Example: A flexible container contains 2.42×10^{-5} m^3 of fluid at room T. Somebody pushes on the container, maintaining a constant 1-atm pressure, and reduces its volume by 25 %. How much work is done on the fluid ?

Work done on the fluid: $W = -P(V_f - V_i) = 1\text{atm}(0.75V_i - V_i) =$

$= -(1.013\text{x}10^5\ \text{Pa})V_i(-0.25) = (1.013\text{x}10^5\ \text{Pa})(2.42 \times 10^{-5}\ \text{m}^3)(0.25) = 0.61\ \text{J}$

100g ice → H_2O at 0°C ; 100g H_2O $\xrightarrow{100°C}$ steam

57. ORGANIZE AND PLAN The entropy change is the heat added to the ice or the water divided by the temperature. The heat added can be calculated using the heats of transformation from Table 13.3.

Known: $m = 100\text{ g};\ T_f = 0°\text{C};\ L_f = 3.33\times10^5\text{ J/kg};\ T_v = 100°\text{C};\ L_v = 2.26\times10^6\text{ J/kg}.$

SOLVE When the ice melts the entropy change is:

$$\Delta S_f = \frac{Q_f}{T_f} = \frac{mL_f}{T_f} = \frac{(100\text{ g})(3.33\times10^5\text{ J/kg})}{(0°\text{C})} = 122\text{ J/K}$$

When the water boils the entropy change is:

$$\Delta S_v = \frac{Q_v}{T_v} = \frac{mL_v}{T_v} = \frac{(100\text{ g})(2.26\times10^6\text{ J/kg})}{(100°\text{C})} = 606\text{ J/K}$$

Problem # 2 How much energy must be transferred as heat for a reversible isothermal expansion of an ideal gas at 132° C if the entropy of the gas increases by 46 J/K ?

- From Eq. 20-2, $\Delta S = S_f - S_i = \frac{Q}{T}$

we obtain

$$Q = T\Delta S = (405\ \text{K})(46.0\ \text{J/K}) = 1.86\times10^{4}\ \text{J}.$$

$\Delta S = ?$ when 75g steam $\xrightarrow{100°C}$ H_2O

56.ORGANIZE AND PLAN The entropy change is the heat removed from the steam divided by the temperature. The heat removed can be calculated using the heat of vaporization from Table 13.3.

Begin

Known: $m = 75$ g; $T = 100°C$; $L_v = 2.26 \times 10^6$ J/kg

SOLVE The heat removed from the steam to condense it is:

$$Q = -mL_v = -(75 \text{ g})(2.26 \times 10^6 \text{ J/kg}) = -1.7 \times 10^5 \text{ J}$$

0.075kg. * Table 13.3

The entropy change is:

$$\Delta S = \frac{Q}{T} = \frac{(-1.7 \times 10^5 \text{ J})}{(100°C)} = \frac{(-1.7 \times 10^5 \text{ J})}{(373 \text{ K})} = -4.5 \times 10^2 \text{ J/K}$$

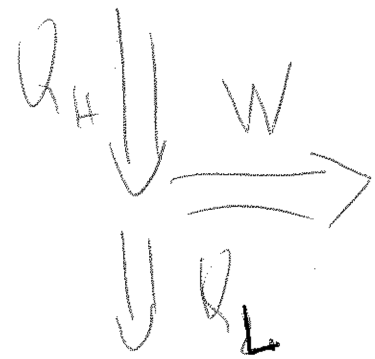
However S ↑ in the Universe since, for example, refrigerator does work to remove the heat and dump it in the Universe

$W = 650\ J \rightarrow Q_L = 1270\ J;\ \varepsilon = ?$

63. . **ORGANIZE AND PLAN** The efficiency is the ratio between work done and heat used.
Known: $W = 650$ J; $Q_H = 1270$ J.
SOLVE The heat engine's efficiency is:

$Q_H = W + Q_L = 1920\ J$

$$e = \frac{W}{Q_H} = \frac{(650\ J)}{1920\ J} = 0.338 \sim 34\%$$



Sample Problem 20-4

Imagine a Carnot engine that operates between the temperatures T_H = 850 K and T_L = 300 K. The engine performs 1200 J of work each cycle, which takes 0.25 s.

(a) What is the efficiency of this engine?

$$\varepsilon = 1 - \frac{T_L}{T_H} = 1 - \frac{300\,K}{850\,K} = 0.647$$

(b) What is the average power of this engine?

$$P = \frac{W}{t} = \frac{1200\,J}{0.25\,s} = 4800\,W = 4.8\,kW$$

Jet engine ; e=?

