Directions:

I. A. Review the chapter using the book, your notes, and the packet
   B. Put them aside and take the test using only the provided useful information sheet with a black pen or pencil
   C. Grade your test following the rubric provided with the solutions (Black grade)

II. A. Review the chapter using the book, your notes, and the packet one more time.
   B. Redo any problems you got right partially or you did not get right at all using your text, notes, and the packet
   C. Grade your test following the rubric provided with the solutions (Blue grade, inclue the black grade)

III. A. Review the chapter using the book, your notes, and the packet one final time.
   B. Redo any problems you got right partially or you did not get right at all using the solutions
   C. Grade your test following the rubric provided with the solutions (Red grade, inclue the black and blue grades)

**Chapters 13-15**

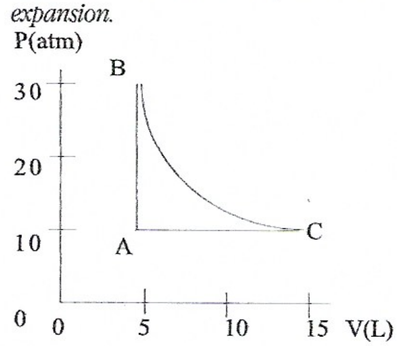
1. What is +40K in Celsius?
2. What is +40K in °F?
3. The length of a copper wire increases by 17 cm when the temperature changes from −10°C in the winter to 40°C in the summer. The average coefficient of linear expansion for copper is $\alpha = 17 \times 10^{-6}\,(°\mathrm{C})^{-1}$. What was the lenght of the wire in the winter?
4. How many Hydrogen atoms would there be at a room temperature (20°C) in a room with dimensions $10m \times 10m \times 3m$ at one atmospheric pressure?
5. What is the average kinetic energy and speed of H-atoms at room temperature (~20°C)?
6. How much energy is needed to change 500-kg ice at -10°C to 2-kg water, 488-kg ice mixture?
7. Calculate the change in entropy when 2 kg ice is melted at 32°F.
8. 5-kg ice at -100°C is heated to a 5-kg vapor at 200°C. How much energy is needed to accomplish this? Remember to include all phase changes in your calculations.
9. How much heat is transferred in 10 hours through a 30m x 20m wooden wall of thickness 0.3 m when the room temperature is 20°C and the outside temperature is -10°C? The conductivity of wood is 0.1 J•m/(s•°C).
10. How much work is done on the gas by changing the volume of 4 moles of ideal gas with the molar specific heat $20 J/(mol \cdot K)$ from 20 $m^3$ to 10 $m^3$ at one atmospheric pressure?

*Questions 11-13. 4 moles of a monatomic ideal gas expands from an initial volume of $0.2m^3$ to a final volume $0.3m^3$ and as the pressure changes from $4 \times 10^5 Pa$ to $2 \times 10^5 Pa$ linearly.*

[11.FRQ] Plot the situation on a P-V diagram

11. Calculate the work done on the gas.
12. Calculate the change in internal energy of the gas.
13. Calculate the thermal energy transferred to the gas.

*Questions 14-20 A heat engine contains an ideal monatomic gas confined to a cylinder by a movable piston. The gas starts at A, where $T = 3 \times 10^2 K$. The process $B \to C$ is an isothermal expansion.*



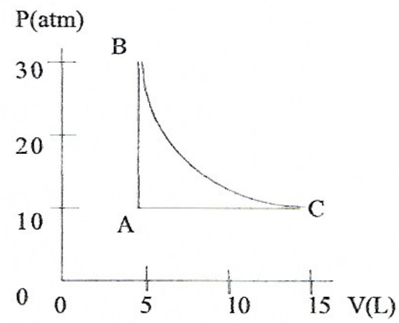

14. Find the number n of moles of gas and the temperature at B.
15. What is the temperature at B?
16. Find $\Delta U$, $Q$, and $W$ for the isovolumetric (constant volume) process $A \to B$.
17. Repeat for the isothermal process $B \to C$.
18. Repeat for the isobaric process $C \to A$.
19. Find the net change in the internal energy for the complete cycle.
20. Find the thermal energy, $Q_H$, transferred into the system, the thermal energy rejected, $Q_C$, the thermal efficiency, and net work on the environment performed by the engine.

