King Abdul-Aziz University
Faculty of Science
Physics Department

PHYS 281
General Physics Laboratory

Student Name:

ID Number:

Introduction

Advancement in science and engineering has emphasized the microscopic world, that is the world of atoms and its parts. This required that scientist develop individual initiatives to see, to question and, if possible, to find out why! This process is not a straight forward procedure but demand a gradual and direct introduction to the fundamentals methods of analysis.

The objectives of a physics laboratory, such as PHYS 281, are not just verification of known laws or the blind substitution of data into a formula. The physics laboratory should bridge the gap between idealized laws discussed in textbooks and the real world. In order to achieve this, the student must master some fundamental tools that would aid his/her curiosity. Nonetheless, the mastery of such tools depends on the attitude of the student toward the laboratory work.

Objectives

The objectives of this laboratory are:

1. To introduce the student to the significance of the experimental approach through actual experimentation.
2. To apply the theories to real-life problems to develop a better understanding.
3. To introduce the student to the methods of data analysis used in science and engineering.
4. To develop an "error conscience" so that the engineer and scientist will at least be aware of the relative worth of all measurements, whatever their type.
5. To familiarize the student, by direct contact, with a great many basic instruments and their applications.
6. To make the student realize that such tools as graphing, use of algebra and calculus, etc. are of fundamental importance.
7. To impress on the student that even an experiment which is apparently unimportant to his/her professional future may contribute directly to the student's mental development because of the analytics and mathematics involved.
8. To improve the student's ability of self expression through report presentation.
9. To give the student direct contact with the instructor, and thus the advantages of close direction and personal discussion of ideas and methods.

Laboratory Operation

1. Assignments

   Each student will work in a team. Laboratory assignment requires the performance of an experiment in the laboratory and the presentation of the data, computations, etc. must be completely worked out in the laboratory worksheets. All the work should be written up in a report and handed to the instructor for inspection and grading no more than the next scheduled laboratory meeting.

2. Data check

   At the completion of the experiment, the laboratory worksheets are to be presented to the instructor to be checked and signed. This permits obvious errors to be found.

3. Student's responsibility toward equipment

   Most equipment is sensitive and expensive. Therefore, apparatus must be treated with respect. Students must leave their tables and apparatus in good order: i.e. weighs put away, instruments returned to cases, water emptied, scrap paper picked up, etc.

The Report

Most experimental work, records of the work done, data taken, and observations made in the laboratory are kept in the laboratory worksheets. The final reports are abstracted from such worksheets and this is the method that your laboratory lab work should be presented to your instructor.

The laboratory report has generally eight parts:

1. Purpose of the experiment (Objective).
2. List of apparatus and a sketch if needed.
3. Equations and their explanation.
4. Data
5. Computation outline
6. Graphs and results
7. Discussion and Conclusion
8. Home work assignments (Bonus marks).

Errors in laboratory work

Physics is an exact science, but the pointer readings of the physicist's instruments do not give the exact values of the quantities measured. No measurement in science is absolutely accurate. The value of physical quantities such as a length, a time-interval or a temperature, are accurate within a limit. The closer these limits, the more accurate the measurement.

The difference between the observed value of any physical quantity and the 'standard' value is called the ***error of observation***. Such errors follow no simple law and, in general, arise from many causes.

Classification of errors

An error which tends to make an observation too high is called a ***positive error*** and one which makes it too low is called ***negative error***. Errors can be grouped in two general classes, ***systematic*** and ***random***.

Systematic error

It is always produces an error of the same sign. Such errors can be subdivided into three groups.

(i) Instrumental error: it is caused by faulty, poorly made or improperly calibrated instruments. For example, a stop watch, that does not run at the proper rate, will cause an instrumental error. A spring balance, which is not properly calibrated, will cause an error to the mass of the body weighed by it. An ammeter or voltmeter is accurate in limited sense. The dial instruments have zero errors i.e., the pointer does not indicate zero when not in use.

(ii) Personal error: it includes errors of judgment, errors in reading instruments, writing down the wrong figures, mistakes in arithmetic or using a calculator. An error, due to parallax, come under this category.

(iii) External errors: these are usually caused by conditions over which the observer has no control. Examples are:

a. Change in atmospheric pressure in Boyle's law experiment
b. Change in room temperature in velocity of sound experiment

Random errors

In random errors positive and negative errors are equally probable. As an example, we can take the measurement of the diameter of a cylinder. Even if the readings are taken with utmost care, the values of the diameter slightly differ from one another. The best value is obtained by taking their arithmetic mean. The observed values of the diameter will be found to lie on both sides of this mean value. The fators causing such types of errors are unknown are variable. The errors are assumed to be a matter of chance. Therefore, positive and negative errors are equally probable. The effect of such errors, on the experimental result, can be made quite small by taking a large number of observations. However, a large number of observations have no effect on systematic errors.

