PHYS 1441 – Section 002
Lecture #9

Monday, Feb. 18, 2013

Dr. Jaehoon Yu

- Free Body Diagram
- Newton's Third Law
- Categories of forces

Announcements

- Term exam results
  - Class average: 60/103
    - Equivalent to 58.2/100
  - Top score: 98.5/103
- Evaluation policy
  - **Homework: 25%**
  - Final comprehensive exam: 23%
  - Midterm comprehensive exam: 20%
  - Better of the two term exams: 12%
  - **Lab: 10%**
  - Pop quizzes: 10%
  - **Extra credit: 10%**

Newton's Second Law of Motion

The acceleration of an object is directly proportional to the net force exerted on it and is inversely proportional to the object's mass.

How do we write the above statement in a mathematical expression?

$$\vec{a} = \frac{\sum_i \vec{F}_i}{m}$$

From this we obtain

$$\sum_i \vec{F}_i = m\vec{a}$$

Newton's 2nd Law of Motion

Since it's a vector expression, each component must also satisfy:

$$\sum_i F_{ix} = ma_x \qquad \sum_i F_{iy} = ma_y \qquad \sum_i F_{iz} = ma_z$$

Unit of the Force

From the vector expression in the previous page, what do you conclude the dimension and the unit of the force are?

$$\sum_i \vec{F_i} = m\vec{a}$$

The dimension of force is $[m][a] = [M][LT^{-2}]$

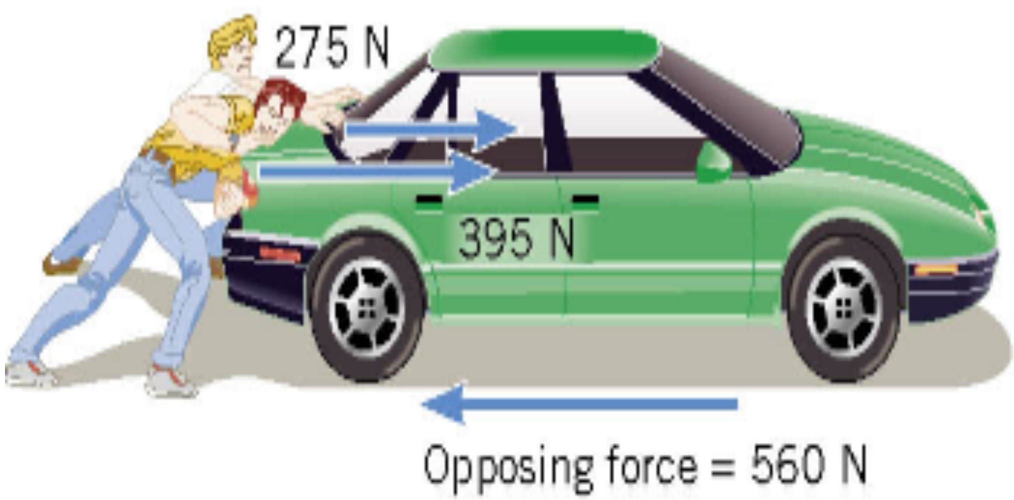
The unit of force in SI is $[Force] = [m][a] = [M][LT^{-2}] = (\mathrm{kg})\left(\frac{\mathrm{m}}{\mathrm{s}^2}\right) = kg \cdot m/s^2$

For ease of use, we define a new derived unit called, Newton (N)

