Physics II
ISI B.Math
Final Exam : April 27, 2011

Total Marks: 100
Answer any five questions

1. 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.
Two thin pieces of different transparent material of identical thickness δ and indices of refraction n_1 and n_2 respectively are placed between each of the slits and the screen, as depicted in the figure , 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? (7)
(b) for what values of δ is the intensity at C a minimum?(5)
(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.(8)

2. The figure shows a plano-convex lens of large radius of curvature R resting on an accurately plane glass plate and illuminated from above by light of wavelength λ. Circular interference fringes(Newton's rings) appear, associated with the varying thickness air film between the lens and the plate.
(a) Will the centre of the interference pattern be dark or bright? Explain.(2)
(b) Show that the radii of interference maxima is given by $r = \sqrt{(m + \frac{1}{2})\lambda R)}$ where m =0,1,2.... How would the above expression be modified if the gap between the lens and the plate were filled with silicone oil of refractive index 1.52 ?(10)
(c) If $\lambda = 5890\text{Å}$,the radius of curvature of the lens is 5 m and its diameter is 2 cm, how many rings are produced ? If the entire arrangement were immersed in water ($n = 1.33$) , how many rings would be produced ?(8)

3. In 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 ($\lambda = 4800$ Å) if $d = 0.10$ mm and if the slit width $b = 0.02$ mm? (8)
What is the linear distance from the central maximum to the first minimum of the fringe envelope?(7)
Approximately how many fringes are contained in the central peak of the fringe envelope ?(5)

4.(a)A body of constant heat capacity C_p and at temperature T_i, is put in contact with a reservoir at a higher temperature T_f. The pressure remains constant while the body comes to equilibrium with the reservoir. Find the entropy change of the universe as a function of $x = (T_i - T_f)/T_f$ and show that it is positive. (15)

(b) Why does an isochoric (constant volume) curve plotted on a $T-S$ diagram have a greater slope than an isobaric(constant pressure) curve at the same temperature? (5)

5. (a) Draw a symbolic diagram of a set of Carnot engines with the following characteristics : Each engine absorbs the heat rejected by the preceding one at the temperature at which it was rejected, and each engine delivers the same amount of work. Show that the temperature intervals between which these engines operate are all equal. (10)
(b) At a power plant that produces 1GW (10^9 watts) of electricity, the steam turbines take in steam at a temperature of 500 °C, and the waste heat is expelled into the environment at 20 °C. (i) What is the maximum possible efficiency of this plant? (ii) Suppose you develop a new material for making pipes which allows the maximum temperature to be raised to 600 °C, how much extra electricity (in watts) will you generate, assuming that the amount of fuel consumed at the plant is unchanged ? (10)

6.(a) For a PVT system, show that

$$\left(\frac{\partial U}{\partial P}\right)_T = -T\left(\frac{\partial V}{\partial T}\right)_P - P\left(\frac{\partial V}{\partial P}\right)_T \quad (6)$$

(b) Hence show

$$\left(\frac{\partial C_p}{\partial P}\right)_T = -T\left(\frac{\partial^2 V}{\partial T^2}\right)_P \quad (5)$$

(c) Prove that C_P for an ideal gas is a function of T only (4)
(d) In the case of a gas obeying the equation of state $Pv = RT + BP$, where B is a function of T only, show that

$$c_P = -T\frac{d^2B}{dT^2}P + (c_P)_0 (5)$$

where $(c_P)_0$ is the value at very low pressures.

Information you may (or may not) need

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

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

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

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

$$F = U - TS$$

$$G = U - TS + PV$$

$$H = U + PV$$