Summer2 2014 Section 01II MTWRF 10:05 – 11:30 p. m.

Signature: ____________________ Name: ____________________

Idnumber: ____________________

1
2
3

ENTER YOUR NAME AND FORM 1 (FM1) IN THE SCANTRON SHEET

AN ERROR IN FORM OR NAME WILL COST YOU 10 POINTS

DO THE FIRST PROBLEM [I], WHICH CONSISTS OF 15 MULTIPLE CHOICE QUESTIONS WORTH 4 POINTS EACH FOR A TOTAL OF 60 POINTS ENTER YOUR CHOICES IN THE SCANTRON SHEET

ALSO DO ONLY ONE OF THE TWO LONG PROBLEMS PROBLEMS [II] or [III] WORTH 40 POINTS

IF YOU DO BOTH THE LAST ONE WILL BE IGNORED

CROSS OUT THE BOX 2 OR 3 OF THE PROBLEM YOU OMIT

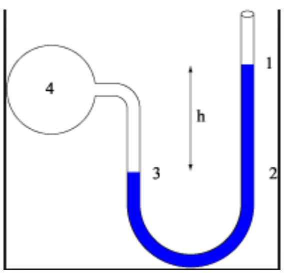
Your signature signifies that you will obey the HONOR CODE
CALCULATORS, CELL PHONES, AND COMPUTER WATCHES ARE NOT ALLOWED
YOU WILL BE CHECKED WITH A METAL DETECTOR
AT THE START OF THE EXAM
TALKING, LOOKING AT OTHER STUDENT PAPERS,
OR HAVING YOUR HANDS UNDER THE DESK ARE NOT ALLOWED
VIOLATORS WILL BE FAILED IN THE COURSE
You may be asked to show your photo ID during the exam.

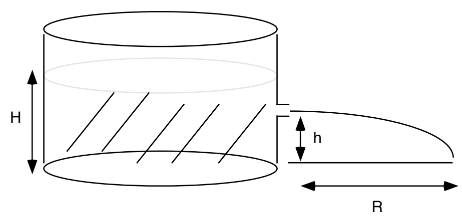
THERE IS A SEPARATE FORMULA SHEET

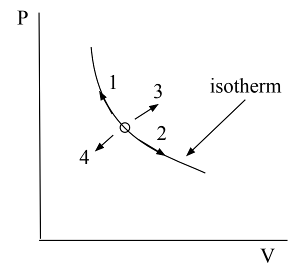
[I.] This problem has 15 multiple choice questions. **The best answer is marked with [X]**.

[I.1] A manometer in the figure to the left below consists of a U-shaped tube with water in it. One end of the U-tube is connected to a container filled with a gas at a pressure P_4. The other end is open to the atmosphere, $P_1 = P_{atm}$. The water is 20 cm higher in the part open to the atmosphere than in the part connected to the gas. Find the gauge pressure of the gas $P_{gauge} \equiv P_{gas} - P_{atm}$.

[A] 2×10^4 Pa [B] $-22,000$ Pa [C] -2×10^3 Pa [D] $18,000$ Pa [X] 2×10^3 Pa







[I.2] A large container has water of density ρ up to a level H. A small hole is punched on the side at a height h as shown in the figure at the center above. Find the speed v of the water as it emerges from the side hole. Neglect the speed at the top of the tank.

[A] $v = \sqrt{2gh}$ [B] $v = \sqrt{2gH}$ [X] $v = \sqrt{2g(H-h)}$ [D] $v = \sqrt{2g(H+h)}$
[E]$v = \sqrt{2\rho g(H-h)}$

[I.3] The state of a gas moves from the initial point in the four directions shown in the figure to the right above. The change of internal energy $\Delta E_{i\to f} = E_f - E_i$ in the four directions is

[A] $\Delta E_{0\to1} = 0, \Delta E_{0\to2} = 0, \Delta E_{0\to3} < 0, \Delta E_{0\to4} > 0$
[X] $\Delta E_{0\to1} = 0, \Delta E_{0\to2} = 0, \Delta E_{0\to3} > 0, \Delta E_{0\to4} < 0$
[C] $\Delta E_{0\to1} > 0, \Delta E_{0\to2} < 0, \Delta E_{0\to3} > 0, \Delta E_{0\to4} < 0$
[D] $\Delta E_{0\to1} < 0, \Delta E_{0\to2} > 0, \Delta E_{0\to3} > 0, \Delta E_{0\to4} < 0$

[I.4] Several cans of different sizes and shapes are open to the atmosphere and are all filled with the same liquid to the same depth. Choose the true statement.

