Classical Mechanics
Lecture 3

Today's Concepts: *Newton's Laws*

a) Acceleration is caused by forces
b) Force changes momentum
c) Forces always come in pairs
d) Good reference frames
e) Using the force probe

Stuff you asked about:

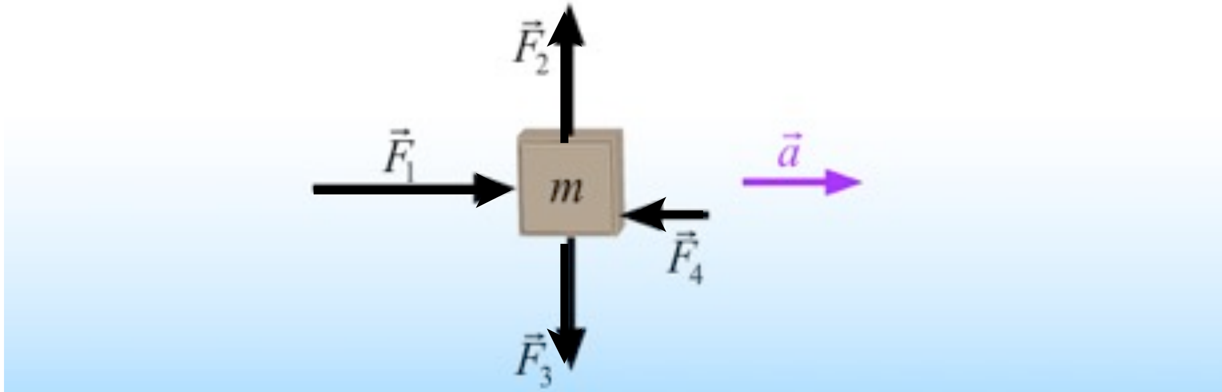
- Do we need to know and fully understand momentum and Fnet = dp/dt. Or are we going into more depth on that subject later?
- How will inertial reference frames be applied in a question?
- Getting momentum from the equation F=ma
- I knew all of these surprisingly well. Or at least I think I do.
- Why (in physics terms) wouldn't an object like a wall move according to Newton's Third Law if it does not have balanced forces on it (net force =/=0, so shouldn't it accelerate per Newton's First Law?
- How does net force differ from other forces? Also, in relation to centripetal motion, in which directions are acceleration, momentum, and velocity.
- Why are smartPhysics hwk question sets so long and tough. T-T You're not going to be that mean on midterms, will you?
- I would like to address the fact that the amount of work in this course is great almost to the point of overwhelming at times.

Newton's 2[nd] Law

$$\vec{a} = \frac{\vec{F}_{Net}}{m}$$

where

$$\vec{F}_{Net} \equiv \sum_{i=1}^{N} \vec{F}_i = \vec{F}_1 + \vec{F}_2 + \ldots + \vec{F}_N$$



Acceleration is caused by force.

A bigger mass makes this harder

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

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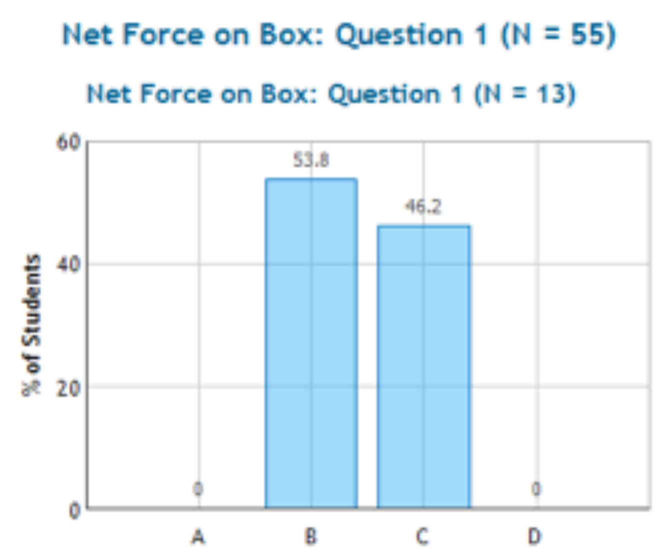
Typical explanations —

B)If the net force acting on an object is in one direction, its acceleration must be in that direction. Velocity, however, could be in any direction at any magnitude below *c*.

C) The acceleration of an object is in the same direction as the net force acting on it, and therefore the velocity will be in that direction as well.

Only if v = 0 before force was applied.
That is: if it starts from rest.



