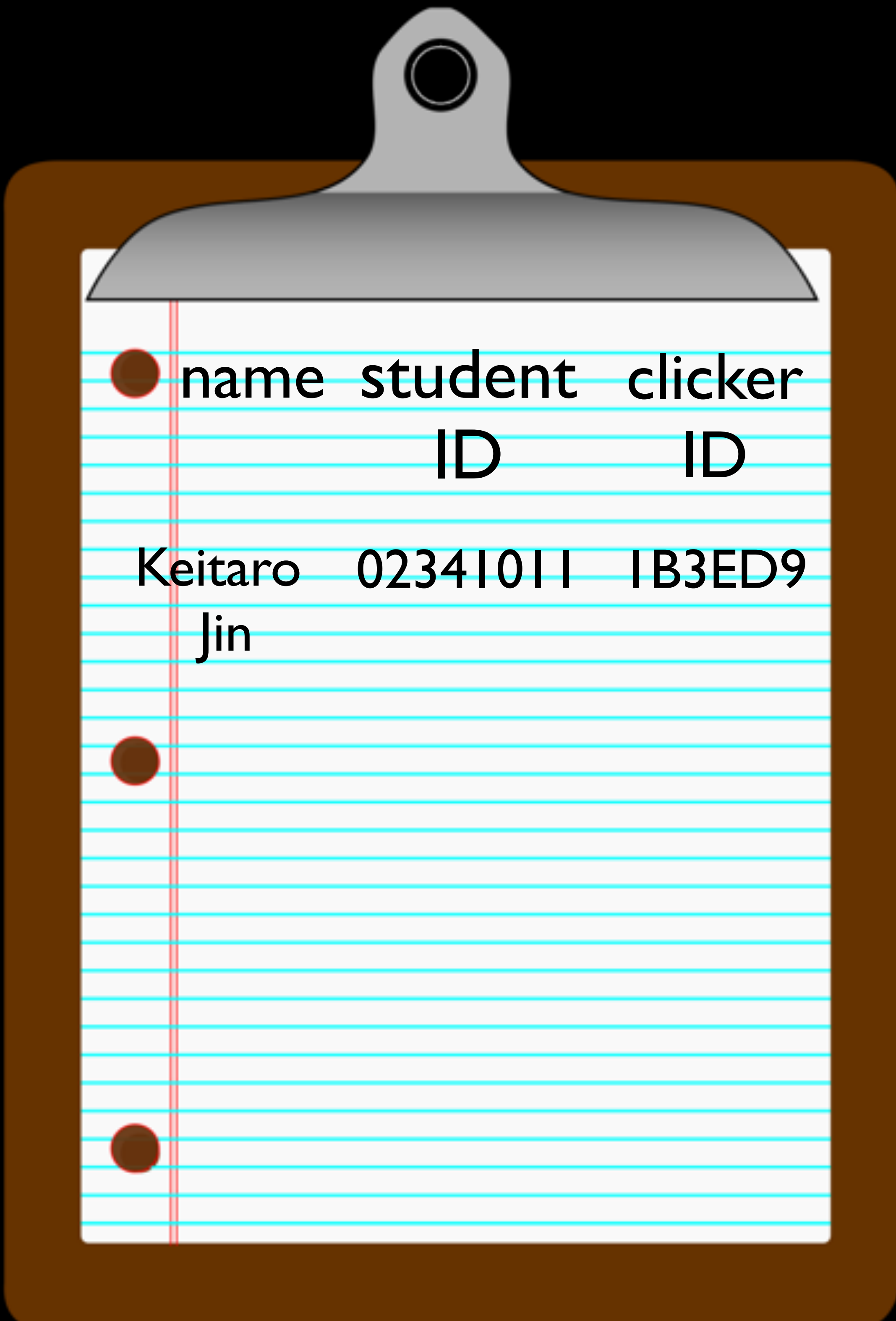
Essential Physics II

英語で物理学の

エッセンス II

Lecture 2:   5-10-15

Course



Remember your clicker number!

e.g. B12

(same every week)

News

Next lecture:

Thursday 2015 / 10 / 15

(１０月１５日木曜日)

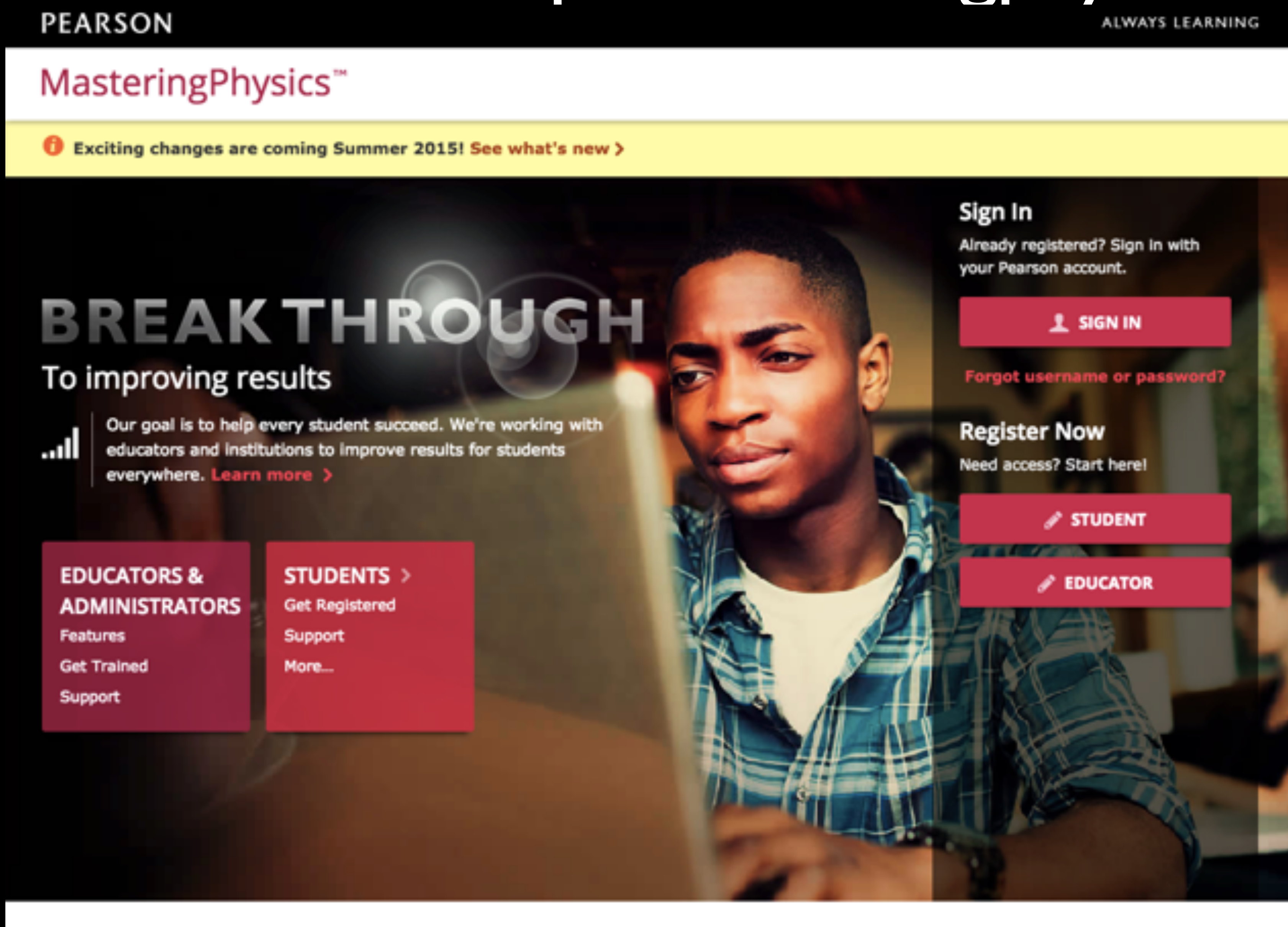
This week's homework:

Also due: 2015/ 10 / 15 (１０月１５日)

on http://masteringphysics.com

News

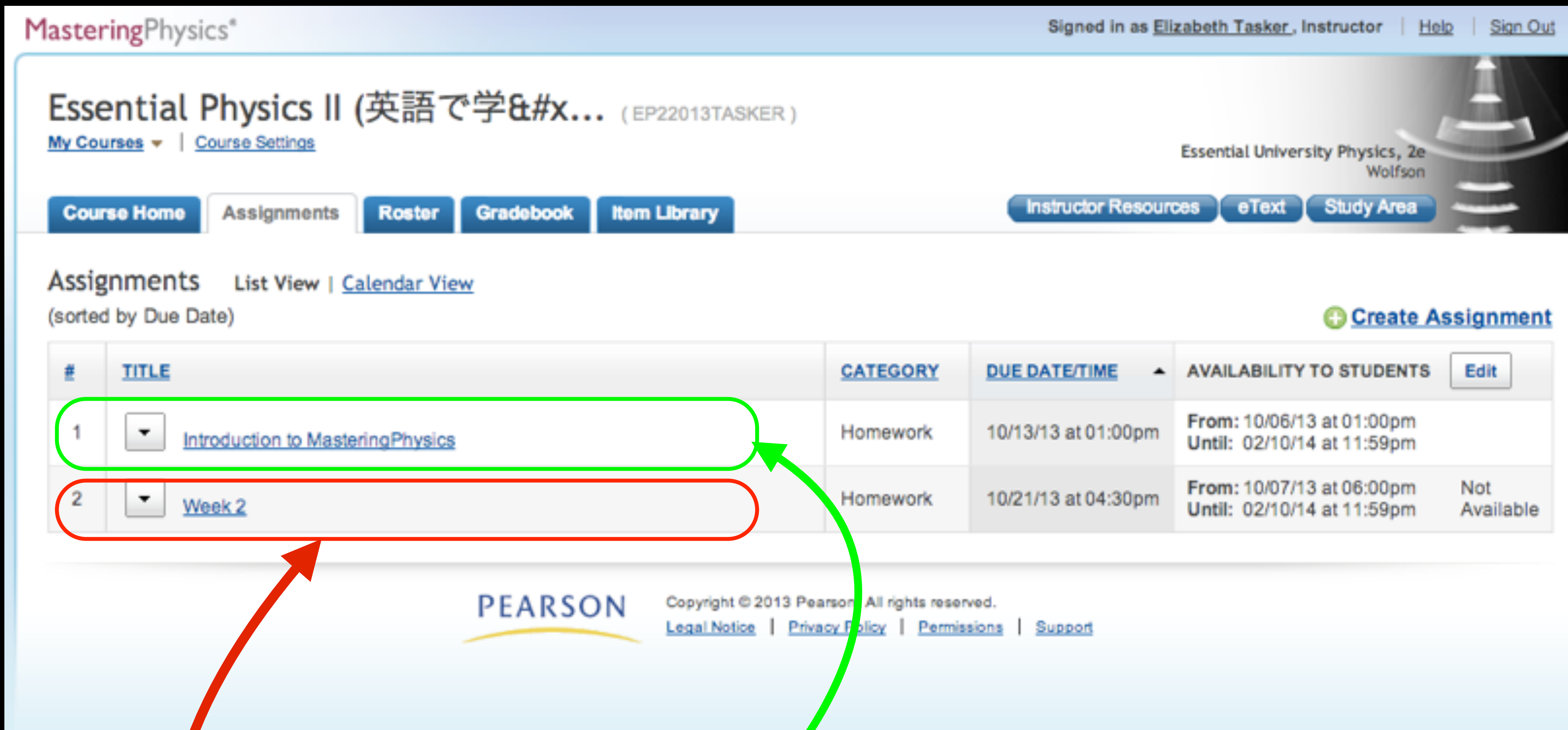
Homework: http://masteringphysics.com



Use your student access code (with textbook) to login

Join course EP22015TASKER

News



First time using MasteringPhysics?
Do this introduction

EVERYONE do this week's homework

News

MasteringPhysics: Week 2

session.masteringphysics.com/myct/assignment?assignmentID=2568858

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Week 2 Resources

Week 2

Due: 4:30pm on Monday, October 21, 2013

You will receive no credit for items you complete after the assignment is due. Grading Policy

Exercise 16.14 is for 1 point(s)
Incomplete

± A Sliding Crate of Fruit is for 4 point(s)
Incomplete

± The Overheated Jogger is for 2 point(s)
Incomplete

Exercise 16.29 is for 2 point(s)
Incomplete

The Size of Stars is for 2 point(s)
Incomplete

Heat Radiated by a Person is for 4 point(s)
Incomplete

Score Summary:
Your score on this assignment is 0.0%.
You received 0 out of a possible total of 15 points.

6 problems

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Week 2 › Exercise 16.14 Resources

« previous | 1 of 6 | next »

Item Type: End-of-Chapter | **Difficulty:** 1 | **Time:** 1m | Contact the Publisher **Manage this Item:** Standard View

Exercise 16.14

A meteorologist predicts an overnight low of -15 $^\circ\mathrm{C}$.

Part A

What is this in Fahrenheit?

Express your answer using two significant figures.

T_F = $^\circ\mathrm{F}$

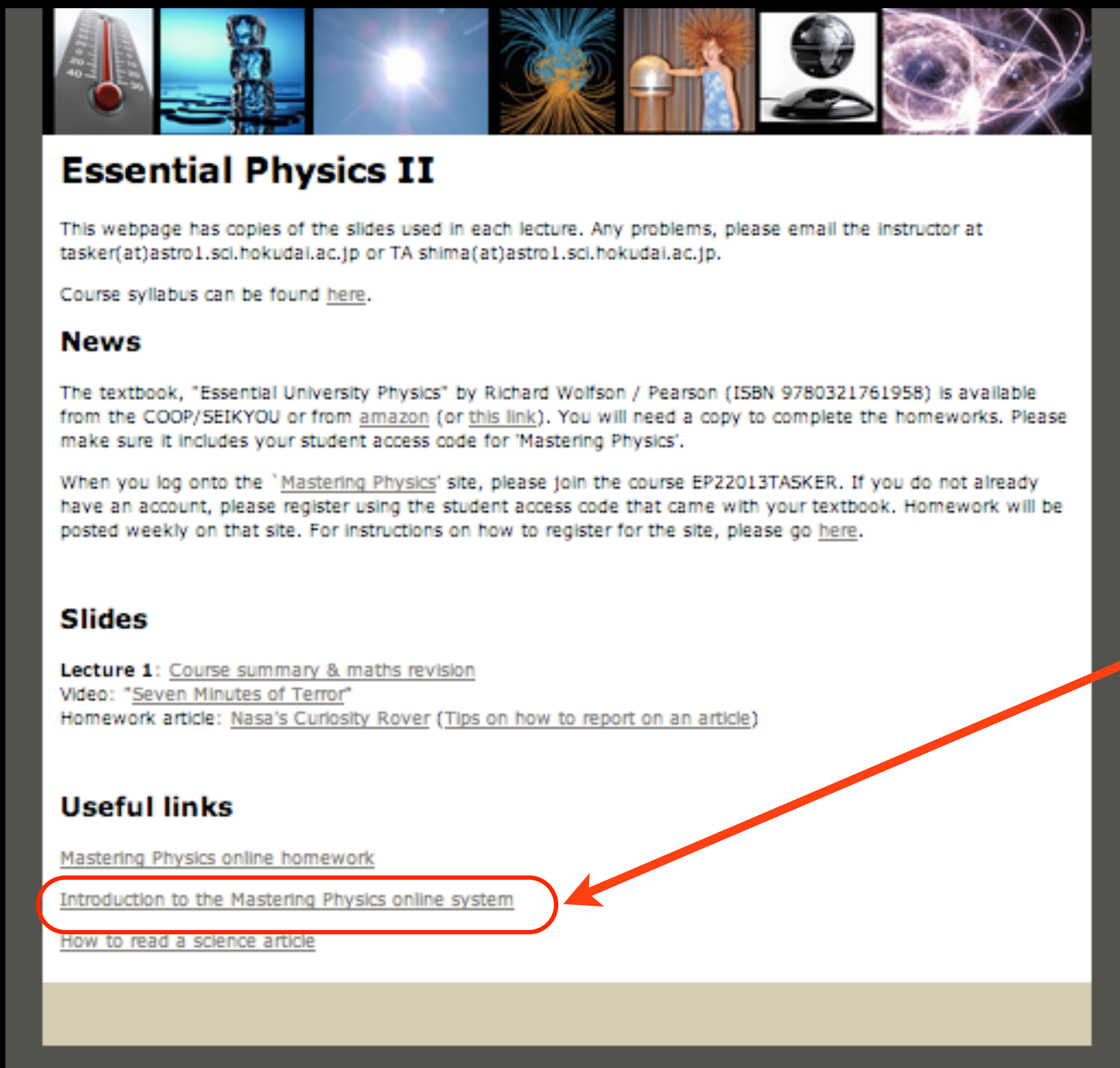
reset shortcuts help

Submit My Answers Give Up

Provide Feedback Continue

News

How do I use MasteringPhysics?



Essential Physics II

This webpage has copies of the slides used in each lecture. Any problems, please email the instructor at tasker(at)astro1.sci.hokudai.ac.jp or TA shima(at)astro1.sci.hokudai.ac.jp.

Course syllabus can be found here.

News

The textbook, "Essential University Physics" by Richard Wolfson / Pearson (ISBN 9780321761958) is available from the COOP/SEIKYOU or from amazon (or this link). You will need a copy to complete the homeworks. Please make sure it includes your student access code for 'Mastering Physics'.

When you log onto the 'Mastering Physics' site, please join the course EP22013TASKER. If you do not already have an account, please register using the student access code that came with your textbook. Homework will be posted weekly on that site. For instructions on how to register for the site, please go here.

Slides

Lecture 1: Course summary & maths revision
Video: "Seven Minutes of Terror"
Homework article: Nasa's Curiosity Rover (Tips on how to report on an article)

Useful links

Mastering Physics online homework
Introduction to the Mastering Physics online system
How to read a science article

Course website:

http://astro3.sci.hokudai.ac.jp/~tasker/teaching/ep2/

Guide to registering

or email me!

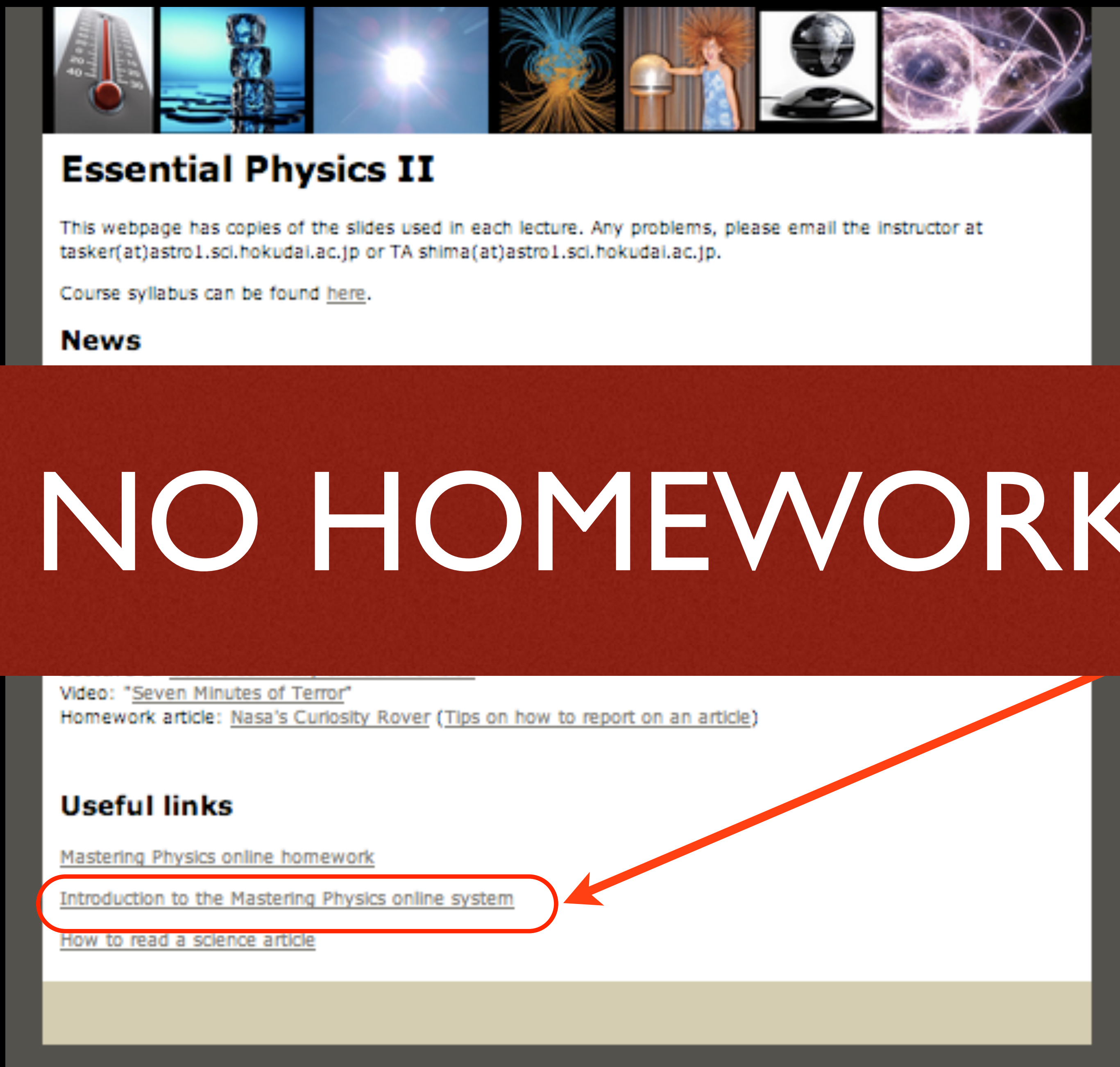
tasker@astro1.sci.hokudai.ac.jp

Homework = 40% of course mark!

Pass mark = 60 %

News

How do I use MasteringPhysics?



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or email me!

