## Physics 12

## - Text: Gordon F




Puppet Theoretical Physics

## Scalars vs. Vectors

- Scalars: have a magnitude but no direction:
- mass
- time
- distance
- speed
- Vectors: have magnitude and direction
- force
- momentum
- displacement
- velocity


## Adding Vectors

- We always rearrange vectors to add them tip-to-tail.
- The resultant is the vector that reaches from the tail of the $1^{\text {st }}$ to the tip of the $2^{\text {nd }}$



## Subtracting Vectors

- We can think of vector $A-B$ as being equivalent to $A+(-B)$



## Exercises

- P. 7\#1-2 (draw the resultant)



## Rules for moving vectors around

- You may slide a vector to a different location
- You may not change its length
- You may not change its direction



## Tug of war!

- Pull 20 N South, other students resist
- What is the resultant?
- Now take a picture!



## Exercises

- P. 7\#1-2 (draw the resultant)
- P. 8 \#1-4
- P. 11 \#1-3
- Set up experiment 1-1 p. 9-10


## Lab 1-1

Purpose: in your own words
Procedure :refer to text p.9, but...
Observations:-measurements, diagram
Questions:
-none
Conclusions:
-summarize your findings, sources of error, and possible improvements

- Draw 2 scale diagrams for the force vectors: one "free body diagram", one "tip-to-tail"
- Solve for the \% error using:

$$
\begin{gathered}
\text { \%error }=\frac{\text { error }}{\text { average }} \\
\text { \%error }=\frac{0.6 \mathrm{~N}}{(3+4+5) / 3} \\
\text { \%error }=\frac{0.6 \mathrm{~N}}{4 \mathrm{~N}} \\
\text { \%error }=15 \%
\end{gathered}
$$



## \% Error

- Use the result from your vector triangle above
- Solve for the \% difference using:

$$
\begin{gathered}
\% \text { Error }=\frac{\text { Error }}{\text { Average }} \times 100 \% \\
=\frac{0.7 N}{4 N} \times 100 \% \\
=18 \%
\end{gathered}
$$



## Conclusion

- Summarize your results, including \% error from the scale diagram
- How confident are you that your results support or refute the hypothesis?
- State sources of error, and possible improvements



# Lab Reports • Observations <br> - data table? <br> - graph? 

- Dark ink or electronic format!
- Headings
- title, name, date, partner
- Purpose
- in your own words
- Questions
- complete sentences
- Conclusions
- Should include a discussion of results, sources of error and possible improvements
- Procedure
- Sample:

- Sample:

$$
\begin{gathered}
c^{2}=a^{2}+b^{2}-2 a b \cos C \\
c^{2}=3^{2}+4^{2}-2 \cdot 3 \cdot 4 \cdot \cos 89 \\
c=4.96 N
\end{gathered}
$$

## \% Difference

- Use the result from your vector triangle above
- Solve for the \% difference using:

$$
\begin{gathered}
\text { \%difference }=\frac{\text { Experimental }- \text { Theoretical }}{\text { Theoretical }} \\
\text { \%difference }=\frac{4.96-5.0}{5.0} \\
\text { \%difference }=-0.8 \%
\end{gathered}
$$

## Graphs

- Must have:
- title
- appropriate labels,
- scaled axes
- best fit line, not connect-the-dots!

- Should take up most of the page
- Should give us useful information...


## I'm going to make you learn to appreciate me, differentiate me

## -Marshall Mathers





## Displacement

- Distance is a measurement of how far you have travelled and depends on the path

57 km

- Displacement is independent of path because it simply measures the change in position
$d=12 \mathrm{~km} \leftarrow W e s t$
- Ex 1. Sebastian walks 15 blocks North then 10 blocks South. Find his:
- distance:
$\mathrm{d}=15$ blocks +10 blocks=25 blocks
- displacement

$$
\begin{gathered}
d=15 \text { blocks }+(-10 \text { blocks }) N \\
d=5 \text { blocks } \uparrow \text { North }
\end{gathered}
$$

