Physics II
ISI B.Math
Backpaper Exam : January 1, 2020

Total Marks: 75
Time: 3 hours
Answer all questions

1. **(Marks : 15 = 5 + 5 + 5)**

(a) Regarding the internal energy of a hydrostatic system to be a function of T and P, derive the following equations

$$\left(\frac{\partial U}{\partial T}\right)_P = C_P - PV\beta$$

$$\left(\frac{\partial U}{\partial P}\right)_T = PV\kappa - (C_P - C_V)\frac{\kappa}{\beta}$$

where κ and β are the isothermal compressibility and the the coefficient of isobaric volume expansion respectively.

(b) An ideal gas with $\gamma = \frac{C_p}{C_v}$ undergoes a quasi-static adiabatic expansion from (P_i, V_i) to (P_f, V_f) Show that the work done by the gas is

$$W = \frac{P_f V_f}{\gamma - 1}\left[1 - \left(\frac{P_i}{P_f}\right)\right]^{(\gamma-1)/\gamma}$$

2. **(Marks : 15 = 3 + 5 + 7)**

A reversible heat engine operates between two reservoirs T_1 and T_2 where $T_1 < T_2$. The reservoir at T_1 can be considered to be of infinite mass, i.e, T_1 remains constant. However the warmer reservoir at T_2 consists of a finite mass of gas (μ moles with specific molar heat capacity C_v).After the engine has operated for a long time period, the temperature of the warm reservoir is lowered to T_1.

(a) What is the heat extracted from the warmer reservoir during this period ?

(b) What is the change of entropy of the warmer reservoir during this period ?

(c) How much work did the engine do during this period ?

3. **(Marks : 15 = 3 + 6 + 6)**

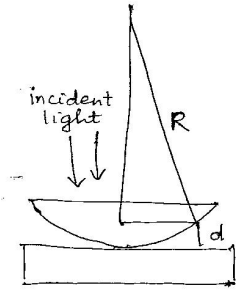
Consider a system of N particles. Each of the particles can be in one of two states with energies 0 and ϵ.

(a) Write down the partition function for the system.

(b) Find the Helmholtz free energy and the average energy of the system

(c) Determine the heat capacity at constant volume for this system and sketch it as a function of temperature

4. **(Marks : 15 = 6 + 2 + 2 + 5)**



(a) In the Newton's ring arrangement of a plano-convex lens of radius of curvature R placed on a glass plate as shown in the figure is illuminated with monochromatic light of wavelength λ. The refractive index of the glass plate and lens is 1.5. Show that the radius r_m of the mth dark ring of the interference pattern at the location where the thickness of the air film is d is given by

$$r_m \simeq \sqrt{m + \frac{1}{2}}\lambda R$$

(b) Will the centre spot of the ring pattern be dark or bright ? Explain.

(c) If the air gap between the lens and the plate is filled with oil of refractive index 1.7 will the central spot be dark or bright ?

(d) Two transparent slabs having equal thickness but different refractive indices μ_1 and μ_2 are pasted side by side to form a composite slab. The slab is placed right after the double slit in Young's experiment such that light from one slit goes through one material and light from the other slit goes through the other material. If the slits are illuminated with light of wavelength λ, what should be the minimum thickness of the slab so that there is a minimum at the point P_0 which is equidistant from both slits on the screen ?

5. **(Marks : 15 = 10 + 2 + 3)**

(a) In a double slit Fraunhofer diffraction what is the fringe spacing on a screen 50 cm away from the slits if they are illuminated with blue light ($\lambda = 4800\mathring{A}$) if the separation between slits $d = 0.10$mm and if the slit width $b = 0.02$ mm ? What is the linear distance from the central maximum to the first minimum of the fringe envelope ? How many interference fringes lie within the central peak of the fringe envelope ?

(b) State one method of obtaining a linearly polarized light wave from an unpolarized light wave.

(c) What is the state of polarization of a wave whose x and y components of the electric field are given by $E_x = E_0 \cos(\omega t + kz)$ and $E_y = \frac{E_0}{\sqrt{2}} \cos(\omega t + kz + \pi)$, where the symbols have their usual meanings?