Today's Concepts: *Newton’s Laws*

a) Acceleration is caused by forces (2\textsuperscript{nd} Law)
b) Force changes momentum (a \textit{little bit} of $\vec{p}$)
c) Good reference frames (1\textsuperscript{st} Law)
d) Forces always come in pairs (3\textsuperscript{rd} Law)
Described different types of motion mathematically

What causes different types of motion
Newton’s 2nd Law

\[ \vec{a} = \frac{\vec{F}_{\text{Net}}}{m} \]

where

\[ \vec{F}_{\text{Net}} = \sum_{i=1}^{N} \vec{F}_i = \vec{F}_1 + \vec{F}_2 + ... + \vec{F}_N \]

Acceleration is caused by force.

A bigger mass makes this harder
Example 4.1 (Units)

Units of force are “Newtons”.  
1N = 1kg m/sec\(^2\)

Example:
A net force of 100N is placed on a 1000kg truck in the positive x direction. What is the acceleration of the truck?
Example 4.2 (Force is a vector)

\[ \sum F_x = ma_x \quad \sum F_y = ma_y \quad \sum F_z = ma_z \]

Example:

A 1000kg truck is driving straight down the road at 30m/sec. The wind and the road suddenly put a net force of 50N on the side of the truck for 3 seconds. What is the velocity of the truck after this period of time?
Question

A force $F$ is applied to a small block, that pushes a larger block. The two blocks accelerate to the right. Compare the NET FORCE on the block with mass $M$, to the net force on the block with mass $5M$.

A) $F_M < F_{5M}$
B) $F_M = F_{5M}$
C) $F_M > F_{5M}$

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

Net Force

Same acceleration, so larger mass has larger net force.
Concerns you raised:

A force $F$ acts on a mass $M$ during the time period from $t = 0$ to $t = 1$ as shown. At $t = 1$, the mass moves with velocity $v_1$ as shown.

Which of the following vectors best represents $v_0$, the velocity of mass $M$ at $t = 0$?
Checkpoint

The net force on a box is in the positive $x$ direction. Which of the following statements best describes the motion of the box:

A) Its velocity is parallel to the $x$ axis
B) Its acceleration parallel to the $x$ axis
C) Both its velocity and its acceleration are parallel to the $x$ axis
D) Neither its velocity or its acceleration need be parallel to the $x$ axis
Newton’s 1st Law

An object subject to no external forces is at rest or moves with constant velocity if viewed from an inertial reference frame.

Inertial Reference Frame ≡ Reference Frame in which Newton’s Laws are valid
Aside: Centripetal acceleration and force

1) Objects moving in a circle always have a component of acceleration, called centripetal, which is toward the center of the circle.*

2) Centripetal acceleration must be caused by a force:
   - Friction, gravity – whatever force keeps it moving in a circle.
   - This force is often called the “centripetal force”

3) There is no “new” kind of force here.

4) There is no such thing as centrifugal force.

* They can have also have tangential acceleration if their speed is not constant
What force causes hurricanes to form in this circular pattern? *None!* They form because the earth’s surface is a slightly a non-inertial frame of reference!
You are driving a car with constant speed around a horizontal circular track. The net force acting on your car

A) Points radially inward toward the center of the circular track
B) Points radially outward, away from the center of the circular track
C) Points forward in the same direction your car is moving
D) Points backward, opposite to the direction your car is moving
E) Is zero.
Students’ Momentum Concerns

- I found the momentum pretty confusing, I would love review that.
- The concept of momentum was very confusing to me.
- Concept of momentum is bit confusing..

\[
\vec{p} = m\vec{v}
\]

We will return to momentum in greater detail later in this course.

**KEY POINT:** \[
\dot{\vec{p}} = \int \vec{F} \, dt = \int m \, \dot{\vec{a}} \, dt
\]

*Just Newton’s Second Law restated!*
Momentum & Force

Momentum

\[ \vec{p} \equiv m\vec{v} \]

Newton's 2nd Law

\[ \vec{F}_{\text{Net}} = \frac{d\vec{p}}{dt} \]

Two Conclusions:

1. If \( \vec{F}_{\text{Net}} = 0 \), then \( \frac{d\vec{p}}{dt} = 0 \), \( \vec{p} \) is constant

2. \( d\vec{p} = \vec{F} \, dt \)

We will return to momentum later!
Checkpoint

You are driving a car with constant speed around a horizontal circular track. The momentum of your car

A) Points radially inward toward the center of the circular track
B) Points radially outward, away from the center of the circular track
C) Points forward in the same direction your car is moving
D) Points backward, opposite to the direction your car is moving
E) Is zero.
A) The object has a momentum that is pointed inwards towards the center because of the centripetal acceleration caused by the turning vehicle which is always directed towards the center and the net force has to be in the same direction as the acceleration so the net force is also pointing inwards towards the center.

C) Speed is constant and non-zero, thus momentum is in the direction of travel. Because the direction of travel is circular, there is centripetal acceleration, which points toward the center of the circle.

Checkpoint Responses
You are driving a car with constant speed around a horizontal circular track. The momentum of your car

A) Points radically inward toward the center of the circular track
B) Points radically outward, away from the center of the circular track
C) Points forward in the same direction your car is moving
D) Points backward, opposite to the direction your car is moving
E) Is zero.
\[ \vec{p} = m\vec{v} \]

\[ \vec{F} = m\vec{a} \]
A child is walking along the sidewalk at a constant speed of 1 m/s while pulling his wagon with his dog sitting in it. The dog has a mass of 30kg and the wagon weighs 50N. If the child pulls the wagon with a force of 60N at an angle of 60°, what is the horizontal frictional force exerted by the wagon on the dog?

A. 50N  
B. 30N  
C. 20N  
D. 10N  
E. 0N

(As always, you can ignore air drag on the dog.)
Newton’s 3\textsuperscript{rd} Law

For every action there is an equal and opposite reaction.

\[ \vec{F}_{AB} = -\vec{F}_{BA} \]

Forces come in pairs!

Fire-cart
Question

A physics book is setting on the top of a table. An action-reaction force pair involved in this situation is

A. the force of gravity on the table and the force of the book on the table
B. the force of gravity on the book and the force of the table on the book
C. the force of book on the table and the force of the table on the book
D. the force of the table on the book and the force of friction on the book
A car travelling at 70 mph down the interstate collides with a bug trying to cross the highway. Which of the following statements best describes this collision?

A. The car exerts a larger force on the bug than the bug exerts on the car.
B. The car exerts a smaller force on the bug than the bug exerts on the car.
C. The car exerts the same sized force on the bug as the bug exerts on the car.
D. The car exerts a force on the bug but the bug does not exert a force on the car.
E. Neither exerts a force on the other. The bug gets smashed because it got in the way of the car.
A small guy and a large football player moving at the same speed collide head-on. Which person experiences the larger force during the collision?

A) The small guy.
B) The football player.
C) They experience the same force.
A small guy and a large football player moving at the same speed collide head-on. Which person experiences the larger acceleration during the collision?

A) The small guy.
B) The football player.
C) The accelerations are the same.