- Ex 2. Gurneet dribbles 7 m East then 10 m North. Find her displacement :
- Ex 2. Gurneet dribbles 7.0 m East then 10.0 m North. Find her displacement :

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

$$
d^{2}=7^{2}+10^{2}
$$

$$
d=12 m
$$

$$
\theta=\tan ^{-1}\left(\frac{y}{x}\right)=\tan ^{-1}\left(\frac{10}{7}\right)
$$

$$
d=12 m, 55^{\circ} N o f E
$$




- Ex 3. Ben skates 7.0 m East then 10 m Northeast. Find his displacement :
$c^{2}=a^{2}+b^{2}-2 a b \cos C$
$d^{2}=7^{2}+10^{2}-2 \cdot 7 \cdot 10 \cdot \cos 135$
$d=16 m$
sin law
$\frac{\sin A}{a}=\frac{\sin B}{b}$

$$
\theta=\sin ^{-1}\left(\frac{10 \cdot \sin 135}{15.75}\right)
$$

$\frac{\sin \theta}{10}=\frac{\sin 135}{15.75}$

$$
d=16 m, 27^{\circ} N o f E
$$

## Exercises

- P. 7 \#1-2
- P. 8 \#1-3
- P. 11 \#1-3
- Hand in experiment 1-1 p. 9-10
- Friday is a quiz day -


Bonus: Vladislav Tretiak attempts to save a hockey puck shot from 12 m away at an angle of 13 degrees above the horizontal. What was the velocity of the puck when it left Paul Henderson's stick, if it reaches the goal in 0.32 s ?


## Components

- Every vector can be written as the sum of its $x$ and $y$ components
- This offers another method for adding vectors. We can add the components to get the $x$ and $y$ components of the resultant
- Ex: Vector $\mathrm{A}=55 \mathrm{~N}, 30^{\circ}$ above horizontal

$$
\begin{aligned}
A_{x} & =A \cos \theta & A_{y} & =A \sin \theta \\
& =48 N & & =28 N
\end{aligned}
$$



- Component method:


$$
\begin{aligned}
& a_{x}=7 m \\
& b_{x}=b \cos \theta=7.07 m \\
& c_{x}=a_{x}+b_{x}=14.07 m
\end{aligned}
$$

$$
b_{y}=b \sin \theta=7.07 m
$$

$$
c_{y}=a_{y}+b_{y}=7.07 \mathrm{~m}
$$


$d=16 m, 27^{\circ} N o f E$

## Exercises

P. 17 q's 2-5 (don't hand in)

Finish experiment 1-1 p. 9-10 (do hand in) \#FIAQD (Friday is a quiz day)

## Relative Velocity

- Since velocity is relative, we need to be specific about the reference frame
- Ex 1: Lindsay can throw the ball $5 \mathrm{~m} / \mathrm{s}$ while running at $3 \mathrm{~m} / \mathrm{s}$. What velocity does Keysha measure? Does direction matter?

$$
v_{a b}=v_{a c}+v_{c b}
$$



$$
v=5+3=8 m / s
$$

$$
v=5+(-3)=2 \mathrm{~m} / \mathrm{s}
$$

## In General:

## $\mathcal{V}_{a b}=\mathcal{V}_{a c}+\mathcal{V}_{c b}$



- If you're not sure the subscripts are set up correctly, note how the inside subscripts "cancel out"


## Ex: Kayaking

- Kobe can paddle his kayak at $3.5 \mathrm{~m} / \mathrm{s}$. Find his velocity WRT* the shore if he is paddling South across a $5.5 \mathrm{~m} / \mathrm{s}$ East current
- *With Respect To (relative to)

$$
\begin{array}{rl}
v^{2}=v_{x}^{2}+v_{y}^{2} & v=6.5 \mathrm{~m} / \mathrm{s} \\
\theta=\tan ^{-1}\left(\frac{y}{x}\right) & =32^{\circ} S \cdot o f \cdot E
\end{array}
$$



