

# ENERGY

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# Energy

**Objective 1: What is the relationship between energy and work?**

**Objective 2: Identify the energy of position.**

**Objective 3: The factors that kinetic energy depends on**

**Objective 4: What is non-mechanical energy?**

In an avalanche, a mass of loose snow, soil, or rock suddenly gives way and slides down the side of a mountain.

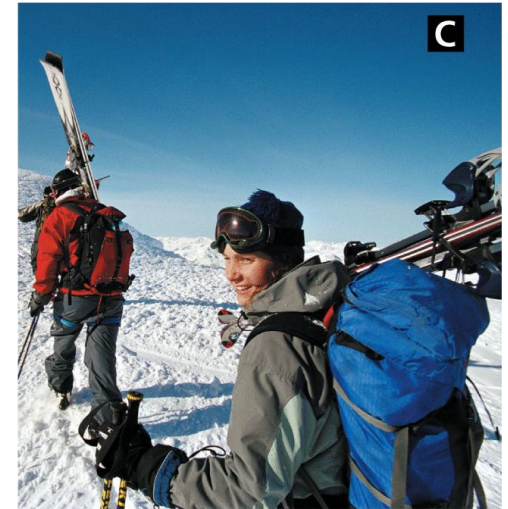
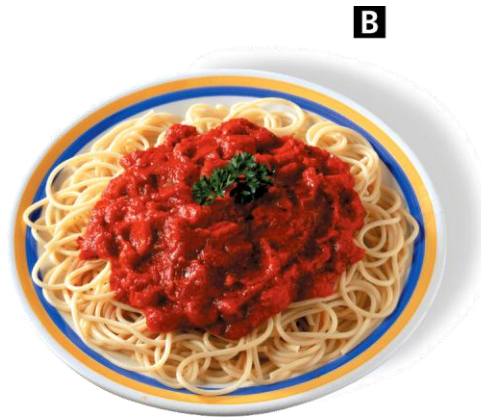
The avalanche releases a great amount of energy.



# Energy and Work

Energy has different forms.

- A. The sun gives off energy in the form of heat and light.
- B. Plants convert sunlight into food.
- C. People convert food energy into muscle movement.

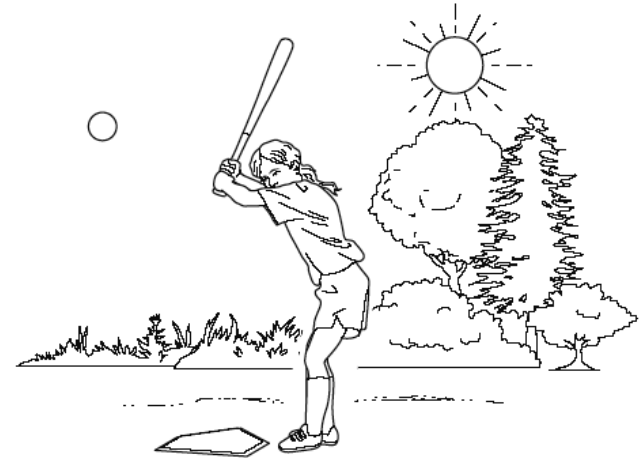


# Energy and Work

Work and energy are closely related.

- Energy is the ability to do work
- Work is done when a force moves an object through a distance.
- Energy is transferred by a force moving an object through a distance.
- It can only be observed when it is transferred
- Both work and energy are typically measured in **joules (J)**.

After the girl hits the ball, the ball moves very fast and has energy. When the ball hits the fielder's glove, it stops moving. Given that energy can never be destroyed but merely changes form, what happens to the energy the ball once had?



# Potential Energy



- **Potential energy** is energy that is stored as a result of position or shape.
  - Ex: Stretched rubber band, compressed spring



No Energy  
Spring Relaxed



Stored Energy  
Spring Compressed

Figure 4. Examples of spring energy



## Potential Energy

When this musician pulls the string of her cello to one side, the string is stretched and gains potential energy.



# Potential Energy

- Gravitational potential energy – any time gravity supplies the force
- Most often because it is raised off the ground.
- Dependent on its mass, its height, and the acceleration due to gravity.

