Office hours today: 3:30-4:30 in Hennings 420

Phys 157 Feedback: please fill out the online survey (will send link by e-mail)

Objects A and B have the same mass and both are at room temperature. We have $c_A > c_B$ and $k_A > k_B$. If each is dropped into an equivalent volume of 80°C water (insulated from the environment), we can say that:

specific heat

thermal conductivity

A) Object A will reach equilibrium faster and end up at a higher temperature.
B) Object A will reach equilibrium faster and end up at a lower temperature.
C) Object A will reach equilibrium slower and end up at a higher temperature.
D) Object A will reach equilibrium slower and end up at a lower temperature.
E) Both objects A and B will end up at the same temperature.

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Objects A and B have the same mass and both are at room temperature. We have $c_A > c_B$ and $k_A > k_B$. If each is dropped into an equivalent volume of 80°C water (insulated from the environment), we can say that:

specific heat

thermal conductivity

A) Object A will reach equilibrium faster and end up at a higher temperature.

larger k ⇒ heat flows in faster (better thermal conductor)

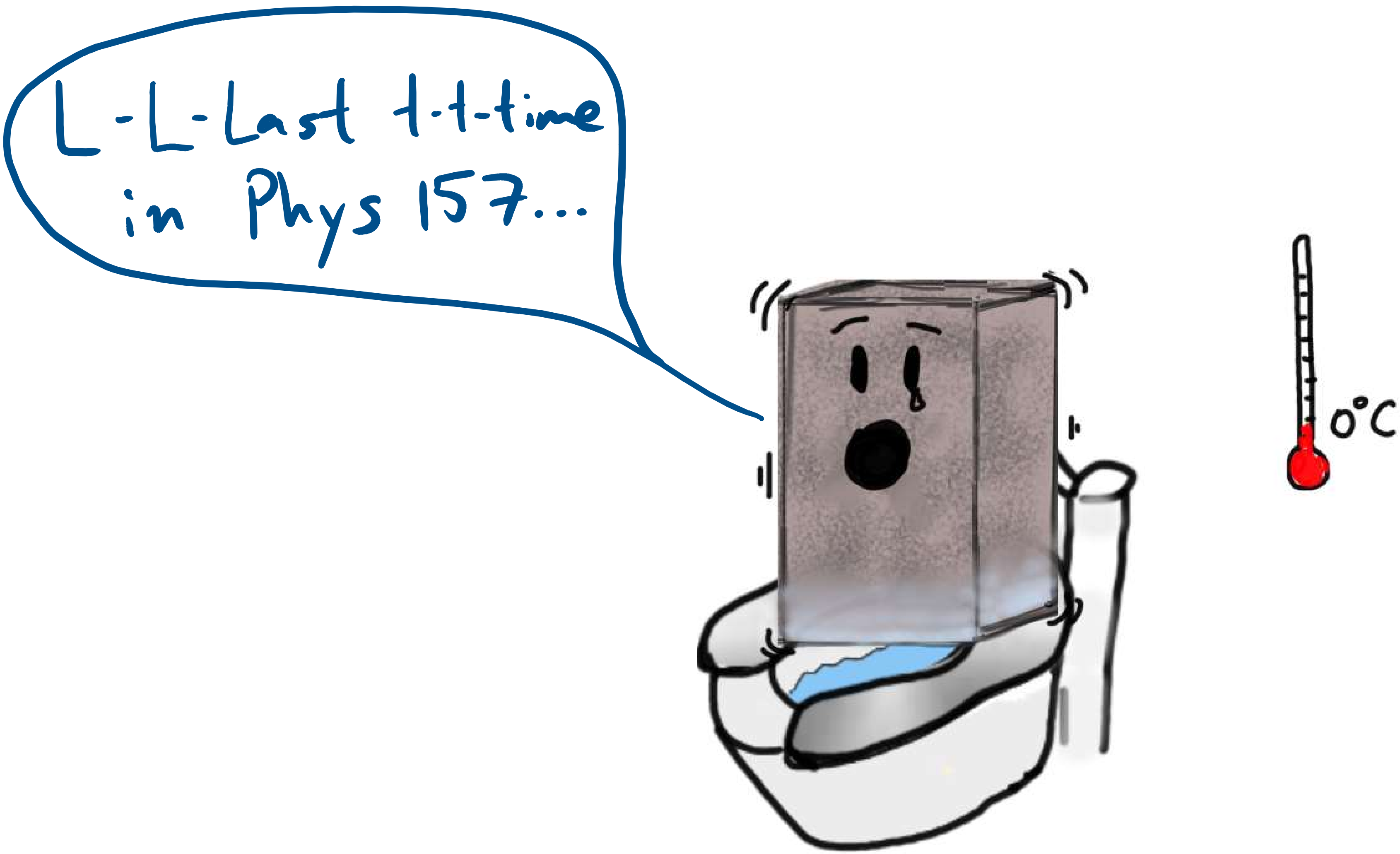
B) Object A will reach equilibrium faster and end up at a lower temperature.

larger c_A: takes more energy for a given temp. change, so heat from water will have less effect.