1. What is +40K in Celsius?
   A. –40°C  B. 40°C  C. –233°C  D. +233°C  E. –388°C
2. What is +40K in °F?
   A. –40°F  B. 40°F  C. –233°F  D. +233°F  E. –388°F
3. The length of a copper wire increases by 17 cm when the temperature changes from –10°C in the winter to 40°C in the summer. The average coefficient of linear expansion for copper is $\alpha = 17\times10^{-6}\,(°C)^{-1}$. What was the lenght of the wire in the winter?
   A. 0.25 m  B. 0.50 m  C. 1.00 m  D. 2.00 m  E. 4.00 m
4. How many Hydrogen atoms would there be at a room temperature (20°C) in a room with dimensions $10m\times10m\times3m$ at one atmospheric pressure?
   A. $7.5\times10^{27}$  B. $5\times10^{27}$  C. $6\times10^{23}$  D. $6\times10^{23}$  E. 3
5. What is the average kinetic energy and speed of H-atoms at room temperature (~20°C)? $m_H \approx m_p$.
   A. $10\frac{m}{s}$  B. $2.7\frac{m}{s}$  C. $2.7\times10^3\ \frac{m}{s}$
   D. $5\times10^7\ \frac{m}{s}$  E. $3\times10^8\ \frac{m}{s}$
6. How much energy is needed to change 500-kg ice at -10°C to 2-kg water, 488-kg ice mixture?
   A. $7.7\times10^5 J$  B. $6.7\times10^3 J$  C. $2.7\times10^3\ \frac{m}{s}$
   D. $5\times10^7\ \frac{m}{s}$  E. $3\times10^8\ \frac{m}{s}$
7. Calculate the change in entropy when 2 kg ice is melted at 32°F.
   A. $32\frac{J}{K}$  B. $2.5\times10^3\ \frac{J}{K}$  C. $6.7\times10^3\ \frac{J}{K}$
   D. $5\times10^2\ \frac{J}{K}$  E. $2.1\times10^4 J$
8. 5-kg ice at -100°C is heated to a 5-kg vapor at 200°C. How much energy is needed to accomplish this? Remember to include all phase changes in your calculations.
   A. $1.701\times10^5 J$  B. $1.7\times10^6 J$  C. $2\times10^6 J$
   D. $1.711\times10^7 J$  E. $3.122\times10^7 J$
9. How much heat is transferred in 10 hours through a 30m x 20m wooden wall of thickness 0.3 m when the room temperature is 20°C and the outside temperature is -10°C? The conductivity of wood is 0.1 J•m/(s•°C).
   A. $3.6\times10^6 J$  B. $1.2\times10^6 J$  C. $1\times10^6 J$
   D. $3.6\times10^3 J$  E. $6\times10^3 J$
10. How much work is done on the gas by changing the volume of 4 moles of ideal gas with the molar specific heat $20J/(mol\cdot K)$ from 20 $m^3$ to 10 $m^3$ at one atmospheric pressure?
   A. $-1\times10^6 J$  B. $2\times10^7 J$  C. $1\times10^6 J$
   D. $3\times10^3 J$  E. Can't be done without n.

*Questions 11-13. 4 moles of a monatomic ideal gas expands from an initial volume of $0.2m^3$ to a final volume $0.3m^3$ and as the pressure changes from $4\times10^5 Pa$ to $2\times10^5 Pa$ linearly.*

11. Calculate the work done on the gas.
   A. $6\times10^3 J$  B. $3\times10^4 J$  C. $6\times10^4 J$
   D. $8\times10^4 J$  E. $-3\times10^4 J$
12. Calculate the change in internal energy of the gas.
   A. $6\times10^3 J$  B. $3\times10^4 J$  C. $6\times10^4 J$
   D. $3\times10^4 J$  E. $-3\times10^4 J$
13. Calculate the thermal energy transferred to the gas.
   A. $6\times10^4 J$  B. $3\times10^4 J$  C. $-6\times10^4 J$
   D. 0  E. $-3\times10^4 J$

*Questions 14-21 A heat engine contains an ideal monatomic gas confined to a cylinder by a movable piston. The gas starts at A, where $T = 3\times10^2 K$. The process $B\rightarrow C$ is an isothermal expansion.*




14. How many moles of gas are there?
   A. 0.25  B. 0.5  C. 1  D. 2  E. 4
15. What is the temperature at B.
   A. 102  B. 150  C. 304  D. 608  E. 914

