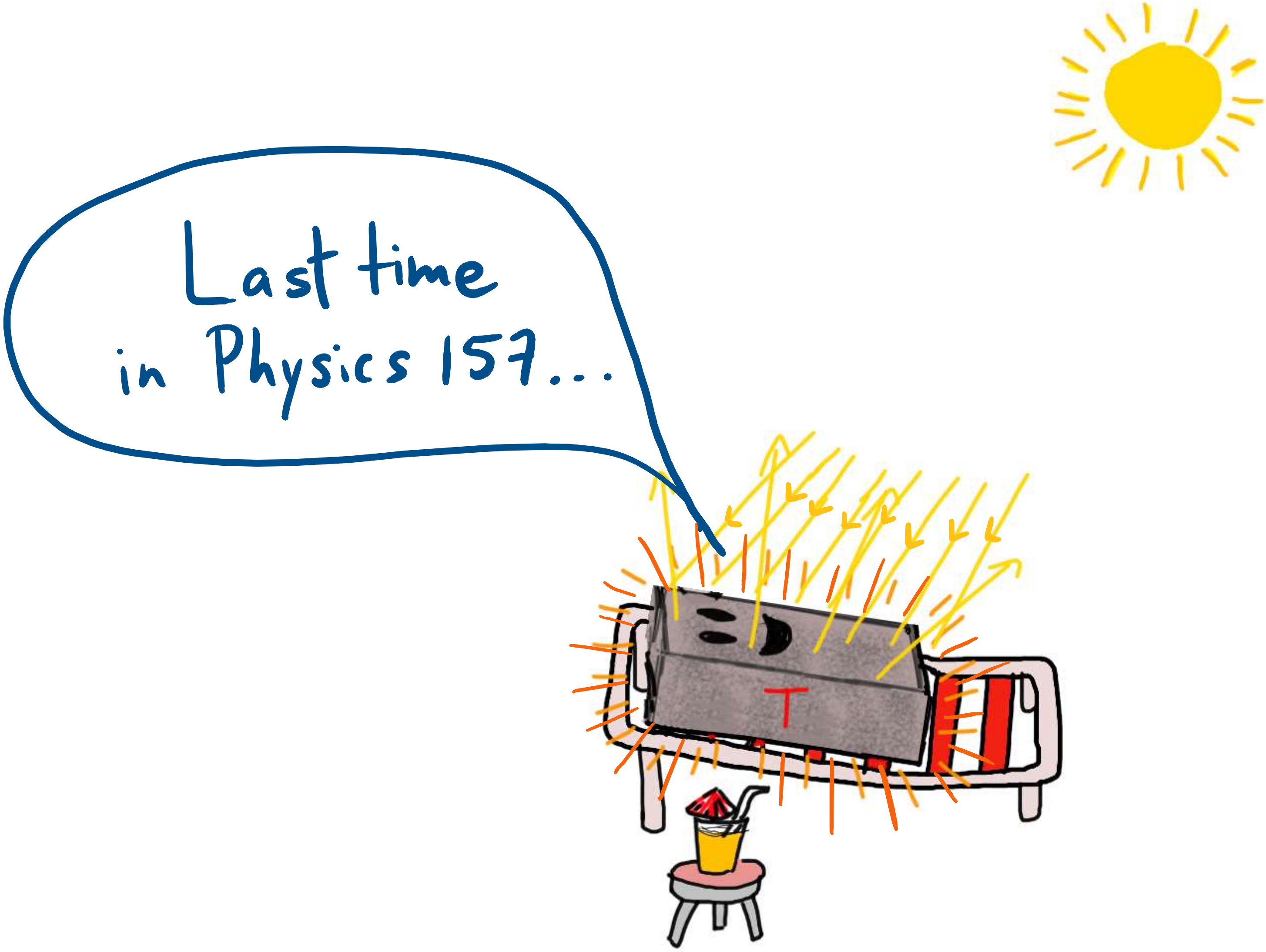
No tutorials this week! Midterm tonight!