[A] The weight of the liquid is the same for all cans
[B] The force of the liquid on the bottom of each can is the same
[X] The pressure of the liquid on the bottom of each can is the same
[D] Choices [A] and [C] are true
[E] Choices [B] and [C] are true

[I.5] A car of mass M traveling at a speed v stops and dissipates its kinetic energy in the brake drums. If each of the four brake drums has a mass m and a specific heat capacity c, find the temperature rise of the brake drums.

[A] $\Delta T = \frac{Mv^2}{mc}$ [B] $\Delta T = \frac{Mv^2}{2mc}$ [C] $\Delta T = \frac{v^2}{8c}$ [D] $\Delta T = \frac{mv^2}{8Mc}$ [X] $\Delta T = \frac{Mv^2}{8mc}$

[I.6] A metal tank with a volume of 50.0 gallons is filled with fluid when the temperature is 10.00°C. It is flown the next day to a place where the temperature is 30.0°C. How much fluid will spill from the tank if it has an escape valve? The volume expansion coefficient for the fluid is $\beta = 940 \times 10^{-6}$ °C^{-1} and for the metal it is $\beta = 40.0 \times 10^{-6}$ °C^{-1}.

[A] 0.98 gallons [B] 0.94 gallons [X] 0.9 gallons [D] 0.04 gallons

[I.7] An athlete did 100,000 J of work and gave off 200,000 J of heat to the environment. The change $\Delta E = E_f - E_i$ in the internal energy of the athlete was

[X] -300,000 J [B] +300,000 J [C] +100,000 J [D] -100,000 J [E] zero

[I.8] How much sweat would have to evaporate from the body of the above athlete to get rid of all the heat by evaporation? The latent heat of evaporation of water is approximately 2.0×10^6 J/kg.

[A] 0.25 kg [B] 0.15 kg [C] 0.2 kg [X] 0.1 kg [E] 0.3 kg

[I.9] An ideal gas at the constant pressure of 4×10^5 Pa undergoes a process in which the gas receives 5000 J of heat while in the process the internal energy increases by 3000 J. Find the change ΔV in the volume of the system.

[A] -20×10^{-3} m^3 [B] 20×10^{-3} m^3 [C] 7.5×10^{-2} m^3 [X] 5×10^{-3} m^3
[E] -5×10^{-3} m^3

[I.10] In class a piece of cotton was ignited

[A] by exposing it to strong radiation [B] by putting it in a flame

[X] by putting it in a cylinder and rapidly pushing a piston into the cylinder

[D] heating it by friction [E] no such demonstration was done in class

[I.11] A blackbody of area surface A at a temperature $T_C = 27\,°C$ is radiating power at a rate P_i. If the Celsius temperature is increased to a final temperature $T_C = 327°C$, the body will radiate power at a rate P_f, where

[A] $P_f = \frac{327}{27} P_i$ [B] $P_f = \left(\frac{327}{27}\right)^4 P_i$ [C] $P_f = 2P_i$ [D] $P_f = 81 P_i$ [X] $P_f = 16 P_i$

[I.12] An incandescent solid produces

[A] a continuous spectrum that depends strongly on both the temperature and the material

[X] a continuous spectrum that depends strongly on the temperature but not so much on the material

[C] a discreet line spectrum that depends strongly on both the temperature and the material

[D] a discreet spectrum that depends strongly on the temperature but not so much on the material

[I.13] A heat engine receives 8,000 J of heat from the burning fuel and releases 5,000 J to the environment in each cycle. The efficiency of the engine is

[A] 8/5 [B] 8/3 [X] 3/8 [D] 5/8 [E] 8/13

[I.14] If the cycle in the previous questions is a Carnot cycle and the hottest temperature in the cycle is 800 K, find the coldest temperature in the cycle.

