ME 322 – Mechanical Engineering Thermodynamics (Exam 2)

Spring 2014

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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.*

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I have read and understand the above statement.

____ ______________

Signature Date

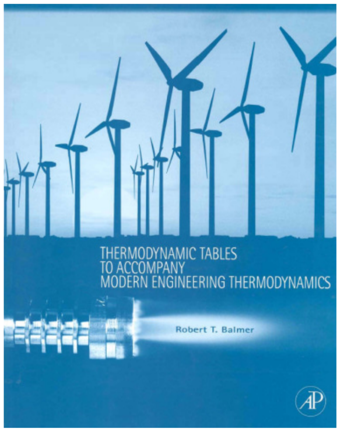
____

Printed Name

EXAM INSTRUCTIONS – PLEASE READ THIS CAREFULLY

You will have 50 minutes to complete this exam. This time limit will be strictly enforced. This is a CLOSED TEXTBOOK exam. The only resources allowed are a hand-held calculator and the course textbook supplement cited below,

> **Balmer, R.T., "Thermodynamic Tables to Accompany Modern Engineering Thermodynamics, Elsevier Inc., Burlington, MA, 2011.**



You may use the blank pages in the booklet to write anything you desire IN YOUR OWN HANDWRITING. Absolutely no cutting and pasting in the book is allowed.

No computers, cell phones, iPhones, iPods, iPads, music players, or any other electronic equipment may be used during the exam with the exception of a hand-held calculator.

Show all of your work in the space provided on the exam. Partial credit cannot be awarded if the work is not shown. There are a total of 80 points on this exam—4 points per problem.

CONVERSION FACTORS

Length

1 m = 3.2808 ft = 39.37 in = 10^2 cm = 10^{10} Å
1 cm = 0.0328 ft = 0.394 in = 10^{-2} m = 10^8 Å
1 mm = 10^{-3} m = 10^{-1} cm
1 km = 1000 m = 0.6215 miles = 3281 ft
1 in = 2.540 cm = 0.0254 m
1 ft = 12 in = 0.3048 m
1 mile = 5280 ft = 1609.36 m = 1.609 km

Energy

1 J = 1 N·m = 1 kg·m^2/s^2 = 9.479 × 10^{-4} Btu
1 kJ = 1000 J = 0.9479 Btu = 238.9 cal
1 Btu = 1055.0 J = 1.055 kJ = 778.16 ft·lbf = 252 cal
1 cal = 4.186 J = 3.968 × 10^{-3} Btu
1 Cal (in food value) = 1 kcal = 4186 J = 3.968 Btu
1 erg = 1 dyne·cm = 1 g·cm^2/s^2 = 10^{-7} J
1 eV = 1.602 × 10^{-19} J

Area

1 m^2 = 10^4 cm^2 = 10.76 ft^2 = 1550 in^2
1 ft^2 = 144 in^2 = 0.0929 m^2 = 929.05 cm^2
1 cm^2 = 10^{-4} m^2 = 1.0764 × 10^{-3} ft^2 = 0.155 in^2
1 in^2 = 6.944 × 10^{-3} ft^2 = 6.4516 × 10^{-4} m^2 = 6.4516 cm^2

Volume

1 m^3 = 35.313 ft^3 = 6.1023 × 10^4 in^3 = 1000 L = 264.171 gal
1 L = 10^{-3} m^3 = 0.0353 ft^3 = 61.03 in^3 = 0.2642 gal
1 gal = 231 in^3 = 0.13368 ft^3 = 3.785 × 10^{-3} m^3
1 ft^3 = 1728 in^3 = 28.3168 L = 0.02832 m^3 = 7.4805 gal
1 in^3 = 16.387 cm^3 = 1.6387 × 10^{-5} m^3 = 4.329 × 10^{-3} gal

Mass

1 kg = 1000 g = 2.2046 lbm = 0.0685 slug
1 lbm = 453.6 g = 0.4536 kg = 3.108 × 10^{-2} slug
1 slug = 32.174 lbm = 1.459 × 10^4 g = 14.594 kg

Force

1 N = 10^5 dyne = 1 kg·m/s^2 = 0.225 lbf
1 lbf = 4.448 N = 32.174 poundals
1 poundal = 0.138 N = 3.108 × 10^{-2} lbf

Power

1 W = 1 J/s = 1 kg·m^2/s^3 = 3.412 Btu/h = 1.3405 × 10^{-3} hp
1 kW = 1000 W = 3412 Btu/h = 737.3 ft·lbf/s = 1.3405 hp
1 Btu/h = 0.293 W = 0.2161 ft·lbf/s = 3.9293 × 10^{-4} hp
1 hp = 550 ft·lbf/s = 33000 ft·lbf/min = 2545 Btu/h = 746 W

