At the end of this worksheet you should be able to

- define a force and discuss the types responsible for most observable interactions
- add vectors graphically
- decompose vectors and recombine components
- discuss Newton's first and third law.

1. What is a force? push or pull

2. List the common forces. Which are non-contact? Which are contact?

4 Known forces:
electromagnetic - noncontact
weak force
strong force
gravity (weight) - noncontact

Contact:
tension - support
friction
normal - support

3. How much force is 250 lbs in newtons? 1 lb = 4.45 Newtons or 1 Newton = 0.225 lb.

$$250\,\text{lb}\left(\frac{4.45\,\text{N}}{1\,\text{lb}}\right) = 1{,}112.5\,\text{N}$$

4. A person has a weight of 1,110 N. What is his mass in kg? $F_g = mg$ where g = 9.8 N/kg.

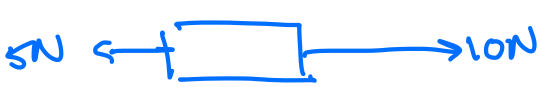
$$1110\,\text{N}\left(\frac{1\,\text{Kg}}{9.8\,\text{N}}\right) = 113\,\text{Kg}$$

<u>Vector Math, Graphical</u>

5. Two children a pulling a wagon. Sam pulls with a 5 N force and Ford pulls with a 10 N force.
   a) What is the net force on the wagon when Sam and Ford pull in the same direction?

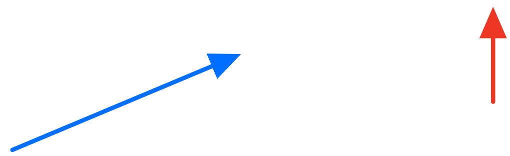
$F_{net} = 15\,\text{N}$ to the right

   b) What is the net force on the wagon when Sam and Ford pull in opposite directions?

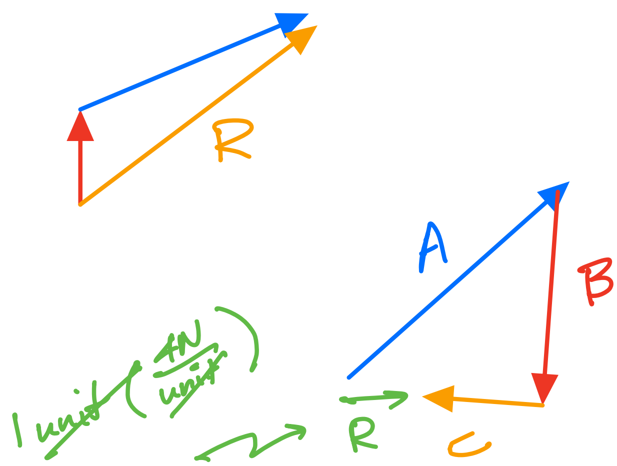


$F_{net} = 10 - 5 = 5\,\text{N}$ to the right

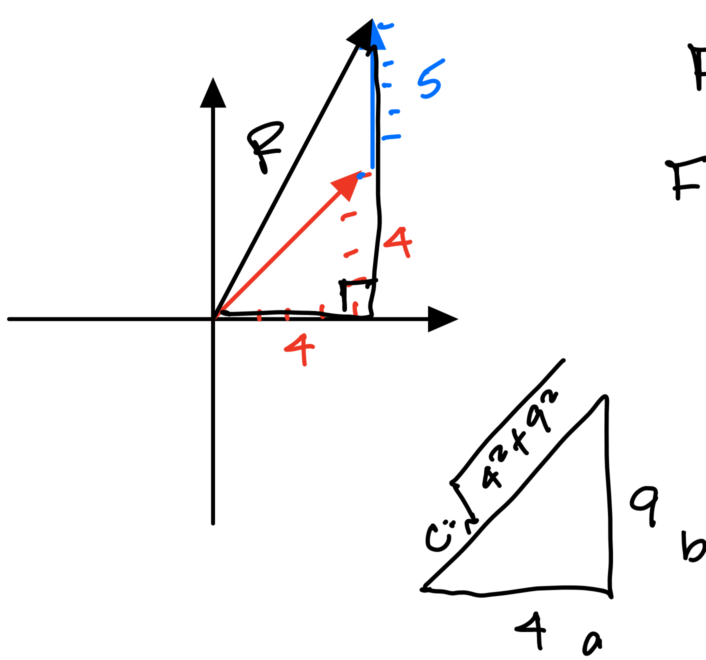
6. Draw two vectors represented as arrows, with one of them being approximately twice as big as the other and pointed in *different non-parallel directions*.