[A] 300 K [B] 308 K [C] 2133 K [X] 500 K [E] 400 K

[I.15] n moles of a monatomic ideal gas undergo a free expansion, in which $Q_{\text{in}} = 0$ and $W_{\text{out}} = 0$, from an initial state (V_i, T_i) to a final state (V_f, T_f) where $V_f = 2V_i$. In this process the changes in temperature and entropy are

[X] $\Delta T = 0$ and $\Delta S = nR\ln 2$. [B] $\Delta T = 0$ and $\Delta S = 0$. [C] $\Delta T = 0$ and $\Delta S = \frac{3}{2}nR\ln 2$.

[D] $\Delta T = -\frac{T_i}{2}$ and $\Delta S = -\frac{1}{2}nR\ln 2$. [E] $\Delta T = T_i$ and $\Delta S = \frac{5}{2}nR\ln 2$.

[II] n moles of an ideal monatomic gas undergo a process that follows a straight line in a PV diagram from (V_i, P_i) to (V_f, P_f), where $V_f = 3V_i$ and $P_f = P_i/2$ as shown in the figure below. All answers are to be given in terms of n, P_i, V_i, and R.

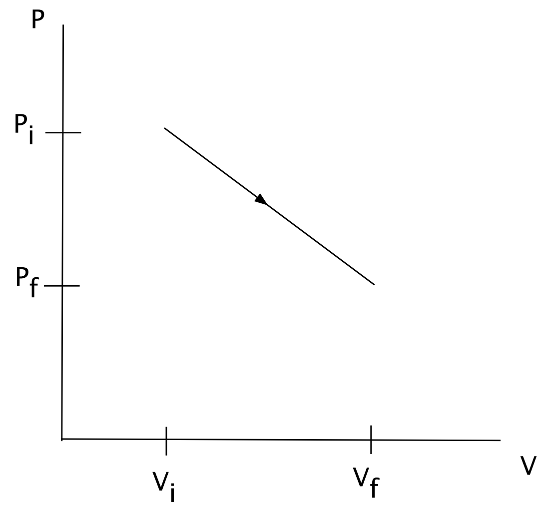
[a] Find the ratio $\frac{T_f}{T_i}$ of the temperatures

[b] Find the change in internal energy $\Delta E = E_f - E_i$.

[c] Find the work done by the gas $W_{i\to f}$.

[d] Find the heat input $Q_{i\to f}$.

[e] Find the entropy change of the gas $\Delta S = S_f - S_i$.



Answers:

[a] $\frac{T_f}{T_i} = \frac{P_f V_f}{P_i V_1} = \frac{3}{2}$

[b]

$$\Delta E = nC_V \Delta T = \frac{3}{2} nR(T_f - T_i) = \frac{3}{2}(P_f V_f - P_i V_i) = \frac{3}{2}(\frac{P_i}{2} 3V_i - P_i V_i) = \frac{3}{2}(\frac{1}{2}) P_i V_i = \frac{3}{4} P_i V_i.$$

[c] The Work is the area under the curve, which can be made with a triangle over a rectangle,

$$W_{i\to f} = \frac{1}{2}(P_i - P_f)(V_f - V_i) + P_f(V_f - V_i) = \frac{1}{2}(P_i + P_f)(V_f - V_i) = \frac{1}{2}(\frac{3}{2}) P_i (2V_i) = \frac{3}{2} P_i V_i.$$

[d]

$$Q_{i\to f} = \Delta U + W_{i\to f} = \frac{3}{4} P_i V_i + \frac{3}{2} P_i V_i = \frac{9}{4} P_i V_i.$$

