Physics 161-001 Spring 2012 Exam 1

Name: ________________________________ **Box#**____________

SHOW ALL WORK!

Multiple Choice (6 points each):

1) A hole in a steel plate (coefficient of linear expansion = 12.0 x 10^{-6} K^{-1}) has a diameter of 20cm at 0°C. What is the diameter of the hole when the steel plate is heated red hot, 700°C?

A) 19.916 cm
B) 19.832 cm
C) 20.0 cm
D) 20.084 cm
E) 20.168 cm

$$\Delta L = \alpha L_o \Delta T$$
$$= (12.0 \times 10^{-6} K^{-1})(0.20 m)(700 K)$$
$$= 0.168 \times 10^{-2} m$$
$$\therefore L = L_o + \Delta L$$
$$= 20.168 \text{ cm}$$

2) 2 liters of an ideal gas is at 10°C. It is heated at constant pressure to 40°C. It will now occupy:

A) 1.81 liters
B) 2.21 liters
C) 2.15 liters
D) 2.0 liters
E) 1.95 liters

$pV = nRT$ with p = const. $\Rightarrow$

$$\frac{nRT_1}{V_1} = \frac{nRT_2}{V_2} \Rightarrow V_2 = \frac{T_2}{T_1} V_1$$

$$V_2 = 2.21 \text{ liters}$$

3) The pressure of an ideal gas is halved during a process in which the heat taken in by the gas equals the work done by the gas. As a result, the temperature of the gas is:

A) doubled.
B) halved.
C) unchanged.
D) need more information to answer.
E) nonsense, the process is impossible.

$Q = W \Rightarrow$

$\Delta U = Q - W = 0$

$\therefore T =$ const.

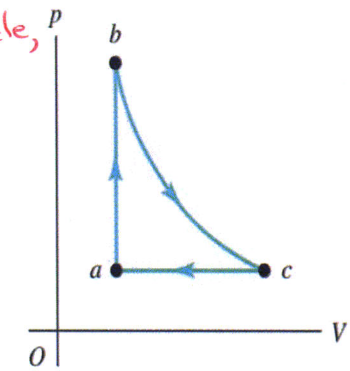
4) **A hot object and a cold object are placed in thermal contact and the combination is isolated. They transfer energy until they reach a common temperature. The change ΔS_h in the entropy of the hot object, the change ΔS_c in the entropy of the cold object and the change ΔS_{total} in the entropy of the combination are:**

A) $\Delta S_h > 0, \Delta S_c < 0, \Delta S_{total} < 0$
B) $\Delta S_h > 0, \Delta S_c > 0, \Delta S_{total} > 0$
C) $\Delta S_h < 0, \Delta S_c > 0, \Delta S_{total} < 0$
D) $\Delta S_h < 0, \Delta S_c > 0, \Delta S_{total} > 0$
E) $\Delta S_h > 0, \Delta S_c < 0, \Delta S_{total} > 0$

Heat leaves the hot object $\Rightarrow \Delta S_H < 0$
Heat enters the cold object $\Rightarrow \Delta S_c > 0$
Since $\Delta S = \frac{Q}{T}$, $|\Delta S_c| > |\Delta S_H| \Rightarrow \Delta S_{Tot} > 0$

5) **An ideal gas in a chamber passes through the cycle shown below. The heat Q_{AB} added during process AB is 55.0J, no heat is transferred during process BC, and the net work done in the cycle is 15.0J. Determine the net heat added to the system during process CA.**

Since $\Delta U_{Net} = 0$ in cycle,
$Q_{Net} = W_{net}$
$Q_{ab} + Q_{CA} = 15.0J$
$55J + Q_{CA} = 15.0J$
$\therefore Q_{CA} = -40J$



A) 70 J
B) -40 J
C) 15 J
D) -10 J
E) -70 J

6) **The "Principle of Equipartition of Energy" states that the internal energy of a gas is shared equally:**

A) among the molecules
B) between kinetic and potential energy
C) among the relevant degrees of freedom
D) between translational and vibrational kinetic energy
E) between temperature and pressure

7) A heat conducting rod, 1.2 m long, is made of an aluminum section that is 0.6 m long and a copper section that is 0.6 m long. Both sections have cross-sectional areas of 0.00040 m^2. The aluminum end and the copper end are maintained at temperatures of 20°C and 270°C, respectively. The thermal conductivity of aluminum is 205 W/m·K of copper is 385 W/m·K. The temperature at the aluminum/copper interface is closest to:

A) 145 °C.
B) 205 °C.
C) 200 °C.
D) 250 °C.
E) 185 °C.