## Ex 3: Flying

- Jack's gyrocopter can fly with an airspeed of $155 \mathrm{~m} / \mathrm{s}$.
- Find his velocity if he flies North into a $35 \mathrm{~m} / \mathrm{s}$ "Northwesterly" headwind
- cf: wind direction is usually given as the direction the wind is coming from!


$$
\begin{aligned}
& v_{c g}=v_{c a}+v_{a g} \\
& c^{2}=a^{2}+b^{2}-2 a b \cos C \\
& \frac{\sin A}{a}=\frac{\sin B}{b}
\end{aligned}
$$

$$
\begin{aligned}
& c^{2}=a^{2}+b^{2}-2 a b \cos C \\
& v=133 m / s \\
& \frac{\sin A}{a}=\frac{\sin B}{b} \\
& \theta=\sin ^{-1}\left(\frac{a \sin B}{b}\right)=\sin ^{-1}\left(\frac{35 \sin 45}{132.5}\right)=11^{\circ} \\
& v=133 m / s \rightarrow 79^{\circ} N \cdot o f \cdot E
\end{aligned}
$$

- Design an experiment to measure relative velocities in 2 dimensions.
- Ex: Was this a forward pass?
- Use video physics (iOS) or vidanalysis (android)
- Use the passer's velocity and ball's velocity to find pass velocity





## - How are we assessed?

Evidence of personal engagement is clear.
A fully focused research question clearly demonstrates inquiry skills.
Significant independent thinking with a well justified hypothesis. Background information enhances understanding. Methodology is fully appropriate.
Full consideration of sufficiency and reliability of data, including uncertainty.
Plans explain safety, ethical and environmental considerations (global citizenship).
The report includes sufficient relevant quantitative and/or qualitative raw data.
Appropriate and sufficient data processing is carried out with accuracy.
Full and appropriate consideration of the impact of measurement uncertainty.

Conclusion is relevant to the research question and is justified with support from the data presented.
Conclusion is correctly described and justified through relevant comparison to the accepted scientific context.

Strengths and weaknesses of the investigation are explained and provide evidence of a clear understanding.
Student has shown adaptability by providing realistic and relevant suggestions for improvement of the investigation. A meaningful extension and real world application is discussed.

The structure and format are appropriate and writing is concise. Excellent use of subject-specific terminology. Any errors do not hamper understanding.

## Ex 4: Hockey

- Joshua skates towards a rebound with a velocity of $15 \mathrm{~m} / \mathrm{s}$ in a direction of $57^{\circ} \mathrm{N}$ of E .
- Find the velocity the goalie observes if the puck leaves his stick at $35 \mathrm{~m} / \mathrm{s} \mathrm{N}$


$$
\begin{gathered}
c^{2}=a^{2}+b^{2}-2 a b \cos C \\
\frac{\sin A}{a}=\frac{\sin B}{b} \quad 48.3 \mathrm{~m} / \mathrm{s}, 10^{\circ} \mathrm{E} \text { of } \mathrm{N}
\end{gathered}
$$

## Part 2

- What direction should he shoot the puck if he wants the puck to go due North WRT (with respect to) the goal?


$$
\begin{aligned}
& v_{p g}=v_{p b}+v_{b g} \\
& \frac{\sin A}{a}=\frac{\sin B}{b} \quad \frac{\sin 33}{35}=\frac{\sin B}{15} \\
& B=\sin ^{-1}\left(\frac{15 \sin 33}{35}\right) \quad B=14^{\circ}
\end{aligned}
$$