Pressure

1 Pa = 1 N/m^2 = 1 kg/(m·s^2) = 1.4504 × 10^{-4} lbf/in^2
1 lbf/in^2 = 6894.76 Pa = 0.068 atm = 2.036 in Hg
1 atm = 14.696 lbf/in^2 = 1.01325 × 10^5 Pa
= 101.325 kPa = 760 mm Hg
1 bar = 10^5 Pa = 0.987 atm = 14.504 lbf/in^2
1 dyne/cm^2 = 0.1 Pa = 10^{-6} bar = 145.04 × 10^{-7} lbf/in^2
1 in Hg = 3376.8 Pa = 0.491 lbf/in^2
1 in H_2O = 248.8 Pa = 0.0361 lbf/in^2

MISCELLANEOUS UNIT CONVERSIONS

Specific Heat Units

1 Btu/(lbm·°F) = 1 Btu/(lbm·R)
1 kJ/(kg·K) = 0.23884 Btu/(lbm·R) = 185.8 ft·lbf/(lbm·R)
1 Btu/(lbm·R) = 778.16 ft·lbf/(lbm·R) = 4.186 kJ/(kg·K)

Energy Density Units

1 kJ/kg = 1000 m^2/s^2 = 0.4299 Btu/lbm
1 Btu/lbm = 2.326 kJ/kg = 2326 m^2/s^2

Energy Flux

1 W/m^2 = 0.317 Btu/(h·ft^2)
1 Btu/(h·ft^2) = 3.154 W/m^2

Heat Transfer Coefficient

1 W/(m^2·K) = 0.1761 Btu/(h·ft^2·R)
1 Btu/(h·ft^2·R) = 5.679 W/(m^2·K)

Thermal Conductivity

1 W/(m·K) = 0.5778 Btu/(h·ft·R)
1 Btu/(h·ft·R) = 1.731 W/(m·K)

Temperature

$T(°F) = \frac{9}{5}T(°C) + 32 = T(R) - 459.67$
$T(°C) = \frac{5}{9}[T(°F) - 32] = T(K) - 273.15$
$T(R) = \frac{9}{5}T(K) = (1.8)T(K) = T(°F) + 459.67$
$T(K) = \frac{5}{9}T(R) = T(R)/1.8 = T(°C) + 273.15$

Density

1 lbm/ft^3 = 16.0187 kg/m^3
1 kg/m^3 = 0.062427 lbm/ft^3 = 10^{-3} g/cm^3
1 g/cm^3 = 1 kg/L = 62.4 lbm/ft^3 = 10^3 kg/m^3

Viscosity

1 Pa·s = 1 N·s/m^2 = 1 kg/(m·s) = 10 poise
1 poise = 1 dyne·s/cm^2 = 1 g/(cm·s) = 0.1 Pa·s
1 poise = 2.09 × 10^{-3} lbf·s/ft^2 = 6.72 × 10^{-2} lbm/(ft·s)
1 centipoise = 0.01 poise = 10^{-3} Pa·s
1 lbf·s/ft^2 = 1 slug/(ft·s) = 47.9 Pa·s = 479 poise
1 stoke = 1 cm^2/s = 10^{-4} m^2/s = 1.076 × 10^{-3} ft^2/s
1 centistoke = 0.01 stoke = 10^{-6} m^2/s = 1.076 × 10^{-5} ft^2/s
1 m^2/s = 10^4 stoke = 10^6 centistoke = 10.76 ft^2/s

COMMON MOLAR MASSES: C=12; H=1; O=16; N=14

NOTE: MULTIPLE CORRECT ANSWERS ARE POSSIBLE ON NON-QUANTITATIVE PROBLEMS.
For PARTIAL CREDIT on non-quantitative problems, supply supporting reasoning as you feel necessary.
For FULL CREDIT quantitative problems, document ALL equations, conversions, and tables used.

