The Flying Toasters

Mechanical Design Part 1 - Fundamentals

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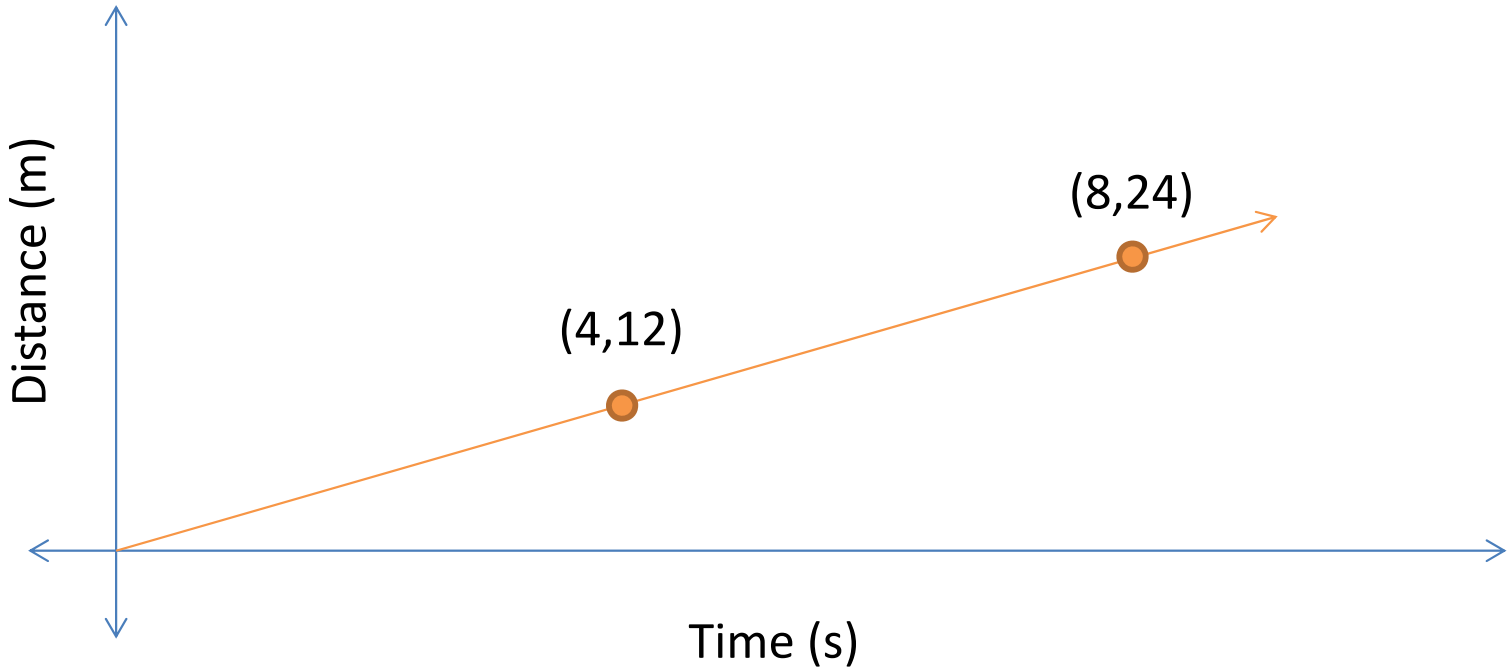
10/24/2016

Agenda

- Session 1 - Fundamentals
  - Distance, Velocity, Acceleration
  - Newton's Laws
    - Energy
    - Vectors, Force, and Torque
    - Friction
    - Free Body Diagrams
    - Work and Power
  - Simple Machines
- Session 2 - Chassis and Drivetrain
  - Fundamentals – Rotation & Centripetal Motion, Torque/Speed/Power
  - Electric Motors
  - Gears/Chain/Belt/Pulleys
  - Bearings
  - Fastener Basics
- Session 3 - Intake and Game Piece Manipulation
  - Fundamentals – Stored Energy – Gravity, Springs, and Pneumatics
  - Mechanical Advantage (Levers)
  - Rotation to Linear Motion

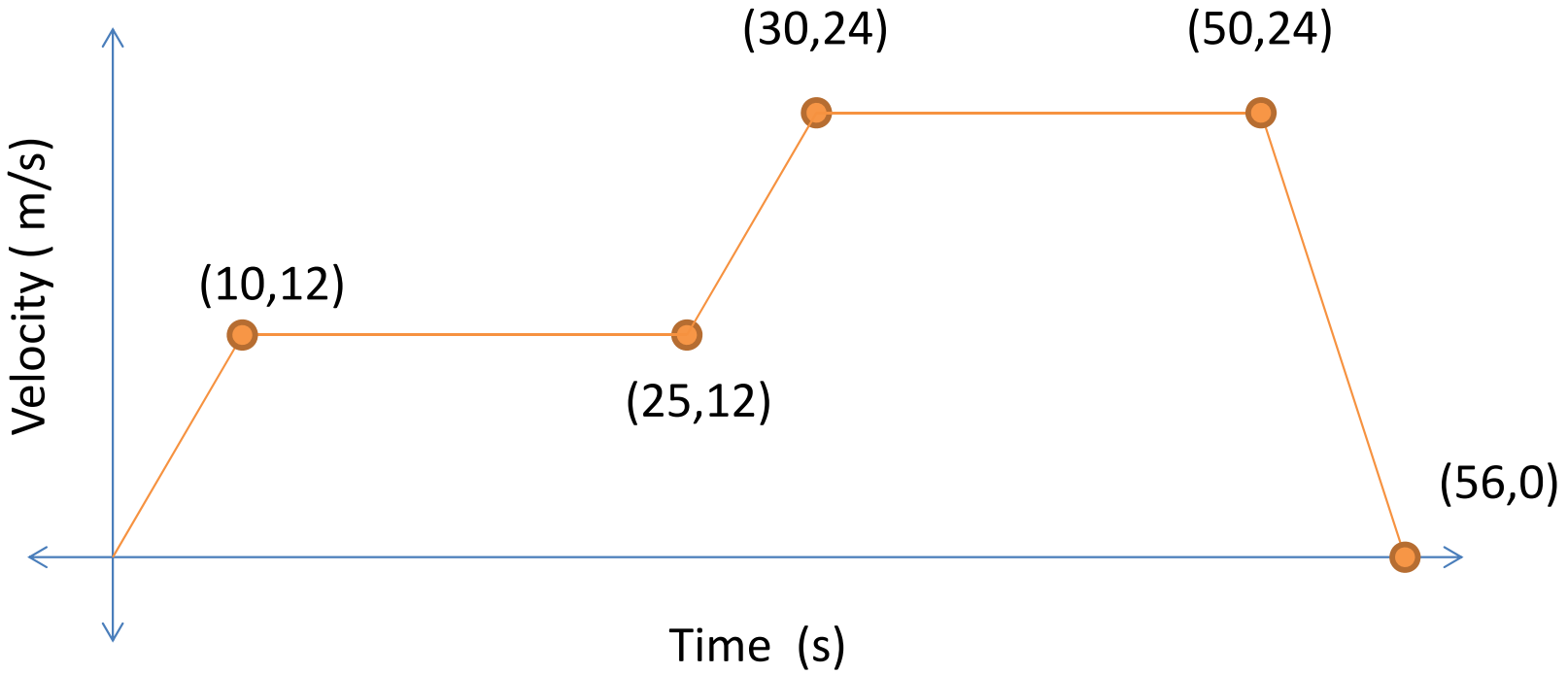
Distance, Velocity, Acceleration

- Distance: length (m, ft)
- Velocity: distance traveled in a given time period (m/s, ft/s)
  - Magnitude and direction



Distance, Velocity, Acceleration

- Distance: length (m, ft)
- Velocity: distance traveled in a given time period (m/s, ft/s)
  - Magnitude and direction
- Acceleration: rate of velocity change (m/s^2, ft/s^2)



Newton's Laws of Motion

- 3 Laws, govern the motion of objects in space.
- First Law of Motion
  - An object either remains at rest or an object traveling at a constant velocity continues to travel at that constant velocity, unless acted upon by an unbalanced force.
- Second Law of Motion
  - The sum of the forces, F, on an object is equal to the mass, m, of that object multiplied by the acceleration, a, of the object:
  - $\Sigma F = ma$
- Third Law of Motion
  - When one body exerts a force on a second body, the second body simultaneously exerts a force equal in magnitude and opposite in direction on the first body.

