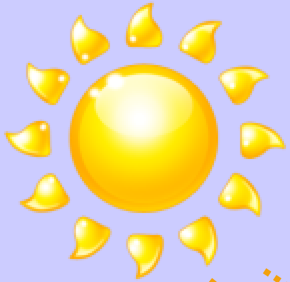
ESSC Hold

- **To remove hold:**
  - **Complete MyPlanner through graduation**
  - **Workshops on MyPlanner**
    - **Sign up for Monday (Engr 391)**
      - 08/27 https://goo.gl/forms/rnUR44UekFgBpIT92
    - **Sign up for Tuesday (Engr 407)**
      - 08/28 https://goo.gl/forms/HHhUmn4Q3HTheI2J2
    - **Video will be made available later (accessible through Engr 10 website)**
  - **General Engineering Majors**
    - **Make an appt with me through the ESSC**

Energy and Power



ENGR 10 – Intro to Engineering

College of Engineering

San Jose State University

Which of the following heaters can heat up a gallon of water to 90^{o} C?

(A) 5 W heater
(B) 90 W heater
(C) 100 W heater
(D) All of the above

Today's Main Concepts

- **Energy**
  - Potential Energy
  - Kinetic Energy
- **Work**
- **Power**
- **Conservation of Energy –** (1st Law Thermodynamics)

What is Energy?

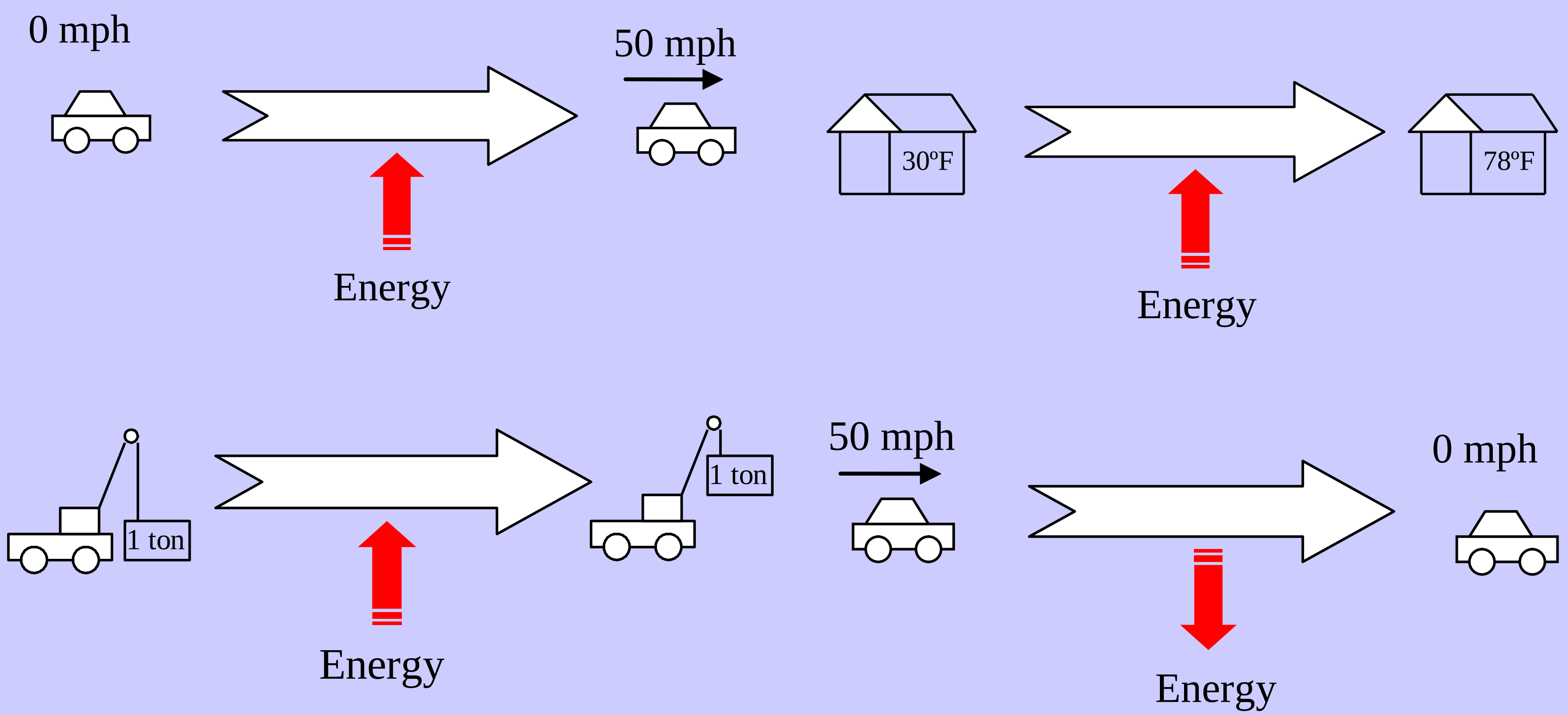
Merriam-Webster → **Energy is** “a fundamental entity of nature that is **transferred** between parts of a system in the production of **physical change** within the system and usually regarded as the capacity for doing work”

Simplified:

In other words, energy measures the **capacity** of an object or system **to do work** on another system or object.

