Unit 9 · Heat and Temperature

STUDY NOTES

WHAT NEB'S GRADE 11 EXAM ASKS

- **CDC's grid (2077):** Heat and Thermodynamics (Units 9–13 together): 15 of 75 marks
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **MCQ (1 mark)**
  - what is equal at thermal equilibrium
  - scales that never read the same
  - spherical vs cylindrical bulb
  - the C–F graph's intercept
  - F = 3C; °C ↔ °F
  - length of thread → °C
  - a faulty thermometer's ice point
  - a rise in °C as K
- **Short (5 marks, in parts)**
  - define thermal equilibrium, absolute zero
  - zeroth law: why temperature needs it
  - prove $C + 40 = \frac{5}{9}(F + 40)$
  - faulty thermometer → true °C
  - 10 °F vs 10 K rise: which is hotter
  - a fall or change in °F, °C, K

Key terms

Thermal energy: energy of the **random motion** of a body's molecules (their KE); part of its internal energy.

Internal energy: total KE + PE of all its molecules (not the motion of the body as a whole).

Heat: energy transferred **because of a temperature difference**, hotter → colder; exists only in transit.

Temperature: degree of hotness; **decides the direction of heat flow**; measure of the **average KE** of the molecules; macroscopic.

Thermal equilibrium: no **net** heat flow between bodies in contact; same temperature (equal flows both ways).

Zeroth law: if A and B are each in thermal equilibrium with C, then A and B are in thermal equilibrium with each other.

Thermometric property: measurable property that changes steadily with temperature.

Lower fixed point (ice point): pure ice melts at standard pressure (101.325 kPa).

Upper fixed point (steam point): pure water boils at standard pressure; bulb in the **steam**, not the water.

Absolute zero: 0 K = −273.15 °C; lowest possible temperature; molecules' random KE least possible.

Adiabatic wall: lets no heat through. **Diathermic wall**: lets heat through freely.

Formulas

$\theta = \frac{X - X_0}{X_{100} - X_0} \times 100\ ^\circ\text{C}$	X_0, X_{100}, X: property at ice point, steam point, unknown **Use:** any thermometer (length, resistance, pressure)
$\frac{C}{5} = \frac{F - 32}{9} = \frac{K - 273}{5}$	C, F, K: readings **Use:** converting scales
$\frac{\text{reading} - \text{LFP}}{\text{UFP} - \text{LFP}}$ same on every scale	LFP, UFP: lower, upper fixed points **Use:** any two scales
$\frac{\theta - L}{U - L} = \frac{C}{100}$	L, U: marked fixed points; θ: its reading **Use:** faulty thermometer
$T = \theta + 273.15$	T (K), θ (°C) **Use:** absolute temperature (273 usually enough)
$\Delta C = \Delta K = \frac{5}{9}\Delta F$	changes, not readings **Use:** a rise or fall

- 1 cal = 4.186 J ≈ 4.18 J (1 g water, 1 °C); 1 kcal (food "Calorie") ≈ 4.2 kJ
- $F = \frac{9}{5}C + 32$; $K = C + 273$
- **prove** $C + 40 = \frac{5}{9}(F + 40)$: $C/5 = (F - 32)/9 \rightarrow 9C = 5F - 160 \rightarrow$ add 360: $9(C + 40) = 5(F + 40)$
- rise of 10 °C = 10 K = 18 °F

Thermal energy, heat, temperature

- thermal energy made from
  - mechanical work (rubbing palms)
  - chemical (fuel, food)
  - electrical (heater)
  - nuclear (Sun, geothermal)
  - radiation (sunlight)

- heat: non-mechanical transfer, by conduction, convection, radiation; SI unit joule
- heat flows from **higher temperature**, not from more thermal energy: hot nail (little energy) → bucket of water at 40 °C (much more)

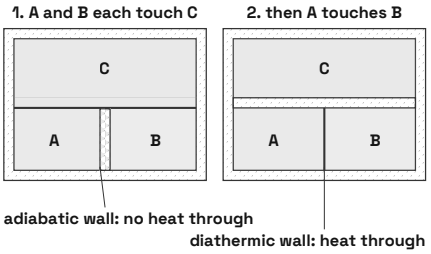
	Thermal energy	Heat
what	energy of molecules' random motion	energy transferred
cause	motion of molecules	temperature difference
where	stays in the body	only while moving
changes	↑ with temperature, amount	hot → cold till equal

