Physics II
ISI B.Math
Backpaper Exam : January 2, 2018

Total Marks: 50
Time: 3 hours
Answer all questions

1. **(Marks : 3 + 4 + 3 = 10)**

Consider the earth's atmosphere as an ideal gas of molecular weight μ in a uniform gravitational field. Let g denote the acceleration due to gravity and γ the ratio between the specific heat at constant pressure and the specific heat at constant volume.
(a) If z denotes the height above sea level, show that the change in atmospheric pressure with height is given by

$$\frac{dp}{p} = -\frac{\mu g}{RT} dz$$

where T is the absolute temperature at height z.
(b) If the decrease in pressure in (a) is due to adiabatic expansion, show that

$$\frac{dp}{p} = \frac{\gamma}{\gamma - 1} \frac{dT}{T}$$

(c) From (a) and (b) calculate $\frac{dT}{dz}$ in degrees per kilometre. Assume the atmosphere to consist of mostly nitrogen , for which $\gamma = 1.4$.

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

(a) 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 energy required.

(b) One mole of ideal gas undergoes a reversible isothermal expansion from a volume V_1 to volume V_2 . Find the change in entropy of the gas and the change in entropy of the universe. Suppose the same expansion takes place as adiabatic free expansion. Find the change in entropy of the gas and the change in entropy of the universe.

3. **(Marks : 3 + 7 = 10)**

(a) Find the partition function for a system with N particles that can exist in only two states, one at energy 0 and one at energy ϵ .

(b) Find the expressions for the Helmholtz free energy, internal energy , entropy and heat capacity at constant volume for the system using the result in (a)

4. **(Marks : 5 + 5 = 10)**

(a) A Young's double slit experiment is performed with light of wavelength $\lambda = 5 \times 10^{-5}$cm. When a thin film of transparent material is placed in front of one of the slits the zero order fringe moves to the position previously occupied by the fourth order fringe. The refractive index of the film is 1.2. Find the thickness of the film.

(b) The rhinestones in costume jewellery are glass with refractive index 1.50. To make them more reflective, they are often coated with a layer of silicon monoxide of index of refraction 2.00. What is the minimum coating thickness needed to ensure that light of wavelength 560 nm and of perpendicular incidence will be reflected from the two surfaces of the coating with fully constructive interference?

5. **(Marks : 3 + 4 + 3 = 10)**

(a) Describe the state of polarization when the x and y components of the electric field are given by $E_x = E_0 \cos(kz + \omega t), E_y = E_0 \sin(kz + \omega t)$ where the symbols have their usual meanings.

(b) Consider Fraunhofer diffraction by a single slit of width a illuminated by coherent light of wavelength λ. Calculate approximately, the relative intensities $\frac{I_\theta}{I_m}$ (I_θ and I_m are respectively the intensity of light diffracted at an angle θ and the maximum intensity) of the secondary maxima. You may use the approximation that the secondary maxima lie approximately halfway between the minima. A derivation of the intensity pattern is not necessary.

(c) For a double slit diffraction pattern with slit width b and slit separation d, if $b = d$, show that the intensity pattern is the same as that for a single slit of width $2b$. You need not derive the intensity patterns in the two cases but may directly use the formulas.