Energy is what it takes to do work or change the physical state of an “object”.

Examples of “Change of state”



Note: Some changes of state release energy.

Change of state is called “Work”.

Energy is the ability to do work, the ability to cause motion and change

Different forms of energy

Kinetic

Potential

Chemical

Mechanical

Magnetic

Electrical

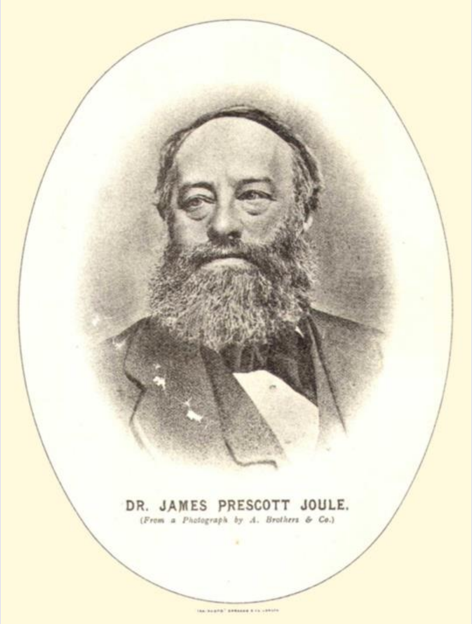
Nuclear

Thermal (Heat)

Sound

Luminous

Units of Energy



www.mlfhs.org.uk/worthies/joule.jpg

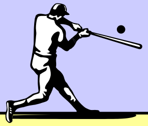
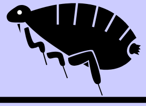
Metric system (SI) Joule (J)

1 Joule = 1 Newton-meter

J = N-m

US units - English system (IPS) ft-lb or in-lb

1 foot-pound force = 1.3558 J (Let's say 1.36 J)

State Change (Work)	**Required Energy (J)**
Creation of the Universe	10^{68}
Starting Earth moving in orbit	10^{33}
Atomic Bomb Explosion	10^{14} (energy release)
Accelerating a 2006 Honda Accord from 0 to 60 mph	$5x10^{5}$ 
Hard-hit baseball	10^{3} 
Lifting an apple by 1 meter	1 
Hopping flea (per hop)	10^{-7} 

Other Energy Units

Energy Unit	In Joules
1 BTU (British Thermal Unit)	1055 joules
1 calorie	4.184 joules
1 food Calorie (kilocalorie)	4184 joules
1 kwH (kilowatt-hour)	3.6×10^6 joules

1 calorie = Amount of energy required to change temperature of one gram of liquid water by one degree Celsius.

1 gram = 0.001 kg

For water: 1 gram=1 cm^3

Energy Conversion

Energy is what it takes to do work, but energy is NOT "consumed" by doing the work. It is transformed from one form to another form.

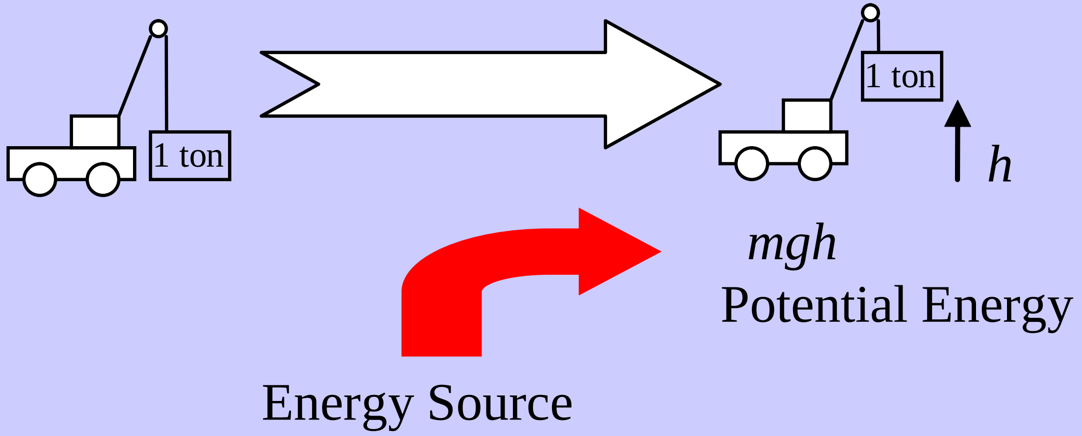
In a gas water heater, the energy is transformed from energy contained in the gas to the heat energy in the water (and other forms in the byproducts such as heat in the exhaust air).

