Physics II
ISI B.Math
Back Paper Exam : July 5, 2010

Total Marks: 100
Answer any five questions

1. (a) A mole of ideal gas with pressure P_1 and volume V_1 is freely and adiabatically expanded to V_2 while maintaining pressure at P_2. Finally the gas is heated quasi-statically until the pressure returns to P_1 while the volume remains V_1. This cycle is called Mayer's cycle. Prove Mayer's relation $c_p - c_v = R$ using this cycle. Assume that the molar specific heat is constant.(10)
(b) Using Maxwell's relations show that

$$C_P - C_V = VT\frac{\alpha^2}{\kappa}$$

where C_P and C_V are the heat capacities at constant pressure and constant volume respectively, α is the coefficient of volume expansion and κ is the isothermal compressibility . Show that it reduces to Mayer's relation in the case of an ideal gas.(10)

2. 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 a pressure of 5 atmospheres; the right compartment is filled with argon gas at 1 atmosphere of pressure. These gases may be considered ideal. The cylinder is submerged in 1 litre of water, and the entire system is initially at the uniform temperature of 25° C. The heat capacities of the cylinder and the piston may be neglected. When the piston is unclamped, a new equilibrium situation is ultimately reached with the piston in a new position.
a) What is the increase in the temperature of the water?(6)
b) What is the final position of the piston ? (7)
c)What is the increase of total entropy of the system? (7)

3. (a) Calculate the maximum work in Joules obtainable from a heat reservoir consisting of 200 kg of iron heated initially to a temperature of 1500° C, using the ocean, at 12° C, as the second heat reservoir. Assume that the specific hear capacity of iron is constant and is equal to 60 joules/gram-deg.(10)
(b) Calculate the entropy change of the universe in this process. (10)

4. The diagram shows a double slit experiment in which monochromatic light of wavelength λ from a distant source is incident upon two slits, each of width w ($w \ll \lambda$) and an interference pattern is seen on a distant screen.
A thin piece of glass of thickness δ and index of refraction n is placed between one of the slits and the screen, and the intensity of the central point C is measured as a function of the thickness δ. If the intensity for $\delta = 0$ is given by I_0
(a) What is the intensity at C as a function of δ ? (5)
(b) for what values of δ is the intensity at C minimum ?(4)
(c) Suppose that the width of one of the slits is now increased to $2w$, the other width remaining unchanged. What is the intensity at point C as a function of δ? Assume that the glass does not absorb any light.(6)
(d) Each of four pairs of light waves arrives at a certain point on the screen. The waves have the same wavelength. At the arrival point their amplitudes and phase differences are

(i)$2E_0, 6E_0$ and π radians (ii)$3E_0, 5E_0$ and π radians (iii) $9E_0, 7E_0$ and 3π radians (iv)$2E_0, 2E_0$ and 0 radians. Rank the four pairs according to the intensity of light at those points, greatest first.(5)

5. (i) A disabled tanker leaks kerosene (n = 1.20) into the Persian Gulf, creating a large slick on top of the water(n=1.30). (a) If you are looking straight down from an airplane , while the sun is overhead, at a region of the slick where its thickness is 460 nm, for which wavelength(s) of visible light is the reflection brightest because of constructive interference(6) ? (b) If you are scuba diving directly under the same region of the slick for which wavelength(s) of visible light is the transmitted intensity strongest ?(6)
(ii) A thin film with index of refraction n = 1.40 is placed in one arm of the Michelson interferometer, perpendicular to the optical path. If this causes a shift of 7 fringes of the pattern produced by light of wavelength 589 nm, what is the film thickness?(8)

6.(a) In a double slit experiment, what ratio of d to b causes diffraction to eliminate the fourth bright fringe ?(4)
(b) What other bright fringes are also eliminated?(4)
(c) Derive the following expression for the intensity pattern for a " three slit grating".

$$I = \frac{1}{9} I_m (1 + 4\cos\phi + 4\cos^2\phi)$$

where $\phi = \frac{(2\pi d \sin\theta)}{\lambda}$ Assume that $(b \ll \lambda)$ and I_m is the intensity of the central maximum.(12)

Information you may (or may not) need

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

$$\left(\frac{\partial T}{\partial P}\right)_S = \left(\frac{\partial V}{\partial S}\right)_P$$

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

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