AP PHYSICS - SUMMER ASSIGNMENT

Introduction

Welcome to AP Physics!

The following text is a review of measurement and trigonometry. There is also a section on vectors, which is most likely a new topic. Please look through the review material, consult the textbook, and attempt the problems at the end of this handout. If you have questions or difficulty with anything, feel free to email ssmith@bishopfeehan.com.

Units and measurement (see p. 1-24)

SYSTEMS OF UNITS

Physics involves an objective description of the world, so measurement is a crucial tool. In measuring, we make use of a group of **standard units** comprising a **system of units**. The **SI system** of units, which is the modern version of the metric system, is the primary system of units that we will use in this class.

Units in the SI system include **base units**, which are defined by standards, and **derived units**, which are defined in terms of the base units. The base units are:

Quantity	**Name of unit**	**Abbrev-iation**	**Definition**
length	**m**eter	m	"… the length of the path traveled by light in vacuum in 1/299,792,458 of a second." (1983)
mass	**k**ilogram	kg	"… this prototype [a certain platinum-iridium cylinder] shall henceforth be considered to be the unit of mass." (1989)
time	**s**econd	s	"… the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom." (1967)
electric current	ampere	A	"… that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2 x 10^{-7} newton per meter of length." (1946)
temperature	kelvin	K	"… the fraction 1/273.16 of the thermodynamic temperature of the triple point of water." (1967)
amount of substance	mole	mol	"… the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12." (1971)

luminous intensity	candela	cd	"… the luminous intensity, in the perpendicular direction, of a surface of 1/600,000 square meter of a blackbody at the temperature of freezing platinum under a pressure of 101.325 newtons per square meter." (1967)

This is called the **mks system** (for **m**eter-**k**ilogram-**s**econd).

Some examples of derived units include:

Quantity	**Name of unit**	**Symbol**
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s
acceleration	meter per second per second	m/s^2
frequency	hertz	Hz $= s^{-1}$
force	newton	N $= kg{\cdot}m/s^2$

You should also be familiar with the SI prefixes:

Multiple	**Prefix**	**Abbreviation**
10^{12}	tera-	T
10^9	**giga-**	G
10^6	**mega-**	M
10^3	**kilo-**	k
10^2	hecto-	h
10	deka-	da
10^{-1}	deci-	d

Multiple	**Prefix**	**Abbreviation**
10^{-2}	**centi-**	c
10^{-3}	**milli-**	m
10^{-6}	**micro-**	μ
10^{-9}	**nano-**	n
10^{-12}	pico-	p
10^{-15}	femto-	f

The prefixes in bold are the most commonly used ones in this class.

Example: How many micrometers are in 3×10^3 kilometers?
3×10^{12} micrometers

DIMENSIONAL ANALYSIS & UNIT ANALYSIS

Dimensional analysis is a procedure that you can use to check whether an equation is dimensionally correct or incorrect. You expect the two sides of an equation to be equal; thus they must have the same dimensions.

To perform dimensional analysis, replace each variable with the type of dimensions it measures, then algebraically manipulate the dimensions to simplify. If the left hand side and right hand side have the same dimensions, the equation is dimensionally correct.

Dimensions of common quantities:

Quantity	**Dimension**	**Unit**
mass (*m*)	[M]	[kg]
time (*t*)	[T]	[s]
length	[L]	[m]

area	$[L^2]$	$[m^2]$
volume	$[L^3]$	$[m^3]$
velocity (v)	[L] / [T]	[m/s]
acceleration (a or g)	$[L] / [T^2]$	$[m/s^2]$

For example, show that the equation for the area of a triangle: $A = ½\, b·h$ is dimensionally correct:

$A = ½\, b·h$

$[L^2] = ½ [L]·[L]$ — replace each quantity with the dimension (L = length)

$[L^2] = [L]·[L]$ — ½ is dimensionless and can be ignored

$[L^2] = [L^2]$ — "length" multiplied by "length" is "length squared"

Notice that this procedure doesn't necessarily tell you that the equation is physically correct, just that the quantities have the correct dimensions.