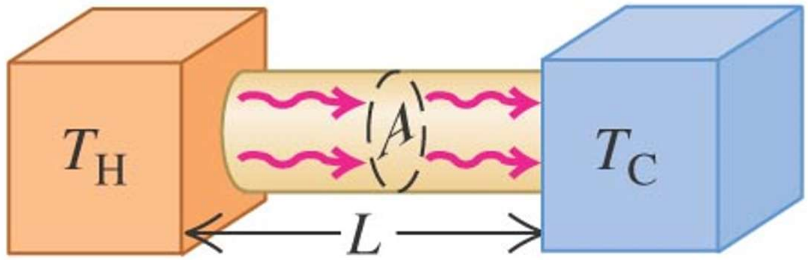
C) Object A will reach equilibrium slower and end up at a higher temperature.

D) Object A will reach equilibrium slower and end up at a lower temperature.

E) Both objects A and B will end up at the same temperature.


L-L-Last t-t-time in Phys 157...
0°C

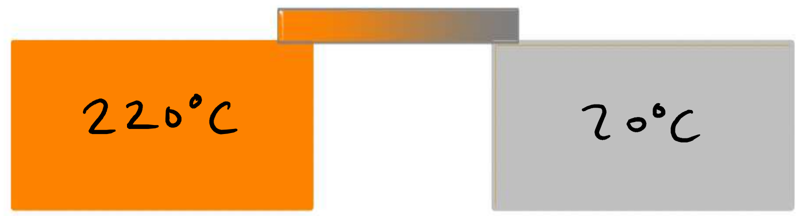
THERMAL CONDUCTIVITY: Determines heat current from temperature gradient.



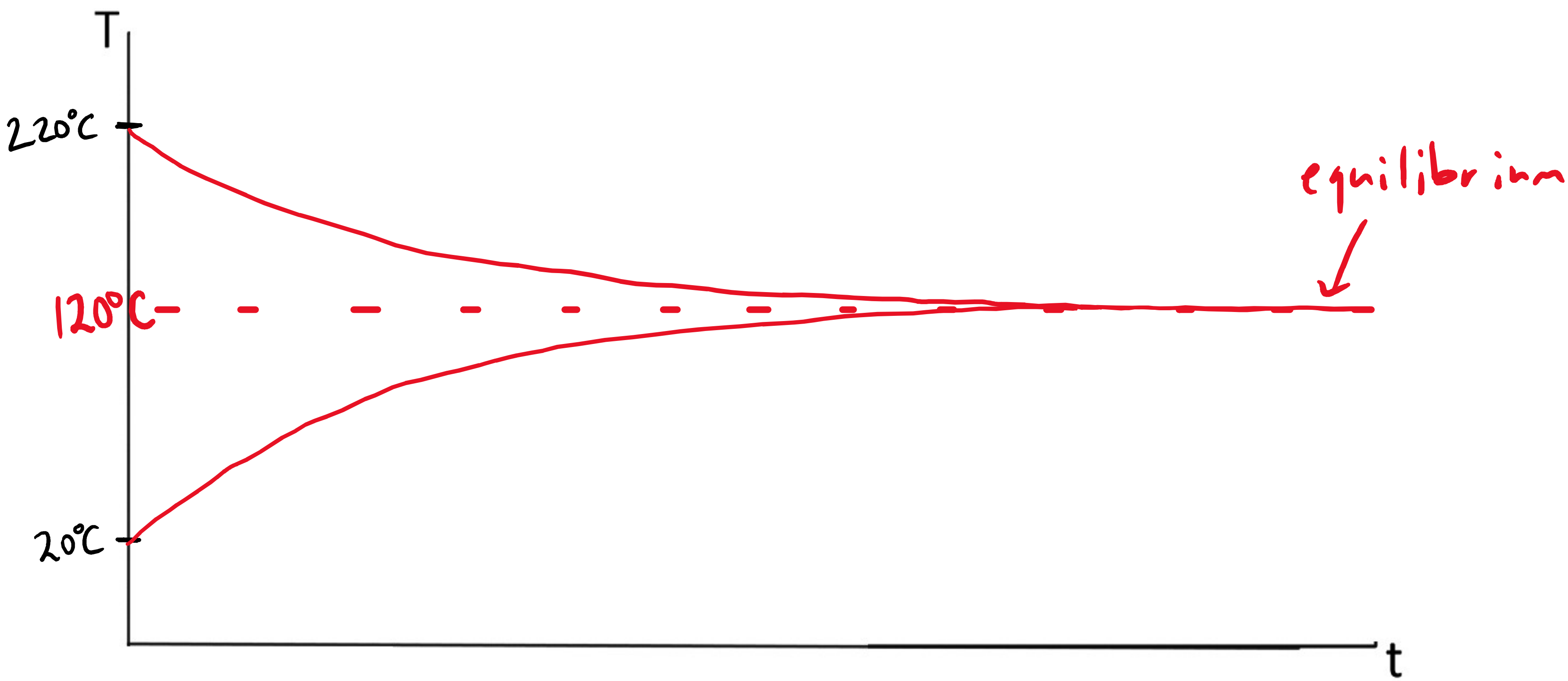
$$H = kA\underbrace{\frac{T_H - T_C}{L}}_{\text{temperature gradient}}$$