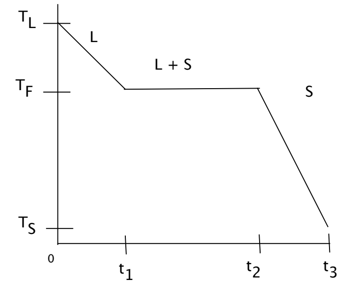
[e]

$$\Delta S = nC_V \ln\left(\frac{T_f}{T_i}\right) + nR \ln\left(\frac{V_f}{V_i}\right) = nC_V \ln\left(\frac{P_f V_f}{P_i V_i}\right) + nR \ln\left(\frac{V_f}{V_i}\right) = \frac{3}{2} nR \ln\left(\frac{(P_i/2)(3V_i)}{P_i V_i}\right) + nR \ln 3,$$

$$\text{or} \quad \Delta S = \frac{3}{2} nR \ln(\frac{3}{2}) + nR \ln 3 = \frac{5}{2} nR \ln 3 + \frac{3}{2} nR \ln(\frac{1}{2}).$$

[III] Heat is removed at a constant rate $\dot{Q}$ from a mass $m = 0.2$ kg of a hypothetical liquid at an initial temperature $T_L = 1200$ K. The liquid has a specific heat capacity $C_L = 1000\ \frac{\text{J}}{\text{kg}\cdot\text{K}}$. The liquid begins to freeze at a temperature $T_F = 1000$ K after an elapsed time $t_1 = 10$ minutes. After 20 more minutes, so $t_2 = 30$ minutes, the mass is all solid. Then after 10 more minutes, so $t_3 = 40$ minutes, the temperature of the solid is $T_S = 600$ K.

[a] Find how much heat was removed from $t = 0$ to $t = t_1 = 10$ minutes.
[b] Find the rate $\dot{Q}$ of heat removal in J/min
[c] Find the heat of fusion L_f of the material
[d] Find the specific heat capacity of the solid.
[e] Find the entropy change in going from 1200 K to 1000 K
[f] Find the entropy change during freezing.



Answers:

[a] In the first 10 minutes, from $t = 0$ to $t = 10$ minutes, the $m = 0.2$ kg of liquid, which starts with initial temperature $T_L = 1200$ K, cools down to $T_F = 1000$ K . The heat removed from the liquid in the first 10 minutes is

$|Q_L| = c_L m|\Delta T| = 1000\ \frac{\text{J}}{\text{kg}\cdot\text{K}} \times 0.2\text{ kg} \times 200\text{ K} = 40,000\text{ J}.$

[b] The rate of heat removal obeys $|\dot{Q}|$

$|Q_L| = |\dot{Q}| \times 10$ minutes, therefore $|\dot{Q}| = \frac{40,000\text{ J}}{10\text{ minutes}} = 4,000\ \frac{\text{J}}{\text{minute}}.$

[c] In 20 minutes, from $t_1 = 10$ minutes to $t_2 = 30$ minutes, the entire mass of liquid froze. The heat Q_F to freeze the mass, removed in those 20 minutes, was

$Q_F = |\dot{Q}| \times 20\text{ minutes} = 4,000\ \frac{\text{J}}{\text{minute}} \times 20\text{ minutes} = 80,000\text{ J}.$

But, in order to freeze the mass, the heat removed must be

$Q_F = mL_f$, therefore $L_f = \frac{Q_F}{m} = \frac{80,000\text{J}}{0.2\text{ kg}} = 400,000\ \frac{\text{J}}{\text{kg}}.$

[d] In the 10 minutes from $t = t_2$ to $t = t_3$, the 0.2 kg of solid cooled 400 K, from 1000 K to 600 K. The heat to cool the solid in 10 minutes was $|Q_S| = |\dot{Q}| \times 10\text{ minutes} = 40,000$ J.

But $|Q_S| = mc_S \times 400$ K, therefore $c_S = \frac{|Q_S|}{m\cdot 400\text{ K}} = 500\frac{\text{J}}{\text{kg}\cdot\text{K}}.$

[e] $\Delta S = cm \ln \frac{T_f}{T_i} = (1000\ \frac{\text{J}}{\text{kg}\cdot\text{K}})(0.2\text{kg}) \ln \frac{1000}{1200} = 200 \ln \frac{1000}{1200}\ \frac{\text{J}}{\text{K}}$

[f] $\Delta S = \frac{Lm}{T_F} = \frac{(400,000\ \frac{\text{J}}{\text{kg}})(0.2\text{ kg})}{1000|,\text{K}} = 80\ \frac{\text{J}}{\text{K}}$