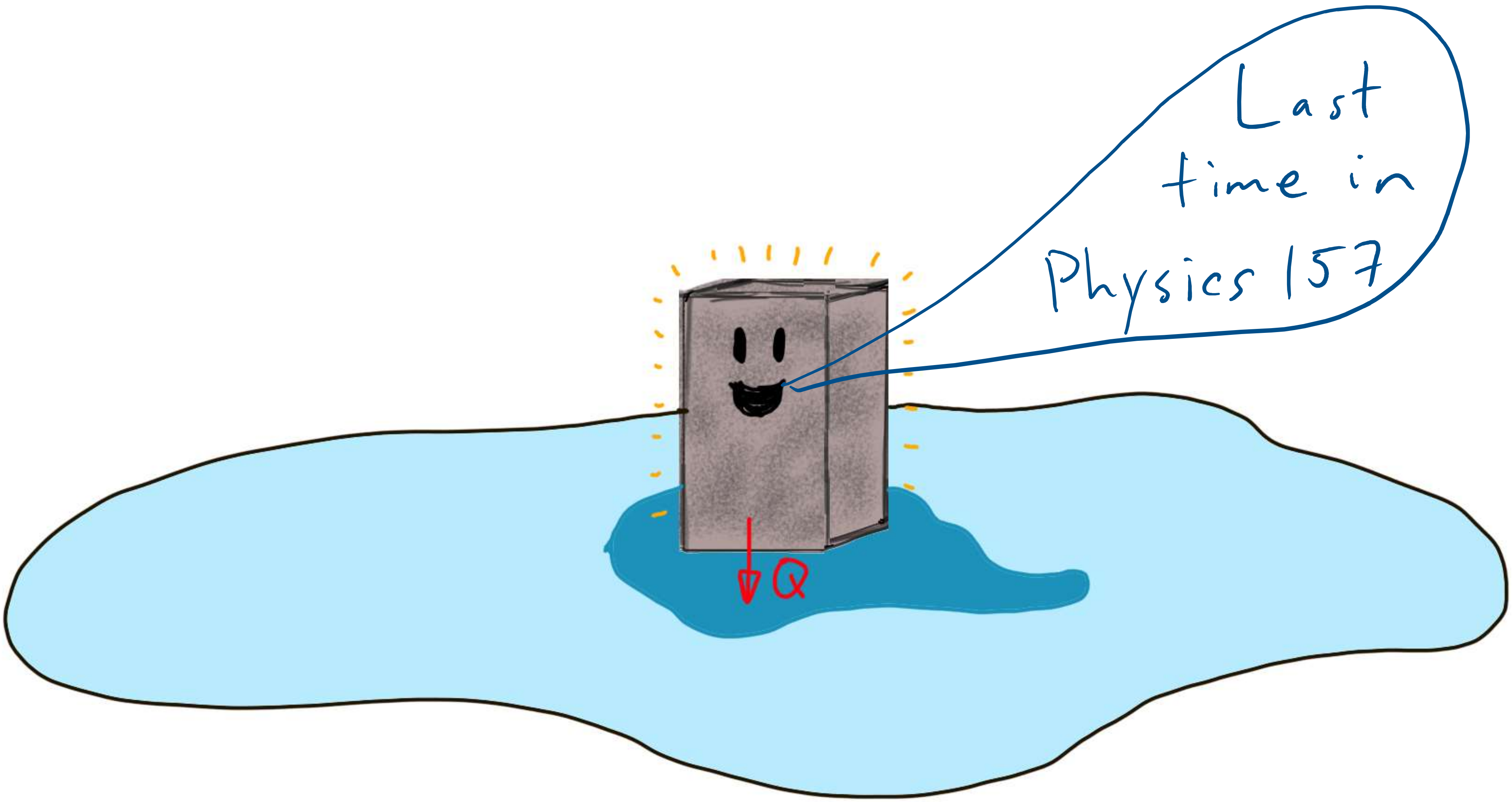
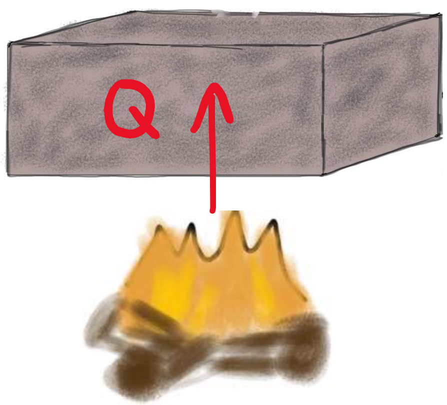
Learning goals:

- Calculate the heat required to bring a material from one temperature to another when we have a phase change occurring at an intermediate temperature
- Explain why some objects feel colder than others even though they are the same temperature
- Explain how the rate of energy flow can be quantified using heat current
- Explain why heat current must be the same in all parts of a system where heat is steadily flowing from one side to another
- Quantitatively predict the heat current through an object given the temperature gradient and properties of the object
- Determine the relative heat currents for different objects subjected to the same temperature gradient
- Explain how thermal conductivity is defined


Last time in Physics 157
Q

Heat required to raise the temperature of a material determined by its SPECIFIC HEAT c:



heat added → Q; mass → m; SPECIFIC HEAT → c

$$Q = m c \Delta T$$

OR:

$$Q = n C \Delta T$$

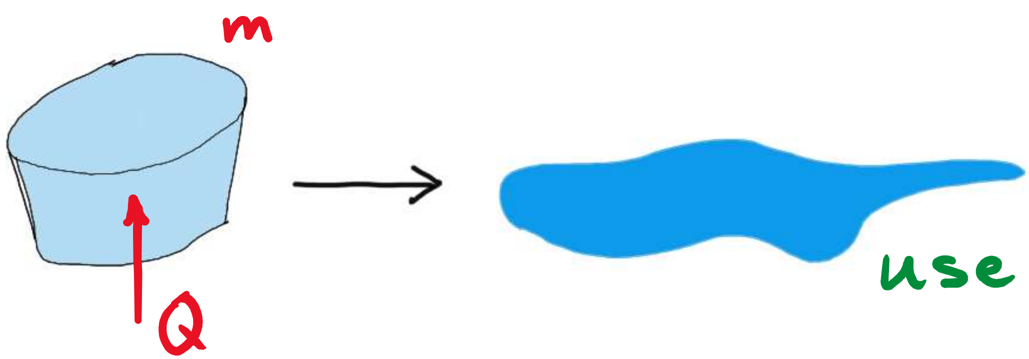
moles → n; MOLAR SPECIFIC HEAT = MOLAR HEAT CAPACITY → C

LATENT HEAT: Heat required to melt / boil a mass m of material (at melting / boiling point) is:

$$Q = mL$$

m ← mass

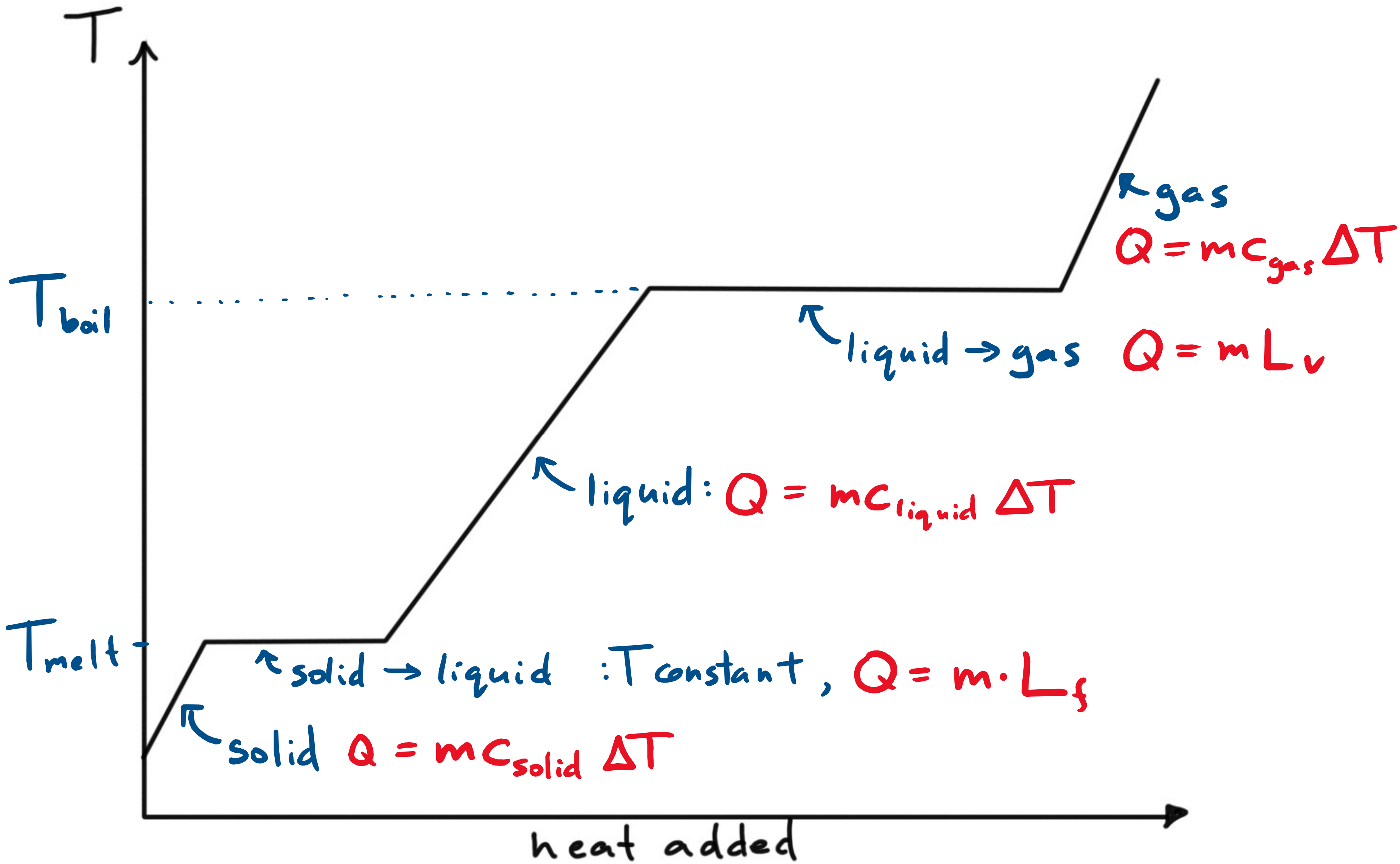
L ← latent heat

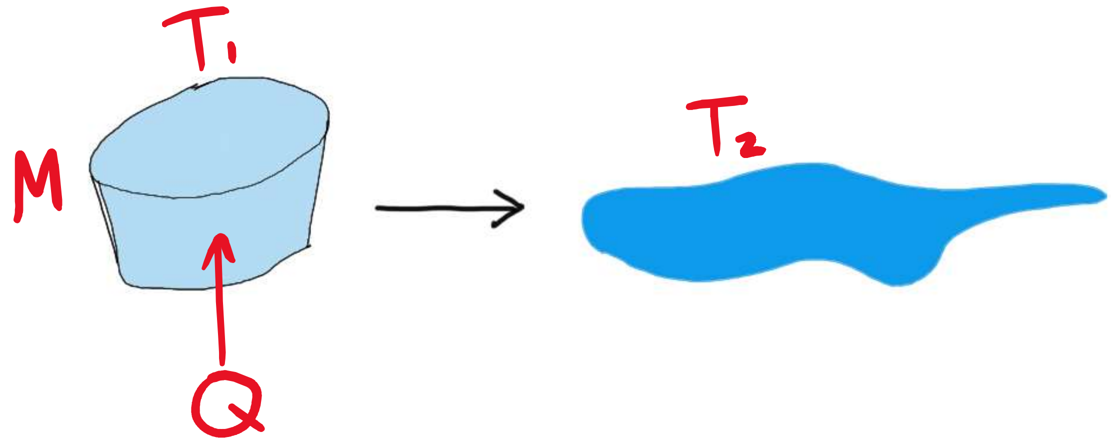


use L_f for melting / freezing

L_v for boiling / condensing

T vs heat added (e.g. water at atmospheric pressure)





