

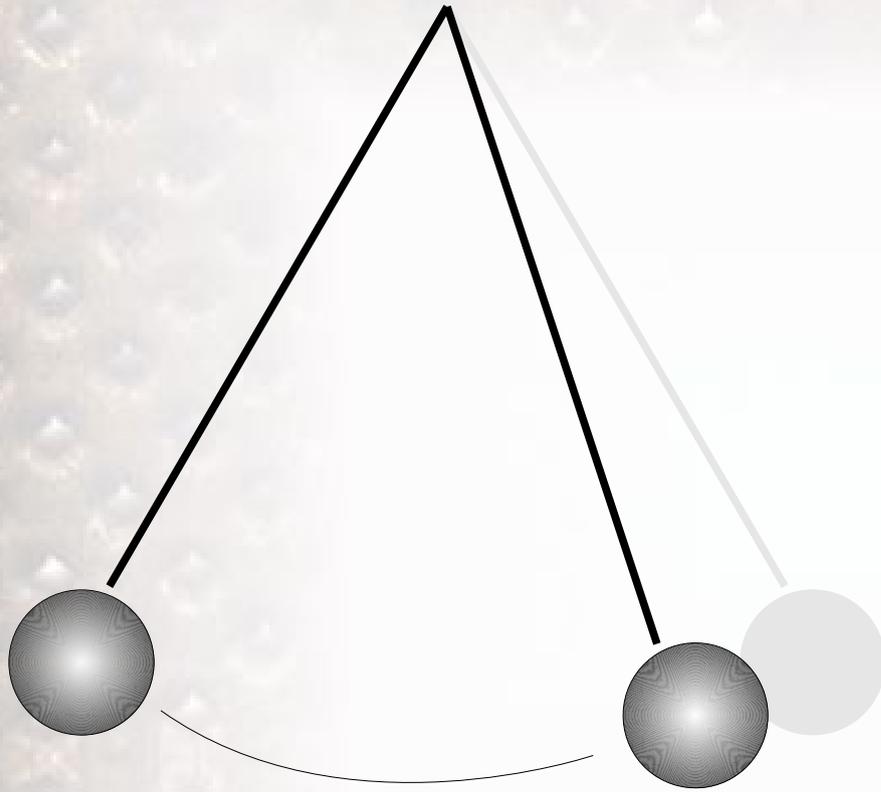
# Law of Conservation of Energy

The sum total energy contained in all the parts of any process remains the same.

So far, the examples we've used have *not* included the effects of **friction**.

Do you think the Law of Conservation of Energy will still hold true when friction is included?

# Lost Energy?



You know that each time a pendulum swings, it doesn't go quite as far over as it did the last time. Why not?

Apparently, it doesn't end up with as much gravitational potential energy as it started out with.

# The Effects of Friction

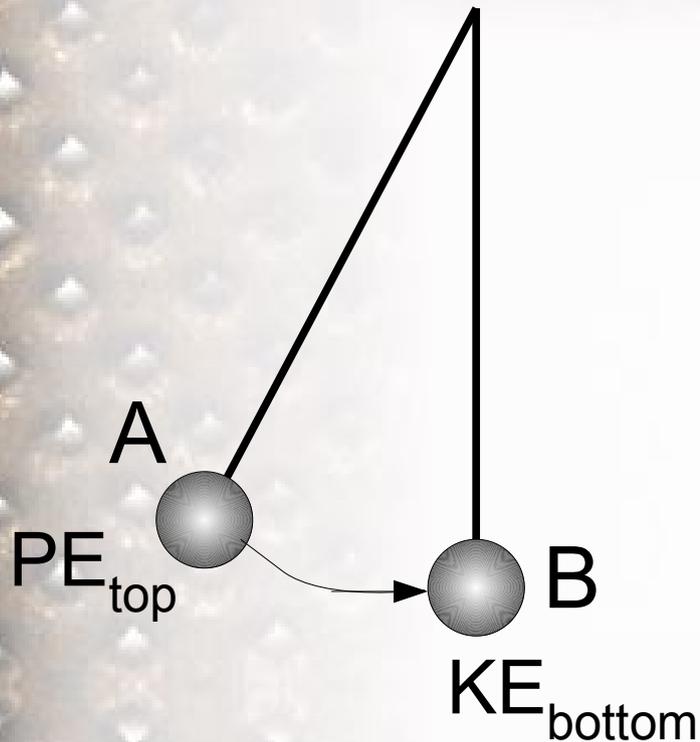
The energy isn't really lost. Some of the pendulum's original potential energy has turned into thermal (heat) energy.

