Topic 2: Measurement and Graphical Analysis

Source: *Glencoe Physics: Principles and Problems* (Chapter 2)
Paul W. Zitzewitz, Ph.D. 2002. Most high school and college textbooks treat measurement and graphical analysis.

Types of Materials: Most high school textbooks such as Zitzewitz's physics book present measurements and graphical analysis.

Building on: Measurement and graphical analysis are introduced through non-threatening activities. Mathematics is minimized in these activities by using graphing and individual measurements.

Leading to: Once measuring skills are presented, they will be repeated in most of the physics topics. Likewise, graphical analysis is often used in mechanics for the study of kinematics and dynamics. Vibration and waves and several other topics also use graphical techniques.

Links to Physics: Both measurement and graphical analysis are common throughout physics topics as tools for understanding. Graphical analysis can be used to solve problems just as with equations. As an example, in kinematics, solve this problem: A car is moving at 5.0 m/s and uniformly speeds up to 10.0 m/s in 5.0s. How far would the car travel? With the kinematics equation $d = vt + 1/2a(t)(t)$, the distance traveled is 37.5 m. However, if you plot a velocity (m/s) vs. time (s) graph and calculate the area under the graph, you get 37.5 m! Graphing also gives a great visual of what is physically happening.

Links to Chemistry: Significant figure and scientific notation are very important in chemistry class as quantitative measurements occurs in most labs and very big and small numbers are often manipulated—numbers of atoms or molecules in a mole and the size of these particles. It is also important that students know how to set up a graph, label axes, determine dependent and independent variables and look at models for graph type. The graphing calculator can make manipulation easier when students are trying to determine the relationship between variables especially with gas laws. Specific measurements include mass, length, time and temperature to name a few.

Links to Biology: Physics, chemistry and biology students need to understand how to measure and how to interpret graphs as well as work with graphs. Examples include taking data for biology experiments such as caloric intake from various food groups. Interpreting graphs such as birth, death and migration rate of people in various countries is another example. Other topics using measurement in biology classes include rates of growth, diffusion Or reaction rate, breathing rate, heart rate and other physiological rates, frequency graphs and pH. Also important is teaching how to set up graphs, labeling of axes, determining dependent and independent variables.

Materials:

(a) Hewitt – None*

(b) Hsu – None*

(c) My Labs/Activities
- C-1: Significant Figures (Popsicle sticks doing measurements)
- C-2: Three-Part Graphing Activity (a, b, c)
- C-3: Significant Digits – Room Volume

(d) Worksheets
1. Scientific Notation (examples using measurements) + Answer Key
2. Significant Figures + Answer Key
3. Metric Prefixes (a, b, c, d e, f, g)
4. Graphical Analysis + Answer Key

(e) Demonstrations
Graphing (plus Some Rules for Graphing) Using Hooke's Law (a, b, c)

(f) Websites and Videos
1. http://www.learnalberta.ca/content/mejhm/html/video_interactives/expo
   (This is an interactive website about scientific notation. The user clicks and drags numbers in the correct bin such as = and -, largest to smallest, greater than 1, 1 to 0, 0 to -1, and less than -1. Each time you check, it shows you any mistakes and makes you correct your mistakes. I like it!

2. http://www.wtamu.edu
   (Several choices available include: conversion of decimal to scientific notation and back; negative exponents and scientific notation, division and multiplication using scientific notation. The program teaches and allows for student input. Not bad!

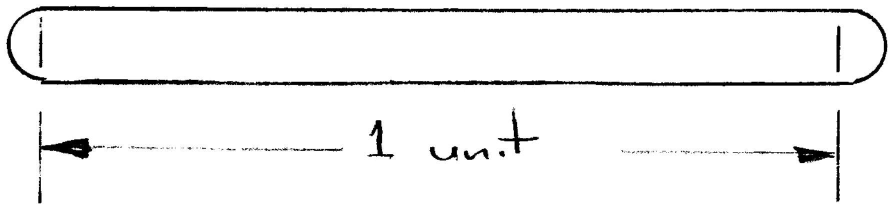
(g) Good Stories
1. Richard Owens – The Worst Lab Partner in the World
2. Standard Units
3. Transit of Venus
4. Tycho Brahe (1546–1601)

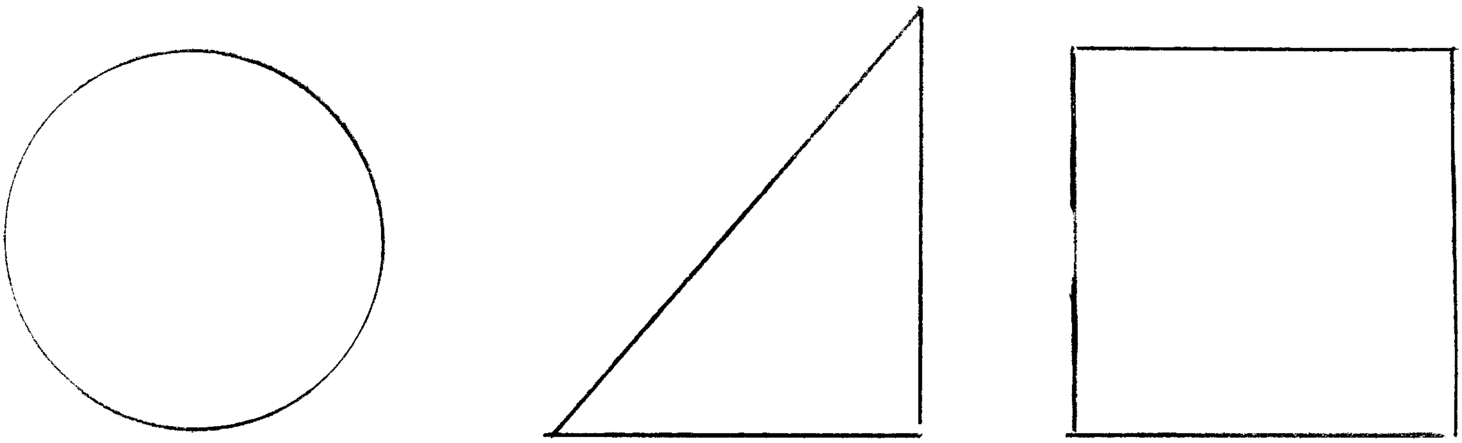
Worksheet - Measurement

Materials: worksheet, popsicle stick

Purpose: - to measure and calculate using the proper number of significant figures.

) Calibrate the popsicle stick for one unit.