Concerns you raised:

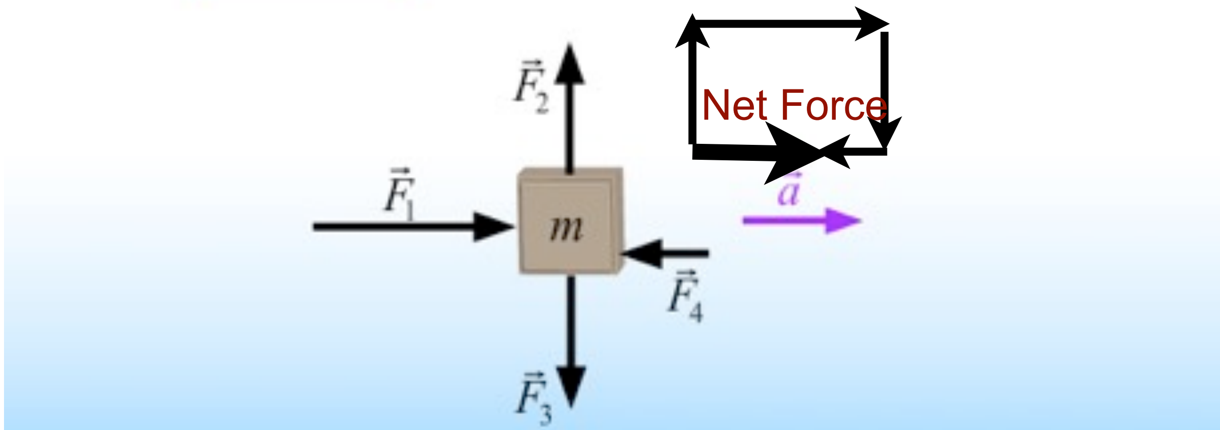
- I did not clearly understand the relation between force and momentum and I hope we go over it in class.
- when to take into consideration two forces acting on an object or when to only take into account one force.

Newton's 2nd Law

$$\vec{a} = \frac{\vec{F}_{Net}}{m}$$

where

$$\vec{F}_{Net} \equiv \sum_{i=1}^{N} \vec{F}_i = \vec{F}_1 + \vec{F}_2 + \ldots + \vec{F}_N$$



Acceleration is caused by force.

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more Concerns you raised:

- The question about the car and the bug is confusing to me. because the car exerts the same force on the bug as the bug exerts on the car, but it is their mass that determines the acceleration of the objects after their collision. I understand this, but the explanation in the right answer says something about the force of the car *prevailing* over the force that the bug exerts on the car, so now I am unsure. If the acceleration of the bug and the car are the same, would that change anything?
  - Later we will smash carts together and measure the forces.
- Can we go over the example given in the pre-lecture, where they express that according to Newton's third law, only the force that the man is exerting on the box is taken into account and not the force back on the man?
  - Try a demo with two ppl on chairs pushing off each other.
- it was kind of lame to have circular motion show up when we haven't covered it yet.
  - Soon!

Clicker 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 $5M$.

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

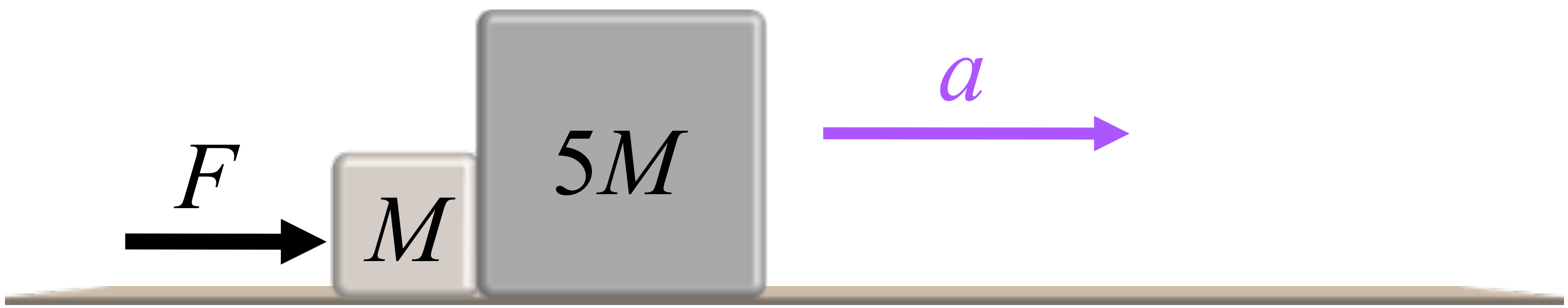
Net Force

A) $F_M < F_{5M}$

B) $F_M = F_{5M}$

C) $F_M > F_{5M}$

Same acceleration, so larger mass has larger net force.



CheckPoint

You are driving a car with constant speed around a horizontal circular track. The net force acting on your car

