Statistical Physics I
Final student reports for Physics 3P41

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December 5, 2006, 14:00–17:00, TA309
and
December 16, 2006, 14:00–17:00, TA309

The abstracts are presented here unedited, as submitted by the students.

Contents

1 Negative Temperature

Mike Potalivo — Dec.5, 14:00–14:25

Abstract

In Thermodynamics $1/\tau$ is defined as $(\partial\sigma/\partial U)_N$, where σ is the entropy, U is the energy, and τ is the temperature. In a two-state system of N particles, it is easy to mathematically show that τ can have a negative value. This can be done by examining the definition of temperature, or by examining the Boltzmann Distribution. The condition to get a negative temperature requires that more particles are in the excited state than in the ground state. Negative temperature becomes harder to attain in systems with more accessible states. When there is an infinite amount of states, negative temperature can not occur. Lasers, before emitting light, have negative temperature. Negative temperatures can also occur by methods of manipulating the nuclear spin orientation on particles. This is done by first applying a magnetic field, to create a two state system, then by exciting the spins that are not excited by using radio frequency techniques.

2 Nuclear Overhauser Effect Spectroscopy

Evan Mercier — Dec.5, 14:25–14:50

Abstract

Nuclear Magnetic Resonance (NMR) spectroscopy is an invaluable tool for molecular structure determination. In an NMR experiment, interactions of magnetic nuclei with an externally applied magnetic field are probed and correlated to chemical environment. In addition, the effect of nuclear magnetic moments on the environments of nearby nuclei occurring through bonds and through space can be observed. Fundamentally, this is represented by system of interacting particles to which statistical analysis can be applied. The nuclear Overhauser effect (NOE), resulting from through space interactions, is dependent on the distance between interacting nuclei. Mathematical treatment reveals the nature of this dependence which can be used with NOE data to predict the distance between nuclei and contribute to solving three dimensional molecular structures including that of proteins.

3 The Techniques of Cooling: Helium Dilution Refrigerator

Peng Jiang — Dec.5, 14:50–15:15

Abstract

Start with the basic mechanical way, the most common way to make the house hold refrigerator. Scientists develop many other ways to find the ultra low temperature. There are gas liquefaction, evaporation cooling, parametric cycling, and more. However, the mos effective so far by my knowledge is the helium dilution refrigerator which can achieve millidegrees. Although there is other ways to reach lower temperature, but helium dilution is far more easy and safe than nuclear demagnetization. There will be roughly three parts in the presentation.

- Comparison to other techniques, why helium dilution is better;
- How helium dilution bring down the temperature;
- the physics behind the technique.

4 Soft Condensed Matter

Dylan Lamport — Dec.5, 15:15–15:40

Abstract

This paper will outline the study of some of the behaviour of colloidal suspensions, polymers, and surfactants, known as soft condensed matter. Soft matter, which has a of size of about 0.3 nm–10 μm, shows interesting physical phenomena such as self-organization, as well as (in certain molecules) the tendency for processes to become stuck in certain states as they evolve towards their equilibrium points. Examples of these states can be those such as gelatines or glasses, or surface freezing, where an extremely thin layer of molecules will freeze, whereas the rest of the liquid will remain a liquid. These phenomenon can be mapped with computers, by graphing the free energies of these substances, and also graphing density fluctuations of these substances, found by light scattering through these materials. Other important implications of soft condensed matter include various biological systems such as self organizations of lipid structures within cells, as well as DNA molecules.

5 Random Walks and Bacterial Movement

Jonathan Meerveld — Dec.5, 15:40–16:05

Abstract

The knowledge of how and why bacteria move is recent to the last 20–30 years and new discoveries are still being made in this field. It is known that bacteria could actually move at a speed of approximately 13 m/s if there were no obstructions to its path. Of course, due to the incredibly viscous solution it is immersed in, movement is very difficult. In fact there is no coasting whatsoever. In order to cope with this situation, a typical bacterium has one or more flagella which will rotate either clockwise or counter-clockwise somewhat like a corkscrew. Although this is a very inefficient propulsion system (as low as 1% efficiency), bacteria do not waste energy by just moving for the sake of moving, and their means or transportation uses many times less energy per weight then humans. They move in two patterns in seemingly random directions, but using statistics and probability distributions, it is possible to map the three-dimensional walk of a bacterium.