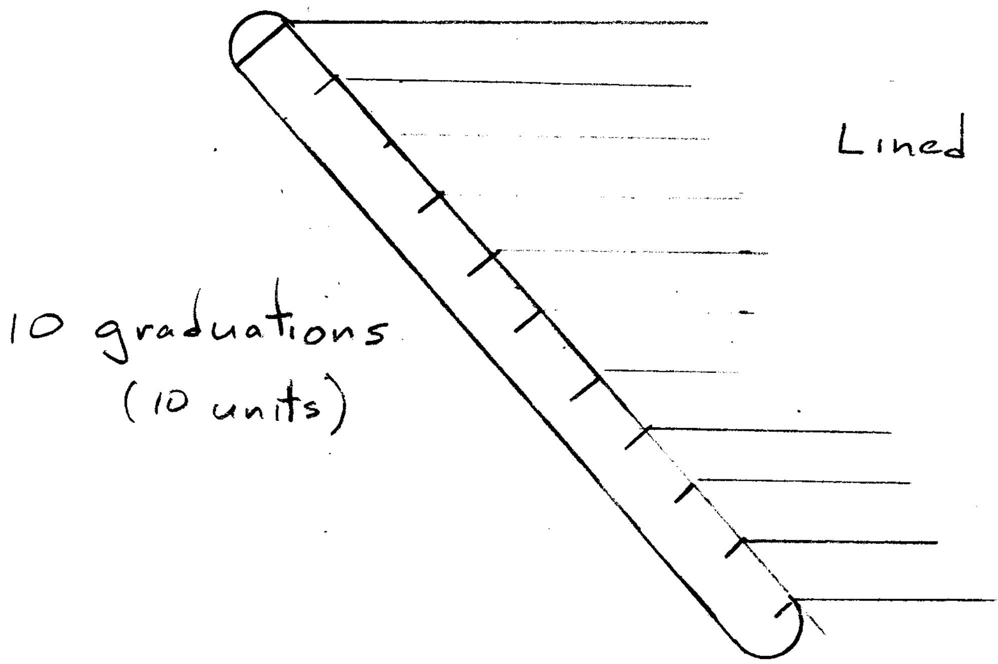


A B C

Measure the circumference of A and the perimeter of B and C using proper significant figures.

A = ____________ B = ____________ C = ____________

2) Calibrate the popsicle stick to .1 unit



place the stick on an angle on lined paper. Select an angle that allows ten divions on the stick. Mark the divisions on the stick.

3.) Measure the perimeter and area of A,B anC using the proper number of significant figures

Perimeter	Area
A = ________	A = ________
B = ________	B = ________
C = ________	C = ________

Popsicle Measurement Significant Figures Answer Sheet

(1) A = 1.5 units (Direct measurement of the circumference with uncalibrated stick allows the 1 to be correct and the 0.5 to be a good guess.)

B = 1.7 units (Add 0.5 + 0.5 + 0.7 = 1.7; estimate to 1/10 of a cycle.)

C = 2.0 units (0.5 + 0.5 + 0.5 + 0.5 = 2.0; estimate to 1/10 of a cycle.)

(2)

Perimeter	Area
A = 1.57 units (direct)	A = 0.50 units^2 (πr^2) = (3.14)(0.25/2)(0.25/2) = 0.050 unit^2 2 sig figs
B = 1.8 units (0.48 + 0.55 + 0.72 = 1.75 to 1/100 place)	B = 0.15 units^2 (1/2 bh) = (1/2)(0.48)(0.55) = 1.8 units^2 2 sig figs
C = 2.0 units (0.50 x 4 – 2 sig figs)	C = 0.25 units^2 (bh) = (0.50)(0.50) = 0.25 units^2 2 sig figs

Graph Activities

Activity 1: Linear Function - Circle Measure

Concept: Circumference as a function of diameter; diameter as the control variable; the notion of pi does not exist yet.

Materials: Assorted plastic lids from household containers, meter stick

Procedure: Select at least five plastic lids of various sizes. Measure and record the diameter and the corresponding circumference. (Hint: Roll the can on the meter stick to get the circumference.)

Graph:

Activity 2: Power Function - The Rolling Marble

Concept: Distance as a function of time

Materials: Ramp (1 meter or more), marble, stopwatch and Popsicle sticks, or paper strips, to be used as markers.

Procedure: By rolling the marble down a ramp, select an incline that allows for a five-second roll time. Put down markers at the one-, two-, three-, four- and five-second time intervals.

Graph:

Activity 3: Inverse Function – Super Ball Bounce

Concept: Rebound height as a function of the bounce number

Materials: A Super Ball and a meter stick

Procedure: From a given height drop the superball and record he rebound height. Repeat the drop several times to get the bet average height. Drop the ball from this rebound height to find the rebound height of the next bounce. Repeat this for 7 or 8 bounces. Use the bounce number as the independent variable.

Graph:

Post-Lab Discussion: Graphic Analysis

How well does the graph conform to the rules for graphing?

Connect the points with a smooth line (not dot to dot).

What is the general shape of the graph?

Straight: Linear, $y = mx + b$

Curved: Parabola, $y = kx^2$

Curved: Hyperbola (Inverse), $y = k/x$

Examine the slope. What are the units of the slope?

Is the slope increasing, decreasing or remaining constant?

What quantity do the slope units describe?

Is the origin an included point on the graph?