$H_{Al} = H_{Cu}$

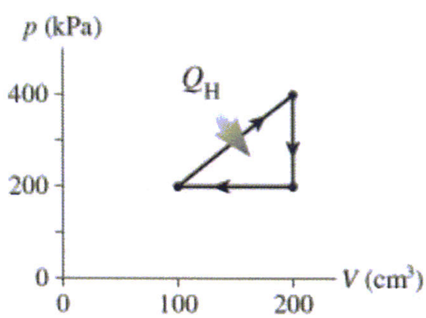
$\left(k\frac{A}{L}\Delta T\right)_{Al} = \left(k\frac{A}{L}\Delta T\right)_{Cu}$

$\left(205\frac{W}{m\cdot K}\right)(T - T_c) = \left(385\frac{W}{m\cdot K}\right)(T_H - T) \Rightarrow T = 183°C$

8) The average molecular translational kinetic energy of an ideal gas can be determined by knowing

A) only the pressure of the gas.
B) only the number of molecules in the gas.
C) only the volume of the gas.
D) only the temperature of the gas.
E) All of the above quantities must be known to determine the average molecular kinetic energy.

9) The graph in the figure shows a cycle for a heat engine for which $Q_H = 77$ J. What is the thermal efficiency of this engine?



$W_{Net} = \frac{1}{2}(200 \times 10^3 \, Pa)(100 \times 10^{-6} \, m^3)$

$= 10 J$

$e = \frac{W_{Net}}{Q_H} = \frac{10 J}{77 J} = 0.13$

A) 26 %
B) 13 %
C) 6.5 %
D) 18 %
E) 20 %

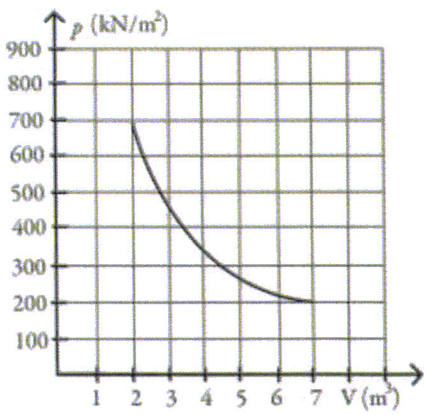
10) A Carnot engine operates between a high temperature reservoir at 825 K and a river with water at 285 K. If it absorbs 2700 J of heat each cycle, how much work per cycle does it perform?

A) 806 J
B) 1798 J
C) 1621 J
D) 902 J
E) 1767 J

$$e_c = 1 - \frac{T_c}{T_H} = 1 - \frac{285\text{ K}}{825\text{ K}} = 0.65$$

$$0.65 = \frac{W_{Net}}{Q_H} \Rightarrow W_{Net} = 1767\text{ J}$$

11) What is the change in entropy of 5.8 moles of *ideal* monatomic gas that reversibly undergoes the isothermal expansion shown in the figure? The ideal gas constant is $R = 8.314$ J/(mol·K).



A) 84 J/K
B) 60.4 J/K
C) 70.7 J/K
D) 90.8 J/K
E) 0 J/K

$$\Delta S = \frac{Q}{T}$$

Since it is isothermal $\Delta U = 0 = Q - W \Rightarrow Q = W$

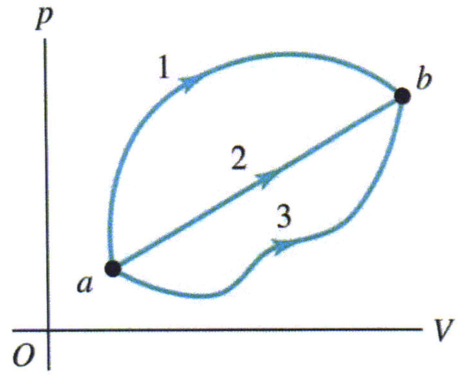
$$W = \int_{V_1}^{V_2} p\,dV = nRT \int_{V_1}^{V_2} \frac{1}{V}\,dV = nRT \ln \frac{V_2}{V_1}$$

$$\therefore \Delta S = \frac{nR\cancel{T} \ln \frac{V_2}{V_1}}{\cancel{T}} = (5.8\text{ mol})\left(8.314\frac{\text{J}}{\text{mol}\cdot\text{K}}\right)\ln\left(\frac{7\text{ m}^3}{2\text{ m}^3}\right)$$

$$= 60.4\text{ J/K}$$

12) A system can be taken from state a to state b along any of the three paths shown in the p-V diagram. Along which path is the absolute value |Q| of the heat transfer the greatest?

A) path 1
B) path 2
C) path 3
D) |Q| is the same for all three paths.
E) not enough information given to decide



Since ΔU is the same for all paths and

$$\Delta U = Q - W$$

path ① has largest W so largest Q

13) You have 1.00 mol of an ideal monatomic gas and 1.00 mol of an ideal diatomic gas whose molecules can rotate. Initially both gases are at room temperature. If the same amount of heat flows into each gas, which gas will undergo the greatest increase in temperature?