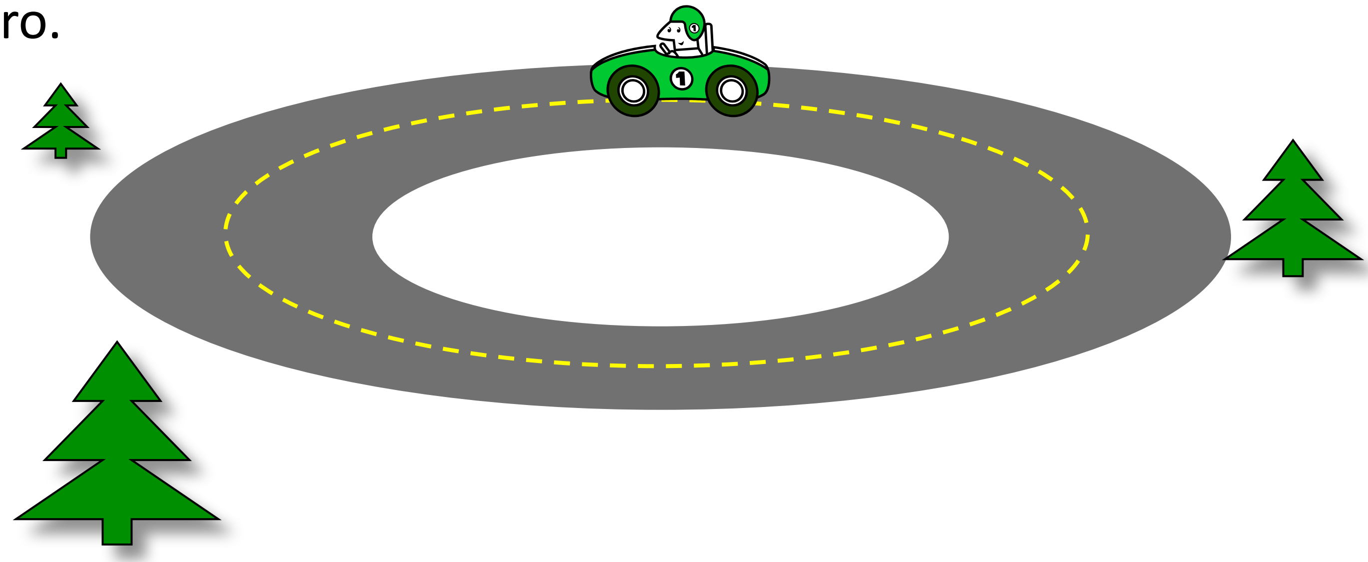
A) Points radically inward toward the center of the circular track

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.



CheckPoint Responses

You are driving a car with constant speed around a horizontal circular track. The net force acting on your car

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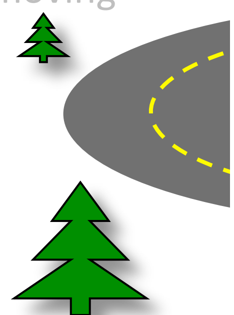
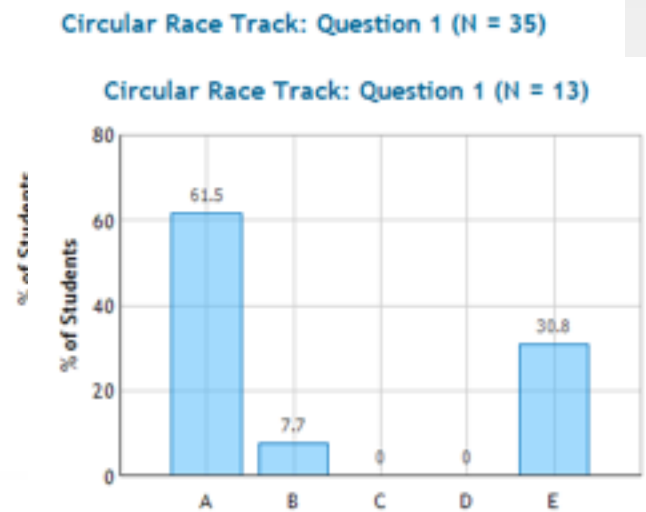




A) Force is in the same direction as acceleration (in this case, centripetal).

B) the acceleration is outwards, therefore the force is outwards

C) The car is moving forward so the net force must be forward.

E) Because the car is moving at a constant speed, so there is no a. We get the net force is zero.

Comment

I found it hard to accept the concept of centripetal and centrifugal force. For Question 2, since the car is moving in the direction that is not to the midpoint nor outward, I thought the direction of the force acting on a car would be the same direction as the car is moving.

Aside: Centripetal acceleration and force

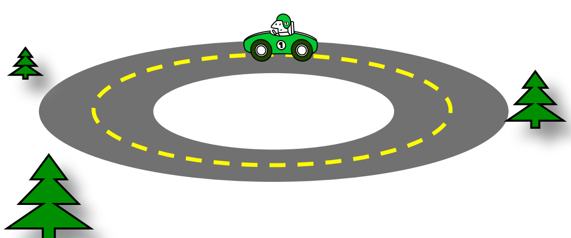
1) Objects moving in a circle always have a component of acceleration, called centripetal, which is toward the center of the circle.*

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

Momentum & Force

Momentum

$$\vec{p} \equiv m\vec{v}$$

Newton's 2nd Law

$$\vec{F}_{Net} = \frac{d\vec{p}}{dt}$$

Two Conclusions:

1. If $\vec{F}_{Net} = 0$, then $\frac{d\vec{p}}{dt} = 0$ ⟶ $\vec{p}$ is constant
2. $d\vec{p} = \vec{F}\,dt$

Students' Momentum Concerns

- Need more feedback on the topic of momentum
- The concept of momentum was very confusing to me.
- Concept of momentum is bit confusing..

