Physics 11

Realms of Physics

Physics attempts to model the behavior of the universe from the very large scale (entire universe, 10^{52} kg, 10^{26} m, 10^{19} s) to the very small (components of a proton, 10^{-28}kg, 10^{-15} m, 10^{-23} s for light to pass a nucleus).

This requires the use of very small and very large numbers.

Examples of some masses:

Observable universe	10^{52} kg	Elephant	10^{4} kg
Milky way galaxy	10^{42} kg	Person	10^{2} kg
Sun	10^{30} kg	Grain of sand	10^{-8} kg
Earth	10^{25} kg	Bacterium	10^{-17} kg
Oceans	10^{21} kg	Proton	10^{-27} kg
Oil supertanker	10^{9} kg	Electron	10^{-30} kg

These quantities are presented in a simplified form by using their order of magnitude. This is the nearest power of ten. To determine this, we can take the logarithm of the number. This gives us the exponent of ten that is equivalent to that number.

Example 1:
The mass of the earth is 5.98×10^{24} kg.
What is its order of magnitude?

What is the order of magnitude for 400?

Different quantities can be compared. The mass of the sun is 5 orders of magnitude greater than the earth (100,000 times as massive)

How many orders of magnitude between your mass and the mass of the earth?

Examples of some lengths:

Universe	10^{26} m	person	10^{0} m
Milky way galaxy	10^{21} m	Thickness of paper	10^{-4} m
Earth to Sun	10^{11} m	Wavelength (visible light)	10^{-7} m
Earth to moon	10^{9} m	Hydrogen atom	10^{-10} m
Radius of earth	10^{7} m	Diameter of Proton	10^{-15} m
Mt. Everest	10^{4} m	Planck length	10^{-35} m

Some times:

Age of universe	10^{19} s	Period for high sound	10^{-3} s
Age of earth	10^{17} s	Light across a room	10^{-8} s
Human lifespan	10^{9} s	Period of visible light	10^{-15} s
year	10^{7} s	Light across an atom	10^{-19} s
day	10^{5} s	Light across a nucleus	10^{-23} s
second	10^{0} s		

We will use SI (metric) system of units.
Fundamental Units

Quantity	SI Unit	SI Symbol
Mass	Kilogram	kg
Length	Metre	m
Time	Second	s
Electric current	Ampere	A
Amount of substance	Mole	mol
Temperature	Kelvin	K
Luminous intensity	Candela	cd

There are also commonly used quantities that are derived from fundamental units.

Quantity	symbol	Derived units
Velocity	v or u	m/s or ms^{-1}
Acceleration	a	m/s/s or m/s^2 or ms^{-2}
Force	F	kgm/s^2 or $kgms^{-2}$ or N (newton)
Work	W	kgm^2/s^2 or kgm^2s^{-2} or J (joule)
Power	P	kgm^2/s^3 or kgm^2s^{-3} or J/s or W (watt)

We will also use standard metric prefixes for orders of magnitude:

Prefix	Symbol	Value
Micro	μ	10^{-6}
Milli	m	10^{-3}
Centi	c	10^{-2}
Kilo	k	10^{3}
Mega	M	10^{6}

Unit conversion will follow the method of unitary rates.
100 cm = 1 m. Therefore:

$$1 = \frac{1\text{ m}}{100\text{ cm}} = \frac{100\text{ cm}}{1\text{ m}}$$

Multiplying by this fraction will not change the value of the quantity, only its units.

Example 2:
For each of the following, identify the equality and convert:

a) 250 cm into meters

b) 0.0342 μm into km

c) 2500 s into minutes

d) 350mg into kg

e) 0.023 cm^3 into m^3

f) 125 km/h into m/s

In physics, numbers usually represent measured values. These measured values are not exact. The way they are written down reflects the precision of that measurement.

We use significant digits to keep track of the precision of our measured values and to keep track of the precision through a calculation.

Significant digits (figures):

1) All non zero digits are significant.
2) All final zeros after the decimal point are significant.
3) Zeros between two other significant digits are significant.
4) Zeros used only for spacing the decimal point are not significant.

