Physics II
ISI B.Math
Mid Semester Exam February 27, 2012

Total Marks: 65
Time: 3 hours

Part A. Answer BOTH questions 1 and 2

Question 1. Total Marks: 2+2+2+2+3+4+8 = 23

a.) Let df, dg be two exact differentials with $df = f_1(x,y)dx + f_2(x,y)dy$ and $dg = g_1(x,y)dx + g_2(x,y)dy$. Is df+dg exact or inexact? Justify your answer.

b.) Let df, dg be two inexact differentials with $df = f_1(x,y)dx + f_2(x,y)dy$ and $dg = g_1(x,y)dx + g_2(x,y)dy$. Is df+dg exact or inexact? Justify your answer.

c.) For a (p,V,T) thermodynamic system consider the differential dH given by $dH = dU + pdV + Vdp$ where U is the internal energy function. Show that H is a state function.

d.) Show that for all gases the following is true: $\left(\frac{\partial \kappa}{\partial T}\right)_p = -\left(\frac{\partial \beta}{\partial p}\right)_T$ where $\kappa(p,T) = -\frac{1}{V}\frac{\partial V}{\partial p}$ and $\beta(p,T) = \frac{1}{V}\frac{\partial V}{\partial T}$.

e.) For each of the statements below, state if it is true or false (proof not needed):

i) $\oint \frac{dQ}{T} \leq 0$ for ALL cycles

ii) $\oint dS = 0$ for only reversible cycles

iii) $S(B) - S(A) = \int \frac{dQ}{T}$ where the integration is over any process (or path) connecting state A and state B.

f.) Show that it is not possible to construct an engine as shown in the given figure in the attachment.

g.) Show that in any p,V,T system, if two adiabatic curves intersect, it will violate the 2nd law of thermodynamics. [If you prove it for an ideal gas, you will get half the marks]

Question 2. Total Marks:5+5+2=12

a.) Using the formula (F1) given at the end of the paper, and using the fact that entropy is a state function, show that

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

b.) Use the above result to show that $\left(\frac{\partial C_v}{\partial V}\right)_T = T\left(\frac{\partial^2 p}{\partial T^2}\right)_V$.

c.) Show that $(\partial C_v/\partial V)_T = 0$ for a gas obeying van der Walls equation of state.

Part B. Answer ANY THREE from below

Question 3. Total Marks:10

Calculate the efficiency of the Sargent ideal-gas cycle engine shown in the figure given in the attachment assuming all processes are quasistatic and the heat capacities are constant. Express the result in terms of γ, T_1, T_2, T_3 and T_4.

Question 4. Total Marks:6+4

a.) One mole of an ideal gas undergoes adiabatic free expansion from volume V_1 to a larger volume V_2. Calculate the change of entropy in the ideal gas.

b.) A Carnot engine is depicted on a PV diagram in the figure given in the attachment. Draw the same engine (with the same processes) on a T-S chart (T on the Y axis, entropy S on the X axis). What does the area enclosed by the curve on a T-S diagram represent?

Question 5. Total Marks:10

One mole of a mono atomic ideal gas initially at temperature T expands quasistatically from volume V to a larger volume $2V$ in two different ways: (a) at constant temperature and (b) at constant pressure.

Calculate the work of expansion and the heat absorbed by the gas in each case. (Express your answers in terms of T and V.

Question 6. Total Marks: 2+5+3

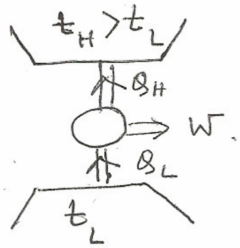
Consider the formation of Newtons rings when two closely spaced wavelengths are present; for example, the D1 and D2 lines of sodium ($\lambda_1 = 5890$ Angstrom and $\lambda_2 = 5896$ Angstrom).

a.) Explain why the central spot is dark.

b.) Show that if the glass lens is pulled up slowly (as shown in the picture), then the interference pattern will disappear if the lens is pulled by a distance $d = \frac{\lambda_1 \lambda_2}{4(\lambda_1 - \lambda_2)}$.What is the value of d in cm for the sodium lines given above?

c.) What will be observed if the lens is pulled further by a distance $2d$?

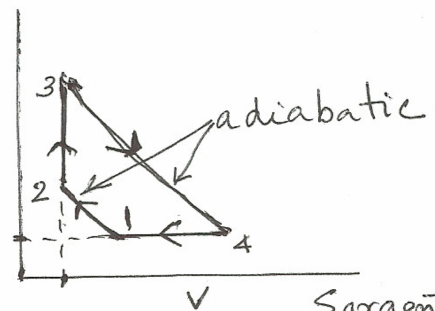
Q 1. f)



$Q_L = W + Q_H$

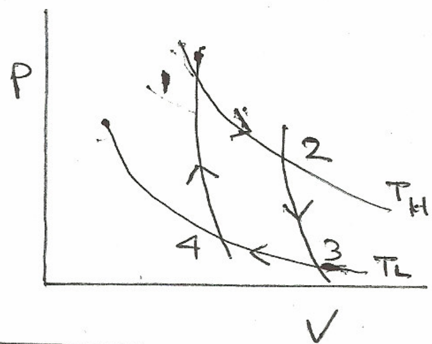
$Q_L, Q_H, W > 0$

Q 3.



Sargent Ideal gas cycle ($1 \to 2 \to 3 \to 4 \to 1$)

Q 4.



$1 \to 2$ and $3 \to 4$ are isothermals
$2 \to 3$, and $4 \to 1$ adiabatic.

Carnot Engine.

Q.6.

Useful Formulae.

$$dQ = \left(\frac{\partial U}{\partial T}\right)_V dT + \left[p + \left(\frac{\partial U}{\partial V}\right)_T\right] dV \quad \text{....(F1)}$$

$$C_V = \left(\frac{\partial U}{\partial T}\right)_V \quad \text{....... (F2).}$$

$$\left(p + \frac{n^2 a}{V^2}\right)(V - nb) = nRT \quad \text{(Van der Waals)}$$

$$U = \frac{3}{2} pV \quad \text{..... for ideal gas}$$

1 Angstrom = 10^{-8} cm.

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