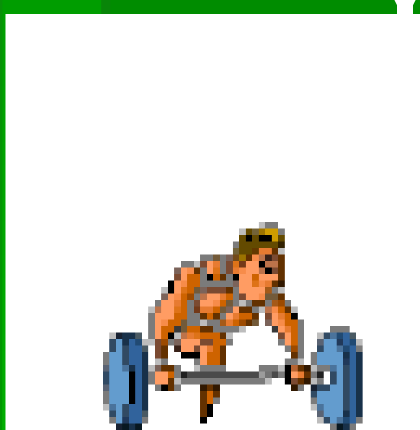
Chapter 14 Work, Power, and Machines

Physical Science

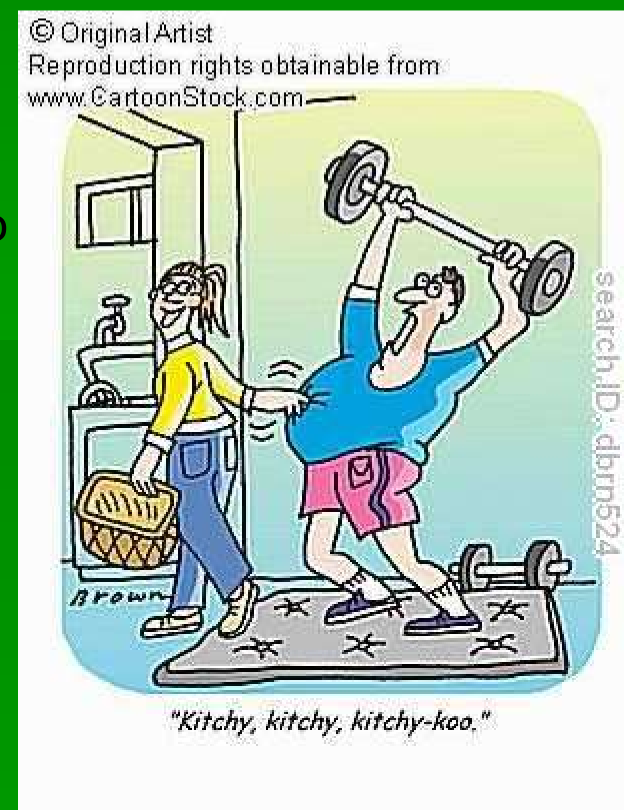
Work and Power 14.1

- Work – done when a force acts on an object in the direction the object moves
  - Requires Motion
    - Man is not actually doing work when holding barbell above his head
    - Force is applied to barbell
    - If no movement, no work done

He does work



They do no work



Work and Power 14.1

Work Depends on Direction

- All force acts in same direction of motion = all force work.
- Part applied force acts in the direction of motion =part force does work.
- none of force in direction of the motion = force does no work.

Work and Power 14.1

Work Depends on Direction Continued…

- All of the force does work on the suitcase.
- The horizontal part of the force does work.
- The force does no work on the suitcase.

Calculating Work 14.1

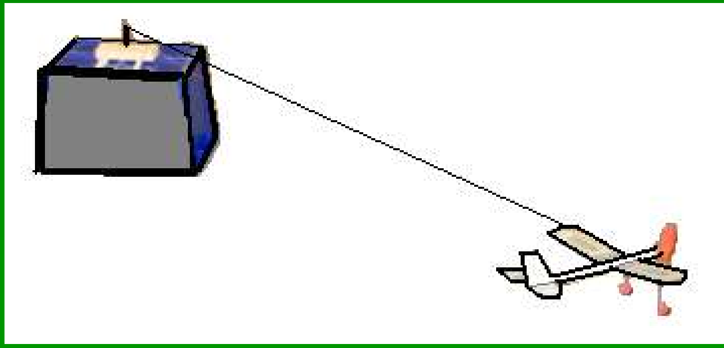
- Work = Force x Distance
  - W = Fd
    - Force = mass x acceleration → F = ma or F = mg
  - Joule (J) = SI unit for work
    - Unit: J = N(m)
    - Named after James Prescott Joule (1818 – 1889)
      - Research work and heat

Example: If a model airplane exerts 0.25 N over a distance of 10m, the plane will expend 2.5 J.