The work of lifting a mass of *m* kg for *h* meters requires the following amount of energy:

Energy = *m (mass) x g(acceleration of gravity) x h (height)*

PE = *m g h*

This amount of energy is transformed to the energy (called Potential Energy) that is contained in the mass situating at a higher elevation. Note: Energy is transformed, not 'used up'.



Which one of the following values is **closest** to the amount of energy that is required to take you from here to the 2nd floor of this building? (Hint: *mgh*)

(A) 40 J
(B) 400 J
(C) 4000 J
(D) 40000 J
(E) 400000 J

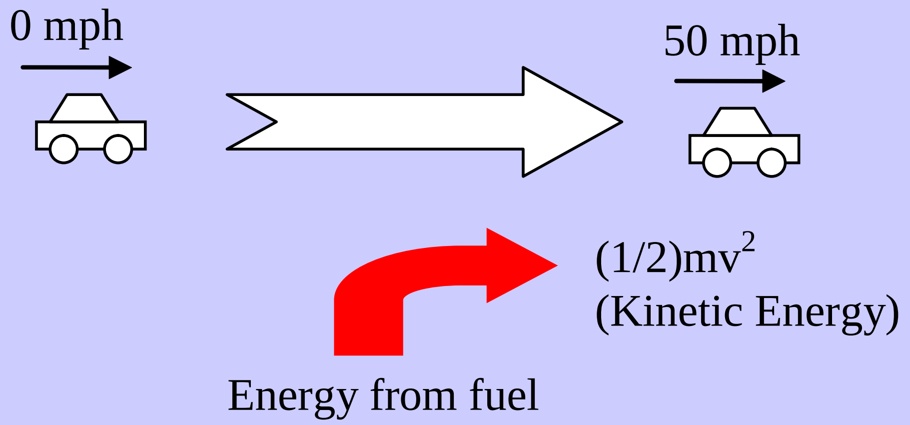
This energy is transformed from the energy in the food that you ate to the potential energy of your body mass on the 2nd floor.

PE = mgh = 150 (lb) x 20 (ft) = 3000 (ft-lb) x 1.3558 J/ft-lb = 4067 J
PE = mgh = 70 (kg) x 9.8 m/s^2 x 7 (m) = 4900 J

The work of accelerating a mass of *m* kg from 0 speed to the speed of v (meter/second) requires the following amount of energy:

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

This amount of energy is transformed from burning fuel to the energy that is contained in the moving mass (called Kinetic Energy). Note: Energy is transformed, not 'used up'.



How much energy is in a Honda Accord (1300 kg) when it is traveling at 30 mph?
(note: 1 mph = 0.447 m/s)

Kinetic Energy = $0.5*1300kg*(13.4\ m/s)^2 = 1.17x10^5$ J

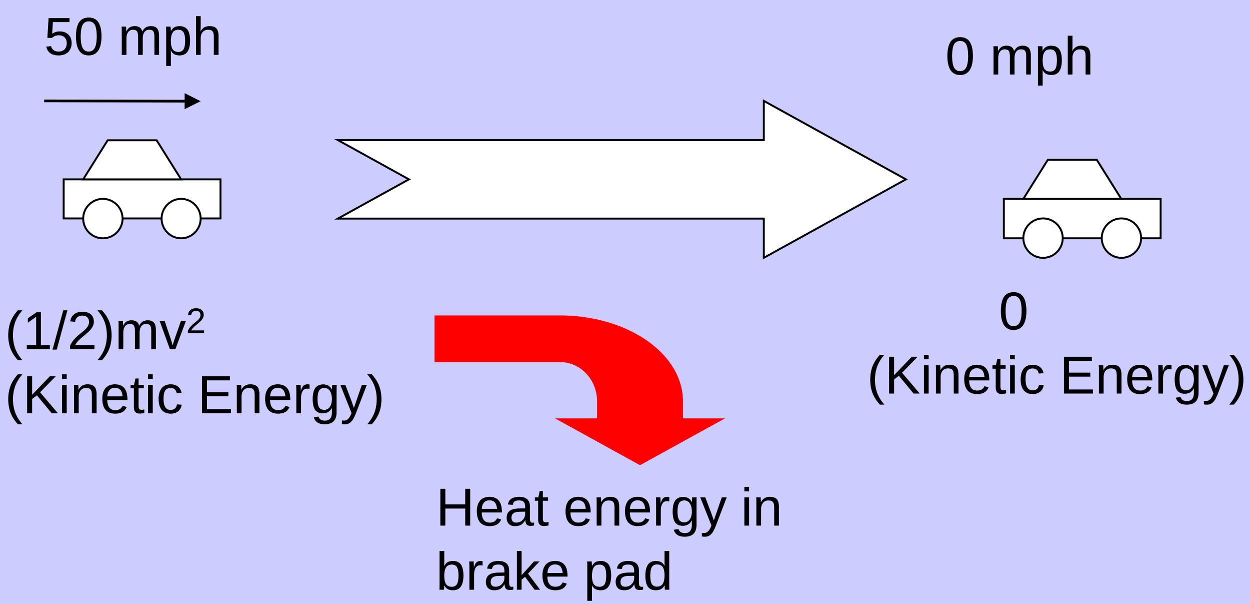
How much energy is needed to accelerate it from 30 to 60 mph?

