Energy Transformations

Rube Goldberg Machine

Clicker Question

A mixture of gases A and B is in thermal equilibrium. The molecules of B have four times the mass of those of A. What is the typical speed of the molecules of type B, compared to that of the A-type molecules?

A. Four times larger.
B. Twice as large.
C. The same.
D. Half as large.
E. One quarter as large.

Average kinetic energy of an atom:

$KE = 3/2\ k\ T$

T = absolute temperature

k = a proportionality constant

$KE = ½\ m\ v^2$

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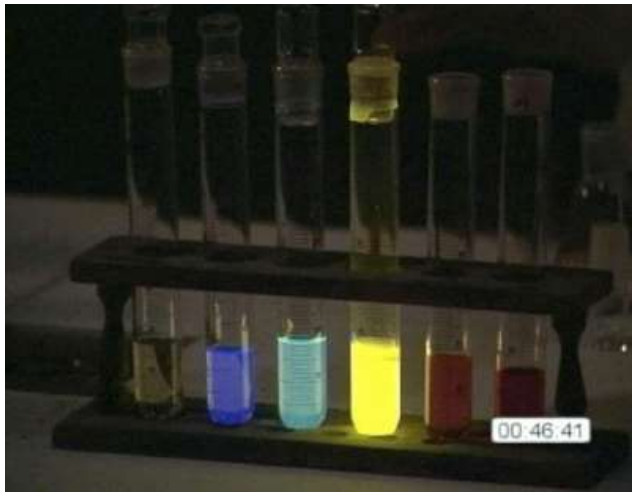
Energy Transformations

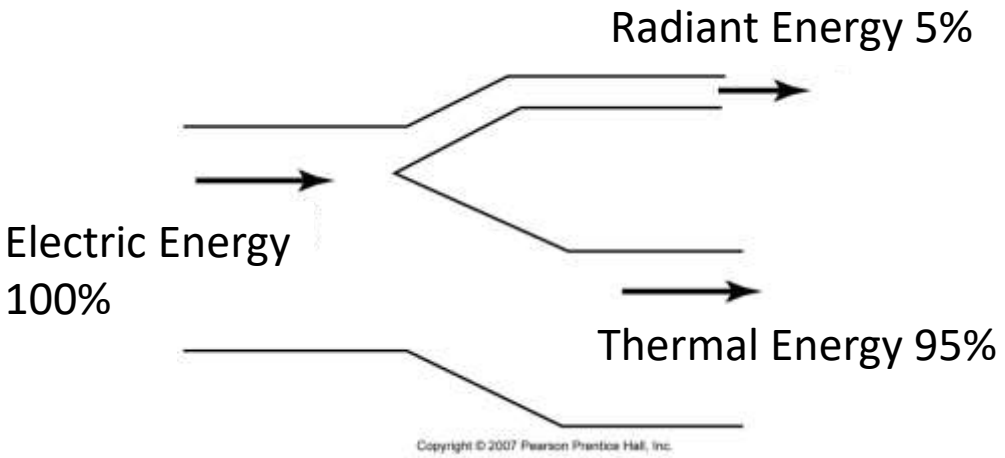
- Electric motor
- Electric generator
- Rising bubbles
- Elliptical orbits
- Trampoline
- Rub hands
- Burning candle
- Photosynthesis
- Solar panels
- Chemiluminescence



Efficiency

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

Incandescent
Light Bulb



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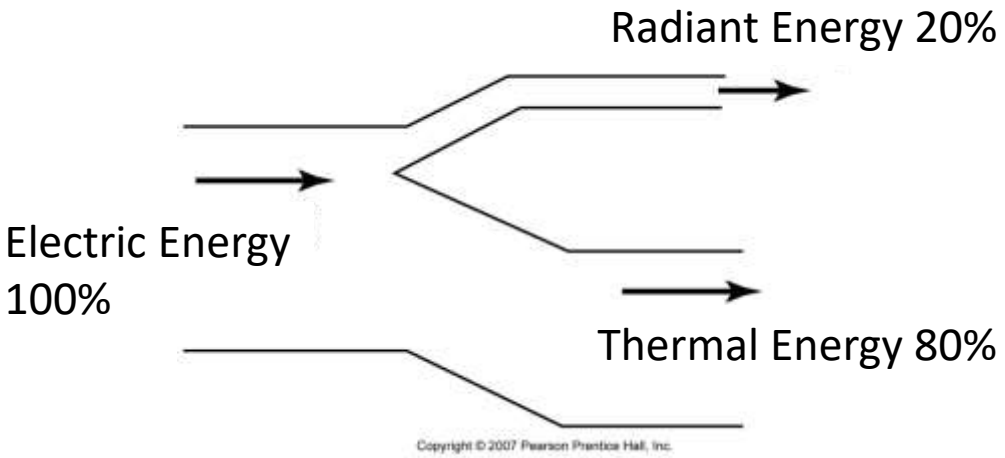
Compact Fluorescent Light Bulb



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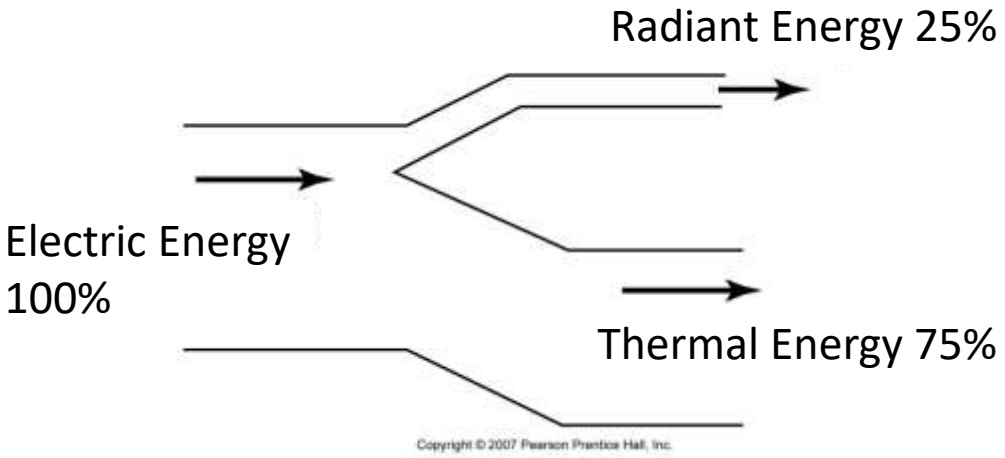
LED
Light Bulb



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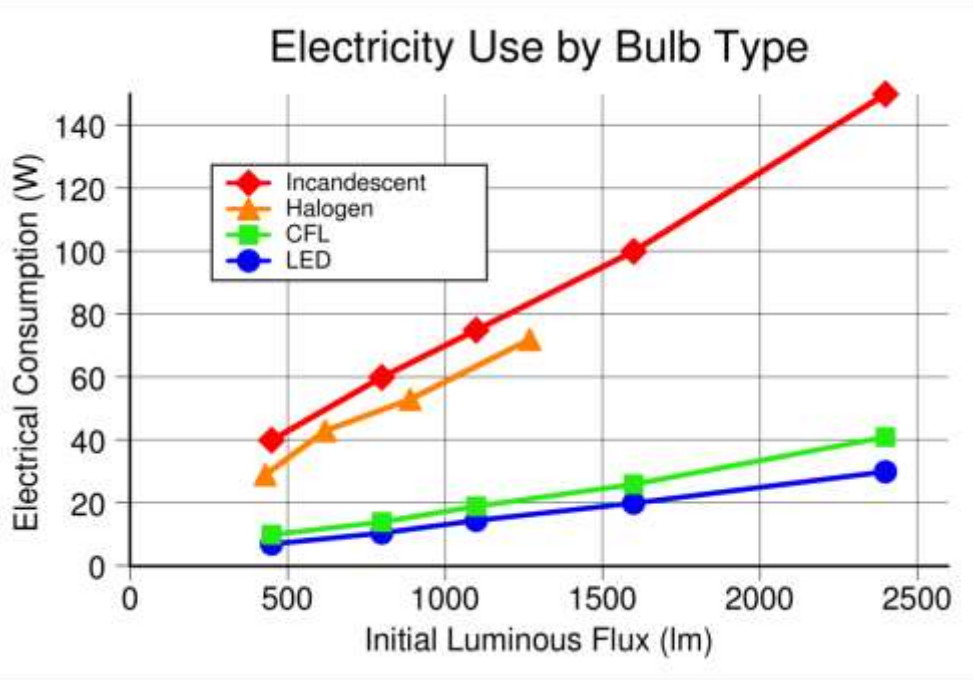