Work = Fd

= .25(10)

= 2.5 J

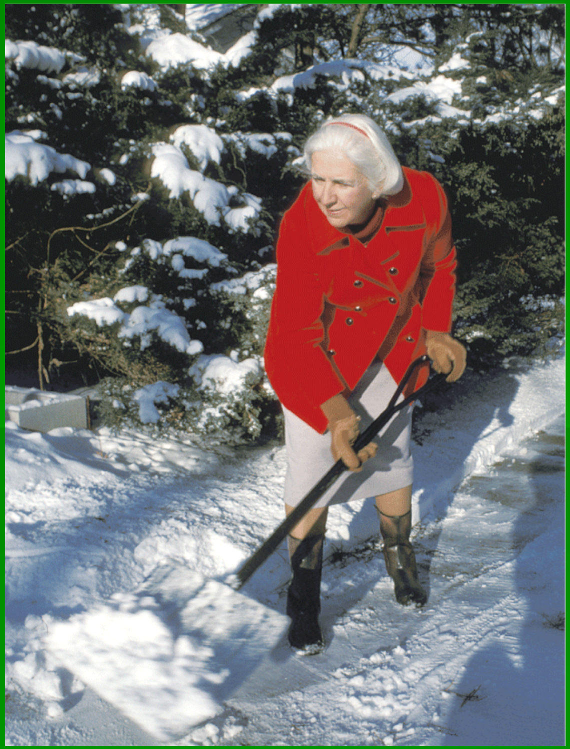


What is Power? 14.1

- Rate of doing work
- More power = work at a faster rate
  - Size of engine often indicates power
    - Can work at a faster rate
- Power = Work/Time
  - P= W/t
  - Watt (W) = SI unit for Power
    - Units: W = J/s

What is Power? 14.1

Because the snow blower can remove more snow in less time, it requires more power than hand shoveling does.



Calculating Power

You exert a vertical force of 72 newtons to lift a box to a height of 1.0 meter in a time of 2.0 seconds. How much power is used to lift the box?

1 Read and Understand

What information are you given?

Force = 72 N Distance = 1.0 m

Time = 2.0 s

2 Plan and Solve

What formula contains the given quantities and the unknown?

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

Replace each variable with its known value and solve.

$$\text{Power} = \frac{72\ \text{N} \times 1.0\ \text{m}}{2.0\ \text{s}} = 36\ \text{J/s} = 36\ \text{W}$$

Math Practice – Page 415 # 1 - 3

James Watt and Horsepower 14.1

- Horsepower (hp) = another unit for power
  - Equals ~746 watts
  - Defined by James Watt (1736- 1819)
    - Trying to describe power outputs of steam engines
      - Horses were most common used source of power in 1700s

James Watt and Horsepower

The horse-drawn plow and the gasoline-powered engine are both capable of doing work at a rate of four horsepower.

Assessment Questions

1. In which of the following cases is work being done on an object?
    a. pushing against a locked door
    b. suspending a heavy weight with a strong chain
    c. pulling a trailer up a hill
    d. carrying a box down a corridor

2. A tractor exerts a force of 20,000 newtons to move a trailer 8 meters. How much work was done on the trailer?
    a. 2,500 J
    a. 4,000 J
    b. 20,000 J
    c. 160,000 J

3. A car exerts a force of 500 newtons to pull a boat 100 meters in 10 seconds. How much power does the car use?
    a. 5000 W
    b. 6000 W
    c. 50 W
    d. 1000 W

