Thermodynamics I

Chapter 1

Lecture no.3-Examples

Heat, Work, System & State of the Working Fluid

Dr. Mahmood Shaker Jamel
Department Of Mechanical Engineering
Engineering College – University Of Basrah

Example 1

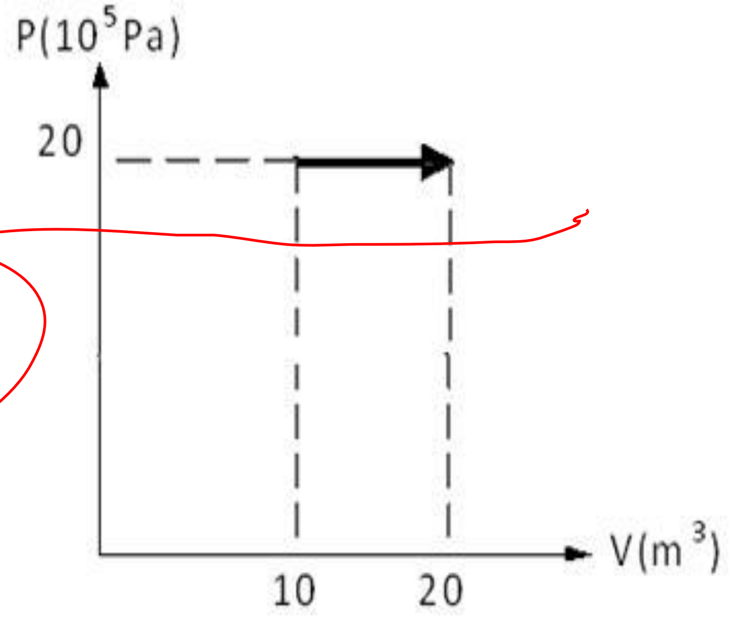
There is an ideal gas in an insulated container. The volume of the container increases from 10 m^3 to 20 m^3 under a constant pressure of 20×10^5 Pa. What was the work done on the gas?

Solution:

We will use the formula **$W = P\Delta V$**

We know that $\Delta V = 10$, $P = 20 \times 10^5$ Pa.

We plug these values in and get **$W = P\Delta V = 2 \times 10^7$ J**



Example2

As shown in the diagram below, firstly, the pressure of an ideal gas changes from 20×10^5 Pa to 40×10^5 Pa at the volume of 10 m^3. Later, the pressure of it changes from 40×10^5 Pa to 20×10^5 Pa while the volume increases from 10 to 20 m^3. What is the work done by the gas?

Solution:

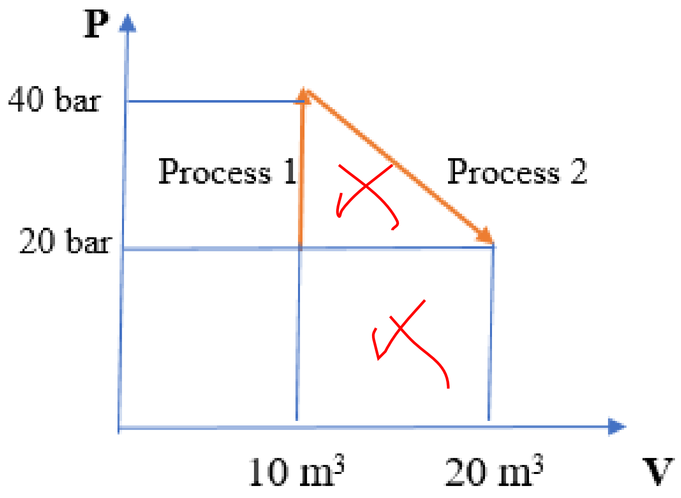
You have a work is equal to **$W = \int P\, dV$**

During process 1. volume did NOT change, **there was no work done.**

However, during process 2, you can solve this by taking the area under the curve.

We see from the graph that the area under the curve can be simplified

to a rectangle and a triangle. If we take the areas of the two and add them together,



$A_{proc.2} = A_{triangle} + A_{rectangle}$ then $A_{proc.2} = \frac{1}{2}\,\Delta V\ \Delta P + p_i\ \Delta V$

where $\Delta P = (P_f - P_i) = 40 - 20 = 20 \times 10^5$ and

$\Delta V = (V_f - V_i) = 20 - 10 = 10$ then $A_{proc.2} = \{\frac{1}{2}(10 \text{ x } 20 \times 10^5)\} + (20 \times 10^5 \text{ x } 10) = 300 \times 10^5$

$A_{proc.2} = W_{proc.2} = 3 \times 10^7$

$W_{total} = W_{proc.1} + W_{proc.2}$

$W_{total} = 0 + 3 \times 10^7 = 3 \times 10^7$ J

Example3

An ideal gas in an insulated container. If the work done on the gas is 4×10^6 J, under a constant pressure of 2×10^5 Pa and the initial volume of the container is 30 m^3, what is the final volume?

Solution:

We will use the formula **$W = P\,\Delta V$**

We know that **$\Delta V = W / P$** $= 4 \times 10^6$ **/** 2×10^5 **$= 20\ m^3$**

$V_f = 30 - 20 = 10\ m^3$

Example 4

An ideal gas in an insulated container. The volume of the container decreases from 25 m^3 to 5 m^3 under a constant pressure of 3×10^5 Pa . What was the work done on the gas?

Solution:

We will use the formula **$W = P\,\Delta V$**

We know that $\Delta V = -\ 20\ m^3$ and $P = 3 \times 10^5$ Pa.