A) The monatomic gas.
B) The diatomic gas.
C) Both will undergo the same temperature change.
D) The answer depends on the molar masses of the gases.

Temperature only depends on K_{trans}.

14) DO THIS PROBLEM LAST! The figure shows a 50-kg frictionless cylindrical piston that floats on 0.25 mol of compressed air at 30°C. The cylinder above the piston is open to air at 1 atm. How far does the piston move if the temperature is increased to 100°C?

A) 20 cm
B) 36 cm
C) 44 cm
D) 11 cm
E) 5 cm

$$p = \frac{nRT}{V} = \text{const.} \Rightarrow$$

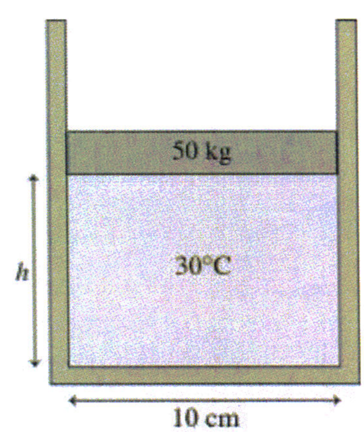
$$\frac{nRT_1}{V_1} = \frac{nRT_2}{V_2} \Rightarrow V_2 = \frac{T_2 V_1}{T_1}$$

$$Ah_2 = \frac{T_2 V_1}{T_1} = \frac{T_2}{T_1}\frac{nRT_1}{P_1}$$

$$\therefore h_2 = \frac{T_2}{T_1}\frac{nRT_1}{P_1 A} = 0.6\,m$$

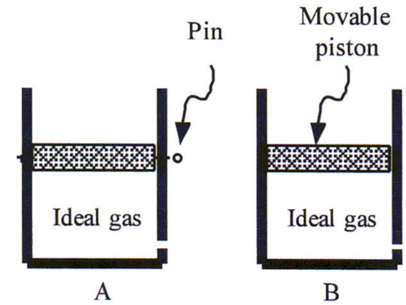
$$h_1 = \frac{nRT_1}{P_1 A} = 0.49\,m$$

$$\therefore \Delta h = .11\,m = 11\,cm$$



WRITTEN PROBLEM:

1. The two cylinders at right contain the same number of moles of the same ideal gas. Cylinder A has a piston that is locked in place. Cylinder B has a piston of mass *M* that is free to move without friction (no gas can enter or leave the cylinder). Initially, both cylinders have the same pressure and volume and both are at 60°C.



cylinders in initial states

The cylinders are placed in identical insulating boxes that contain identical amounts of an ice and water mixture at 0°C. The cylinders are allowed to come to thermal equilibrium with the ice and water mixture. (Not all of the ice is melted.)

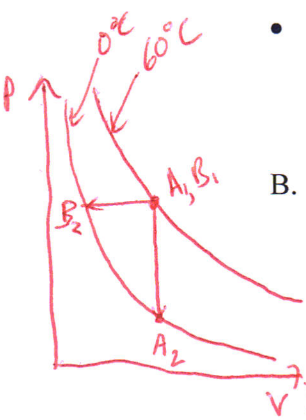
A. For each of the following quantities, decide whether its value for cylinder A is *greater than, less than,* or *equal to* the value for cylinder B. Circle the correct answer ***and explain briefly***.

- (3 points) temperature of the gas *(T)*: $T_A > T_B$ $T_A = T_B$ $T_A < T_B$

Both are in equilibrium with ice/water bath at 0°C

- (3 points) volume of the gas *(V)*: $V_A > V_B$ $V_A = V_B$ $V_A < V_B$

V_A is fixed, but since B is isobaric $\frac{nRT_B}{V_B}$ = const. and T_B decreases, then V_B decreases.



- (3 points) pressure of the gas *(P)*: $P_A > P_B$ $P_A = P_B$ $P_A < P_B$

V_A is fixed and undergoes isochoric process, so $\frac{nRT}{P}$ = const., so as T_A decreases, P_A decreases. P_B is const.

B. (7 points) Is the amount of ice melted in the box containing cylinder A, *greater than, less than,* or *equal to* the amount of ice melted in the box containing cylinder B? ***Explain your reasoning.***

The gas in B does negative work on piston, while that in A does no work. Since $\Delta U_A = \Delta U_B$

$$Q_A - \cancel{W_A}^{0} = Q_B - W_B = Q_B + |W_B|$$

$$Q_A = Q_B - |W_B|$$

But since $\Delta U < 0$, then $Q_A < 0 \Rightarrow$

$$Q_B = |W_B| - |Q_A|$$

And since Q_B is also <0, $|Q_B| > |Q_A| \Rightarrow$ more ice melts in B