Work and Machines 14.2

Machine	Increases or Decreases Input Force	Increases or Decreases Input Distance
Tire jack	a. ____?____	b. ____?____
Lug wrench	c. ____?____	d. ____?____
Rowing oar	e. ____?____	f. ____?____
Summary:	g. ________?________	

Machines Do Work 14.2

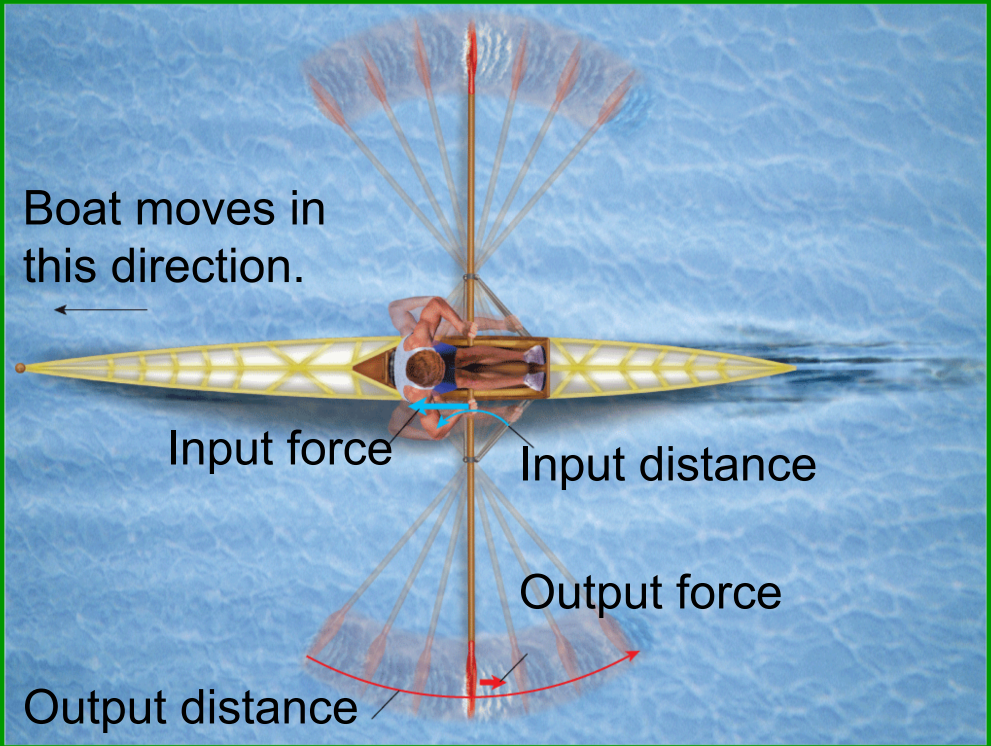
- **Machine – device that change force**
  - Car jack
    - You apply force → jack changes force → applies much stronger force to lift car
    - Jack increase force you exerted
  - **Make work easier**
  - **Change size of force needed, direction of force, and distance over which force acts**

Machines Do Work 14.2

- Increasing Force
  - Small force exerted over a large distance = large force over short distance
    - Like picking books up one at a time to move them --- trade off = more distance but less force

Machines Do Work 14.2

- **Increasing Distance**
  - Decreases distance for force exerted and increases amount of force required
    - Tradeoff = increased distance = greater force exerted
- **Changing Direction**



Work Input and Work Output 14.2

- **Work input to a Machine**
  - **Input Force – Force you exert on a machine**
    - Oar = force exerted on handle
  - **Input Distance – Distance the input force act thru**
    - How far handle moves
  - **Work Input – work done by the input force**
    - **F x d**
- **Work Output of a Machine**
  - **Output Force- force exerted by machine**
  - **Output Distance – distance moved**
  - **Work output – F x d**
    - Less than input work b/c of friction
    - All machines use some input work to overcome