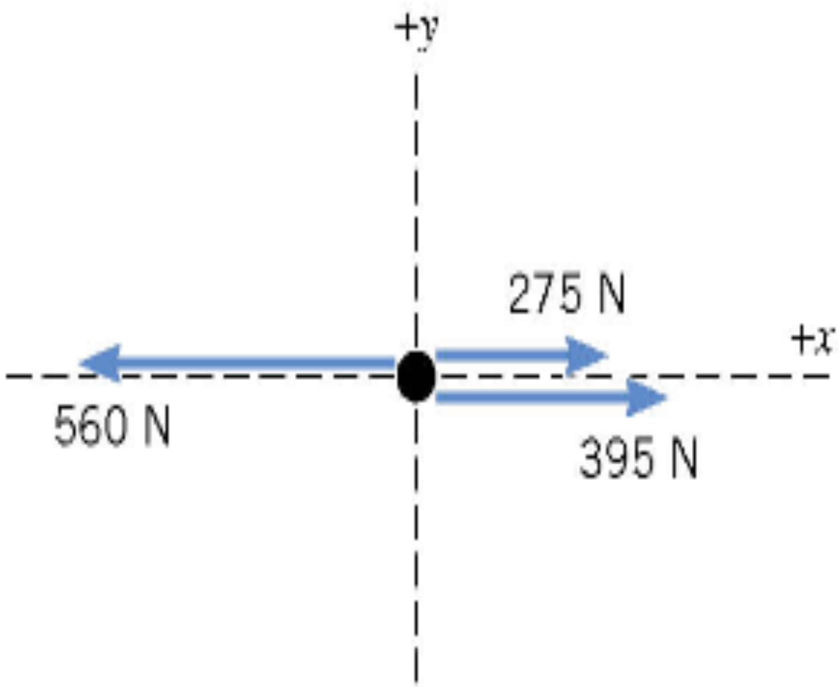
$$1N \equiv 1kg \cdot m/s^2 \approx \frac{1}{4} lbs$$

Free Body Diagram

A ***free-body-diagram*** is a diagram that represents the object and the forces that act on it.

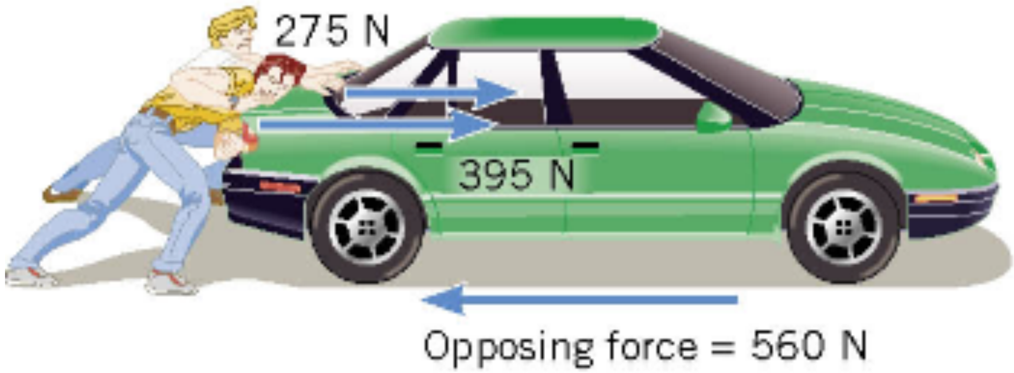


(a)

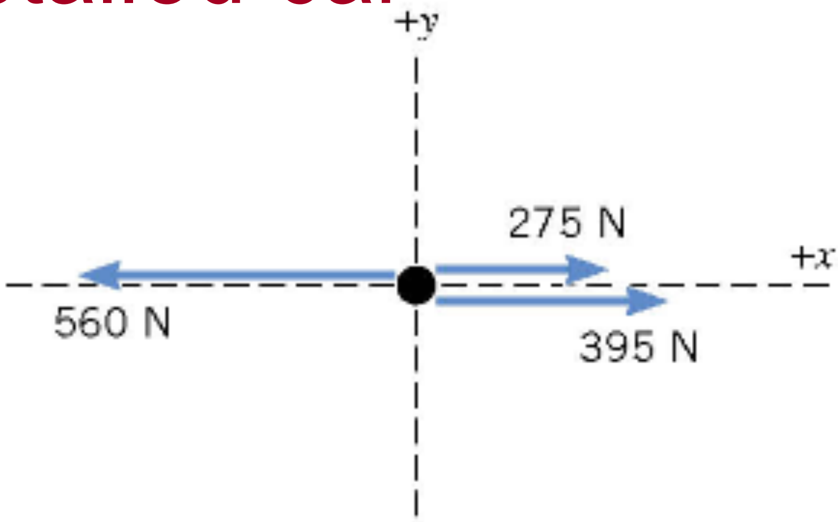


(b) Free-body diagram of the car

Ex. Pushing a stalled car



(a)



(b) Free-body diagram of the car

What is the net force in this example?

