Hugh McRoberts Secondary

Physics 11: Course Outline

Teacher: Mr. B. Powell

Course Objectives

This course is intended to be an introductory physics course that focuses on principles and theories, that encourages investigation of physical relationships, and illustrates the relationship between theory and application. The application of physics to everyday situations will be emphasised throughout the course. It is intended that the skills and knowledge gained will provide a solid base for further study.

Course Content

The following is an overview of the topics to be covered.

Core topics:

1. **Introduction to Physics**

It is expected that students will demonstrate an understanding and appreciation of the role of physics in society and will be encouraged to develop the skills and methods employed by physicists.

2. **Wave Motion and Geometrical Optics**

It is expected that students will demonstrate an ability to describe and apply the characteristics and properties of waves to light and other everyday phenomena, analyse situations in which light reflects from plane and curved mirrors and analyse situations in which light is refracted.

3. **Kinematics**

It is expected that students will demonstrate an understanding of the relationships between time, displacement, and velocity, and apply these relationships to problems in everyday one-dimensional situations, demonstrate an understanding of the relationships between time, velocity, displacement, and acceleration and apply these relationships to calculations in common situations and apply the principles learned in kinematics to situations involving simple projectile motion.

4. **Dynamics in One Dimension**

It is expected that students will demonstrate an ability to apply in a variety of situations concepts related to the force of gravity, demonstrate an ability to describe and apply the concept of friction to everyday situations and determine the factors that affect it, demonstrate an ability to describe and apply Hooke's law to everyday situations, demonstrate knowledge of Newton's laws and apply them to common situations and demonstrate an ability to describe and apply the concept of momentum to everyday situations.

5. **Energy**

It is expected that students will demonstrate an understanding of the relationship between work and the different forms of energy, demonstrate an understanding of the law of conservation of energy and the relationships among work, kinetic energy, potential energy, and thermal energy and demonstrate an ability to describe and apply the concepts of power and efficiency to everyday situations.

6. **Nuclear Fission and Fusion**

It is expected that students will demonstrate an understanding of the implications of using nuclear processes.

Attendance and Punctuality

Regular attendance is a must if students are to work to the best of their ability. Absences are, however, sometimes necessary. Students who have been absent should see me upon their return to school, before their next physics class, in order to get information about missed work. For extended absences, students should contact me for home study material.

Students are expected to be on time and in their assigned seats with their books open and their materials (pens, books, calculators, etc.) ready before the bell rings.

Missed Work and Tests

Students are responsible for catching up on all work that has been missed. Late work or assignments may not be accepted.

Ample notice will be given of any tests. Students who miss writing a test will be expected to bring a note (from their doctor in the case of illness) explaining their absence and write the test as soon as possible. Any test written late may have up to 10% per day deducted from the student's score. When marked tests have been returned to the class, missed tests will receive a score of zero.

Students cheating on exams will receive zero on the exam and will have their parents or guardians contacted.

Safety

Students are expected to follow the safety rules of the school and other rules discussed prior to demonstrations and laboratories.

School Supplies

All school supplies must be brought to class daily including the textbook, a 3-ring binder, lined loose-leaf paper, graph paper, pens, pencils, erasers, ruler, and a scientific calculator.

Students

The school year can be a very enjoyable and successful year for you. See me whenever you have any difficulties or concerns so that we may eliminate any problems as quickly as possible.

Parents/Guardians

Please read and have the student read the sections in the student handbook (Premier School Agenda) entitled "Student Responsibilities", "Homework Hints", and "Preparing for Examinations".

If you have any concerns at any time about this student's progress, please call me. School phone: 604 - 668 - 6600

<u>Measurement and Significant Figures</u>

Physics, more than any other branch of science, concerns itself with the observation and measurement of a great many different quantities. Measurements provide the final test of the theories and laws of physics. You must, therefore, become familiar with the methods used by scientists to express their measurements.

You may already be aware of the fact that there is no such thing as the perfect measurement. We constantly try for perfection in our measurements but we are always limited by the precision of the measuring instruments as well as unavoidable errors we make in our methods and in our ability to read the instruments.

Despite the belief in science that there are ultimate limits to the accuracy of measurements, we keep trying to improve our instruments and techniques. In this way, the laws of physics are refined, extended, or sometimes even discarded. Progress made in scientific theory often depends on progress made in improving measurement techniques.

A measurement is simply the process of comparing some quantity with a known standard. The size of the standard is referred to as a "unit". All measured values can be expressed as a multiple of some standard unit. A metre, for example, is a unit of length. All measured lengths can be expressed as multiples of the metre.

Keep in mind, when making measurements, that both the multiple (the numerical value) and the unit must be recorded. After all, the statement that something is eight long is meaningless. Is it eight centimetres, eight metres, or eight kilometres? A numerical value without units is totally useless. In fact, in this course, marks will be deducted if answers are given without including the proper units.

When making a measurement you should choose an instrument which will provide you with the accuracy to suit your purpose. For instance, if you want to paint a wall and need to know the quantity of paint to buy, you could probably measure the length and width of the wall to the nearest metre. However, if you want to wallpaper the wall, you must know the dimensions much more accurately so that you can cut the wallpaper to fit. You would want a metre stick that was divided at least into millimetres.

When using the metre stick, (or any measuring instrument), it is agreed <u>by convention</u>, that it should be possible to judge a measurement to the nearest of the small divisions on any scale without making an error of more than half a division. If you are using a metre stick that is divided into tenths you will be able to measure the length of the wall to be, let's say, four and two-tenths (4.2) metres without being out more than half of one-tenth (0.05) metre. If you use a metre stick that is divided into hundredths (millimetres), you will be able to measure the length to be, say, four and twenty-three hundredths (4.23) metres without being out more than half a hundredth (0.005) of a metre. It should be obvious by this process that each time the smallest division on your scale is divided by ten you may add another digit to your measurement. The digits obtained by this measurement process are called significant digits. It should be seen at once that the more significant digits there are in a measurement the more accurate the measurement. Therefore, a measurement with three significant digits is more accurate than one with only two significant digits. Significant digits are more often called significant figures or "sig figs".

Throughout all of your work, whether it be experimental or problem solving, you must work with the correct number of significant figures. Again, marks will be deducted for the incorrect use of sig figs. Practice is the best way to become familiar with sig figs, however, there are some rules which, by convention, scientists use to determine which digits in the numerical value of a measurement are "significant" and indicate accuracy.

1. All non-zero digits are significant.

2. All zeros between non-zero digits are significant.

3. In a number containing a decimal, all zeros to the right of the last non-zero digit are significant.

4. All other zeros are not significant. (Such zeros indicate size, not accuracy.)

Here are some numbers with their significant figures indicated as based on the above rules.

a)	93 000 000	2 significant figures	(rules 1 and 4)
b)	106 000	3 significant figures	(rules 1, 2 and 4)
c)	0.000 04	1 significant figure	(rules 1 and 4)
d)	0.000 050 6	3 significant figures	(rules 1, 2 and 4)
e)	0.002 400 0	5 significant figures	(rules 1, 3 and 4)
f)	130.000 0	7 significant figures	(rules 1 and 3)
g)	2.300 00	6 significant figures	(rules 1 and 3)

Now, look at examples (b) and (d) again. Both have three "sig figs" which to the physicist means they both have the same degree of accuracy of measurement. This seems contrary to the commonly held idea that a number like 0.000 075 is more accurate than 0.075 or 75. However, most frequently the position of the decimal is determined by the choice of units and has no bearing on the accuracy of the measurement. For example:

75 millimetres
= 0.075 metre
= 0.000 075 kilometre.

To the physicist, all three of the above lengths have the same degree of accuracy, and so have the same number of significant figures. Note again that the zeros in this example only indicate size.

PRACTICE:

How many significant figures are there in these measurements?

a) 186 000 m	f) 0.000 000 402 0 s
b) 20 030 s	g) 4.10 m
c) 0.000 5 m	h) 104 000 m
d) 2.00 m	i) 220 s
e) 4.050 0 s	j) 1 000 m

ANSWERS:

a) 3	e) 5	h) 3
b) 4	f) 4	i) 2
c) 1	g) 3	j) 1
d) 3		

We shall now return our discussion to the actual taking of a measurement. When making a measurement, we must often make an estimate of some decimal fraction of the smallest division on the scale of the measuring instrument. However, in making such an estimate, scientific practice allows us to use and record only one doubtful digit. We could not record three-quarters (0.75) of the smallest division on a scale but we can record 0.7 or 0.8 of it. In 0.75 we are not certain of the 7 so how could we possibly be certain of the 5? To record 0.75 would add an extra, and unjustified, significant figure.

There is still another aspect to the making and recording of a measurement. An estimate must be made of the maximum possible error involved in making the measurement. This error is called the tolerance and is recorded following the measurement as a ± value. For example: 34.7 ± 0.05 cm. There is a convention in stating tolerance, however, this can also be left up to the judgment of the observer. This can create some difficulties as we will see. An observer may decide that a measurement cannot be out more than 0.1 or 0.2 of the smallest division, but unless this is stated as the tolerance of the measurement, by convention the tolerance is understood to be half of the smallest division on the measuring instrument. Consider the following example.

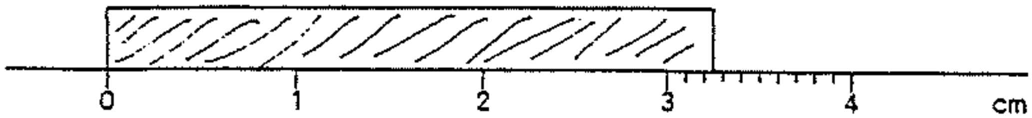

Figure 1

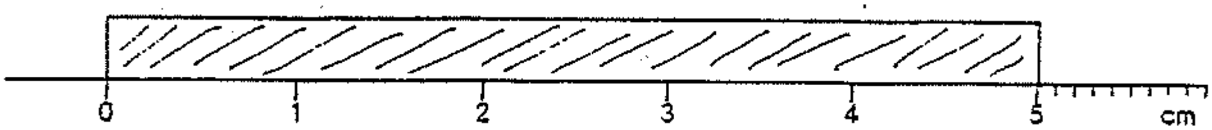

Figure 2

In recording the measurement shown in Figure 1 the observer might record either:

1) 3.3 cm
meaning that the measurement has been rounded off to the nearest tenth (to 2 sig figs). Since the tolerance has not been recorded we assume, by convention, that it is one half of 0.1 (that is 0.05) and that the true value lies between 3.25 cm and 3.35 cm, which it does, or

2) 3.26 cm ± 0.02 cm
meaning that the measurement lies between 3.24 cm and 3.28 cm, which it does. In this case, the tolerance of ± 0.02 cm is what the observer felt capable of estimating.

The observer should never write:
3.26 cm
which, by convention, means that the measurement has been rounded off to the nearest hundredth (giving a tolerance of half of 0.01) and therefore lies between 3.255 cm and 3.265 cm, which is not at all likely. Written this way, someone might conclude that the ruler was graduated in hundredths, which of course is not the case.

As well as not making exaggerated claims as to the accuracy of a measurement, it is equally important not to lose any of the accuracy available from the measuring instrument by failing to record a measurement properly. As a general rule, a measurement should be recorded to the nearest small division on the scale, or the tolerance should be stated. Look at Figure 2. The observer might record either:

1) 5.0 cm or
2) 5.02 cm ± 0.01 cm

but if the observer records 5 cm we assume, by convention, that the measurement has been estimated to the nearest centimetre and therefore lies between 4.5 cm and 5.5 cm. In this case the measuring instrument has not been used to its full potential.

Operations with Significant Figures

Addition and Subtraction

Rule:

The precision of the answer is equal to that of the least precise quantity used in the operation.

In a measurement like 2.345 metres the 2 is the most significant figure and the 5 is the least significant figure. When all of the quantities to be added and/or subtracted are expressed in the same unit, the least significant figure furthest to the left in any number determines the position of the least significant figure in the answer, or the precision of the answer. Stated more simply: When adding or subtracting, do not carry the result beyond the first column which contains a doubtful figure.

There are three acceptable methods of performing the operation:

1. Before performing the operation, round off all measurements to the required precision.

2. Before performing the operation, get rid of all digits more precise than the precision of the least significant in any number.

3. Perform the operation, using zeros where necessary, and round off the answer.

Since we will be using calculators, it will be more convenient to use method #3.

PROBLEMS:

Perform the following operations.

a) (2.489 m) - (1.96 m)
b) (2400 s) + (4.5 s)
c) ((120 s) + (4.5 s) + (10.34 s)

ANSWERS:

a)
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  2.489 m
 -1.96  m
  0.529 m
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which should be rounded off to 0.53 m. Since the least precise measurement, 1.96 m, is precise to the nearest hundredth metre the answer must be expressed to the nearest hundredth metre. Although the values used have 4 sig figs and 3 sig figs respectively, the answer has only 2 sig figs.

b) 2400 s
+ 4.5 s
2404.5 s which should be rounded off to 2400 s. The least precise measurement, 2400 s, is precise to the nearest hundred, therefore, the answer must be expressed to the nearest hundred.

c) 120 s
4.5 s
10.34 s
134.84 s which should be rounded off to 130 s. The least precise measurement, 120 s, is precise to the nearest ten, therefore, the answer must be expressed to the nearest ten.

SOME EXTRA PRACTICE:

1. How many significant figures are given in the following quantities?

a)	454 g	e)	0.0353 L	h)	93 000 000 km
b)	2.2 kg	f)	1.0080 g	i)	0.001 118 m
c)	2.205 kg	g)	14.0 mL	j)	10 300 g/cm^3
d)	0.3937 cm				

a)___ b)___ c)___ d)___ e)___ f)___ g)___ h)___ i)___ j)___

2. Add:

a) 703 g
7 g
0.66 g

b) 18.425 cm
7.21 cm
5.0 cm

c) 0.0035 L
0.097 L
0.225 L

3. Subtract:

a) 7.26 kg
0.2 kg

b) 562.4 m
16.8 m

c) 34. g
0.2 g

Operations With Significant Figures

Multiplication and Division

The understanding of significant figures and the rules for their use in addition, subtraction, multiplication, and division saves us time and effort and helps us to avoid exaggerated claims for the accuracy of an answer. Usually after a calculation has been made the answer will contain an unreasonable number of digits. A calculator might display ten digits but they are not all significant. Those which are not significant must be dropped. The rules most commonly used for rounding off digits which are not significant are as follows:

1. The last digit to be retained remains unchanged if the digit following on the right is less than five.

2. The last digit to be retained is increased by one if the following digit is equal to or greater than five.

PROBLEMS:

Round off the following numbers to three significant figures:

a) 5.353
b) 5.356
c) 5.344 99
d) 5.895
e) 82 643
f) 0.003 826

ANSWERS:

a) 5.353 becomes 5.35 (Rule 1)
b) 5.356 becomes 5.36 (Rule 2)
c) 5.344 99 becomes 5.34 (Rule 1)
d) 5.895 becomes 5.90 (Rule 2)
e) 82 643 becomes 82 600 (Rule 1)
Note that in this case the dropped digits have been replaced by zeros to retain the proper size of the number.
f) 0.003 826 becomes 0.003 83 (Rule 2)

Now, let's look at multiplication and division with significant figures.

RULE:

If *N* is the smallest number of significant figures in any of the multipliers or divisors, then the answer must be rounded off to *N* significant figures.

PROBLEMS:

Compute the following and round off the answer to the correct number of significant figures.

a) (3.524)(1.1)

b) $\frac{28.0}{7.0}$

c) $\frac{(265)(43.82)(0.006\ 38)}{(2.4)(3.67)}$

ANSWERS:

a)

3.524	(4 sig figs)
× 1.1	(2 sig figs)
3.8764	(5 sig figs)

Since the lesser number of significant figures in the values which were multiplied was two, the answer must contain two significant figures. Therefore:

(3.524)(1.1) = 3.9 correct to two sig figs

b)

28.0	(3 sig figs)
÷ 7.0	(2 sig figs)
4	(1 sig fig)

Since the lesser number of significant figures in the values used to obtain the quotient was two, the answer must also contain two significant figures. Therefore:

(28.0) ÷ (7.0) = 4.0 correct to two sig figs.

c) $\frac{(265)(43.82)(0.006\ 38)}{(2.4)(3.67)}$

= 8.411 27 = 8.4 correct to two sig figs.

Since there are only two significant figures in the divisor (ie. 2.4) and this is the smallest number of significant figures in all of the numbers used, the answer must contain two significant figures.

As a final note, there are certain numbers called pure numbers which should never be used to determine sig figs. When using a formula such as $C = 2\pi r$ to find the circumference of a circle, the 2 is a pure number, not a measurement, and is presumed to be perfectly accurate or to have an infinite number of significant figures. The pure number π can be chosen to have as many significant figures as the measurement of the radius r requires (π = 3.141 592 654...) so that only the number of sig figs in the measurement of the radius r determines the number of sig figs in the answer for the circumference C.

Also, if you were asked to determine the time required for a bicycle wheel to make 8 rotations, you would not use 8 in determining sig figs since the 8 is a pure number rather than a measurement.

Worksheet
Significant Figures - Multiplication and Division

1. a) (12.5)(3.2) b) (12.52)(5.1) c) (562.4)(16.8)

   d) (34)(0.2) e) (12.009)(12.01) f) (43.96789)(12.987)

2. a) $\frac{120.0}{3.0}$ b) $\frac{6666}{.0030}$ c) $\frac{97.52}{2.54}$

   d) $\frac{14.28}{0.714}$ e) $\frac{0.032}{0.004}$ f) $\frac{43.96789}{12.987}$

3. a) $\frac{(2.45)(6347)}{38}$ b) $\frac{(4.560)(20.300)}{0.0000503}$

   c) $\frac{(5.790)(3.400\ 000)}{(25.0)(0.003)}$ d) $\frac{(0.0020)(4.5600)}{19009}$

   e) $\frac{(120.0)(14.28)}{(2.54)(97.52)}$ f) $\frac{(12.987)(16.8)(0.714)}{(19009)(5.790)(1.234)}$

Funsheet #1-2 – Multiplication and Division with Significant Figures

1. How many significant figures does each number have?

a. 6.09	e. 2.09×10^2	i. 0.008
b. 6.090 0	f. 9.000×10^{-5}	j. 10.00
c. 0.000 452 1	g. 1.2×10^{20}	k. 170 000.
d. 0.002 340 0	h. 7.100×10^{-3}	l. 90 000.0

2. Round off to 3 significant figures.

a. 2.004 0	e. 40 741.	i. 16.859
b. 800 000.0	f. 0.000 005 752	j. 8.990 0
c. 902 780.	g. 0.028 359	k. 3.825 999
d. 1.999 9	h. 10.850×10^{-4}	l. 969 520.9

3. Rewrite each in scientific notation.

a. 0.000 067	d. 930 000.	g. 98.0
b. 98 568.0	e. 96 830.0	h. 0.00 07
c. 9.387 09	f. 0.000 059 70	i. 7 770.0

4. Write with no exponentials.

a. 3.0×10^{-6}	c. 3.010×10^2
b. 9.00×10^{-1}	d. 2.24×10^5

5. Add.

a. 964.0 + 2.976 + 12.98

b. 23.9865 + 1.2 + 233.7

c. 209.875 + 120. + 1.986

d. 45.98 + 12.23 + 60.00

6. Subtract.

a. 8.374 - 0.8

b. 3 292.0 - 0.357

c. 867.974 - 99.9

d. 9.238 9 - 1.11

7. Multiply

a. (21.83)(0.033)

b. (9.00)(6.98)(0.22)

c. (234.54)(12)(1.245)

d. (0.007)(45.7)

8. Divide

a. $\frac{123.67}{9.2}$

c. $\frac{14.280}{0.714}$

b. $\frac{0.0497}{0.70}$

d. $\frac{625}{3}$

9. Solve

a. $\frac{6.40 \times 10^6}{8.0 \times 10^{-3}}$

b. $\frac{0.0040 \times 2.2 \times 8000 \times 0.004}{1600 \times 15 \times 0.020}$

Scientific Notation

efinition:

A number is said to expressed in scientific notation if it is written in decimal notation as a number between one and ten and multiplied by a power of ten.

