1.
Compare the efficiency of a water-cooker and a stove.

$$c_{water} = 4.19 \frac{kJ}{kg * K}$$

$$T_1 = 10°C$$

$$T_2 = 100°C$$

$$W_{watercoo\ \mathrm{ker}} = 1800W = 1800 \frac{J}{s}$$

$$W_{stove} = 1800W = 1800 \frac{J}{s}$$

$$Q = \int_{U1}^{U2} dU = mc\Delta T = 1[kJ] * 4.19 \left[\frac{kJ}{m * K}\right] * 90[T] = 360\,kJ$$

Using 1800 W, without losses the heating should take about:´

$$t = \frac{360[kJ]}{1.8\left[\frac{kJ}{s}\right]} = 200s$$

Approximate actual time:

$$t_{watercoo\ \mathrm{ker}} = 4\min = 240\,s \rightarrow Q = 432\,kJ$$

$$t_{stove} = 9\min = 540\,s \rightarrow Q = 972\,kJ$$

Efficiency water-cooker:

$$\frac{360[kJ]}{432[kJ]} = 83\%$$

Efficiency stove:

$$\frac{360[kJ]}{972[kJ]} = 37\%$$

2.
Assume an 1m3 balloon filled with He2, pressure is 0.1MPa. The balloon is cooled down 20 degrees (Q=-5kJ), what is the change in volume?

$$Q = m * c_p * \Delta T + p(V_2 - V_1) \rightarrow V_2 = \frac{Q - m * c_p * \Delta T + pV_1}{p}$$

$$c_{p\_He} = 5.1932 kJ/(kg * K)$$

$$p_1 = p_2 = 0.1 MPa$$

$$V_1 = 1m^3, V_2 = ?$$

$$T_1 = 25, T_2 = 5$$

$$PV = mRT \rightarrow m = \frac{PV}{RT}$$

$$R = \frac{8314}{M_{He}} = \frac{8314}{4} = 2078$$

$$V_2 = \frac{-5000 - \frac{0.1*10^6 *1}{2078*(273+25)} * 5.1932 * (-20) + 0.1*10^6 *1}{0.1*10^6} = 0.95m^3$$

Answer: The balloon has shrunk 5 %, new volume is 0.95m3

3.

2 m3 of argon @ 300 K, expands adiabatically, preassure changes from 0.1 MPa till 0.4MPa What is the end volume and temperature?

argon is an inert gas -> k = 1.66

$$P_1 V_1^{\kappa} = P_2 V_2^{\kappa} = constant$$

$$T_1 V_1^{(\kappa-1)} = T_2 V_2^{(\kappa-1)} = constant$$

$$V_2 = ?$$

$$T_2 = ?$$

$$V_2 : 0.1*2^{1.66} = 0.4*V_2^{1.66} \rightarrow V_2 = \sqrt[1.66]{0.4*2^{1.66}} = \sqrt[1.66]{1.25} = 1.14m^2$$

$$T_2 : 300*2^{0.66} = T_2 * V_2^{0.66} \rightarrow T_2 = \frac{300*2^{0.66}}{1.14^{0.66}} = 434K$$

4.

A hard-working but absent-minded student forgets about her tea so it gets cold (i.e. room temp). What is the increase in enthropy ?

$$m = 0.3kg$$
$$c_v = 4.19\left[\frac{kJ}{kg * K}\right]$$
$$T_1 = 95°C = 273 + 95K = 368K$$
$$T_2 = 25°C = 273 + 25K = 298K$$
$$Q = U_2 - U_1 = mc_v T_2 - mc_v T_1 = 0.3 * 4.91 * (368 - 298) = 103kJ$$
$$S = \frac{Q}{T_2} - \frac{Q}{T_1} = \frac{103[kJ]}{298[K]} - \frac{103[kJ]}{368[K]} = 3.04\frac{kJ}{K}$$

Answer: The increase in enthropy is 3.04 kJ/K

5.
Water has been heated so that the specific entropy is 4.33 kJ/(kg*K) at a point where half of the water has evaporated. As half of the remaining water has evaporated in the same conditions the specific entropy is 5.84kJ/(kg*K) What is the pressure, temperature and specific volume?

$$s = x * s_g + (1 - x) * s_f$$
$$s_1 = 4.33kJ/(kg * K)$$
$$s_2 = 5.84kJ/(kg * K)$$
$$x_1 = 0.5$$
$$x_2 = 0.75$$

$$s_1 \rightarrow 4.33 = 0.5 * s_g + 0.5 * s_f \rightarrow s_f + s_g = 8.66$$
$$s_2 \rightarrow 5.84 = 0.75 * s_g + 0.25 s_f \rightarrow 5.84 = 0.75 * (8.66 - s_f) + 0.25 s_f = 6.495 - 0.5 s_f$$

$$s_f = \frac{6.495 - 5.84}{0.5} = 1.31$$
$$s_g = 8.66 - 1.31 = 7.35$$

Steam tables gives:
P = 1 bar
Ts = 99,6059
vf = 0,00104315
vg = 1,69393

v1=x*vg+(1-x)vf
$$v = x * v_g + (1 - x) v_f$$
$$v_1 = 0.5 * 1.69393 + 0.5 * 0.00104 = 0.8474$$
$$v_2 = 0.75 * 1.69393 + 0.25 * 0.00104 = 1.2706$$

6.

a) How much exergy power is needed to maintain a 10 degree indoor temp in an igloo when it is -20 C outdoors?
b) How many persons is needed to maintain that temp? Assuming only heat radiation from the human body.

Solution:

$$\Delta P_{ex} = \frac{\lambda}{d} A \frac{T_0}{T_H T_L} (T_H - T_L)^2$$

Assume sphere with a 4m diameter.

Area : $\dfrac{4\pi * r^2}{2} = \dfrac{4 * \pi * 2^2}{2} = 8\pi$

Thickness d* = 8 inch = 2.54*8 cm = 0.20 m
*)According to howstuffworks.com

$$T_0 = T_L = -20°C = 253K$$
$$T_H = 10°C = 283K$$

Heat conductivity of ice: 2 W/m*K

$$\Delta P_{ex} = \frac{2}{0.025 * 8} 8\pi \frac{253}{283 * 253} (283 - 253)^2 \approx 0.8kW$$

Heat radiation from a human body:

$$P_{en} = \varepsilon \sigma A T^4$$

Emission coefficient for a human body: $\varepsilon = 0.7$
Area: $A \approx 2m^2$
Temperatur $T = 37°C = 310K$

$$P_{en} = 0.7 * 5.67 * 10^{-8} * 1.5 * 310^4 \approx 550W$$

Answer: Hmm, sounds too good to be true, less than 2 persons are needed to maintain at least a 10 degree temperature in the igloo. But with conductivity of 2W/m*K ice is a relatively good insulator.