Lecture 6

April 13, 2012

Heat Engines
Thermodynamics
and
Efficiency

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

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

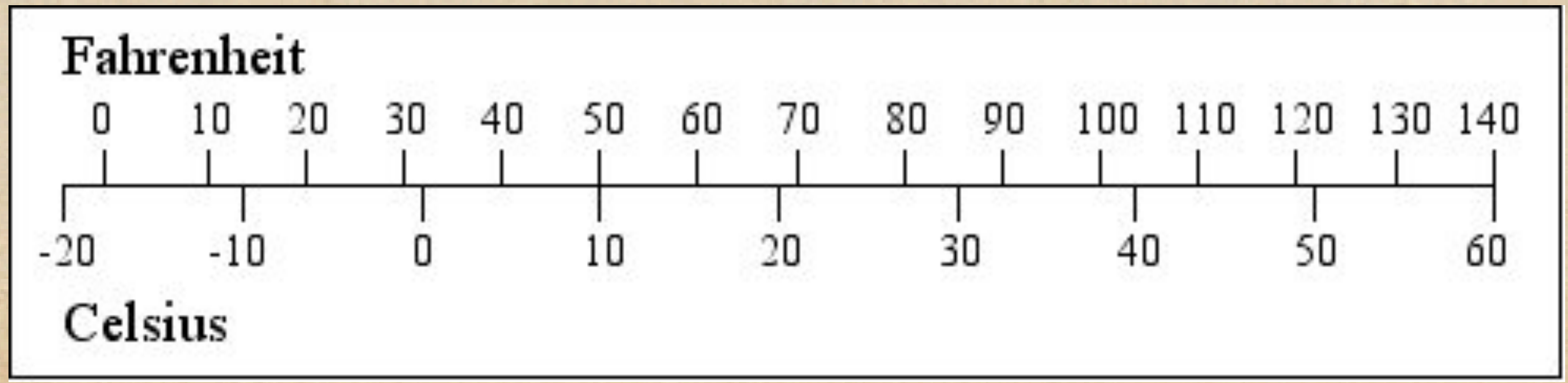
$$^0K = ^0C + 273^0 \qquad C/5 = (F - 32)/9$$

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

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



Heat is written as ΔQ.

Here and everywhere Δ (pronounced as delta) 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.

"Path dependence" analogous to work done.

Heat capacity: and Specific Heat

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

Incomplete eqn $\Delta Q = C\ \Delta T$ x (something)

C= heat capacity that differs from material to material.

C itself depends on the amount of matter present

c= C/M (c= specific heat)

$$C = cM$$

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

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

Water has highest specific heat (more than copper here)

What is T anyway? (microscopic level)

T is definable from Maxwell Boltzmann theory of gases/liquids

Thermal agitation. Here Boltzmann's constant makes its appearance.

$$T = \frac{m}{3k_B}\langle v^2 \rangle$$

$$k_B = 1.38 \times 10^{-23} J/K$$

http://www.chm.davidson.edu/vce/kineticmoleculartheory/basicconcepts.html

Problems

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

• A piece of copper of weight 2 kg is heated up by 10C° Calculate the heat absorbed.

Specific heat	kJ/(kg x C°)	calories/gm x C°
Cu	.268 .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

Solution:

(1) $\Delta Q = 2\text{kg} \times .3\text{kJ}/(\text{kg} \times C^{o}) \times 10\, C^{o} = 6\text{ kJ}$

• (2) 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

(2) Solution

(a) $\Delta T = 40^{o}F = 22.22\, C^{o}$

(b) $\Delta Q = 1000\text{ kg} \times 0.924\text{ kJ}/(\text{kg} \times C^{o}) \times 22.22\, C^{o} =$ 20533.3 kJ = 20.533 MJ

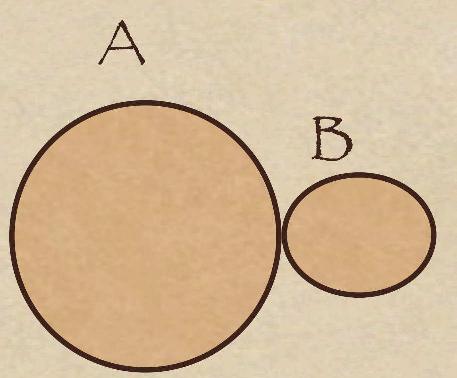
(c) 1 J = 9.49×10^{-4} Btu from tables. Hence

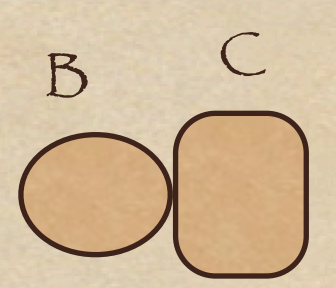
(d) $\Delta Q = 1.95 \times 10^{4}$ Btu

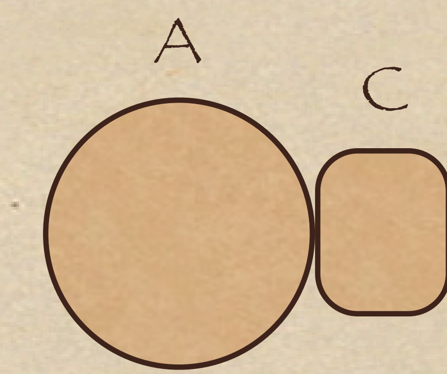
0^{th} law of Thermodynamics

if A and B are in (thermal) "equilibrium" and
B and C are in "equilibrium"
then A and C are in "equilibrium"

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:

$1 calorie = 4.2 J$

$J = Newton\ meter$