## Ex: set up the triangle and solve:

- Ian is flying with an airspeed of 150 km/h South, with a $55 \mathrm{~km} / \mathrm{h}$ North by Northwesterly tailwind. Find his ground speed and direction

$$
\begin{gathered}
v_{p g}=v_{p a}+v_{a g} \\
v_{e g}^{2}=55^{2}+150^{2}-2 \cdot 55 \cdot 150 \cdot \cos 157.5 \\
v_{e g}=202 \mathrm{~km} / \mathrm{h}
\end{gathered}
$$



$$
\begin{gathered}
\frac{\sin \theta}{55}=\frac{\sin 157.5}{202} \\
\theta=5.98^{\circ} \\
v=202 \mathrm{~km} / \mathrm{h} 84^{\circ} \mathrm{Sof} E
\end{gathered}
$$

## Ex 2b: What course to correct to true South?

- lan is flying with an airspeed of $150 \mathrm{~km} / \mathrm{h}$, with a $55 \mathrm{~km} / \mathrm{h}$ North by Northwesterly tailwind.

$$
\begin{aligned}
& \frac{\sin \theta}{55}=\frac{\sin 22.5}{150} \\
& \theta=\arcsin \frac{55 \sin 22.5}{150} \\
& \theta=8 \mathrm{O} \text { WofS }
\end{aligned}
$$



# Ex 3: set up the triangle and solve: 

- David is flying with an speed of $150 \mathrm{~km} / \mathrm{h}$ into a $55 \mathrm{~km} / \mathrm{h}$ North by Northwesterly wind. What direction does he have to fly to have a resultant direction $31^{\circ} \mathrm{S}$ of W ?

$$
v_{p g}=v_{p a}+v_{a g}
$$




$$
\frac{\sin \theta}{55}=\frac{\sin 81.5}{150}
$$

$$
\theta=21.3^{\circ}
$$

fly $\rightarrow 9.7^{\circ}$ SofW

## Exercises

- P. 20 \#1-3
- Start P. 20-21 \#1-8


## Try it!

- Design an experiment for adding vector velocities
- Film two videos of the motion, one in $x$ direction, one in y-direction
- Draw a large "birds eye view" diagram
- Calculate resultant velocity
- Conclusion: state strengths, weaknesses, possible improvements



## How do you reach equilibrium?



## Translational Equilibrium

- This is a fancy way of saying $a=0$
- It then follows from Newton's 2nd that:

$$
F_{\text {net }}=0 \propto \quad \sum F=0
$$

- Since we deal with Newton's $2^{\text {nd }}$ law in one dimension at a time, we can also say:

$$
\sum F_{x}=0 \quad \text { and } \quad \sum F_{y}=0
$$

- Ex 1: Traffic light equilibrium
- find the weight of the traffic light from the following diagram:

Todar's Lesson: Wo or "Witten's Dog" - $W_{0}$ N Nevteon Enerusted



$$
c^{-}+p-a+\nu
$$

 StRn'G THEORY"

- First find the tension in the second cable

$$
\begin{gathered}
F_{n e t}=0 \quad F_{x}=0 \quad F_{1 x}+F_{2 x}=0 \\
F_{2 x}=-F_{1 x} \\
F_{2} \cos \theta_{2}=-F_{1} \cos \theta_{1} \\
F_{2}=\frac{-427 N \cos 118}{\cos 42}
\end{gathered}
$$

## How much tension?

- Find the tension in each of these strings

- Now the vertical forces:

$$
F_{n e t}=0 \quad F_{y}=0 \quad F_{1 y}+F_{2 y}+F_{g}=0
$$

$$
\begin{aligned}
& F_{g}=-F_{1 y}-F_{2 y} \\
& =-F_{1} \sin \theta_{1}-F_{2} \sin \theta_{2}
\end{aligned}
$$

$$
=-558 N
$$

$$
=-427 N \sin 118-270 N_{2} \sin 42
$$

- Find the mass of the light:

$$
\frac{\sin 104}{F_{g}}=\frac{\sin 48}{427 N}
$$



- Find F1:

$\frac{8.3}{\sin 46}=\frac{F_{1}}{\sin 23}$

$$
F_{1}=4.5 \mathrm{~N}
$$

## Exercises

- P. 20-21 \#1-8
- \#6: note rope should be horizontal

