AP Physics C Mechanics

Summer Introductory Packet 2018

Mrs. Neary

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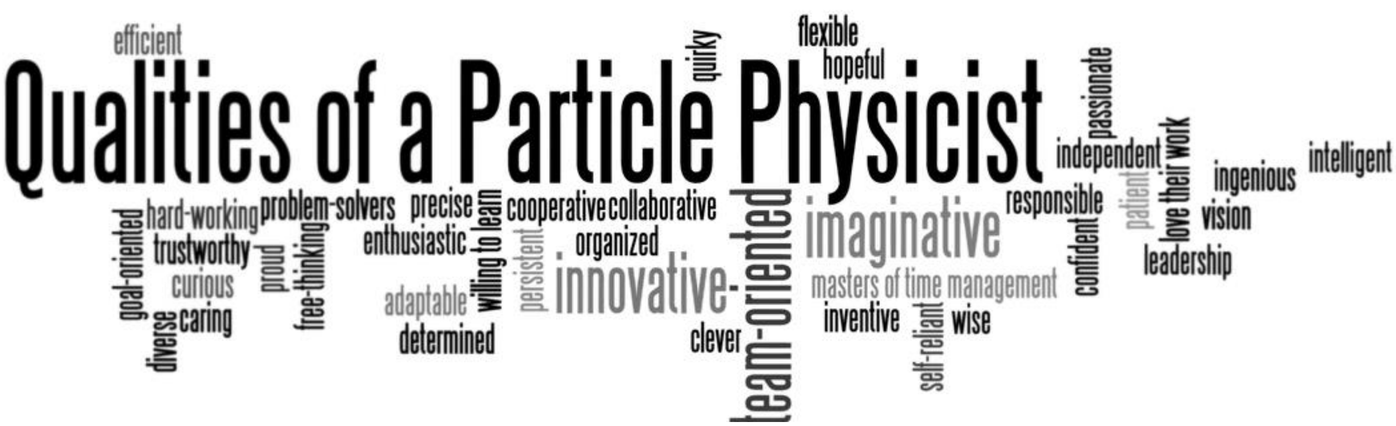

Name: ______________________________

Welcome to AP Physics C – Mechanics!

I am so happy you have decided to join this class. You can count yourself among the 5% of elite US high school students who chose to challenge themselves with a rigorous AP physics class. Congratulations! *Please feel free to contact me with any questions throughout the summer at patricia_neary@hcpss.org* I can also e-mail you this packet.

Summer Packet

This packet is intended to familiarize you with a couple topics we will start out with in the fall as well as serve as a review for some concepts you have learned in previous classes. Mathematics and measurements are essential components of AP Physics C. It is important that you be able to readily convert numbers from one set of units to another. For example, converting centimeters to meters or grams to kilograms. In addition, dimensional analysis is an important concept that is quite useful in physics. *On the 1st day back if you show me any AP Physics C work you did over the summer, you will earn extra credit on your first unit test!*

AP Physics C Course Content

This course is equivalent to a one-semester, calculus based, college-level physics course, especially appropriate for students planning to specialize or major in any STEM field. The course explores the topics listed below and detailed on the following page. The application of introductory differential and integral calculus is used throughout the course. It is most beneficial if you have already taken or are concurrently taking AP calculus or pre-calculus. However, if you have not, do not fear! I will guide you through the application of calculus needed for this AP physics C course.

1) Kinematics (18%)
2) Newton's Laws of Motion (20%)
3) Work Energy & Power (14%)
4) Systems of particles and linear momentum (12%)
5) Circular Motion & Rotational Motion (18%)
6) Oscillation & Universal Gravitation (18%)

A few words about the final assessment

It is highly recommended and encouraged that you take the AP Physics C exam. Even if you plan on taking 1st year physics at college you may still be able to use the course as 3 credits toward an elective science, depending on your major. This will ease your credit load 1st semester, as you begin your collegial journey. Financial assistance may be available to you to cover the cost of the AP exam, please see your counselor to discuss this.

AP Exam Overview

The AP C exam consists of 2 sections. Next year's exam is Monday, May 13, 2019.

Section I: Multiple Choice | 35 Questions | 45 Minutes | 50% of Exam Score
- Discrete Questions
- Questions in Sets

Section II: Free Response | 3 Questions | 45 Minutes | 50% of Exam Score
- 1 Laboratory Based (graphing calculator permitted)
- 2 Discrete Questions (graphing calculator permitted)

Have a Great Summer!

Mrs. Neary

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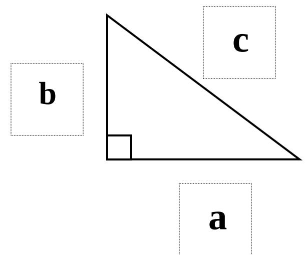
Mathematics & Measurement

Use the attached resource pages and the internet to complete and/or derive the following problems. Record answers in this packet and attach all work on a separate piece of paper.

