PHYS 1441 – Section 002
Lecture #10

Monday, Feb. 25, 2008

Dr. Jaehoon Yu

- Newton's Laws of Motion
  - Force
  - Newton's first law: Inertia & Mass
  - Newton's second law of motion
  - Newton's third law of motion

Today's homework is homework #5, due 9pm, Monday, Mar. 3!!

Announcements

- Term exam grading half way done
- Homework #4 due has been extended to 9pm Thursday, Feb. 28

Force

We've been learning kinematics; describing motion without understanding what the cause of the motion is. Now we are going to learn dynamics!!

Can someone tell me what FORCE is?

FORCE is what causes an object to move.

The above statement is not entirely correct. Why?

Because when an object is moving with a constant velocity no force is exerted on the object!!!

FORCEs are what cause changes to the velocity of an object!!

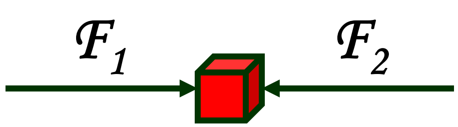
What does this statement mean?

When there is force, there is change of velocity!!

What does force cause? It causes an acceleration.!!

What happens if there are several forces being exerted on an object?

Forces are vector quantities, so vector sum of all forces, the NET FORCE, determines the direction of the acceleration of the object.



NET FORCE, $F = F_1 + F_2$

*When the net force on an object is **0**, it has constant velocity and is at its equilibrium!!*

Newton's First Law

Aristotle (384-322BC): *A natural state of a body is rest. Thus force is required to move an object. To move faster, ones needs larger forces.*

Galileo's statement on natural states of matter: *Any velocity once imparted to a moving body will be rigidly maintained as long as the external causes of retardation are removed!!*

Galileo's statement is formulated by Newton into the **1st law of motion (Law of Inertia)**: *In the absence of net external force, an object at rest remains at rest and an object in motion continues in motion with a constant velocity.*

Newton's First Law and Inertial Frame

Newton's 1st law of motion (Law of Inertia): *In the absence of net external force, an object at rest remains at rest and an object in motion continues in motion with a constant velocity.*

What does this statement tell us?

- When no force is exerted on an object, the acceleration of the object is 0.
- Any isolated object, the object that do not interact with its surroundings, is either at rest or moving at a constant velocity.
- Objects would like to keep its current state of motion, as long as there are no forces that interfere with the motion. This tendency is called the Inertia.

A frame of reference that is moving at a constant velocity is called the ***Inertial Frame***

Is a frame of reference with an acceleration an ***Inertial Frame?***

NO!

Mass

Mass: *A measure of the inertia of a body* or *quantity of matter*

- Independent of the object's surroundings: The same no matter where you go.
- Independent of the method of measurement: The same no matter how you measure it.

The heavier the object, the bigger the inertia !!

It is harder to make changes of motion of a heavier object than a lighter one.

The same forces applied to two different masses result in different acceleration depending on the mass.

$$\frac{m_1}{m_2} \equiv \frac{a_2}{a_1}$$

Note that the mass and the weight of an object are two different quantities!!

Weight of an object is the magnitude of the gravitational force exerted on the object.

Not an inherent property of an object!!!

Weight will change if you measure on the Earth or on the moon but the mass won't!!

Unit of mass? kg

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

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

Newton's 2nd Law of Motion

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

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

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?

