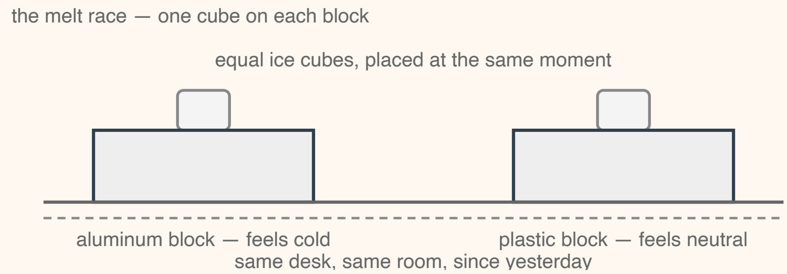
THERMO DAY 7: SPECIFIC HEAT & THERMAL CONDUCTIVITY

WARMUP The Melt Race — predict first

Two blocks have sat on the same desk since yesterday: one **aluminum**, one **thick plastic**. Your teacher passes both around — the aluminum block feels distinctly colder to the touch. Then the teacher sets one ice cube on each block and starts a timer.



The setup. Commit to a prediction before the cubes go down.

Prediction — circle one. Which ice cube melts first?

(A) the cube on the plastic block — the plastic feels warmer **(B)** the cube on the aluminum block **(C)** essentially a tie — both blocks spent the night in the same room

In one line, why did you pick your prediction?

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WHAT YOUR HAND ACTUALLY MEASURES

A THERMOMETER READS A LEVEL; YOUR PALM READS A FLOW

A thermometer taped to each block overnight would show the **same reading**: both blocks sit at the room's temperature. What differs is how fast each block carries energy away from your hand, which is warmer than the room at roughly 35°C of skin temperature.

Skin nerves respond to the **rate at which energy leaves them**: a fast drain registers as "cold," a slow drain as "cool." The material property that sets that rate is **thermal conductivity,** k — quantified on page 3. Keep the two questions separate all day: *what temperature is it?* versus *how fast is energy moving?*

QUICK Reading the Two Blocks

(a) Circle one: after a night on the same desk, the aluminum block's temperature is **lower than / equal to / higher than** the plastic block's temperature.

(b) In one line: what does the aluminum block do to your hand *faster* than the plastic block does?

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SPECIFIC HEAT: THE ENERGY COST OF A TEMPERATURE CHANGE

Q = MCΔT

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

Q = heat that enters (+) or leaves (−) the sample (J)
m = mass of the sample (kg)

c = specific heat, in J/(kg·K) — the sample's price per kilogram per kelvin
$\Delta T = T_f - T_i$ = temperature change (K)

material	c, J/(kg·K)
copper	390
water	4186

Every material posts a price: c joules buys a 1 K temperature change for each kilogram. Water's price is nearly 11× copper's — which is why the ocean warms and cools far more sluggishly than the land beside it.

ΔT needs no +273. One Celsius degree is the same *size* as one kelvin, so a temperature *difference* is the same number on both scales: warming from 15°C to 85°C is ΔT = 70 K. Contrast with Day 1's kinetic-theory formulas, where the absolute temperature T itself appears and must be in kelvin.

WE DO **Heating the Kettle**

A kettle holds 0.50 kg of water at 15°C. How much energy must the water absorb to reach 85°C?

Step 1 — the change: $\Delta T = 85^\circ\mathrm{C} - 15^\circ\mathrm{C} =$ _________ K

Step 2 — compute, carrying units: $Q = mc\Delta T = (0.50\text{ kg})\left(4186\ \frac{\text{J}}{\text{kg}\cdot\text{K}}\right)(\_\_\_\_\_\ \text{K}) =$ __________ J

YOU DO **The Cooling Copper Block**

A 0.20 kg copper block cools from 85°C to 15°C. How much energy does the copper block release? Carry units through the computation.

QUICK **Same Mass, Same ΔT**

Equal masses of water and copper each warm by the same ΔT. Using the table, $Q_{water}/Q_{copper} =$ _________ (one division).

MIXING: THE INSULATED-CUP BALANCE

ENERGY RELEASED = ENERGY ABSORBED

Drop hot copper into cool water in an insulated cup and wait: both settle at one shared final temperature T_f. If the cup leaks negligible energy, the bookkeeping closes with a single line — the energy the copper releases equals the energy the water absorbs:

$$m_{Cu}\,c_{Cu}\,(T_{hot} - T_f) \;=\; m_w\,c_w\,(T_f - T_{cool})$$

Write each side as a positive quantity: (the hot object's drop) on the left, (the cold object's rise) on the right. T_f is the only unknown.

WE DO **Hot Copper Meets Cool Water**

A 0.25 kg copper block at 85°C is lowered into 0.35 kg of water at 20°C in an insulated cup.

(a) Compute each object's mc product: copper $m_{Cu}c_{Cu} =$ __________ J/K water $m_w c_w =$ __________ J/K

(b) Before solving, circle one: T_f will land **close to 20°C / near the midpoint, 52.5°C / close to 85°C**.

(c) Solve the balance equation for T_f, carrying units.

THERMAL CONDUCTIVITY: HOW FAST HEAT CROSSES A MATERIAL

THE CONDUCTION RATE EQUATION

$$\frac{Q}{\Delta t} = \frac{k\,A\,\Delta T}{L}$$

$Q/\Delta t$ = energy conducted per second (W)
k = thermal conductivity, W/(m·K)
A = cross-sectional area (m²)
ΔT = temperature difference between the two faces (K)
L = length (or thickness) the energy crosses (m)

Inside a solid, faster-vibrating particles on the hot face hand energy to slower neighbors, collision by collision, down the bar. k measures how readily a material passes energy along: copper $k \approx 390$ W/(m·K); most plastics sit near 0.2 W/(m·K).

WE DO **The Copper Bar Bridge**

A copper bar of length $L = 0.50$ m and cross-section $A = 4.0 \times 10^{-4}$ m² connects a plate held at 85°C to a plate held at 15°C. Find the energy the bar conducts per second, carrying units.

Back to the two blocks: aluminum's k is roughly a thousand times the plastic's, while the two blocks share one temperature. The aluminum delivers energy from its whole warm bulk to the ice contact patch through a high-k channel; the plastic passes energy so slowly that its cube gets most of its melting energy from the air. The property that made the aluminum feel cold to your 35°C hand feeds the 0°C ice quickly — the same k, driving energy in opposite directions.

PRACTICE

1 The Tea Urn

An urn warms 0.45 kg of water from 20°C to 70°C. **(a)** $\Delta T =$ ________ K **(b)** Find the energy the water absorbs (carry units).

2 Name That Metal

A 0.35 kg metal sample absorbs 5,733 J and warms from 15°C to 57°C. **(a)** Find the sample's specific heat c (carry units). **(b)** Which material from the page-2 table matches the sample?

3 Mixing Two Waters

In an insulated cup, 0.20 kg of water at 85°C is poured into 0.30 kg of water at 15°C. Find the final temperature of the mixture. (Both liquids are water — watch what happens to c in the balance equation.)

4 Heat Leak Down the Bar

A copper bar ($k = 390$ W/(m·K)) of length 0.25 m and cross-section 2.0×10^{-4} m² connects a plate at 60°C to a plate at 15°C. Find the energy the bar conducts per second (carry units).

5 Fix the Claim

A student watching the melt race says: *"The metal block feels cold because metal is always a few degrees colder than the room."* Rewrite the student's claim in 2–3 sentences so that **temperature** and **heat-flow rate** each do their correct job, and use the rewrite to explain which ice cube melted first.