Office hours today: after class in Remo

Learning goals for today

- Explain quantitatively how the intensity of light from an object radiating uniformly in all directions varies with the distance to the object
- Describe which molecular properties of a gas affect the pressure on the walls of a container, and what proportionality relationship each of these quantities has with the pressure
- Describe the microscopic origin of the ideal gas law


Last time
in Physics 157...
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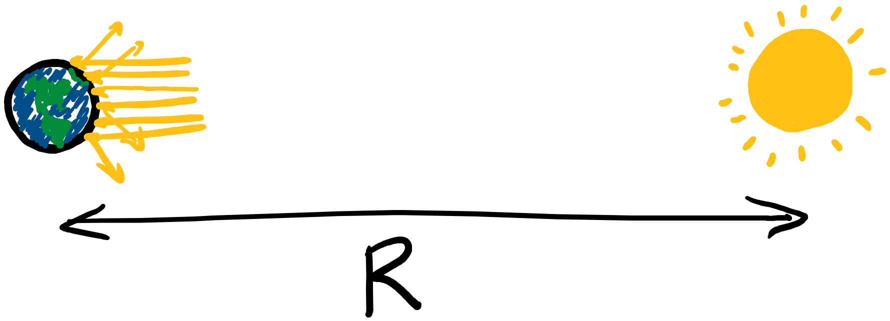
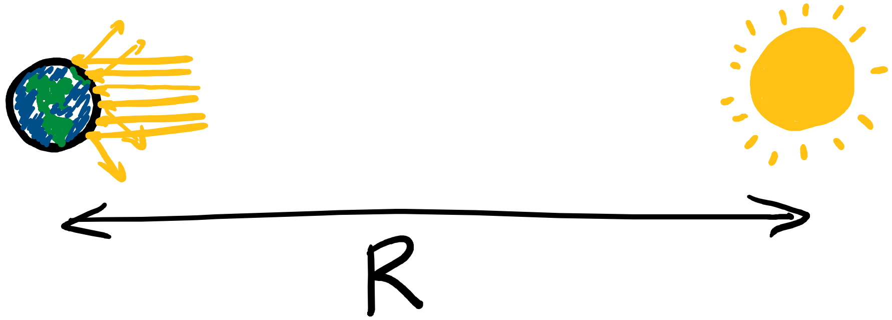


If we moved the Earth twice as far away from the Sun, the power of solar radiation hitting the Earth would be

A) twice as much as before.
B) the same as before.
C) half as much as before
D) one quarter as much as before.
E) one eighth as much as before.



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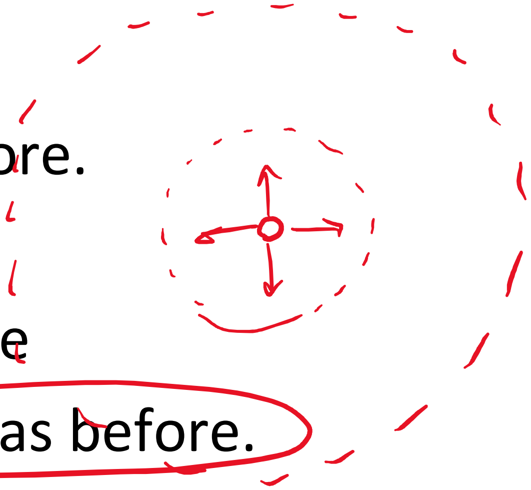


A) twice as much as before.

B) the same as before.

C) half as much as before

[✓ D) one quarter as much as before.]