Energy

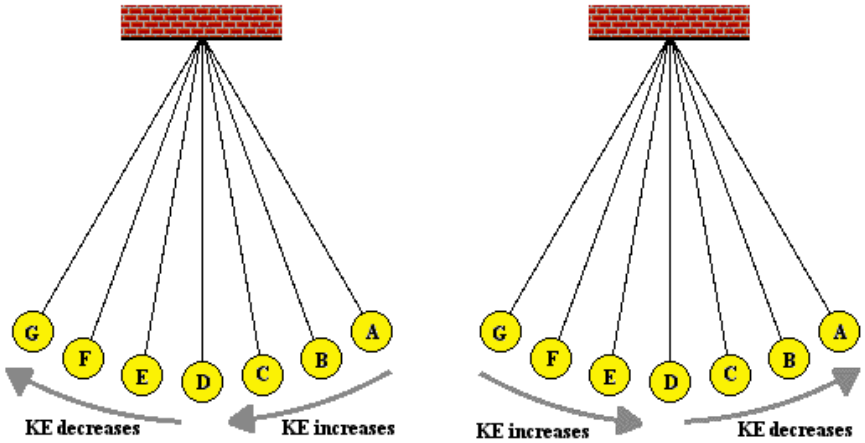
- Energy
  - The ability to perform work

- Energy cannot be created or destroyed, only transferred from one type to another, or from one object to another.
- Conservation of Energy

- Types of Energy
  - Electrical: Potential energy stored by a particles position in an electric field
  - Chemical: Potential energy is stored in chemical bonds, bonds can be broken to release energy
  - Gravitational: Potential energy stored by an object's position in a gravitational field
  - Thermal: Potential energy stored as heat (vibration of molecules)
  - Nuclear: Potential energy stored in the internal forces of atomic nuclei
  - Mechanical: Potential, Kinetic

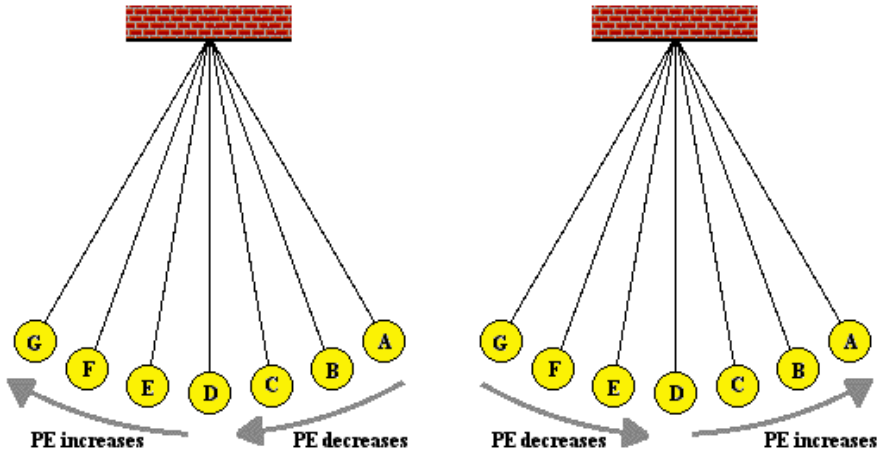
Mechanical Energy

- Kinetic (KE) – energy from an object with mass and velocity



$$KE = \frac{1}{2} \cdot m \cdot v^2$$

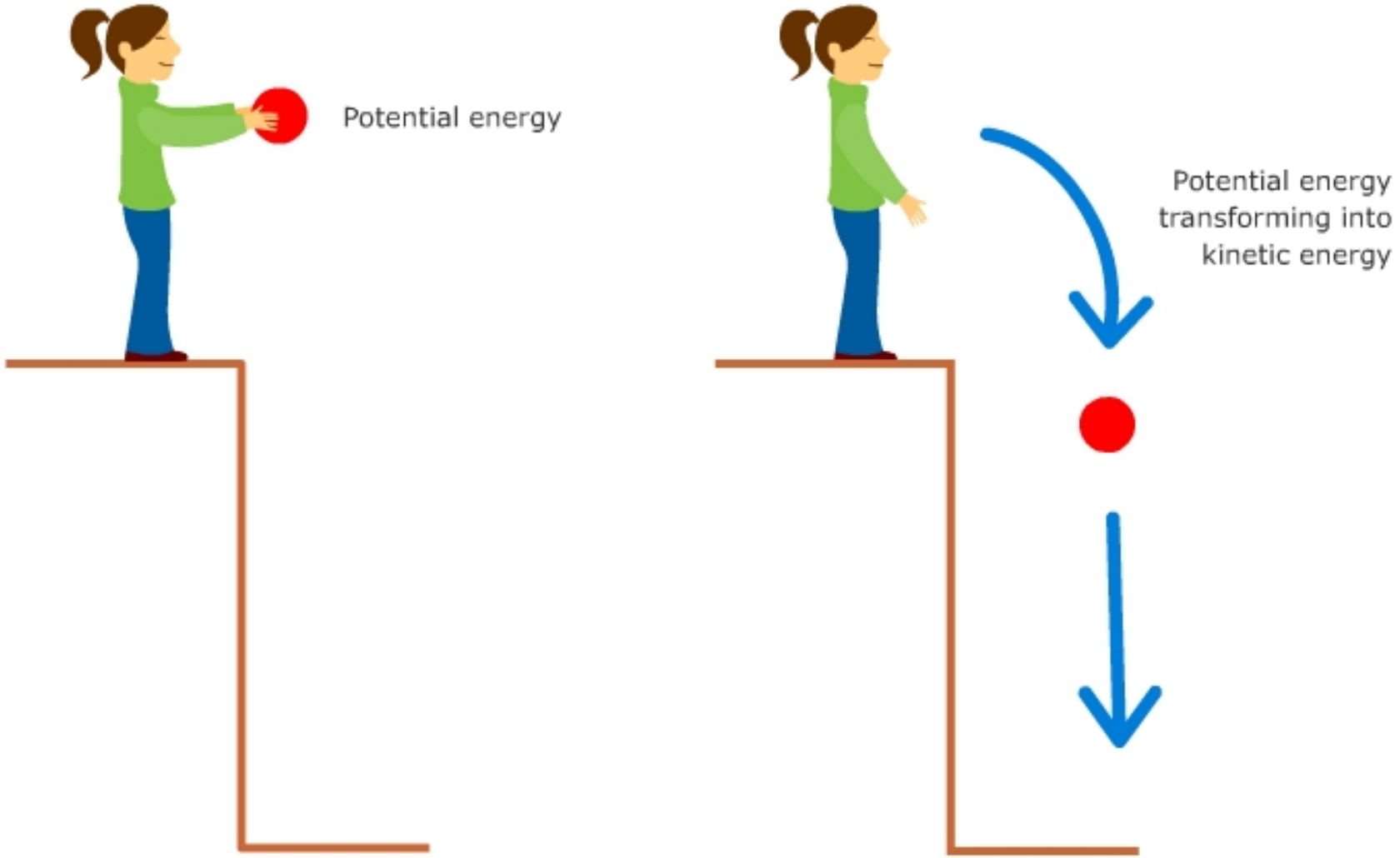
- Potential (PE) – energy stored in an object due to its relative position in a gravitational field



