FREE NOTES · NCERT + JEE/NEET LEVEL

Thermodynamics

Zeroth, first aur second law, internal energy, isothermal, adiabatic, isobaric aur isochoric process, PV graphs, heat engine, refrigerator aur Carnot engine. Har process ka formula ek table me.

01 System, surroundings & equilibrium
02 Zeroth law
03 Heat, work & internal energy
04 First law of thermodynamics
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01 System, surroundings & equilibrium

System: jis cheez ko hum study kar rahe hain (cylinder me gas). **Surroundings:** baaki sab. Inke beech heat aur work ka len-den hota hai.

Thermodynamic equilibrium: jab system ke macroscopic variables (P, V, T, mass) time ke saath nahi badalte.

STATE VARIABLES

P, V, T, U: sirf state pe depend karte hain, raaste pe nahi. **Heat (Q) aur work (W) state variables nahi**, ye raaste (process) pe depend karte hain. Intensive (size pe depend nahi): P, T, density. Extensive (size ke saath badhte): V, U, mass.

02 Zeroth law

STATEMENT

Agar A aur B dono alag-alag C ke saath thermal equilibrium me hain, toh A aur B bhi aapas me thermal equilibrium me hain.

Isse **temperature** ka concept aata hai: jo cheezein equilibrium me hain, unka temperature barabar. Thermometer (C) isi pe kaam karta hai.

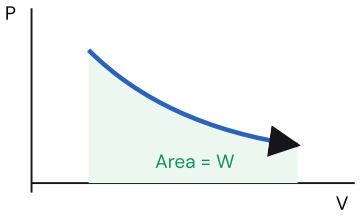
03 Heat, work & internal energy

- **Internal energy U:** molecules ki KE + PE ka total. Ideal gas me sirf KE, aur **U sirf T pe depend** karta hai.
- **Heat Q:** temperature ke fark se energy ka len-den.
- **Work W:** gas phaile toh piston ko dhakelta hai.

GAS KA WORK

$$W = \int P \, dV$$

PV graph ke neeche ka area. Phailaav (expansion): W positive. Sikudna (compression): W negative.



Expansion me area = gas ka kiya work

04 First law of thermodynamics

STATEMENT (ENERGY CONSERVATION)

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

System ko di gayi heat = internal energy ka badlav + system ka kiya work.

Quantity	Positive (+)	Negative (−)
ΔQ	System ko heat di gayi	System ne heat di
ΔW	System ne work kiya (expansion)	System pe work hua (compression)
ΔU	Temperature badha	Temperature ghata

LIMITATION

First law nahi batata ki process kis direction me hoga (garam se thanda ya ulta). Ye second law batata hai.

05 Specific heats of gases

C_v: constant volume pe 1 mol ko 1 K garam karne ki heat

C_p: constant pressure pe

$$C_p - C_v = R$$

$$\gamma = C_p/C_v$$

$C_p > C_v$: constant pressure pe kuch heat gas ke phailne (work) me chali jaati.

Gas	C_v	C_p	γ
Monoatomic (He, Ar)	3R/2	5R/2	5/3 ≈ 1.67
Diatomic (O_2, N_2)	5R/2	7R/2	7/5 = 1.4
Polyatomic (CO_2)	3R	4R	4/3 ≈ 1.33

Ideal gas ke liye har process me: $\Delta U = n\,C_v\,\Delta T$ (sirf T ke badlav pe depend).

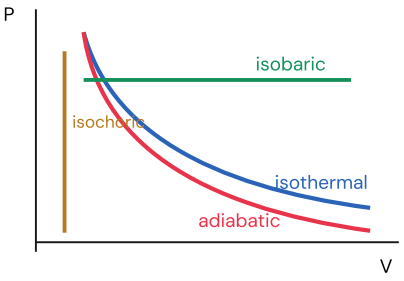
06 Thermodynamic processes

Process	Kya constant	Equation	Work W	First law
Isothermal	T	$PV = \text{const}$	$nRT\ln(V_2/V_1)$	$\Delta U = 0,\ Q = W$
Adiabatic	Q = 0	$PV^{\gamma} = \text{const},\ TV^{\gamma-1} = \text{const}$	$(P_1V_1 - P_2V_2)/(\gamma - 1)$	$W = -\Delta U$
Isobaric	P	$V/T = \text{const}$	$P\Delta V = nR\Delta T$	$Q = nC_p\Delta T$
Isochoric	V	$P/T = \text{const}$	0	$Q = \Delta U = nC_v\Delta T$
Cyclic	Wapas shuru ki state	—	Loop ka area	$\Delta U = 0,\ Q = W$

KAB KAUNSA PROCESS

- **Isothermal:** dheere-dheere, conducting deewar wala bartan, heat reservoir ke saath.
- **Adiabatic:** bahut tezi se, ya insulated bartan. Cycle tyre ka achanak phatna (hawa thandi lagti), sound waves.
- Adiabatic expansion me gas **thandi** hoti, compression me **garam** (diesel engine).