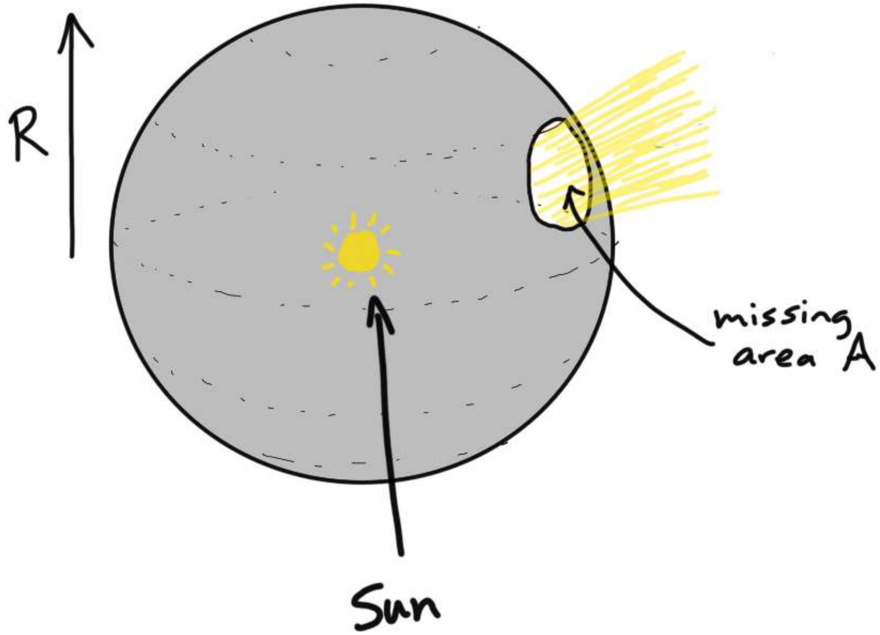
E) one eighth as much as before.

At twice the distance, sunlight spreads over 4 x the area, so Power/Area is $\frac{1}{4}$

↑ intensity

No tutorials this week.

Midterm Q&A
Tuesday 5-7
Henn 202



Power through hole is

$$H_{sun} \cdot \frac{A}{4\pi R^2}$$

INTENSITY of sunlight (power per area) is

$$I = \frac{H_{sun}}{4\pi R^2} \longrightarrow \text{double } R \Rightarrow \frac{1}{4} I$$

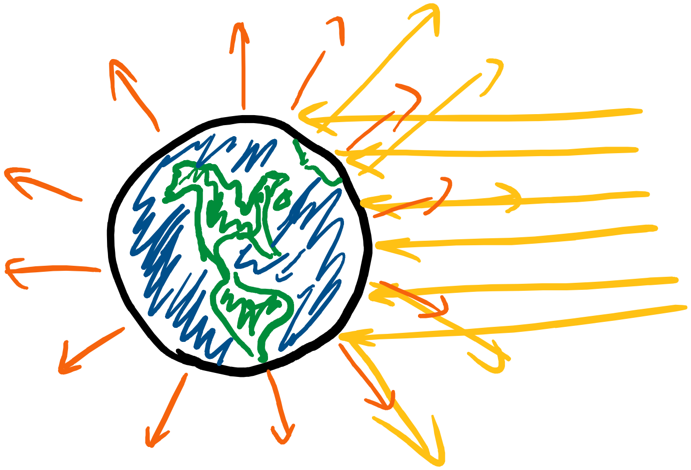
At distance of Earth, $I = I_{sc} = 1367 \ W/m^2$

Key relation for steady-state heat flow:

$$H_{in} = H_{out}$$

$$H_{in} \rightarrow \boxed{\text{const } T} \rightarrow H_{out}$$

Our problem:



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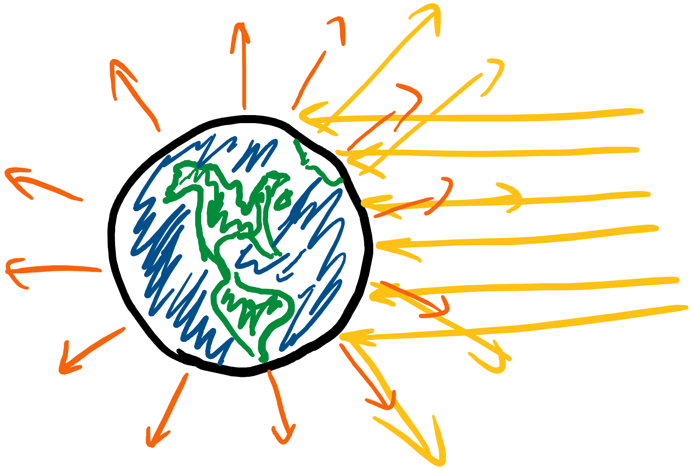

