significant figures in the result should be equal to the number of <u>significant digits</u> in the least precise number (the number with the fewest significant digits given).

Q: How many digits are in the "original" numbers?

[redacted]

Example 2.

Ok, divide 4.2608 by 12.2.

[redacted]

Example

4.2608 x 12.2 = 51.9876

[redacted]

TRY THESE:

1) 13.7 x 2.5 =

2) 200 x 3.58 =

3) 0.00003 x 727 =

4) 5003 / 3.781 =

5) 89 / 9.0 =

6) 5000 / 55 =

ADDITION and SUBTRACTION

IN ADDITION AND SUBTRACTION THE NUMBER OF DECIMAL PLACES IN YOUR ANSWER MUST BE THE SAME AS THE SMALLEST NUMBER OF *DECIMAL PLACES* THAT WERE IN THE NUMBERS ADDED (OR SUBTRACTED)

Do you notice anything?
Did you notice that in the rule for division and multiplication we used the words

SMALLEST NUMBER OF SIGNIFICANT DIGITS, (x and ÷)

and now, for addition and subtraction we are using the words:

SMALLEST NUMBER OF DECIMAL PLACES (+ and -)

Example 3.
3.447 + 637.56 + 0.6279 = 641.6349
Solution.
Q. How many **decimal places** are in the number with the smallest number of decimal places?

1) 4.60 + 3 =
2) 0.008 + 0.05 =
3) 22.4420 + 56.981 =
4) 200 - 87.3 =
5) 67.5 - 0.009 =
6) 71.86 - 13.1 =

Using Scientific Notation

There are at least two reasons for being familiar with scientific notation. Firstly, it provides a convenient way to write numbers that are very big and very small. It works like this:

a big number

3,200,000 = 3.2 x (1,000,000) = 3.2 x 10^6

a small number

0.000 000 043 = 4.3 x (0.000 000 01) = 4.3 x 10^{-8}

You will probably find it easier to leave out the middle steps and just apply these rules:

Put the decimal after the first digit that is not zero.
Count the number of places that you moved the decimal. This number will be the “power” that you put on the 10.
If you moved the decimal to the right, the power of 10 will be negative; if you moved the decimal to the left, the power of 10 will positive.
Try it on

5,670,000,000: 5,670,000,000 = 5.67 x 10^9

0.000,000,649 : 0.000.000.649 = 6.49 x 10^{-7}

Recall that at the beginning of this part we said there were two good reasons for using scientific notation. One is to conveniently write large and small numbers as shown above. The other is to indicate to a reader exactly how many significant digits there might be in a particular measurement.

Suppose for example you have to carefully divide up a parcel of land that lies on a country road that is 13,200 m long. You would probably want to know how many significant digits are in this measurement, but as it stands now it is impossible to tell because you don’t know with what precision it was measured.
For example, if 13,200 has three significant digits, then the “2” is the estimated digit, meaning that the road could very well be as long as 13,300 m, or as short as 13,100 m. On the other hand, if 13,200 has 5 significant digits, the last “0” is estimated, giving you a much greater precision. Now the road might be as long as 13,201 m or as short as 13,199m.
Let’s suppose, in fact, that the surveyor measured the road to an accuracy of 4 significant digits. In that case the surveyor should write the length of the road not as 13,200 m, but as 1.320 x 10^4 m. Note that 1.320 x 10^4 is equivalent to 13,200, and the four digits in 1.320 tell you there are 4 significant digits. This also indicates to you that the actual length of the road is probably between 13,190 m and 13,210 m long.

Scientific Notation.

A number between 1 and 10 multiplied by base 10.

a) 2748312 2.748312×10^{6}

b) 0.007841 $7,841 \times 10^{-3}$

c) 472,3 $4,723 \times 10^{2}$

d) 0.0431 $4,31 \times 10^{-2}$

e) 6928,13 $6,92813 \times 10^{3}$

f) 42.568 $4,2568 \times 10^{1}$

g) 0.013 $1,3 \times 10^{-2}$

h) 4.231 4.231×10^{0}

Put the following in scientific notation with 2 significant digits

3256703942

0.003906261

500660

0.000 000 2

MORE PRACTICE:

Express the following measurements in scientific notation to 4 significant digits:

a. 87,932,000 km

b. 0.000060476 kg

c. 3,263,700 yr

d. 0.00621 s

34 min = ____ h

$34\,min \times \frac{1\,h}{60\,min} = 0.56\,h$

b) 2.35 h = ______ min

c) 425 m = ____ km

d) 1.25 m = ______ cm

* $1.25\,m \times \frac{100\,cm}{1.0\,m} = 125\,cm$

e) 378 min = ______ h

$378\,min \times \frac{1\,h}{60\,min} = 6.3$

6.30 h

f) 426 h = ______ s

$426\,h \times \frac{60\,min}{1\,h} \times \frac{60\,s}{1\,min}$

1533600

$1.53 \times 10^{7}\,s$