Newton's Second Law of Motion
Vector Components

by

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P3.4A Predict the change in motion of an object acted on by several forces.

Items:

1. Newton’s Second Law of Motion.

2. X and Y Components of the Net Force.

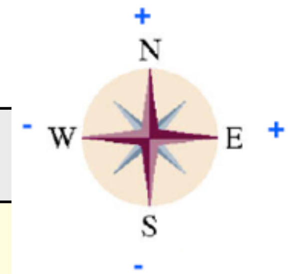
3. Acceleration along the X and Y axis.

4. X and Y Components of Displacement.

Newton's Second Law of Motion

If an unbalanced force (F) acts on on object of mass (m), the object accelerates in the direction of the force.

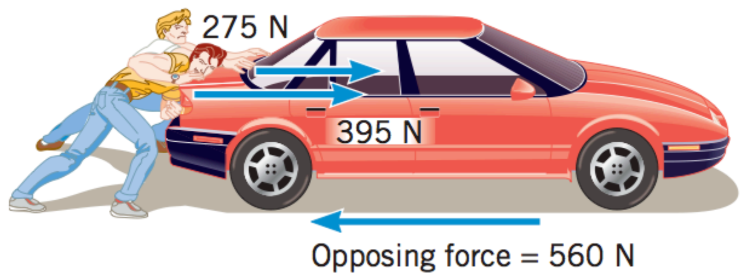
Net Force (N) = Mass (g) x Acceleration (m/s²)



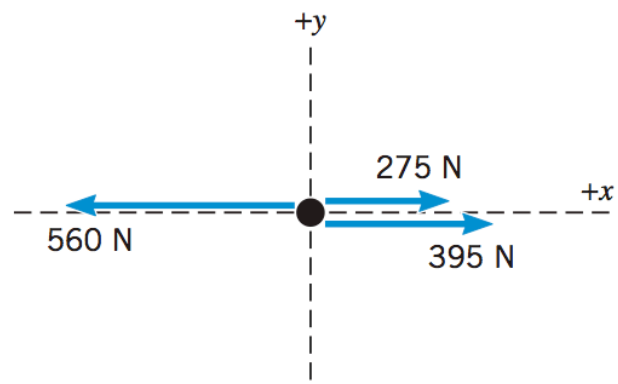
Newton's Second Law of Motion	
F net: net external Force in Newton (N). **It is the sum of all the external forces acting on the object.** m: Mass in kilogram (kg) a: Acceleration in m/s^2	$\vec{F}_{net} = m\,\vec{a}$
The acceleration varies directly with the unbalanced force.	$\vec{a} = \vec{F}_{net} / m$
The acceleration varies inversely with the mass of the object.	$m = \vec{F}_{net} / \vec{a}$

Example 1: *Two people are pushing a stalled car.*

Two people are pushing a stalled car of mass 1850 kg, as shown below. One person pushes with a force of 275 N. The other pushes with a force of 395 N. A third force of 560 N in opposing direction is the friction of the pavement.



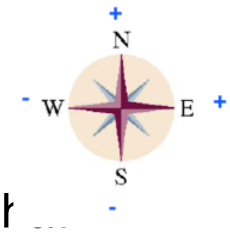
(*a*)



(*b*) Free-body diagram of the car

Figure (a): two people push a stalled car, in opposition to a force created by friction and the pavement. Figure (b): a free-body diagram that shows the horizontal forces acting on the car. In the diagram, the car is represented as a black dot, and its motion is along the +x axis. The free - body diagram is very helpful when applying Newton's second law and to determine the net force (F net).

