Thermal Physics

Exam 1 Outline

Heat *Q*

- What is heat?
- How are heat and work different? How similar?
- What are three types of heat?
- Why is it wrong to say that one object has "more heat" than another?

Thermal Energy *U*

- What is thermal energy (or internal energy)? How is it manifested?
- What is a degree of freedom?
- What is a quadratic degree of freedom?
- What is the equipartition theorem, and what does *f* mean?
- When is the equipartition theorem valid?
- How does one find *f* in the presence of the following degrees of freedom?
  - translational
  - rotational
  - vibrational
- What does it mean when a d.o.f. "freezes out"?

Absolute Temperature *T*

- What is an absolute temperature scale?
- What units do we use to measure absolute temperature?
- When is it okay to use Celsius temperatures in a formula?

Heat Capacity *C* and Specific Heat *c*

- Define heat capacity *C*
- If rock A has twice the heat capacity of rock B, which rock will warm up faster in the sun?
- Define specific heat *c*.
- Given two objects with temperatures T_i and heat capacities C_i, find the final temperature
- What is the heat capacity of an object that obeys the equipartition theorem?

Latent Heat *L*

- Define latent heat.
- Heat flows at an even rate into ice (at -5°C), transforming it into water (5°C),
  - Find the total heat that enters the ice
  - Sketch a graph of the change in the water's temperature over time
  - Why is ice so good at cooling things?

Ideal Gas

- What is an ideal gas?
- What is the ideal gas law equation?
- What are the SI units for pressure? What is the standard pressure?
- If the volume of an ideal gas increases by ΔV, is work done on the gas or by the gas? How much work flows?

- Define quasistatic limit
- What is the difference between the heat capacity at constant volume, and the heat capacity at constant pressure?
- Understand the statistical mechanical derivation of the ideal gas law.
- Define root-mean-square (from homework).
- What is the root-mean-square speed of one molecule of an ideal gas?

Counting

- What does the variable Ω represent?
- If event A has 6 possible outcomes, and event B has 5, how many possible outcomes are there when considering A and B together?
- If an event has k possible outcomes, how many possible outcomes are there if you repeat the event N times?
- How many ways can you rearrange N different items?
- How does this result change if some of the items are duplicates?
- What is a permutation? How do you calculate Ω for a permutation?
- What is a combination? How do you calculate Ω for a combination?
- What is "a choose b" equal to?
- How many ways can you put q balls into N boxes, if the boxes can contain more than one ball?

Probabilities

- If all outcomes are equally likely, what is the probability that any one outcome will occur?
- What is the difference between a microstate and a macrostate?
- What is the multiplicity of a macrostate?
- How do you calculate the probability of a macrostate?

Very Large Numbers

- What kinds of numbers qualify as very large numbers?
- What approximations can we make when working with VLNs?
- What is Stirling's approximation? Be able to use it.

Paramagnet

- Describe the two-state paramagnet model.
- How many microstates does a N-dipole paramagnet have?
- What is the energy of a dipole that points against an external magnetic field? In the same direction as that field?
- Consider the energy macrostates of an N-dipole paramagnet in a magnetic field:
  - How many macrostates are there?
  - How would you characterize each macrostate? (i.e. what variable can we use to distinguish one macrostate from another?)
  - What is the multiplicity of each macrostate?

Einstein Solid

- Describe the Einstein solid model. What do N and q represent?
- How many microstates does an Einstein solid have, given N and q?
- Why is it called an Einstein "solid"?

- If N and q are both large numbers, what is Ω…
  - …in the high-temperature limit?
  - …in the low-temperature limit?
- In a single Einstein solid, we say all "accessible" microstates are equally likely. What does accessible mean, in this context?

Two Einstein Solids

- How do we characterize the energy macrostates of two Einstein solids which can exchange energy with each other?
- What is the multiplicity of a given energy macrostate?
- How would you go about finding the most likely macrostate?
- For large systems, what shape does the probability function have? What happens to that curve as the size of the system increases?

Entropy

- How is entropy related to the number of microstates of a system?
- What do we mean when we say that entropy is additive?
- What is the second law of thermodynamics?

Ideal Gas

- How many microstates does a single particle in a 1-dimensional box have? Explain each part of the equation.
- Describe the properties of the gamma function.
- What is $\Gamma(0)$, $\Gamma(1/2)$, $\Gamma(1)$, $\Gamma(3/2)$, $\Gamma(2)$?
- What is the surface area of an n-dimensional sphere with radius R?
- How many microstates do N particles in a 3-dimensional box have? Explain each part of the equation.
- What is the Sackur-Tetrode equation?
- What is the Gibbs paradox and how is it resolved?

Thermal Equilibrium

- What are two conditions that determine if two systems are in thermal equilibrium with each other?
- What is the definition of temperature in terms of entropy?
- Understand the derivation we did with $\partial S/\partial U$, etc.
- In the expression $(\partial x/\partial y)_z$, what does the z signify?
- By looking at the entropy function of a system, how can we determine whether it satisfies the equipartition theorem, and determine its number of degrees of freedom?

Heat and Entropy

- What is the relationship between heat and entropy?
- What is the only way that the entropy of a system can decrease?
- What is the change in entropy of a system which changes temperature with constant heat capacity?
- What does the Third Law of Thermodynamics say?
- What does the Third Law imply about heat capacity? About the number of degress per freedom in a material?