AP Physics 1
Summer Assignment

Scientific Notation
Metric Unit Conversion
Standard Unit Conversion*
Exponent Properties*
Operations with Scientific Notation
Rearranging Equations*
Dimensional Analysis
Sketching Vectors
Calculating Vector Components*
Calculating Vector Magnitude & Direction
Vector Addition
1D Motion
2D Motion
~~Word Problems~~*

Solve problems on separate sheet of paper

* = very important!

Dear Student,

Welcome to AP Physics 1 (Algebra-Based)! I'm excited to have you in the class and to get to know you. This course is extremely challenging and will carry a high workload, but I believe that with the right attitude and work ethic, each of you has the potential to be successful in this class.

To help prepare you for our work together, I've created the following summer assignment. Each topic is important—I cut out other topics like significant figures, which aren't a huge deal in Physics class—but the starred topics on the next page are of particular importance.

If you get stuck on any section, I've included links to online tutorials for each topic. Regarding the use of AI, I recommend you use it to *teach* you the topic in general. If you simply use AI to solve the problem for you, I don't think you will learn very much, which defeats the purpose.

There's not quite enough space in the packet to show all your work, so please complete the assignment on separate paper, labeling each problem and **showing your work**. The summer assignment will be due the first week of class in the fall.

During the first couple weeks of class, we will take quizzes very similar to the "quizzes" in this packet, so if you can do those, you'll be all set. Treat the quizzes here as practice for the real thing, and try to do them on your own, with only the equations provided and a calculator.

If you get stuck or need additional resources, please email me at William.Cunningham@k12.dc.gov and I'll get back to you with additional resources within a couple of days.

I look forward to working with you next year!

Best,

Mr. Cunningham

William Cunningham

William Cunningham

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Links to Tutorials

Scientific Notation: https://tinyurl.com/CunninghamAPP1

Metric Unit Conversion: https://tinyurl.com/4cd7xtx5

Standard Unit Conversion: https://tinyurl.com/3xp55edr

Exponent Properties: https://tinyurl.com/3ure9x4f

Operations with Scientific Notation: https://tinyurl.com/44aj8txf

Rearranging Equations**: https://tinyurl.com/yt3swrv4

Dimensional Analysis: https://tinyurl.com/p6m4e4am

Sketching Vectors: https://tinyurl.com/yz3ek2wd

Calculating Vector Components: https://tinyurl.com/yz3ek2wd

Calculating Vector Magnitude & Direction: https://tinyurl.com/yz3ek2wd

Vector Addition: https://tinyurl.com/yz3ek2wd

1D Motion: https://tinyurl.com/3u9ub2pr

2D Motion: https://tinyurl.com/3u9ub2pr

Word Problems: https://tinyurl.com/2s42rf2d

Part 1
Scientific Notation

★★★★☆

You'll notice the stars under each section. These indicate how important this concept is to your success in AP Physics. The more stars, the more likely you'll use this topic regularly- so you should dedicate more time to higher starred material.

Often measurements can be too big or too small to write out in full. To combat this, we use scientific notation. Any number can be expressed in scientific notation following the model to the right:

$$a \cdot 10^b$$

Where $1 \leq a < 10$ and b is an integer.

Example 1	**Example 2**	**Example 3**
820,000,000,000	0.000 000 000 000 005 840	154.8×10^4
8.2×10^{11}	5.84×10^{-15}	1,548,000

Practice:

Convert the following values into scientific notation

1.1) 268,000,000,000,000,000

1.2) $730{,}000 \times 10^4$

1.3) 0.000 000 158

1.4) 12.1×10^5

1.5) 895,684,000,000

1.6) $0.000\,000\,846 \times 10^3$

1.7) 0.000 000 000 000 087

1.8) $1.95 \times 10^5 \times 10^3 \times 10^{-2}$

1.9) 7.84×2^4

1.10) 84,125

1.11) 7.5

1.12) 0.000 000 1

1.13) 94841×10^{-5}

1.14) $654 \times 10^{-2} \times 10^{-8} \times 10^3$

1.15) $23.7 \times 3^2 \times 9^4$

Part 2
Metric Unit Conversion

These are the most common S.I. units and the symbols used to represent them. These units are all base units with the exception of kg.

UNIT SYMBOLS						
	meter,	m	kelvin,	K	watt,	W
	kilogram,	kg	hertz,	Hz	coulomb,	C
	second,	s	newton,	N	volt,	V
	ampere,	A	joule,	J	ohm,	Ω

Example 1

12 kN to N

$12\,kN \cdot \frac{1000\,N}{1\,kN} = \boxed{12{,}000\,N}$

Example 2

1.5 Tm to μm

$1.5\,Tm \cdot \frac{10^{12}\,m}{Tm} \cdot \frac{\mu m}{10^{-6}\,m} = \boxed{1.5 \times 10^{6}\,\mu m}$

Example 3

190,000 pΩ to mΩ

$190000\,p\Omega \cdot \frac{10^{-12}\,\Omega}{p\Omega} \cdot \frac{m\Omega}{10^{-3}\,\Omega} = \boxed{190000 \times 10^{-9}}$

Example 4

5.124 kJ to cJ

$5.124\,kJ \cdot \frac{1000\,J}{kJ} \cdot \frac{cJ}{10^{-2}\,J} = \boxed{5.124 \times 10^{5}\,cJ}$

Example 5

3 x 10^8 Hz to MHz

$3E8\,Hz \cdot \frac{MHz}{10^{6}\,Hz} = \boxed{3 \times 10^{2}\,MHz}$

Example 6

4.5E-5 V

0.000 045 V to mV

$4.5E\text{-}5\,V \cdot \frac{mV}{10^{-3}\,V} = \boxed{4.5 \times 10^{-2}\,mV}$

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Practice:

Convert each measurement into its indicated unit.