Unit analysis is very similar, but instead of using the dimensions (e.g. "length"), you use the units of measurement (e.g. "meters").

For example, show that the equation: $v = v_0 + at$ is dimensionally correct:

$v = v_0 + at$

$[m/s] = [m/s] + [m/s^2][s]$ — replace quantities with units

$[m/s] = [m/s] + [m/s]$ — multiply units

$[m/s] = [m/s]$ — add units

UNIT CONVERSION

Unit conversion is a vitally important technique in physics. In order to convert a quantity from one unit to another, multiply by the correct **conversion factor** – a statement of equivalence in the form of a ratio.

For example, convert 100 yards into feet (using the conversion 3 ft = 1 yd):

$$100 \text{ yd} \cdot \frac{3 \text{ ft}}{1 \text{ yd}} = 300 \text{ ft}$$

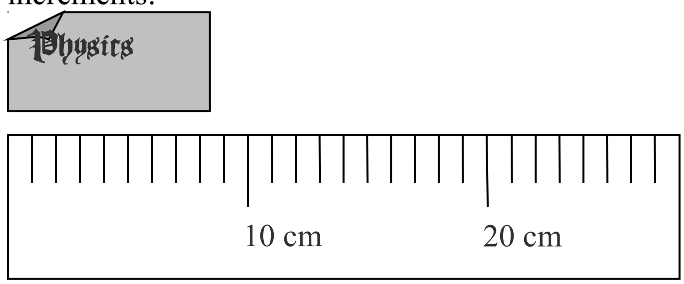
Convert 1 day into seconds:

$$1 \text{ day} \cdot \frac{24 \text{ hr}}{1 \text{ day}} \cdot \frac{60 \text{ min}}{1 \text{ hr}} \cdot \frac{60 \text{ s}}{1 \text{ min}} = 86400 \text{ s}$$

SIGNIFICANT FIGURES

Significant figures are one method that physicists can use to convey the uncertainty or error in a measurement. The accuracy of a measurement depends on the measurement scale of the instrument being used – 5.1 m is a less accurate measurement than 5.12 m. "The significant figures in any measurement are the digits that are known with certainty, plus one digit that is uncertain." When taking a measurement, write down the digits that can be read directly from the instrument, and obtain another digit "by estimating the fraction of the smallest division of the instrument's scale."

For example, if you were measuring a piece of paper using a ruler divided into 1 cm increments:



you would start by writing 8. cm, because you are certain it is 8 cm, and then estimate another digit based on the fraction. So 8.4 cm would be a valid measurement. It has two significant figures, one that is known with certainty and one that is estimated.

The rules for determining how many significant figures a written number has are:
1. Zeros at the beginning of a number are not significant. They merely locate the decimal point. For example,
   0.0254 m has three significant figures (2, 5, 4)
2. Zeros within a number are significant. For example,
   104.6 m has four significant figures (1, 0, 4, 6)
3. Zeros at the end of a number after the decimal point are significant. For example,
   2705.0 m has five significant figures (2, 7, 0, 5, 0)
4. In whole numbers without a decimal point that end in one or more zeros (trailing zeros) – for example, 500 kg – the zeros may or may not be significant. In such cases, it is not clear which zeros serve only to locate the decimal point and which are actually part of the measurement. To avoid this, use scientific notation.

Exact numbers are numbers without any uncertainty or error. For example, there are exactly 60 seconds in a minute. The radius is exactly half the diameter of a circle.

When performing calculations, use the following rules:
1. When multiplying or dividing quantities, leave as many significant figures in the answer as there are in the quantity with the least number of significant figures.
2. When adding or subtracting quantities, leave the same number of decimal places (rounded) in the answer as there are in the quantity with the last number of decimal places.

You can use SI prefixes or scientific notation to control the number of decimal places given in your answer.

Use these rules for rounding:
1. If the first digit to be dropped is less than 5, leave the preceding digit as is.
2. If the first digit to be dropped is 5 or greater, increase the preceding digit by one.

