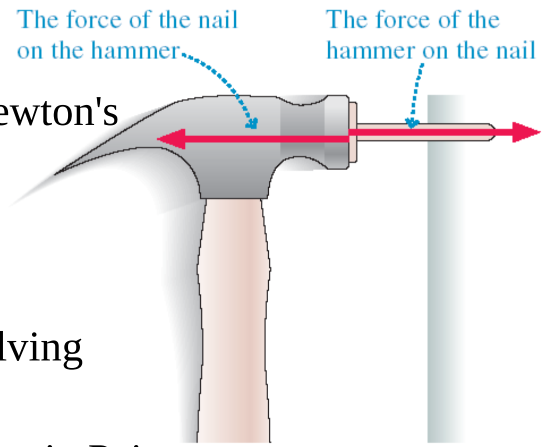
PHY131 F   Fall 2020
Class 7



Today:

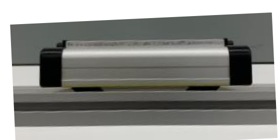
- 3.4 Inertial Reference Frames and Newton's First Law
- 3.5 Newton's Second Law: $a = \Sigma F/m$
- 3.6 Gravity Near Earth's Surface
- 3.7 Drawing Force Diagrams and Solving Dynamics Problems
- 3.8 Newton's Third Law: Forces Come in Pairs

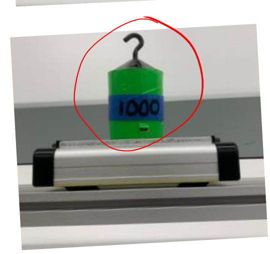
1

Let's Review Newton's Second Law

The acceleration of a system is proportional to the vector sum of all forces being exerted on the system and inversely proportional to the mass of the system.

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





Two carts are at rest. One has a lot of mass on it.
An equal positive force (to the right) is applied to both.
Over the same amount of time, which travels farther?

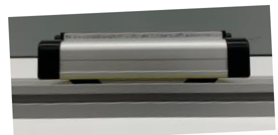
A. The less-massive cart.
B. The more-massive cart.
C. Both will travel the same distance.

2

Let's Review Newton's Second Law

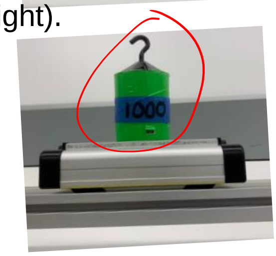
The acceleration of a system is proportional to the vector sum of all forces being exerted on the system and inversely proportional to the mass of the system.

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



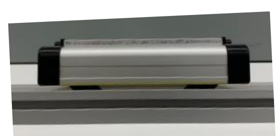
Two carts are moving at the same positive velocity (to the right).
One has a lot of mass on it.
An equal negative force (to the left) is applied to both.
Over the same amount of time, which travels farther?

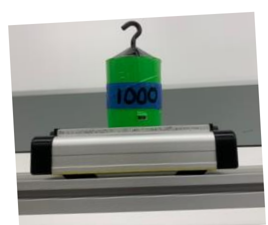
A. The less-massive cart.
B. The more-massive cart.
C. Both will travel the same distance.



3

Newton's Second Law
Let's Try it!



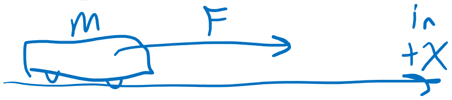


4

Solving Dynamics Problems

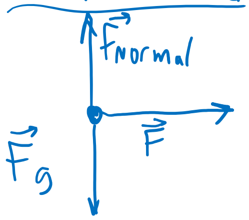
A cart of mass m is at rest. A constant positive force, F, (in the $+x$ direction) is applied to it. How far does it travel in time, t?

SKETCH & TRANS — How far in time, t?



$v_0 = 0$

SIMP. & DIAG: Neglect friction



$\vec{F}_{Normal}$ & $\vec{F}_g$ cancel, since there is no vertical acceleration.
$\Sigma \vec{F} = F$, $+x$.

REP. MATH — Newton's 2nd Law:

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

Use $x = x_0 + v_0 t + \frac{1}{2} a t^2$

Set $x_0 = 0$, $v_0 = 0$ known.