At 60 mph: Kinetic Energy = $0.5*1300*(26.8)^2 = 4.67x10^5$ J

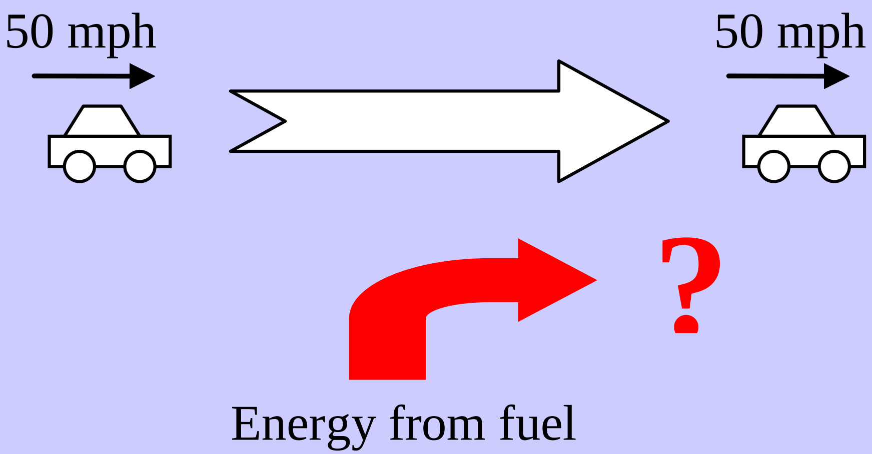
Required energy = $KE_{60}-KE_{30}$

$= 4.67x10^5$ J - $1.17x10^5$ J = $3.5x10^5$J

When friction brake is applied, the kinetic energy of a moving car is converted into heat energy in the brake pads and later, ambient air. In this case, the energy is transformed, not created.



Fuel (energy) is required to keep a car moving at a constant speed on a level ground. In this case, the energy from the fuel is transformed mostly into which one of the following forms?



A. Potential energy of the car
B. Kinetic energy of the car
C. Heat energy of the air
D. Heat energy of the car engine
E. Kinetic energy of the air

Energy Content

Energy is ‘stored’ in various forms around us.

	Energy Content (J)
Gallon of gasoline	1.3×10^8
Pound of coal	1.6×10^7
Candy bar	2×10^5
A passenger car at 60 mph	5×10^5
AA battery	10^3
30 mph wind through an area of 100 m^2 for 1 hour.	5.3×10^8

A pound of TNT is about 2.42 mega (10^6) joules.

Energy Transformation Machines

Some energy transformation is done naturally such as releasing energy contained in a log by burning for heat.

To better suit our needs, we build machines to facilitate, manage, and control the energy transformation.

Example: A car's engine

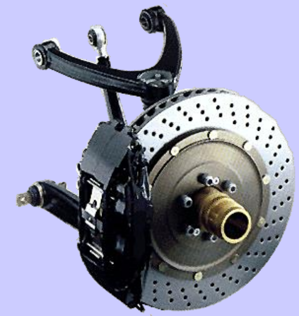
- Spark plugs initiate the combustion of fuel vapor in the engine cylinder, which releases <u>energy from the gasoline</u>.