In modern science numbers are needed to describe quantities so large or so small that customary methods of writing or saying them are much too awkward. For example, it has been estimated that there are about 600 000 000 000 000 000 000 stars like our sun in the universe, while the mass of a large molecule would be about 0.000 000 000 000 000 000 004 gram. In both cases the zeros are not significant. They only indicate the size of a number in terms of multiples of ten or division by ten. Therefore, in scientific notation we abbreviate numbers by simply indicating the power of ten. Using scientific notation the number of stars can be written as 6×10^{23} while the mass of the molecule would be 4×10^{-21} gram.

Scientific notation may also be used to distinguish "significant zeros" from non significant zeros. If, for example, the number 93 000 000 is known to be correct to the nearest 10 000 (4 sig figs), it would be impossible to indicate this by simply adding a decimal. We could avoid confusion by writing the number in scientific notation as 9.300×10^7. Written this way, the number has the correct number of significant figures (four) while 93 000 000 has only two.

Scientific notation is not usually used for small or easily recognized numbers. Few scientists would write 25 as 2.5×10^1 or 0.6 as 6×10^{-1}.

The process of writing a number in scientific notation is based on the fact that any decimal number can be written as a number between one and ten and multiplied or divided by a power of ten.

For example: 93 000 000 = 9.3 × 10 000 000

and 0.000 000 52 = 5.2 ÷ 10 000 000

Since 10 000 000 can be obtained by using ten as a factor seven times

10 000 000 = 10 × 10 × 10 × 10 × 10 × 10 × 10

we abbreviate it as 10^7. The number 10^7 is said to written in <u>exponential notation</u>; 7 is called the <u>exponent</u> and 10 is called the <u>base</u>.

Likewise 10 × 10 × 10 × 10 × 10 × 10 = 1 000 000 = 10^6

1 000 = 10^3

100 = 10^2

10 = 10^1

1 = 10^0

and $\frac{1}{10} = 0.1 = 10^{-1}$

$\frac{1}{100} = 0.01 = 10^{-2}$

$\frac{1}{1000} = 0.001 = 10^{-3}$

Practice:

1. Express the following numbers in the power of ten notation.

   a) 100 000 b) 1/1 000 000 c) 0.000 001

2. Express the following numbers in standard decimal notation.

   a) 4.98×10^{4} b) 3.6×10^{-5} c) 4.20×10^{3}

   d) 7.3×10^{2} e) 8.6×10^{0} f) 7.14×10^{-6}

3. Express the following numbers in scientific notation.

   a) 28
   b) 6 120 000
   c) 8
   d) .023
   e) .000 162
   f) 25 000 000
   g) 0.000 000 23
   h) 4 567.89
   i) 0.000 90
   j) 0.008 060

Answers:

1. a) 10^{5} b) 10^{-6} c 10^{-6}

2. a) 49 800 b) 0.000 036 c) 4200
   c) 730 d) 8.6 e) 0.000 007 14

3. a) 2.8×10^{1}
   b) 6.12×10^{6}
   c) 8×10^{0}
   d) 2.3×10^{-2}
   e) 1.62×10^{-4}
   f) 2.5×10^{7}
   g) 2.3×10^{-7}
   h) $4.567\ 89 \times 10^{3}$
   i) 9.0×10^{-4}
   j) 8.060×10^{-3}

Worksheet
Scientific Notation

1. Simplify the following and express your answers in scientific notation. (Assume that all numbers are known to three significant figures.)

   a) $(2 \times 10^3)(4 \times 10^4)$ b) $(3 \times 10^2)(4 \times 10^4)(6 \times 10^3)$

   c) $(6 \times 10^4)(2 \times 10^{-7})$ d) $(2 \times 10^{-3})(4 \times 10^{-4})$

   e) $(5 \times 10^3)(8 \times 10^{-6})$ f) $(3 \times 10^{-5})(6 \times 10^4)(8 \times 10^{-3})$

   g) $\dfrac{(2 \times 10^6)(8 \times 10^5)}{4 \times 10^3}$ h) $\dfrac{(3 \times 10^{-4})(6 \times 10^5)}{2 \times 10^{-7}}$

   i) $\dfrac{(0.000\,006)(0.000\,005)}{0.000\,000\,3}$ j) $\dfrac{(1.2 \times 10^{-4})(2.2 \times 10^{-6})}{1.44 \times 10^{-8}}$

   k) $\dfrac{1}{8 \times 10^{-3}}$

2. The Earth has a mass of 5.980×10^{24} kg and the mass of Mars is 6.37×10^{23} kg.
   a) What is the difference in their masses?
   b) How many times more massive than Mars is the Earth?

3. A city has an annual budget of $\$6.23 \times 10^7$ of which $\$2.46 \times 10^6$ is to be spent on upgrading sewers. How much money is available for other purposes?

Answers:

1. a) 8.00×10^7 b) 7.20×10^{10} c) 1.20×10^{-2}
   d) 8.00×10^{-7} e) 4.00×10^{-2} f) 1.44×10^{-2}
   g) 4.00×10^8 h) 9.00×10^8 i) 1.00×10^{-4}
   j) 1.83×10^{-2} k) 1.25×10^2

2. a) 5.343×10^{24} kg b) 9.39 times

3. $\$5.98 \times 10^7$ (correct to the nearest $100 000)

Order of Magnitude

Sometimes numbers are not known very accurately, or they may be extremely large or extremely small. In these cases, scientists may simply estimate the number to the nearest power of ten. For example, it has been estimated that there are about 10^{80} atoms in the universe. This estimation to the closest power of ten is called the order of magnitude. It is often (but not always) indicated with the "approximately equal" symbol "≈". We can say there are $\approx 10^{80}$ atoms in the universe.

The order of magnitude is defined as the power of ten nearest the number. There are three methods for determining the power of ten. Scientists use the "rounding off method" which is the simplest of the three.

The rounding off method uses the method for rounding off with which we are already familiar. If the part of the number between one and ten is five or greater, round the power of ten up one. If the part of the number between one and ten is less than five, leave the power of ten as it is. Here are some examples.

The number 6100 in scientific notation is 6.1×10^3. 6 is greater than 5, therefore, round the power of ten up to four. $6100 \approx 10^4$.

The number 0.000 049 in scientific notation is 4.9×10^{-5}. 4 is less than 5, therefore, leave the power of ten as it is. $0.000\ 049 \approx 10^{-5}$.

Remember, when rounding negative powers of ten off, that 10^{-5} for example is a smaller number than 10^{-4}.

Examine the following examples to test your understanding of the process.

a) the order of magnitude of 426 000 is 10^5.
b) the order of magnitude of 5 432 000 is 10^7.
c) the order of magnitude of 0.000 004 6 is 10^{-6}.
d) the order of magnitude of 0.000 000 053 4 is 10^{-7}.
e) Determine the approximate number of seconds in a year.

year → days → hours → minutes → seconds

$1 \times 365 \times 24 \times 60 \times 60$

$$(1 \times 10^0)(3.65 \times 10^2)(2.4 \times 10^1)(6.0 \times 10^1)(6.0 \times 10^1)$$

$$\approx 10^0 \times 10^2 \times 10^1 \times 10^2 \times 10^2$$

now, just add the powers of ten, and one year $\approx 10^7$ s.

See over for some practice.

Practice:

1. Simplify where necessary and express the answer as an order of magnitude.

   a) 89 000 000 b) 0.000 000 57 c) 6.4×10^8

   d) $\dfrac{1}{8 \times 10^5}$ e) $\dfrac{(2.4 \times 10^3)(1.2 \times 10^{-4})}{4.8 \times 10^5}$

   f) $\dfrac{1}{0.000\,007}$ g) $\dfrac{1}{1.2 \times 10^{-4}}$

2. Estimate (order of magnitude) the volume of water in a round reservoir which is 1.0 km in diameter, if the average depth of the water is 15 m. (The volume of a cylinder = $\pi r^2 h$)

3. Approximately how many lego blocks with sides of 1.8 cm could you put into a classroom whose dimensions are 18 m by 11 m by 4.0 m?

Answers:

1. a) 10^8 b) 10^{-6} c) 10^9 d) 10^{-6} e) 10^{-6} f) 10^5 g) 10^4
2. 10^7 m^3
3. 10^8 blocks

Funsheet #1-5 – Significant Figures

1. How many significant figures are there in each of the following measurements?

a. 728.33 mm
b. 3640. m
c. 0.025 s
d. 10.00100 km
e. 1.0605 m
f. 0.0004 L
g. 0.0630 cm
h. 0.01001 m
i. 106.05 cm
j. 64.6 s
k. 32.0000 g
l. 63000100 m
m. 186000 m
n. 20030 s
o. 0.005 m
p. 2.00 kg
q. 4.0500 s
r. 0.02030 s

2. State the number of significant figures that the answer to each of the following calculations should contain.

a. $\dfrac{(2.45)(6347)}{38}$

b. $\dfrac{(4.560)(20.300)}{0.0000503}$

c. $\dfrac{(5.790)(3.400000)}{(25.0)(0.003)}$

d. $\dfrac{(0.0020)(4.560)}{19009}$

3. Add the following quantities and state your answer with the proper number of significant figures.

a.
4.560 cm
0.23 cm
45.1 cm
0.007 cm

b.
20.0 s
0.04 s
240 s
1.6 s

c.
4.234 m ± 0.0005 m
2.360 m ± 0.0003 m
4.51 m ± 0.002 m

4. Subtract 4.52 m ± 0.005 m from 7.234 m ± 0.0002 m.

5. What is the area of a rectangular desk top which measures 84.5 cm by 168 cm? State your answer with the appropriate number of significant figures.

6. If 456 g of candy is to be divided among six people, how much should each receive? Express your answer with the correct number of significant figures.

Answers:

1. a. 5 b. 4 c. 2 d. 7 e. 5 f. 1
   g. 3 h. 4 i. 5 j. 3 k. 6 l. 6
   m. 3 n. 4 o. 1 p. 3 q. 5 r. 4

2. a. 2 b. 3 c. 1 d. 2

3. a. 49.9 cm b. 260 s c. 11.10 m ± 0.003 m

4. 2.71 m ± 0.005 m

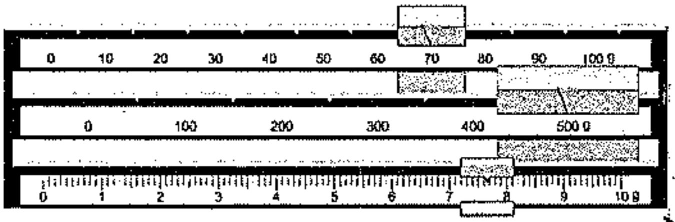
5. 14200 cm^2

6. 76.0 g

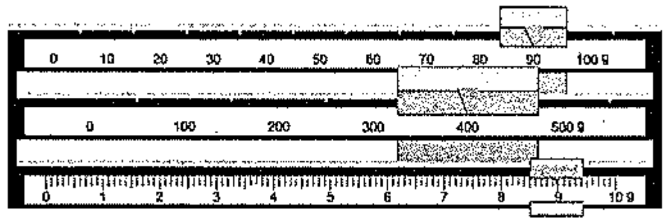
Reading Instruments With Significant Figures Worksheet

Name: ______________________ **Period:** ______

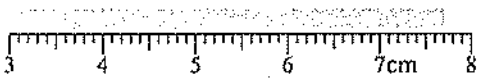
Please read each instrument to their limits. Include units and correct number of SigFigs.



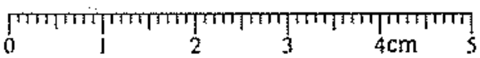
1) ________



2) ________

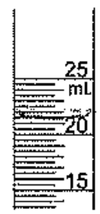


3) ________

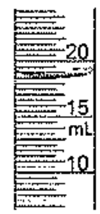


4) ________

5) ________

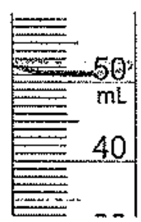


6) ________

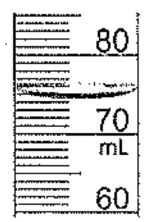


7) ________

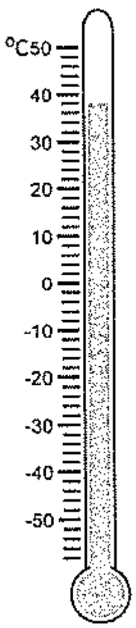
8) ________



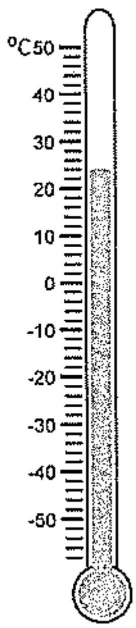
9) ________



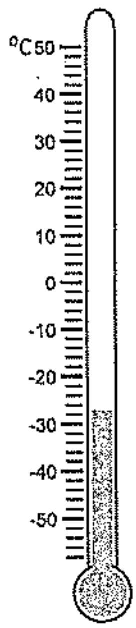
10) ________



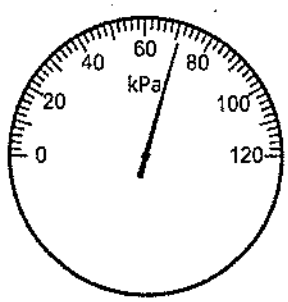
11) ________



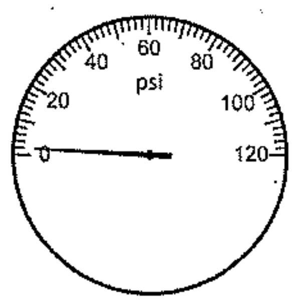
12) ________



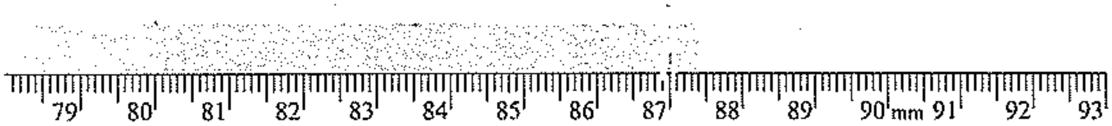
13) ________



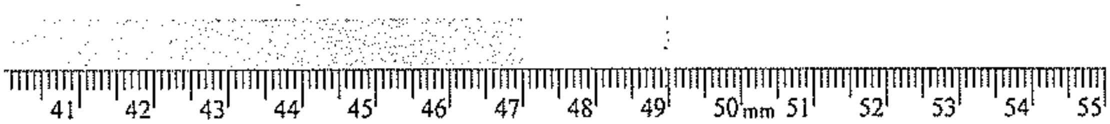
14) ________



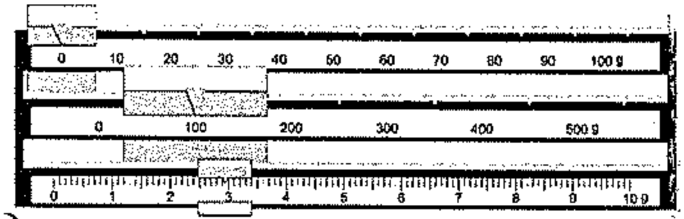
15) ________



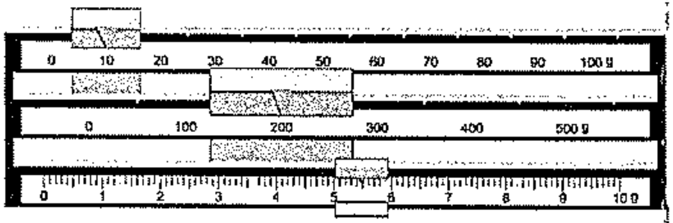
16) ________



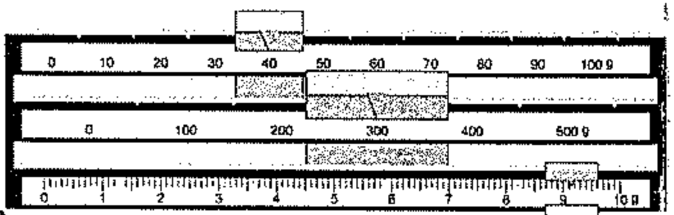
17) ________



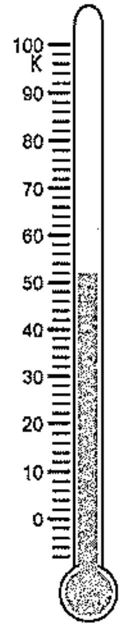
18) ______

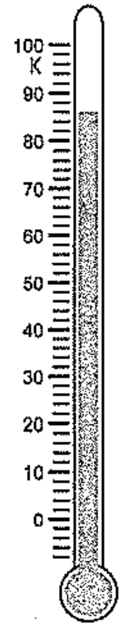


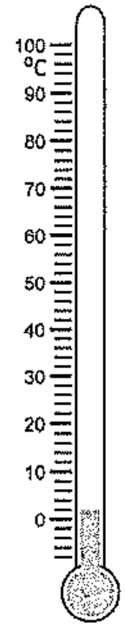
19) ______



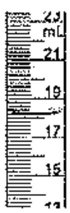
20) ______

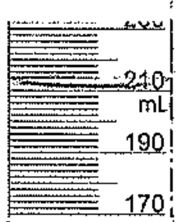




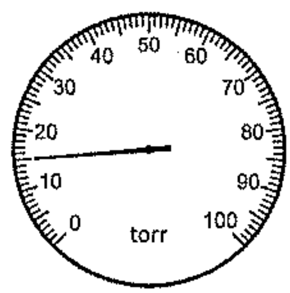


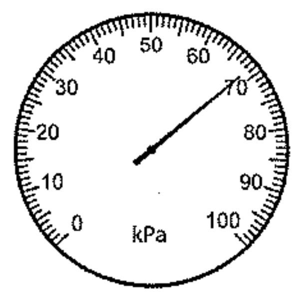
21) ______ 22) ______ 23) ______





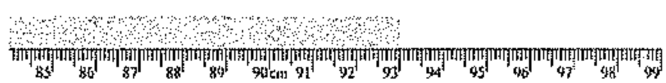
24) ______ 25) ______ 26) ______



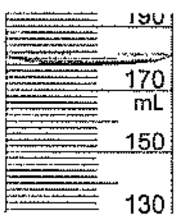


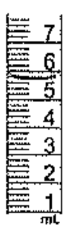
27) ______ 28) ______

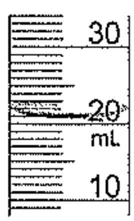
29) ______



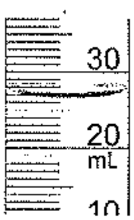
30) ______

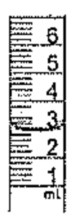




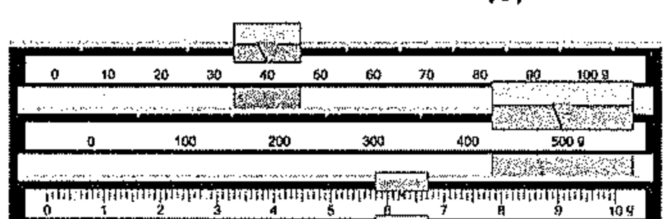


31) ______ 32) ______ 33) ______





34) ______ 35) ______ 36) ______



37) ______

38) ______

DATE ———— PERIOD ———— NAME ————————————

6 Physics Skill

GRAPHING TECHNIQUES

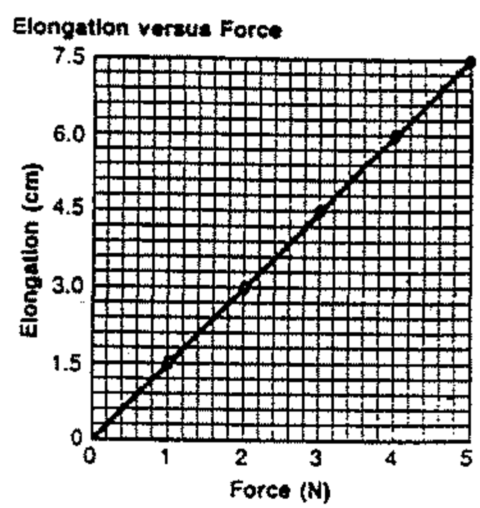
Frequently an investigation will involve finding out how changing one quantity affects the value of another. The quantity that is deliberately manipulated is called the *independent variable*. The quantity that changes as a result of the independent variable is called the *dependent variable*.

