**ME 322 – Mechanical Engineering Thermodynamics (Exam 3)**

**Fall 2021**

THIS IS A TAKE-HOME EXAM. YOU HAVE SEVERAL DAYS TO WORK ON THIS EXAM, AND SEVERAL CLASS PERIODS WHERE YOU CAN ASK QUESTIONS. THE WORK PRESENTED ON THIS EXAM NEEDS TO BE YOURS, AND YOURS ALONE. PRESENTING SOLUTIONS FROM SOMEONE ELSE WILL RESULT IN A GRADE OF F IN THE COURSE.

Please read the following statement:

Article II, Section 1 of the University of Idaho Student Code of Conduct states,

*Cheating on classroom or outside assignments, examinations, or tests is a violation of this code. Plagiarism, falsification of academic records, and the acquisition or use of test materials without faculty authorization are considered forms of academic dishonesty and, as such, are violations of this code. Because academic honesty and integrity are core values at a university, the faculty finds that even one incident of academic dishonesty seriously and critically endangers the essential operation of the university and may merit expulsion.*

Passing on exam information to someone who has not taken the exam constitutes cheating on an examination. Such action is a violation of the University of Idaho Student Code of Conduct.

I have read and understand the above statement.

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Signature Date

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Printed Name

**EXAM INSTRUCTIONS – PLEASE READ THIS CAREFULLY**

**You need to show your work for each of the problems to get credit.**

* **If values from a table are cited, you need to indicate which table was used, and what inputs were used to find the value.**
* **Equations used should be written down, and the numbers used in those equations should also be shown.**
* **You should include units in your calculations, as many times there will be unit conversions necessary.**
* **You may work your problems on these pages, or work them on separate pages. You will scan and upload a PDF of your submission to BbLearn.**
* **If you have questions about problems on the exam you should ask those of the instructor.**
* **You are not allowed to work with other people (in person, or online) on this exam.**
* **Many problems on this exam are similar to past homework problems. You can certainly work with other students to make sure you know how to solve past homework problems.**

# Instructions

This exam has five problems on it. You are only required to do three of the five problems to get full credit for the exam. Any additional problems you solve (correctly) will be awarded as extra credit homework points (10 HW points per problem).

For scoring, if you do all five problems, I will score your exam based on your three problems with the highest score. Then I will apply extra credit HW points from your other problems. For example, if you do all five problems and three are correct, and two are only 75% correct you would get:

* 100 Exam 3 points (100%, based on three correct solutions)
* 15 extra credit homework points (based on 7.5 points for each of your two extra problems that were 75% correct)

# Problem 1: Internal Combustion Engine Simulation

You decided to build a Jurassic Park Jeep Wrangler, but rather than use the original engine you would like to build a small block V8 for the Jeep. The engine you are looking at is a four-stroke gasoline spark ignition 8-cylinder engine that has a total displacement volume of 383 cubic inches. The compression ratio is 9.0:1, and peak power is produced at 6200 rpm. Use ‘air\_ha’ as the working fluid in an EES model to predict the power output of this engine in several configurations. Model this engine as an Ideal Otto Cycle.  
**Note:** The temperature of state 3 will be out of range. This is okay for your calculation of power output.

* 1. Using 87 Octane fuel, the change in specific internal energy of the fluid in the cylinder (modeled as air\_ha) between states 2 and 3 will be 600 Btu/lbm. Inlet conditions for the engine are P[1] = 14.7 psia, and T[1] = 80 °F. Calculate the power [hp] that this engine will produce.
  2. For an additional $5,000 you can add a supercharged to this engine. The supercharged engine has the same specifications, except that P[1] = 24.7 psia, T[1] = 200 °F, and when using 93 octane fuel the change in specific internal energy of the fluid in the cylinder (modeled as air\_ha) between states 2 and 3 will be 675 Btu/lbm. Calculate the power [hp] for this engine.
  3. For an additional $4000 you can add an intercooler for the supercharged engine. All the specifications are the same as in part b, except now T[1] = 100 °F. Calculate the power [hp] for this engine.