Example 3:
Give the number of significant digits in:

a) 16.392 m

b) 2.035 L

c) 5.900 cm

d) 0.00506 K

e) 120 000 km

f) 350 000.0 J

g) 0.00300 μg

Scientific notation is very useful in designating significant figures. Any digit shown in the numeric part of scientific notation is significant.

How can you show 200 km with 2 s.f.?

2.0×10^2 km.

In our experiments, where we have detailed information about errors, we must be very careful to use significant figure rules carefully, because the errors in our answers give us valuable information about our experimental results.

In text questions, we will use significant digit rules to determine the significant digits in our answers.

Significant Figure Rules:
In multiplication and division, the answer has the same number of S.F. as the least number of S.F. in the question.

Example 4:

a) 30.0 N x 12 m

b) 1.3975 m / 0.84 s

c) 80.034 kg x 1.3 m / 17.3985 s

In addition and subtraction, the answer must have the same precision and the least precise value in the question (fewest decimal points or smallest place value).

Example 5:

a) 121.45 m + 17.2 m

b) 5.743 L - 2 L

c) 12.034 m / 1.08 s - 8.392 m/s

Accuracy and Precision

Accuracy and Precision are two words that must be used carefully.

Accuracy indicates how well a measured result indicates the real or “correct” result.

Precision indicates how well the equipment was used and the quality of the equipment in getting a result. Precision is indicated by the number of significant figures used in a measurement.

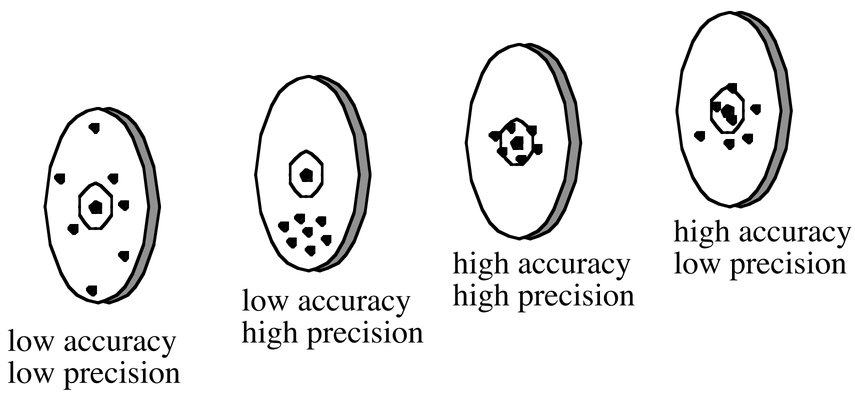
A good way to indicate accuracy is to use a percentage difference.
For comparing to a known value:

$$\% \text{ error} = \left(\frac{|\text{accepted value - experimental value}|}{\text{accepted value}} \right) \text{ x } 100\%$$

For comparing two experimental values:

$$\% \text{ difference} = \left(\frac{|\text{value 1 - value 2}|}{\text{mean value}} \right) \text{ x } 100\%$$

Here is a good visual representation of accuracy and precision:



Precision can be estimated from:

- knowledge of the equipment you are using, ie. a centigram balance is ±0.01g
- Half of the smallest scale marking
- Experience with your skill using a piece of equipment.
- Calculation from repeated measurements
  ± x = |(farthest from mean) - (mean)|

Accuracy involves an understanding of your experiment, with a standard to compare with, or other information that tells you about your experiment.

We will address these through experiments this semester.

Skill WS # 1
Chapter 1 Supp. Prob. # 1-4, 6, 8, 10-12

Graphing

Graphing is used extensively in Physics. It is a very powerful method to show the relationship between two variables.
The relationship is between an independent variable and a dependant variable.

The independent variable is the variable that the experiment intentionally changes.

The dependant variable is then measured to find if it changes, to determine if it is dependant on the independent variable.

With a few notable exceptions, a graph is made with the independent variable plotted on the x-axis, and the dependant variable on the y-axis.

The shape of the graph will give us a strong indication of the relationship between the variables.

See handout for rules for graphing.