7. Graphically add these vectors up.



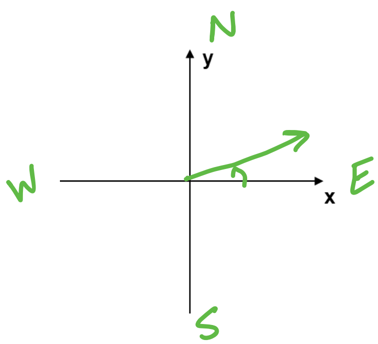
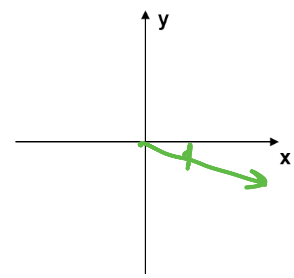
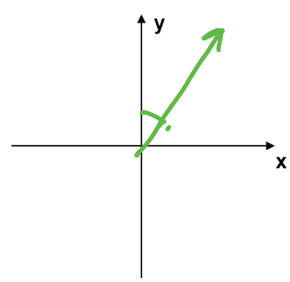
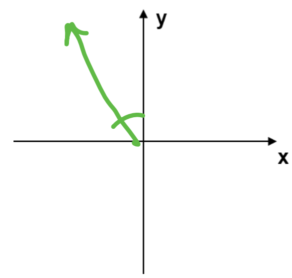
8. Show your results to someone else and look at their results. Draw their vector problem in the space below.



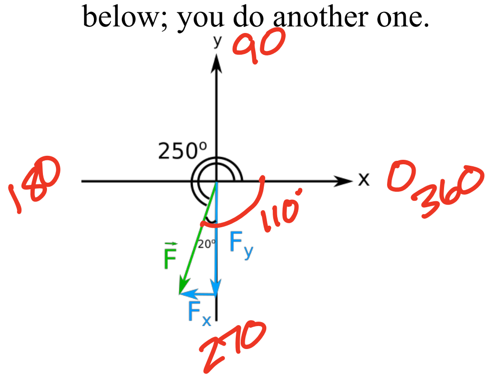
$F_x = 4 + 0 = 4$

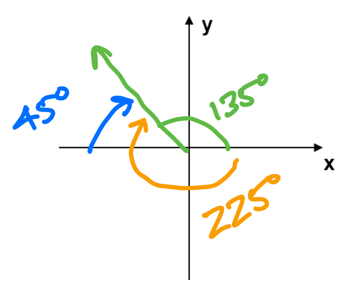
$F_y : 4 + 5 = 9$

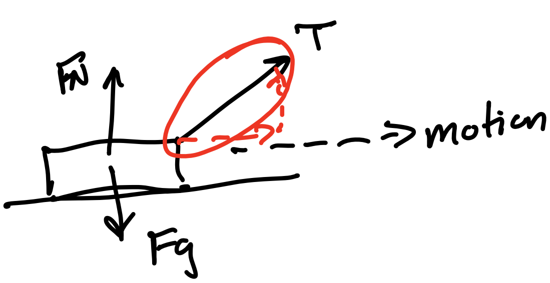
9. Draw a sketch of the following vectors and their components on the coordinate planes.

A vector is described as 20° *north of east*.  	A vector is described as 20° *south of east*. 
A vector is described as 20° *east of north*.  	A vector is described as 20° *west of north*. 

10. Draw out your own vector in any direction on the *x*-y coordinate plane, and describe its coordinates from both the nearest axis, and from the positive *x*-axis. I have done an example of this in the space below; you do another one.

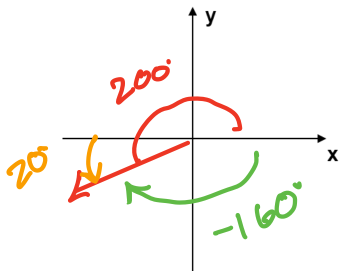




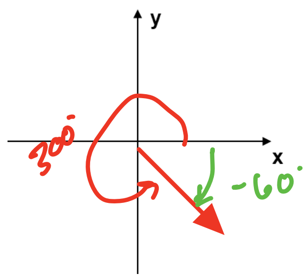


break Forces ∥ to motion
⊥ to motion

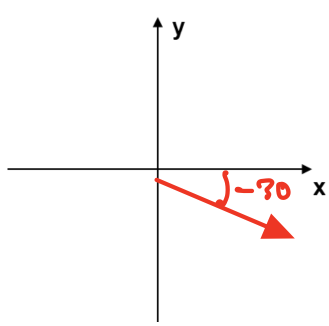
11. Draw a force that pulls 200° from the positive x-direction. Express this in three other equivalent ways.



