AP Physics C: Mechanics
Summer Work

Included in this packet are 6 topics to review:

- Metric System
- Dimensional Analysis
- Pythagorean Theorem
- Right Triangle Trigonometry
- Linear Graphing Review
- Significant Figures

Please review the material in this packet. Answers are provided in the back to help you study. *You will be given a quiz on this material during the first week of school*. If you have any questions, then please send an email: adam.alster@detroitk12.org. If you have a question, please submit a copy of your work so I can see what you are thinking to better assist you. Please realize that I will not check this email on a regular basis over the summer –so have patience with getting a response.

Caution: This course is often described as an "calculus" based physics. This means your need to have a strong background in mathematics. A strong base in algebra and trigonometry is critical to doing well in this course. A strong background in calculus is not necessary, but helpful. We will work through the calculus together. Therefore, this summer packet is mainly to help you sharpen your math skills rather than science concepts.

Materials needed for the course:

- Notebook paper
- Pencils
- 3-ring binder
- Graphing Calculator
- Internet access outside of school is very helpful

Section 1: Metric System

There are several videos on youtube.com to supplement this material. I would recommend starting with "Easy Method to Convert Metric Measurements – Part 1" by BrainSTEM.

Metric Chart of Units

(numerical values of international metric prefixes)

All metric prefixes are powers of 10. The most commonly used prefixes are highlighted in bold.

Prefix	**Symbol**	**Factor/Value**
Yotta	Y	10^{24}
Zeta	Z	10^{21}
Exa	E	10^{18}
Peta	P	10^{15}
Tera	T	10^{12}
Giga	G	10^{9}
Mega	M	10^{6}
Kilo	k	10^{3}
Hecto	h	10^{2}
Deka	da	10^{1}
Deci	d	10^{-1}
Centi	c	10^{-2}
Milli	m	10^{-3}
Micro	µ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
Femto	f	10^{-15}
Atto	a	10^{-18}
Zepto	z	10^{-21}
Yocto	y	10^{-24}

*Symbols are case sensitive and should have no "." at the end.

*These work for measurements of distance (meters) and volume (liters)

<u>Converting in the Metric System</u>

-Converting is straightforward (just move the decimal point). Note the table below for distance (meters). If you move to the right in the table, then the decimal moves to the right. If you move to the left in the table, then the decimal point should be moved to the left.

Kilometer	Base unit (meter)	Centimeter	Millimeter	Micrometer	Nanometer
0.001	1	100	1000	1000000	1000000000

For example, when converting 350,000 micrometers to centimeters, you are moving to the left in the table. So move the decimal to the left. Since there are 4 fewer 0's, then you move the decimal 4 places to the left and get 35 centimeters.

Convert the following:

1) 2.5 km to m

2) 3.25 km to cm

3) 2.5 mm to cm

4) 55.2 mm to m

5) 3.5 g to kg

6) 75 m/h to km/h

7) 25 m/s to cm/s

8) 550 cm to m

9) 5000 nm to m

10) 0.05 m to nm

11) 50 cm to mm

12) 850 mm to cm

13) 7500 cm to km

14) 400 µm to nm

15) 500 nm to µm

16) 3.5×10^{8} nm to m

17) 4.0×10^{-5} m to nm

18) 2.8 GHz to Hz

19) 5000 MHz to Hz

20) 12.5 kg to g

Section 2: Dimensional Analysis/Factor Label Method

To supplement the material about dimensional analysis, there are several videos on youtube.com. Start by checking out the videos "Rate Conversions" by Allen Morris and "Dimensional Analysis/Factor Label Method – Chemistry Tutorial" by TheChemistrySolution.

Dimensional analysis is not only a great way to convert units but is also great for making sure units are correct or that you recalled a formula correctly.

You start with the quantity that you want to convert and then multiply it by one or more fractions until you are left with the units you want. These fractions will contain equivalent measurements so the ratio will be equal to one –so basically you will not change the value of the original amount.