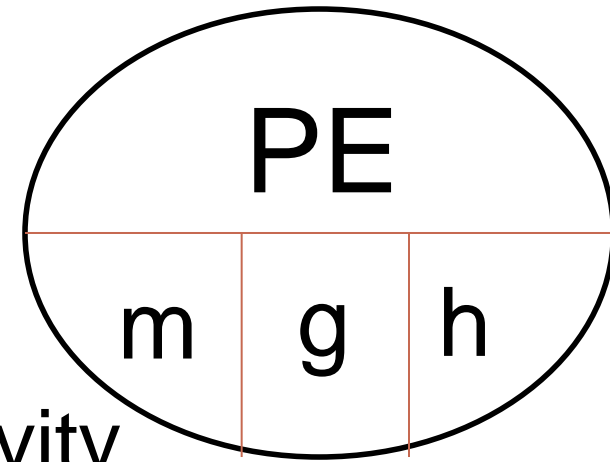
[Video Clip](#)





# Calculating Gravitational Potential Energy

- Depends on mass and height
- $PE = m \times g \times h$
- $m$  is mass in kilograms
- $g$  is acceleration caused by gravity
- $h$  is distance it can fall in meters.



• **Weight =  $m \times g$  (N)**      x      **Height (m)**

Force                      x                      Distance      →      ~~PE~~ Work

SI unit for PE is Joules

# Practice Problems: PE

1. A 100 kg boulder is on the edge of the cliff 10 m off the ground. How much energy does it have?

$m = 100 \text{ kg}$   
 $g = 9.8 \text{ m/s}^2$   
 $h = 10 \text{ m}$   
 $PE = ?$

$$PE = mgh$$

$$PE = 9800 \text{ J}$$

$$PE = 100 \text{ kg} \times 9.8 \text{ m/s}^2 \times 10 \text{ m}$$

$$PE = 10,000 \text{ J or } 1 \times 10^4 \text{ J}$$

2. A 0.5 kg ball is thrown 15 m into the air. How much potential energy does it have at its highest point?

$m = 0.5 \text{ kg}$   
 $g = 9.8 \text{ m/s}^2$   
 $h = 15 \text{ m}$   
 $PE = ?$

$$PE = mgh$$

$$PE = 73.5 \text{ J}$$

$$PE = 0.5 \text{ kg} \times 9.8 \text{ m/s}^2 \times 15 \text{ m}$$

$$PE = 70 \text{ J}$$

# Practice Problems: PE

3. The potential energy of an apple is 6.00 joules. The apple is 3.00 m high. What is the mass of the apple?

$$m = ?$$

$$g = 9.8 \text{ m/s}^2$$

$$h = 3.00 \text{ m}$$

$$PE = 6.00 \text{ J}$$

$$m = \frac{PE}{gh}$$

$$m = 6.00 \text{ J} / (9.8 \text{ m/s}^2 \times 3.00 \text{ m})$$

$$m = 6.00 \text{ J} / 29.4$$

$$m = 0.20408$$

$$m = 0.204 \text{ kg}$$

4. An 1750 kg weather satellite moves in a circular orbit with a gravitational potential energy of  $1.69 \times 10^{10}$  J. At its location, free-fall acceleration is only  $6.44 \text{ m/s}^2$ . How high above Earth's surface is the satellite?

$$m = 1750 \text{ kg}$$

$$g = 6.44 \text{ m/s}^2$$

$$h = ?$$

$$PE = 1.69 \times 10^{10} \text{ J}$$

$$h = \frac{PE}{mg}$$

$$h = 1.69 \times 10^{10} \text{ J} / (1750 \text{ kg} \times 6.44 \text{ m/s}^2)$$

$$h = 1.4995 \times 10^6$$

$$h = 1.50 \times 10^6 \text{ m}$$

# Kinetic Energy

- The energy of motion
- Depends on two things
  - Mass and velocity
- Twice the mass, twice the kinetic energy
- Twice the velocity four times the kinetic energy
- 