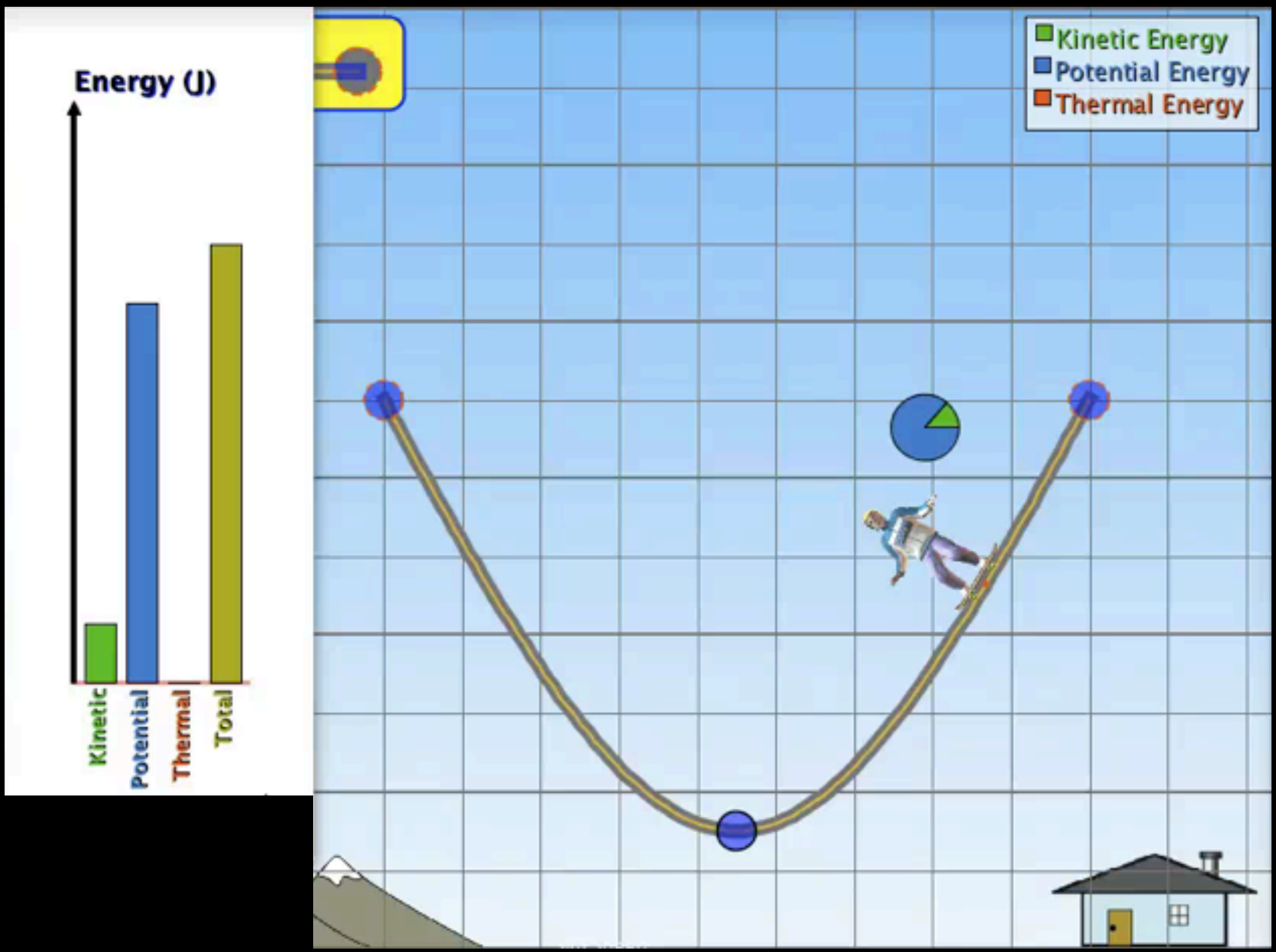
tasker@astro1.sci.hokudai.ac.jp

NO HOMEWORK = FAIL COURSE!

Homework = 40% of course mark!

Pass mark = 60 %

Last semester: Energy conservation



Frictionless track

Potential Energy

Kinetic Energy

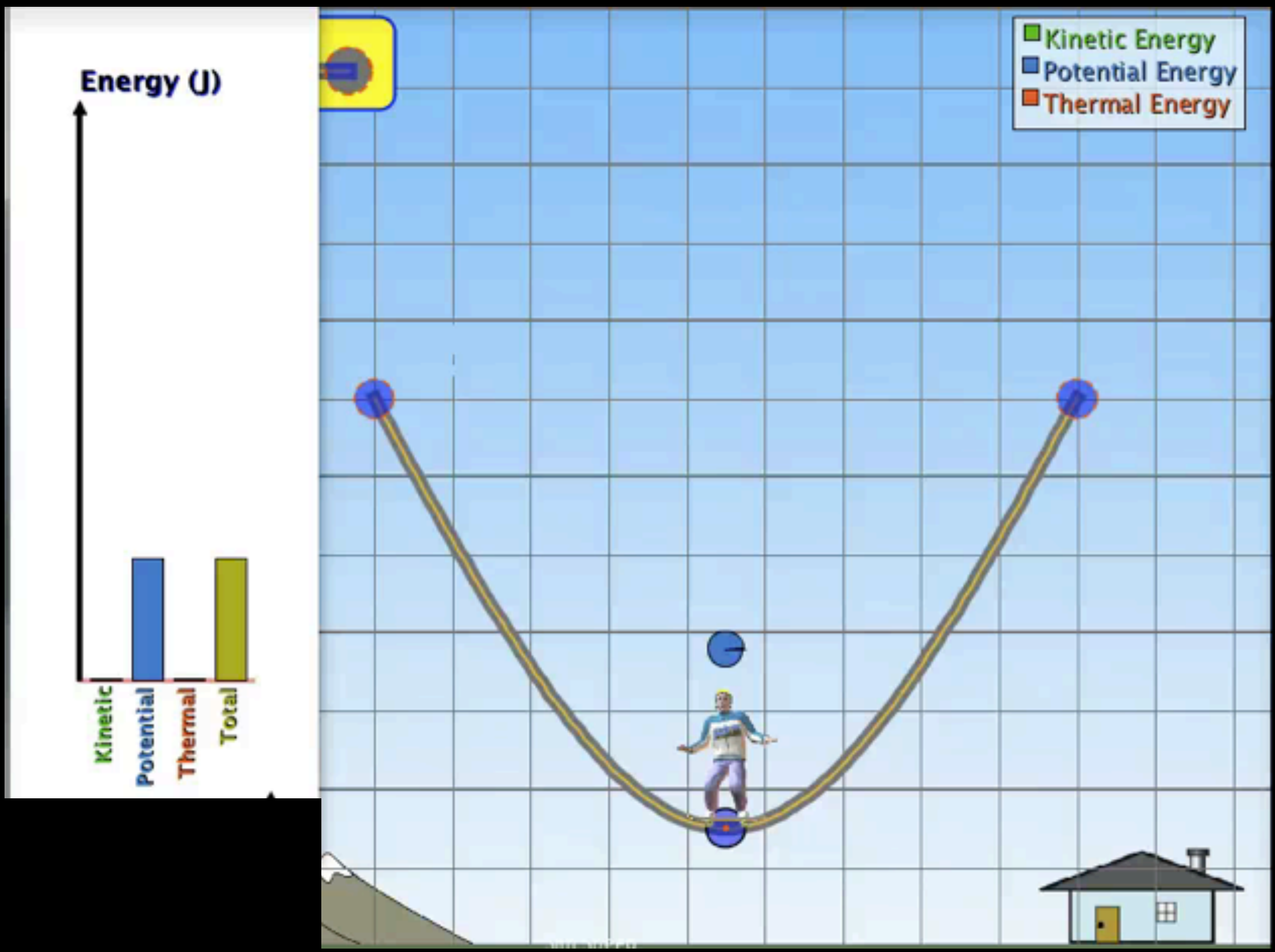
Potential Energy

Kinetic Energy

conversion

Total energy is unchanged

Last semester: Energy conservation



Friction track

Potential Energy

Kinetic Energy
+ Thermal Energy

Potential Energy
+ Thermal Energy

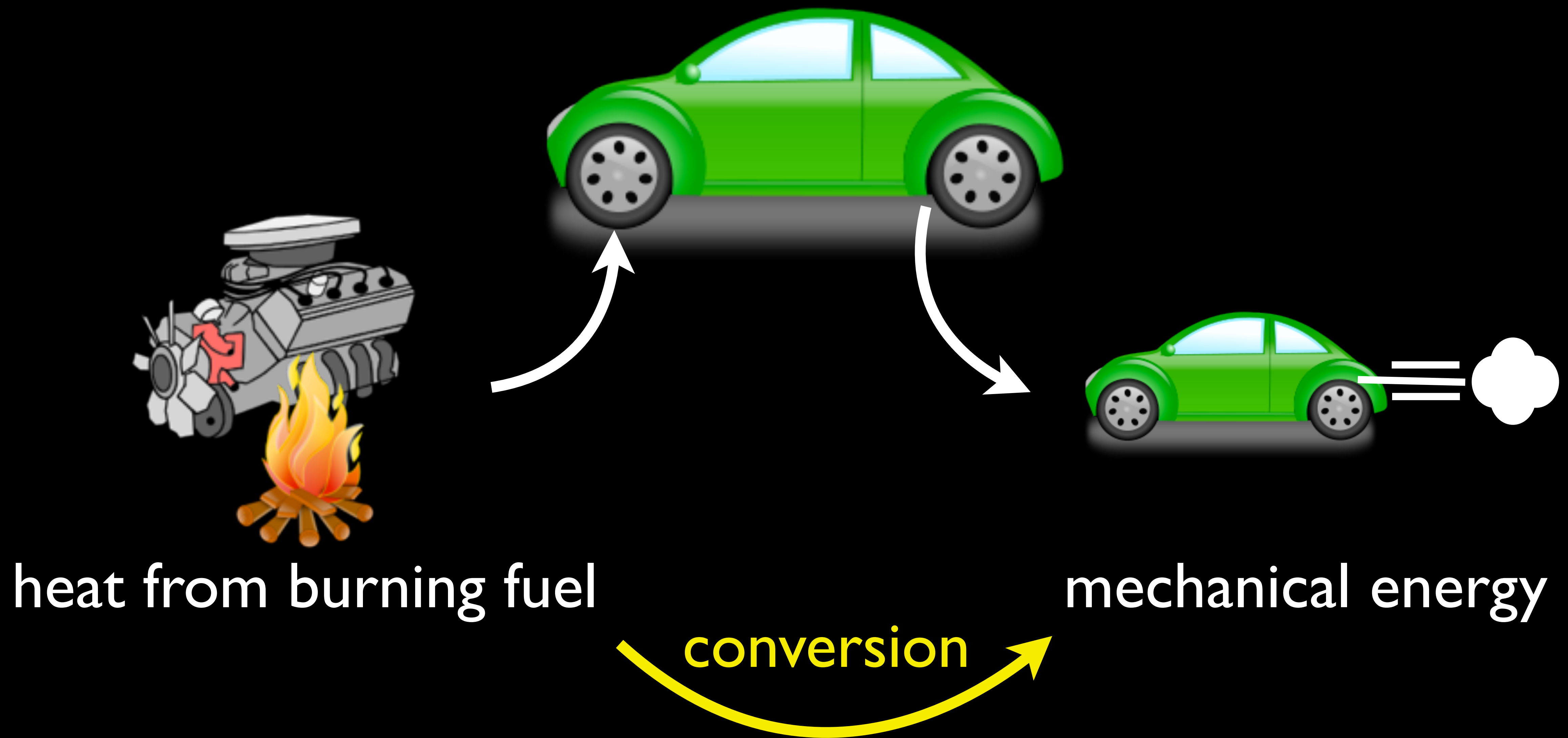
Kinetic Energy
+ Thermal Energy

conversion

Total energy is unchanged

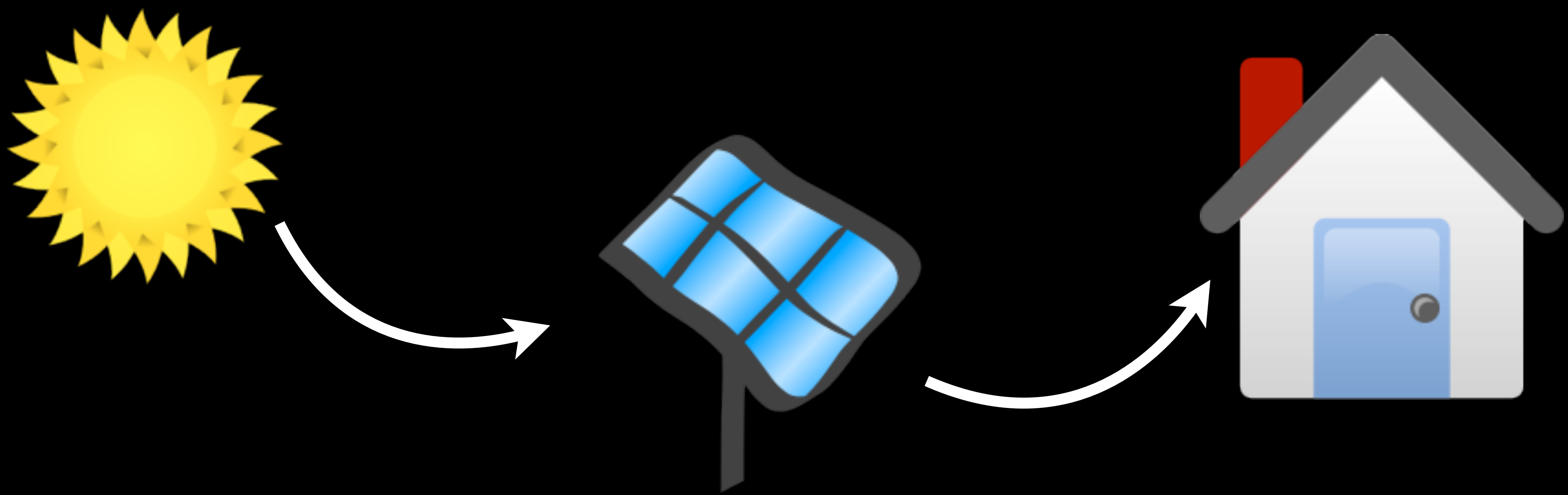
Thermal to mechanical energy

Most of our energy is from heat:



Thermal to mechanical energy

Most of our energy is from heat:



heat from the sun — conversion → mechanical energy

Can we convert 100% of heat energy to mechanical energy?

No! → Laws of thermodynamics

This lecture ...

... studies thermal (heat) energy

What is thermal equilibrium?

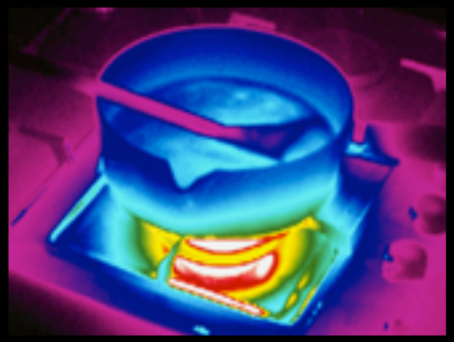
Meaning of heat and temperature

(and the *difference* between them)

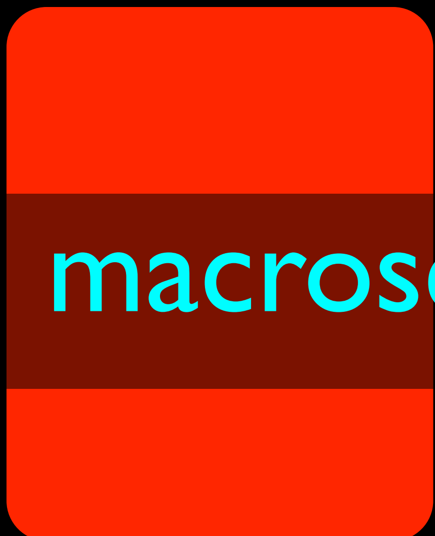
How temperature is measured

How to use heat capacity to find equilibrium temperatures

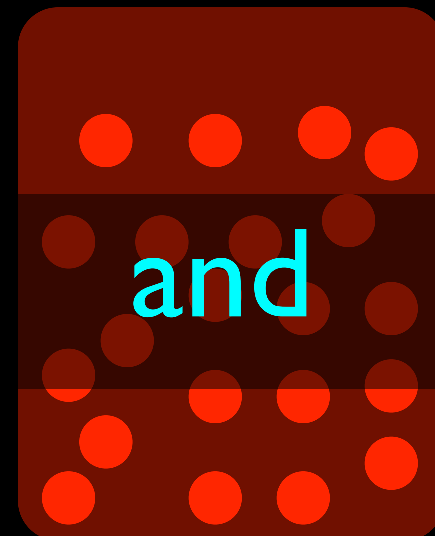
The 3 methods of heat transfer



Thermodynamics = macroscopic



macroscopic



and

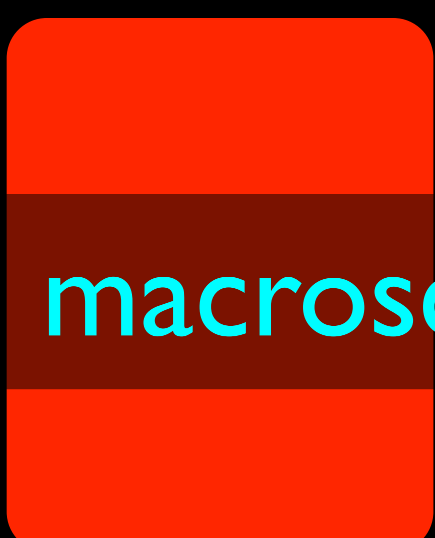
microscopic

mass

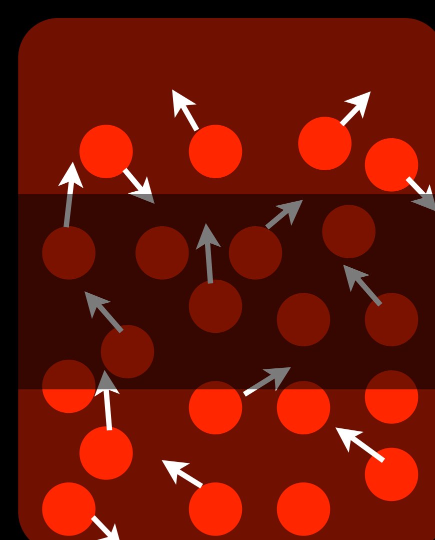
kinetic energy

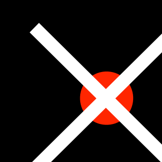
mass

kinetic energy



macroscopic only





pressure

temperature

depends on motion
of all molecules

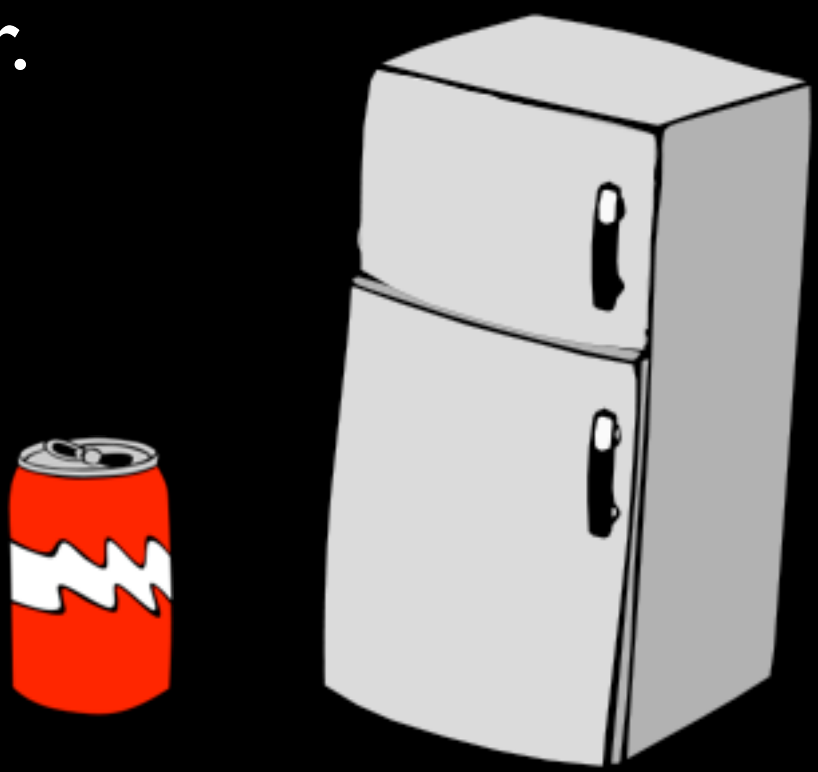
~~pressure~~

~~temperature~~

Thermodynamic equilibrium Quiz

You remove a cold drink from the refrigerator.