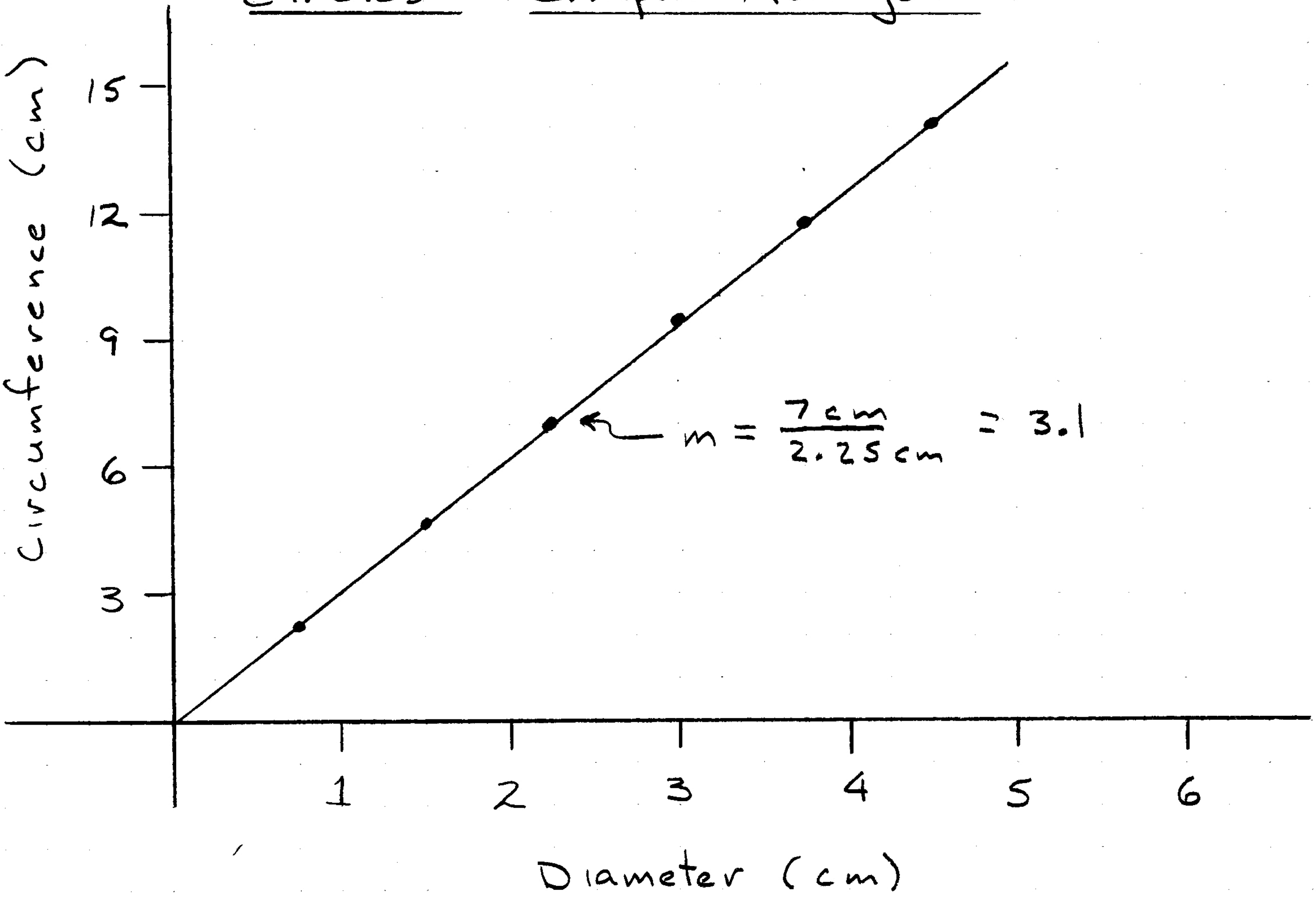
If an intercept is present, what is its significance?

Substitute meaningful, variable names in place of x and y.

Does the area under the curve yield any useful information?

Write an equation that describes the relationship between the dependent and the independent variable.

Circles - Graphic Analysis



General Shape - Linear $y = mx + b$

Origin Included - no diameter, no circum.

$\therefore b = 0$

Slope - remains constant

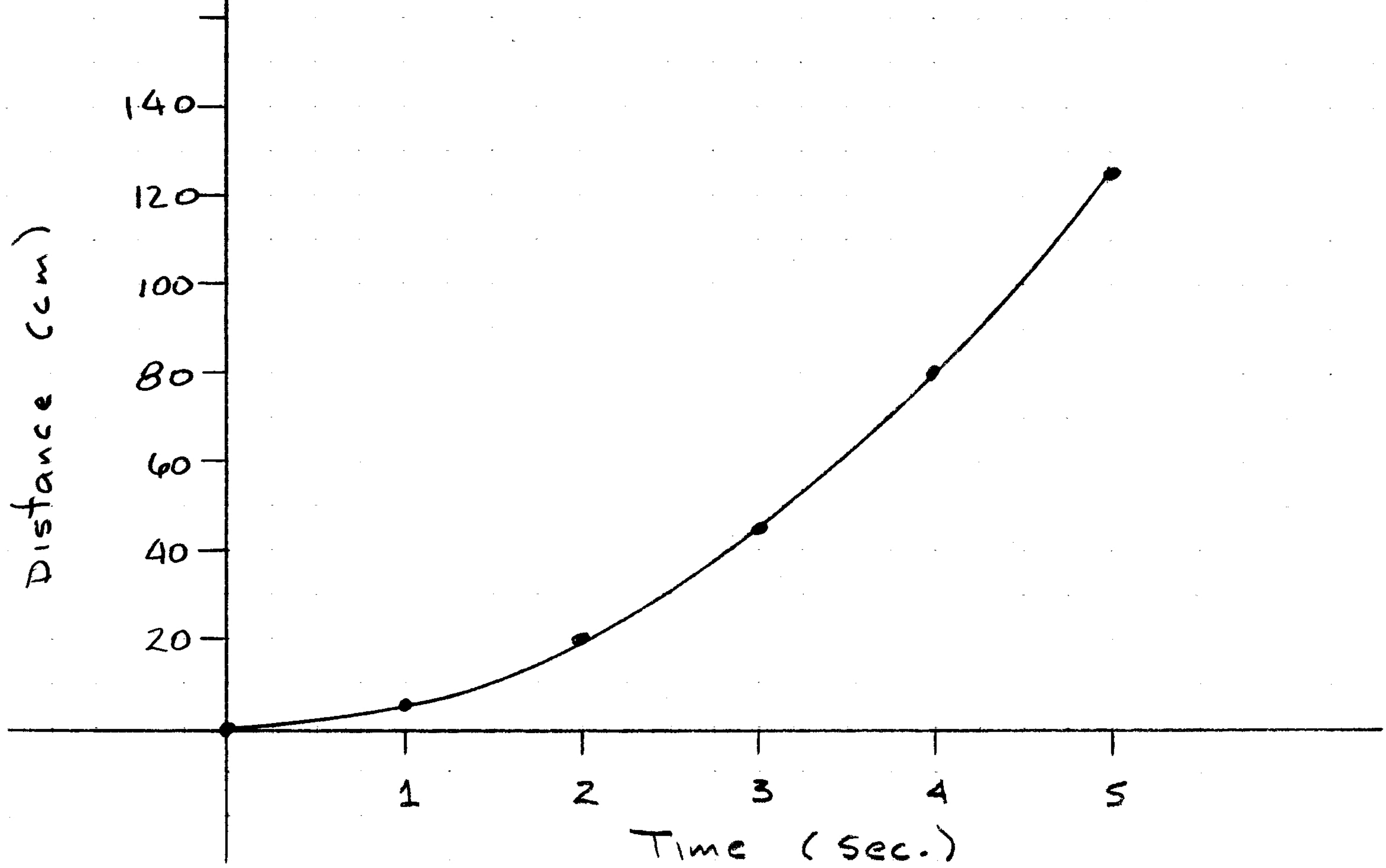
units cm/cm cancel · no units 3.1

Mathematical Relationship :

$m = 3.1$, $b = 0$ D - diameter, C - circum.