In our lab we will use the following equation to calculate the percentage error of our final result relative to the known theoretical value of the calculated quantity:

$$\%\ Error = \left|\frac{experimental\ value - theoretical\ value}{theoretical\ value}\right| \times 100$$

Measurements - Worksheet

1. **Investigate some parameters we can measure in the lab and the instruments required for these measurement. Fill in the below table showing the different instruments in the lab and the parameter it measures.**

Parameter									
Instrument									

2. **Look at the different measuring devices in front of you and answer the following questions.**

   1. **The ruler, vernier caliper and micrometer:**
      a. What is the physical quantity measured by each of them?

      b. What is the measuring unit of each of them?

      c. What is the value of the major mark?

d. What is the value of the minor mark?

e. Using the different object in front of you, take some measurements by using each of them?

2. The mass balance:

a. What is the physical quantity measured by a balancing scale?

b. What is the measuring unit of a balancing scale?

c. How many scales does the balancing scale in front of you have?

d. In the front scale, what is the value of the major and minor marks?

e. In the middle scale, what is the value of the major and minor marks?

f. In the rear scale, what is the value of the major and minor marks?

g. Take some measurement using the balancing scale and the object around you.

3. The stop watch:

a. What is the physical quantity measured by a stop watch?

b. What is the measuring unit of a stop watch?

c. What is the value of the major marks?

d. What is the value of the minor marks?

e. Using the stop watch, measure the number of pulses you heart makes in one minute. Does your pulse rate falls in the normal heart pulse rate?

4. The dynamometer:

a. What is the physical quantity measured by a dynamometer?

b. What is the measuring unit of the dynamometer?

c. What is the value of the major and minor marks in the dynamometer?

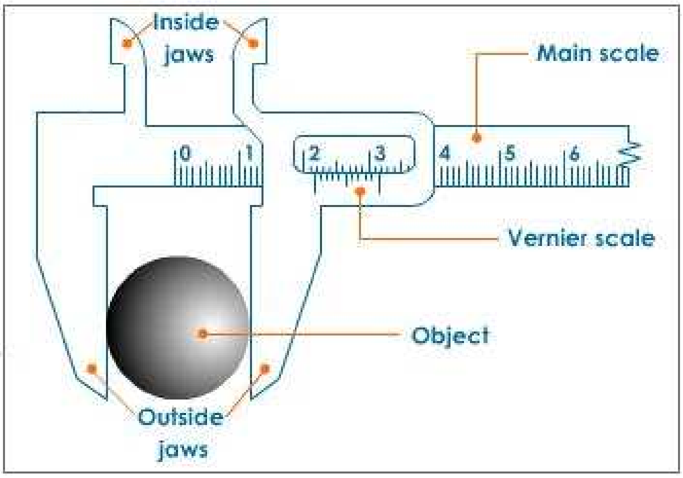
d. Take some measurements by using the dynamometer and some objects in the lab.

Measurements

Precision Measurement Tools

The vernier caliper:

The vernier caliper is used in length measurements to gain an additional digit of accuracy compared to a simple ruler. The details of the vernier principle are shown in the illustrations below.