Pythagorean Theorem ~ $a^2 + b^2 = c^2$

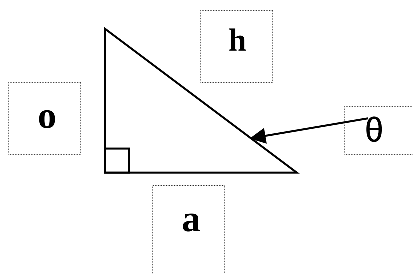
Solve for the unknown information
Round to the nearest tenth.



1. a = 9, b = 9, c = _______
2. a = 4 , b = _______, c = 12
3. a = 4 , b = 6, c = _______
4. a = _______, b = 20, c = 25
5. a = _______, b = 10, c = 13

Trigonometry ~ Solve for the unknown.

Round to the nearest tenth.



SOH CAH TOA

$\sin\theta = \frac{o}{h}$ $\cos\theta = \frac{a}{h}$ $\tan\theta = \frac{o}{a}$

$o = h\sin\theta$ $a = h\cos\theta$ $o = a\tan\theta$

$h = \frac{o}{\sin\theta}$ $h = \frac{a}{\cos\theta}$ $a = \frac{o}{\tan\theta}$

1. $\theta = 50^0$, o = _____, a = 10, h = _____

$o = 10\tan 50^0 = 11.9$ $h = \frac{10}{\cos 50^0} = 15.6$

2. $\theta = 60^0$, o = _____, a = _____, h = 2
3. $\theta = 37^0$, o = 6, a = _____, h = _____
4. $\theta = 50^0$, o = _____, a = _____, h = 13
5. $\theta = 53^0$, o = _____, a = 12, h = _____
6. $\theta = 18^0$, o = _____, a = _____, h = 10
7. $\theta = 56^0$, o = 6, a = _____, h = _____
8. $\theta = 21^0$, o = 9, a = _____, h = _____
9. $\theta = 22^0$, o = _____, a = _____, h = 10
10. $\theta = 45^0$, o = _____, a = _____, h = 17

Use the attached resource pages and the internet to complete and/or derive the following problems. Record answers in this packet and attach all work on a separate piece of paper.

Manipulating Formulas ~ Solve for the variable.

$v = \frac{x}{t}$ $\quad t = \frac{x}{v}$ $\quad x = vt$

$x = vt + x_o$ $\quad v =$ ______________, $t =$ _______________, $x_o =$ _______________

$a = \frac{v}{t}$ $\quad v =$ ______________, $t =$ _______________

$v = v_o + at$ $\quad v_o =$ ______________, $a =$ _______________, $t =$ _______________

$a = \frac{\mathbf{F}}{m}$ $\quad \mathbf{F} =$ ______________, $m =$ _______________

CHALLENGING MANIPULATIONS

$x = x_o + v_o t + \frac{1}{2} at^2$ $\quad x_o =$ ______________________,

$v_o =$ ______________________,

$a =$ ______________________,

$t =$ ______________________ (quadratic formula)

$v^2 = v_o^2 + 2a(x - x_o)$ $\quad v =$ ______________________,

$v_o =$ ______________________,

$a =$ ______________________,

$x =$ ______________________,

$x_o =$ ______________________

Use the attached resource pages and the internet to complete and/or derive the following problems. Record answers in this packet and attach all work on a separate piece of paper.

Vector Addition Problems

HARD

1. A girl delivering newspapers covers her route by traveling 3.00 blocks west, 4.00 blocks north, then 6.00 blocks east. What is her resultant displacement magnitude and direction?
2. A quarterback takes the ball from the line of scrimmage, running backward for 10.0 yards, and then runs to the right parallel to the line of scrimmage for 15.0 yards. At this point, he throws a 50.0-yard forward pass straight downfield, perpendicular to the line of scrimmage. What is the magnitude of the football's resultant displacement?

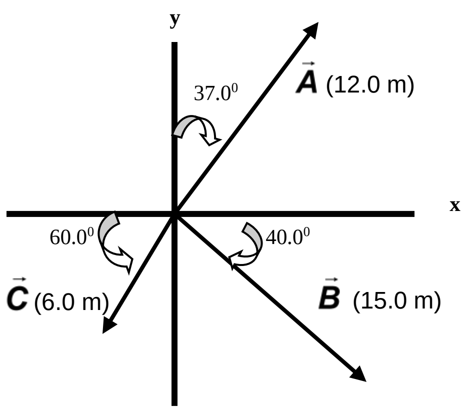
HARDER

3. A car travels 20 km due north and then 35 km in a direction 60^0 west of north. Find the magnitude and direction of the resultant displacement vector that gives the net effect of the car's trip.
4. A hiker begins a trip by first walking 25.0 km southeast from her base camp. On the second day she walks 40.0 km in a direction 60.0^0 north of east, at which point she discovers a forest ranger's tower. What is the magnitude and direction of the resultant displacement of the ranger's tower to the base camp?
5. While exploring a cave, a spelunker starts at the entrance and moves the following distances. She goes 75.0 m north, 250 m east, 125 m at an angle 30.0^0 north of east, and 150 m south. Find the resultant displacement from the cave entrance.

