Solutions Exam-4 Spring '16

1.) *Multiple Choice* *(18 pts.)*

For each statement below, circle the correct answer (TRUE or FALSE, no reasoning required).

(a) If the intensity of a sound wave increases tenfold, its intensity level increases by $10\,dB$.
TRUE FALSE

(b) When a police car with its sirene on is approaching you, the sirene frequency you are hearing is smaller.
TRUE FALSE

(c) When adding heat to a substance during a phase change, the temperature of the substance keeps increasing.
TRUE FALSE

(d) The internal energy of an ideal gas is nothing but the sum of the kinetic energies of all gas particles.
TRUE FALSE

(e) Irreversible processes do not change the total entropy of the Universe.
TRUE FALSE

(f) If the entropy of a substance decreases, there must be some other substance whose entropy increases by at least as much.
TRUE FALSE

No.	Points
1	YZ
2	JW
3	CH
4	RR
5	TW
Sum	

2.) *Mathematical Description of a Wave* *(16 pts.)*

A transverse wave is propagating in x-direction and described by the equation

$$y(x,t) = 3m\ \sin[(\mathbf{2}\ /s)t - (0.\mathbf{8}/m)x]\ . \qquad (1)$$

Extract the amplitude, frequency, wavelength, and propagational speed of the wave.

$$y(x,t) = A\ \sin\left[2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)\right]$$

$$\Rightarrow \quad \boxed{A = 3m}$$

$$\frac{2\pi}{T} = 2\pi f = 2\ \text{Hz} \quad \Rightarrow \quad \boxed{f = \frac{2}{2\pi}\ \text{Hz} = 0.32\ \text{Hz}}$$

$$\frac{2\pi}{\lambda} = \frac{0.8}{m} \quad \Rightarrow \quad \boxed{\lambda = \frac{2\pi}{0.8}\ m = 7.85\ m}$$

$$\boxed{v = f\lambda = 2.5\ \frac{m}{s}}$$

3.) *Heat and Temperature* *(18 pts.)*

A bullet (mass $22\,g$) at a speed of $930\,m/s$ is shot into a bucket of $10\,\text{kg}$ of water at room temperature ($20°C$) and gets stopped in it.

(a) How much energy does the bullet deposit into the water?

(b) Estimate the maximal increase of the water temperature once it is equilibrated. (Neglect any temperature changes of the bullet.)

(a) $\boxed{\Delta E = |KE_f - KE_i| = \frac{1}{2} m v_i^2 = 9513.9\,\text{J}}$

(b) $Q = m c \Delta T$

$$\Rightarrow \boxed{\Delta T = \frac{Q}{mc} = \frac{\Delta E}{m_w c_w} = 0.23\,C^\circ}$$

4.) *Thermal Processes for an Ideal Gas* *(24 pts.)*

A fixed amount of ideal gas of initial volume $0.1\,m^3$ and initial pressure $6 \cdot 10^5 Pa$ is first cooled isochorically (at constant volume) down to a pressure of $2 \cdot 10^5 Pa$, and then expanded isobarically (at constant pressure) to a final volume of $0.3\,m^3$.

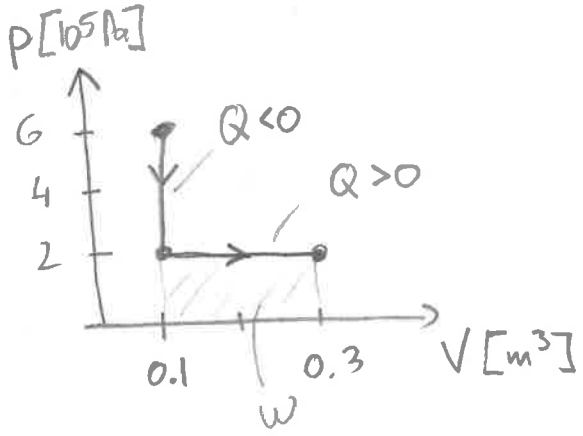
(a) Draw the p-V diagram of this 2-step process and state whether heat has been added or taken out of the gas in each step (no calculation necessary).

(b) What is the ratio of initial to final temperature?

(c) How much work does the gas do during the process?

(d) How much total heat is exchanged between the gas and the environment during the total process?

(a)



(b) $p_i V_i = n R T_i$

$p_f V_f = n R T_f$

$$\frac{T_f}{T_i} = \frac{p_f V_f}{p_i V_i} = \frac{2 \cdot 0.3}{6 \cdot 0.1} = 1$$

(c) $$W = p\,\Delta V = 2 \cdot 10^5 \cdot 0.2 = 0.4 \cdot 10^5\,J$$

(d) total $\Delta U = Q - W = 0$ (since $\Delta T = 0$)

$\Rightarrow Q = W = +0.4 \cdot 10^5\,J$ into the gas

5.) *Carnot Refrigerator* *(24 pts.)*

A refrigerator with perfect efficiency cools its compartment at constant temperature of $-15°C$ and exhausts heat into the surrounding room at $20°C$. Two kilogram of water at room temperature are put into the freezer.

(a) Calculate the coefficient of performance of the refrigerator.

(b) Calculate the heat to be extracted from the water to cool it to the temperature inside the freezer.

(c) How much work (electrical energy) must be done by the freezer?

(d) How much heat does the freezer exhaust into the environment?

(a) $\boxed{K = \frac{Q_C}{W} = \frac{Q_C}{Q_H - Q_C} = \frac{1}{\frac{Q_H}{Q_C} - 1} = \frac{1}{\frac{T_H}{T_C} - 1} = 7.376}$

(b) $\boxed{Q_c = c_w m_w \Delta T_w + m_w L_f + c_{ice} m_w \Delta T_{ice}}$

$= 2(4190 \cdot 20 + 334000 + 2010 \cdot 15) = \boxed{895900\,J}$

(c) $W = \frac{Q_C}{K} = 121500\,J$

(d) $\boxed{Q_H = W + Q_C = 1.017 \cdot 10^6\,J}$