We plug these values in and get **$W = P\,\Delta V = -\ 6 \times 10^6$ J**

Example5

Unit mass of a certain fluid is contained in a cylinder at an initial pressure of 20 bar. The fluid is allowed to expand reversibly behind a piston according to a law pV^2 = Constant until the volume is doubled. The fluid is then cooled reversibly at constant pressure until the piston regain its original positions; heat is then supplied reversibly with piston firmly locked in position until the pressure rises to the original value of 20 bar. Calculate the network done by the fluid, for an initial volume of 0.05 m^3

Solution:

$$p_2 = p_1\left(\frac{V_1}{V_2}\right)^2 = \frac{20}{2^2} = 5 \text{ bar}$$

$$W_{12} = \int_1^2 p\,dV$$

i.e. $W_{12} = \int_{V_1}^{V_2} \frac{c}{V^2} dV$ where $c = p_1 V_1^2 = 20 \times 0.05^2$ bar m^6

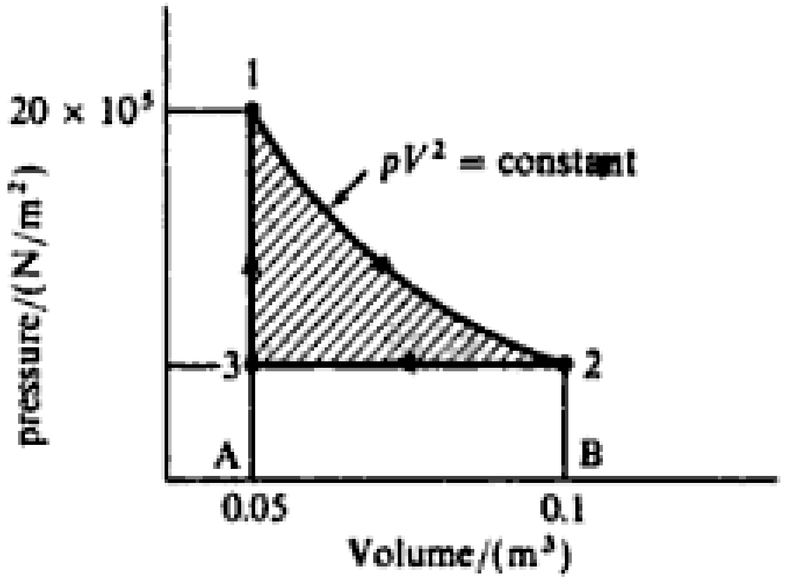
therefore

$$W_{12} = 10^5 \times 20 \times 0.0025\left[-\frac{1}{V}\right]_{0.05}^{0.1}$$

$$= 10^5 \times 20 \times 0.0025\left(\frac{1}{0.05} - \frac{1}{0.1}\right) = 50\,000 \text{ N m}$$

$$W_{23} = \text{area 32BA3} = p_2(V_2 - V_3) = 10^5 \times 5 \times (0.1 - 0.05)$$

$$= 25\,000 \text{ N m}$$



Work done from 3 to 1 is zero since the piston is locked in position. Therefore

$$\text{Net work done} = W_{12} + W_{23} = \text{(enclosed area 1231)}$$

$$= 50\,000 - 25\,000 = 25\,000 \text{ N m}$$

Hence the net work done by the fluid is +25 000 N m.

HOME WORK

1.1 A certain fluid at 10 bar is contained in a cylinder behind a piston, the initial volume being 0·05 m^3. Calculate the work done by the fluid when it expands reversibly,

(a) At constant pressure to a final volume of 0·2 m^3.
(b) According to a linear law to a final volume of 0·2 m^3 and a final pressure of 2 bar.
(c) According to a law pV = constant to a final volume of 0·1 m^3.
(d) According to a law pV^3 = constant to a final volume of 0·06 m^3.
(e) According to a law $p=(A/V^2)-(B/V)$ to a final volume of 0·1 m^3 and a final pressure of 1 bar. A and B are constants.

Sketch all processes on the p-V diagram.
(150 000; 90 000; 34 700; 7640; 19 200 N m)

1.2 1 kg of a fluid is compressed reversibly according to a law $pv=0{\cdot}25$ where p is in bar and v is in m^3/kg. The final volume is $\frac{1}{4}$ of the initial volume. Calculate the work done on the fluid and sketch the process on a p-v diagram. (34 660 N m)

1.3 0·05 m^3 of a gas at 6·9 bar expand reversibly in a cylinder behind a piston according to the law $pv^{1{\cdot}2}$=constant until the volume is 0·08 m^3. Calculate the work done by the gas and sketch the process on a p-v diagram. (15 300 N m)

1.4 1 kg of a fluid expands reversibly according to a linear law from 4·2 bar to 1·4 bar. The initial and final volumes are 0·004 m^3 and 0·02 m^3 respectively. The fluid is then cooled reversibly at constant pressure and finally compressed reversibly according to a law pv=constant back to the initial conditions of 4·2 bar and 0·004 m^3. Calculate the work done in each process stating whether it is done on or by the fluid and calculate the net work of the cycle. Sketch the cycle on a p-v diagram. (4480; −1120; −1845; 1515 N m)

1.5 0·09 m^3 of a fluid at 0·7 bar are compressed reversibly to a pressure of 3·5 bar according to a law pv^n=constant. The fluid is then heated reversibly at a constant volume until the pressure is 4 bar; the specific volume is then 0·5 m^3/kg. A reversible expansion according to a law pv^2=constant restores the fluid to its initial state. Calculate the mass of fluid present, the value of n in the first process, and the net work done on or by the fluid in the cycle. Sketch the cycle on a p-v diagram. (0·0753 kg; 1·85; 676 N m)