L 17 - Thermodynamics [2]

Science dealing with the relationship between thermal energy (random molecular motion) and work (organized motion), and the conversion of one into the other

Today's topics

- Practical thermal effects
- Devices for temperature measurement
- Mechanisms of heat transfer

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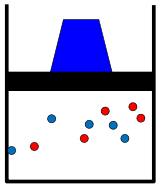
Thermal Energy and Work Energy



- The random motion of the atoms is thermal energy
- The upward motion of the piston is work energy

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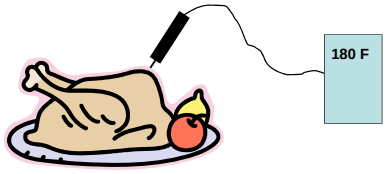
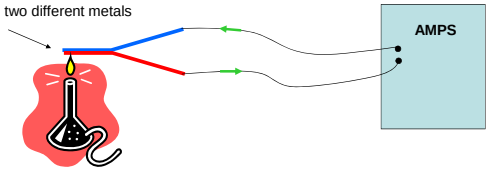
Thermocouples





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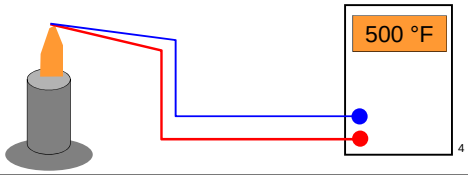
Thermocouples- measure Temp.

- Is composed of 2 wires of different metals welded together
- when the tip gets hot an electrical current is produced
- The current is proportional to the temperature
- It can be used over a wide range of temperatures



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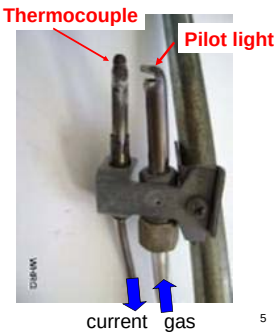
Thermocouples used as safety devices

- a thermocouple is used in gas heaters, dryers, and fireplaces to protect against explosions
- a thermocouple is placed in the pilot light
- as long as the pilot light is on, the thermocouple is hot and current flows
- a circuit detects the current and allows the main gas valve to open
- if the pilot light is out, the circuit prevents the main gas valve from opening



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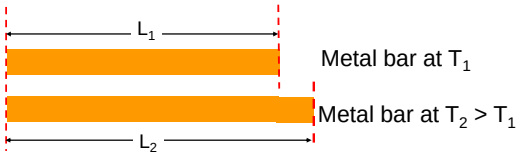
Thermal Expansion



- The length of a bar of metal increases when it is heated
- Actually, all dimensions expand by the same percentage
- Expansion must be taken into account when designing roads and bridges in climates that vary significantly from winter to summer – **all** materials expand, steel, concrete, asphalt . . .

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Thermal Expansion

- Most substances expand when heated
- We use a parameter, α called the coefficient of thermal expansion to quantify this effect
- The length of a metal bar increases from L_0 to L ($\Delta L = L - L_0$), when it is heated from T_1 to T_2 ($\Delta T = T_2 - T_1$)
- Change in length = $\Delta L = \alpha L_0 \Delta T$
- For copper, $\alpha = 17 \times 10^{-6}$ per deg. C
- Change ΔL = (17×10^{-6} per C)(1 m)(100 C-22 C) = 0.0013 m = 1.3 mm

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Coefficients of linear expansion

SUBSTANCE	α (per deg C)
aluminum	23×10^{-6}
brass	19×10^{-6}
glass	9×10^{-6}
rubber	80×10^{-6}
Ice	51×10^{-6}
lead	29×10^{-6}
steel	11×10^{-6}
concrete	10×10^{-6}

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winter/summer expansion gaps

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expansion gaps on bridges

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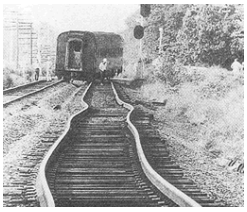
Thermal expansion problems



No room for thermal expansion result ➔ buckling

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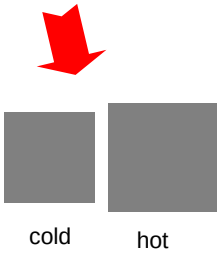
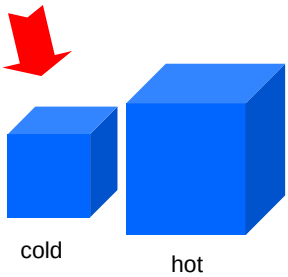
Areas and volumes expand too!





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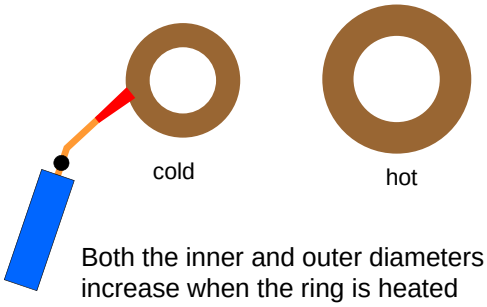
Does the whole get bigger or smaller when heated?



