EF 152 Exam #3, Fall, 2012

Name: ___________________________ Section: ________

Guidelines:
• Assume 3 significant figures for all given numbers.
• Show all of your work – no work, no credit
• Write your final answer in the box provided - include units for all answers.

Thermal Expansion
Linear
\[ \Delta l = \alpha l_0 \Delta T \]

Linear, Stresses
\[ \sigma = \alpha E \Delta T \]

Volumetric
\[ \Delta V = \beta V \Delta T \]

Work of Thermal Systems
\[ W = \int p \, dv \]

Isobaric (constant pressure)
\[ W = p(V_f - V_i) \]
\[ \Delta Q = n c_p \Delta T \]

Isochoric (constant volume)
\[ W = 0 \]
\[ \Delta Q = n c_v \Delta T \]

Isothermal (constant temp)
\[ W = nRT \ln \left( \frac{V_f}{V_i} \right) \]
\[ \Delta Q = W \]

Adiabatic (\( \Delta Q = 0 \))
\[ W = \frac{1}{\gamma - 1} \left( p_A V_A - p_B V_B \right) \]
\[ pV^\gamma = \text{constant} \]
\[ TV^{\gamma - 1} = \text{constant} \]

Ideal Gas Law
\[ pV = nRT \]
\[ R = 8.314 \, \text{J/(mol-K)} \]
Avogadro’s Number: 6.02x10\(^{23} \)

Standard Pressure and Temp
273K 1.00 atm (101.3kPa)

1st Law of Thermodynamics
\[ U = \text{internal energy} \]
\[ W = \text{work done by thermal system} \]
\[ Q = \text{heat flow into thermal system} \]
\[ \Delta U = -W_{A \rightarrow B} + Q_{A \rightarrow B} \]

Molecular Thermal Physics
\[ m = \text{mass of a molecule} \]
\[ M = \text{molecular mass} \]
\[ n = \text{number of moles} \]
\[ N = \text{number of molecules} \]
\[ k = \text{Boltzmann constant} = 1.38065 \times 10^{-23} \, \text{J/K} \]
\[ U = N \left( \frac{1}{2} m \left( v^2 \right) \right) \]
\[ U = \frac{3}{2} nRT \]
\[ v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}} \]

Conversions
1 cal = 4.186 J
1 L = 1000 cm\(^3\)
1 m\(^3\) = 1000 L

Heat
\[ Q = \text{heat} \]
\[ c = \text{specific heat} \]
\[ \kappa = \text{thermal conductivity} \]
\[ R = \text{thermal resistance} \]

Heat Capacity
\[ Q = mc\Delta T \]

Thermal Conductivity
\[ \Delta Q = -\kappa A \frac{T_2 - T_1}{L} = -A \frac{T_2 - T_1}{R} \]

Thermal Resistance
\[ R = \frac{L}{\kappa} \]

Thermal Resistance, Series
\[ R_{\text{eff}} = R_1 + R_2 \]

Thermal Resistance, Parallel
\[ \frac{1}{R_{\text{eff}}} = \frac{1}{A_1} + \frac{1}{A_2} \left( \frac{R_1}{R_2} \right) \]

Refrigerators
General
\[ h_c = \text{coefficient of performance} \]
\[ H = \text{heat current} \]
\[ P = \text{power input} \]
\[ |Q_h| = W + |Q_c| \]
\[ K = \frac{|Q_h|}{|W|} = \frac{H}{P} \]

Carnot
\[ K_{\text{Carnot}} = \frac{T_c}{T_c - T_h} \]

Entropy
\[ \Delta S = \frac{\beta \, dQ}{T} \]
\[ \Delta S = \frac{Q}{T} \]
\[ \Delta S = mc \ln \left( \frac{T_2}{T_1} \right) \]

Ideal Gas
\[ \Delta S = C_v \ln \frac{T_2}{T_1} + nR \ln \frac{V_2}{V_1} \]
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1. (14 pts) $1.6 \times 10^7$ J of heat is added to 25 L of water that is at 30°C. Determine the percentage of the water that is converted to steam.

2. (14 pts) An outside wall of a house is 9 ft high and 40 ft long. The wall has a thermal resistance of $R\text{-}12 \text{ ft}^2\text{-h} \cdot \text{°F}/\text{Btu}$. The wall contains a window that measures 4 ft high and 10 ft long. The window has a thermal resistance of $R\text{-}7 \text{ ft}^2\text{-h} \cdot \text{°F}/\text{Btu}$. Determine the number of BTUs lost through the wall system in 1 hour if there is a 35°F temperature difference between the inside and outside.
3. (14 pts) A 0.3 m$^3$ tank contains 0.8 kg of nitrogen at 20°C. Determine the gage pressure of the tank. (molecular weight of nitrogen = 14)

4. (14 pts) Determine the amount of work done by a heat engine during one cycle as shown. There are 13 moles of gas in the system.
5. (14 pts) A refrigerator extracts 43 kJ of heat at -10°C from inside and exhausts 53 kJ of heat into a 18°C room. Determine the coefficient of performance of the refrigerator as a percentage of the Carnot coefficient of performance.

6. (14 pts) A 30 kg block of ice at 0°C is placed in a 23°C large room. Determine the total change in entropy of the system when the ice just melts (turns to water at 0°C).
7. (2 pts) One method of getting a tight fit of a metal peg in a hole in a metal block is to manufacture
the peg slightly larger than the hole. The peg is then inserted when at a different temperature than
the block. Should the block be hotter or colder than the peg during insertion?
   a) hotter       b) colder

8. (2 pts) Two objects are made of the same material, but have different masses and temperatures. If
the objects are brought into thermal contact, which one will have the greater temperature change?
   a) the one with the higher initial temperature
   b) the one with the lower initial temperature
   c) the one with the greater mass
   d) the one with the smaller mass
   e) the one with the higher specific heat

9. (2 pts) What is the change in internal energy in a constant volume process?
   a) $W$       b) $-W$       c) $Q$       d) $-Q$       e) 0

10. (2 pts) How much heat flows into a system if the internal energy decrease by 20 J and the system
does 30 J of work?
    a) -10 J      b) 10 J       c) -50 J      d) 50 J

11. (2 pts) Which cyclical process represented by the two closed
    loops, ABCFA and ABDEA, on the PV diagram in the figure below
    produces the greatest net work?
    a) cycle ABCFA
    b) cycle ABDEA
    c) both produce the same amount of net work

12. (2 pts) The pressure of a gas is doubled while the temperature
    remains constant. What happens to the internal energy?
    a) internal energy doubles
    b) internal energy stays the same
    c) internal energy is cut in half
    d) not enough information

13. (2 pts) The absolute temperature of a mole of gas doubles. What happens to the $r_{ms}$ speed of the
    molecules?
    a) $v_{rms}$ stays the same       b) $v_{rms}$ increases by 1.4     c) $v_{rms}$ doubles       d) $v_{rms}$ increases by 4

14. (2 pts) A diatomic molecule has how many degrees of freedom?
    a) 1       b) 2       c) 3       d) 4       e) 5       f) 6