**FRQ** SHOW WORK!

16. Find $\Delta U, Q, W, \Delta S$ for the isovolumetric (constant volume) process $A\rightarrow B$.
17. Repeat for the isothermal process $B\rightarrow C$.
18. Repeat for the isobaric process $C\rightarrow A$.
19. Find the net change in the internal energy for the complete cycle.
20. Find the thermal energy, $Q_H$, transferred into the system, the thermal energy rejected, $Q_C$, the thermal efficiency, and net work on the environment performed by the engine and the net change in the entropy.
21. A black body emmits energy at a rate $\frac{dQ}{dt} = -\varepsilon\sigma A T^4$. At what rate does the entropy of the black hole change?
22. How would your answer to the previous question change if the temperature of the black hole changes from $T_i$ to $T_f$. Hint: You may need to differentiate with respect to T, then integrate dS.
23. Assume you have flipped a coin N times and you had tail n of those. Obtain the number of microstates and the entropy of this state. What is the number of microstates and the entropy if $N = N_A$ and $n = \frac{N_A}{2}$? Compare this to the case where all $N_A$ tries give tails or heads.
24. In units where $\hbar = k_B = c = G = 1$, obtain a relation between
   A. mass and energy
   B. temperature and time
   C. energy and time
   D. length and energy
   E. length and time
   F. temperature and mass
   G. mass and time

$R = 8.31 \dfrac{J}{mol \cdot K} = 0.0821 \dfrac{L \cdot atm}{mol \cdot K}$

$k_B = 1.38 \times 10^{-23} \frac{J}{K}$

$PV = nRT$

$PV = Nk_BT$ ,

$\Delta U = W + Q$

$P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$\Delta S \equiv \int \dfrac{dQ}{T}$

$S \equiv k_B \ln \Omega$

$\Delta L = \alpha L_o \Delta T$

$\Delta A = 2\alpha A_o \Delta T$

$\Delta V = 3\alpha V_o \Delta T$

$T_F = \dfrac{9}{5} T_C + 32$

$Q = mc\Delta T$ or $\pm mL$

$Q = mc\Delta T = nC\Delta T$

$Q = \dfrac{3}{2} nR\Delta T = nC_V \Delta T$

$Q = \dfrac{5}{2} nR\Delta T = nC_P \Delta T$

$C_V = \dfrac{3}{2} R$

$C_P = C_V + R$

$U = \dfrac{3}{2} Nk_BT = \dfrac{3}{2} nRT = nC_VT$

$U = N \dfrac{1}{2} mv^2$

$W = -P\Delta V$

$W = nC_V \Delta T$

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

$c_{ice} = 2.09 \times 10^3 \dfrac{J}{kg \cdot °C}$

$c_{water} = 4.19 \times 10^3 \dfrac{J}{kg \cdot °C}$

$c_{steam} = 2.01 \times 10^3 \dfrac{J}{kg \cdot °C}$

$L_f = 3.33 \times 10^5 \dfrac{J}{kg}$

$L_v = 2.26 \times 10^6 \dfrac{J}{kg}$

$1 atm = 1 \times 10^5 Pa$

$m_p = 1.67 \times 10^{-27} kg$

$\wp = kA \dfrac{\Delta T}{\Delta L}$

$\dbinom{N}{n} = \dfrac{N!}{n!(N-n)!}$

Ch 13-15 test

1) 40 K ~~$T_C = 273 - T_K - 273$~~

$T_K = T_C + 273$

$T_C = T_K - 273 = 40 - 273 = -233\ C$

(MC 1 C)

2) $T_F = \frac{9}{5} T_C + 32$

$= \frac{9}{5}(-233\ C) + 32\ F = -387.4\ F$

(MC 2 E)

3) ~~$\Delta l$~~ $\Delta l = \alpha l \Delta T$

~~$l = \frac{\Delta l}{\alpha \Delta T} = \frac{\ }{(17\times10^{-5})\ 50k} = \ $~~

$l = \frac{\Delta l}{\alpha \Delta T} = \frac{0.17\ m}{(1.7\times10^{-5}\ \frac{1}{C})\ 50\ K} = 200\ m?$

MC 3 D

4) $PV = nRT = NkT$

$N = \frac{PV}{kT} = \frac{(101325\ Pa)(10\cdot10\cdot3\ m^3)}{(1.38\times10^{-23}\ \frac{J}{K})(293\ K)}$

$= 7.52\times10^{27}$ atoms

MC 4 A

5) $KE_{avg} = \frac{3}{2}kT = \frac{3}{2}(1.38\times10^{-23}\ \frac{J}{K})(293\ K)$

$= 6.065\times10^{-21}\ J$

$KE = \frac{1}{2}mv^2 \quad v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2(6.065\times10^{-21}\ J)}{1.67\times10^{-27}\ kg}}$

$= 2.7\times10^{3}\ m/s$

MC 5 C

6) assuming 498 kg of ice?

