Physics 111, Exam #1
Spring 2000

Name: Key ____________________ (1 point)

Multiple Choice: Choose the ***best*** answer (3 points each)

1 D Which of the following are true regarding an adiabatic process?
- a) The temperature of the gas remains constant. No
- b) The entropy of the gas remains constant. Yes
- c) No energy is added or removed from the gas. Yes
- d) Both b) and c).
- e) All of the above.

2 A An aluminum ring is firmly affixed about an iron rod. The coefficient of expansion of aluminum is larger than the coefficient of expansion of iron. If we wish to remove the ring we should:
- a) heat the system.
- b) cool the system.
- c) hit the system with a big rock.

3 A During an isothermal process, it is observed that the pressure of an ideal gas is doubled. Which of the following ***must*** be true? $PV = nRT = const$
- a) The volume of the gas is halved. Yes
- b) The temperature of the gas is doubled. No
- c) The entropy of the gas increases.
- d) None of the above.

4 B If the temperature of an ideal gas is increased at constant volume, the mean free path of the particles in the gas will
- a) decrease.
- b) remain the same.
- c) increase.

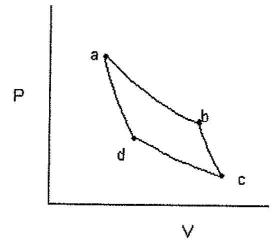
5 A Temperature is a direct measurement of...
- a) the average kinetic energy of the particles in the body.
- b) the heat energy contained in a body.
- c) the potential energy stored in the body
- d) the entropy in a body.

6 C When an ideal gas goes from state 1 to state 2 in the P-V diagram, which of the following will be the same for all possible paths (i.e. processes) going between the two states?
- a) The energy added to the gas in going between the two states.
- b) The work done by the gas in going between the two states.
- c) The difference in entropy between the two states.
- d) None of the above.

7 D Which of the following would violate the 2nd law of thermodynamics but not the 1st?
- a) A heat engine that converts of heat into work with an efficiency of 100%. Y
- b) A block of ice spontaneously getting colder by converting some of its thermal energy into kinetic energy.
- c) Spontaneous heat flow from a hot object to a cold object.
- d) All of the above.

8 A A hot steel ball ejected from a space ship in deep space will lose heat mainly by:
- a) radiation.
- b) convection.
- c) ablation.
- d) conduction

2. In the process shown, 0.05 moles of Helium (a good approximation to an ideal monatomic gas)is taken through a Carnot cycle between a hot reservoir at T_H=500K and a cold reservoir atT_C=300K.



a) What is the efficiency of this heat engine? (4 pts)

$$e = 1 - \frac{T_C}{T_H} = 1 - \frac{300}{500} = 0.4$$

b) In the isothermal process from $a \rightarrow b$ the gas starts with a volume V_a=200 cm^3 and expands to 5 times it initial volume. How much energy is input into the gas during this process? (Hint Q=W for isothermal.)(5 pt)

$$W = nRT \ln\left(\frac{V_f}{V_i}\right)$$

$$= (0.05)(8.31)(500) \ln\left(\frac{5V_0}{V_0}\right)$$

$$= \boxed{334\ J}$$

c) How much energy is expelled into the cold reservoir ***and*** how much work is done in each cycle? (6 pts)

$$e = \frac{W}{Q_H} \Rightarrow W = eQ = 0.4(334\ J) = \boxed{137\ J}\ (W)$$

$$Q_C = Q_H - W = (334\ J) - (137\ J) = \boxed{197\ J}\ (Q_C)$$

d) What is the volume of the gas at the point d? (5 pts) $\gamma = \frac{5}{3}$; $\gamma - 1 = 2/3$ $\quad \frac{1}{\gamma - 1} = \frac{3}{2}$

$$TV^{\gamma-1} = \text{const}$$

$$T_H V_a^{\gamma-1} = T_C V_d^{\gamma-1}$$

$$V_d^{\gamma-1} = \left(\frac{T_H}{T_C}\right) V_a^{\gamma-1}$$

$$V_d = \left(\frac{T_H}{T_C}\right)^{\frac{1}{\gamma-1}} V_a$$

$$= \left(\frac{500}{300}\right)^{1.5} 200\ cm^3$$

$$= \boxed{430\ cm^3}$$

e) What is the net change in the internal energy of the gas in going through the complete cycle $a \rightarrow b \rightarrow c \rightarrow d \rightarrow a$? (5 pts)

$\Delta U = 0$ in a complete cycle.