$$\vec{p} = m\vec{v}$$

Oooomf

CheckPoint

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

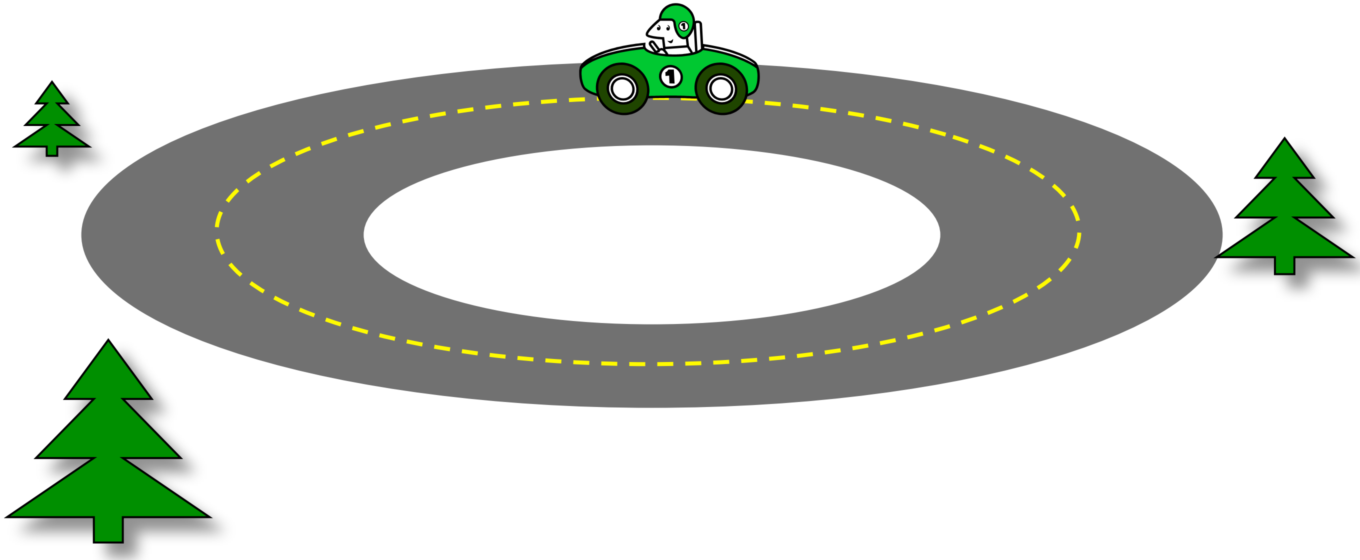
A) Points radically inward toward the center of the circular track

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.



CheckPoint Responses

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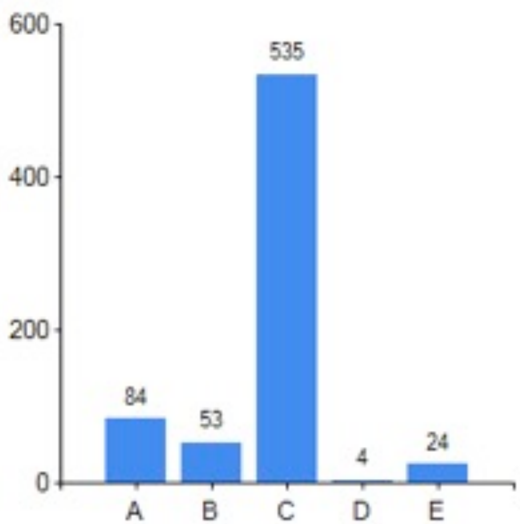
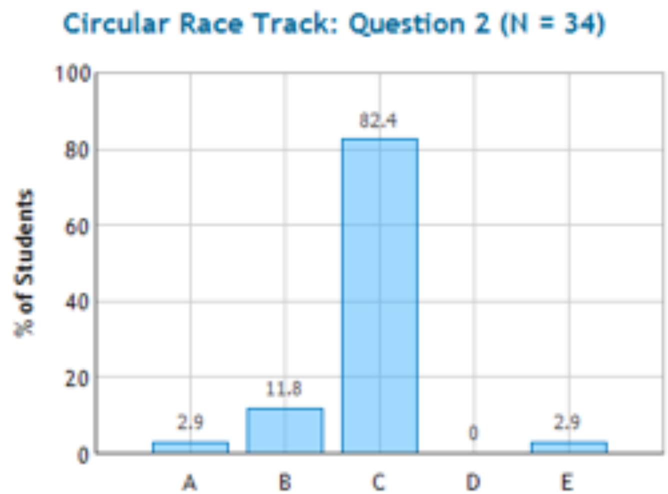
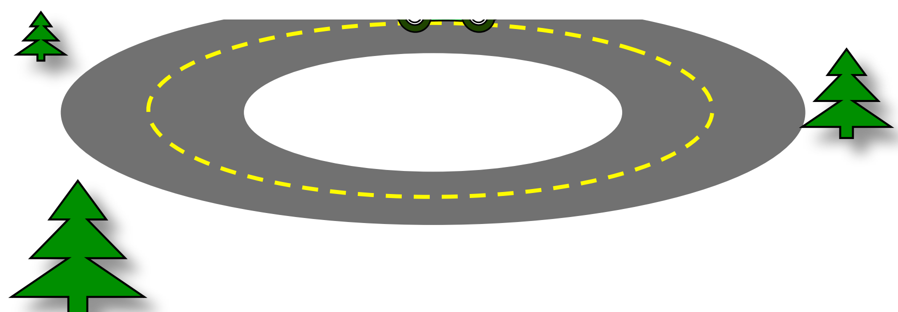