$Q_1 = mc_{ice}\Delta T = (500\ kg)(2050\ \frac{J}{kg\,C})(10\ C)$

$= 1.03\times10^{7}\ J$

$Q_2 = m_2 L = (2\ kg)(3.335\times10^5\ J)$

$= 6.67\times10^5\ J$

$Q_{total} = 1.097\times10^{7}\ J$

MC 6?

Kurep

7) $\Delta S = \frac{mL}{T} = \frac{(2\ kg)(3.335\times10^5\ \frac{J}{kg})}{273\ K}$

$= 2.44\times10^{3}\ J/K$

MC 7 B

8) 5 kg $-100C \rightarrow 800C$

$Q = m(c_{ice}\Delta T_1 + L_{melt} + c_{water}\Delta T_2 + L_{vap} + c_{steam}\Delta T_3)$

$= (5\ kg)((2108\ \frac{J}{kg\,K})(100\ K) + 3.335\times10^5\ J + (4186\ \frac{J}{kg\,C})(100\ K)$
$+ 2260000\ J/kg + (1996\ \frac{J}{kg\,K})(100\ K))$

$= 1.71\times10^{7}\ J$

MC 8 D

9) $\frac{Q}{t} = A\frac{T_H - T_C}{R}$

$Q = \frac{At(T_H - T_C)}{R} \qquad R = \frac{d}{k}$

$= \frac{Atk(T_H - T_C)}{d}$

$= \frac{(30\cdot20\ m^2)(3.6\times10^4\ s)(0.1\ \frac{J}{m\,s\,C})(30\ K)}{0.3\ m}$

$= 2.16\times10^{8}\ J$

MC 9?

10) $W = nRT\ln\frac{V_f}{V_0}$

~~$= (1)(8.3145\ \frac{J}{mol\,K})(\ )$~~

$PV = nRT$ isobaric compression

$\Delta U - W = Q$

$W = \Delta U - Q$

$W = \Delta U$

$W = \int_{V_0}^{V_f} P\,dV = P\int_{V_0}^{V_f} dV$

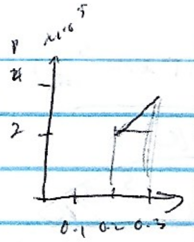
$= PV_f - PV_0$

$= (101325\ Pa)(10 - 20\ m^3)$

$= -1.01\times10^{6}\ J$ by the gas

$\therefore$ on it $W = 1.01\times10^{6}$

MC 10 C

11) 

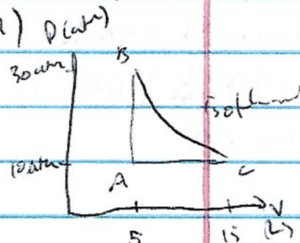

$W =$ area under the curve

$= (0.1)(2\times10^5) + (2\times10^5)(0.1)(\frac{1}{2})$

$= 3.0\times10^4\ J$ ✓ MC 11 B

12) $\Delta U = Q - W = -W = -(3.0\times10^4 J)$ ✓ MC 12 E

13) $Q = 0$ ✓ MC 13 D

14) 


$PV = nRT$

$n = \frac{PV}{RT}$

$= \frac{(10.101325 m)(0.005 m^3)}{(8.314)(300 K)}$

$= 2.0\ mol$ ✓ MC 14 D

15) $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ $\quad T_2 = T_1 \frac{P_2}{P_1}$

$= (300 K)(\frac{30}{10}) = 900 K$ ✓

MC 15 E

16) $W = \int_{V_0}^{V_2} P\,dV$ $\quad P = \frac{nRT}{V}$

$= nRT \int_{V_0}^{V_2} \frac{dV}{V}$ $\quad = nRT$

$W = n C_V \Delta T = n \frac{3}{2} R\, \Delta T$

$= (2.0 mol)(\frac{3}{2})(8.314)(600 K)$

$= 1.5\times10^4\ J$ ~

$\Delta U = \frac{3}{2} nR(T_f - T_0)$

$= \frac{3}{2}(2.0 mol)(8.314)(600 K)$

$= 1.5\times10^4\ J$ ✓

$\Delta U = Q - W$

$Q = \Delta U + W = 3\times10^4\ J$ ~

17) $W = nRT \ln\frac{V_2}{V_0}$

$= (2.0 mol)(8.314)(900 K)(\ln\frac{15}{5})$

$Q = 1.6\times10^4\ J$

18 - 20

21) $\frac{dQ}{dt} = -\varepsilon\sigma A T^4$

$\Delta S = \int\frac{dQ}{T} = \int -\varepsilon\sigma A T^3\, dt$

$\cancel{\frac{dS}{dt} = \int\frac{dQ}{T\,dt}}$

$\frac{dS}{dt} = -\varepsilon\sigma A T^3$ (?)