When you rub your hands together vigorously, you feel the heat building up. You are converting kinetic energy into heat energy.



**Blame it on the force of friction!**

# Friction in the Pendulum



When the pendulum swings from A to B, it “feels” the air rubbing against it and flowing around it. This stirs up the air, making the air molecules move faster.

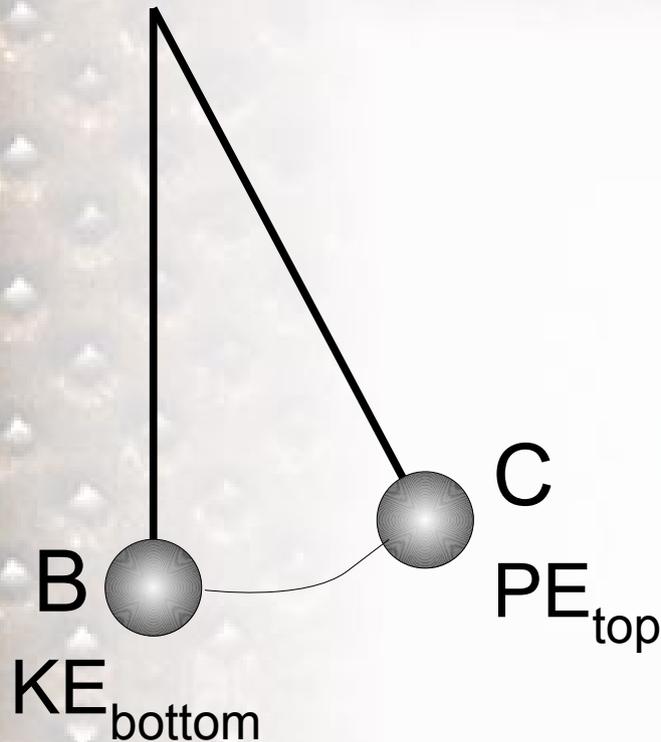
We call this thermal energy or heat.

# Friction in the Pendulum

If you add the thermal energy to the kinetic energy the pendulum acquired by the time it got to the bottom of its swing, it turns out to be equal to the original gravitational potential energy at the top.

$$PE_{\text{top}} = KE_{\text{bottom}} + \text{thermal energy}$$

# Friction in the Pendulum

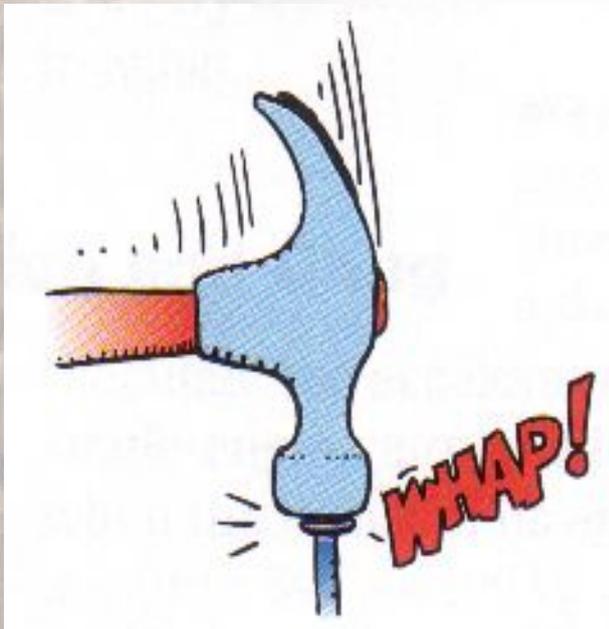


When the pendulum swings from B to C, once again, some of its kinetic energy that would have changed back to potential energy, changes over to heat instead.

$$KE_{\text{bottom}} = PE_{\text{top}} + \text{thermal energy}$$

# Energy Transformations

Consider the hammer hitting the nail.

