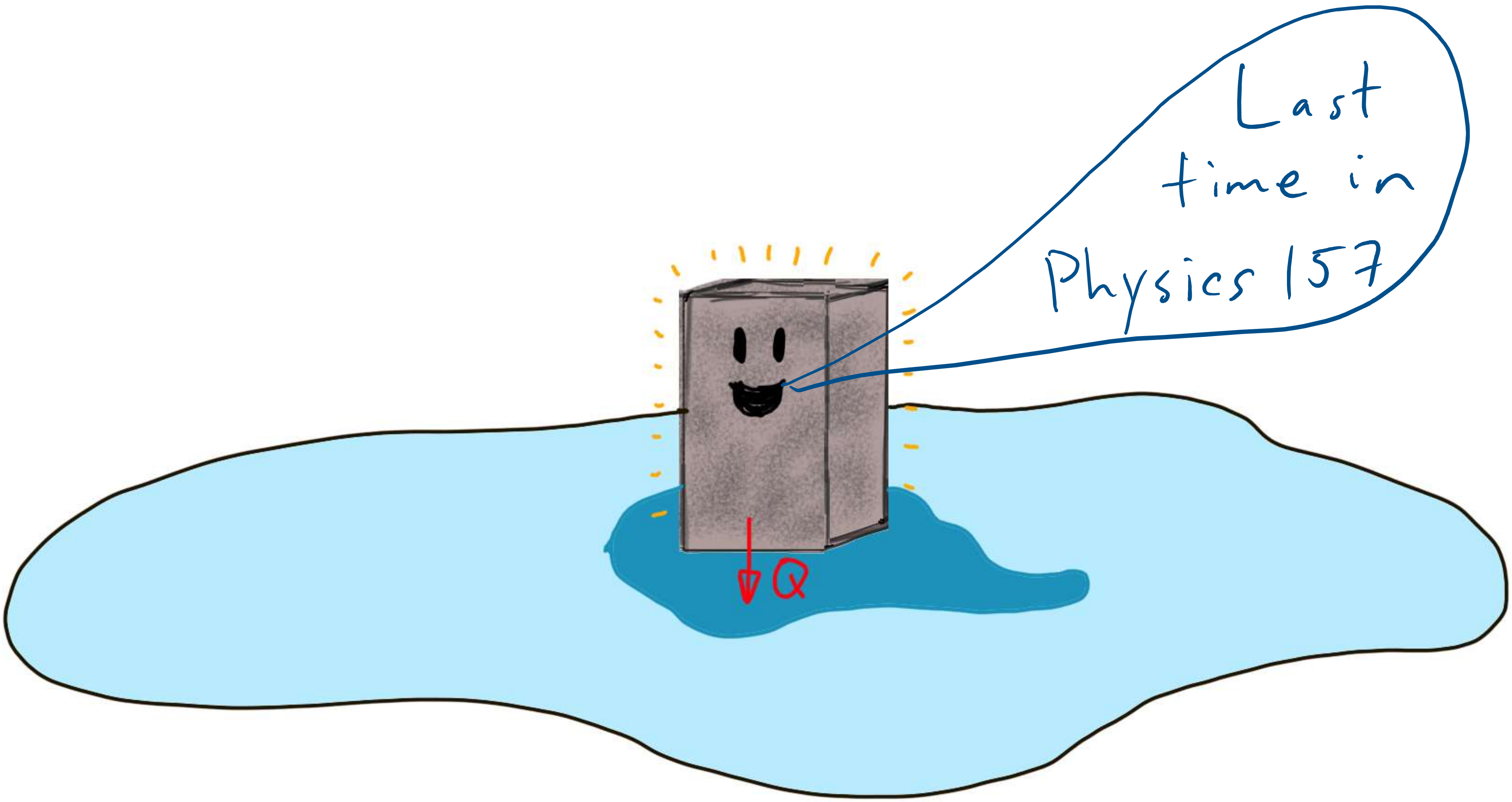
Quiz 2 is Thursday (available 5pm-3am)!

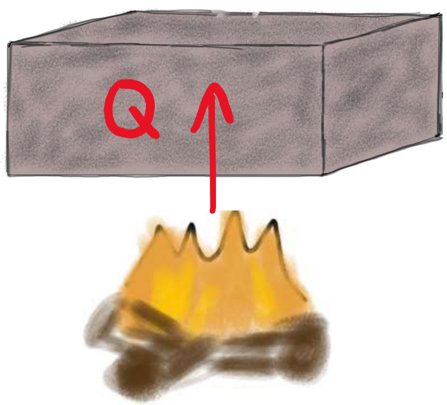
I will be available after class as long as needed, first answering questions for everyone and then at the tables.