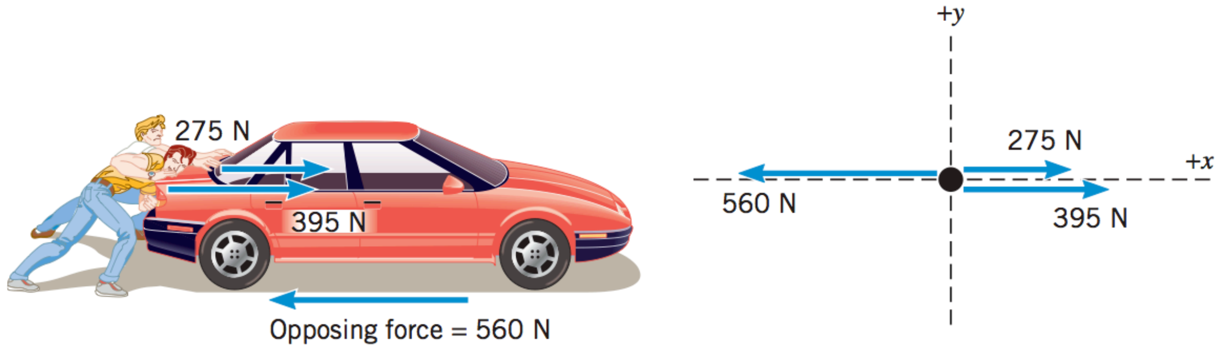
One person applies a force of 275 N to the car, while the other applies a force of 395 N. Both forces act in the forward positive direction along the x axis. So, they are both positive (+275 N, +395 N).



A third force of 560 N also acts on the car, but in a direction opposite to th... which the people are pushing. So, it is negative (-560 N). It arises because of friction and the extent to which the pavement opposes the motion of the tires.

Data Table				
F [East direction]	*F [west direction]*	*m*	*a*	*Fnet*
275 + 395	-560	1850 kg	?	?

The acceleration of the car (a) is calculated to be 0.059 m/s^2 as shown below when applying Newton's Second Law of Motion.



(*a*)

(*b*) Free-body diagram of the car

Newton's Second Law of Motion	
F net: net external Force in Newton (N). m: Mass in kilogram (kg) a: Acceleration in m/s^2	$\vec{F}_{net} = m\,\vec{a}$
$\vec{F}_{net} =$ sum of all the external forces acting on the object $= +275\ N + 395\ N - 560\ N = +110\ N$	
$\vec{a} = \vec{F}_{net}/m$ $= +110\ N / 1850\ kg = +0.059\ m/s^2$	

Example 2: *A man is standing on a raft.*

A man is standing on a raft. The mass of the raft and man is 1300 kg. By padding, he applied an average force P of 17 N to the raft in the east or x direction. The wind also exerts a force A of 15 N on the raft points 67° north of east. Ignoring any resistance from the water, find the x and y components of the raft's acceleration.

(*a*)

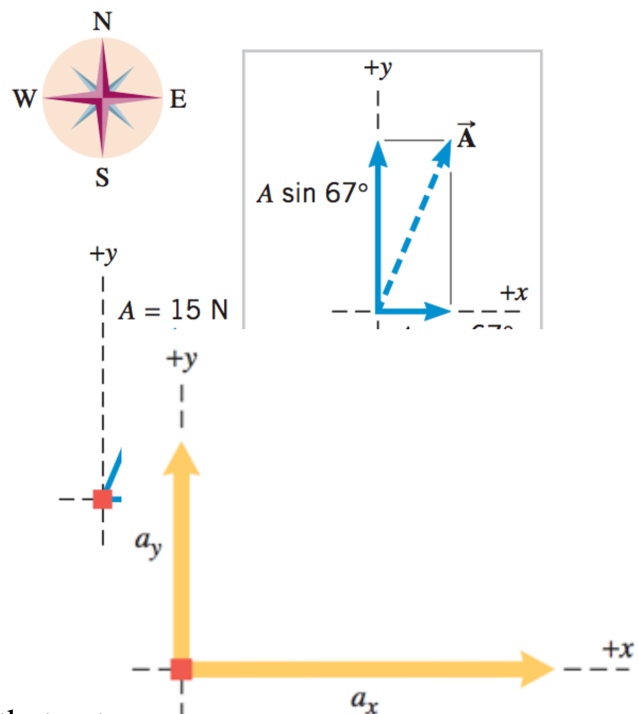


Figure (a) a man is padding a raft.
Figure (b) the free-body diagram shows the forces P and A that act (… ections due east is +X direction and due north is +Y direction. **The raft is represented as a red dot**.

Newton's second law of motion is used in the calculation of the acceleration

$$\vec{a} = \vec{F}_{net} / m$$

The net force (F net) has two components, one along the x axis and one along the y axis.

F net (x) = sum of forces along the x axis

F net (y) = sum of forces along the y axis

Each component of the net force leads to a corresponding components of the acceleration. The acceleration component in a given direction is the component of the net force in that direction divided by the mass.