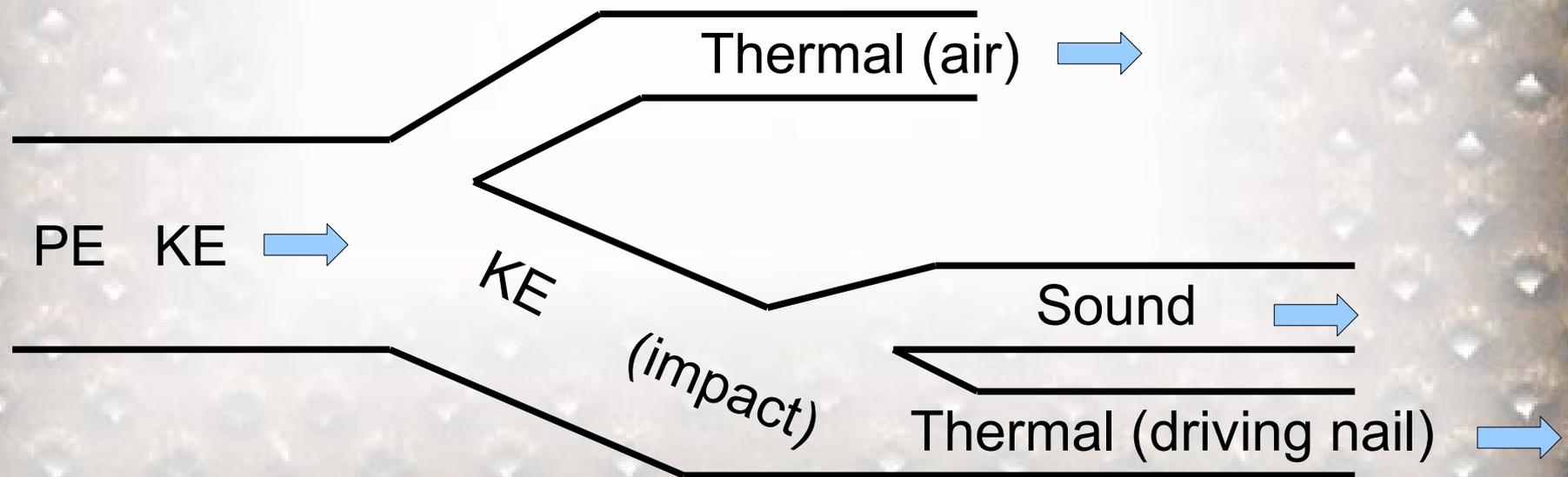


The hammer starts out with potential energy and the kinetic energy you give (by swinging it.) As the hammer drops, the potential energy turns into more kinetic.

Upon impact, the energy becomes thermal and sound.