First, write the starting value as a fraction (if necessary). Identify the unit you want to get rid of. If it is in the numerator, then put it in the denominator of the next fraction. Or vice versa. This will have that unit "cancel." Put an equivalent amount in the top of the fraction (preferably a unit that you want).

Example: Convert 2.5 km to cm.

Equivant unit goes on top (1 km = 1000 m)

$$\frac{2.5\text{ km}}{1} \cdot \frac{1000\text{ m}}{1\text{ km}} \cdot \frac{100\text{ cm}}{1\text{ m}} = 250000\text{ cm}$$

Want to get rid of km so it goes on bottom (since it was on top)

Keep going until cm remain

Example: Convert 25 km/h to m/sec

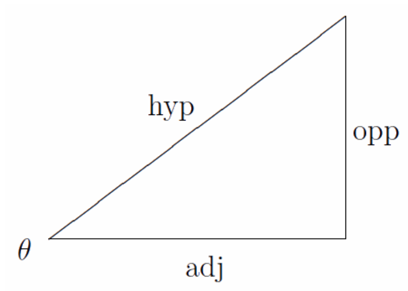
$$\frac{25\text{ km}}{1\text{ h}} \cdot \frac{1000\text{ m}}{1\text{ km}} \cdot \frac{1\text{ h}}{60\text{ min}} \cdot \frac{1\text{ min}}{60\text{ sec}} = 6.94\text{ m/sec}$$

1 hr = 60 min	1 min = 60 sec	1 ton = 2000 lbs	7 days = 1 week
24 hrs = 1 day	1 kg = 2.2 lbs	1 gal = 3.79 L	264.2 gal = 1 cubic meter
1 mi = 5,280 ft	1 kg = 1000 g	1 lb = 16 oz	20 drops = 1 mL
365 days = 1 yr	52 weeks = 1 yr	2.54 cm = 1 in	1 L = 1000 mL
0.621 mi = 1.00 km	1 yd = 36 inches	1 cc is 1 cm^3	1 mL = 1 cm^3

DIRECTIONS: Solve each problem using dimensional analysis (even if you see an easier method). Every number must have a unit. Work must be shown. Conversion factors are given above. It is recommended doing the work on a separate sheet of paper.

1. 261 g $\rightarrow$ kg
2. 3 days $\rightarrow$ seconds
3. 9,474 mm $\rightarrow$ cm
4. 0.73 kL $\rightarrow$ L
5. 5.93 cm $\rightarrow$ m
6. 498.82 cg $\rightarrow$ mg
7. 2.5 ft $\rightarrow$ cm
   (Note: 3.28 ft = 1 m)
8. 1 year $\rightarrow$ minutes
9. 175 lbs $\rightarrow$ kg
   (Note: 2.2 lb = 1 kg)
10. 4.65 km $\rightarrow$ ft.
11. 22.4 kg/L to kg/mL
12. 0.74 Kcal/min to cal/sec
13. 1.42 g/cm to mg/mm
14. 10095 m/s to miles/s
15. 9.81 m/s^2 to ft/s^2
16. 8.41 g/mL to Kg/L
17. 3.8 Km/sec to miles/h
18. 7.68 cal/sec to Kcal/min
19. 8.24 g/cm to mg/mm
20. 25 m/s to miles/hr

Section 3: Right Triangle Trigonometry

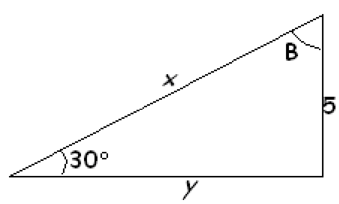


$$\sin\theta = \frac{opposite}{hypotenuse} = \frac{a}{c} \qquad \cos\theta = \frac{adjacent}{hypotenuse} = \frac{b}{c} \qquad \tan\theta = \frac{opposite}{adjacent} = \frac{a}{b}$$

You must memorize and be able to use the above three trigonometric functions (sine, cosine, and tangent). To help memorize, remember the saying, "SOH CAH TOA." This, of course, means "sine is opposite over hypotenuse," "cosine is adjacent over hypotenuse," and "tangent is opposite over adjacent."