3. Five moles of diatomic Hydrogen (a good approximation of an ideal diatomic gas) has an initial temperature of 27°C and an initial pressure of 1.0×10^5 Pa..

a) What is the initial volume of the gas? (4 pts)

$27°C = 300K$

$PV = nRT$

$V = \frac{nRT}{P} = \frac{(5\text{ mole})(8.31\text{ J/mole K})(300\text{ K})}{1.0\times10^5\text{ Pa}} = \boxed{0.125\text{ m}^3}$

b) If 10,000 J of energy is added to the gas at constant pressure, what is the change in the temperature of the gas? (5 pts)

$C_p = \frac{7}{2}R$

$Q = n C_p \Delta T$

$\Rightarrow \Delta T = \frac{Q}{nC_p} = \frac{10^4\text{ J}}{5(\frac{7}{2})\,8.31\text{ J/mol K}} = \boxed{68.8\text{ K}}$

c) What is the change in the internal energy of the gas and how much work is done by the gas during the process described in part (b)? (6 pts)

$C_p = \frac{7}{2}R \quad C_v = \frac{5}{2}R$

$\gamma = \frac{7}{5} = 1.4$

$\Delta U = n C_v \Delta T$

$= n C_v \frac{Q}{nC_p}$

$= \frac{C_v}{C_p} Q$

$= \frac{1}{\gamma} Q = \frac{10^4}{1.4} = \boxed{7143\text{ J}}$

$W = Q - \Delta U$

$= 10{,}000\text{ J} - 7143\text{ J}$

$= \boxed{2857\text{ J}}$

d) What is the change in the volume of the gas during the process described in part (b)? (5 pts)

$P\Delta V = W$

$\Delta V = \frac{W}{P} = \frac{2857\text{ J}}{1\times10^5\text{ Pa}} = \boxed{0.0286\text{ m}^3}$

e) What is the change in the entropy of the gas during the process described in part (b)? (5 pts)

$\Delta S = n C_p \ln\left(\frac{T_f}{T_i}\right) = 5\left(\frac{7}{2}\right)(8.31)\ln\left[\frac{368.8}{300}\right]$

$= \boxed{30.03\text{ J/K}}$

4A. a) In addition to some interesting physics dealing with convection, adding cream to your coffee produces some interesting physics that we can actually do some calculations on. Consider a styrofoam cup filled with 200 g of coffee that has an initial temperature of 95°C (way too hot to drink). How much cream with an initial temperature of 5°C must we add to the coffee if we want the final temperature of the coffee cream mixture to be 80°C? You may neglect any effects due to the styrofoam cup and you may assume that both the coffee and the cream are essentially water with a specific heat of 4.2 J/g°C. (9 pts)

Heat loss by coffee = Heat Gain by Cream

$m_F C_F \Delta T_F = m_c C_c \Delta T_c$

$(200g)(4.2\ J/g°C)(95-80)°C = m_c (4.2\ J/g°C)(80°-5°)C$

$(15)(200) = m_c (75)$

$m_c = (\frac{15}{75}) 200 = \boxed{40g}$

b) Assuming that the addition of the cream to the coffee described in part (a) can be modeled as a constant volume process, calculate the change in entropy of the coffee/cream system. (You may assume that both the coffee and the cream have a specific heat at constant volume of 4.2 J/g°C.)(8 ts)

$\Delta S_c = m C_v \ln(T_f/T_i) =$

$= (40g)(4.2) \ln(\frac{80+273}{5+273}) = \boxed{+40.126\ J/K}$

$\Delta S_F = m C_v \ln(T_f/T_i)$

$= (200g)(4.2\ J/g°C) \ln(\frac{273+80}{273+95})$

$= \boxed{-34.957\ J/K}$

$\Delta S_{TOT} = \Delta S_c + \Delta S_F = \boxed{5.169\ J/K}$

4B. The New River Gorge Bridge in West Virginia is a steel arch 518m in length when the temperature is 30°C. What is the length of the bridge when the temperature drops to –20°C? (8pts)

$\alpha = 11 \times 10^{-6} (°C)^{-1}$

$\Delta l = \alpha L_0 \Delta T$

$= (11 \times 10^{-6})(518) 50$

$=$ ~~0.3134 m~~ $0.285\ m$

$L = 517.715\ m$