FREE NOTES · NCERT + JEE/NEET LEVEL

Thermal Properties of Matter

Temperature scales, thermal expansion, specific heat, calorimetry, latent heat, conduction, convection, radiation aur Newton's law of cooling. Roz ki zindagi ke examples aur solved numericals ke saath.

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02 Temperature scales
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01 Heat vs temperature

	Heat	Temperature
Kya hai	Temperature ke fark ki wajah se behne wali **energy**	Kitna garam/thanda hai uska **naap**
Unit	joule (J), calorie (1 cal = 4.186 J)	kelvin (K), °C, °F
Behta hai	Zyada temperature se kam ki taraf	—

Ek garam chammach aur ek garam balti paani: temperature same ho sakta hai, par balti me heat (energy) kahin zyada hai.

02 Temperature scales

$$(C - 0)/100 = (F - 32)/180 = (K - 273.15)/100$$

Kisi bhi scale ke liye: (reading - lower fixed point)/(upper - lower) sab scales me barabar.

Scale	Barf pighalna	Paani ubalna
Celsius	0 °C	100 °C
Fahrenheit	32 °F	212 °F
Kelvin	273.15 K	373.15 K

YAAD RAKHO

-40 °C = -40 °F (dono barabar). 1 °C ka badlav = 1 K ka badlav = 1.8 °F ka badlav. Kelvin me koi negative value nahi (absolute zero = 0 K = -273.15 °C).

Ideal gas equation: $PV = \mu RT$ (μ = moles, R = 8.314 J/mol·K). Constant volume gas thermometer ka basis yahi hai.

03 Thermal expansion

Garam karne pe zyada tar cheezein phailti hain kyunki atoms zyada hilte hain aur unke beech ki average doori badhti hai.

Type	Formula	Coefficient
Linear (length)	$\Delta L = \alpha\, L\, \Delta T$	α
Area	$\Delta A = \beta\, A\, \Delta T$	$\beta = 2\alpha$
Volume	$\Delta V = \gamma\, V\, \Delta T$	$\gamma = 3\alpha$

RISHTA

$\alpha : \beta : \gamma = 1 : 2 : 3$. Ideal gas ke liye constant pressure pe $\gamma = 1/T$.

ROZ KI ZINDAGI ME

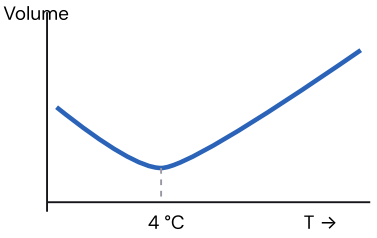
- Railway patri aur pul me gap chhodte hain.
- Bimetallic strip (do metal jude): garam hone pe zyada α wale ki taraf **bahar** mudti hai. Thermostat aur fire alarm me use.
- Jar ka tight dhakkan garam paani me daalo, dhakkan zyada phailta, khul jaata.
- Pendulum clock garmi me dheemi chalti (length badhti, T badhta).
- Chhed wali plate garam karo: chhed bhi **bada** hota hai (jaise photo zoom ho).

04 Paani ka anomalous expansion

0 °C se 4 °C tak garam karne pe paani **sikudta** hai, 4 °C ke baad phailta hai. Isliye **4 °C pe paani ki density sabse zyada**.

ISKA FAYDA

Sardi me jheel ki upar ki satah jamti hai, neeche 4 °C ka paani rehta hai, machliyan zinda rehti hain. Barf halki hai, tairti hai aur neeche ke paani ko insulate karti hai.



4 °C pe volume minimum ⇒ density maximum

05 Specific heat & calorimetry

HEAT AUR TEMPERATURE CHANGE

$$Q = m\, s\, \Delta T$$

s = specific heat (J/kg·K): 1 kg ko 1 K garam karne ki heat. Paani ka s = 4186 J/kg·K (= 1 cal/g·°C), bahut zyada. Heat capacity = ms.

MOLAR SPECIFIC HEAT

$$C = Q/(\mu\, \Delta T)$$

Gases ke do: C_p (constant pressure) aur C_v (constant volume). $C_p - C_v = R$ (Mayer). Solids ke liye $C \approx 3R$ (Dulong–Petit).

PRINCIPLE OF CALORIMETRY

Band system me (heat bahar na jaaye): **garam cheez ki di gayi heat = thandi cheez ki li gayi heat**. $m_1 s_1 (T_1 - T) = m_2 s_2 (T - T_2)$.

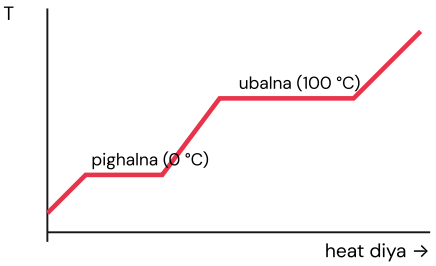
Paani ka zyada s isliye: car radiator me coolant, garam paani ki bottle, samundar ke kinare ka mausam narm (din me jaldi garam nahi, raat me jaldi thanda nahi).