1. What is the correct definition of quality within the two phase region?
   a) mass fraction of saturated liquid
   b) mass fraction of saturated vapor
   c) volume fraction of saturated liquid
   d) volume fraction of saturated vapor

2. Which of the following statements are true about the entropy balance equation, $\mathbf{S_T + S_p = S_g}$?
   a) S_g is the entropy gain of the system during a finite interval
   b) S_T is a transport term that includes effects of only heat transfer and mass transfer
   c) S_g can be positive, negative, or zero depending on the process
   d) S_p is zero for reversible processes

3. Saturated liquid water is in thermodynamic equilibrium inside a cylinder covered with a massless, moveable piston subjected to an external pressure of 1 MPa. What is the temperature of this fluid?
   a) 100 C
   b) 140 C
   c) 180 C
   d) 220 C

4. If 1 kg of saturated liquid water at 1 MPa is heated isobarically until the quality is 0.5, how much heat is added?
   a) +1008 kJ
   b) +1296 kJ
   c) +1390 kJ
   d) +2015 kJ

5. What is the specific entropy of water at 1 MPa if has a quality of 0.5?
   a) 2.1391 kJ/kg-K
   b) 3.2937 kJ/kg-K
   c) 4.3632 kJ/kg-K
   d) 4.4482 kJ/kg-K

6. How many kgmol are in 1 kg of liquid water (H_2O)?
   a) .056 kgmol
   b) .061 kgmol
   c) .066 kgmol
   d) .071 kgmol

7. What process condition(s) might you apply when modeling/analyzing a turbine?
   a) aergonic
   b) isenthalpic
   c) adiabatic
   d) isentropic

8. What process condition(s) might you apply when modeling/analyzing a valve?
   a) aergonic
   b) isenthalpic
   c) adiabatic
   d) isentropic

9. Which of the following are thermodynamic state functions (as opposed to path functions)?
   a) specific internal energy
   b) specific entropy
   c) specific enthalpy
   d) specific heat transfer

10. What is the value of the polytropic exponent for isentropic expansion of air?
    (Assuming constant heat capacities. HINT: Use data from Table C.13a.)
    a) 1.00
    b) 1.33
    c) 1.40
    d) 1.67

11. An ideal gas must always satisfy which of the following relationships?
    a) Cp-Cv = R
    b) pv = mRT
    c) $p_1v_1/T_1 = p_2v_2/T_2$
    d) dq = Tds

12. Air at 727 C and .8 MPa enters a gas turbine at 10 kg/s and exits at 327 C and .1 MPa. What is the power output of this device, assuming variable specific heats. HINT: Use the air tables.
    a) 3240 kW
    b) 4390 kW
    c) 4410 kW
    d) 6070 kW

13. If a fluid with a specific volume of 1.5 m^3/kg flows at 3 kg/s through a 20 cm diameter pipe, what is its velocity?
   a) 35 m/s
   b) 57 m/s
   c) 143 m/s
   d) 173 m/s

14. In what thermodynamic state is water at 375 C and 25 MPa?
   a) compressed liquid region
   b)two phase region
   c) superheated vapor region
   d) supercritical region

15. Which of the following statements are true for a Carnot Heat Pump?
   a) the coefficient of performance (COP) is independent on the working fluid selected
   b) the COP has an upper limit of 100%
   c) the COP increases as the temperature difference between the heat source and heat sink increases
   d) the COP is greater than the COP for the same device operating as a refrigerator

16. What is the change in entropy of an ideal gas that is heated isochorically from 27 C to 327 C? For this gas, C_p = .280 Btu/lbm-R and C_v=.130 Btu/lbm-R.
   a) .0901 Btu/lbm-R
   b) .1941 Btu/lbm-R
   c) .3243 Btu/lbm-R
   d) .6984 Btu/lbm-R

17. What information can be extracted from a temperature-entropy diagram for a closed system?
   a) heat transfer for any reversible thermodynamic process
   b) net heat transfer for any reversible thermodynamic cycle
   c) work transfer for any reversible thermodynamic process
   d) net work transfer for any reversible thermodynamic cycle

18. What does the first law reduce to for filling a tank with flexible, but insulated walls that are exposed to atmosphere? Neglect kinetic and potential energy terms. State 1 is the entering stream. State 2 is after filling.
   a) $Q + m_2h_1 = m_2u_2$
   b) $-W + m_2h_1 = m_2u_2$
   c) $Q - m_2h_2 = m_2u_2$
   d) $- W - m_2h_2 = m_2u_2$

Problems 19 and 20 apply to an oceanic thermal energy system that operates in a cyclic fashion between a high temperature at 80 F (at the surface) and a low temperature at 40 F (deep under water).

19. What is the maximum thermal efficiency of a heat engine operating between these reservoirs?
    a) 5.5%
    b) 7.5%
    c) 16.5%
    d) 50%

20. What is the maximum power output of this heat engine if 5 MW of thermal power flows from the high temperature source?
    a) 370 kw
    b) 530 kw
    c) 750 kw
    d) 1000 kw