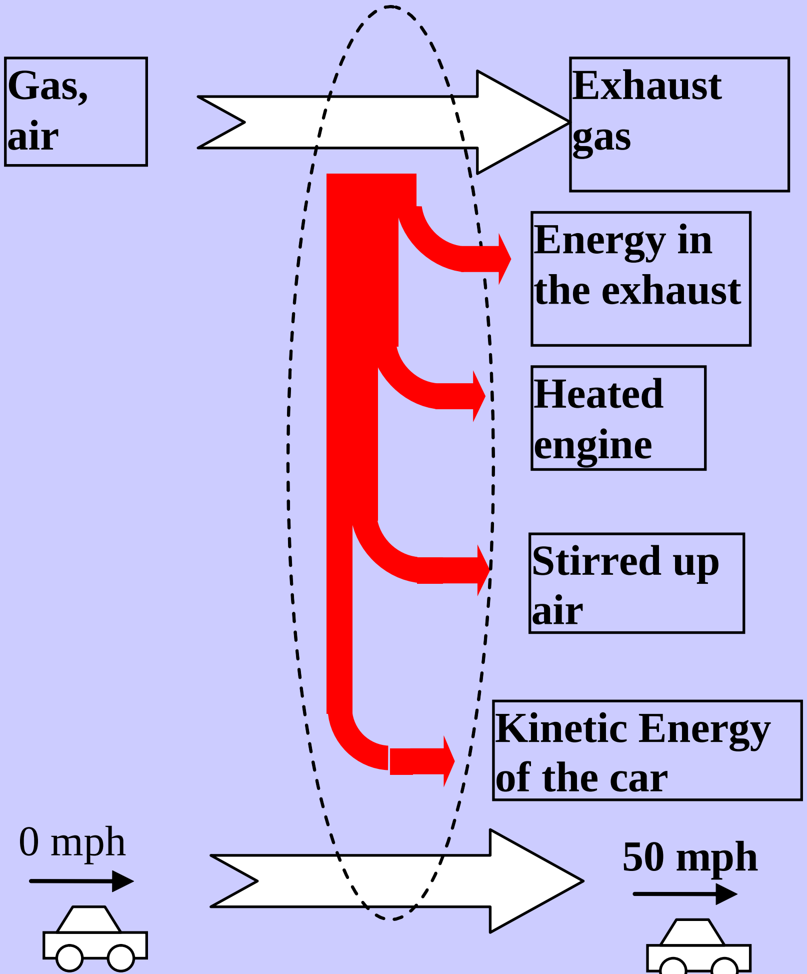
- Cylinders and pistons transform the expansion force of the combusted fuel/air to mechanical force, which in turn accelerates the car and increases the car's <u>kinetic energy</u>.

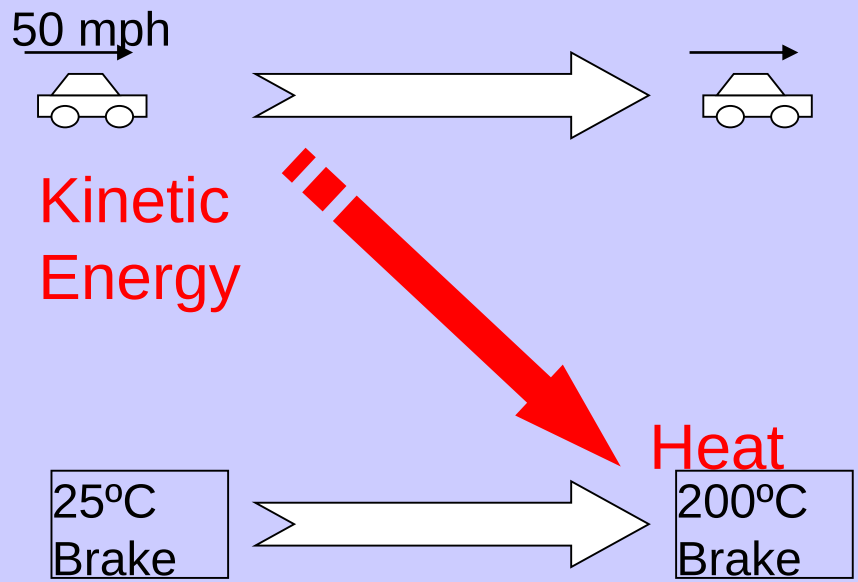
- Cooling systems take the <u>heat energy</u> (a byproduct) away from the engine.