SOLVE & EVAL

$$x = \frac{1}{2}\left(\frac{F}{m}\right) t^2$$

$$x = \frac{F t^2}{2m}.$$

Lower m, higher x

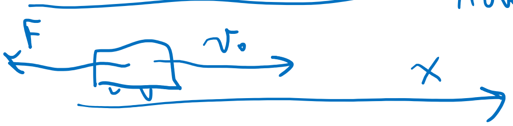
Less massive cart goes farther.

5

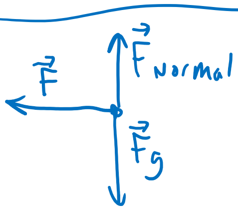
Solving Dynamics Problems

A cart of mass m is moving at initial positive velocity v_0 in the $+x$-direction. A constant negative force, $-F$, is applied to it. How far does it travel in time, t?

SKETCH & TRANS — How far?



SIMP & DIAGRAM.



$\Sigma F_x = -F$

(F is a positive #)

REP MATH

$$a_x = \frac{\Sigma F}{m}$$

Use $x = x_0 + v_0 t + \frac{1}{2} a_x t^2$

Set x_0

SOLVE & EVAL

$$x = v_0 t - \frac{F t^2}{2m}$$

Evaluate

$v_0 t$, which is large, is the same for different mass carts. More massive, $\left(\frac{F t^2}{2m}\right)$ is less, so $\left(-\frac{F t^2}{2m}\right)$ is less negative, so x is higher.

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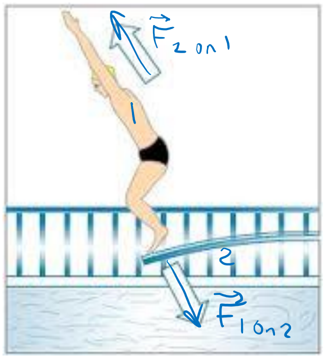
3 Newton's Third Law

When two objects interact, object 1 exerts a force on object 2. Object 2 in turn exerts an equal-magnitude, oppositely directed force on object 1:

$$\vec{F}_{1 \text{ on } 2} = -\vec{F}_{2 \text{ on } 1}$$



⚠ Note that these forces are exerted on **different objects** and *cannot* be added to find the sum of the forces exerted on one object.

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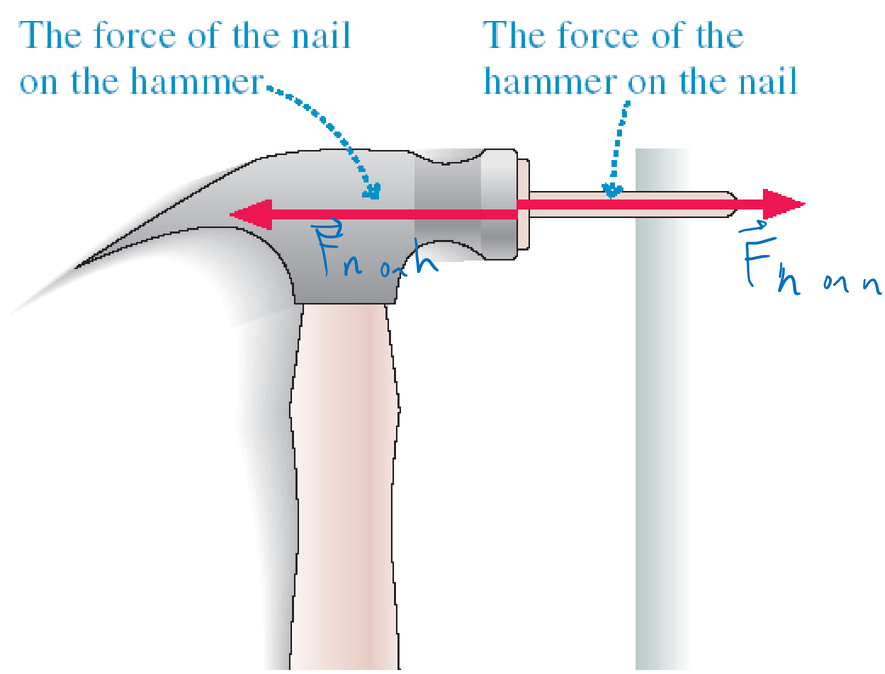

