Learning Activities and Learner Interactions

Two power cycles each receive the same amount of heat energy, Q_{in} = 500 MJ, and discharge heat energy Q_{out} into the same lake. If one cycle A has a thermal efficiency of 40% and the other B has an efficiency of 35%. Calculate the values of Q_{out} for both cycles. which one discharges a greater amount of Q_{out}? What are the potential environmental implications of the differences in the heat discharged by these cycles.

$W_{cycle} = Q_{in} - Q_{out}$ (power cycle)

$\boldsymbol{\eta = \frac{W_{cycle}}{Q_{in}}}$ **(power cycle)**

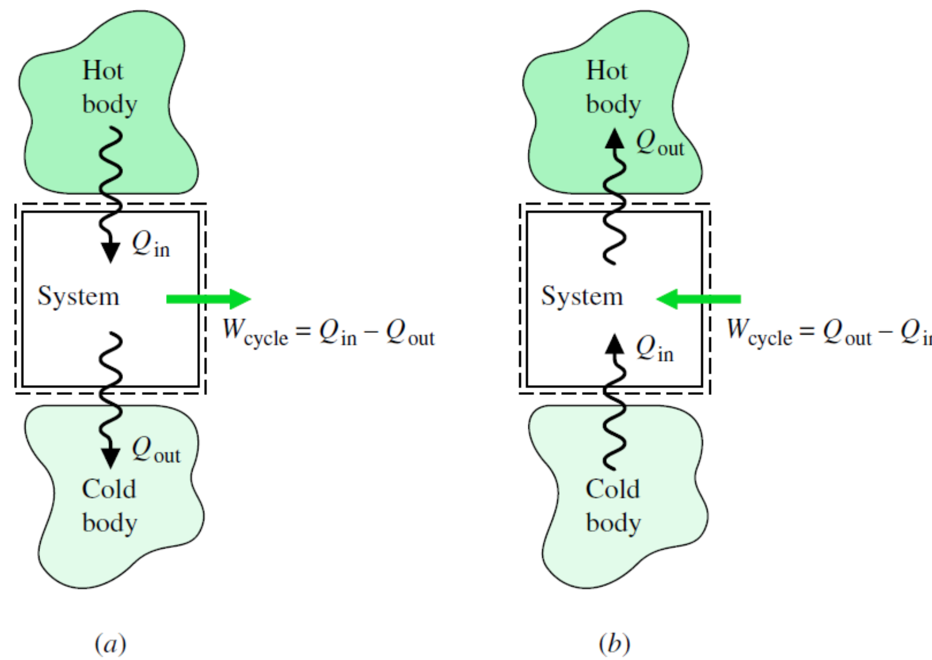
$W_{cycle} = \eta\, Q_{in} = Q_{in} - Q_{out}$

$Q_{in} - \eta\, Q_{in} = Q_{out}$

$Q_{out} = (1 - \eta) Q_{in}$

Caso A: $Q_{out} = (1 - 0.4)500\ MJ = 300\ MJ$

Caso B: $Q_{out} = (1 - 0.35)500\ MJ = 325\ MJ$

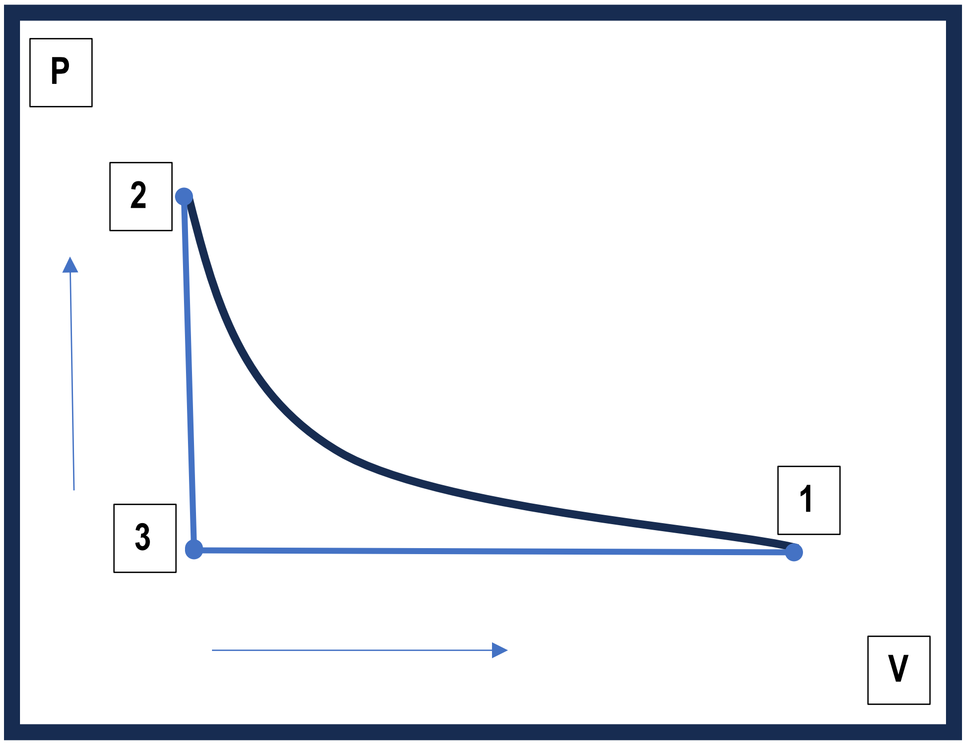


Activity II

100 moles of an ideal gas monoatomic undergoes a thermodynamic cycle consisting of three processes:

Process 1–2: compression with $pV = constant$, from $p_1 = 1.5\ bar$, $V_1 = 2.0\ m^3$ to $V_2 = 0.5\ m^3$, $\Delta U_{21} = 0$
Process 2–3: constant volume to $V_3 = V_2$
Process 3–1: constant pressure

There are no significant changes in kinetic or potential energy. Define the type process in each step. Determine the heat transfer, work and internal energy for each step and for the total cycle. Is this a power cycle or a refrigeration cycle?