$C = 3.1 D$

The Rolling Marble - Graphic Analysis



General Shape - Parabola - Power Function

$$y = Kx^2$$

Origin Included time → 0 , d → 0

Slope · Changing - increasing

For the constant $K = y/x^2$

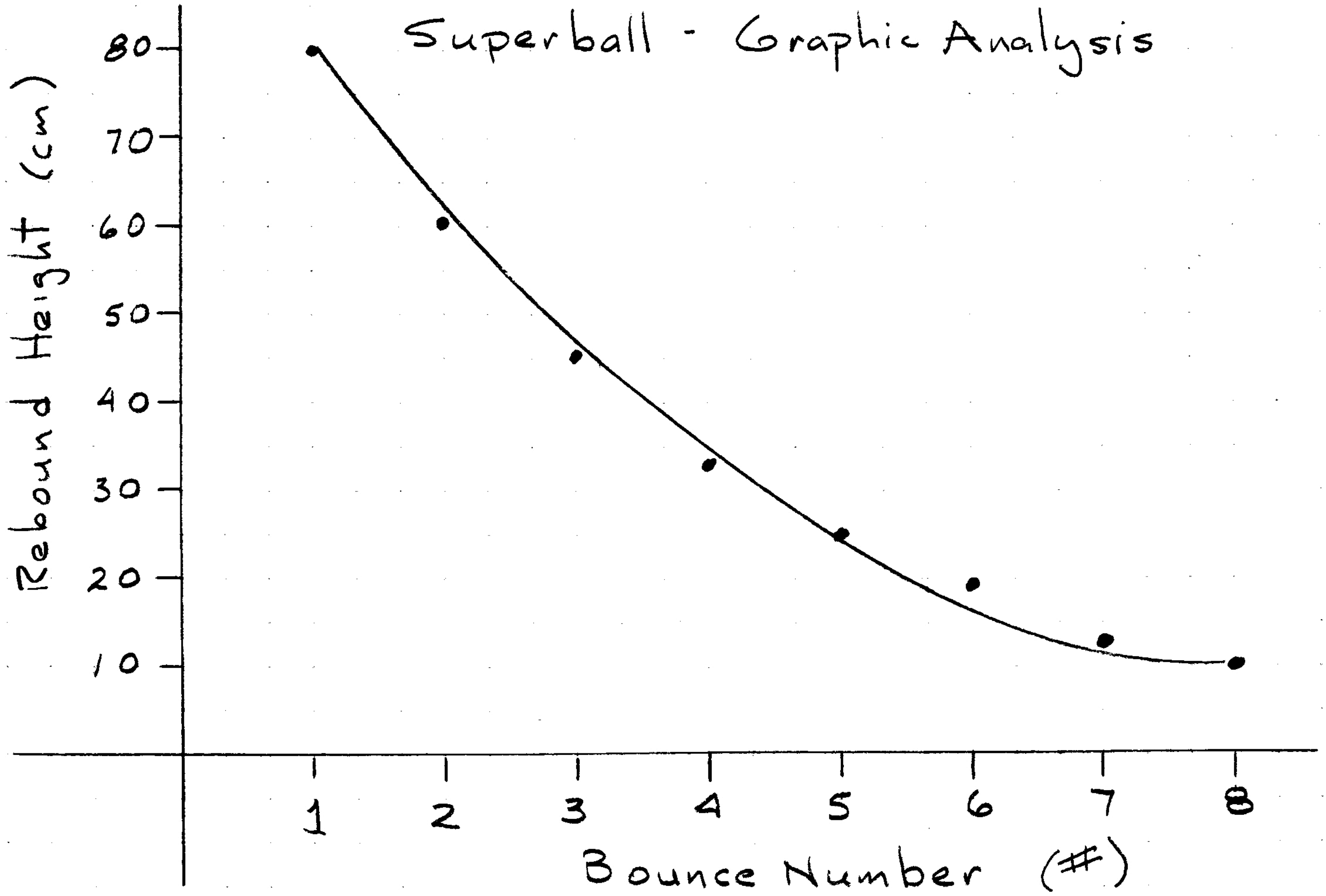
$$K = 5 \ cm/sec^2$$

Mathematical Relationship

$$y = Kx^2$$

$$D = (5 \ cm/sec^2)(t^2)$$

Superball - Graphic Analysis



General Shape - Inverse - $y = K/x$

Origin not included no bounce, no rebound

Slope - changing - increasing

slope units $cm/\#$

$K = x\,y$

K = (Bounce Number)(Rebound Height)

K = constant

Mathematical Relationship

Rebound Height = Constant $\left(\frac{cm}{\#}\right)$ × Bounce Numbe

Activity: Significant Digits/Room Volume

Purpose: To measure and calculate the volume of the classroom to the nearest .1 cm.

Materials: Meter stick, paper, pencil, calculator

Concept: What volume of Styrofoam peanuts is required to fill the classroom?

Allow for a wide range of answers in order to have a meaningful post-lab discussion.

Possible Topics for Post-Lab Discussion:

How precise are the measurements?

What measurements are important? Cabinets? Desks? Books? People?

The advantage of scientific notation to represent very large numbers

How can the room volume be estimated?

Appropriate choice of units (cm^3? m^3?)

Using scientific notation with the calculator

Conversion of units

Scientific Notation/Conversion Worksheet

Express the following in scientific notation:

1) 6800 m ____

2) 550,000 m ____

3) 303,000,000 kg____

4) 85,000,000 m ____

5) 0.0035 g ____

6) 0.004 m ____

7) 0.000,000,015 g ____

8) 324 cm ____

9) 40900 m ____

10) 0.103 g ____

Convert each of the following length measurements to its equivalent in meters:

1) 7.66 mm

2) 1.1 cm

3) 76.2 pm

4) 0.123 km

5) 89.2 mm

Scientific Notation / Conversion Worksheet

Express the following in scientific notation.