A mass M of ice at temperature $T_1 < 0$ is heated until we have water at temperature $T_2 > 0$. How much heat has been added?

A) $M\, c_{ice}\,(T_2 - T_1)$

B) $M\, c_{water}\,(T_2 - T_1)$

C) $M\, L_f$

D) $M\, c_{ice}\,(-T_1) + M\, c_{water}\,(T_2)$

E) $M\, c_{ice}\,(-T_1) + M\, L_f + M\, c_{water}\,(T_2)$

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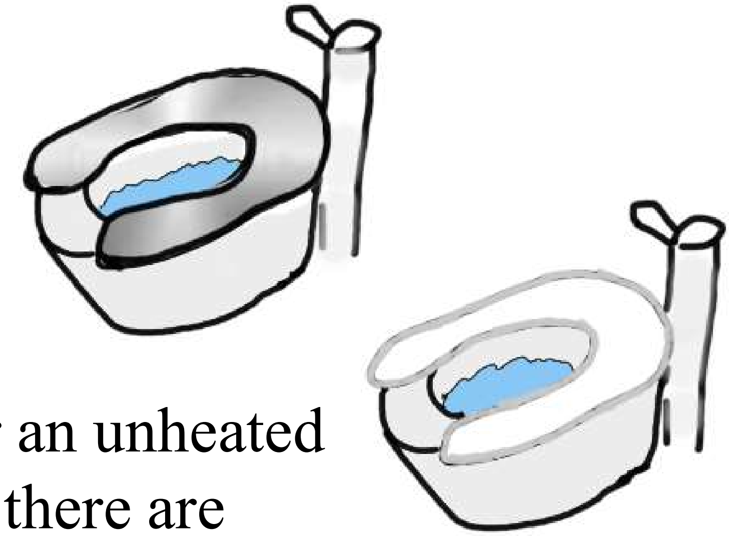
↑ Q to heat ice from T_1 to 0°C

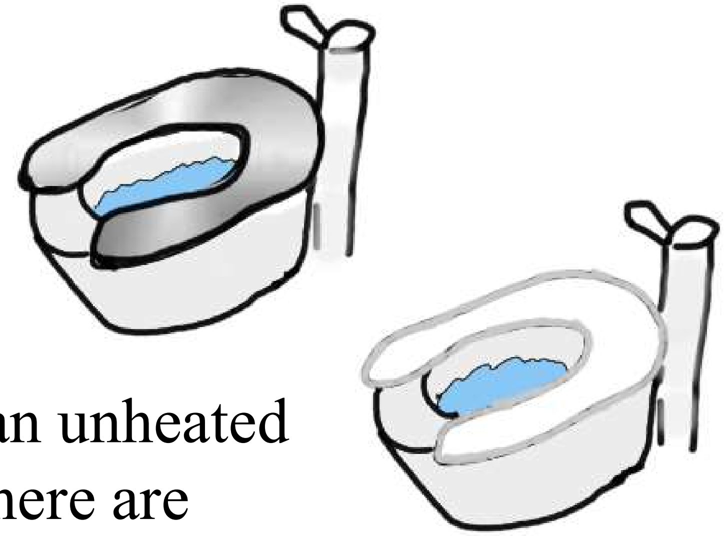
↑ Q to melt

↑ Q to heat from 0°C water to T_2



During a break from skiing, you enter an unheated washroom building (0ºC). You notice there are two toilets, one with a metal seat (c ~ 200 J/kg·K) and one with a plastic seat (c ~ 1600 J/kg·K). Assuming that you need to sit down, and that both seats are clean, which do you choose?

