

Chapter 5:
Application of the Laws of Motion

Did you read chapter 5 before coming to class?
A. Yes
B. No

Review

- Explain to your neighbor the difference between force, velocity, and acceleration.

Review

- We now have the tools to analyze macroscopic motion:
 - Newton's three laws of motion
 - Force laws describing the gravitational and electromagnetic interaction.

How about contact force?

- Contact forces are due to air friction, sliding friction, cutting, touching, pushing, resting on something, connected by a rope, etc.
- It only exists when things touch.
- The positive and negative elements rearrange when brought close to other charged elements. The net result is observed as a contact force.

Example

- Swinging a ball on a string
 - What are the forces
 - What type of motion is this
- How do we get tension on a string from electric forces?

The Fly and the Train

- No interaction yet.
- Mass of train = 100 tons
- Mass of fly = 10^{-8} tons

The force of the fly on the train will be

- a) Smaller than the force of the train on the fly
- b) Equal to the force of the train on the fly
- c) Greater than the force of the train on the fly
- d) Cannot be determined without more information



The acceleration of the fly will be

- a) Smaller than the acceleration of the train
- b) Equal to the acceleration of the train
- c) Greater than the acceleration of the train
- d) Cannot be determined without more information



The Fly and the Train

Mass of train = 100 tons
 Mass of fly = 10⁻⁸ tons



- Interaction!
- 3rd Law:
 Force of fly on train = Force of train on fly
- 2nd Law: $m_{fly}a_{fly} = m_{train}a_{train}$
- Or $a_{train}/a_{fly} = m_{fly}/m_{train} = 10^{-8}/100 = 10^{-10}$
- So the train accelerates 10⁻¹⁰ as much as the fly!

How does the acceleration of a battleship compare to the acceleration of the shells when it fires a broadside?

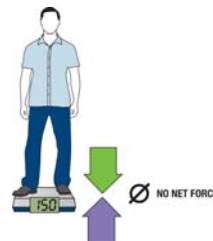
- A shell weighs 2,700 pounds (times 9 for a broadside)
- The ship weighs 130,000,000 lbs
- With 9 shells, the boat is 5,346 more massive than the shells
- The acceleration of the boat is 5,346 times less than the shells
- In the absence of friction, the final velocity of the boat would be 6 inches per second vs. 2,500 feet per second for the shells. In reality, the motion is a very slight rolling that is quickly damped by the water.



A strategy for analyzing motion

1. What role does gravity play? Is it balanced, unbalanced, or insignificant?
2. Are charged objects, current-carrying conductors, or magnets involved?
3. What does the object touch? (Contact forces)
4. Do air or contact forces cause friction? (What direction is frictional force?)

Riding in an elevator



Jumping

- What role does gravity play? Is it balanced, unbalanced, or insignificant?
- Are charged objects, current-carrying conductors, or magnets involved?
- What does the object touch? (Contact forces)
- Do air or contact forces cause friction? (What direction is frictional force?)



At the top of his jump, the basketball player throws the ball down (through the hoop, of course). This action

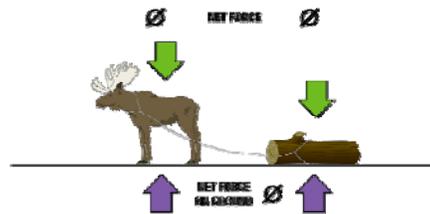
- Decreases hang time (ever so slightly)
- Increases hang time (ever so slightly)
- Does not affect hang time a bit
- Is impossible



A moose is chained to a log...

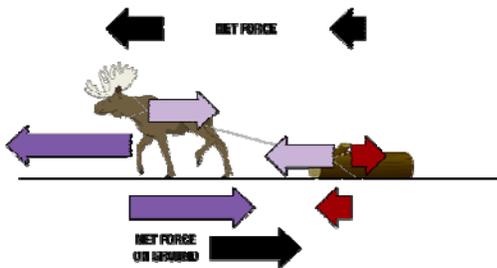
- You tell him to pull the log, but he says he can't, because every time he pulls on the log it pulls back with an equal force (via Newton's third law). Thus he cannot move the log. Explain to the moose why he is wrong.

