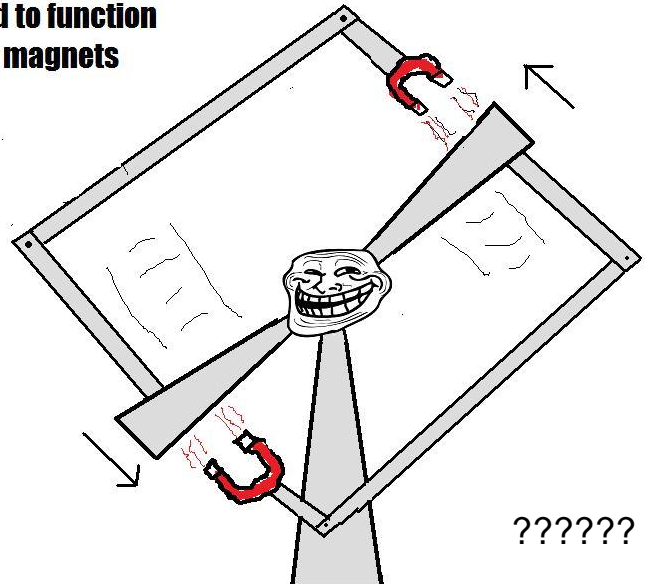# PHY131H1F - Class 12

Wind turbines do not need wind to function if you use magnets

Today, Chapter 7:

- Newton's Third Law
- Force Interaction Pairs
- Ropes and Pulleys

??????

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

A. The Mack Truck exerts a greater force on the mosquito than the mosquito exerts on the Mack Truck.
B. The mosquito exerts a greater force on the Mack Truck than the Mack Truck exerts on the mosquito.
C. The Mack Truck exerts the same force on the mosquito as the mosquito exerts on 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

Class 12 Preclass Quiz on MasteringPhysics

- This was due this morning at 8:00am
- 910 students submitted the quiz on time.
- 79% of students answered correctly that **the mosquito exerts the same amount of force on the truck as the truck exerts on the mosquito.**
- 77% of students answered correctly that **the propulsion force which accelerates a car is actually static friction!!** (18% answered "the car engine")
- 82% of students answered correctly that **the "acceleration constraint" in Chapter 7 problems is that two objects have accelerations with the same magnitude.**

Class 12 Preclass Quiz on MasteringPhysics

- Some interesting student comments/feedback:
- *I don't like mosquitos*
- *The part about static friction really "propelled" me through the reading. I also found Newton's Third Law to be very "interactive"*
- *Dynamics is like accounting. …We are keeping track of forces and balancing the second law of newton like accountants balance their cash statements.*
- *I like Newton's third law, if action-reaction force is equal, why someone likes to punch the other? dont they get hurt?*
- *Why in a car-crash one car could get damaged when another remains intact.*
- *Calculus midterm today! #rekt*
- 那么问题来了，挖掘机技术哪家强？

Last day I asked at the end of class:

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.
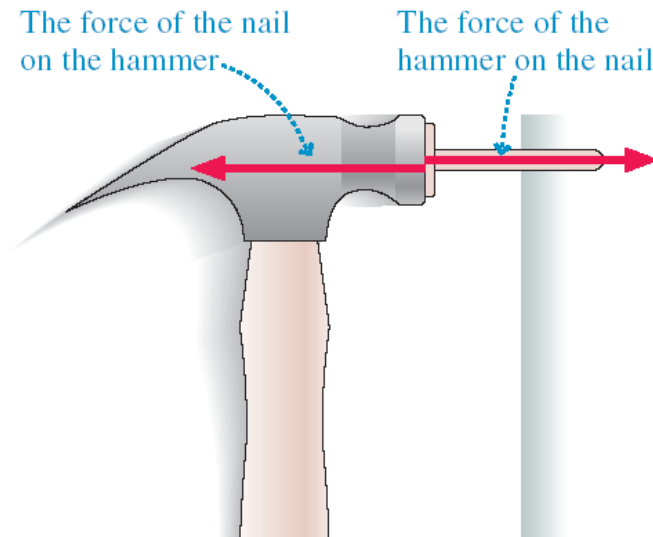
3 Newton's Third Law

If object 1 acts on object 2 with a force, then object 2 acts on object 1 with an equal force in the opposite direction.

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

FIGURE 7.1 The hammer and nail are interacting with each other.

The force of the nail on the hammer

The force of the hammer on the nail

Clicker 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

$$F = ma$$
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.

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.)
 - always act on *different* objects.

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FIGURE 7.3 The ocean tides are an indication of the long-range gravitational interaction of the earth and the moon.
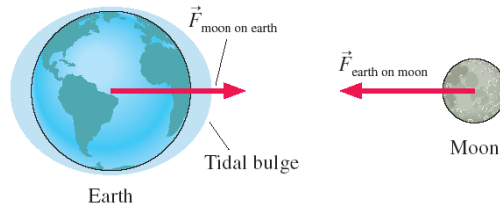
- The entire Earth accelerates toward the Moon, due to this pulling force.