Its temperature :



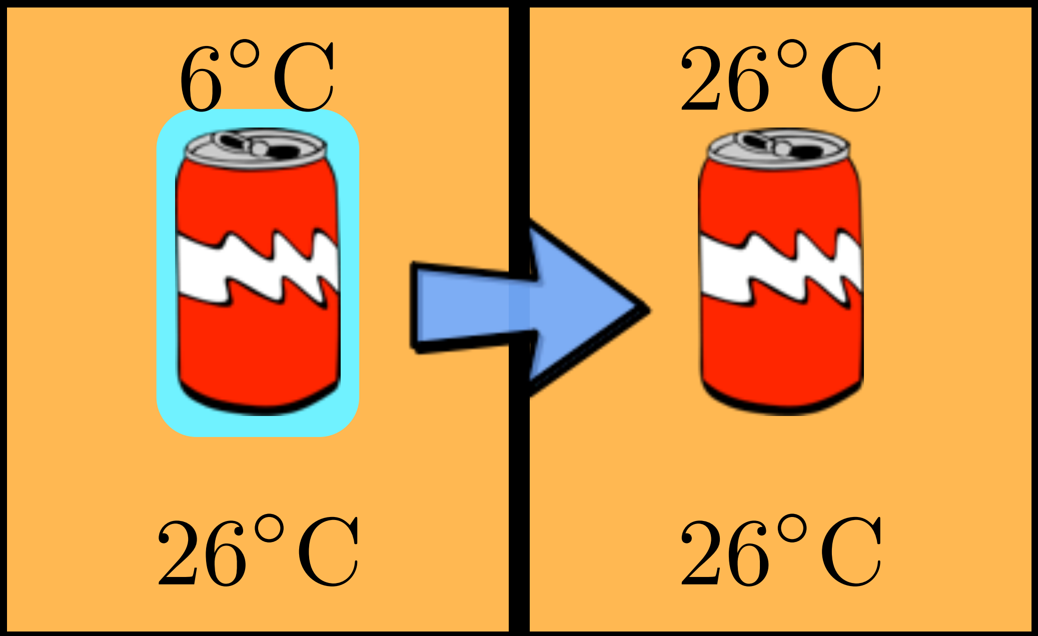
(A) Stays the same

(B) Changes to room temperature

(C) Changes to hotter than room temperature

(D) Stays colder than room temperature

Thermodynamic equilibrium



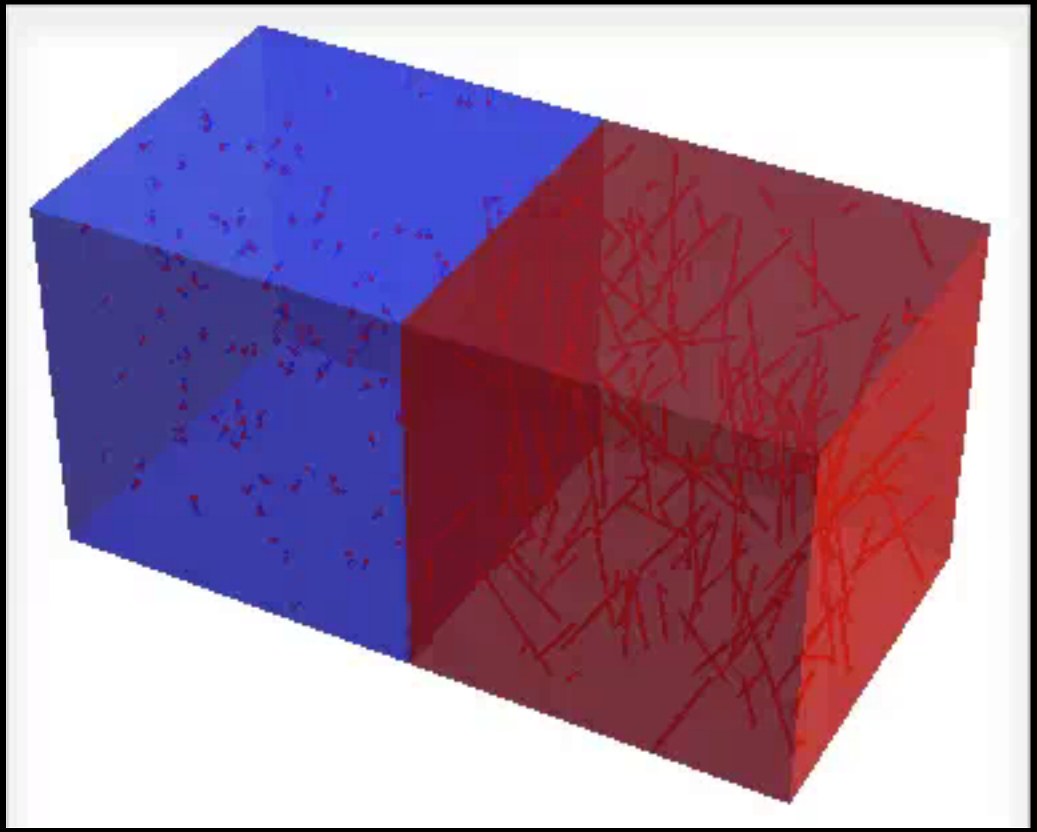
When drink = room temperature:

temperature stops changing

thermodynamic equilibrium

When 2 systems are placed together and macroscopic properties do not change

- pressure
- length
- volume

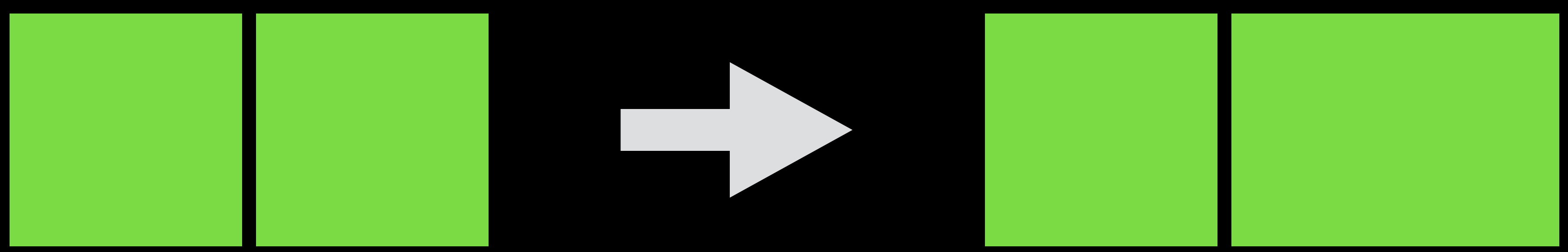


Cold Hot

Thermodynamic equilibrium Quiz

2 blocks are placed together.

1 block expands (volume increase) but its pressure stays constant



Was it in thermodynamic equilibrium?

(A) No

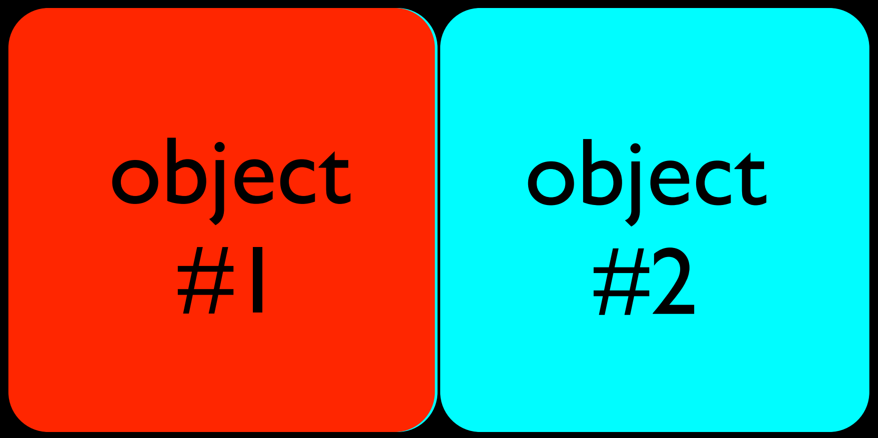
(B) Yes

(C) Can't know

If ANY macroscopic property changes, they were not in thermodynamic equilibrium

Thermodynamic equilibrium

“Placed together” → in thermal contact



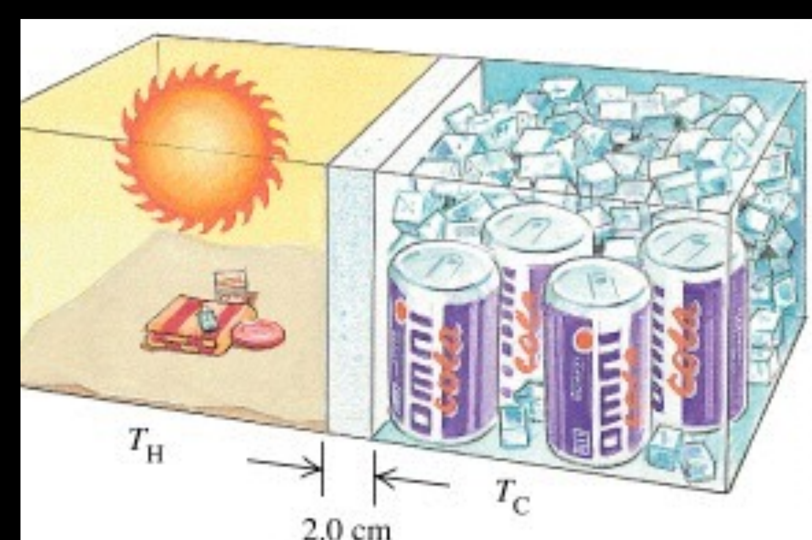
Heating object #1 changes macroscopic properties (e.g. pressure) of object #2

Thermodynamic equilibrium

"Placed together" → in thermal contact

object #1 | object #2

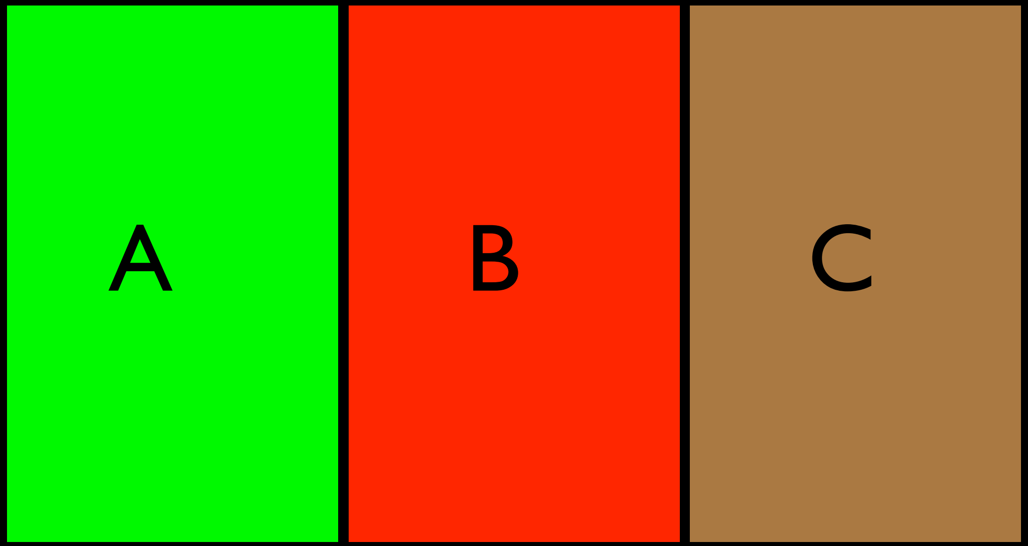
Heating object #1 changes macroscopic properties (e.g. pressure) of object #2



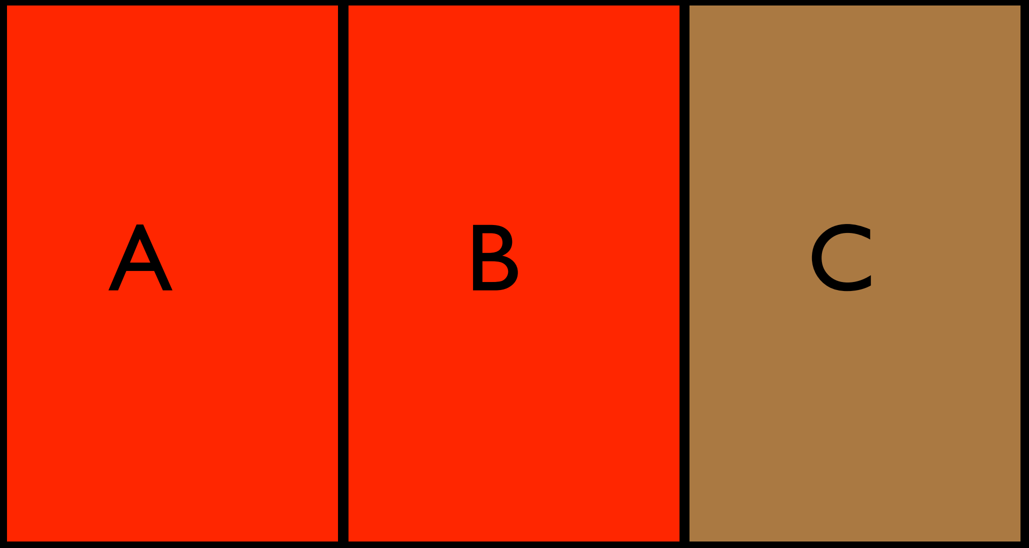
Not in thermal contact

object #2 's properties are unchanged

Thermodynamic equilibrium

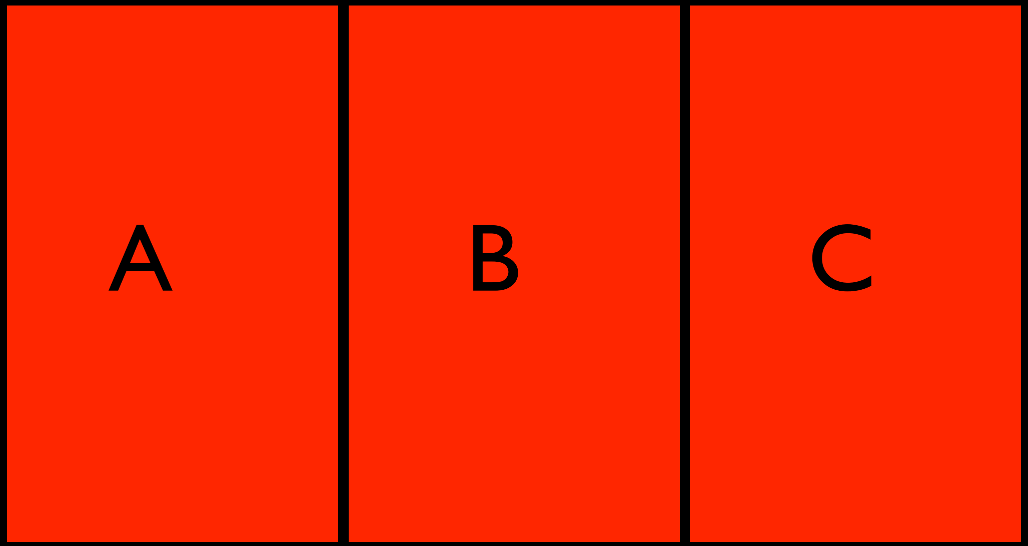


Thermodynamic equilibrium



If "A" is in thermal contact (and thermodynamic equilibrium) with "B"

Thermodynamic equilibrium



If "A" is in thermal contact (and thermodynamic equilibrium) with "B"

And "C" is in thermal contact (and thermodynamic equilibrium) with "B"

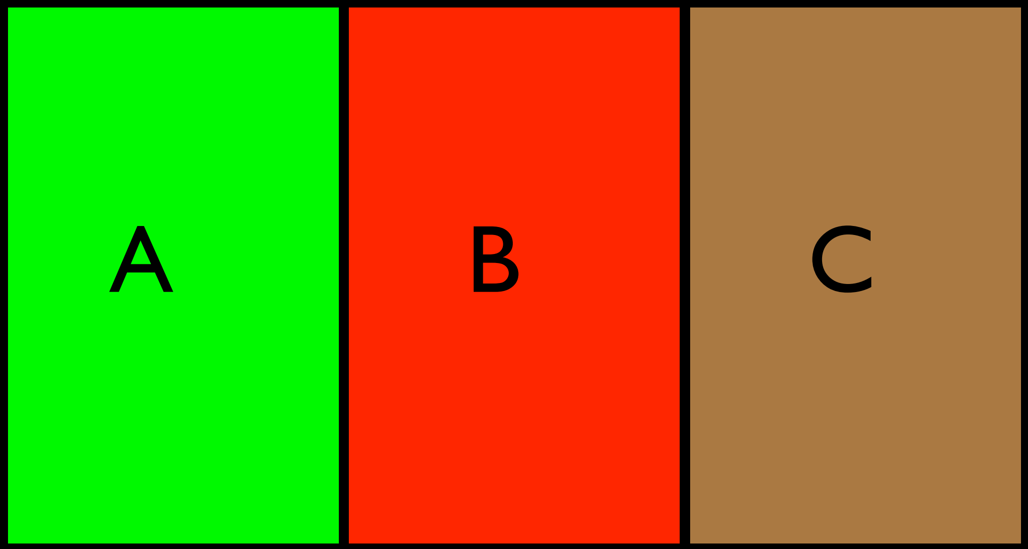
Then "A" and "C" are in thermodynamic equilibrium

(but not in contact)

Thermodynamic equilibrium

The zeroth (0th) law of thermodynamics:

2 systems in equilibrium with a 3rd system are in equilibrium with each other.



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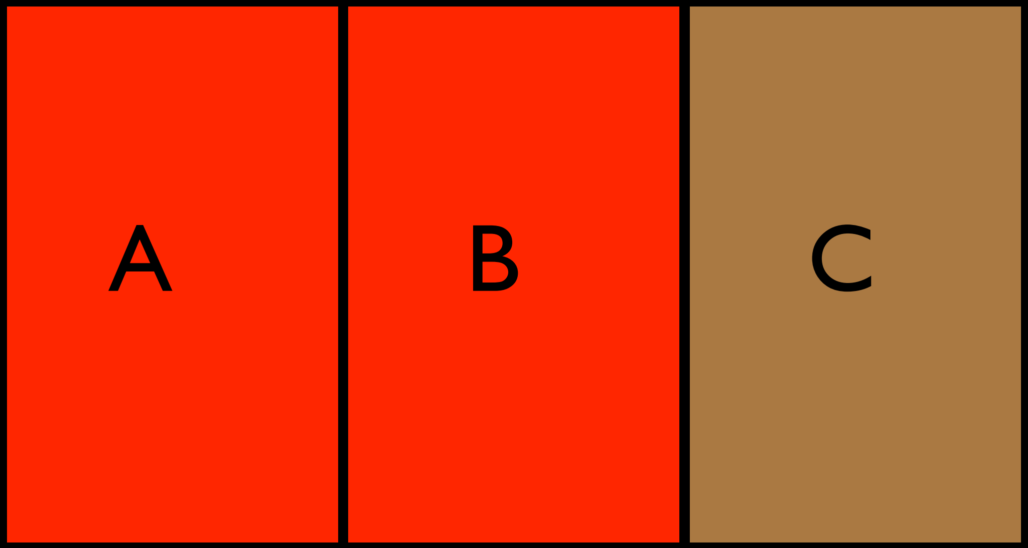

(If "A" is in equilibrium with "B"

Thermodynamic equilibrium

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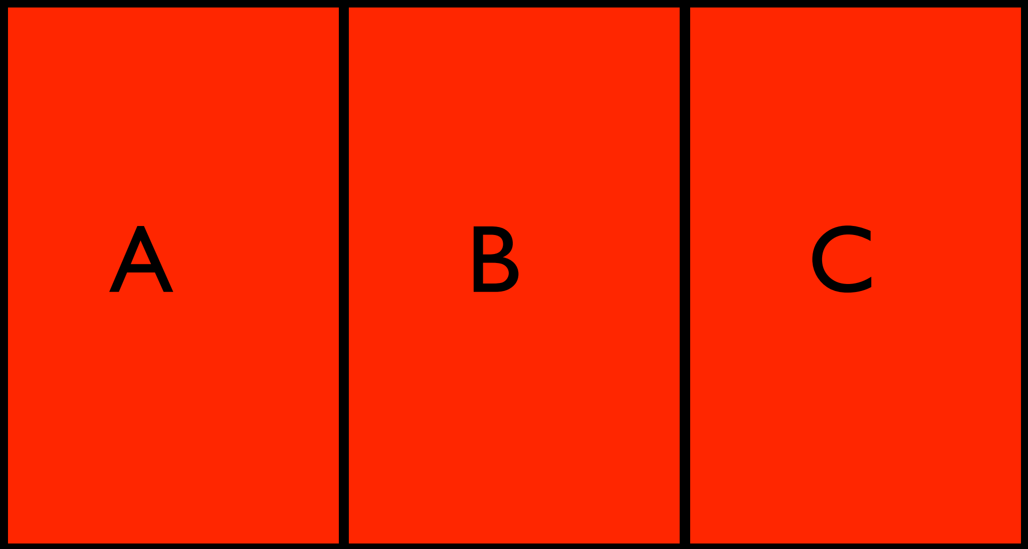

(If "A" is in equilibrium with "B"

and "C" is in equilibrium with "B"

Thermodynamic equilibrium

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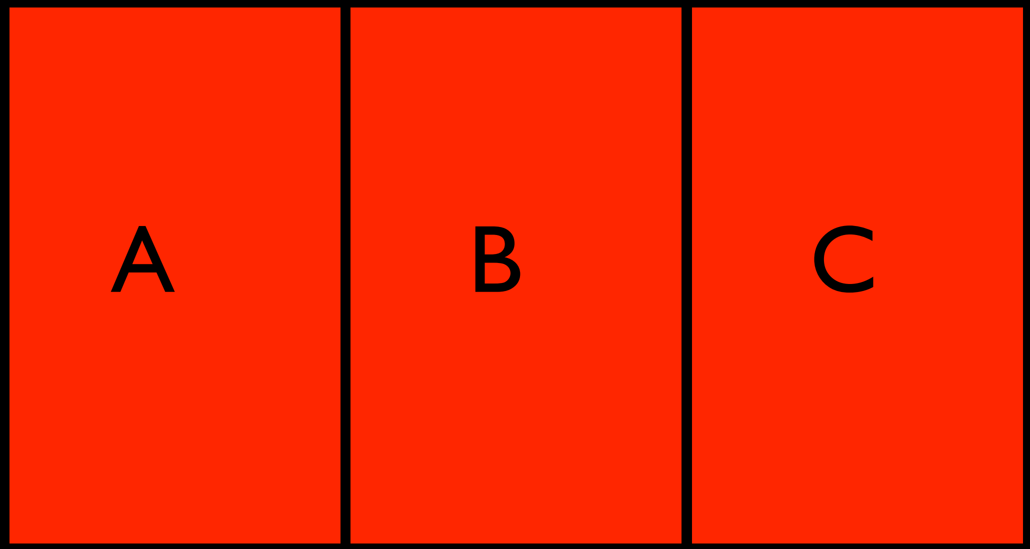


(If "A" is in equilibrium with "B"

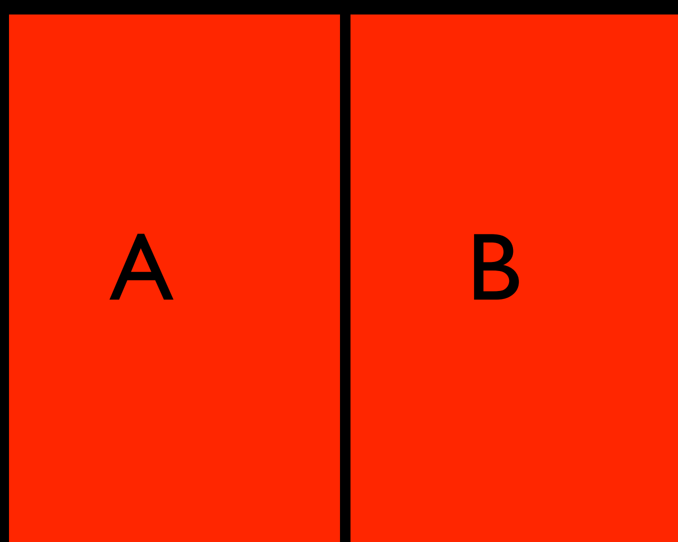
and "C" is in equilibrium with "B"

then "A" is in equilibrium with "C")

Thermometer

What is temperature?

