ME 410 FALL 2002
INTERNAL COMBUSTION ENGINES
TEST #3
October 24, 2002

NAME________________________________

INSTRUCTIONS:

This test is open notes. The following formulas are also given with little explanation.

$\bar{S}_p = 2LN$ $\qquad r_c = \dfrac{V_d + V_c}{V_c}$ $\qquad P_{ig} = P_b + P_f$

$\eta_m = \dfrac{P_b}{P_{ig}}$ $\qquad mep = \dfrac{Pn_R}{V_d N}$ $\qquad P = 2\pi NT$

$mep(kPa) = \dfrac{P(kW)n_R \times 10^3}{V_d(l)N(rev/s)}$ $\qquad mep = \dfrac{P(hp)n_R \times 396000}{V_d(in^3)N(rev/\min)}$

$\eta_f = \dfrac{1}{sfc \cdot Q_{HV}}$ $\qquad \dfrac{F}{A} = \dfrac{\dot{m}_f}{\dot{m}_a}$ $\qquad \eta_v = \dfrac{2\dot{m}_a}{\rho_{a,i} V_d N}$

$\eta_v = \dfrac{m_a}{\rho_{a,i} V_d}$ $\qquad P = \dfrac{\eta_f \eta_v N V_d Q_{HV} \rho_{a,i}(F/A)}{2}$ $\qquad mep = \eta_f \eta_v Q_{HV} \rho_{a,i}(F/A)$

$$T = (1/4\pi) \cdot mep \cdot V_d$$

Additional Ideal Gas Relations

$\gamma = c_P / c_V$ $\qquad PV = mRT$ $\qquad R = c_P - c_V$

1. A limited pressure cycle is modeled with air in EES. Here are the data points generated by the program.

- V_1 (all cylinders) is 0.00675 m^3. V_2 (all cylinders) is 0.00045 m^3.
- Inlet temperature is 290 K.
- The air fuel ratio is 20.
- The lower heating value of the fuel is 42000 kJ/kg.

Point	P (kPa)	T (K)	v (m^3/kg)	u (kJ/kg)	h (kJ/kg)	s (kJ/kg k)
1	100	304.6	0.8743	217.6	305.1	5.717
2	4209	854.8	0.05828	637.2	882.5	5.717
3a	9532	1936	0.05828	1615	2171	6.449
3b	9532	2709	0.08156	2371	3149	6.874
4	435.4	1326	0.8743	1046	1427	6.874
5	100	921	2.644	692.2	956.6	6.874

a. Calculate the compression ratio.

$$r_c = \frac{V_1}{V_2} = \frac{0.00675}{0.00045} = 15$$

b. Calculate the residual fraction.

$$x_r = \frac{(v_4 / v_5)}{r_c} = \frac{(0.8743 / 2.644)}{15} = 0.022$$

c. Calculate the total mass in the cylinder at the start of the compression stroke.

$$v_1 = V_1 / m \qquad m = \frac{0.00675 \text{ m}^3}{0.8743 \text{ m}^3/\text{kg}} = 0.00772 \text{ kg}$$

d. Calculate the total heat release. It will be the sum of the constant volume heat release and the constant pressure heat release. Your answer should be in kJ.

$$Q = m(u_{3a} - u_2) + m(h_{3b} - h_{3a}) = 0.00772[(1615 - 637.2) + (3149 - 2171)] = 15.098 \text{ kJ}$$

e. Calculate the indicated work per cycle, also in kJ.

$$W_c = -m(u_2 - u_1) + m(p_{3b}(v_{3b} - v_{3a})) + m(u_{3b} - u_4) =$$

$$0.00772[-(637.2 - 217.6) + 9532(0.08156 - 0.05828) + (2371 - 1046)] = 8.703 \text{ kJ}$$

f. Calculate the fuel conversion efficiency of the engine.

$$\eta_f = \frac{W_c}{Q} = \frac{8.703}{15.098} = 0.576$$

2. This is a continuation of the previous question.

a. What is the imep/P_3 ratio for this engine? Explain the importance of this ratio.

$$imep = \frac{W_c}{V_d} = \frac{8.703\ kN-m}{(0.00675 - 0.00045)m^2} = 1381\,kPa \qquad \frac{imep}{P_3} = \frac{1381}{9532} = 0.145$$

The imep reflects the engine's design, efficient use of displacement to produce power and work. The P_3 reflects the peak pressure and indicates the need for strength and size of engine components to resist it. Therefore we want imep/P_3 to be as large as possible.

b. Suppose that all of the heat were released at constant volume. What would happen to the fuel conversion efficiency? Explain.

Naturally if we could release all the heat, or have combustion at constant volume at TC, all of the expansion stroke would then be available for producing work.
The fuel conversion efficiency would be higher.

c. Why is the inlet temperature different from T_1?

This is because the incoming charge in the induction system is diluted with hot exhaust temperature residual gas left behind in the cylinder.

d. Write a brief essay in which you compare the accuracy of this cycle (air, non-constant γ) with (a) a cycle in which γ is constant, and (b) a fuel air cycle.

This process would be more accurate than the one which just uses a constant γ, although a judicious choice of γ would probably cause it to be close. The fuel air cycle is more accurate than either.

3. An Otto Cycle has the following information:

$V_d = 2.0 \times 10^{-3}$ m^3, total engine displacement
Q = 5.0 kJ, total heat added per cycle
$\gamma = 1.3$

	1	2	3	4
Temperature	330	629.3	2817	1477

Based on this information, calculate

- fuel conversion efficiency
- an estimate of the engine's imep.

$$\eta_f = 1 - \frac{T_4 - T_1}{T_3 - T_2} = 1 - \frac{1477 - 330}{2817 - 629.3} = 0.475$$

$$W_c = \eta_f Q = 0.475\,(5) = 2.379\ \text{kJ}$$

$$\text{imep} = \frac{W_c}{V_d} = \frac{2.379}{0.002} = 1190\ \text{kPa}$$