F= 275 N + 395 N – 560 N = +110 N

Which direction? The + x axis of the coordinate system.

What is the acceleration the car receives?

If the mass of the car is 1850 kg, then by Newton's second law, the acceleration is

$$\sum \vec{F} = m\vec{a}$$

Since the motion is in 1 dimension

$$\sum F = ma$$

Now we solve this equation for a

$$a = \frac{\sum F}{m} = \frac{+110\,\mathrm{N}}{1850\,\mathrm{kg}} = +0.059\,\mathrm{m/s^2}$$

Vector Nature of the Force

The direction of the force and the acceleration vectors can be taken into account by using x and y components.

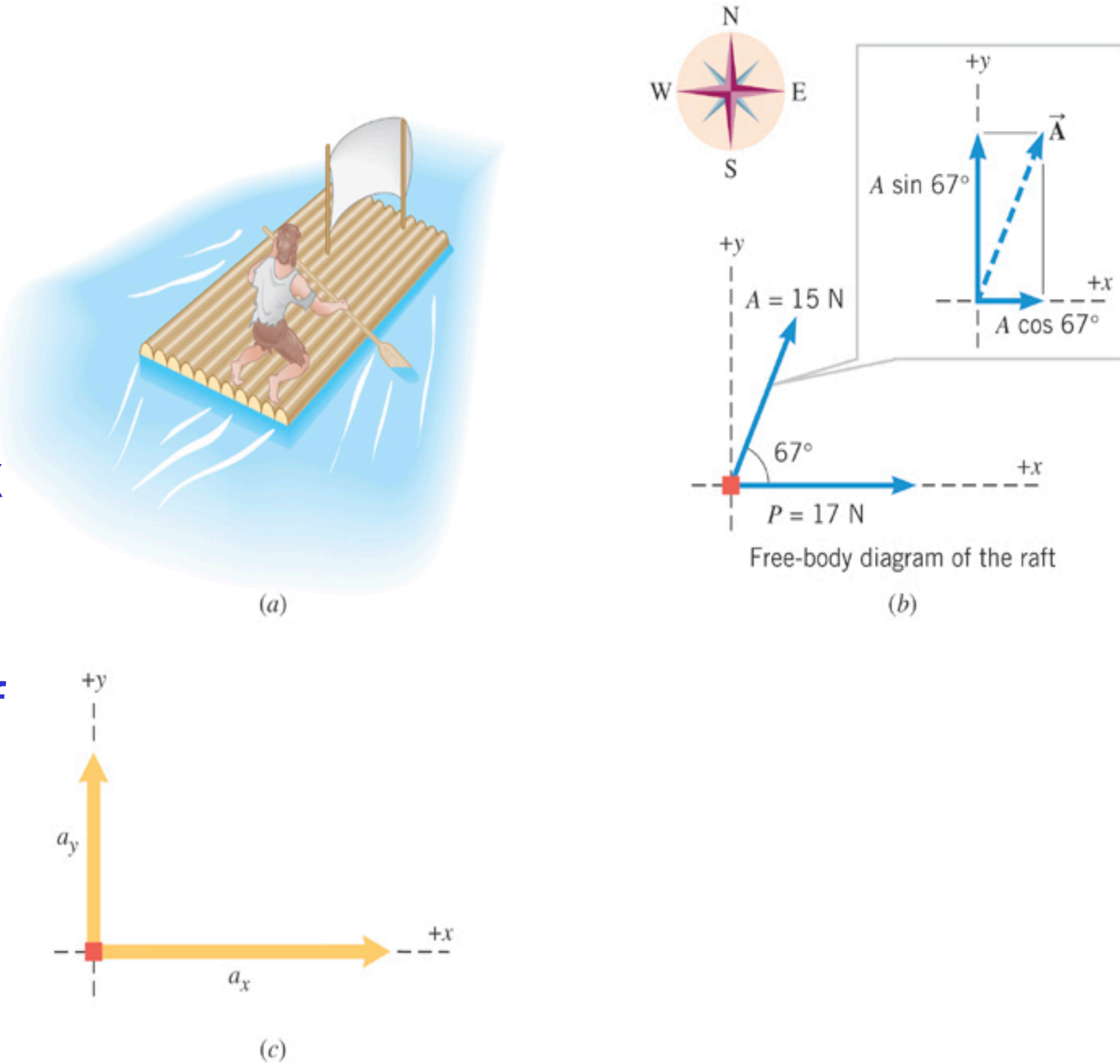
$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