In physics, we will mostly measure angles with degrees. Therefore, make sure your calculator is in "degree" mode.

Example: Find the length of the missing sides.

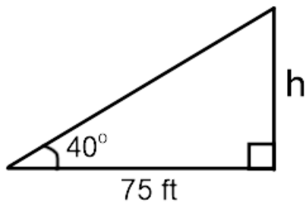


$$\tan 30° = \frac{5}{y} \rightarrow y = \frac{5}{\tan 30°} \rightarrow y = 8.66$$

$$\sin 30° = \frac{5}{x} \rightarrow x = \frac{5}{\sin 30°} \rightarrow x = 10$$

Exercises: Find the length of the unknown side(s).

1)



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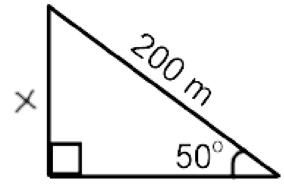

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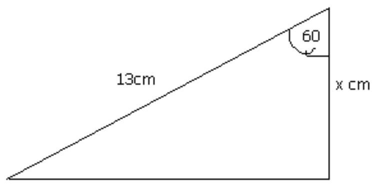

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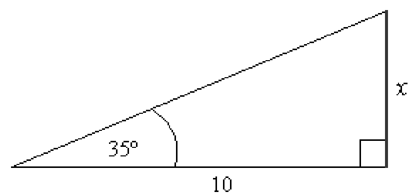
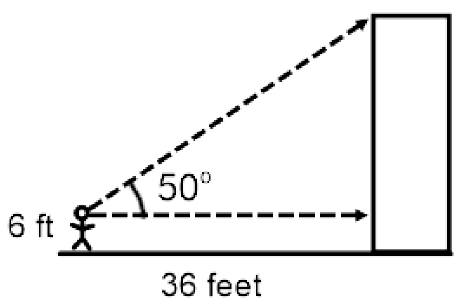
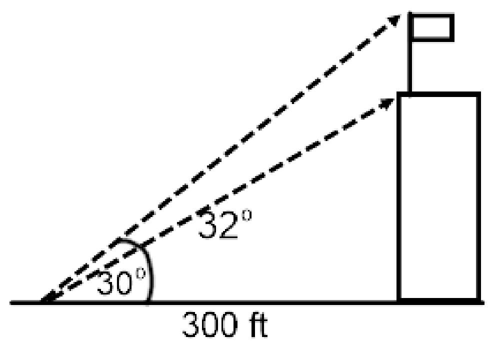


5) How tall is the building?
(don't forget the height of the man)



6) How tall is the building?
How tall is the flag?



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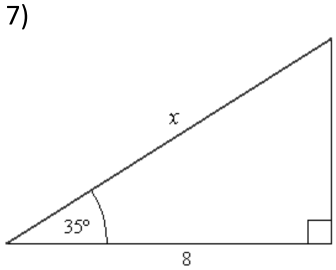

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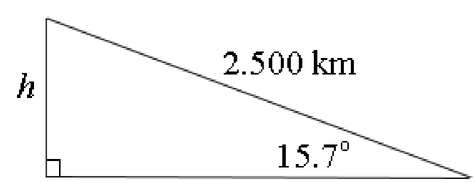
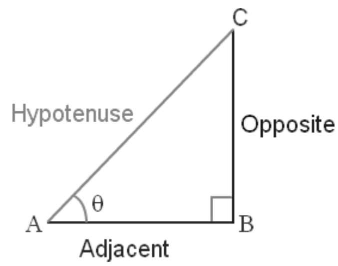


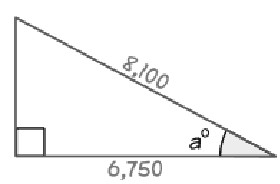
Find the Unknown Angle

To find an unknown angle, use the "inverse." This is found on the calculator by pressing "shift" or "2nd" and then the usual sine, cosine, or tangent button.



