PHY293F1 - Particles Part

Lecturer: Prof. Kaley Walker

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- Replies to e-mail within 2 business days (i.e. excluding weekends) but will not answer detailed questions by e-mail

Office hours: Fridays 14:00 – 15:00

Course website for Particles Part:

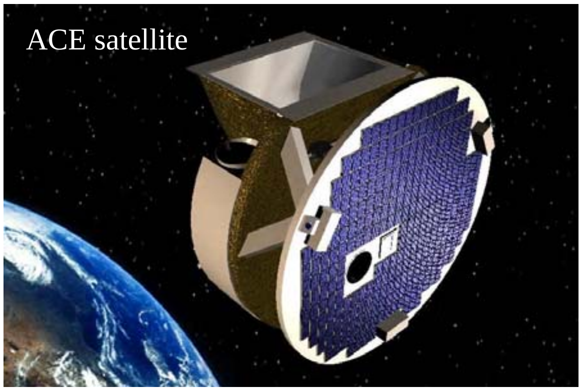
- http://www.physics.utoronto.ca/~phy293h1f/293_particles.html
- Class announcements given on the website

Lectures: 3 hours/week in MP203

- Mon. 15:00-17:00, Tues. 15:00-17:00 and Fri. 15:00-17:00

My research (1)

- I am the Deputy Mission Scientist for the Atmospheric Chemistry Experiment (ACE) satellite
- Launched in August 2003 for a two-year mission and still going strong…
- We measure over 30 different species in the Earth's atmosphere each day to study the changing composition relating to
  - Ozone depletion
  - Air quality
  - Climate change



My research (2)

- Studying the Arctic atmosphere from the Canadian high Arctic - PEARL in Eureka, Nunavut
- A team of researchers will be going up there to see what happens when sunlight returns to the high Arctic (Feb.- Apr.)

- On Ellesmere Island, 1100 km from the North Pole
- PEARL is the most northern civilian research laboratory in the world
- Nearest community is 420 km south at Grise Fiord

PEARL, Eureka, Nunavut, 80 °N

Textbook and Resources

An Introduction to Thermal Physics, Daniel V. Schroeder (Addison Wesley Longman, 2000)

- Available at UoT bookstore etc., should be some used ones

Additional references available on short-term loan from the Physics and Gerstein libraries – listed under PHY293

- *Thermal Physics*, Kittel and Kroemer (Freeman, 1980)
- *Thermal Physics*, Ralph Baierlein (Cambridge University Press, 1999)
- *Fundamentals of Statistical and Thermal Physics*, Frederick Reif (McGraw Hill, 1965)

Course Evaluation Recap

- Problem Sets (four in the Particles Section)
  - Posted Mondays due following Monday by 5 PM
  - Only one question (or sometimes two) will be marked and solutions will be posted
  - Answers should be written up independently
  - *Late problem sets (after 5:10 PM) will not be accepted*
- Midterm Test
  - Thursday 19 Nov. at 9:30 - 10:20 AM (50 min.) in EX200
- Final Exam
  - During Dec. exam period - TBA
  - Will cover all course material (Waves and Particles)

293F1 – Particles Course Schedule

Monday	Tuesday	Wednesday	Thursday	Friday
26 Oct First lecture	27 Oct	28 Oct	29 Oct	30 Oct
2 Nov Problem Set #1 due	3 Nov	4 Nov	5 Nov	6 Nov
9 Nov Problem Set #2 due	10 Nov	11 Nov	12 Nov	13 Nov
16 Nov	17 Nov	18 Nov	19 Nov **Midterm 2 - 9:30 in EX 200**	20 Nov
23 Nov Problem Set #3 due	24 Nov	25 Nov	26 Nov	27 Nov
30 Nov Problem Set #4 due	1 Dec	2 Dec	3 Dec	4 Dec
7 Dec Last class	8 Dec Course review	9 Dec	10 Dec **EXAMS Start**	

Outline of Course

- Course will generally follow the textbook and will cover most of Chapters 1-3 and 5-7
- No prior knowledge of statistical physics is assumed but will assume that you are familiar with thermodynamic functions such as enthalpy, entropy, etc.
- Some quantum mechanics would be helpful but not required
  - Appendix A in textbook provides a very brief introduction to quantum mechanics - we will review this in class
- Lecture notes will be posted after each day of class
- The best way to learn this material is by solving problems
  - Try to do the problem sets yourself

Tentative outline of topics (with ref.)