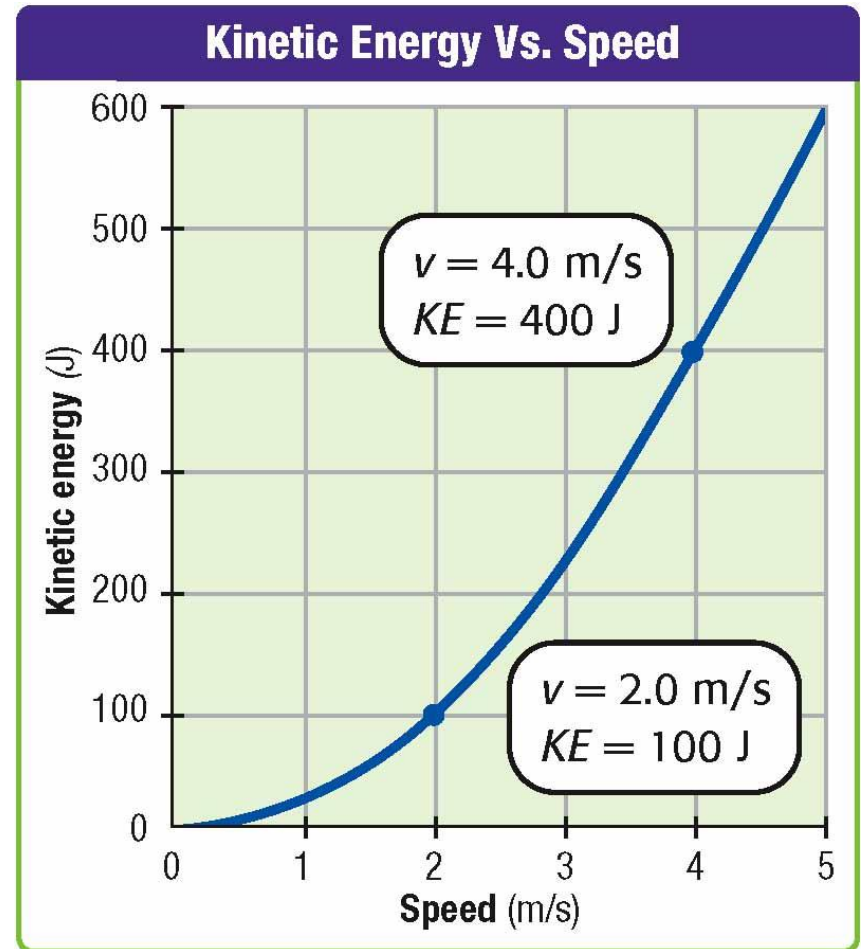


## **Kinetic Energy**

$$\text{Kinetic energy (KE)} = \frac{1}{2}mv^2$$

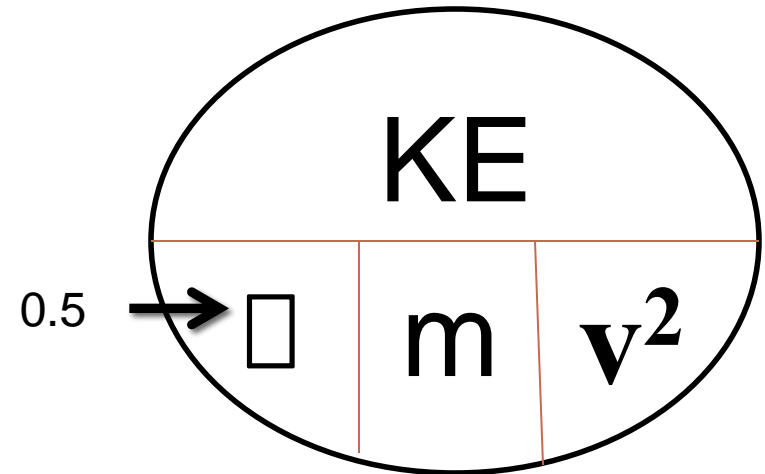
# Kinetic Energy

- Kinetic energy depends on speed more than mass.



# Calculating Kinetic Energy

- $KE = \frac{1}{2} \times \text{mass} \times \text{speed squared}$
- $KE = \frac{1}{2} m v^2$
- $m = \text{mass (kg)}$
- $v = \text{speed (m/s)}$
- SI unit for KE is Joules



1. What is the kinetic energy of a 44 kg cheetah running at 31 m/s?

$$KE = ?$$

$$m = 44 \text{ kg}$$

$$v = 31 \text{ m/s}$$

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

$$KE = \frac{1}{2} (44 \text{ kg})(31 \text{ m/s})^2$$

$$KE = 21142$$

$$KE = 21000 \text{ J or } 2.1 \times 10^4 \text{ J}$$



# Practice Problems: KE

2. What is the kinetic energy of a 100 kg man moving 5 m/s?

$$\begin{aligned} \text{KE} &= ? \\ m &= 100 \text{ kg} \\ v &= 5 \text{ m/s} \end{aligned}$$