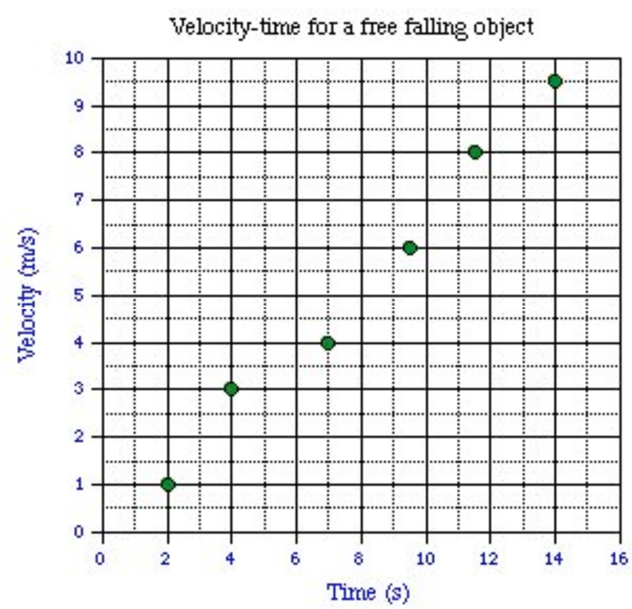
We will be graphing variables to find the relationships between those variables.

There are many complex mathematical relationships. We will examine a few of them: linear, quadratic, and inverse.

The simplest is a line $y = \mathrm{m}\,x + \mathrm{b}$

A linear graph is the most useful for us because we know a great deal of math about straight lines.
We can calculate the slope (with units)
The degree of agreement between the line and points of the graph tells us about our experiment.
The y-intercept also gives us information about errors in the experiment.

Give the equation of the line for:

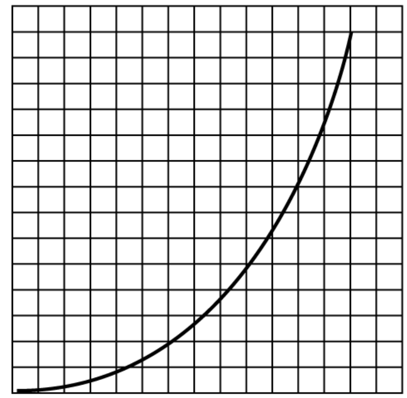


A quadratic graph will have a general shape as follows:

The general form is:

$y = ax^2 + bx + c$

C



$y = kx^2$

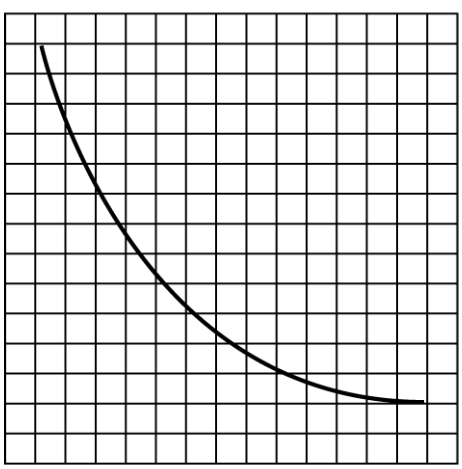
An inverse graph will have the y-variable increasing with the decrease in the x-variable.

A linear inverse graph will have a negative slope.

A non-linear relationship can look like part of a hyperbola. This will have the general form of $y = k/x$ or $xy = k$

An inverse relationship

B



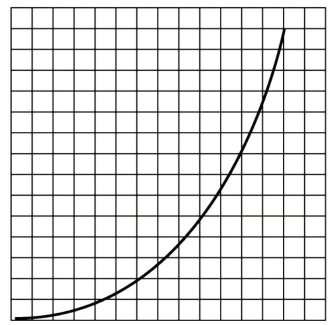
$y = k/x$

Complete Graphing Handout

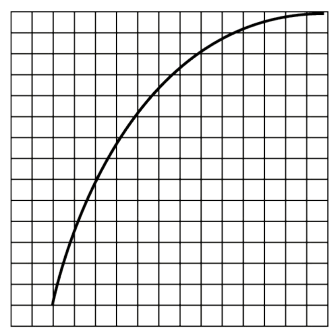
3 Manipulating Graphs

Some relationships can be manipulated to form a straight line graph.
The advantage of a straight line is that we can perform simple calculations with linear relationships.
The basic form of the line equation will be used to get information from the straight line: $y = \mathrm{m}\,x + \mathrm{b}$
3 — Introduction — Manipulating Graphs