2.1) 500,000 ms to ks

2.2) 120 A to mA

2.3) 0.000 25 MW to cW

2.4) 10^8 N to GN

2.5) 1.160352 Mg to kg

2.6) 0.000 872 pC to mC

2.7) 5.2 x 10^5 W to nW

2.8) 4.2952 x 10^{-2} cg to ng

2.9) 7.2 nK to μm

2.10) 0.000 42 GV to V

2.11) 9.82 x 10^{10} mN to kN

2.12) 1.28 μC to nC

2.13) 98,000,000,000 μJ to kJ

2.14) 0.000 087 km to cm

2.15) 5.2 TΩ to cΩ

Part 3
Standard Unit Conversion

The United States continues to reject the universally adopted (and objectively better) metric system. This means you need to be able to convert from standard to metric units. To do this, you'll need to know a few conversion factors:

Length	Volume	Mass
1 mi = 5280 ft	1 gal = 4 qt	1 kg = 2.2 lb
1 mi = 1.6 km	1 qt = 2 pt	1 lb = 16 oz
1 mi = 1609 m	1 pt = 2 cups	1 lb = 454 g
1 m = 3.28 ft	1 cup = 8 fl oz	**Time**
1 ft = 12 in	1 fl oz = 29.6 mL	1 min = 60 s
1 yd = 3 ft	1 gal = 3.79 L	1 hr = 60 min
1 in = 2.54 cm	1 L = 1000 mL	1 day = 24 hr
1 m = 100 cm	1 kL = 1000 L	1 year = 365 day

Example 1 : (to cm) $5.2\ \cancel{in} \cdot \frac{2.54\,cm}{1\ \cancel{in}} = \boxed{13.21\,cm}$

Example 2 : (to min) $1.9\ \cancel{days} \cdot \frac{24\ \cancel{hr}}{1\ \cancel{day}} \cdot \frac{60\,min}{1\ \cancel{hr}} = \boxed{2736\,min}$

Example 3 : (to mi/hr) $60\frac{\cancel{m}}{\cancel{s}} \cdot \frac{1\,mi}{1609\ \cancel{m}} \cdot \frac{60\ \cancel{s}}{1\ \cancel{min}} \cdot \frac{60\ \cancel{min}}{1\,hr} = \boxed{134.2\,\frac{mi}{hr}}$

Example 4 : (to g/cm²) $23\frac{\cancel{lb}}{\cancel{in^2}} \cdot \frac{454\,g}{1\ \cancel{lb}} \cdot \frac{1\ \cancel{in}}{2.54\,cm} \cdot \frac{1\ \cancel{in}}{2.54\,cm} = \boxed{1618.5\ g/cm^2}$

Practice:

Convert each measurement into its indicated unit.

3.1) $2678\ cm\ to\ ft$

3.2) $8\ gal\ to\ pints$

3.3) $5.1\ mi\ to\ cm$

3.4) $22{,}647\ in^2\ to\ cm^2$

3.5) $900\ mL\ to\ qts$

3.6) $12{,}080\ \frac{gal}{day}\ into\ \frac{L}{hr}$

3.7) $1100\ \frac{ft}{s}\ to\ \frac{mi}{hr}$

3.8) $13\ \frac{m}{s^2}\ into\ \frac{km}{min^2}$

3.9) $0.52\ \frac{qt^2}{hr}\ to\ \frac{cup^2}{min}$

3.10) $1.7\ \frac{min}{L\cdot km}\ to\ \frac{hr}{mL\cdot mi}$

Quiz 1 Conversions

Convert each measurement into its indicated unit ***and*** *convert each answer into scientific notation.*

PREFIXES		
Factor	Prefix	Symbol
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Length	Volume	Mass
1 mi = 5280 ft	1 gal = 4 qt	1 kg = 2.2 lb
1 mi = 1.6 km	1 qt = 2 pt	1 lb = 16 oz
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1 ft = 12 in	1 fl oz = 29.6 mL	1 min = 60 s
1 yd = 3 ft	1 gal = 3.79 L	1 hr = 60 min
1 in = 2.54 cm	1 L = 1000 mL	1 day = 24 hr
1 m = 100 cm	1 kL = 1000 L	1 year = 365 day

1a) $2{,}986{,}000{,}000\ cm\ to\ m$

1b) $2678\ mi\ to\ ft$

1c) $89.4 \times 10^{10} g\ to\ kg$

1d) $9.78\ gal\ to\ mL$

1e) $900\ ft^2\ to\ cm^2$

1f) $6847 \frac{mi}{hr}\ to\ \frac{cm}{day}$

1g) $12{,}080\ \frac{gal}{day}\ into \frac{L}{hr}$

1h) $10^5\ \frac{km}{L}\ into \frac{m}{mL}$

1i) $700 \frac{mV}{in} to \frac{V}{ft}$

1j) $91 \times 10^{-4}\ \frac{m}{s^2}\ into \frac{km}{hr^2}$

1k) $0.52\ \frac{mL^2}{\mu\Omega} to \frac{L^2}{k\Omega}$

1l) $98{,}840{,}000\ \frac{min}{km}\ to \frac{sec}{mi}$

Part 4
Exponent Properties

Exponents be popping up a lot. You must be prepared to simplify them to make sense of the reality of the universe.

Zero Rule	Product Rule	Quotient Rule
$x^0 = 1$ $(x \neq 0)$	$x^a \cdot x^b = x^{a+b}$	$\frac{x^a}{x^b} = x^{a-b}$
Power Rule	**Multiple Power Rule**	**Negative Rule**
$(x^a)^b = x^{a \cdot b}$	$(x^a y^b)^c = x^{a \cdot c} y^{b \cdot c}$	$x^{-a} = \frac{1}{x^a}$

Example 1	Example 2	Example 3
$x^4 \cdot x^3 \cdot y^0 = \boxed{x^7}$	$(x^3y^{-2})^2 = x^6y^{-4} = \frac{x^6}{y^4}$	$(-2b^{-5}c^8)^6 = 64b^{-30}c^{48} = \boxed{\frac{64c^{48}}{b^{30}}}$
Example 4	**Example 5**	**Example 6**
$(3g^{-5}t^8)^{-3} = \boxed{\frac{g^{15}}{27t^{24}}}$	$\frac{\cancel{f^5}\cancel{d^{-8}}z^3}{d^2\cancel{f^2}\cancel{y^{-3}}z^5} = \boxed{\frac{f^3y^3}{d^{10}z^2}}$	$\left(\frac{(a^5d^2)^2}{(ad^3)^3}\right)^2 = \left(\frac{a^{10}d^4}{a^3d^9}\right)^2 = \left(\frac{a^7}{d^5}\right)^2 = \boxed{\frac{a^{14}}{d^{10}}}$

Practice:

Simplify each expression. Your answer should only contain positive exponents.

