Physics 161-001 Spring 2014 Exam 1

Name: ______________________________ **Box#**__________

SHOW ALL WORK!

1) A hole in a steel plate (coefficient of linear expansion = 12.0 x 10^{-6} K^{-1}) has a diameter of 30cm at 0°C. What is the diameter of the hole when the steel plate is heated red hot, 750°C?

- A) 29.730 cm
- B) 29.816 cm
- C) 29.910 cm
- D) 29.955 cm
- E) 30.000 cm
- F) 30.015 cm
- G) 30.045 cm
- H) 30.090 cm
- I) 30.184 cm
- J) 30.270 cm

$\Delta L = \alpha L_0 \Delta T$
$= (12\times10^{-6} K^{-1})(0.3 m)(750 K)$
$= .0027 m$
$\therefore L = L_0 + \Delta L$
$= .30 m + .0027 m = 30.27 cm$

2) 3 liters of an ideal gas is at 0°C. It is heated at constant pressure to 100°C. It will now occupy:

- A) 2.81 liters
- B) 2.95 liters
- C) 3.00 liters
- D) 3.55 liters
- E) 4.10 liters
- F) 4.76 liters
- G) 4.98 liters
- H) 5.23 liters
- I) 5.66 liters
- J) 6.12 liters

$pV = nRT$ with $p = const \Rightarrow$
$\frac{nRT_1}{V_1} = \frac{nRT_2}{V_2} \Rightarrow V_2 = V_1 \frac{T_2}{T_1}$
$V_2 = 3 \ell \frac{373 K}{273 K} = 4.10 \ell$

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.
- F) more than doubled.
- G) absolute zero.

$Q = W \Rightarrow$
$\Delta U = Q - W = 0$
$\therefore T = const.$

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:**

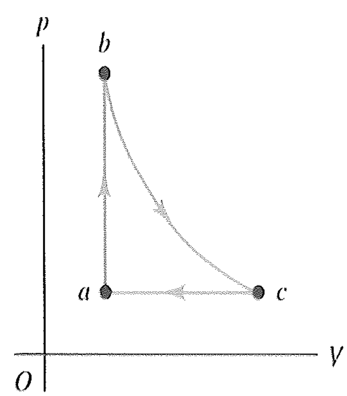
A) $\Delta S_h > 0, \Delta S_c > 0, \Delta S_{total} > 0$
B) $\Delta S_h > 0, \Delta S_c > 0, \Delta S_{total} < 0$
C) $\Delta S_h > 0, \Delta S_c > 0, \Delta S_{total} = 0$
D) $\Delta S_h > 0, \Delta S_c < 0, \Delta S_{total} > 0$
E) $\Delta S_h > 0, \Delta S_c < 0, \Delta S_{total} < 0$
F) $\Delta S_h > 0, \Delta S_c < 0, \Delta S_{total} = 0$
G) $\Delta S_h < 0, \Delta S_c > 0, \Delta S_{total} > 0$
H) $\Delta S_h < 0, \Delta S_c > 0, \Delta S_{total} < 0$
I) $\Delta S_h < 0, \Delta S_c < 0, \Delta S_{total} < 0$
J) $\Delta S_h < 0, \Delta S_c < 0, \Delta S_{total} = 0$

Heat leaves the hot object
$\therefore Q_H < 0 \Rightarrow \Delta S_H = \frac{Q_H}{T_H} < 0$
Heat enters the cold object
$\therefore Q_c > 0 \Rightarrow \Delta S_c = \frac{Q_c}{T_c} > 0$
but $|Q_H| = |Q_c|$ (the heat that goes into the cold object comes from the hot one) and since $T_c < T_H$, $|\Delta S_c| > |\Delta S_H| \Rightarrow \Delta S_{tot} > 0$

5) **An ideal gas in a chamber passes through the cycle shown below. The heat Q_{AB} added during process AB is 75.0J, no heat is transferred during process BC, and the net work done in the cycle is 25.0J. Determine the net heat added to the system during process CA.**

A) 0 J
B) 50 J
C) -50 J
D) 100 J
E) -100 J
F) 25 J
G) -25 J
H) 75 J
I) -75 J
J) Cannot determine without more information.

Since $\Delta U_{Net} = 0$ in cycle
$Q_{net} = W_{net}$
$Q_{ab} + Q_{ca} = 25 J$
$75 J + Q_{ca} = 25 J$
$\therefore Q_{ca} = -50 J$



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, 1.0 m long, is made of an aluminum section that is 0.5 m long and a copper section that is 0.5 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 0°C and 300°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.
F) 155 °C.
G) 196 °C.
H) 287 °C.
I) 212 °C.
J) 120 °C.

$H_{Al} = H_{Cu}$

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

$205 \frac{W}{mK}(T - T_c) = 385 \frac{W}{mK}(T_H - T) \Rightarrow T = 469\,K$

$= 196°C$

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.
F) Any of the above quantities can be used.

9) The graph in the figure shows a cycle for a heat engine for which $Q_H = 97$ J. What is the thermal efficiency of this engine?