Mechanical Advantage and Efficiency 14.3

- Mechanical Advantage
  - Number of times that the machine increases an input force
    - @ position 1, nutcracker exerts 7x force so mechanical advantage of 7
    - @ position 2, nutcracker exerts 3x force so mechanical advantage of 3
  - **Actual (AMA)= Output Force/Input Force**
    - Mechanical advantage of ramp with rough surface is less than that of a ramp with a smo
  - **Ideal (IMA) = Input Distance/Output Dis**
    - Mechanical advantage w/ no friction
    - Actual is always less than ideal

Calculating Mechanical Advantage 14.3

Calculating IMA

A woman drives her car up onto wheel ramps to perform some repairs. If she drives a distance of 1.8 meters along the ramp to raise the car 0.3 meter, what is the ideal mechanical advantage (IMA) of the wheel ramps?

1 Read and Understand

What information are you given?

Input distance = 1.8 m

Output distance = 0.3 m

2 Plan and Solve

What unknown are you trying to calculate?

IMA = ?

What formula contains the given quantities and the unknown?

$$\text{IMA} = \frac{\text{Input distance}}{\text{Output distance}}$$

Replace each variable with its known value and solve.

$$\text{IMA} = \frac{1.8\ \text{m}}{0.3\ \text{m}} = 6$$

Math Practice:
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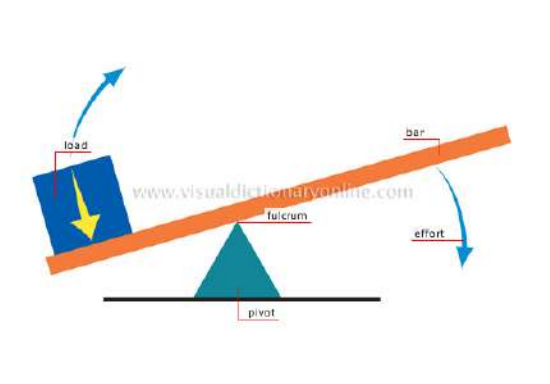
Efficiency 14.3

- % of work input that becomes work output
- Some work always used to overcome friction
  - **Work output < work input**
    - **Efficiency always less than 100% b/c of friction**
- **Work output/work input x 100% = efficiency**
- **Example: If efficiency of machine is 75% and machine requires 10J of work input, what is work output?**
  - Work output/10 J x 100% = 75%
  - Work output = (75%/100%) x 10
  - Work output = 7.5 J
- Reducing friction increases efficiency

Simple Machines 14.4

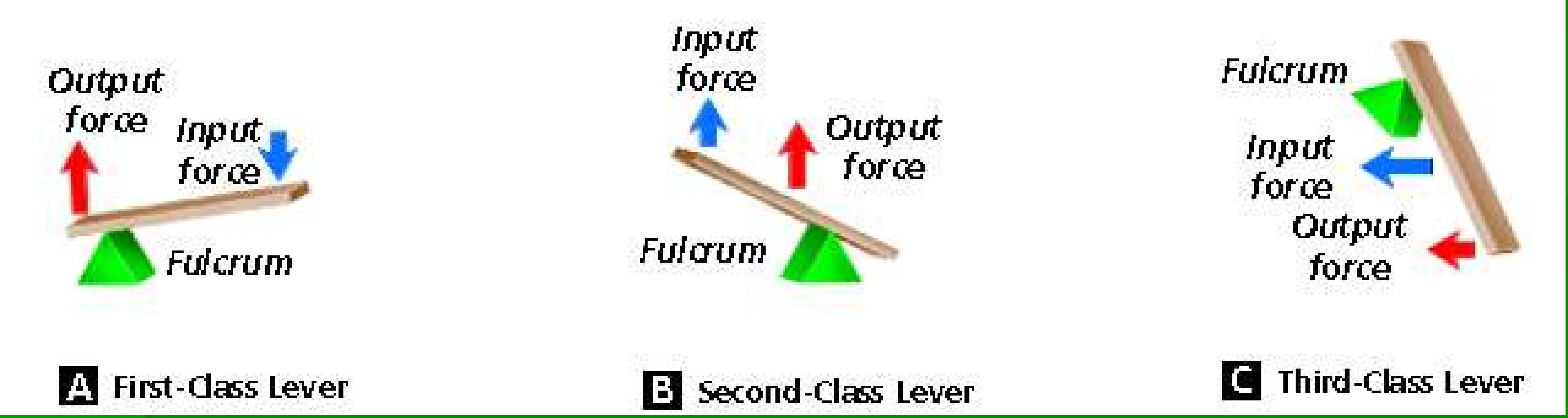
- 6 different simple machines
  - http://www.teachertube.com/view_video.php?viewkey=56ac902e14526e63081d – 2 minutes
  - http://www.edheads.org/activities/simple-machines/ - fun activity – at least 10 minutes
- Often combined