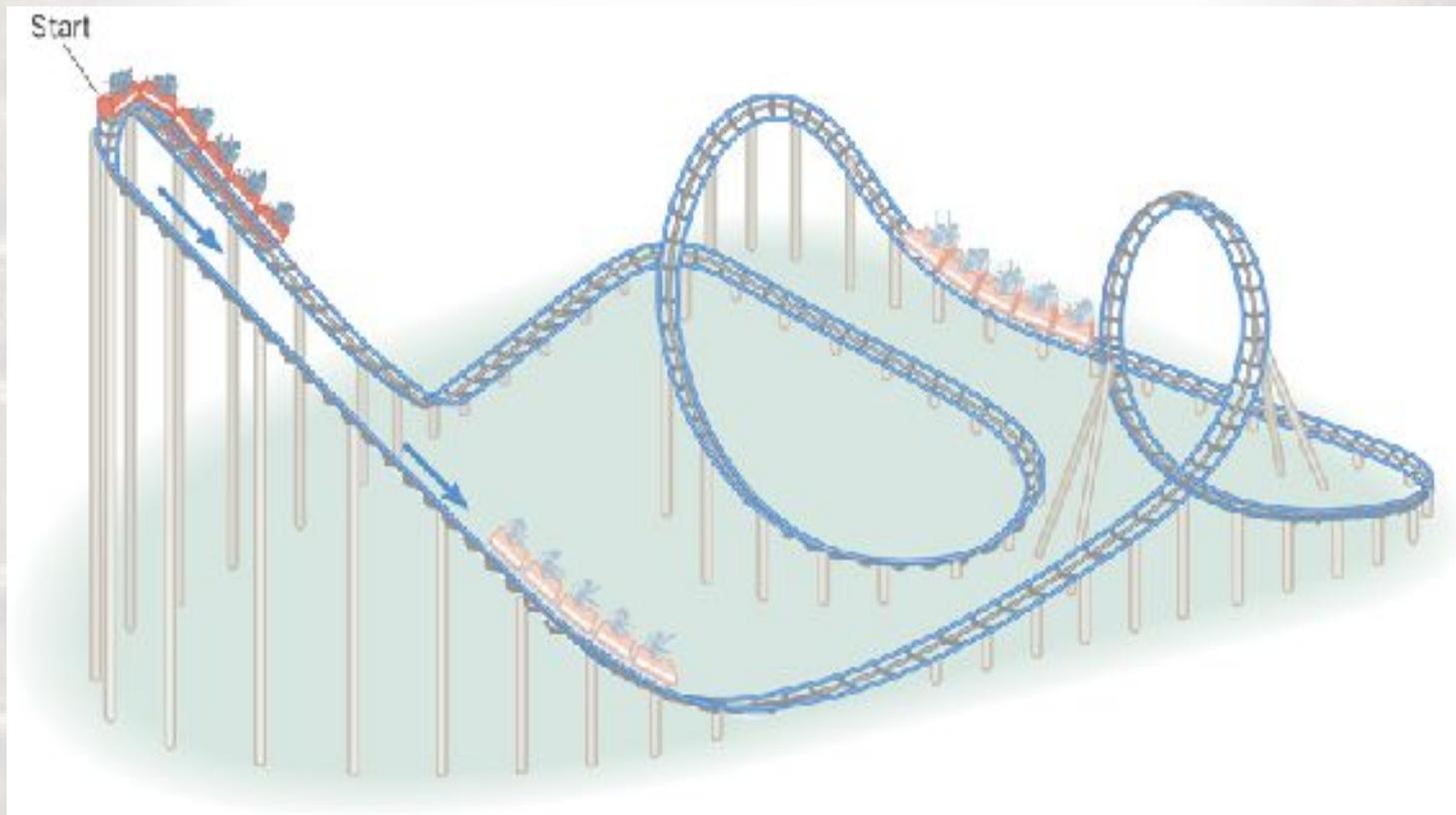
# Energy Flow Diagram Driving the Nail

The heat energy at the end mostly comes from the extreme force of friction the nail feels as it's gripped by the piece of wood it is being driven into.