H_{out}: $\overset{\text{thermal}}{\text{IR}}$ radiation

$$= \underset{\nwarrow A_{surface}}{(4\pi r^2)}\, e\, \sigma\, T^4$$

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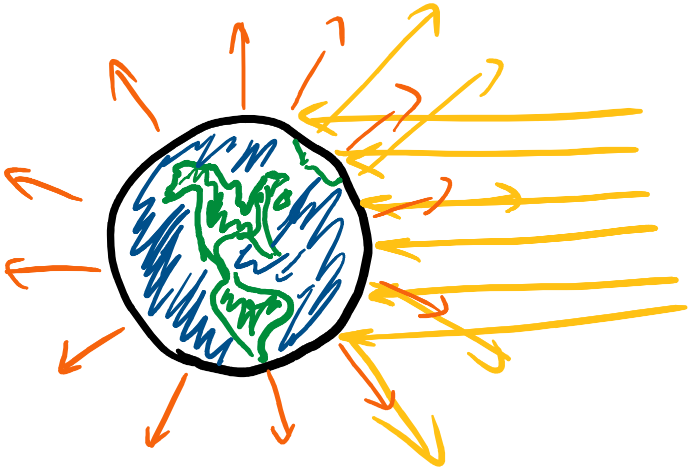

H_{out}: thermal IR radiation

$$= \underbrace{(4\pi r^2)}_{A_{surface}} e \sigma T^4$$

H_{in}: absorbed sunlight

$$I_{sc} \cdot \pi r^2 \cdot (1 - \underbrace{a}_{\text{albedo = fraction reflected}})$$

★ set equal & solve for T ★

Result:

$$T = \left(\frac{I_{sc} \cdot (1-a)}{4 e \sigma} \right)^{\frac{1}{4}}$$

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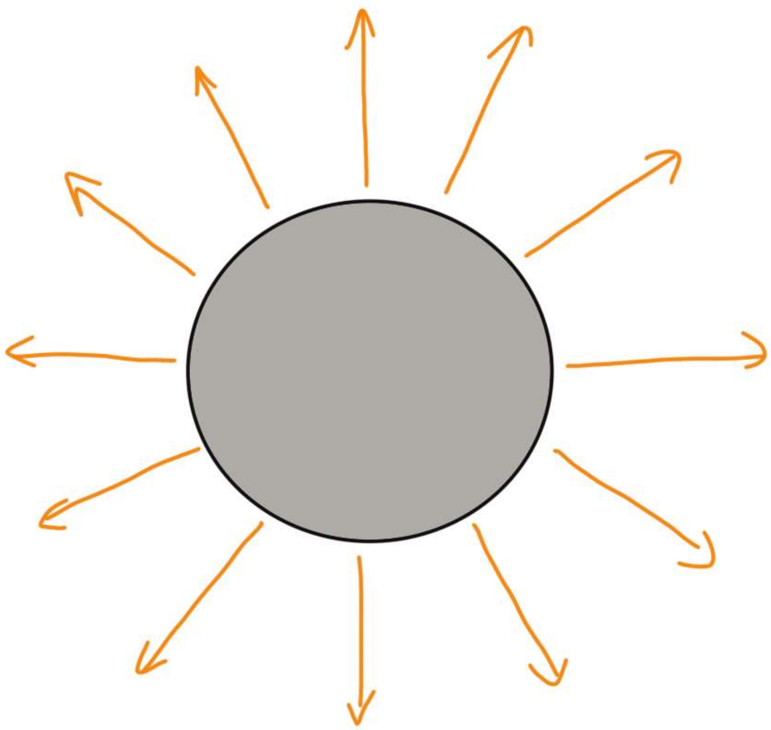
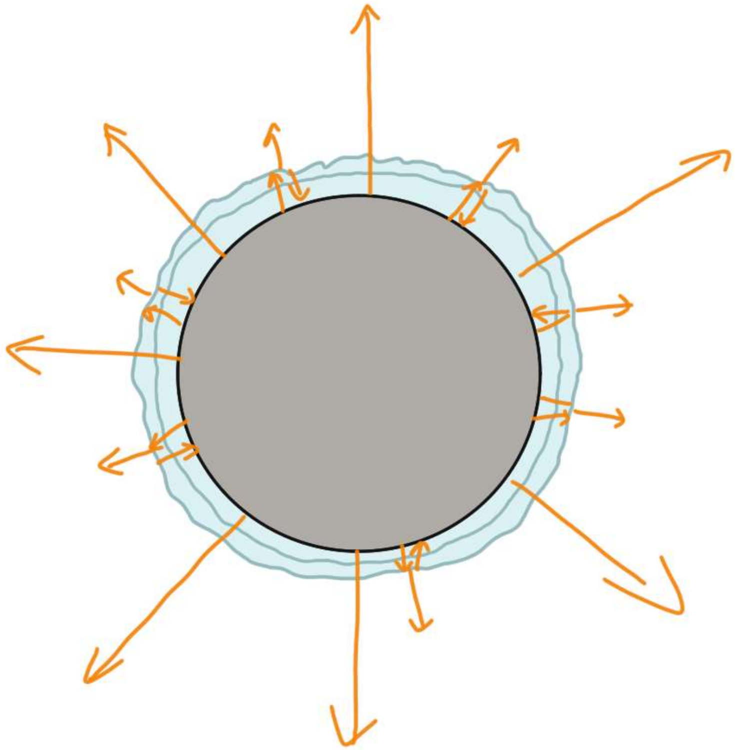