4.1) $2x^2y^{-3}(2x^{-1}y^2)^{-2}$

4.2) $\frac{-2m^3k^2}{-4m^{-2}k^0}$

4.3) $\left(\frac{(v^3b^2)^{-1}}{(vd^3)^{-3}}\right)^2$

4.4) $(2x^3)^{-2}(2x^4)^2$

4.5) $y^{-2}((3x^3)y^2)^4$

4.6) $\frac{x^2y^4z^{-3}}{x^3y^4z^5}$

4.7) $\left(\frac{(g^3f^2)^{-2}}{(fg^2)^3}\right)^{-2}$

4.8) $5a^2d^3(3b^1d^{-2})^2$

4.9) $\frac{18q^3r^{-4}s^4}{(6r^3q^4s)^2}$

4.10) $4mn^3(2mn)^{-2}$

4.11) $\left(\frac{(e^2c^3)^0}{(ec^3)^{-1}}\right)^2$

4.12) $\frac{(4k^{-2}j^4)^2k^3}{(2jk)^2(ki)^{-3}}$

4.13) $\frac{(4y^2k^{-1})^{-2}}{(2k^{-1}y^4)^{-3}}$

4.14) $3^2(c^2j^4)(3j^1c^{-2})^2$

4.15) $\left(\frac{2q^3d^{-4}o^{-1}}{(2^{-1}d^3q^4o)^2}\right)^2$

Additional Practice on Kuta

Part 5
Operations with Scientific Notation

You'll be exposed to big and small values frequently in this class so it's important we know how to math them. You will have access to a calculator at all times to assist you with these calculations, however, understanding how to complete them without a calculator saves you time and energy.

Example 1 $(5 \cdot 10^4)(2 \cdot 10^5) = 10 \cdot 10^9 = \boxed{10^{10}}$	**Example 2** $(1.5 \cdot 10^4)(2 \cdot 10^{-3}) = 3 \cdot 10^1 = \boxed{30}$
Example 3 $\frac{1}{2}(9 \cdot 10^{-2})(6 \cdot 10^{-5}) = 27 \cdot 10^{-7} = \boxed{2.7 \cdot 10^{-6}}$	**Example 4** $\sqrt{\frac{(2 \cdot 10^{10})}{(4 \cdot 10^6)}} = \sqrt{\frac{10^4}{2}} = \boxed{\frac{10^2}{\sqrt{2}}}$
Example 5 $\frac{(4 \cdot 10^7)^2}{(2 \cdot 10^6)} = \frac{16 \cdot 10^{14}}{2 \cdot 10^6} = \boxed{8 \cdot 10^8}$	**Example 6** $\frac{(4 \cdot 10^5)^2}{(2 \cdot 10^6)(2 \cdot 10^{-3})} = \frac{16E10}{4E3} = \boxed{4E7}$

Practice:

Simplify each expression without using a calculator. Express each answer in scientific notation.

5.1) $\frac{1}{2}(4 \cdot 10^{-30})(3 \cdot 10^5)^2$

5.2) $\sqrt{(6 \cdot 10^3)(6 \cdot 10^5)}$

5.3) $\frac{(8 \cdot 10^7)^2}{(2 \cdot 10^6)(4 \cdot 10^3)}$

5.4) $\frac{(18 \cdot 10^{12})}{(9 \cdot 10^{13})}$

5.5) $(2\pi(8 \cdot 10^{-2}))^2$

5.6) $\sqrt{\frac{(5 \cdot 10^8)^2}{(5 \cdot 10^6)}}$

5.7) $\sqrt{\frac{20 \cdot 10^{-12}}{5 \cdot 10^{-16}}}$

5.8) $\frac{(3 \cdot 10^9)(2 \cdot 10^{-6})(6 \cdot 10^{-6})}{2^2}$

5.9) $\frac{(6 \cdot 10^5)^2}{(9 \cdot 10^{-3})}$

5.10) $\frac{1}{3}(9 \cdot 10^{-4})(3 \cdot 10^{15})^3$

5.11) $\frac{(4 \cdot 10^6)^2}{\sqrt{(4 \cdot 10^5)(4 \cdot 10^3)}}$

5.12) $(10^4)^3(0.5 \cdot 10^2)$

5.13) $\sqrt{4 \cdot 10^6}\sqrt{25 \cdot 10^8}$

5.14) $\frac{\sqrt{144 \cdot 10^{16}}}{(\sqrt{9 \cdot 10^2})^4}$

5.15) $(4 \cdot 10^3)^3\sqrt{2 \cdot 10^6}^2$

Quiz 2
Simplification

Simplify each expression.

2a) $(8g^2hj^{-2})(2j^4hg^3)$

2b) $(2 \cdot 10^4)(5 \cdot 10^6)$

2c) $\left(\frac{t^2m}{m^3t^{-3}}\right)^4$

2d) $\frac{4 \cdot 10^{12}}{(2 \cdot 10^4)^2}$

2e) $\frac{x^6y^{-3}}{\sqrt{x^4}}$

2f) $\frac{(2 \cdot 10^5)^2}{\sqrt{(4 \cdot 10^5)(4 \cdot 10^3)}}$

2g) $\left(\frac{r^3e^{-2}}{p^8}\right)\left(\frac{e^{-1}}{p^4}\right)^2$

2h) $\frac{1}{5}(3 \cdot 10^{-4})(5 \cdot 10^7)^3$

2i) $\left(\frac{v^{-1}}{s^6}\right)^{-2}\left(\frac{v^{-2}s^{-3}}{s}\right)^3$

2j) $(2 \cdot 10^2)^3\left(4\sqrt{\frac{1}{2}} \cdot 10^6\right)^2$

2k) $\frac{(2x^3y^{-2})^2}{\sqrt{(4x^4)(16\,y^6)}}$

2l) $\frac{(4 \cdot 10^5)^{-2}}{(2 \cdot 10^6)(4 \cdot 10^3)^{-3}}$

Part 6
Rearranging Equations

★★★★★ *The more we move forward in the class the less we'll calculate numerical values. Instead, we will focus on the effect changing certain quantities will have on other quantities. To determine this, you must be able to rearrange an equation using algebra to solve for a given variable.*

Example 1 $\frac{2}{v^2}\cdot K = \frac{1}{2}mv^2 \cdot \frac{2}{v^2}$	Solve for m $\boxed{m = \frac{2K}{v^2}}$ $\frac{2}{m}K = \frac{1}{2}mv^2 \cdot \frac{2}{m}$	Solve for v $\Rightarrow \sqrt{v^2} = \sqrt{\frac{2K}{m}} \Rightarrow \boxed{v = \sqrt{\frac{2K}{m}}}$
Example 2 $(T_p)^2 = \left(2\pi\sqrt{\frac{l}{g}}\right)^2 \Rightarrow T_p^2 = 4\pi^2\frac{l}{g}$	Solve for ~~l~~ $\Rightarrow \boxed{l = \frac{T_p^2 g}{4\pi^2}}$	Solve for g $\boxed{g = \frac{4\pi^2 l}{T_p^2}}$
Example 3 $q = 5b^2 - \frac{\beta}{z} \Rightarrow \frac{\beta}{z} = 5b^2 - q$	Solve for z $\Rightarrow \boxed{z = \frac{\beta}{5b^2 - q}}$	$\frac{5b^2}{5} = q + \frac{\beta}{z} = \frac{qz+\beta}{5z}$ Solve for b $\Rightarrow \boxed{b = \sqrt{\frac{qz+\beta}{5z}}}$

