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 source decreases by a factor of 100, the corresponding intensity level decreases by 20dB.
   TRUE   ~~FALSE~~

(b) Longitudinal waves cannot form standing waves.
   TRUE   **FALSE**

(c) If two substances are in thermal equilibrium with each other, the temperatures of the two substances must be identical.
   TRUE   FALSE

(d) The kinetic theory of ideal gases states that, at a fixed temperature, the average kinetic energy of a gas molecule increases with the mass of that molecule.
   TRUE   **FALSE**

(e) Spontaneous heat flow increases the total entropy of the universe.
   TRUE   FALSE

(f) In a reversible process, the total entropy of the universe increases.
   TRUE   **FALSE**

No.	Points
1	TS
2	PJ
3	KR
4	RR
5	MS
6	DX
Sum	

V_2: F
T
F
T
T
F

2.) *Doppler Effect*   *(15 pts.)*

An Aggie student is driving in his car on a highway at a speed of 70*mph*. In front of him, a police car (at a speed of 95*mph*) is drawing away, while behind him a fire truck (at a speed of 55*mph*) is trailing him. All vehicles move straight ahead in the same direction. Both the police car and fire truck have their sirens on, both of which emit a pure tone of frequency 750*Hz*. (speed of sound: $v = 340m/s$; $1m/s=2.25mph$)   [600Hz]

(a) With what frequency does the student hear the police car?

(b) With what frequency does the student hear the fire truck?

(b) What is the beat frequency the student hears?

- (a) $\boxed{f_L^{pol} = \dfrac{v + v_L}{v + v_S^{pol}}}$ $= \underline{728\ Hz}$ [583 Hz]

(b) $\boxed{f_L^{truck} = \dfrac{v - v_L}{v - v_S^{truck}}}$ $= \underline{734\ Hz}$ [587 Hz]

(c) $\boxed{f_{beat} = f^{truck} - f^{pol},}$ $= \underline{6\ Hz}$ [4 Hz]

3.) *Stefan Boltzmann Radiation Law* (12 pts.)

The Sun has a radius of $R_S = 7 \cdot 10^8 m$ and a surface temperature of $T_S = 6000°K$. The distance from Sun to Earth is $R_{SE} = 1.5 \cdot 10^{11} m$. Assume the Sun to be an ideal blackbody radiator. (the surface area of a sphere is $S = 4\pi R^2$)

(a) How much total power does the Sun radiate from its surface?

(b) Assuming the Sun's power output to propagate spherically into space without losses, what is the intensity of its radiation on the Earth's surface (assume that no radiation is absorbed in the atmosphere)?

(c) What is the equilibrium temperature on the Earth surface facing the Sun (neglect again the atmosphere and assume the Earth surface to be a blackbody)?

(a) $$P = H = A e \sigma T^4 \quad = 4.52 * 10^{26} \, W$$

(b) $$I_E = \frac{P}{A} = \frac{P}{4\pi R_{SE}^2} \quad = 1600 \, \frac{W}{m^2}$$

(c) $$I = \frac{P}{A} = e \sigma T^4$$

$$\Rightarrow \quad T = \sqrt[4]{\frac{I}{e\sigma}} \quad = 410 °K$$

4.) *Ideal Gas Law and 1. Law of Thermodynamics*   *(20 pts.)*

The *p-V* diagram below illustrates an isothermal ‹éxpansion of an ideal gas at temperature $T = 320°K$.

[480]

(a) How many moles of the gas are involved?

(b) What is the volume of the gas at the initial point a?

(c) How much work is done by the gas from a to b?

(d) By how much did the internal energy of the gas change?

P [10^5 Pa]

0.5 ┄┄ a

0.15 ┄┄┄┄┄ b

0.2   V (m^3)
[0.3]
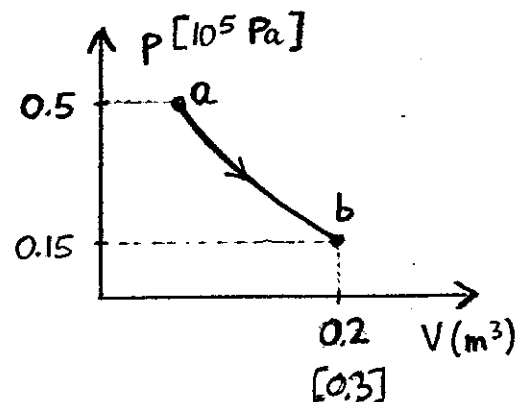
(a) at point b: $pV = nRT$

$$\Rightarrow \boxed{n = \frac{pV}{RT}} = \underline{1.128\ mol}$$

(b) $p_a V_a = p_b V_b$ $\Rightarrow$ $\boxed{V_a = V_b \frac{p_b}{p_a}} = \underline{0.06\ m^3}$ [$0.09 m^3$]