The relationship between the independent and dependent variable may not be obvious from simply looking at the written data. However, if one quantity is plotted against the other, the resulting graph gives evidence of what sort of relationship, if any, exists between the variables. When plotting a graph, take the following steps.

1. Identify the independent and dependent variables.
2. Choose your scale carefully. Make your graph as large as possible by spreading out the data on each axis. Let each space stand for a convenient amount. For example, choosing three spaces equal to ten is not convenient because each space does not divide evenly into ten. Choosing five spaces equal to ten would be better. To avoid a cluttered appearance, you do not need to number every space.
3. All graphs do not go through the origin (0,0). Think about your experiment and decide if the data would logically include a (0,0) point. For example, if a cart is at rest when you start the timer, then your graph of speed versus time would go through the origin. If the cart is already in motion when you start the timer, your graph will not go through the origin.
4. Plot the independent variable on the horizontal (x) axis and the dependent variable on the vertical (y) axis. Plot each data point.
5. Label each axis with the name of the variable and the unit. Using a ruler, darken the lines representing each axis.
6. If the data points appear to lie roughly in a straight line, draw the best straight line you can with a ruler and a sharp pencil. Have the line go through as many points as possible with approximately the same number of points above the line as below. Never "connect the dots." If the points do not form a straight line, draw the best smooth curve possible.
7. Title your graph. The title should clearly state the purpose of the graph and include the independent and dependent variables.

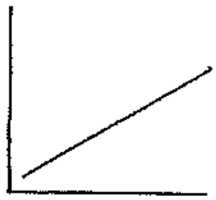
The graph shown was prepared using good graphing techniques. Go back and check each of the items mentioned above.

Force (N)	Elongation (cm)
0	0.0
1	1.5
2	3.0
3	4.5
4	6.0
5	7.5



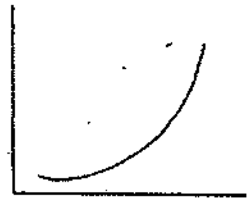
6. Physics Skills - Graphing techniques Cont'd

Relationships:



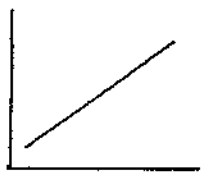
Linear: $y=Kx$, K=constant

Inverse: $y=K/x$

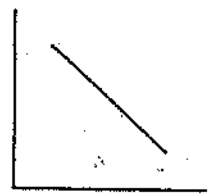


Quadratic: $y=Kx^2$

Positive slope



Negative slope



Slope = rise/run = (vertical change)/(horizontal change) = $\Delta y / \Delta x$

NB: select two points as far apart as possible on your line (not necessarily data points). Choose cross-over points and (0,0) if appropriate. Watch your units!!

PRACTICE: Graph the following sets of data using proper graphing techniques and identify th type of relationship.

A)

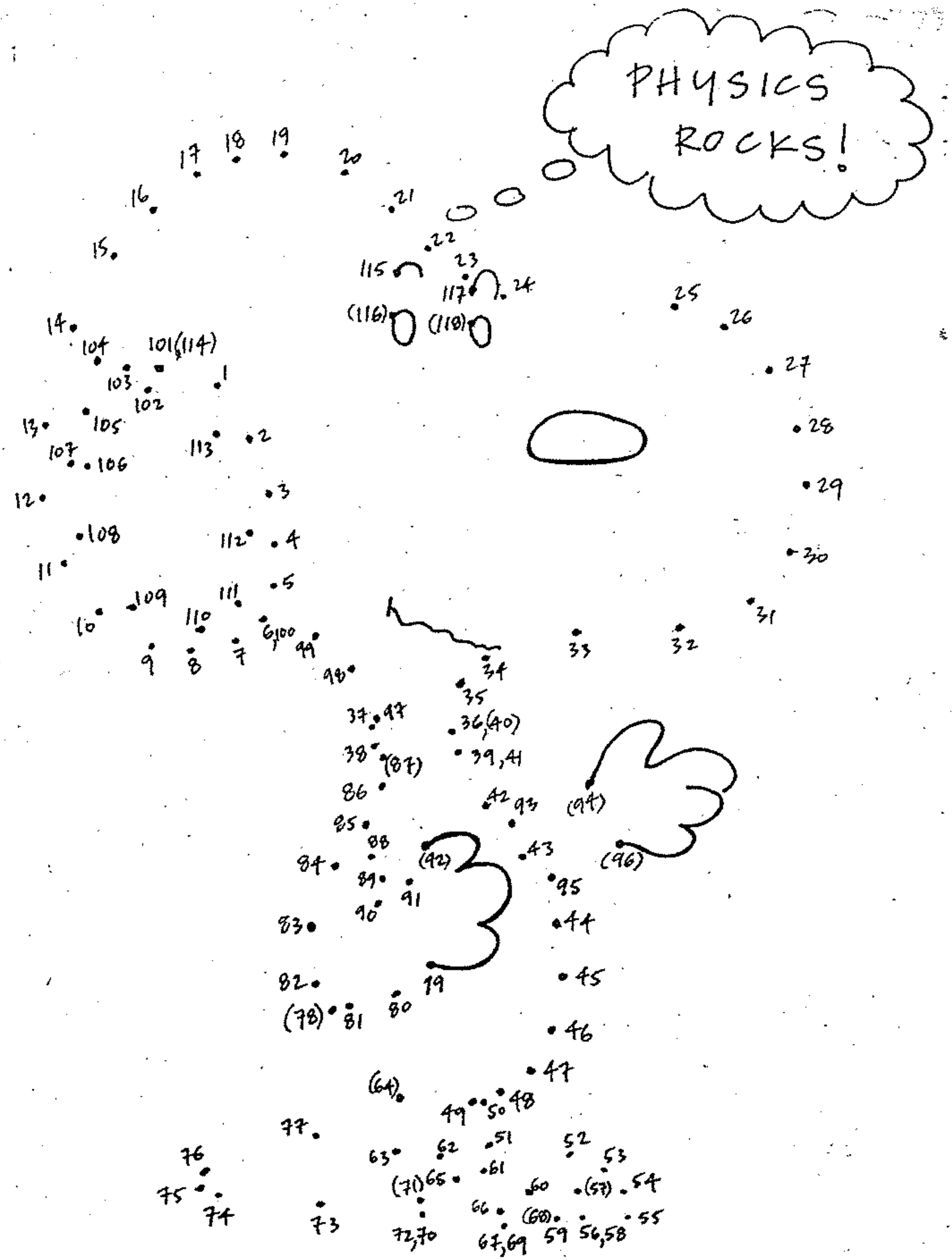
Pressure (torr)	Volume (mL)
100	800
200	400
400	200
600	133
700	114
800	100
1000	80

B)

Time (s)	Distance (m)
0	0
1	5
2	20
3	45
4	80
5	125

C)

Time (s)	Speed (m/s)
0	0
1	20
2	45
3	60
4	84
5	105


PHYSICS ROCKS!

CHECKLIST FOR USE WHEN PLOTTING GRAPHS OF EXPERIMENTAL DATA

1. Have you chosen a convenient scale for the axes of your graph? An example of a poor choice of scale would be using 7 squares to represent 10 units of say, distance. Imagine how difficult it would be to plot 8.37! It is better to choose 2, 5, 10, or 20 squares so that it is a simple matter to estimate where to plot fractional values.

2. Is your graph large enough to display your data clearly? In most cases the whole page should be used, but in any case, use at least half the page. Quite often several graphs can be plotted on the same axes.

3. Are the axes clearly ruled in with pen or pencil?

4. Is the origin, i.e. the point (0,0), included at the intersection of the two axes?

5. Is the graph completely labelled with the quantity being plotted shown on each axis with proper units used? Is the graph given a meaningful title?

6. If the graph is linear, are construction lines shown for the calculation of the slope?

7. Are the intervals $(y_2 - y_1)$ and $(x_2 - x_1)$ large enough so that the slope can be accurately determined?

8. Does the line drawn through experimental points "average the errors"? Have you included as many "strays" on one side of the line as on the other?

9. Have you calculated the slope and shown the result, expressed in proper units, on the graph itself?

10. Is the slope <u>correctly</u> calculated? ($m = \frac{\text{vertical change}}{\text{horizontal change}}$)

11. Have you derived the functional relation? For a straight line (linear) graph, the equation is always of the form:

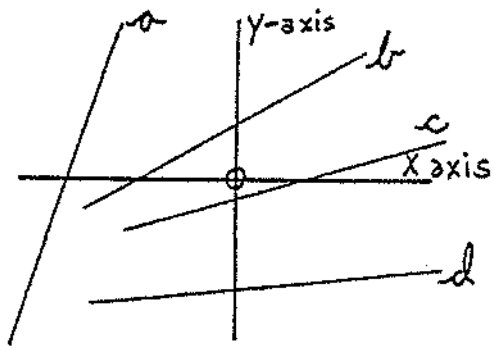
$$\underline{y = mx + b}$$

where x = independent variable
y = dependent variable
m = slope
b = y-intercept (the value of y when x = 0)

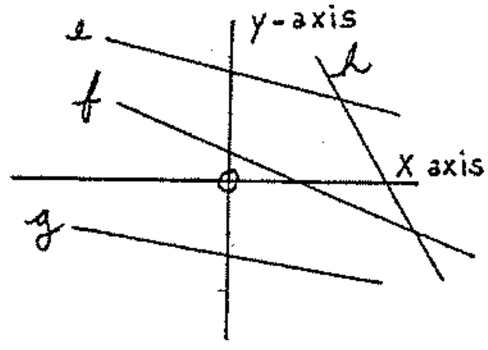
Include the actual numerical value of m and of b in the final equation.

Slopes in a Straight Line

If the line rises as it moves towards the right, we say that the slope is <u>positive</u>. If the line falls as it moves towards the right, we say that the slope is <u>negative</u>.

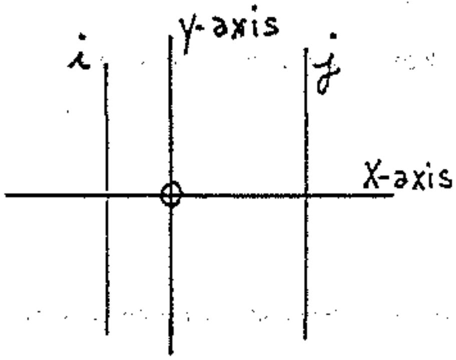


Positive slopes

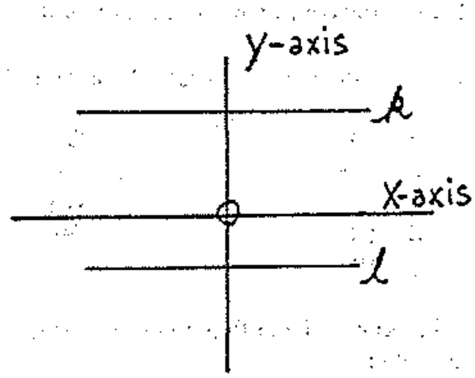


Negatives slopes

In addition, some cliffs are perfectly vertical; we say they have <u>no slope</u>. Some are perfectly level; we say they have <u>zero slope</u>.



No slope



Zero slopes

Practice:

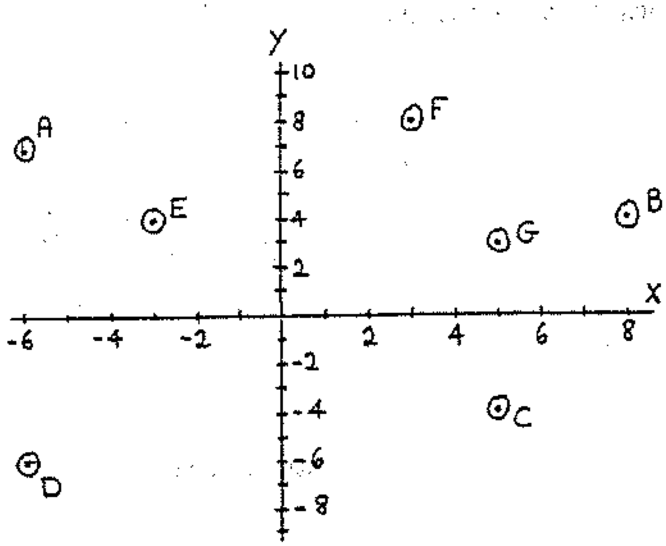


Figure 1

1. State the coordinates of the points shown in figure 1.

2. Using the dots from figure 1, find the slope of each of the following line segments:

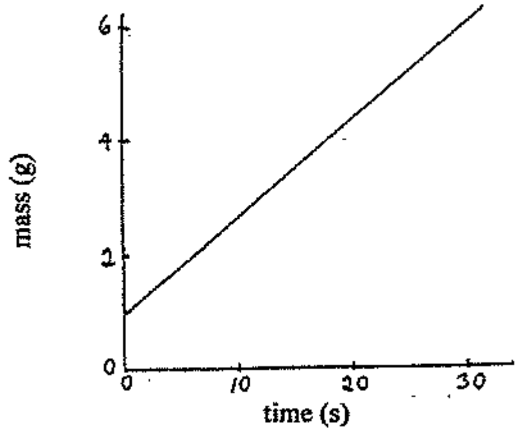
a. AF	f. DC
b. AB	g. DE
c. AE	h. DA
d. BF	i. EB
e. BC	j. EC

3. In figure 1, identify the line segments which pass through the point stated with the slope indicated.

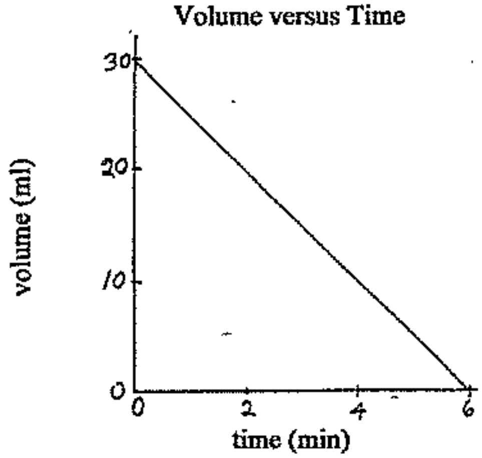
a. A, slope = $\frac{1}{9}$	f. G, slope = $\frac{-5}{2}$
b. A, slope = -1	g. E, slope = $\frac{-1}{8}$
c. B, slope = $\frac{1}{3}$	h. G, slope = $\frac{9}{11}$
d. A, no slope	i. G, slope = $\frac{-4}{11}$
e. G, slope = $\frac{-5}{2}$	

4. Determine the slope with the correct units of the following graphs:

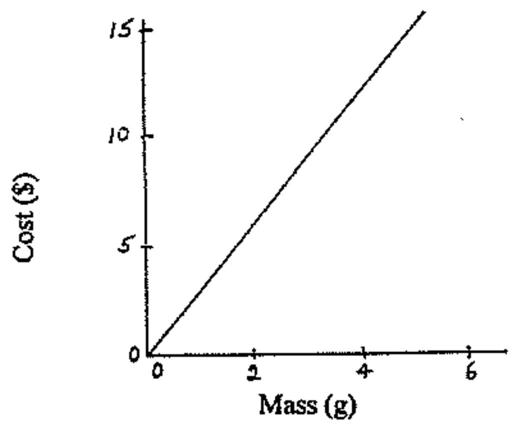
Mass versus Time



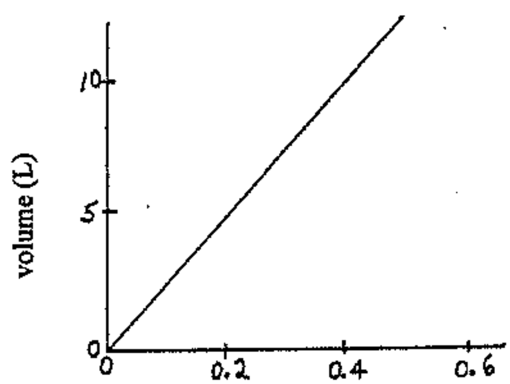
Volume versus Time



Cost versus Mass

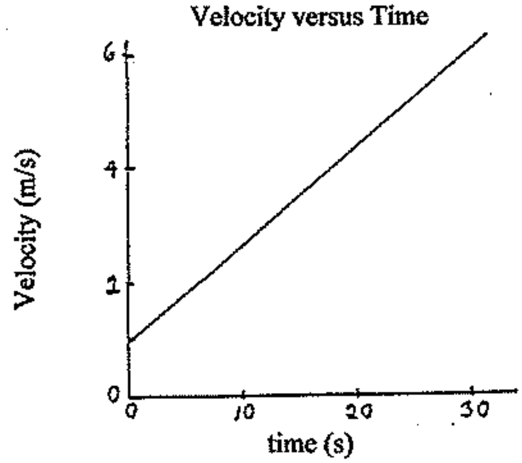


Volume versus Time

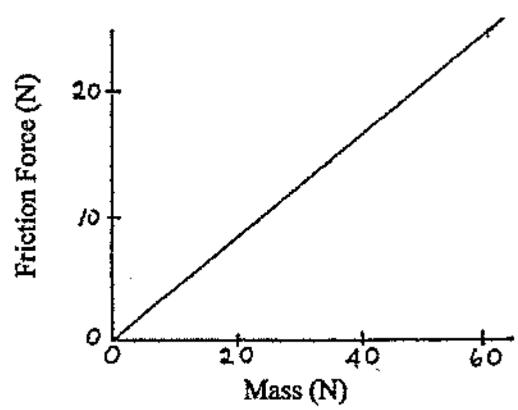


$\frac{1}{\text{pressure}}\ (\frac{1}{\text{kPa}})$

Velocity versus Time



Friction Force versus Mass



General Comments:

Many of the laws of physics can be expressed in the mathematical relations which show how one thing depends on or changes when another thing is varied or changed. We usually have two physical quantities and we wish to find how one varies when the other is varied.

For example, we may wish to know how the volume of a sphere varies as we vary the radius of the sphere. A relation between any two variables (eg. volume and radius) is called a functional relation. Thus, if we have two variables, say x and y, we can say y is a function of x and write mathematically:

$$y = f(x)$$

which is read as "y equals a functionof x."

For example, if y happens to be the area of a circle (A) and x is the radius of the circle (r), then the functional relation which relates these two variables to each other is:

$$1) \quad A = \pi r^2$$

If y happens to be the circumference of a circle (C) and x is the radius of the circle (r) then the functional relation which relates these two variables to each other is:

$$2) \quad C = 2\pi r$$

Quite often in science we also do experiments in order that we may determine the functional relation between the two variables.

For example, if we wished to determine how atmospheric pressure varied with height above the earth we could send up a balloon to measure these two variables (P and H). That is, find how P varies with H.

Many times in physics we find that a contant of proportionality relates one variable to another. In Formula 1, the constant of proportionality that relates A to r is the number (constant) π. In Formula 2 the constant of proportionality is the number 2π. This number relates C to r.

