Equilibrium & Equilibrant

An object in a state of equilibrium has zero net force acting on it.

According to Newton's second law, the acceleration of the object would be zero.

Static equilibrium occurs when the object is at rest.

Dynamic equilibrium occurs when an object is in motion (at a constant velocity).

An old term (as used in the previous textbook ***Merrill Physics: Principles and Problems***) that can be useful is equilbrant force, $F_{E.}$

Equilibrant force is a force that when added to pre-existing forces causes an object to obtain equilibirum.

An object that is not in equilibrium is accelerating.

The unbalanced forces that cause the acceleration can be added to get a "resultant" force.

Applying a new force that is **equal in size** but **opposite in direction to the original resultant force** will make the new net force of zero newtons.

any # of forces

$$\vec{F}_R + \vec{F}_E = \vec{F}_{net} = 0N$$

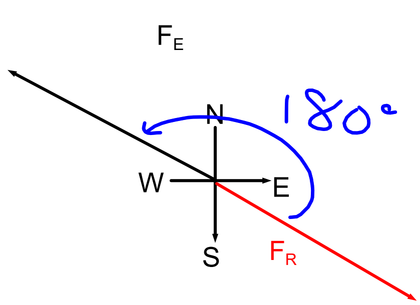
$\boxed{\vec{F}_E = -\vec{F}_R}$

$-\vec{F}_E = \vec{F}_R$

old resultant force

equilibrant force

new net force



Ex. 1 Three students are pushing simultaneously on a cart at rest.

Tharuka pushes with 150 N [E 65° N].
Channing pushes with 160 N [N 45° W].
And, Will is pushing with 110 N [W 15° S].

from above

All forces were applied horizontally. ← Keeps it in 2D

a) What is the resultant horizontal force applied by the guys?

b) What force would Laura need to apply in order to prevent the cart from moving?

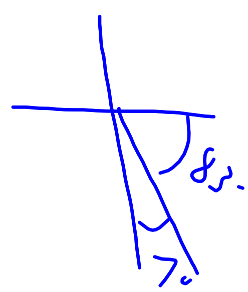
Ex. 2 Brian, Dom, and Letty are pulling a car down the road when the driver of the car applies to brakes in order to stop moving.

Brian pulls with 175 kN [N]
Dom pulls with 220 kN [N 30^0 E]
Letty pulls with 190 kN [N 60^0 W]

What is the minimum force the brakes must apply in order to slow down the car?

$\vec{F}_E = 463.7$ kN [E 83° S]

Do Practice Problems 7 - 9 on Page 467



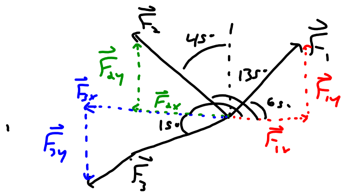
Ex 1)

$\vec{F_1} = 150\,N\,[E\,65^\circ\,N]$

$\vec{F_2} = 160\,N\,[N\,45^\circ\,W]$

$\vec{F_3} = 110\,N\,[W\,15^\circ\,S]$

$\vec{F_R} = ? = \vec{F_1} + \vec{F_2} + \vec{F_3}$



X-dir $F_x = F\cos(\theta)$

$F_{1x} = (150\,N)\cos(65^\circ) = 63.3927\,N$

$F_{2x} = (160\,N)\cos(135^\circ) = -113.137\,N$

$F_{3x} = (110\,N)\cos(195^\circ) = -106.252\,N$

$F_{Rx} = F_{1x} + F_{2x} + F_{3x} = -155.996\,N$

$= -160\,N$

Y-dir $F_y = F\sin\theta$

$F_{1y} = (150\,N)\sin(65^\circ) = 135.946\,N$

$F_{2y} = (160\,N)\sin(135^\circ) = 113.137\,N$

$F_{3y} = (110\,N)\sin(195^\circ) = -28.47009\,N$

$F_{Ry} = F_{1y} + F_{2y} + F_{3y} = 220.613\,N$

$= 220\,N$

$F_R = \sqrt{F_{Rx}^2 + F_{Ry}^2}$

$= \sqrt{(-155.996\,N)^2 + (220.613\,N)^2}$

$= 270.1943\,N = 270\,N$

Q2

$\theta = \tan^{-1}\left(\frac{F_{Ry}}{F_{Rx}}\right) = \tan^{-1}\left(\frac{220.613\,N}{-155.996\,N}\right) = -54.73^\circ$

$= -55^\circ$

$+180^\circ$

125°

$\boxed{\vec{F_R} = 270\,N\,[125^\circ]}$

[W 55° N]

35° 125° 55°

b) $\vec{F_E} = -\vec{F_R} = \boxed{270\,N\,[305^\circ]}$

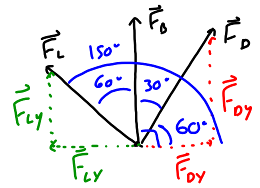
[E 55° S]

Ex2)

$\vec{F}_B = 175\ kN\ [N]\ \ [90^\circ]$

$\vec{F}_D = 220\ kN\ [N\ 30^\circ\ E]\ [60^\circ]$

$\vec{F}_L = 190\ kN\ [N\ 60^\circ\ W]\ [150^\circ]$



X-dir $F_x = F\cos\theta$

$F_{Bx} = 0N$

$F_{Dx} = (220\ kN)\cos(60^\circ) = 110\ kN$

$F_{Lx} = (190\ kN)\cos(150^\circ) = -164.54\ kN$

$F_{Rx} = F_{Bx} + F_{Dx} + F_{Lx} = -54.5448\ kN$

y-dir $F_y = F\sin\theta$

$F_{By} = 175\ kN$

$F_{Dy} = (220\ kN)\sin(60^\circ) = 190.526\ kN$

$F_{Ly} = (190\ kN)\sin(150^\circ) = 95\ kN$

$F_{Ry} = F_{By} + F_{Dy} + F_{Ly} = 460.5256\ kN$

$F_R = \sqrt{F_{Rx}^2 + F_{Ry}^2}$

$= \sqrt{(-54.5448\ kN)^2 + (460.5256\ kN)^2}$

$= 463.74449\ kN = 460\ kN$

$\theta = \tan^{-1}\left(\frac{F_{Ry}}{F_{Rx}}\right) = \tan^{-1}\left(\frac{460.5256\ kN}{-54.5448\ kN}\right) = -83.24^\circ$

$= -80^\circ$

Q2

$+180^\circ$

100°

$\vec{F}_R = 460\ kN\ [100^\circ]$

$\vec{F}_E = -\vec{F}_R = 460\ kN\ [280^\circ]$

$[E\ 80^\circ\ S]$

I said 83° in class for more precision, but should only be 1 sf.