$$\text{KE} = \frac{1}{2}(m) \times (v^2)$$

$$\text{KE} = \frac{1}{2} (100 \text{ kg}) \times (5\text{m/s})^2$$

$$\text{KE} = 50 \text{ kg} \times 25 \text{ m/s}$$

$$\text{KE} = 1250 \text{ J}$$

$$\text{KE} = 1000 \text{ J}$$

3. A 0.10 kg bird is flying at a constant speed of 8.0 m/s. What is the bird's kinetic energy?

$$\begin{aligned} \text{KE} &= ? \\ m &= 0.10 \text{ kg} \\ v &= 8.0 \text{ m/s} \end{aligned}$$

$$\text{KE} = \frac{1}{2}(m) \times (v^2)$$

$$\text{KE} = \frac{1}{2} (0.10 \text{ kg}) \times (8.0\text{m/s})^2$$

$$\text{KE} = 0.05 \text{ kg} \times 64 \text{ m/s}$$

$$\text{KE} = 3.2 \text{ J}$$

4. A 50.0 kg cheetah has a kinetic energy of 18,000 J. How fast is the cheetah running?

$$\begin{aligned} \text{KE} &= 18,000 \text{ J} \\ m &= 50.0 \text{ kg} \\ v &= ? \end{aligned}$$

$$v = \sqrt{2(\text{KE})/m}$$

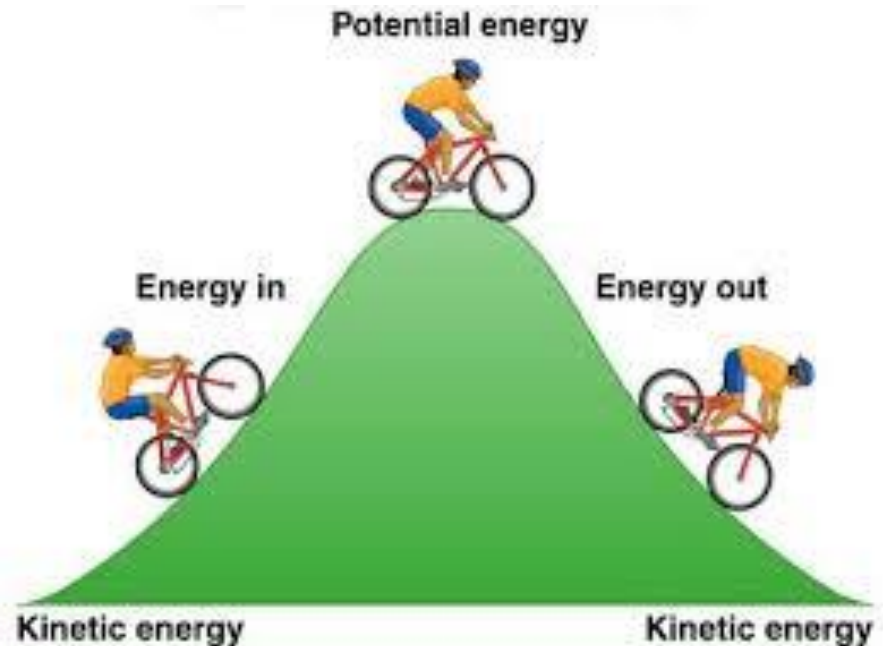
$$v = \sqrt{2(18,000 \text{ J})/50.0 \text{ kg}}$$

$$v = 26.83 \text{ m/s}$$

$$v = 27 \text{ m/s}$$

# Mechanical Energy

- The sum of the potential and kinetic energy.
- Before an apple falls it has all potential energy
- Just before it hits the ground it has all kinetic energy
- In between it has some potential energy, and some kinetic energy



# Other forms of energy

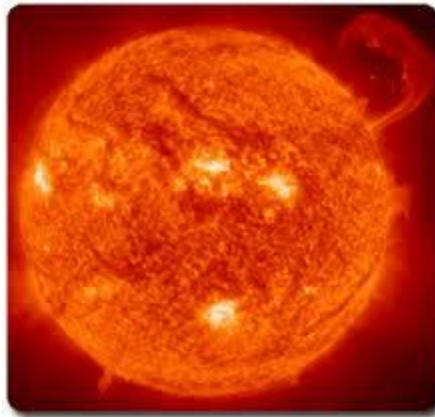
- **Chemical energy** – stored in the bonds between atoms
  - Reactions release or absorb energy
- **Temperature** – measures the kinetic energy of the particles
- **Heat** – the total kinetic energy of the particles of a substance

This family is using the chemical energy of burning wood to produce thermal energy for heating marshmallows.