07 PV diagrams



Adiabatic curve zyada steep (γ guna)

SLOPES

Isothermal: $dP/dV = -P/V$

Adiabatic: $dP/dV = -\gamma P/V$

CYCLIC PROCESS

Loop ka area = net work. **Clockwise** loop: net work positive (engine). **Anticlockwise**: negative (refrigerator).

Same V_1 se V_2 tak expansion: isobaric > isothermal > adiabatic (work).

08 Second law of thermodynamics

KELVIN-PLANCK STATEMENT

Aisa koi engine nahi ban sakta jo ek source se heat le ke **poori** ki poori work me badal de. Kuch heat thande sink ko deni hi padegi. Yaani **100% efficient engine possible nahi**.

CLAUSIUS STATEMENT

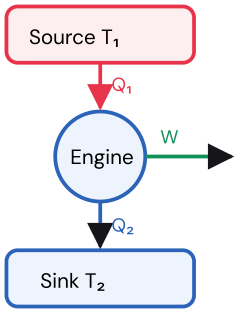
Heat **apne aap** thandi cheez se garam cheez me nahi ja sakti. Iske liye bahar se work lagana padta hai (refrigerator).

Dono statements ek hi baat ke do roop hain.

09 Reversible & irreversible process

Reversible	Irreversible
Ulta chalaane pe system aur surroundings dono wapas purani state me	Wapas purani state possible nahi
Bahut dheere (quasi-static), friction nahi, heat loss nahi	Friction, tez process, free expansion, heat ka behna
Ideal (asli me nahi hota)	Asli duniya ke saare process

10 Heat engine & refrigerator



Engine: $Q_1 = W + Q_2$

HEAT ENGINE EFFICIENCY

$$\eta = W/Q_1 = 1 - Q_2/Q_1$$

REFRIGERATOR (COP)

$$\beta = Q_2/W = Q_2/(Q_1 - Q_2)$$

Thande andar se Q_2 nikaal ke, W lagake, bahar Q_1 phenkta hai. β 1 se bada ho sakta hai. Engine aur fridge (same T_1, T_2, reversible): $\beta = (1 - \eta)/\eta$.

11 Carnot engine

Do temperatures ke beech chalne wala **sabse efficient** ideal (reversible) engine. Cycle: isothermal expansion → adiabatic expansion → isothermal compression → adiabatic compression.

$$\eta_{\text{Carnot}} = 1 - T_2/T_1$$

T kelvin me. Carnot ke liye $Q_2/Q_1 = T_2/T_1$. Fridge ke liye $\beta = T_2/(T_1 - T_2)$.

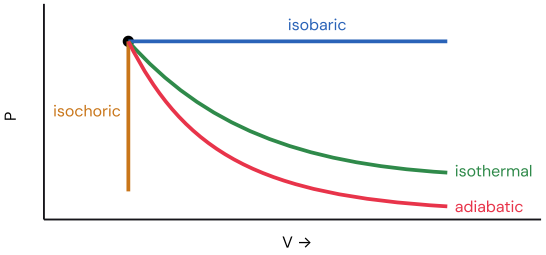
CARNOT THEOREM

(1) Same source-sink ke beech koi bhi engine Carnot se zyada efficient nahi ho sakta. (2) Carnot efficiency working substance pe depend nahi karti. 100% tabhi jab $T_2 = 0$ K, jo possible nahi.

12 JEE Extra + Tricks

JEE LEVEL

- Gas ka kaam = P–V curve ke neeche ka area; cyclic process: $\Delta U = 0$, net work = band area (clockwise = positive).
- Isothermal $W = nRT \ln(V_2/V_1)$; adiabatic $W = (P_1V_1 - P_2V_2)/(\gamma - 1)$; isobaric $W = P\Delta V$; isochoric $W = 0$.
- Adiabatic ka slope = γ × isothermal ka slope (adiabatic zyada steep).
- Mayer: $C_p - C_v = R$. Ideal gas ke **har** process me $\Delta U = nC_v\Delta T$.
- Carnot efficiency $\eta = 1 - T_2/T_1$; refrigerator COP $\beta = T_2/(T_1 - T_2) = (1 - \eta)/\eta$.



