Lecture 5

April 12, 2011

Natural gas:

Reasons for Optimism:

1) undiscovered resources

2) Methane is now more "tamed" lots of methane in coal beds

3) ~1100 Tcf estimated left (used up 1000Tcf)

Heat Engines
Thermodynamics
and
Life with Sadi Carnot

Energy equivalents:
1 Gallon gas= 1.25×10^5 Btu
1 Btu=$.8 \times 10^{-5}$ Gallon gas = 1 match stick
= 778 ft-pounds (lift up 1 pound by 778 ft! That is a lot)

But:

Useful energy content is much less: Carnot efficiency limits us in converting heat into energy. Entropic loss.

Concepts:

Temperature T, Heat ΔQ, Specific heat C, Latent heat L, Pressure

Laws of Thermodynamics 0,1,2,3

Mixtures and resulting temperatures

Carnot Cycle for efficiency

Quality of Heat and 2nd law efficiencies

T scale: Celsius, Kelvin and Fahrenheit

$$0^0C = 273^0K = 32^0F$$

$$^0K =^0 C + 273^0 \qquad C/5 = (F-32)/9$$

Ice at melting temp at sea level = 0^0 C=273^0 K=32^0 F

Heat is written as ΔQ.

Here and everywhere Δ represents a change i.e. a difference.

Why cant we speak of Q?

Heat is energy in flow (or motion), whereas we can speak of energy itself as a characteristic of a state.

Example: A piece of copper may be said to have a total energy of 4.2 GJ but we cannot say it has a heat content of 1 G calorie.

$$1calorie = 4.2J$$

Heat capacity: and Specific Heat

When we add heat ΔQ to a material, its temperature increases ΔT

$$\Delta Q = C \ \Delta T$$

C= heat capacity that differs from material to material.

C itself depends on the amount of matter present

c= C/M (c= specific heat)

$$C = cM$$

$$\Delta Q = c \ M \Delta T$$

We will see typical numbers for c as kJ/kg x ° C

or

calories/gm C°

Specific heat	kJ/(kg x C°)	calories/gm x C°
Cu	0.39	0.093
Carbon (gr)	0.712	0.169
Granite	0.82	0.195
Window Glass	0.84	0.2
Water	4.2	1.0
Concrete	0.924	0.22
Brick	0.84	0.20
Wet Earth	2.1	0.50
Dry Earth	0.84	0.19

ADDED NOTE: water indeed has highest "c" (more than copper here)

Problems

- A piece of copper of weight 2 kg is heated up by 10C° Calculate the heat absorbed.
- A floor made of concrete of weight 1 Tonne (metric) is heated up by the sun from 40 °F to 80°F in a day. Calculate the heat absorbed. Use kJ and convert to Btu

Relevant Formula: Heat absorbed= $M \times c \times \Delta T$

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Solutions:

(1) Q= 2kg x .3kJ/(kg x C°) x 10 C° = 6 kJ

(2)

(a) ΔT=40°F=22.22 C° (caution banana skin here.)

(b) Q= 1000 kg x0.924 kJ/(kgx C°) x 22.22 C°= 20533.3 kJ= 20.533 MJ

(c)1 J= 9.49×10^{-4} Btu from tables. Hence

(d) Q= 19486 Btu

Cautionary note regarding conversion from F to C

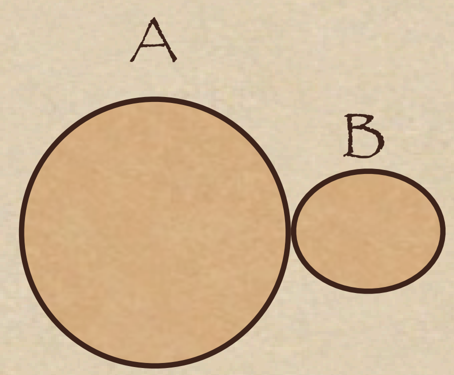
$C/5=(F-32)/9$ is used for converting a given temperature from one scale to another

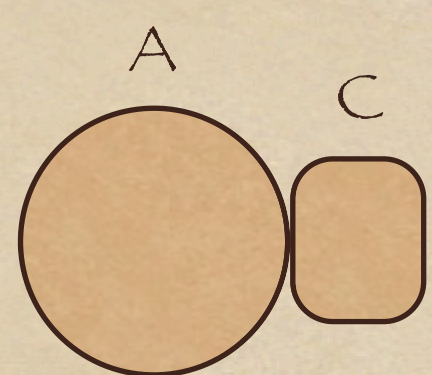
However to convert temperature differences, we should use