# Other forms of energy

- **Nuclear energy**- energy from changing the nucleus of atoms
- The sun's energy comes from fusion – putting two hydrogen atoms to make helium atoms
- $E = mc^2$  mass is converted to energy



# Other forms of energy

- **Electricity**- the energy of charged particles
- **Light**- energy that can travel through empty space in electromagnetic waves



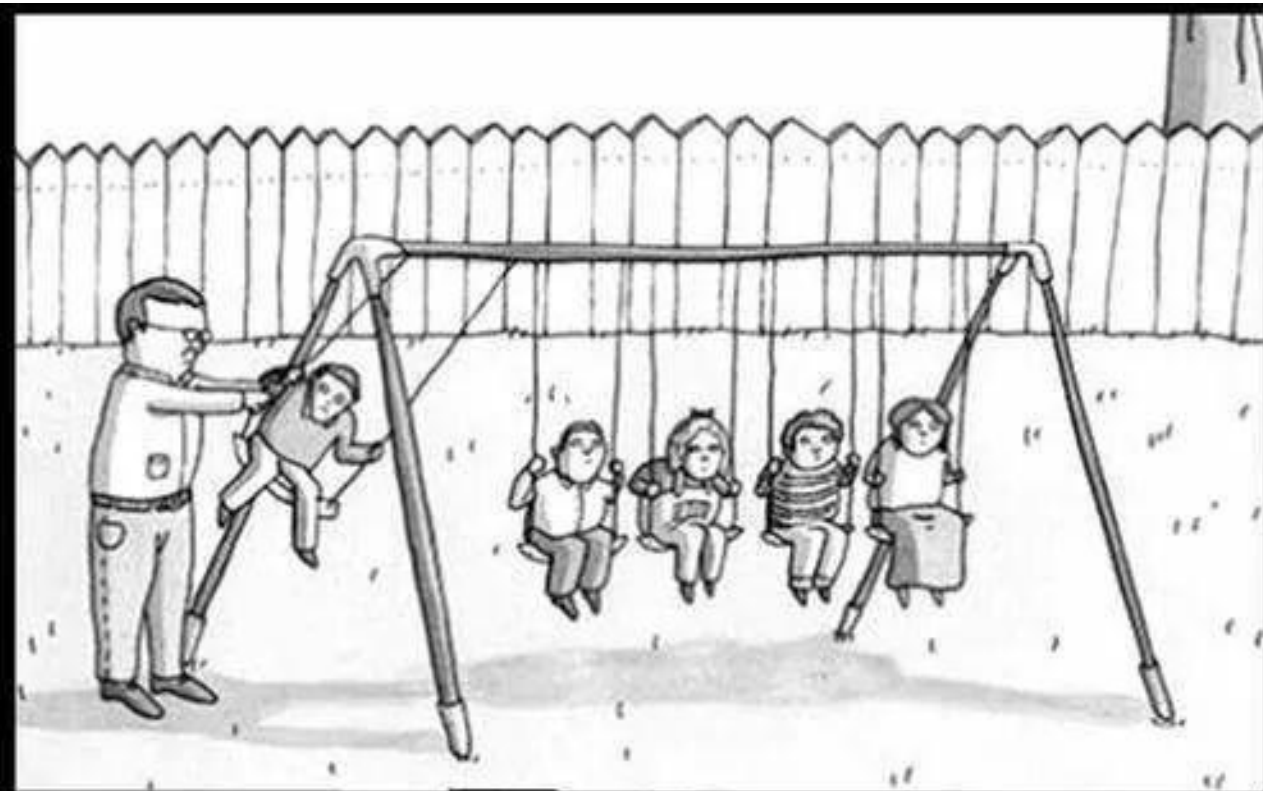
# Conservation of energy

**Objective 1: How does energy change?**

**Objective 2: State the law of conservation of energy.**

**Objective 3: How much work done by a machine is useful work?**



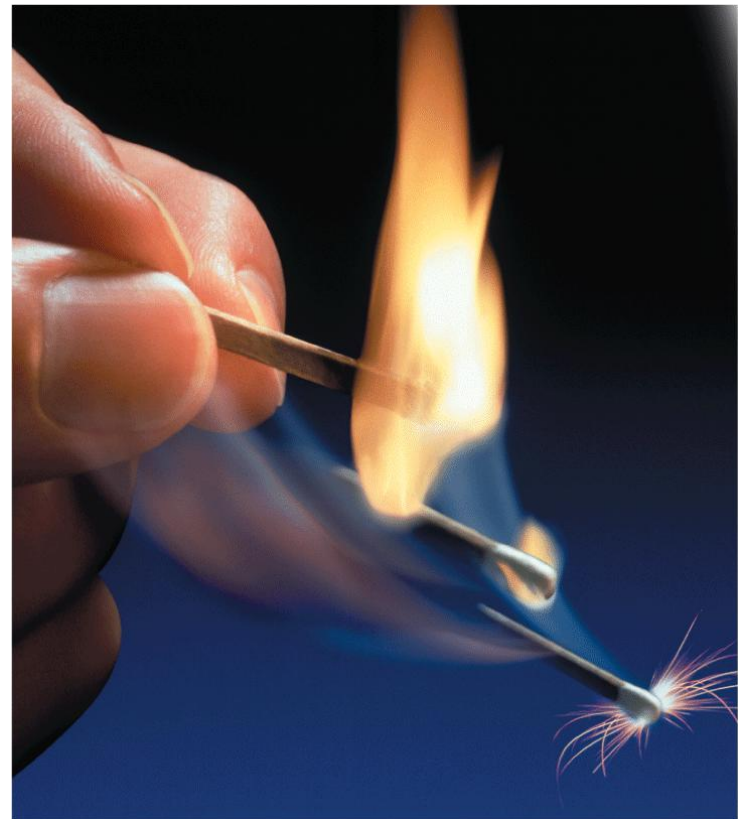


Why science teachers  
should not be given  
playground duty.

# Energy Transformation

The process of changing energy from one form to another is **energy conversion**. The striking of a match is a good example.

- Muscles use chemical energy to move the match.
- Friction between the match and the matchbox converts kinetic energy into thermal energy.
- Chemical energy is converted into thermal energy and electromagnetic energy in the flame.



# Energy is transformed

- Potential energy can become kinetic energy.
  - Example: As a roller coaster car goes down a hill,  $PE$  changes to  $KE$ .
- Kinetic energy can become potential energy.
  - Example: The  $KE$  of a roller coaster car at the bottom of a hill can do work to carry it up another hill.
- Mechanical energy can change to other forms of energy.
  - Due to friction
  - Changes to nonmechanical forms

# Conservation of Energy

The image shows a screenshot of a physics simulation interface. The main window displays a roller coaster track with a character on it. The track starts at a high point on the left, goes down to a loop, and then up to a high point on the right. The background shows a landscape with mountains and a house. The interface includes a control panel on the right and a status bar at the bottom.