1) 6800 m 6.8×10^{3} m

2) 550,000 m 5.5×10^{5} m

3) 303,000,000 kg 3.03×10^{8} kg

4) 85,000,000 m 8.5×10^{7} m

5) 0.0035 g 3.5×10^{-3} g

6) 0.004 m 4×10^{-3} m

7) 0.000,000,015 g 1.5×10^{-8} g

8) 324 cm 3.24×10^{2} cm

9) 40900 m 4.09×10^{4} m

10) 0.103 g 1.03×10^{-2} g

Convert each of the following length measurements to its equivalent in meters.

1) 7.66 mm 0.00766 m

2) 1.1 cm 0.011 m

3) 76.2 pm 7.62×10^{-11} m

4) 0.123 km 123 m

5) 89.2 mm 0.0892 m

Significant Digits – Practice Worksheet

1) 3803 m ___________

2) 2081 m ___________

3) 0.0019 m ___________

4) 2.81 m ___________

5) 0.0019 m ___________

6) 0.003 m ___________

7) 56000 m ___________

8) 40700 m ___________

9) 46000 m ___________

10) 75 m ___________

11) 48.006 cm ___________

12) 5300.0 m ___________

13) 63.001 kg ___________

14) 8765.4 cm ___________

15) 101 m ___________

16) 814 kg ___________

17) 0.0964 m ___________

18) 1.046 kg ___________

19) 93.0600 cm ___________

20) 1001.10 m ___________

Significant Digits ----- Practice Worksheet

1) 3803 m ___4___
2) 2081 m ___4___
3) 0.0019 m ___2___
4) 2.81 m ___3___
5) 0.0019 m ___2___
6) 0.003 m ___1___
7) 56000 m ___2___
8) 40700 m ___3___
9) 46000 m ___2___
10) 75 m ___2___
11) 48.006 cm ___5___
12) 5300.0 m ___5___
13) 63.001 kg ___5___
14) 8765.4 cm ___5___
15) 101 m ___3___
16) 814 kg ___3___
17) 0.0964 m ___3___
18) 1.046 kg ___4___
19) 93.0600 cm ___6___
20) 1001.10 m ___6___

Metric Fun – A First-Day Activity

- Using book tables and/or reference pages, try to form names, phrases or puns using the metric prefix as a clue along with a lot of imagination.
- Students can work in pairs or small groups to brainstorm.
- Do several examples.
- Review some of the tough ones.

METRIC PREFIX --- REFERENCE

NAME	SYMBOL	MULTIPLICATION FACTOR
exa	E	1 000 000 000 000 000 000 = 10^{18}
peta	P	1 000 000 000 000 000 = 10^{15}
tera	T	1 000 000 000 000 = 10^{12}
giga	G	1 000 000 000 = 10^{9}
mega	M	1 000 000 = 10^{6}
kilo	k	1 000 = 10^{3}
hecto	h	100 = 10^{2}
deka	da	10 = 10^{1}
deci	d	0.1 = 10^{-1}
centi	c	0.01 = 10^{-2}
milli	m	0.001 = 10^{-3}
micro	μ	0 000 001 = 10^{-6}
nano	n	0.000 000 001 = 10^{-9}
pico	p	0.000 000 000 001 = 10^{-12}
femto	f	0.000 000 000 000 001 = 10^{-15}
atto	a	0.000 000 000 000 000 001 = 10^{-18}

Metric Fun

Name ______________________

Period ______ Date ______

1) 10^{6} Phone
2) 10^{-6} Phone
3) 10^{-3} Tary
4) 10^{3} Arney
5) 10^{1} Cards
6) 10^{-1} Cate
7) 10^{9} Lo
8) 10^{-9} Goat
9) 10^{-12} Boo*
10) 10^{12} Bull
11) 10^{-2} Pede
12) 10^{-12} Lo
13) 10^{12} Firma
14) 10^{1} Dence
15) 10^{-1} Arnez
16) 10^{-6} Scope
17) Physics is 10^{2} Learn
18) 10^{-1} Bad Pun
19) Don't 10^{6} Mistake
20) Some of you may 10^{3} Ver from that one
21) O 10^{6}
22) MI 10^{3} B
23) Ano 10^{-3}
24) 10^{-6} The boat ashore
25) 10^{9} Goes Hawaiian

* 1 Boo^{2} = 1 Boo Boo

Metric Fun

Name Ans Key
Period ______ Date ______

1) 10^6 Phone — megaphone
2) 10^{-6} Phone — microphone
3) 10^{-3} Tary — military
4) 10^3 Arney — Kilarney
5) 10^1 Cards — Deck of Cards
6) 10^{-1} Cate — Decimate
7) 10^9 Lo — Gigalo
8) 10^{-9} Goat — Nanny Goat
9) 10^{-12} Boo* — Peek a Boo
10) 10^{12} Bull — Terabull
11) 10^{-2} Pede — Centipede
12) 10^{-12} Lo — Picalo
13) 10^{12} Firma — Terra Firma
14) 10^1 Dence — Decadance
15) 10^{-1} Arnez — Desi Arnez
16) 10^{-6} Scope — microscope
17) Physics is 10^2 Learn — Heck to learn
18) 10^{-1} Bad Pun — This is (Deci) ban pun
19) Don't 10^6 Mistake — make a
20) Some of you may 10^3 Ver from that one — keel over
21) O 10^6 — omega
22) MI 10^3 B — Micholob (beer)
23) Ano 10^{-3} — anomoly
24) 10^{-6} The boat ashore — Michael row
25) 10^9 Goes Hawaiian — Giget

* 1 Boo^2 = 1 Boo Boo

26) Tom 10^{-10}

27) Dill 10^{-12} L

28) 10 Da Halls

29) 10^{-6} YKO (Newspaper readers)

30) Don't Blame 10^{-1} Nex

31) 10^{-2} Mental

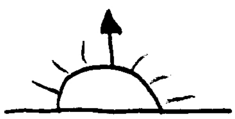
32) 6×10^{-3} N \$ 

33) 10^{-18} M 

34) "$10^{-9} \cdot 10^{-9}$"