6 Why is the Sky Blue?

Violet Zizian — Dec.5, 16:05–16:30

Abstract

Why is the sky blue? This question has most likely crossed everyone's mind at one point in their lives. For many, it was probably as a young child during their questioning stage. However, many years later you may still be curious about this fact of life. This presentation will discuss the reasoning behind the appearance of the blue sky and what factors contribute to this interesting outcome. This presentation will explain how the scattering of light due to Rayleigh scattering, also known as the Tyndall Effect, causes us to see the sky as blue. However, other factors such as the atmosphere (and the components that create it), the wavelength of the light, the size of the particles/molecules that the light hits, and the colour receptors of the human eye play a significant role in how we perceive the sky and these will be examined as well. Another important aspect that will be discussed is how the molecules cause the light to scatter as a result of the electromagnetic field of the light waves. As one can see, many elements work together to create a blue sky, and this discussion will aim to create a better understanding of how this occurs.

For more information, check out these websites:

- `http://www.math.ucr.edu/home/baez/physics/General/BlueSky/blue_sky.html`
- `http://www.sciencemadesimple.com/sky_blue.html`
- `http://en.wikipedia.org/wiki/Diffuse_sky_radiation`

7 Measuring Cosmic Microwave Background Radiation

Ivana Komljenovic — Dec.5, 16:30–16:55

Abstract

One of the most important cosmological discoveries in the last century and the most conclusive piece of evidence for the Big Bang is the existence of cosmic microwave background radiation (CMBR). This conclusion has come about through the study and analysis of pictures of the galaxies and stars. More specifically, physicists are able to look at a picture of colourful gases and determine what parts of the two-dimensional image specify a black-body, a star, or planet through statistical calculations. This presentation will focus on the methods used by physicists to understand CMBR and how the analysis of measurements allow scientists to determine the current temperature of the universe. By studying CMBR, we are also able to construct a better understanding of the thermal history of the universe.

8 CMB Radiation and the Early Universe

Jeremy Robic — Dec.16, 14:00–14:25

Abstract

Abstract not submitted on time, an automatic 5/35 deduction. This student has been assigned the above presentation topic.

The Cosmic Microwave Background Radiation is a phenomenon that has been known about for decades. The anisotropic nature of the CMBR give added detail about the universe we live in, as well as its origins. The fact that the CMBR is not constant throughout itself gives a deeper understanding about the state the universe was in during the recombination stage. By understanding the meaning behind this fluctuation of radiation, or Anisotropy, a broader understanding of the matter density distribution can be made. Though these fluctuations are only on the order of 10-5, the conclusions it draws provide information on two separate quantities of the anisotropies:

1. Primary Anisotropies, which provide details on the curvature of the universe as well as the baryon and matter densities,
2. Secondary Anisotropies, which arise from effects along the photon path AFTER recombination.

9 Chaotic Behaviour

Stuart Bell — Dec.16, 14:25–14:50

Abstract

Using examples of distributions introduced in class, and other simple examples, this presentation will introduce the basic concepts of information theory, followed by an application of information theory to an example of a dynamic system. In this case a dripping faucet. This is done in hope of being able to predict future behaviour of the system by knowing its past behaviour. Of course, other features of dynamic systems will also be introduced through simple examples (*i.e.* attractors and entropy). The presentation will also discuss each phase of the dynamic system, from periodic behaviour through to its chaotic behaviour.

10 The Monte Carlo Method

Brian Eng — Dec.16, 14:50–15:15

Abstract

Monte Carlo methods are stochastic techniques used to simulate the behavior of physical and mathematical systems. This presentation will give a brief history, a basic understanding, and some examples of Monte Carlo methods. Of the several types of Monte Carlo algorithms, one of the most common subsets, Monte Carlo integration, will be explained. Common applications, efficiency, and the dependence on random (or rather, pseudo-random) numbers will be discussed.

Follow these links for more information:

- Wikipedia:
  `http://en.wikipedia.org/wiki/Monte_Carlo_method`
- Wolfrom MathWorld:
  `http://mathworld.wolfram.com/MonteCarloMethod.html`
- The Computational Science Education Project:
  `http://www.phy.ornl.gov/csep/CSEP/MC/MC.html`

11 Phase Trasition

Lingyu, Wei — Dec.16, 15:15–15:40

Abstract

First I will describe six types of the phase trasitions: melting, freezing, boiling(evaporation), condensation, sublimation and deposition. Then, i will tell the classification of phase transitions: First-order phase transitions, second-order phase transitions(also called continuous phase transitions) and infinite-order phase transitions. And then i would introduce some Properties of phase transitions, like Critical points, Symmetry and Critical exponents and universality classes. Aftermost, i'd like talk about the phase-change data storage, two representative examples: Phase change and optical disc technology and Phase-change memory. And some other properties...

12 Antiferromagnetism in Ising model systems

Jason Tang — Dec.16, 15:40–16:05

Abstract

Abstract not submitted on time, an automatic 5/35 deduction. This student has been assigned the above presentation topic.

13 Renormalization group methods

Kyle Weymark — Dec.16, 16:05–16:30

Abstract

Abstract not submitted on time, an automatic 5/35 deduction. This student has been assigned the above presentation topic.