

AME 436, Prof. Paul Ronney
Midterm Exam Study Guide
March 24, 2009

Format of the exam

The midterm exam will be open book, 90 minutes long. You may use any reference materials you want, but laptops, Pocket PCs, etc. capable of running GASEQ, aircycles4recips.xls, etc. will NOT be permitted. The exam will have three types of questions: (1) numerical problems, for example chemical equilibrium/adiabatic flame temperature, (2) graphical problems, for example P-V and T-S diagrams, and (3) short-answer questions.

Material covered

The exam may cover any material through the end of section on Unsteady Flow engines (i.e. material on Thrust, Compressible Flow, and Airbreathing Propulsion won't be on the exam). The material covered on the midterm includes:

- Classifications of IC engines; advantages and disadvantages of each type
- Introduction to combustion
 - Fuel types
 - Chemical thermodynamics
 - Stoichiometry
 - Heating value
 - Adiabatic flame temperature
 - Isentropic expansion with frozen and equilibrium products
 - Elementary combustion theory
 - Chemical reaction rates
 - Homogeneous reaction
 - Premixed flames (deflagration)
 - Effects of turbulence
 - Non-premixed flames
- Unsteady flow engines
 - Design parameters
 - r_c , V_d , N
 - Performance parameters
 - Indicated and Brake torque, power, MEP
 - Efficiency - thermal, mechanical, volumetric
 - Emissions
 - Ideal-gas cycle analysis
 - KNOW T-S AND P-V DIAGRAMS BACKWARDS AND FORWARDS!
 - Otto and Diesel cycles and variations (e.g. complete expansion)
 - Cycle comparisons
 - Fuel-air cycles
 - Modifications to ideal cycles
 - Slow burn
 - Friction
 - Heat loss

- Combustion in unsteady flow engines
 - Knock
 - What is it and why is it bad?
 - Effect of fuel type and fuel structure
 - Effect of operating conditions
 - Flammability/misfire limits
 - Incomplete combustion / flame quenching

Last year's midterm exam (should look familiar) (Average score was 70/100)

Instructions:

Open book exam. Use any reference materials you want, other than laptop computers, Palm Pilots, Pocket PCs, etc. capable of running spreadsheets like AIRCYCLES4RECIPS.XLS or GASEQ. 90 minutes allowed. Show all work; partial credit given if you can show you have a valid approach!

Problem #1 (chemical thermodynamics) (25 points total, 6 points each part, 1 point free)

On Jupiter is an atmosphere of 60% hydrogen (H₂) and 40% helium (He) (60%/40% on a molar basis) at a pressure of 0.2 MPa (2 earth atmospheres) total pressure at 200K. Deep underground are deposits of pure O₂ that the Jovians (residents of Jupiter) pump out of the ground. Unfortunately, most of the O₂ wells are located in politically unstable regions of Jupiter, so this O₂ is a valuable resource which they call "fuel." The hydrogen/helium mixture in the atmosphere, which they call "air," is "free" as far as Jovians are concerned.

Thermodynamic data: average mixture properties $\gamma = 1.3$, $R = 300 \text{ J/kgK}$, $C_v = 1000 \text{ J/kgK}$

	H ₂	O ₂	He	H ₂ O
Δh_f° (kJ/mole)	0	0	0	-241.83
Molecular weight (g/mole)	2	32	4	18

- What is the "heating value" (in J/kg) of the O₂ "fuel" that they burn with the H₂-He "air," assuming the combustion products are only H₂O and He?
- What is the stoichiometric "fuel" to "air" mass ratio?
- What is the constant-**pressure** adiabatic flame temperature of stoichiometric "fuel" + "air" mixtures?
- Estimate the BMEP of stoichiometric premixed-charge naturally-aspirated Jovian engines at wide-open throttle, with compression ratio 8.