Learning goals for today:

- 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
- Quantitatively predict the heat current through an object given the temperature gradient and properties of the object


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, ↓ c

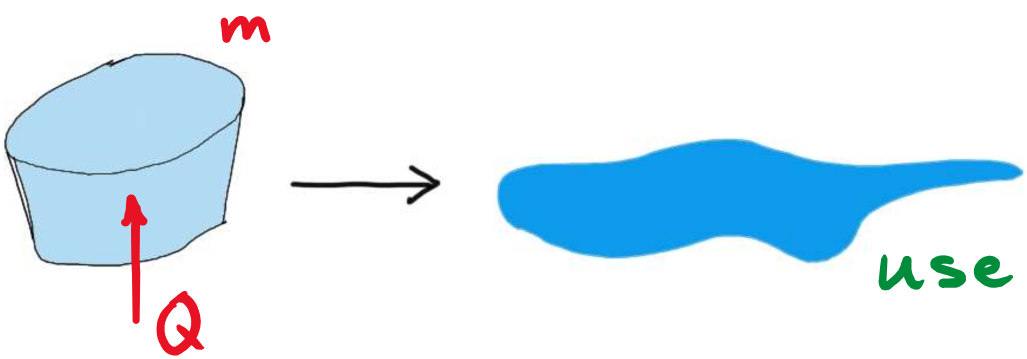
$$Q = m\,c\,\Delta T$$

Latent Heat

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

$$Q = \pm m L$$

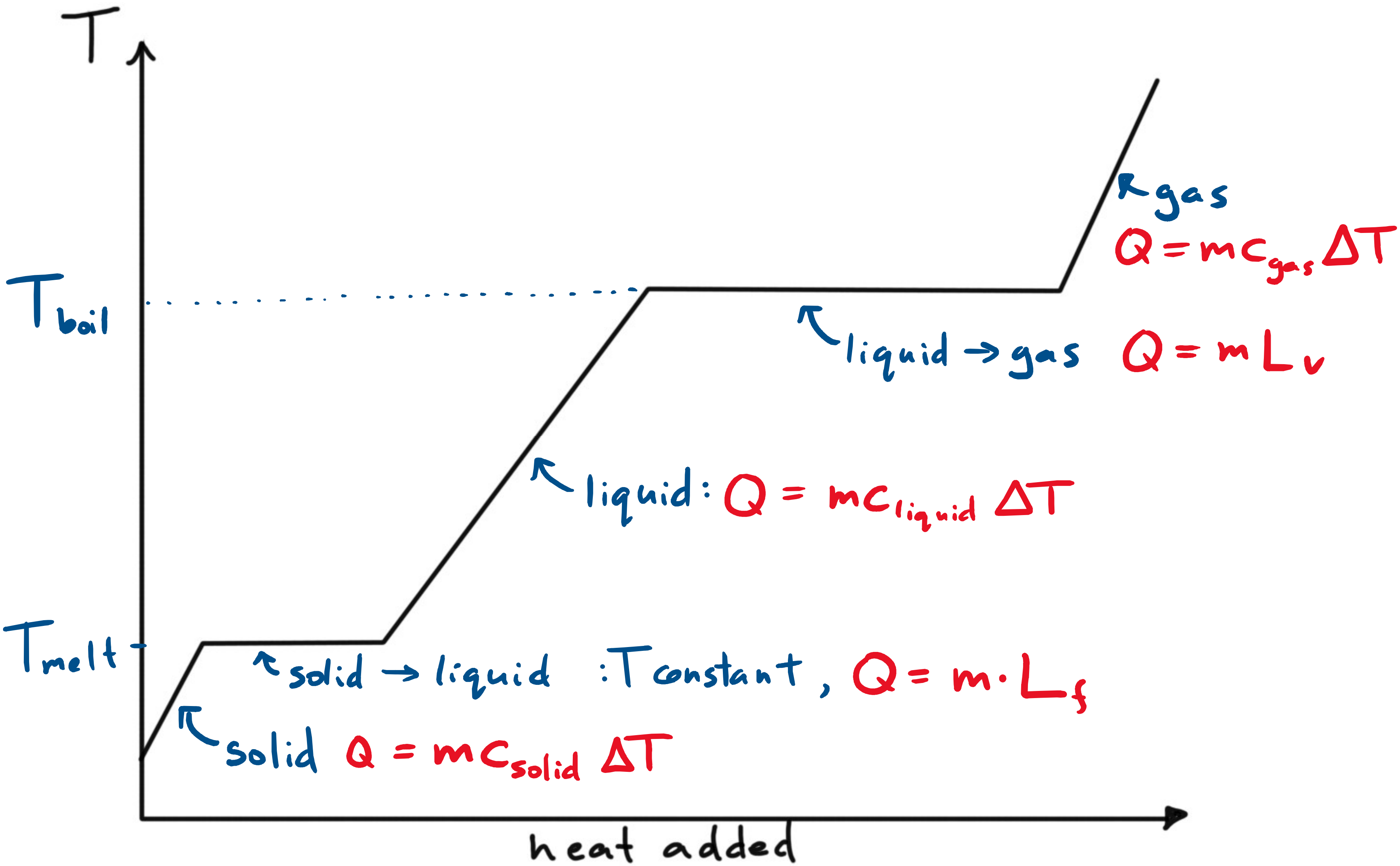
(m = mass, L = latent heat)