HARDEST

6. Indiana Jones is trapped in a maze. To find his way out, he walks 10.0 m, makes a 90.0^0 right turn, walks 5.00 m, makes another 90.0^0 right turn, and walks 7.00 m. What is his displacement from his initial position?
7. Instructions for finding a buried treasure include the following: Go 75 paces at 240.0^0, turn to 135.0^0 and walk 125 paces, then travel 100 paces at 160.0^0. Determine the resultant displacement from the starting point.

Use the attached resource pages and the **internet to complete and/or derive the following** problems. Record answers in this packet and attach all work on a separate piece of paper.



For the vectors $\vec{A}$, $\vec{B}$, and $\vec{C}$ shown above, find the scalar products

a) $\vec{A} \cdot \vec{B}$

b) $\vec{B} \cdot \vec{C}$

c) $\vec{A} \cdot \vec{C}$

Introduction to Equation Editor

In this activity you will learn how to use Equation Editor to type professional-looking equations in a document.

1. Check to see if your version of Microsoft Word has the Equation Editor installed.
   - Open a new blank document in Word.
   - Click Insert on the menu bar at the top of the screen. On the list that appears, click Object.
   - On the box that opens up, scroll through the list of object types to locate Microsoft Equation 3.0 and click OK.
   - If you don't see Microsoft Equation 3.0 listed, you will need to install it as follows. If it is already there proceed to step 4 of these instructions.

2. Once you have Equation Editor available, you should make a convenient button for it on your toolbar. Follow these steps.
   - If you haven't already, open a new blank document in Word.
   - Click Tools on the menu bar at the top of the screen and then click Customize.
   - On the box that opens, click on the Commands tab and then click Insert on the categories list.
   - Scroll through the list of commands until you find Equation Editor.
   - Drag the Equation Editor icon (a square root symbol over a Greek letter alpha) up to any of your toolbars at the top of the screen to a position you like and let it go.
   - Close the Customize box.
   - Now when you click on the new button, it will automatically insert an empty equation box into your document.

3. Use the Equation Editor to type the following equations into your document. Type them *exactly* as shown. Print & turn in on the 1st day of class! ☺

$$K = \frac{1}{2}mv^2 \qquad F = \frac{Gm_1m_2}{r^2} \qquad n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$T = 2\pi\sqrt{\frac{l}{g}} = 2(3.14)\sqrt{\frac{1.5m}{9.80\frac{m}{s^2}}} = 2.46s$$

Resource Information

SI UNITS

SI Units are the standard units of measurements accepted in science.
Below are three of the base units used in Physics.

Starting SI Base Units		
Base Quantity	Base	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Seconds	s

Below are the prefixes used with the basic and derived SI units.

Derived units are a combination of base units such as velocity is meters per second or m/s.

Prefixes Used with SI Units			
Scientific Notation	Prefix	Symbol	Example
10^{-15}	femto-	f	femtosecond (fs)
10^{-12}	pico-	p	picometer (pm)
10^{-9}	nano-	n	nanometer (nm)
10^{-6}	micro-	μ	microgram (μ g)
10^{-3}	milli-	m	milliamps (mA)
10^{-2}	centi-	c	centimeter (cm)
10^{-1}	deci-	d	deciliter (dL)
10^{3}	kilo-	k	kilometer (kg)
10^{6}	mega-	M	megagram (Mg)
10^{9}	giga-	G	gigameter (Gm)
10^{12}	tera-	T	terahertz (THz)

<u>**Scientific Notation**</u>

$M \times 10^{n} \qquad 1 \leq M < 10$

"***M***" represents the multiplier
The multiplier is always greater than or equal to one or less than ten.

Mathematically, **10** is the base of the exponent and "***n***" is the exponent.

If "***n***" equal +4 then **10** is raised to the **positive** fourth power.
$\mathbf{10^4}$ is the same as **10 x 10 x 10 x10**
If "***M***" equals 3 and "***n***" equals 4 then
3 x $\mathbf{10^4}$ equals 3 x **10 x 10 x 10 x10**, which equals **30,000**

If "***n***" equal -4 then **10** is raised to the **negative** fourth power.
$\mathbf{10^{-4}}$ is the same as **.1 x .1 x .1 x.1**
If "***M***" equals 3 and "***n***" equals -4 then
3 x $\mathbf{10^{-4}}$ equals 3 x **.1 x .1 x .1 x.1**, which equals **.0003**

<u>**Standard Notation**</u>

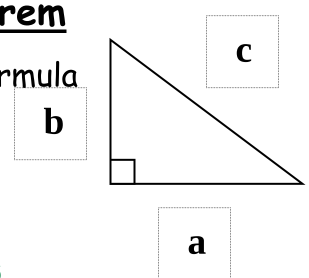
Standard Notation is writing a number in decimal form.