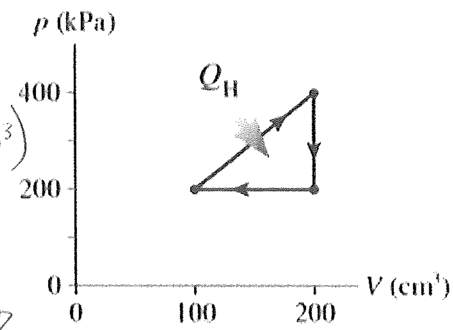
A) 8 %
B) 10 %
C) 12 %
D) 13 %
E) 15 %
F) 18 %
G) 19 %
H) 21%
I) 23 %
J) 25%

W_{Net} = area inside cycle

$= \frac{1}{2}\left(200 \times 10^3 \frac{N}{m^2}\right)\left(100 \times 10^{-6} m^3\right)$

$= 10\,J$

$e = \frac{W_{Net}}{Q_H} = \frac{10\,J}{97\,J} = 10.3\%$



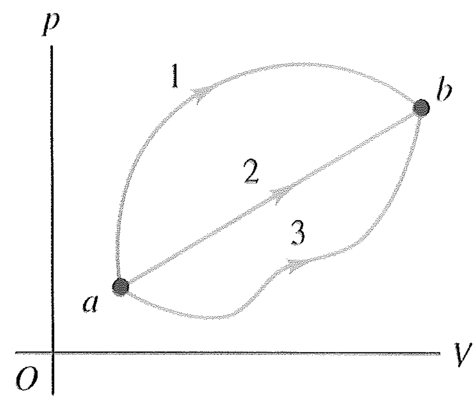
10) **A Carnot engine operates between a high temperature reservoir at 700 K and a river with water at 285 K. If it absorbs 2700 J of heat each cycle, how much work per cycle does it perform?**

$$e_c = 1 - \frac{T_c}{T_H} = 1 - \frac{285\,K}{700\,K} = 59.2\%$$

$$0.59 = \frac{W_{Net}}{Q_H} \Rightarrow W_{Net} = 1600\,J$$

A) 1600 J
B) 1798 J
C) 1621 J
D) 902 J
E) 1967 J
F) 2123 J
G) 2400 J
H) 725 J
I) 855 J
J) 1200 J

11) **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.

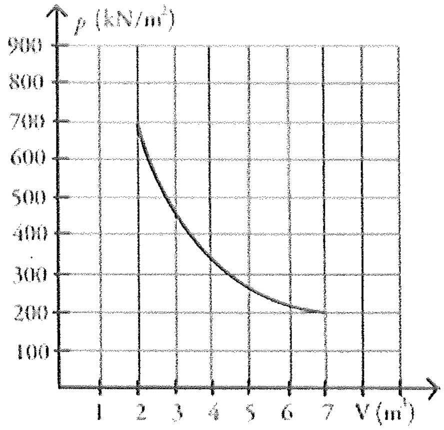
Since ΔU is same for all paths and W is max for path 1

12) **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.

T only depends on $K_{tr.}$

13) **What is the change in entropy of 2.8 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
F) 23.1 J/K
G) 40.6 J/K
H) 29.2 J/K
I) 105 J/K
J) 10.3 J/K

$$dS = \frac{dQ}{T}$$

but since $T = \text{const} \Rightarrow$

$$\int dS = \Delta S = \int \frac{dQ}{T} = \frac{1}{T}\Delta Q$$

or

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

Since the process is isothermal:

$$\Delta U = 0 = Q - W \Rightarrow Q = W$$

So, to find Q, find W:

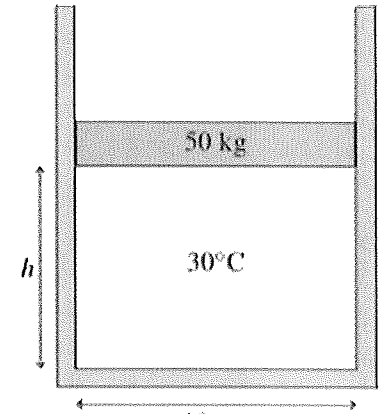
$$W = \int_{V_1}^{V_2} p\,dV = \int_{V_1}^{V_2} \frac{nRT}{V}\,dV$$

$$= nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$\therefore \Delta S = \frac{nRT\ln\left(\frac{V_2}{V_1}\right)}{T} = (2.8\text{ mol})\left(8.314\frac{J}{mol\,K}\right)\ln\left(\frac{7\,m^3}{2\,m^3}\right)$$

$$= 29.2\ J/K$$

14) **The figure shows a 50-kg frictionless cylindrical piston that floats on 0.12 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 heat is added to the gas such that the temperature is increased to 100°C?**



A) 5 cm
B) 7 cm
C) 9 cm
D) 11 cm
E) 13 cm
F) 15 cm
G) 17 cm
H) 19 cm
I) 21 cm
J) 23 cm

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

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

$A h_2 = \frac{T_2 V_1}{T_1} = \frac{T_2}{T_1} \frac{nRT_1}{P_1}$

$\therefore h_2 = \frac{T_2}{T_1} \frac{nRT_1}{P_1 A} = 0.288\,m$

and $h_1 = \frac{nRT_1}{P_1 A} = 0.2352\,m$

$\therefore \Delta h \approx 5\,cm$