(c) $\boxed{W = nRT\ ln\left(\frac{V_b}{V_a}\right)} = \underline{3613\ J}$ [$5420 J$]

(d) $\boxed{\Delta U = \frac{3}{2} nR\Delta T = 0}$

5.) *Heat Extraction and Refrigerator* [4.5] (15 pts.)

A freezer has a coefficient of performance of 3.2. A person puts $2.5kg$ of water at an initial temperature of $20°C$ into a freezer whose inside temperature is at a constant $-8°C$.

($L_f = 3.34 * 10^5 \, J/kg$, $c_w = 4.186 * 10^3 \, J/kg°k$, $c_{ice} = 2.01 * 10^3 \, J/kg°k$)

(a) How much heat must be removed from the water to convert it into ice at $-8°C$?

(b) How much electrical energy does the freezer need for the freezing process in part (a)?

(c) How much excess heat does the freezer dumb into it's environment?

(a) $Q_c = m \left(\Delta T_w \, c_w + \Delta T_i \, c_i + L_f \right)$

$\boxed{Q_c = 1.085 * 10^6 \, J}$ $[1.952 * 10^6 \, J]$

(b) $K = \dfrac{Q_c}{W}$ $\Rightarrow$ $\boxed{W = \dfrac{Q_c}{K} = 3.39 * 10^5 \, J}$ $[6.10 * 10^5 \, J]$

(c) $\boxed{Q_H = Q_c + W = 1.42 * 10^6 \, J}$ $[2.56 \; 10^6 \, J]$

6.) *Heat Pump and Entropy*   [S°F]   (20 pts.)

During winter time (outside air temperature $T_{out} = 25°F$), a person would like to heat his living room from $55°F$ to $75°F$ using his Carnot heating system. The room, which has a volume of $120m^3$, is filled with air of density $\rho_{air} = 1.3 kg/m^3$. Treat the inside air as an ideal monatomic gas with a molar mass of $32g$ at constant volume. Be sure to use SI units in your calculations.

[105 m³]

(a) How many moles of air are in the room?   (*recall: density=mass per volume*)

(b) How much heat needs to be added to the room to achieve the desired increase in temperature?

(c) Calculate the Carnot efficiency of the heating system using the average temperature of the inside air during the heating process.

(d) Using the Carnot efficiency from part (c), calculate the work required by the heating system to heat up the room.

(e) Calculate the entropy change of: (i) the inside air; (ii) the outside reservoir; (iii) the universe.

(a) $n = \dfrac{M_{tot}}{M_{mol}}$

$M_{mol} = 0.032\,kg$

$M_{tot} = V\rho = 156\,kg$

$\Rightarrow$ $n = 4875\,mol$

[4266 mol]

(b) $Q_H = n\,C_V\,\Delta T = n\dfrac{3}{2}R\,\Delta T = 6.75 \times 10^5 \, J$ $[5.91 \times 10^5 \, J]$

$\Delta T\,[K°] = \Delta T\,[F°] * \dfrac{5}{9}$

(c) $e_{Carnot} = 1 - \dfrac{T_c}{T_H} = 1 - \dfrac{269.3}{291.5} = 0.07616$ $[0.1144]$

$T_c = 269.3°K, \quad \overline{T}_H = 291.5°K$

[258.15]

(d) $W = e\,Q_H = 5.14 \times 10^4 \, J$ $[6.76 \times 10^4 \, J]$

(e) (i) $\Delta S_{in} = \dfrac{Q_H}{T_H} = \dfrac{6.75 \times 10^5}{291.5} = +2316 \, \dfrac{J}{K}$ $[2027.5 \, J/°K]$

ΔS_{tot}

(ii) $\Delta S_{out} = \dfrac{-Q}{T_c} = \dfrac{-(Q_H - W)}{269.3} = -2316 \, \dfrac{J}{K}$ $[-2027.5 \, J/°K]$

$= 0$
(reversible!)