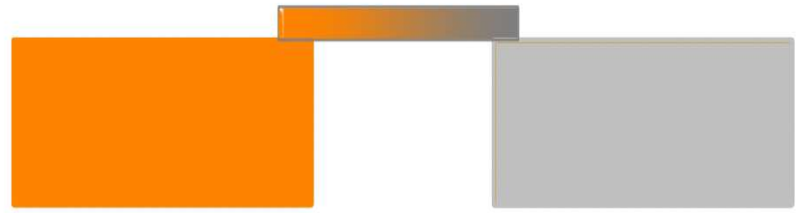
Heat current = Heat per time

Thermal conductivity

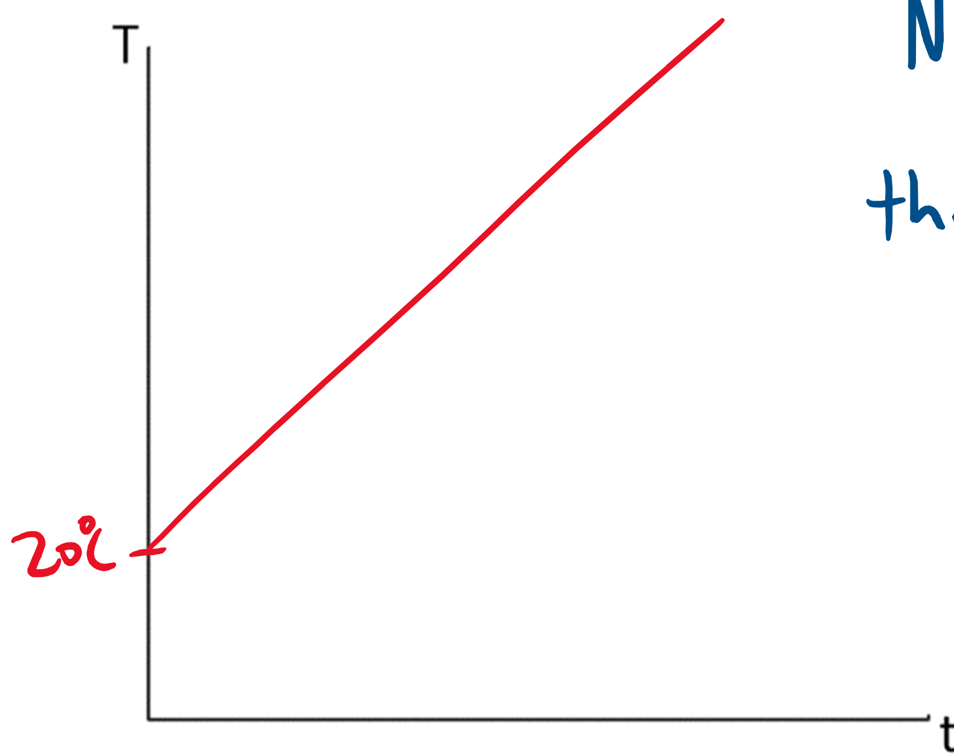


Sketch graphs (one for each block) showing how you expect the temperatures of the two blocks to behave as a function of time.