Practice:
Solve each equation for the indicated variables

6.1) $F_g = G\frac{m_1 m_2}{r^2}$ for m_1 and r

6.2) $mgh = \frac{1}{2}mv^2$ for h and v

6.3) $\Delta x = v_0 t + \frac{1}{2}at^2$ for v_0 and a

6.4) $v^2 = {v_0}^2 + 2a\Delta x$ for v_0 and Δx

6.5) $F_c = \frac{mv^2}{r}$ for v and r

6.6) $\Delta E = Fd\cos\theta$ for d and θ

6.7) $x = A\sin(2\pi f t)$ for A and t

6.8) $\frac{1}{2}mv^2 + mhg = \frac{1}{2}kx^2$ for g and x

6.9) $\mu mg = \frac{mv^2}{r}$ for μ and r

6.10) $2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{l}{g}}$ for k and g

Part 7
Dimensional Analysis

★★★★★ *Physics deals with a lot of equations and its easy to get those equations wrong. Dimensional analysis is your most powerful tool to determine an equations validity.*

Dimension	Variable	SI Unit
Length	Δx, L, r, x	m
Mass	m	kg
Time	t	s
Velocity	v	m/s
Acceleration	a	m/s^2
Force	F	$kg{\cdot}m/s^2$
Energy	E	$kg{\cdot}m^2/s^2$
Momentum	p	kg·m/s

Example 1

$$p = \frac{mv}{L}$$

$\frac{kg \cdot m}{s} = \frac{kg \cdot \cancel{m}}{s \cdot \cancel{m}}$

$\frac{kg \cdot m}{s} \neq \frac{kg}{s}$

$\boxed{\text{NOT consistent}}$

Example 2

$$m\left(\frac{p}{m}\right)^2 = am\Delta x$$

$\frac{p^2}{m} = am\Delta x$

$\frac{kg^2 m^2}{s^2 \cdot \cancel{kg}} = \frac{m \cdot kg \cdot m}{s^2}$ Consistent

$\frac{kg\, m^2}{s^2} = \frac{kg\, m^2}{s^2}$

Example 3 → Find unit for C to make eqn consistent

$$\frac{E}{m\cancel{t}} = C\frac{ma^2}{4\cancel{t}}$$

$\frac{E}{m^2 a^2} = \frac{C}{4} \Rightarrow \frac{\cancel{kg}\cancel{m^2}}{\cancel{s^2}} \cdot \frac{s^{\cancel{4}2}}{kg^{\cancel{2}} \cdot \cancel{m^2}} = \boxed{\frac{s^2}{kg} = C}$

Practice:

Determine if each equation is dimensionally consistent.

7.1) $\Delta x = vt$

7.2) $p = ma$

7.3) $E = ma^2$

7.4) $a = \frac{F}{m}$

7.5) $t = \frac{mv}{p}$

7.6) $E = 2mat$

7.7) $mE = 9(mv)^2$

7.8) $amt = p^2t^{-2}$

7.9) $\frac{p^2}{m^2} = \pi F t^2$

Determine the unit of the value C that makes the equation dimensionally consistent.

7.10) $a = CEv$

7.11) $L = C\frac{v^2}{2a}$

7.12) $a = C\frac{pt}{m}$

7.13) $Ep = Cma\Delta x$

7.14) $\frac{v}{t} = C\frac{2p}{mt}$

7.15) $\frac{p}{a} = C\sqrt{\frac{Fr}{p}}$

Quiz 3
Equations

*Determine if the given equation is dimensionally valid **and** solve for the indicated variable*

Dimension	Variable	SI Unit
Acceleration	a	m/s^2
Force	F	$kg{\cdot}m/s^2$
Energy	E	$kg{\cdot}m^2/s^2$
Momentum	p	$kg{\cdot}m/s$

3a) $v = \sqrt{2mar}$ for m

3b) $m = E/p^2$ for E

3c) $t^2 = \frac{4\pi l}{a}$ for a

3d) $x = \frac{mv^2}{F} + \frac{Ep}{a}$ for v

3e) $t = 2\pi\sqrt{\frac{mx}{F}}$ for F

3f) $at = \frac{x}{t} + \frac{p}{m}$ for m

3g) $E = max\cos\theta$ for θ

3h) $\frac{mv^2}{r} = \frac{E}{mx^2}$ for r

Solve for C and determine the units for C that makes the equation dimensionally consistent.

3i) $p = C\frac{E}{ma^2}$

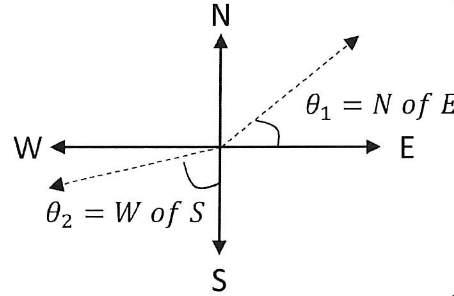
3j) $mtx = C\frac{ma}{E}$

3k) $Ep = C\frac{F^2}{m}$

3l) $\sqrt{\frac{E}{p}} = Cmat^2$ for C

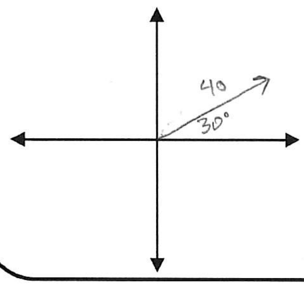
Part 10
Sketching Vectors

A vector is any quantity that has both magnitude & direction. Many of the quantities studied in physics are vectors. Knowing how to visualize both size and direction is the first step to understanding vectors.