2 systems have the same temperature if they are in thermodynamic equilibrium.



thermal contact

Same temperature

Thermodynamic equilibrium

No macroscopic changes

measure temperature difference

measure macroscopic change…

Thermometer

A system with a macroscopic property that changes with temperature

height of mercury (Hg)

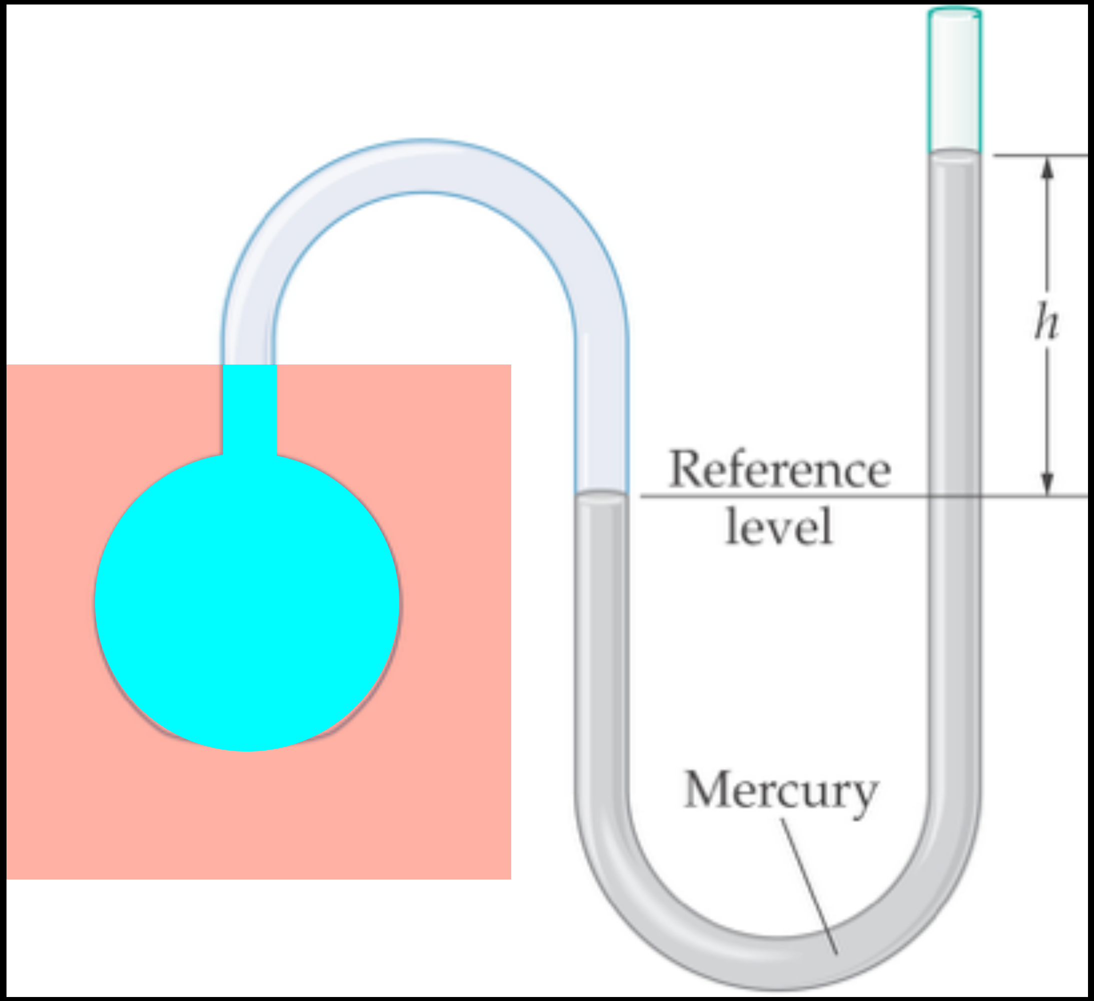
gas pressure

electrical resistance

bending of bimetal (2 metals) strip

The gas thermometer

Constant-volume gas thermometer



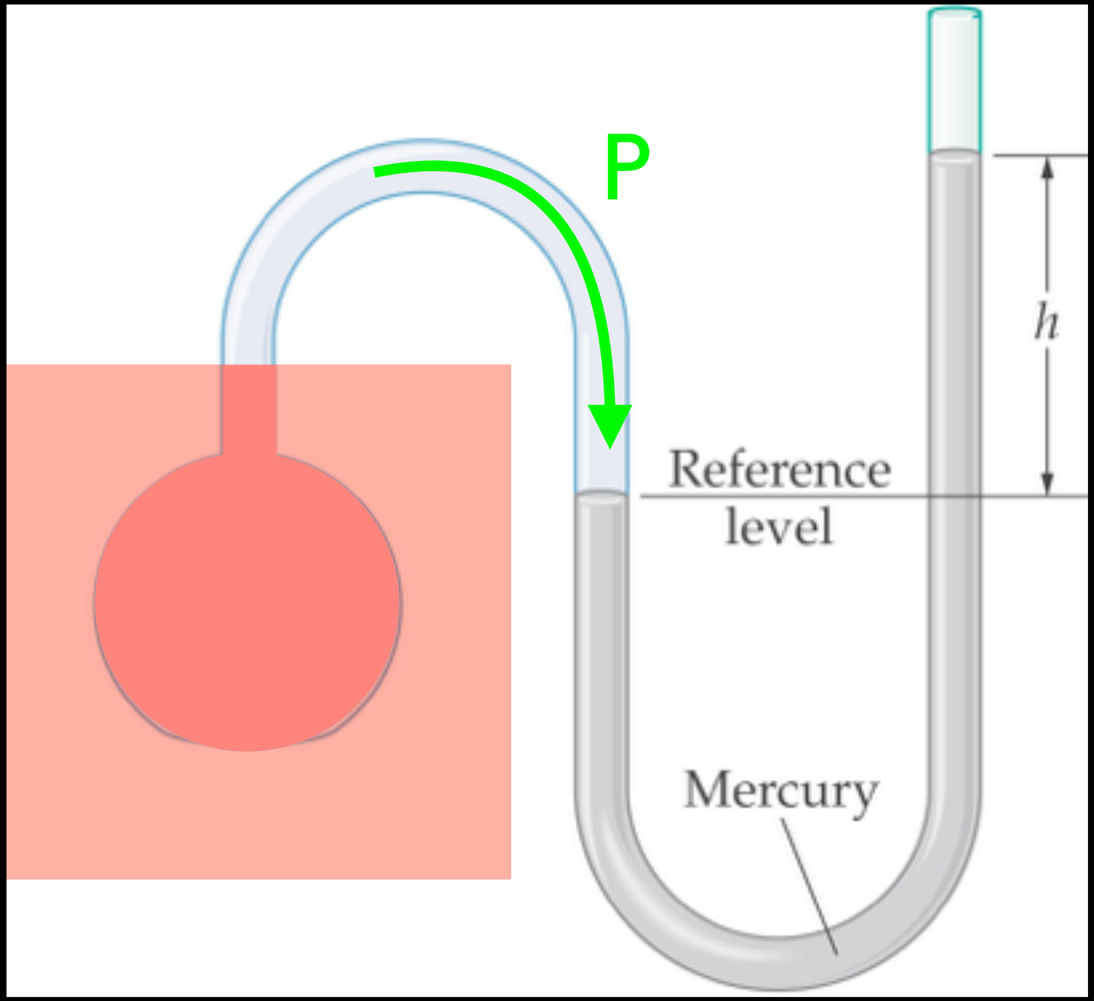
The gas thermometer

Constant-volume gas thermometer

Gas reaches thermodynamic equilibrium with system

↓

Pressure changes



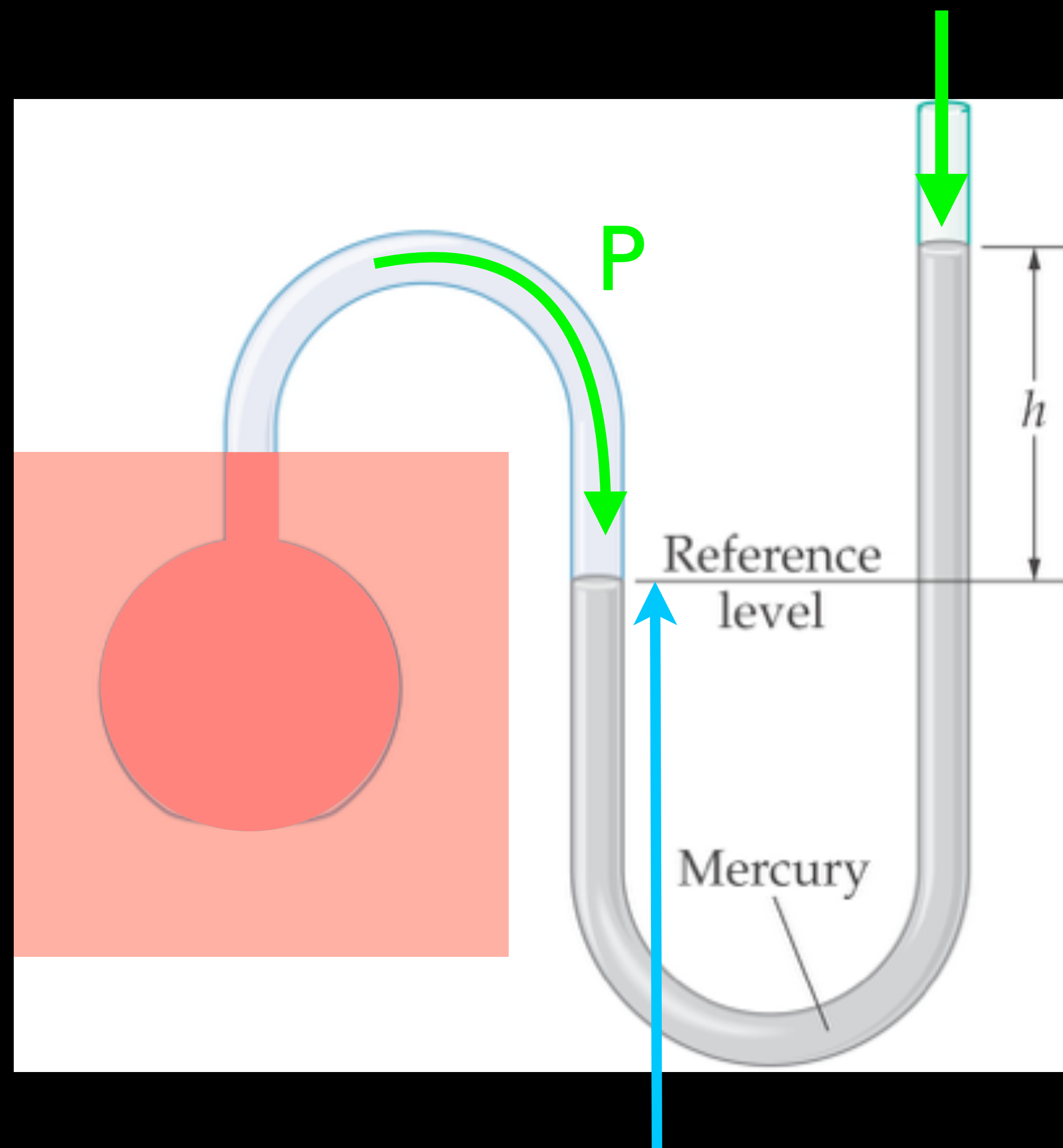
The gas thermometer

Constant-volume gas thermometer

Gas reaches thermodynamic equilibrium with system

↓

Pressure changes

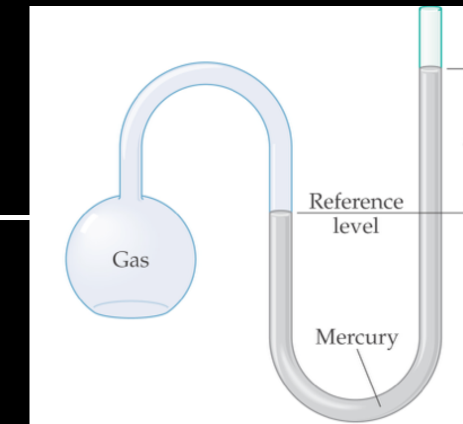


tube is moved ↓↑ to **+/-** atmospheric pressure

... so level is constant

'h' measures change in gas pressure and therefore, temperature

The gas thermometer



Need a temperature scale:

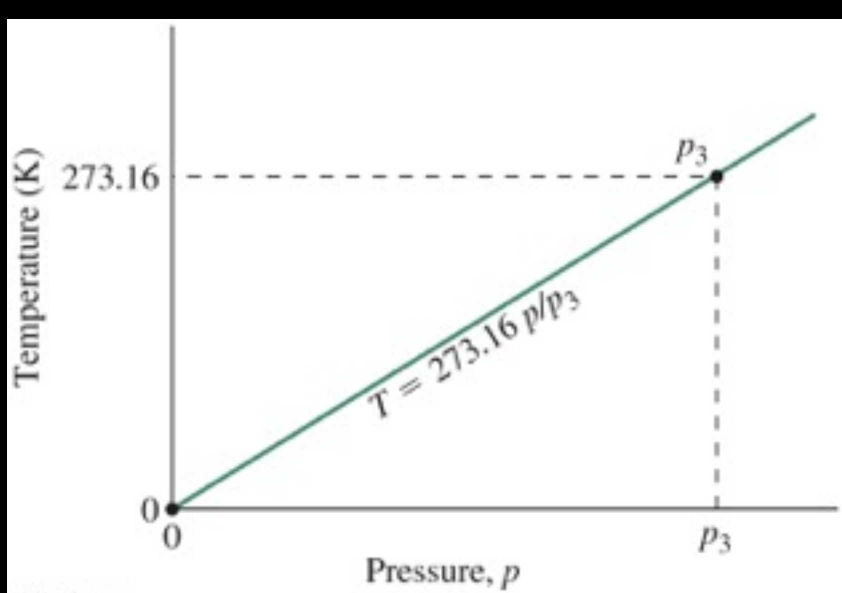
Define 2 points:

'0' temperature = gas pressure is 0 → 0 K

Triple point for water: solid, liquid & gas water exist together → 273.16 K

(see next lecture)

kelvin (K)
SI unit



Since pressure cannot be < 0,
0 K = absolute zero

can't go lower!

Temperature scales

Celsius $^\circ\mathrm{C}$

2 points: melting point of ice $0\,^\circ\mathrm{C}$
(standard atmospheric P)

Boiling point $100\,^\circ\mathrm{C}$

ΔT in $^\circ C$ = ΔT in K

$$\boxed{T_C = T - 273.15}$$

Fahrenheit $^\circ F$

ΔT in $^\circ F \neq \Delta T$ in K

$$\boxed{T_F = \frac{9}{5}T_C + 32}$$

Rankine $^\circ R$

ΔT in $^\circ R$ = ΔT in $^\circ F$ $\neq$ ΔT in K

$$0^\circ R = 0K$$

Temperature scales

Quiz

When do the temperatures in centigrade and fahrenheit agree?

(A) Never

(B) At 0 degrees

(C) At 100 degrees

(D) At -40 degrees

(E) At -215 degrees

$$T_F = \frac{9}{5}T_C + 32$$

$$T_F = T_C$$

$$T = \frac{9}{5}T + 32$$

$$T = -40^\circ$$

Energy

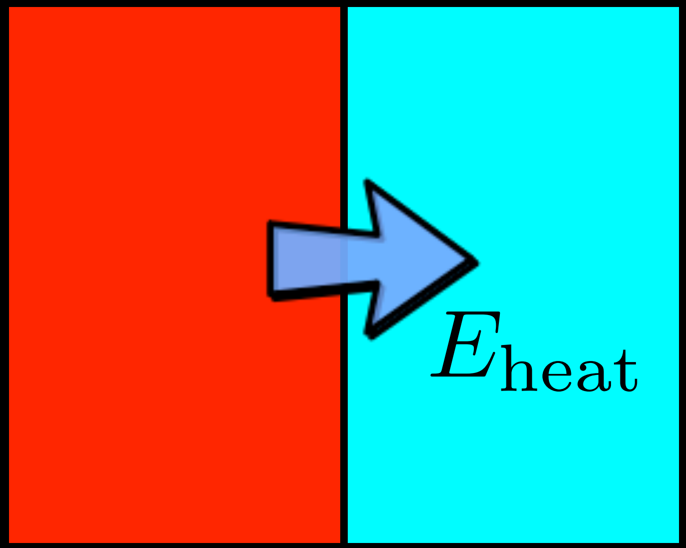
How does a system reach thermodynamical equilibrium?

...T changes

Why?

because energy is moving.

Heat is energy moving because of a difference in temperature (ΔT)



Temperature change → Energy change

ΔT ΔE

Heat increases internal energy

Heat capacity

Heat energy transferred $\propto$ Temperature change

$E_{\text{heat}} = \Delta Q \;\; [\mathrm{J}]$ $\qquad \Delta T \;\; [\mathrm{K}]$

$$\Delta Q = C \, \Delta T$$

heat capacity

depends on mass + material

$$\Delta Q = mc \, \Delta T$$

specific heat capacity $[\mathrm{J/kg \cdot K}]$

depends on what object is made of ... not how large it is

Heat capacity

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

Mass, m

Specific heat, c

Temperature, T

Add energy

ΔQ

Temperature increase,

ΔT

$$\Delta Q = mc\Delta T$$

Heat capacity

Substance	Specific Heat, c	
	SI Units: J/kg·K	cal/g·°C, kcal/kg·°C, or Btu/lb·°F
Aluminum	900	0.215
Concrete (varies with mix)	880	0.21
Copper	386	0.0923
Iron	447	0.107
Glass	753	0.18
Mercury	140	0.033
Steel	502	0.12
Stone (granite)	840	0.20
Water:		
Liquid	4184	1.00
Ice, −10°C	2050	0.49
Wood	1400	0.33

Old units for heat

1 calorie: heat needed to raise T of 1g of water from 14.5 $^\circ\mathrm{C}$ to 15.5 $^\circ\mathrm{C}$

$= 4.184\,\mathrm{J}$

Heat capacity

Quiz

The mass of an object is 199.0 g

It takes 16.0 J to raise the temperature by 10.0 °C

What is the specific heat?

(A) $8.04\,\mathrm{J/kg \cdot K}$

(B) $1600\,\mathrm{J/kg \cdot K}$

(C) $0.00120\,\mathrm{J/kg \cdot K}$

(D) $3.18 \times 10^6\,\mathrm{J/kg \cdot K}$

$$\Delta Q = mc\Delta T$$

$$c = \frac{\Delta Q}{m\Delta T}$$

$$= \frac{16.0}{0.199 \times 10}$$

Heat capacity

Quiz

A 905 g meteor hits the Earth at a speed of 1629 m/s

If all the energy is converted to heat in the meteor, what is the temperature rise?

specific heat of meteor: $472\,\mathrm{J/kg\cdot K}$

(A) $2810\,^\circ\mathrm{C}$

(B) $2,540,000\,^\circ\mathrm{C}$

(C) $3.10\,^\circ\mathrm{C}$

(D) $11,700\,^\circ\mathrm{C}$

Initial kinetic energy: $\mathrm{KE} = \frac{1}{2}mv^2$

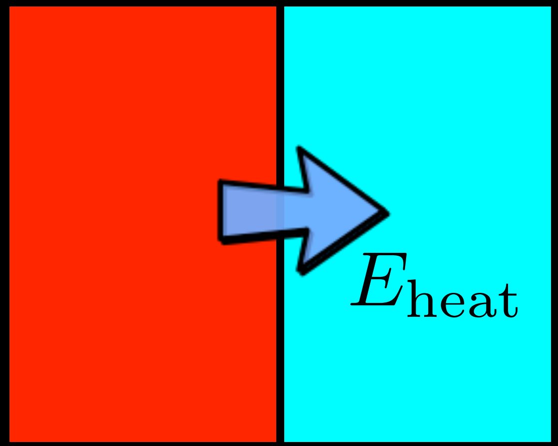
$$= \frac{1}{2}(0.905)(1629)^2 = 1,200,773\,\mathrm{J}$$

= heat energy $= \Delta Q = mc\Delta T$

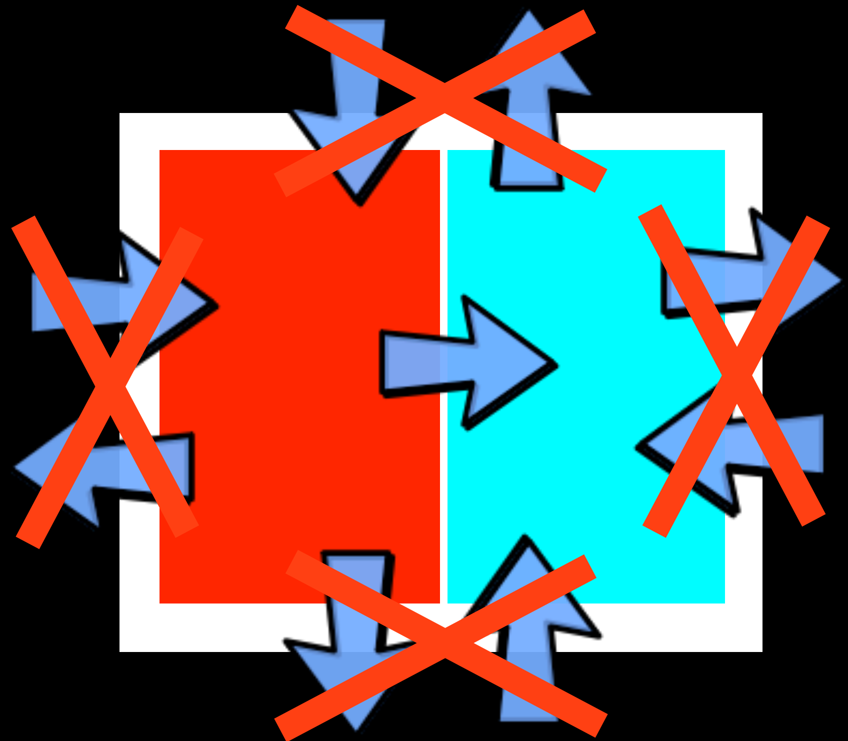
$$\Delta T = \frac{1,200,773}{0.905 \times 472}$$

Equilibrium Temperature

When 2 objects are in thermal contact, heat flows from the hotter to the colder object



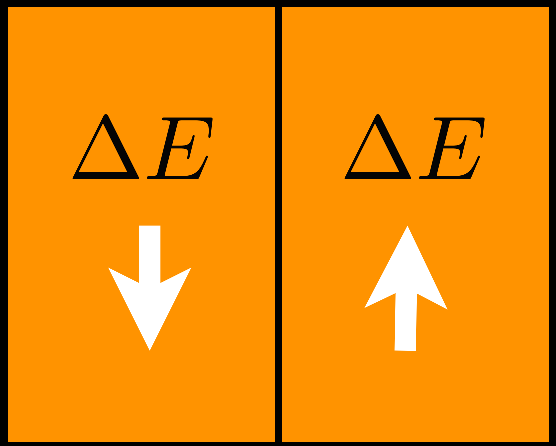
If objects are thermally insulated from the outside (no energy in or out) ....