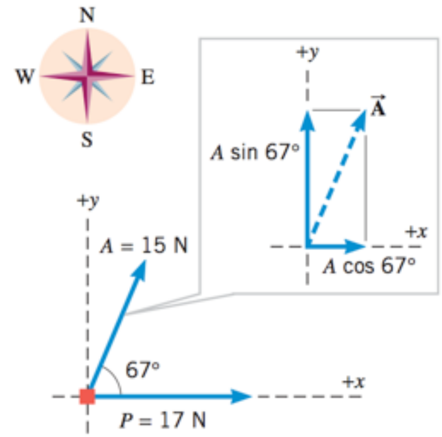
Acceleration along the x axis:

$$a_x = F_{net}(x) / m$$

Acceleration along the y axis:

$$a_y = F_{net}(y) / m$$

The free-body diagram is used to calculate $F_{net\ (x)}$ and $F_{net\ (y)}$ in the table below:



Free-body diagram of the raft

(b)

Force	x Component	y Component
$\vec{P}$ (padding)	+ 17 N	0 N
$\vec{A}$ (wind)	+ (15 N) cos 67°= 6N	+(15 N) sin 67° = +14N

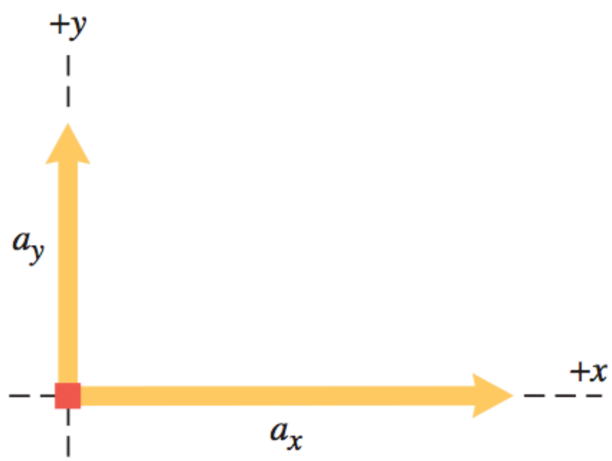
$F_{net\ (x)}$ = 17 N + (15 N) cos 67°
= +17 N + 6 N
= + 23 N

$F_{net\ (y)}$ = 0 N +(15 N) sin 67°
= + 14 N
= + 14 N

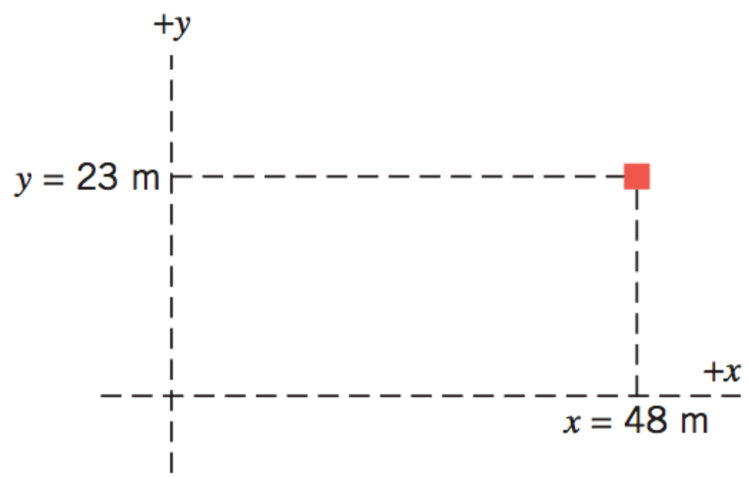
The acceleration along the x and y axis:

$$a_x = F_{net\,(x)} / m = +\,23\ N/1300\ kg = +\,0.018\ m/s^2$$

$$a_y = F_{net\,(y)} / m = +\,14\ N/1300\ kg = +\,0.011\ m/s^2$$



(c)



(d)

The raft's acceleration components are shown in figure (c).

The red square represents the raft.

The raft's displacement is shown in figure (d) when we assume that the initial velocity of the craft if 0.15 m/s in the east direction and that the forces are maintained for 65 s.

References:

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2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

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5) Nada H. Saab (Saab-Ismail), (2010-2013) Westwood Cyber High School, Physics.

6) Nada H. Saab (Saab-Ismail), (2009- 2014) Wayne RESA, Bilingual Department.

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