Effects of heat

- **thermoelectric (Seebeck)**: two metals' junctions at different temperatures → e.m.f. (thermocouple)
- **emits light**: iron dull red ≈ 600 °C, orange ≈ 1100 °C, white ≈ 1300 °C
- **resistance**: metal ↑, semiconductor (thermistor) ↓
- **physical**: temperature, volume, state, color, viscosity, elasticity, solubility, surface tension, reaction rate
- **chemical**: paper burns, egg sets, rice cooks

Equilibrium and the zeroth law

- thermometer reads **its own** temperature → contact, **wait for equilibrium**, read; small next to the body
- zeroth law: an experimental fact; makes temperature meaningful; thermometer = body C



Zeroth law: A, B each in equilibrium with C (diathermic walls); then A–B wall made diathermic → no heat flows.

Thermometry

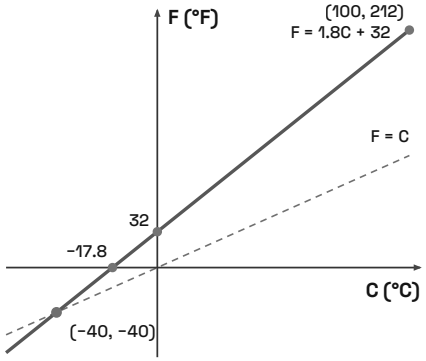
Thermometric property	Thermometer
length of a solid	bimetallic strip
volume of a liquid	mercury, alcohol in glass
gas volume, constant p	constant-pressure gas
gas pressure, constant V	constant-volume gas (standard)
magnetic property	magnetic (near 0 K)
resistance	platinum resistance; thermistor
e.m.f.	thermocouple (furnaces)
radiation	infrared (no contact)

- good thermometer: **construction** (uniform bore, property changes uniformly), **calibration** (fixed points, equal degrees), **sensitivity**
- **mercury**: expands uniformly, conducts well, opaque and shiny, doesn't wet glass, liquid −39 °C to 357 °C
- **alcohol**: freezes −114 °C (cold places), safer; mercury poisonous
- **sensitivity**
  - thin-walled small bulb → quick, takes little heat
  - **cylindrical** bulb → more surface than spherical → faster
  - **narrow bore** → long thread movement per degree
- fixed points need standard pressure: Kathmandu (≈ 1400 m) water boils ≈ 95 °C

Scale	Ice	Steam	Steps	Zero
Celsius	0	100	100	ice point
Fahrenheit	32	212	180	—
Kelvin	273.15	373.15	100	absolute zero
Réaumur	0	80	80	ice point
Rankine	491.67	671.67	180	absolute zero

Absolute zero and the scales

- gas at constant volume: p falls in a straight line with temperature → $p = 0$ at −273.15 °C, every gas
- absolute temperature ∝ average KE of gas molecules → a true zero; all gas laws use K
- write 300 K, no degree sign
- Kelvin and Rankine never negative; Kelvin and Celsius never equal



$F = \frac{9}{5}C + 32$: slope 9/5, cuts F axis at +32, C axis at −17.8; meets $F = C$ at −40.

COMMON MISTAKES

✗ a body "contains heat"
✓ it has **thermal energy**; heat is energy in transit.

✗ heat flows from more thermal energy to less
✓ from **higher temperature** to lower.

✗ molecules stop at absolute zero
✓ their random KE is the **least possible** (zero-point energy remains).

✗ rise of 27 °C = 300 K
✓ a change: 27 °C = **27 K**.

✗ convert a change with $F = \frac{9}{5}C + 32$
✓ changes: $\Delta F = \frac{9}{5}\Delta C$, no 32.

✗ steam point in boiling water
✓ bulb in the **steam** (impurities raise the water's boiling point).

✗ equilibrium: energy stops passing
✓ passes both ways **at equal rates**.