Instead of 8.5 x 10^{6} meters in scientific notation this number would be written as 8,500,000 meters in standard notation.

Instead of6.0 x 10^{-2} seconds in scientific notation this number would be written as 0.06 seconds in standard notation.

<u>**Pythagorean Theorem**</u>

Pythagorean's basic formula
$\mathbf{a^2 + b^2 = c^2}$



Example:

a = ______ , b = 3 , c = 5

$a^2 + (3)^2 = (5)^2$
$a^2 + (9) = (25)$
$a^2 = 16$
$a = 4$

Significant Digits Rules

1. Nonzero digits ARE significant.
2. Final zeros after a decimal point ARE significant.
3. Zeros between two significant digits ARE significant.
4. Zeros used only as placeholders are NOT significant.

There are two cases in which numbers are considered EXACT, and thus, have an infinite number of significant digits.

1. Counting numbers have an infinite number of significant digits.
2. Conversion factors have an infinite number of significant digits.

Examples:

5.0 g has two significant digits.
14.90 g has four significant digits.
0.0 has one significant digit.
300.00 mm has five significant digits.
5.06 s has three significant digits.
304 s has three significant digits.
0.0060 mm has two significant digits (6 & the last 0)
140 mm has two significant digits (1 & 4)

Rounding Rules

1. When the leftmost digit to be dropped is < 5, that digit and any digits that follow are dropped. Then the last digit in the rounded number remains unchanged.

   8.7645 rounded to 3 significant digits is 8.76

2. When the leftmost digit to be dropped is > 5, that digit and any digits that follow are dropped, and the last digit in the rounded number in increased by one.

   8.7676 rounded to 3 significant digits is 8.77

3. When the leftmost digit to be dropped is 5 followed by a nonzero number, that digit and any digits that follow are dropped. The last digit in the rounded number increases by one.

   8.7519 rounded to 2 significant digits is 8.8

4. If the digit to the right of the last significant digit is equal to 5, and 5 is followed by a zero or no other digits, look at the last significant digit. If it is odd, increase it by one; if it is even, do not round up.

   92.350 rounded to 3 significant digits is 92.4
   92.25 rounded to 3 significant digits is 92.2

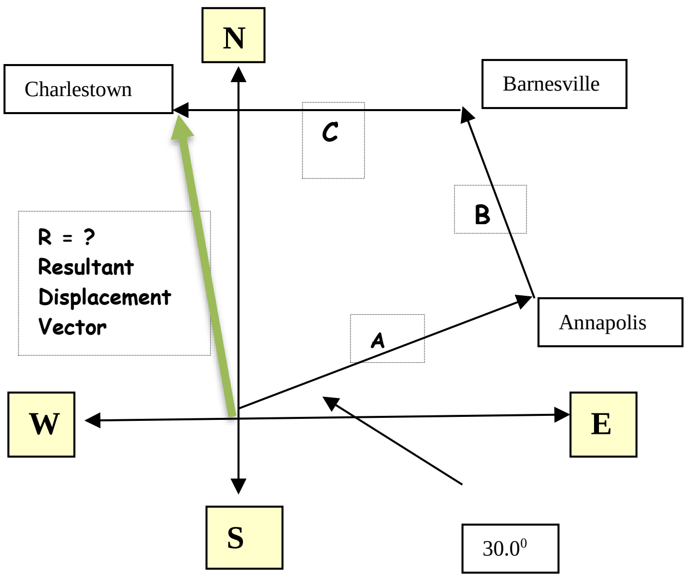
Vector Addition with XY Components

Physical quantities that have both numerical and directional properties are represented by vectors. Some examples of vector quantities are force, displacement, velocity, and acceleration. Numerical and directional can be referred to as magnitude and direction.

Instead of saying vector A, vectors are represented in bold print such as **A**.

Example:

A commuter airplane starts from an airport and takes the route shown below. It first flies 175 km in a direction 30.0^0 north of east to the city of Annapolis following route **A**. Next, it flies 150 km in a direction 20.0^0 west of north to Barnesville following route **B**. Finally, it flies 190 km due west to Charlestown following route **C**. Find the location of Charlestown from the location of the starting point to be labeled route **R** which is the resultant displacement.



