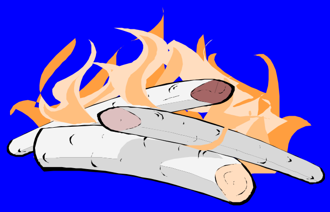
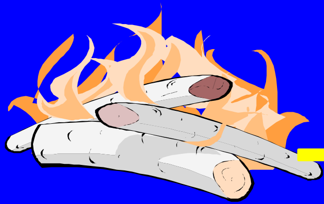


Chapter 5

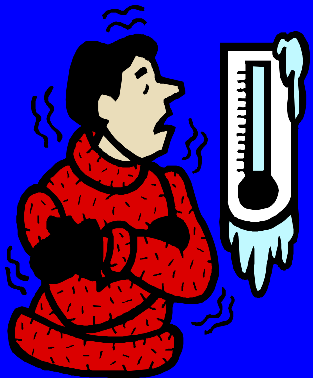
Temperature

And

Heat

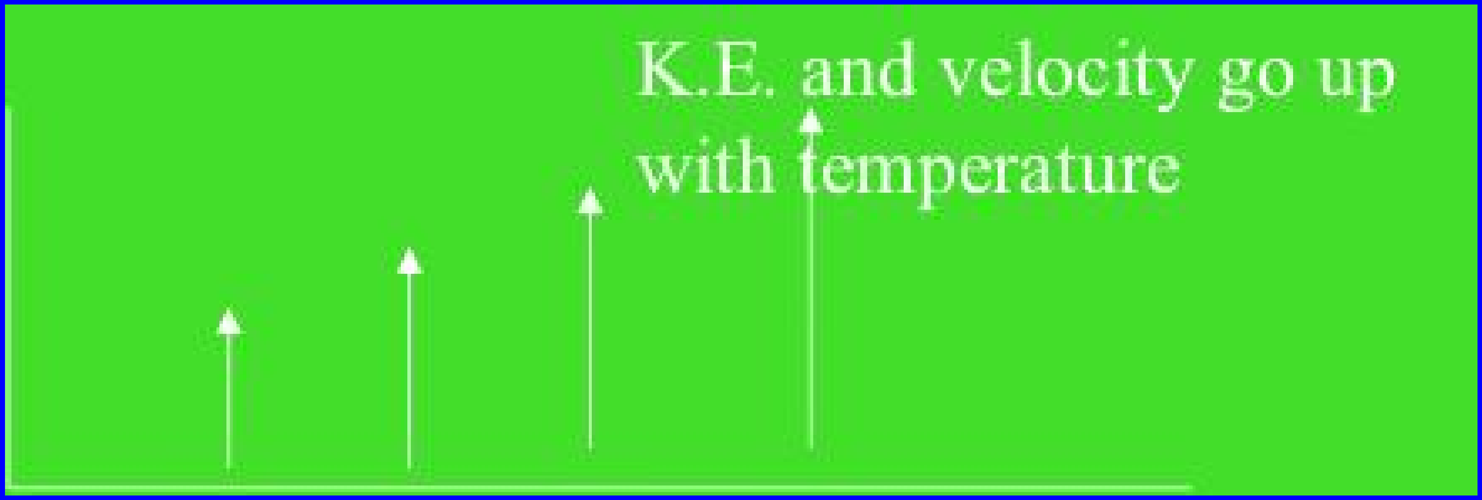


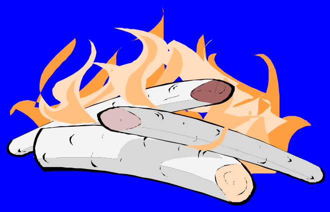
Temperature (T)



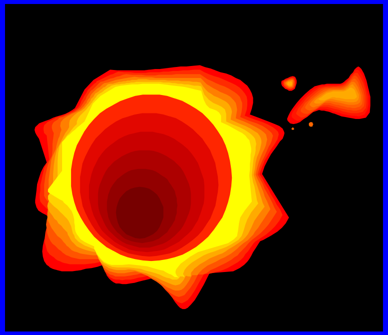
- The measure of hotness or coldness.
- The temperature of matter depends on the average kinetic energy of atoms and molecules.
- Feelings of hot and cold depend on temperature and conductivity.
- Touch metal and wood, which feels warmer?

Kinetic Energy and Temperature

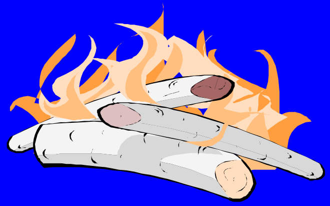




The Sun

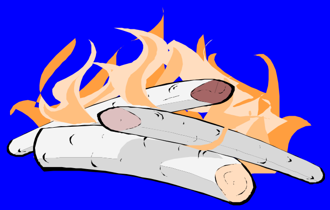


For example on the sun, the temperature is very high, in fact so high that atoms and molecules do not even exist! The sun is a Plasma.