A) The metal seat.
B) The plastic seat.
C) It doesn’t matter: they are the same temperature.
D) My head says A) but my heart says B).



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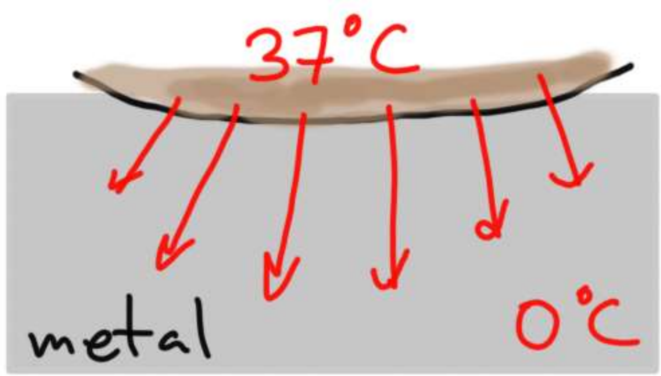
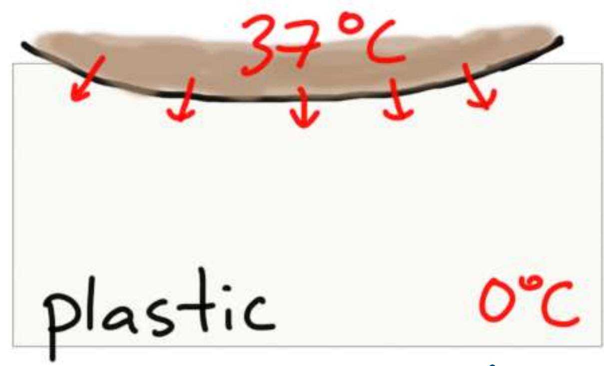
C) It doesn't matter: they are the same temperature.
D) My head says A) but my heart says B).

I'm not here to give you advice about using the bathroom, but personally, I would go for the plastic one.

THERMAL CONDUCTIVITY: Heat moves more quickly through some materials than others in response to a temperature gradient.



good thermal conductor



poor thermal conductor (insulator)

- the metal feels colder since it cools our skin quicker

Would an ice cube melt faster on metal or styrofoam, if the metal and styrofoam were both at room temperature?

A) Metal
B) Styrofoam

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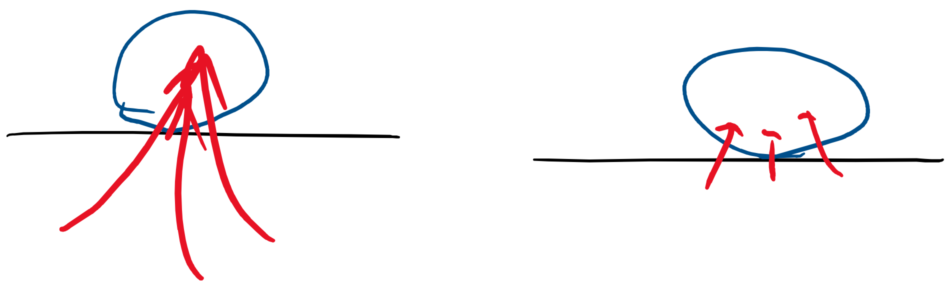
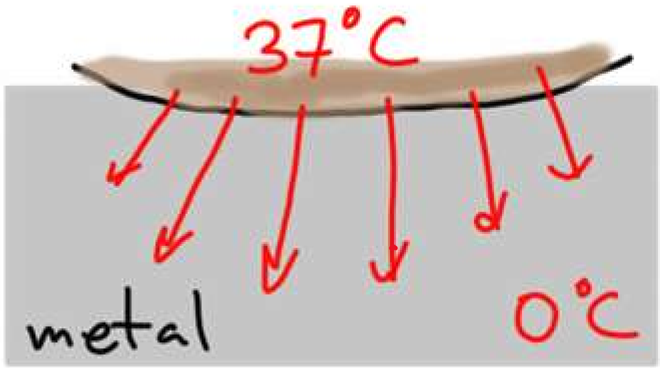


Heat flows faster through metal.