$$\boldsymbol{\theta = \sin^{-1}\left(\frac{a}{c}\right)} \qquad \boldsymbol{\theta = \cos^{-1}\left(\frac{b}{c}\right)} \qquad \boldsymbol{\theta = \tan^{-1}\left(\frac{a}{b}\right)}$$

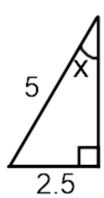
Example: Find the unknown angle.



$$a = \cos^{-1}\left(\frac{6750}{8100}\right) = 33.6°$$

Exercises: Find the unknown angle.

1)



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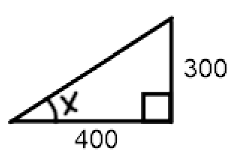

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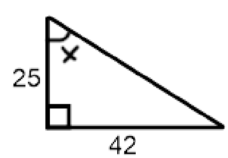

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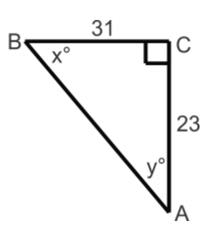

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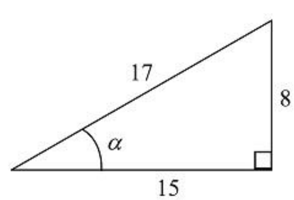

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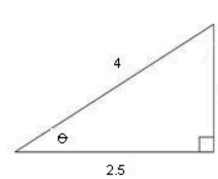
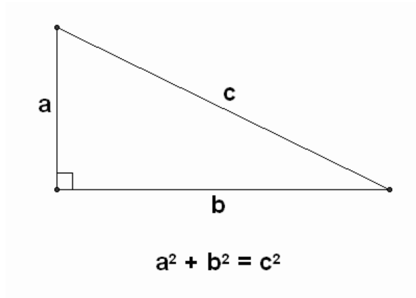


Section 4: Pythagorean Theorem



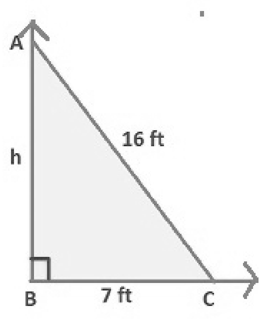
Example: A 52 ft long ladder is leaning against a wall. The bottom of the ladder is 35 ft horizontally from the wall. How high up the wall does the ladder touch?

$$(35\,ft)^2 + h^2 = (50\,ft)^2$$
$$1225\,ft^2 + h^2 = 2500\,ft^2$$
$$h^2 = 1275\,ft^2$$
$$h = \sqrt{1275\,ft^2} = 35.7\,ft$$

Practice problems:

1) A 10 m long ladder is leaning against a wall. The bottom of the ladder is 5 m horizontally from the wall. How high up the wall does the ladder touch?

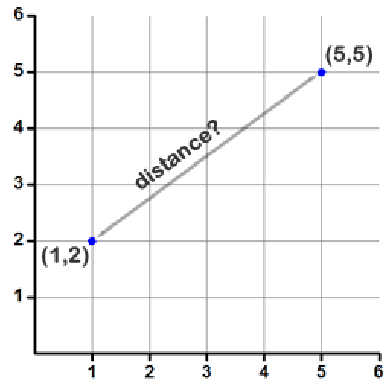
2) Find the length of the unknown side.



3) A baseball diamond is actually a 90-foot square. How far must a catcher throw the ball to 2nd base to try to get a runner out that is attempting to steal?

Coordinate System and Two Points

Example:
Find the distance between the two points shown below. Then find the “angle of elevation.”