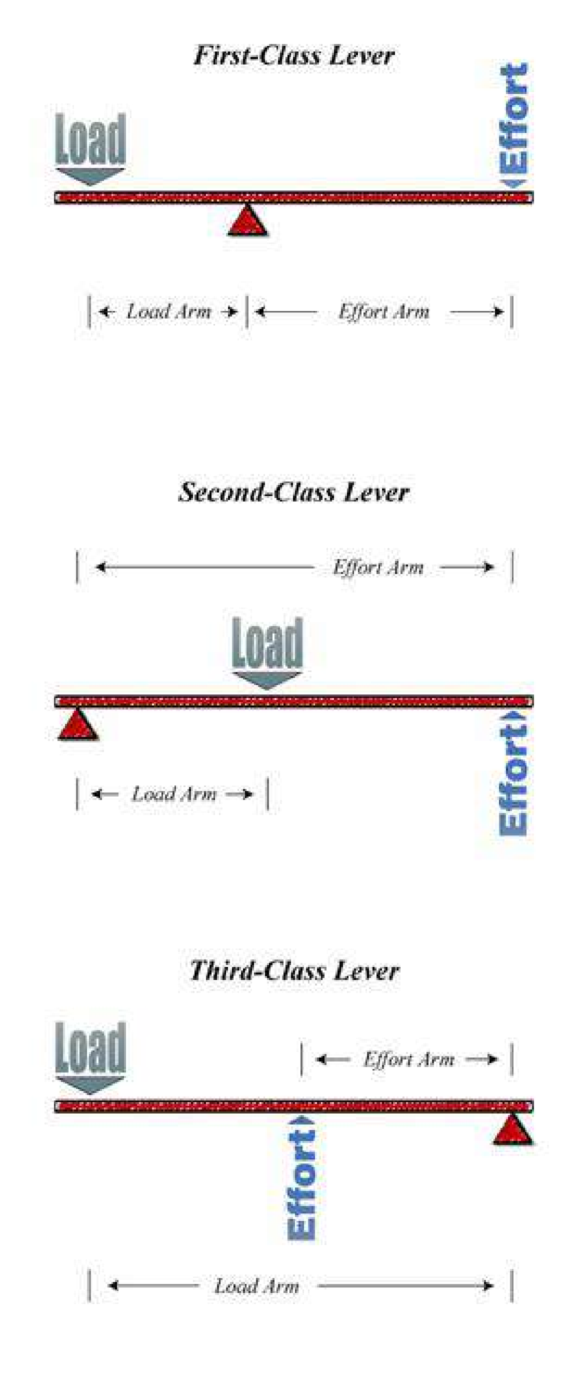
1. **Lever**
   - **Rigid bar that is free to move around a fixed point**
   - **Fulcrum – fixed point the bar rotates around**
   - **3 classifications based on input arm (distance between input force and fulcrum**
   - **Output are – distance between output force and fulcrum**