Ek hi state se chaar processes

13 Solved numericals (R = 8.3 J/mol·K)

Q1. Gas ko 500 J heat di, usne 200 J work kiya. ΔU?
$\Delta U = Q - W = 300$ J. **Ans: 300 J (temperature badha)**

Q2. 2 mol ideal gas 300 K pe isothermal expand hoke volume 2 guna. Work? (ln 2 = 0.693)
$W = nRT \ln 2 = 2 \times 8.3 \times 300 \times 0.693 \approx 3451$ J. $Q = W$ ($\Delta U = 0$). **Ans: ≈ 3.45 kJ**

Q3. 1 mol monoatomic gas ko constant pressure pe 10 K garam kiya. Q, ΔU, W?
$Q = nC_p\Delta T = 2.5 \times 8.3 \times 10 = 207.5$ J. $\Delta U = 1.5 \times 8.3 \times 10 = 124.5$ J. $W = 83$ J. **Ans: 207.5 J, 124.5 J, 83 J**

Q4. Diatomic gas (γ = 1.4) ka adiabatic compression, volume 1/32 ho gaya, shuru 300 K. Final T?
$TV^{\gamma-1}$ const ⇒ $T_2 = 300 \times 32^{0.4} = 300 \times 4 = 1200$ K. **Ans: 1200 K**

Q5. Carnot engine 527 °C aur 127 °C ke beech. Efficiency?
$T_1 = 800$ K, $T_2 = 400$ K ⇒ $\eta = 1 - 0.5 = 50\%$. **Ans: 50%**

Q6. Fridge andar −3 °C, bahar 27 °C (Carnot). COP? 1 kJ work se andar se kitni heat?
$\beta = 270/30 = 9$. $Q_2 = 9$ kJ. **Ans: 9, 9 kJ**

14 Common mistakes

- Carnot efficiency me °C daal dena. Kelvin lo.
- Isothermal me "heat nahi di" maan lena. Heat di jaati hai, par $\Delta U = 0$.
- Adiabatic aur isothermal ko same maan lena. Adiabatic me $Q = 0$, T badalta.
- Work ka sign ulta lena (compression me W negative).
- Q aur W ko state variable maan lena.
- Refrigerator ka COP 1 se zyada dekh ke ghabra jaana: ye normal hai.

15 Formula sheet

First law	$\Delta Q = \Delta U + \Delta W$
Work	$W = \int P\, dV$
Internal energy	$\Delta U = nC_v\Delta T$
Mayer, γ	$C_p - C_v = R,\ \gamma = C_p/C_v$
Isothermal work	$nRT \ln(V_2/V_1)$
Adiabatic	$PV^\gamma = \text{const},\ W = (P_1V_1 - P_2V_2)/(\gamma - 1)$
Isobaric	$W = P\Delta V$
Engine	$\eta = 1 - Q_2/Q_1$
Carnot	$\eta = 1 - T_2/T_1$
Refrigerator	$\beta = Q_2/W = T_2/(T_1 - T_2)$

16 Practice questions

1. Cyclic process me net heat 100 J li gayi. Net work?
2. Isochoric process me gas ko 50 J heat di. ΔU aur W?
3. Engine ki efficiency 25%, source 400 K. Sink ka temperature?
4. Gas ka γ = 1.5. C_v kitna (R ke terms me)?
5. Carnot engine 1000 J leta hai, 600 J sink ko deta hai. Efficiency aur work?

ANSWERS

1) 100 J · 2) ΔU = 50 J, W = 0 · 3) 300 K · 4) $C_v = R/(\gamma - 1) = 2R$ · 5) 40%, 400 J

17 Quick revision: exam se pehle 5 minute

LAWS

- Zeroth: temperature ka concept.
- First: $\Delta Q = \Delta U + \Delta W$.
- Second: 100% engine nahi; heat apne aap thande se garam nahi.

PROCESSES

- Isothermal: $\Delta U = 0$, $W = nRT \ln(V_2/V_1)$.
- Adiabatic: $Q = 0$, PV^{γ} const.
- Isochoric: $W = 0$. Isobaric: $W = P\Delta V$.
- Cyclic: $\Delta U = 0$, W = loop area.

GASES

- $C_p - C_v = R$.
- γ: mono 5/3, di 7/5, poly 4/3.
- $\Delta U = nC_v\Delta T$ (har process me).

ENGINES

- $\eta = 1 - Q_2/Q_1$; Carnot $1 - T_2/T_1$.
- Fridge $\beta = T_2/(T_1 - T_2)$.
- Clockwise loop = engine.

Doubt hai? padhaiadda.netlify.app pe AI Doubt Solver se poocho, ya is chapter ka mock test do.