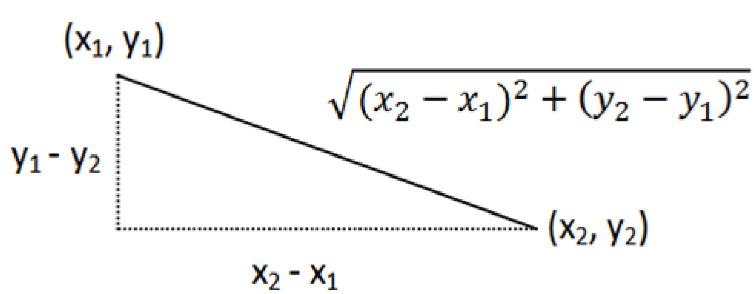


Solution:
Sketch a right triangle with corners at (1, 2) and (5, 5). The 90_o angle will be located at point (5, 2).
The base, which goes from (1, 2) to (5, 2), has a length of 4 units.
The height, which goes from (5, 2) to (5, 5) has a length of 3 units.
With this in mind, you must find the length of the hypotenuse.
From your geometry class, you might recognize this as a 3-4-5 right triangle. Therefore, the distance between the points is 5 units. For most cases, however, you can expect to use the Pythagorean Theorem to find the distance between the points.

To find the “angle of elevation” or the angle at the corner located at (1, 2), use an inverse trigonometric function.

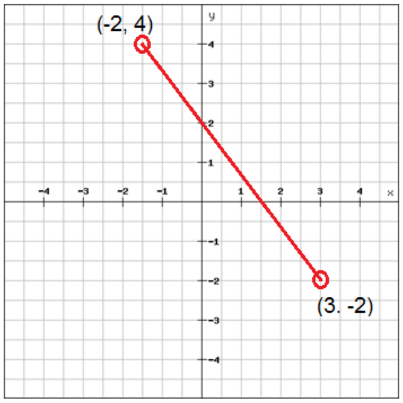
$$\theta = \tan^{-1}\left(\frac{3}{4}\right) = 36.9^\circ$$

Distance Formula
The distance formula comes from the Pythagorean Theorem. You can use it to find the distance between two points.

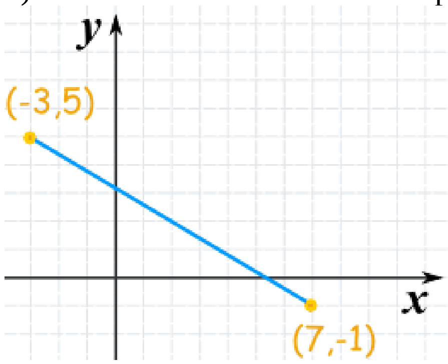


Exercises:

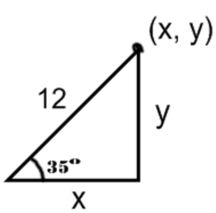
1) Find the distance between the points below.



2) Find the distance between the points below.



3) Find values for x and y for the ordered pair (x, y). Assume the bottom left corner of the triangle starts at the origin.



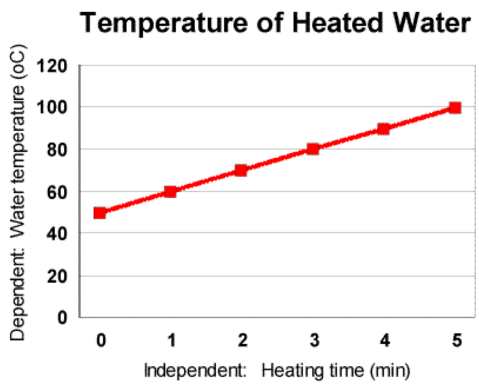
Section 5: Graphing Review

What is the Slope of a Line?

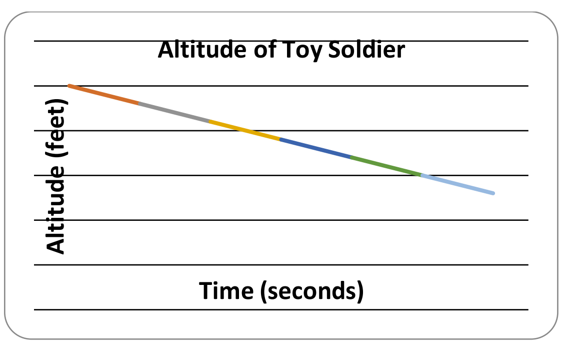
Most of the time people answer, “rise over run.” However, that is how you find it and not really what it means. The slope of a line is a measure of the ***rate of change*** of a line. This idea is incredibly important. Any time we discuss rate, we are referring to the slope of a line.