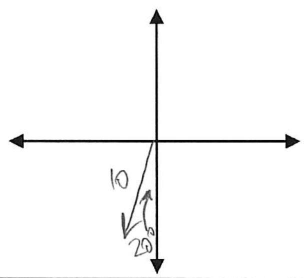


Examples:

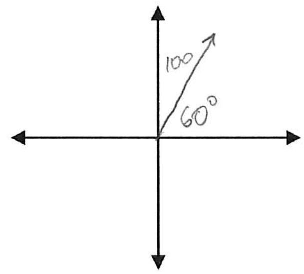
$\vec{v} = 40\ m, 30°\ N\ of\ E$



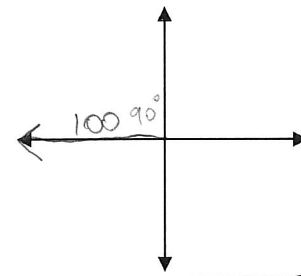
$\vec{a} = 10\ m, 20°\ W\ of\ S$



$\vec{F} = 100\ m, -60°\ S\ of\ E$



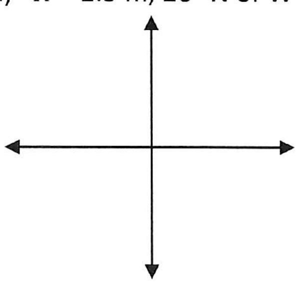
$\vec{z} = 100\ m, 90°\ W\ of\ N$



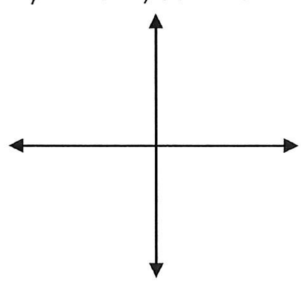
Examples:

Sketch each vector in the coordinate plane provided.

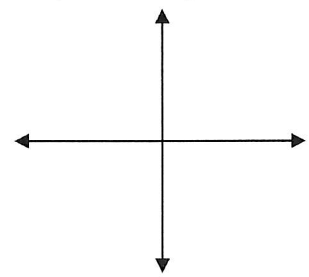
10.1) $\vec{R}$ = 2.5 m, 20° N of W



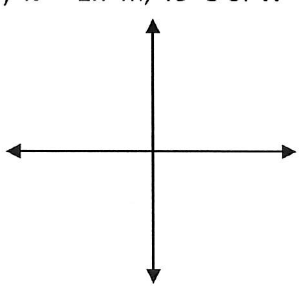
10.2) $\vec{Z}$ = 3 m, 80° W of N



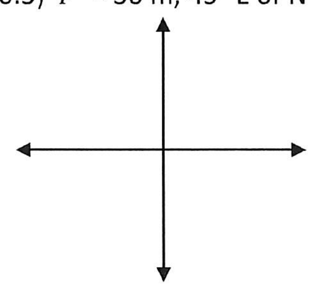
10.3) $\vec{C}$ = 15 m, 70° N of E



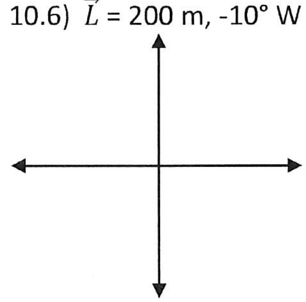
10.4) $\vec{h}$ = 1.7 m, 40° S of W



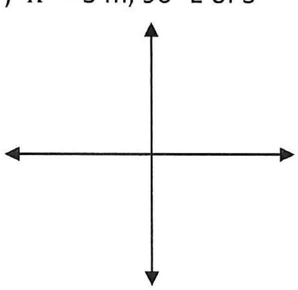
10.5) $\vec{F}$ = 30 m, 45° E of N



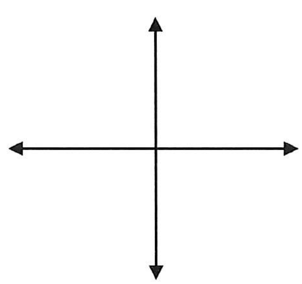
10.6) $\vec{L}$ = 200 m, -10° W of N



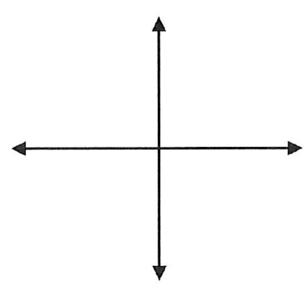
10.7) $\vec{K}$ = 5 m, 90° E of S



10.8) $\vec{E}$ = 49 m, 45° S of E



10.9) $\vec{g}$ = 4 m, 20° W of S



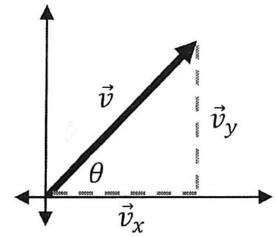
* Convert angles to starting from x-axis (horizontal) *
Then we can always use $V_x = V\cos\theta$, $V_y = V\sin\theta$

Part 11
Calculating Components

★★★★★

All vectors can be expressed by how much they extend into the x & y axis. These values are known as components. By considering a vector to be a right triangle, trigonometry can be used to find the components of any vector.

C = cos, S = sin



$\sin\theta = \frac{opp}{hyp}$

$\cos\theta = \frac{adj}{hyp}$

$V_x = V\cos\theta$, $V_y = V\sin\theta$

Examples:

$\vec{v} = 40\,m, 30°\ N\ of\ E$	$\vec{a} = 10\,m, 20°\ W\ of\ S$	$\vec{F} = 100\,m, -60°\ S\ of\ E$	$\vec{z} = 100\,m, 90°\ W\ of\ N$
40, 30° $\boxed{\langle 40\cos 30, 40\sin 30\rangle}$	10, 20, 70° $\boxed{\langle -10\cos 70°, -10\sin 70°\rangle}$ or $\boxed{-10\langle \cos 70°, \sin 70°\rangle}$	100, 60° $\boxed{\langle 100\cos 60°, 100\sin 60°\rangle}$	90, 100 $\langle -100\cos 0, 100\sin 0\rangle$ $\Rightarrow$ $\boxed{\langle -100, 0\rangle}$

Practice:

Find the x & y components of each vector. Questions 1-9 are the same vectors from the previous page.

