PHY2001 Assignment 3
Statistical Mechanics Assignment:
Deadline Mon 6th Dec 22:00

- Assignments to be submitted electronically to Canvas (via appropriate "Assignment" page).
- Please upload a single pdf file, and make sure the scan is readable.
- All students should attempt all questions.
- Show your working and explain your reasoning in all cases.
- The assignment will be marked out of 50.
- For each question, what you need to do depends on the last digit of your student number: make sure your solutions correspond to the correct case.

Q1:

Consider a system of N distinguishable particles that are distributed across single-particle states with energies of 0, 1 eV, 2 eV, 3 eV, 4 eV, 5 eV... etc. The total energy of the system is U. For your calculations, adopt values for N and U that correspond to your student number from this Table:

Last digit of student number	N	U
1, 5, 9	5	3 eV
2, 6, 0	3	6 eV
3, 7	2	9 eV
4, 8	4	4 eV

(a) Find all the possible distributions of the particles in the system and hence calculate the total number of microstates of the system, Ω.

[10 marks]

(b) If one of the particles were removed from the system but the energy of the system remains the same, what is the change in entropy? (I.e. calculate $\Delta S = S_f - S_i$ where S_i is the initial entropy and S_f is the entropy after one particle is removed.)

[8 marks]

(c) Explain the physical interpretation of the sign of your answer to part (1b).

[2 marks]

Q2:

Consider a system of hydrogen atoms in equilibrium at temperature, T. For your calculations, you may assume that the system is governed by Boltzmann statistics, and you should adopt the value of T corresponding to your student number from this Table:

Last digit of student number	T
1, 4, 0	30,000 K
3, 6, 9	50,000 K
5, 8	90,000 K
7, 2	120,000 K

(a) Use your knowledge of the energy levels and degeneracies of the hydrogen atom to calculate the fraction of the hydrogen atoms in the system that will occupy the $n = 2$ energy level. Only consider the $n = 1$ and 2 energy levels when estimating the partition function.

[7 marks]

(b) By what factor would your answer to (2a) change if you were to include the $n = 3$ and 4 energy levels in your calculation of the partition function?

[4 marks]

(c) Estimate the temperature at which the number of particles in the $n = 1$ energy level would be equal to the number in the $n = 2$ energy level.

[4 marks]

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Q3:

A population of particles is confined to a 3D cubic box. For your calculation, assume the particle type and box size are those corresponding to the last digit of your student number in this Table:

Last digit of student number	Particle	Particle Spin, s	Box side length (m)
1, 2, 3	Electrons	1/2	10^{-2}
4, 5, 6	O_2 molecules	0	10^{+1}
7, 8	Protons	1/2	10^{-1}
9, 0	Alpha particles ($={}^4$He)	0	10^{-5}

(a) Taking spin degeneracy into account, estimate the number of single-particle states available to the particles that have energy between 0.060 and 0.061 eV.

[6 marks]

(b) Estimate the total number of single-particle states available that have energy less than $k_B T$ for a temperature $T = 350\text{K}$.

[6 marks]

(c) If the system contains $N = 10^{22}$ particles, state whether you expect that it can be well-described as a *dilute gas* at $T = 350\text{K}$. Briefly explain your reasoning.

[3 marks]

[END OF ASSIGNMENT]