... all energy leaving hotter object ends up in the colder object.

$$m_1 c_1 \Delta T_1 + m_2 c_2 \Delta T_2 = 0$$

negative for hotter object



Equilibrium Temperature Ex.

An aluminum frying pan of mass 1.5 kg is at 180°C.

It is dropped into 8 kg of water at 20°C.

Assuming water does not boil and no heat is lost, what is the equilibrium temperature of pan and water?

$$c_p = 900\,\mathrm{J/kg\cdot K}$$

$$c_w = 4184\,\mathrm{J/kg\cdot K}$$

$$m_p c_p \Delta T + m_w c_w \Delta T = 0$$

$$m_p c_p (T - T_p) + m_w c_w (T - T_w) = 0$$

equilibrium temperature

$$T = \frac{m_p c_p T_p + m_w c_w T_w}{m_p c_p + m_w c_w} = \frac{1.5 \times 900 \times 180 + 8.0 \times 4184 \times 20}{1.5 \times 900 + 8.0 \times 4184}$$

$$= 26^\circ C$$

Equilibrium Temperature Quiz

A hot rock with mass 250 g is dropped into an equal mass of water.

Which temperature changes more?

(specific heat of water > rock)

(A) rock

(B) water

(C) their temperature change is equal

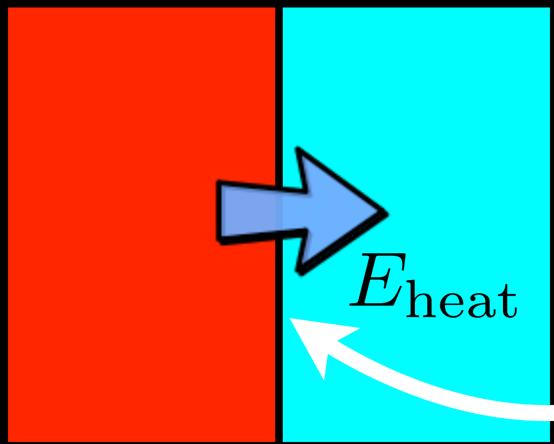
$$mc_r \Delta T_r + mc_w \Delta T_w = 0$$

$$c_r \Delta T_r = -c_w \Delta T_w$$

since: $c_r < c_w$

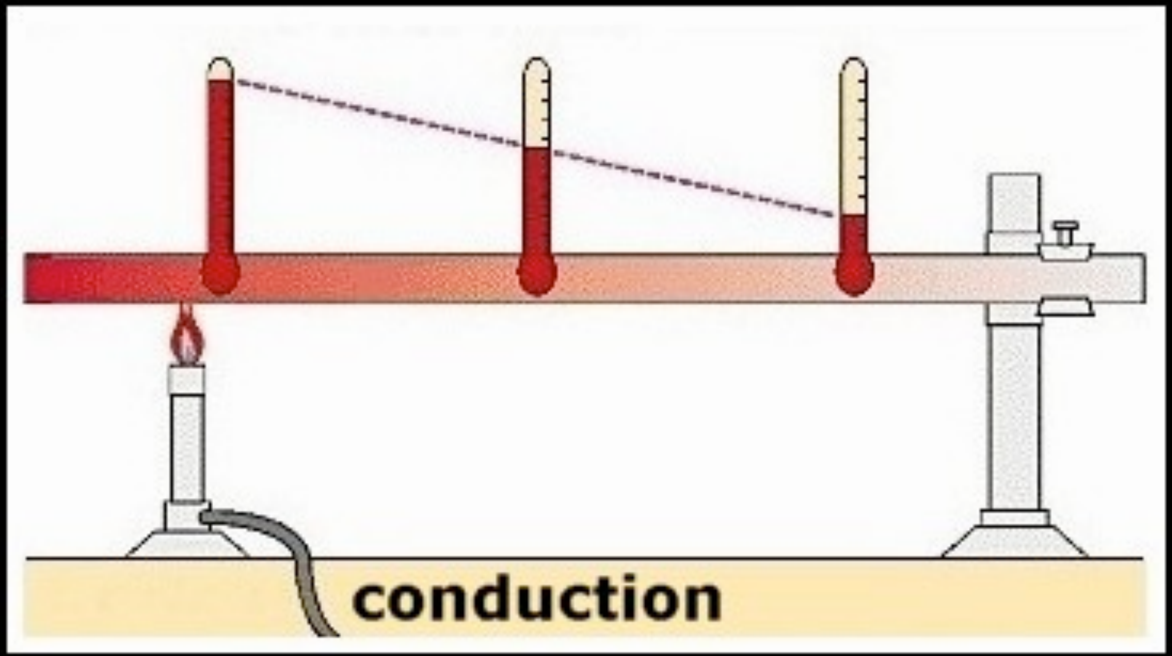
$$\Delta T_r > \Delta T_w$$

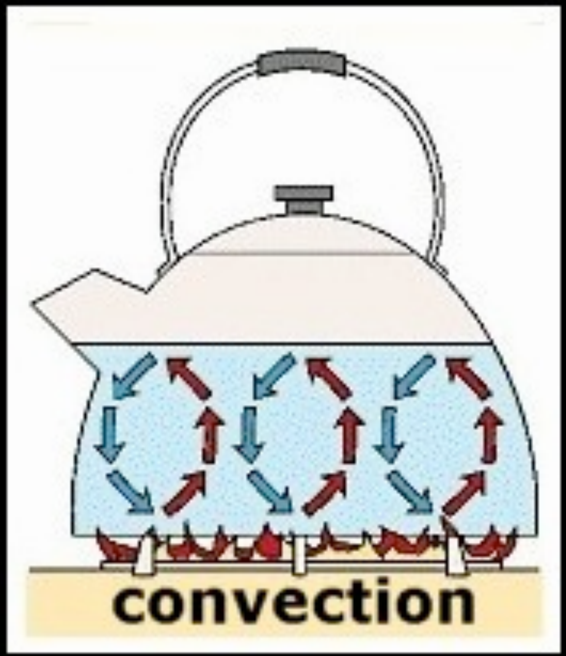
Heat Transfer

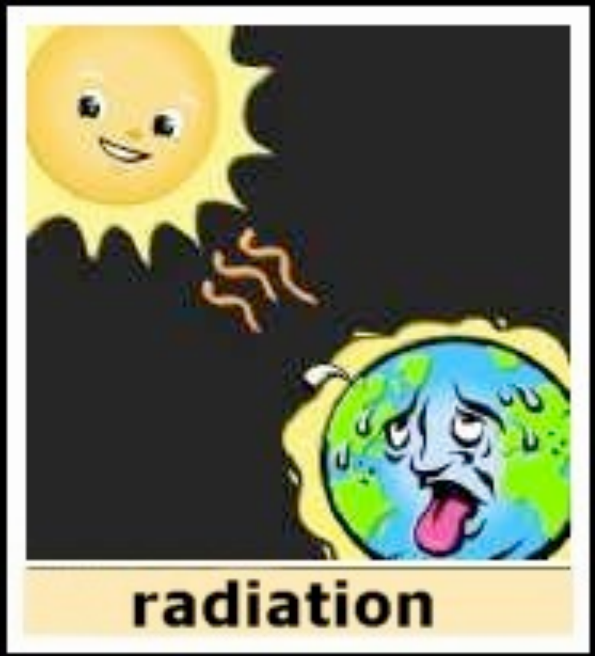


HOW is heat transferred?

3 mechanisms:







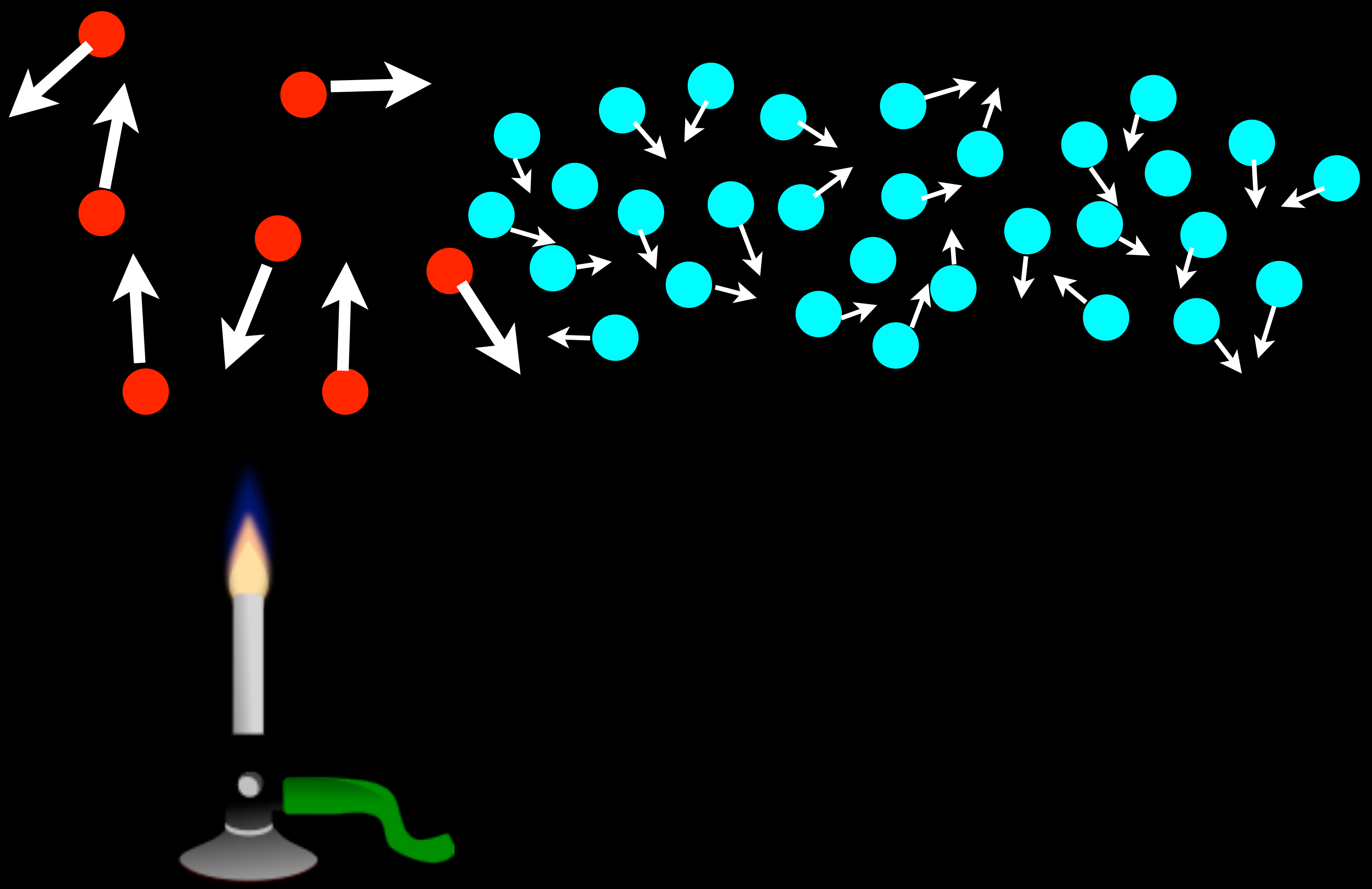
Conduction

Convection

Radiation

Heat Transfer: Conduction

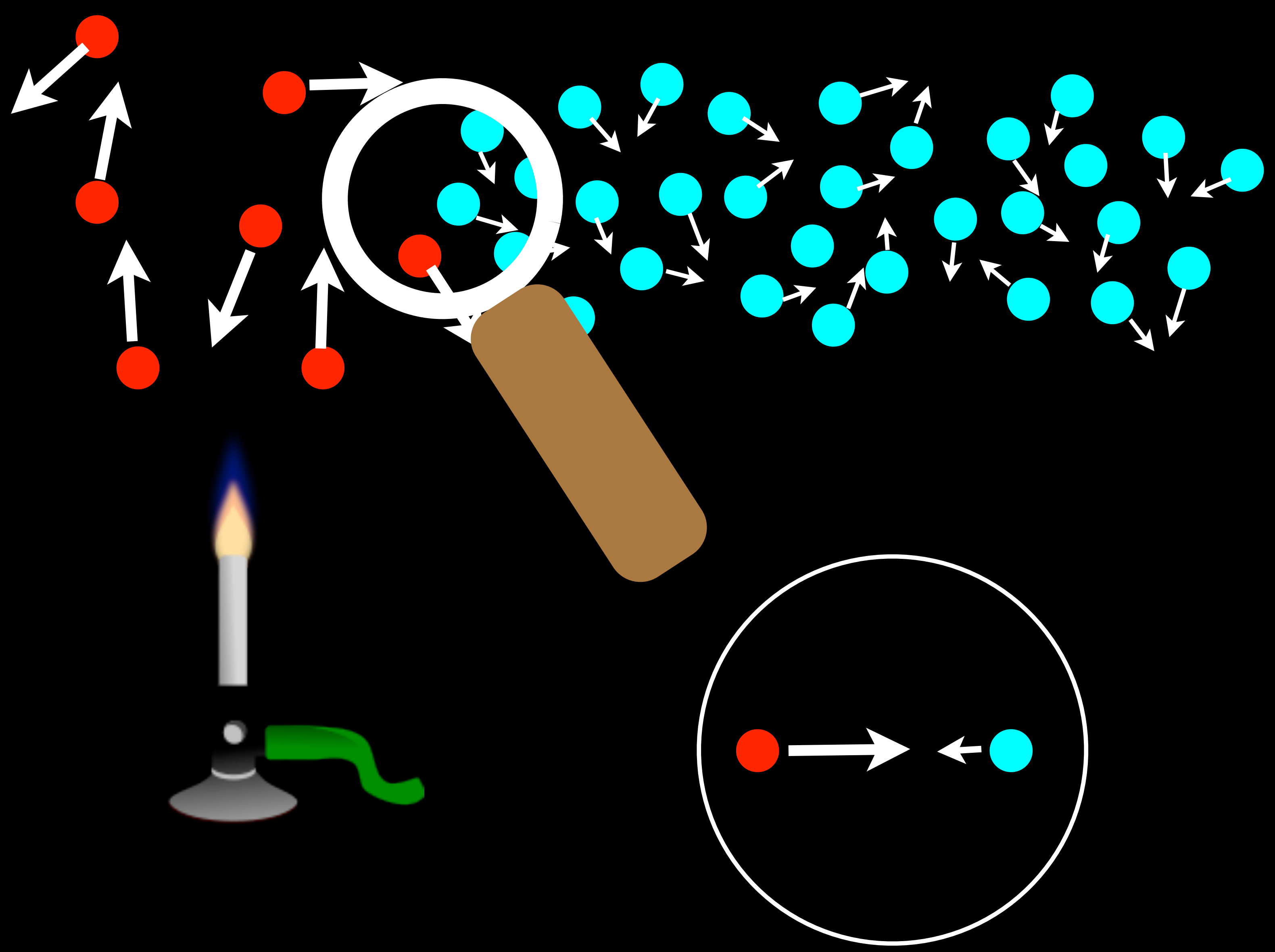
Conduction: heat transfer from contact



molecules in a
hot region have
more energy

Heat Transfer: Conduction

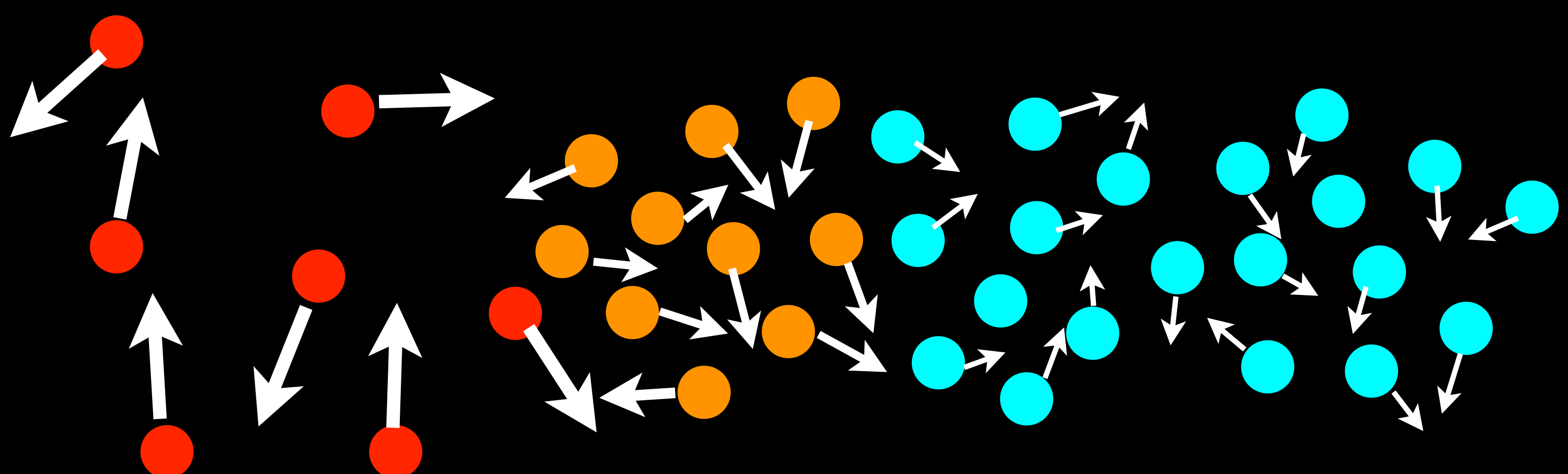
Conduction: heat transfer from contact

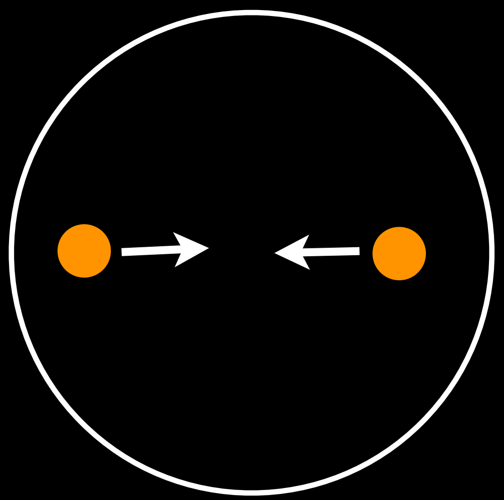


molecules in a hot region have more energy → collide with cold molecules

Heat Transfer: Conduction

Conduction: heat transfer from contact

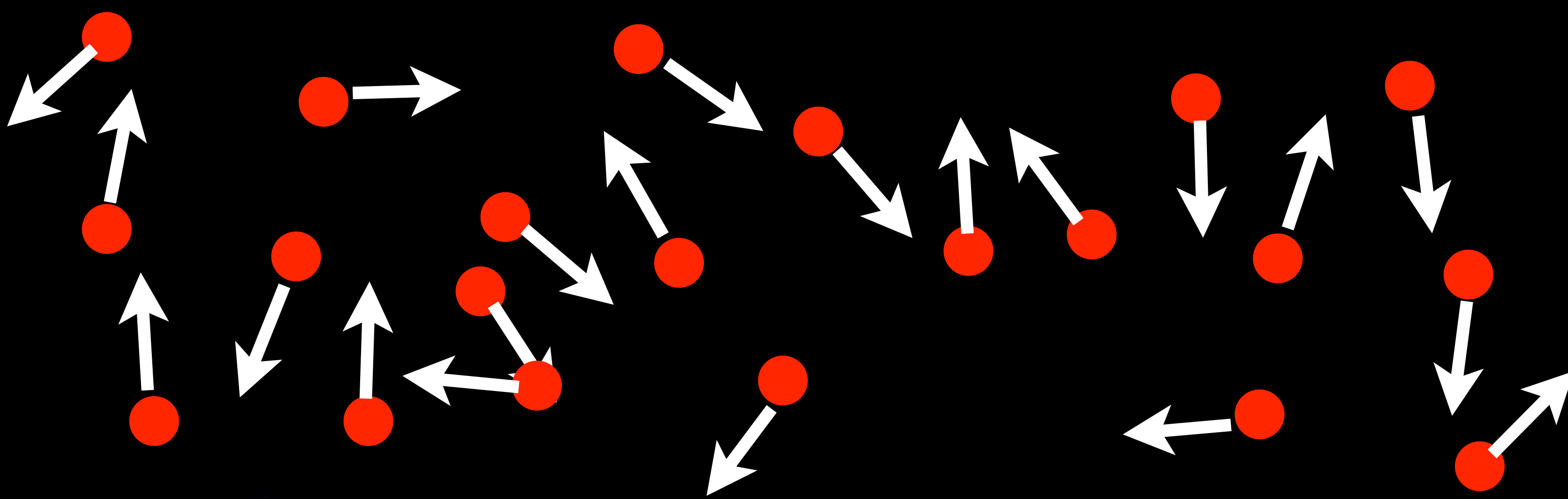


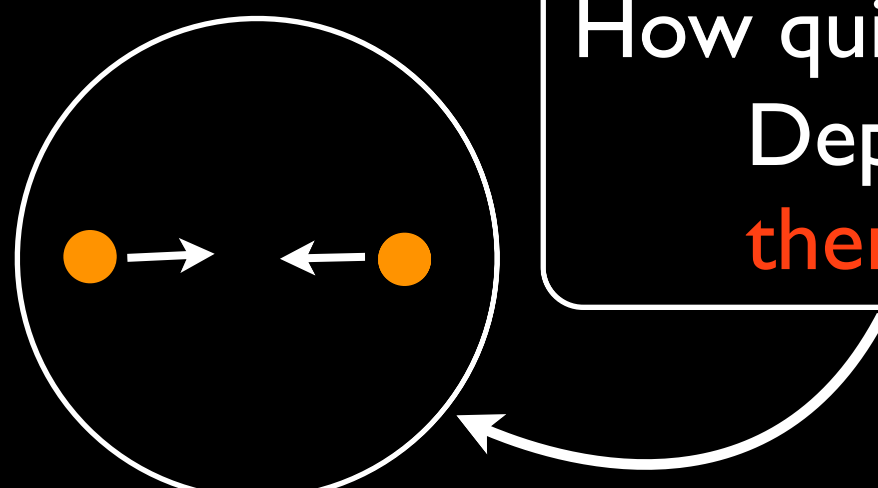


molecules in a hot region have more energy → collide with cold molecules → and transfer energy