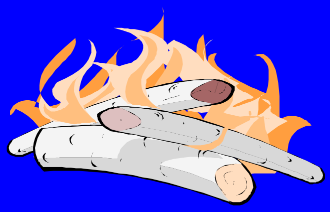
Temperature scales.

- We normally measure temperature with three different temperature scales, or units.
- Fahrenheit, ^oF, (British)
- Celsius, ^oC, (Original Metric) and
- Kelvin, K (no degrees) (Modern Metric)



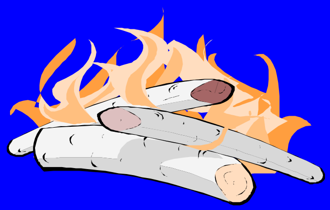
Celsius and Fahrenheit

- In the Celsius Scale water boils at 100 deg. And freezes at 0 deg.
- In Fahrenheit water boils at 212, and freezes at 32,
- so 100 °C = 212 –32 or 180 °F.
- The ratio of the sizes is 100/180 = 5/9



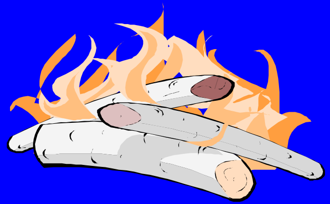
Converting from ^oF to ^oC

- To convert from ^oF use
- $^oC = 5/9 \times (^oF-32)$
- E.G. convert 50 ^oF to ^oC.
- 50 deg.F = 5/9 (50-32) = 5/9 x 18 =
- 5 x 18/9 = 10 deg.C



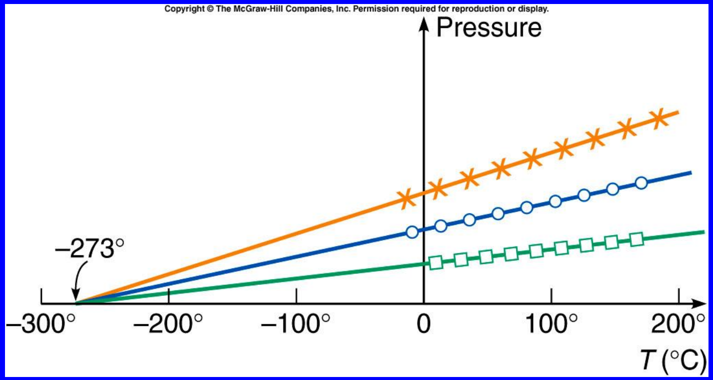
Converting from C to F

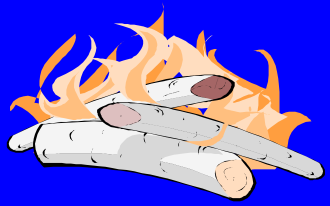
- To convert from C use F= 9/5C + 32
- For example 80 C = 9/5 x 80 + 32
- = (9 x 80/5) +32 = (9 x 16) + 32
- = 144 + 32 = 176
- 80 ^{o}C = 176 ^{o}F



Absolute Zero

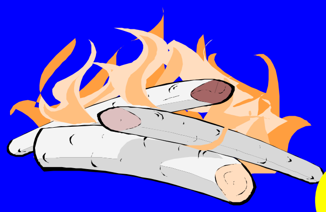
- After the Celsius scale was devised in the 1800's, it was discovered through the study of gases, that there seemed to be a limit on how low temperature could go.
- This was called absolute zero.





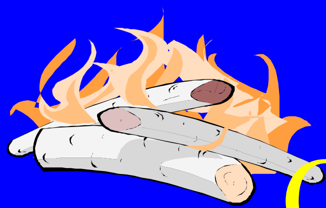
Kelvin Degrees

- Same size units as ° C
- Starts with zero at absolute zero instead of the freezing of water.
- First called the absolute temperature
- Later renamed The Kelvin Scale, in honor of Lord Kelvin. (Not °K, just K or Kelvins!)