22) $\cancel{\int_{T_0}^{T_f} -\varepsilon\sigma A T^3\, dt}$

$\cancel{\frac{dS}{dT}\ \varepsilon\sigma A T^3 = -3\varepsilon\sigma A T^2}$

$\frac{dS}{dT}\cdot\frac{dT}{dt} = -\varepsilon\sigma A T^3$

$\frac{dS}{dT} = -\varepsilon\sigma A T^3 \cdot \frac{dt}{dT}$

$= -3\varepsilon\sigma A T^2$

$dS = -3\varepsilon\sigma A T^2\, dT$

$S = \int_{T_i}^{T_f} -3\varepsilon\sigma A T^2\, dT$

$= -\varepsilon\sigma A(T_f^3 - T_0^3)$

23) $\binom{N}{n} = \frac{N!}{n!(N-n)!}$

$S = k \ln\left(\frac{N!}{n!(N-n)!}\right)$

24

6) 50 kg ice → 2 kg water, 48 kg ice

$Q = mc\Delta T + mL_f$

$= (50\,kg)(2108\,\frac{J}{kg\,K})(10\,K) + (2\,kg)(3.335\times10^5\,\frac{J}{kg})$

$= 1.7\times10^6\,J$ $\quad 7.7\times10^5\,J?$

9) $\frac{dQ}{dt} = A\frac{(T_H - T_C)}{R}$ $\quad R = \frac{d}{k}$

$= \frac{Ak(T_H - T_C)}{d} = \frac{(30\times20)(0.1\,\frac{J}{m\,s\,C})(30\,K)}{0.3\,m}$

$= 6\times10^3\,J/s$

$Q = (6\times10^3\,J/s)(10\,hr\times60\,\frac{min}{hr}\times60\,\frac{s}{min})$

$= 2.16\times10^8\,J$

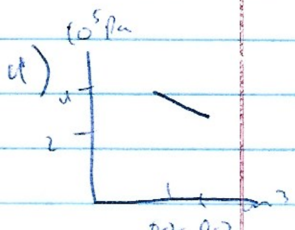
$3.6\times10^6\,J$

13) $\Delta U = Q + W$

$Q = \Delta U - W = -3.0\times10^4\,J - 3.0\times10^4\,J$

$= -6.0\times10^4\,J$

14)




16) $W = 0$ for const. volume

$\Delta U = \frac{3}{2}nR\Delta T = 1.52\times10^4\,J$

17) $Q = 1.4\times10^6\,J$, not W

$\Delta U = 0$

18) $\Delta U = -1.52\times10^4\,J$

~~W~~ $W = 1.01\times10^4\,J$

$Q = \Delta U - W = -2.53\times10^4\,J$

19) $\Delta U_{total} = 0$

$Q_{total} = 6.6\times10^3\,J$

$W_{net} = -6.6\times10^3\,J$

20) $Q_H = 3.19\times10^4\,J$

$Q_C = -2.53\times10^4\,J$

$\varepsilon = 1 - \frac{|Q_H|}{|Q_C|} = 0.207$

$W_{engine} = -W_{net} = 6.6\times10^3\,J$

1. $T_F = T_K - 273 = -233°C$
2. $T_F = \frac{9}{5}(T_K - 273) + 32 = -388°F$
3. $\Delta L = \alpha L_o \Delta T$

   $0.17m = 17 \times 10^{-6} (°C)^{-1} L_o (40 - (-10))°C$

   $L_o = 200m$
4. $PV = Nk_B T$

   $10^5 300 = N 1.38 \times 10^{-23} 293$

   $N = 7.5 \times 10^{27}$
5. $N \frac{1}{2} mv^2 = \frac{3}{2} Nk_B T$

   $v = \sqrt{\frac{3 x 1.38 \times 10^{-23} 293}{1.67 \times 10^{-27}}} = 2700 \frac{m}{s}$
6. $Q = m_{ice} c \Delta T + m_{ice \to w} L$

