Physics II
ISI B.Math
Back Paper Exam : January 6, 2013

Total Marks: 50
Time: 3 hours
Answer any 5 questions

1. **(Marks = 3 + 3 + 4)**

A cylindrical container 80 cm long is separated into two compartments by a thin piston, originally clamped in position 30 cm from the left end. The left compartment is filled with one mole of helium gas at pressure of 5 atmospheres; The right compartment is filled with argon gas at 1 atmosphere of pressure. These gases are monatomic and can be considered ideal. The cylinder is then submerged in one litre of water and the entire system is initially at a uniform temperature of $25°C$. The heat capacity of the cylinder and the piston may be neglected. When the piston is unclamped, a new equilibrium situation is reached, with the piston in a new position.

(a) What is the increase in temperature of the water ?
(b) How far from the left end of the cylinder will the piston come to rest?
(c) What is the increase of the total entropy of the system ?

2. **(Marks = 5 + 5)**

(a) Show that

$$\left(\frac{\partial U}{\partial V}\right)_T = T\left(\frac{\partial P}{\partial T}\right)_V - P$$

(b)Show that a gas which obeys the van der Waals equation $(p + \frac{a}{V^2}) \times (V - b) = RT$ and whose molar specific heat at constant volume C_V is a constant and independent of temperature, the internal energy (per mole) U is given by

$$U = C_V T - \frac{a}{V} + const$$

3. **(Marks = 10)**

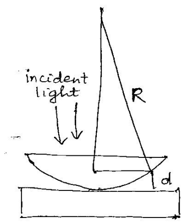
The heat capacity of nonmetallic solids at sufficiently low temperatures is proportional to T^3, as $C = aT^3$. Assume it were possible to cool a piece of such a solid to $T = 0$ by means of a reversible refrigerator that uses the solid specimen as its low-temperature (variable!) reservoir, and for which the high temperature reservoir has a fixed temperature T_h equal to the initial temperature T_i of the solid. Find an expression for the electrical energy required.

4. **(Marks = 4 + 6)**

A simple harmonic one-dimensional oscillator has energy levels given by $E_n = (n + \frac{1}{2})\hbar\omega$, where ω is the angular frequency of the oscillator and the quantum number n can assume possible integral values $n = 0, 1, 2, \cdots$. Suppose such an oscillator is in thermal contact with a heat reservoir at temparature T low enough so that $\frac{kT}{\hbar\omega} \ll 1$.
(a) Find the ratio of the probability of the oscillator being in its first excited state ($n = 1$) to the

probability of being in its ground state ($n = 0$).
(b) Assuming only the ground state and the first excited state are appreciably occupied, find the mean energy of the oscillator as a function of the temperature T.

5. **(Marks = 5 + 2 +)**



The above figure shows a lens of radius of curvature R resting on an accurately plane glass plate and illuminated from above by light of wavelength λ. Circular interference fringes appear, associated with the variable thickness air film between the lens and the plate. $R \gg r$.
(a) Show that the radius of the bright ring of radius r is given by $r = \sqrt{(m + \frac{1}{2})\lambda R}$ where $m = 0, 1, 2, \cdots$. Is the central spot, seen by reflection, dark or bright?
(b) If the radius of curvature of the lens is 5.0 m and its diameter is 2 cm, how many rings will be produced ? Will the number of rings increase, decrease or remain the same if the arrangement were immersed in water? Explain.

6. **(Marks = 5 + 5)**

In a double-slit experiment, the wavelength λ of the light source is 405 nm, the slit separation is 19.44 μm and the slit width is 4.050 μm. Consider both interference and diffraction of light from the two slits.
(a) How many bright interference fringes are within the central peak of the diffraction envelope?
(b)How many bright fringes are within either of the first side peaks of the diffraction envelope ?