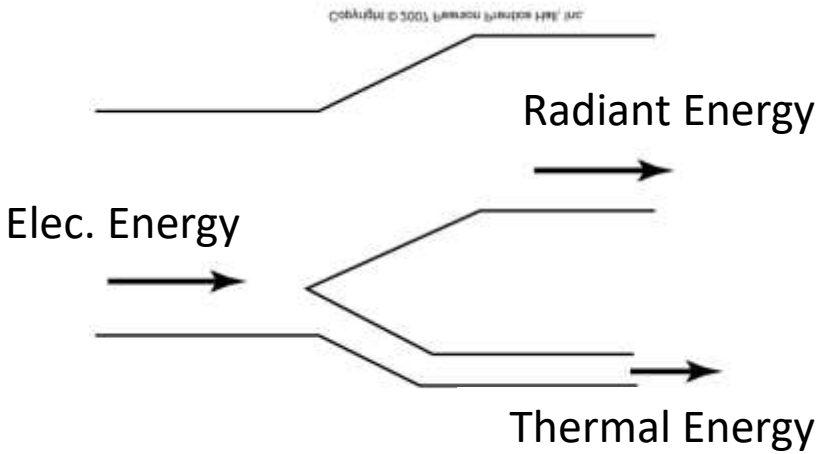

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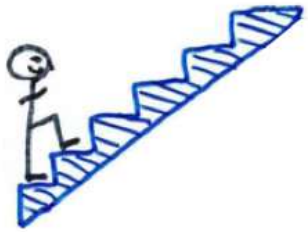
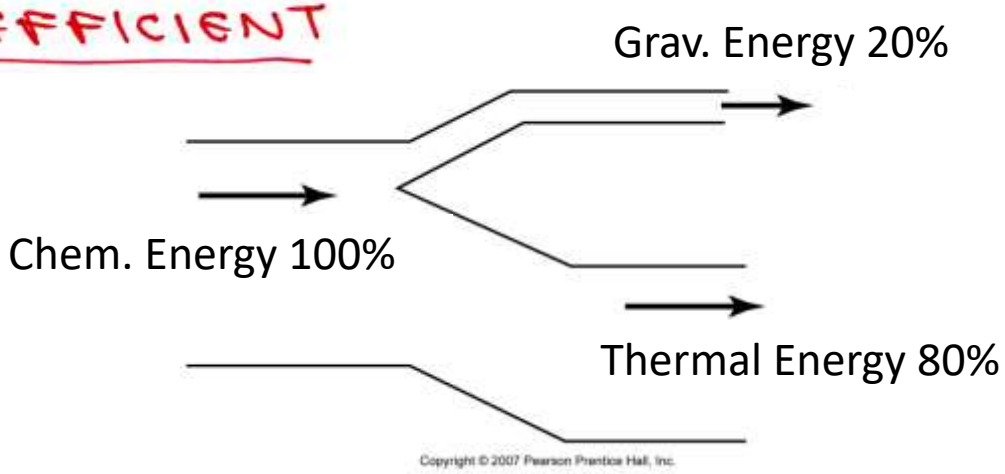
BODY IS 20% EFFICIENT





Clicker Question

A particular automobile operates at an efficiency of 10%. Suppose that 20 gallons of gasoline are put into the auto's tank. Of this 20 gallons, how much will be "wasted" in ways that don't help get the car down the road?

A. 2 gallons
B. 10 gallons
C. 18 gallons
D. 19 gallons
E. 20 gallons

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If you walk up a flight of stairs, you have turned chemical energy (in your body) to gravitational energy.

What if you run up the stairs? The energy converted is the same, but now you are out of breath.

Why?

Power

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

Power = rate at which energy is transformed

Units: 1 joule per second = 1 J/s = 1 W = 1 watt

Table 6.1

Power consumption of household appliances while the appliance is turned on and consuming electric energy

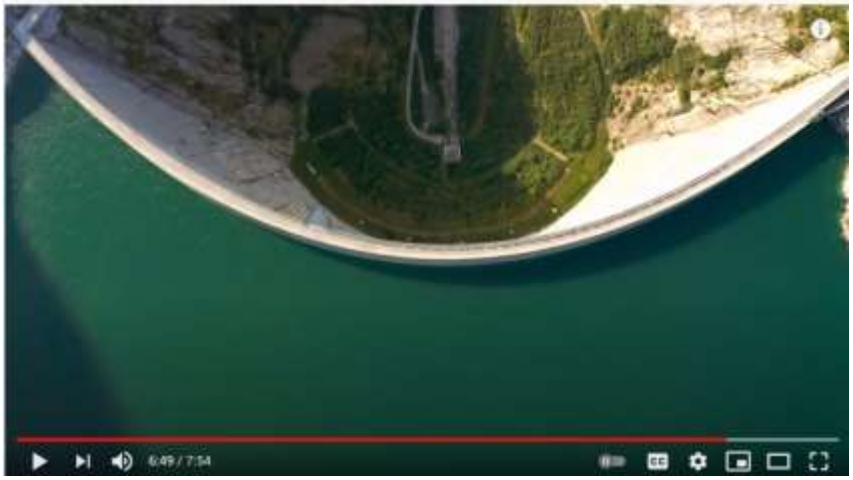
Appliance	Power (W)
Cooking range	12,000
Clothes dryer	5,000
Water heater	4,500
Air conditioner, window	1,600
Microwave oven	1,400
Dishwasher (incl. hot water)	1,200
Toaster	1,200
Hair dryer	1,000
Refrigerator, frostless	600
Refrigerator, not frostless	300
TV, color	350
Stereo set	100

Another energy unit:

1 kilowatt-hour = 1000 J/s x 3600 s = 3.6×10^6 J

Inside a Hydroelectric Power Generating Station

Kolnbrein Dam, Austria



Video

Clicker Question

A low-power source of energy could put out a lot of work provided it

A. operated for a short time.
B. exerted a sufficiently strong force.
C. exerted its power over a short enough distance.
D. operated for a long time.
E. Nonsense – there is no way that a low-power source can do a large amount of work.