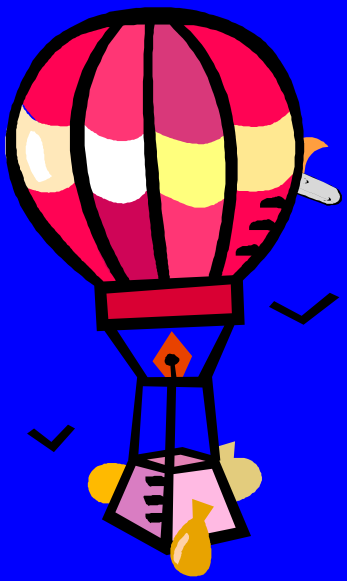
Converting from deg C to K

- K = C + 273
- Kelvin temperature is proportional to the average kinetic energy of the constituent particles.
- 30 deg C = ? K   K = 30 + 273 = 303

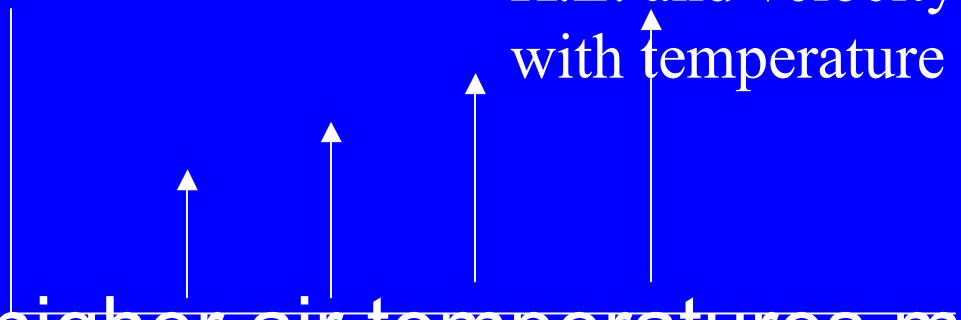


Converting from deg K to C

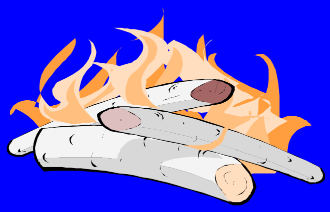
- C = K - 273
- 430 K = ?C C = 430 - 273 = 157 ° C



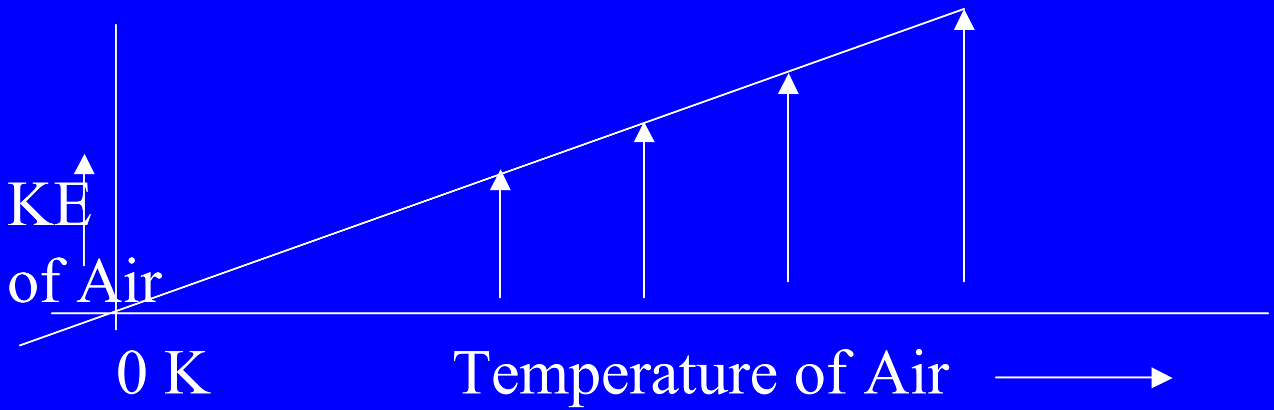
Hot Air



- On Earth higher air temperatures mean the air molecules are moving faster,) i.e. they have more kinetic energy ($KE = \frac{1}{2} mv^2$)



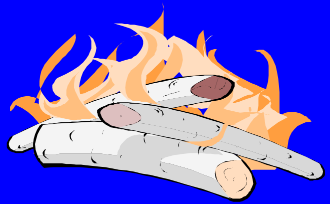
Air KE vs. Temperature



- At 0 K, there would be no air motion

Planetary Atmosphere

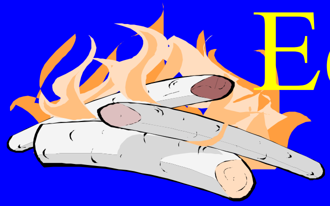
- A planet's gravity and temperature govern the composition of its atmosphere.
- Higher temperature means higher energy of particles in the atmosphere, meaning more kinetic energy and greater potential to escape gravity.
- Greater gravity means they have less chance to escape the planet.