11.1) $\vec{R}$ = 2.5 m, 20° N of W

11.2) $\vec{Z}$ = 3 m, 80° W of N

11.3) $\vec{C}$ = 15 m, 70° N of E

11.4) $\vec{h}$ = 1.7 m, 40° S of W

11.5) $\vec{F}$ = 30 m, 45° E of N

11.6) $\vec{L}$ = 200 m, -10° W of N

11.7) $\vec{K}$ = 5 m, 90° E of S

11.8) $\vec{E}$ = 49 m, 45° E of S

11.9) $\vec{g}$ = 4 m, 20° W of S

11.10) $\vec{b}$ = 20 m, 40° W of S

11.11) $\vec{D}$ = 15 m, 90° N of W

11.12) $\vec{A}$ = 88 m, 12° S of E

11.13) $\vec{J}$ = 6 m, 6° E of S

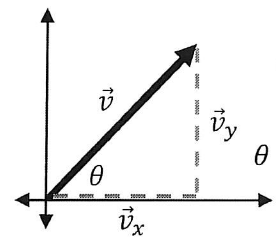
11.14) $\vec{P}$ = 100 m, -15° N of E

11.15) $\vec{q}$ = 45 m, 5° W of N

Additional Instruction from Khan Academy

Part 12
Calculating Magnitude & Direction

Since any vector can be expressed by its components, the information about the vector's magnitude and direction must be stored within those components. With a little more trigonometry, we can determine these values.



$$a^2 + b^2 = c^2$$

$$\theta = \tan^{-1}\left(\frac{opp}{adj}\right)$$

Examples:

$a_x = 4\,m \quad a_y = 8\,m$	$\vec{w} = <3, -5> m$	$m_x = -4\,m \quad m_y = -4\,m$	$k_x = -3\,m \quad k_y = 10\,m$
8, 4, θ	3, 5, θ	4, 4, θ	10, 3, θ
hyp = 8.94m	hyp = 5.83m	hyp = 5.66m	hyp = 10.44m
$\theta = \tan^{-1}\left(\frac{8}{4}\right)$	$\theta = \tan^{-1}\left(\frac{5}{3}\right)$	$\theta = 45°$	$\theta = \tan^{-1}\left(\frac{10}{3}\right)$
$\theta = 63.4°$	$\theta = 59.04°$		$\theta = 73.3$
$\boxed{8.94m, 63.4° \text{ N of E}}$	$\boxed{5.83m, 59.04° \text{ S of E}}$	$\boxed{5.66m, 45° \text{ S of W}}$	$\boxed{10.44m, 73.3° \text{ N of W}}$

Practice:

Sketch each vector and calculate its magnitude and direction.

12.1) $r_x = 2\,m \quad r_y = 10\,m$

12.2) $m_x = -14\,m \quad m_y = 20\,m$

12.3) $v_x = 0\,m \quad v_y = 4\,m$

12.4) $\vec{g} = <-50, 250> m$

12.5) $c_x = 40\,m \quad c_y = -60\,m$

12.6) $r_x = -5.5\,m \quad r_y = -10.2\,m$

12.7) $q_x = 10\,m \quad q_y = -0.5\,m$

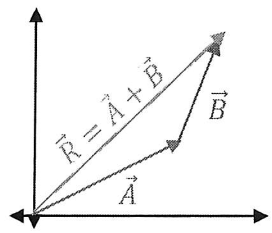
12.8) $\vec{a} = <-14, \ -14> m$

12.9) $b_x = 120\,m \quad b_y = 210\,m$

Additional Instruction from Khan Academy

Part 13
Vector Addition

Since vectors have direction, you cannot add and subtract them without taking their directions into consideration. Luckily, you can simply add their components together, since their components are always in the same direction:



$$R_x = A_x + B_x$$
$$R_y = A_y + B_y$$
$$|\vec{R}| = \sqrt{{R_x}^2 + {R_y}^2}$$
$$\theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$

Examples:

$\vec{A} = <3\,,6>m$	$\vec{B} = <4\,,-1>m$	$\vec{C} = <-5\,,3>m$	$\vec{D} = 10\,m, 30°\,S\ of\ E$
$\vec{A}+\vec{B}$ $<3,6> + <4,-1>$ $\Rightarrow \boxed{<7,5>}$	$\vec{B}+\vec{C}$ $<4,-1> + <-5,3>$ $\Rightarrow \boxed{<-1,2>}$	$\vec{A}-\vec{C}$ $<3,6> - <-5,3>$ $\Rightarrow <3,6> + <5,-3>$ $\Rightarrow \boxed{<8,3>}$	$\vec{A}+\vec{D}$ 30° 10m $<3,6> + <10\cos 30°, -10\sin 30°>$ $\Rightarrow <11.66, 1>$

Practice:

For each question, add the vectors given. Find the magnitude and direction of the resultant vector and sketch it.

13.1) $\vec{E} = <-8,3>m \quad \vec{L} = <-5,-2>m$

13.2) $\vec{S} = <10,3>cm \quad \vec{V} = <-5,7>cm$

13.3) $\vec{D} = <2,2>in \quad \vec{X} = <4,4>in$

13.4) $\vec{F} = <-10,-4>mi \quad \vec{K} = <15,-2>mi$

13.5) $\vec{Z} = <5,4>m \quad \vec{T} = 5$ m, 30° E of N

13.6) $\vec{S} = <-6,-10>m \quad \vec{J} = 20$ m, 30° S of W

13.7) $\vec{F} = 8$ N, 60° N of E $\quad \vec{M} = 10$ N, 20° E of N

13.8) $\vec{O} = 5$ m, 60° N of E $\quad \vec{P} = 400$ cm, 20° S of W

Additional Instruction from Khan Academy

Quiz 5
Vectors

Sketch the vector and determine its components.

5a) $\vec{A} = 10\ m, 30^\circ\ N\ of\ E$

Sketch the vector and determine it's magnitude and direction

5b) $\vec{B} = < 5 , 7 >\ m$

5c) $\vec{C} = 8\ m, 40^\circ\ W\ of\ N$

5d) $D_x = 6\ m \quad D_y = -12\ m$

5e) $\vec{E} = 15\ m, 80^\circ\ S\ of\ E$

5f) $\vec{F} = < -10 , -8 >\ m$

Determine the magnitude & direction of the resultant vector, then sketch it.

5g) $\vec{A} + \vec{C}$

5h) $\vec{B} - \vec{D}$

5i) $\vec{C} + \vec{E}$

5j) $\vec{A} + \vec{F} + \vec{B}$

Part 14
1D Motion

★★★☆☆

Distance and Displacement are our basic tools for establishing motion. Speed and Velocity are the rates of change of both respectively. All of physics stems from a core understanding of these four concepts.

d =distance total length traveled	$s = \frac{d}{t}$
$\overrightarrow{\Delta x}$ =displacment change in position from starting point	$\vec{v} = \frac{\overrightarrow{\Delta x}}{t}$

ΔX = Final pos. − initial pos. $= X_f - X_0$

Examples: .

