Newton's Laws

1) Inertia - objects in motion stay in motion
2) F=ma
3) Equal and opposite reactions

Newton's 1st Law

- What is the "natural" state of motion of an object?
  - An object at rest remains at rest, and an object in motion continues to move in a straight line at constant speed, unless acted upon by an external force.
- Also known as the "law of inertia"
  - Inertia: Tendency of an object to resist changes in motion.
  - An object will continue to do whatever it has been doing until it is "forced" to move in a different way. (Demos)

Newton's 2nd Law of Motion

- Recalling Newton's first law of motion, how will an object be affected when the forces acting on it are not in equilibrium?
- What is the cause of this change?

Newton's 2nd Law of Motion

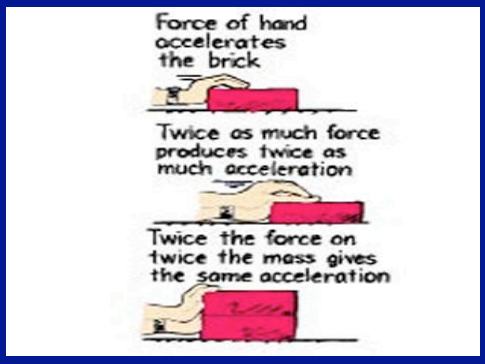
- Recalling Newton's first law of motion, how will an object be affected when the forces acting on it are not in equilibrium?
  - The object will accelerate.
- What is the cause of this change?
  - The net force (the applied force that is not cancelled by other forces) on the object causes the acceleration.

Newton's Second Law (cont.)

- How do you expect the acceleration to depend on the applied force?
- What property of an object determines how much acceleration a given force will cause?

Newton's Second Law (cont.)

- How do you expect the acceleration to depend on the applied force?
  - The greater the applied force, the greater the acceleration
- What property of an object determines how much acceleration a given force will cause?
  - The inertia of the object (as measured by its mass)



Newton's Second Law (cont.)

- Given everything you now know and using *`**a**' for acceleration, `**F**' for net force, and `m' for mass, how would you write Newton's 2nd law as an equation?*

Newton's 2nd Law - Defined

- "*The acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object.*"

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

- Inversely Proportional?
  - Acceleration decreases as mass increases (for same amount of force)

Clicker Question:

Suppose you give a 10 Newton push to Ryan on skis (he weighs 50 kg), how much will he accelerate?

A: 2 m/s^2

B: 0.2 m/s^2

C: 5 m/s^2

D: infinite

Clicker Question:

Suppose you give a 10 Newton push to Nicki on skis (she weighs half as much as Ryan), how much will she accelerate?

A: half as much as Ryan

B: the same as Ryan

C: twice as much as Ryan

D: infinite

Clicker Question:

If Ryan has a mass of 50 kg on Earth, how much mass does he have on the Moon?

A: 1 kg

B: 5 kg

C: 10 kg

D: 50 kg

Mass vs. Weight

- *How is mass related to weight, and how are the two concepts different?*
- *Demo - Weight of a 1 kg object*
- *Would the weight of an object change if it was brought to the moon? What about its mass?*

Detecting Mass in Outer Space

- Mass is a fundamental property of an object, while weight is not.
  - How could we detect the mass of an anvil in outer space?

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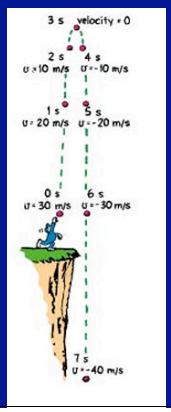
- Mass is a fundamental property of an object, while weight is not
  - How could we detect the mass of an anvil in outer space?
    - Shake it – just as difficult as on Earth!
    - Throw it – will cause you to recoil!

Magic Trick?

- A magician tells you that he is going to throw a ball at a certain speed so that it: travels for awhile, comes to a complete stop, and returns to his hand at the same speed that he threw it (but in the opposite direction). All of this, without having the ball bounce off of anything and with nothing attached to the ball.
- Can the magician do this without violating any of the laws of physics that we have learned?

A Ball Thrown Straight Up

- What is the speed of the ball at its highest point?
- What is the acceleration of the ball at its highest point?



Slinky Drop

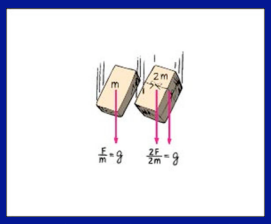
- What will happen to the bottom end of the slinky when I let go of the top end?

Free Fall in a Vacuum

- In a vacuum, a coin and a feather will fall at the same rate. Does this mean that equal gravitational forces acts on both the coin and the feather?

Why not Galileo's Laws of Motion?

- Galileo
  - Founded concepts of inertia and acceleration
  - First to measure acceleration of falling objects
  - But, could not explain why different masses fall freely at the same rate!
- Newton
  - Second law explains why!



An object with mass *m* feels a gravitational force *F*.