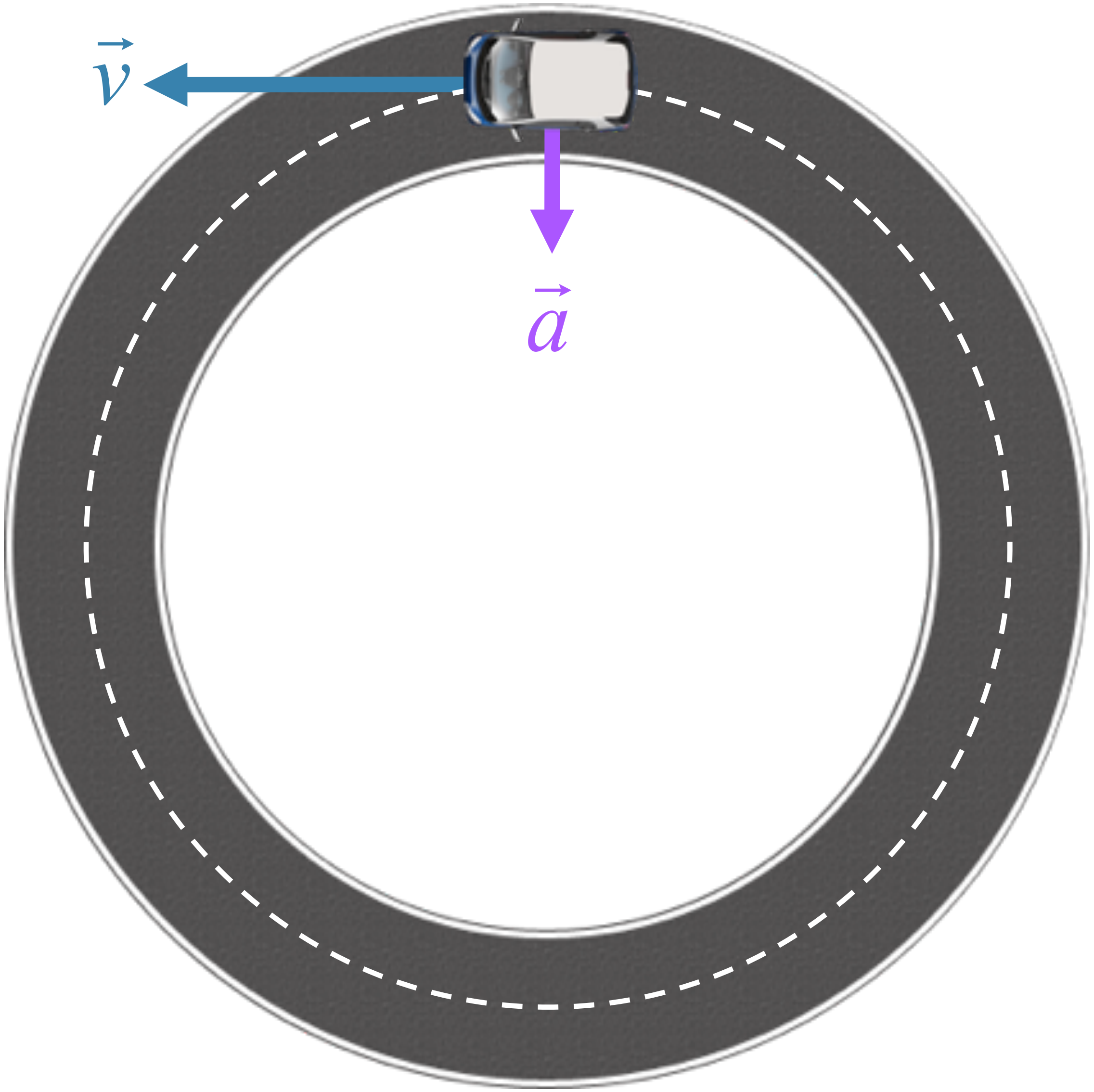




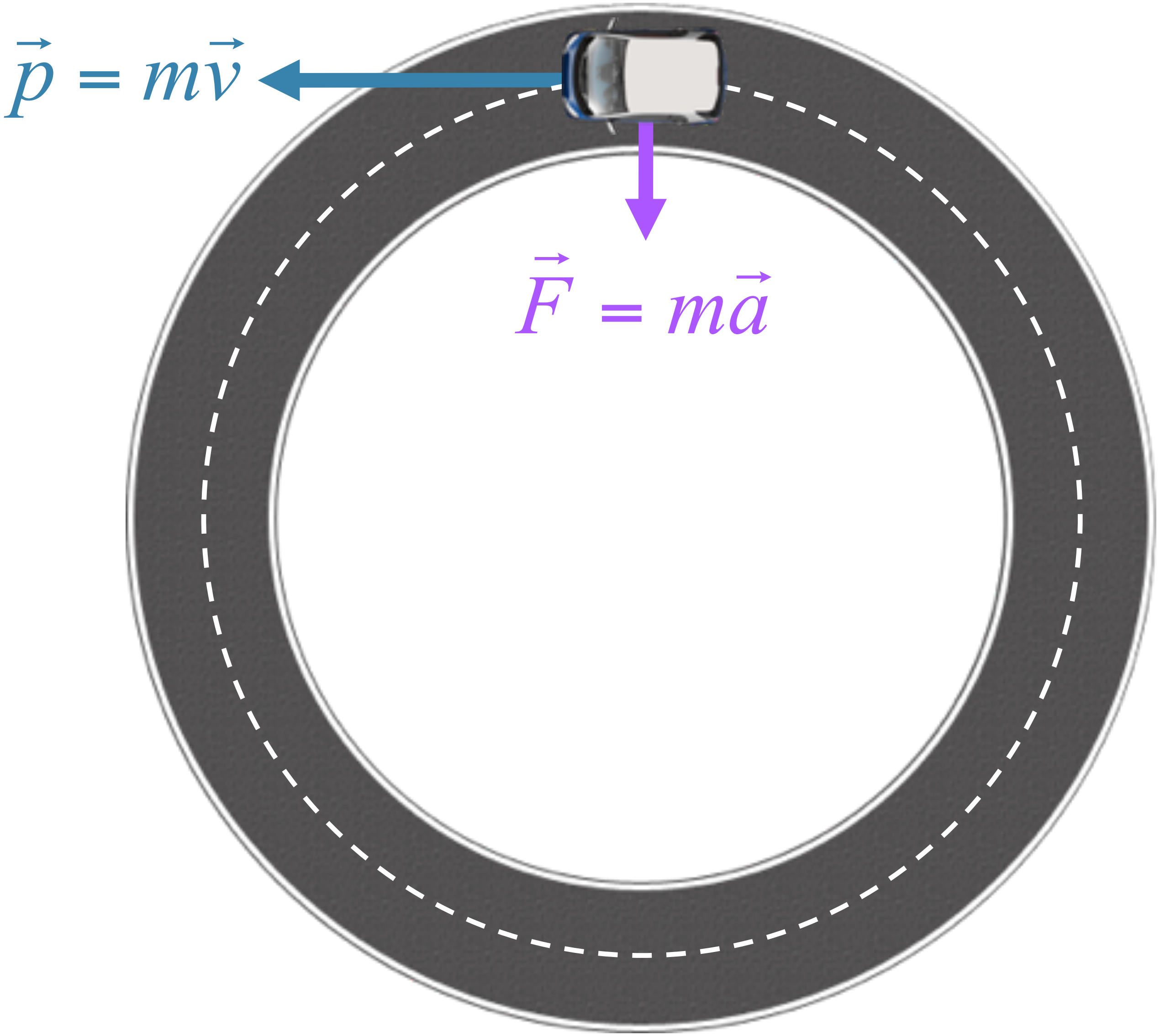
A) The momentum is in the same direction as the force.

C) It points in the same direction as v, which is forward

Acceleration is always towards the center of a circle during uniform circular motion because the change in velocity between one point of the circle and the next is in that direction. Acceleration describes the force being applied, therefore the force must be towards the center of the circle as well. In question 2, momentum is given by: p = mv, showing the