Bold Print letters are vectors

$\mathbf{R} = \mathbf{A} + \mathbf{B} + \mathbf{C}$

Non-bold letters are magnitudes

$R \neq A + B + C$

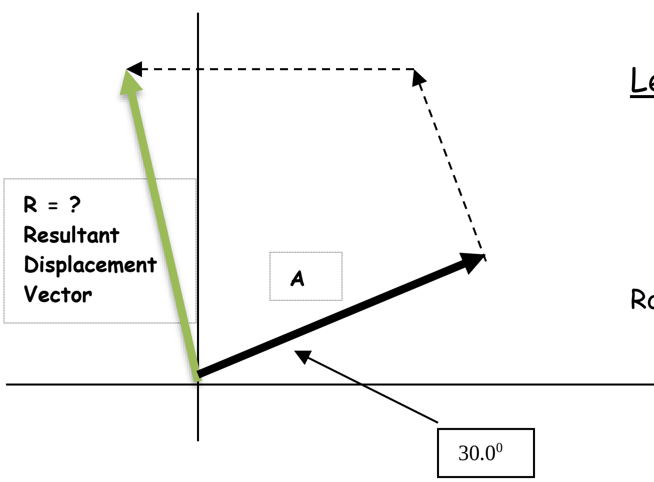
$R \neq 175 \text{ km} + 150 \text{ km} + 190 \text{ km}$