Heat Transfer: Conduction

Conduction: heat transfer from contact





How quick is the energy transfer?
Depends the material's
thermal conductivity, k

molecules in a hot region have more energy → collide with cold molecules → and transfer energy

Heat Transfer: Conduction

Table 16.2 Thermal Conductivities*

	Thermal Conductivity, k	
Material	**SI Units: W/m·K**	**British Units: Btu·in./h·ft^2·°F**
Air	0.026	0.18
Aluminum	237	1644
Concrete (varies with mix)	1	7
Copper	401	2780
Fiberglass	0.042	0.29
Glass	0.7–0.9	5–6
Goose down	0.043	0.30
Helium	0.14	0.97
Iron	80.4	558
Steel	46	319
Styrofoam	0.029	0.20
Water	0.61	4.2
Wood (pine)	0.11	0.78

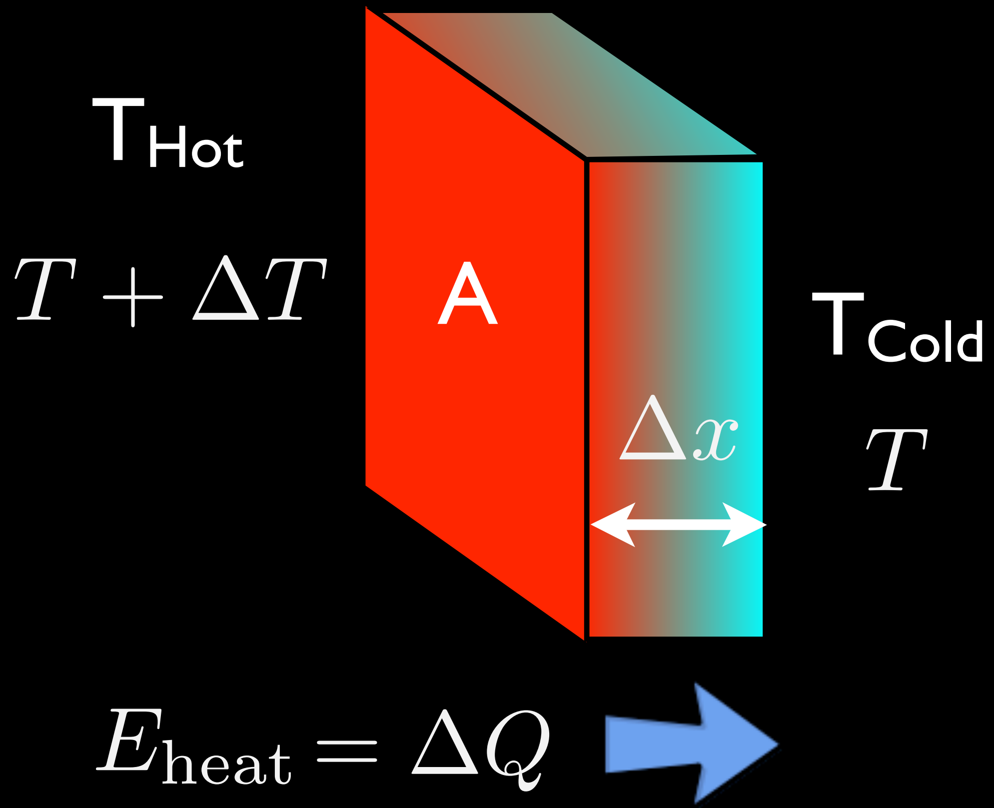
*Temperature range 0°C to 100°C.

metals are good thermal conductors:

contain free electrons that move fast

Styrofoam is an insulator because it traps air.

Heat Transfer: Conduction



Heat flow depends on...

- thermal conductivity, k ↑
- area, A ↑
- thickness, Δx ↓
- temperature difference, ΔT ↑

Conductive heat flow: $H = -kA\dfrac{\Delta T}{\Delta x}$

$\dfrac{dQ}{dt}$

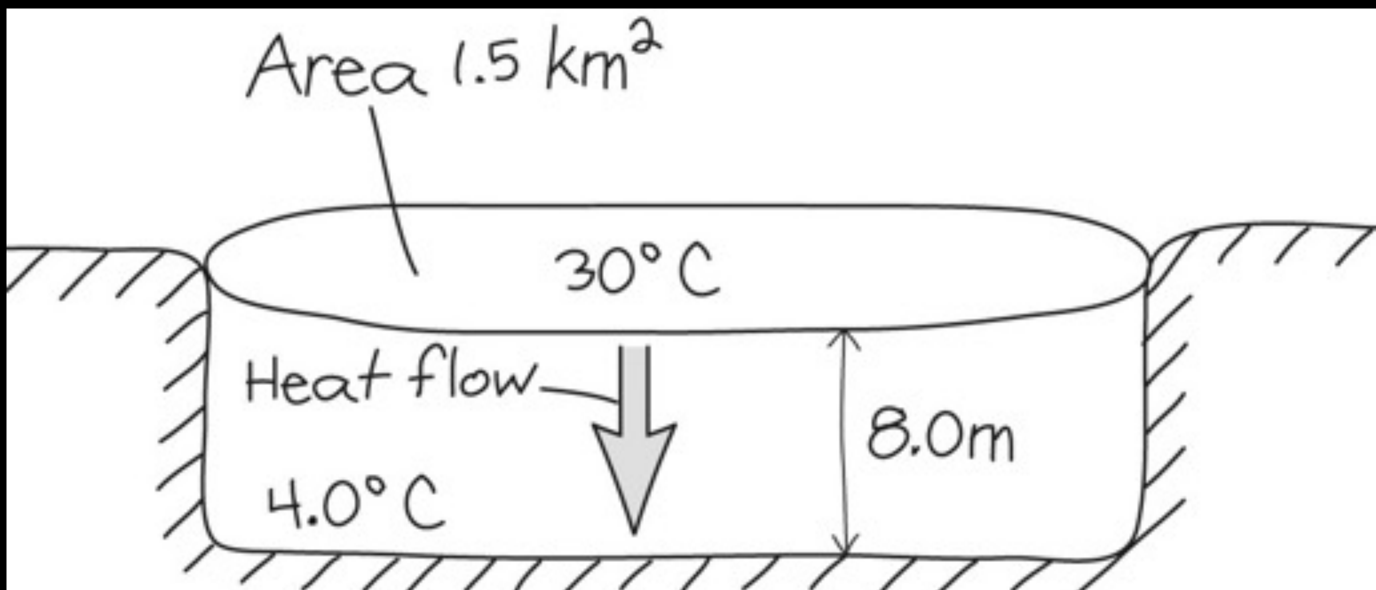
rate of heat flow [W]

$\longrightarrow \dfrac{dT}{dx}$

when area is not constant

Heat Transfer

Ex.



What is the rate of heat conduction through the lake?

Water thermal conductivity:

$k = 0.61\,\mathrm{W/m \cdot K}$

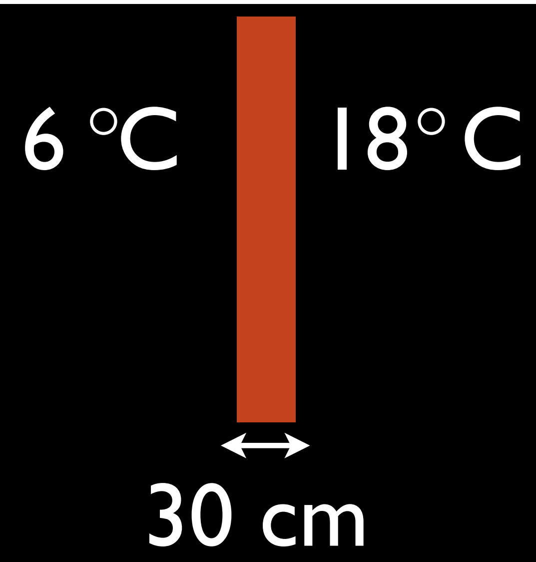
$$H = -kA\frac{\Delta T}{\Delta x}$$

$$= -(0.61\,\mathrm{W/m \cdot K})(1.5 \times 10^6\,\mathrm{m}^2)\frac{30°\mathrm{C} - 4.0°\mathrm{C}}{8.0\,\mathrm{m}}$$

$$= -3.0\,\mathrm{MW}$$

Heat Transfer

Quiz



A solid concrete wall with area 4.0 m x 2.4 m

Thermal conductivity, $k = 1.3\,\mathrm{W/m\cdot K}$

How much heat flow through the wall in 1 hour?

(A) 1.8 MJ

(B) 1.8 kJ

(C) 500 J

(D) 5.0 MJ

$$H = -kA\frac{\Delta T}{\Delta x}$$

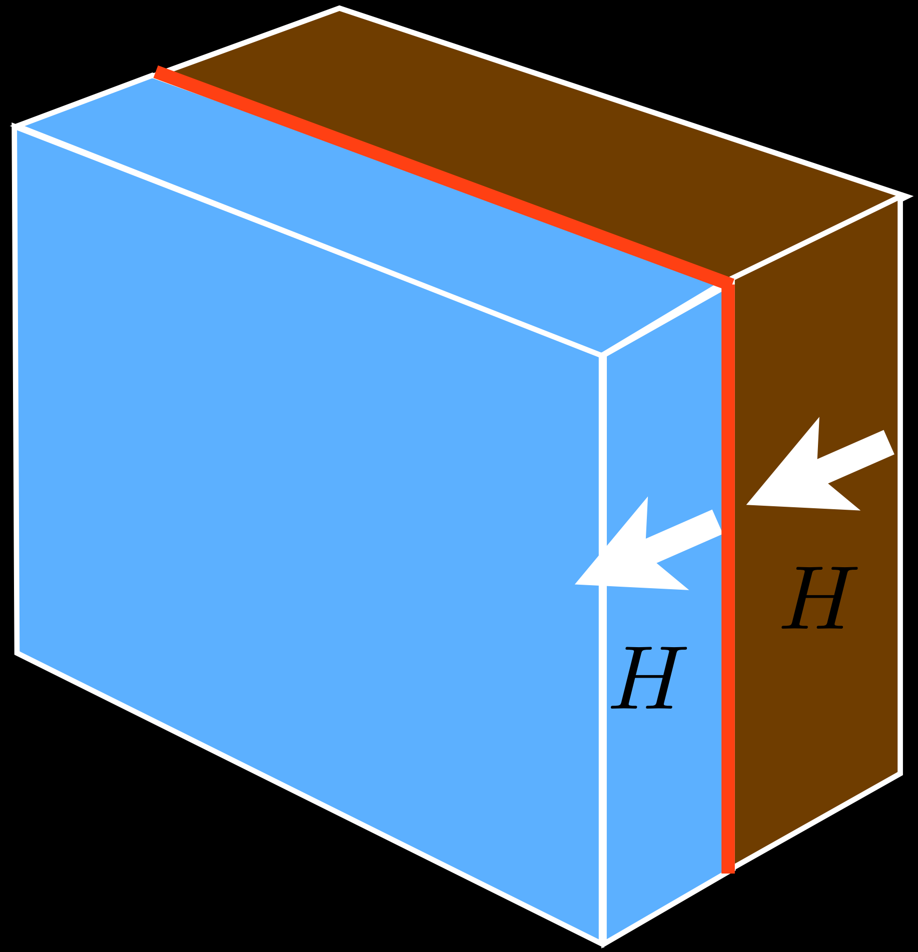
$$= -(1.3\,\mathrm{W/m\cdot K})(4.0\,\mathrm{m}\times 2.4\,\mathrm{m})\frac{6^\circ\mathrm{C} - 18^\circ\mathrm{C}}{0.3\,\mathrm{m}}$$

$$= 499.2\,\mathrm{W} = \frac{dQ}{dt}$$

$$Q = 499.2\,\mathrm{W}\times 3600\,\mathrm{s} \quad = 1.8\,\mathrm{MJ}$$

Heat Transfer: Conduction

What if heat flows through different materials?

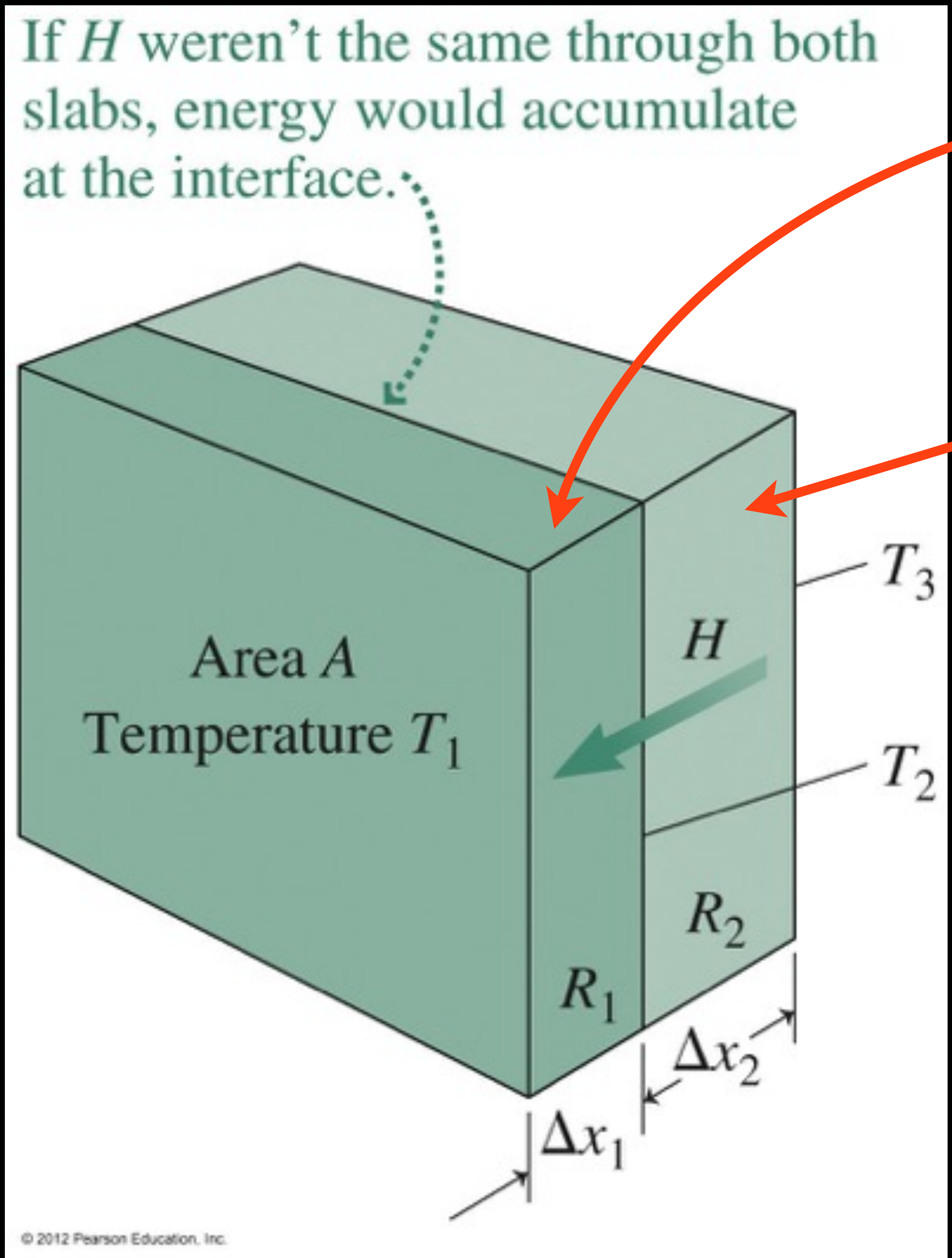


The heat flow rate, H, must be the same through each material....

... or it would collect between them

Therefore...

Heat Transfer: Conduction



$$H = -k_1 A \frac{T_2 - T_1}{\Delta x_1} = -k_2 A \frac{T_3 - T_2}{\Delta x_2}$$

Define: $$R = \frac{\Delta x}{kA}$$ Thermal resistance [K/W]

Property of material and geometry (shape)

$$H = -\frac{T_2 - T_1}{R_1} = -\frac{T_3 - T_2}{R_2}$$

Heat Transfer: Conduction

From: $$H = -\frac{T_2 - T_1}{R_1} = -\frac{T_3 - T_2}{R_2}$$

So: $R_1 H = T_1 - T_2$ & $R_2 H = T_2 - T_3$

Adding: $$(R_1 + R_2)H = T_1 - T_2 + T_2 - T_3$$

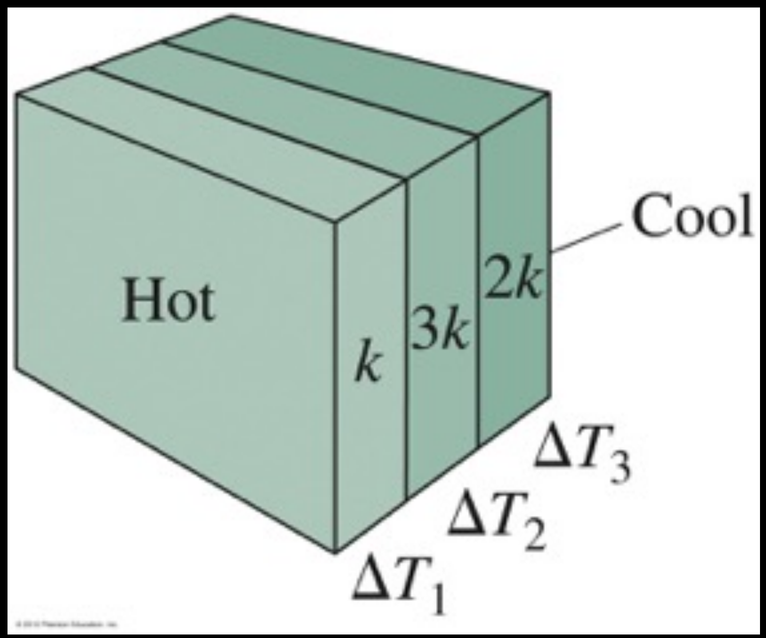
$$= T_1 - T_3$$

$$\boxed{H = \frac{T_1 - T_3}{R_1 + R_2}}$$

Composite slab acts like a single slab with R = R1 + R2.

Heat Transfer

Quiz



3 slabs:

Same area, A, and same thickness, x.

Different thermal conductivities, k

Which has the greatest temperature difference between its faces?

