After this lecture you should be able to:

- define what a force is and give examples
- describe how multiple forces on a single object can be though of as a single net force
- identify the units of force
- describe the fundamental, long range forces in physics and differentiate between fundamental forces and contact forces
- discuss Newton's Third Law and its importance for measuring forces
- describe how to measure a force

"Classical Mechanics"

Mechanics - branch of physics that is concerned with how and why large things move slowly (compared to the speed of light)

- statics - forces on things that do not move
- dynamics - forces on things that do move and where they go

Force - a push or pull

- vague but we will fill in more types
- units of push - Newton in SI, pound in US Customary system
- 1 Newton = 0.225 lbs

Force is a new kind of quantity: a **vector** quantity

Scalar vs Vector

Scalar is a “normal” quantity like number of apples, or temperature, or mass.

Ex: If I have 10 apples in bucket and I add 5 more, then I always have 15 apples.

But vector quantities are quantities **with direction**

Ex: I have a 50 N push on an object and a 100 N push on the object,

I do not always get a 150 Newton push as a result!

It depends on the **direction** in which the forces are applied.

So the result of multiple forces acting on an object is called the **net force** or the **resultant**.

So what are some types of forces and how can we describe them?

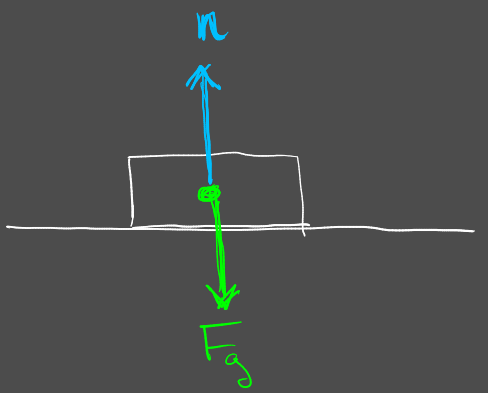
Fundamental Long Range forces - caused by force fields excited from a property of matter

- gravitational force
  - gravitational field excited by mass of an object
  - exerts a force on the mass of another object
  - also called "weight" on the surface of a planet/moom

- electromagnetic force
  - -electromagnetic field excited by stationary and moving charges
  - deal with this next semester

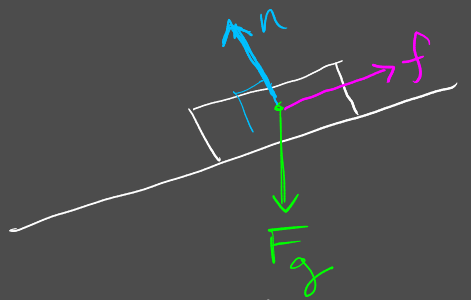
Contact forces

- not fundamental! (caused mostly by electromagnetic force and electron repulsion)
- but they are usefully and found in everyday life
- not a comprehensive list, we will cover others later



Normal force

- from a surface to an object that is resting or moving on that surface
- always perpendicular to the surface
- always prevents motion in the perpendicular direction to the surface

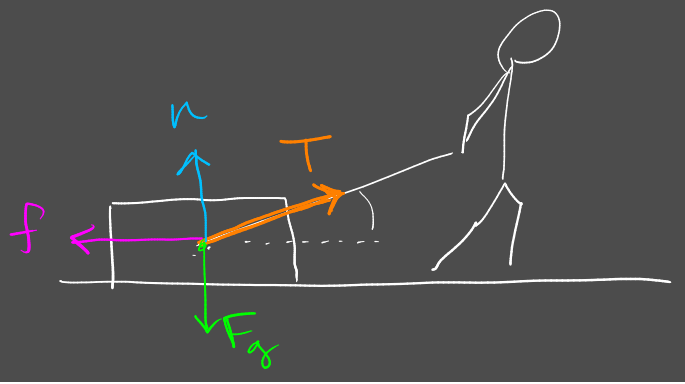


Friction

- from a surface to an object that is resting or moving on that surface
- always parallel to the surface in the opposite direction as the motion or to prevent motion
- kinetic friction vs. static friction
  - → on an object in motion
  - → on an object at rest

Tension

- force applied by a rope, wire, chain, string etc. to an object
- always applied to the object in the same direction as the rope



Measuring Forces

Newton's third law – "Every action has an equal & opposite reaction.

