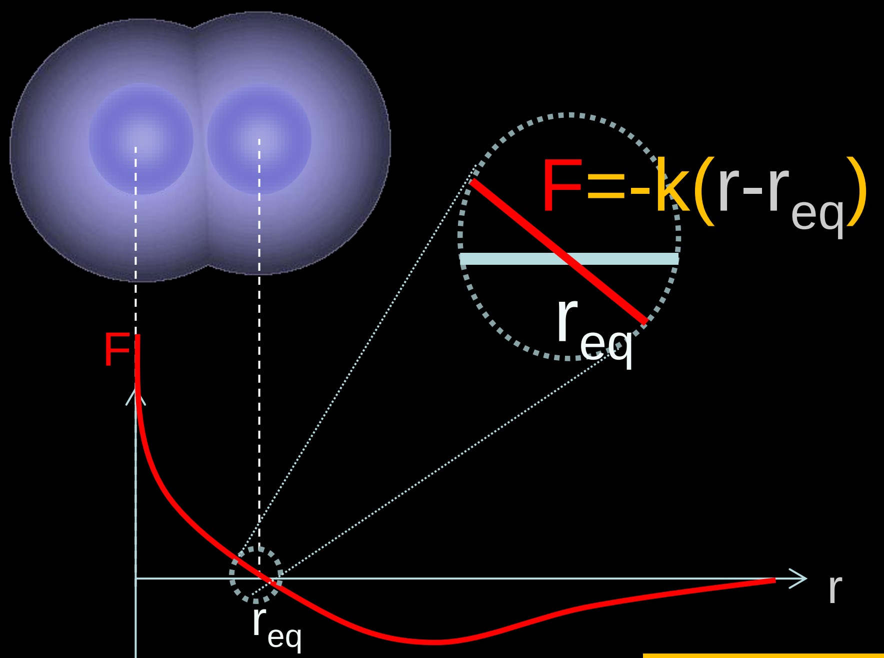
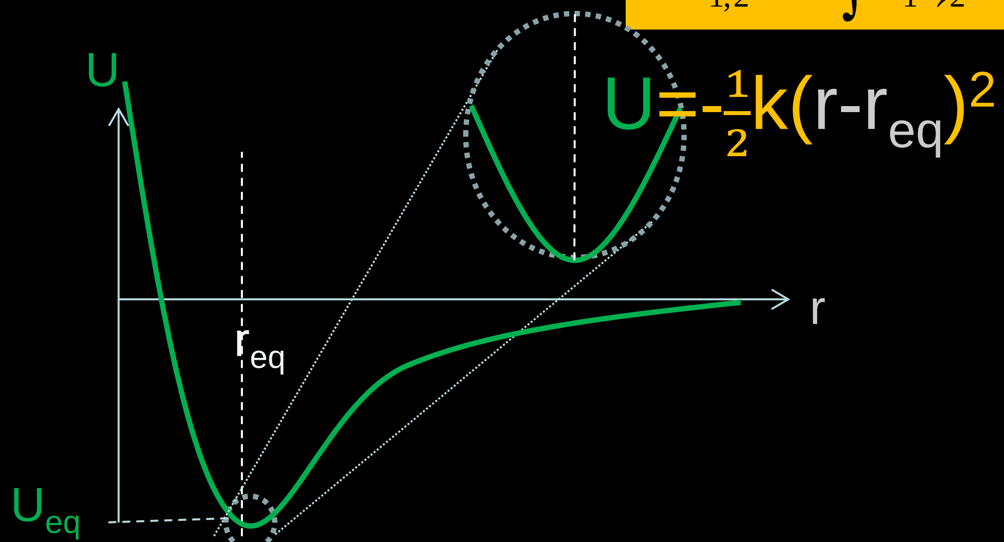
Fri.	7.5-.9 Energy Transfer	RE 7.b
Mon.	7.10-.12 Energy Dissipation & Resonance	RE 7.c
Tues.	Math/Phys Research Pres – 6pm	EP7, HW7: Ch 7 Pr's 31, 32, 45, 62 & CP