96. ORGANIZE AND PLAN The maximum efficiency is that of a Carnot engine, one minus the temperature ratio between the cold and hot reservoirs.

Known: $T_H = 1050°\text{C}$; $T_C = 590°\text{C}$.

SOLVE The maximum efficiency is:

$$e_{\text{Carnot}} = 1 - \frac{T_C}{T_H} = 1 - \frac{(590°\text{C})}{(1050°\text{C})} = 0.348 \;\; = \;\; 1 - \frac{(590 + 273)}{(1050 + 273)}$$

REFLECT If you could invent a way of operating a jet engine such that the exhaust temperature is that of the surrounding air (typically $-40°\text{C}$ at the cruising height of commercial airliners), you would raise the maximum efficiency to better than 0.8!

$T_H = ?$ if $T_L = 20°C$

68. **ORGANIZE AND PLAN** In a Carnot cycle, the efficiency is one minus the temperature ratio between the cold and hot reservoirs.

Known: $T_C = 20°C$; $e_{Carnot} = 0.5$.

SOLVE The Carnot efficiency is:

$$e_{Carnot} = 1 - \frac{T_C}{T_H}$$

$\rightarrow \frac{T_C}{T_H} = 1 - \varepsilon \rightarrow T_H = \frac{T_C}{1-\varepsilon}$

which we can rewrite for to calculate the maximum temperature:

$$T_H = \frac{1}{1 - e_{Carnot}} T_C = \frac{1}{1-0.5} 20°C =$$

$\rightarrow 293K = (20+273)$

$\approx 600\,K$

REFLECT ~~When the Carnot efficiency is 0.5, the hot reservoir is twice the temperature of~~ the cold reservoir. (in K)

Problem

$$K = \frac{\textit{what we want}}{\textit{what we pay for}} = \frac{|Q_L|}{|W|}$$

$$|W| = |Q_H| - |Q_L|$$

$$K = \frac{|Q_L|}{|Q_H| - |Q_L|}$$

A Carnot refrigerator does 200 J of work to remove 600 J from its cold compartment. *(a)* What is the refrigerator's coefficient of performance? *(b)* How much energy per cycle is exhausted to the kitchen as heat?

34. (a) We use Eq. 21-12,

$$\frac{Q_L}{Q_H - Q_L} = K = \frac{|Q_L|}{|W|} = \frac{600}{200} = 3\ .$$

(b) Energy conservation for a refrigeration cycle requires $|Q_L| + |W| = |Q_H|$, so that the result is 800 J.

$Q_H - Q_L = W$

$Q_H = W + Q_L = 200\,J + 600\,J = 800\,J$

$T_H = 310\,°C$ | winter ($T_c = 0\,°C$) $P = 650\,MW$
$e_{winter} = ?$; $P_{summer} = ?$ when $T_c = 38\,°C$

89. ORGANIZE AND PLAN We will assume that the power plant operates at the maximum thermodynamic efficiency, i.e., the efficiency of a Carnot cycle, where the efficiency is one minus the temperature ratio between the cold and hot reservoirs. The power produced is proportional to the efficiency, so from knowing the winter production and both the winter and summer efficiencies we can calculate the summer production.

Known: $T_H = 310°C$; $P_{winter} = 650$ MW; $T_{C,winter} = 0°C$; $T_{C,summer} = 38°C$.

SOLVE (a) The theoretical maximum winter efficiency is:

$$e_{Carnot,winter} = 1 - \frac{T_{C,winter}}{T_H} = 1 - \frac{(0°C)}{(310°C)} = 0.532$$

+273

+273

(b) The theoretical maximum summer efficiency is:

$$e_{Carnot,summer} = 1 - \frac{T_{C,summer}}{T_H} = 1 - \frac{(38°C)+273}{(310°C)+273} = 0.466$$

The production is proportional to efficiency, so comparing the winter and summer numbers we must have:

$$1222\,MW = \frac{P_{winter}}{e_{winter}} = \frac{P_{summer}}{e_{summer}}$$

If we assume that the efficiencies are the Carnot efficiencies, we have:

$$\frac{P_{winter}}{e_{Carnot,winter}} = \frac{P_{summer}}{e_{Carnot,summer}}$$

$$P_{summer} = \frac{e_{Carnot,summer}}{e_{Carnot,winter}} P_{winter} = \frac{(0.466)}{(0.532)}(650\text{ MW}) = 570\text{ MW}$$