1. Overview of statistical mechanics
2. Temperature and review of thermodynamics (1.1 – 1.4; 1.6)
3. Two-state system and multiplicity (2.1 – 2.3)
4. Large systems and multiplicity (2.4)
5. Entropy (2.6)
6. Temperature and entropy (3.1 – 3.2)
7. Paramagnetism (3.3)
8. Pressure and thermodynamic identity (3.4, 5.1 – 5.2)
9. Boltzmann factor and partition function (6.1)
10. Paramagnetism revisited (6.2)
11. Partition function and free energy (6.5 – 6.6)
12. Ideal gas (6.7)
13. Blackbody radiation (7.4)
14. Blackbody radiation continued (7.4)
15. Debye theory of solids (7.5)
16. Chemical potential and Gibbs factor (3.5, 7.1)
17. Quantum statistics (7.2)
18. Degenerate Fermi gases (7.3)

approx.
mid →
term

What is Statistical Mechanics?

- Here we start with thermodynamics
  - Study of properties of matter that do not depend on microscopic details of atoms

- Statistical mechanics - provides underlying explanation of thermodynamics at microscopic level
  - Using quantum mechanics, we can calculate (in most cases, with some difficulty) behavior of one atom or molecule
  - To explain and predict average behavior of 10^{23} atoms or molecules, need to use statistics to go from one to many

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Why Statistical Mechanics?

- Using the microscopic theory of thermodynamics
- To investigate something that we can measure
  - Temperature
  - Specific heat (heat capacity)
  - Magnetization
- Applications
  - Condensed matter physics → magnetics, supercond.
  - Atomic and molecular physics → primarily gas phase
  - Atmospheric physics, astronomy and astrophysics

    ↳ remote sensing of properties

Temperature

- What is temperature?
  - Operational definition: Temperature is what you measure with a thermometer
  - Theoretical definition: The thing that is the same for two objects, after they've been in contact long enough
- More terminology
  - After two objects have been in contact long enough, they are in thermal equilibrium.
  - The time required for a system to come to thermal equilibrium is called the relaxation time.
  - Contact is when two objects can exchange energy spontaneously in the form of heat.

→ conduction
or radiation

More about Equilibrium

Exchanged quantity	Type of equilibrium
energy	thermal
volume	mechanical
particles	diffusive

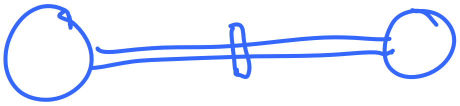
- Temperature is a measure of the tendency of an object to spontaneously give up energy to its surroundings.
  - When two objects are in thermal contact, the one that tends to spontaneously *lose* energy is the one at *higher* temperature.

- But how do you assign a numerical value for temperature?

Thermometers

- How to measure temperature
  - Thermal expansion → alcohol or mercury
  - Thermo-electric effect (thermocouple)
    ↳ related change V to T
  - Blackbody radiation
    ↳ "in ear" thermometer
  - Other electrical properties
    - e.g. Change in resistance of standard object
  - Gas thermometer

fixed volume of gas

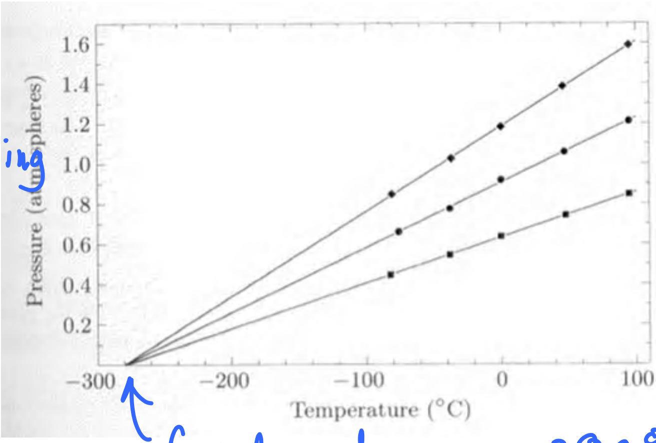


gauge relates change in pressure to temperature

Temperature Scale

- Celsius (centigrade)
  - Uses water: freezing point at 0 ºC and boiling point at 100 ºC
- Kelvin (absolute temperature scale)
  - 273.15 ºC = 0 K

extrapolate to find zero due to liquifying of gas



starting with different volumes

fairly close ~ -280°C
differ due to different volumes

Ideal Gas

This is one of three model systems we will be using

- Ideal gas:

number of moles

pressure in Pa → $$PV = nRT$$ ← temperature in K

Volume m^3 ↗ ↖ $R = 8.31$ J/mol/K

← Boltzmann constant 1.381×10^{-23} J/K

$$PV = NkT$$

↑ number of molecules

- Not exactly true for real gas so when is this model usable?
  - It is valid is the limit of low density
  - For most purposes, accurate enough for air (and other common gases) at room temperature and atmospheric pressure

~10 x size of molecule for average distance