(A) ΔT_1

(B) ΔT_2

(C) ΔT_3

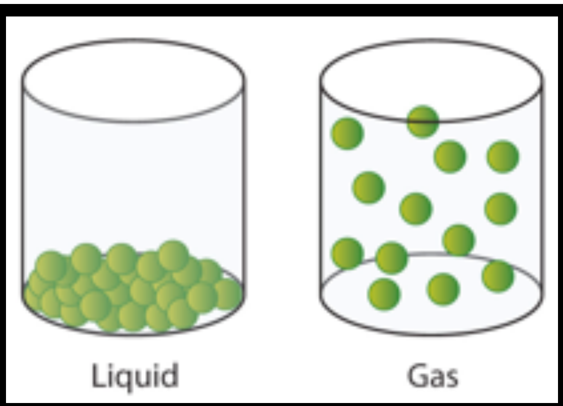
$$H = -\frac{\Delta T_1}{R_1} = -\frac{\Delta T_1}{R_2} = -\frac{\Delta T_1}{R_3}$$

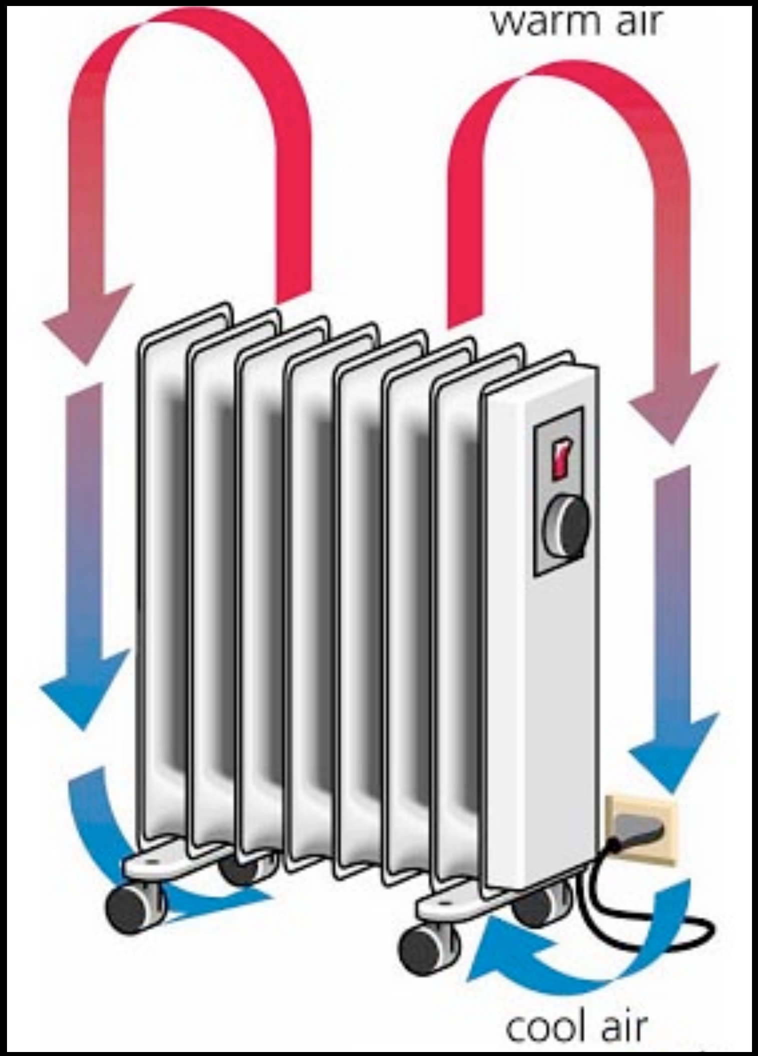
$$-\Delta T_1(k) = -\Delta T_2(3k) = -\Delta T(2k)$$

$$\Delta T_1 = 3\Delta T_2 = 2\Delta T_3$$

Heat Transfer: Convection

Convection: heat transfer by fluid motion

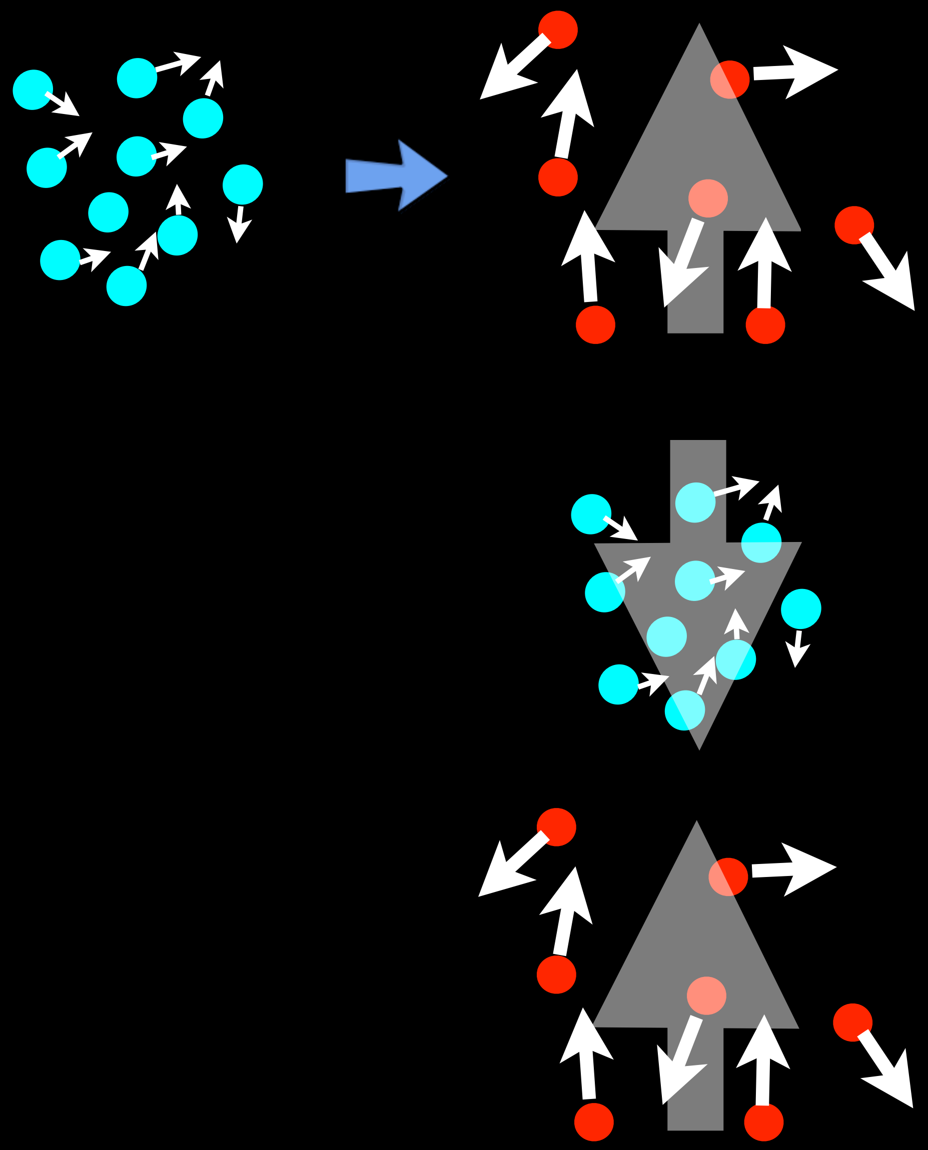




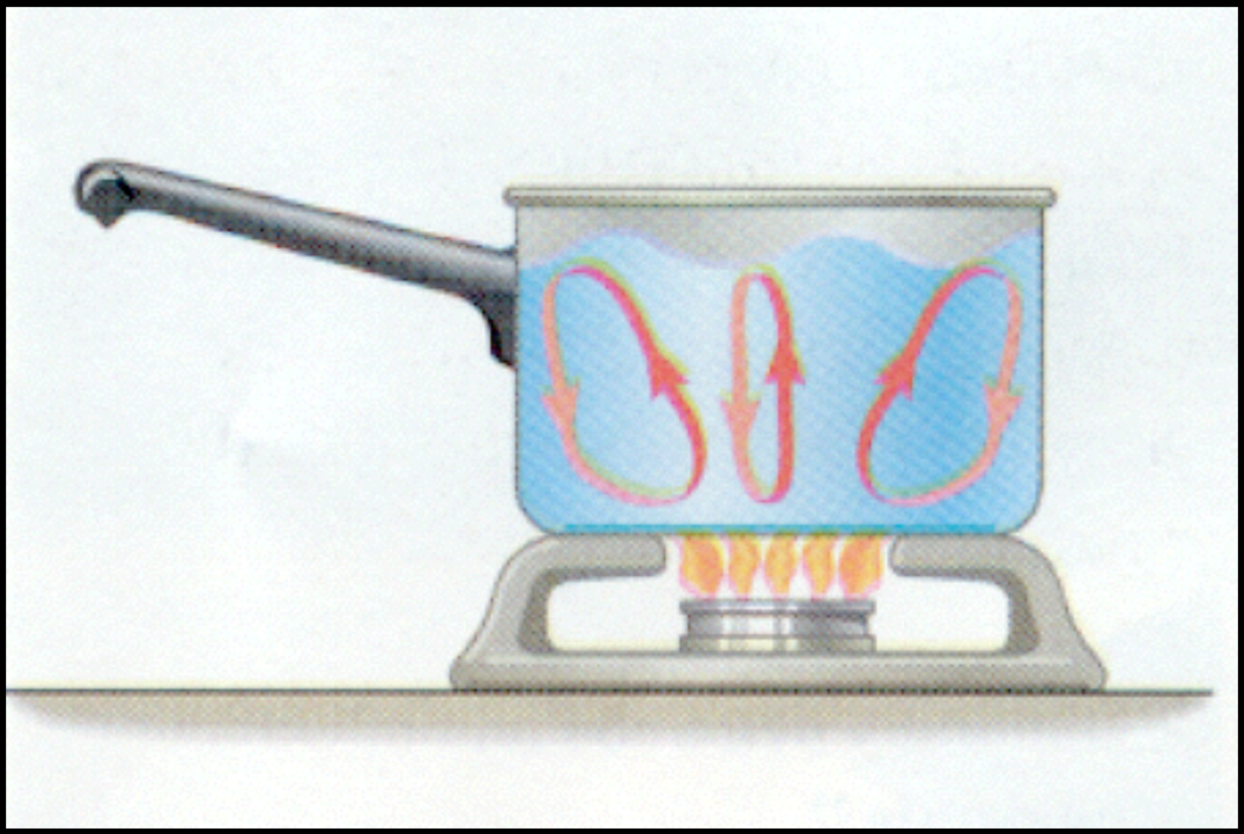
Heated fluid becomes less dense and rises

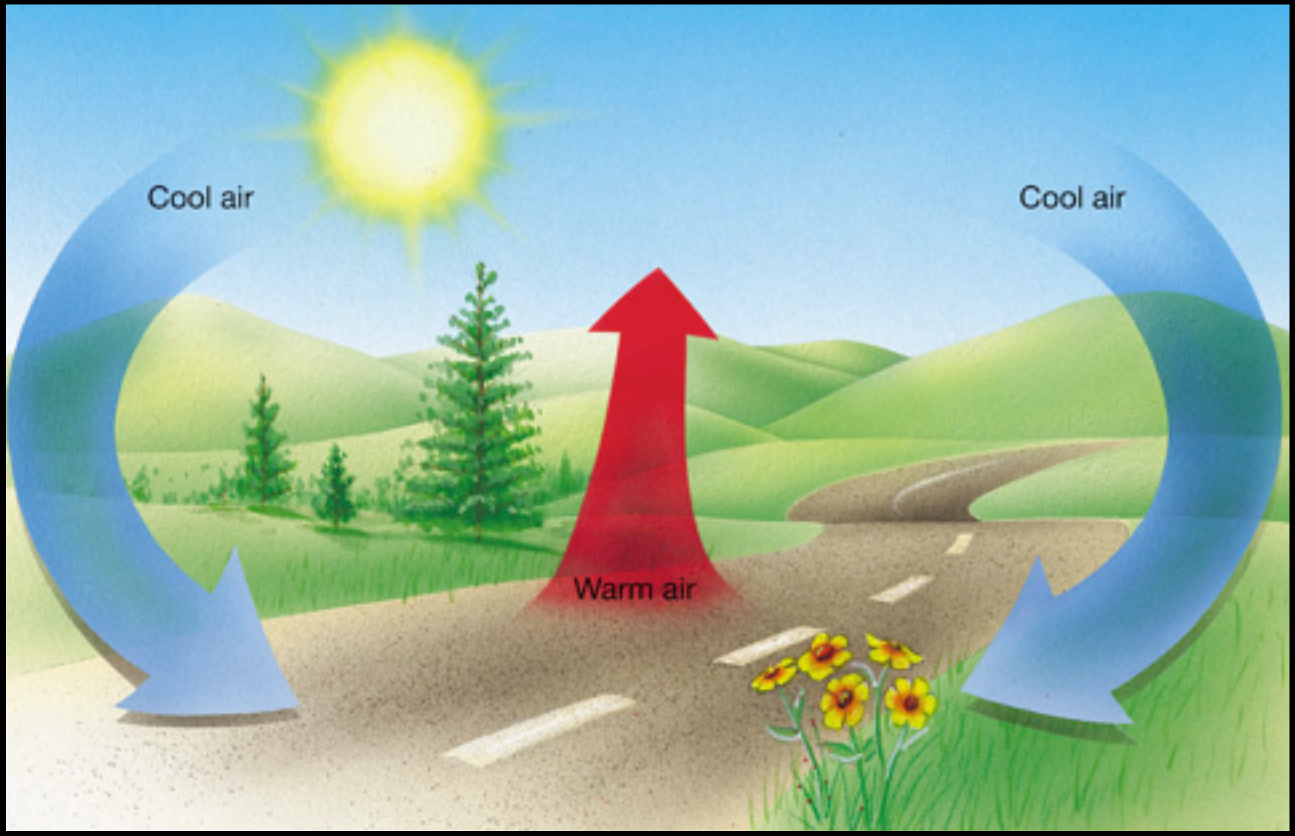
It cools and sinks

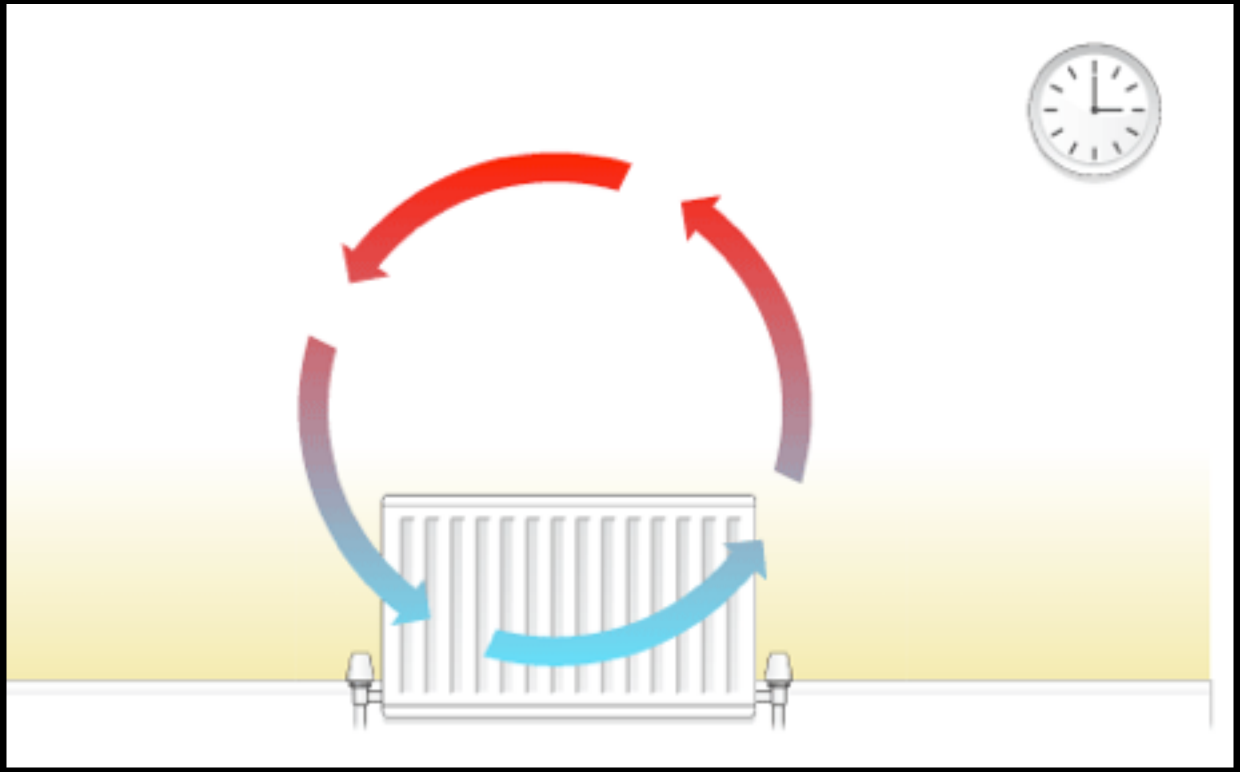
Heats again and rises

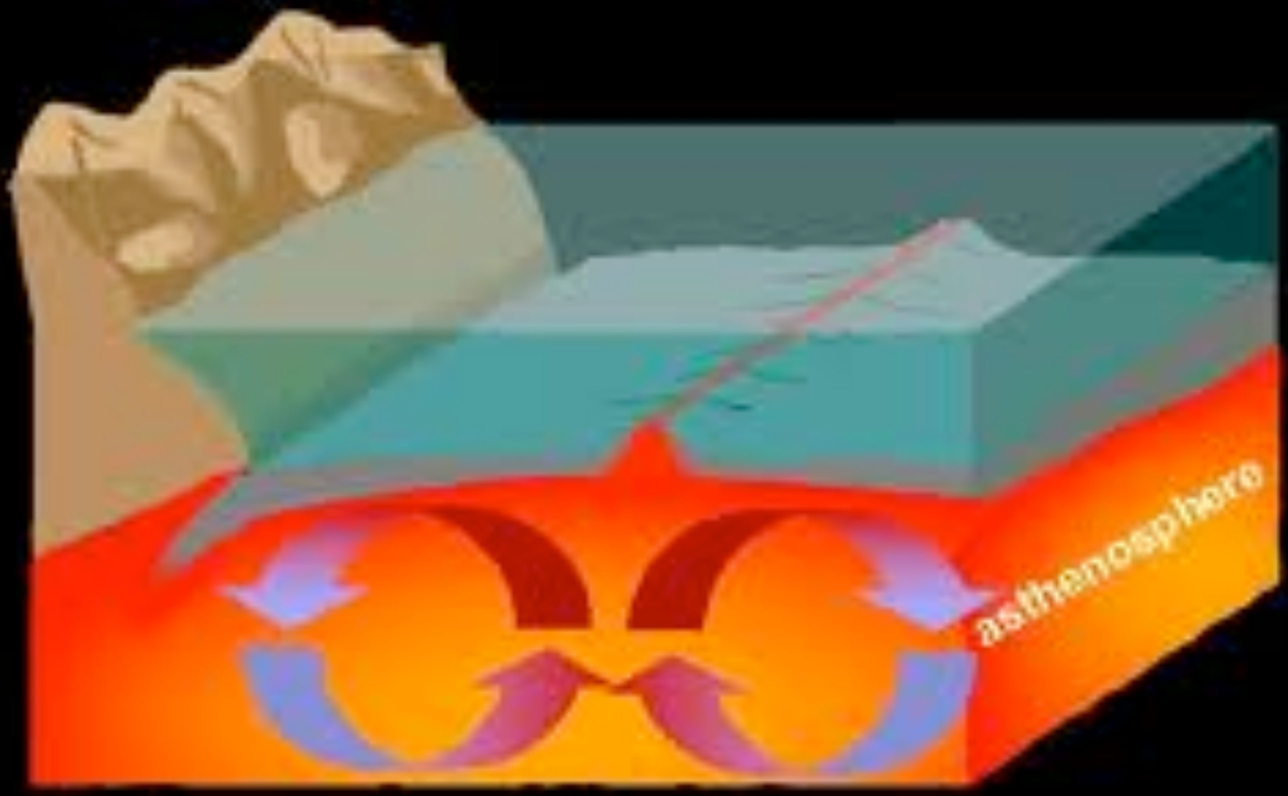


Heat Transfer: Convection



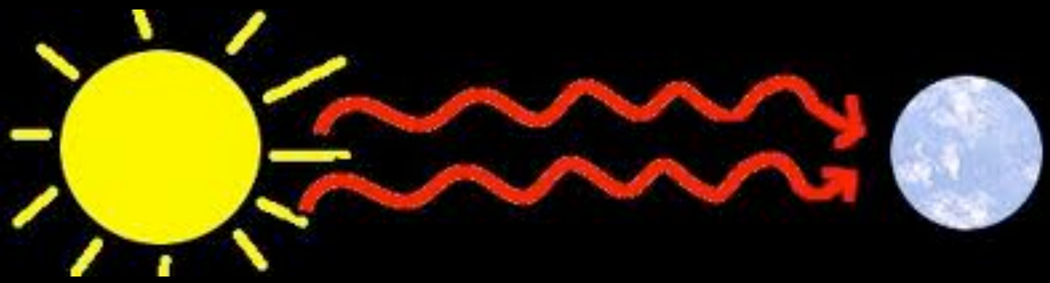




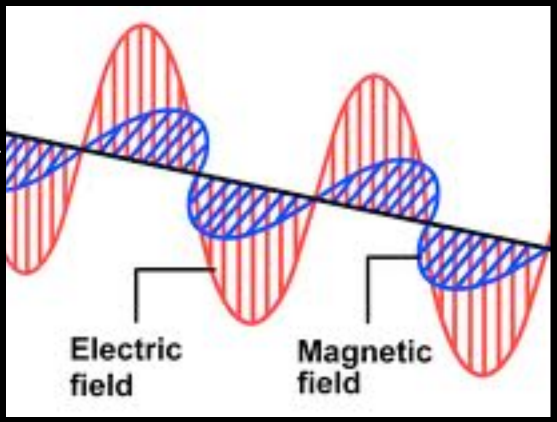


Heat Transfer: Radiation

How do you feel heat from a stove? .... or the sun? .... or a lightbulb?



Electromagnetic waves or radiation



Heat Transfer: Radiation

$$P = \epsilon\sigma A T^4$$

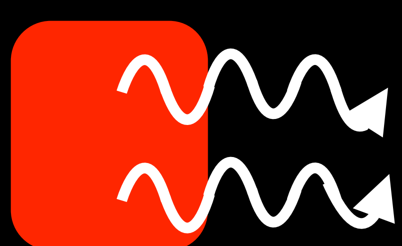
object temperature

Stefan-Boltzmann law

$$\sigma = 5.67 \times 10^{-8}\,\mathrm{W/m^2 \cdot K^4}$$

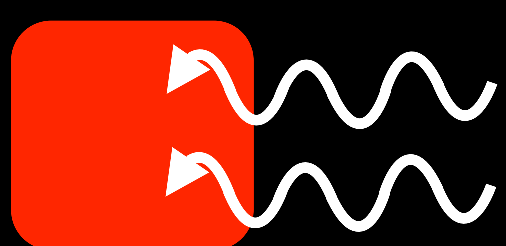
emissivity:

between 0 - 1, measures ability to emit radiation



object emit radiation but....

... they also absorb radiation



Rate of absorption: $P = \epsilon\sigma A T_{\mathrm{a}}^4$ background temperature

Net radiated power: $P = \epsilon\sigma A(T^4 - T_a^4)$

Ignore if object T >> background T :

sun = ignore

human body = important

Heat Transfer: Radiation

$P = \epsilon \sigma A T^4$

$P \propto T^4$ ➡ At high T, radiation is **dominant** heat loss mechanism

... at low T, radiation is less important

In a vacuum (e.g. space) : **only radiation**

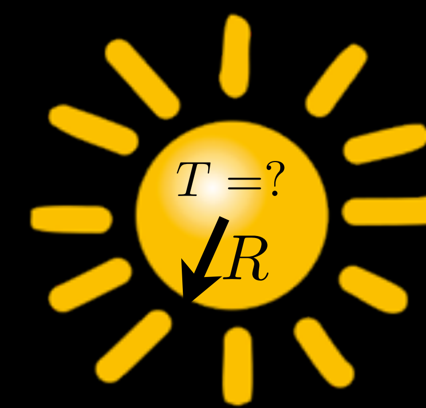
[conduction & convection need a material (e.g. air) to transfer heat]

Heat Transfer: Radiation

Ex.