- Forces always occur in pairs
- These interaction pairs always act **on different objects** interacting

Measure force by its effect on something else

- distortion
- motion

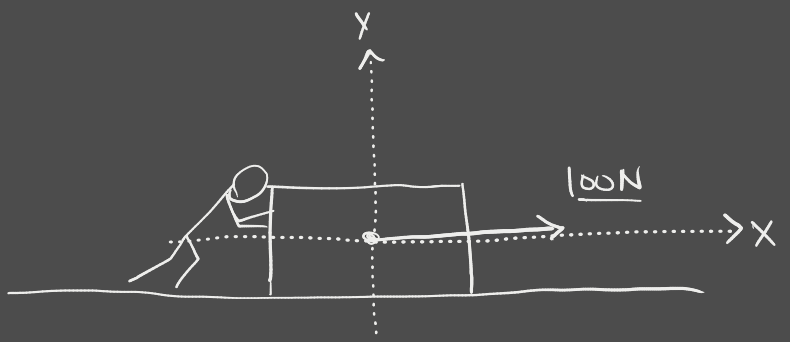
Distortion of a spring is easy to see and calibrate - usually against the force of gravity

At the end of this video you can:

- identify key features of vectors.
- describe how to graphically find the result of many vector forces acting together
- analyze a situation involving forces and create a free body diagram

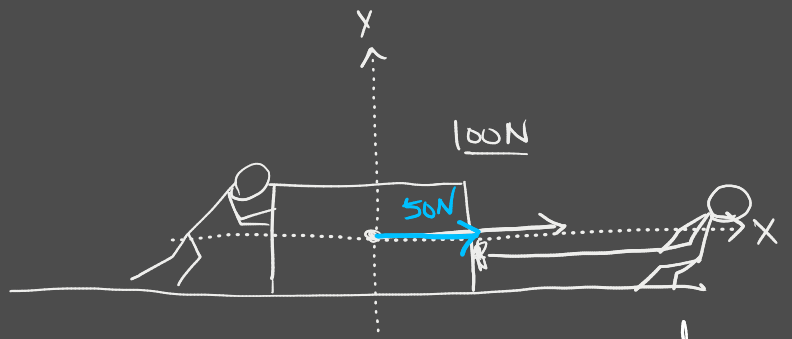
Vector quantities → magnitude
→ direction

→ graphical representation
- length is dir. prop. to the magnitude
- direction of arrow is the direction of the vector



$\vec{F_1} = +100N$

$|F_1| = 100N$



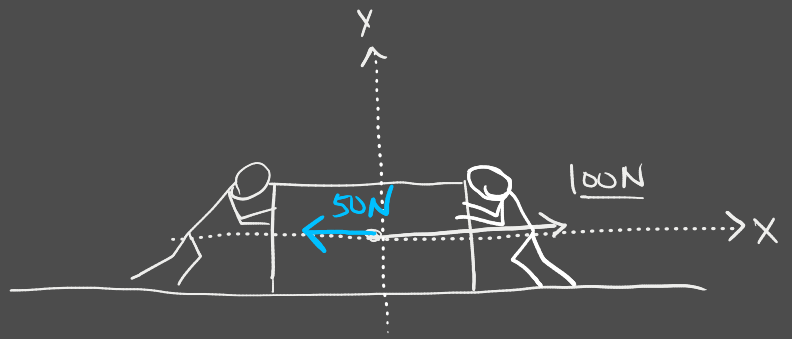
$F_1 = +100N$

$F_2 = +50N$

on net:

$F_{NET} = +100N + 50N$

$F_{NET} = +150N$



$F_1 = +100N$

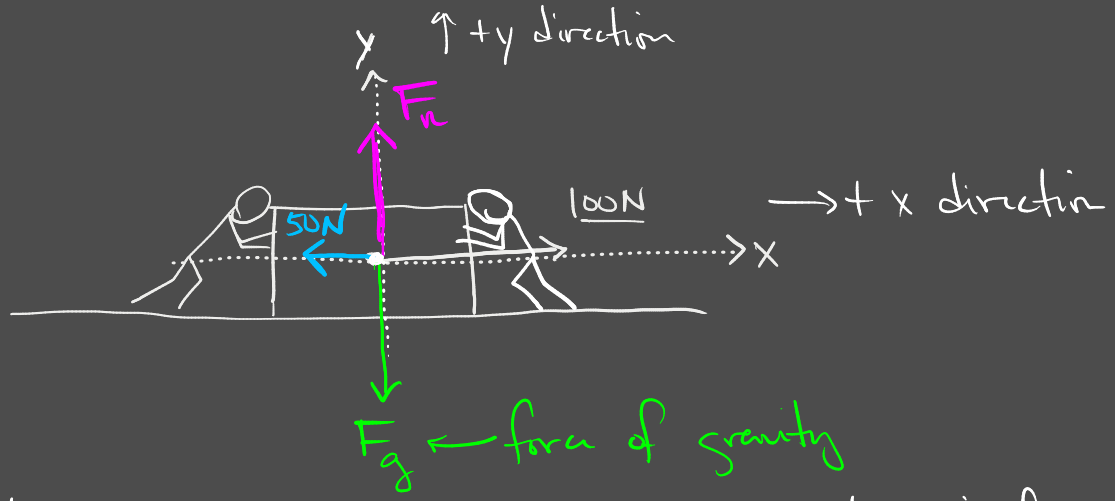
$F_2 = -50N$

$F_{NET} = +100N + (-50N)$

$= 100N - 50N$

$F_{NET} = +50N$

← −x-direction



Horizontal

$F_1 = +100N$

$F_2 = -50N$

← −x-direction

$F_{NET,X} = +100N + (-50N)$

$= 100N - 50N$

$F_{NET,X} = +50N$

Vertical

$\vec{F}_g = -1000N$ ← down

$\vec{F}_n = +1000N$ ← up

$F_{NET,Y} = -1000N + 1000N$

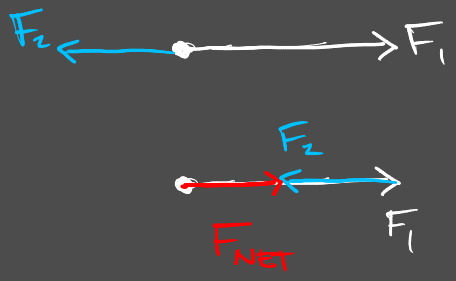
$F_{NET,Y} = 0N$

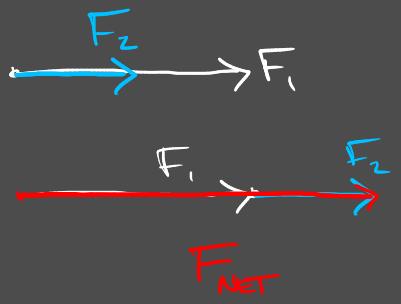
Net Force = Resultant

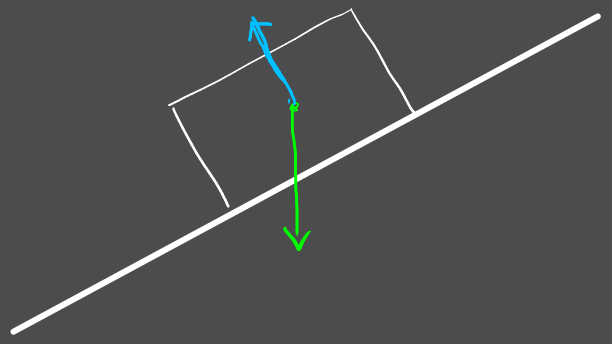
To sum up so far:

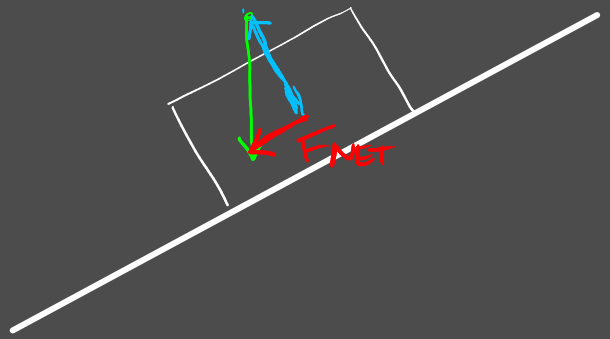
- take forces in the x-direction and give them a +/- sign
- add up those to get a net force (resultant) in the x-direction
- take forces in the y-direction and give them a +/- sign
- add them up to get a net force in the y-direction

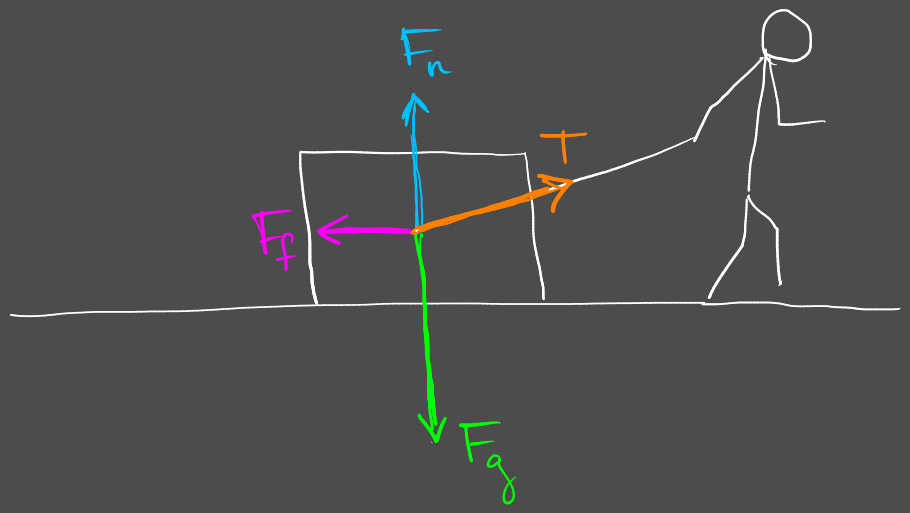
Graphical Vector Addition - tail to head method