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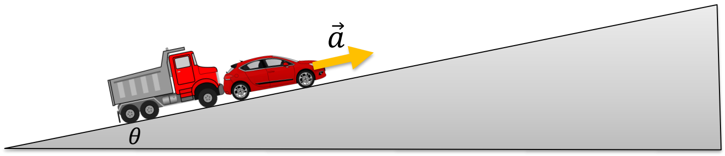
Poll



A truck is pushing a car up an incline with a constant forward acceleration $\vec{a}$. The incline has an angle θ with respect to the horizontal. Note: the car and the truck remain in contact during this acceleration. Which is **larger**, the magnitude of the force the truck applies on the car or the magnitude of the force the car applies on the truck?

A. The magnitude of the force the truck applies to the car.
B. The magnitude of the force the car applies to the truck.
C. The magnitude of the two forces are the same.
D. We must know the angle θ to answer this question.
E. We must know the masses of the truck and the car to answer this question.

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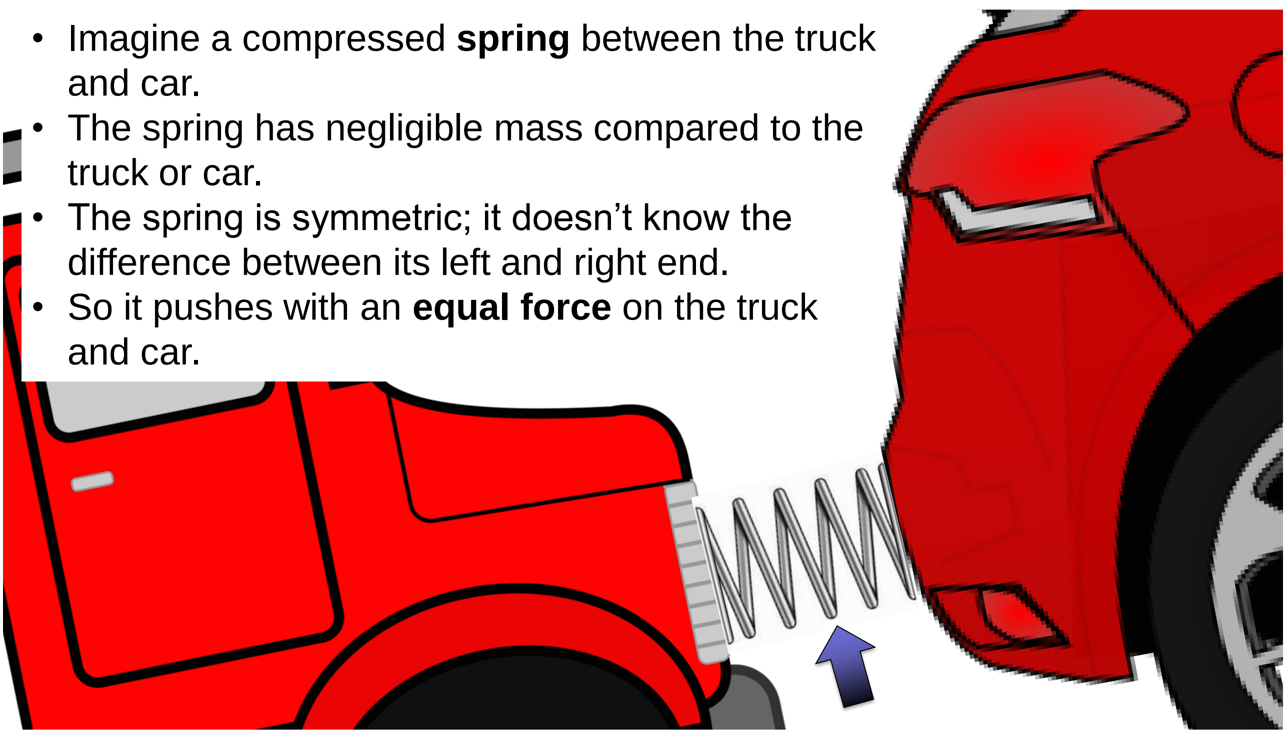
- Imagine a compressed **spring** between the truck and car.
- The spring has negligible mass compared to the truck or car.
- The spring is symmetric; it doesn't know the difference between its left and right end.
- So it pushes with an **equal force** on the truck and car.