Energy is transformed into several forms

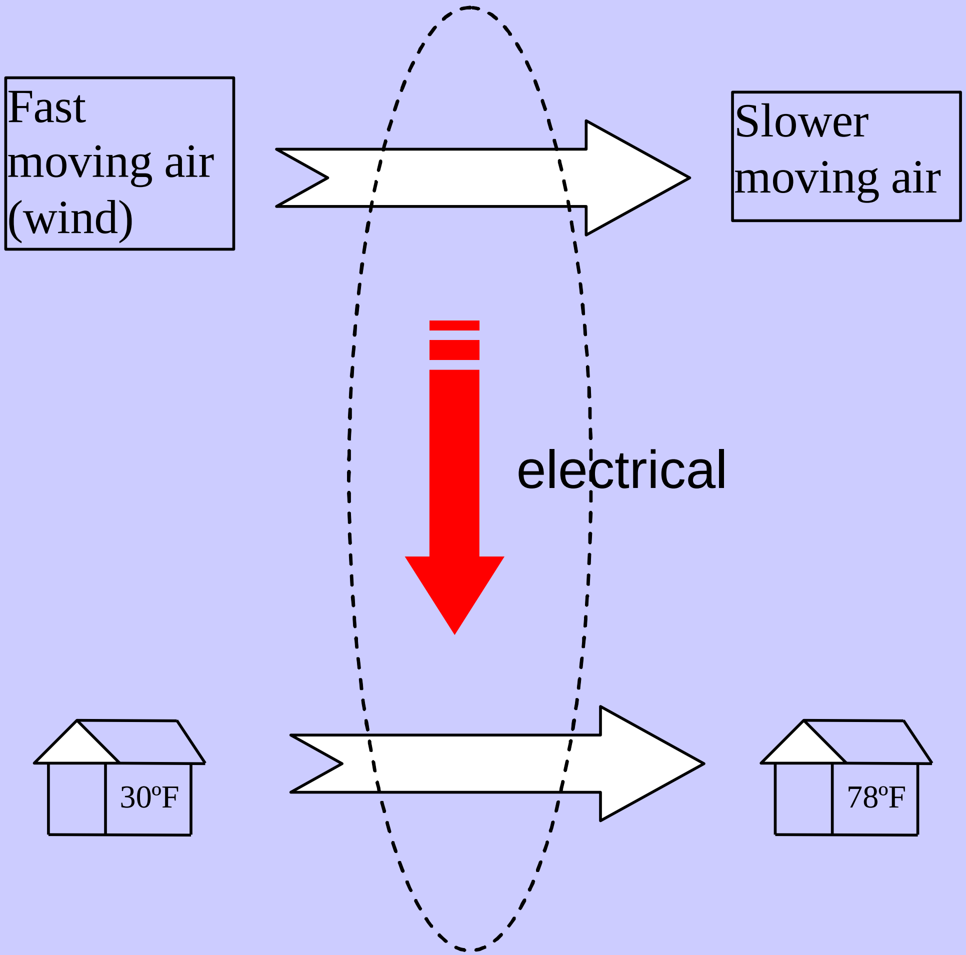
Mechanical energy is transformed to heat







Energy is converted into several forms using transformation machines



Can energy be destroyed?
No!

Conservation of Energy

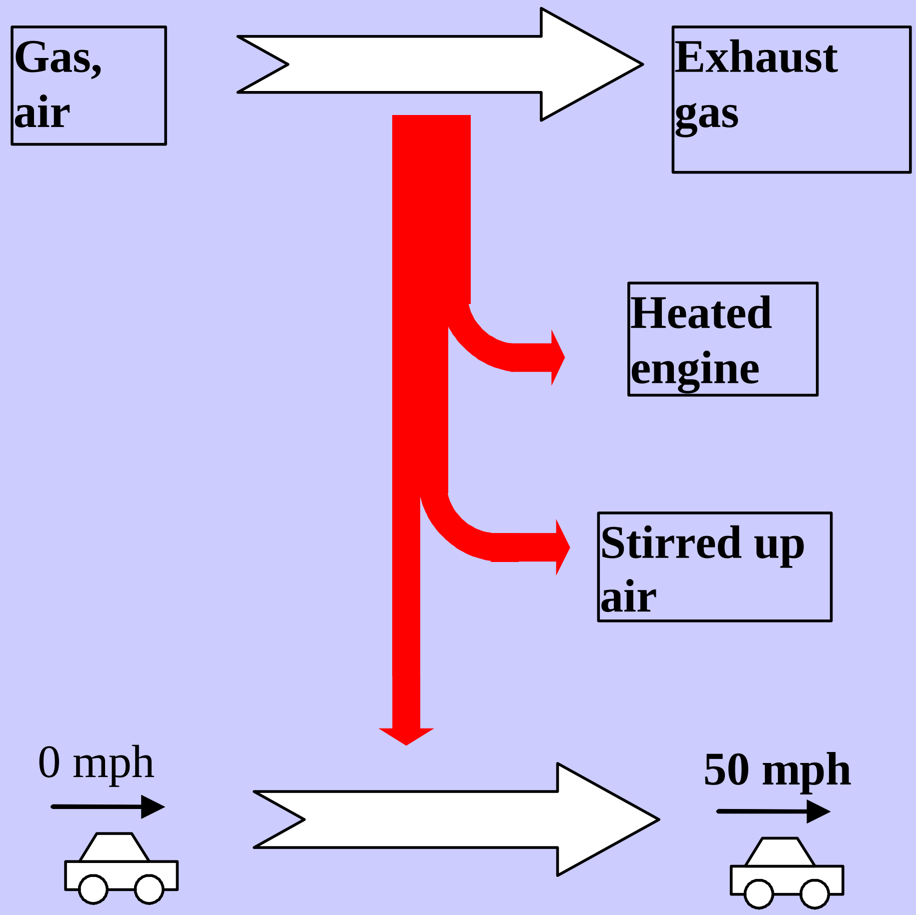
Energy never vanishes.
Energy only changes into different forms.