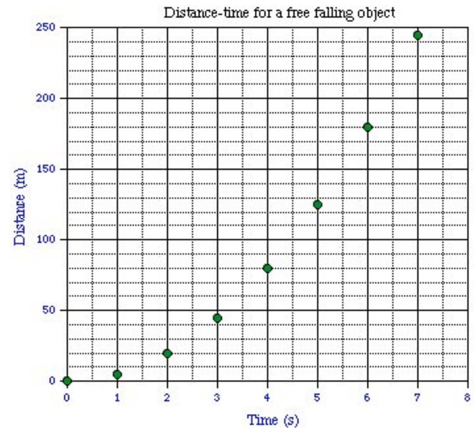
A graph that is a quadratic graph, the data can be regraphed with one of the variables squared.
A quadratic graph that looks like this can be regraphed with the x-variable squared.

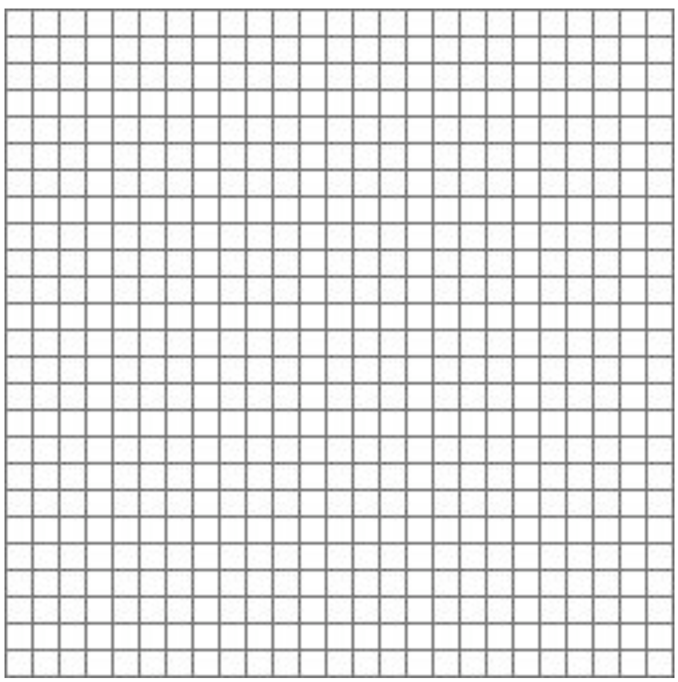


A quadratic graph that looks like this can be regraphed with the y-variable squared.
This may yield a straight line.



d(m)	t(s)	
0	0.0	
5	1.0	
20	2.0	
45	3.0	
80	4.0	
125	5.0	
180	6.0	
245	7.0	



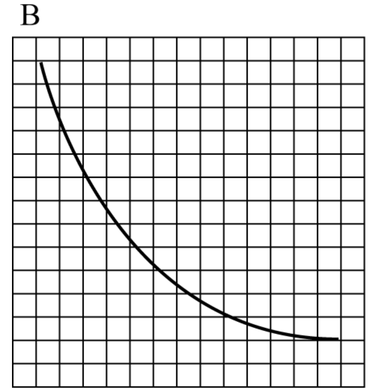


A graph that is an inverse hyperbolic graph can be converted to a straight line graph by regraphing with the inverse of one of the variables (x^{-1} or y^{-1}).

These are some approaches to some simple mathematical relationships. These techniques may need to be combined, or they may not work at all, or the data may be so poor that you draw the wrong conclusion.

Regraph Handout # 3, 4
Text p. 26, # 67 - 79

B



$y = k/x$