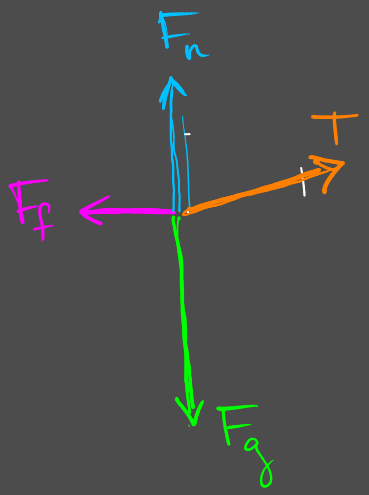


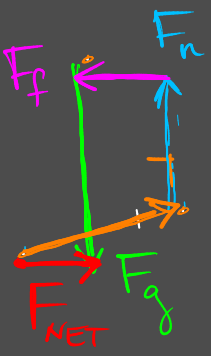


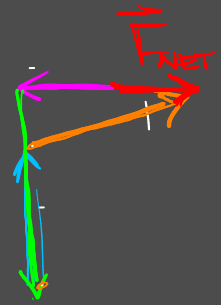




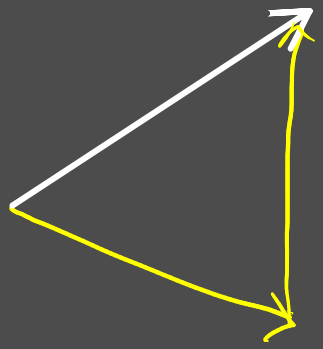


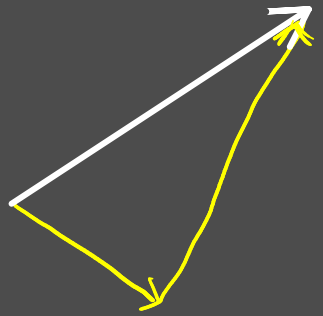


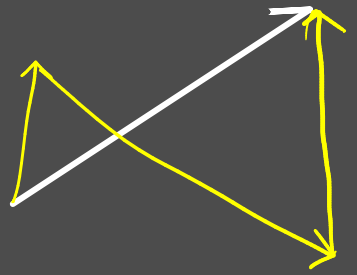


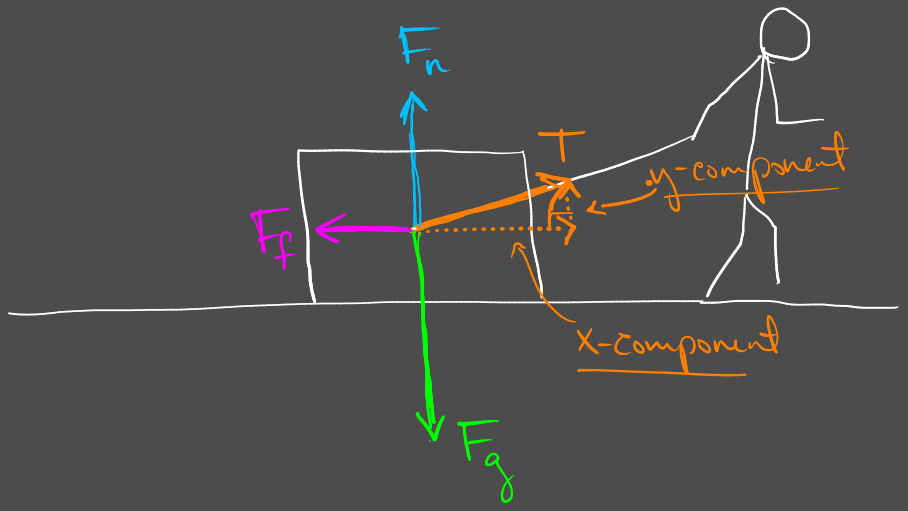


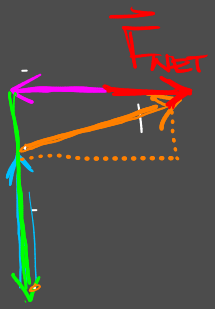
Vector decomposition

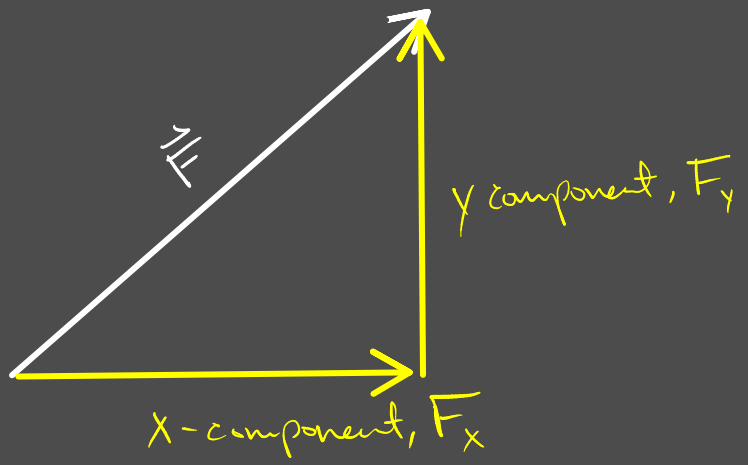







F_n
T
F_f
y-component
X-component
F_g


$\vec{F}_{NET}$

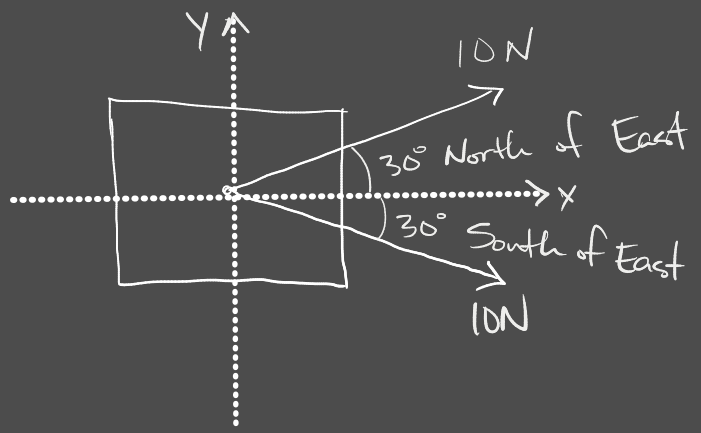