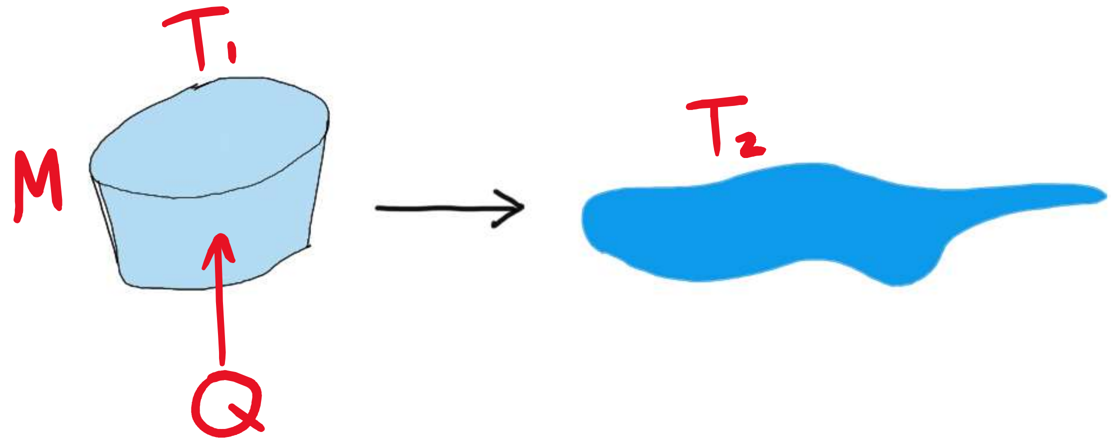


use L_f for melting (+) / freezing (−)

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

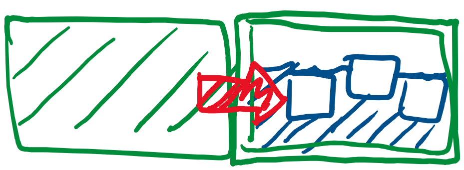
Heat transfer problems: general approach:

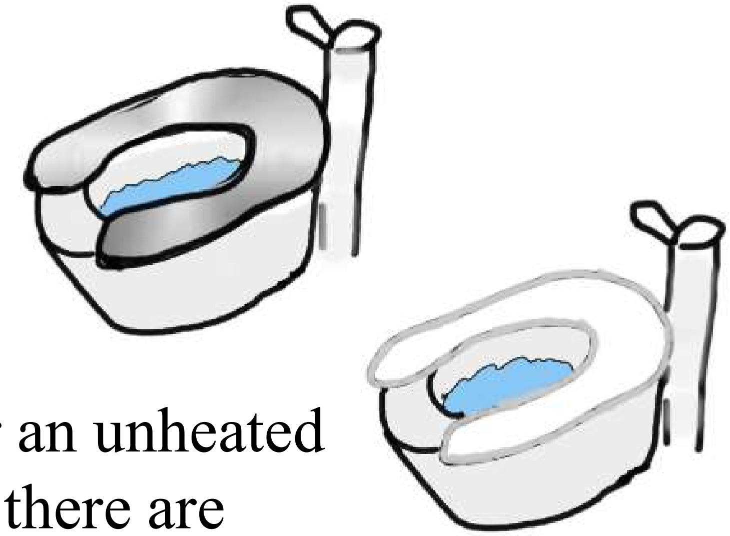
① Write Q for each part.

