Foundations of Physics 2B
Thermodynamics

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Contents

Lecture 1

1.

This course will frame concepts in concrete maths from last year

Laws:

- Zeroth establishes the meaning of temperature
- First is a statement of energy conservation [we can only break even]
- Second defines entropy – why things do or do not happen
  - Entropy measures energy quality [you can only break even at 0 K]
- Third doesn't define thermodynamic property; tells us we can't get to 0 K

Thermodynamics developed by engineers wanting to develop machines that turn heat to work
Wanted most work for least effort
Subject developed had a number of under-ranging consequences
When it emerged, atoms were unknown – considered average properties of bulk material
There was no attention paid to what was inside
Macroscopic approach to look at 'black box':

- This approach is general and difficult to 'see the point'
  All good having relationships about heat capacities and expansicities but tells us nothing about the physics

e.g. why a material has a certain temperature dependence for its heat capacity

Opening the black box gets microscopic picture (atomic) but this can be very detailed ($N_A \approx 6 \times 10^23$)
Statistical mechanics instead looks at average properties of all atoms in the thermodynamic limit

Example: Counting Molecules – simpler than recording position and motion as fewer DoFs

Lecture theatre has 10^29 molecules (3×10^6 litres of air)
A 10GhZ processor can count 10^17 molecules per year (each cycle counts one) $\approx 3 \times 10^11$ years to count all molecules
Thermodynamic limit – things tend to the average (to infinity)

Rains drops hit small and large roof:

Fluctuations in force smooth out, even through force increasing
Consider pressure, $p = \frac{F}{A}$, same in both cases if you consider the average
Thermodynamic limit – $A \to \infty$

2. Thermo Systems and States

	Extensive – System Extent	Intensive – Independent
	Volume, V Energy, U	Temp, T Pressure, P
	$V = V_A = V_B = \frac{V}{2}$ $U = U_A = U_B = \frac{U}{2}$	$T^* = T_A = T_B = T$ $p^* = p_A = p_B = p$

Relate properties by equation of state, $f(p, V, T) = 0$
Most well known as the ideal gas law: $pV = nRT$

Thermal Equilibrium (TE), Heat, and Temperature

Can prepare sample of gas by suitable treatment to take a range of values of pressure and volume

$$p_1 V_1 = a > b = p_2 V_2$$ – Sample 1 is hotter than Sample 2

Equation of state, $pV = f(T)$

Heat is thermal energy in transit, heat transferred from hot to cold (under its own action)
In transit is important – can't say object contains an amount of heat
Addition/subtraction of heat changes temperature
If two objects have the same temperature, they're in TE

Heat capacity – $\Delta Q = mc\Delta T$
More rigorously, a small change, dT, in a substance's temperature, requires the addition/subtraction of a differention and of heat, δQ:

$$\delta Q = mcdT$$

Capital C: Heat capacity of whole substance
Lower c: Specific heat capacity per unit mass/mole
$C = mc$

Total heat energy to change temperature, $T_1 \to T_2$:

$$\Delta Q = \int_{T_1}^{T_2} \delta Q = \int_{T_1}^{T_2} mcdT$$

Most changes take place whilst some other property is held constant:

$$C_V = \left(\frac{\partial Q}{\partial T}\right)_V; \quad C_p = \left(\frac{\partial Q}{\partial T}\right)_p C_p > C_V$$

Work is needed to keep at constant pressure – work is a form of energy so requires more heat energy in to get to the same temperature at constant pressure

Zeroth Law

"If two system are separately in TE with a third system, they must be in TE with each other"