A perfect emitter : $\epsilon = 1$ blackbody
(and absorber)

e.g.
The Sun



The Sun radiates energy at the rate $P = 3.9 \times 10^{26}\ \mathrm{W}$
and its radius is $7.0 \times 10^{8}\ \mathrm{m}$. What is its surface T?

$$P = \epsilon \sigma A T^4$$

$$A = 4\pi R^2$$
$$\epsilon = 1$$

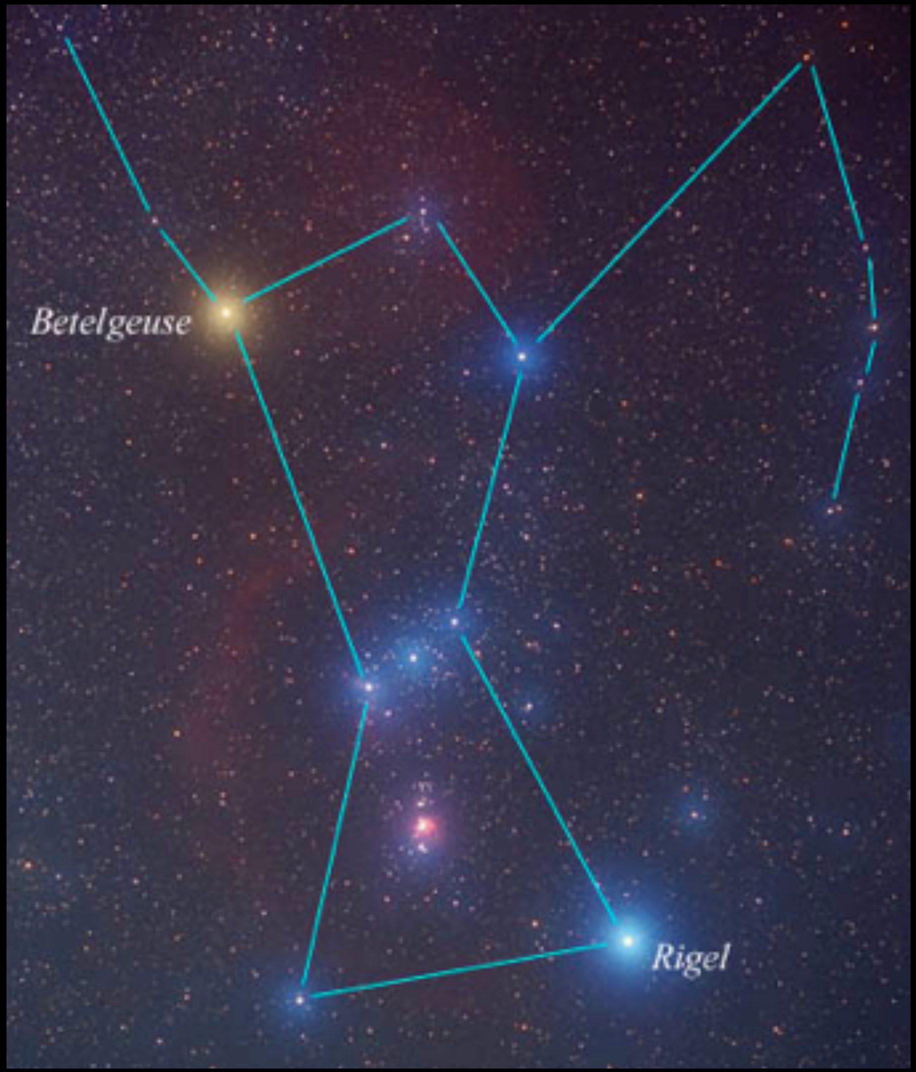
$$T = \left(\frac{P}{4\pi R^2 \sigma} \right)^{1/4}$$

$$= \left[\frac{3.9 \times 10^{26}\ \mathrm{W}}{4\pi (7.0 \times 10^{8}\ \mathrm{m})^2 (5.7 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4})} \right]^{1/4}$$

$$= 5.8 \times 10^{3}\ \mathrm{K}$$

Heat Transfer: Radiation

Quiz



Betelgeuse is a red super giant star

Radiates heat at the rate of $2.70 \times 10^{30}\,\mathrm{W}$

Surface T $= 3000\,\mathrm{K}$

Assuming it is a perfect emitter ($\epsilon = 1$),

what is the radius?

$\sigma = 5.67 \times 10^{-8}\,\mathrm{W/m^2 \cdot K^4}$

(A) $7.80 \times 10^{11}\,\mathrm{m}$

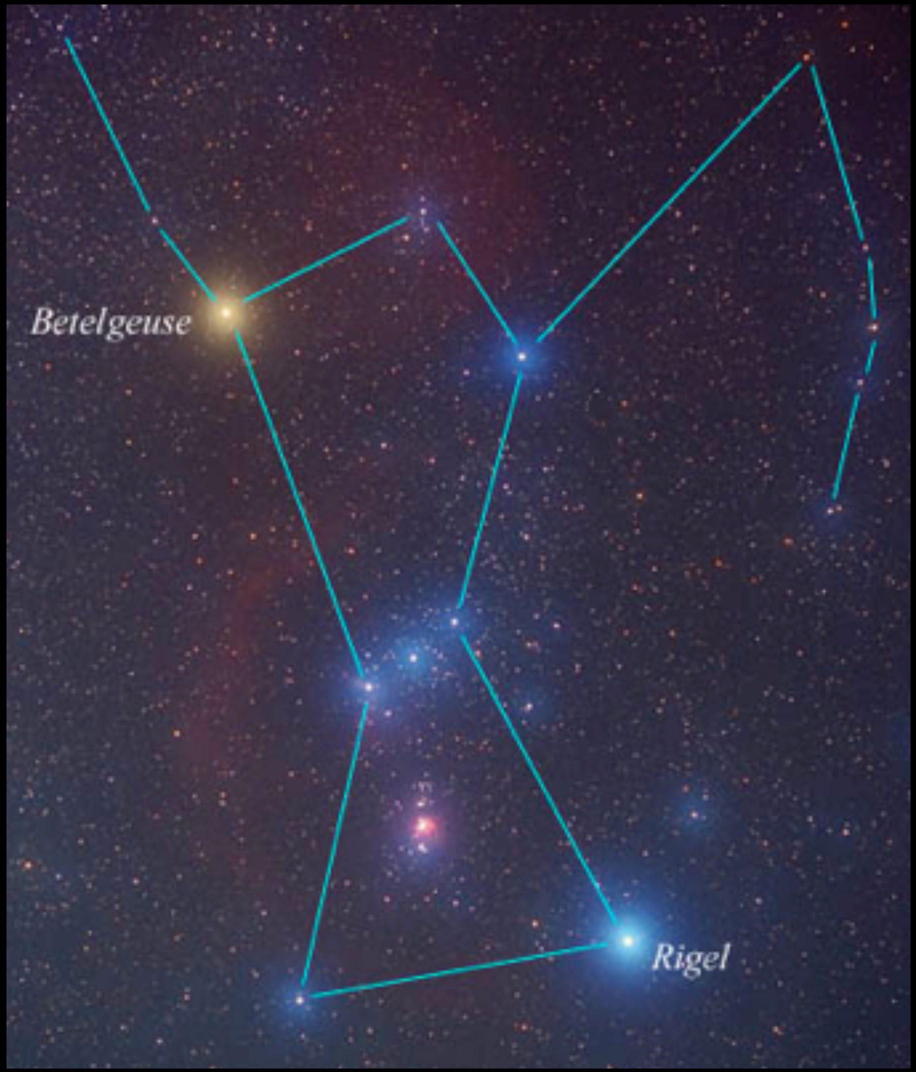
(B) $8.70 \times 10^{11}\,\mathrm{m}$

(C) $1.90 \times 10^{11}\,\mathrm{m}$

(D) $2.16 \times 10^{11}\,\mathrm{m}$

Heat Transfer: Radiation

Quiz



Betelgeuse is a red super giant star

Radiates heat at the rate of $2.70 \times 10^{30}\ \mathrm{W}$

Surface T $= 3000\,\mathrm{K}$

Assuming it is a perfect emitter ($\epsilon = 1$),

what is the radius?

$$P = \epsilon\sigma A T^4 \longrightarrow A = \frac{P}{\sigma T^4}$$

$$4\pi R^2 = \frac{P}{\sigma T^4} \longrightarrow R = \sqrt{\frac{P}{4\pi\sigma T^4}}$$

$$R = \sqrt{\frac{(2.70 \times 10^{30}\ \mathrm{W})}{4\pi(5.67 \times 10^{-8}\ \mathrm{W/m^2 \cdot K^4})(3000\,\mathrm{K})^4}} = 2.16 \times 10^{11}\ \mathrm{m}$$

Heat Transfer

Quiz

What is the dominant (main) form of heat transfer from a red-hot stove burner with nothing on it.

(A) conduction

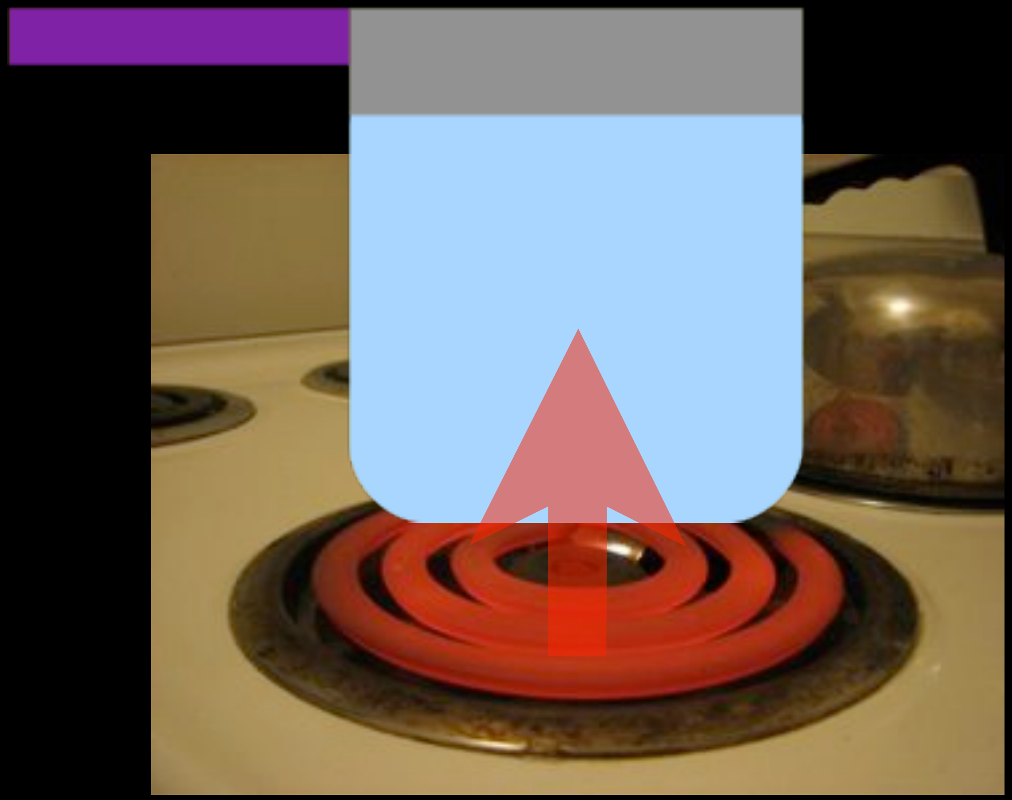
(B) convection

(C) radiation

(D) insulation

Heat Transfer

What is the dominant (main) form of heat transfer from a red-hot stove burner to a pot.



(A) conduction

(B) convection

(C) radiation

(D) insulation

Heat Transfer Quiz

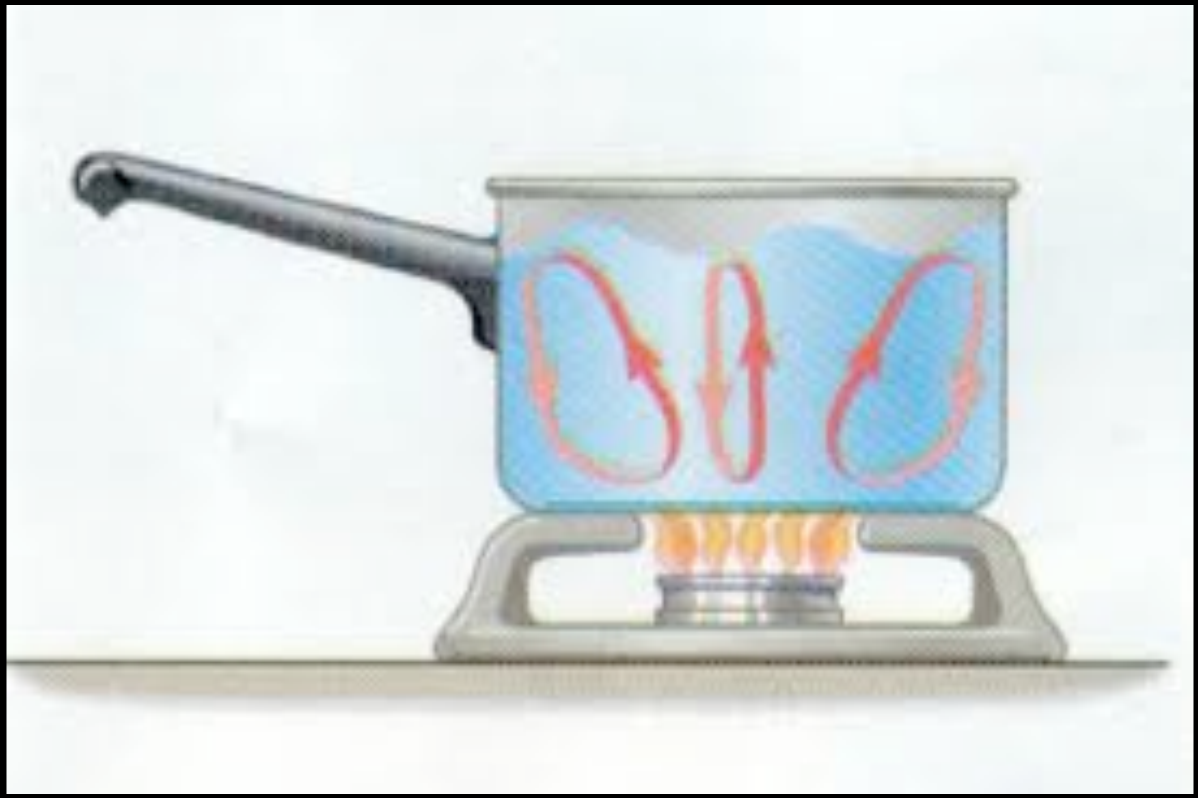
What is the dominant (main) form of heat transfer from the bottom to the top of a pot containing boiling water.

(A) conduction

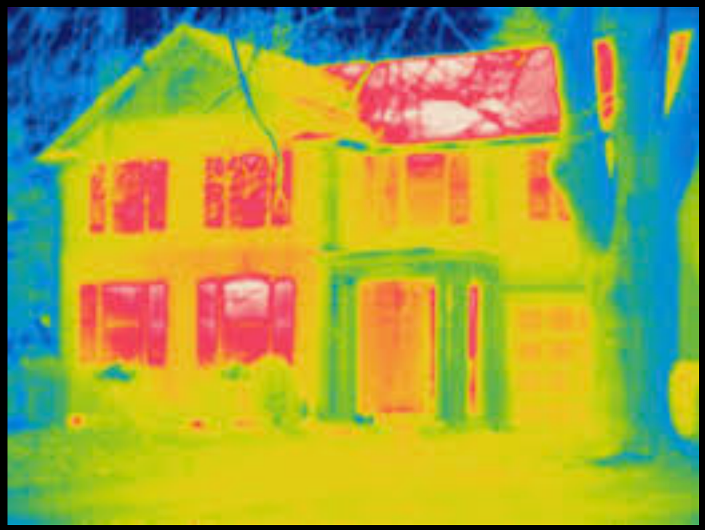
(B) convection

(C) radiation

(D) insulation



Thermal - Energy Balance



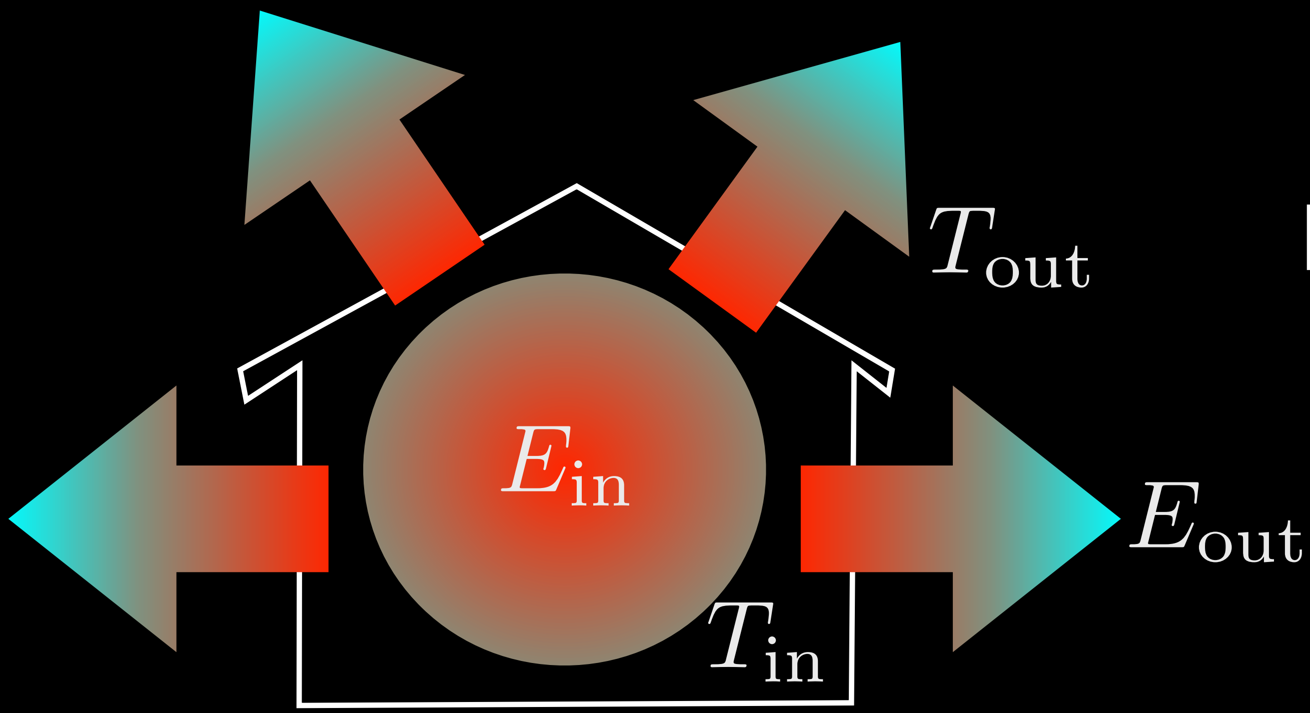
heat loss

You home is warm in winter ...

... but it is losing energy

Heat loss $E_{\text{out}} \propto T_{\text{in}} - T_{\text{out}}$

$$\propto \Delta T$$



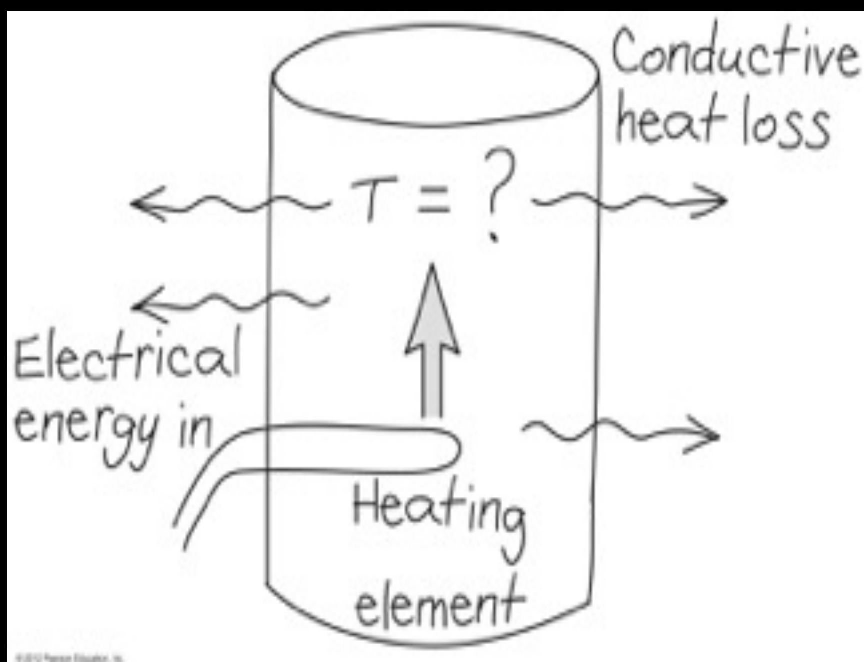
House stays warm if:

heat loss rate = heat in rate

$$\frac{dE_{\text{out}}}{dt} = \frac{dE_{\text{in}}}{dt}$$

Thermal - Energy Balance Ex.

A water heater loses heat at a rate of 120 W for each Celsius degree difference between the water and outside.



$$\frac{dE_{\text{out}}}{dt} = (120\,\text{W}/°\text{C})(\Delta T)$$

$$\Delta T = T_{\text{in}} - T_{\text{out}}$$

It is heated by a 2.5 kW heater and the outside T = 15 °C

What is the water temperature?

Thermo-energy balance: $$\frac{dE_{\text{out}}}{dt} = \frac{dE_{\text{in}}}{dt}$$

$$(120\,\text{W}/°\text{C})(\Delta T) = 2.5 \times 10^3\,\text{W} \longrightarrow \Delta T = 21°\text{C}$$

$$T_{\text{in}} = 21°\text{C} + 15°\text{C} \ = 36°\text{C}$$