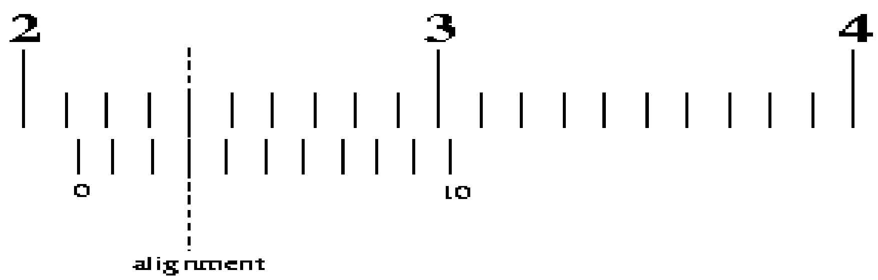


1. Instructions on use

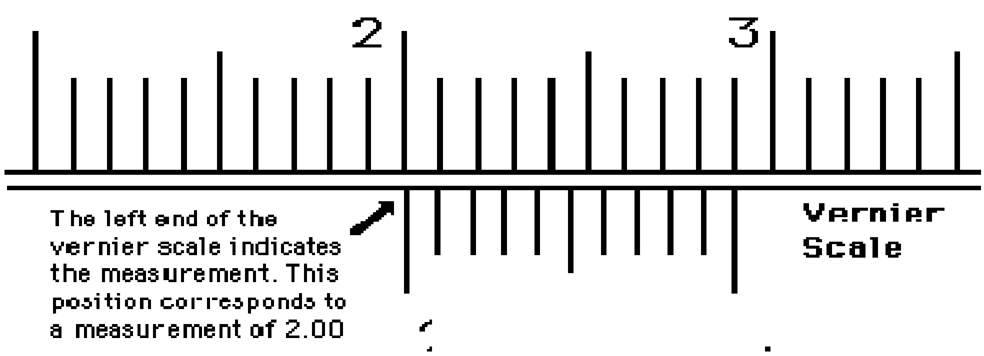
- Close the jaws **lightly** on the object to be measured.
- If you are measuring something with a round cross section, make sure that the axis of the object is perpendicular to the caliper.
- Ignore the top scale, which is calibrated in inches.
- Use the bottom scale, which is in metric units.
- When the jaws are brought together the zero mark on the vernier should coincide with zero on the rule, if not correction must be applied to readings obtained with the callipers.

2. Reading the scale:

- Read the centimeter mark on the fixed scale to the left of the 0-mark on the vernier scale. (2.1 cm)
- Look along the ten marks on the vernier scale and the millimeter marks on the adjacent fixed scale, until you find the two that most nearly line up. (0.03 cm)
- To get the correct reading, simply add this found digit to your previous reading. (2.13cm)

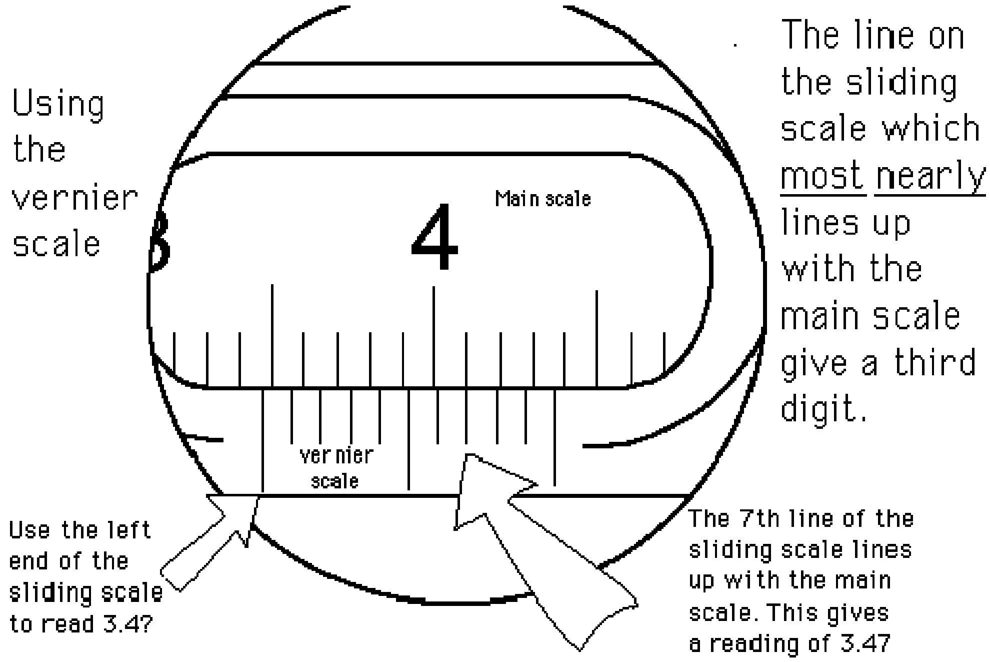


Example 1:



The measured length is 2 cm

Example 2:



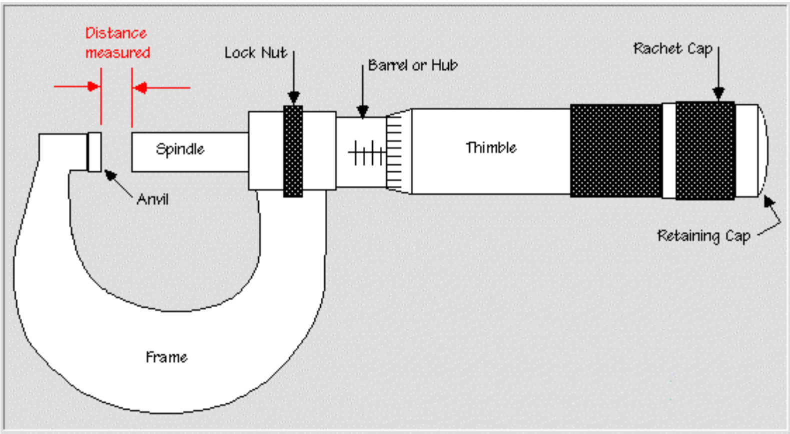
The main scale=3.4 cm

The vernier scale=0.07

The measured length =3.47 cm

The Micrometer:-

Micrometers are Instruments that measure the thickness or the diameter of relatively small parts; it produces finer results than a vernier caliper.



1. How to use it?

In order to measure an object, the object is placed between the jaws and the thimble is rotated using the ratchet until the object is secured. Note that the ratchet knob must be used to secure the object firmly between the jaws, otherwise the instrument could be damaged or give an inconsistent reading.

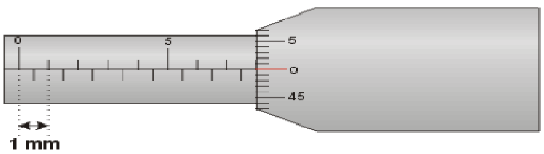
2. How to read it?

The diagram to the right is a close-up of the micrometer showing the thimble.

The main scale reading (the last visible line)=8mm

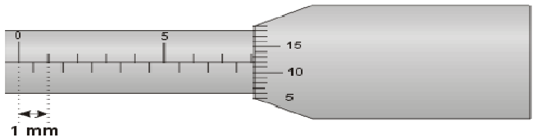
The vernier scale=0

The measured length = 8mm.



Now imagine we turn the thimble just a little bit more, and end up with the situation shown.

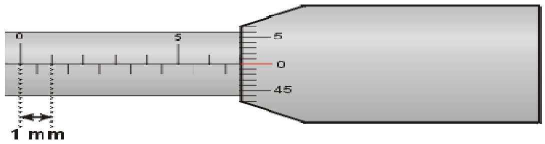
The main scale reading(the last visible line)=8mm



The vernier scale=0.12

The measured length = 8.12 mm.

Exercise



The main scale reading (the last visible line)= ……mm

The vernier scale=………….

The measured length = ……………….

Graphs - Worksheet

1. **Look at the three different tables below. Can you determine the type of relation between the parameters *x* and *y* in each table?**

Table A:

x	1	2	3	4	5	6	7	8	9	10
y	2	4	6	8	10	12	14	16	18	20

Table B:

X	1	2	3	4	5	6	7	8
y	1	8	27	64	125	216	343	512

Table C:

x	0	30	60	90	120	150	210	240	270	300	330	360
y	0	0.5	0.8	1	0.8	0.5	-0.5	-0.8	-1	-0.8	-0.5	0

2. **In an experiment we studied the relation between the mass (*m*) and the weight (*w*) for some objects. In each step we changed the mass and measured the weight experimentally. The results of these measurements are shown in the following table**:

m (kg)	1	2	3	4	5	6
w (N)	10	20	30	40	50	60

From the above table answer the following questions:,

a. What is the weight of a 4.35 kg object?

b. What is the mass of a body that has a weight equal to 27.5 N?

c. Is the above table enough to find accurate answers for parts a and b?

d. How can you better visualize the results of this experiment and the relation between its parameters?

e. Use a graph paper to plot the data by choosing a suitable scale. What are the independent and dependant variables?

f. What scale will you use for the x and y axes? What are the values of the major and minor marks in both axes? Remember to label the axes correctly.

g. Repeat parts a and b. Are your answers different from the previous ones? Explain.

h. Calculate the slope of the resulting line. What does this slope represent?

3. Using the below table, plot the graph that represent these data. Make sure you take the below points into consideration:

a. Correctly determine the dependant and independent data.
b. Determine the values of the major and minor marks in both axes.
c. Place the title of each axes and its measurement unit.