12. A force pulls 300° from the positive x-direction. Express this in three other equivalent ways.

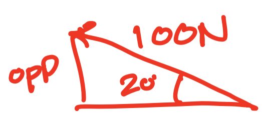


13. A vector is −30° from the positive x-direction. Express this in three other equivalent ways.

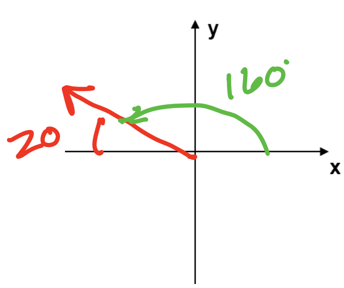


14. What are the x- and y-components of a 100 N force that is acting on an object at an angle that is 20° *north of west*?

SOH · CAH · TOA



$\sin\theta = \frac{opp}{hyp}$ $\cos\theta = \frac{adj}{h}$ $\tan\theta = \frac{opp}{adj}$



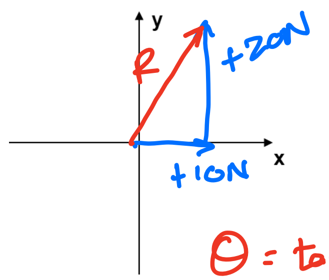
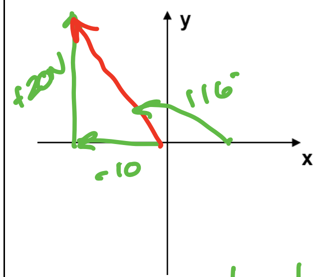
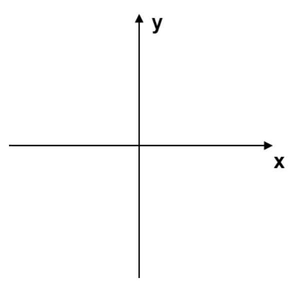
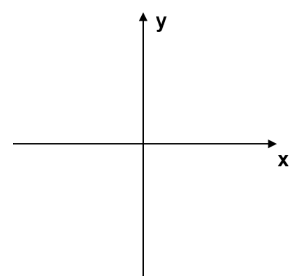
$opp = hyp * \sin\theta$

$adj = hyp * \cos\theta$

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

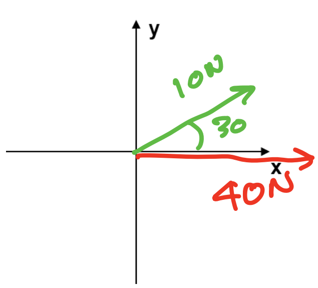
$\theta = \tan^{-1}\left(\frac{opp}{adj}\right)$

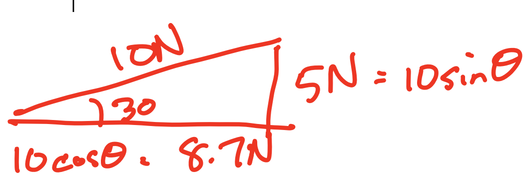
15. Determine the magnitude and direction of the following vectors.

A vector with an x-component of +10 N, and a y-component of +20 N  $R = \sqrt{10^2 + 20^2}$ $R = 22.4\ N$ $\theta = \tan^{-1}\left(\frac{20}{10}\right) = 63.4°$	A vector with an x-component of −10 N, and a y-component of +20 N  R: 22.4N θ: 116° calculator = −63.4° +180
A vector with an x-component of +10 N, and a y-component of −20 N 	A vector with an x-component of −10 N, and a y-component of −20 N 

Adding Vectors using Components

16. Vector $\vec{A}$ is 10 N 30° *north of east* and vector $\vec{B}$ is 40 N *east*. What is the vector sum of $\vec{A} + \vec{B}$?