For example,
$(6.12\text{ m}) * (2.9\text{ m}) = 17.748\text{ m}^2 = 18\text{ m}^2$
(3 sig figs) (2 sig figs) (round to 2 sig figs)

(1054.00 m^2) / (0.0910 m) = 11582 m = 1.16 x 10^4 m   or   11.6 km

(6 sig figs)   (3 sig figs)   (round to 3 sig figs)

Trigonometry (see appendix p. A-4 – A-5)

Remember the trigonometric ratios for right triangles:

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} \qquad \cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} \qquad \tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

The Pythagorean theorem is very useful: $a^2 + b^2 = c^2$.

For a nonright triangle, you can use the Law of Sines:

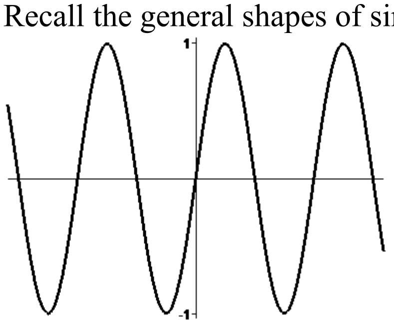
$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

a, b, c are sides; A, B, C are the opposite angles

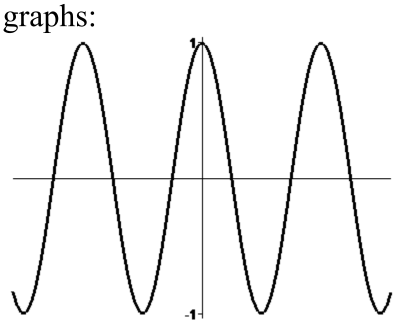
or the Law of Cosines:

$$c^2 = a^2 + b^2 - 2\,ab\cos C \qquad \text{or} \qquad \cos C = \frac{a^2 + b^2 - c^2}{2\,ab}$$

Recall the general shapes of sine and cosine graphs:



SINE



COSINE

For the functions $y = a \sin bx$ and $y = a \cos bx$:
The **amplitude** represents half the distance between the minimum and the maximum and is given by amplitude = $|a|$.
The **period** is the horizontal distance over which the graph repeats one cycle and is given by period = $2\pi / b$.

Understanding these functions will be important when we study oscillation and waves.

Scalars and vectors (see p. 73-79)

FYI: There are MANY helpful tutorials on vectors and vector addition available on the web.

DEFINITIONS AND CONVENTIONS

A **vector** is a quantity with magnitude and direction. For example, displacement is a measure of the straight line distance between two points, and the direction. You could say "I walked 5 miles to the east." This is a vector quantity, as it includes magnitude (5 miles) and direction (to the east). Another example would be if you launched a cannonball with a speed of 50 m/s aimed at 10º above the horizontal. Some other quantities often measured with vectors include velocity and force.

A **scalar** quantity only includes magnitude (e.g. a distance of 5 miles, a time of 10 seconds, a temperature of 100 degrees).

Since **vectors** include magnitude *and* direction, special techniques must be used to add them. For example, if you walk in a straight line and end up 2 miles north and 5 miles east, the total distance from your starting point to your ending point is *not* 2 miles + 5 miles = 7 miles.

When writing the names of vectors, the vector itself will generally be identified with a bold letter (e.g. **A** or **B**) and its magnitude by an italic letter (e.g. *A* or *B*). When handwriting vector names, we will use an arrow over the letter to indicate the vector (e.g. $\vec{A}$ or $\vec{B}$) and an ordinary letter to indicate the magnitude (e.g. A or B).

When drawing a vector, draw an arrow in the appropriate direction that has a length proportional to the vector's magnitude.

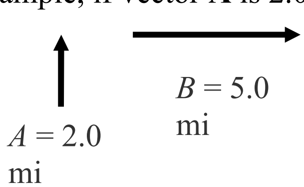
There are two methods for adding vectors that we will use. The **(triangle) graphical** technique is easier to visualize, but the **analytical component** method is more efficient.

