THERMAL AND KINETIC PHYSICS (PHY 214)

Coursework 1 : Week 1

ISSUE: Tuesday 28 September, 2010 HAND-IN: Tuesday 05 October, 2010

Hand-in of worked exercises must take place by 4:00 p.m. on the above date at the labeled box provided outside the Teaching Administrators office on the first floor. This time will be strictly adhered to and no late working will be accepted without written explanation to the course organiser. The solutions will appear shortly after this time on the TKP website.

Each coursework is worth 40 marks and the aggregate coursework mark will count 10% towards the final mark. An indicative mark scheme is given with each question.

Course title, exercise number, student's name and exercise group (eg. KJD1) should appear on every sheet of the submitted coursework and sheets should be firmly held together (stapled).

Students should collect new exercise sheets in the Tuesday lecture or download them from the Web. Marked exercises will be returned in exercise classes or via the box outside the Teaching Administrators office on the first floor.

I will frequently use questions taken from Finn (Appendix 4 or (D)) for homework. Note that although the correct answers are given in the book, I want to see the method of solution. No credit will be given for simply writing down the answer.

QUESTION 1: **[10 Marks]** (Question 1 Chapter 1 in Finn). The length of the mercury column in a mercury-in-glass thermometer is 5 cm when the bulb is immersed in water at its triple point. What is the temperature on the mercury-in-glass scale when the length of the column is 6 cm ? **[3mks]**

What will the length of the column be when the bulb is immersed in a liquid at 100 degrees above the ice point, as measured on the mercury-in-glass-scale? **[3mks]**

If the length of the column can be measured to within only 0.01 cm, can this thermometer be used to distinguish between the ice point and the triple point of water? You may take the temperature of the ice point, as measured on the mercury-in-glass scale, as 273.15 degrees **[4mks]**

QUESTION 2:[10 Marks] (Question 3 Chapter 1 in Finn) The table below lists the observed values of the pressure P of a gas in a constant-volume gas thermometer at an unknown temperature, and at the triple point of water, as the mass of gas used is reduced.

P_{TP} (torr)	100	200	300	400
P (torr)	127.9	256.5	385.8	516

By considering the limit, $\lim_{P_{TP} \to 0} (P/P_{TP})$, determine the ideal gas temperature T to two decimal places.

Is this ideal gas temperature greater than or less than the empirical temperature that would be given by any one of the experimental data sets listed above? NOTE: You may do this question graphically or by numerical extrapolation. Be careful that you make the right choice of variables to plot or extrapolate. **[10 mks]**

QUESTION 3: **[20 Marks]** The simple kinetic theory argument sketched in the lectures and in Feynman's lecture notes shows that the ideal gas temperature T is a measure of the mean kinetic energy of a molecule of mass m,

$$\overline{\frac{mv^2}{2}} = \frac{3}{2} k_B T$$

Conversely, we define the root mean square speed of a typical gas molecule by

$$v_{rms} = \sqrt{\bar{v}^2} = \sqrt{\frac{3k_B T}{m}}$$

a) (From the 2005 examination paper) A mixture of Argon atoms (A, atomic weight 40 amu) and molecular Nitrogen (N_2, molecular weight 28 amu) is in equilibrium.

(i) Calculate the temperature T of this gas, given that the mean kinetic energy of the N_2 molecules is 0.05 eV. **[2 mks]**

(ii) Calculate also the root mean square velocity of the A atoms and N_2 molecules **[4 mks]**

b) In our Condensed Matter research group carbon nanotubes are being studied. The simplest member of this family of giant molecules is a "buckyball" which is a molecule made of 60 carbon atoms (each atom of atomic mass 12 amu) which form a closed structure much like the surface of a football. If such a molecule escapes into the atmosphere at a temperature of 300 K, what will be its root mean square speed? **[3 mks]**

c) In the centre of a star, matter exists as a gas of completely ionised nuclei and electrons. How hot would the star have to be in order that the root mean square speed of an electron should be about $0.1c$ where c is the speed of light in vacuum? **[5 mks]**

d) What would the temperature of the atmosphere have to be at sea level in order that the root mean square speed of an oxygen molecule (O_2,molecular weight32 amu) be equal to the escape velocity from the Earth's surface?

[6 mks]