T
Y component, F_y
X-component, F_x

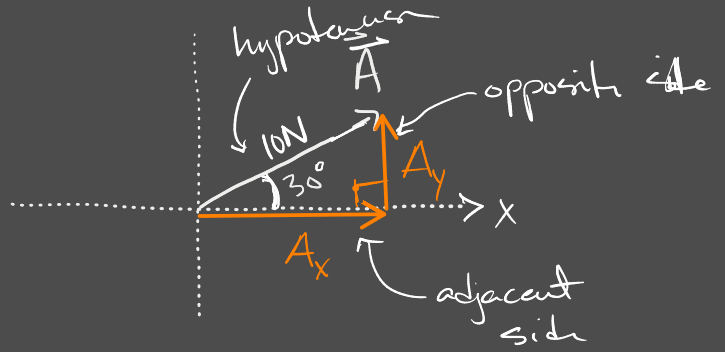
At the end of this video you can

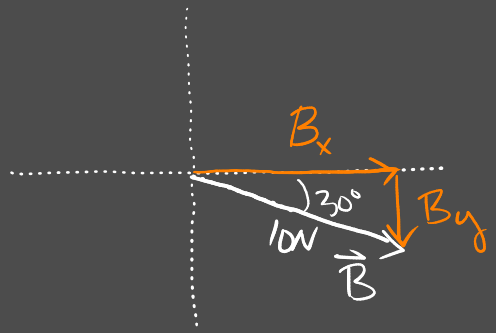
- use trigonometry to find the components of a vector
- add any number of vectors in any direction to find the components of the net force
- use the net force components to find the net force magnitude
- use the net force components to find the net force direction

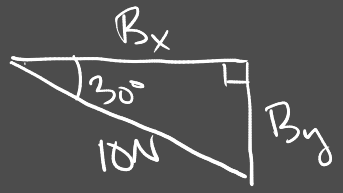
To sum up (modified now)

