FROM THE DESK OF PROF. MUHAMMAD YOUNUS

FIRST LAW OF THERMODYNAMICS

Formulae:

- $\Delta W=P\Delta V$
- $\Delta V=A\ s$
- $\Delta Q=\Delta U+\Delta W$
- **For isobaric process:** $\Delta Q_P=\Delta U+P(V_2-V_1)$
- **For isochoric process:** $\Delta Q_v=\Delta U$
- **For isothermal expansion:** $\Delta Q=\Delta W$
- **For isothermal compression:** $-\Delta Q=-\Delta W$
- **For adiabatic expansion:** $\Delta W=-\Delta U$
- **For adiabatic compression:** $\Delta U=-\Delta W$
- **For cyclic process:** $\Delta U=0$

Book Q1(P#34): A gas undergoes isothermal expansion at a constant temperature of 300 K. If the gas absorbs 500 J of heat during the process, calculate the work done by the gas.

Ans:

$T=300K$

$\Delta Q=500\ J$

$\Delta W=?$

According to First Law of thermodynamics,

$\Delta Q=\Delta U+\Delta W$

For isothermal process, $\Delta U=0$ so

$\Delta Q=\Delta W$

$\Delta W=500J$ (Ans)

Book Q2(P#34): A piston compresses a gas isothermally. If the initial volume is 0.02 m³ and the final volume is 0.01 m³ and the initial pressure is 200kPa, determine the final pressure. Assume the gas behaves ideally.

Ans:

$V_1=0.02\ m^3$

$V_2=0.01\ m^3$

$P_1=200kPa=200x1000=200000Pa$

$P_2=?$

In isothermal processes Boyle's Law is followed so,

$P_1V_1=P_2V_2$

$(200000)(0.02)=P_2(0.01)$

$P_2=400000Pa$ (Ans)

Book Q3(P#34): A system undergoes an isobaric process where the pressure is kept constant at 15 kPa. If the volume increases from 0.05 m³ to 0.08 m³ and internal energy changes to 150J, calculate the heat added to the system. [2025-PE & PM]

Ans:

$P=15kPa=15x1000=15000Pa$

$V_1=0.05\ m^3$

$V_2=0.08\ m^3$

$\Delta U=150J$
$\Delta Q=?$
$\Delta Q=\Delta U+\Delta W=\Delta U+P\Delta V=150+(15000)(0.08-0.05)=600J$ (Ans)

Book Q4(P#34): During an isochoric process, the internal energy of a gas increases by 300 J. If no work is done, determine the heat added to the system.

Ans:
$\Delta U=300J$
$\Delta Q=?$
According to First Law of thermodynamics,
$\Delta Q=\Delta U+\Delta W$
For isochoric process, $\Delta W=0$ so
$\Delta Q=\Delta U$
$\Delta Q=300J$ (Ans)

Book Q5(P#34): A gas undergoes a cyclic process, starting at point A with volume of 0.02 m^3 going to B(isochoric heating) then to C(isothermal expansion) and finally back to A. If the heat added during isothermal expansion is 1000J and the heat rejected during isochoric heating is 500J, calculate the net work done by the system.

Ans:
$V=0.02\ m^3$
Heat added=1000J
Heat rejected=500J
$\Delta W=?$
ΔQ=Heat added-Heat rejected=1000-500=500J
According to First Law of thermodynamics,
$\Delta Q=\Delta U+\Delta W$
In cyclic process, $\Delta U=0$
$\Delta Q=0+\Delta W$
$\Delta W=\Delta Q$
$\Delta W=500J$ (Ans)

Book Q6(P#34): A gas expands from 0.03 m^3 to 0.06 m^3 against a constant pressure of 10 kPa. Calculate the work done in both a reversible and an irreversible process, and compare the results.

Ans:
$V_1=0.03\ m^3$
$V_2=0.06\ m^3$
$P=10kPa=10x1000=10000Pa$
$W_r=?$
$W_i=?$

Work Done in an Irreversible Process
$\Delta W_i=P_{ext}\Delta V=(10000)(0.06-0.03)=300J$ (Ans)

Work Done in a Reversible Process
$\Delta W_r=P_{ext}\Delta V=(10000)(0.06-0.03)=300J$ (Ans)
Work done in reversible process remains same as that of irreversible process.

Worked Example 16.2(P#23): When a balloon is inflated, its rubber walls push against the air around it. Calculate the work done when the balloon is blown up from 0.015 m^3 to 0.030 m^3. Atmospheric pressure=1.0×10^5 Pa.

Ans:

$V_1=0.015\ m^3$
$V_2=0.030\ m^3$
$P=1.0\times10^5\ Pa$
$\Delta W=?$
$\Delta W=P\Delta V=P(V_2-V_1)=1.0\times10^5(0.03-0.015)=155J$ (Ans)

Worked Example 16.1(P#22): The volume occupied by 1.00 mole of a liquid at 50°C is 2.4×10^{-5} m^3. When the liquid is vaporized at an atmospheric pressure of 1.03×10^5 Pa, the vapor has a volume of 5.9×10^{-2} m^3. The latent heat to vaporize 1.00 mole of this liquid at 50°C at atmospheric pressure is 3.48×10^4J. Determine change in internal energy ΔU of the system.