Table 1:

t(s)	**0.1**	**0.15**	**0.2**	**0.3**	**0.45**
v(m/s)	**0.49**	**0.61**	**0.93**	**1.25**	**2.19**

Table 2:

m(kg)	**2**	**4**	**5**	**7**	**8**
Δx (m)	**0.245**	**0.53**	**0.625**	**0.888**	**1.095**

Graphs

Wherever possible, the results of an experiment should be presented in graphical form. A graph provides the best means of averaging a set of observations. A graph gives an immediate visual picture about the dependence of one variable quantity on the other. In plotting the results, the dependent variable should be plotted as ORDINATES on the Y axis and the independent variable as ABSCISSAE on the X axis. The use of a graph to obtain readings between experimental points is called INTERPOLATION. The extending of a graph to obtain values outside the experimental range is called EXTRAPOLATION. One should be cautious in doing extrapolation.

The most satisfactory 'shape' of a graph is the straight line. This is done more accurately, and deductions from such a graph are more reliable than with curved graphs. If the relationship between two quantities is not a simple linear one, the quantities plotted are so chosen that the graph of the equation is a straight line. Some of the methods of doing this are described below:

In equation of the form

$y=ax^2$ or $y=bx^3$

if y is plotted against x, curves are obtained. The resulting graph may be a straight line if y is plotted against x^2 or x^3.

The time-period of a simple pendulum is given by $T=2\pi\sqrt{l/g}$.

If T is plotted against 1, a quadratic curve is obtained. The equation can be converted to the form $T^2 = 4\pi^2 \cdot l/g$ to give a straight line between l and T^2.

The curve, between the pressure p and the volume V of a given mass of gas at constant temperature, is an inverse curve as the relation between them is expressed as

pV = k , where k is a constant.

The equation can be written in the form

$$p = k \cdot \frac{1}{V}$$

The graph of p, when plotted against $1/V$, is a straight line.

GRAPHING Data

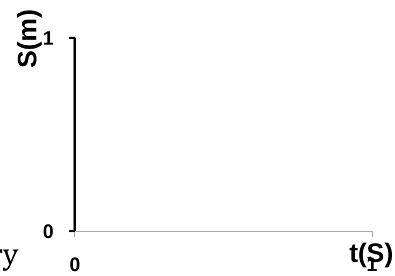
Steps in Plotting a Graph:-

1. Plotting the variables:

When a student is told to plot, say, S versus t, it is important that he understands the following:

1- t is the independent variable, which is the quantity that is deliberately varied or changed. The independent variable is plotted on the "x" or horizontal axis.

2- S is the dependent variable, which is the quantity that changes due to the variation in the independent variable. The dependent variable is plotted on the "y" or vertical axis. This is a convention (agreement) which should be memorized.

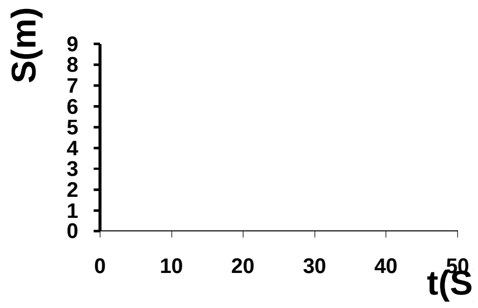


2. Labeling the axes:

The vertical and horizontal axes of the graph paper should carry labels indicating the quantities plotted, with units. In our previous example the label on the y-axis would be: S (m).

3. Choosing the scale:

The scale for a variable is the number of centimeters of length of the graph paper given to a unit of the variable being plotted. For example, one might allow 1 cm for each 10 seconds of time. **Note that in general the scales along the x and y axes may be different.**



Two things need careful consideration before choosing the scales for a graph, the ranges of the variables, and convenience in plotting:

a) **<u>Range of the variable</u>-**

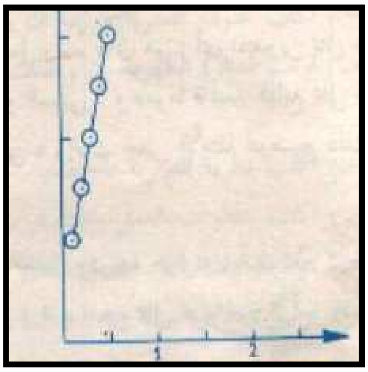
Suppose a student has some data for a variable S which ranges from 5*10-2 m to 125*10-2 m. He then should choose a scale which allows him to plot S values from zero to values somewhat greater than 125*10-2 m.

Notice in this case that, unless told to do so by the instructor, he does not choose to suppress the zero and start the S scale from 5*10-2 m. The reason is that later he may need to use the graph to find values extrapolated (continued) to the origin. Also, he allows space on the graph for values somewhat greater than the largest value in the data set (in our example, 125*10-2 m). He does this because later some more data, with larger values, may be acquired, or he might need to extrapolate the graph to larger values.