Ball-Spring Model

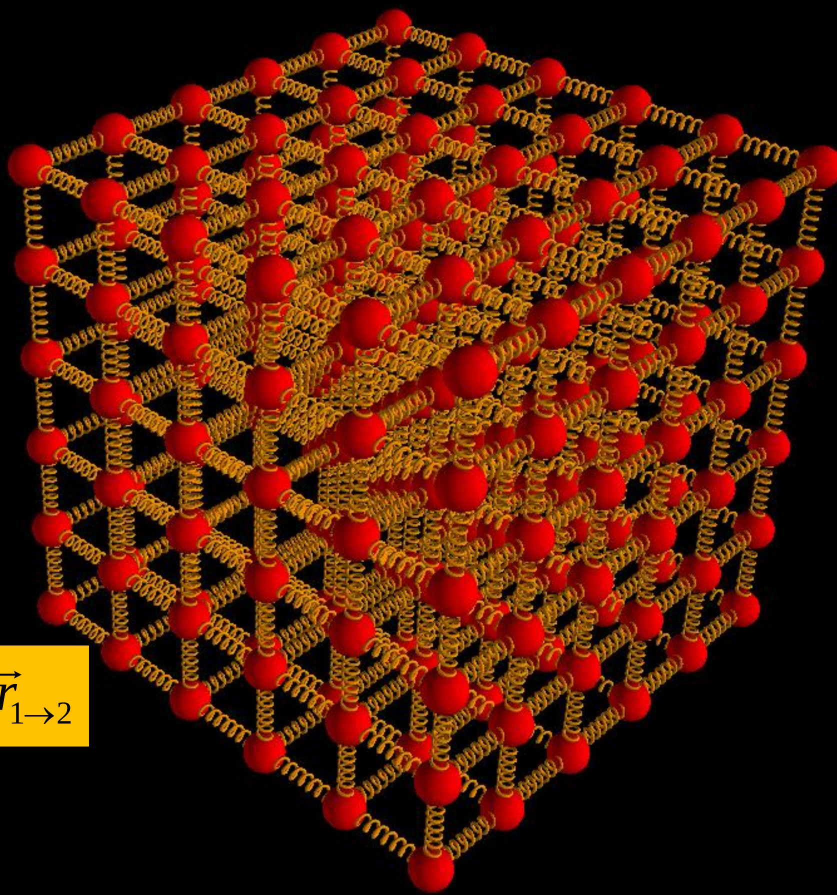
Molecule

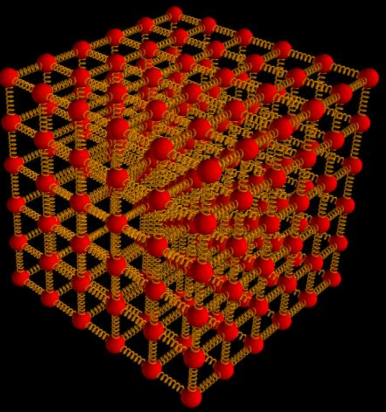


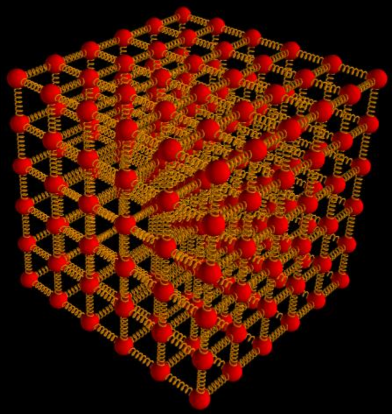
$$\Delta U_{1,2} = -\int \vec{F}_{1\to 2} \cdot d\vec{r}_{1\to 2}$$



Solid





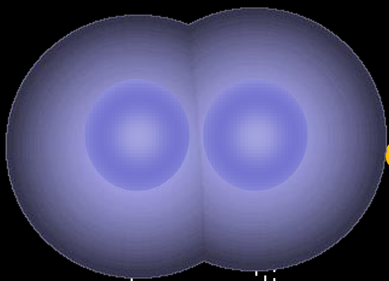


Two lead bricks moving in the +x and –x directions, each with kinetic energy K, smash into each other and come to a stop. What happened to the energy?

1) The observable kinetic energy changed to thermal energy, a form of rest energy.
2) The total energy of the system decreased by an amount $2K$.
3) Since the blocks were moving in opposite directions, the initial kinetic energy of the system was zero, so there was no change in energy.