35) 1×10^{-3}  ♀

36) 10^{-18} 

37) 2×10^{3} 

38) Baa 10^{-9} Split

39) 10^{-12} $(Li)^2$

40) 10^{-18} M 

41) 10^{-6} 

42) Sweet 10^{-18} ______

43) 10^{-12} S Bill

44) 10^{-1} integrate

45) 10^{-12} nics

46) 10^{12} tories

47) 2×10^{3} Mockingbird

48) 10^{15} Bismol

49) 10^{-2} Mental

50) 2×10^{-2} enial

26) Tom 10^{-18} — Tomato

27) Dill 10^{-12} L — Dill Pickle

28) 10 Da Halls — Deck the halls

29) 10^{-6} YKO (Newspaper readers) — Mike Royko

30) Don't Blame 10^{-1} Nex — Desinex (foot pow

31) 10^{-2} Mental — sentimental

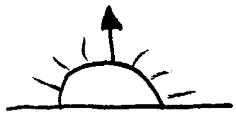
32) 6×10^{-3} N \$  — six million dollar man

33) 10^{-18} M  — Atom Bomb

34) "$10^{-9} \cdot 10^{-9}$" — Nanu Nanu (mork &

35) 1×10^{-3}  ♀ — one militant woman

36) 10^{-18}  — atto boy

37) 2×10^{3}  — Tequila sun rise

38) Baa 10^{-9} Split — Banana split

39) 10^{-12} $(Li)^2$ — picolili (relish)

40) 10^{-18} M  — a tom ant

41) 10^{-6}  — microwave

42) Sweet 10^{-18} ______ — sweet adeline

43) 10^{-12} S Bill — Pecos Bill

44) 10^{-1} integrate — disintegrate

45) 10^{-12} nics — picnic

46) 10^{12} tories — teritories

47) 2×10^{3} Mockingbird — to kill a mockingbir

48) 10^{15} Bismol — pepto bismol

49) 10^{-2} Mental — sentimental

50) 2×10^{-2} enial — centineal

METRIC MANIA

10^6 PHONES = 1 MEGAPHONE

10^{-6} PHONES = 1 MICROPHONE

10^1 CARDS = 1 DEKACARD

10^9 LOS = 1 GIGALOS

10^{12} BULLS = 1 TERABULL

10^{-1} MATES = 1 DECIMATE

10^{-2} PEDES = 1 CENTIPEDE

10^{-9} NANNETTES = 1 NANONANETTE

10^{-12} BOOS = 1 PICOBOO

10^{-18} BOYS = 1 ATTOBOY

2×10^2 WITHITS = 2 HECTOWITHITS

2×10^3 MOCKINGBIRDS = 2 KILOMOCKINGBIRDS

Some Rules for Graphing

1) Use a RULER AND GRAPH PAPER.

2) Select a TITLE. Give the graph a meaningful name.

3) Position the ORIGIN for the graph to fill the paper.

4) Select a UNIFORM SCALE for the x-axis and the y-axis.

5) LABEL the x-axis and the y-axis. What are the variable quantities?

6) Put the INDEPENDENT variable on the x-axis.

7) Put the DEPENDENT variable on the y-axis.

8) Put the UNITS on the appropriate scale.

9) Complete the graph with a SMOOTH CURVE.

10) IDENTIFY THE RELATIONSHIP (direct, power, inverse, etc.).

11) IDENTIFY THE MATHEMATICAL RELATIONSHIP. State an equation if possible.

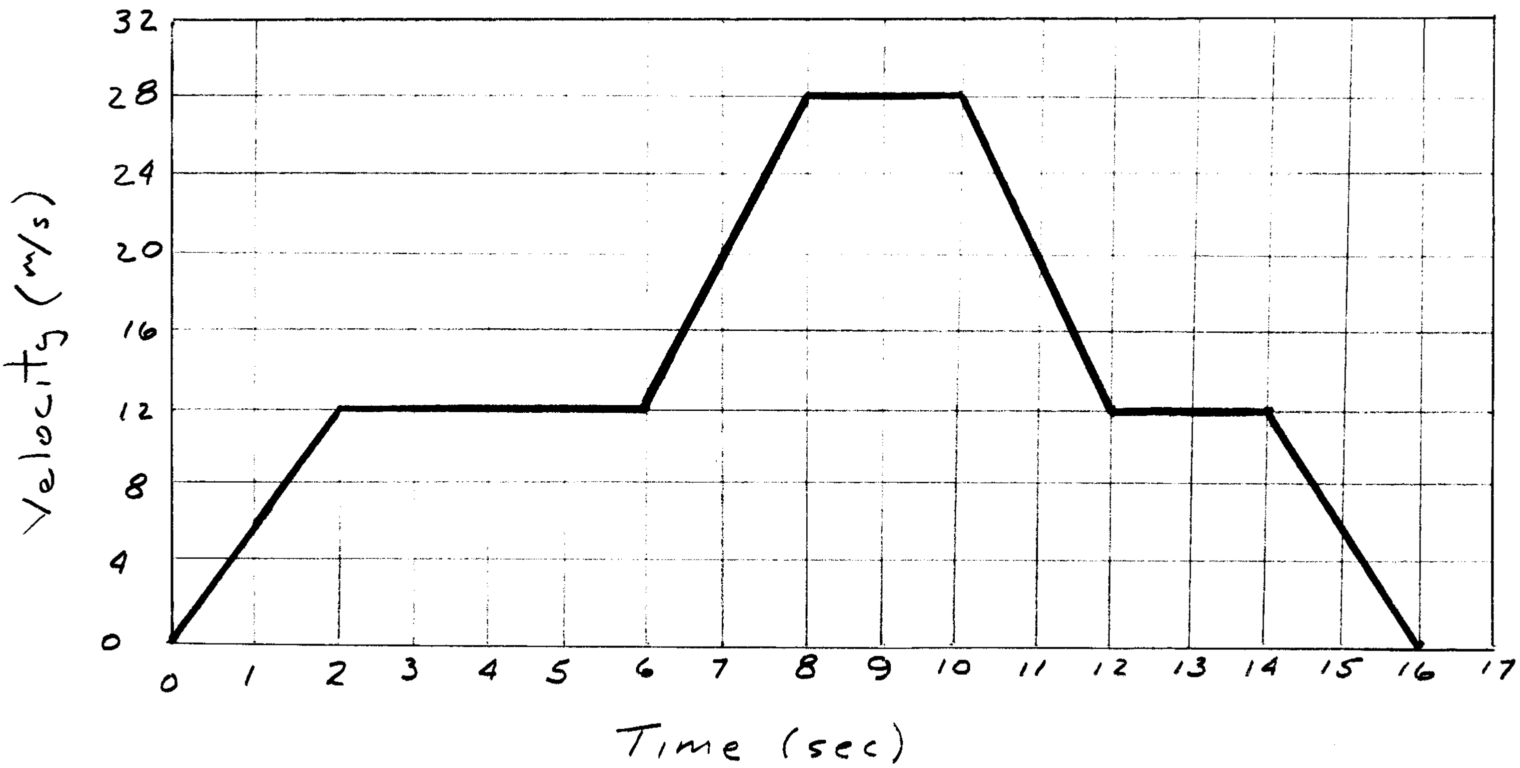
Put only one graph on a page.

