MECHANICAL ENGINEERING SCIENCE (UE25ME141A/B)

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1. During one cycle, the working fluid of an engine engages in two work interactions : 15 kJ to the fluid and 44 kJ from the fluid, and three heat interactions, two of which are known : 75 kJ to the fluid and 40 kJ from the fluid. Evaluate the magnitude and direction of the third heat transfer.

Important Observations

Heat transferred to the fluid is taken with ***a positive sign***, while that transferred ***from*** the fluid is with ***a negative sign***.

Work transferred to the fluid is taken with a ***negative sign***, while that transferred ***from*** the fluid is with ***a positive sign***.

Solution

$$\sum_{\text{cycle}} Q = \sum_{\text{cycle}} W$$

$$+75 - 40 + Q = 44 - 15$$

Q = -6 kJ.

2. A closed system passes through a complete cycle of 4 processes. The sum of all heat transfers is –170 kJ/cycle. The system completes 100 cycles/min. Complete the following table showing the method for each item and compute the net rate of work output in kW.

PROCESS	Q (kJ/min)	W (kJ/min)	ΔE (kJ/min)
a –b	0	2,170	
b–c	–21,000	0	
c–d	–2,100		–36,600
d–a			

Important Observations

The values of heat, work and energy change are given in kJ/min.

The sum of all heat transfers is mentioned in kJ/cycle.

Data Provided

$$\sum_{\text{cycle}} Q = -170 \frac{\text{kJ}}{\text{cycle}}$$

Number of cycles per minute = 100

PROCESS	Q (kJ/min)	W (kJ/min)	ΔE (kJ/min)
a –b	0	2,170	-2,170
b–c	–21,000	0	-21,000
c–d	–2,100	34,500	-36,600
d–a			59,770

Solution

Process a–b

$Q_{a\text{-}b} = W_{a\text{-}b} + \Delta E_{a\text{-}b}$

$0 = 2{,}170 + \Delta E_{a\text{-}b}$

$\Delta E_{a\text{-}b} = -2{,}170$ kJ/min

Process b–c

$Q_{b\text{-}c} = W_{b\text{-}c} + \Delta E_{b\text{-}c}$

$-21{,}000 = 0 + \Delta E_{b\text{-}c}$

$\Delta E_{b\text{-}c} = -21{,}000$ kJ/min

Process c–d

$Q_{c\text{-}d} = W_{c\text{-}d} + \Delta E_{c\text{-}d}$

$-2100 = W_{c\text{-}d} - 36{,}600$

$W_{c\text{-}d} = 34{,}500$ kJ/min

$\Sigma \Delta E = 0$

$\Delta E_{a\text{-}b} + \Delta E_{b\text{-}c} + \Delta E_{c\text{-}d} + \Delta E_{d\text{-}a} = 0$

$-2{,}170 - 21{,}000 - 36{,}600 + \Delta E_{d\text{-}a} = 0$

$\Delta E_{d\text{-}a} = 59{,}770$ kJ/min

$\Sigma Q = -170$ kJ / cycle

= -170 x 100 cycles / min = -17,000 kJ / min

$Q_{a-b} + Q_{b-c} + Q_{c-d} + Q_{d-a} = -17,000$

$0 - 21,000 - 2,100 + Q_{d-a} = -17,000$

$Q_{d-a} = 6,100$ **kJ / min**

PROCESS	Q (kJ/min)	W (kJ/min)	ΔE (kJ/min)
a –b	0	2,170	-2,170
b–c	–21,000	0	-21,000
c–d	–2,100	34,500	-36,600
d–a	6,100	-53,670	59,770

Process d–a

$Q_{d-a} = W_{d-a} + \Delta E_{d-a}$

$6,100 = W_{d-a} + 59,770$

$W_{d-a} = -53,670$ kJ/min

By First Law of thermodynamics $\Sigma Q = \Sigma W = -17,000$ kJ/min

Therefore the **net work output** = –17,000 kJ/min = $\frac{-17,000}{60} = -283.33$ kW

3. 1.5 kg of liquid having constant specific heat of 2.5 kJ/kg K is stirred in a well insulated chamber, causing the temperature to rise by 15°C. Find ΔE and W for the process.

Important Observations

The temperature of the liquid rises in spite of no transfer of heat.

This is because of conversion of the stirring work to heat by friction.

Data Provided

Mass of the liquid = m = 1.5 kg

Specific Heat of the liquid = C = 2.5 kJ/kg-K

Temperature Rise = ΔT = 15 ^{0}C

Solution

$$\Delta E = mC\Delta T = 1.5 \times 2.5 \times 15$$

$$\Delta E = 56.25\ kJ$$

$$Q = \Delta E + W$$

$$0 = \Delta E + W$$

$$W = -\Delta E$$

$$W = -56.25\ kJ$$

THANK YOU

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