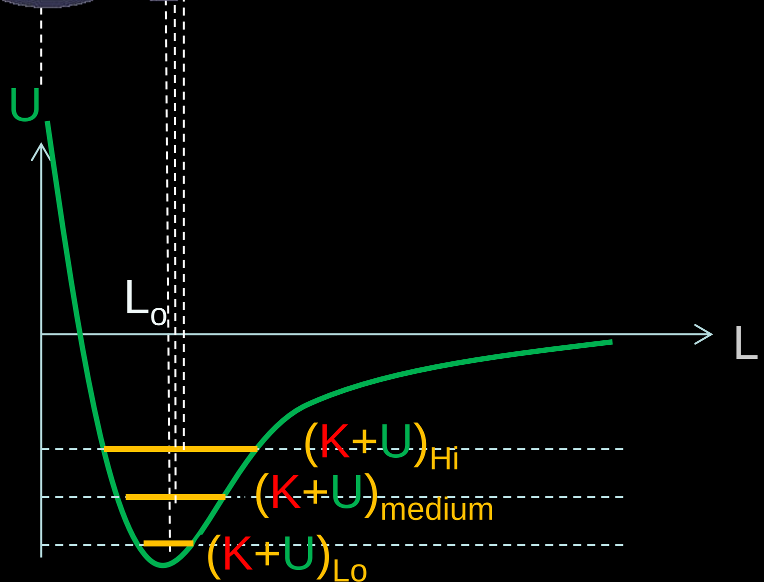
Ball-Spring Model

Molecule

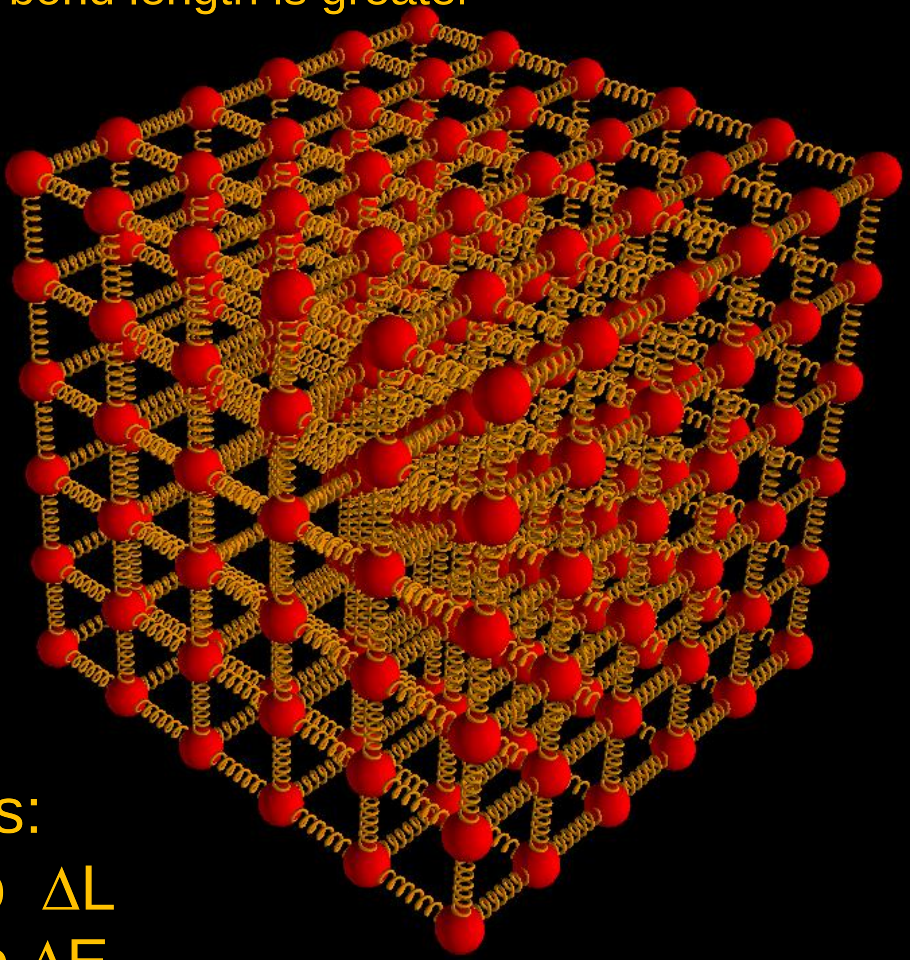


Thermal Expansion

or higher energies, average bond length is greater



ΔL proportional to ΔE



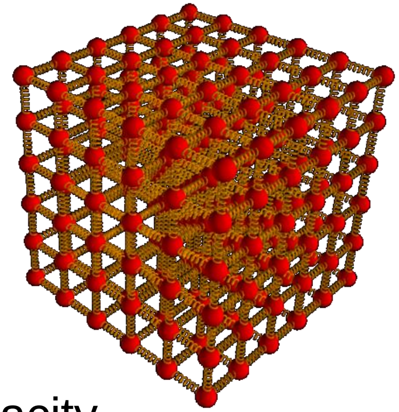
Thermomenters:

ΔT proportional to ΔL

ΔL proportional to ΔE

ΔT proportional to ΔE

Heat Capacity



ΔT proportional to ΔE_{int}

$$\Delta E_{\text{int}} = C\Delta T$$

C = Heat capacity

C should be material specific and scale with amount of material

$$C = c_v m$$

c_v = (mass) specific Heat capacity

$$\Delta E_{\text{int}} = c_v m \Delta T$$

Warning: 3 common flavors of *c*

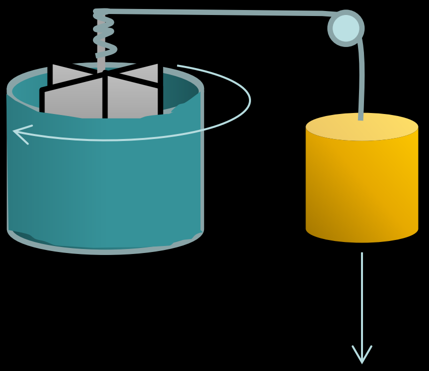
Mass-specific Heat capacity $$\Delta E_{\text{int}} = c_v m \Delta T$$

Particle-specific Heat capacity $$\Delta E_{\text{int}} = c_v N \Delta T$$

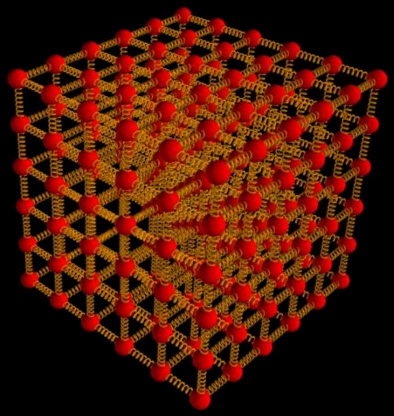
Mole-specific Heat capacity $$\Delta E_{\text{int}} = c_v n \Delta T$$

What *is* Temperature?

Say you do the historic falling-weight / paddle-wheel in bucket experiment. The mass drops, the wheel spins, and the 10 kg's of water warm up. We find that the difference between the change in gravitational potential and change in kinetic energies is 40×10^3 J. A thermometer stuck in the water tells you that its temperature has risen $\Delta T=0.96$ Kelvin. What's the mass-specific heat capacity of water?



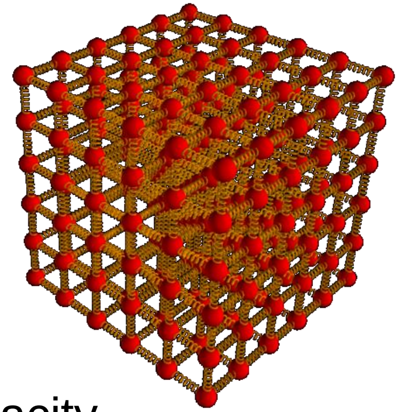
Heat Capacity



Calorimetery:

Imagine a compound system of 1 kg of water and 0.1 kg of aluminum. If the aluminum starts at room temperature (300 K) and the water starts at boiling (373 K), put them together and the water will cool and the metal will warm until they're at the same temperature, in this case, 366 K. What's the mass-specific heat of aluminum?

