Thermal Physics

Aug 31st, 2014

0. Overview of course & Survey
I Review of Thermodynamics

II Probability as elaborated counting.

III Polymers as random walkers (next time)

Q2: Have you taken advanced classical mechanics? Comfort level? Do you know what a Hamiltonian is? Phase space?

Q3: Are there particular areas of thermal physics you'd particularly like to cover?

0. Go through syllabus and website; discuss choice of text.

bohr.physics.berkeley.edu/hal/teaching/phys314Fall4

Survey: Q1: Have you taken quantum mechanics? (Give some context, e.g. in course, level etc). Rate your confort level: very confortable
comfortable
uncomfortable

I Our text doesn't touch ~~Thermodynamics~~ temperature for the first 100pp! This is wonderful but may be a bit disconcerting. Let's remind ourselves briefly what thermodynamics is all about before we veer off into understanding where it comes from.

Laws of Thermodynamics:

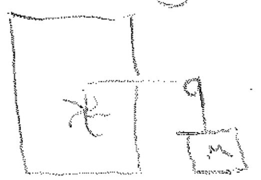
0th law: If two systems are in thermal equilibrium with a 3rd system then they must be in thermal equilib. with each other

This law brings about the practical utility of temperature — you can measure it with a thermometer!

$\text{đ}W$ = work is representative of a whole mess of methods for transfering energy by changing external parameters; e.g.

$$W = \int_{V_i}^{V_f} \bar{p}(V)\,dV \quad \left(\begin{array}{c}\text{quasistatic}\\ \text{process}\end{array}\right)$$

You could mix the system with a paddle wheel



and so on.

1st law: A form of conservation of energy, it reads

$$dE = \text{đ}Q - \text{đ}W$$

change in internal energy

heat absorbed by system

work done by system

$$= \text{đ}Q + \text{đ}W$$

adding these up does not depend on the process

adding these up depends on the process

work done on system

$\text{đ}Q$ = heat; a particularly thermal form of energy, it is the energy transfered between two systems when their external (macroscopic) parameters are fixed.

2nd law: An equilibrium macrostate has entropy S.

The entropy satisfies

$$\Delta S \geq 0$$

in any thermally isolated process that connects two macrostates.

For processes where the system is not isolated

$$dS = \frac{\text{đ}Q}{T} \quad \left(\begin{matrix}\text{quasistatic} \\ \text{process}\end{matrix}\right)$$

$\uparrow$ Temperature

3rd law: The entropy satisfies

$$S \xrightarrow[T \to 0_+]{} S_0$$

where S_0 is a constant independent of the parameters of the system.

These laws use (E, S, T) and, remarkably, make no reference to the underlying structure (atoms, molecules, etc) of the system. This is both their great strength – they are amazingly general, applying to all sorts of situations – and their great weakness – where on Earth did they come from?

This last question is what we'll spend the next few weeks figuring out and as a wonderful benefit we will set ourselves up for doing a whole lot more physics.

II The foundation of probability theory is just counting – no need for intimidation

The surprising thing is that counting can be hard! ~~Let's~~ ~~try~~ Discrete systems with a finite total number of possibilities are simplest, then the probability is just the ratio of two counts:

$$P(\text{event } e) = \frac{\#\text{ events } e}{\text{total }\#\text{ of events}}$$

Ex: A bag contains three red marbles, 2 black and 1 white. What's the probability of drawing a red?

$$P(\text{red}) = \frac{3\text{ reds}}{6\text{ total}} = \frac{1}{2}$$

Easy coherence check: If you draw a marble what's the probability of drawing a marble?

$$P(\text{marble}) \underset{\underset{\text{boring}}{\uparrow}}{=} 1 = P(\text{red}) + P(\text{black}) + P(\text{white})$$

$$= \frac{1}{2} + \frac{1}{3} + \frac{1}{6}$$

$\uparrow$ more interesting

Exposes relationships btwn events (types).

Let's try: Poker hands, 5 card draw, single deck.

Hands:

Royal Flush

10, J, Q, K, A all of one suit

Straight Flush:

4, 5, 6, 7, 8 all of one suit and not royal

4 of a kind:

2, 2, 2, 2, 5

Full house: (3 kind + 2 kind)

8, 8, 8, K, K

Flush (all same suit, exc. royal and straight)

2♡, 4♡, J♡, 10♡, 7♡

Straight ("Numerical" order, different suits)
= rank

7♡, 8◇, 9, 10, J

3 of a kind

Q, Q, Q, 5, 2

2 pair

3, 3, 6, 6, K

Pair

5, 5, J, Q, 2

$$P(\text{pair}) = \frac{2}{4} = \frac{1}{2}$$

2 suits, 3 ranks, 2 or 3 etc.
card hands

Polya's great book "How to solve it"

"Make an orderly list", "Elliminate possibilities"

"solve a simpler problem"!

No pair / High card

A, 2, 4, 7, Q

Take aways: Do the simplest possible version first:

2 suits, 2 ranks, 2 card hand

$$\left.\begin{array}{l} 1♡,\ 1◇ \\ 1♡,\ 2◇ \\ 2♡,\ 1◇ \\ 2♡,\ 2◇ \end{array}\right\} \text{4 hands}$$

My philosophy: Doing physics is the art of choosing what to ignore; plus, having the courage to make predictions & the wisdom to learn from constant Mistakes. SO, I want you all to place bets on your predictions.

Hand out coin. Theirs to keep, w/
3 ~~two~~ requests:
~~Prediction: Do two p~~
1. Don't spend until end of term
2. Always make the size of your bet proportional to your certainty.
3. Acquire a 1 subject notebook for bet tracking alone

I will figure out a way for us to leave coin there.

Hal: 5 Emily: 25, Trevor, 15

Pool: 45 Hal X

Winners: 40 units Emily gets $\frac{25}{40} \cdot 45 = 28$¢

Trevor $\frac{15}{40} \cdot 45 = 17$¢

Happy to adopt new systematics from suggestions.

<u>Prediction 1</u>: Is there a pair of people in this room w/ the same b-day?

Systematics:

Initially we will pool the bets. If your prediction is wrong you will get zero return. If correct, you will get a weighted return. How shall we weight it?

<u>Prediction 2</u>: Has there been more improvement in weather predictions or economic predictions in the last 20 yrs?

Feel free to recuse yourself if you feel you have insider information.

Brief discussion of error/uncertainty.