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Clicker Question

A gas can with a gallon of gasoline in it contains

A. Energy
B. Work
C. Power
D. Kilowatts
E. Joules/second

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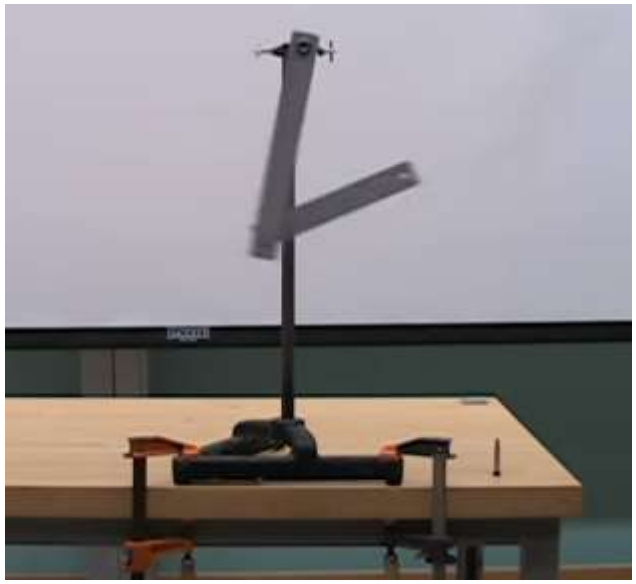
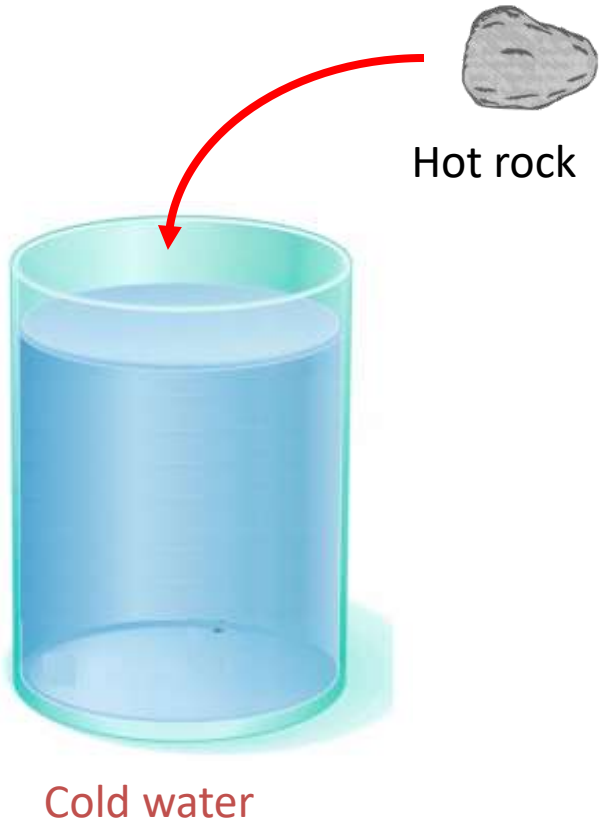
Euler's disk video

Double pendulum



Temperature and Heat



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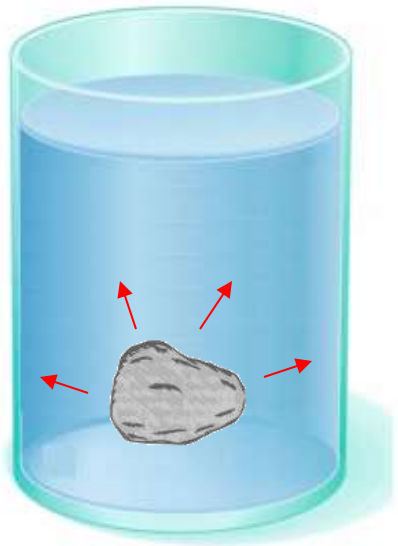


Cold water

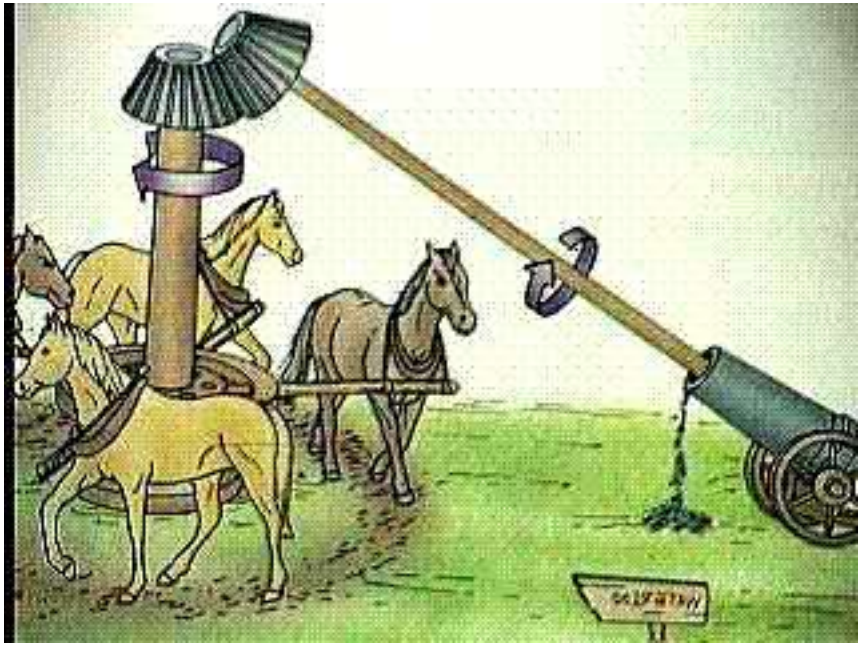
Caloric theory

Heat consists of a fluid (or gas) called caloric that flows from hotter to colder bodies.

Caloric is weightless and can pass in and out of pores in solids and liquids.

Evidence against caloric theory

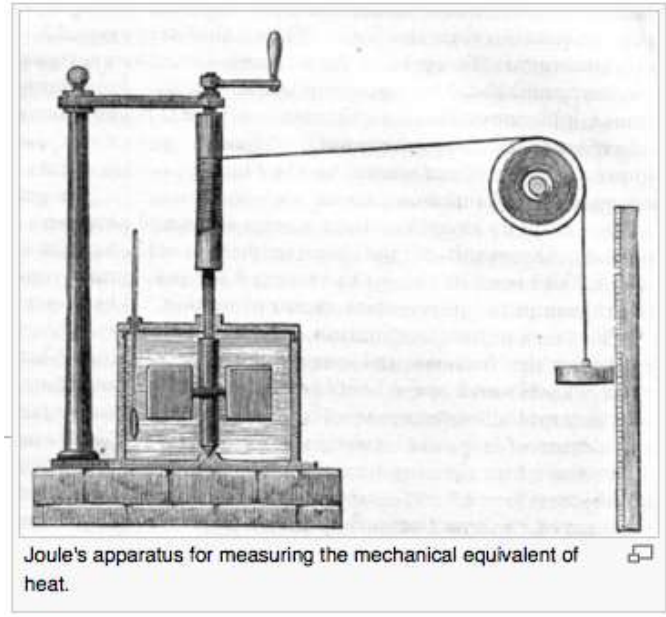
Count Rumsford
(Benjamin Thompson)
(American!)
1798



Heat generated during boring of a canon seems to be inexhaustible

Evidence against caloric theory

James Joule
(English)
circa 1850

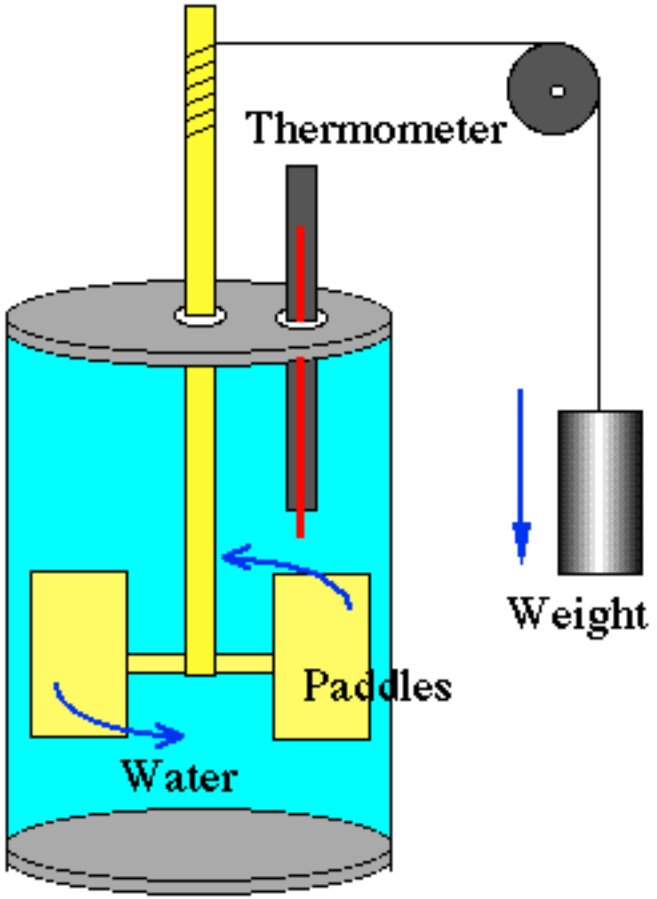


Joule's apparatus for measuring the mechanical equivalent of heat.