Direct Proportionality

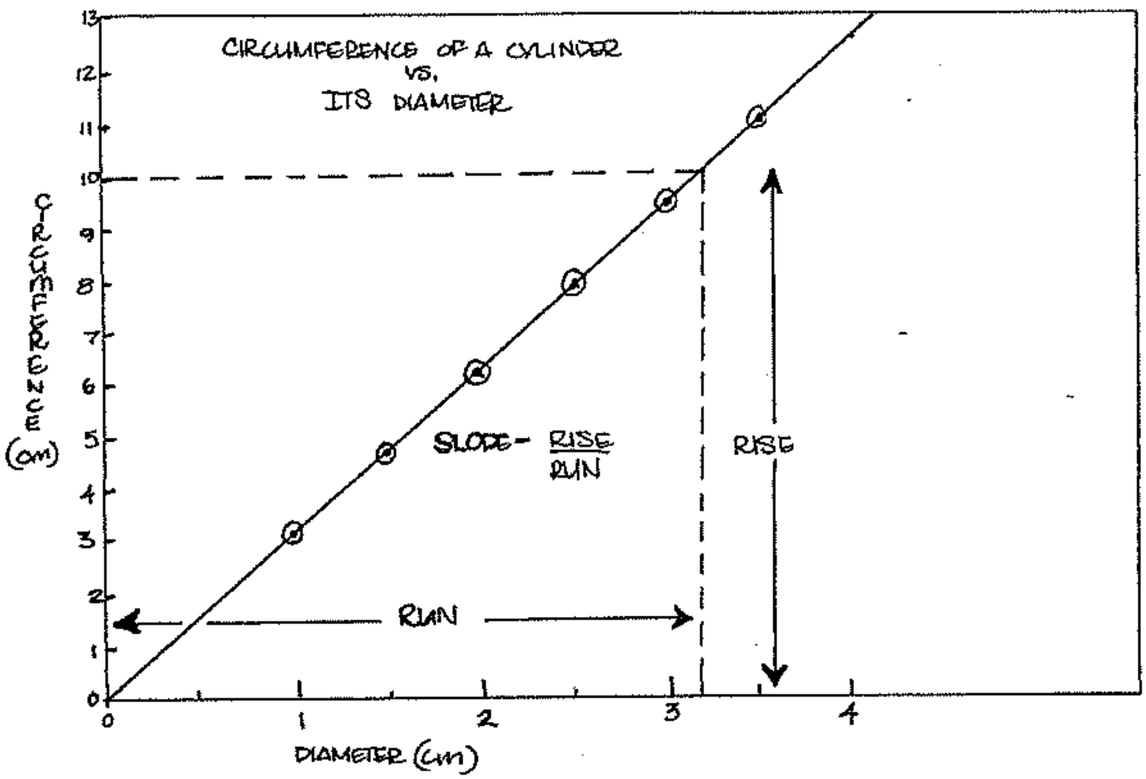
Let us assume now that we wish "to discover" the functional relation between the circumference (C) of a circle to its diameter (D). That is, we wish to find the function given by:

$$C = f(d)$$

Assume now that we measure the diameter of a number of cylinders. The circumferences are measured by wrapping string around the cylinders and then measuring the length of the string. The data is as follows:

Circumference (cm)	3.1	4.7	6.2	7.9	9.4	11.0	12.6
Diameter (cm)	1.0	1.5	2.0	2.5	3.0	3.5	4.0

If this data is plotted we get a graph of C vs D as follows:



When the data is plotted, a straight line is produced. We can therefore conclud that the circumference of a circle (cylinder) is directly proportional to the diameter. This means that if the diameter is doubled the circumference will double. If the diameter increases by a factor of three so will the circumference, etc. This means we can say mathematically that:

$C \propto D$ where the symbol is read as "directly proportional to"

Since we can write that C is directly proportional to D or

$$C \propto D$$

then we can also write:

$$3) \quad C = kD$$

where k is called the constant of proportionality that relates C to D. The problem now is to find the value of k. This is done using the graph. From Formula 3 we can write: $k = \frac{C}{D}$

Phys 11

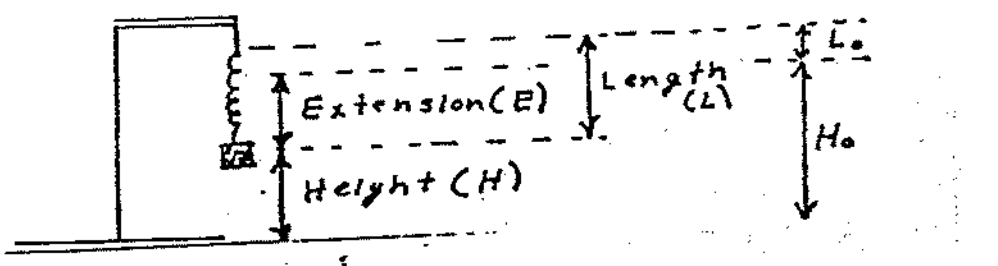
Graphing: Spring experiment (Hookes Law)

Hypothesis:

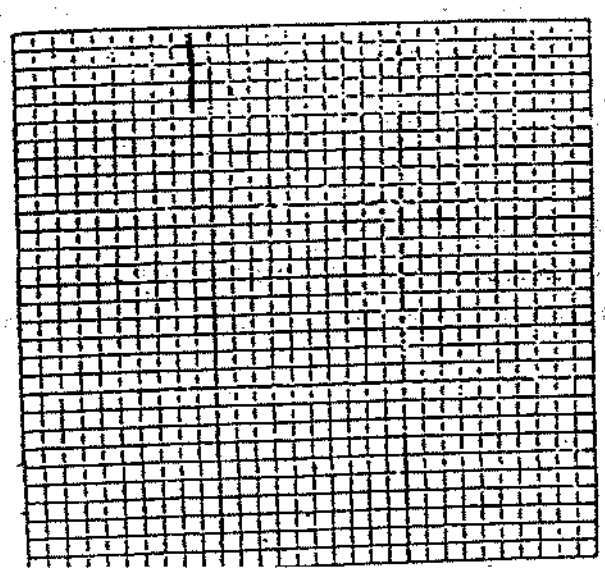
Data:

Load W (g)	Length L (cm)	Extension E (cm)	Height H (cm)	Obs.

Method:



Graph:



Assignment:

Use the data collected to complete the graph.
Be sure to label the axes and include numbers and units.
Choose a scale to use the entire graph.
Measure the rise and the run. Calculate the slope (include units).
Determine an equation for the line.

Make a conclusion about what happens to a spring when load is increased.

What is this type of relationship called?

Exercise:

1.

Mark in Physics	Mins. of Home study
10±10%	20 min.±5
30±10%	65 min.±5
50±10%	95 ±5min.
60±10%	120 ±5 min.
70±10%	130 ±5 min.

2.

Vertical Jump (cm)	Radius of leg (cm)
20cm ±5%	3±.5cm.
41cm ±5%	6±.5cm.
57cm ±5%	9±.5cm.
80cm ±5%	11±.5cm.
95cm ±5%	16±.5cm.

Plot the above on separate sheets of graph paper and:-

i. Label both axes.
ii. Show error bars.
iii. Show rise, run and slope with error.
iv. Write out the conclusion on the back.

DATE ________ PERIOD ________ NAME ____________________________

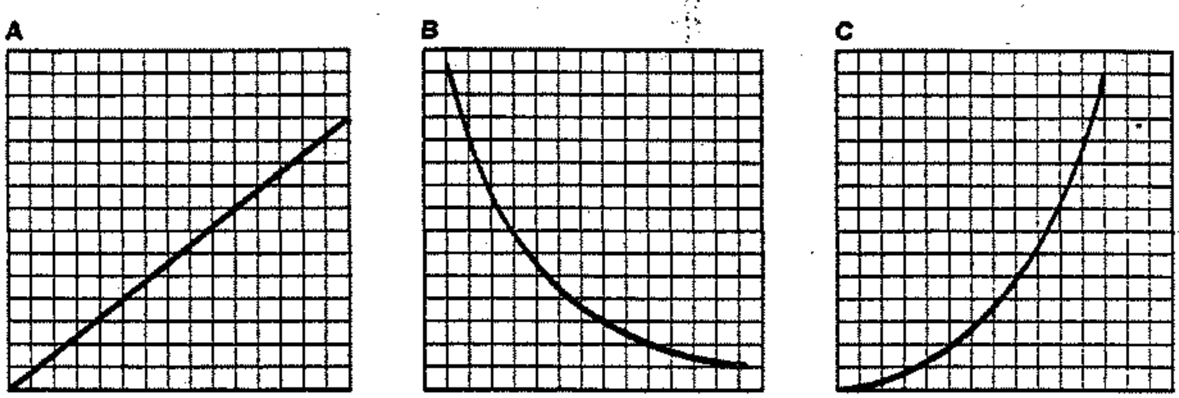
7 Physics Skill

Use with Chapter 2.

INTERPRETING GRAPHS

In laboratory investigations, you generally control one variable and measure the effect it has on another variable while you hold all other factors constant. For example, you might vary the force on a cart and measure its acceleration while you keep the mass of the cart constant. After the data are collected, you then make a graph of acceleration versus force using the techniques for good graphing. The graph gives you a better understanding of the relationship between the two variables.

There are three relationships that occur frequently in physics. If the dependent variable varies directly with the independent variable, the graph will be a straight line, as shown in graph **A**. If y varies inversely with x, the graph will be a hyperbola as shown in graph **B**. The third relationship, in which y varies directly with the square of x, gives a parabola (graph **C**).



$y = kx$ $y = k/x$ $y = kx^2$

Sometimes you need information about a value that you have not determined experimentally. Reading from the graph between data points is called *interpolation*. Reading from the graph beyond the limits of your experimentally determined data points is called *extrapolation*. Extrapolation must be used with caution because you cannot be sure that the relationship between the variables remains the same beyond the limits of your investigation.

1. Suppose you recorded the following data during a study of the relationship of force and acceleration. Prepare a graph showing these data.

Force (N)	Acceleration (m/s^2)
10	6.0
20	12.5
30	19.0
40	25.0

   a. Describe the relationship between force and acceleration as shown by the graph.

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NAME ______________________________

b. What is the slope of the graph? Remember to include units with your slope. One newton equals 1 kg•m/s².

c. What physical quantity does the slope represent?

y=mx+b

d. Write an equation for the line. y=

e. What is the value of the force for an acceleration of 15 m/s²?

f. What is the acceleration when the force is 50.0 N?

2. The following data show the distance an object travels in certain time periods. Prepare a graph showing these data.

Time (s)	Distance (cm)
0	0
1	3
2	12
3	27
4	48

a. Describe the relationship between *x* and *y* and write a general equation for the curve.

b. Is the distance traveled greater between 0 s and 1 s or 3 s and 4 s?

c. Is the slope of the curve greater between 1 s and 2 s or 3 s and 4 s?

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7 Physics Skill

NAME ______________________________

3. Answer the questions about the sets of data below. First try answering the questions by simply looking at the data. Then prepare a graph of each set and see if the questions are easier to answer.

A.

x	y
1	3
2	6
3	9
4	12
5	15

B.

x	y
0	0
1	2
2	8
3	18
4	32

C.

x	y
1	80
2	40
3	27
4	20
5	16

D.

x	y
0	2
1	4
2	6
3	3
4	2

a. In which graph is y directly proportional to x?

b. In which graph does y decrease as x increases?

c. In which set of data is y inversely proportional to x?

d. Which graph does not seem to picture a simple relationship?

e. Which graph has the general equation $y = kx^2$?

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Tolerance in Data, Results, and Conclusions

Whenever measurements are multiplied, divided, added, or subtracted their tolerances should also be taken into account. After all, if there are uncertainties in the data (measurements), then there will be an error of uncertainty in the result. There are two methods for working with tolerances depending on the operations involved. One method applies to multiplication and division. The other method applies to addition and subtraction.

Multiplication and Division with Tolerances:

Rule:

If two or more measurements are multiplied or divided, the total uncertainty (error) is the sum of the percent possible errors in the individual measurements.

Example with multiplication of measurements:

$$l = 10.0 \text{ cm} \pm 0.2 \text{ cm}$$
$$w = 20.0 \text{ cm} \pm 0.2 \text{ cm}$$
$$h = 50.0 \text{ cm} \pm 0.2 \text{ cm}$$

Before multiplying these measurements, their tolerances must be expressed as a percentage of the measurement.

$$0.2 \text{ cm} = 2.0\% \text{ of } 10.0 \text{ cm}$$
$$0.2 \text{ cm} = 1.0\% \text{ of } 20.0 \text{ cm}$$
$$0.2 \text{ cm} = 0.4\% \text{ of } 50.0 \text{ cm}$$

By convention, percent uncertainties in measurements and final results are expressed to no more than two significant figures, regardless of how many significant figures appear in the measurements.

Now, rewrite the measurements with the tolerances expressed as percentages.

$$l = 10.0 \text{ cm} \pm 2.0\%$$
$$w = 20.0 \text{ cm} \pm 1.0\%$$
$$h = 50.0 \text{ cm} \pm 0.4\%$$

then $lwh = 1.00 \times 10^4 \text{ cm}^3 \pm 3.4\%$

The percent possible errors were added according to the rule to give a total possible error of ± 3.4%.

At this time, if we want to know the actual error in $1.00 \times 10^4 \text{ cm}^3$, we would simply calculate ± 3.4% of $1.00 \times 10^4 \text{ cm}^3$.

$$(\pm 0.034)(1.00 \times 10^4 \text{ cm}^3) = \pm 340. \text{ cm}^3$$

therefore $lwh = 1.00 \times 10^4 \text{ cm}^3 \pm 340. \text{ cm}^3$

which means the answer lies somewhere between 9.66×10^3 cm^3 and 1.03×10^4 cm^3.

Example with division of measurements:

if distance $d = 150$ m ± 1.0%
and time $t = 2.0$ s ± 0.5%

then $$\frac{d}{t} = \frac{150 \text{ m} \pm 1.0\%}{2.0 \text{ s} \pm 0.5\%} = 75 \text{ m/s} \pm 1.5\%$$

Again, the individual percent errors have been added to give a total estimated percent error of ± 1.5%.

Addition and Subtraction with Tolerances

When adding or subtracting measurements, add the actual individual uncertainties (not the percentages). Then, express the total uncertainty as a percentage of the final result to obtain the total estimated percent error.

Example with addition of measurements:

$l = 46.00$ cm ± 0.20 cm
$w = 31.73$ cm ± 0.02 cm

$l + w = 77.73$ cm ± 0.22 cm

To obtain the total percent error:

$$\frac{\pm 0.22 \text{ cm}}{77.73 \text{ cm}} (100\%) = \pm 0.28\%$$

The answer may then be expressed as 77.73 cm ± 0.28%. Remember, the uncertainty does not require more than two significant figures.

Example with subtraction of measurements:

$l = 46.00$ cm ± 0.20 cm
$w = 31.73$ cm ± 0.02 cm

$l - w = 14.27$ cm ± 0.22 cm

Even in subtraction, the actual individual uncertainties are added. As with addition, the total uncertainty can be converted to a percentage.

ote: The rule for precision must be applied even when adding tolerances so as to avoid exaggerated answers. Consider these two examples.

Example 1:

$$\begin{array}{lr} \text{Add} & 4.567 \text{ g} \pm 0.0005 \text{ g} \\ & \underline{1.234 \text{ g} \pm 0.0002 \text{ g}} \\ \text{total} = & 5.801 \text{ g} \pm 0.0007 \text{ g} \end{array}$$

which is correct.

Example 2:

$$\begin{array}{lr} \text{Subtract} & 6.74 \text{ g} \pm 0.002 \text{ g} \\ & \underline{3.421 \text{ g} \pm 0.0005 \text{ g}} \\ \text{difference} = & 3.319 \text{ g} \pm 0.0025 \text{ g} \end{array}$$

which is rounded off to give 3.32 g ±0.003 g (which indicates that the true value should lie between 3.317 g and 3.323 g) when the rule for precision is applied.

Tolerance in Conclusions

The purpose of some experiments is to gain a better understanding of an aspect of physics by attempting to determine the value of an already known physical constant. The experiment would be carried out paying attention to tolerances as explained in the preceding pages. A final result would be obtained. This result with its tolerance should be stated in the conclusion of the experiment. Also, some indication should be given as to how the experimental result compares to the accepted value. The accepted value is the value accepted by scientists as being most correct.

The experimental value is compared to the accepted value by determining the percent difference between the two using this equation.

$$\text{percent difference} = \frac{\text{experimental value} - \text{accepted value}}{\text{accepted value}} (100\%)$$

Notice that the percent difference can only be positive or negative depending on whether the experimental result is bigger or smaller than the accepted value.

Example:
Suppose an experiment was conducted and the value of the acceleration due to gravity (g) was determined to be 8.46 m/s^2. The accepted value of g = 9.80 m/s^2.

The percent difference

$$= \frac{(8.46 - 9.80)\ m/s^2}{9.80\ m/s^2} (100\%) = -14\%$$

The negative sign in -14% means the experimental value of g was lower than the accepted value.

Finally, this information should be reported in the conclusion to the experiment by simply stating, "The value of the acceleration due to gravity was determined to be 8.46 cm/s^2. This differs from the accepted value by -14%.".

Tolerance - Percent Error - Worksheet

The sides of a rectangular block of wood are measured and found to be as follows:

length = l = 25.0 cm ± 0.5 cm
width = w = 12.5 cm ± 0.5 cm
height = h = 10.0 cm ± 0.5 cm

1. What is the percent possible error in each of the three measurements?

2. What is the volume of the block of wood? V = lwh

3. What is the percent possible error in the volume?

4. The block of wood has three possible perimeters (distance around the outside). Calculate the three perimeters and the uncertainty in each of the perimeters.

5. What is the percent uncertainty in each of the three perimeters?

Answers:

1. in length ±2% in width ±4% in height ±5%

2. $V = 3.13 \times 10^3\ cm^3$

3. percent possible error = ±11%

4. 75.0 cm ± 2cm 70.0 cm ± 2cm 45.0 cm ± 2cm

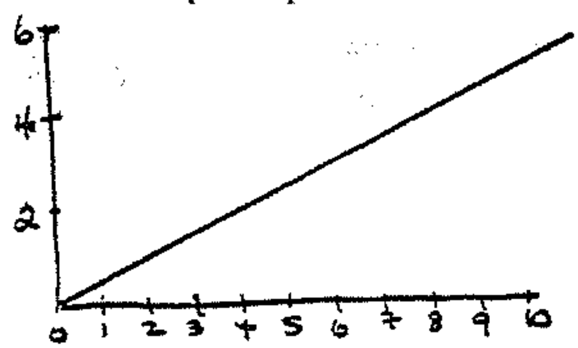
5. ±2.7% ±2.9% ±4.4%

8. Give an example for each from question #7.

9. Find the order of magnitude estimate of each one.

a. 3×4
b. $3 \times 10^2 \times 4 \times 10^3$
c. 6.79×10^{-5}

10. Calculate the slope and equation of the line below. Remember to include units.



Slope

11. Using the following data, determine the type of relationship and find an equation to describe the relationship. Tolerance

Study Time (hours per week)	Mark in Physics (percentage)
0.0 ± 0.5 hr	23.0 ± 0.5%
1.0 ± 0.5 hr	46.0 ± 0.5%
2.0 ± 0.5 hr	55.0 ± 0.5%
3.0 ± 0.5 hr	64.0 ± 0.5%
4.0 ± 0.5 hr	69.0 ± 0.5%
5.0 ± 0.5 hr	74.0 ± 0.5%
6.0 ± 0.5 hr	79.0 ± 0.5%
7.0 ± 0.5 hr	83.0 ± 0.5%
8.0 ± 0.5 hr	87.0 ± 0.5%
9.0 ± 0.5 hr	90.0 ± 0.5%
10.0 ± 0.5 hr	92.0 ± 0.5%

For more practice, do problems #1 – 24 in your textbook for chapter #2 (pages 16 – 34). Answers are given in Appendix A (page 656).