- To find the total acceleration, you use the force as calculated for the centre-to-centre distance.

- Since $F_G = GMm/r^2$, the force on the ocean nearer to the moon will be greater, so it will accelerate more than the rest of the Earth, bulging out.

FIGURE 7.3 The ocean tides are an indication of the long-range gravitational interaction of the earth and the moon.
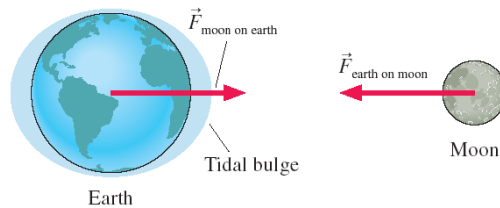
- Similarly, since $F_G = GMm/r^2$, the force on the ocean further from the moon will be less, so it will accelerate *less* than the rest of the Earth, remaining behind, forming a bulge.

- In general, tidal effects tend to *stretch* objects both toward and away from the object causing the tides.

Clicker Question

- A cyclist is pushing on his pedals, and therefore accelerating to the left.

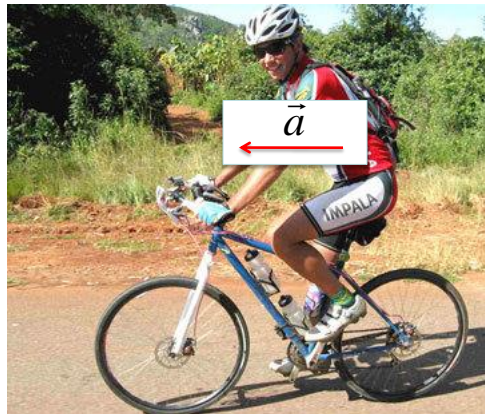- What is the direction of the force of static friction of the ground on the **back wheel?**

A. Left
B. Right
C. Up
D. Down
E. zero
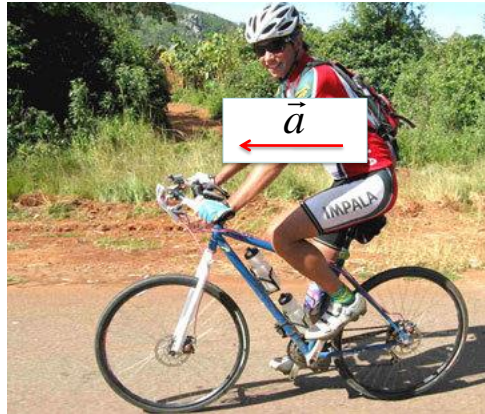
Clicker Question

- A cyclist is pushing on his pedals, and therefore accelerating to the left.

- What is the direction of the force of static friction of the ground on the **front wheel?**
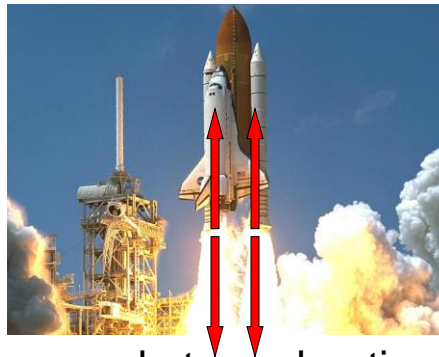
A. Left
B. Right
C. Up
D. Down
E. zero

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).

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).

Man/Rope Tension Interaction

- This man is pulling the rope to the left.
- What is the other force in this interaction?

A. His feet are pushing the ground to the right.
B. The ground is pushing his feet to the left.
C. The rope is pulling the man to the right.
D. Gravity of the Earth is pulling the man down.
E. Gravity of the man is pulling the Earth up.

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.

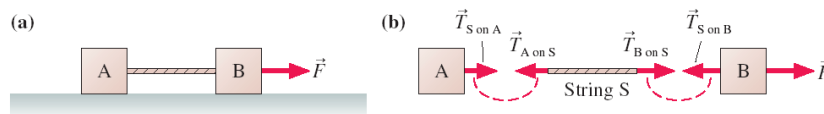# Basketball/Earth Gravity Interaction

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

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

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

The Massless String Approximation

FIGURE 7.22 The string's tension pulls forward on block A, backward on block B.

Often in physics problems the mass of the string or rope is much less than the masses of the objects that it connects. In such cases, we can adopt the following **massless string approximation**:

$$T_{\text{B on S}} = T_{\text{A on S}} \qquad \text{(massless string approximation)}$$

Pulleys

Acceleration constraints

Objects that are constrained to move together must have accelerations of equal magnitude: $a_A = a_B$. This must be expressed in terms of components, such as $a_{Ax} = -a_{By}$.
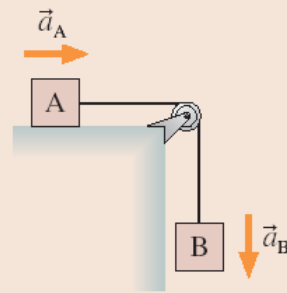
Example $M = 500 g, \ m = 50 g$