06 Change of state & latent heat

$$Q = m\, L$$

State badalte waqt **temperature constant** rehta hai, heat sirf bonds todne me jaati hai. Barf $L_f = 3.33 \times 10^5$ J/kg (80 cal/g), bhaap $L_v = 22.6 \times 10^5$ J/kg (540 cal/g).

Isliye bhaap (steam) se jalna ubalte paani se zyada khatarnaak: bhaap pehle 540 cal/g extra deti hai.



Flat hisse: latent heat (T same)

- **Pressure badhe** toh boiling point badhta (pressure cooker me ~120 °C), aur barf ka melting point thoda ghatta (**regelation**: taar barf ke andar se nikal jaata, ice skating).
- Pahaad pe pressure kam ⇒ paani 100 °C se pehle ubalta ⇒ khana der se pakta.
- **Sublimation:** solid seedha gas (kapoor, dry ice, naphthalene).
- **Triple point** of water: 273.16 K aur 0.006 atm, jahan teeno state saath rehti hain.

07 Conduction

Bina khud hile, atoms ke takrane se heat ka aage badhna. Solids me (khaaskar metals, free electrons ki wajah se).

FOURIER'S LAW

$$H = dQ/dt = K\,A\,(T_1 - T_2)\,/\,L$$

K = thermal conductivity (W/m·K). Silver/copper zyada K, lakdi/hawa/oon kam K.

THERMAL RESISTANCE

$$R = L\,/\,(K\,A)$$

Current jaisa: H = ΔT/R. Series: R = R_1 + R_2. Parallel: 1/R = 1/R_1 + 1/R_2.

DO RODS SERIES ME (SAME A)

Junction ka temperature: $T = (K_1T_1/L_1 + K_2T_2/L_2)/(K_1/L_1 + K_2/L_2)$. Same length ho toh equivalent K = $2K_1K_2/(K_1 + K_2)$. Parallel me (same L, same A) K = $(K_1 + K_2)/2$.

Examples: khana banane ke bartan ka tala copper ka, handle plastic ka; sardi me oon ke kapde (andar hawa phansi, hawa achha insulator); igloo andar se garam.

08 Convection

Fluid ke **khud behne** se heat ka jaana. Garam fluid halka hoke upar, thanda neeche: **convection current**. Sirf liquids aur gases me.

- **Natural:** sea breeze (din me hawa samundar se zameen ki taraf), land breeze (raat me ulta), trade winds, monsoon.
- **Forced:** pankha, AC, car ka radiator pump, khoon ka bahav.
- Heater kamre me neeche, AC upar lagaate hain.

09 Radiation

Electromagnetic waves (infrared) se heat. **Kisi medium ki zaroorat nahi**, vacuum me bhi, light ki speed se. Sun ki garmi isi se aati hai.

STEFAN-BOLTZMANN LAW

$$H = e\,\sigma\,A\,T^4$$

$\sigma = 5.67 \times 10^{-8}$ W/m²K⁴, e = emissivity (black body e = 1). Net loss surroundings (T_o) me: $e\sigma A(T^4 - T_0^4)$.

WIEN'S DISPLACEMENT LAW

$$\lambda_m\,T = b$$

$b = 2.9 \times 10^{-3}$ m·K. Garam cheez ka peak wavelength chhota: laal → peela → safed → neela. Neela taara laal taare se garam.

KIRCHHOFF KA IDEA

Achha absorber achha emitter bhi hota hai. Kaala surface zyada absorb aur zyada emit karta. Isliye sardi me kaale kapde, garmi me safed. Thermos flask: chamakdaar deewar (radiation kam), vacuum (conduction, convection band).

10 Newton's law of cooling

$$dT/dt = -k\,(T - T_0)$$

Thanda hone ki rate **temperature ke fark** ke proportional (fark chhota ho tab). T_o = surroundings ka temperature.

EXAM KA SHORTCUT (AVERAGE FORM)

$$(T_1 - T_2)/t = k\,[\,(T_1 + T_2)/2 - T_0\,]$$

Pehle wale data se k nikaalo, phir doosre sawaal me lagao.

Exact solution: $T - T_0 = (T_i - T_0)\,e^{\wedge}(-kt)$, graph exponential girta hua.

11 JEE Extra + Tricks

JEE LEVEL

- Expansion: $\beta = 2\alpha$, $\gamma = 3\alpha$ (isotropic solid). Paani 4 °C pe sabse ghana (anomalous expansion).
- Newton ka law of cooling (average form): $(T_1 - T_2)/t = k[(T_1 + T_2)/2 - T_s]$.
- Wien ka law $\lambda_m T = b$ (2.9×10^{-3} m K); Stefan law $E = \sigma e A T^4$.
- Series slabs me conduction: $R = L/(KA)$ resistors ki tarah jodo; barabar lambai series me $K_{eq} = 2K_1K_2/(K_1 + K_2)$.
- Calorimetry trick: heat lost = heat gained; hamesha check karo saari barf pighli ya nahi.