Funsheet #1-7 – Test Review

1. How many significant figures in these numbers?

a. 864
b. 9000
c. 0.003002
d. 8.26×10^4
e. 0.0001
f. 40020

2. What is the difference between counting numbers and measured numbers?

3. What is the correct "sig figs" answer to these arithmetic equations with measured numbers?

a. $\begin{array}{r} 0.321 \\ \underline{+1.5} \end{array}$

b. $\begin{array}{r} 462.85 \\ \underline{\times\ 5} \end{array}$

c. $\begin{array}{r} 1.8329 \\ \underline{-\ .526} \end{array}$

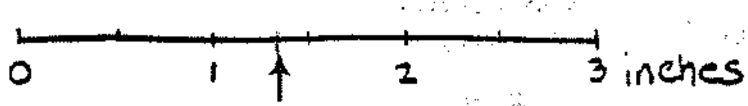
d. $20\overline{)60}$

4. Convert.

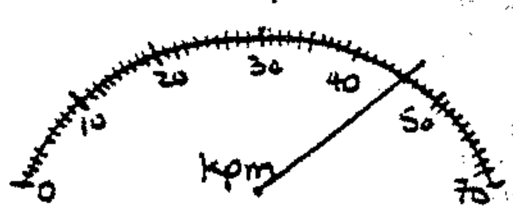
a. 46 ms → s
b. 3.9 kJ → J
c. 4.85×10^3 m → M
d. 10 000 m → mi (1 km = .621 mi)

5. What is the water meter reading and the absolute and relative uncertainty of the readings?

a.



b.



6. How do you do this arithmetic (Express answer ± absolute uncertainty)

a. $\dfrac{43.64 \pm 0.05\ \text{km}}{1.50 \pm 0.05\ \text{hr}}$

b. $\dfrac{300\,000 \pm 1\,000 \frac{\text{m}}{\text{s}}}{43 \pm 5\text{s}}$

7. Sketch the graph of each of the following relationships.

a. Linear direct
b. Linear, not direct
c. Inverse
d. Power (>1)
e. Power (<1)

SCIENCE LABORATORY REPORTS

PRELAB When assigned, it is important that the readings, objectives, data tables and prelab questions be completed ahead of time. Students who fail to complete the prelab may not be permitted to participate in the lab activity.

LABORATORY REPORT Presentation is important, therefore ensure that your handwriting is legible (or type it) and that your lab report follows the proper format as detailed below. Your title page or report header should include your name and student number, your lab partner's name, your block, the title and date of the lab.

****

OBJECTIVE A short statement specifying the purpose of the experiment.

APPARATUS AND MATERIALS A statement such as « As per lab manual page #_____ » or « As per lab sheet, entitled______ » is sufficient. Any changes should be noted.

PROCEDURE A statement such as « As per lab manual page #_____ » or « As per lab sheet, entitled______ » is sufficient. Any changes to this section should be noted.

PREDICTION/HYPOTHESIS Predict the outcome or provide a possible explanation of the outcome of the experiment if applicable.

OBSERVATIONS AND DATA Pertinent observations should be in the form of brief statements using proper scientific language. Describe what you observed during the experiment. Data should be presented in a table with proper titles and units. This portion must be completed during the lab period.

RESULTS AND CALCULATIONS Calculations must be shown. Accuracy (« sig figs ») does count! Be sure to properly label your calculations so that they are easily understood. Calculations of slopes can be done right on the graph. Attach all properly labelled graphs to the back of the report.

QUESTIONS Questions from the text or lab sheet should be answered in full sentences.

CONCLUSION /DISCUSSION In this section you will discuss the results you obtained, therefore it is imperative that you refer directly to your data and results. Your discussion should also make reference to your objective. Pose questions of your own and relate your results to real life situations where possible. An examination of the errors that likely influenced your accuracy should also be included. Discuss only errors which are unavoidable, significant and/or peculiar to the experiment. Do not include human error which you corrected and therefore did not affect your results.

EVALUATION OF LAB REPORTS

Lab reports will be evaluated holistically on a four-point scale based on the following:

GRADE	CRITERIA
4	- all parts of lab completed according to format given - typed or neatly written/printed in ink (no pencil) - title and all headings underlined - data table is easy to follow - calculations are correctly done (correct units and sig. figs too) - graph is completed according to criteria discussed in class - text questions are answered correctly & thoughtfully - observations and discussion go beyond the obvious by showing thought, posing questions of your own, relating previous knowledge or information from other references to the experiment and discussing possible implications of the results for real-life situations where appropriate.
3	- all parts of lab completed according to format given - typed or neatly written/printed in ink (no pencil) - title and all headings underlined - data table is easy to follow - calculations are correctly done (correct units and sig. figs too) - graph is completed according to criteria discussed in class - most of text questions are answered correctly & thoughtfully - observations and discussion show a bit more thought than just stating the obvious.
2	- all parts of lab completed according to format given - typed or neatly written/printed in ink (no pencil) - title and all headings underlined - data table is easy to follow - calculations are correctly done (correct units and sig. figs too) - graph is completed according to criteria discussed in class - text questions answered correctly but don't show much thought, detail, or explanation - observations and discussion state the basic results without evidence of additional reflection.
1	- some parts of lab are incomplete or missing - messy or some parts written in pencil - title and headings not all underlined - data table not well organized - errors in calculations, graph, answers to text questions - observations and discussion lack understanding or thoughtfulness

Manipulating Formulae

Rule: whatever you do to one side of the formula, you must do exactly the same to the other side.

Eg 1) $d = \frac{1}{2} g t^2$ solve for t.

$$\frac{d}{g} = \frac{\frac{1}{2} g t^2}{g} \qquad \frac{d}{g} = \frac{1}{2} t^2 \frac{\cancel{g}}{\cancel{g}} = \frac{1}{2} t^2$$

$$2 \times \frac{d}{g} = \frac{1}{2} t^2 \times 2 \qquad \frac{2d}{g} = t^2 \qquad t = \sqrt{2d/g}$$

Eg 2) $d = \frac{1}{2} g t^2$ solve for g

$$\frac{d}{\frac{1}{2} t^2} = \frac{\frac{1}{2} g t^2}{\frac{1}{2} t^2} = g = \frac{d}{\frac{1}{2} t^2}$$

Eg3) $d = Vt + \frac{1}{2}at^2$ solve for V

$$d - \tfrac{1}{2}at^2 = Vt + \tfrac{1}{2}at^2 - \tfrac{1}{2}at^2$$

$$\frac{d - \frac{1}{2}at^2}{t} = \frac{Vt}{t} = V$$

Eg4) $d = Vt + \frac{1}{2}at^2$ solve for a

$$d - vt = vt + \tfrac{1}{2}at^2 - vt = \tfrac{1}{2}at^2$$

$$\frac{d - vt}{\frac{1}{2}t^2} = \frac{\frac{1}{2}at^2}{\frac{1}{2}t^2} = a$$

Eg5) $d = Vt + \frac{1}{2}at^2$ solve for t

In grade 12 will solve using quadratic

$ax^2 + bx + c = 0$ $\qquad x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

But in gr 11 d, V, or a

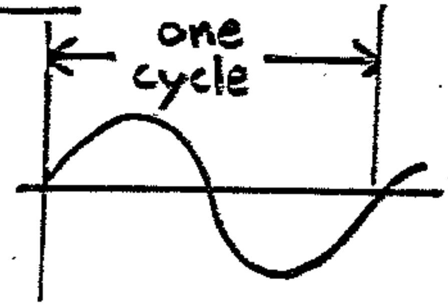
will be zero so we don't have to solve with quadratic, solve via method 3

Period and Frequency

Repeated motion = oscillation

vibration

cycle



Frequency = number of cycles per second *(f)*

$$f = \frac{N}{t}$$

Where, N = # of cycles

t = time in seconds

Example: 216 vibrations in 3.41 seconds

$$f = \frac{N}{t} = \frac{216 \text{ cycles}}{3.41 \text{ seconds}} = 63.3 \text{ cycles/second} = 63.3 \text{ Hz}$$

Period = time required for one cycle *(T)*

$$T = \frac{t}{N}$$

Where, t = time in seconds

N = # of cycles

Example: 216 vibrations in 3.41 seconds

$$T = \frac{t}{N} = \frac{3.41 \text{ seconds}}{216 \text{ cycles}} = 0.0158 \text{ s/cycle}$$

Note that, $$T = \frac{1}{f} \text{ and } f = \frac{1}{T}$$

Homework: calculate f and T of your pulse.

Recording Timers

In many of the investigations of motion that follow, you will be using a recording timer as a clock. A photograph of one of these is shown. A moving arm, driven by an electromagnet, strikes a metal block at a high frequency. A long strip of ticker tape, attached at one end to the moving object under study, slides between the moving arm and the metal block. A circular piece of carbon paper, attached so that it can rotate, makes a dot on the ticker tape every time the moving arm strikes it. In this way, a complete record is made of the motion. An analysis of the marks on the paper tape will give information about distance, time, speed, and acceleration.

Examine your timer carefully. Does it work in the same way as the one shown? Follow your teacher's directions and be sure to connect your timer correctly to the power supply. When you turn your timer on, it should make a regular sound.

Investigation: The Period of a Recording Timer

Problem:
What are the period and the frequency of the recording timer?

Materials:
recording timer
power supply
2 m ticker tape
carbon paper disc
stopwatch

Procedure

1. Connect the timer to the power supply.
2. Attach the carbon paper disc to the timer, with the carbon side up.
3. Thread one end of the paper tape into the timer, over the carbon paper disc.
4. Pull the tape through the timer for exactly 3 s. One person pulls the tape while the other uses the stopwatch.

Observations
In a data table, record the time for the run, in seconds, and the number of dots. Calculate and record the frequency and the period of the timer.

Questions

1. Why is it important in this investigation not to pull the tape too quickly?
2. Why is it equally important not to pull the tape too slowly?
3. Does it matter whether the dots are unevenly spaced along the tape? What would that indicate?
4. The period of many recording timers is 1/60 s or 0.017 s. If this is true for your timer (your teacher can tell you whether it is), calculate the **percentage error** in your measurement of the period. (See Appendix C)
5. What are the major sources of error that could affect your measurements and your calculation of the period? How could you allow for each of these sources of error, so as to obtain a more accurate value for the period?

Conclusion

Each investigation must have a conclusion. The conclusion is the best answer you can give to the problem posed at the start of the investigation. If the answer is a number, as in this investigation, it is a good idea whenever possible to give its percentage error as well. After you have done each investigation, you should come to a conclusion and include it in your written report.

Practice

1. A recording timer makes 540 dots in 4.0 s. What is its period?
2. A recording timer has a period of 0.025 s. How many dots does it make in 0.80 s?
3. A recording timer has a period of 0.04 s. How many dots does it make in 0.20 s?
4. A recording timer makes 465 dots in 8.5 s.
   (a) Calculate its period.
   (b) Its actual period is 0.020 s. Calculate the percentage error.

Sample problem

A recording timer makes 125 dots in 2.5 s. What are (a) its period and (b) its frequency?

(a) Period

$$T = \frac{2.5\ \text{s}}{125} = 0.020\ \text{s}$$

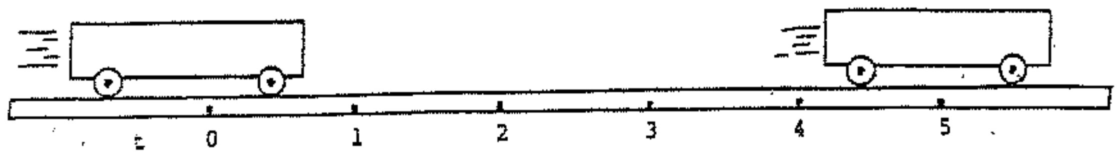
(b) Frequency

$$f = \frac{125}{2.5\ \text{s}} = 50\ \text{s}^{-1} = 50\ \text{Hz}$$

or

$$f = \frac{1}{T} = \frac{1}{0.020\ \text{s}} = 50\ \text{Hz}$$

Funsheet #2 – 1 – Motion with Constant Speed



1. The marks on the board sketched above show where the front of a moving cart was at t = 0, 1, 2, 3, 4, and 5 seconds. The total distance from A (t = 0) to B (t = 5 s) is 75 cm. Describe how you could use the board and the blackboard to make a graph showing the relationship between position and time for the motion of the cart.

2. Make a graph of the position of the cart versus time. Label the axes with the quantity being plotted and the unit of measurement. Put the appropriate scales on the axes for time and position.

3. How do the marks on the board show that the cart's speed is nearly constant?

4. What is constant about graph 1 in question 2? Name and define this quantity.

5. State the relationship between the constants of questions 3 and 4 in algebraic symbols. Find the value of the speed. (Be sure to include the units as well as the numbers for the rise and the run.)

6. Make a graph of the speed of the cart versus time. Label the axes with the quantity being plotted and the unit of measurement. Put the appropriate scales on the axes for speed and time. (Note: v is the usual symbol for speed.)

7. From t = 5 seconds on the time axis, draw a vertical line upward until it intersects the graph. What is the shape of the area enclosed by this line and the axes?

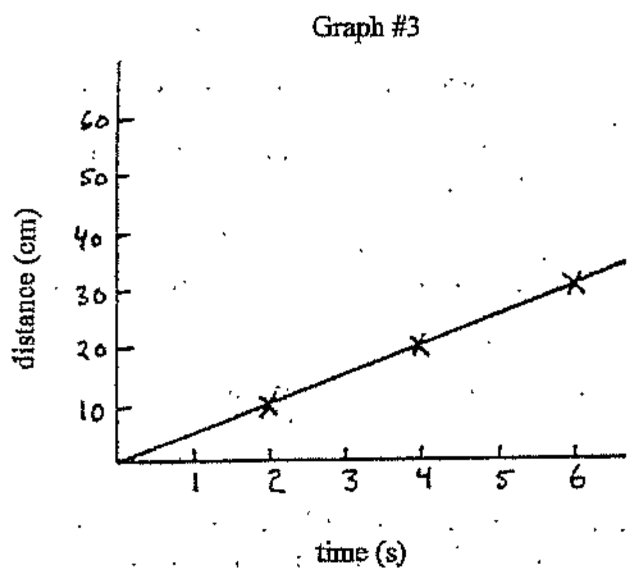
8. The enclosed area of question 7 has a base t and a height v. What does its area represent? (Be sure to include the units as part of the measurement and the calculations.) Does your answer check with what you know about the motion from the experiment?

9. Does the "area under the graph" concept work for finding the distance traveled between t = 2 and t = 4 seconds? What adjustment would you need to make?

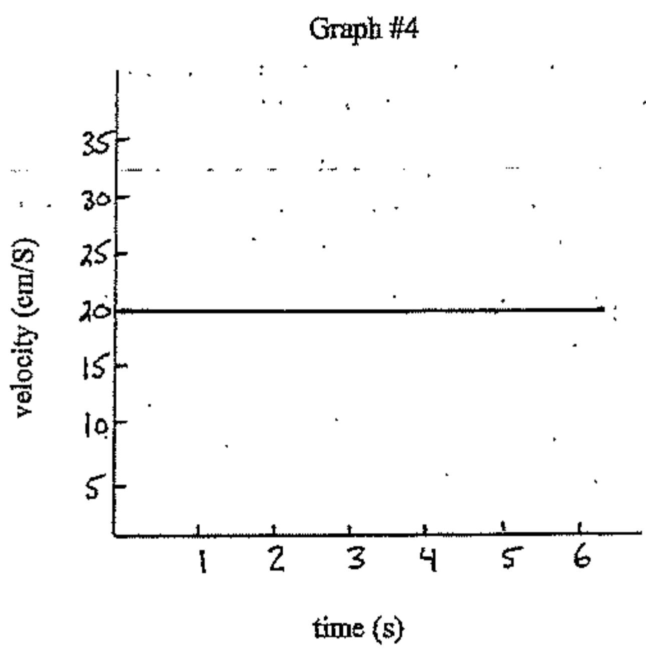
10. Using the area under the graph concept, write an equation in algebraic symbols expressing the relationship between v, Δt, and Δd. Then compare this equation with the one you wrote in question 5 using the slope concept.

More practice questions on the back.

11. The first motion is described on the Graph #3 below. Make a velocity (speed) versus time graph.



12. Another motion is described on the Graph #4 below. Make a distance versus time graph.



Experimental Error

In conducting an experiment a person encounters one or more of three general types of errors: **human error**, **systematic error**, and **random error**.

Human error (a mistake) occurs when you, the experimenter, make a mistake. Examples would be when you set up your experiment incorrectly, when you misread an instrument, or when you make a mistake in a calculation. Human errors are not a source of experimental error; rather, they are "experimenter's" error. **Do not** mention human error as a source of error in your lab report.

Systematic error is an error inherent in the experimental set up which causes the results to be skewed in the same direction every time, i.e., always too large or always too small. One example of systematic error would be trying to measure the fall time of a ping-pong ball to determine the acceleration due to gravity. Air resistance would systematically reduce the measured acceleration, producing a systematic error. Some systematic errors can be easily corrected. For example, if a balance reads 0.25 g when there is no mass on it, this would introduce a systematic error to each mass measurement—they would all be too large by 0.25 g. This can be corrected by zeroing the balance. Other systematic errors can only be eliminated by using a different experimental setup. Most of the simple experiments you do will have some systematic error.

All experiments have **random error**, which occurs because no measurement can be made with infinite precision. Random errors will cause a series of measurements to be sometimes too large and sometimes too small. An example of random error could be when making timings with a stopwatch. Sometimes you may stop the watch too soon, sometimes too late. Either case introduces random error in your measurements. (Note that when a human is involved in the actual measurement process, he/she can introduce valid experimental error that is not within the definition of human error. Your finite reaction time is not a mistake; it is a limitation of one part of the experimental process, the human making the measurement.) Random error can be reduced by averaging several measurements.

Physics 11

Lab #1: UNIFORM MOTION

Objective: How does a distance-time graph show uniform motion?

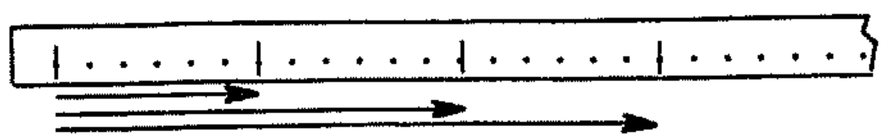
Apparatus:
- recording timer
- ticker tape

Procedure:
1. Set up the timer and thread one end of the tape into it.
2. Holding onto the end of the tape, walk several steps at a constant speed while your partner operates the timer. Pull the tape as smoothly and steadily as possible.
3. Each partner should make their own recording and attach their tape to their lab report.

Analyse the tape as follows:

4. Select a convenient unit of time. Your timer has a frequency of 60. Hz (ie. it makes 60 dots in each second). Therefore, six dots would represent 0.10 s, a convenient unit of time.
5. Draw a line across the tape through the first dot on the tape.
6. Draw a line through every sixth dot all the way along the tape.

7. Now measure, to the nearest tenth of a centimetre, the total distance travelled from the first dot up to the end of each marked time interval.



8. Record this information in a data table similar to this:

time, t (s)	0.0	0.10	0.20	0.30	0.40	0.50	0.60	0.70
distance, d (cm)	0.0							

9. Draw a distance-time graph, with time plotted horizontally and distance vertically. Make the graph as large as possible.

Questions:
1. Calculate the average speed for the trip by dividing the total distance travelled by the total time taken. Be sure to express your answer with correct sig. figs and units.
2. Draw a straight line from the first point on your graph to the last point on your graph. Calculate the slope of this line. Express your answer with correct sig. figs and units.
3. How do your answers for #1 and #2 compare? Therefore, what information does the slope of a distance-time graph give you?
4. What shape would the graph have if the motion were absolutely uniform?
5. What shape would the graph have if the motion were uniform, but
   (a) faster? (b) slower?

Uniform Motion

If an object moves so that the distance it moves is proportional to the time interval (i.e. if you triple the time interval, the object moves through triple the distance) then you can say that the change in distance (Δd) is proportional to the change in time (Δt) or...

