Physics 112 : Lecture 1

Notes for the Fall 2017 Physics 112 Course taught by Professor Holzapfel
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1 BASIC LOGISTICS

In the bcourses page for this course, the syllabus has been uploaded, where the Office Hours, (for both the professor and the GSI), the textbook, the homework, and general policies are listed. If you don't have access to bcourses, you can contact the professor at swlh@cfpa.berkeley.edu to request a copy of the syllabus for now.

2 OVERVIEW

In this course we will be talking about macroscopic objects, things you can see and interact with (unlike Quantum Physics, which at the introductory level mainly deals with systems such as a single electron, a particle in a box, or possibly a few entangled particles). The focus of this course will be on large systems of particles that are near equilibrium.
In this regime, you no longer have to worry about the individual behaviour of each particle, which would be an impracticality; imagine simulating every particle of air in the room, you would never have enough resources! Instead, we look at the macroscopic behaviour of the system of particles in question. For example, the ideal gas law:

$$PV = NkT$$

describes macroscopic properties of the system (pressure, temperature) without explicit reference to the behaviour of the individual particles themselves.
To tackle the kinds of problems we face in thermodynamics, there are two main methods we could try:

- We could try the 'Top Down' method. Around the 1850s, most of the laws of 'classical thermodynamics' had been observed and written down by scientists, who never fundamentally understood how the individual particles behaved! How could they, when Quantum Mechanics had not yet been discovered! Instead, these scientists simply performed experiment after experiment, compressing and heating different gases and liquids to derive a set of empirical laws that seemed to hold.

- Or we could try the more modern 'Bottom Up' method, with our newfound knowledge of how particles behave (this is what we shall attempt in this course). By investigating how particles behave individually, we derive mathematically the laws of thermodynamics by building upwards, by considering what happens when we have a large collection of particles together that interact with each other. This method has the benefit that we gain a more fundamental understanding of what the laws of thermodynamics are actually saying, and also that we can apply this method to many different kinds of systems, such as Bose Einstein condensates, magnets,... to gain a wide understanding of how the world works.

3 BASIC PROBABILITY AND STATISTICS

- For any event i, the probability P_i that the event occurs obeys the rule: $0 \leq P_i \leq 1$ by definition.

- If we have two mutually exclusive events i and j, (in other words, if i occurs then j does not occur, and if j occurs then i does not occur), then we know that

$$P_{(i+j)} = P_i + P_j$$

where $P_{(i+j)}$ is the probability that either i or j occurs. We can generalize this idea to n mutually exclusive events, where:

$$P = \sum_i^n P_i$$

where each P_i is some event which is mutually exclusive with any other event, and P is the probability that one of the events occur. As an example, consider drawing a random card from a standard deck of cards (without Jokers). Then the probability of drawing either a 6 or a 7 is given by:

$$P_{6 \text{ or } 7} = P_6 + P_7 = \frac{1}{13} + \frac{1}{13} = \frac{2}{13}$$

- Suppose we have two independent events i and j, which simply means that the chance that j occurs does not depend on whether i occurs, and vice versa. Then we have the formula:

$$P_{ij} = P_i P_j$$

and of course, if we have n independent events this formula generalises in the natural way:

$$P = \prod_i^n P_i$$

As an example, consider the following example. Suppose you have two separate decks of cards, and you draw one card from each deck. What is the probability that you will draw two aces? Since the decks do not 'communicate' with each other (they aren't entangled or anything, they are macroscopic decks) the chance of drawing an ace from the first deck is independant of the chance of drawing an ace from the second deck. Hence:

$$P_{2\text{ aces}} = P_{ace}P_{ace} = \frac{1}{13}\cdot\frac{1}{13} = \frac{1}{169}$$

- If we want to arrange n items in a line, then there are $n!$ ways of doing it, since we have n choices for the first item, $(n-1)$ choices for the second item, and so on. If we want to arrange n items in a line, but p of the items are indistinguishable, then the number of ways of doing it is $n!/p!$, since we simply divide by the number of ways of permuting the p elements that are indistinguishable.

- If we want to pick k items from n items (i.e. we care about the order in which we pick the k items), the number of ways of doing this is given by:

$$^nP_k = \frac{n!}{(n-k)!}$$

  If we want to choose k items from n items (i.e. we don't care about the order) then the number of ways of doing this is given by:

$$^nC_k = \frac{n!}{(n-k)!k!}$$

- Suppose we had N balls, that we were placing in three different bins, of size n_1, n_2 and n_3, and that the balls are distinguishable. The number of ways of doing this is given by:

$$N = {}^NC_{n_1}\,{}^{N-n_1}C_{n_2}\,{}^{N-n_1-n_2}C_{n_3} = \frac{N!}{n_1!n_2!n_3!(N-n_1-n_2-n_3)!}$$

  where the first term is from choosing the n_1 balls to go on the first bin, the second term comes from choosing the n_2 balls from the $(N-n_1)$ remaining balls to go into the second bin, and the third term comes from choosing the n_3 balls from the $(N-n_1-n_2)$ remaining balls to go into the third bin. The final expression comes from our formula for choosing k items from n total items. Notice that if $N = n_1+n_2+n_3$, then we have:

$$N = \frac{N!}{n_1!n_2!n_3!}$$

- A couple of examples were discussed in lecture. The chance of drawing four aces in a row from a standard deck of cards is:

$$P = \frac{4}{52}\frac{3}{51}\frac{2}{50}\frac{1}{49}$$

  since we have 4 aces to draw from initially, then 3 (since we drew one of the aces), then 2 and finally 1 remaining. The chance of drawing a Royal Flush from a standard deck of cards is:

$$P = 4\cdot\frac{5}{52}\frac{4}{51}\frac{3}{50}\frac{2}{49}\frac{1}{48}$$

  where the 4 accounts for the four different suits that we could be drawing.