"$\neq$" this symbol means "not equal to"
magnitudes cannot simply be added

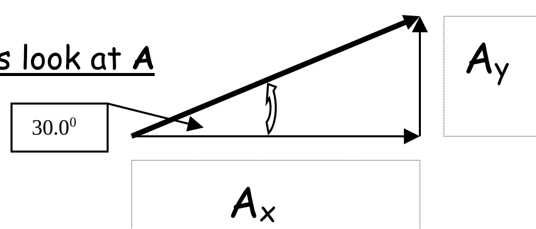
Magnitude's XY Components

$R_x = A_x + B_x + C_x$

$R_y = A_y + B_y + C_y$



Let's look at ***A***

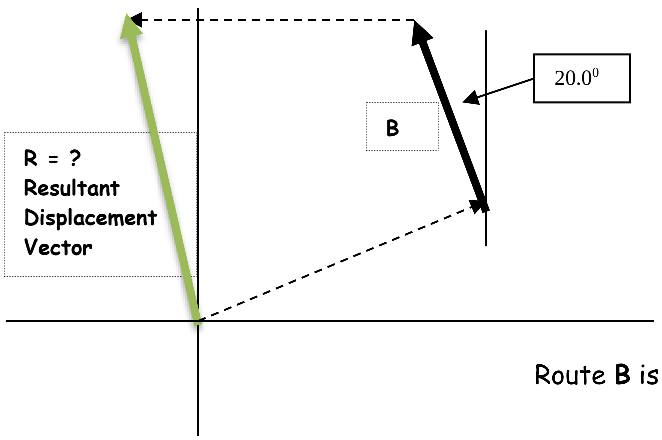


Route **A** is 175 km in a direction 30.0^0 north of east

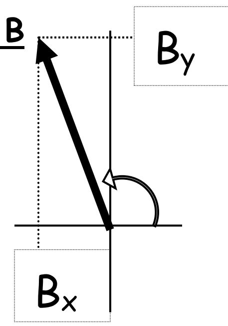
$A = 175 \text{ km}$ $\theta = 30.0^0$

$A_x = A\cos\theta$ $A_y = A\sin\theta$

$A_x = 175\cos(30.0^0)$ $A_y = 175\sin(30.0^0)$



Let's look at **B**



$\theta = 90.0^0 + 20.0^0$

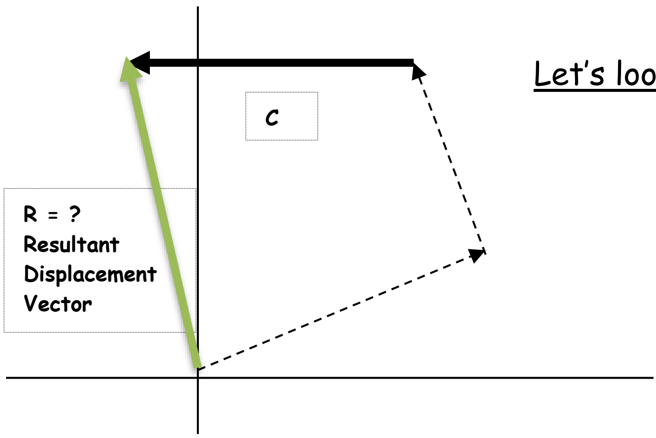
$\theta = 110.0^0$

Route **B** is 150 km is a direction 20.0^0 west of north

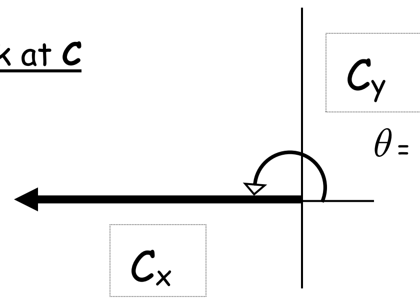
B = 150 km $\qquad \theta = 110.0^0$

$B_x = B\cos\theta \qquad B_y = B\sin\theta$

$B_x = 150\cos(110.0^0) \qquad B_y = 150\sin(110.0^0)$



Let's look at ***C***



$\theta = 180.0^0$

Route ***C*** is 190 km due west

C = 190 km $\qquad \theta = 180.0^0$

$C_x = C\cos\theta \qquad C_y = C\sin\theta$

$C_x = 190\cos(180.0^0) \qquad C_y = 190\sin(180.0^0)$

Vector Addtion

R = A + B + C

Remember Magnitudes cannot be added

R $\neq$ A + B + C

Summary of XY Components

$A_x = 175\cos(30.0^0) \quad A_y = 175\sin(30.0^0)$

$B_x = 150\cos(110.0^0) \quad B_y = 150\sin(110.0^0)$

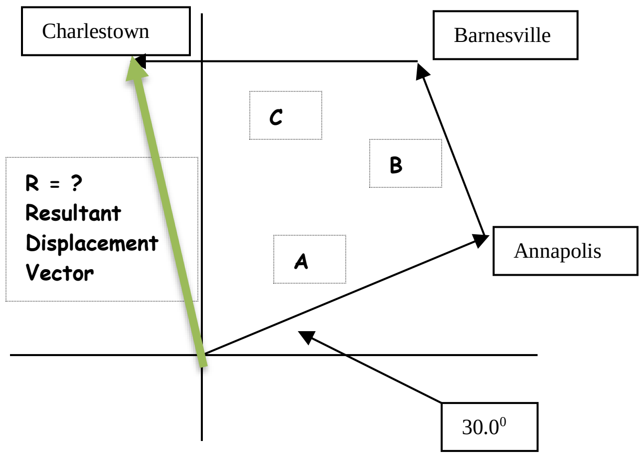
$C_x = 190\cos(180.0^0) \quad C_y = 190\sin(180.0^0)$

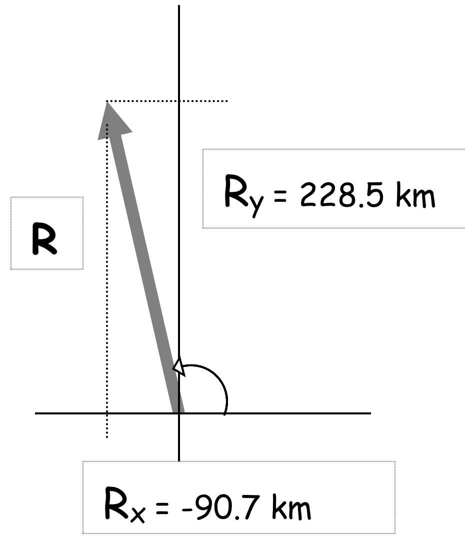
Magnitudes of XY Components

$R_x = A_x + B_x + C_x \qquad R_x = 175\cos(30.0^0) + 150\cos(110.0^0) + 190\cos(180.0^0) = -90.7\text{km}$

$R_y = A_y + B_y + C_y \qquad R_y = 175\sin(30.0^0) + 150\sin(110.0^0) + 190\sin(180.0^0) = 228.5\text{km}$

$R_x = -90.7\text{km} \qquad R_y = 228.5\text{km}$





Pythagoreans Theorem

$R^2 = R_x^2 + R_y^2 = (-90.7)^2 + (228.5)^2$

$R^2 = 60438.7$

R = 245.8 km

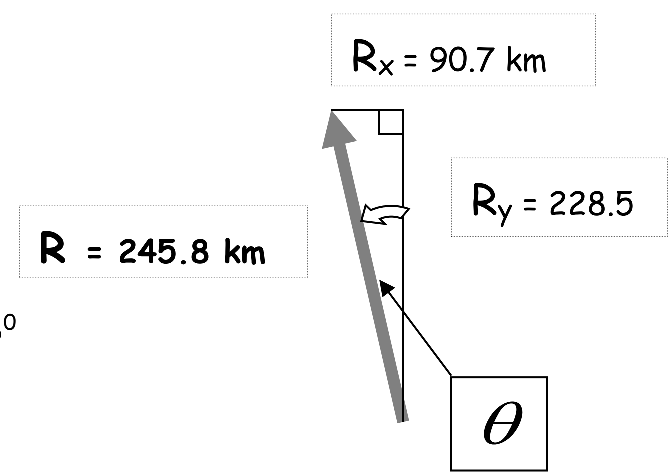
Trigonometry

$\theta = \tan^{-1}(o/a)$

$o = R_x = (90.7)$

$a = R_y = 228.5$

$\theta = \tan^{-1}(90.7/228.5) = 21.6^0$



Conclusion

Find the location of Charlestown from the location of the starting point.
Route **R**, the airplane's resultant displacement.