- put down a coordinate system (cleverly)
- find the x and y components for all the vectors that point diagonally to the coordinate system
- take forces in the x-direction and give them a +/- sign
- add up those to get a net force (resultant) in the x-direction
- take forces in the y-direction and give them a +/- sign
- add them up to get a net force in the y-direction
- use the net force components to find the magnitude and direction









horizontal

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

$\cos(30°) = \frac{A_x}{10N}$

$10N \cdot \cos(30°) = A_x$

$A_x = +8.66N$

horizontal

$B_x = +8.66N$

Vertical

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

$\sin(30°) = \frac{A_y}{10N}$

$10N \sin(30°) = A_y$

$A_y = +5N$

vertical

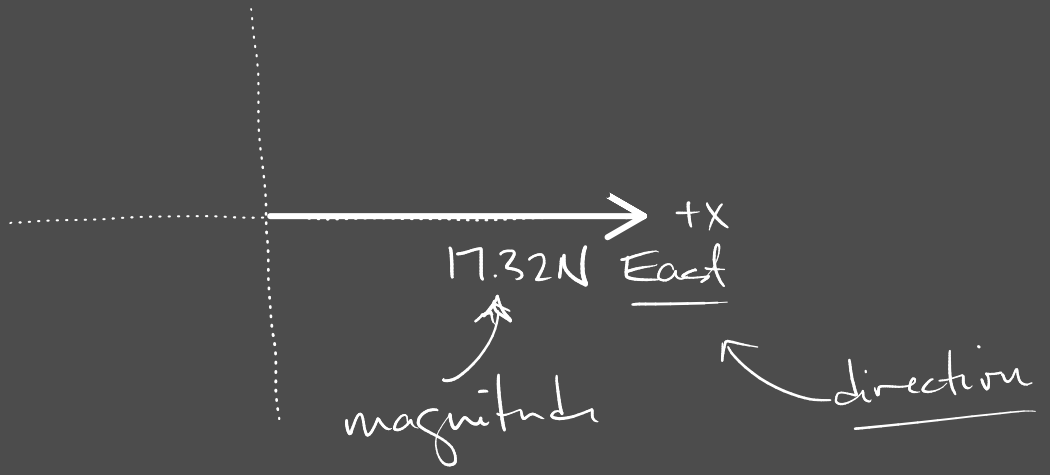
$B_y = -5N$

put this here

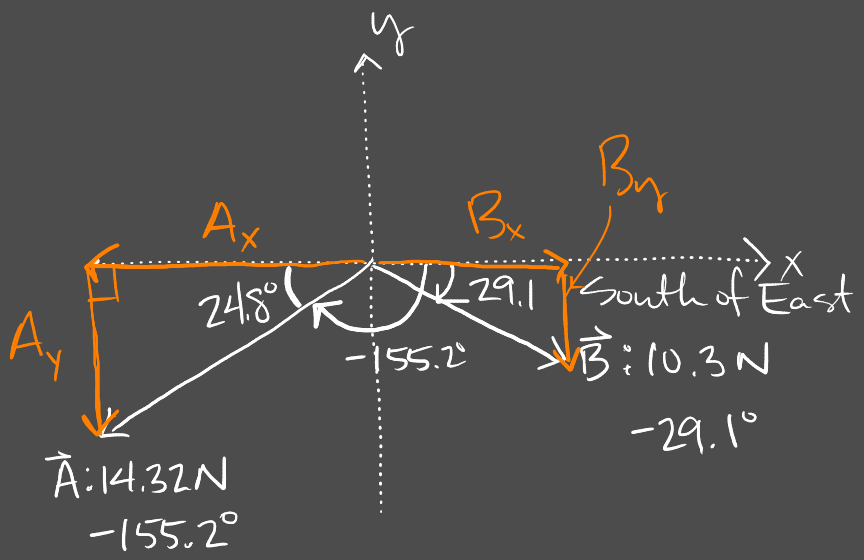
	X	y
A:	+8.66N	+5N
B:	+8.66N	−5N
Result	+17.32N	0N