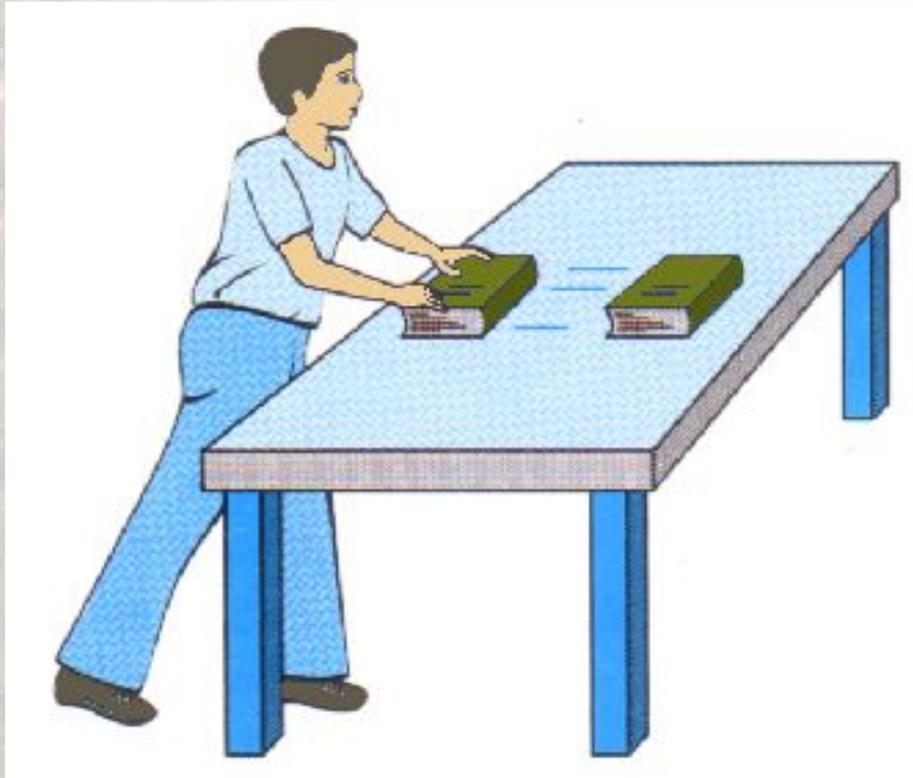


# Energy Transformations

Can you describe the energy transformations occurring in this roller coaster ride?



# Energy Transformations

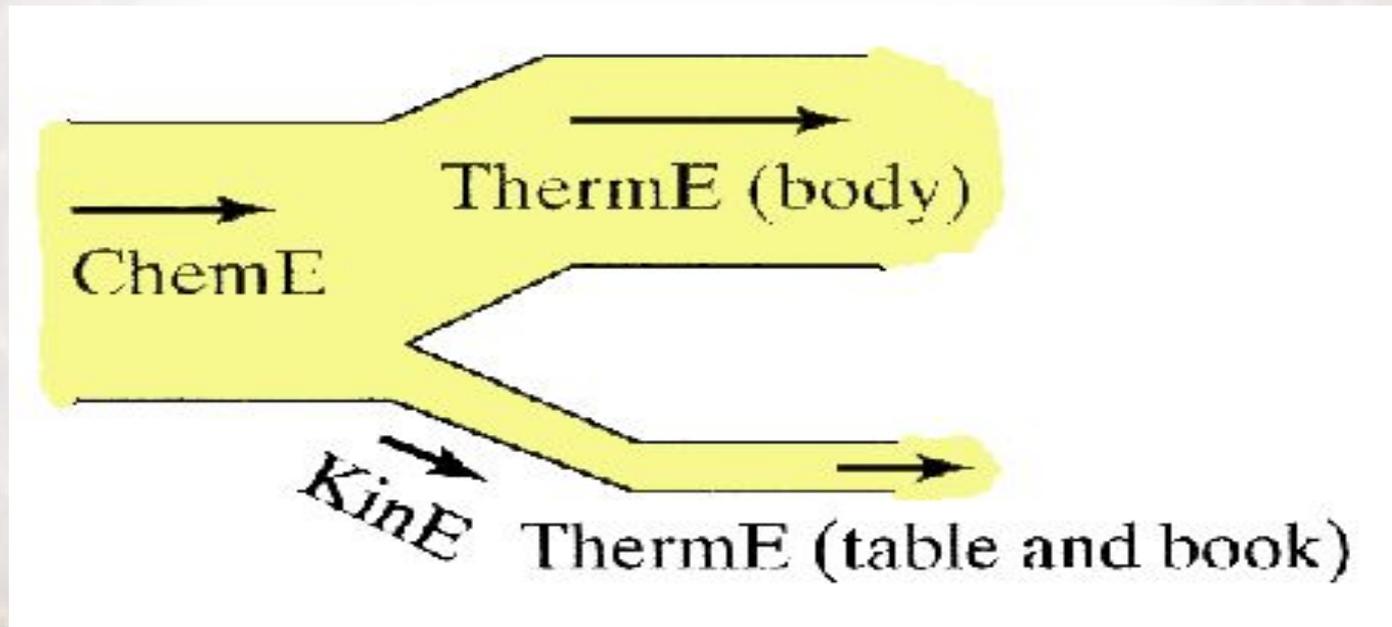


What energy transformations occur when you briefly push a book and then let it slide?