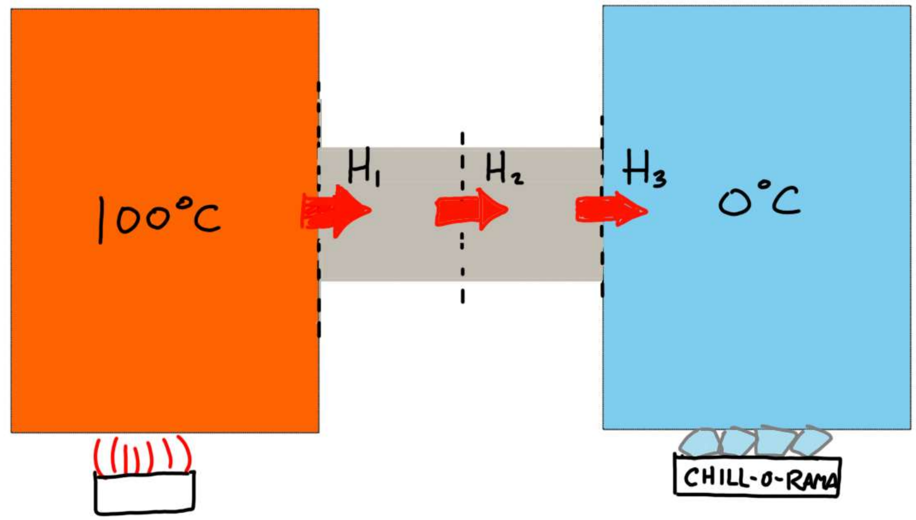
Quantifying thermal conductivity:



Heat dQ flows out in time dt

Define **HEAT CURRENT**: energy per unit time flowing from one part of a system to another:

$$H = \frac{dQ}{dt}$$

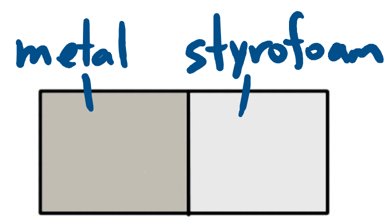


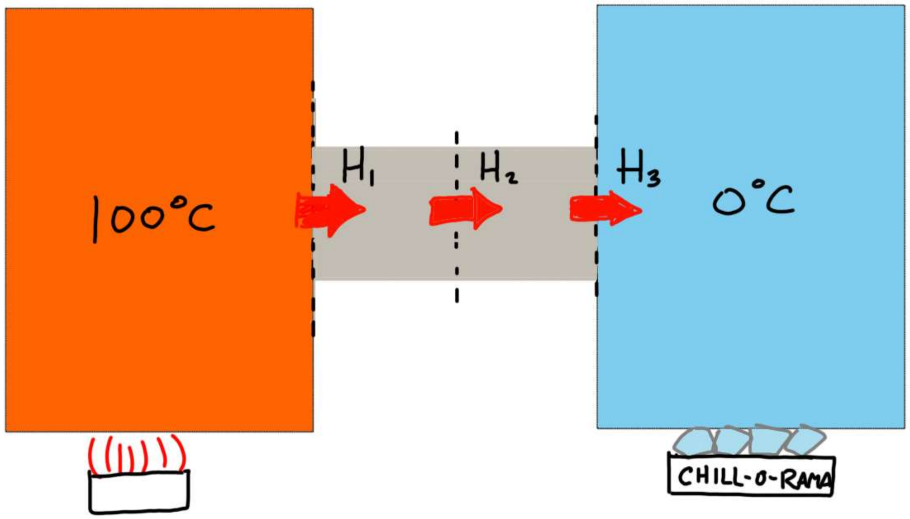
In the picture, the object on the left is kept at 100 °C while the object on the right is kept at 0 °C. Heat flows through the object in the middle, which has been in place for a long time. The system is insulted from the environment. For the heat current through the three surfaces shown, we can say that:

A) $H_1 > H_2 > H_3$ B) $H_1 = H_2 = H_3$ C) $H_1 < H_2 < H_3$

D) $H_1 = H_3 > H_2$ E) $H_1 = H_3 < H_2$

EXTRA: What if the object in the middle were this:





→ means temperatures are no longer changing.
→ energy is not building up anywhere
→ energy in = energy out for any part
→ energy currents all same

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Like current in a circuit.