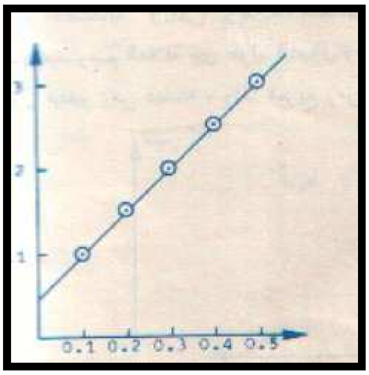
Finally, the scale should be chosen to most nearly use the whole of the graph paper. Just because a simple choice (say, 1 cm to 1 second of time) makes a graph easy to plot, this should not be done if it results in a tiny graph "hiding" in a corner of the sheet of paper! Besides not looking "nice", such a graph is also inaccurate when used to analyze the data.

b) <u>Convenience in plotting</u>-

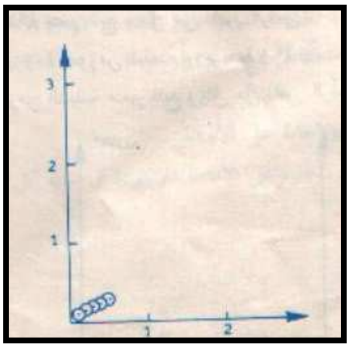
It turns out that scales of 1, 2, 5 and 10 (and multiples of 10 of these) per centimeter are easiest to use; a scale of 4 per centimeter is somewhat more difficult but can be used. Scales of 3, 6, 7, 9, etc. per centimeter are very difficult to plot and read and In choosing scales it sometimes helps to turn the paper so that the "x-axis" is either the long or short dimension of the paper.



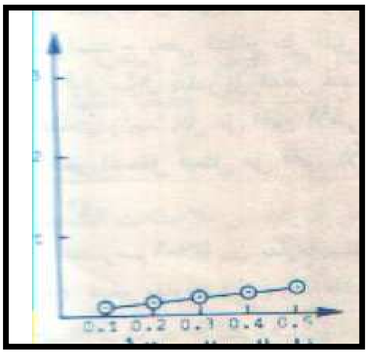
Unsuitable scale for x- axes



suitable scale for both

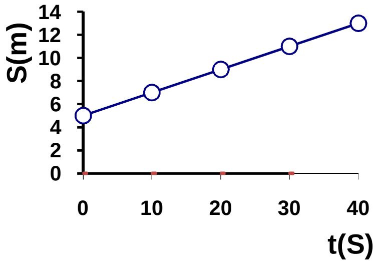


Unsuitable scale for both axes



Unsuitable scale for y-axes

4. Circling the data Points:



When plotting graphs by hand use a pencil. Pencil marks are easier to erase if you make a mistake! Use a dot enclosed in a circle, or a cross.

5. Drawing a Straight Line through the Data Points

When the data fall on a straight line (or are expected theoretically to do so) a ruler may be used to draw a straight line through the points. Observe the following rules: the line is drawn to match the data trend, and for data with some "scatter" balance some points above and below the line. In general, the best straight line is the line that, on average, is closest to all of the points. Finally, points which fall far outside **the** general data trend should be *double-checked* for correct plotting, then, if found correctly plotted, ignored in drawing the line.

Graphical Analysis

Calculating the slope:

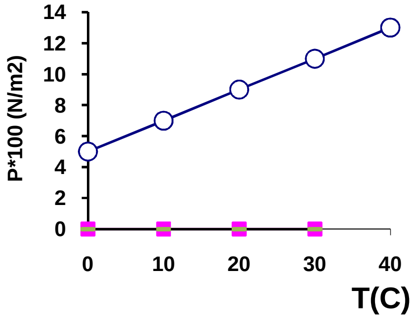
For data sets (x, y) obeying a linear relation $y = mx + b$, we can use a graph of the data to determine the values of m and b. On the graph these are found to be:

b: y-intercept of the graph (value of y when x = 0.)

(**b= V.I=5*100 N/m^2**)

***m*: slope of the graph** = $\frac{\Delta y}{\Delta x} = \frac{y_2 - y_1}{x_2 - x_1}$.

(**m=** $\frac{(7-5)*100}{10-0} = 20$ **N/m^2*C**)



Note that in finding the slope we should choose the points (x_1, y_1), (x_2, y_2) relatively far apart for accuracy. These values should **__not__** be chosen to correspond to data points even if they appear to lie on the straight line.