

**YOU HAVE SEVERAL DAYS TO WORK ON THIS TAKE-HOME 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.

Signature

Date

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.
- 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 😊
- Remember that you can check your past homework against the posted solutions on Canvas.

Part 1: Engineering Calculations – 75 Points

For this section you may do problems by-hand or using EES.

1. (25 points) A large home-shop air compressor operates under the following conditions:
 - State 1 is air entering the compressor at 14.7 psia and 75 °F.
 - State 2 is air leaving the compressor at 104.0 psia.
 - For both the Ideal and Real conditions the steady-State volume flow rate exiting the compressor is 19 ft³/min
 - Isentropic efficiency of the compressor under these conditions is 80 %
 - For both Ideal and Real calculations assume that heat transfer from the compressor is negligible.

Note: Even though volume flow rate will be the same for ‘Ideal’ and ‘Real’ conditions, mass flow rates will not.

- a. Give explanation to justify if you are going to assume specific heat capacity to be constant or variable from State 1 to State 2. You can use calculations to support your decision if you like. If you choose to assume heat capacity is constant, provide reasoning about how you got the value you used.
 - b. For the ‘Ideal’ compressor (read that as: isentropic) calculate the outlet temperature [°F] of the air and the power input [hp] required to operate the compressor under these conditions.
 - c. For the ‘Real compressor calculate the outlet temperature [°F] of the air and the power input [hp] required to operate the compressor under these conditions.
2. (25 points) You are going to use your compressor from Problem 1 to fill a smaller (portable) air storage tank. Assume the small portable tank is rigid.

- a. Simplify the two equations below as they pertain to this problem. Cross out terms that do not apply.

$$\dot{Q} - \dot{W} + \sum_i \dot{m}_i \left(h_i + \frac{V_i^2}{2g_c} + \frac{g}{g_c} z_i \right) - \sum_e \dot{m}_e \left(h_e + \frac{V_e^2}{2g_c} + \frac{g}{g_c} z_e \right) = \frac{d}{dt} (U + KE + PE)$$
$$\sum_i \dot{m}_i - \sum_e \dot{m}_e = \frac{dm}{dt}$$

- b. Use substitution, then separate and integrate the equation to get rid of the time derivatives. You should end up with an equation that relates Q_{12} , h_{in} , u_1 , u_2 , m_1 , and m_2 . What is this relationship?
 - c. The small storage tank has a volume of 5 gallons and the air inside is initially at 30 [psia] and 75 [°F]. You are going to add air to the small tank until it reaches a pressure of 139.7 [psia], but you also want to make sure the temperature of the air in the tank doesn’t get above 100 [°F]. When your large compressor tank is full it has pressure and temperature of 150 [psia] and 75 [°F] (assume it is large enough for these to remain constant as you fill the little tank). Calculate the amount of heat [Btu] you will need to remove from the system to make sure the air stays below 100 [°F]
3. (25 points) For the compressor in Question 1, use the Gibbs equation(s) to calculate the change in specific entropy [Btu/lbm-R] between the inlet and outlet conditions.

Part 2: Short Calculations – 25 Points

4. (5 points) You purchase a portable refrigerator for camping. The specs say that the inside can be kept at 40 °F when the outside temperature is 90 °F. Calculate the maximum theoretical COP for this freezer.
5. (5 points) Rank the following devices in order of least efficient to most efficient. Consider all devices to be operating between the same high and low temperature reservoirs.
- Heat pump Combustion heat engine Refrigerator Carnot heat engine
6. (5 points) Using your supplemental tables, find the specific internal energy [Btu/lbm] of R-134a at 400.22 psia and 29.04 °F? Make sure to note which table(s) you used, and what inputs you used to find the value.

True/False in regards to entropy and entropy production (2 point each):

7. T / F In some real processes the system experiences no change in entropy
8. T / F Entropy inside a system is always increasing
9. T / F Friction, heat addition, mixing, and chemical reactions each increase entropy
10. T / F Some real processes have no entropy production
11. T / F Entropy is a conserved quantity