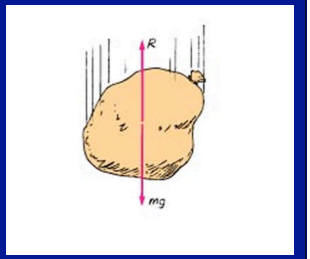
An object with twice the mass feels twice the force, but the ratio is the same in either case.

Terminal Velocity

- A sky diver jumps out of a plane.
  - How does his velocity change with time?
  - How does his acceleration change with time?
  - When terminal velocity is reached, what is the net force acting on him? What is his acceleration?

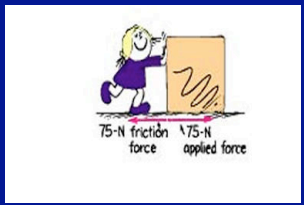
Air Resistance

- *Air resistance (R) is a force directed opposite the motion*
  - *increases with increasing velocity*
- *Terminal velocity*
  - *Speed at which air resistance balances gravity*
    - *R = mg*



Friction

- Friction acts between objects that `slide' against one another.
  - Due to surface irregularities
  - Always opposes the motion of an object



How would you describe the motion of the box?

What will happen if she stops pushing?

Newton's 3rd Law of Motion

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  - How do the magnitudes and directions of the two forces compare?
    - The forces are equal in magnitude and opposite in direction.

Newton's 3rd Law - Defined

- Newton recognized that this is true for all interactions between objects . His 3rd law states that:
  - *Whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first.*
  - Or, *to every action there is always an equal and opposite reaction.*
    - *Action-reaction distinction arbitrary. But, one cannot exist without the other!*
    - *Ex. A car on a normal road vs. a car on an icy road (no force of friction).*

Clicker Question:

Which of the following has the highest terminal velocity if dropped out of a plane?

A: feather

B: small child

C: average size phys 102 student

D: average size house cat

Clicker Question:

In which orientation does a penny fall faster?

A: |

B: \

C: –

D: no difference

Clicker Question:

If the terminal velocity for a skydiver is 90 m/s (about 200 mph), about how long does it take to reach this velocity in freefall?

A: 1 second

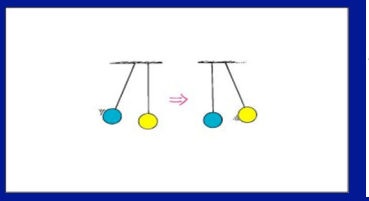
B: 10 seconds

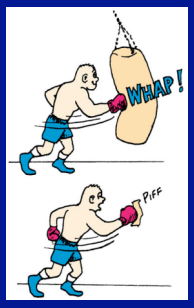
C: 100 seconds

D: 1000 seconds

The Role of Inertia

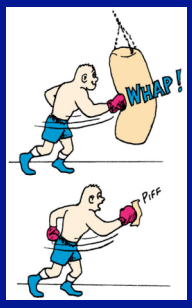
- What role do the masses of the interacting objects play in Newton's third law?





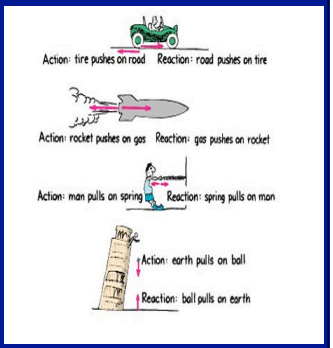
The Role of Inertia

- What role do the masses of the interacting objects play in Newton's third law?
  - The masses (or inertias) of the interacting objects determine how much force one body can exert on another.
- Is force (like velocity or mass) a property of an individual object?



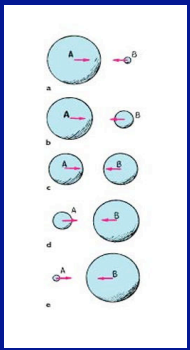
Action and Reaction

- Cars and rockets rely on Newton's third law for their operation.
- Also holds for objects at rest.
- What is the action-reaction pair for the case of an object in free fall?



Acceleration of a Planet

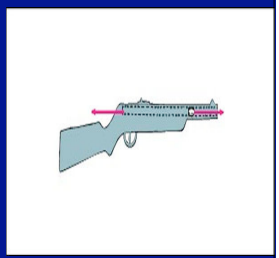
- How do the accelerations of A and B change as we move from top to bottom in the diagram?



Recoil

- According to Newton's 3rd law, the recoil force on the gun is the same as the force on the bullet. So, why does the bullet accelerate more than the gun?

Cart DEMO



Jet Propulsion

- Does a rocket need something to push against (like the Earth's surface or atmosphere) in order to work?

Jet Propulsion

- Does a rocket need something to push against (like the Earth's surface or atmosphere) in order to work?
  - No. A rocket continually recoils from the `molecular bullets' that it expels as exhaust gas.
    - This is why rockets work even in the vacuum of space!