Process 1–2: compression

$$pV = constant$$
$$p_1 = 1.5\ bar$$
$$V_1 = 2.0\ m^3$$
$$V_2 = 0.5\ m^3$$
$$U_2 - U_1 = 0$$

Isothermal Process for ideal gas → $\Delta U_{21} = 0$

$$W_{12} = \int_{V_1}^{V_2} pdV = \int_{V_1}^{V_2} \frac{constant}{V} dV = (constant) ln\left(\frac{V_2}{V_1}\right)$$

$$constant = p_1 V_1$$

$$W_{12} = (1.5\ bar)(2.0\ m^3)\left(\frac{10^5\ N/m^2}{1\ bar}\right)\ ln\left(\frac{0.5}{2.0}\right)\left(\frac{1\ kJ}{10^3\ Nm}\right) = -415.9\ kJ$$

$$\Delta U_{21} = Q_{12} + W_{12} = 0 \ \rightarrow \ Q_{12} = -W_{12} = +415.9\ kJ$$

Process 2–3: constant volume

$$V_3 = V_2 = 0.5\,m^3$$
$$p_1 = p_3 = 1.5\,bar$$
$$V_1 = 2.0\,m^3$$

Isochoric Process for ideal gas → $\Delta V = 0$

$$W_{23} = \int_{V_2}^{V_3} pdV = 0$$

$$p_1V_1 = nRT_1$$

$$\frac{p_1V_1}{nR} = T_1 = T_2$$

$$T_2 = \frac{(1.5\,bar)(2.0\,m^3)}{(100\,mol)(8.314\,J/(mol\,K))}\left(\frac{10^5\,N/m^2}{1\,bar}\right)\left(\frac{1\,J}{1Nm}\right) = 360.8\,K$$

$$T_3 = \frac{p_3V_3}{nR} = \frac{(1.5\,bar)(0.5\,m^3)}{(100\,mol)(8.314\,J/(mol\,K))}\left(\frac{10^5\,N/m^2}{1\,bar}\right)\left(\frac{1\,J}{1Nm}\right) = 90.2\,K$$

$$\Delta U_{32} = \int_{T_2}^{T_3} C_v dT = C_v(T_3 - T_2) = \frac{3}{2}nR\Delta T = \frac{3}{2}(100\,mol)\left(8.314\frac{J}{(mol\,K)}\right)(90.2 - 360.8)K = -337.5\,kJ$$

$$\Delta U_{32} = Q_{23} + W_{23} \rightarrow Q_{23} = \Delta U_{32} = -337.5\,kJ$$

Process 3–1: constant pressure,

$$U_1 - U_3 = -2500\ kJ$$
$$V_3 = V_2 = 0.5\ m^3$$
$$p_1 = p_3 = 1.5\ bar$$
$$V_1 = 2.0\ m^3$$
$$T_1 = T_2 = 360.8\ K$$
$$T_3 = 90.2\ K$$

Isobaric Process for ideal gas → $\Delta p = 0$

$$W_{31} = \int_{V_3}^{V_1} pdV = p(V_1 - V_3)$$

$$W_{31} = (1.5\ bar)((2.0 - 0.5)\ m^3)\left(\frac{10^5\ N/m^2}{1\ bar}\right)\left(\frac{1\ kJ}{10^3\ Nm}\right) = +225\ kJ$$

$$\Delta U_{13} = \int_{T_3}^{T_1} C_v dT = C_v(T_1 - T_3) = \frac{3}{2}nR\Delta T = \frac{3}{2}(100\ mol)\left(8.314\frac{J}{(mol\ K)}\right)(360.8 - 90.2)K = +337.5\ kJ$$

$$\Delta U_{13} = Q_{31} + W_{31} = +337.5\ kJ$$

$$Q_{31} = \Delta U_{13} - W_{31} = 337.5\ kJ - (225\ kJ) = +112.5\ kJ$$

W, Q for the cycle

$$W_{cycle} = W_{12} + W_{23} + W_{31}$$

$$W_{cycle} = -415.9\ kJ + 0 + 225\ kJ = -190.9\ kJ$$

$$Q_{cycle} = Q_{12} + Q_{23} + Q_{31}$$

$$Q_{cycle} = +415.9\ kJ - 337.5\ kJ + 112.5\ kJ = 190.9\ kJ$$

$$\Delta U_{Cylce} = \Delta U_{21} + \Delta U_{32} + \Delta U_{13} = 0 - 337.5\ kJ + 337.5\ kJ = 0$$

$W_{cycle} = \mathrm{Q_{out}} - \mathrm{Q_{in}}$ (refrigeration and heat pump cycles)
$W < 0$ or $Q > 0$ if energy is transferred to the system
$W > 0$ or $Q < 0$ if energy is lost from the system

Since W_{cycle} is negative, Q_{out} is smaller than Q_{in}, refrigeration efficiency:

$$\beta = \frac{Q_{in}}{W_{cycle}} = \frac{112.5\ kJ}{190.9\ kJ} = 0.59$$