② Use energy conservation to say how Qs are related: e.g.

$Q_1 + Q_2 = 0$ if no net heat added to system

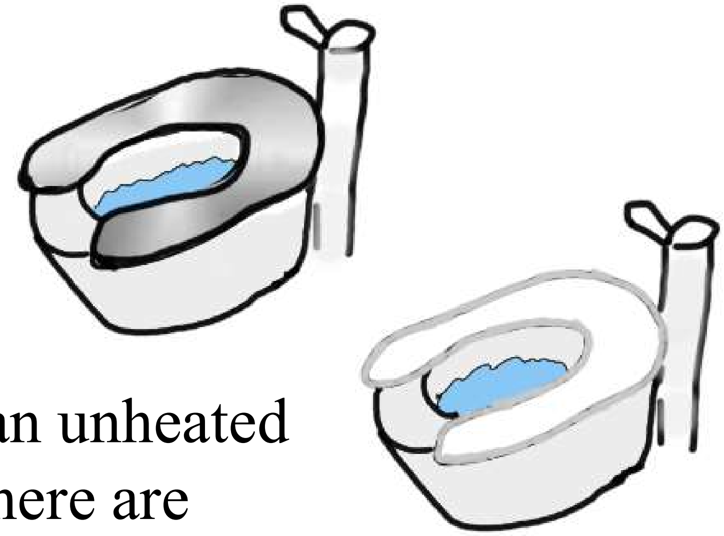
$Q = Pt$ if energy added with power P for time t





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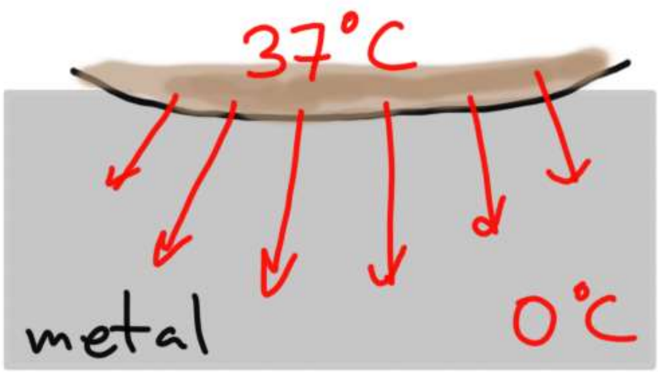
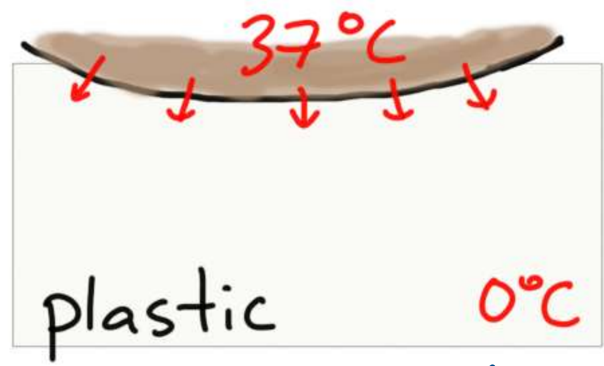
A) The metal seat.
B) The plastic seat.
C) It doesn't matter: they are the same temperature.
D) My head says A) but my heart says B).