Paddle wheel
experiment

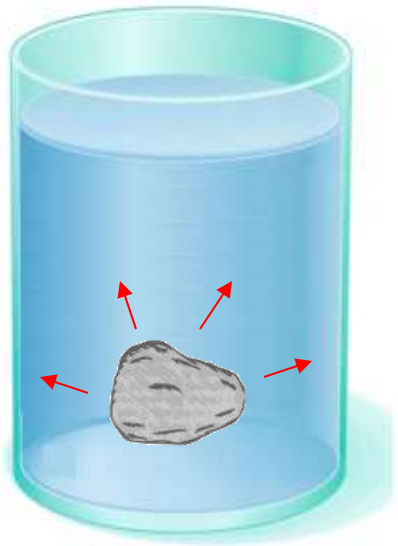
Mechanical equivalent of heat

The measured variables (mass, height, temperature) gave one of the first accurate measures of the mechanical equivalent of heat (motion and heat are interchangeable – work generates same amount of heat/energy).



Result: 1,000 cal = 1 kcal = 1 Calorie = 4,200 J

Temperature and heat



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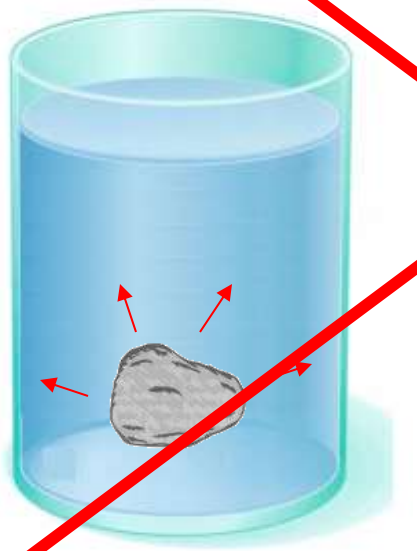

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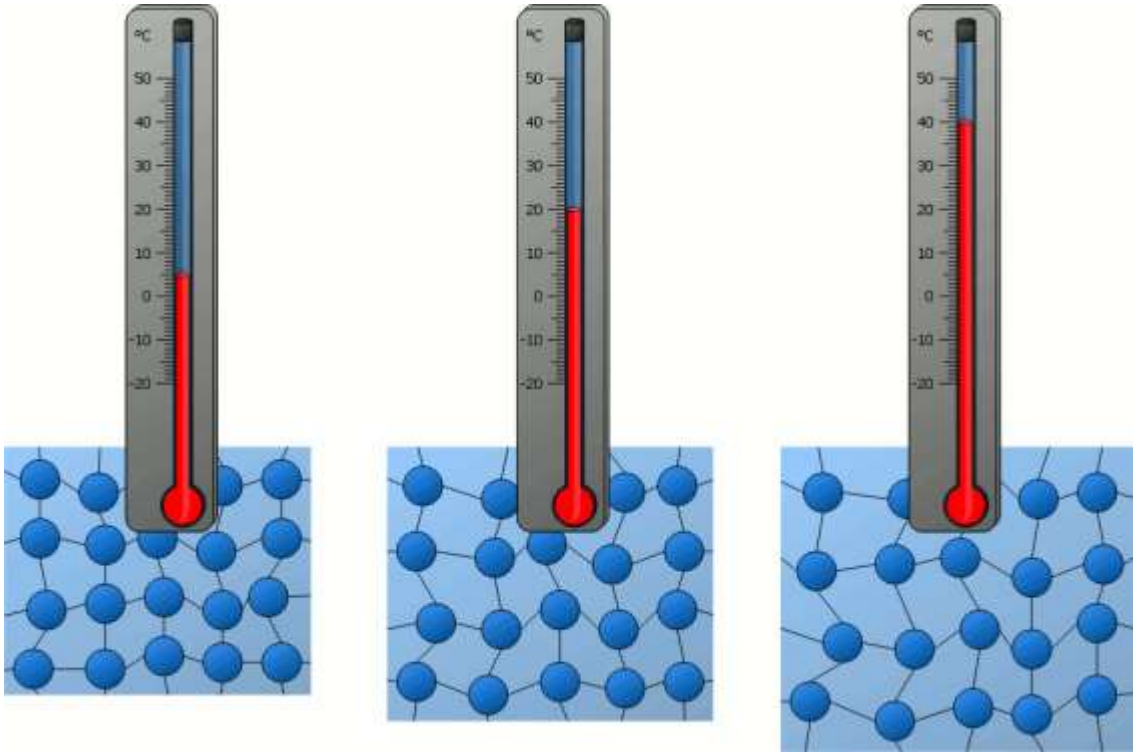
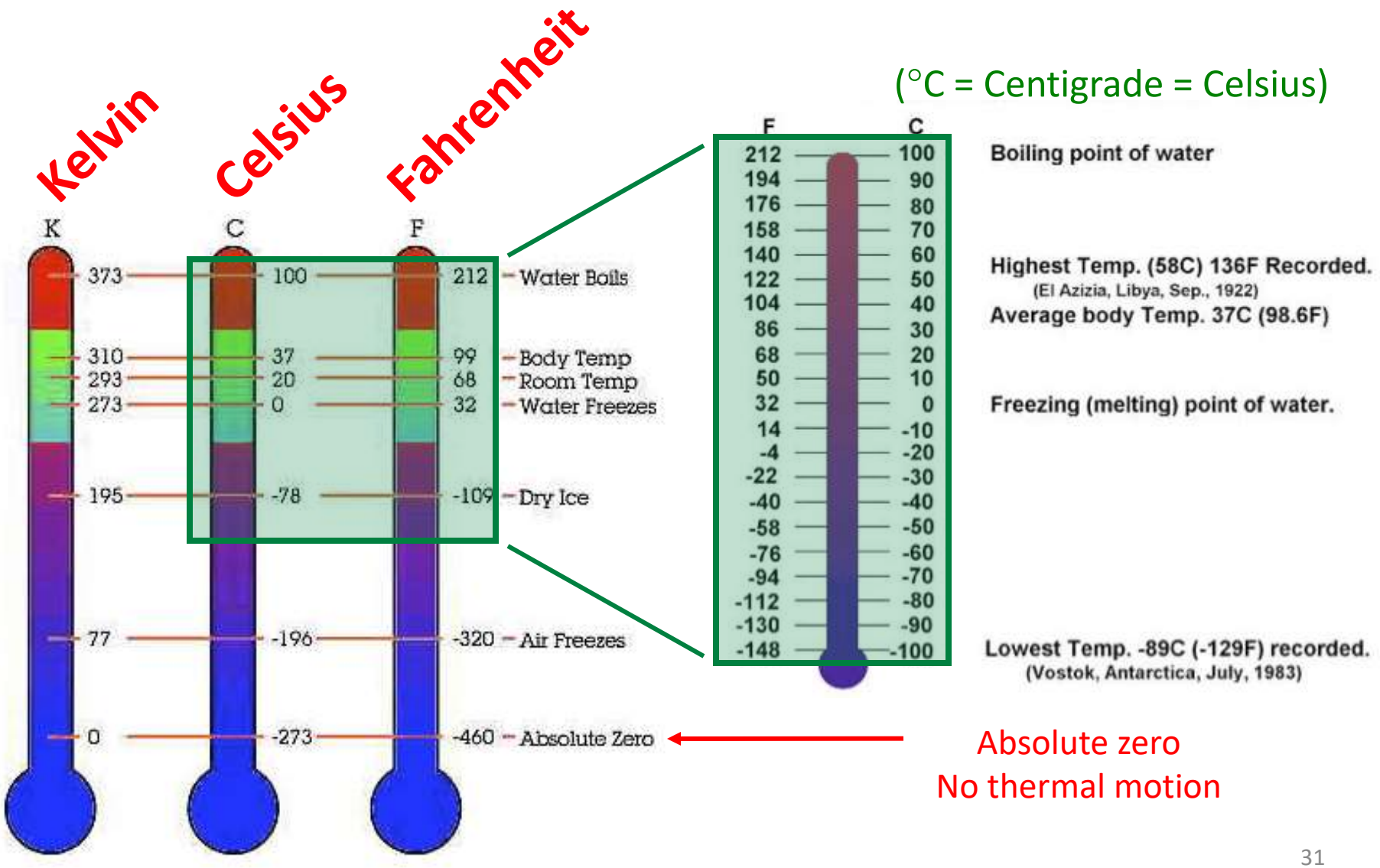
Mechanical equivalent of heat