TRIANGLE METHOD OF VECTOR ADDITION

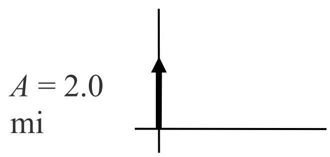
To add vectors **A** and **B** with the triangle method:

1. First draw **A** from the origin.
2. Then draw the second vector **B** from the tip of the first vector.
3. Draw the resultant (sum) vector **R** from the tail of **A** to the tip of **B**.
4. Use trigonometry to find the necessary sides and angles.

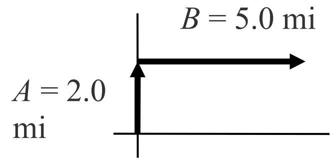
For example, if vector **A** is 2.0 miles north and vector **B** is 5.0 miles east:



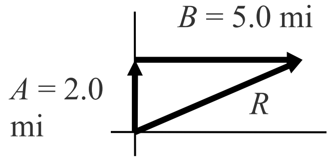
1.) Draw vector **A** from origin:



2.) Draw vector **B** from **A**:



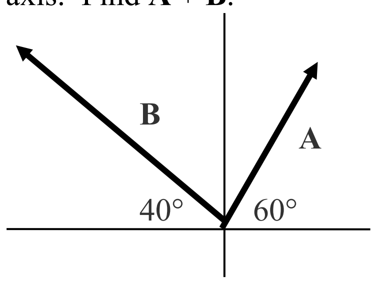
3.) Draw resultant **R** starting at the origin:



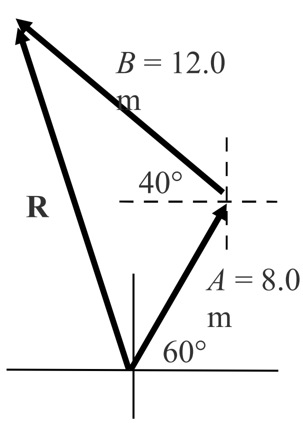
By the Pythagorean Theorem, the length of R is 5.4 mi. The angle between A and R can be found using the inverse tangent – it is 68°. So the resultant R is at an angle of 22° above the $+x$-axis, or at a bearing of N68°E. (Remember that since it is a vector, you need to find the resultant's magnitude *and* direction!)

More complicated problems will require you to use the Law of Sines or the Law of Cosines, as they may not be based on right triangles.

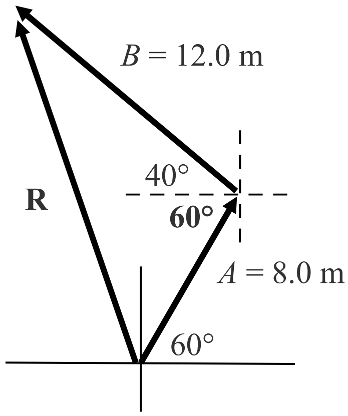
For example, **A** is 8.0 m at 60° above the $+x$-axis and **B** is 12.0 m at 40° above the $-x$-axis. Find **A** + **B**.



Draw the vectors in the appropriate places:

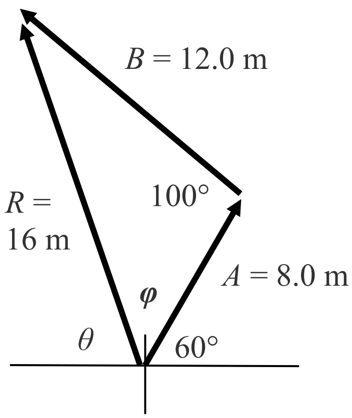


(Notice how a line parallel to the x axis was drawn, in order to keep the 40° angle present.)



The other 60° angle is an alternate interior angle. Adding that to 40° yields an "SAS" triangle that can be solved with the Law of Cosines.

$c^2 = a^2 + b^2 - 2ab \cos C$
$R = 15.53$ m = 16 m (round to two sig figs)



Find the angle φ using the Law of Sines.