Short flight to Charlestown would be to fly Route **R**
245.8 km in a direction 21.6^0 west of north

Products of Vectors

We have seen how to add vectors from the previous problem where we combined displacements in each direction (x and y), and we will use vector addition for calculating many other vector quantities throughout the year. We can also express many physical relationships concisely by using *products* of vectors. Vectors are not ordinary numbers, so ordinary multiplication is not directly applicable to vectors. We will define two different kinds of products of vectors. The first, called the scalar product, yields a result that is a scalar quantity. The second, the vector product, yields another vector.

Scalar Product

The **scalar product** of two vectors, $\vec{A}$ and $\vec{B}$ is denoted by $\vec{A}\cdot\vec{B}$. Because of this notation, the scalar product is also called the **dot product.**

To define the scalar product $\vec{A}\cdot\vec{B}$ of two vectors $\vec{A}$ and $\vec{B}$, we draw the *two* vectors with their tails at the same point (Figure 1a). The angle between their directions is Φ as shown; the angle Φ always lies between 0^0 and 180^0. (As usual, we use Greek letters for angles.) Figure 1b shows the projection of the vector $\vec{B}$ onto the direction of $\vec{A}$; this projection is the component of $\vec{B}$ parallel to $\vec{A}$ and is equal to $B\cos\Phi$. (We can take components along any direction that's convenient, not just the *x*- and *y*-axes.) We define $\vec{A}\cdot\vec{B}$ to be the magnitude of $\vec{A}$ multiplied by the component of $\vec{B}$ parallel to $\vec{A}$. Expressed as an equation,

$$\boxed{\begin{array}{c}\vec{A}\cdot\vec{B} = AB\cos\Phi = |\vec{A}|\,|\vec{B}|\cos\Phi \\ \text{(definition of the scalar (dot) product)}\end{array}}$$

where Φ ranges from 0^0 to 180^0.

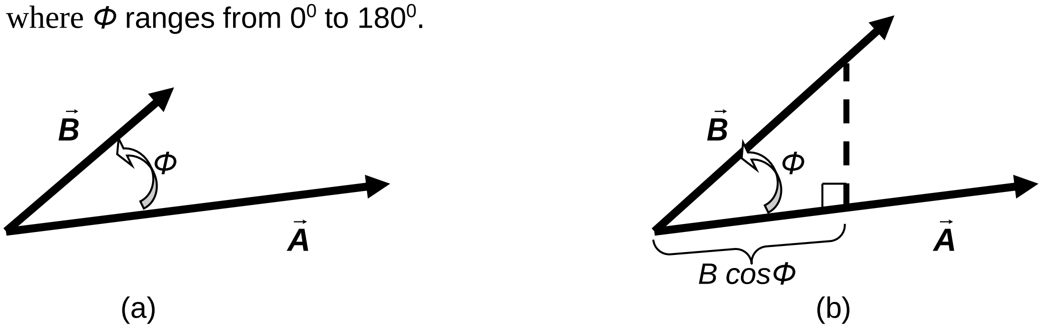


Figure 1 (a) Two vectors drawn from a common starting point to define their scalar product $\vec{A}\cdot\vec{B} = AB\cos\Phi$, (b) $B\cos\Phi$ is the component of $\vec{B}$ in the direction of $\vec{A}$, and $\vec{A}\cdot\vec{B}$ is the product of the magnitude of $\vec{A}$ and this component.

Introduction to Calculus

- ❖ Calculus is the study of how things change; with a focus on rate of change.
- ❖ It provides a framework for modeling systems in which there is change.
- ❖ And a way to make predictions or deduce consequences based on those changes.

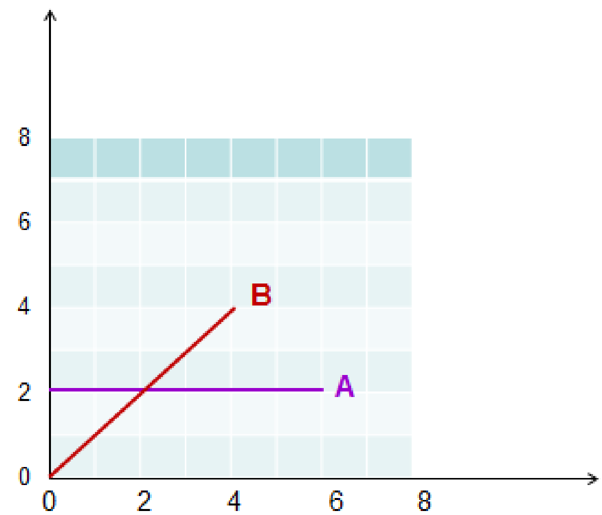
Calculus is the branch of mathematics that deals with the finding and properties of derivatives and integrals of functions, by methods originally based on the summation of infinitesimal differences.

Calculus is divided into 2 categories, differential calculus (rate of change) and integral calculus (accumulation).