Heat Capacity



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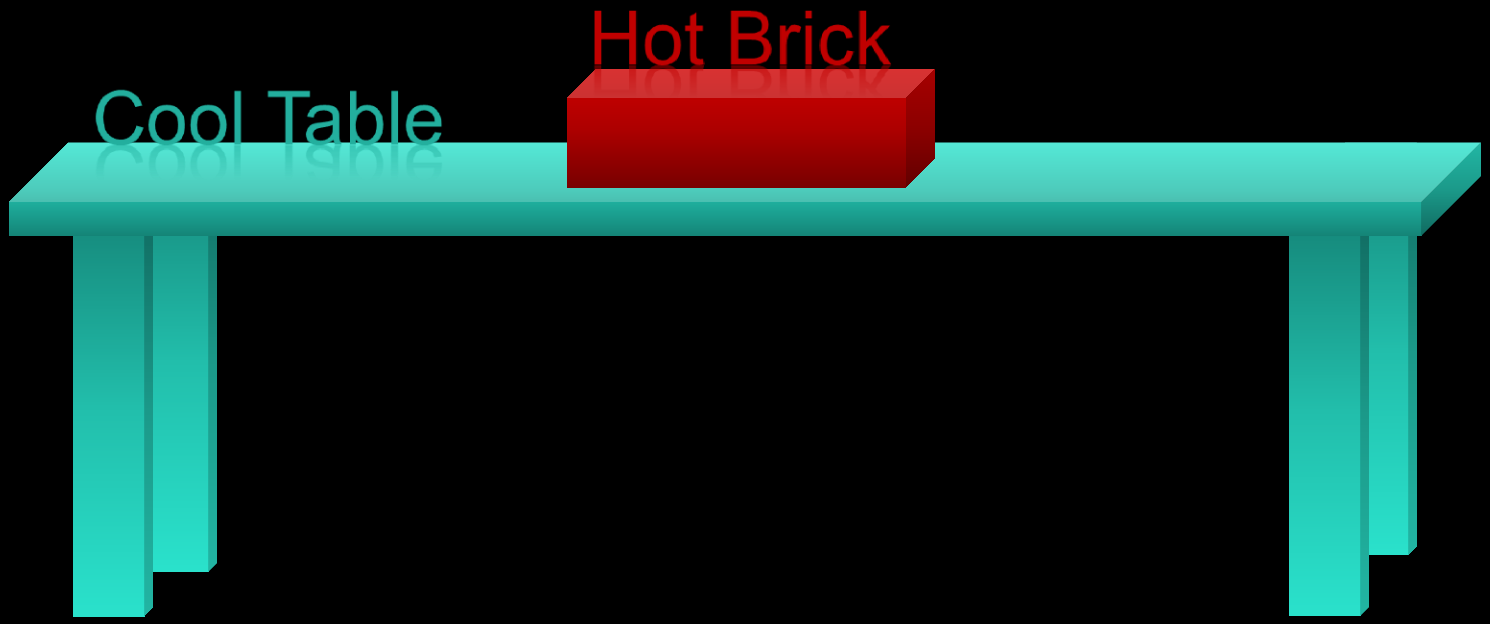
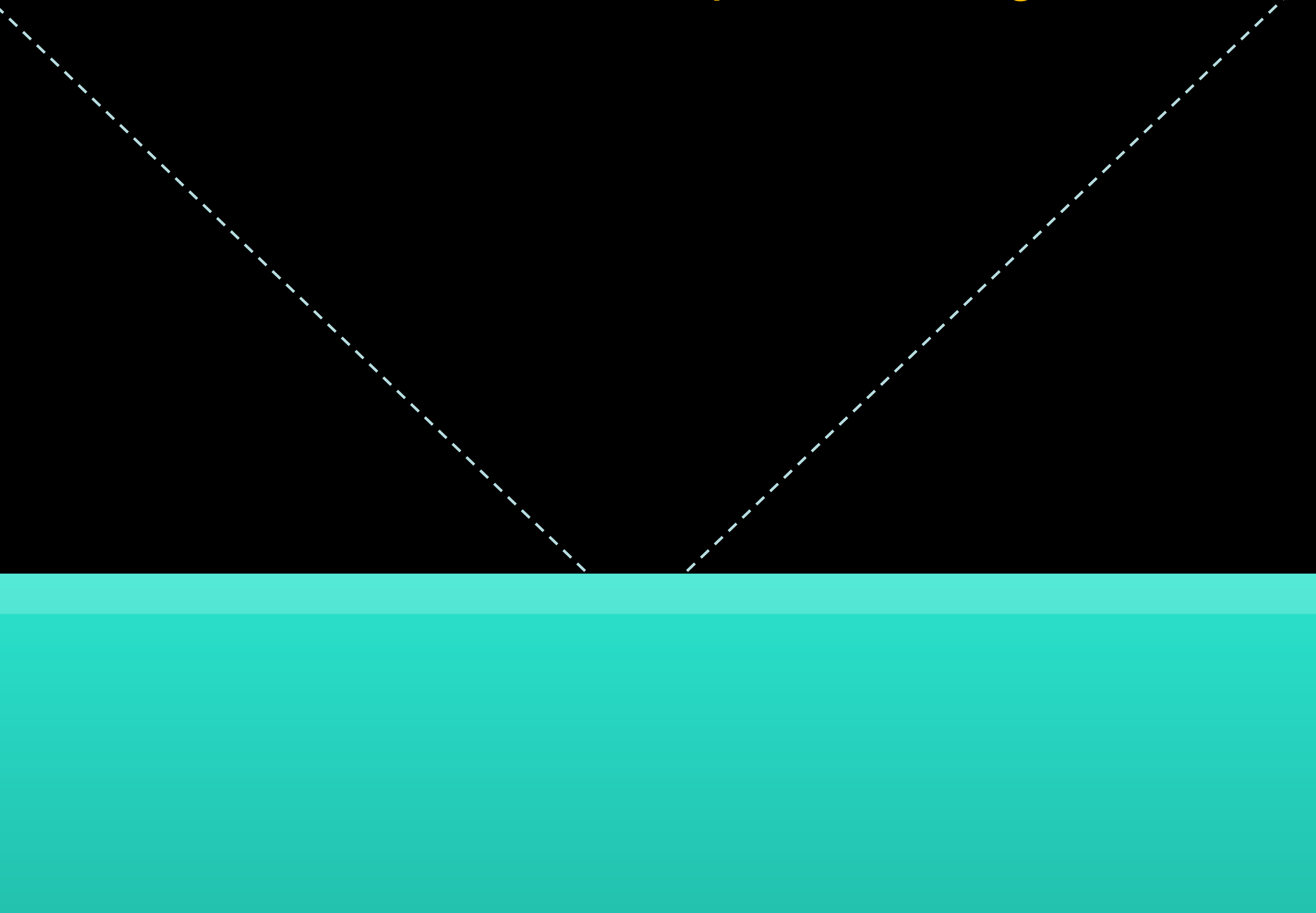
$$\Delta E_{\text{int}} = c_v m \Delta T$$