$$PE = m \cdot g \cdot h$$

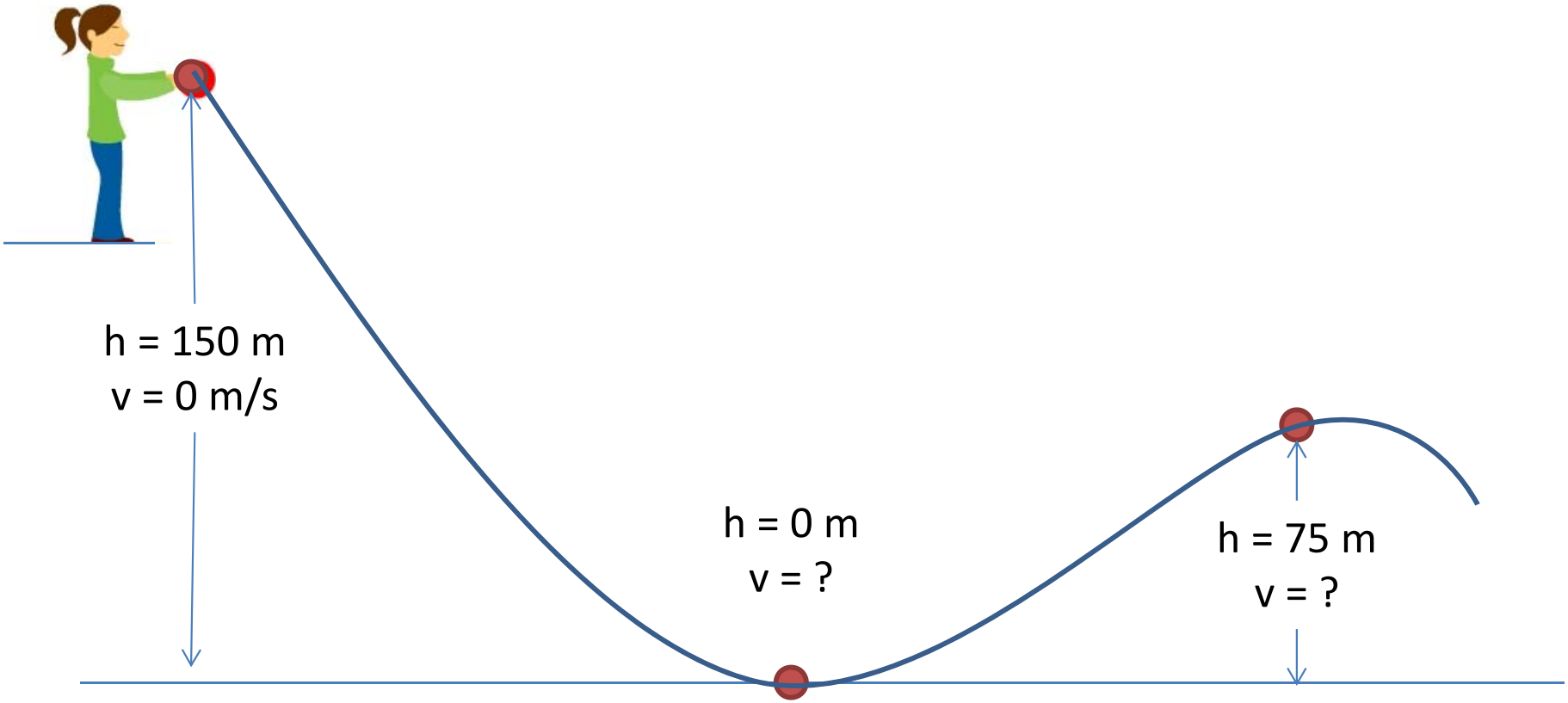
Units: $kg \cdot m^2/s^2$

Mechanical Energy



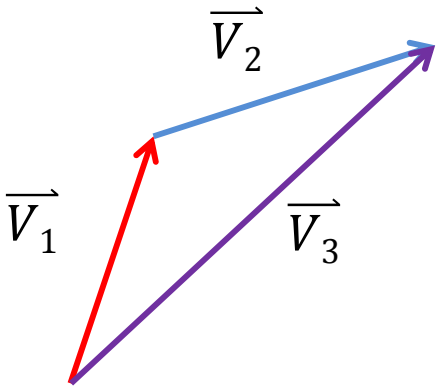
Mechanical Energy

- Energy – $kg \cdot m^2/s^2$



Forces and Vectors

- Force
  - A push or pull on an object resulting from an object's interaction with another object
  - Results in linear motion of objects
  - Units: Newtons ($kg \cdot m/s^2$)
- Vector
  - A quantity having both a magnitude and direction
  - A vector can be described as the sum of it's components



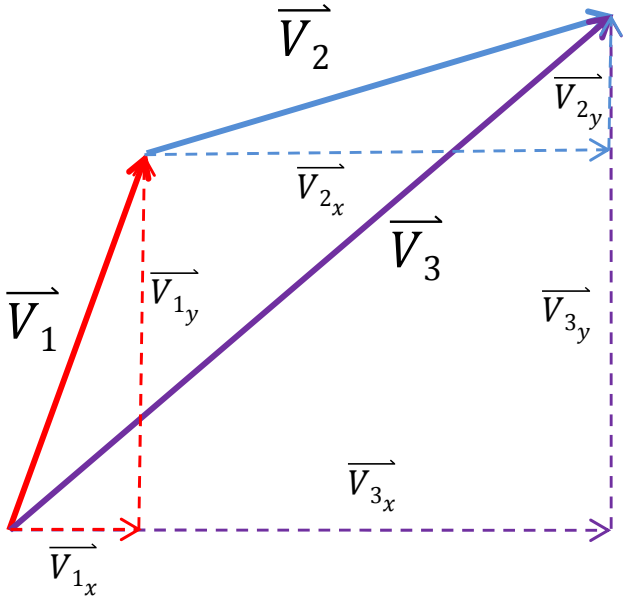
$$\overrightarrow{V_1} + \overrightarrow{V_2} = \overrightarrow{V_3}$$

$$\overrightarrow{V_{1_x}} + \overrightarrow{V_{1_y}} = \overrightarrow{V_1}$$

$$\overrightarrow{V_{2_x}} + \overrightarrow{V_{2_y}} = \overrightarrow{V_2}$$

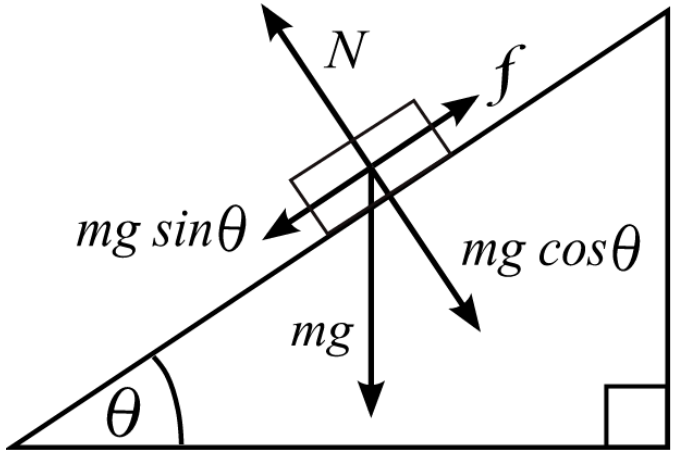
$$\overrightarrow{V_{1_x}} + \overrightarrow{V_{2_x}} = \overrightarrow{V_{3_x}}$$

$$\overrightarrow{V_{1_y}} + \overrightarrow{V_{2_y}} = \overrightarrow{V_{3_y}}$$