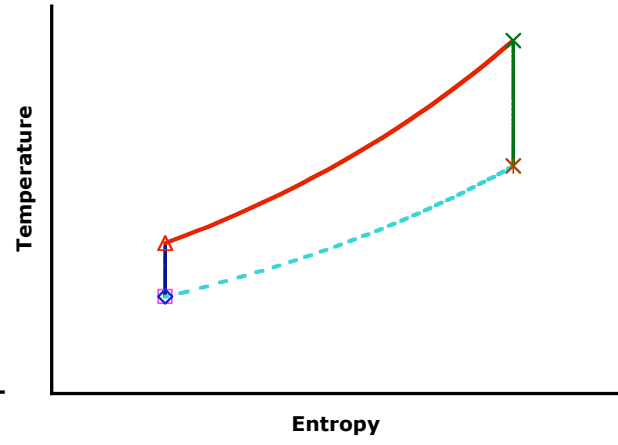
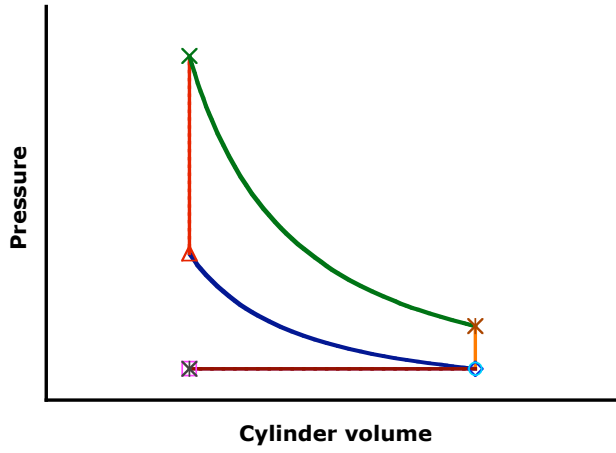
Problem #2 (P-v and T-s diagrams) (30 points total, 5 points each diagram)

Consider the "baseline" ideal Otto cycle shown on the P-V and T-s diagrams (next page). Sketch modified P-V and T-s diagrams if

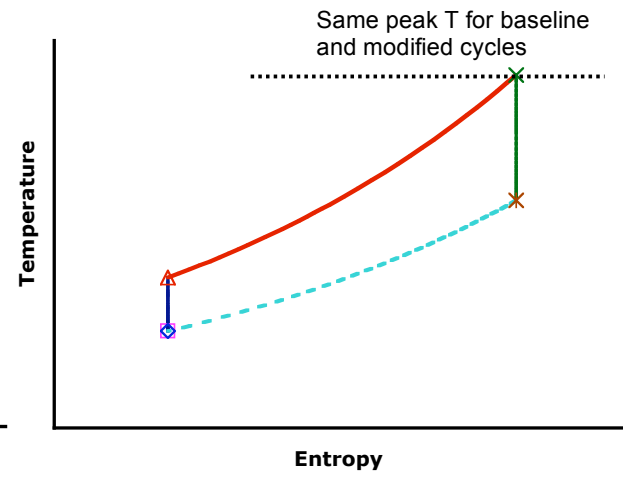
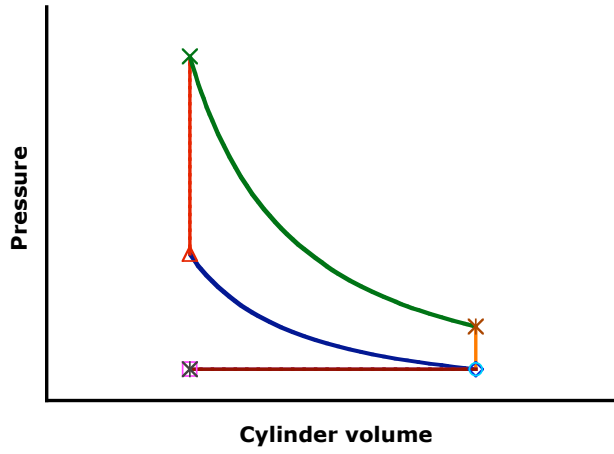
- Knocking occurs and all of the fuel-air mixture burns instantaneously before the piston reaches Top Dead Center (minimum cylinder volume)
- A new fuel with 10% higher heating value is used (fuel mass fraction not changed), but to avoid overheating the engine, the compression ratio is changed so that *the peak temperature is the same for the baseline cycle and the modified cycle.*

- c) The vehicle drives into a dense fog where the air contains much more moisture, thus C_v increases and γ decreases.