Efficiency

$$= \frac{\text{Desired Energy Out}}{\text{Energy In}}$$

In this case:

$$= \frac{\text{Kinetic energy of the car}}{\text{Total energy released from gas combustion}}$$



How difficult is it to convert energy from one form to another (a more useful) form?

Very Easy:

Burning wood, coal, fossil fuel, potential energy stored in the water in a reservoir, nuclear reaction, energy stored in a battery, etc.

Not difficult but higher cost:

Solar, wind (kinetic energy of the air mass), ocean current (kinetic energy of water).

Impossible to transform <u>efficiently</u> to a 'useful' form:

Energy in the exhaust gas from a car engine.

Energy in the warm ocean water in a tropical region.

Key Concept

We see work being done (for example, a car is accelerated by the engine), but we don't always realize this is a process of energy transformation (from energy in the fuel to the car's kinetic energy).

vroom . . .

Key Concepts

- Energy is added or released to change the physical state of an “object”.
- Energy cannot be ‘created’ or ‘destroyed’.
- Efficiency is the ratio of the part of output energy that is beneficial to us and the total input energy
- We build machines to ‘manage’ energy conversion.
- While energy cannot be destroyed, once it is transformed into a certain form (heat, often the case), it is basically difficult to use (some say “lost” but we cannot actually lose energy).

Energy Transformation

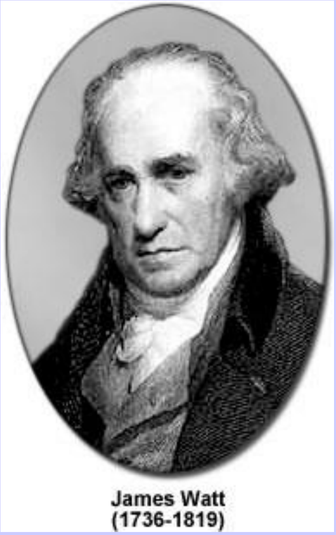
Phet Interactive Simulations, University of Colorado

What is **power**?

It takes <u>time</u> to transform energy from one form to another (i.e., to do work)!

Power is a measure of **how fast** energy is converted.

Power = work done / time taken



www.magnet.fsu.edu/education/tutorials/pioneers/watt.html

A unit of power in metric system is the WATT.

1 watt = 1 joule/second

Power

Mechanical Power

Power produced by motion

Hydraulic Power

Pneumatic Power

Thermal Power

Electrical Power

Electric power is the **rate** at which electrical energy is transferred by an electric circuit. It's a product of voltage and current (P=V x I)

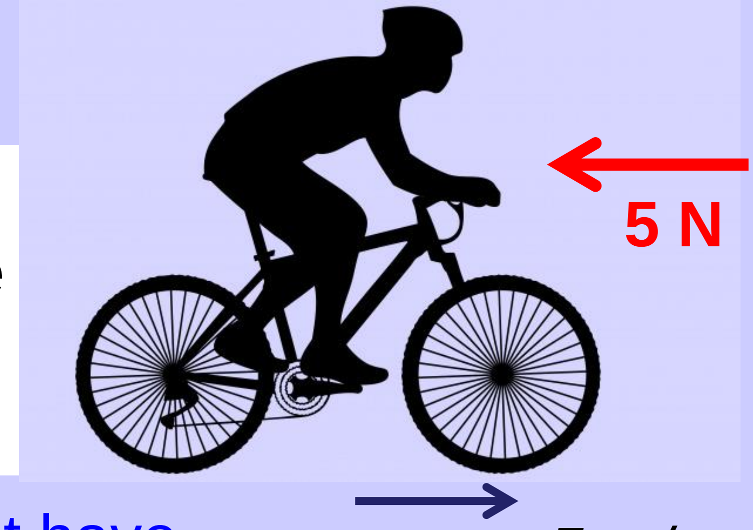
Back to Earlier Question

Which of the following heaters can heat up a gallon of water to 90^{o} C?

(A) 5 W heater
(B) 90 W heater
(C) 100 W heater
(D) All of the above

Mechanical Power - Example

A cyclist is travelling at a constant speed of about 5 m/s (18 km/hr). The retarding forces (resisting motion) acting on the cyclist are about 5 N.



How much <u>energy</u> does the cyclist have to provide to travel 15 m?

Work = ΔEnergy = force x distance moved
= 5 N x 15 m = 75 N-m = 75 J

Calculate the <u>power</u> of the cyclist.