The forces standing still

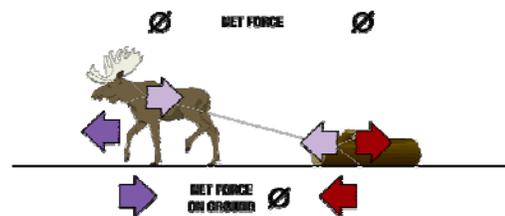


Draw all of the horizontal force arrows for the moose and the log as the moose begins to pull on the log

While accelerating



In uniform motion



In the absence of any other forces on the earth, the moose accelerating forward causes:

- a) The earth to also accelerate forward
- b) The earth to accelerate backward
- c) No effect

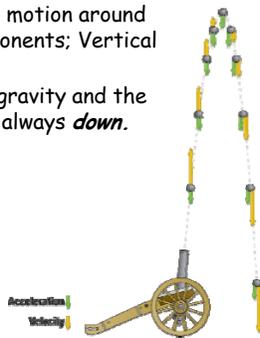
Projectile Motion

- Throwing a ball straight up
 - What are the forces acting on the ball while you are throwing it?
 - What type of motion is this?
- After you let go
 - What are the forces acting on the ball after you release it?
 - What kind of motion does it experience?
 - What is its acceleration when it momentarily stops at the top?



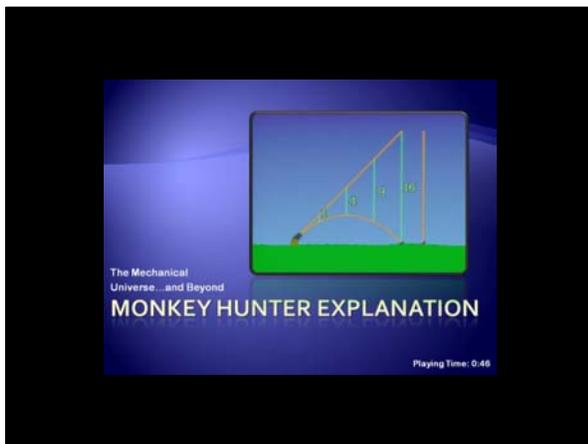
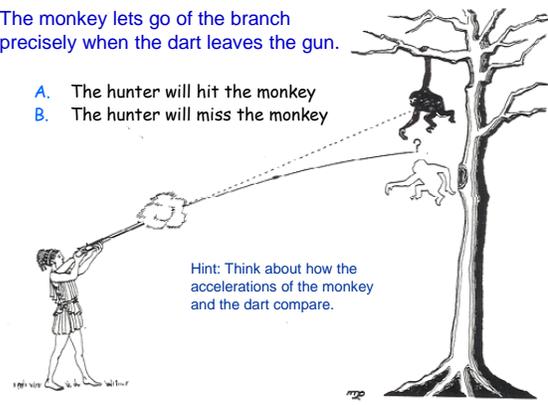
Review: Going ballistic

- We can break all motion around us into two components; Vertical and Horizontal.
- The force from gravity and the acceleration are always **down**.



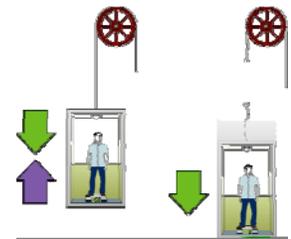
The monkey lets go of the branch precisely when the dart leaves the gun.

- A. The hunter will hit the monkey
- B. The hunter will miss the monkey



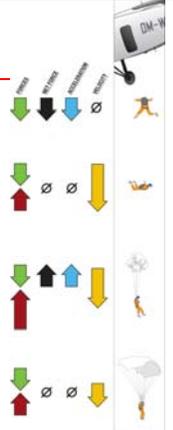
A falling elevator

- What role does gravity play? Is it balanced, unbalanced, or insignificant?
- Are charged objects, current-carrying conductors, or magnets involved?
- What does the object touch? (Contact forces)
- Do air or contact forces cause friction? (What direction is frictional force?)



Add some air resistance: Sky Diving

- In the presence of air resistance, a falling object will reach terminal velocity
- Terminal velocity depends on the mass and geometry of an object



Movie physics: What's wrong with Flash Gordon's rocket?

- What forces act on the ship?

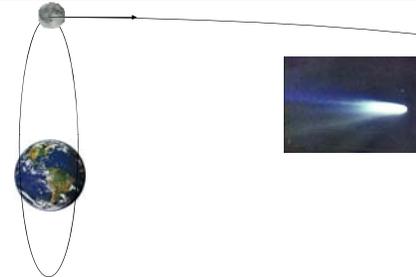


You turn left in a car at a constant speed. The horizontal force **on you**

- Pushes you to the right
- Pushes you to the left
- Pushes you straight ahead



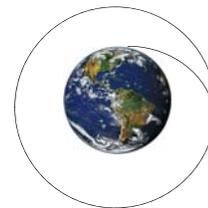
Centripetal Acceleration



Your assignment: get the moon to orbit in a circle

$$a = \frac{\text{speed}^2}{d} = \frac{F}{m} = G \frac{M_e}{d^2}$$

Visiting the moon



Visiting the moon