Thermal Expansion

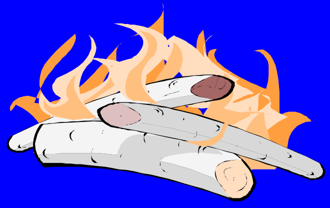
- **Most objects expand when they are heated.**
- **Solids expand in amounts dependant on their length, L and the change in temperature, ΔT, but the change in length also depends on the composition of the material.**

Δl change in l
ΔT = change in T



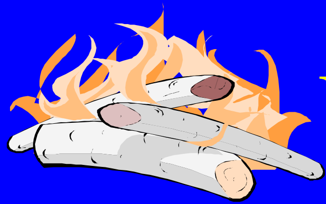
Equation for Thermal Expansion

- The equation is $\Delta l = \alpha l \Delta T$
- *l=length of the material, Δl = change in length, and ΔT = change in temperature of the object.*
- α, the coefficient of linear expansion, we have to measure or look up for a given material.



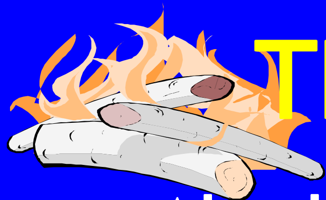
Different Objects Expand Different Amounts

- α, The coefficient of linear expansion varies greatly. Some things expand a lot, others a little. (See table 5.2 p. 179)
- E.G. α for Al 25, Brick 9, Ice 51, Glass 9
- (all x 10^{-6}/deg.C)



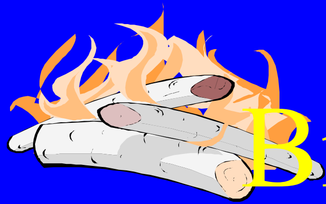
Windows.

- If we put glass in a metal frame in a window subject to large temperature variations we will have a problem.
- Aluminum expands and contracts faster and more than the glass.
- If the window cools suddenly the aluminum will contract and shrink and may break the glass.

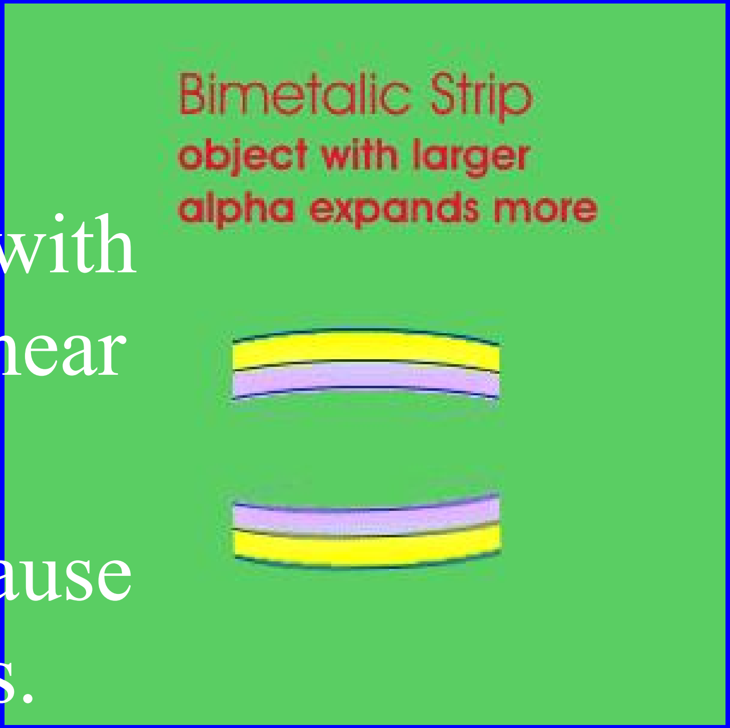


Thermal Expansion Problem.

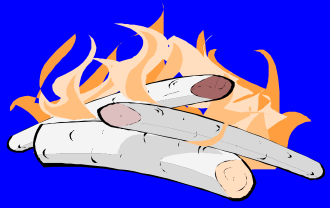
- $\Delta l = \alpha l \, \Delta T$:Change in length = coef. of exp. x length x change in temp.
- Example: α for Al = 25 x $10^{-6}/^{o}C$, T_f=100 ^{o}C T_0=50 ^{o}C
- **For l_o = 2 m, ΔT = 50 ^{o}C Note Negative ΔT means contraction!**
- Δl = 2m x 25 x 10^{-6} /^{o}C x 50 ^{o}C=2500x 10^{-6}
- **= 2.5 x 10^{-3} = .0025 m = 2.5 mm (l_f=2.0025m)**



Bimetallic Strip

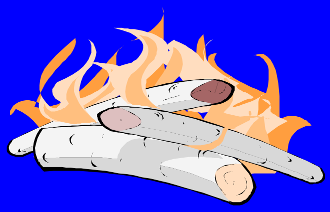


- 2 metals bonded together with different coefficients of linear expansion.
- When heated it bends because of the different expansions.
- Used in thermostats and thermometers see p.181



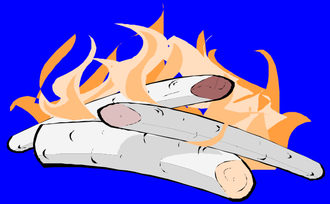
Noteworthy properties of water

- its high specific heat capacity
- unusual thermal expansion properties).
- Water contracts on cooling, but between 1 and 0, it expands.(p 182)
- Thus just before freezing it rises, making ice on the top of the lake, etc.