Ans:

$n=1$
$V_1=2.4\times10^{-5}\ m^3$
$V_2=5.9\times10^{-2}\ m^3$
$P=1.03\times10^5\ Pa$
$\Delta Q=3.48\times10^4 J$
$\Delta U=?$
$\Delta W=P\Delta V=P(V_2-V_1)=1.03\times10^5\ (5.9\times10^{-2}-2.4\times10^{-5})=6074.528J$
$\Delta Q=\Delta U+\Delta W$
$3.48\times10^4=\Delta U+6074.528$
$\Delta U=28725.472J$ (Ans)

Worked Example 16.3(P#28): A gas confined in a cylinder undergoes an expansion from an initial volume of 2.0 L to a final volume of 4.0 L against a constant external pressure of 2.0 atm. Calculate the work done by the gas during this process.

Ans:

$V_1= 2.0\ L=2/1000=2\times10^{-3}\ m^3$
$V_2= 4.0\ L=4/1000=4\times10^{-3}\ m^3$
$P=2.0\ atm=2\times1.01\times10^5=2.02\times10^5\ N/m^2$
$\Delta W=?$
$\Delta W=P\Delta V=2.02\times10^5(4\times10^{-3}-2\times10^{-3})=404J$ (Ans)

LAW OF HEAT EXCHANGE

Formulae:

Heat lost by hot boy=Heat gained by cold body

- If no state change, $c=\frac{\Delta Q}{m\Delta T}$
- If state changes from solid to liquid or vice versa, $L_f=\frac{Q}{m}$
- If state changes from liquid to gas or vice versa, $L_v=\frac{Q}{m}$

Book Q7(P#34): A 50 g piece of copper at 100°C is placed in 200 g of water at 20°C. If the final temperature of the system is 21.8°C, calculate the specific heat capacity of copper. (Specific heat capacity of water = 4.18 J/g°C)

Ans:

m_c=50 g
T_1=100°C
m_w=200 g
m_c=50 g
c_w=4.18 J/g°C
T_2=20°C
T_3=21.8 °C
c_c=?

According to Law of Heat Exchange,
Heat lost by copper=Heat gained by water body

$m_c c_c(T_1-T_3)= m_w c_w(T_3-T_2)$
$(50)c_c(100-21.8)=200(4.18)(21.8-20)$
c_c=0.384 J/g°C (Ans)

SPECIFIC HEAT AND MOLAR SPECIFIC HEAT

Formulae:

- $C = \frac{\Delta Q}{\Delta T}$
- $c = \frac{\Delta Q}{m\Delta T}$
- $C_m = \frac{\Delta Q}{n\Delta T}$
- $C_v = \frac{\Delta Q_v}{n\Delta T}$
- $C_P = \frac{\Delta Q_P}{n\Delta T}$

Book Q8(P#34): How much heat is required to raise the temperature of 1 kg of lead from 25°C to 100°C? (Specific heat capacity of lead = 0.128 J/g°C).

Ans:

m=1 kg=1000g
T_1=25 °C
T_2=100 °C
c=0.128 J/g°C
ΔQ=?
ΔQ=mcΔT
ΔQ=(1)(0.128)(100-25)
ΔQ=9600 J (Ans)

Worked Example 16.4(P#30): Calculate the molar specific heat capacity of a gas when 2 moles of the gas absorb 1500 J of heat energy, and its temperature increases by 25 degrees Celsius.

Ans:

n=2

$\Delta Q = 1500J$
$\Delta T = 25\ ^oC$
$C_m = \frac{\Delta Q}{n\Delta T}$
$C_m = \frac{1500}{2x25}$
$C_m = 30\ J/mol\text{-}^oC$ (Ans)

Worked Example 16.5(P#31): A sample of water with a mass of 200 grams is heated, and its temperature rises from 25°C to 45°C. Calculate the heat transferred to the water. Given the specific heat capacity of water (c) is 4.18 J/g°C.

Ans:
m=200 gm
$T_1 = 25\ ^oC$
$T_2 = 45\ ^oC$
c=4.18 J/g°C
$\Delta Q = mc\Delta T = 200(4.18)(45-25) = 200(4.18)(20) = 16720J$ (Ans)

Additional Questions:

Q1: How much heat will be required to raise the temperature of 1 kg of lead from 30°C to 105°C? (Specific heat capacity of lead = 0.128 J/kg^{o}C). [2025-PE & PM]

Ans:
m=1 kg
$T_1 = 30\ ^oC$
$T_2 = 105\ ^oC$
$c = 0.128\ J/kg^oC$
$\Delta Q = ?$
$\Delta Q = mc\Delta T$
$\Delta Q = (1)(0.128)(105-30)$
$\Delta Q = 9.6\ J$ (Ans)

Q2: How much heat is required to raise the temperature of 1 kg of lead from 25°C to 100°C? (Specific heat capacity of lead =128.1 J/kg-K). [2025-Sc.Gen.]

Ans:
m=1 kg
$T_1 = 25\ ^oC$
$T_2 = 100\ ^oC$
$c = 128.1\ J/kg^oC$
$\Delta Q = ?$
$\Delta Q = mc\Delta T$
$\Delta Q = (1)(128.1)(100-25)$
$\Delta Q = 9607.5\ J$ (Ans)