The thermal energy of the 1000 grams of water increased 7000 J. What was the temperature increase in Kelvins of the water? The heat capacity of water is c_v = 4.2 J/K on a per-gram basis.	1) 0.0006 K 2) 0.6 K 3) 1.7 K 4) 1667 K 5) Insufficient information

Thermal Microscopic Work: “Heating”



Thermal Microscopic: “Heating”



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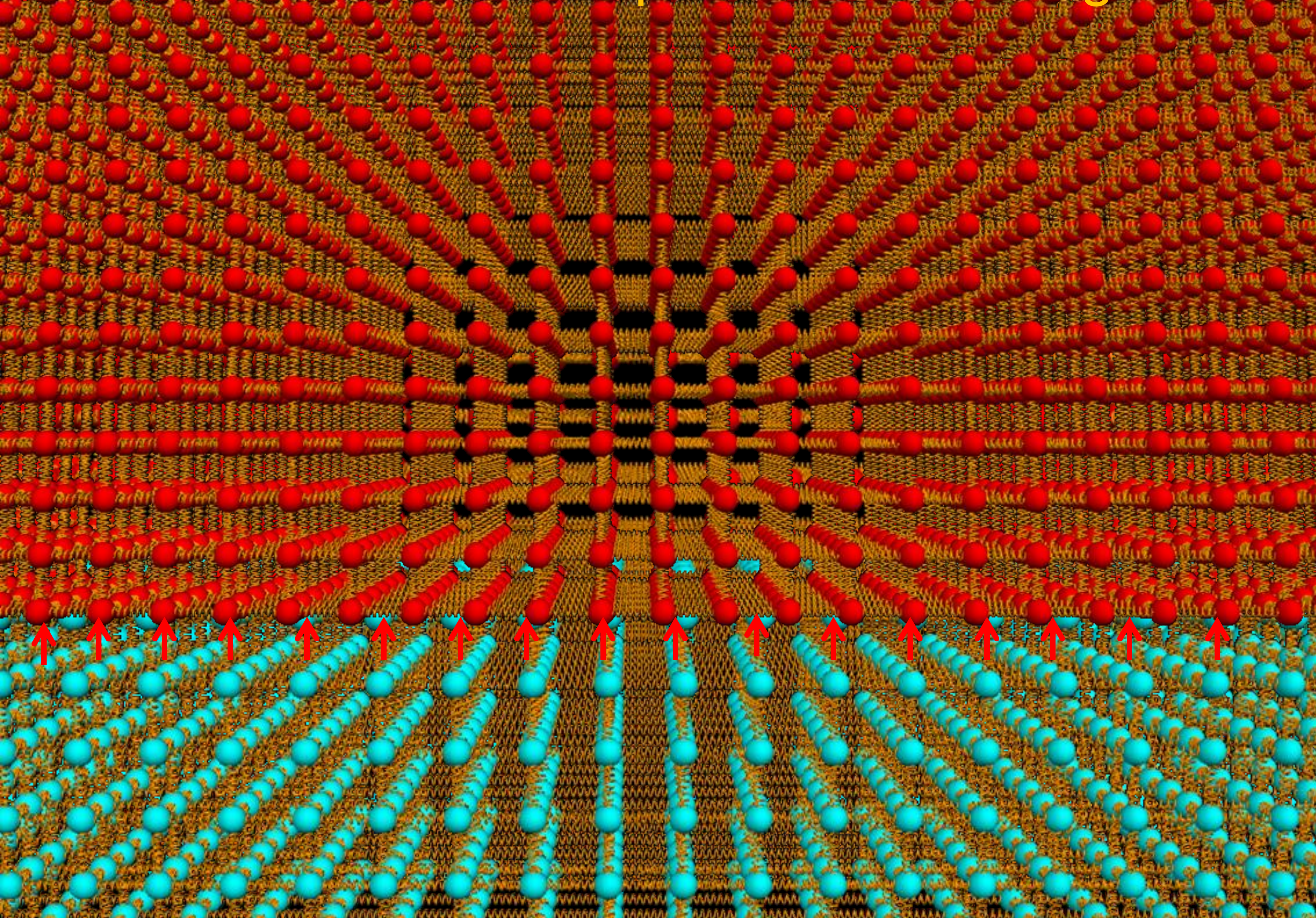