add down each column

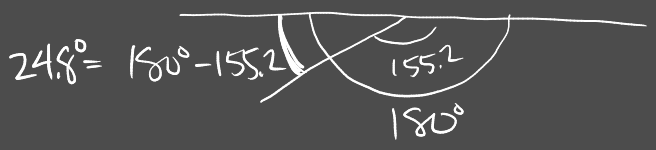
components of the net force

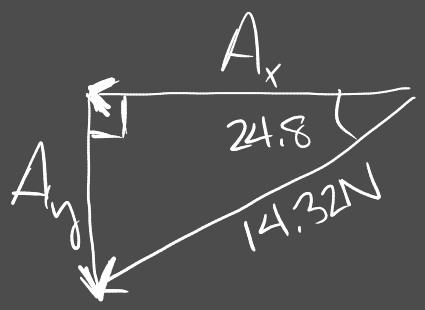


Another Example



	x	y
A:	-13N	-6N
B:	+9N	-5N
R:	-4N	-11N





$$\cos(24.8^\circ) = \frac{A_x}{14.32N}$$

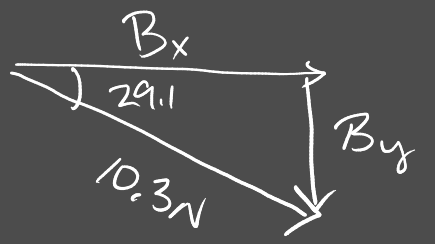
$$14.32\cos(24.8) = A_x$$

$$A_x = 13N$$

$$\sin 24.8 = \frac{A_y}{14.32N}$$

$$14.32N \sin 24.8 = A_y$$

$$A_y = 6N$$

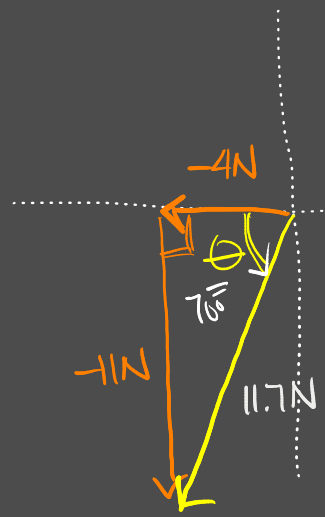


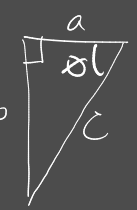
$$B_x = 10.3N \cdot \cos 29.1 = 9N$$

$$B_y = 10.3N \cdot \sin 29.1 = 5N$$

For the resultant

$$F_{NET,X} = -4N \qquad F_{NET,Y} = -11N$$





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

$$R^2 = (4N)^2 + (11N)^2$$

$$R = \sqrt{(4N)^2 + (11N)^2}$$

$$\boxed{R = 11.7N}$$

$$\tan\theta = \frac{\text{opp}}{\text{adj}}$$

$$\tan\theta = \frac{11N}{4N}$$

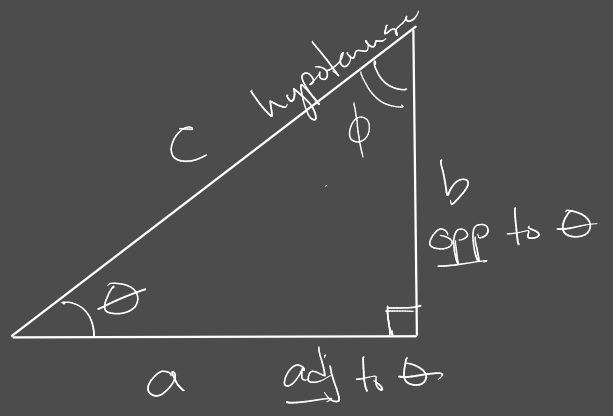
$$\tan^{-1}(\tan\theta) = \tan^{-1}\left(\frac{11}{4}\right)$$

$$\theta = 70^\circ$$

needs an interpretation ?