Think about it. Plenty of things in the real world change. The speed of the vehicle you rode in to get to school went faster and slower. The temperature outside rises and falls throughout the day. Populations increase and decrease. The altitude of a thrown baseball will increase then decrease. And so on and so on.

When you find the slope (the rise over run), be sure to include units! This helps with interpretation.



Notice that in the graph above, the temperature increased from 50$_o$ to 100$_o$ over 5 minutes. Therefore, the slope of this line is $\frac{50°}{5\,\text{minutes}}$ or 10$_o$ per minute. The interpretation of this slope is simply that the temperature is increasing at a rate of 10 degrees every minute.



The altitude of a toy paratrooper is represented above. It reached terminal velocity very quickly –a linear graph indicates that the rate of falling is constant. How fast is the soldier falling towards the ground? This is asking the rate of change of the toy’s altitude or what is the slope of the line. For this situation, notice that the altitude dropped from 50 ft to 30 ft from 1 to 6 seconds. Since the altitude is dropping, this has a negative slope. The slope is $\frac{-20\,ft}{5\,\mathbf{sec}}$ or -4 ft/sec.

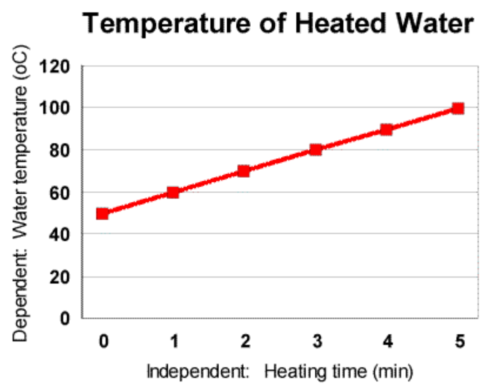
Finding the Equation of a Line

Usually, we will use a graphing calculator's regression feature to find an equation of a line of best fit. However, for this review, we will avoid using this.

Using Slope-Intercept Form

If you have the slope and y-intercept, then use the slope-intercept form which is $y = mx + b$. The slope is *m* and the y-intercept is *b*.

Example: Find an equation that predicts the temperature of the heated water.

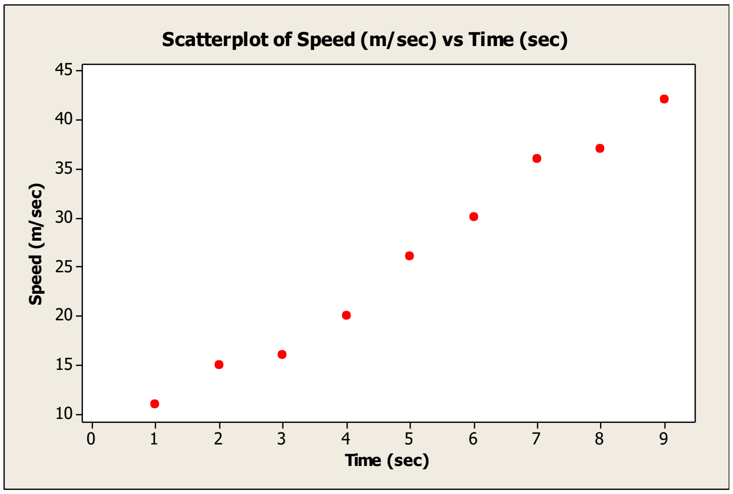


Solution: Let *C* represent the temperature in Celsius and *t* represent the heating time in minutes. We will estimate the slope to be 10^o per minute and the vertical intercept to be 50^o.
Therefore, the equation is $C = (10^o/\text{min})t + 50^o$.