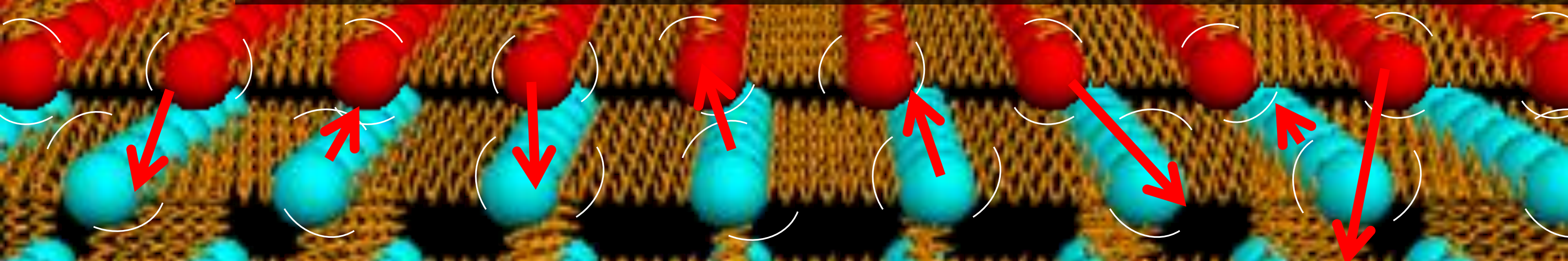
Thermal Microscopic Work: "Heating"

All atoms jiggle

Average atom in Hot brick jiggles more violently than average atom in cold table

At interface, more-energetic atoms in hot brick tend to do more positive work on less-energetic atoms in cold table

Net energy transfer is *from* hot brick *to* cold table



$$Q_{t\leftarrow b} \equiv \sum_{\substack{\text{brick atoms} \\ \text{on table atoms}}} W$$

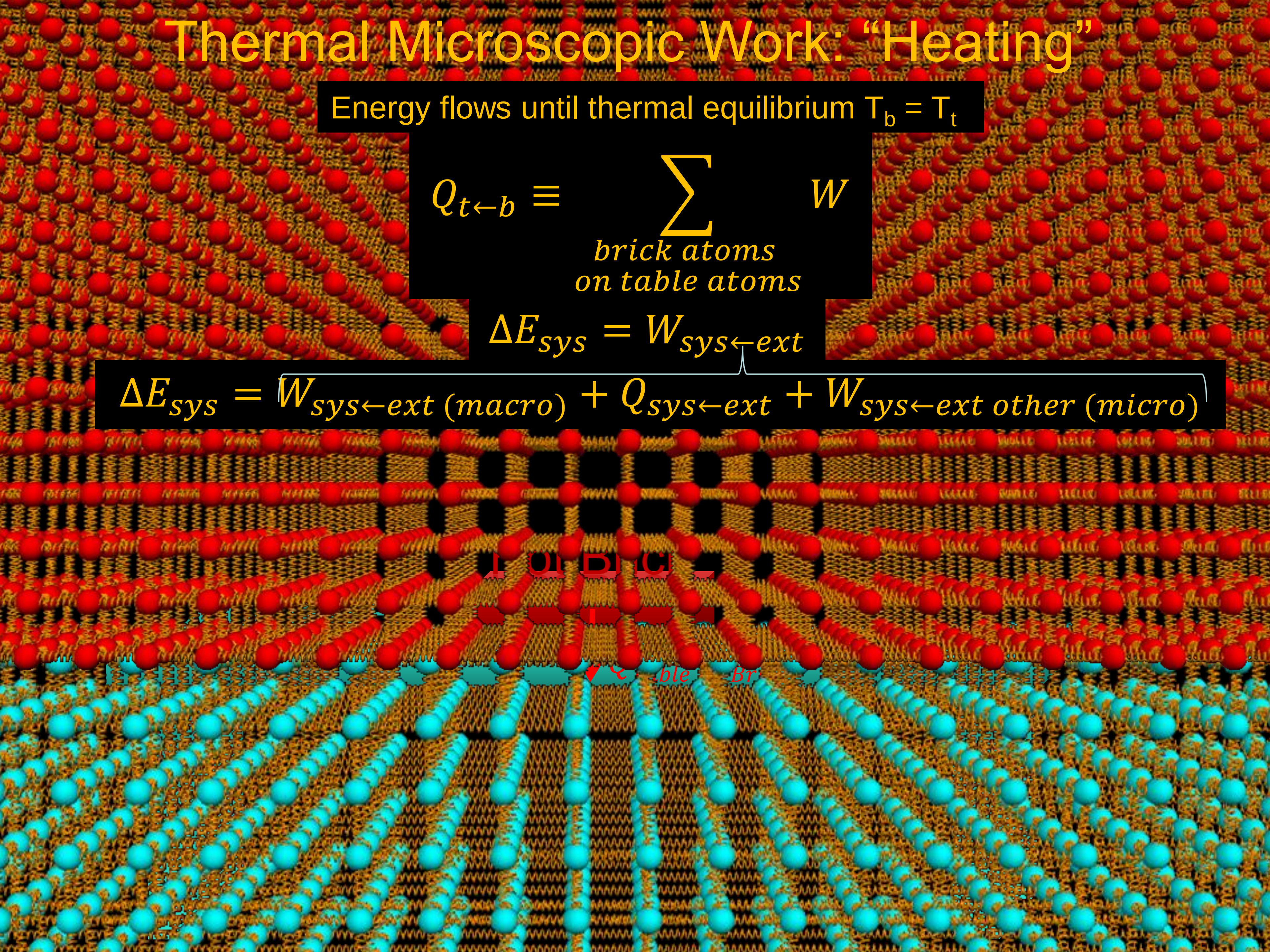
Thermal Microscopic Work: "Heating"