Sketch a graph of how the temperature behaves as a function of time at early times (remembering that the two blocks have already been connected for a while).

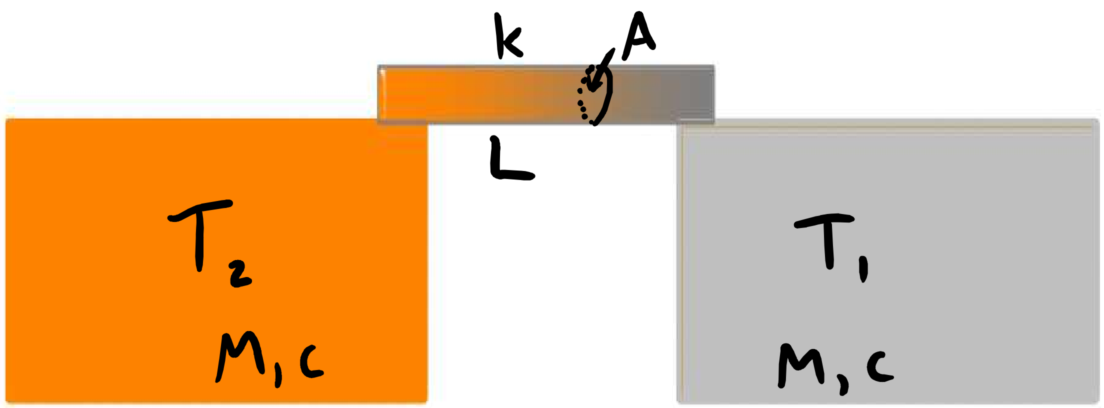


NEXT: what determines the slope here?

Goals for today:

- understand $T(t)$ quantitatively using conduction formula

- applications to thermal insulation



$$Q = Mc\,\Delta T$$

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

Worksheet #4: what is the change in temperature dT of the cooler block that occurs in a small time dt?

strategy: first consider the parts separately

$$\boxed{Q = Mc\Delta T}$$

A heat current **H** flows into the cooler block. In a time **dt**, what is the change **dT** in the temperature of this block (in terms of dt and the quantities shown)?

Hint: how much heat enters the block during this time?

Click A if you are done and complete question 4.
Click B if you and your neighbors are stuck.

EXTRA: If we define $\Delta = T_2 - T_1$, can you find what $d\Delta/dt$ is is in terms of Δ, k, A, c, L, and M?

$$\boxed{Q = Mc\,\Delta T}$$

A heat current **H** flows into the cooler block. In a time **dt**, what is the change **dT** in the temperature of this block (in terms of dt and the quantities shown)?

Hint: how much heat enters the block during this time?

In time dt, heat added is $Q = H dt$.

time

Heat per time

$$\boxed{Q = Mc\,\Delta T}$$

A heat current **H** flows into the cooler block. In a time **dt**, what is the change **dT** in the temperature of this block (in terms of dt and the quantities shown)?

Hint: how much heat enters the block during this time?

In time dt, heat added is $Q = H\,dt$.

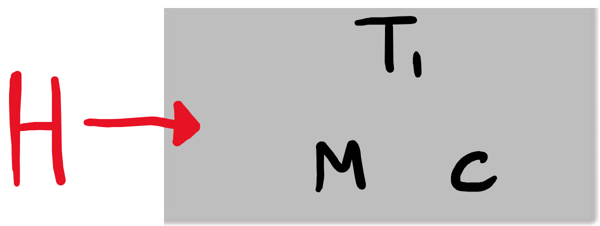
We have $dT = \dfrac{Q}{Mc}$.   So: $dT = \dfrac{H}{Mc}\,dt$

What is the change in temperature dT of the cooler block that occurs in a small time dt?