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

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

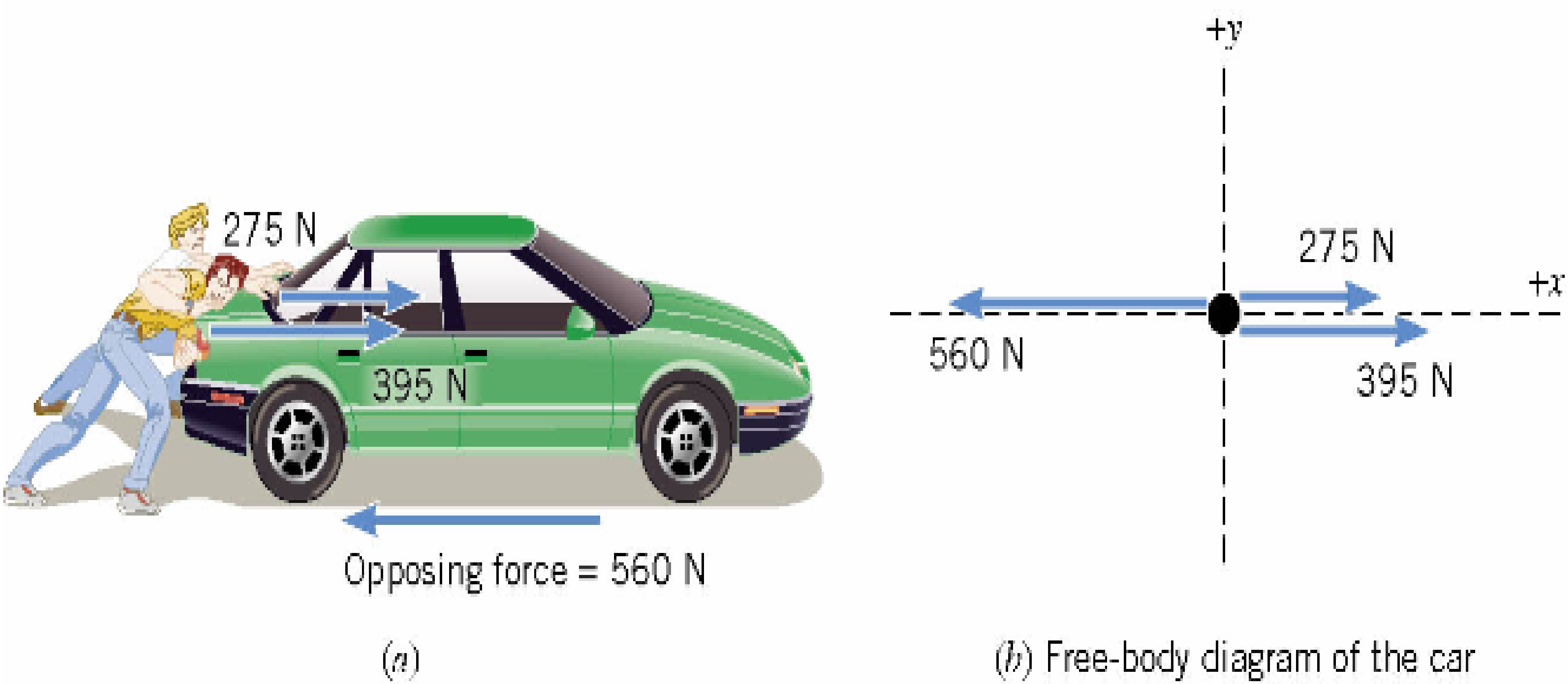
The unit of force in SI is $[Force] = [m][a] = [M][LT^{-2}] = (\mathrm{kg})\left(\frac{\mathrm{m}}{\mathrm{s}^2}\right) = kg \cdot m/s^2$

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

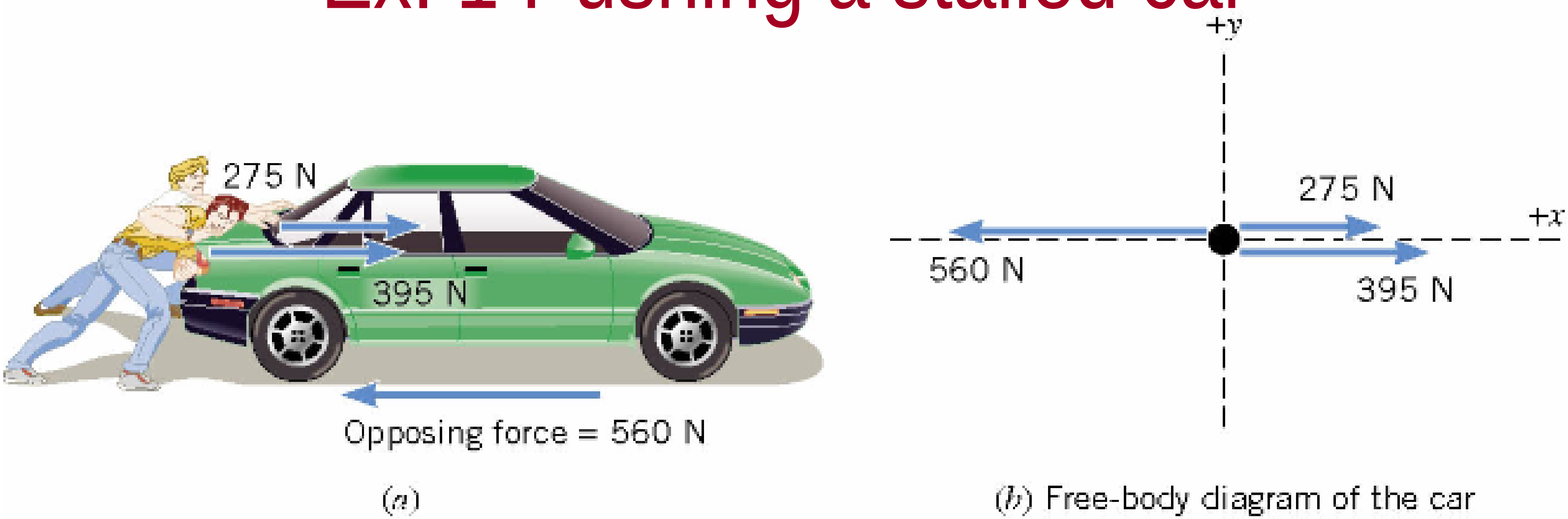
$$\boxed{1N \equiv 1kg \cdot m/s^2 \approx \frac{1}{4} lbs}$$

Free Body Diagram

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



Ex. 1 Pushing a stalled 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 force and acceleration vectors can be taken into account by using x and y components.