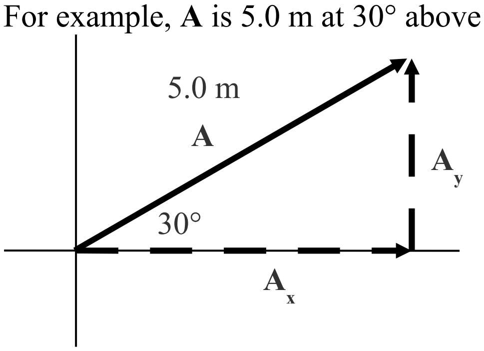
$b / \sin \mathrm{B} = c / \sin \mathrm{C}$
$\varphi = 47.6° = 48°$

Find θ, since θ, φ, and 60° add to 180°.

Finally, express as an angle relative to the x-axis:
R is 16 m at 72° above the $-x$-axis.

ANALYTICAL COMPONENT METHOD
The most widely used method of adding vectors is the analytical component method. It involves resolving the two vectors into their rectangular components – vectors at right angles from each other – and then adding the pairs of rectangular components together.

Illustration of vector components:
For example, **A** is 5.0 m at 30° above the $+x$-axis.



Vector **A** is resolved into an x component ($\mathbf{A}_x$) and a y component ($\mathbf{A}_y$). The magnitudes of these components can be found using right triangle trigonometry:

$A_x = A \cos \theta = 4.3$ m
$A_y = A \sin \theta = 2.5$ m

One way of writing a vector in terms of its components is to use **unit vectors**. A unit vector, written with a "hat" over the letter, has a magnitude of 1 and a specific direction.

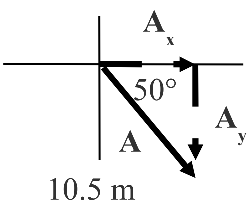
The **x** unit vector is in the *x* direction; the **y** unit vector is in the *y* direction. Thus the vector **A** in the example above can be written as the sum of its components:

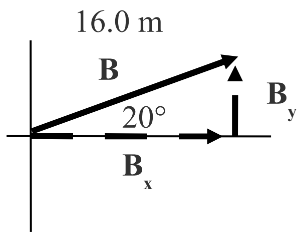
$$A = (4.3\ \text{m})\hat{x} + (2.5\ \text{m})\hat{y}$$

To add two vectors together using the analytical component method:
1. Resolve each vector into components.
2. Then add the *x* components and *y* components of each vector together independently.
3. Finally, you can resolve the resultant back into a magnitude and angle using the Pythagorean Theorem and right triangle trigonometry.

For example, add together the vectors:
A: 10.5 m at 50.0° below the +*x*-axis
B: 16.0 m at 20.0° above the +*x*-axis

Resolve into components. Notice that the *y*-component of **A** needs to be negative, since the vector is in the fourth quadrant.



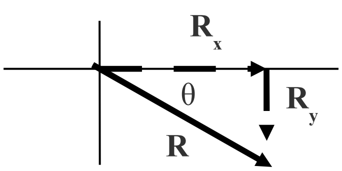


$A_x = (10.5\ \text{m}) \cos 50.0° = 6.75\ \text{m}$
$A_y = -(10.5\ \text{m}) \sin 50.0° = -8.04\ \text{m}$

$B_x = (16.0\ \text{m}) \cos 20.0° = 15.0\ \text{m}$
$B_y = (16.0\ \text{m}) \sin 20.0° = 5.47\ \text{m}$

Now add the components to get the resultant's components:
$R_x = A_x + B_x = 21.8\ \text{m}$ and $R_y = A_y + B_y = -2.57\ \text{m}$

Sum in component form: $R = (21.8\ \text{m})\hat{x} + (-2.57\ \text{m})\hat{y}$



To find the magnitude and angle of the resultant:

$R = \sqrt{R_x^2 + R_y^2}$ (Pythagorean Theorem)

$\theta = \tan^{-1} \frac{R_y}{R_x}$ (inverse tangent to find angle)

R is 22.0 m at 6.72° below the +*x*-axis.