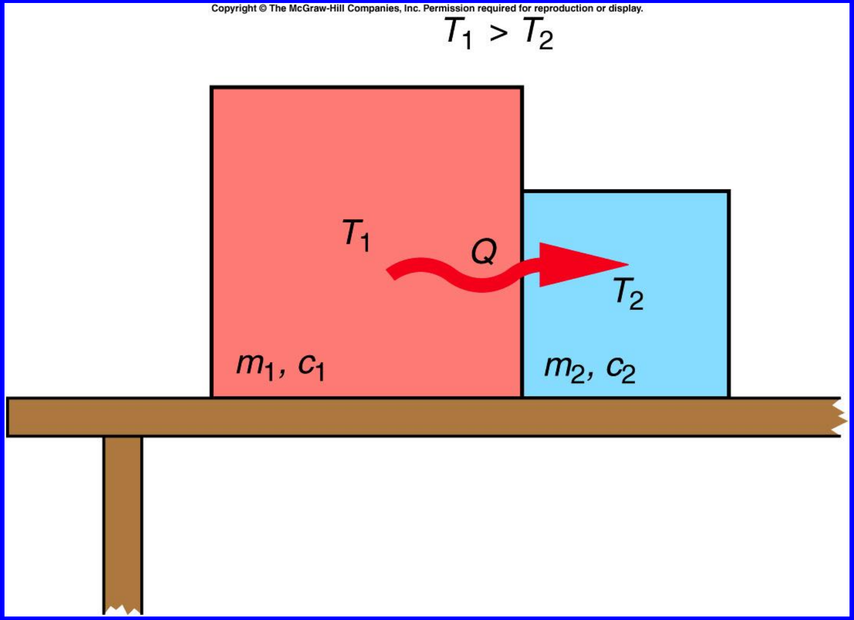
Use the ideal gas law.

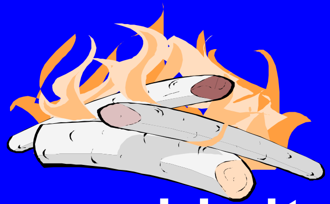
- PV =kT
- Pressure x Volume is proportional to Kelvin Temperature in a gas
- We can also state this as
- PV/T = constant



Heat (Q)

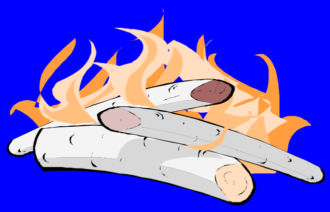
- The form of energy that is transferred between two substances at different temperatures.





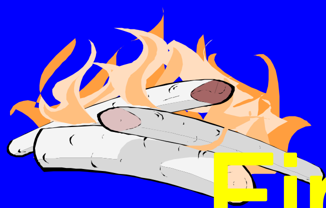
Heat and Internal energy

- Units of heat and early confusion.
- Calorie: Heat necessary to raise one G of water 1 deg. C.
- KG Cal or big Calorie.
- Caloric… Heat was something in itself, separate from matter and energy.



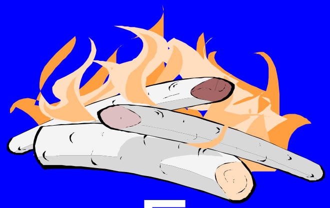
Internal energy (U)

- The sum of the kinetic energies and potential energies of all the atoms and molecules in a substance.



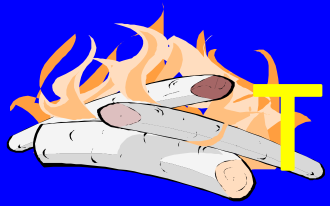
First law of thermodynamics

- The change in internal energy of a substance equals the work done on it plus the heat transferred to it.
- ΔU=work + Q
- Change in internal energy = work + heat change (+ or -)



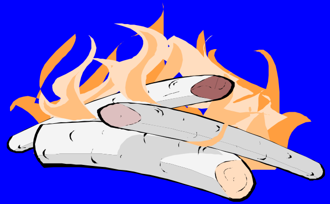
First Law Problem

- For example 50 Joules of heat are added to a substance and 30 Joules of work are done on it. What is the change in energy?
- **ΔU=work + Q**
- **ΔU = 30 + 50 = 80 Joules.**



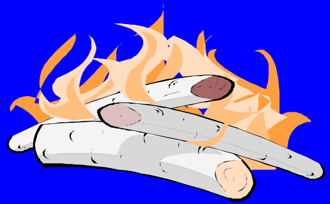
Three types of heat transfer

- Conduction The transfer of heat by direct contact between atoms and molecules
- Convection The transfer of heat by buoyant mixing in a fluid.
- Radiation Heat transfer in the form of electromagnetic energy.