   $Q = 50 \times 2.09 \times 10^3 \times 10 + 2 \times 3.33 \times 10^5 = 7.7 \times 10^5 J$
7. $Q = m_{ice \to w} L \quad \Delta S = \frac{Q}{T} = \frac{6.7 \times 10^5 J}{273K} = 2.5 \times 10^3 \frac{J}{K}$
8. $Q = mc_{ice} \Delta T + mL_f + mc_w \Delta T + mL_v + mc_v \Delta T$

   $Q = 5 \times [2.09 \times 10^3 \times (0 - (-100))$

   $+ 3.33 \times 10^5$

   $+ 4.19 \times 10^3 (100 - 0)$

   $+ 2.26 \times 10^6$

   $+ 2.01 \times 10^3 (200 - 100)]$

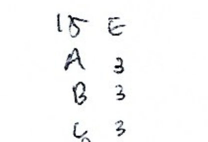
   $= 5 \times [2.09 \times 10^5 + 3.33 \times 10^5 + 4.19 \times 10^5$

   $+ 22.6 \times 10^6 + 2.01 \times 10^5]$

   $Q = 1.711 \times 10^7 J$
9. $\wp = kA \frac{\Delta T}{\Delta L}$

   $Q = \wp t = 0.1 \times 600 \frac{30}{0.3} \times 10 \times 60 = 3.6 \times 10^6 J$
10. $W = P \Delta V = 1 \times 10^6 J$

[11.FRQ] Plot the situation on a P-V diagram



11. $W = \frac{1}{2}(P_1 + P_2) \Delta V = 3 \times 10^4 J$

12.

$$\Delta U = \frac{3}{2} nR(T_2 - T_1) = \frac{3}{2}(P_2 V_2 - P_1 V_1)$$
$$= \frac{3}{2}(6 \times 10^4 - 8 \times 10^4) = -3 \times 10^4 J$$

13.

$$\Delta U = Q + W$$
$$Q = \Delta U - W = -6 \times 10^4 J$$

14. Use PV=nRT at A, then

$$n = \frac{PV}{RT} = \frac{10 \times 5}{0.0821 \times 300} = 2.03$$

15. $T = \frac{PV}{nR} = \frac{30 \times 5}{2 \times 0.0821} = 900J$

16. $\Delta U = \frac{3}{2} nR(T_B - T_A) = 3.045 \times 8.31 \times 600 = 1.52 \times 10^4 J$

W=0 since the volume is constant.

$\Delta U = Q + W \Rightarrow Q = \Delta U = 1.52 \times 10^4 J$

17. $\Delta U = 0$ since $\Delta T = 0$ for an isothermal process.

$$Q = -W = -nRT \ln\left(\frac{V_f}{V_i}\right) = -2.03 \times 8.31 \times 914 \times \ln\left(\frac{15}{5}\right)$$
$$Q = -W = 1.67 \times 10^4 J$$

18.

$$\Delta U = \frac{3}{2} nR(T_A - T_C) = 3.05 \times 8.31 \times (-600)$$
$$= -1.52 \times 10^4 J$$
$$W = -P \Delta V = -1.01 \times 10^6 (5 \times 10^{-3} - 15 \times 10^{-3})$$
$$= 1.01 \times 10^4 J$$
$$Q = \Delta U - W = -1.52 \times 10^4 J - 1.01 \times 10^4 J = -2.53 \times 10^4 J$$

19.

$$\Delta U_{net} = 1.52 \times 10^4 J + (-1.52 \times 10^4 J) = 0$$
$$Q_{net} = 1.52 \times 10^4 J + 1.67 \times 10^4 J - 2.53 \times 10^4 J$$
$$= 6.6 \times 10^3 J$$
$$W_{net} = -1.67 \times 10^4 J + 1.01 \times 10^4 J$$
$$= -6.6 \times 10^3 J$$

Notice that $\Delta U_{net} = Q_{net} + W_{net}$

20.

$$Q_H = Q_{AB} + Q_{BC} = 1.52 \times 10^4 J + 1.67 \times 10^4 J$$
$$= 3.19 \times 10^4 J$$
$$Q_C = Q_{CA} = -2.53 \times 10^4 J$$
$$e = 1 - \frac{|Q_H|}{|Q_C|} = 0.207$$
$$W_{engine} = -W_{net} = 6.6 \times 10^3 J$$

MC

1 C
2 E
3 D
4 A
5 C
6 A
7 B
8 D
9 A
10 C
11 B
12 E
13 B
14 D
15 E

A 3
B 3
C 3
D 9
E 3