is equivalent to

$$\sum F_y = ma_y \qquad \sum F_x = ma_x$$

Ex. Stranded man on a raft

A man is stranded on a raft (mass of man and raft = 1300kg) as shown in the figure. By paddling, he causes an average force P of 17N to be applied to the raft in a direction due east (the +x direction). The wind also exerts a force A on the raft. This force has a magnitude of 15N and points 67° north of east. Ignoring any resistance from the water, find the x and y components of the rafts acceleration.



(a) (b) (c)

First, let's compute the net force on the raft as follows:

Force	*x* component	*y* component
$\vec{\mathbf{P}}$ $\vec{\mathbf{A}}$	+17 N +(15N)cos67^{o}	0 N +(15N)sin67^{o}
$\vec{F} = \vec{P} + \vec{A}$	+17+15cos67^{o}= +23(N)	+15sin67^{o}= +14(N)

Now compute the acceleration components in x and y directions!!

$$a_x = \frac{\sum F_x}{m} = \frac{+23\text{ N}}{1300\text{ kg}} = +0.018\text{ m/s}^2$$

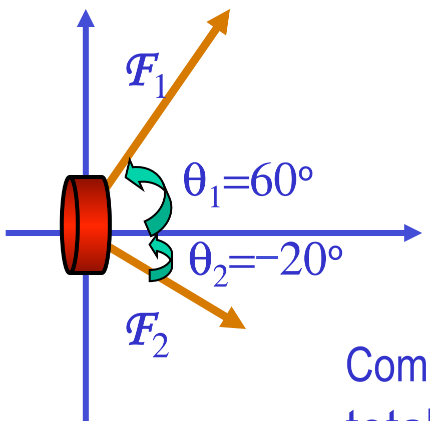
$$a_y = \frac{\sum F_y}{m} = \frac{+14\text{ N}}{1300\text{ kg}} = +0.011\text{ m/s}^2$$

And put them all together for the overall acceleration:

$$\vec{a} = a_x\vec{i} + a_y\vec{j} = \left(0.018\vec{i} + 0.011\vec{j}\right)m/s^2$$

Example for Newton's 2nd Law of Motion

Determine the magnitude and direction of the acceleration of the puck whose mass is 0.30kg and is being pulled by two forces, **F1** and **F2,** as shown in the picture, whose magnitudes of the forces are 8.0 N and 5.0 N, respectively.



Components of F_1

$$F_{1x} = \left|\vec{F}_1\right|\cos\theta_1 = 8.0\times\cos\left(60^\circ\right) = 4.0N$$

$$F_{1y} = \left|\vec{F}_1\right|\sin\theta_1 = 8.0\times\sin\left(60^\circ\right) = 6.9N$$

Components of F_2

$$F_{2x} = \left|\vec{F}_2\right|\cos\theta_2 = 5.0\times\cos\left(-20^\circ\right) = 4.7N$$

$$F_{2y} = \left|\vec{F}_2\right|\sin\theta_2 = 5.0\times\sin\left(-20^\circ\right) = -1.7N$$

Components of total force F

$$F_x = F_{1x} + F_{2x} = 4.0 + 4.7 = 8.7N = ma_x$$

$$F_y = F_{1y} + F_{2y} = 6.9 - 1.7 = 5.2N = ma_y$$

Magnitude and direction of acceleration a

$$a_x = \frac{F_x}{m} = \frac{8.7}{0.3} = 29m/s^2 \quad a_y = \frac{F_y}{m} = \frac{5.2}{0.3} = 17m/s^2 \quad \left|\vec{a}\right| = \sqrt{\left(a_x\right)^2 + \left(a_y\right)^2} = \sqrt{\left(29\right)^2 + \left(17\right)^2} = 34m/s^2$$

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) = \tan^{-1}\left(\frac{17}{29}\right) = 30^\circ$$

Acceleration Vector *a*

$$\vec{a} = a_x\hat{i} + a_y\hat{j} = \left(29\hat{i} + 17\hat{j}\right)m/s^2$$