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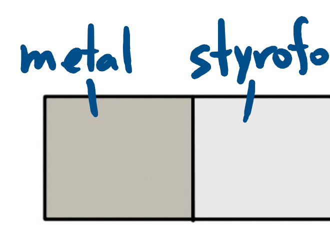

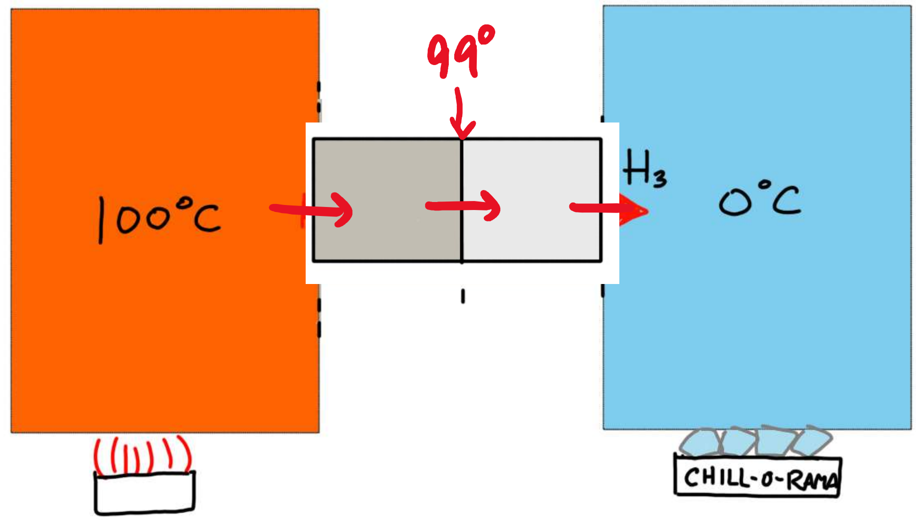

still the same currents if we wait for steady state situation.
*Temperature gradient through metal will be smaller

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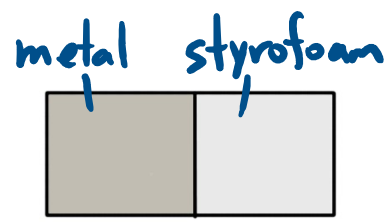
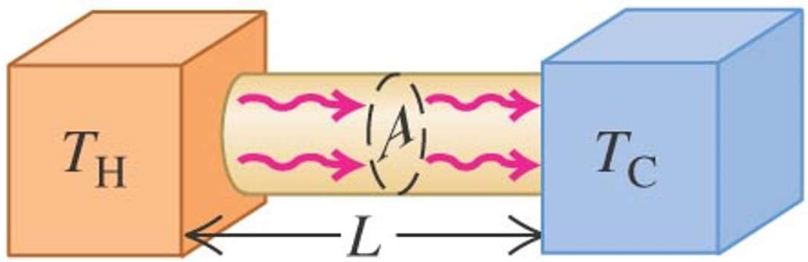