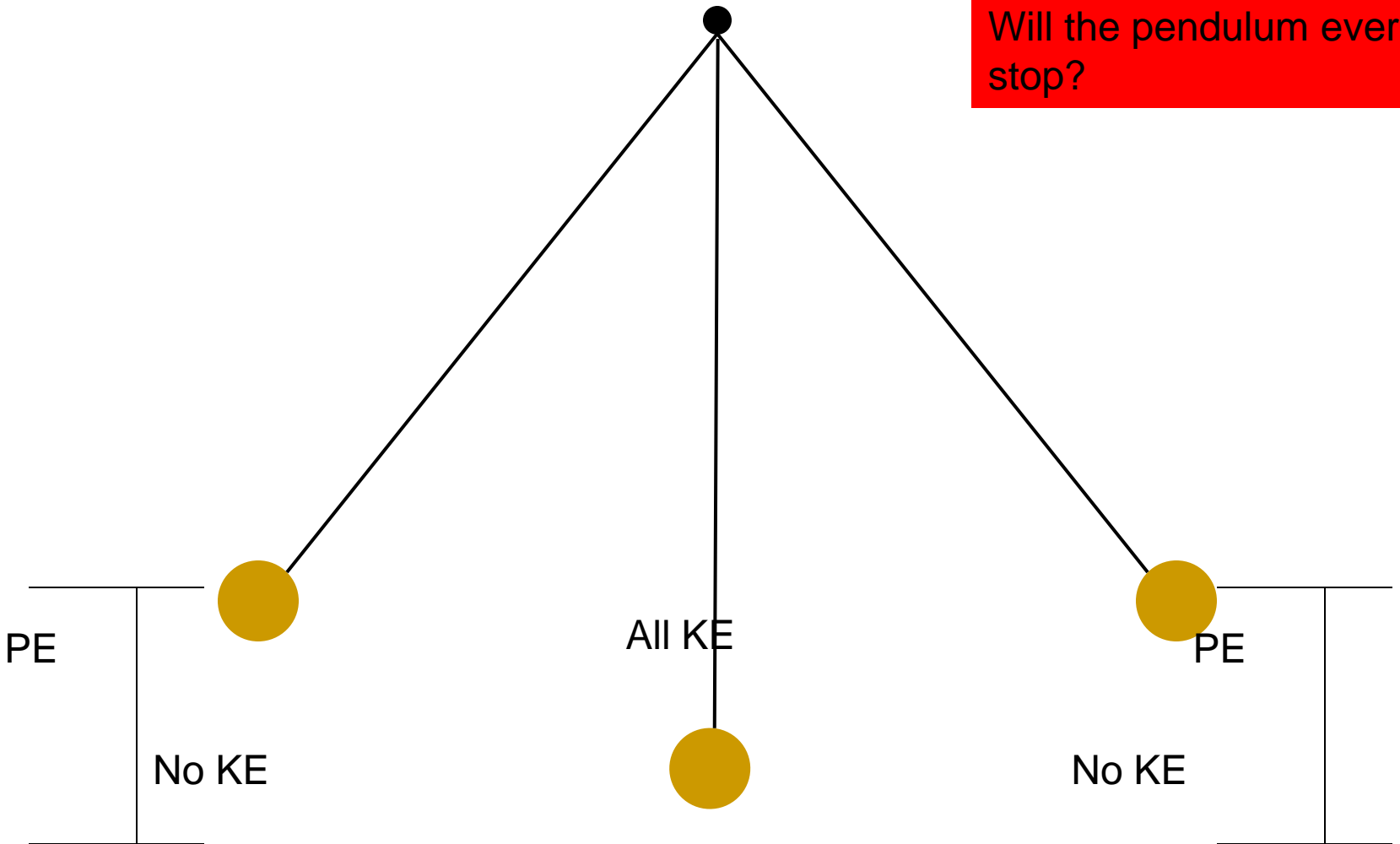
**Control Panel (Right Side):**

- Choose Character: [Dropdown]
- Measuring Tape
- Potential Energy Reference
- Show Grid
- Path:
  - Show Path
  - Clear
- Energy Graphs:
  - Show Pie Chart  with Thermal
  - Bar Graph
  - Energy vs. Position
  - Energy vs. Time
- Location:
  - Show Background
  - Space
  - Moon
  - Earth
  - Jupiter
- Gravity: 9.81 N/kg
- Slider: Space | Earth | Jupiter
- Clear Heat
- Track Friction: [Slider]
- Edit Skater: [Slider]

**Status Bar (Bottom):**

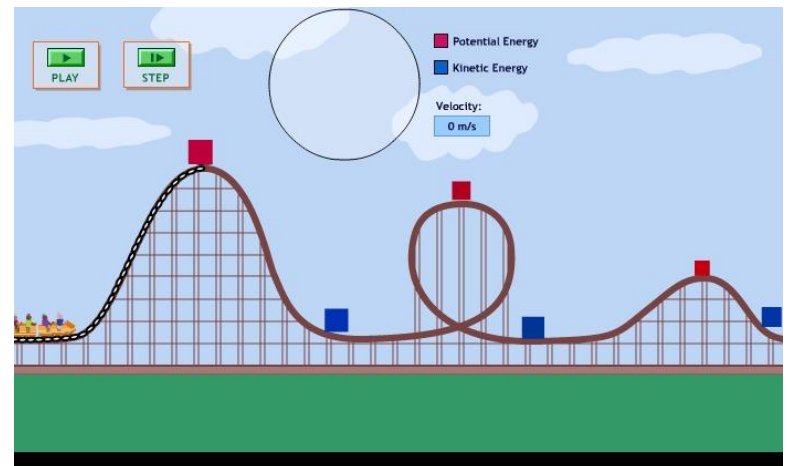
- slow | normal | fast
- Pause
- Stop

# Example: A Pendulum



# Conservation of energy

- Law of Conservation of Energy states:
  - Energy can't be created or destroyed but it does change from one form to another.
- The total energy remains constant, it just changes its form