Energy flows until thermal equilibrium $T_b = T_t$

$$Q_{t\leftarrow b} \equiv \sum_{\substack{brick\ atoms\\ on\ table\ atoms}} W$$

$$\Delta E_{sys} = W_{sys\leftarrow ext}$$

$$\Delta E_{sys} = \overbrace{W_{sys\leftarrow ext\ (macro)} + Q_{sys\leftarrow ext} + W_{sys\leftarrow ext\ other\ (micro)}}$$



Working & Heating. You have a pot containing 1.0 kg of water over a fire, and you are also stirring the water with a ladle. Take the water as the system. Because the fire is at a higher temperature than the water, there is microscopic work $Q_{fire\text{->}water}$ = 5000 J on the water due to the fire. At the same time, there is external work $W_{you\text{->}water}$ = 2000 J done by you.

- What is the increase in the internal energy of the water?
- What was the temperature increase in Kelvins of the water? The mass-specific heat capacity of water is c_v = 4200 J/(kg K).

Which of the following statements is correct?

1) Q and $\Delta E_{\text{internal}}$ are the same thing.
2) Q and $\Delta E_{\text{internal}}$ are not the same thing, but they are always equal.
3) $\Delta E_{\text{internal}}$ can be nonzero even if Q is zero.
4) Q and $\Delta E_{\text{internal}}$ are both always positive.

Misc.

"Thermal" Energy

Feeling hot or cold

Power

Choosing Systems: Open and Closed

Q7.8.b. A horse of mass *M* gallops with constant speed *v* up a long hill of height *h* and horizontal extent *d*. Choose the horse as the system to analyze. Start from the energy principle,

$$\Delta E_{sys} = W_{sys \leftarrow ext\ (macro)} + Q_{sys \leftarrow ext} + W_{sys \leftarrow ext\ other\ (micro)}$$

First, work on *right side* of equation.
What objects in the surroundings exert forces on our chosen system, the horse?

1) Earth (gravitational)
2) Earth (gravitational) and ground (electric; interatomic)
3) Earth (gravitational), ground (electric; interatomic), and air (electric; air resistance)
4) Earth (gravitational), ground (electric; interatomic), air (electric; air resistance), and horse's hooves (electric; interatomic)

The horse's hooves don't slip on the rocky ground, so the work done by the ground on the horse is

1) *W* > 0 because the force points upward
2) *W* > 0 because work is a positive quantity
3) *W* = 0 because there is no displacement of the force
4) *W* < 0 because the hooves move downward
5) *W* < 0 because the hill doesn't speed up the horse

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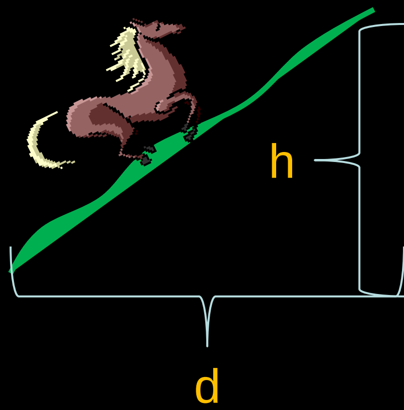


1) $W > 0$ because the force points upward
2) $W > 0$ because work is a positive quantity
3) $W = 0$ because there is no displacement of the force
4) $W < 0$ because the hooves move downward
5) $W < 0$ because the hill doesn't speed up the horse

The displacement of the horse is $< d, h, 0 >$, and the force of the Earth on the horse is $< 0, -Mg, 0 >$. The work done by the Earth on the horse is $W_{h<-E} = -Mgh$.

The term "Q" in the energy principle,

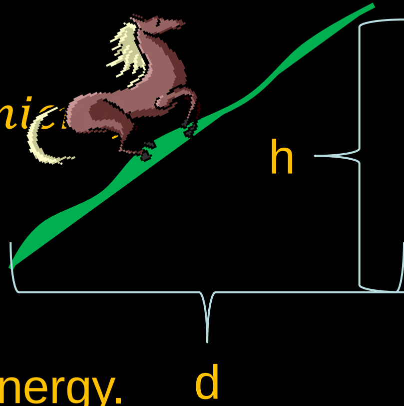
$$\Delta E_{sys} = W_{sys\leftarrow ext\ (macro)} + Q_{sys\leftarrow ext} + W_{sys\leftarrow ext\ other\ (micro)}$$

is microscopic work done on the system due to a temperature difference between the system and the surroundings. When the horse started running, its temperature quickly rose, and its temperature is quite a bit higher than the surroundings. Which of the following is true?