No atmosphere: $e \approx 1$

$T \approx -18°C$



Effect of greenhouse gases

$e \approx 0.6$ $T = 14.5C$

2. Mars albedo, the reflection coefficient for sunlight from Mars, is 0.250. The radius of Mars is 3397 km. The Solar constant at Earth is 1367 W/m^2 and the distance from Mars to the Sun is 1.52 times the Earth to Sun distance.

a) Find the temperature of Mars.

power of absorbed sunlight

↓

Q: Write an expression for H_{in} in terms of the information provided

(you don't need to evaluate it)

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power of absorbed sunlight

Q: Write an expression for H_{in} in terms of the information provided

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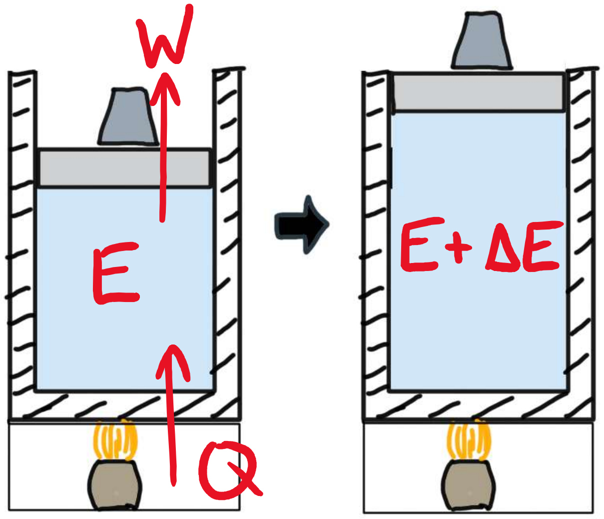
for Earth $H_{in} = I_{sc} \times \pi r_E^2 \times (1-a_E)$

for Mars: $H_{in} = I_{Mars} \times \pi r_M^2 \times (1-a_M)$

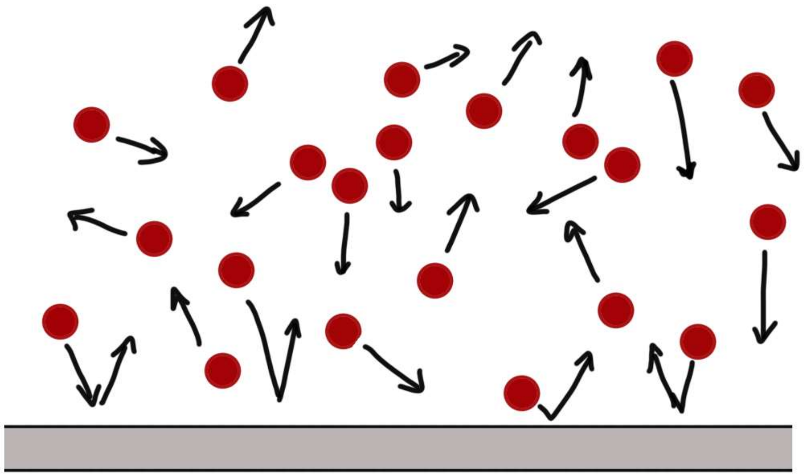
$R_{Mars} = 1.52\, R_{Earth}$ so $I_{Mars} = \frac{1}{1.52^2} I_{Earth}$