Use only one side of the paper for the graph.

Physics - Graphic Analysis

Name ______________

Period _____ Date _____



1) What would be the instantaneous velocity at

a) 1 sec _____ b) 2 sec _____ c) 7 sec _____ d) 11 sec _____

2) What would be the distance traveled in

a) 2 sec _____ b) 6 sec _____ c) 8 sec _____ d) 10 sec _____

e) 12 sec _____ f) 16 sec _____

3) What would be the average velocity over the first

a) 2 sec _____ b) 6 sec _____ c) 8 sec _____ d) 10 sec _____

e) 12 sec _____ f) 16 sec _____

4) What would be the acceleration over the following time intervals?

a) 0-2 sec _____ b) 2-6 sec _____ c) 6-8 sec _____

d) 10-12 sec _____ e) 14-16 sec _____

Graph Demo

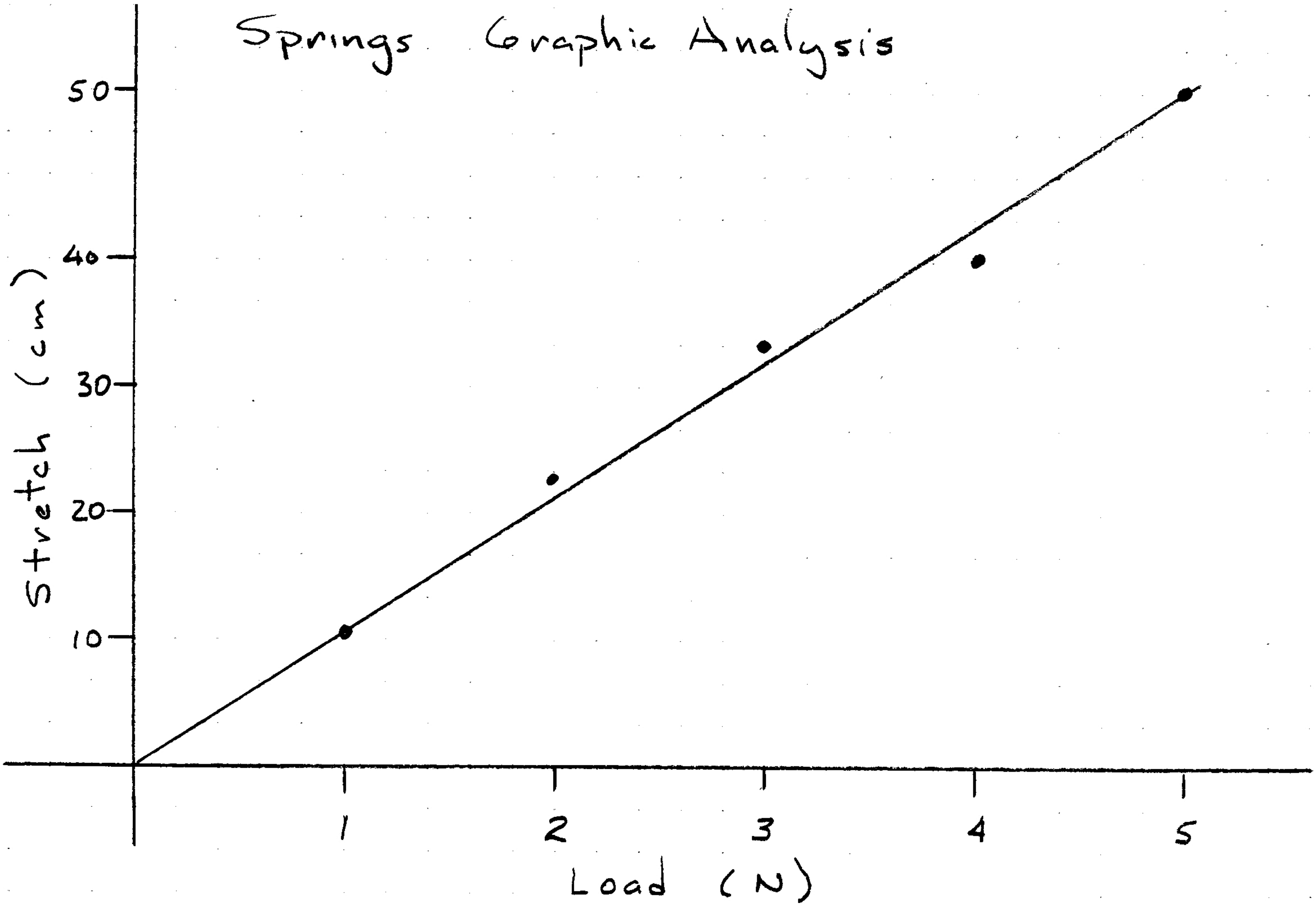
Demo: Linear Function – Hooke's Law

Concept: Stretch as a function of load.

Materials: Meter stick, spring, spring hanger, assorted small weights

Procedure:

1. Hang the spring and record the no-load position of the spring.
2. Attach the weights, in increasing order, to the spring and record the corresponding stretch values. Obtain at least five data pairs.



General Shape - Linear $y = mx + b$

Include the origin -

as load → 0 stretch → 0

$\therefore b = 0$

Slope - remains constant

Units N/cm - elasticity of the spring

Mathematical Relationship

$m = 10$ N/cm , $b = 0$ S - stretch L - Load

$$S = (10\ \text{N/cm})(L)$$

Richard Owen – The Worst Lab Partner in the World

Richard Owen grew up in northern England where he had studied to become a medical doctor. Owen displayed a natural talent for anatomy and, to further his studies, he often illegally obtained limbs, internal organs and other body parts from cadavers. These he took home to dissect at the first opportunity. On one occasion he was returning home with the head of an African sailor in a bag. Owen slipped on the wet street, dropped the head and watched in terror as the head bounced down the street and through the door of a nearby home where it finally stopped. Owen, not to be put out, dashed into the house grabbed the head and rushed out.