1) $Q < 0$ because there is energy transfer from the horse to the surrounding air
2) $Q = 0$ because air is a thermal insulator
3) $Q > 0$ because the horse is hotter than the surrounding air

We now know a lot about the right side of

$$\Delta E_{sys} = W_{sys \leftarrow ext\ (macro)} + Q_{sys \leftarrow ext} + W_{sys \leftarrow ext\ other\ (mic}$$



= 0 - Mgh - $|Q_{horse\text{->}air}|$

(due to ground) (due to Earth) + (from horse to air)

Next let's look at the *left side*. It has internal / rest energy and kinetic energy.

$$\Delta E_{sys} = \Delta E_{int} + \Delta K$$

The internal energy can change with increasing thermal motion and breaking / making of chemical bonds.

$$\Delta E_{sys} = \Delta E_{thermal} + \Delta E_{chemical} + \Delta K$$

Which of the following energy terms change during the run at constant speed and constant body temperature (constant because there is energy transfer |*Q*| to the surrounding air)?

1) only K

2) only $E_{thermal}$

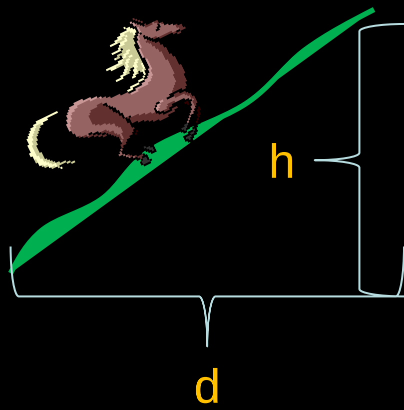
3) only $E_{chemical}$

4) K and $E_{thermal}$

5) K and $E_{chemical}$

6) K and $E_{thermal}$ + $E_{chemical}$

7) $E_{thermal}$ and $E_{chemical}$



What is true about the change in $E_{chemical}$ inside the chosen system (the horse)?

1) $\Delta E_{chemical} > 0$ because the horse provides chemical energy to go up the hill
2) $\Delta E_{chemical} = 0$ because the horse's temperature doesn't change
3) $\Delta E_{chemical} < 0$ because the horse provides chemical energy to go up the hill

Put it all together for system = horse:

$$\Delta E_{chemical} = -Mgh - |Q|$$

The horse's store of chemical energy decreases. The energy principle relates this energy decrease to the energy transfers out of the system (negative work done by Earth, energy transfer from hot horse to cool air).

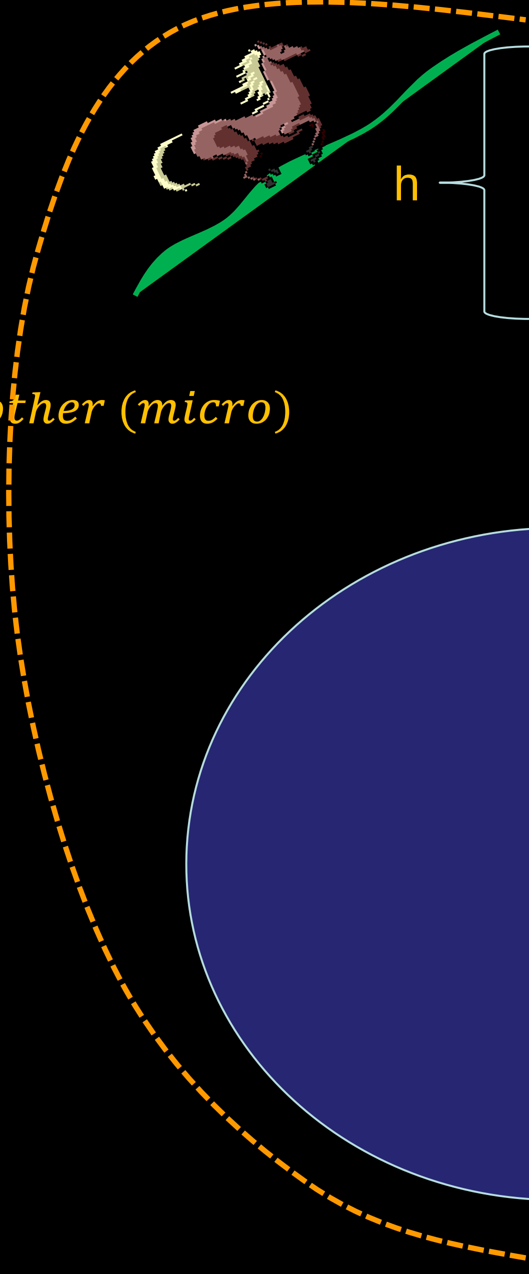
A horse of mass *M* gallops with constant speed *v* up a long hill of height *h* and horizontal extent *d*.

Choose the horse and Earth as the system to analyze.

Start from the energy principle,

$$\Delta E_{sys} = W_{sys\leftarrow ext\ (macro)} + Q_{sys\leftarrow ext} + W_{sys\leftarrow ext\ other\ (micro)}$$

What would be different in our analysis?



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