relationship between velocity and momentum. Since velocity is used to determine the direction of momentum, then momentum must point in the direction of velocity in circular motion as well; which lies tangent to the circle, and in the direction you are currently moving.



$\vec{v}$
$\vec{a}$



$\vec{p} = m\vec{v}$
$\vec{F} = m\vec{a}$

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.

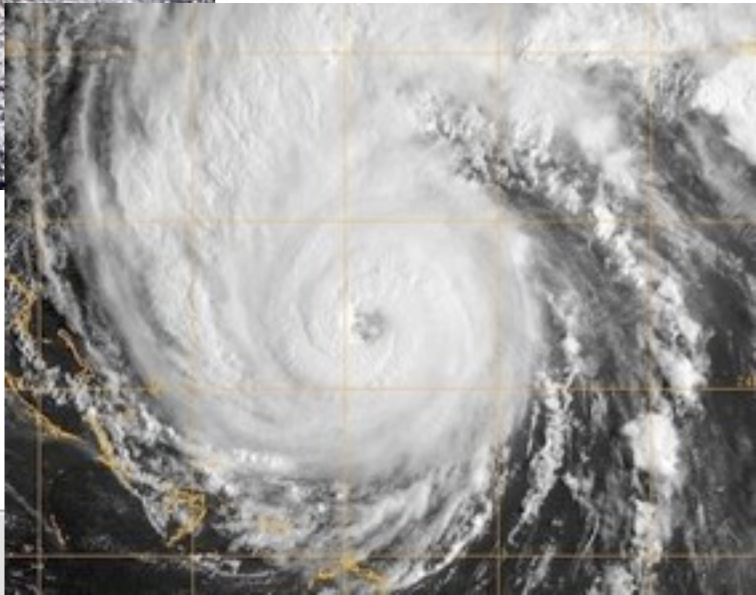
Inertial Reference Frame ≡ Reference Frame in which Newton's Laws are valid

Ice-puck

Fake Forces: Coriolis (YouTube)