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Forces always come in pairs.

- Every force interaction involves two objects, and two forces.
- These forces
  - are equal in strength and opposite in direction.
  - are always the same kind of force (ie gravity, normal, friction, tension, etc.)

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Poll Question

A Mack Truck drives North on the highway, and collides head-on with a mosquito. Which is true?

A. The Mack Truck does more damage to the mosquito than the mosquito does to the Mack Truck.
B. The mosquito does more damage to the Mack Truck than the Mack Truck does to the mosquito.
C. The Mack Truck does the same amount of damage to the mosquito as the mosquito does to the Mack Truck.
D. Impossible to determine without knowing the speeds of the truck and mosquito.
E. Don’t know or none of the above

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$$F = ma$$
or
$$a = F / m$$

- If the force is equal on the truck and the mosquito, is the acceleration equal?
- Acceleration is *higher* if m is *lower* (F divided by m)
- Mosquito accelerates more, so it receives more damage.

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Last time I asked:

Consider the following reasoning, and identify the mistake:

"When you pull a wagon, Newton's 3rd Law states that the wagon pulls back on you with an equal and opposite force. These forces should cancel each other. So it is impossible to accelerate the wagon!"

ANSWER:

First sentence is correct: the wagon really does pull back on you with an equal opposite force that you pull on the wagon!

Second and third sentences are not correct: **forces cannot cancel each other if they are on different objects.**

The forward static friction on your feet is larger than the backward rolling friction on the wheels of the wagon, so the system of **you and the wagon** has a forward net force, provided by the Earth (static friction). That is why you both accelerate.

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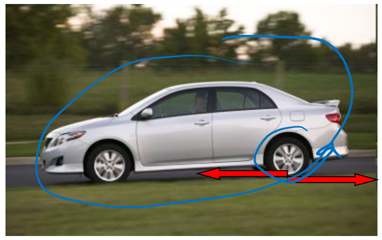
Car/Earth Friction Interaction



- Consider an accelerating car.
- The tires of the car are pushing backward on the Earth (static friction).
- The Earth is pushing forward on the tires of the car (static friction).

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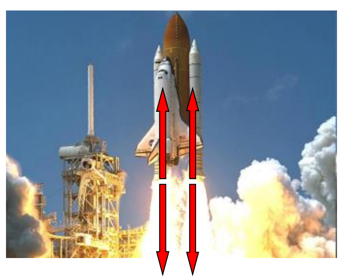
Rocket/Gas Pressure Interaction



- Consider a rocket accelerating upward.
- The rocket is pushing down on the expelled gas (pressure).
- The expelled gas is pushing up on the rocket (pressure).

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Poll Question

Basketball/Earth Gravity Interaction

- Consider a basketball in freefall.
- Gravity is pulling this ball down.
- What is the other force in this interaction?

A. The thrower's feet are pushing the ground down.
B. The ground is pushing the thrower's feet up.
C. Gravity of Earth is pulling the thrower down.
D. Gravity of the ball is pulling the Earth up.
E. Air is pushing the ball up.

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Basketball/Earth Gravity Interaction

$m_b = 0.5\ kg$
$m_E = 6 \times 10^{24}\ kg$
$\Sigma F = F_g = 4.9\ N$

$$a_{ball} = \frac{\Sigma F}{m_b} = \frac{4.9\ N}{0.5\ kg} = 9.8\ m/s^2$$

$$a_{Earth} = \frac{\Sigma F}{m_E} = \frac{4.9\ N}{6 \times 10^{24}\ kg} = 8 \times 10^{-25}\ m/s^2 \approx 0$$

- The Earth is pulling down on the ball.
- The ball is pulling up on the Earth.