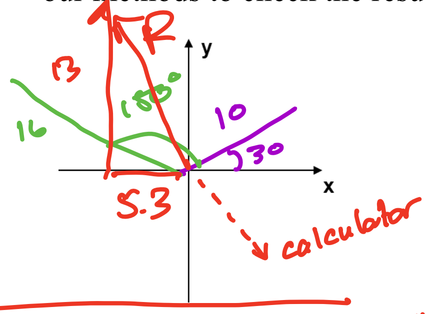
	x (N)	y (N)
10N	8.7	5
4N	40	0
	48.7	5

$R = \sqrt{48.7^2 + 5^2} = 49N$

$\theta = \tan^{-1}\left(\frac{5}{48.7}\right) = 5.9°$ ~~east of North~~

North of east

17. Use the simulation at https://phet.colorado.edu/sims/html/vector-addition/latest/vector-addition_all.html (Tab Explore 2D) to create a vector addition problem, and work through it with our methods to check the results.



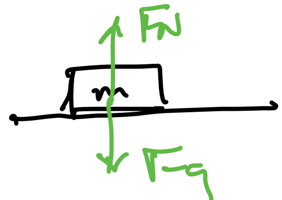
	x	y
10N @30°	10 cos 30 = 8.7	10 sin 30 = 5.0
16N @ 150°	16 cos 150 = -14	16 sin 150 = 8
Sum	-5.3	13

$R = \sqrt{(-5.3)^2 + (13)^2} = 14N$

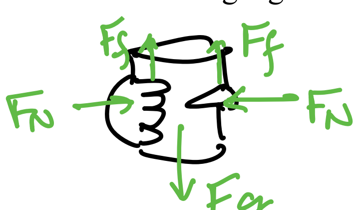
$\theta = \tan^{-1}\left(\frac{13}{-5.3}\right) = -68°$
$+180$
$112°$

Newton's Laws

18. A book is resting on a table. What forces are acting on the book? What forces are acting on the table?



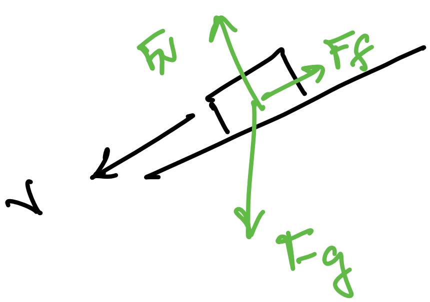
19. You are holding a glass in your hand. What forces are acting on the glass?



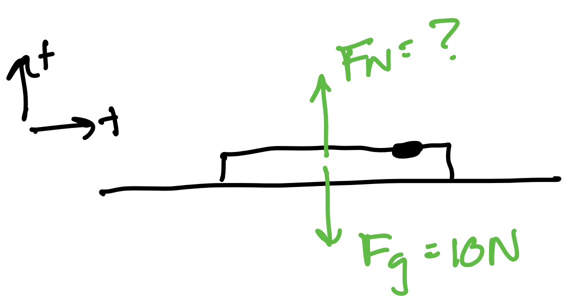
if an object is at rest, all forces must cancel (sum to zero)

$\Sigma F_x = 0 \qquad \Sigma F_y = 0$

20. A book is sliding down a *rough* table that is inclined on one side. What forces are acting on the book?



21. A phone rests on a horizontal table. The phone has a weight (Force of gravity) of 10 N. What must the normal force from the table be? (Rest = 0 N *net force* on the phone)



$F_{net} = m\cancel{a} \rightarrow 0$

$F_N - F_g = 0$

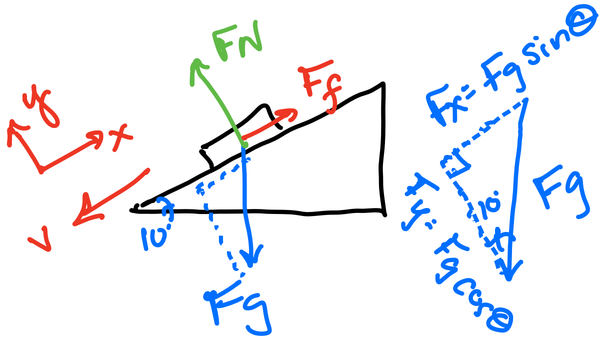
$F_N = F_g = 10N$ up

22. One side of the table that the 10-N phone is resting on is raised so that the surface is at a 10° angle with respect to the horizontal. For this problem, make your coordinate system so that the *x*-axis is parallel to the surface of the table, and the *y*-axis is perpendicular to the table.

   a) With this coordinate system, what are the *x*- and *y*- components of the weight of the phone?

   b) What would the normal force need to be so that the net force in the *y*-direction is 0 N?

   c) What would the force of friction need to be so that the net force in the *x*-direction is 0 N?