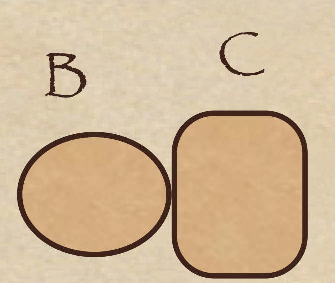
$$\Delta C / 5 = \Delta F / 9$$

0 th law of Thermodynamics

if A and B are in "equilibrium" and B and C are in "equilibrium" then A and C are in "equlibrium"







Equilibrium means Temperatures equalize!!

$$T_A = T_B \quad \& \quad T_A = T_C \implies T_B = T_C$$

First Law

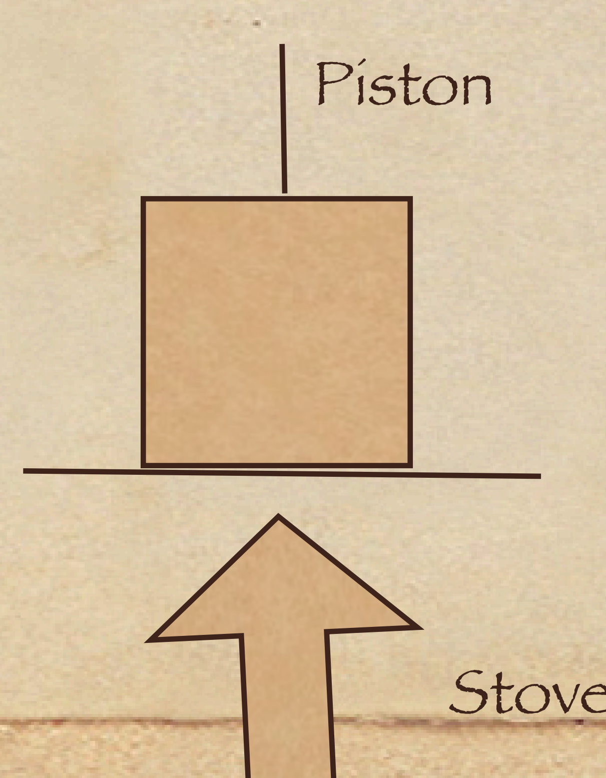
Heat is energy and energy is conserved!!

$$\Delta E = \Delta Q + \Delta W$$

We can increase the energy by either working on a system or by adding heat energy to it. Hence work done and heat have identical units:

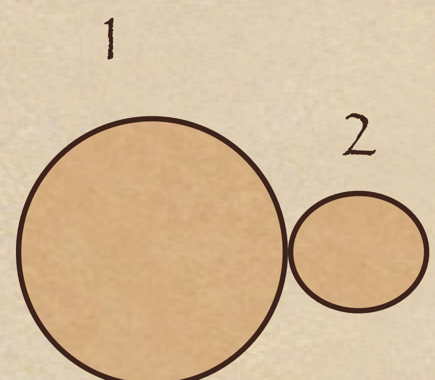
$1 calorie = 4.2 J$

$J = Newton\ meter$



Since energy is conserved, we have many applications of this idea.

Mixtures: two bodies with masses M1 and M2 are brought together with temperatures T1 and T2 what is the final temperature? (T1>T2)



$$\Delta Q_1 = M_1 c_1 \Delta T_1$$

$$\Delta T_1 = T_1 - T_f$$

$$\Delta Q_2 = M_2 c_2 \Delta T_2$$

$$\Delta T_2 = T_f - T_2$$

$$\Delta Q_1 = \Delta Q_2$$

$$T_f = \frac{M_1 c_1 T_1 + M_2 c_2 T_2}{M_1 c_1 + M_2 c_2}$$

Mixing Problems and solution

A 2 kg block of copper at 90C° is dumped into 2 gallon bucket of water at 20 C°. What is the final temperature of the water?

Answer: First convert 2 gallons = 2x 3.78 Litre = 7560 cm³. Its weight is 7560 gm since density is 1 gm/cm³

Next use the formula given in last slide.

$$T_f = \frac{M_1 c_1 T_1 + M_2 c_2 T_2}{M_1 c_1 + M_2 c_2}$$

In applying this:

M1= 2kg ; c1= 27 kJ/kg C°; T1= 90 C° Copper

M2= 7.56kg; c2= 4.2 kJ/kg C°; T2= 20 C° Water

Hence T_f = 21.7C°

Note added:

In class I used a wrong value of c for copper and hence got a large change of temperature. In fact 2 kg copper makes very little difference to the final temperature.