- Thermal energy is nothing other than the **microscopic kinetic energy** of atoms and molecules
- Higher temperature is a higher degree of agitation of atoms and molecules
- “Absolute zero” would be zero motion of atoms and molecules → **Never happens.**

Temperature as thermal motion



Temperature scales



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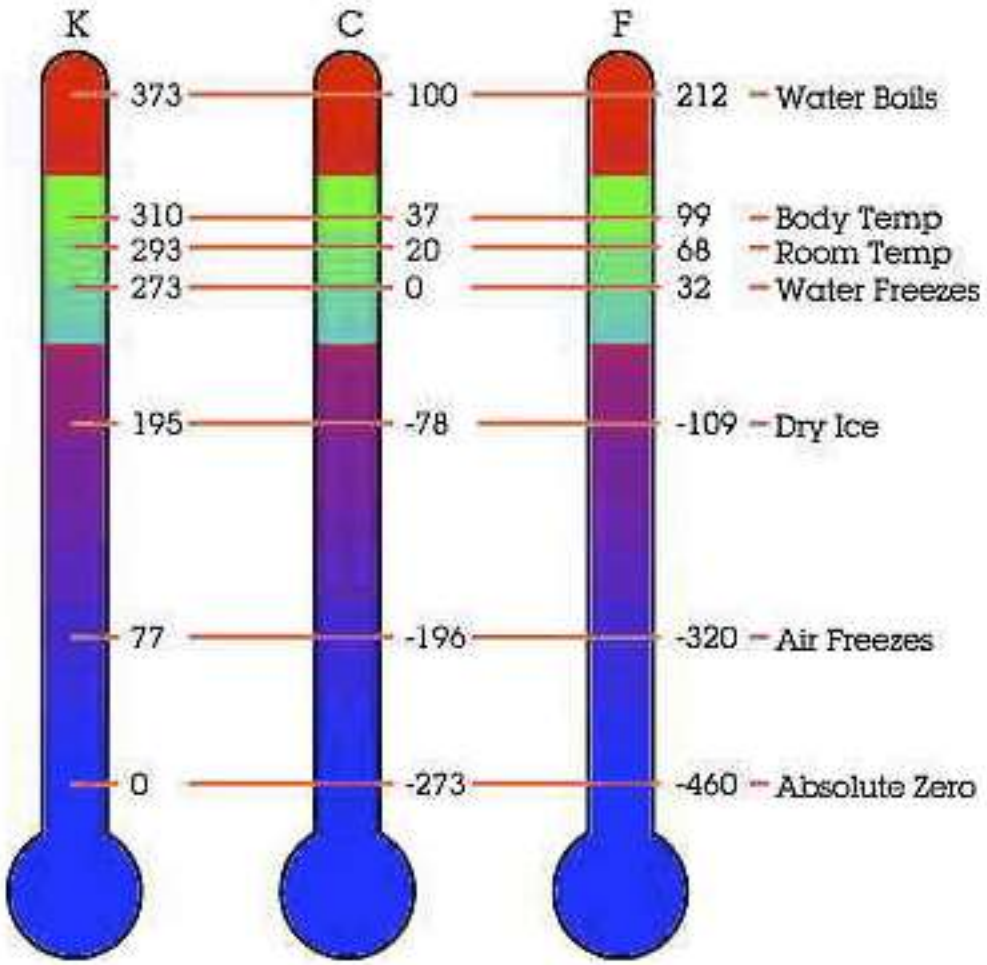
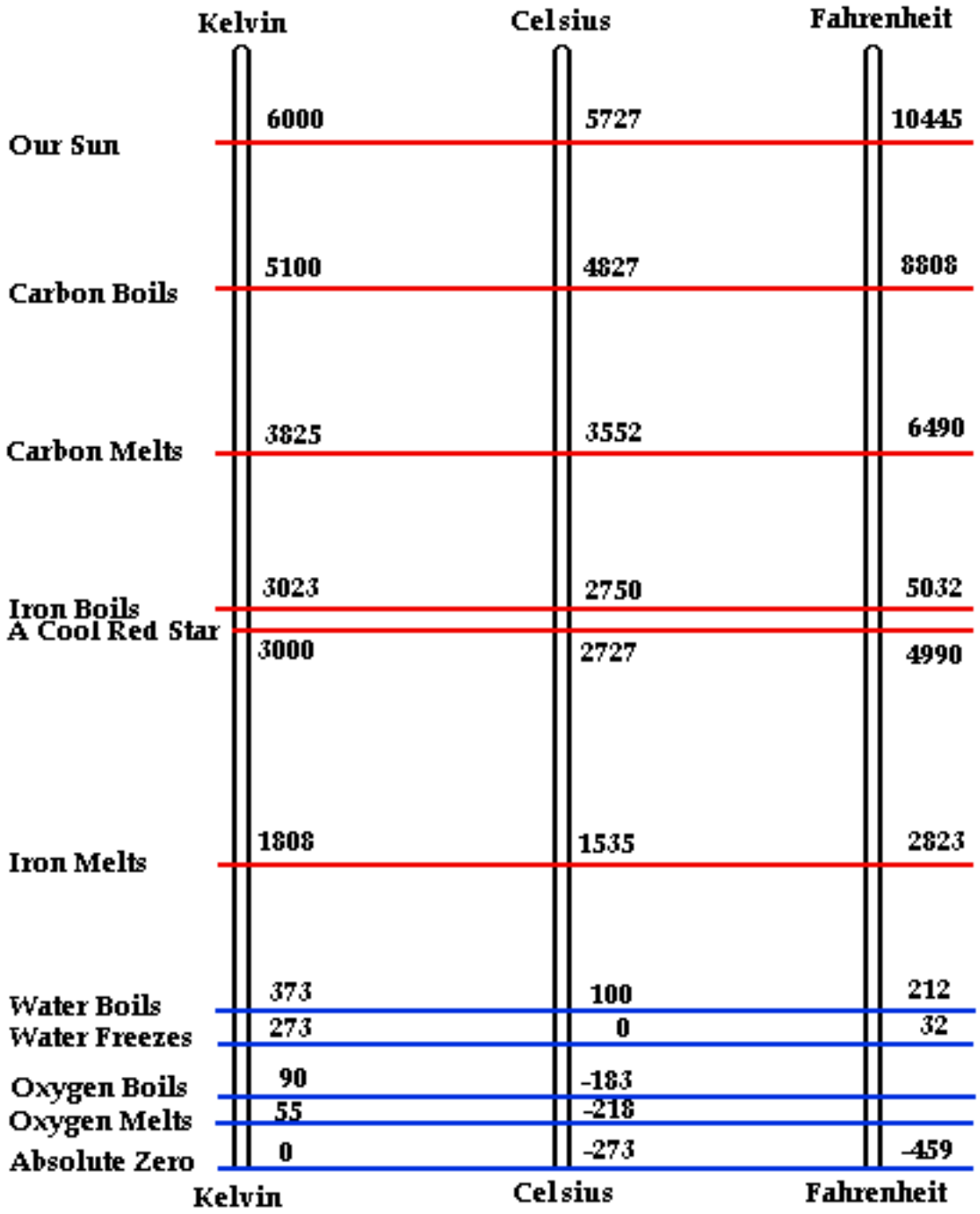


H_2O boiling point

CO_2 boiling point

N_2 boiling point

No thermal motion


Kelvin
Celsius
Fahrenheit
Our Sun
6000
5727
10445
Carbon Boils
5100
4827
8808
Carbon Melts
3825
3552
6490
Iron Boils
3023
2750
5032
A Cool Red Star
3000
2727
4990
Iron Melts
1808
1535
2823
Water Boils
373
100
212
Water Freezes
273
0
32
Oxygen Boils
90
-183
Oxygen Melts
55
-218
Absolute Zero
0
-273
-459
Kelvin
Celsius
Fahrenheit

Clicker Question

Thermal energy is actually

A. the presence of a fluid called “caloric”.
B. a completely new form of energy, unrelated to anything else in physics.
C. the energy of motion of atoms and molecules at a microscopic scale.
D. a form of momentum.
E. a manifestation of “the force”.