AP PHYSICS – SUMMER PROBLEM SET – please show work

MEASUREMENT

1.) [p.26 #2] The only SI standard represented by an artifact is the (a) meter, (b) kilogram, (c) second, or (d) electric charge.

2.) Which of the following is *not* an SI base unit? (a) length, (b) mass, (c) weight, or (d) time.

3.) [p.26 #3] Which one of the following is the SI unit of mass? (a) pound, (b) gram, (c) kilogram, or (d) ton.

4.) [p.27 #8] Can unit analysis tell you whether you have used the correct equation in solving a problem? Explain.

5.) [p.28 #9] If x refers to distance, v_0 and v to speeds = [distance/time], a to acceleration = [distance / time^2], and t to time, which of the following equations is dimensionally correct?
(a) $x = v_0t + at^3$, (b) $v^2 = v_0^2 + 2at$, (c) $x = at + vt^2$, or (d) $v^2 = v_0^2 + 2ax$.

6.) Is the equation $v = v_0 \sin \theta - gt^2$ dimensionally correct? Use SI unit analysis to find out. (v and v_0 are velocities, θ is an angle, t is time, and g is acceleration.)

7.) [p.28 #16] Newton's second law of motion is expressed by the equation $F = ma$, where F represents force, m is mass, and a is acceleration. (a) The SI unit of force is, appropriately, called the newton (N). What are the units of the newton in terms of base quantities? (b) An equation for force associated with uniform circular motion is $F = mv^2 / r$, where v is speed and r is the radius of the circular path. Does this equation give the same units for the newton?

8.) Standing at 452 m, the Petronas Twin Towers in Malaysia is one of the tallest buildings in the world. What is its height in feet?

AP PHYSICS – SUMMER PROBLEM SET – please show work

9.) If blood flows with an average speed of 0.35 m/s in the human circulatory system, how many miles does a blood cell travel in 1 h?

10.) [p.30 #38] The density of metal mercury is 13.6 g/cm^3. (a) What is this density as expressed in kg/m^3? (b) How many kilograms of mercury would be required to fill a 0.250-L container?

11.) Which of the following has the greatest number of significant figures? (a) 103.07, (b) 124.5, (c) 0.09916, or (d) 5.408 x 10^5.

12.) In a multiplication and/or division operation involving the numbers 15437, 201.08, and 408.0 x 10^5, the result should be rounded to how many significant figures? (a) 3, (b) 4, (c) 5, or (d) any number.

13.) If a measured length is reported as 25.483 cm, could this length have been measured with an ordinary meterstick whose smallest division is millimeters? Discuss in terms of significant figures.

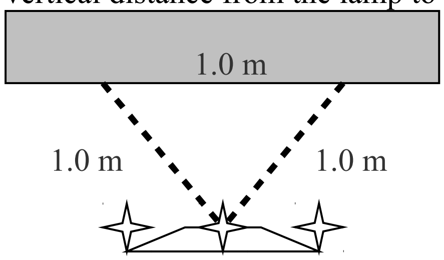
14.) A compact disc (CD) has a diameter of approximately 12 cm. What is its area in m^2?

15.) [p.30 #52] In doing a problem, a student adds 46.9 m and 5.72 m and then subtracts 38 m from the result. (a) How many decimal places will the final answer have, (1) zero, (2) one, or (3) two? (b) What is the final answer?