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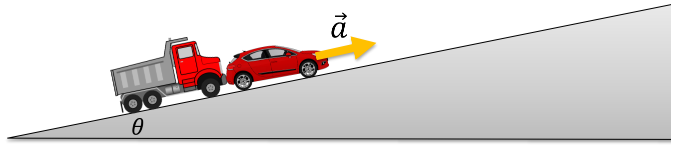
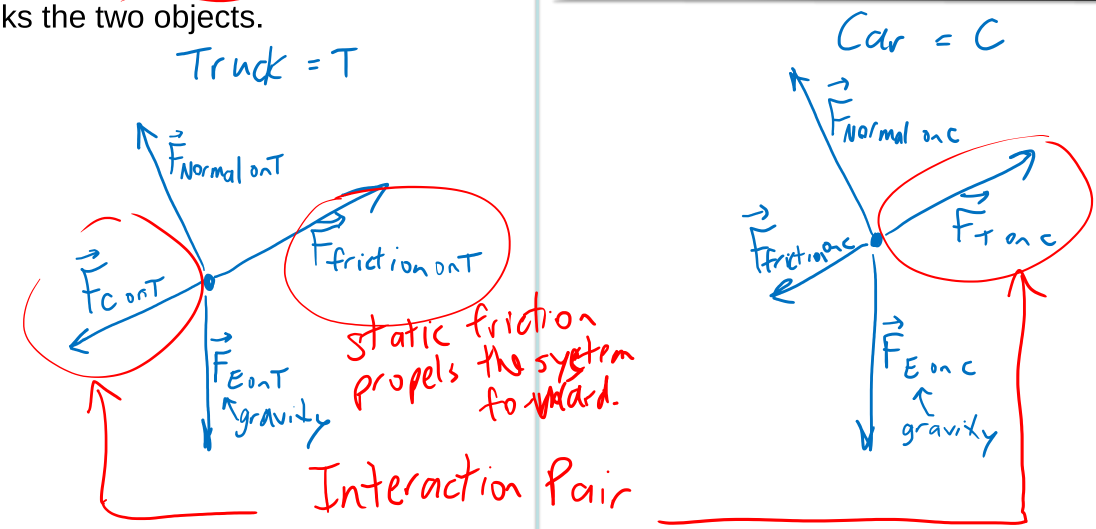
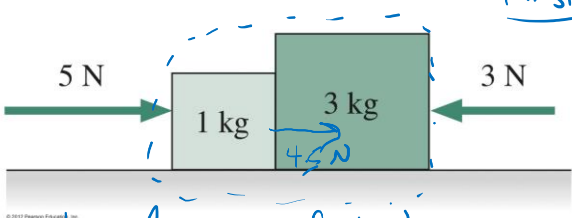
Draw **Force Diagrams** for the Truck and Car.
Identify the **Interaction Pair** that links the two objects.





Poll Question



Note: Assume frictionless surface.

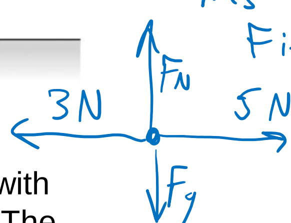
- The figure shows two blocks with two forces acting on the pair. The net force on the larger block is

$\Sigma F = 1.5$ N

A. less than 2 N.
B. equal to 2 N.
C. greater than 2 N.

First, consider "system" to be both blocks. Define +x

$m_s = 1\ kg + 3\ kg = 4\ kg$. Find a.



$\Sigma F_y = 0$ (no y-acceleration)

$\Sigma F_x = +5 - 3 = +2$ N.

$a_x = \frac{\Sigma F_x}{m_s} = \frac{2}{4\ kg} = 0.5\ m/s^2$

Second - consider Larger block as "system"
Know $a = +0.5\ m/s^2$
Solve $a = \frac{\Sigma F}{m}$ for $\Sigma F = ma$
$= (3\ kg)(0.5\ m/s^2)$

Before Class 8 on Monday

- Finish your study of Chapter 3.
- Tuesday's 30-minute test at 8pm will be based on all of Chapters 1, 2 and 3. Strong emphasis on Chapters 2 and 3.
- To consider:
- "After having been thrown upward, a 100-g apple falls back into your hand and you catch it. While you are catching it, is the force that you exert on the apple more than, less than, or the same as the force that you exert on the apple when you are holding it at rest?"

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