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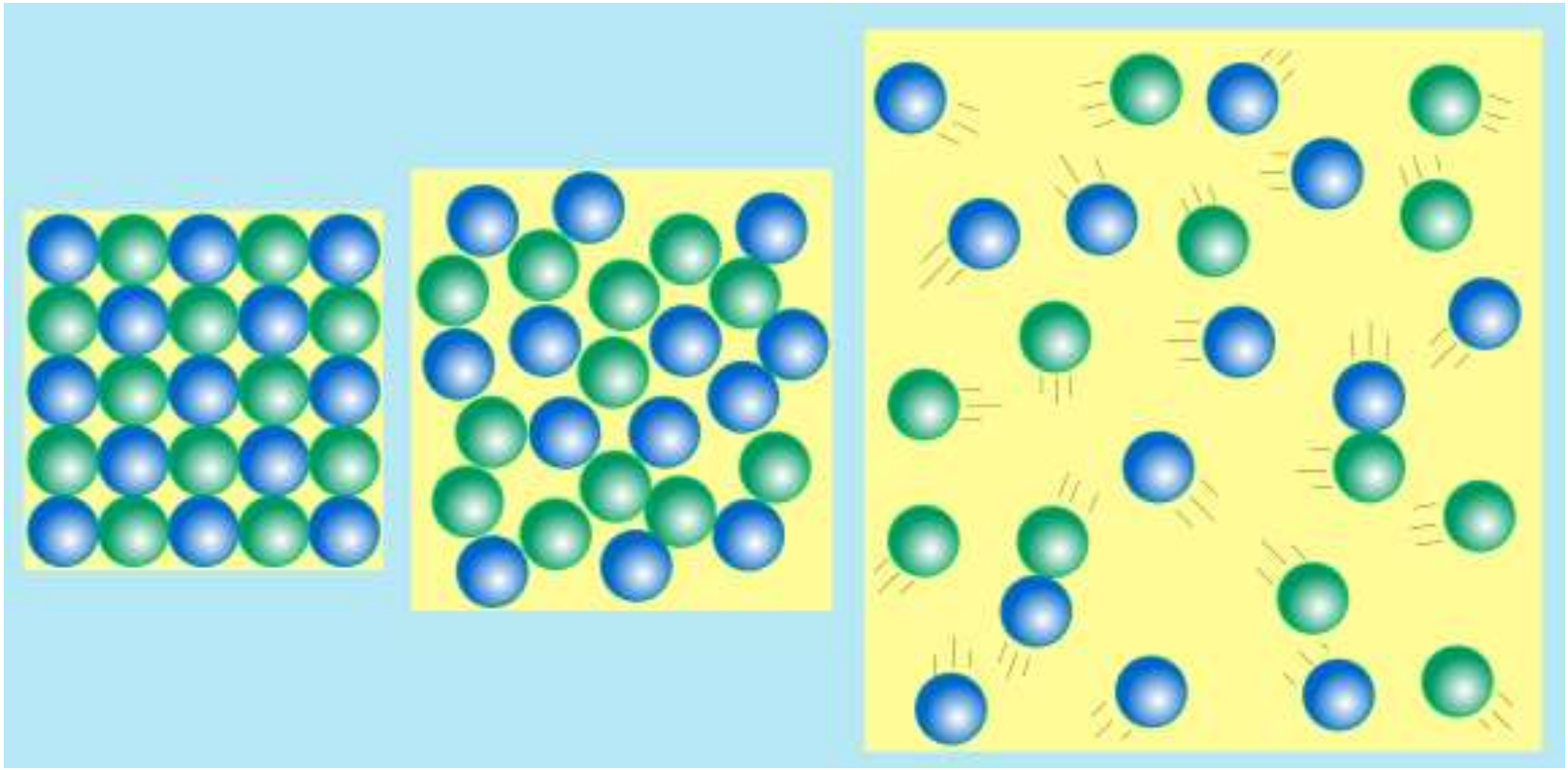
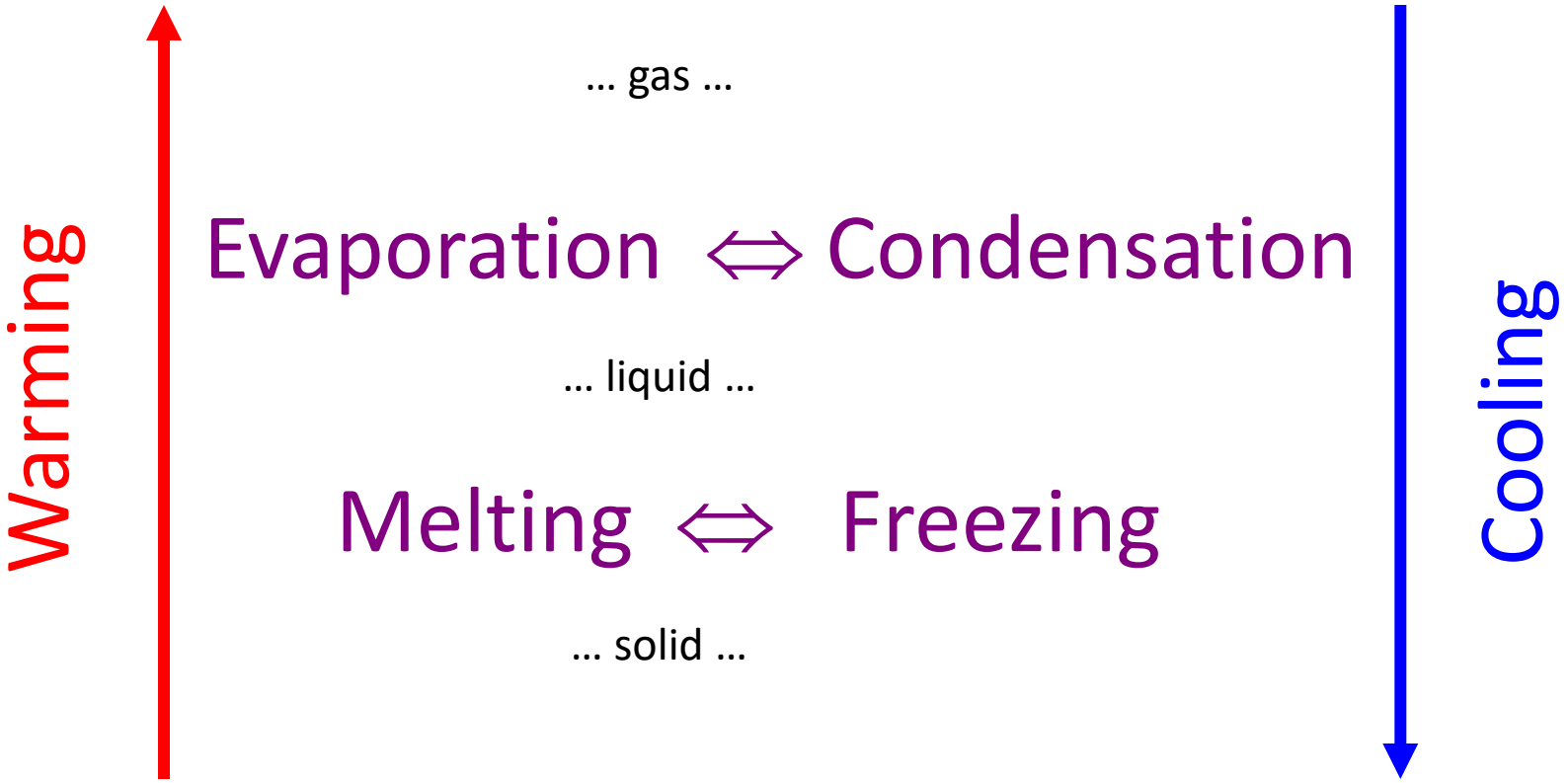
Phase changes