Friction

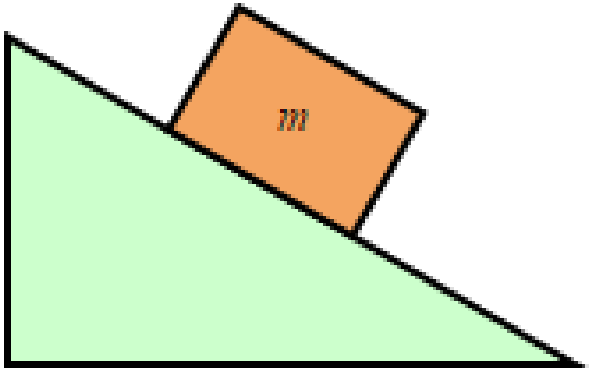
- A force that resists the relative motion of surfaces
- Frictional force is relative to the force pushing the surfaces together
- Due to roughness of surfaces
- $F_f = F_n \cdot \mu$



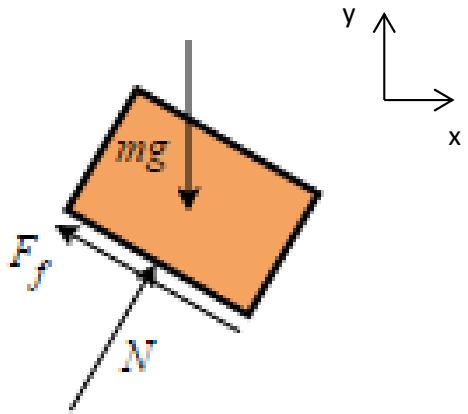
Free Body Diagram

- A graphical illustration used to visualize the applies forces, movements, and resulting reactions on a body, in steady state conditions (no acceleration)
- If acceleration (a) = 0, then ΣF must also = 0

A block on a ramp



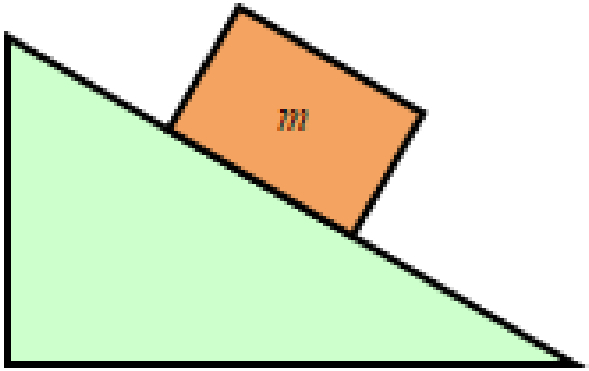
Free body diagram of just the block



Free Body Diagram

- m = 10 kg
- Ramp angle = 30˚
- What is the minimum coefficient of friction?

A block on a ramp



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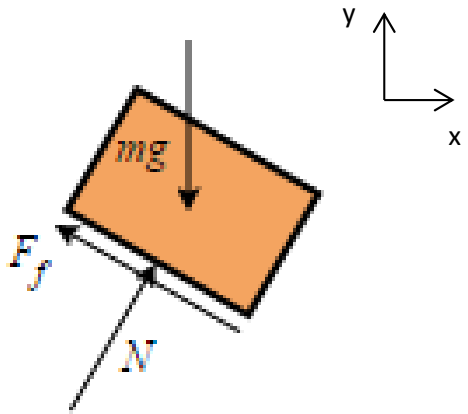
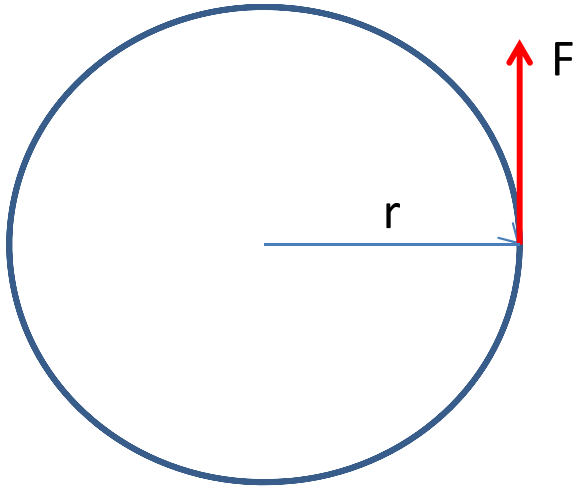
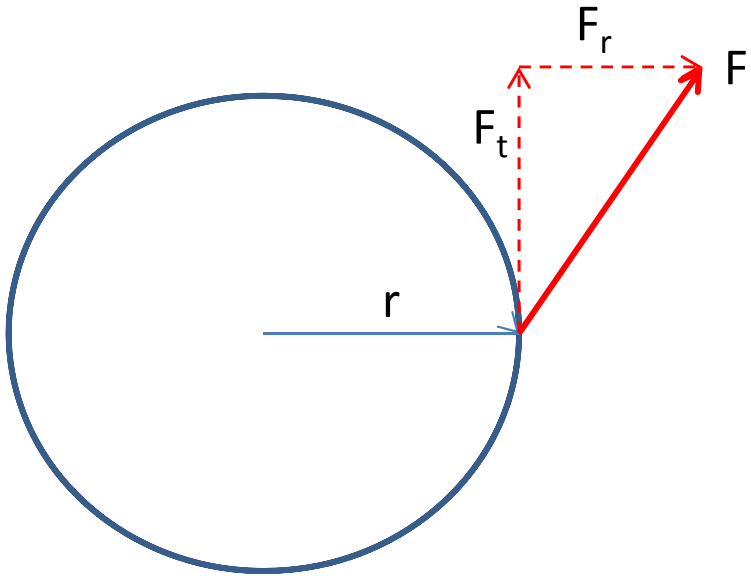


Torque

- Torque
  - Rotational analog of force
  - Force applied at a distance from the center of rotation
  - Results in the rotational motion of objects
  - $\tau = F \times r$
  - Units = N·m, lb·ft





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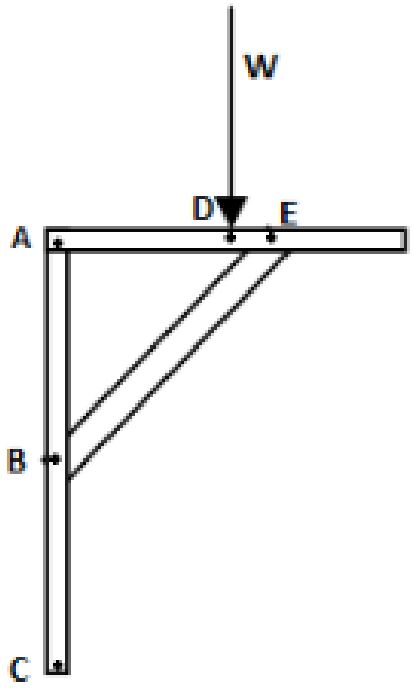