Resultant : 11.7N, 70° South of West

Trig Review



$$90 = \theta + \phi$$

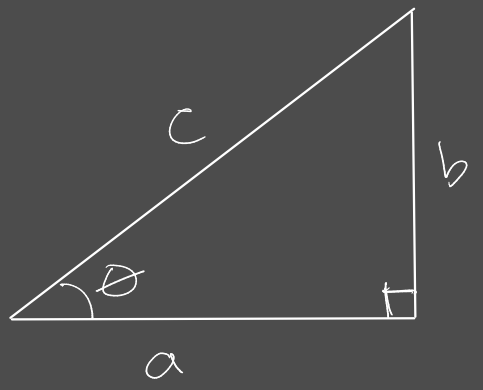
$$\phi = 90 - \theta$$

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

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

$$a^2 = c^2 - b^2$$

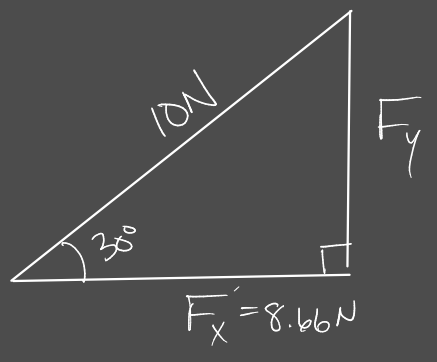
$$a = \sqrt{c^2 - b^2}$$



$$\sin\theta = \frac{b}{c} = \frac{\text{opp}}{\text{hyp}}$$

$$\cos\theta = \frac{a}{c} = \frac{\text{adj}}{\text{hyp}}$$

$$\tan\theta = \frac{b}{c} = \frac{\text{opp}}{\text{adj}}$$



$$\cos 30° = \frac{F_x}{10N}$$

$$10N \cos 30° = F_x = 8.66N$$

$$\rightarrow \sin 30° = \frac{F_y}{10N}$$

$$10 \sin 30 = F_y = 5N$$

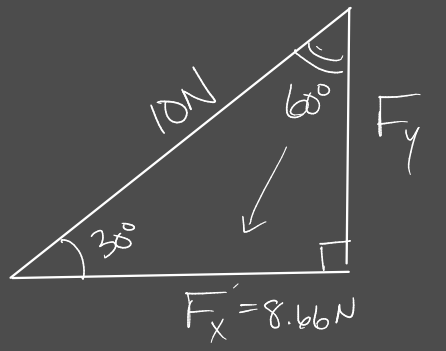
$$c^2 = a^2 + b^2$$

$$(10N)^2 = (8.66N)^2 + (F_y)^2$$

$$10^2 - 8.66^2 = F_y^2$$

$$\sqrt{10^2 - 8.66^2} = F_y$$

$$F_y = 5N$$



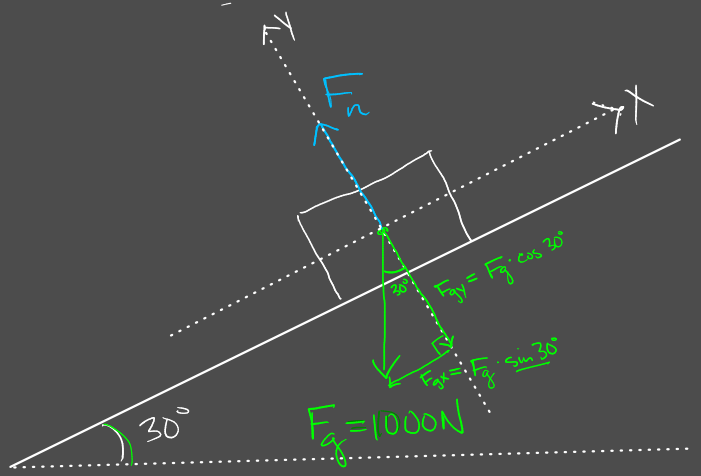
$$\sin 60 = \frac{F_x}{10N}$$

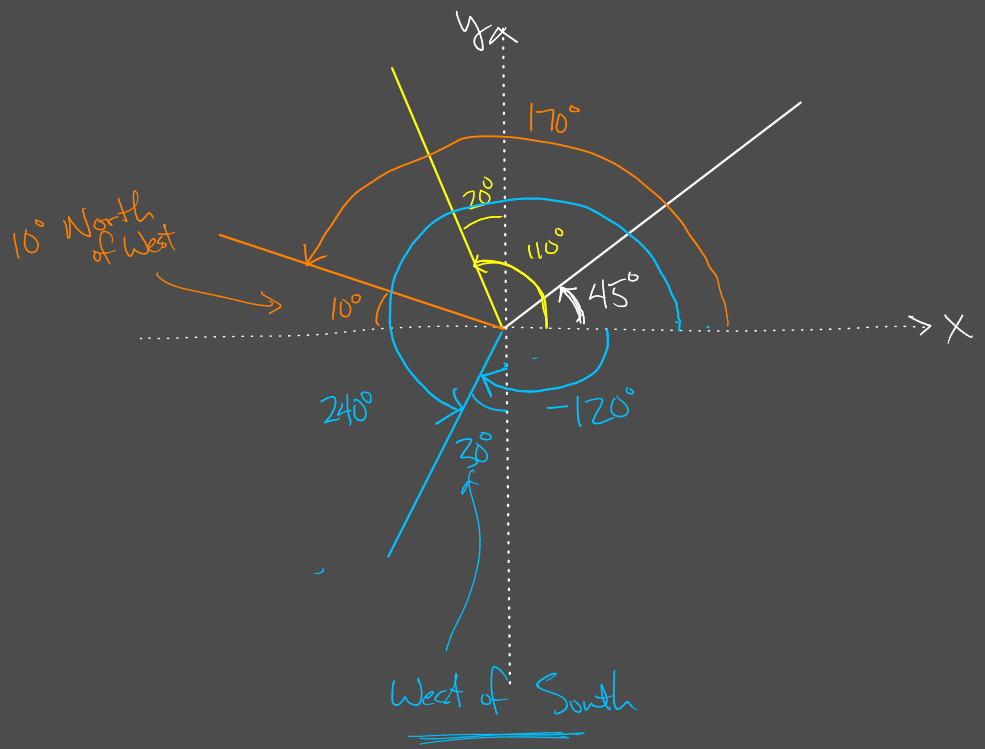
$$10N \sin 60 = F_x$$

$$F_x = 8.66N$$

$$\cos 60 = \frac{F_y}{10N}$$

$$F_y = 5N$$




y
x
170°
20°
110°
45°
10° North of West
10°
240°
−120°
30°
West of South