F_g components
$\sin\theta \rightarrow$ slides x
$\cos\theta \rightarrow$ contact y

	x	y
F_g	$F_g \sin\theta$ (1.7)	$F_g \cos\theta$ (9.8)
F_f	F_f	0
F_N	0	F_N
	0 at rest	0 at rest

$F_{net} = ma$

y: $9.8 - F_N = m\cancel{a}^{\,0}$ so $F_N = 9.8\,N$

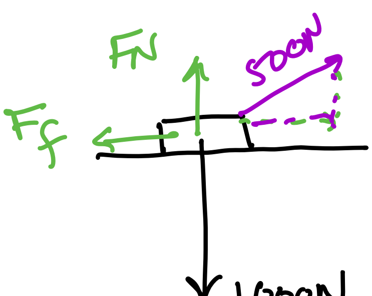
x: $F_f - 1.7 = m\cancel{a}^{\,0}$ so $F_f = 1.7\,N$

23. A person pulls a sled with a rope across a level icy ground ~~(frictionless)~~ friction. The sled has a weight of 1000N, and the person pulls with a force of 500 N at an angle 37° aove the horizontal. at constant speed (velocity)

   a) What are the *x*- and *y*- compotents of the tension force?

   b) What is the normal force acting on the sled?

   c) What is the net force in the *x*-direction?



align x,y with velocity

a) $F_x = F\cos\theta = 500N \cos 37°$
$F_x = 500N\left(\frac{4}{5}\right) = 400N$
$F_y = F\sin\theta = 500\left(\frac{3}{5}\right) = 300N$

	x (N)	y (N)
F_T	+400	+300
F_g	0	−1000
F_N	0	F_N
F_f	F_f	
	0 constant velocity (a = 0)	0 at rest vertically

$F_{net} = ma$

at rest vertically

y: $+300 - 1000 + F_N = m\cancel{a}^{\,0} = 0$
$F_N = 1000 - 300 = 700N$

x: $+400 - F_f = m\cancel{a}$ constant velocity
$F_f = 400N$ to left

Common Forces (Newtons)

Gravity, Weight F_g

Force between object + planet

always to center of planet

depends on density, size of planet

and object's mass

$$F_g = m\,g$$

g ← $9.8\,m/s^2$ on earth

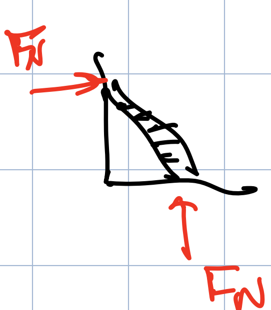
$9.8\,N/kg$

m ← mass (Kg)

depends on atoms

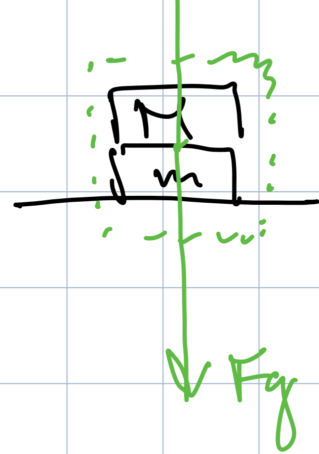
on moon (same mass, same clothes
different weight

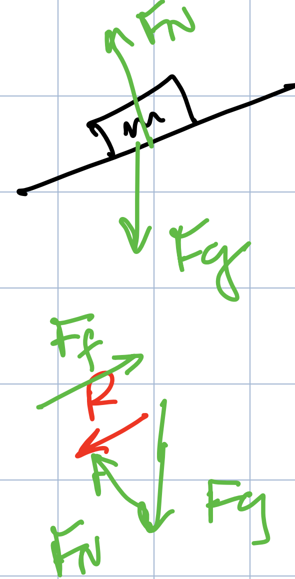
Normal Force, F_N



- perpendicular $\perp$ to surface
- support
- changes with load

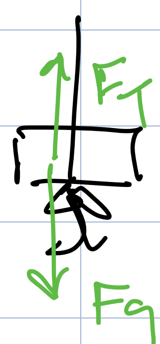
$\uparrow F_N$





Tension, F_T

- Support force
- changes with load
- directed along string



Friction, F_f

- Slows down, opposes velocity
- Keeps something stationary