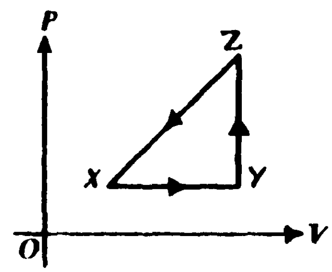
Name: ______________________

1. A thermodynamic system is taken from an initial state ***X*** along the path ***XYZX*** as shown in the PV-diagram to the right.



a. For the process $X \rightarrow Y$, ΔU is greater than zero and
   a) $Q < 0$ and $W = 0$
   b) $Q < 0$ and $W > 0$
   c) $Q > 0$ and $W < 0$
   d) $Q > 0$ and $W = 0$
   e) $Q > 0$ and $W > 0$

b. For the process $Y \rightarrow Z$, Q is greater than zero and
   a) $W < 0$ and $\Delta U = 0$
   b) $W = 0$ and $\Delta U < 0$
   c) $W = 0$ and $\Delta U > 0$
   d) $W > 0$ and $\Delta U = 0$
   e) $W > 0$ and $\Delta U > 0$

a. answer c)
   From X to Y, the pressure is constant (isobaric), and the volume is increasing. So, work is being done BY the system, so $W<0$. Since the problem states that $\Delta U>0$, then $Q>0$ (and $Q>|W|$).

b. answer c)
   From Y to Z, the volume is constant (isochoric or isovolumetric), and the pressure is increasing. $W=-P\Delta V$, so $W=0$. Since $Q>0$, then $\Delta U>0$.

2. A piece of metal with a mass of 1.20 kilograms, specific heat of 390 J/kg · C°, and initial temperature of 87 °C is dropped into an insulated jar that contains 4.5 kg of water at 20.0°C. The metal is removed after 12 seconds, at which time its temperature is 35 °C. Neglect any effects of heat transfer to the air or to the insulated jar. What is the temperature of the liquid after the metal is removed?

heat lost by metal = heat gained by liquid

$m_1c_1\Delta T_1 = m_2c_2\Delta T_2$

$1.2\ \text{kg} \cdot 390\ \text{J/kg°C} \cdot 52\ \text{°C} = 4.5\ \text{kg} \cdot 4186\ \text{J/kg°C} \cdot \Delta T_2$

$\Delta T_2 = 1.29192547\ \text{°C} = 1.3\ \text{°C}$

$T_f = T_i + \Delta T = 20.0\ \text{°C} + 1.3\ \text{°C} = \boxed{21.3\ \text{°C}}$

3. A steam engine operates on a warm 28.0 °C day. If the ideal efficiency for this engine is 24%, what is the high temperature for the engine?

$e = (T_H - T_L)/T_H$

$0.24 = (T_H - 301\ K)/T_H$

$0.24\ T_H = T_H - 301\ K$

$301K = 0.76\ T_H$

$T_H =$ 396 K or 123 °C

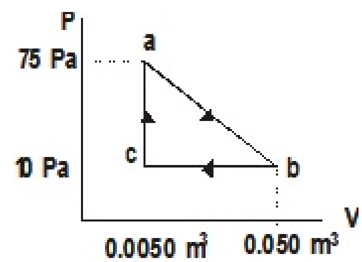
4. What is the average velocity of the particles of nitrogen at 22.0°C?

$v_{rms} = (3k_BT/\mu)^{\frac{1}{2}}$

$= (3 \cdot 1.38\times10^{-23}\ J/K \cdot 295\ K\ /\ (28\ amu \cdot 1.67\times10^{-27}\ kg/amu))^{\frac{1}{2}}$

$=$ 511 m/s

5. A gas undergoes a thermodynamic expansion process as shown. Process ***ab*** represents the output work, process ***bc*** represents input work, all three processes involve heat transfer. (a) what is the work accomplished along path ***ca***? (b) What is the work along path ***ab***, (c) What is the work along path ***bc***? (d) What is the net work for the entire thermo cycle?



a. $W = -P\Delta V = -P \cdot 0 =$ 0 J

b. $W = -P\Delta V = -42.5\ Pa \cdot 0.045\ m^3$

$=$ -1.91 J or 1.91 J work done by system

c. $W = -P\Delta V = -10\ Pa \cdot (-0.045\ m^3)$

$=$ 0.45 J or 0.45 J work done on system

d. $W_{net} = W_{out} + W_{in} = -1.91\ J + 0.45\ J =$ -1.46 J or 1.46 J work done by system

6. A heat engine makes use of 785 kJ of heat to produce 245 kJ of work. It operates at a temperature of 285°C. It exhausts heat to the 22.5°C atmosphere. What is (a) its ideal efficiency and (b) its actual efficiency? (c) Why are these two quantities so different?

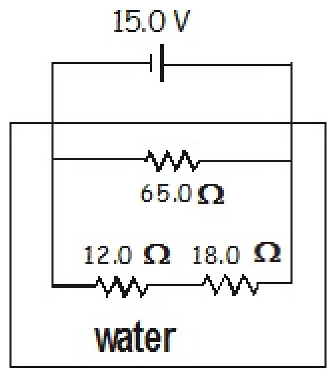
a. $e_{ideal} = (T_H - T_L) / T_H$

$= (558\text{ K} - 295.5\text{ K})/558\text{ K} = 0.4704301 = \boxed{47.0\ \%}$

b. $e_{actual} = 245\text{ kJ}/785\text{ kJ} = \boxed{31.2\ \%}$

c. Friction within the engine would cause the engine itself to heat up. So, some of the heat that could be used for work would be lost to friction or engine heating.

7. A circuit exists as shown below – the three resistors are immersed in a tank of water. The battery is connected to the resistors for 12.0 min. (a) How much heat is generated in the 12.0 min? (b) The water in the tank has a mass of 1.25 kg and a beginning temperature of 24.0 °C, so what is the final temperature of the water if all the heat goes into it?



a. $R_{total} = (65.0^{-1}\ \Omega + (12.0 + 18.0)^{-1}\ \Omega)^{-1} = 20.5\ \Omega$

$P = V^2/R = (15.0\text{ V})^2/20.5\ \Omega = 10.98\text{ W}$

$P = W/t$ so $Q = P \cdot t$

$Q = 10.98\text{ J/s} \cdot 720\text{ s}$

$= 7902\text{ J} = \boxed{7900\text{ J or }7.9\text{ kJ}}$

b. $Q = mc\Delta T$

$\Delta T = Q/mc$

$= 7900\text{ J}/(1.25\text{ kg} \cdot 4186\text{ J/kg}) = 1.51\ °C$

$T_f = T_i + \Delta T$

$= 24.0\ °C + 1.5\ °C = \boxed{25.5\ °C}$