A ball rolls 4 m forward in 2 s, 10 m backward in 4 seconds, then 22 m forward in 10 seconds.	A cart starts at x = 0 m. It moves to x = 14 m in 5 seconds, then to x = 22 m in 2 seconds, then to x = -20 m in 8 seconds.
distance $= 4+10+22 = \boxed{36m} \leftarrow d$ displacement $= 4-10+22 = \boxed{16m} \leftarrow \Delta X$ $t = 2+4+10 = \boxed{16s}$ $S = \frac{36}{16} = \boxed{2.25 m/s = S}$ $\vec{V} = \frac{\Delta X}{t} = \frac{16}{16} \Rightarrow \boxed{V = 1 m/s}$	$d = 14 + 8 + 42 = \boxed{64 m = d}$ $\Delta X = -20 - 0 \Rightarrow \boxed{\Delta X = -20m}$ $t = 5+2+8 = 15s$ $S = \frac{d}{t} = \frac{64}{15} \Rightarrow \boxed{S = 4.27 m/s}$ $V = \frac{\Delta X}{t}$ $V = \frac{-20}{15}$ $\boxed{V = -1.33 m/s}$

Practice:

Find the distance, displacement, speed and velocity in each problem.

14.1) A car moves 3 mi North then 11 mi south, which takes 3 hours.

14.2) A swimmer swims 100 yds forwards in 35 seconds, then another 50 yards forwards in 10 s.

14.3) A boat moves 10 km west in 2 hours, 1 km east in 1 hour, then 4 km west in 2 hours.

14.4) An airplane travels 600 mi north in 4 hours, then 1000 mi south in 14 hours.

14.5) A train travels from 400 mi Buffalo to NYC in 10 hours. It then makes the return trip in 8 hrs.

14.6) A ball starts at x = 0 and travels to x = 14 m in 2 seconds, then travels to x = -42 m in 10 seconds, then travels to x = 2 m in 8 seconds.

14.7) A man starts at his house and walks 150 m forward in 70 seconds. He then runs backward for 20 seconds, ending 50m behind his house.

14.8) A girl runs forward at 5 m/s for 14 seconds, then walks backward at 2 m/s for 20 seconds, then sprints backward at 8 m/s for 5 seconds.

Additional Instruction from Mr. Williams

Part 15
2D Motion

In the real world, objects are not limited to moving only forwards or backwards. In this section we examine how to analyze motion when an additional degree of freedom is added.

$$s = \frac{d}{t} \qquad |\vec{R}| = \sqrt{{R_x}^2 + {R_y}^2}$$

$$\vec{v} = \frac{\overrightarrow{\Delta x}}{t} \qquad \theta = \tan^{-1}\left(\frac{R_y}{R_x}\right)$$

Examples:

1. A man walks 50 m North in 5 seconds, 40 m west in 8 seconds, then 20 m South in 2 seconds. $d = 50 + 40 + 20$

$X_f = \langle -40, 30 \rangle \Rightarrow \boxed{|\vec{x}| = 50\,m}$ $\boxed{t = 15\,s}$ $\boxed{d = 110\,m}$

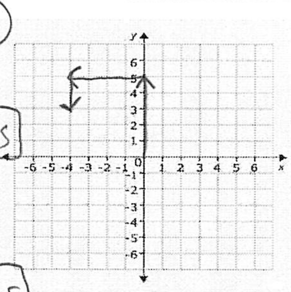
$S = \frac{d}{t} = 110/15 \Rightarrow \boxed{7.33\,m/s = S}$ $V = \Delta x / t = 50/15 \Rightarrow \boxed{V = 3.33\,m/s}$

2. A hiker moves 4 km South, 5 km West, 10 km North, 8 km East, then 2 km South. This takes 15 hours. $\boxed{d = 29\,km}$

$X_f = \langle 3, 4 \rangle\,km \Rightarrow \boxed{|\vec{x}| = 5\,km}$ $\boxed{t = 15\,hr}$

$S = d/t = 29/15 \Rightarrow \boxed{S = 1.93\,km/hr}$ $V = \frac{\Delta x}{t} = \frac{5}{15} \Rightarrow \boxed{V = \frac{1}{3}\,km/hr}$

1



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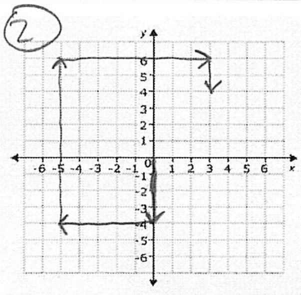
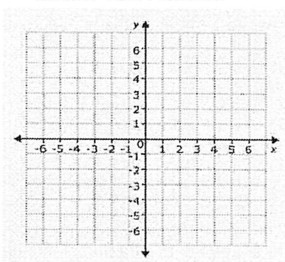


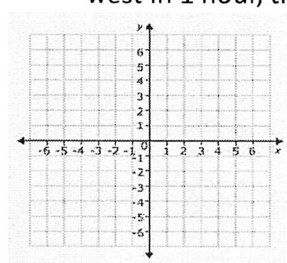
Practice:

Find the distance, displacement, speed and velocity in each problem.

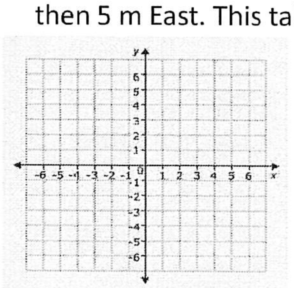
15.1) A cat moves 3 mi North then 7 mi East, which takes 1.5 hours.



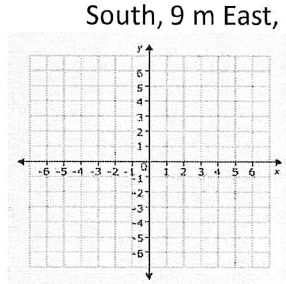
15.2) A hiker walks 5 miles north in 2 hours, 3 miles west in 1 hour, then 8 miles south in 3 hours.



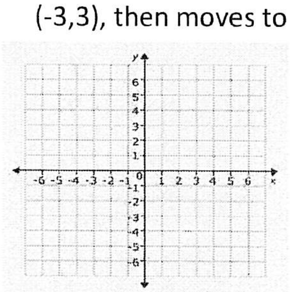
15.3) A car travels 6 m South, 3 m West, 9 m North, then 5 m East. This takes 10 seconds.