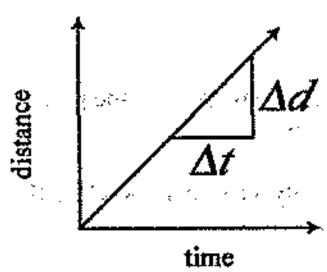
$$\Delta d \propto \Delta t$$

...where "Δ" is the Greek letter "delta" and is read as "change in." And since $\Delta d \propto \Delta t$ it is obvious that...

$$\Delta d = v\Delta t$$

... where "v" is the constant of proportionality linking the variable "d" to the variable "t." This constant (v) is called the speed (if distance of travel is not specified) or the velocity (if direction is specified).

If we plotted a graph of distance versus time for motion where d is proportional to t it would look as follows:



The slope of the line is given by:

$$slope = \frac{\Delta d}{\Delta t} = v$$

Therefore, the slope of the line on a distance-time graph for an object moving with uniform motion equals the speed of the object. The speed (v) has units of distance divided by time (km/h, m/s, etc.)

Average and Instantaneous Speed

So far we have discussed objects moving with constant speed. In many cases objects are accelerating (speeding up, slowing down or stopping). In such cases, the speed is not constant but is changing. We can, however, determine two quantities of importance, the average speed (v_{av}) and the instantaneous speed ($v_{inst.}$).

Average Speed

The average speed during a time interval is the total distance travelled by the total time taken. It is defined by the equation:

$$v_{av} = \frac{\Delta d}{\Delta t}$$

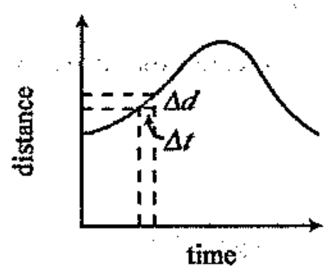
For example, if you drive 100 km in a total time of 4 hours (2 hours in motion and 2 hours for lunch) your average speed is:

$$v_{av} = \frac{\Delta d}{\Delta t} = \frac{100\text{ km}}{4\text{ h}} = 2.5\text{ km/h}$$

Note that during the time interval you may have been travelling at 50 km/h for a while and of course at 0 km/h while having lunch.

Instantaneous Speed

Instantaneous speed is the speed of an object at a particular instant in time. In a car, the speed at some particular time is the sped that the speedometer of the car measures. Instantaneous speed can be determined from a distance-time graph as follows:

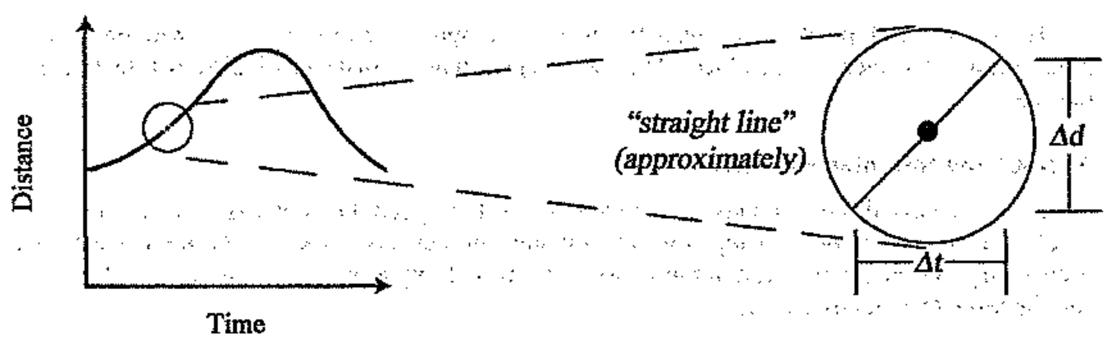


If the time interval (Δt) is very small, then the portion of the curve within this time interval is approximately a straight line. We can find the slope of this line by finding the ratio of (Δd) to (Δt) or...

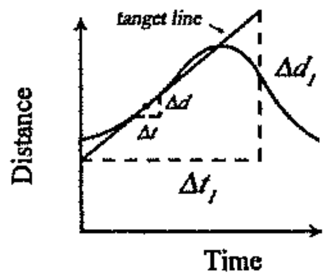
$$slope = \frac{\Delta d}{\Delta t} = v$$

This is the instantaneous speed at the point shown on the graph.

Obviously the triangle used to determine the value is extremely small and therefore the value of v_{inst} if determined using this method would be very inaccurate.



Since the time interval (Δt) is small, the curve is almost straight and therefore we can draw the tangent to the curve at the desired point. That is, we extend the "straight" line section of the curve and find the slope using a much larger triangle.



$$v_{inst} = \frac{\Delta d}{\Delta t} \text{ (small triangle)}$$

$$v_{inst} = \frac{\Delta d_1}{\Delta t_1} \text{ (using tangent line)}$$

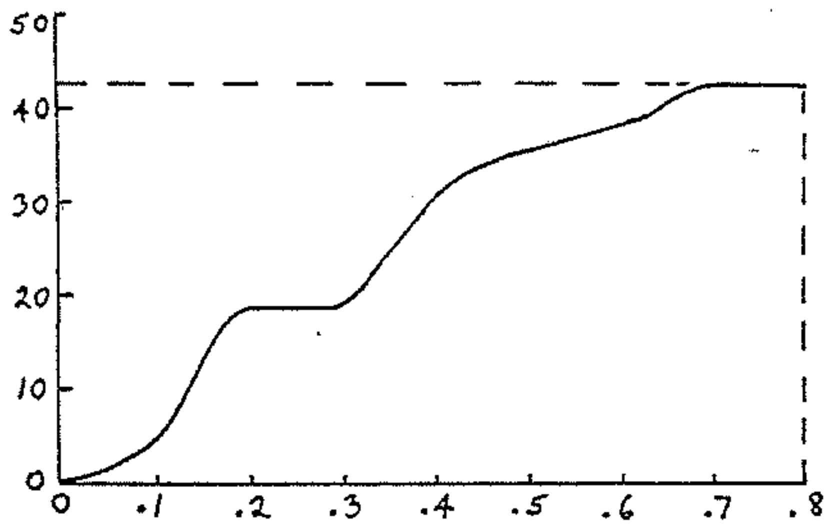
In summary, the instantaneous speed is the speed of an object at a particular instant in time. It is numerically equal to the slope of the tangent to the curve on a distance-time graph. It is determined using the equation $v = \frac{\Delta d}{\Delta t}$ where Δt is made as small as possible.

Funsheet #2-2 – Motion in One Dimension

1. A train travels a distance of 600 km in 20 hours. What is the average speed of the train?

2. A car travels at a constant speed of 60 km/h along a highway. How far does the car travel in 15 minutes? How long odes it take for the car to travel 9 km?

3. Use the following graph to determine the instantaneous speed of a car at the indicated times.



a. .35 h
b. .5 h
c. .15 h
d. .25 h

Also:
What is the average speed of the car during the time interval of 0 to .8 hours?

PHYS 11 - REVIEW OF KEY WORDS

1. Scalar - A scalar quantity is a quantity that has only a magnitude (size).

2. Vector - A vector quantity has both magnitude (size) **AND** direction.

3. Distance - A length measurement **WITHOUT** direction, eg. 20 m.

4. Displacement -

   The change of position of an object. A length measurement **WITH** direction, eg. 20 m West.

5. Speed - The magnitude (size) of velocity **WITHOUT** direction, eg. 50 km/hr

6. Velocity - The change in displacement divided by the time over which it occurred, **WITH** direction, eg. 50 km/hr, West

6A. Average velocity -

Total displacement divided by the time over which it occurred, eg. 200 km in 4 hours = 50 km/hr - even if you took a 1/2 hour lunch break.

6B. Constant velocity -

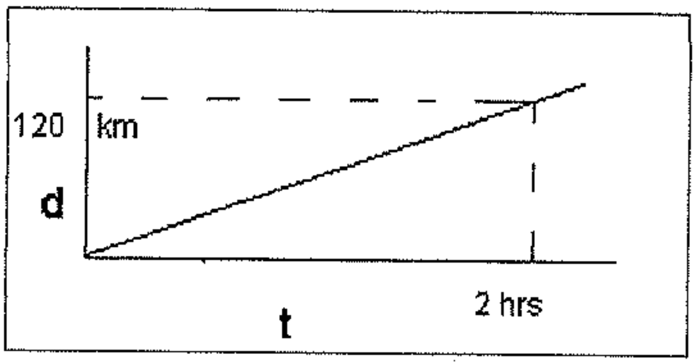
The ratio of the (change in displacement)/(change in time) = constant

6C. Instantaneous velocity -

The ratio of (change in displacement)/(change in time) at a particular instant in time.

Velocity and Graphs

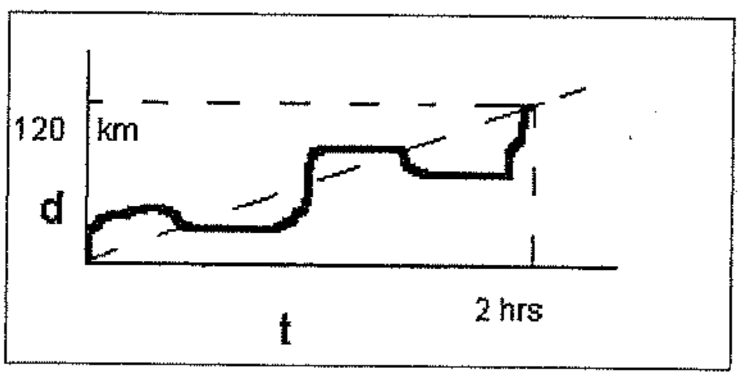
A) Constant (Uniform) Velocity



slope of line $= \Delta d/\Delta t$

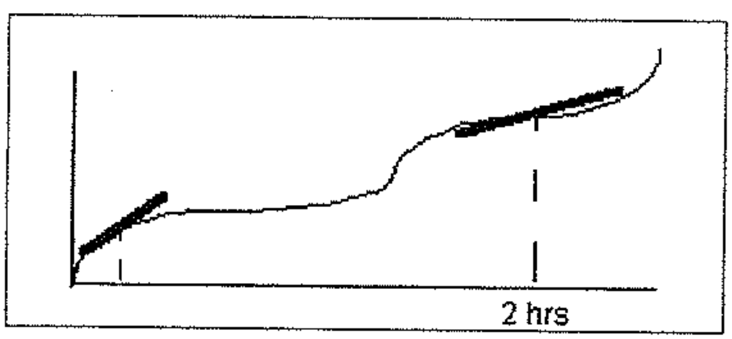
120 km/2 hr =
60 km/hr

B) Average Velocity



slope = ave velocity
$= \Delta d/\Delta t$
= total displ./tot. time
= 120 km/ 2 hrs
= 60 km/hr

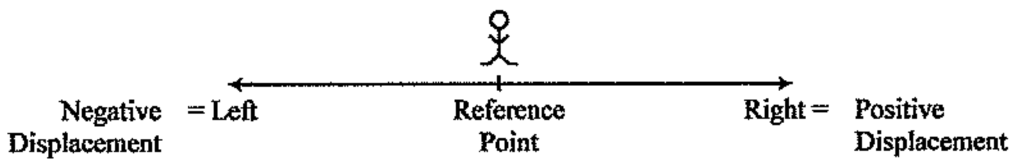
C) Instantaneous Velocity



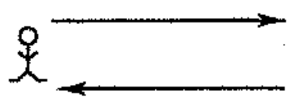
slope =
instantaneous
velocity at 2 hrs

Non-Uniform Motion

The concepts of position and velocity are not laws of nature that were discovered by scientists. Rather, they were invented or created by humans to help describe the motion of objects. We choose a frame of reference for our observations and select a measuring scale. We can also decide which direction is positive and which is negative.



Also



+ Away from starting point.

- Back towards starting point.

*Since velocity includes both speed and direction, it can be positive or negative. Positive velocity is movement away from the starting point or in the "positive" direction. Negative velocity is the movement back towards the starting point or movement in the "negative direction."

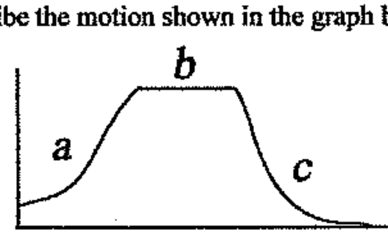
Velocity-Time Graphs

Uniform Motion (Constant Velocity)

Increasing Velocity:

Decreasing Velocity:

Describe the motion shown in the graph below:



A → v increases

B → v constant

C → v decreases to stop

EXPERIMENT **4.1**

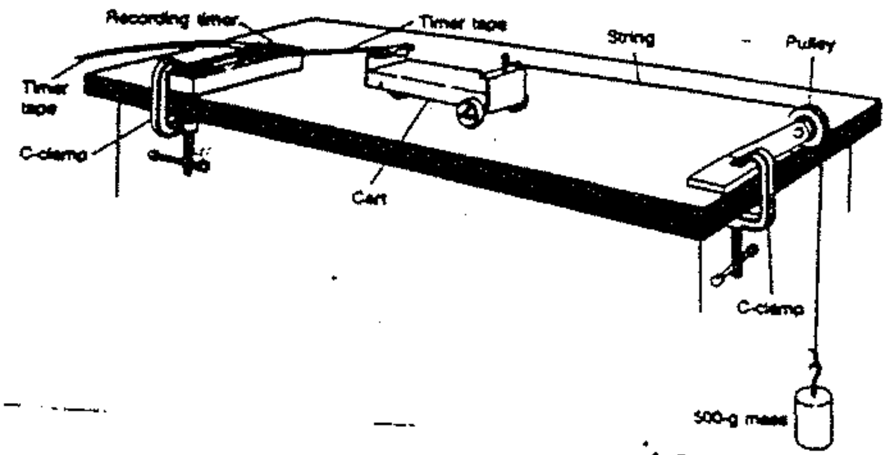
Accelerated Motion

Purpose

Observe and analyze the motion of a uniformly accelerated body moving in a straight line.

Concept and Skill Check

The recording timer can be used to record the movement of a small cart as it is pulled across a table top by a falling mass. The resulting timer tape measures displacement of the moving cart per interval of time. From Experiment 3.1, you know that average velocity is equivalent to displacement for a given interval of time. The ratio of a change in velocity to a change in time yields acceleration [$a = (v_2 - v_1)/(t_2 - t_1)$]; this is the equation for the slope of a velocity versus time graph. With the data from this experiment, you will construct three graphs to analyze the motion of the cart: displacement versus time, velocity versus time, and acceleration versus time.



Observations and Data

Table 1

Time (s)	~~Individual~~ Individual Displacement (cm) — for each interval	Total displacement (cm) — measured from the beginning
.1		
.2		
.3		
.4		
.5		

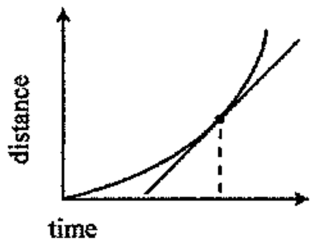
Table 2

Time (s)	Average velocity (cm/s) — over each interval (Indiv. disp / time)	Acceleration (cm/s²) ($\Delta v/\Delta t$) — slope of v-t graph
.1		
.2		
.3		
.4		
.5		

Analysis

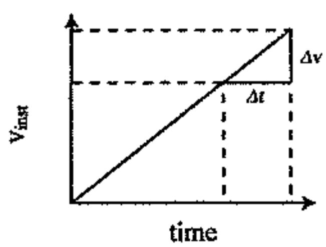
1. On graph paper plot the total displacement of the cart versus the time interval. Use the values from Table 1. Plot total disp vs time (in .1s)
2. On graph paper, plot the average velocity versus the time interval. Use the values from Table 2.
3. Describe the graph of displacement versus time. What is the meaning of the graph? what is the cart doing?
4. Describe the velocity versus time graph. What is the meaning of the graph? what is the cart doing?
5. Calculate the slope of the velocity versus time graph for each time interval. Write the results of your calculations in Table 2. What is the unit for the slope? (slope of entire V-t graph) (last column = "acceleration")
6. On graph paper, plot acceleration versus time. Describe this graph. What does your graph show about the acceleration of the cart?

Consider the following distance time graph.



We have seen that v_{inst} can be determined at any particular time by determining the slope of the tangent to the curve at that particular time.

Imagine that we calculate the slope (v_{inst}) of the curve at various instants of time. Then we use the calculated instantaneous speeds and their corresponding times and plot a second graph, a speed-time graph.



From this straight line graph, we can see that:

$v_{inst} \propto t$

or $v_{inst} = at$

Where "a" is the constant of proportionality relating the variable "vinst" to the variable "t." This constant is called acceleration. It has the units of speed divided by time squared (i.e. km/h^2, cm/s^2, etc.)

It should be obvious that the value of "a" can be found by taking the slope of the line.

$$a = \frac{\Delta v}{\Delta t}$$

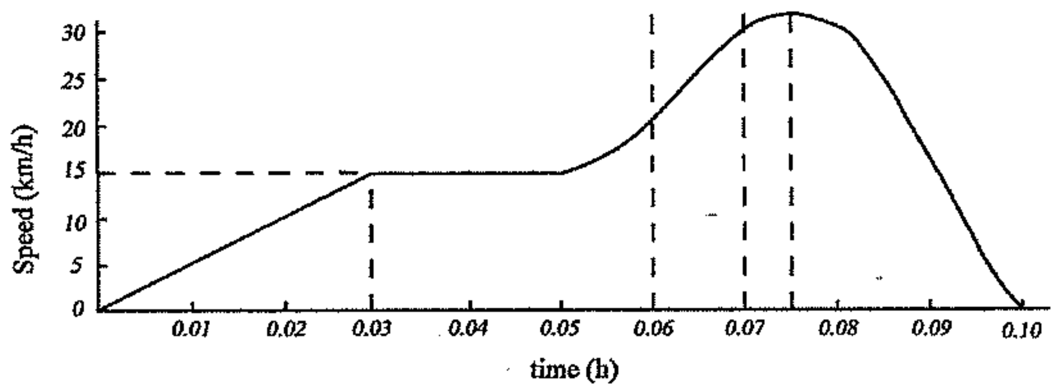
Summary

1. V_{inst} = the slope of a distance-time graph at a given instant of time
2. a_{inst} = the slope of a speed-time graph at a given instant of time
3. $v_{av} = \frac{d}{t} = \frac{\text{total distance travelled}}{\text{total time taken}}$

1. A car starts from rest and accelerates uniformly to 60 km/h in 10 s. What is the acceleration of the car?

2. An object traveling at 40 m/s increases its speed to 85 m/s in 15 s. What is the object's acceleration?

3.



From the above graph, determine the acceleration of a moving body at the following times:

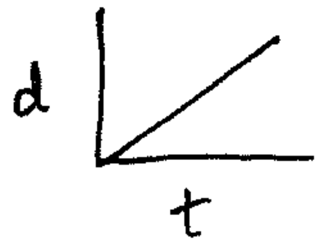
a. t = 0.02 h
b. t = 0.04 h
c. t = 0.06 h
d. t = 0.07 h
e. t = 0.075 h
f. t = 0.10 h

4. From the above graph, at what times is the body not moving?

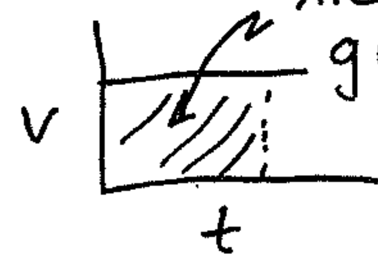
5. Is the body at rest when its acceleration is 0 km/h^2?