It takes the cyclist 3 seconds to travel 15 m
Power = energy transferred/ time taken = 75 J/ 3 s= 25 watt

Power = force x distance/time → **P = force x velocity**
= 5 N x 5 m/s = 25 watt

Define the term ‘**gps**’ for water flow rate:

1 **gps** = 1 gallons per second

A 50-gallon barrel is filled to capacity in 10 seconds, <u>what is the flow rate </u>of the in-flow water (**in gps**)?

If you can do this problem, you understand the relationship between <u>Energy</u> and <u>Power</u>.

Example:

1500 J of energy per second carried by electricity

1500 J heat energy per second produced

This heater converts 1500 J of energy carried by electricity into heat energy **<u>per second</u>**.

This electric heater's power rating is 1500 J/s or <u>1500 watts</u>.

Equipment power consumption/generation (strictly speaking, energy transformation rate)

Equipment	Watts
iPod	0.3
Flash light	1
Compact fluorescent light bulb	10
Incandescent light bulb	100
Hair dryer	1000
Electric Range (with oven)	10000
Engine in a compact car	100000
A wind turbine with 30-meter blades in 12 m/s wind (power generation)	1000000

Power output of a 60 kg (132 lbs) person

	Speed (mph)	Output (watts)
at rest (0 mph)	0	70
walking (1~4 mph)	2	179
	3	233
	4	286
	5	610
running (5~15 mph)	10	1150
	15	1690

Where does the energy go?

- Kinetic energy in the speed of the body. (a small fraction)
- Overcoming air resistance. (a small fraction)
- Operating body's biological function e.g., breathing, heart pumping blood, maintaining body temperature, etc. (lots)

Other Units of Power

<u>HorsePower (HP)</u> **1HP = 746 watts**

(Used mostly for mechanical systems)

<u>kiloWatt (kW)</u> **1kW = 1000 watts**

<u>BTU per Hour (BTUH)</u> **1BTU/h = 0.3 watts**

(Used mostly for thermal systems)

Back to Energy - Example

kilowatt-hour (kWh) is a unit of energy.

Since 1 W=1 joule/second

1 kWh=1000 (J/s) * 3600 (s) = $3.6*10^6$ joules

Your monthly energy consumption is measured in kWh. You pay about 25 cents for 1 kWh of energy these days.

More on Energy vs. Power

Information about a certain amount of energy (J) **does not** involve a sense of time.

(Analogy: 100 gallon of water)

Power (J/s=W), on the other hand, tells how fast the energy being converted or how fast the work can be done.

(Analogy: 2 gallon/sec)

More on Energy vs. Power

Energy conversion machines (car engine, hair dryer, microwave oven, light bulb etc.) are rated by how fast they can transform energy (i.e., how fast they do work).

Therefore, they are rated by Watt (J/S).

Which of the following heaters can heat up a gallon of water from 10^oC to 90^oC faster?

(A) 5 W heater
(B) 90 W heater
(C) 100 W heater
(D) All heaters above will take the same amount of time.

Analogy

1500 gallons per minute

This pump is rated 1500 gpm

1500 gallons per minute

Analogy:

Gallon is like ???

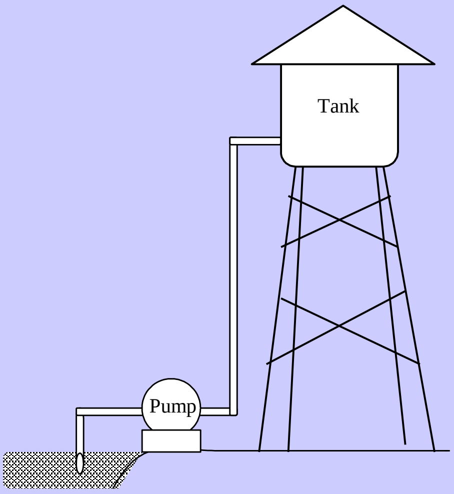
Gallons per minute is like ????

Both your and your neighbor's basement are flooded. You have a 5 HP gasoline power pump and your neighbor a 10 HP pump. You each have only 1 gallon of gasoline.

If both pumps have the same efficiency, which one can pump more water out of the basement with the 1 gallon of gasoline?

(A) You
(B) Your neighbor
(C) Same
(D) Insufficient information.

Another Analogy



It makes sense to say:

- The tank contains 500 gallons of water.
- The pump is pumping 10 gallons per minute.

It does not make sense to say:

- The tank contains 10 gallon per minute of water.
- The pump is pumping 500 gallons.

Polling Question

Which equipment's energy bill is the highest per month?

(A) a 5 W nightlight
(B) a 50 W soldering iron
(C) a 100 W light bulb
(D) a 1000 W heater
(E) Insufficient information

Summary

Energy is what it takes to change the physical state of an “object”.

Power is a measure of **how fast** energy is converted.