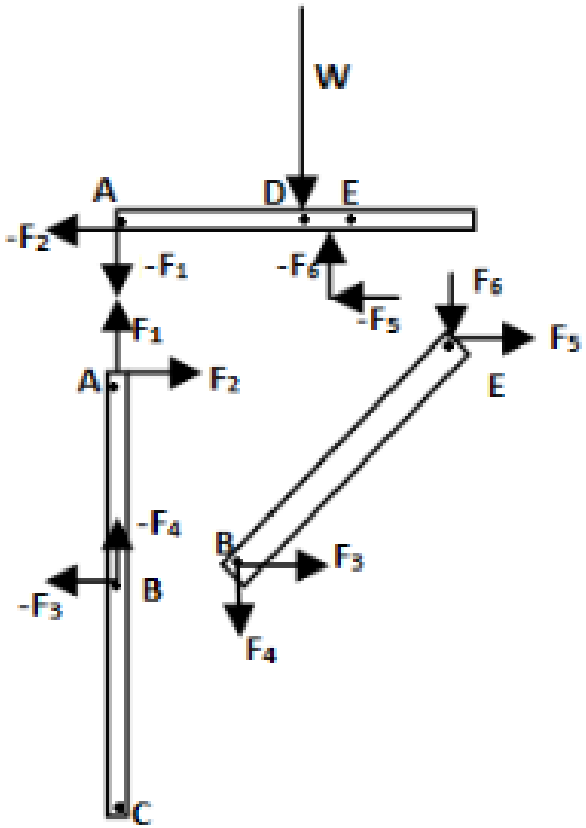

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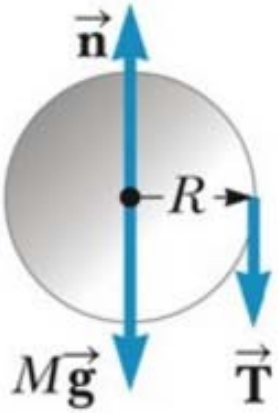
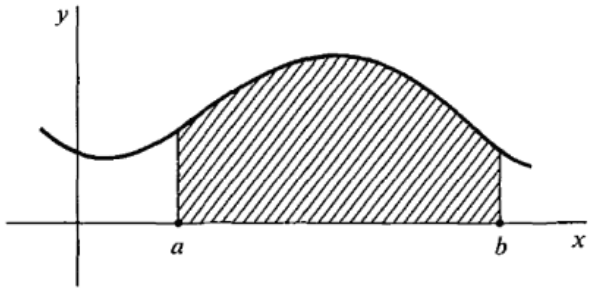


Work and Power

- Work
  - Application of force, over a distance
  - Work is a scalar quantity, not a vector
  - $W = F \cdot D$
  - Units = Joule (N·m), Calorie
- Power
  - Work per unit time
  - $P = W/t$
  - Units = Watt (J/s), Hp (33,000 ft·lb/s)



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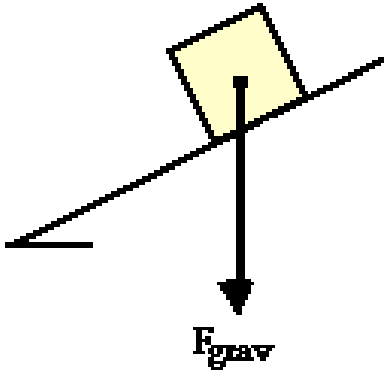
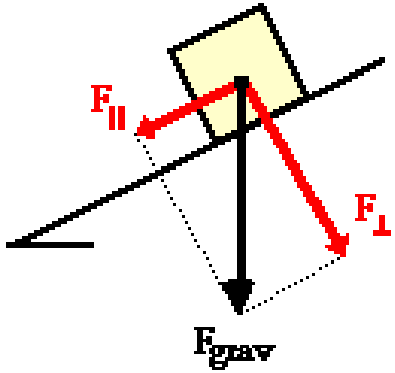
Simple Machines

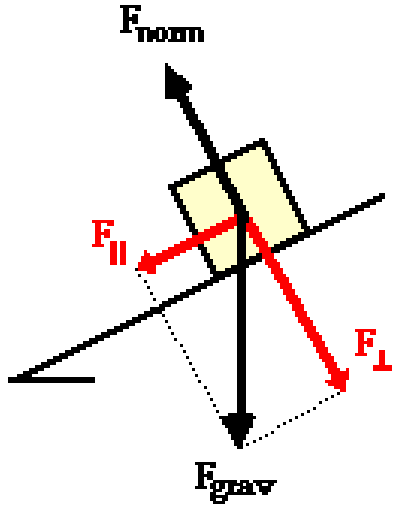
- A Simple Machine is a mechanical device with no or few moving parts that is used to change the direction or magnitude of a force.
- They do no contain energy sources, and they cannot output more work than is input.
- Building blocks of more complicated machines.
- 6 classic simple machines
  - Inclined Plane
  - Lever
  - Wheel & Axle
  - Wedge
  - Screw
  - Pulley

Simple Machines – Inclined Plane

- A flat supporting surface tilted at an angle with one end higher than the other
- Decreases the force necessary to lift an object by increasing the distance that the object is lifted over





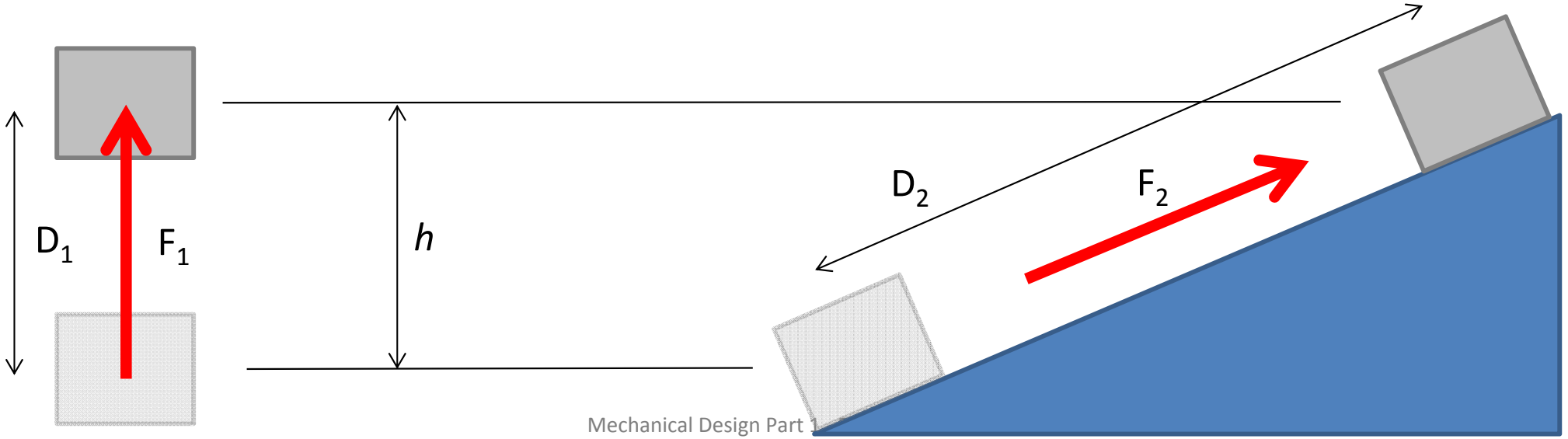


Simple Machines – Inclined Plane

- Conservation of Work
- Either lifting the block straight up, or sliding it up the ramp adds the same amount of potential energy to the block
- Sliding the block up the ramp requires the block to move further, therefore it must take less force