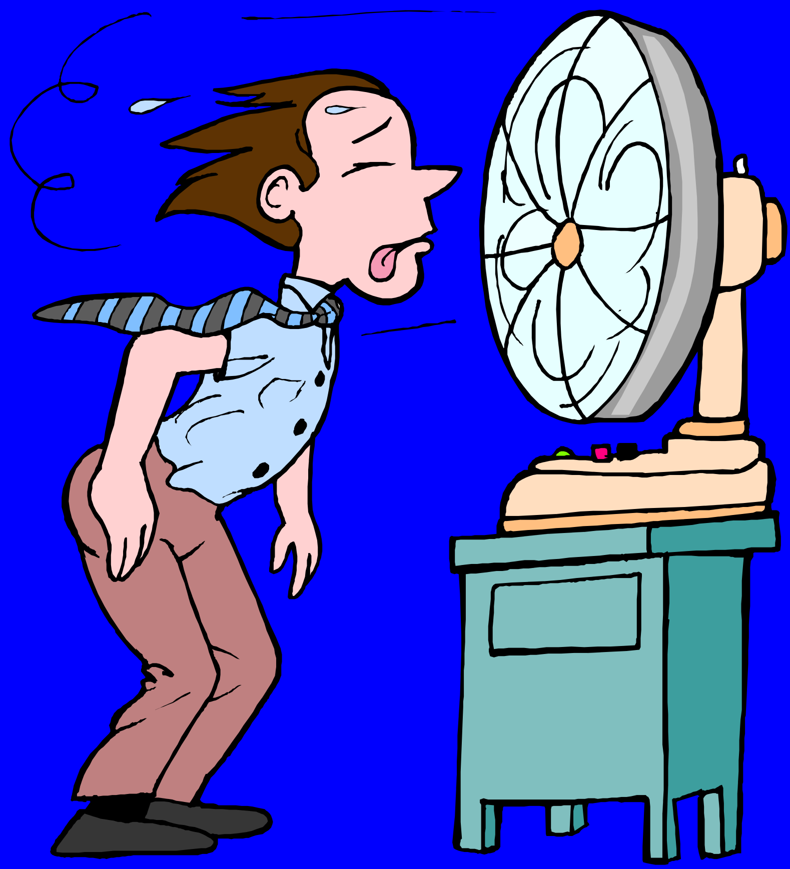


Conduction

- The metal worker wears insulated gloves to slow down conduction to his hands from the hot tongs he is holding.
- The heat is conducted from the hot metal through the cup through the tongs, and then through the gloves.

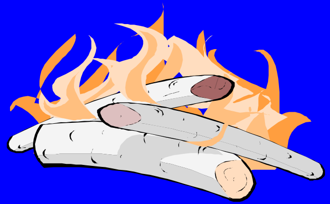


Convection



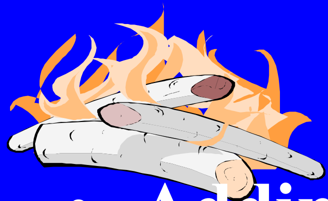
Wind passes by your hot body, picks up the heat and takes it away with the air.

Convection occurs in solids or liquids.