# Energy Transformations

Pushing a book is a rather inefficient activity. Most of the energy goes into heating up your body.

## Energy Flow Diagram (Pushing a Book)



# Energy Efficiency

This equation shows how the useful energy you get out of an activity compares with the energy you put into it.

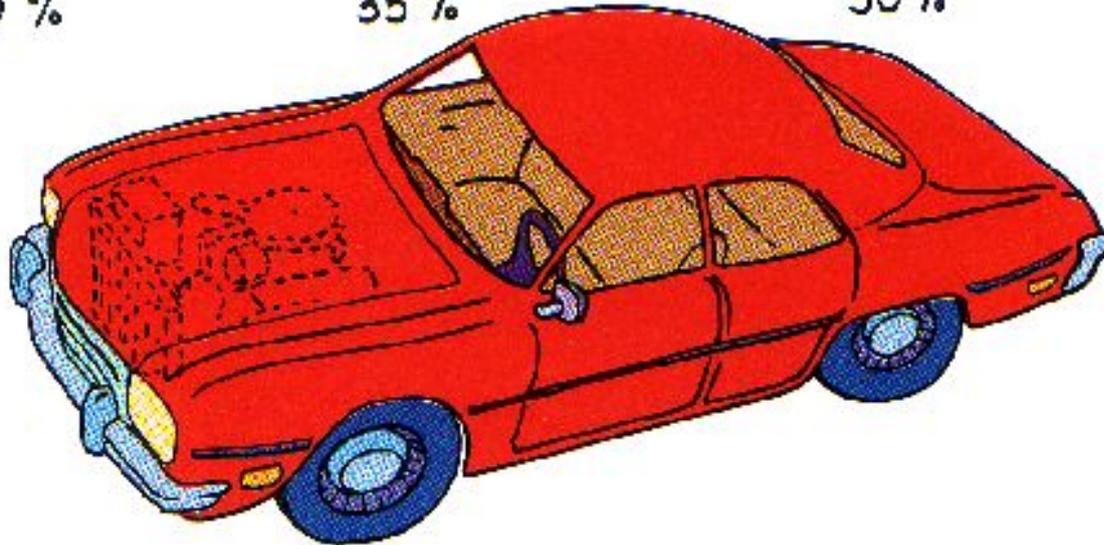
$$eff = \frac{E_{out}}{E_{in}} \times 100\%$$

$$\text{energy efficiency} = \frac{\text{useful output energy}}{\text{total input energy}}$$

# Energy Efficiency

Typically, an automobile is only 30% efficient.

FUEL ENERGY IN = COOLING WATER LOSSES + ENGINE OUTPUT + EXHAUST HEAT  
100 %                      35 %                      30 %                      35 %



# Power



**Power** is how quickly you can do work.

Power is also the rate at which energy is transformed.

If you can run upstairs in only  $\frac{1}{2}$  the time, you've developed twice as much power.

# Equation for Power

$$P = \frac{W}{t}$$

$$\text{power} = \frac{\text{work done}}{\text{time to do it}}$$

# Units of Measurement

Power is measured in Watts.

Work & Energy are measured in Joules.

Time is measured in seconds.

# Power

What most people call power is really energy.

For example: A utility company bills you for electrical energy, not power, but people still say, “I got the power bill from the power company.”

A **kilowatt-hour** is a unit of energy. It is equivalent to  $3.6 \times 10^6$  joules.

# Energy Transformations

Other forms of energy:

Elastic potential energy (bow & arrow)  
\*Thermal or internal energy (heat)  
Electric potential energy (capacitors)  
\*Radiant energy (electromagnetic and sound)  
Chemical potential energy (batteries)  
Nuclear energy

\*These forms of energy dissipate or spread out.