Both the inner and outer diameters increase when the ring is heated

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Hot water causes the lid to expand, making it easier to unscrew it.

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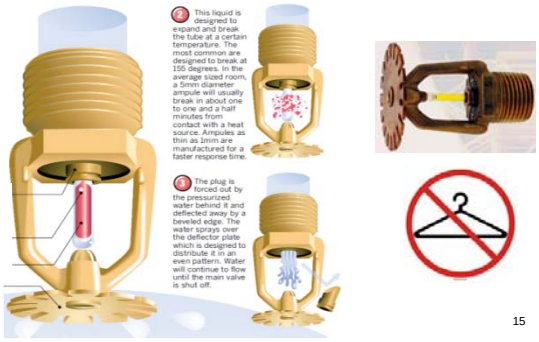
Fire sprinklers are triggered by thermal expansion of a liquid



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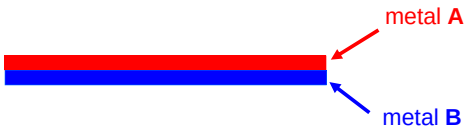
Bi-Metal strips

- thermal expansion of metals is put to good use in a bi-metallic strip.
- it is two strips of different metals bonded together



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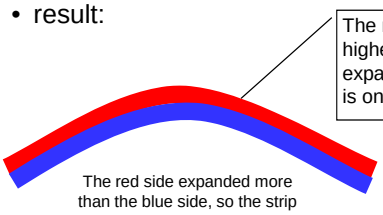
Heating a Bi-metal strip

- when heat is applied to the bi-metallic strip, both metals expand, but by *different* amounts!
- result:



The metal with the higher thermal expansion coefficient is on top

The red side expanded more than the blue side, so the strip bends toward the blue side.

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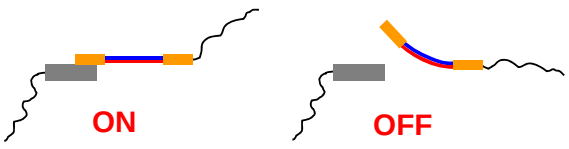
Bi-Metal strip thermal switch used to turn power off when a preset temperature is reached



Used in coffee makers and hair dryers

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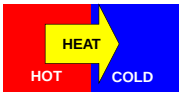
Heat Flow



- Heat is the energy that flows from one body to another because of their temperature difference
- There are 3 ways that heat can be transferred:
  - convection
  - conduction
  - radiation

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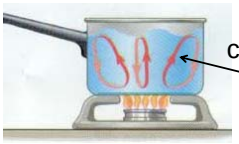
Heat transfer by Convection

- heat is transferred from one location to another by the bulk movement and subsequent mixing of liquids or gases (fluids), but NOT in solids.
- when water is boiled, hot water at the bottom rises and mixes with cooler water at the top
- Hot air rises:
  - in winter, want hot air in at lower level
  - in summer, cold air in at upper level



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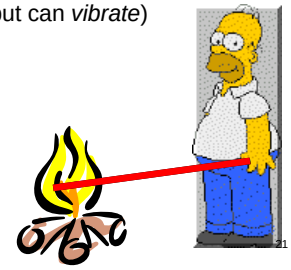
Heat transfer by conduction

- heat is transferred directly through a material, with no bulk movement of material
- only energy moves (molecules in a solid are not free to move, but can *vibrate*)

iron is a poor conductor of heat



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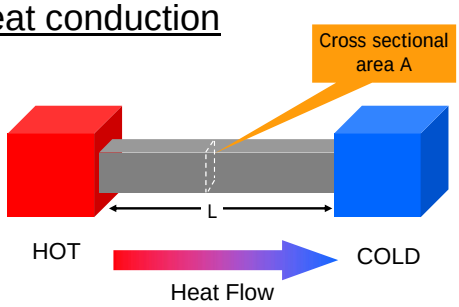
heat conduction



Heat Flow rate depends on A / L and a property unique to the material, called thermal conductivity

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Thermal Conductivity: a parameter that quantifies the ability of a material to conducting heat.

Material	Thermal conductivity	Metal	Thermal Conductivity
metals	14 - 400	Silver	406
wood	0.15	Copper	385
glass	0.8	Aluminum	205
wool	0.04	Brass	109
Goose down	0.025	Iron	80
Styrofoam	0.01	Steel /SS	50/14

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Heat transfer by Radiation

- The warmth you feel from the sun is the sun's thermal radiation
- It travels through the vacuum of space to reach earth, no material is necessary (takes 8 minutes)
- you can feel its effects even though you cannot see the radiation.
- you can feel the thermal radiation from a fireplace
- Objects not in contact with liquids gases or other solids loose heat by radiation

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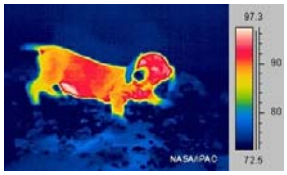
Thermal Radiation

- The amount of thermal radiation emitted by an object is proportional to its temperature raised to the fourth power $\sim T^4$
- Doubling the temperature will increase the amount of thermal radiation by $2^4 = 2 \times 2 \times 2 \times 2 = 16$



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