Radiation

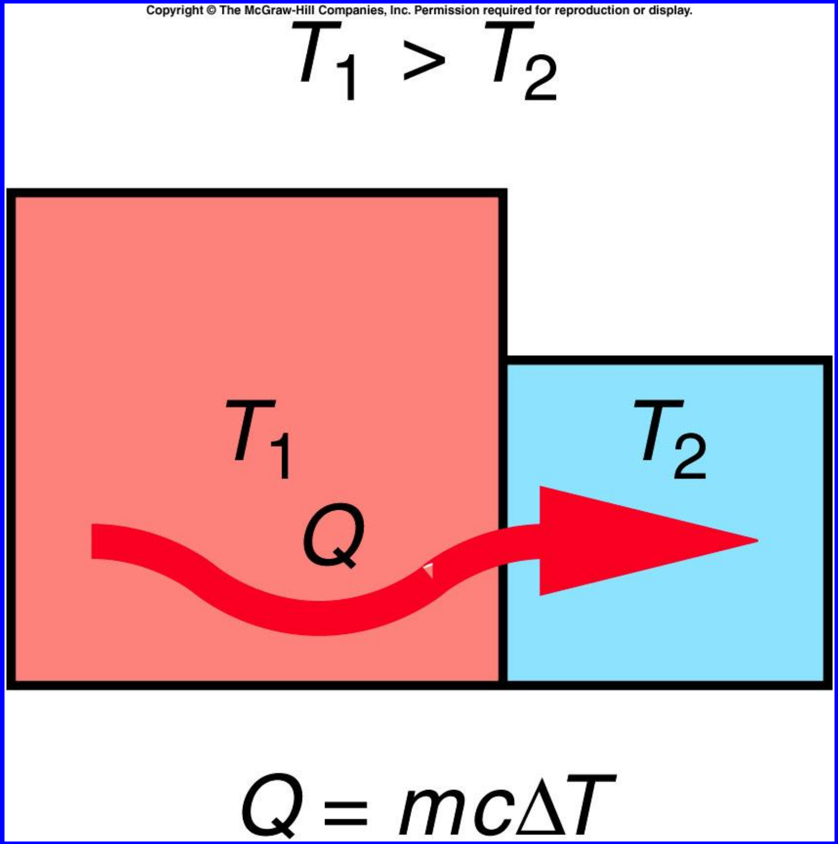
- See the heat radiating out from the hot metal.
- Radiation can travel through a vacuum.
- Light is radiation.
- Some radiation we can not see, for example heat radiation or infra-red radiation.

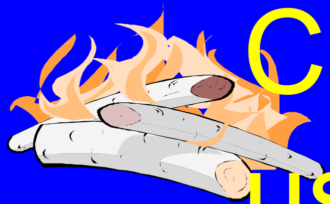


Specific Heat Capacity

- **Adding heat to a substance generally raises its temperature, as long as it does not change phase.**
- **We find if we double the heat added we double the temperature rise for a certain amount and type of substance.**
- **This can be expressed mathematically like this:** $Q = Cm\Delta T$

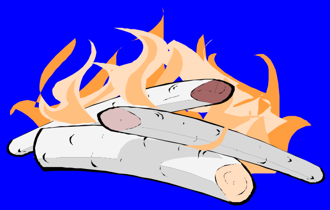
Diagram of Heat Capacity





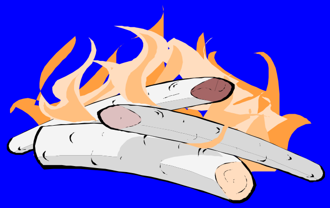
Calculations of heat transfer using specific heat capacity.

- $Q = Cm\Delta T$:Heat Gained = Heat Cap. x mass x change in Temp.
- For ice, C = 2000 J/Kg °C
- **To raise 10Kg by 20 °C we need**
- **Q = 2000 x 10 x 20 (J/(Kg °C) x kg x °C)**
- **Q = 400,000 Joules!**



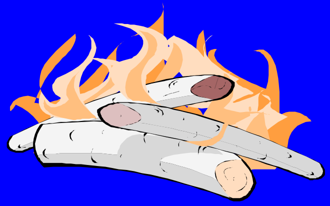
Phase transitions

- Changing from liguid, solid, or gaseous form to one of the other forms. E.G. liguid to gas
- The temperature stays constant during a phase transition.



Latent Heat of Fusion

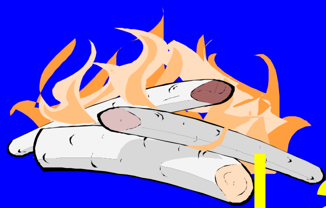
- Heat necessary to melt 1 kg of a substance



Sample Problem

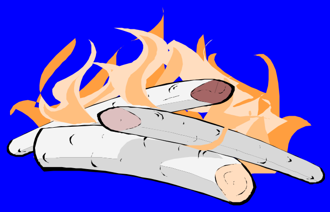
The latent heat of fusion of ice is 334,000 joules.

- How much heat is released when 4 kilos of ice melts?
- Q = m x Hf = 4 kg x 334,000 J/kg =
- 1.336×10^6 J



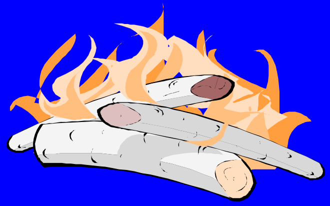
Latent Heat of Vaporization.