$$\boxed{Q = Mc\,\Delta T}$$

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

Cool block:



$$dT = \frac{H}{Mc} \cdot dt$$

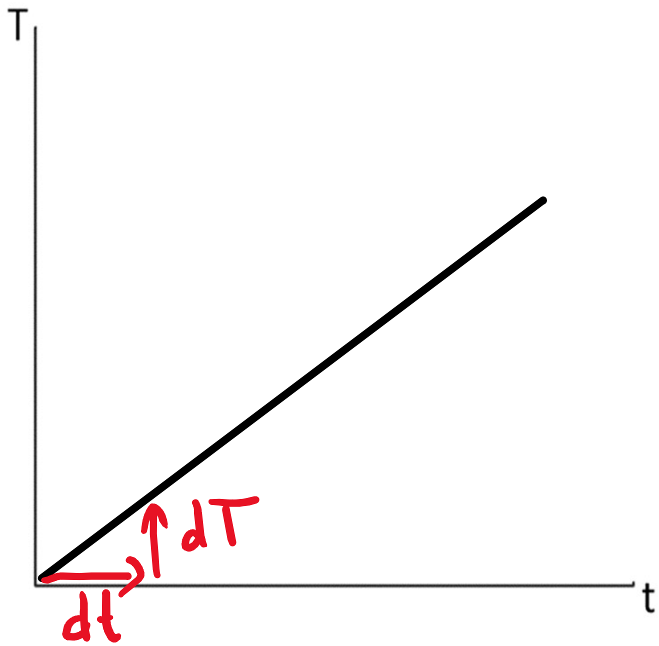
Strip:

$$H = k \cdot A \cdot \frac{T_2 - T_1}{L}$$

(all Hs same by energy conservation)

Combine:

$$dT = \frac{kA}{McL} \cdot (T_2 - T_1) \cdot dt$$

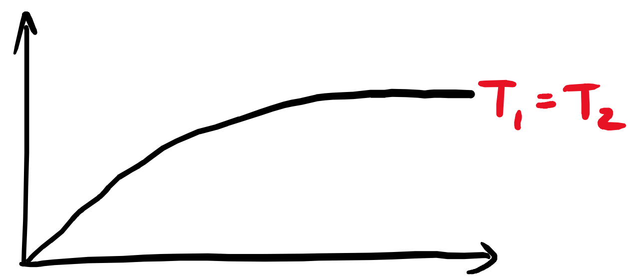


Slope is $\frac{dT}{dt}$

From previous slide:

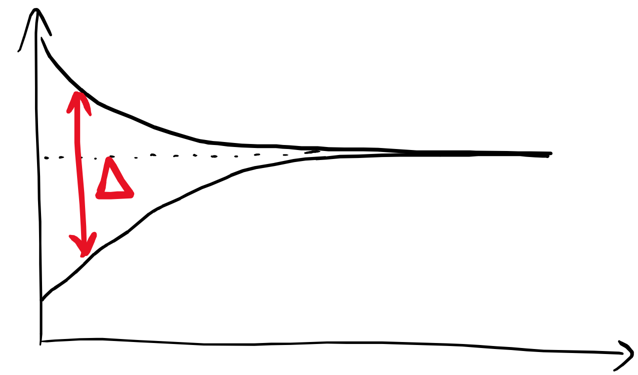
$$\frac{dT}{dt} = \frac{kA}{McL}(T_2 - T_1)$$

- decreases as T_2 gets closer to T_1 :



Extra part:

$\Delta = T_2 - T_1$ decreases twice as fast as T_1 increases:

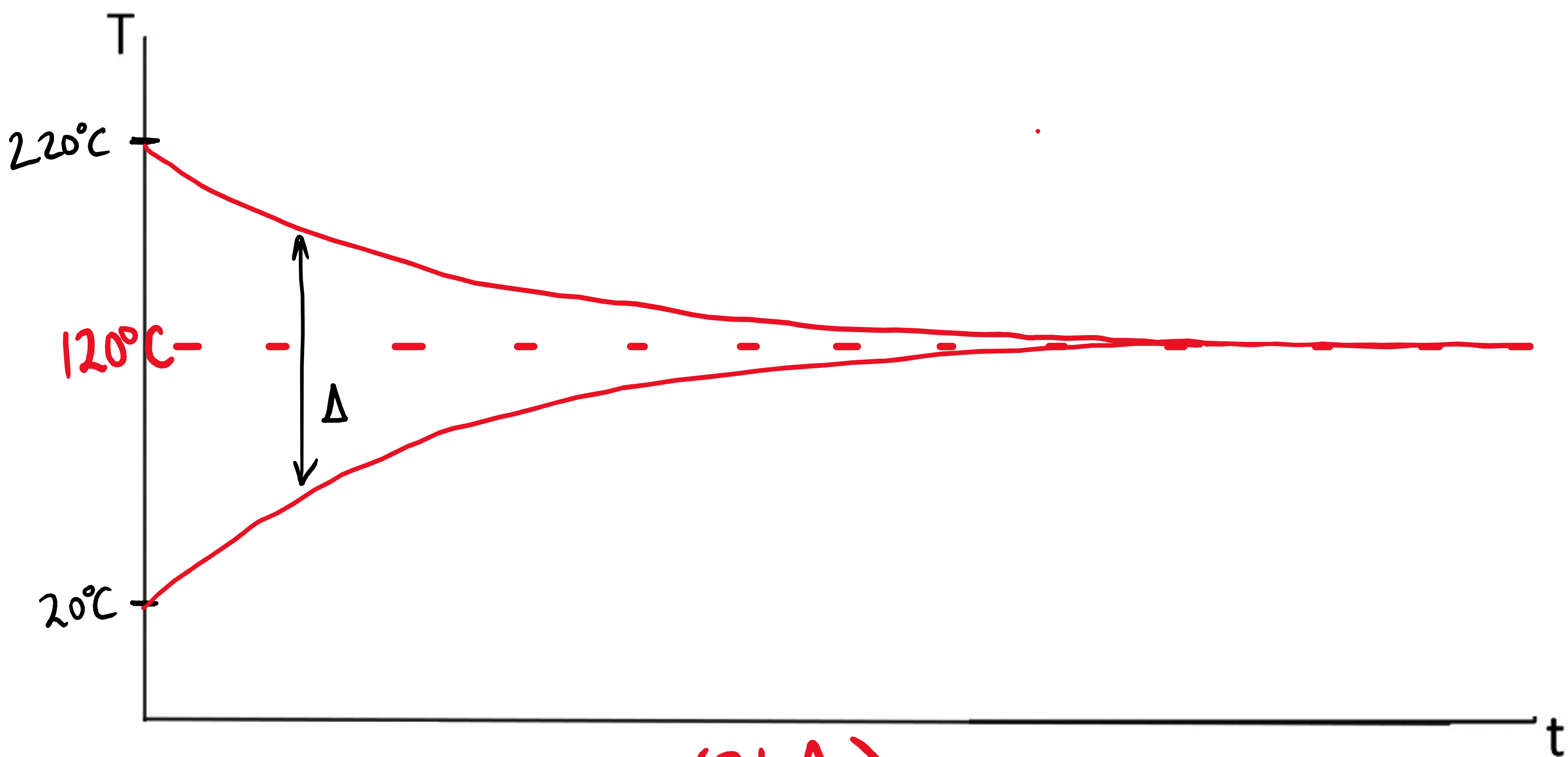


$$\frac{d\Delta}{dt} = -\frac{2kA}{McL} \cdot \Delta$$

Rate of decrease of Δ is proportional to Δ.

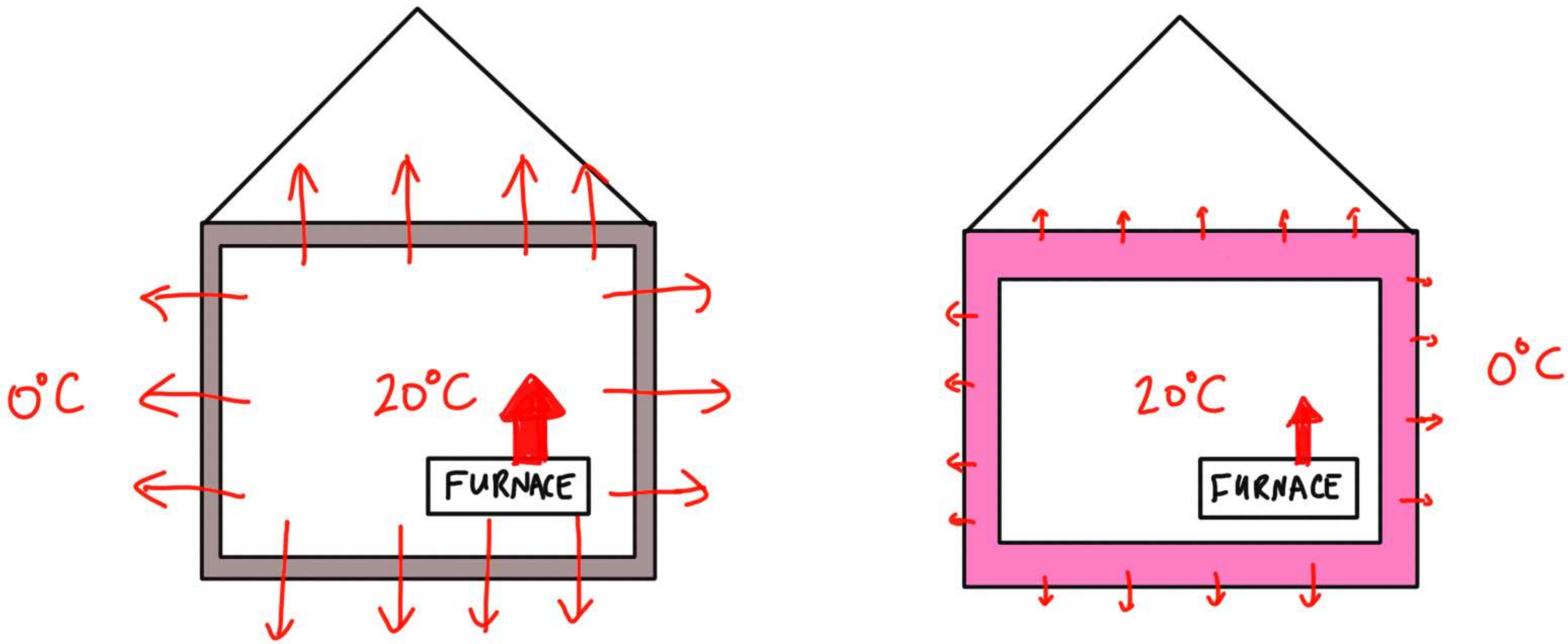
Math: this means $\Delta(t)$ is an EXPONENTIAL