SUMMARY

1) Uniform V:



$d = vt$



2) average $v = \frac{\Delta d}{\Delta t} = \frac{d_f - d_i}{t_f - t_i}$

3) instantaneous v = slope of tangent line through a point on the curve of a d vs. t graph

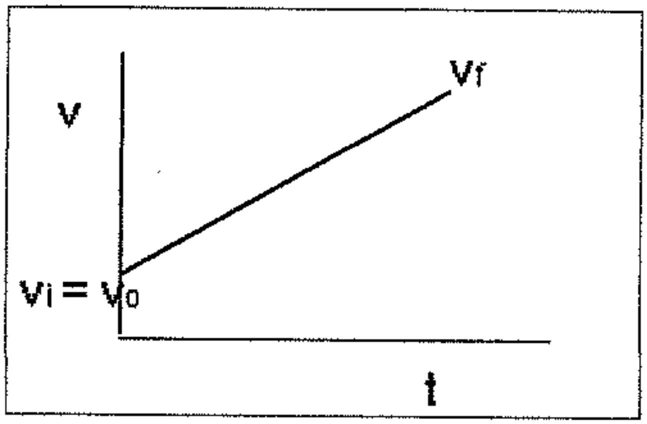
4) velocity is equal to $\frac{\text{displacement}}{\text{time}}$ (vector = $\bar{v}$ or $\vec{v}$)

5) Acceleration (the change in velocity in a given time interval.
↳ slope of V vs t graph

average $a = \frac{\Delta V}{\Delta t} = \frac{V_f - V_i}{t_f - t_i}$

6) Instantaneous a = slope of tangent line through point on curve of a V vs t graph

UNIFORM ACCELERATION



$V_i = V_o$ = initial velocity

V_f = final velocity

a = acceleration

t = time

Average velocity

$$V_{av} = \frac{V_i + V_f}{2}$$

Instantaneous velocity

From our graph the equation of the line becomes

$$y = mx + b$$

$V = at + V_i$ rearrange $V_f = V_i + at$ where t is total time

Distance

$$d = V_{av}\, t = \frac{(V_i + V_f)}{2}\, t$$

$$= 1/2\,(V_i + V_f)\, t$$

Uniform Accel p2

By combining two of our formulae from above we can create two more useful formulae.

Since I) $d = 1/2\ (V_o + V_f)\ t$ and II) $V_f = V_o + at$

substituting for V_f into I) gives us

$$d = 1/2\ (V_o + (V_o + at))\ t$$

$$= 1/2\ (2V_o + at)\ t$$

III) $d = V_o t + 1/2(at^2)$

which gives us displacement when V_o, Acceleration, and time are known.

Example:

A car starting from rest accelerates uniformly at 6.1 m/s^2 for 2 sec.

How far does it go?

$d = ?$, $v_o = 0$ (at rest), $a = 6.1\ m/s^2$, $t = 7.0\ s$

$d = V_o t + 1/2(at^2) = (0)(7.0) + 1/2(6.1)(7.0)^2 = 150m$

Uniform Accel p3

Also again I) $d = 1/2\ (V_o + V_f)\ t$

and II) $V_f = V_o + at$, solving for t, $t = (V_f - V_o)/a$

substituting this formula for t into I) gives us:

$d = 1/2\ (V_o + V_f)(V_f - V_o)/a$

$d = (V_o + V_f)(V_f - V_o)/2a = (V_oV_f - V_o^2 + V_f^2 - V_oV_f)/2a$

$d = (V_f^2 - V_o^2)\ /2a$

which gives us displacement when velocity and acceleration are known.

But a more useful formula is:

rearranging gives:

IV) $V_f^2 = V_o^2 + 2ad$

Which gives us final velocity when initial velocity, acceleration and distance covered are known.

Uniform Accel p4

Example:

An airplane which must reach a speed of 100. km/h (28 m/s) before takeoff can accelerate at 2.0 m/s^2.

a) if it is on a 150.m long runway, can it reach the takeoff speed before it runs out of runway?

Let v = ?, a = 2.0 m/s^2, d = 150.m, V_o = o (at rest)

IV) $V_f^2 = V_o^2 + 2ad = 0 + 2(2.0)(150.) = 600\ (m/s)^2$

$V = (600)^{-2} = 24$ m/s which is NOT fast enough!!

b) How long a runway is needed for this plane?

Let d = ?, V = 27.8m/s, a = 2.0 m/s^2, V_o = o (at rest)

$V_f^2 = V_o^2 + 2ad$ gives $(27.8)^2 = 0 + 2(2.0)d$ solve for d

$d = (27.8)^2 /2(2.0) = 190m$

Combination problem:

As the traffic light changes, a truck moving at a constant velocity of 14.0 m/s passes into the intersection and your car accelerates from rest at a constant $2.20 m/s^2$

a) how long before you catch the truck?

Let car $V_0 = 0$, $a = 2.20\ m/s^2$

truck V = 14 m/s

the car catches the truck when $d_{car} = d_{truck}$

(car accelerating) so $d_{car} = V_o t + 1/2(a_{car}\, t^2)$ and

(truck constant Vel) so $d_{truck} = V_{truck}\, t$

which means if $d_{car} = d_{truck}$ then

$V_o t + 1/2(a_{car}\, t^2) = V_{truck}\, t$ $(0)t + 1/2(2.20)t^2 = (14.0)t$

divide both sides by t $(1.10t^2)/t = (14.0\ t)/t$ $t = 12.7$ s

b) distance travelled: $d_{car} = V_o t + 1/2(a_{car}\, t^2)$

$d_{car} = 0 + 1/2(2.20)(12.7)^2 = 178m$

same as $d_{truck} = V_{truck}\, t = (14.0)(12.7) = 178m$

UNIFORM ACCELERATION p6

SUMMARY OF FORMULAE

I) $d = 1/2\,(V_o + V_f)\,t$ when constant a is ~~un~~known not

II) $V_f = V_o + at$ when d is ~~un~~known not

III) $d = V_o t + 1/2(at^2)$ when is V_f ~~un~~known not

IV) $V_f^2 = V_o^2 + 2ad$ when t is ~~un~~known not

Note: $V_o = V_i = 0$ if accelerating from rest
$V_f = V_2 = 0$ if stopped

Read p 69, 71-74

Text Q: 13-16 p 72
17-20 p 74
21-24 p 75

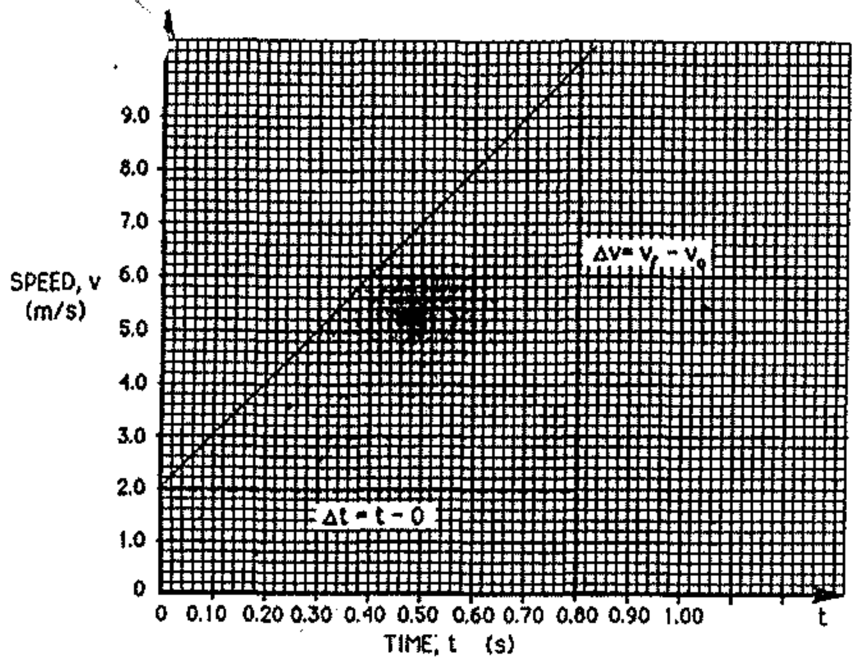


Figure 2.11

A Specific Example

Figure 2.11 is a graph illustrating the uniform acceleration of a rock after it was dropped off a cliff.

(a) What was the acceleration of the rock?
(b) Write an equation for the graph in Figure 2.11.

Solution (a) The acceleration is determined from the slope of the speed–time graph.

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t - 0} = \frac{10.0 \text{ m/s} - 2.0 \text{ m/s}}{0.80 \text{ s} - 0 \text{ s}} = \frac{8.0 \text{ m/s}}{0.80 \text{ s}} = \underline{1.0 \times 10^1 \text{ m/s}^2}.$$

(b) The general equation for any straight line is $y = b + kx$. For *this* line, the slope k is the acceleration, and the y-intercept, by inspection of the graph, is 2.0 m/s. Therefore the equation for this specific line is

$$v_f = 2.0 \text{ m/s} + (1.0 \times 10^1 \text{ m/s}^2)\, t .$$

Notice that the final, *specific equation* for this graph includes the *actual numerical values* of the y-intercept and slope, complete with their measuring units. Once this equation has been established, it can be used in place of the graph, since it describes every point on the line.

EXERCISES

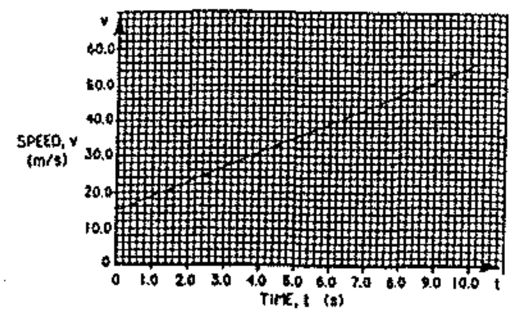


Figure 2.12(a)

1. (a) What is the y-intercept (v_0) for the graph in Figure 2.12(a)?
   (b) What is the slope of this graph?
   (c) What property of the moving object does this slope measure?
   (d) Write the *specific equation* for the graph, using symbols v for speed and t for time.

2. The following equation describes the motion of a ball thrown straight down by someone leaning out of a window of a tall building. $v_f = 5.0 \text{ m/s} + (9.8 \text{ m/s}^2)\, t$.
   (a) At what speed was the ball initially thrown out of the window?
   (b) What was the acceleration of the ball?
   (c) How fast was the ball moving after 1.2 s?

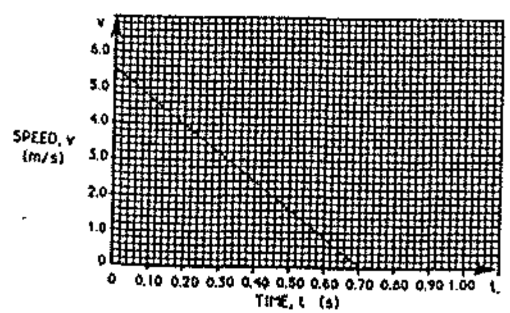


Figure 2.12(b)

3. (a) What is the y-intercept (v_0) of the graph in Figure 2.12(b)?
   (b) What is the acceleration of the moving object?
   (c) What is the *specific equation* for this graph?

4. A cyclist coasting along the road allows her bike to come to rest with the help of a slight upslope in the road. The motion of her bike is described by the equation,

$$v_f = 6.6 \text{ m/s} - (2.2 \text{ m/s}^2)\, t .$$

   (a) What was the initial speed of the bike?
   (b) At what rate did the bike accelerate while coming to rest?
   (c) How long did the bike take to come to rest?

Gore p33

Funsheet #2b – 3 (p37 Gore)

1. A truck parked on a down slope slips its breaks and starts to coast downhill accelerating from rest at a constant rate of 0.80 m/s2.
    a. How fast will the truck be moving after 5.0 s?
    b. How far will the truck coast during the 5.0 s?

2. A policeman travelling 60.0 km/h (16.7 m/s) spots a speeder ahead, so he accelerates his vehicle at a steady rate of 2.22 m/s2 for 4.00 s, at which time he catches up with the speeder.
    a. How fast is the police car moving after 4.00 s?
    b. How far does the police car travel during the 4.00 s?

3. A motocross rider travelling 65.0 km/h (18.0 m/s) collides with a haystack and is brought to rest in a distance of 4.5 m. What is the average acceleration of the motorbike and rider while being brought to rest?

4. A motorbike accelerates at a constant rate from a standing start. After 1.2 s it is travelling 6.0 m/s. How much time will have been elapsed (starting from rest) before the bike is moving with a speed of 15.0 m/s?

5. An aircraft starts from rest and accelerates at a constant rate down a runway.
    a. After 12.0 s its speed is 36.0 m/s. What is its acceleration?
    b. How fast is the plane moving after 15.0 s?
    c. How far down the runway will the plane travel in 15.0 s?

6. On a certain asteroid, a steel ball drops a distance of 0.80 m in 2.00 s from rest. What is the value of g on the asteroid?

7. What is the rate of acceleration of a mountain bike that slows down from 12.0 m/s to 8.0 m/s in a time of 3.25 s?

8. A body in free fall accelerates at 9.8 m/s2.
    a. How far does it fall during the first second?
    b. The second second?

Purpose:

Observe a falling object and determine the acceleration due to gravity.

Concept and Skill Check:

The recording timer can be used to record the displacement of a falling mass. The resulting tape is used to analyse the accelerated motion of the mass. In this lab, you must know the period of the timer. If the period is unknown, use the procedure described in the previous labs to determine the value.

The average velocity during an interval of time is found by the equation:

$$v = \frac{\Delta d}{\Delta t}$$

Where Δd is the distance travelled during an interval of time, Δt. A uniformly accelerated object *will produce a straight (but not horizontal) line on a graph that plots velocity versus time.* The slope of the velocity versus time graph is the acceleration. The slope is found from the ratio:

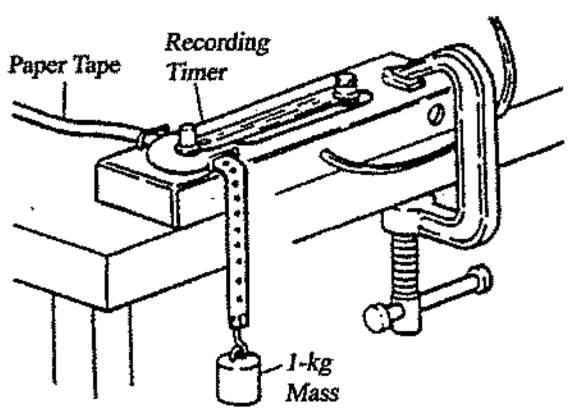
$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{v_f - v_i}{t_f - t_i}$$

An object dropped from rest will travel a distance given by the following equation:

$$d = \frac{1}{2} g t^2$$

Therefore, since d and t have been measured, g may be calculated from:

$$g = \frac{2d}{t^2}$$



Lab #2b-2 – Acceleration Due to Gravity

Observations and Data:

Table 1

Interval	Time (s)	Displacement cm	Displacement m	Total Displacement (m)	Average Velocity (m/s)
1					
2					
3					
4					
5					
6					
7					
8					
9					

Analysis:

1. On graph paper, plot the total displacement of mass versus time. Use values in table 1.
2. On graph paper, plot the average velocity versus time. Use the values in table 1.
3. Write a brief explanation describing what the graph of total displacement versus time indicates about the motion of the falling mass.
4. Study the graph of velocity versus time. Write a brief explanation of what the graph indicates about the motion of a falling mass.
5. Calculate the slope of the velocity versus time graph. Compare your results for acceleration due to gravity to the reference value, 9.80 m/s2, by finding the relative error.

$$\text{relative error} = \frac{\text{experimental result} - \text{reference value}}{\text{reference value}} \times 100\%$$

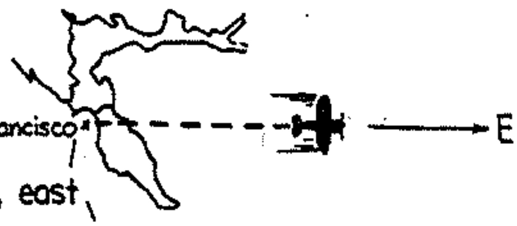
Description of Motion

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

Time = 1 hour

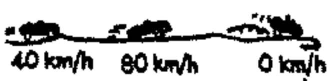
$$\text{Speed} = \frac{80\ \text{km}}{1\ \text{h}} = 80\ \text{km/h}$$

$$\text{Velocity} = \left\{\begin{matrix}\text{speed } \textit{and} \\ \text{direction}\end{matrix}\right\}$$

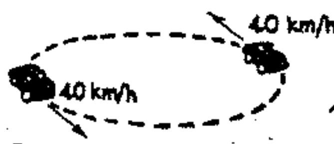


Velocity = 300 km/h, east

Acceleration = {Rate of change in velocity} *due to* {change in speed and/or direction}

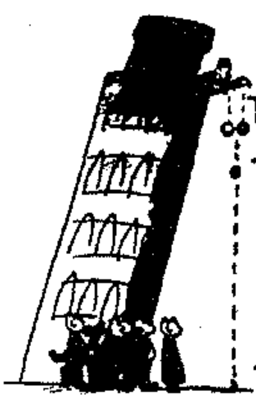


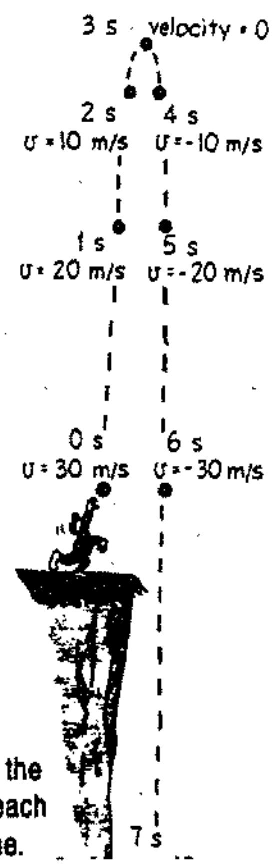
Change in speed but *not* direction



Change in direction but *not* speed

Change in speed *and* direction





$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time}}$$

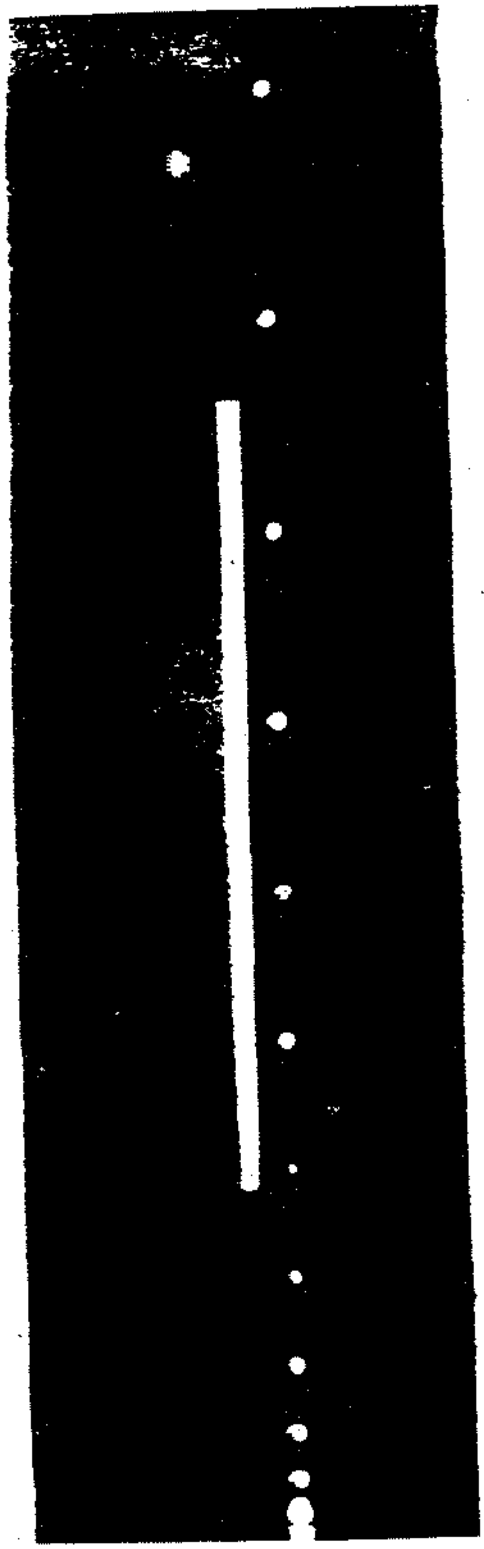
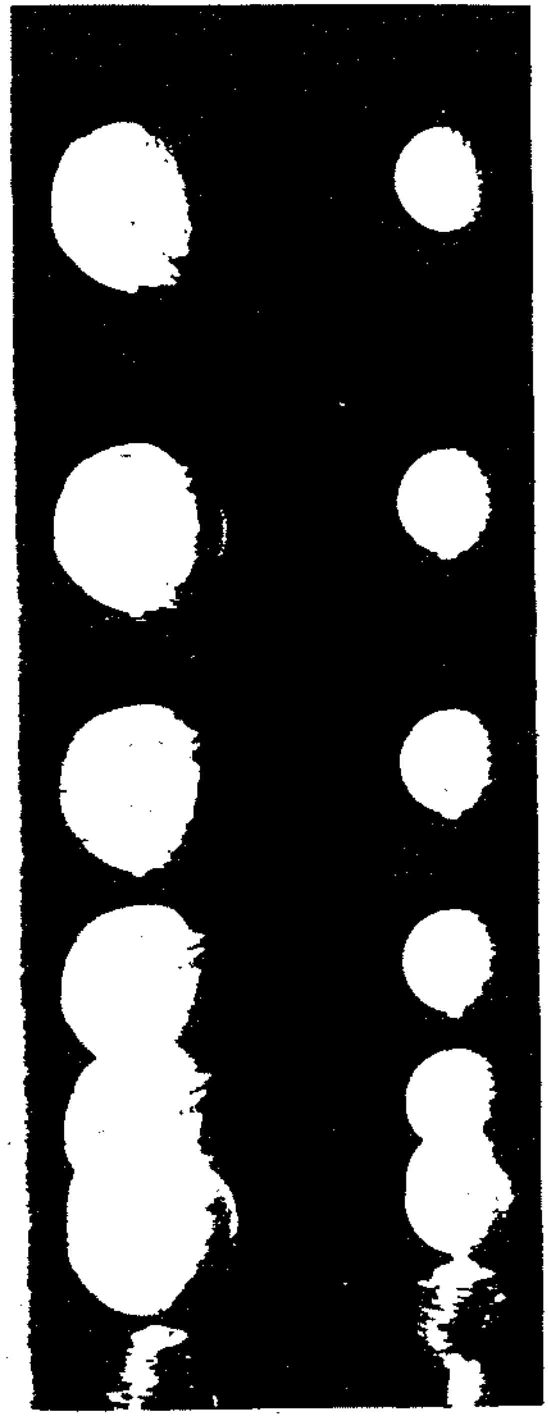
$$\text{Acceleration} = \frac{19.6\ \text{m/s}}{2\ \text{s}}$$