Solid Liquid Gas

Phase changes



Three materials properties

- Thermal expansion:

  Expansion or elongation as *T* is increased

- Thermal conductivity:

  Rate of transfer of heat through a material

- Specific heat:

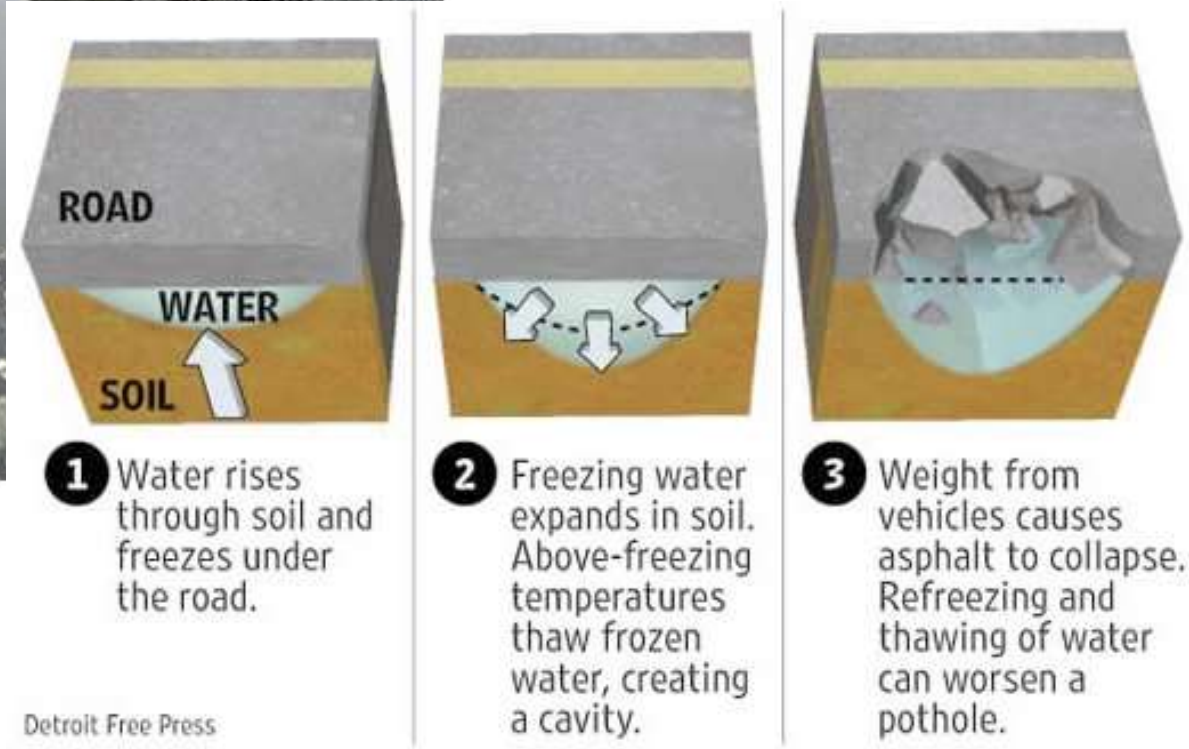
  Amount of energy needed to increase *T*

Thermal expansion

Expansion or elongation as *T* is increased

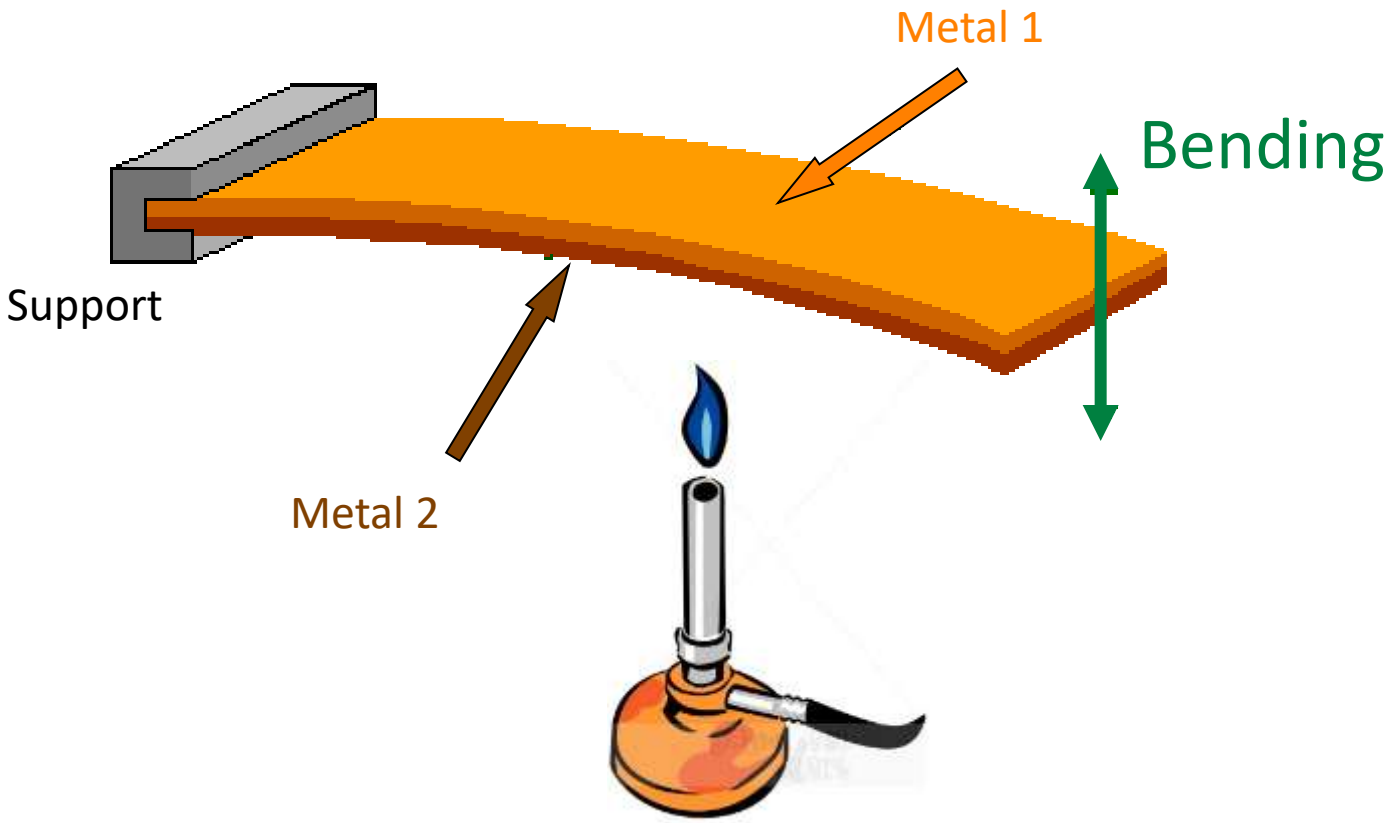
Expansion upon phase change: Pot Holes

Water expands when it freezes! Ice is *less dense* than the water from which it freezes.