Using Point-Slope Form

If you have the slope and just one point, then you can use the point-slope form to find an equation. The point-slope form is $y - y_1 = m(x - x_1)$ where m is the slope and the given/known point is (x_1, y_1).

Example: The graph below gives the speed of an object after a certain amount of time (in seconds). Estimate an equation for the line of best fit.



Solution: Again, the preferred approach is to use technology. However, for practice, the point- slope form will be used.

First, you should sketch a line over the graph that you think best represents the points. Then pick two points that will be representative of this line. For this example, I will choose the points at 1 sec and 9 sec.

Next, find the slope: $\boldsymbol{m} = \dfrac{43\,\text{m/sec} - 12\,\text{m/sec}}{9\,\text{sec} - 1\,\text{sec}} = 3.9\,\text{m/sec}^2$

Pick one of the points. I will use (1, 12).

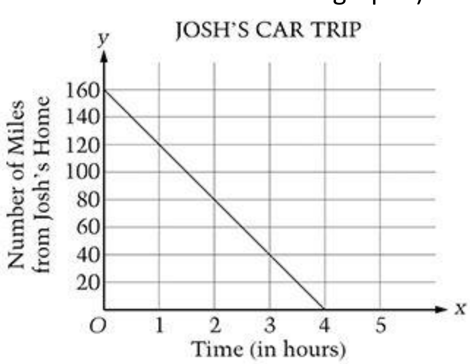
$y - 12 = 3.9(x - 1)$

$y - 12 = 3.9x - 3.9$

$y = 3.9x + 8.1$

Exercises:

1) Find the slope of the line below. Be sure to include units. Interpret the meaning of the slope (what does it mean in terms of this graph?). How did you come up with this meaning?



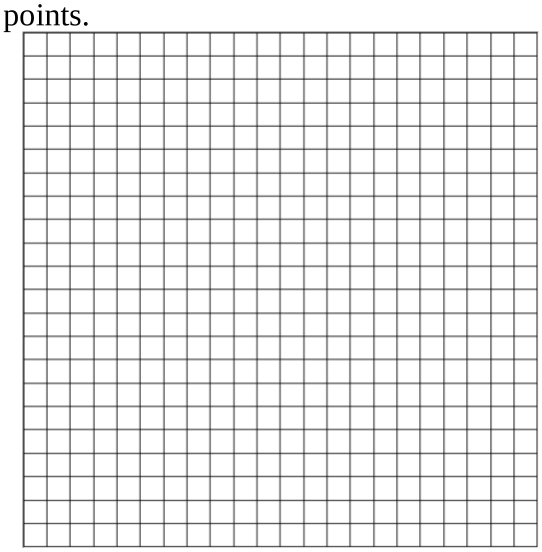
2) The heavier an object is the harder it is to push it. The amount of force (measured in pounds) applied by a machine to keep an object moving at a certain speed as the mass of the object increases is given in the table below. What is the rate of change of the force given mass? (a.k.a. slope of the line if the data were graphed)

Mass (kg)	Force (lb)
10	22.7
20	45.4
30	68.1
40	90.8
50	113.5

3) John attached a small parachute to his toy soldier and then dropped it from the top of a tall building. The height of the toy above the ground given a certain time is given below.

Time (seconds)	**Height Above Ground** (feet)
0	21
1	16.5
2	13.2
3	8.6
4	5

a) Create a graph for the above table. Plot the values given in the table and draw the line that best fits all the points.



b) What is the slope of your line? Interpret its meaning.

c) What is the y-intercept of your line? Interpret its meaning.

d) What is an equation for the height of the toy soldier in terms of time?

4) During an experiment, a student measured the mass of 10.0 cm^3 of alcohol. In this way, the data in the table below were collected.

Volume (cm^3)	Mass (g)
10	7.9
20	15.8
30	23.7
40	36
50	39.6

a) Plot the values given in the table and draw a line that best fits all the points.

b) What is the slope of your line? Interpret its meaning.

c) What is the y-intercept of your line? What should it be?

d) What is the mass of 32.5 cm^3 of alcohol?

e) What is the equation for the line of best fit?