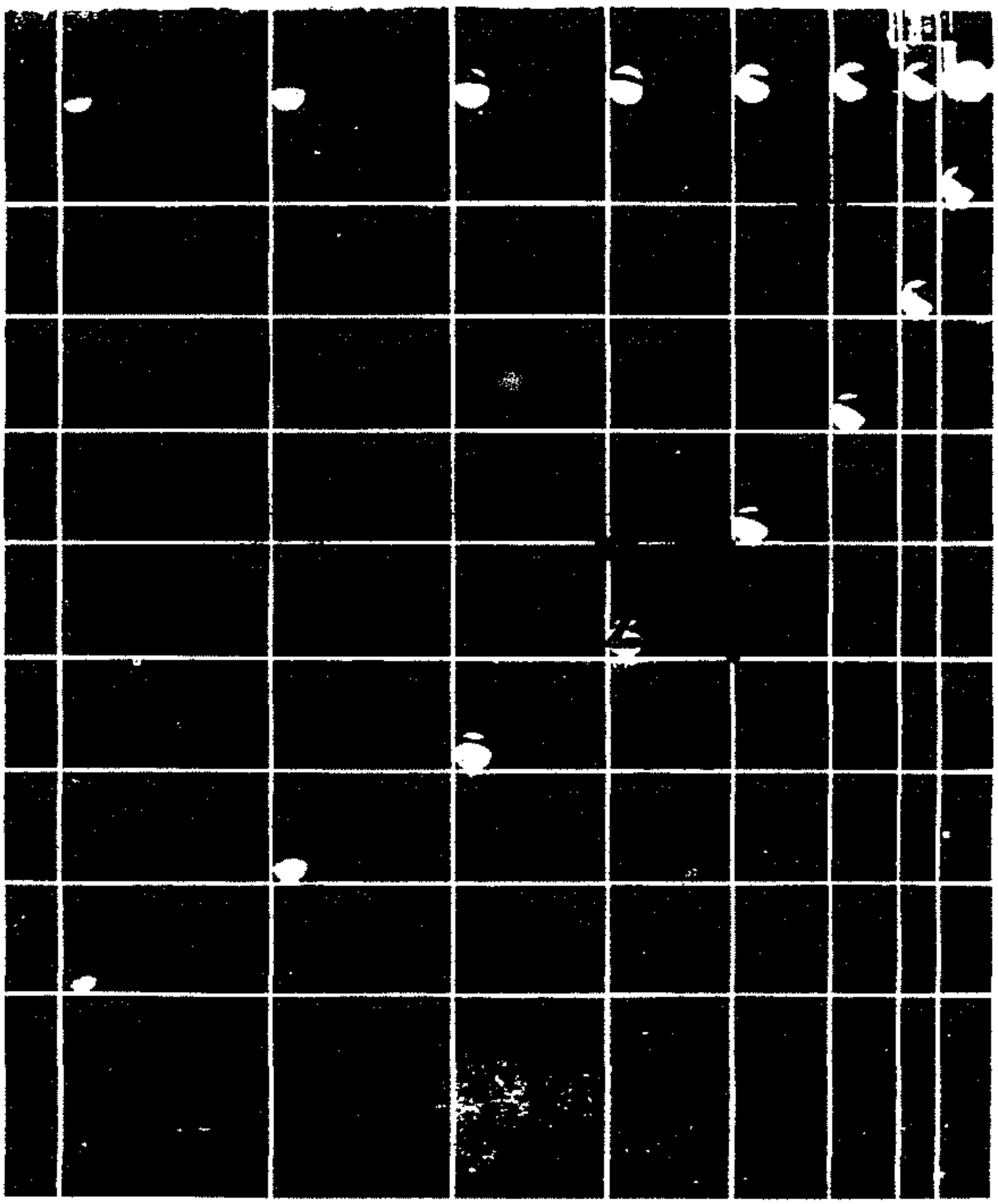
$$a = 9.8\ \frac{\text{m/s}}{\text{s}}$$

$$a = 9.8\ \text{m/s s}$$

$$a = 9.8\ \text{m/s}^2$$

The rate at which the velocity changes each second is the same.



ACCELERATION DUE TO GRAVITY

Regardless of the MASS of the object, the DISTANCE it falls, whether it is DROPPED or THROWN, the acceleration due to gravity is the SAME (ignoring air resistance and for all objects at the same location on Earth).

Acceleration due to gravity => $g = -9.8\ m/s^2$,

this means the velocity INCREASES 9.8 m/s in each second in the DOWNWARD direction, or DECREASES 9.8 m/s in each second in the UPWARD direction.

Assuming no air resistance, all problems involving motion of falling objects use "g" in place of "a" in the kinematic formulae.

eg. $v_f = v_i + gt$, where $g = -9.80\ m/s^2$

Ex. A tennis ball is thrown straight up with $V_i = 25.0$ m/s

a) how long to reach max height?

$V_i = 25.0$ m/s, $g = -9.80\ m/s^2$, $v_f = 0$ (stops at top)

$v_f = v_i + gt$,

solve for $t = (v_f - v_i)/g = (0 - 25.0 m/s)/-9.80\ m/s^2$

$t = 2.55$ s

b) How high does it reach?

$V_i = 25.0$ m/s, $g = -9.80$ m/s^2, $v_f = 0$ (stops at top)
$V_f^2 = V_i^2 + 2gd$,
$d = (V_f^2 - V_i^2)/2g = (0^2 - (25.0)^2)/2((-9.80)) = 31.9$m

c) time to fall back to starting point?

$V_i = 0$ m/s (stopped at top), $g = -9.80$ m/s^2, $d = -31.9$m
$d = V_i t + 1/2(gt^2)$, $-31.9\text{m} = 0t + 1/2(-9.80 \text{ m/s}^2)t^2$
solve for $t = 2.55$s NOTE: time up = time down!!

d) Impact speed?

$v_f = ?$, $V_i = 0$ m/s (stopped at top), $g = -9.80$ m/s^2,
$d = -31.9$m, $t = 2.55$s

$v_f = v_i + gt = 0 + (-9.80 \text{ m/s}^2)(2.55\text{s}) = -25.0$m/s
NOTE: this is the speed at which it was thrown upwards!!
Negative sign indicates it is going downwards.

e) total time for trip?

total time = time up + time down

= 2.55s + 2.55s = 5.10s

Kinematics Review Questions

1. When an object moves with constant velocity, does its average velocity during any time interval differ from its instantaneous velocity at any instant?

2. Can the velocity of an object be zero at the same instant its acceleration is not zero? Give an example.

3. Can you conclude that a car is not accelerating if its speedometer indicates a steady 60 km/h?

4. A bell, thrown vertically upward, returns to the thrower's hand. Which part of the journey requires the longer time, upward or downward?

5. A person jogs eight complete laps around a quarter-mile track in a total time of 13.5 min.
   a. What is the person's average speed?
   b. What is the person's average velocity?

6. A dog runs 100 m away from its master in a straight line in 8.4 s and then runs halfway back in one-third the time. Calculate (a) its average speed and (b) its average velocity.
   a. What is the dog's average speed?
   b. What is the dog's average velocity?

7. Two locomotives approach each other on parallel tracks. Each has a speed of 120 km/h with respect to the earth. If they are initially 8.5 km apart, how long will it be before they pass each other?

8. At highway speeds, a particular automobile is capable of an acceleration of about 1 7 m/s^2. At this rate how long does it take to accelerate from 15 km/h to 100 km/h.

9. A sports car is advertised to be able to stop, from a speed of 100 km/h, within 45 m. What is its acceleration in mis2? How many g's is this ($g = 9.80\ m/s^2$)?

10. A car accelerates from 12 m/s to 25 m/s in 5.0 s. What was its acceleration? How far did it travel in this time? Assume constant acceleration.

11. How long did it take for a car to decelerate from a speed of 25 m/s to rest in a distance of 120 m?

12. In coming to a stop, a car leaves skid marks on the highway 320 m long. Assuming a deceleration of 10 m/s^2 (roughly the maximum for rubber tires on dry pavement), estimate the speed of the car just before braking.

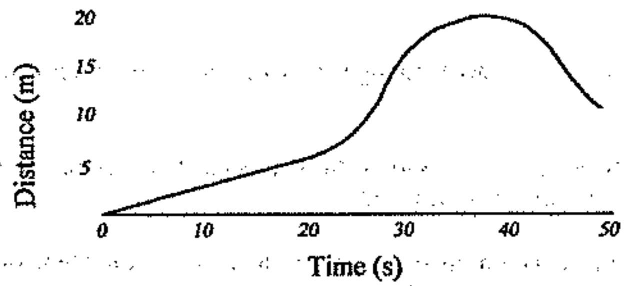
13. A stone is dropped, from the top of a cliff. It's seen to hit the ground below after 1.5 s. How high is the cliff?

14. A brick is dropped from a height of 50 m.
    a. How long will it take to hit the ground?
    b. What will be its velocity just before it reaches the ground?

Kinematics Review Questions

15. A baseball is thrown vertically into there with a speed of 24.0 m/s.
    a. How high does it go?
    b. How long does it take to return to the ground?

16.

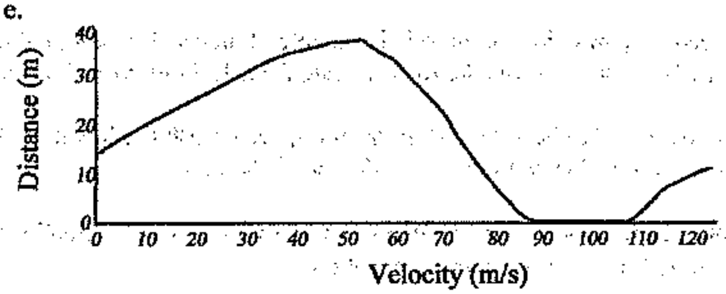


What is the instantaneous velocity...

a. At t = 10.0 s?
b. At t = 30.0 s?

17. In the picture above,
    a. During what time periods, if any, is the rabbit's velocity constant?
    b. At what time is its velocity the greatest?
    c. At what time, if can, is the velocity zero?
    d. Does the rabbit run in one direction or in both along its tunnel during the time shown?
    e.

18.



a. At what time was its velocity greatest?
b. During what periods, if any, was the velocity constant?
c. During what periods, if any, was the acceleration constant?
d. When was the magnitude of the acceleration greatest?

Answer

5a. 3.89 m/s	5b. 0 m/s	6a. 13.4 s
6b. 4.46 s	7. 126 s	8. 2.5 s
9. 6.57 m/s^2, 0.875 g	10a. 2.6 m/s^2	10b. 93 m
11. 9.6 s	12. 80 m/s	13. 60.0 m
14a. 3.19 s	14b. 31.3 m/s	15a. 29.4 m
15b. 4.90 s	16a. 0.28 m/s	16b. 1.1 m/s
16c. 0.28 m/s	16d. 1.5 m/s	16e. -0.9 m/s
17a. 0 s to 20 s	17b. 27 s to 28 s	17c. 0.28 m/s
17d. 20 m forwards, 10 m back	18a. 50 s	18b. 90 s to 107 s
18c. 0 s to 15 s, 65 s to 75 s, 90 s to 107 s		18d. 70 s

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Seeing Spiderwoman

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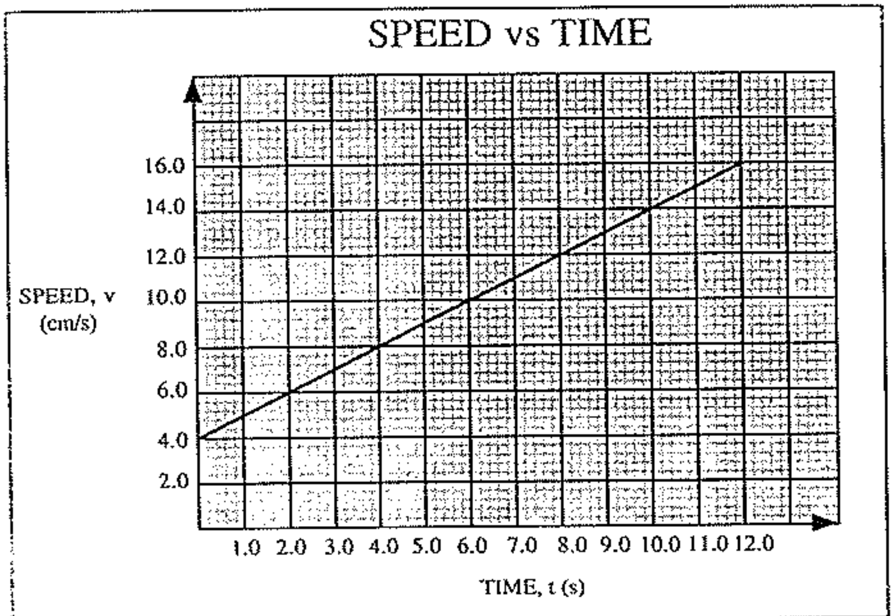
Test Yourself!



1. (a) What is the **y-intercept** of the above graph? (Include **units**.)
   (b) What is the **slope** of the above graph? (Include **units**.)
   (c) What is the **equation** for the above graph? (Use **symbols** *v*, *t*, in the equation.)

2. An aircraft, preparing for take-off, accelerates uniformly from 0 m/s to 20.0 m/s, in a time of 5.00 s.
   (a) What is the acceleration of the aircraft?
   (b) How long will the plane take to reach its take-off speed of 36.0 m/s?

3. At an airshow, a jet car accelerates from rest at a rate of 3*g*, where *g* is 9.80 m/s². How far does the jet car travel down the runway in a time of 4.0 s?

4. The CN Tower in Toronto is about 530 m high. If air friction did not slow it down, how much time would it take for a penny to fall from the top of the tower to the ground below? ($g = 9.80$ m/s²)

Challenge Question! Try it!

5. A motocross rider is coasting at a speed of 2.00 m/s. He then decides to accelerate his bike at a rate of 3.00 m/s² for a distance of 100.0 m.
   (a) How fast is the bike moving, in m/s, at the end of the 100.0 m stretch?
   (b) Convert your answer to (a) from m/s to km/h.

6. A mountain bike rider, after coming down a steep hill, loses control of her bike while moving with a speed of 5.00 m/s. Fortunately, she collides with a hay stack, which brings her to rest in a distance of 0.625 m. What was the acceleration of the bike and rider *while colliding with the haystack?*

7. A policeman on a mountain bike is cruising at a speed of 4.00 m/s, when he sees a wanted criminal, standing on a corner, 100.0 m ahead of him. If the policeman accelerates at a rate of 2.00 m/s², how much time will he take to reach the corner?

8. A child on a a toboggan slides down a snowy hill, accelerating uniformly at 2.8 m/s^2. When the toboggan passes the first observer, its speed is 1.4 m/s. How fast will it be moving when it passes the second observer, who is 2.5 m downhill from the first observer?

9. A space vehicle is orbiting the earth at a speed of 7.58×10^3 m/s. In preparation for a return to earth, it fires retro–rockets which provide a negative acceleration of 78.4 m/s^2. Ignoring any change in altitude that might occur, how long will it take the vehicle to slow down to 1.52×10^3 m/s?

10. A truck is moving along at 80.0 km/h when it hits a gravel patch, which causes it to accelerate at –5.0 km/h/s. How far will the truck travel before it slows to 20.0 km/h?

11. A very frustrated physics student drops a physics textbook off the top of the CN Tower. If the tower is 5.3×10^2 m high, how long will the book take to reach the ground, assuming negligible air resistance? (g = 9.8 m/s^2)

12. If an electron inside a TV tube accelerates in a space of 5.0 cm from rest to $\frac{1}{10}$ c, (where c is the speed of light, 3.00×10^8 m/s) what is its acceleration?

13. Snoopy is taking off in his WW I biplane. He coasts down the runway at a speed of 40.0 m/s, then accelerates for 5.2 s at a rate of ½g, where g is the acceleration due to gravity (9.81 m/s^2). How fast is the plane moving after 5.2 s?

14. A girl biker (leader of the local chapter of *Heck's Angels*) is driving along the highway at 80.0 km/h in a 60.0 km/h speed zone. She sees a police car ahead, so she brakes so that her bike accelerates at –8.0 km/h/s. How far along the road will she travel before she is at the legal speed limit?

15. Spiderman is crawling up a building at a speed of 0.50 m/s. He sees Spiderwoman 56 m ahead of him, so he accelerates at 2.3 m/s^2.

    (a) How fast will he be moving when he reaches Spiderwoman?
    (b) How much time will it take him to reach Spiderwoman?
    (c) When he reaches Spiderwoman, Spiderman discovers that she is a Black Widow and as you may know, black widows eat their mates! He is 200.00 m from the road below. How long will it take him to reach the safety of the road, if he drops with an acceleration of g = 9.81 m/s^2?
    (d) Why will Spiderman not be killed by the fall?*

16. A stone is dropped from the top of a tall building. It accelerates at a rate of 9.81 m/s^2. How long will the stone take to pass a window that is 2.0 m high, if the top of the window is 20.0 m below the point from which the stone was dropped?

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*No matter how far a spider falls, it never reaches the road because it always has eight feet left to go!