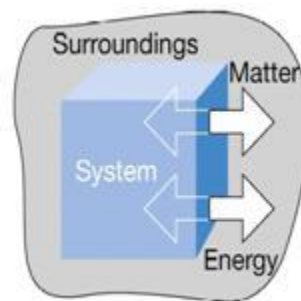


# Conservation of Energy

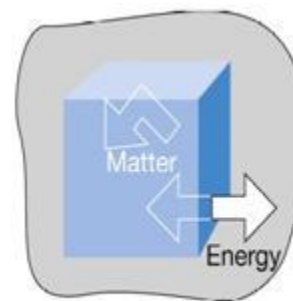
- Energy does not appear or disappear.
  - Whenever the total energy in a system increases, it must be due to energy that enters the system from an external source.
- Thermodynamics describes energy conservation.
  - For any system, the net change in energy equals the energy transferred as work and as heat.
  - This form of the law of energy conservation is called the *first law of thermodynamics*.

# Energy is Conserved

- All the energy can be accounted for
- It can be hard to conserve
- Three types of systems
  1. Closed system let energy and not matter exchange.
    - Used by scientists to limit variables. Ex: Earth
  2. Open system does let energy and matter exchange.
    - Much more common. Ex: Water cycle
  3. Isolated system is one which neither energy nor matter is exchanged.
    - A thermo flask containing hot or cold liquid.



(a) Open



(b) Closed



(c) Isolated

# Efficiency of Machine



- Efficiency is the ratio of useful work out to work in.
- Not all the work done is useful work
  - Some gets turned into other forms
    - Often heat (the least organized of all types of energy)
- **Always** less than 100% efficient



# Calculating Efficiency

- Efficiency =  $\frac{\text{Useful work or Work Output}}{\text{Work Input}}$
- Or % Efficiency =  $\frac{\text{Useful work or Work output}}{\text{Work input}} \times 100\%$
- Efficiency is given as a percent
- Work in/out is in Joules

$$\frac{W_{\text{out}}}{W_{\text{in}}} \times 100\%$$

1. A sailor uses a rope and an old, squeaky pulley to raise a sail that weighs 140 N. He finds that he must do 180 J of work on the rope to raise the sail by 1 m. (He does 140 J of work on the sail.) What is the efficiency of the pulley?

W input= 180 J  
W output= 140 J  
Efficiency=?

$$\text{Eff} = \frac{W_{\text{out}}}{W_{\text{in}}} \times 100\%$$

$$\text{Eff} = 140 \text{ J} / 180 \text{ J}$$

$$\text{Eff} = 0.78$$

$$\text{Eff} = 0.78 \times 100\%$$

Eff= 78%

# Practice Problems: Efficiency

2. A forklift developed in Sweden is able to do  $1.8 \times 10^6$  J of useful work in lifting a heavy load. Suppose  $7.6 \times 10^6$  J must be done by the lift's motors on the load in order to accomplish this task. What is the efficiency of the forklift?

$$W_{\text{input}} = 7.6 \times 10^6 \text{ J}$$

$$W_{\text{output}} = 1.8 \times 10^6 \text{ J}$$

Efficiency = ?

$$\text{Eff} = \frac{W_{\text{out}}}{W_{\text{in}}} \times 100\%$$

$$\text{Efficiency} = \frac{1.8 \times 10^6 \text{ J}}{7.6 \times 10^6 \text{ J}}$$

$$\text{Efficiency} = 0.24$$

$$\text{Efficiency} = 0.24 \times 100\%$$

$$\text{Efficiency} = 24\%$$

3. The resistance of water on an oar in a rowboat limits the oar's efficiency to 0.450. If the rower does 145 J of work on the oar with each stroke, how much useful work is done by the oar?

$$\text{Work output} = ?$$

$$\text{Work input} = 145 \text{ J}$$

$$\text{Efficiency} = 0.450$$

$$\text{Work output} = \text{efficiency} \times \text{work input}$$

$$\text{Work output} = 0.450 \times 145 \text{ J}$$

$$\text{Work output} = 65.3 \text{ J}$$

# Perpetual Motion Machines

- Machines that would run forever without energy input
- Or machines that put out more energy than you put in.
- They don't exist.
- Would require a complete absence of friction.
- They would break the law of conservation of energy



[Video](#)