Significant Figures

Significant Figures Rules

- All non-zero digits are significant
  - Example: 597.4 has 4 significant figures
- Leading zeros are not significant
  - Example: 0.64 has two significant figures
  - Example: 0.0005 has one significant figure
- Zeros between two non-zero digits are significant
  - Example 405 has three significant figures
- Zeros to the right of the decimal are significant
  - 564.00 has five significant figures
- Zeros on the right with no decimal are not significant
- Exact values have an infinite number of significant figures
  - This is applies to numbers that are definitions
  - Example: 1 m is the same as 1.0 m or 1.000 m
- All digits (except for the 10 and its exponent) are significant when a value is in scientific notation
  - Example: 5.401 X 10^5 has four significant figures

Operations and Significant Figures

Adding/Subtracting

-Round the result to the number of decimal places that the number with the smallest amount of decimal places in the problem had.

-For example: When doing 3.25 + 4.628, the answer is 7.878 before rounding. Since 3.25 has the smallest amount of decimal places (2), then round the answer to the hundredths place to get 7.88.

Multiplying or Dividing

-Round the answer so that it has the same number of significant figures as the measurement with the fewest significant figures.

-For example: 3.48 X 5.1 would be 17.748 before rounding. Since 5.1 has the least amount of significant figures (2), round the answer to two decimal places to get 18.

Practice Problems

1) Identify the number of significant figures in the following:

a) 3.14	b) 502.0	c) 2045	d) 230
e) 2.405	f) 3.21 X 10^5	g) 5.40 X 10^4	h) 0.004

2) Simplify the following. Give the answer rounded to the correct number of significant figures.

a) 5.471 + 2.5

b) 0.405 + 23.4

c) 1027.05 – 4.76

d) 5.246 – 1.43

e) 1058 + 543

f) 235 + 42.5

g) 327.85 – 314.1

h) 23.5 + 2.156

i) 5401 X 43

j) 54.26 X 3.14

k) 302.41 X 4.5

l) 43.24 X 0.05

m) 29.16 ÷ 1.2

n) 5.292 ÷ 3.15

Answers to Questions

Section 1: Metric System

1) 2500 2) 325000 3) 0.25 4) 0.0552 5) 0.0035 6) 0.075
7) 2500 8) 5.5 9) 0.000005 10) 50000000 11) 500 12) 85
13) 0.075 14) 400000 15) 0.5 16) 0.35 17) 40000
18) 2800000000 19) 5000000000 20) 12500

Section 2: Dimensional Analysis

1) 0.261 2) 259200 3) 947.4 4) 730 5) 0.0593
6) 4988.2 7) 76.2 8) 525600 9) 79.5 10) 15246.8
11) 0.0224 12) 12.3 13) 142 14) 6.27 15) 32.2
16) 8.41 17) 8495.3 18) 0.4608 19) 824 20) 55.89

Section 3: Trigonometry

Find the length of the unknown side:
1) 62.9 ft 2) 153.2 m 3) 6.5 cm 4) 7 5) 48.9 ft
6) 173.2 ft (building); 14.3 ft (flag) 7) 9.8 8) 0.68 km

Find the unknown angle:
1) 26.6^{o} 2) 36.9^{o} 3) 59.2^{o} 4) x = 36.6^{o}; y = 53.4^{o} 5) 28.1^{o}
6) 51.3^{o}

Section 4: Pythagorean Theorem

1) 8.7 m 2) 14.4 ft 3) 127.3 ft

Distance Problems: 1) 7.8 2) 11.7 3) x = 9.8, y = 6.9

Significant Figures

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

2) a) 8.0 b) 23.8 c) 1022.29 d) 3.82
e) 1601 f) 278 g) 13.8 h) 25.7
i) 23000 j) 170 k) 1400 l) 2
m) 24 n) 1.68