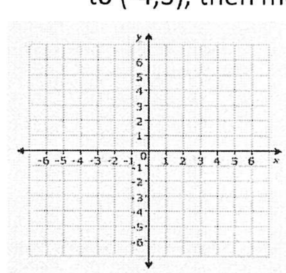
15.4) A dog runs 4 m West, 3 m North, 2 m West, 8 m South, 9 m East, then 8 m North. This takes 3 s.



15.5) A woman starts at (0 m, 0 m) moves to (0,-5), to (-3,3), then moves to (4,3). This takes 20 s.



15.6) A man starts at (0 m, 0 m) moves to (5,3), moves to (-4,3), then moves to (0,-4). This takes 30 s.



Part 16
Word Problems

★★★★☆ *Much of physics is being given a situation and asked to solve for some unknown value. This is an exercise in identifying what is known and using the correct equation to solve for the unknown.*

$$s = \frac{d}{t} \qquad t = \frac{d}{s} \qquad d = st$$

$$\vec{v} = \frac{\overrightarrow{\Delta x}}{t} \qquad t = \frac{\overrightarrow{\Delta x}}{\vec{v}} \qquad \overrightarrow{\Delta x} = \vec{v}t$$

Examples:

west = negative

A train is traveling at an average rate of 30 km per hour. How far does the train travel (in mi) after 3.5 hrs.	A cow runs at a velocity of 5 mi/hr to the west. How long does it take the cow to move 30 m west?
$s = \frac{30\,km}{hr}$, $t = 3.5\,hr$, $d = ?$ $s = \frac{d}{t} \Rightarrow d = st \Rightarrow d = \frac{30\,km}{\cancel{hr}} \cdot 3.5\,\cancel{hr}$ $\Rightarrow d = 105\,km$ $105\,\cancel{km} \cdot \frac{1\,mi}{1.6\,\cancel{km}} \Rightarrow \boxed{d = 65.6\,mi}$	$V = -5\,mi/hr$, $\Delta X = -30\,m$, $t = ?$, $1\,mi = 1609\,m$ $V = \frac{-5\,\cancel{mi}}{hr} \cdot \frac{1609\,m}{1\,\cancel{mi}} \Rightarrow V = -8045\,m/hr$ $V = \frac{\Delta X}{t} \Rightarrow t = \frac{\Delta X}{V} \Rightarrow t = \frac{-30\,m}{-8045\,m/hr}$ $\boxed{t = 0.0037\,hr}$

Practice:

Solve each problem for the indicated quantity.

16.1) A car travels at 18 km/hr for 0.8 hrs. What is the cars distance traveled in meters?

16.2) A ball rolls at a speed of 2.5 m/s. It rolls 25 m forward then 1800 cm backward. How long does this take?

16.3) A plane travels 18 mi North then 22 mi East. This takes 5 hrs. What is the velocity of the plane in m/s?

16.4) A car travels once around a 200 m long circular track, taking 12 seconds. What is the car's speed and velocity?

16.5) A ball is rolling at -2 m/s for 10 seconds. It's then kicked and travels 100 m forward, which takes 20 seconds. What is the ball's average distance, displacement, speed, and velocity?

16.6) A boat travels at a heading of 20° E of N. After 2 hours the captain knows his x-displacement is 3,000 m. What is his y-displacement? What is his total displacement? Total velocity?

16.7) A woman sprints at 5 m/s forward for 25 seconds then walks at 2 m/s backward for 2 mins. Find d, Δx, s, and v.

16.8) A pilot flies at 100 km/hr for 2 hours at a heading of 30° S of E. They then turn and fly at 150 km/hr for 2.5 hours due West. What is the total displacement of the plane?

Quiz 6
1D Motion

Answer the questions about the following situation:

A sprinter is training for the Olympics and is doing some practice runs. He starts by running forward 2.8 x 10^{-8} Gm, which takes him 22 seconds (Part A). He then takes a break for 30 seconds to catch his breath (Part B). He then turns around and runs back towards where he started, but ends up 244 inches past that point. He makes that run in 1.2 minutes (Part C).

6a) What was the sprinter's velocity (in m/s) of Part A? What about in (ft/min)

6b) What was the sprinter's velocity (in m/s) of the Part B? What about in (cm/year)

6c) What was the sprinter's velocity (in m/s) of the Part C? What about in (mm/hour)

6d) Would the speed in Parts A-C be any different than the velocities you found?

6e) What was the sprinter's total distance traveled in μm? Write your answer in scientific notation.

6f) What was the sprinter's total displacement in Gm? Write your answer in scientific notation.

6g) What was the sprinter's average speed in m/s (over the whole time)

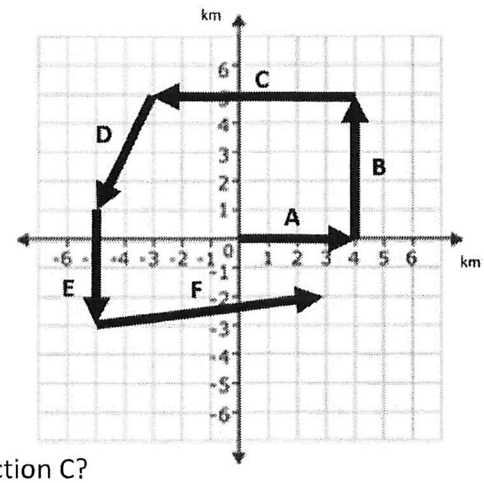
6h) A student derives an equation to determine the average velocity: Rearrange the equation for Δx_B

$$\vec{v}_{avg} = \frac{\Delta x_A + \Delta x_B + \Delta x_C}{t_{total}}$$

6i) Is the equation valid (does it correctly relate these quantities this way)? Support your answer.

Quiz 7
2D Motion

Answer the questions about the following situation:



Kathy goes for a jog around the neighborhood as shown in the diagram to the right.

The time it take her to complete each section is given below:

A = 0.5 hrs	B = 1.25 hrs	C = 2 hrs
D = 1 hr	E = 0.25 hrs	F = 3 hrs

Note the scale of the graph. You may express all distances in km and times in hours, unless otherwise indicated.

7a) What is Kathy's displacement (magnitude and direction) during section C?

7b) What is Kathy's displacement (magnitude and direction) from sections A through C?

7c) What is Kathy's velocity (magnitude and direction) during section D?

7d) What is Kathy's velocity (magnitude and direction) during section F?

7e) In which section (out of them all) is Kathy's *speed* the largest? Smallest?

7f) What was the total distance traveled by Kathy?

7f) What is Kathy's average speed over the entire time?

7f) What is Kathy's average velocity (magnitude and direction) over the entire time?