- Heat necessary to turn 1kg of a substance from liguid to vapor.
- Heat of vaporization of water is 2,260,000 J/kg



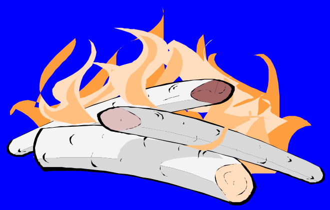
Humidity

- The mass of water vapor in the air per unit volume. The density of water vapor in the air.



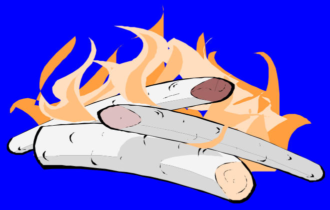
Saturation Density.

- The amount of water absorbed by air depends on the temperature and pressure.
- Higher temperature air can hold more water.
- The saturation density is the amount of moisture that water can hold at that temperature.



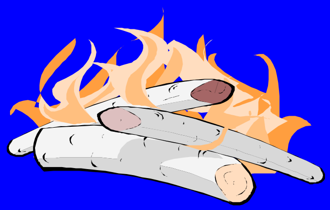
Relative humidity

- Humidity expressed as a percentage of the saturation density.
- See page 202 for chart and 203 for graph of saturation densities, then divide your humidity by this number



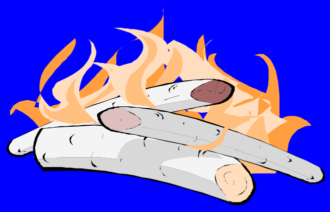
Rel. Hum Problem

- The humidity at 10 deg. C is .006 kg/cu m
- what is the relative humidity?
- From the chart p 202 sat. density = .01 at 10 Deg.C
- Rel. Hum= .006/.01 = .60 = 60%



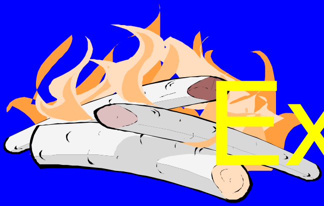
Dew point

- The temperature at which water in the air condenses.
- From the previous example for a humidity of .6 kg/cu.m and T = 10 deg.C
- On the graph p. 203 we find the dew point for .6kg/cu.m to be 5 deg.C
- Therefore, when this air cools to 5 deg. C there will be dew, fog, rain, snow, etc.

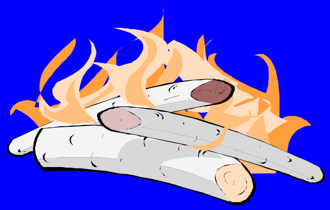


Second law of thermodynamics

- No device can be built that will repeatedly extract heat from a heat source and deliver mechanical work or energy without ejecting some heat to a lower-temperature reservoir.

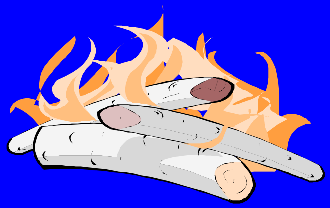


Explain how refrigerators and heat pumps work.



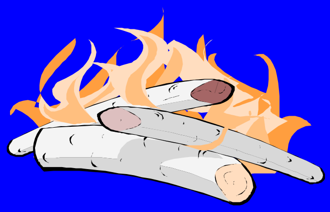
Heat engine

- A device that converts heat into mechanical energy or work. It absorbs heat from a hot source such as burning fuel, converts some of this energy into usable mechanical energy or work, and outputs the remaining energy as heat at some lower temperature.



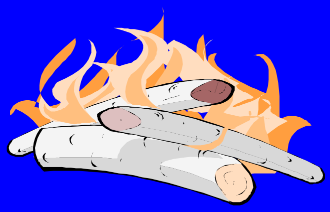
Normal Efficiency

- Eff = Output/Input
- Efficiency = Work or Energy Output/Input



Efficiency Problem.

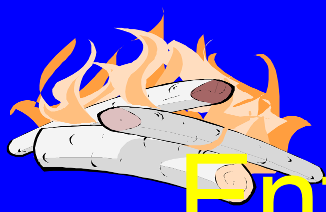
- An elevator uses 500 Joules to do 350 Joules of useful work. What is it’s efficiency?
- E = Wout/Win = 350/ 500J = .7 or 70%



Carnot Efficiency

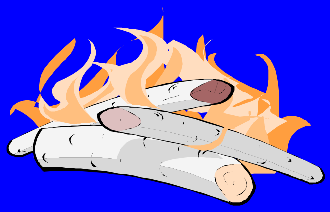
- $T_i - T_o / T_i$ =Carnot Eff. (*Input Temp – Output Temp/ Input Temp.*)
- **as a % = 100 x(Tin - T out)/ Tin**

Theoretical limit to the efficiency of a heat system. See problem #27.



Entropy.

- The disorder or entropy of the universe is increasing.



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