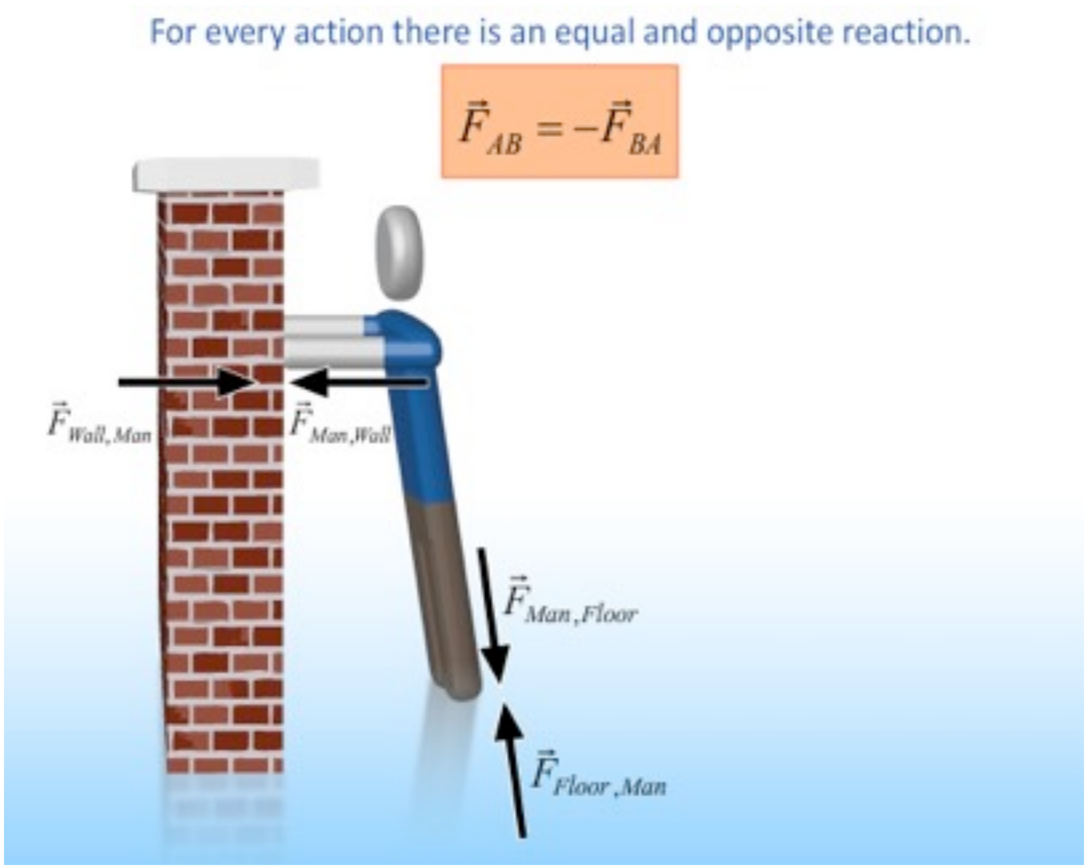
This effect can make cannons miss their target if you don't take it into account.

Hurricane Earl



And makes hurricanes rotate CCW in the Northern hemisphere — CW in Southern.

Newton's 3rd Law

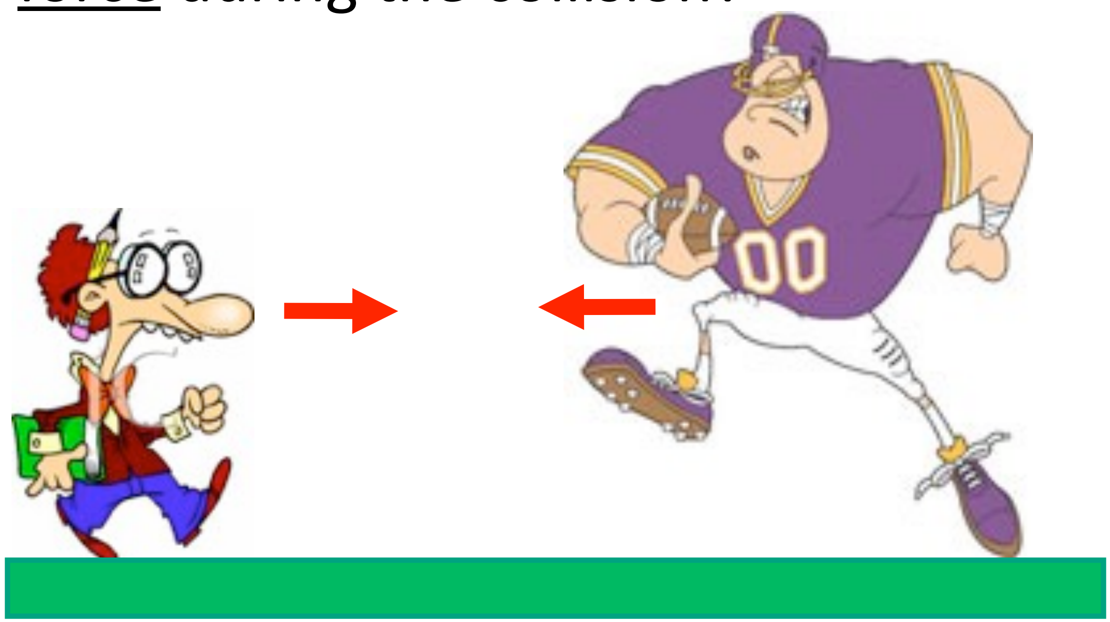


Forces come in pairs!

