Forces in One Dimension

Ch 5

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Objectives

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- Draw free-body diagrams to describe all the forces in a system
- Explain the meaning of Newton's three laws of motion
- Perform calculations using Newton's second law

Free-body Diagrams

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- Force = push or pull
- Represent all forces
  - Forces are vectors
  - You can add and subtract vectors

Free-body Diagrams

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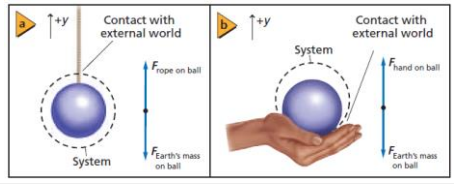
- Use dot in place of object
  - No pretty drawings here



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- Forces can include force due to gravity, weight, normal force, friction, tension (ropes, etc), thrust (cars, rockets, etc), lift (airplanes)

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- Net force = sum of forces
- Draw free-body diagrams for:
  1. A book is resting on the table.
  2. Now you push on the book. Draw another diagram.
  3. You suspend a bucket with a rope. Draw the free-body diagram.

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- Draw the diagrams for these situations:
  4. You drop your pencil.
  5. You are driving at a constant velocity.
  6. You drop a feather and it falls at a constant **terminal** velocity due to air resistance.

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Terminal Velocity

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Second Law: $\Sigma F = ma$

- Units of force = N (Newton)
  $1\ N = 1\ kg \cdot m/s^2$
- Forces can be contact forces
  - Push, pull, hit, etc
- Forces can be field forces
  - Gravity, electric fields, magnetic fields, etc

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7. You have a mass of 43 kg. What is your weight (a force) on Earth?
8. You go to the moon. Does your mass change? Weight? Why?
9. What is your weight on the moon, where $a = -1.62\ m/s^2$?

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10. Two people push a 25 kg table. Person A pushes with a force of 12 N and Person B pushes with a force of 15 N.
    a. What is the acceleration of the table if both people are pushing in the same direction? (Draw a free-body diagram, determine net force)
    b. What is the acceleration of the table if they push in opposite directions? In which direction is acceleration? (Draw diagram, determine F_{net})

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Newton's First Law—Inertia

- Inertia = tendency to resist change
- "An object at rest stays at rest and an object stays in motion at constant v unless acted upon by an unbalanced force"
- Constant motion or rest if $F_{net} = 0$
- Net force = 0 therefore a = 0

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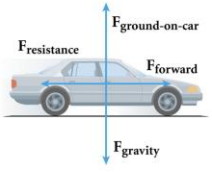

- Car is in constant motion (constant v)
- $-F_g = F_{ground\text{-}on\text{-}car}$
- $F_{forward} = -F_{resistance}$

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Third Law: Paired forces

- For every action there is an equal and opposite reaction
- Hang a bucket on a rope
  - Bucket exerts force on rope due to gravity
  - Rope exerts force on bucket due to tension

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- Dropping a softball
  - Earth exerts a force on softball, $F_{Earth\ on\ ball}$
  - Softball exerts equal and opposite force on Earth, $F_{ball\ on\ Earth}$
  - The forces are equal in magnitude, opposite in direction
  - The $a_{ball\ toward\ Earth} >>>>>> a_{Earth\ toward\ ball}$

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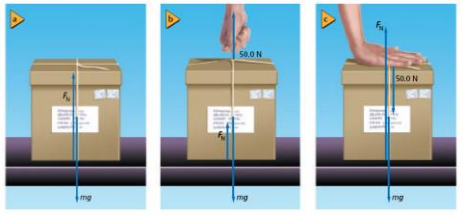
- Hammer a nail into wood
  - The hammer exerts a force on the nail at the same time the nail exerts an equal and opposite force on the hammer
  - $F_{wood\ on\ nail} = -F_{nail\ on\ wood}$

Net Forces



F_N = normal force

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11. A helicopter is used to lift a heat pump to the roof of a building. The mass of the helicopter is 5.0×10^3 kg and the mass of the pump is 1500 kg.
    a. Calculate the thrust force required to hover with the pump above the ground.
    b. Calculate the thrust force required to lift the pump with an acceleration of 0.50 m/s^2.

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12. During the zombie apocalypse, you need to get drinking water from a well. The bucket and water together have a mass of 7.5 kg.
    a. What is the tension on the rope if you are hauling the bucket up at a constant velocity?
    b. What is the tension if the bucket is accelerating at 0.25 m/s^2?