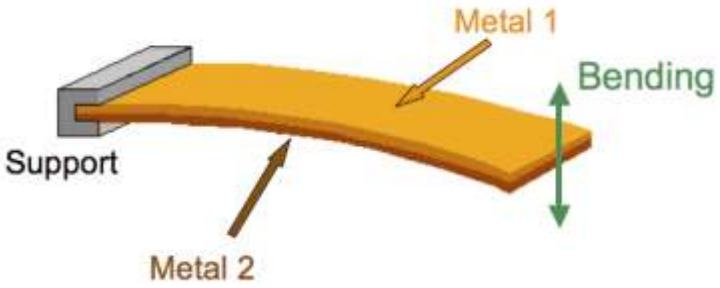
Thermal expansion

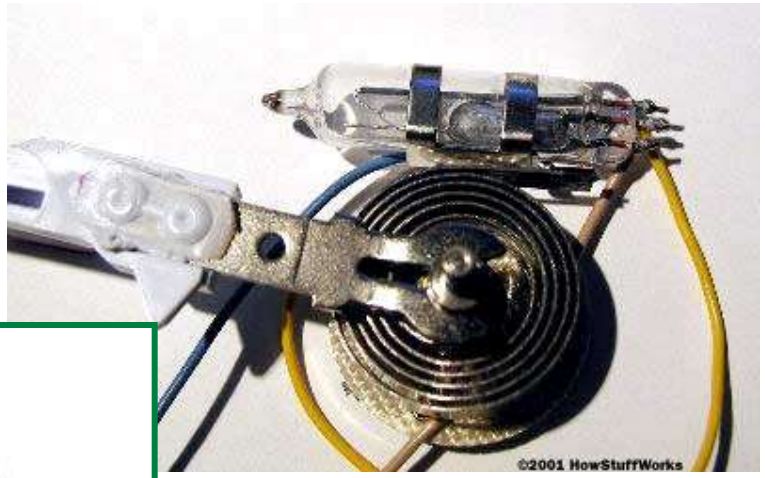
Bi-metallic strip

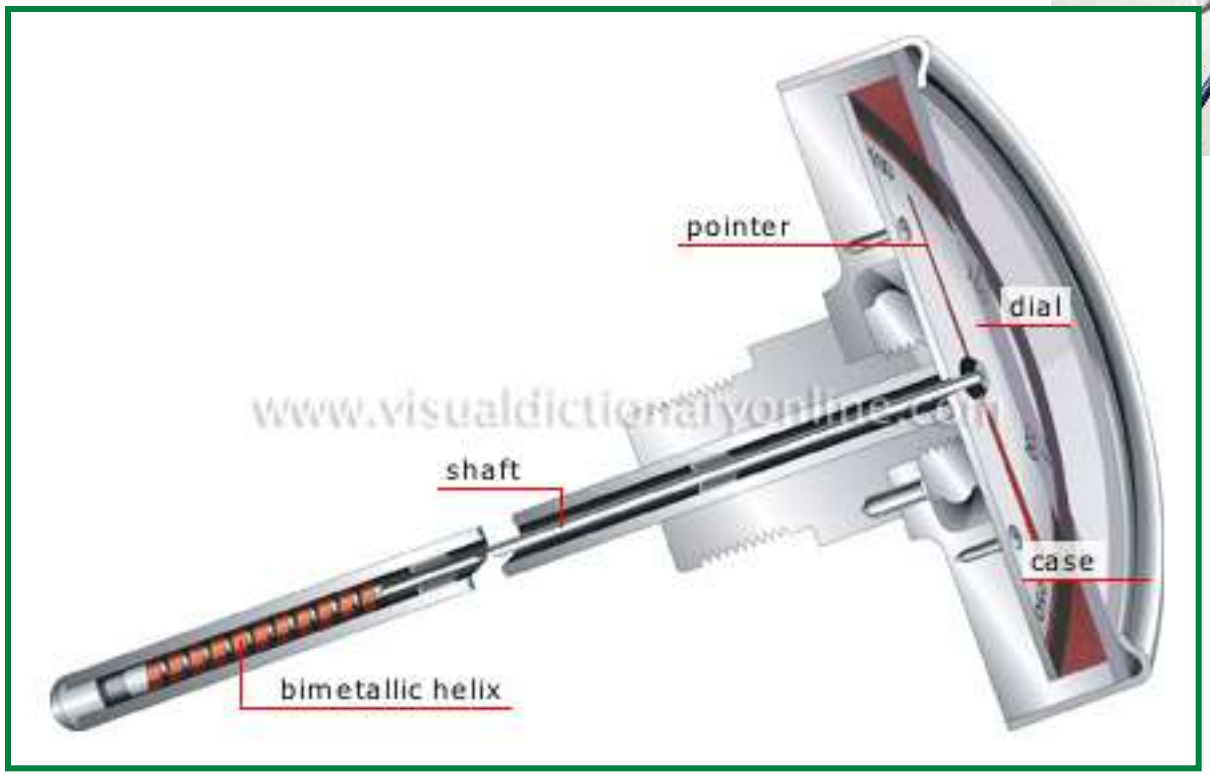


Video: Bi-metallic strip

Thermal expansion: bimetallic strip

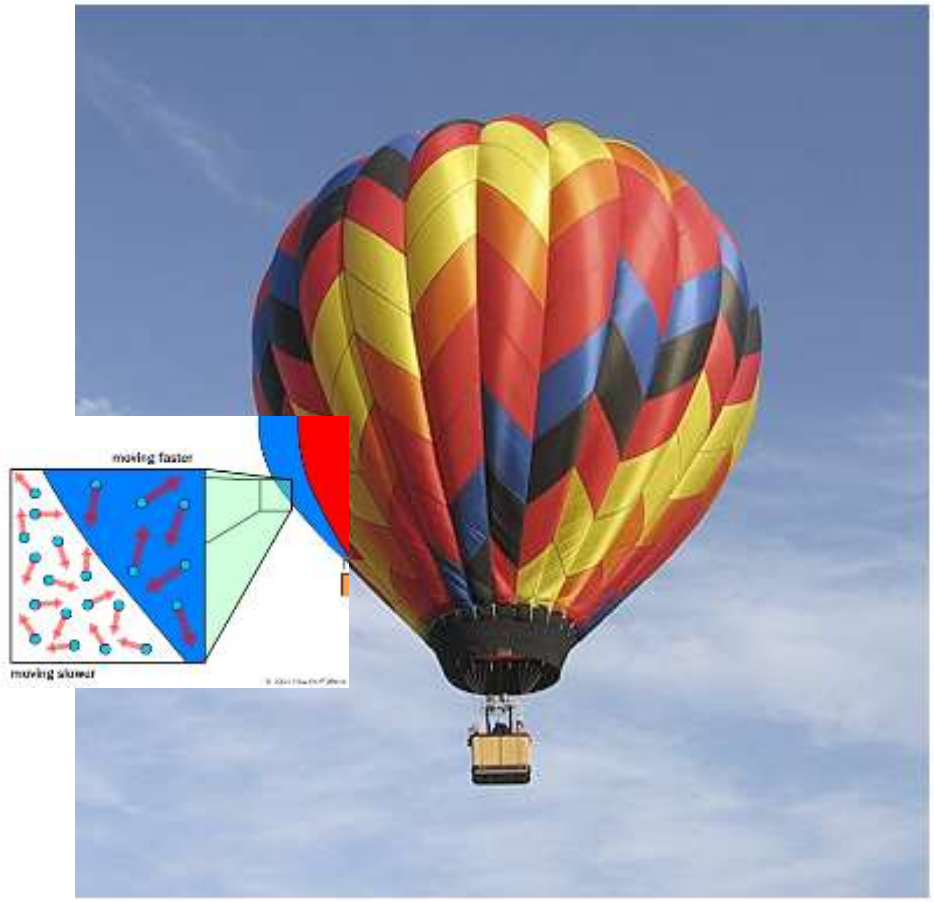






demos

Thermal Expansion of a Gas



Can a hot air balloon lift more on a hot day or a cold day?

Video: Cooling balloon

Thermal expansion of a liquid

Galileo thermometer

Kerosene vapor

Kerosene liquid

Temp. increases
⇓
Kerosene expands
⇓
Boyancy reduced
⇓
Swimmers fall

Clicker Question

We can tell a rod made of gold from a rod made of copper if we can measure its

A. thermal expansion coefficient
B. thermal conductivity
C. specific heat
D. density
E. all of the other answers

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