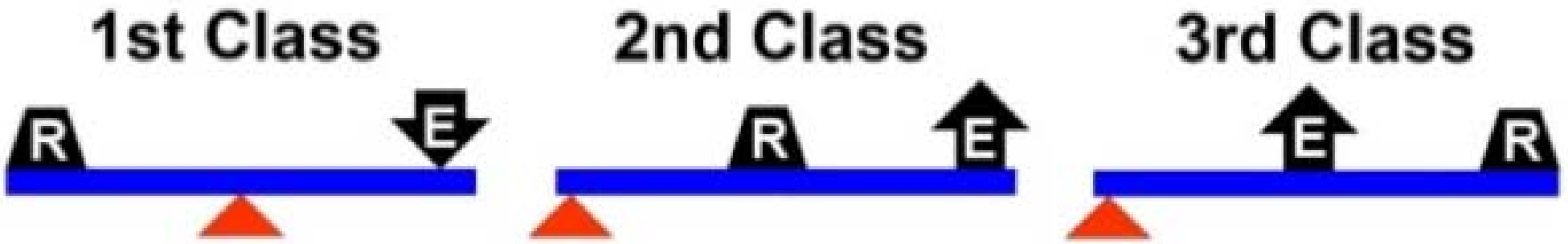
$$W = F_1 \cdot D_1 = F_2 \cdot D_2$$

$$D_2 > D_1 \text{ therefore } F_2 < F_1$$



Simple Machines – Lever

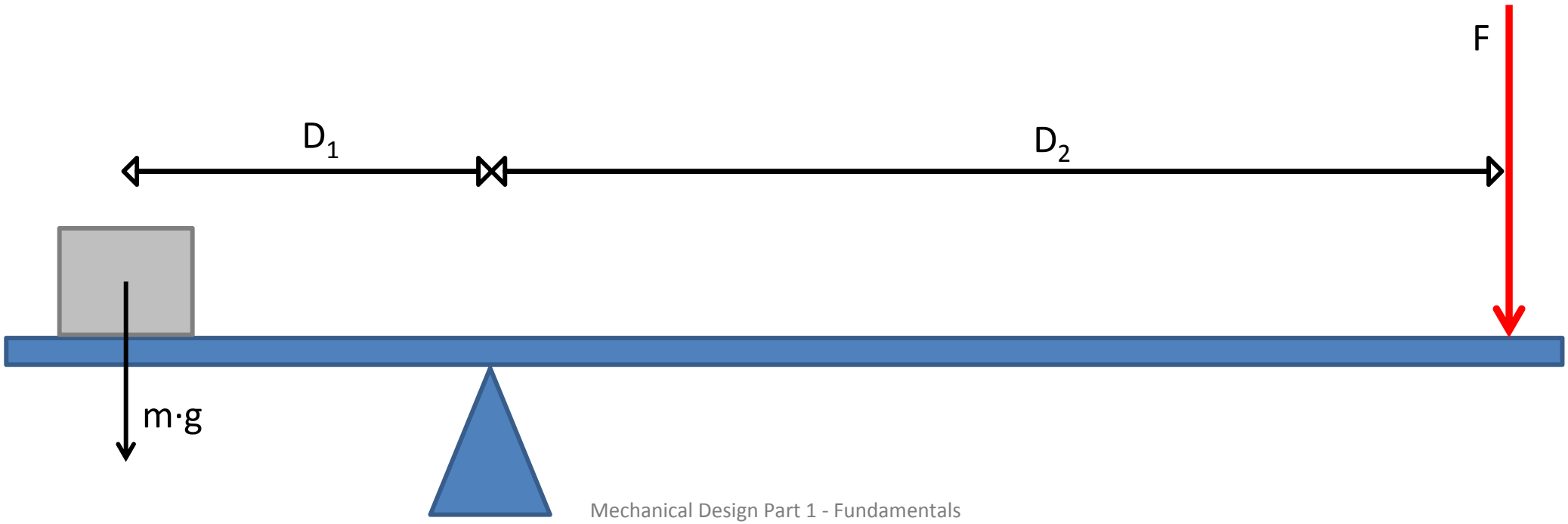
- A rigid body capable of rotation, used to magnify force
- 3 parts
  - Effort – input force
  - Resistance – output force
  - Fulcrum - pivot
- 3 types
  - Class 1
    - Fulcrum in the middle, mechanical advantage depends on fulcrum location
  - Class 2
    - Resistance in the middle, less force required to move the resistance, but force application point must move further than resistance moves
  - Class 3
    - Effort in the middle, more force required to move the resistance, but resistance moves further than the force application point moves



Simple Machines – Lever

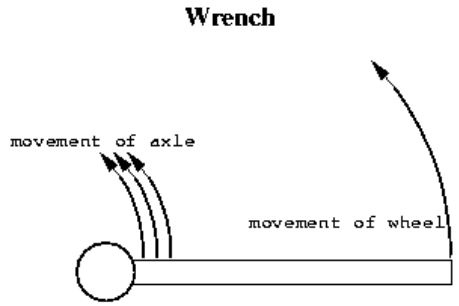
- Equilibrium means that $\Sigma\tau = 0$
- $F_1 \times D_1 = F_2 \times D_2$