AP PHYSICS – SUMMER PROBLEM SET – please show work

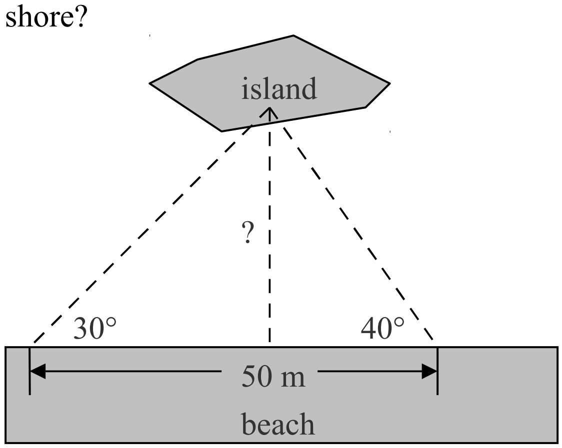
TRIGONOMETRY

1.) [p.31 #61] Two chains of length 1.0 m are used to support a lamp, as shown in Fig. 1.21. The distance between the two chains is 1.0 m along the ceiling. What is the vertical distance from the lamp to the ceiling?



2.) The shortest distance between the bases in a baseball field is 90 ft. What is the straight-line distance in meters between first base and third base?

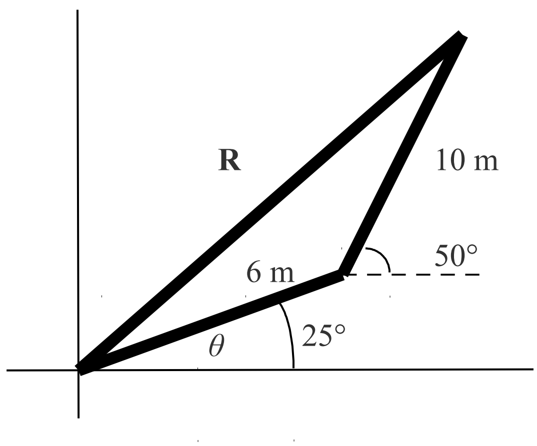
3.) [p.32 #72] A student wants to determine the distance of a small island from the lakeshore (Fig. 1.23). He first draws a 50-m line parallel to the shore. Then, he goes to the ends of the line and measures the angles of the lines of sight from the island relative to the line he has drawn. The angles are 30° and 40°. How far is the island from the shore?



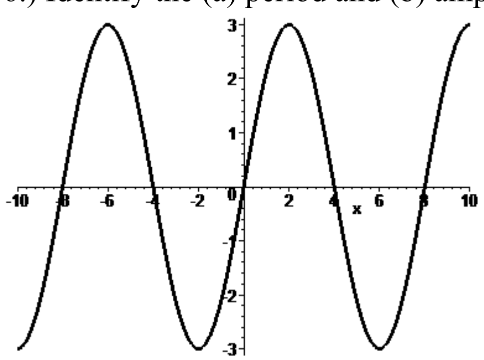
4.) [p.31 #68] A car is driven 13 miles east and then a certain distance due north and ends up at a position 25 degrees north of east. (a) The distance traveled by the car due north is (1) less than, (2) equal to, or (3) greater than 13 miles. Why? (b) What distance does the car go due north?

AP PHYSICS – SUMMER PROBLEM SET – please show work

5.) Find (a) the side **R** and (b) the angle θ (between side **R** and the x-axis) for the triangle depicted below. The 10 m side forms a 50° angle with a line drawn parallel to the x-axis. The 6 m side forms a 25° angle with the x-axis.



6.) Identify the (a) period and (b) amplitude of the graph below.



(c) Write a sine function corresponding to this graph.

AP PHYSICS – SUMMER PROBLEM SET – please show work

SCALARS AND VECTORS

1.) Give an example of a vector quantity. Give an example of a scalar quantity.

2.) If the magnitude of a velocity vector is 7.0 m/s and the *x*-component is 3.0 m/s, what is the *y*-component?

3.) A student walks 100 m west and 50 m south. (a) To get back to the starting point, the student must walk in a general direction of (1) south of west, (2) north of east, (3) south of east, or (4) north of west. (b) What displacement will bring the student back to the starting point?

4.) A dog walks northeast for 15 m and then east for 25 m. Find the resultant (or sum) displacement vector by (a) the graphical method and (b) the component method.

5.) [p.98 #29] For the velocity vectors shown in Fig. 3.28, use the analytical component method to determine **A** + **B** + **C**.