$$\Delta(t) = \Delta_{t=0} \cdot e^{-\frac{2kA}{McL} \cdot t}$$



$$\Delta(t) = 200° \times e^{-\left(\frac{2kA}{McL}\right)t}$$

Application: insulation

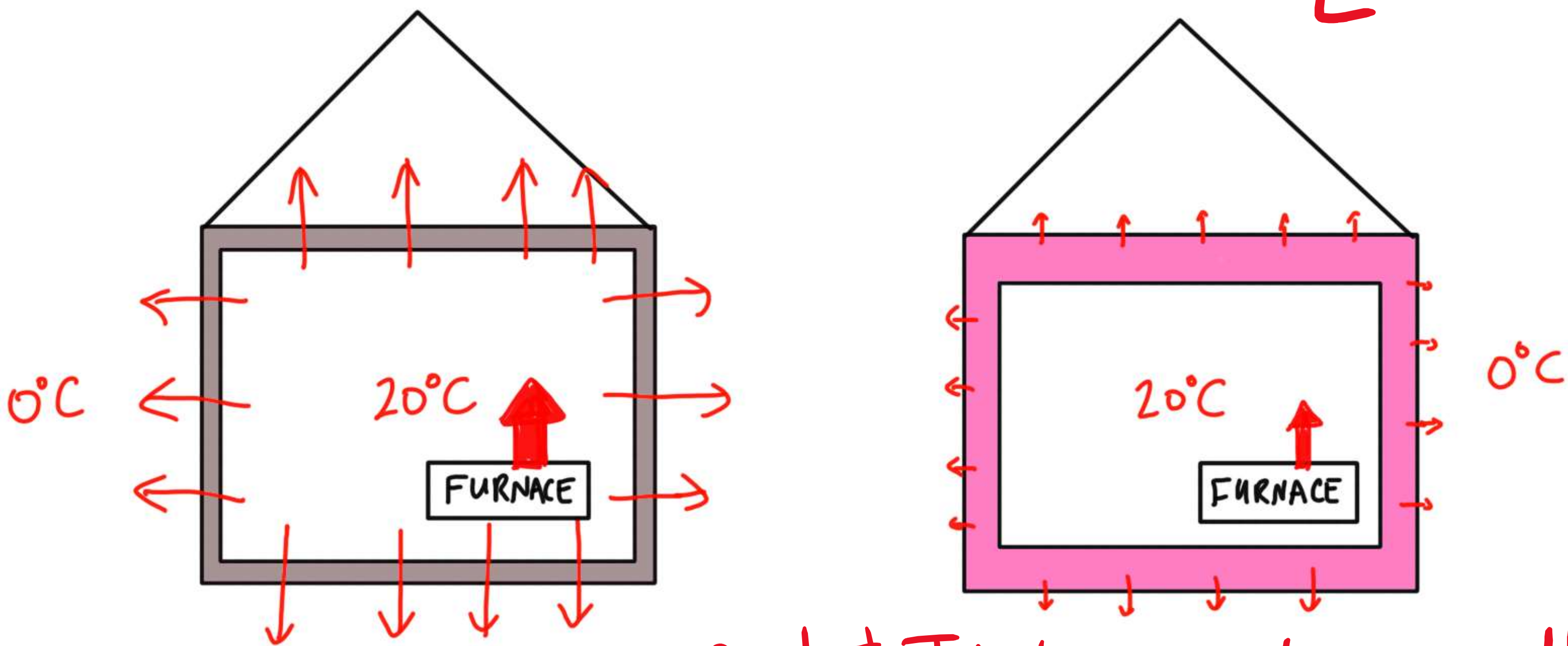


The second house has insulation that is twice as thick and made with a material that has half the thermal conductivity. To maintain the same inside temperature, the amount of fuel needed to be burned by the furnace in the second house is:

A) The same B) 1/2 as much C) 1/4 as much D) 1/8 as much E) 1/16 as much

Application: insulation

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



Constant T in house $\Rightarrow H_{furnace} = H_{through\ walls}$

The second house has insulation that is twice as thick and made with a material that has half the thermal conductivity. To maintain the same inside temperature, the amount of fuel needed to be burned by the furnace in the second house is:

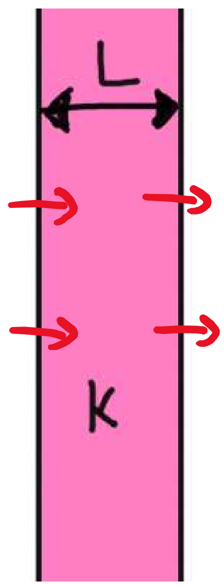
L is double

k is half

A) The same B) 1/2 as much C) 1/4 as much D) 1/8 as much E) 1/16 as much

$\therefore H$ is $\frac{1}{4}$