12 Solved numericals

Q1. 98.6 °F kitne °C aur K?
C = (98.6 − 32) × 5/9 = 37 °C. K = 310.15 K. **Ans: 37 °C, ≈ 310 K**

Q2. 1 m ki steel rod ($\alpha = 1.2 \times 10^{-5}$ /°C) 100 °C garam. Length kitni badhi?
$\Delta L = 1 \times 1.2 \times 10^{-5} \times 100 = 1.2 \times 10^{-3}$ m. **Ans: 1.2 mm**

Q3. 200 g paani 80 °C aur 300 g paani 20 °C mila diya. Final temperature?
200(80 − T) = 300(T − 20) ⇒ 16000 + 6000 = 500T ⇒ T = 44 °C. **Ans: 44 °C**

Q4. −10 °C ki 100 g barf ko 100 °C ki bhaap banane me kitni heat? ($s_{ice} = 0.5$, $s_{water} = 1$ cal/g°C)
Barf garam: 100 × 0.5 × 10 = 500. Pighalna: 100 × 80 = 8000. Paani 0→100: 10000. Bhaap: 100 × 540 = 54000. Total = 72500 cal. **Ans: 72.5 kcal ≈ 3.03×10^5 J**

Q5. 50 cm lambi, 10 cm² area wali copper rod (K = 400), sire 100 °C aur 0 °C. Heat flow rate?
$H = 400 \times 10^{-3} \times 100/0.5 = 80$ W. **Ans: 80 W**

Q6. Sun ka $\lambda_m \approx 480$ nm. Surface temperature?
$T = b/\lambda_m = 2.9 \times 10^{-3}/(4.8 \times 10^{-7}) \approx 6000$ K. **Ans: ≈ 6000 K**

Q7. Body 80 °C se 60 °C 5 min me thandi (room 20 °C). 60 se 40 °C kitne min me?
20/5 = k(70 − 20) ⇒ k = 0.08. 20/t = 0.08(50 − 20) = 2.4 ⇒ t ≈ 8.3 min. **Ans: ≈ 8.3 min**

13 Common mistakes

- Stefan's law me °C daal dena. Hamesha **kelvin** me T^4.
- Latent heat ke time temperature badhta maan lena.
- Chhed wali plate garam karne pe chhed chhota maan lena (bada hota hai).
- $\beta = \alpha^2$ ya $\gamma = \alpha^3$ likhna. Sahi: $\beta = 2\alpha$, $\gamma = 3\alpha$.
- Calorimetry me phase change (barf pighalna) ki heat bhool jaana.
- Newton's cooling me average temperature ki jagah shuru ka temperature lena.

14 Formula sheet

Scales	$C/100 = (F - 32)/180 = (K - 273)/100$
Expansion	$\Delta L = \alpha L \Delta T$, $\beta = 2\alpha$, $\gamma = 3\alpha$
Heat	$Q = ms\Delta T$, $Q = mL$
Calorimetry	heat lost = heat gained
Mayer	$C_p - C_v = R$
Conduction	$H = KA\Delta T/L$, $R = L/KA$
Stefan	$H = e\sigma AT^4$
Wien	$\lambda_m T = 2.9 \times 10^{-3}$ m·K
Newton's cooling	$dT/dt = -k(T - T_0)$
Latent heats (water)	80 cal/g (fusion), 540 cal/g (vaporisation)

15 Practice questions

1. Kis temperature pe Fahrenheit reading Celsius ki 2 guna hogi?
2. Cube ka $\alpha = 2 \times 10^{-5}$. Volume me % badlav jab 50 °C garam?
3. Black body ka temperature 2 guna. Radiated power kitna?
4. Do rods same length, K aur 2K, series me. Equivalent K?
5. 0 °C ki 10 g barf ko 0 °C ka paani banane me kitni heat?

ANSWERS

1) $F = 2C \Rightarrow C = 160$ °C ($F = 320$ °F) · 2) $\gamma\Delta T = 6 \times 10^{-5} \times 50 = 0.3\%$ · 3) 16 guna · 4) $2 \times K \times 2K/(K + 2K) = 4K/3$ · 5) 800 cal

16 Quick revision: exam se pehle 5 minute

TEMPERATURE & EXPANSION

- −40 °C = −40 °F.
- $\alpha : \beta : \gamma = 1 : 2 : 3$.
- Paani 4 °C pe sabse dense.
- Bimetal: zyada α wala bahar.

HEAT

- $Q = ms\Delta T$; $Q = mL$ (T same).
- Paani s = 1 cal/g°C (sabse zyada).
- $L_f = 80$, $L_v = 540$ cal/g.
- Pressure ↑ ⇒ boiling point ↑.

TRANSFER

- $H = KA\Delta T/L$; $R = L/KA$.
- Convection sirf fluids me.
- Radiation: vacuum me bhi.

RADIATION & COOLING

- $H \propto T^4$ (kelvin!).
- $\lambda_m T$ = constant.
- Achha absorber = achha emitter.
- $dT/dt \propto (T - T_o)$.

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