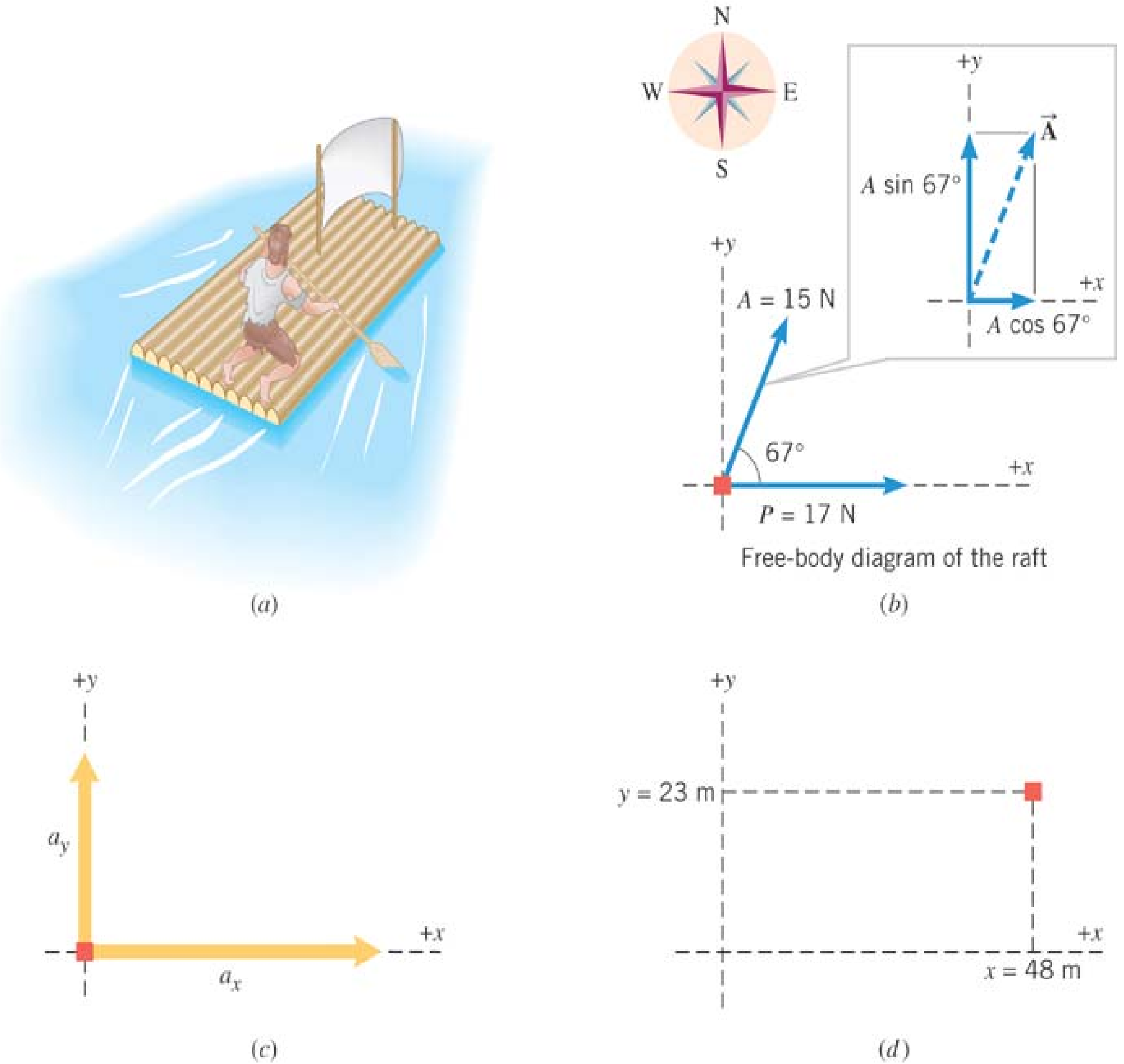
$$\sum \vec{\mathbf{F}} = m\vec{\mathbf{a}}$$

is equivalent to

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

Ex. 2 A stranded man on a raft

A man is stranded on a raft (mass of man and raft = 1300kg)m 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^o north of east. Ignoring any resistance from the water, find the x and y components of the rafts acceleration.



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

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

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

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

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

The overall acceleration is

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