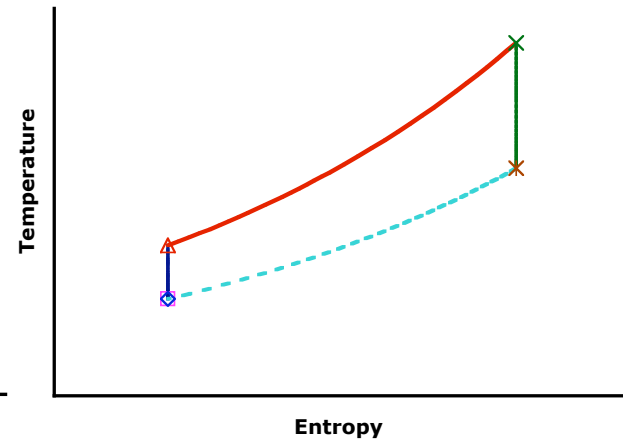
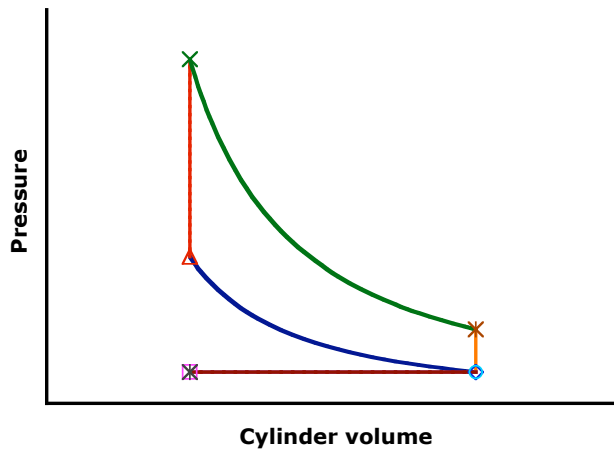
Unless otherwise noted, assume in each case the initial temperature and pressure, compression ratio, fuel mass fraction, heating value, etc. are unchanged. Where useful for clarity, label plots with phrases like "this area = that area," "these two temperatures are the same," etc. *In some cases there may be no change to the P-V or T-s diagram.* **Unintelligible scribbles on P-V and T-s diagrams don't get much credit!**



a)



b)



c)

Problem #3 (20 points total, 5 points each part)

Ronney Oil and Gas Company claims to have developed a fuel, called PDR[®], that has all the same thermodynamic properties, transport properties, chemical reaction rate parameters, etc. as octane except that PDR[®] has **10% higher heating value per unit mass** than octane. If PDR[®] fuel were used instead of octane, how would each of the following be affected? In particular, state whether each of the above will increase or decrease or remain constant, and by less than 10%, more than, or exactly 10% **and briefly explain why**.

- a) The laminar burning velocity (S_L) of a premixed flame in a stoichiometric mixture (hint: how does the 10% higher heating value change the adiabatic flame temperature?)
- b) The burning rate constant (K) of a liquid fuel droplet
- c) The thermal efficiency of an **ideal** Diesel cycle
- d) BMEP of a premixed-charge engine burning a stoichiometric mixture

Problem #4 (engine performance) (25 points total, 4 points each part, 1 point free)

A four-stroke gasoline engine with a displacement of 3.05 liters is tested in the laboratory at 3000 RPM and found to have the following performance characteristics: net IMEP 107.9 pounds per square inch, 70.32 brake horsepower, fuel flow rate 16.66 kg/hr, and air flow rate 269.6 kg/hr. The fuel is iso-octane, C_8H_{18} (heating value 4.3×10^7 J/kg.) The ambient air temperature is 295K. The intake pressure gauge is broken, so the intake pressure is not known. Determine the following performance parameters.

(Possibly useful information: 1000 liters = 1 m^3 ; 1 hp = 746 Watts; 1 atm = $1.01325 \times 10^5 \text{ N/m}^2$; 1 pound = 4.448 Newtons = 4.448 kg m/s^2 ; 1 inch = 0.0254 m; 1 hour = 3600 seconds.)

- a) BMEP
- b) friction MEP
- c) equivalence ratio
- d) brake thermal efficiency
- e) indicated torque
- f) Is this engine throttled, turbocharged or neither? Explain. (Hint: compute the volumetric efficiency.)