Owen became such a leading expert on animal anatomy that the London Zoological Gardens gave him first pick of any animal that died at the zoo. On one occasion his wife came home only to find a recently deceased rhinoceros filling the hallway. Before long Owen had a reputation as an expert on animals both living and extinct. It was his work with dinosaurs that Owen is best remembered for, for it was he that first used the term Dinosauria in 1841.

Owen was an unattractive and mean-spirited man. He was tall, thin, had long straight black hair and bulging eyes. His appearance was that of a sinister villain, and it was with a villainous attitude that he furthered his ambitions by any means necessary. Owen had given himself titles to which he had no claim and took credit for the discoveries of others. Some accused him of taking specimens and later denying hat he had done so. Richard Owen attempted to discredit anyone who opposed him. In the end his dishonesties caught up with him; he was discredited and never again did scientific research.

Standard Units

The development of a strong central government, especially in England, tended to produce common units. Early English rulers established a “furlong” (a furrow long) as 220 yards. During her reign, Queen Elizabeth I decreed that the Roman mile of 5,200 feet should be defined more precisely as 5,280 feet, exactly eight furlongs. After Saxon times the “pound” could be either weight or money. However, at least three different standards for the pound were in general use. A clove, a stone or a sack could also be used to measure weight. For capacity there was the pottle, the gallon, the bushel, the firkin, the stake and the cartload. Every working group had its own vocabulary. For example, sailors measured speed in “knots” and distance was measured in “fathoms” and “cable lengths.” Every vocabulary had its known set of problems such as is a bushel rounded or level?

Human body dimensions were probably the most common forms of measurement reference. A “ digit” was the width of a finger. The “palm” was the width of four fingers and the “cubit” was the distance between the elbow and the tip of the middle finger. A “pace” was one step and the “fathom” was the distance between outstretched arms.

The rest of Europe was no better off. A local dictionary of local units could easily exceed several hundred pages. In spite of all the confusion, these “rules of thumb” allowed for the construction of monuments such as the Great Pyramid to have a disparity of only one part in four thousand. This degree of precision is only possible if there is agreement on whose thumb to use.

Transit of Venus

In 1761 a most important astronomical event was about to take place, the passage of Venus across the face of the sun. Edumud Halley had suggested that if you could measure this passage from widely spaced places on earth, then the distance to the sun could be triangulated. This event occurs in pairs eight years apart and then again 150 years later. Scientists were dispatched to places all over the globe, packing with them all the necessary instruments ad supplies needed for a long journey to far and remote places.

One such journey was that of Guillaume Le Gentil from France. He left home for India a year before the transit but due to setbacks, his schedule left him on the ocean on the day of the event. A pitching, rolling ship is not a good place to take delicate celestial readings. A disappointed Le Gentil did not give up. He continued on to India to prepare for the next transit eight years later in 1769. He constructed an elaborate viewing station checking and rechecking hidden instruments. Le Gentil left nothing to chance. He was not about to lose his second and last chance to record the transit. Le Gentil was as ready as anyone could be. On the day of the second transit, June 4, 1769, he awoke to find a fine sunny day, but as the transit began, a cloud passed in front of the sun for precisely the amount of time needed for the observation.

Discouraged, Le Gentil decided to pack it up and head for home, but while waiting in port for a ship, he contracted dysentery. Finally, a year later, he shipped out for home. A hurricane off the African coast almost cost him his life. He finally got home after almost twelve years having accomplished nothing. In addition, upon his arrival, he found that he had been declared dead and that his family had dispersed all of his possessions.

Tycho Brahe (1546 – 1601)

Tycho was born the son of a Danish nobleman of Swedish descent. Predating Galileo's telescope, Tycho was probably the last of the naked-eye astronomers. In 1572, after a period of alchemical studies, he established his reputation as an astronomer when he observed the flaring of a new star. Sometimes called "Tycho's Star" he documented the event in a book titled *De Nova Stella* (Concerning the New Star). Tycho's title coined the term Nova for all exploding stars. The star became as bright as Venus and remained visible for more than a year.

Tycho's fame, in part, results from precise and massive astronomical instruments that he designed and built. In 1577 Tycho observed a great comet and recorded his observations with unparalleled precision. Brahe in studying the apparent motion of the comet realized that the orbit could not be circular but rather elongated. And, as in the Nova observation, the lack of parallax indicated that the distance to these events would put their location well beyond the moon, in the region of the fixed stars.

The Nova observation dispelled Aristotle's notion that the fixed stars were unchanging and furthermore an elongated orbit could not support the idea of concentric spherical shells, which were thought to describe the location of the planetary orbits. The death of Aristotle's astronomy had begun in earnest.

In the end, Tycho adopted a system that was neither Aristotelian on Copernican. In the Tychonic heavens all of the planets except earth revolve around the sun. This heliocentric system in turn revolves around the earth.

Topic 2 – Checkpoint Quiz

1) How many significant figures are in each of the following numbers?

853 __________ 1045 __________

456.33 _________ 90 ___________

100.10 _________ 100.01 _________

2) Put the following numbers into scientific notation:

9483 ______________ 150 ______________

14.2 _______________ .456 ______________

0.7043 _____________ 0.00682 ____________

3) Express the following metric prefixes as powers of ten:

milli __________ centi ___________

micro __________ kilo ___________

4) Freddy is a marble collector. At the end of each of the following weeks, Freddy has the following number of marbles in his collection. Draw and interpret the graph of Freddy's marble collection.

Week 1: 14 marbles

Week 2: 28 marbles

Week 3: 42 marbles

Week 4: 56 marbles

Week 5: 70 marbles

5) Use your Popsicle stick to measure the following line:

——————————————▶ _________________ units

Topic 2 Iza

Topic 2 --- Checkpoint Quiz

1) How many significant figures are in each of the following numbers?

853 3 | 1045 4

456.33 5 | 90 1

100.10 5 | 100.01 5

2) Put the following numbers into scientific notation.

9483. 9.48×10^2 | 150 1.5×10^2

14.2 1.42×10^1 | .456 4.56×10^1

0.7043 7.04×10^{-1} | 0.00682 6.82×10^3

3) Express the following metric prefixes as powers of ten.

milli 10^{-3} | centi 10^{-1}

micro 10^{-6} | kilo 10^3

4) Freddy is a marble collector. At the end of each the following weeks Freddy has the following number of marbles in his collection. Draw and interpret the graph of Freddys marble collection.

Week 1 --- 14 marbles

Week 2 --- 28 marbles

Week 3 --- 42 marbles

Week 4 --- 56 marbles

Week 5 --- 70 marbles

5) Use your Popsicle stick yo measure the following line.

------------------------------------> ________________units