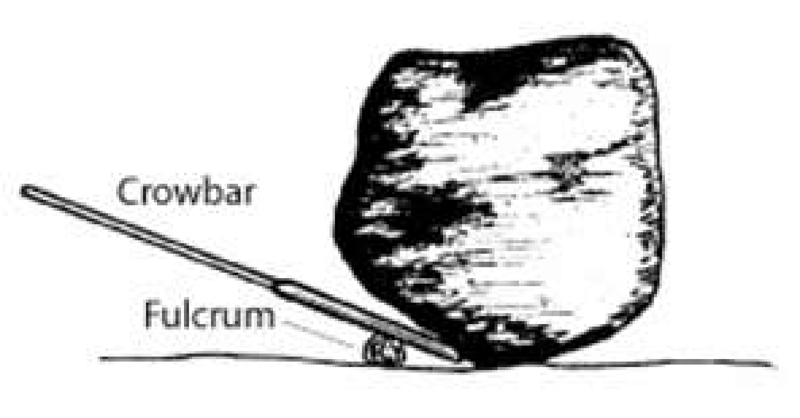


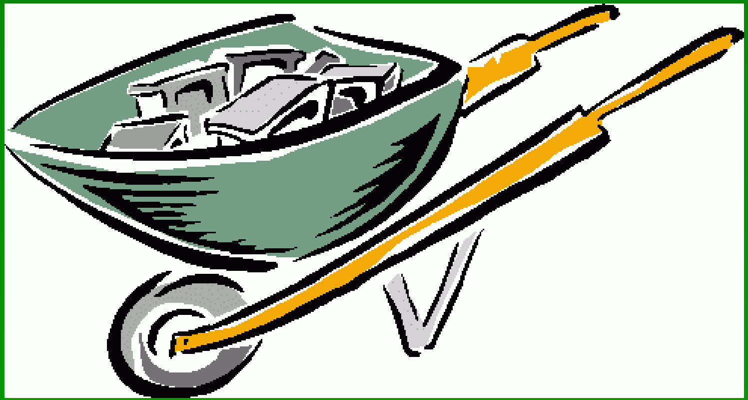
Types of Levers 14.4

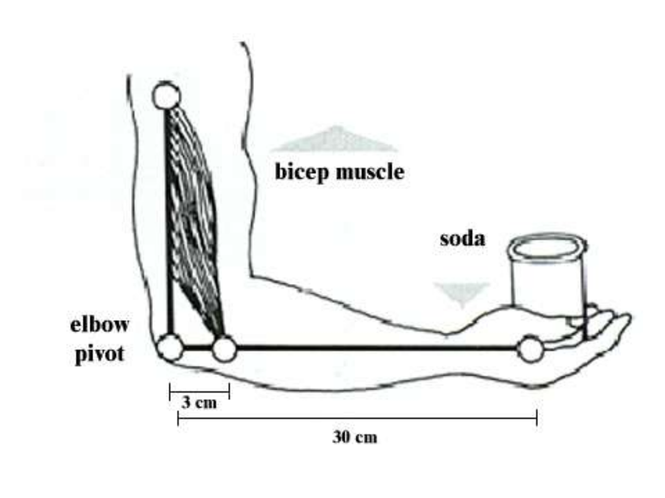
- First-Class Levers
  - Fulcrum = always between the input force and the output force
  - Example: seesaw, scissors, and tong
  - Mechanical Advantage: greater, less, or equal to 1
- Second-Class Levers
  - Output force is located between input force and fulcrum
  - Example: wheelbarrow
  - Mechanical advantage: always greater than 1
- Third-Class Lever
  - Input force between fulcrum and output force
  - Example: baseball bats, hockey sticks, golf clubs
  - Mechanical advantage less than 1


Output force
Input force
Fulcrum
A First-Class Lever
Input force
Output force
Fulcrum
B Second-Class Lever
Fulcrum
Input force
Output force
C Third-Class Lever