THERMAL RESISTANCE: measures effectiveness of insulation layer



thickness

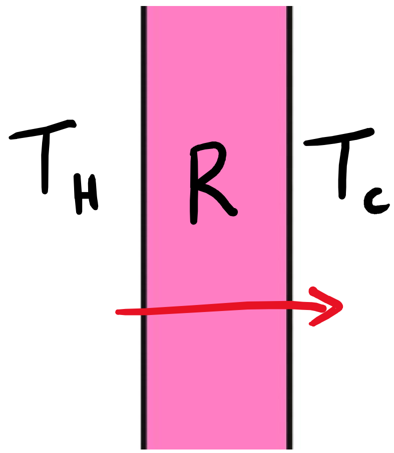
$$R = \frac{L}{k}$$

thermal conductivity

"R-value" is this quantity in units of

$$ft^2 \cdot F^\circ \cdot \frac{\text{hours}}{\text{Btu}}$$

Larger is better

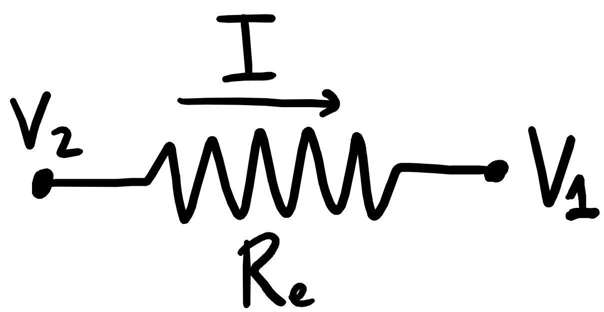


$$\frac{H}{A} = \frac{T_H - T_c}{R}$$

heat current per area

thermal resistance $\frac{L}{k}$

Analogy with electrical resistance + Ohm's Law:



$$I = \frac{V_2 - V_1}{R_e}$$

current

electrical resistance

Material	R value($ft^2 \cdot °F \cdot hr/BTU$)
Hardwood siding (1 in. thick)	0.91
Wood shingles (lapped)	0.87
Brick (4 in. thick)	4
Concrete block (filled cores)	1.93
Fiberglass batting(3.5 in. thick)	10.9
Fiberglass batting(6 in. thick)	18.8
Fiberglass board (1 in. thick)	4.35
Cellulose fiber(1 in. thick)	3.7
Flat glass (0.125 in thick)	0.89
Insulating glass(0.25 in space)	1.54
Air space (3.5 in. thick)	1.01
Free stagnant air layer	0.17
Drywall (0.5 in. thick)	0.45
Sheathing (0.5 in. thick)	1.32

Multiple layers:
add R values
(like resistors
in series)