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

DEMO:
https://youtu.be/CZysKM4kJTs

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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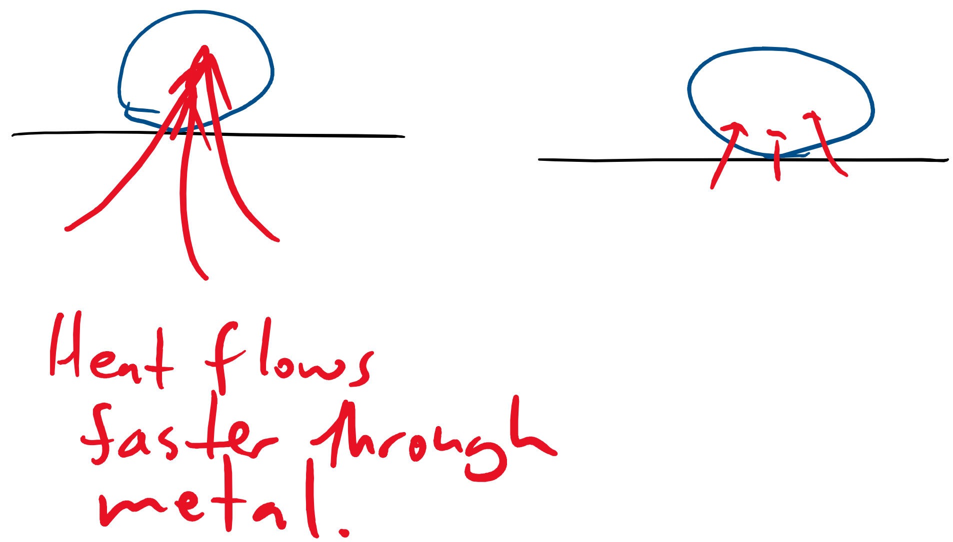
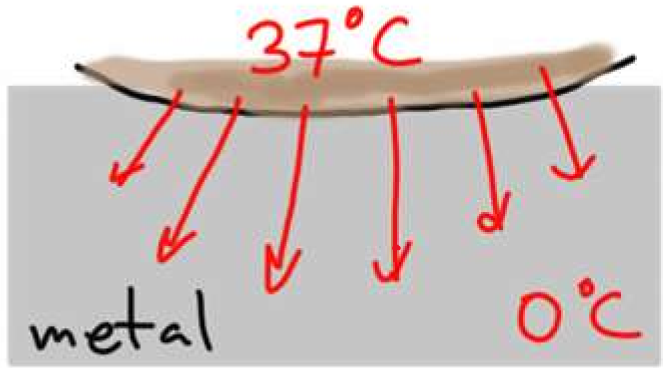


LIVE DEMO

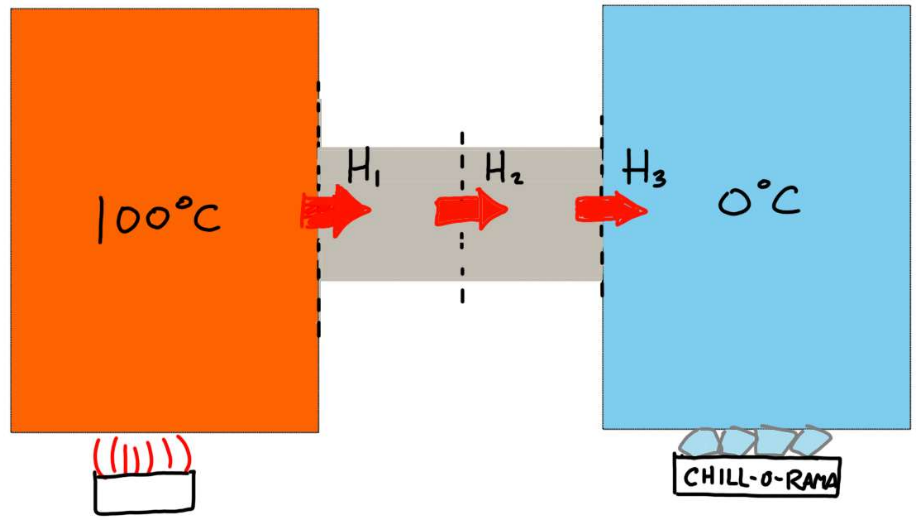
Quantifying thermal conductivity:



Heat dQ flows out in time dt

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

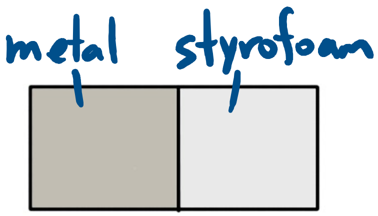
$$H = \frac{dQ}{dt}$$

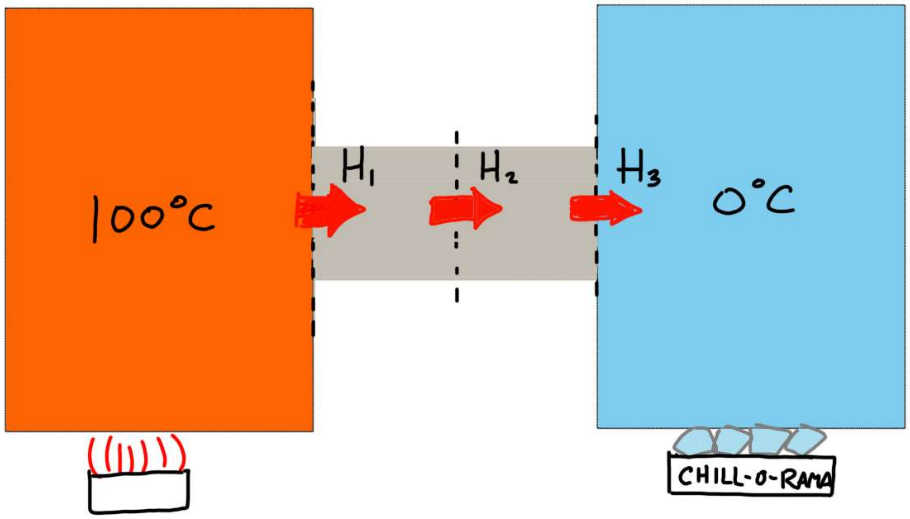


In the picture, the object on the left is kept at 100 °C while the object on the right is kept at 0 °C. Heat flows through the object in the middle, which has been in place for a long time. The system is insulted from the environment. For the heat current through the three surfaces shown, we can say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

A) $H_1 > H_2 > H_3$

B) $H_1 = H_2 = H_3$

C) $H_1 < H_2 < H_3$

D) $H_1 = H_3 > H_2$

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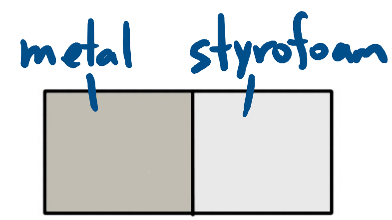

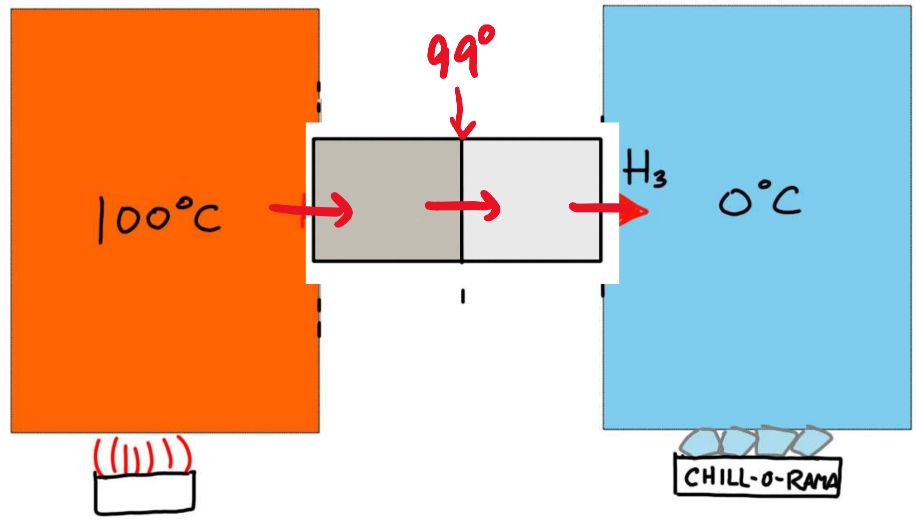

still the same currents if we wait for steady state situation.
*Temperature gradient through metal will be smaller

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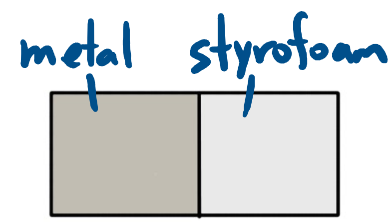
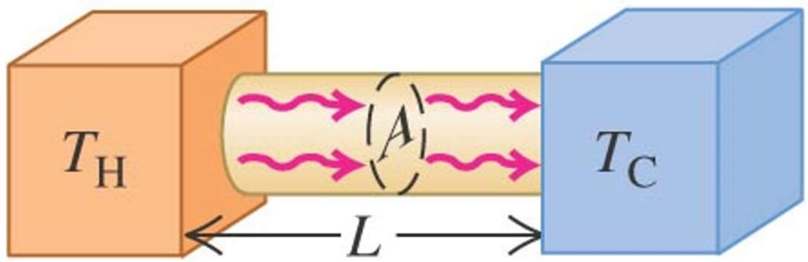