First-Class Lever
Load
Effort
Load Arm
Effort Arm
Second-Class Lever
Effort Arm
Load
Load Arm
Effort
Third-Class Lever
Load
Effort Arm
Effort
Load Arm


Crowbar
Fulcrum




bicep muscle
soda
elbow
pivot
3 cm
30 cm

Wheel and Axle 14.4

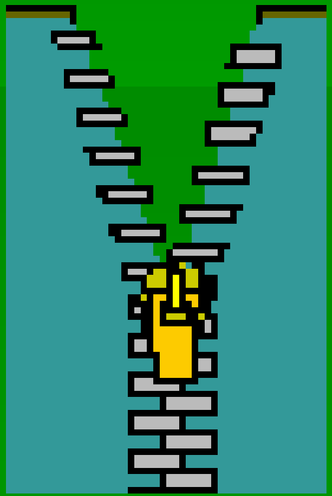
- Consists of 2 disks with different radius
- Depending on purpose of machine, input can be put on wheel or axel
- **Ideal mechanical advantage = radius where input force is exerted/radius when output force is exerted**
- **Mechanical advantage greater or less than 1**
  - If input distance is larger than output distance = great than 1
- Example: steering wheel, screw driver

Inclined Planes 14.4

- Slanted surface along which force moves and object to a different elevation
- Is it easier to wind up a mountain or walk straight up it?
  - Input force is decreased when the input distance is greater than the output distance
  - Easier to get there, but longer distance
- **Ideal mechanical advantage = distance of inclined plane/height**
- Example: ramps

Wedge 14.4

- Similar to incline plane b/c sloping surface but wedges move
- V-shaped object whose sides are2 inclined planes sloped toward each other
- Mechanical advantage great than 1
  - Thinner wedge of same length as a thick one has great mechanical advantage
- Example: knife and zippers

