Thermal Physics
PHYS 3343
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The subject of our course is thermal physics. Thermal physics is a combination of two historic disciplines: thermodynamics and statistical mechanics.

THERMODYNAMICS

Thermodynamics developed before the atomic nature of of matter was understood. Major developments occurred in the first half of the nineteenth century. The names Carnot, Clausius, W. Thompson (Kelvin) are major names associated with these developments. Tsallis is a notable current worker in this field.

Thermodynamics is based on a small number of basic principles (the laws of thermodynamics.) These are deductions from and generalizations of a large number of the results of a large number of experiments on macroscopic systems. They are phenomological descriptions and are not based on microscopic structure at all.

Thermodynamics uses exclusively macroscopic variables such as p, V, T. Equations of state such as $pV=NkT=nRT$ are experimentally derived.

STATISTICAL MECHANICS

Statistical mechanics developed along with the understanding of the atomic nature of matter at the end of the nineteenth century and the beginning of the twentieth century. Names associated with these developments are Boltzmann, Maxwell, Ehrenfest, Gibbs, Planck, Fowler, Dirac, Bose, Einstein, Fermi, Rushbrooke, Onsager, and others on to today like Kadanoff and P.W. Anderson.

There are both classical and quantum versions. In statistical mechanics macroscopic laws are derived from microscopic properties.

THERMAL PHYSICS

The newly merged discipline incorporates probabilistic derivations into thermodynamics. We’ll develop the entire theory with special interest in simple systems – gases, atomic magnets, simple solids and stars.

Thermal physics is the study of the properties of macroscopic physical systems.

Macroscopic systems are systems that contain a large number of atoms (molecules).

Avogadro's number is N_A=6.022X10^{23}/mole. Note that physicists are increasingly using SI units and so you'll see N_A=6.022X10^{26}/kmol.

With particle numbers of this order we can't obtain a complete microscopic (that is atomic) specification. Even if we could specify the configuration, we would be unable to follow its time evolution.

However, macroscopic bodies follow definite laws that can be phrased in term of the macroscopic variables, p,V, and T etc. You've also seen that such expressions can be developed statistically. (You should have calculated the pressure in a gas in University Physics.)

Thermal Variables and Concepts

Temperature

Perhaps the basic concept, without doubt the most misunderstood.

Properties: If two objects are placed in contact, energy flows from the hot body to the cooler body until temperature equalizes. The flow of energy is what called heat. When the flow of heat ceases the objects are said to be in thermal equilibrium.

Zeroth law

If two objects are in thermal equilibrium with a third, then they are in thermal equilibrium with each other. (This law is due to R.H. Fowler, of the four laws of thermodynamics it was discovered last.) This allows the development of the theory of thermometry. By using a physical property and two fixed points, we develop temperature scales. Such scales tend to agree only at the fixed points. We remove the arbitrariness by introducing absolute scales through the second law.

Equilibrium

We use thermal equilibrium to denote an equality of temperature. Consider an isolated system – it could contain pressure differences, temperature gradients, density variations, etc. A system in such a state is not in equilibrium, it will change over time – pressures will equalize, thermal conduction, diffusion etc. will occur. When the system evolves to a state in which nor further macroscopically observable changes take place has achieved equilibrium. We call it an equilibrium state. Nothing else will ever happen if the system remains islolated.

Description of equilibrium states

Equilibrium states can be described and are fully determined by a few macroscopic variables. (It is necessary to specify $\rho(\mathbf{r})$ etc.

These few variables then determine all other macroscopic variables.

Properties that depend only on the state of the system are call *functions of state*.

The state of a homogeneous fluid is determined by M, V, and P.

We can write T=f(p,V,M), note that in thermodynamics we will prefer to write:

T=T(p,V,M)

This equation is called the equation of state for the fluid. We could equally well write p=p(M,V,T). Knowledge of a single equation of state does not constitute complete thermodynamic knowledge of a system – you need to know all the equations of state.

Actually, you'll see that we'll reserve the term equation of state for more specialized equations.