HEAT CURRENT is propoportional to TEMPERATURE GRADIENT



cross sectional area

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

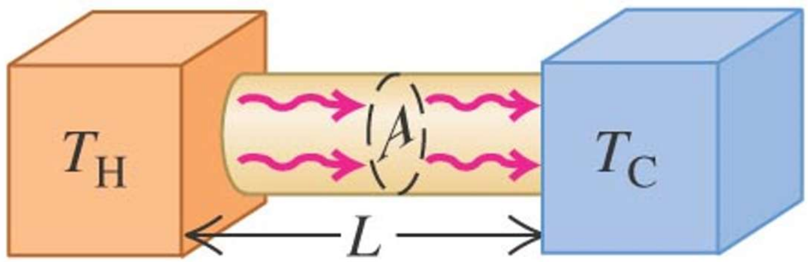
$\frac{T_H - T_C}{L}$ } temperature gradient

Heat current (Joules/second)

THERMAL CONDUCTIVITY

→ a basic property of a material

HEAT CURRENT is propoportional to TEMPERATURE GRADIENT



cross sectional area

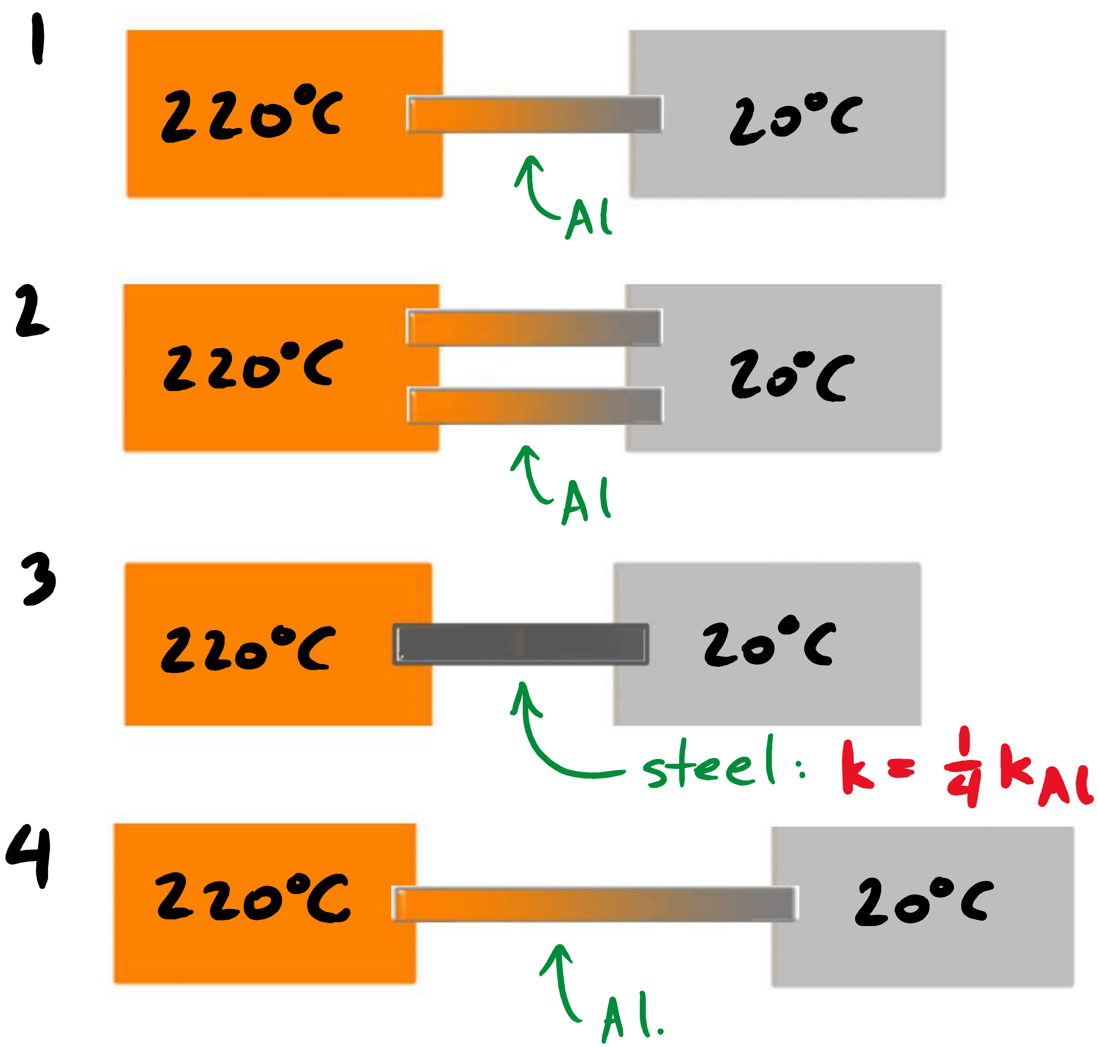
$$H = kA\frac{T_H - T_c}{L}$$

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

Heat current (Joules/second)