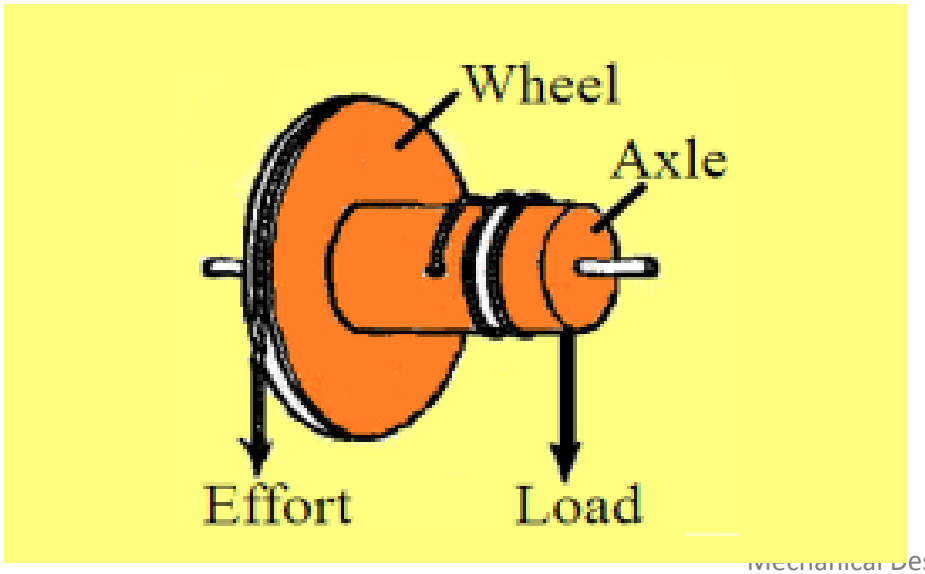
$$m \cdot g \times D_1 = F \times D_2$$

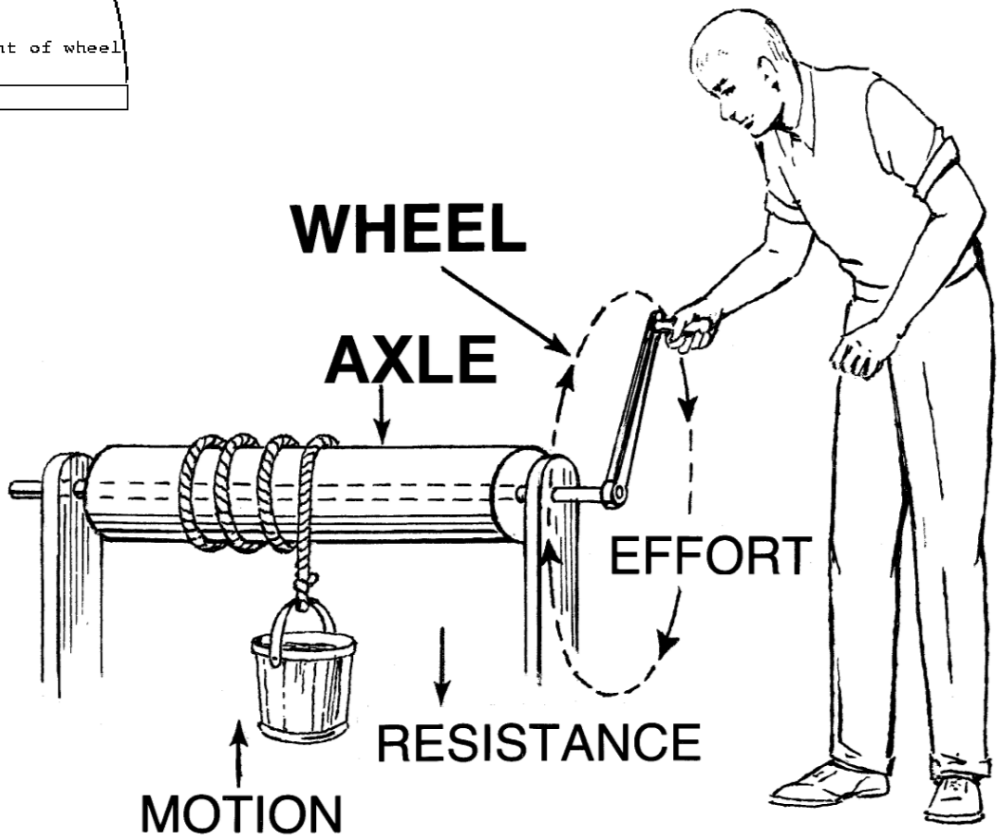


Simple Machines – Wheel & Axle

- A wheel, fixed to an axle. Force can be transferred from wheel to axle and vice versa
- Simply, a rotational lever
- Can magnify force – a small force at the rim of the wheel can move a larger load attached to the axle

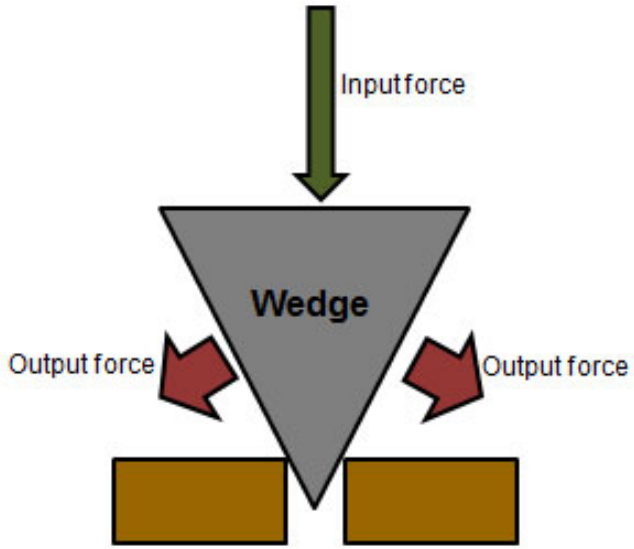


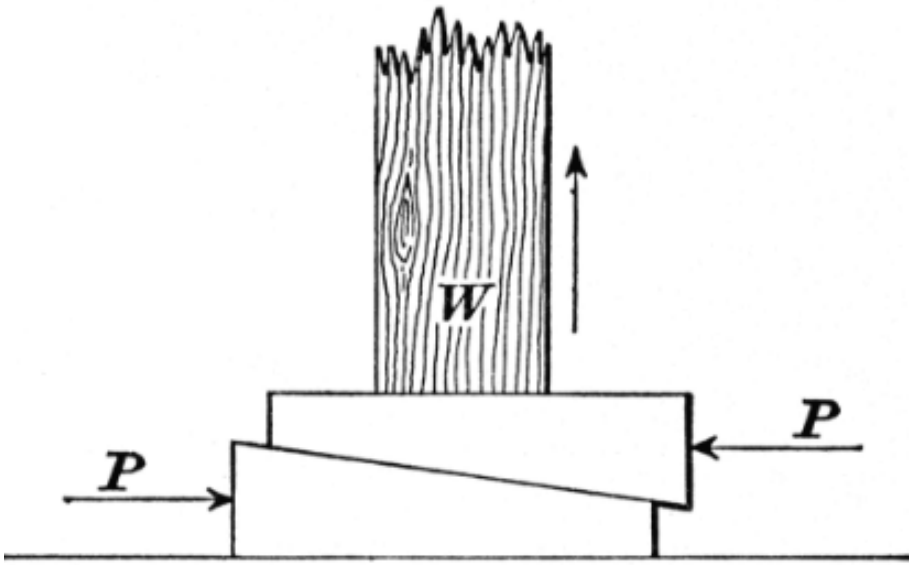




Simple Machines - Wedge

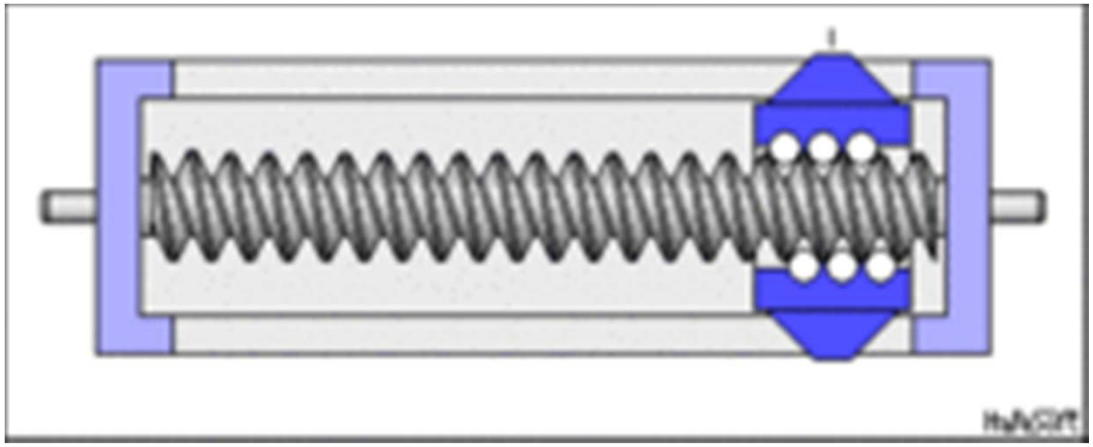
- Changes the direction of a force through geometry
- Force is applied through the blunt end, transferred into forces perpendicular to it's inclined surfaces
- Portable inclined plane