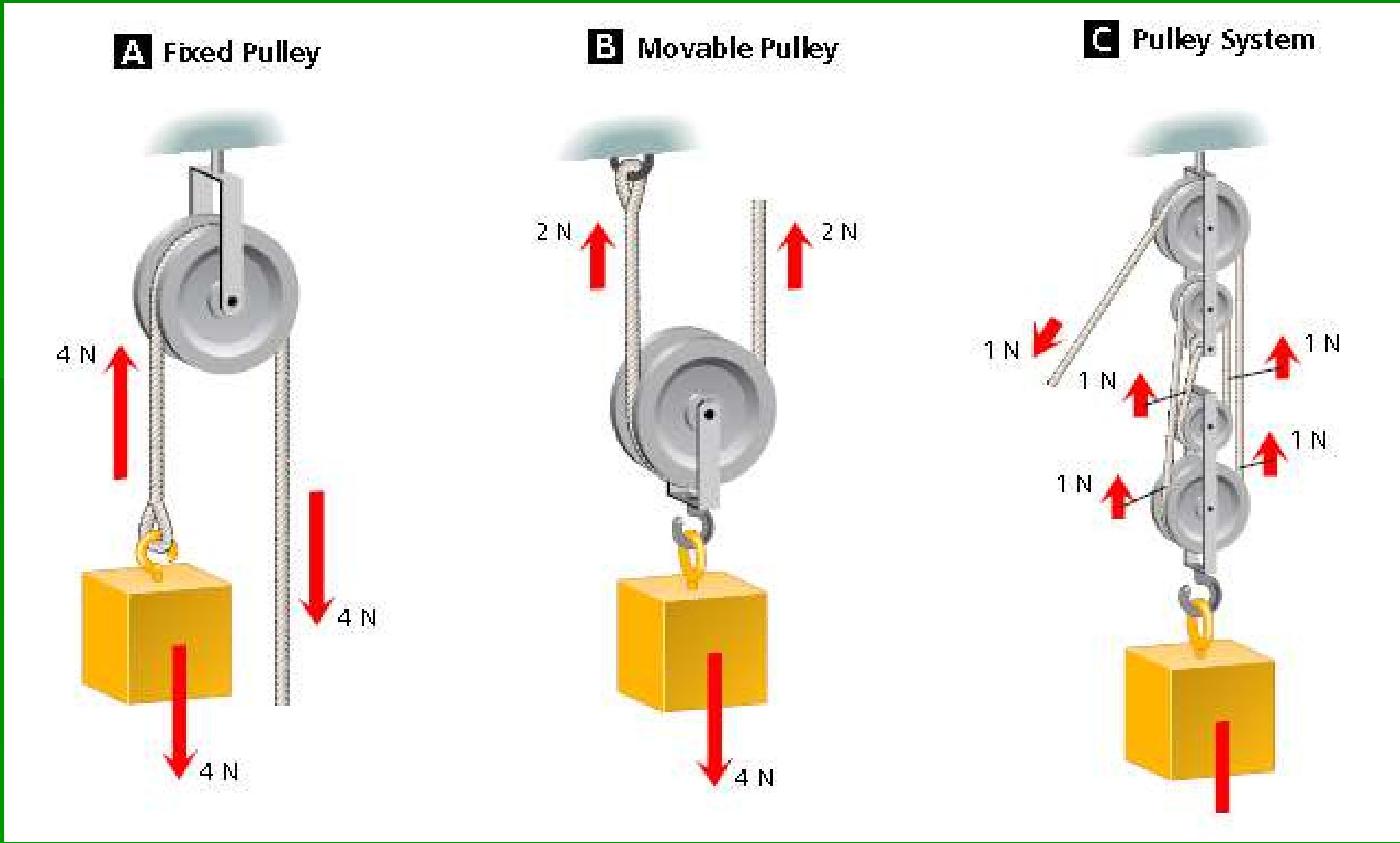


Screws 14.4

- Similar to inclined plane b/c sloping surface but moves
- Inclined plane wrapped around a cylinder
- If threads are closer together, screw moves forward less for each turn
  - Bigger threads require greater input force to drive in
  - Closer together threads = greater ideal mechanical advantage

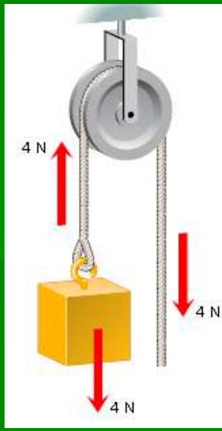
Pulleys 14.4

- Consists of a rope that fits into a groove in a wheel
- Ideal mechanical advantage of a pulley equals # of rope sections supporting the load being lifted
- 3 types



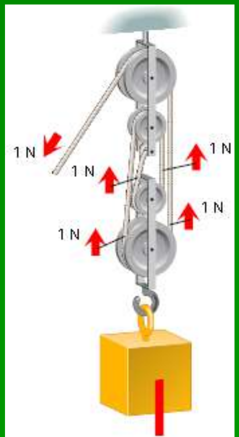
3 types of Pulleys 14.4

- Fixed Pulley – wheel attached to a fixed location
  - Output direction opposite than input direction
  - Input force = output force
    - Mechanical advantage = 1
  - Examples: flagpole, pulleys on blinds



- Movable Pulley – attached to the object being moved
  - Pull up with 10 N force, force is doubled = 20
  - Used to reduce input force

- Pulley System – combined fixed and movable pulley into a system
  - Large mechanical advantage



Compound Machines 14.4

- Combination of 2 or more simple machines
- Scissors
  - Wedge (blades) + levers (handles)
- Cars, washing machines, clocks, etc

http://video.google.com/videoplay?docid=8517358537561483069 – 13 minutes

http://videos.howstuffworks.com/hsw/16886-compound-machines-the-six-simple-machines-video.htm
- lots of videos to watch!