Problem 2: Heat Pumps

You purchase a house that has a heat pump with an earth-coupled isothermal source. However, the system lost its refrigerant. You have repaired the leak and are going to refill the system. Originally the system was designed to use R134a. However, due to the cost of R134a you are considering using R22 instead. Regardless of which refrigerant is used, at the depth of the heat source the earth’s temperature can be assumed to be constant year-round. This results in a year-round standard evaporating temperature of 55°F. Thermal energy from the condenser is available at 125 °F. The compressor has an isentropic efficiency of 90%. Assume pressure drops through plumbing are negligible. The refrigerant leaves the condenser with 8 degrees of subcooling and it enters the compressor with 15 degrees of superheat. The mass flow of the refrigerant is 750 lbm/hr. Compare the following between R134a and R22:

R134a R22

* 1. The high pressure in the cycle [psia] \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_
  2. The low pressure in the cycle [psia] \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_
  3. The power requirement [hp] of the compressor \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_
  4. Rate of heat going into the house [Btu/hr] \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_
  5. Coefficient of performance for heating \_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_

# Problem 3: Mixtures

In Problem 5 of this exam we assume a composition of natural gas of C1.2H­5O1.75. For this mixture, calculate M­mix [lb/lbmol]. How does your answer compare to the assumed value in Problem 5?

# Problem 4: HVAC Processes on the Psychrometric Chart

You are designing a HVAC system for your house that is in a warm, humid climate. At State 1 Air entering the HVAC system is at a dry bulb temperature of 95°F and 80% relative humidity. You would like the air circulating through the building (State 3) to be similar to typical ambient conditions in Moscow, Idaho during the early summer, which is about a dry bulb temperature of 70°F and 50% relative humidity. You will use a cooling process (to remove moisture from the incoming air), then a heating process (to get the air to the desired temperature and humidity ratio). The incoming air flow rate for the HVAC system at State 1 condition is 1500 cubic feet per minute. Answer the following questions:

Use the ASHRAE English Unit psychrometric chart (a copy can be printed from our BbLearn site, under the “Homework Solutions” menu) to draw the process. Clearly draw and label the:

* 1. State 1 (air entering HVAC system)
  2. State 2 (air leaving the cooling section)
  3. State 3 (air leaving the heating section)
  4. Path taken for these two processes.

# Problem 5: Combustion

You are modeling combustion in a steam plant boiler that uses natural gas. The boiler has a maximum capacity of 75 x 106 Btu/hr. The natural gas being used has an average composition of C1.2H­5O1.75 and is assumed to have a higher heating value of 20,000 Btu/lbm, and a lower heating value of 18,000 Btu/lbm. You can calculate the molecular mass of natural gas, or you may use the assumed value of 19 lb/lbmol. The boiler has a 82% conversion efficiency (from chemical energy to boiler heat). For improved emissions, you are burning with 150% theoretical air. Exhaust temperature leaves the boiler at 120 °F. Calculate the following:

* 1. Balanced chemical equation for the actual reaction (not stoichiometric coefficients)
  2. Dew point temperature (°F) of the products of combustion.   
     Hint: Use this to decide if you should use the HHV or LHV of the fuel
  3. Mass flow of air (in lbm/hr, at standard pressure and temperature) consumed in the combustion reaction   
     Note: You will find the mass flow of air by first finding the mass flow of fuel, then multiplying it by AFRmass.

C1.2H­5O1.75 + \_\_\_\_ (O2 + 3.76\*N2) 🡪 \_\_\_\_ CO2 + \_\_\_\_ H2O + \_\_\_\_ O2 + \_\_\_\_ N2

T­dew point = ­­­­­\_\_\_\_\_\_\_\_\_ °F (based on this answer you will need to use either the HHV or LHV for the fuel)

\_\_\_\_\_\_\_\_\_\_ lbm/hr