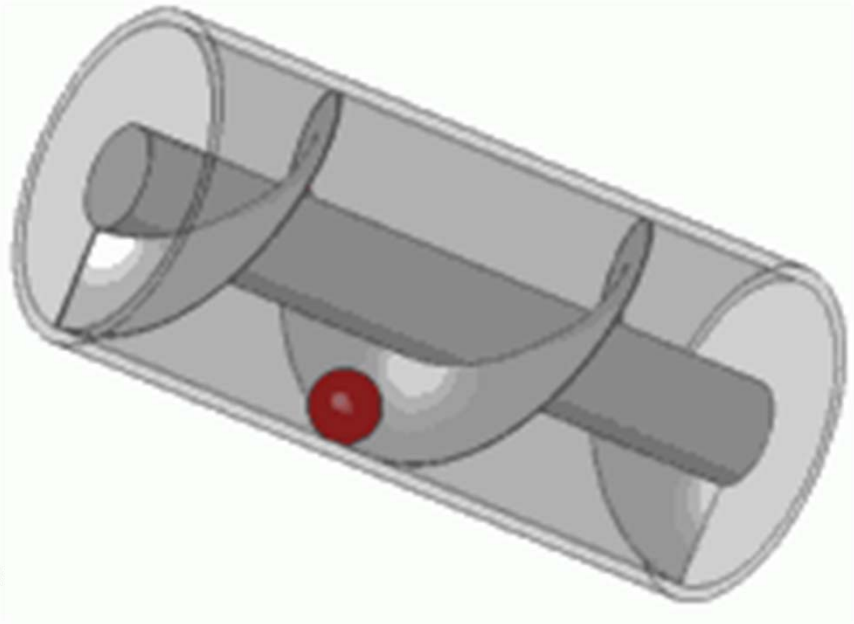




Simple Machines - Screw

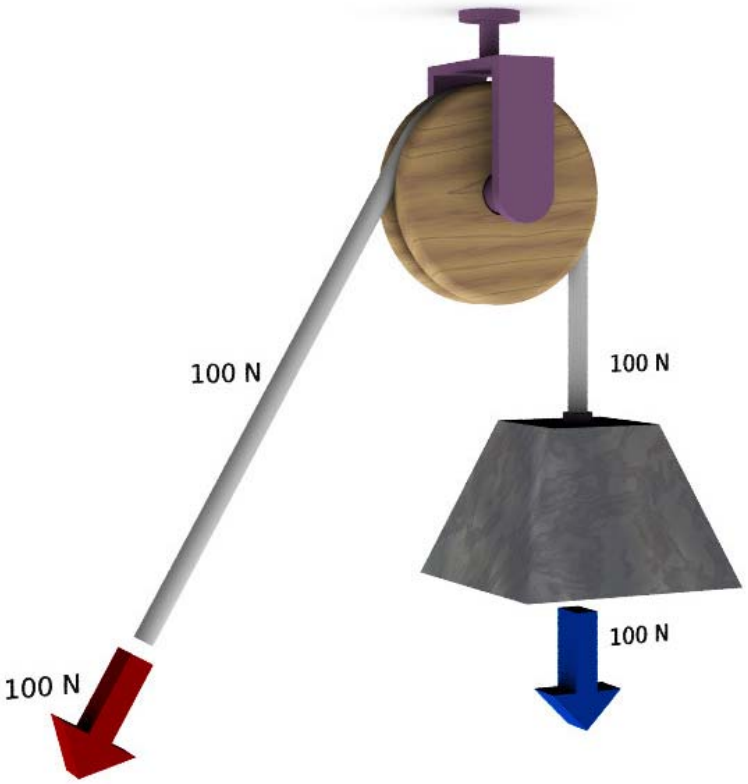
- Converts rotational motion to linear motion
- Simply an inclined plane wrapped around an axis

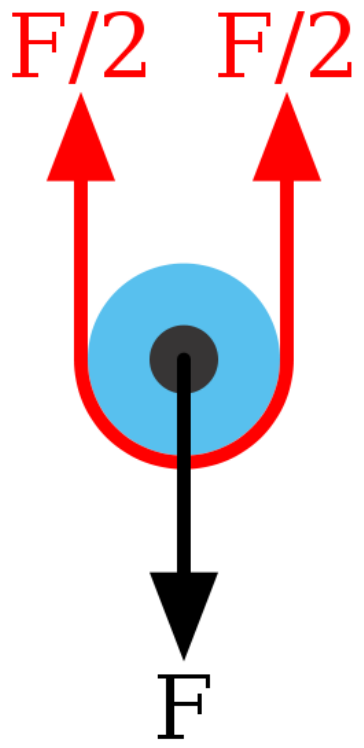




Simple Machines - Pulley

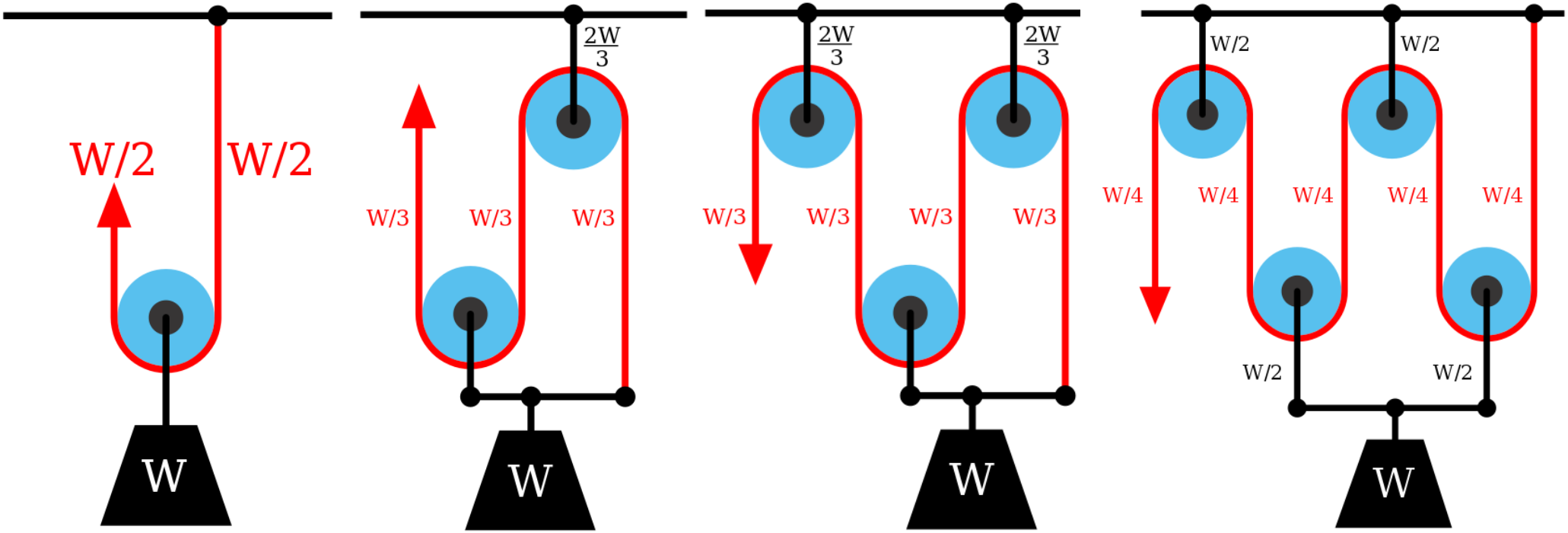
- A pulley is a wheel and axle that uses a rope to apply force to the rim of the wheel
- A pulley / rope can be used to change the direction and/or magnitude of a force





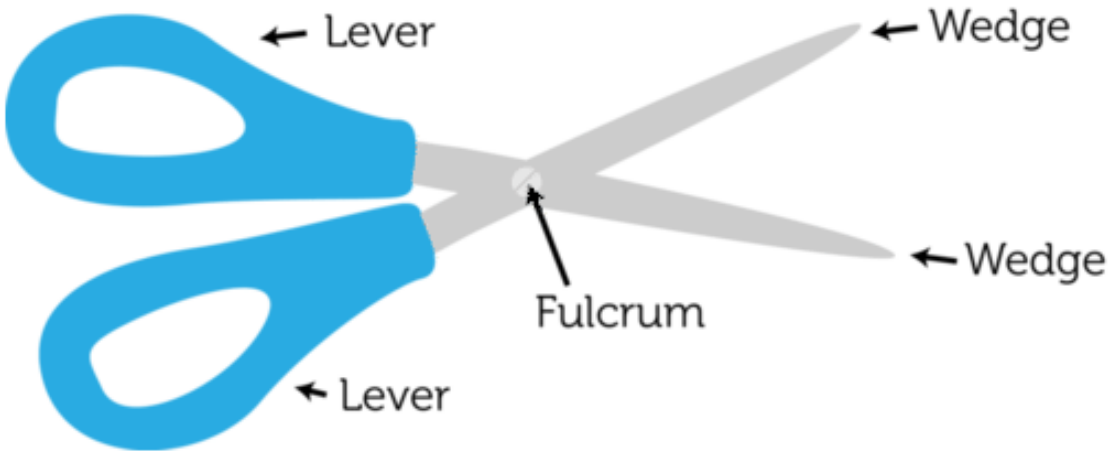
Simple Machines - Pulley

- Multiple pulleys can be arranged in different sequences to achieve the desired mechanical advantage



Compound Machines

- The output of one simple machine is fed into the input of another
- Serrated Knife: Wedges on a wedge!



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