A cart of mass M is on a track which is at an angle of θ above the horizontal.
The cart is attached to a string which goes over a pulley; the other end of the string is attached to a hanging mass, m.
What is the acceleration of the cart?
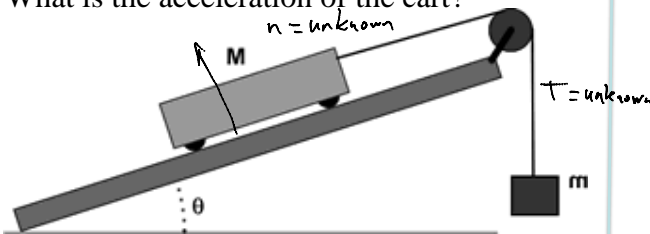
2 objects
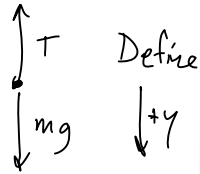$\Rightarrow$ 2 free-body diagrams.

f.b.d. of m:

Define: $+y$

f.b.d. for M:

Define:

	x	y
$\vec{T}$	T	0
$\vec{n}$	0	n
$M\vec{g}$	$-Mg \sin\theta$	$-Mg \cos\theta$

$\vec{F}_{net}$

$n = $ unknown
$T = $ unknown

11

f.b.d. for m:

$\uparrow T$ Define
$\downarrow mg$ $\downarrow +y$

f.b.d. for M:

Mg $(F_g)_y$ (no friction)
$(F_g)_x$
for M:

$\nwarrow n$ $\nearrow T$
$-\theta$
$\downarrow Mg$

Define:
$\nwarrow +y$ $\nearrow +x$

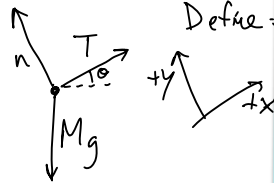|	x	y
$\vec{T}$	T	0
$\vec{n}$	0	n
$\vec{F_g}$	$-Mg\sin\theta$	$-Mg\cos\theta$
$\vec{F}_{Net}$		

$(F_{net})_x = Ma_x = T - Mg\sin\theta$

$\Rightarrow a_x = \dfrac{T - Mg\sin\theta}{M}$ for M

don't know T....

For m, the hanging mass, acceleration constraint is
$a = (a_y)_m = (a_x)_M$ (since +y is down)

$(F_{net})_y = ma_y = mg - T$, $\boxed{T = mg - ma}$

Solve for T in M case
$\boxed{T = Ma + Mg\sin\theta}$

eliminate T: $T = T$

$(F_{net})_x = Ma_x = T - Mg\sin\theta$

$\Rightarrow a_x = \dfrac{T - Mg\sin\theta}{M}$ for M.

don't know T...

For m, the hanging mass, acceleration constraint is
$a = (a_y)_m = (a_x)_M$ (since +y is down).

$(F_{net})_y = ma_y = mg - T$, $\boxed{T = mg - ma}$

Solve for T in M case,
$T = Ma + Mg\sin\theta$

eliminate T: $T = T$

$Ma + Mg\sin\theta = mg - ma$
solve for a:
$Ma + ma = mg - Mg\sin\theta$
$a(M + m) = mg - Mg\sin\theta$
$a = \dfrac{mg - Mg\sin\theta}{m + M}$
$a = g\left(\dfrac{m - M\sin\theta}{m + M}\right)$

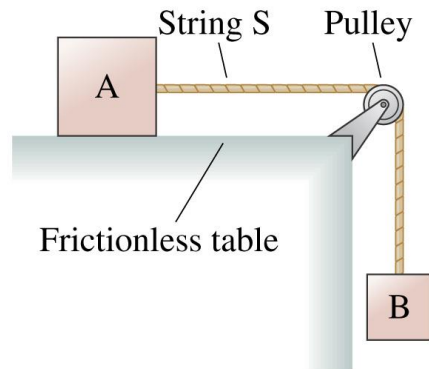Can be + or − or zero.
$a = 0$ at $\theta = \theta_{critical}$, where
$m - M\sin\theta_{crit} = 0$
$\theta_{crit} = \sin^{-1}\left(\dfrac{m}{M}\right) = \sin^{-1}\left(\dfrac{50g}{500g}\right)$
$\boxed{\theta_{crit} = 5.7°}$

In the figure to the right, is the tension in the string greater than, less than, or equal to the force of gravity on block B?

String S   Pulley

A

Frictionless table

B

    A. Equal to
    B. Greater than
    C. Less than

Before Class 13 on Wednesday
… my last class!

- Please read the first 3 sections of Knight **Chapter 8**
- If you haven't done Problem Set 5 yet – it's due tonight by 11:59pm!
- Something to think about: A ball is whirled on a string in a vertical circle. As it is going around, the tension in the string is

A. constant.

B. greatest at the top of the motion

C. greatest at the bottom of the motion

D. greatest somewhere in between the top and bottom.