1. Which of the following statements is correct?

A. \((u_2 - u_1)_A > (u_2 - u_1)_B > (u_2 - u_1)_C\)

B. \((u_2 - u_1)_A = (u_2 - u_1)_C > (u_2 - u_1)_B\)

C. \((u_2 - u_1)_B > (u_2 - u_1)_C\)

D. \((u_2 - u_1)_B = (u_2 - u_1)_A\)

Solution:

Since ‘u’ is a thermodynamic property it is path independent. Hence the change in internal energy following the non-equilibrium path B (indicated by the dotted line) and quasi-equilibrium path A is the same.

Answer: D
2. Which of the following statements is correct?

A. Process C is an isochoric process.
B. Process A is an isothermal process.
C. Process B is a non-equilibrium process.
D. None of the above.

Solution:

During the process C, specific volume ‘v’ changes. Hence it is not isochoric.

The process A is not isothermal since an isothermal process (for an ideal gas) has the shape as shown in the figure.

Since the process B is indicated by dotted line, it must be non-equilibrium in nature.

Answer: C
3. For an ideal gas, which of the following statements is correct?

A. \( T_2 > T_3 \)
B. \( T_2 < T_3 \)
C. \( T_2 = T_3 \)
D. None of the above

Solution:

For an ideal gas,

\[
\frac{P_2 v_2}{T_2} = \frac{P_3 v_3}{T_3}
\]

Since \( P_2 = P_3 \) and \( v_3 > v_2 \) (see above figure),

\( T_2 < T_3 \)

Answer: C
4. Which of the following statements is correct?

A. \( 1W_3 > 1W_2 \)
B. \( 1W_3 < 1W_2 \)
C. \( 1W_3 = 1W_2 \)
D. Not enough information

Solution:

\[
1W_2 = \int_{V_1}^{V_2} PdV = m \int_{v_1}^{v_2} Pdv = (\text{Area under the path } 1 \rightarrow 2) \times m
\]

\[
1W_3 = \int_{V_1}^{V_3} PdV = m \int_{v_1}^{v_3} Pdv = (\text{Area under the path } 1 \rightarrow 3) \times m
\]

Since the area under the path \( 1 \rightarrow 3 \) is greater than the area under the path \( 1 \rightarrow 2 \),

\( 1W_3 > 1W_2 \)

Answer: A
Solution:

First Law: Path $1 \rightarrow 3$

$1Q_3 = 1W_3 + (U_3 - U_1)$

$1Q_3 - 1W_3 = U_3 - U_1 = mc_{v0}(T_3 - T_1)$

(for an ideal gas with constant specific heats)

Also,

$\frac{P_3v_3}{T_3} = \frac{P_1v_1}{T_1}$; and $P_3v_3 = P_1v_1$ along $1 \rightarrow 3$.

Hence $T_3 = T_1$. As a result $(T_3 - T_1) = 0$.

or, $1Q_3 = 1W_3$

Answer: C
6. 10 kg of air (ideal gas with constant specific heats, $C_{p0} = 1.005 \text{ kJ/kg K}$, $C_{v0} = 0.717 \text{ kJ/kg K}$, $R = 0.287 \text{ kJ/kg K}$) is heated in a rigid (closed) tank from 300 K to 600 K.

The change in enthalpy in (kJ) is:

A. 6040
B. 3015
C. 1980
D. None of the above

Solution:

$H_2 - H_1 = m(h_2 - h_1)$

For an ideal gas with constant specific heats,

$(h_2 - h_1) = c_{p0}(T_2 - T_1)$

$H_2 - H_1 = 10 \times 1.005 \times (600 - 300) = 3015 \text{ kJ}$

Answer: B
7. Consider a system containing air in a piston-cylinder configuration shown in the figure. You assume air to be an ideal gas with constant specific heats ($C_p = 1.005 \text{ kJ/kg K}$, $C_v = 0.717 \text{ kJ/kg K}$, $R = 0.287 \text{ kJ/kg K}$). The system is compressed (1 $\Rightarrow$ 2) in an irreversible adiabatic process until the final pressure is 500 kPa and the final temperature is 500K.

The magnitude of work done during the process in (kJ) is:

A. 333
B. 233
C. 133
D. 33

Solution:

For an ideal gas,

$$\frac{P_2 v_2}{T_2} = \frac{P_1 v_1}{T_1}$$

$$v_2 = \frac{P_1 v_1}{T_1} \times \frac{T_2}{P_2} = \frac{100 \times 1 \times 500}{500 \times 300} = 0.333 \text{ m}^3$$

In a non-equilibrium process, the work done is given as,

$$1W_2 = F_{Driving} \times displacement = P_2(v_2 - v_1)$$

$$= 500 \times (0.333 - 1) = -333 \text{ kJ}$$

$$|1W_2| = 333 \text{ kJ}$$

Answer: A
Solution:

For an ideal gas,
\[
\frac{P_2V_2}{T_2} = \frac{P_1V_1}{T_1}
\]

\[P_2 = 4000 \text{ kPa}\]

\[\therefore T_2 = \frac{P_2V_2}{P_1V_1} T_1 = \frac{4000}{2000} \times \frac{0.3}{0.2} \times 600 = 1800 \text{ K}\]

Answer: D
9. Work done in process 1 ==> 2 is:

A. 0.1 MJ
B. 0.2 MJ
C. 0.3 MJ
D. 0.4 MJ

Solution:

\[ 1W_2 = \int_{V_1}^{V_2} PdV \text{ the area under the process line } 1 \rightarrow 2 \]

\[ = \text{the area of the trapezoid} \]

\[ = \frac{P_1 + P_2}{2} (V_2 - V_1) \]

\[ = \frac{(2000 + 4000)(0.3 - 0.2)}{2} = 300 \text{ kJ} = 0.3 \text{ MJ} \]

Answer: C
10. How much heat, in kJ must be transferred to 10 Kg of air with constant specific heats ($C_{pa} = 1.005$ kJ/kg K, $C_{vo} = 0.717$ kJ/kg K, $R = 0.287$ kJ/kg K), contained in a cylinder-piston system, to increase the temperature from 10 deg C to 230 deg C if the pressure is maintained constant at 100 kPa?

A. 2200  
B. 2090  
C. 1890  
D. 1620

Solution:

The first law for the isobaric process is as follows:

$$1Q_2 = U_2 - U_1 + 1W_2 = m(u_2 - u_1) + 1W_2$$

$$= mc_{vo}(T_2 - T_1) + 1W_2$$

$$1W_2 = \int_{V_1}^{V_2} PdV = P_1((V_2 - V_1)) = P_2V_2 - P_1V_1$$

$$= mRT_2 - mRT_1$$

$$= mR(T_2 - T_1)$$

$$= 10 \times 0.287(230 - 10) = 631 \text{ kJ}$$

$$1Q_2 = mc_{vo}(T_2 - T_1) + 1W_2$$

$$= 10 \times 0.717(230 - 10) + 631 = 2208 \text{ kJ}$$

Answer: A
11. 10 kg air (assume ideal gas with constant specific heats, \( C_{p0} = 1.005 \) kJ/kg K, \( C_v = 0.717 \) kJ/kg K, \( R = 0.287 \) kJ/kg K) contained in a cylinder-piston configuration undergoes a non-equilibrium process due to a fast expansion process resulting from sudden removal of some weights. As a result temperature and pressure fell to 20 deg C and 1 MPa from initial temperature and pressure values of 620 deg C and 10 MPa.

The work done during the process is (in kJ) is:

A. 485  
B. 585  
C. 685  
D. 785  

Solution:

In a non-equilibrium process work is given by the expression,

\[ 1W_2 = F_{Resisting} \times displacement = P_2(V_2 - V_1) \]

\[ = P_2V_2 - P_2V_1 = P_2V_2 - \frac{P_2}{P_1}P_1V_1 \]

\[ = mRT_2 - \frac{P_2}{P_1} mRT_1 = mR\left(T_2 - \frac{P_2}{P_1}T_1\right) \]

\[ = 10 \times 287\left(293.15 - \frac{1}{10} \times 893.15\right) = 585 \text{ kJ} \]

Answer: B
Solution:

**In a quazi-equilibrium polytropic process,**

\[ PV^n = C \quad \text{or} \quad P_2 V_2^n = P_1 V_1^n \]

\( n = 2, \ V_1 = 2 \ \text{m}^3, \ V_2 = 1 \ \text{m}^3 \) and \( P_1 = 100 \ \text{kPa} \)

\[
P_2 = P_1 \left( \frac{V_1}{V_2} \right)^n = 100 \times \left( \frac{2}{1} \right)^2 = 400 \ \text{kPa}
\]

**Answer: C**
Solution:

\[
\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1}
\]

Note that \( P_2 \) is known from the previous problem (\( P_2 = 400 \text{ kPa} \)).

\[
T_2 = \frac{P_2 V_2}{P_1 V_1} T_1 = \frac{400}{100} \times \frac{1}{2} \times 300 = 600 \text{ K}
\]

**Answer:** C
14. Consider a system containing air undergoing a polytropic process with exponent of 2 \((PV^n = C)\). Air is compressed slowly, until the final volume is 1 m\(^3\). You may assume ideal gas behavior with constant specific heats \((C_p = 1.005 \text{ kJ/kg K}, C_v = 0.717 \text{ kJ/kg K}, R = 0.287 \text{ kJ/kg K})\).

The magnitude of work done in the process is:

A. 100 KJ  
B. 200 KJ  
C. 400 KJ  
D. None of the above

Solution:

In a polytropic process work can be expressed as,

\[
1W_2 = \frac{P_2V_2 - P_1V_1}{(1 - n)} = \frac{400 \times 1 - 100 \times 2}{1 - 2} = -200 \text{ kJ}
\]

\[|1W_2| = 200 \text{ kJ}\]

Answer: B