HEAT CURRENT is propoportional to TEMPERATURE GRADIENT



cross sectional area

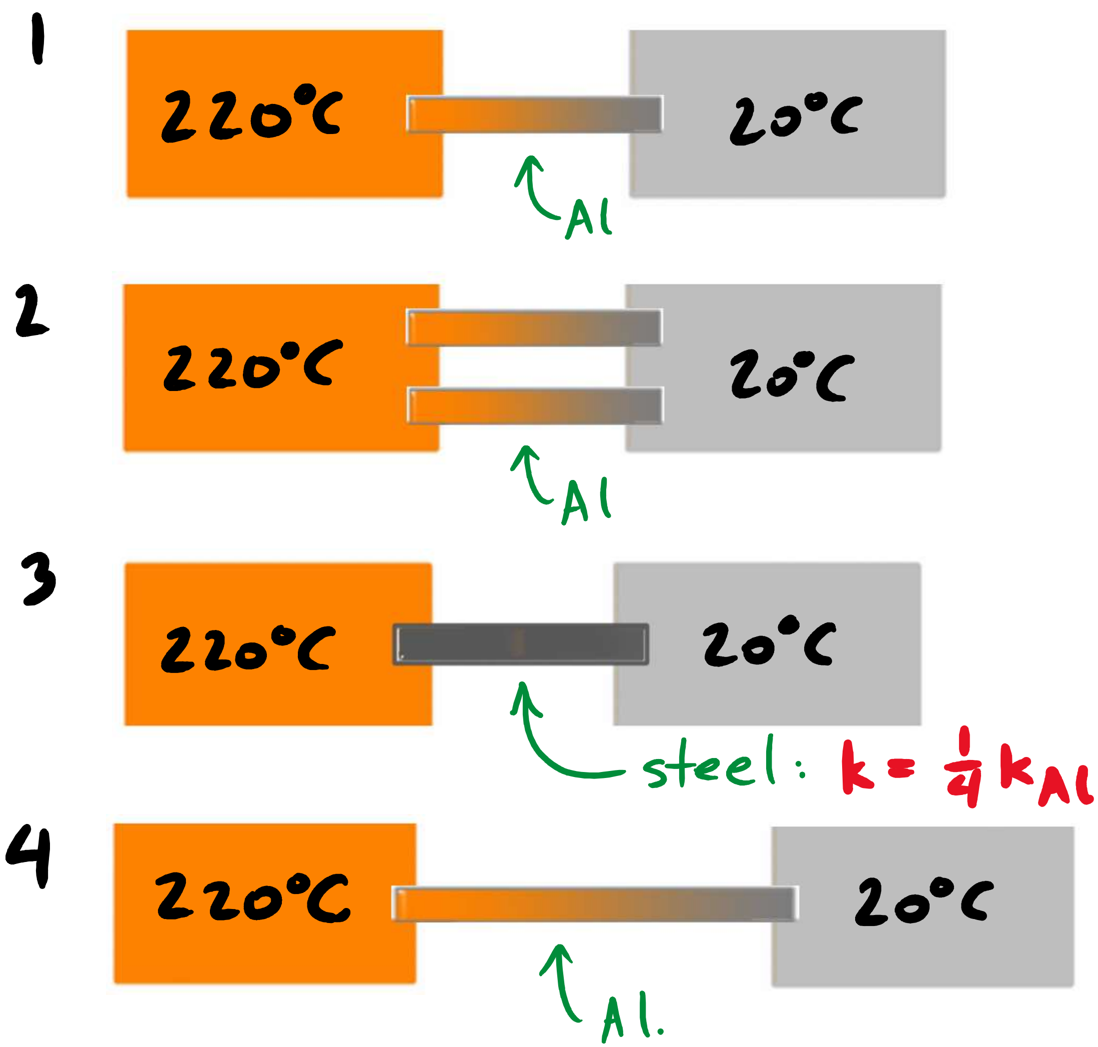
$$H = kA\frac{T_H - T_C}{L}$$

} temperature gradient → calculus version $\frac{dT}{dx}$

Heat current (Joules/second)

THERMAL CONDUCTIVITY

→ a basic property of a material



Rank the heat flow from smallest to largest

A) 1 > 2 > 3 > 4
B) 2 > 1 > 3 > 4
C) 2 > 1 > 4 > 3
D) 4 > 2 > 1 > 3
E) 3 > 2 > 1 > 4

$$H = kA\frac{T_H - T_c}{L}$$