THERMAL CONDUCTIVITY

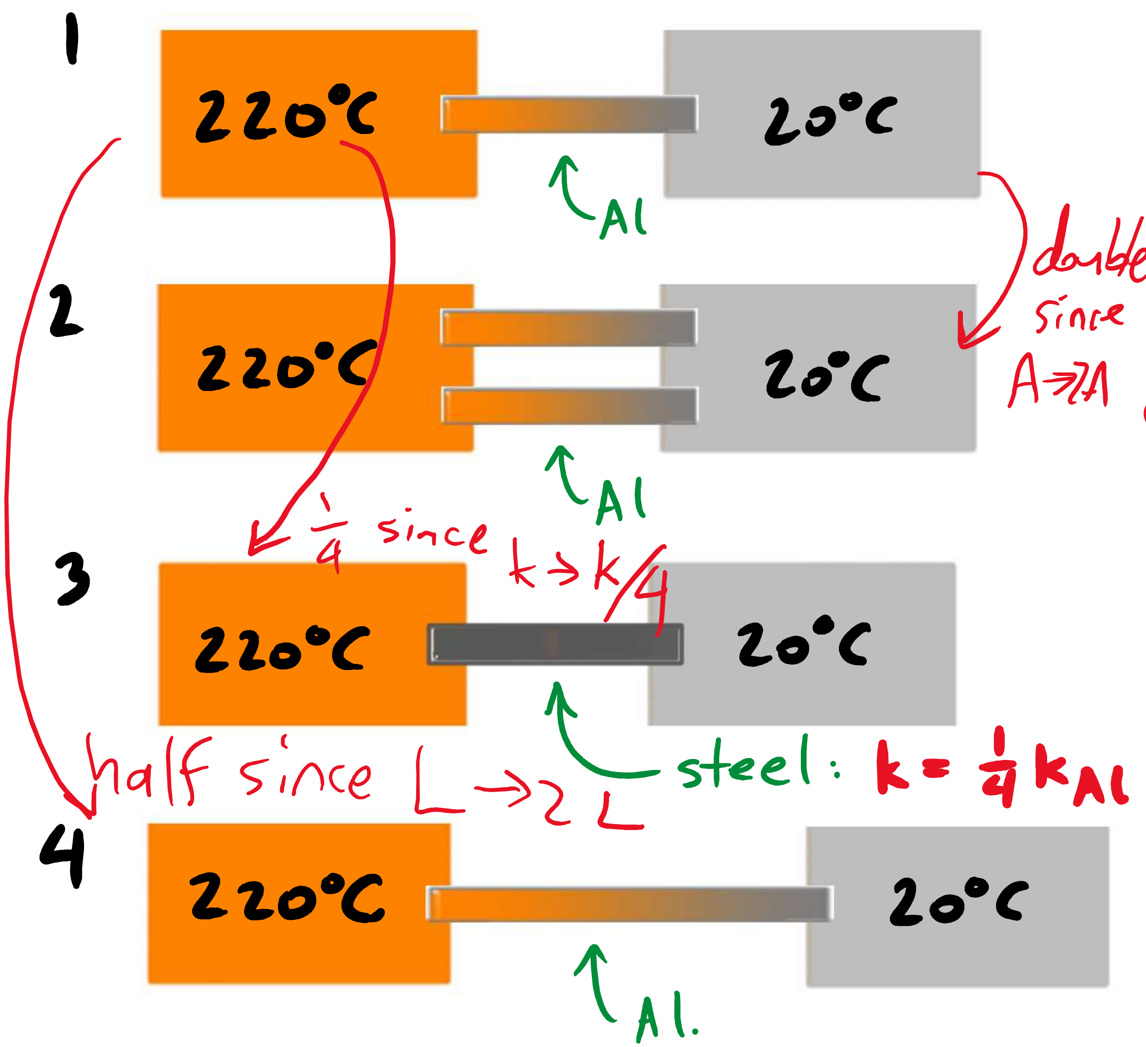
→ a basic property of a material



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

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



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