Fire-cart

Clicker Question

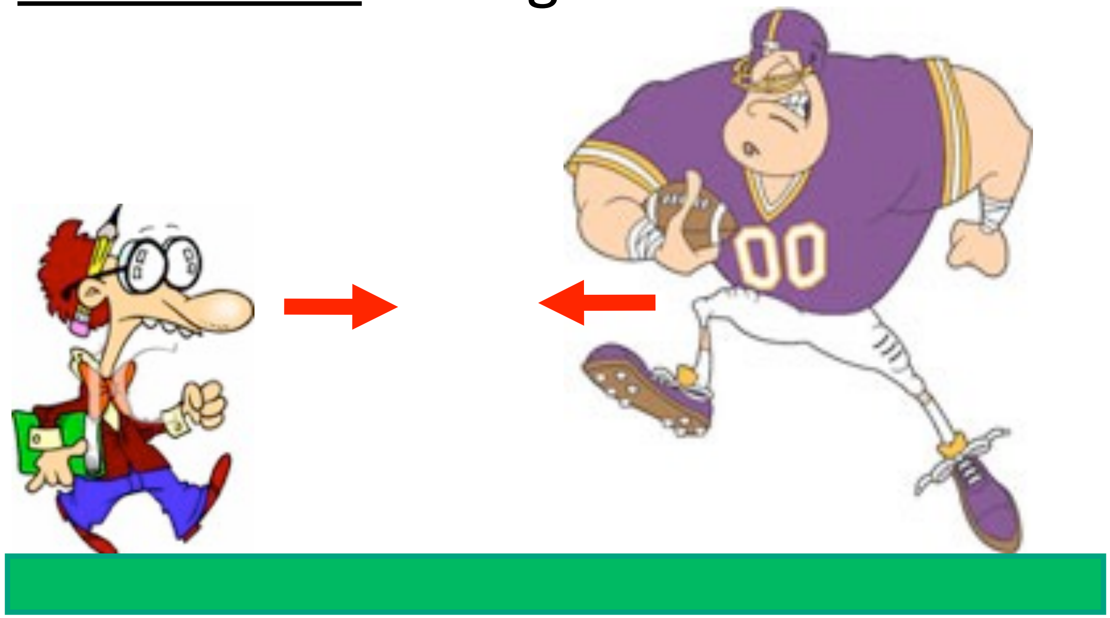
A small guy and a large football player <u>moving at the same speed</u> collide head-on. Which person experiences the larger <u>force</u> during the collision?



A) The small guy.
B) The football player.
C) They experience the same force.

Clicker Question

A small guy and a large football player <u>moving at the same speed</u> collide head-on. Which person experiences the larger <u>acceleration</u> during the collision?



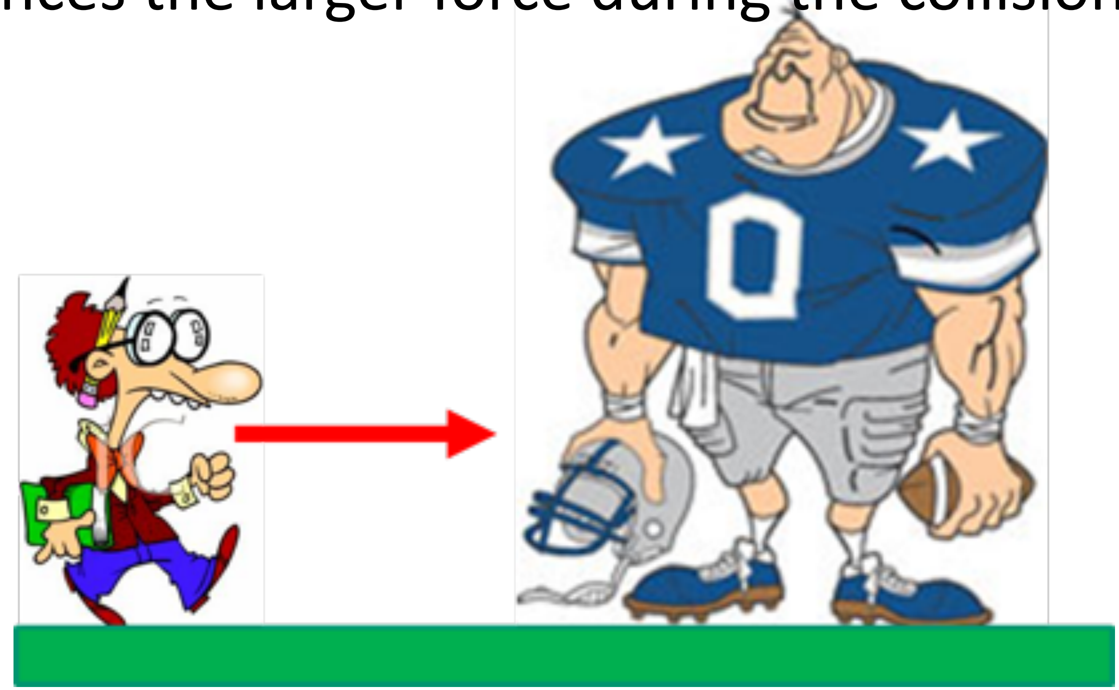
A) The small guy.

B) The football player.

C) The accelerations are the same.

Clicker Question

A small guy moving at a high speed collides with a stationary large football player. Now, which person experiences the larger force during the collision?



A) The small guy experiences the larger force.
B) The football player experiences the larger force.
C) Both experience the same force.