Differential Calculus

The derivative tells us the slope of the function at any given point. Slope of the tangent line.

- Find the slope of lines A & B

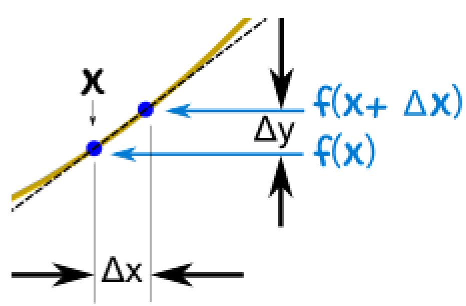


Finding a Derivative

$$\text{Slope} = \frac{\textit{Change in Y}}{\text{Change in X}} = \frac{\Delta y}{\Delta x}$$ to find the derivative of a function $y = f(x)$

x changes from x to $x+\Delta x$

y changes from $f(x)$ to $f(x+\Delta x)$



STEPS:

1) Fill in this slope formula: $\dfrac{\Delta y}{\Delta x} = \dfrac{f(x+\Delta x) - f(x)}{\Delta x}$

•2) Simplify it as best we can, 3) then make **Δx** shrink towards zero.

Example 1: the function $f(x) = x^2$

We know $\mathbf{f(x) = x^2}$, and can calculate $\mathbf{f(x+\Delta x)}$:

Start with: $\mathbf{f(x+\Delta x) = (x+\Delta x)^2}$

Expand $(x + \Delta x)^2$: $\mathbf{f(x+\Delta x) = x^2 + 2x\, \Delta x + (\Delta x)^2}$

The slope formula is: $$\frac{f(x+\Delta x) - f(x)}{\Delta x}$$

Put in **f(x+Δx)** and **f(x)**: $$\frac{x^2 + 2x\,\Delta x + (\Delta x)^2 - x^2}{\Delta x}$$

Simplify (x^2 and $-x^2$ cancel): $$= \frac{2x\,\Delta x + (\Delta x)^2}{\Delta x}$$

Simplify more (divide through by Δx): $\mathbf{= 2x + \Delta x}$

And then **as Δx heads towards 0** we get: $= 2x$

Result: the derivative of x^2 is 2x

We write **dx** instead of **"Δx heads towards 0"**, so "the derivative of" is commonly written $\frac{d}{dx}$

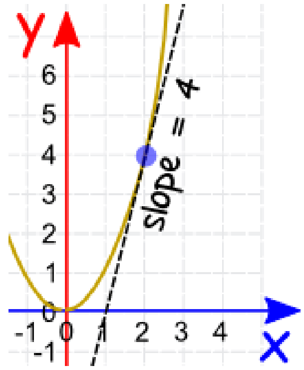
$$\frac{d}{dx} x^2 = 2x$$

"The derivative of $\mathbf{x^2}$ equals **2x**" or simply "d dx of $\mathbf{x^2}$ equals **2x**"

What does $\frac{d}{dx} x^2 = 2x$ mean?

It means that, for the function x^2, the slope or "rate of change" at any point is **2x**.

So when **x=2** the slope is **2x = 4**, as shown here:



Or when **x=5** the slope is **2x = 10**, and so on.

Note: sometimes f ’(x) is also used for "the derivative of":

f’(x) = 2x "The derivative of **f(x)** equals **2x**"

Try 2 examples using the power rule:

The power rule: If the function = X^n then the derivative is $nX^{(n-1)}$

i.e: Multiply X by the power, then subtract 1 from the power to find the new power for the derivative!

Example 2: What is $\frac{d}{dx}x^3$?

$$\frac{d}{dx}x^3 =$$

Example 3: What is $\frac{d}{dx}2x^3$?

$$\frac{d}{dx}2x^3 =$$

Voila! You just did some calculus!

Suggested Summer Exploration

1. Dimensional Analysis – view Kahn Academy: Intro to dimensional analysis https://www.khanacademy.org/math/algebra/units-in-modeling/intro-to-dimensional-analysis/v/dimensional-analysis-units-algebraically

2. Purchase an AP Physics 1 review book: 5 Steps to a 5 is recommended. You can get a 2017 edition on-line for a reasonable price. Read the first 3 introductory chapters.

3. Explore the AP Physics C College Board website – try some practice problems! Show them to me for extra credit http://apcentral.collegeboard.com/apc/public/courses/teachers_corner/2262.html

Videos to Explore:

- Khan Academy - Significant Figure Review
- AP Physics 1- College Board website
- PhysicsClassroom.com
- Bozeman's AP Physics 1 Video Series
- Kahn Academy AP Physic 1 Videos

References:

Calculus: http://www.mathscoop.com/calculus/what-is-calculus.php
Derivatives: https://www.mathsisfun.com/calculus/derivatives-rules.html

Please feel free to e-mail throughout the summer with any questions!

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