New Topic: PUTTING GASES TO WORK!



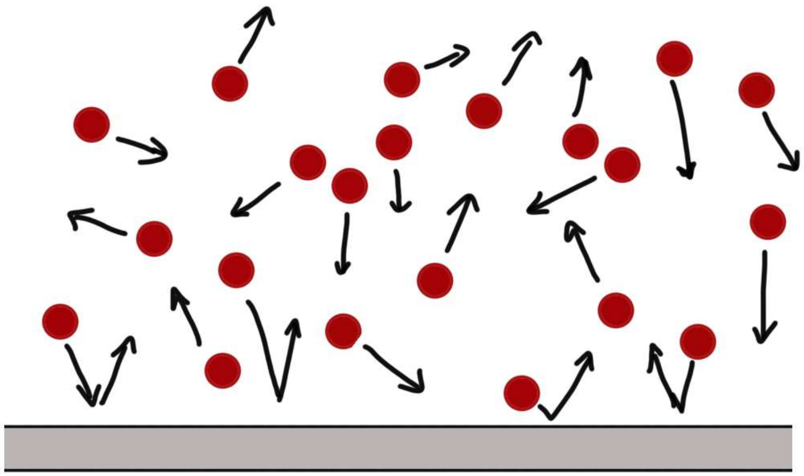
$$\Delta E_{gas} = Q - W$$

work done by gas



The picture shows molecules of an ideal gas near the wall of a container. What properties of these molecules does the pressure on the wall (force per unit area) depend on?

EXTRA: for each quantity you identify, what would happen to the pressure if you double that quantity?



The picture shows molecules of an ideal gas near the wall of a container. What properties of these molecules does the pressure on the wall (force per unit area) depend on?

double density → double P

double mass → double P

double velocity → quadruple P

(twice as many collisions
twice as much impact)

$$P = \text{const} \cdot \frac{\overset{\text{density}}{N}}{V} \cdot \overbrace{m \cdot v_{avg}^2}^{\text{2x kinetic energy per molecule}}$$

TEMPERATURE + KINETIC ENERGY

If we define $T = \text{constant}_1 \times E_{kin}^{avg}$

Molecular model gives:

$$P = \text{constant}_2 \times \frac{N}{V} \times T$$

So P is proportional to T for fixed N, V

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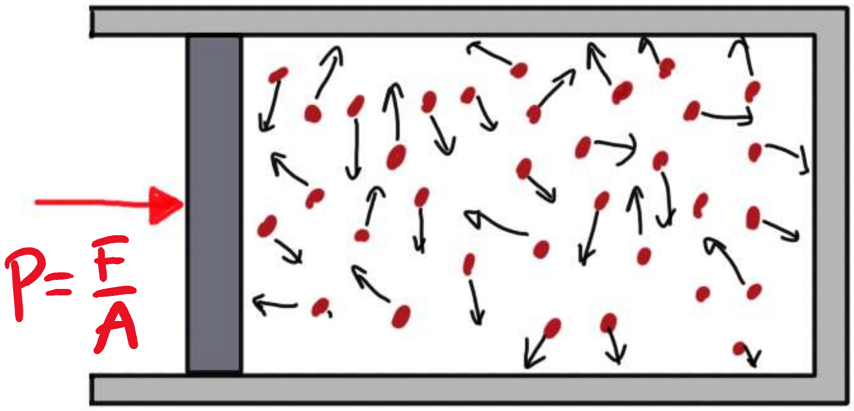
★ Molecular definition of temperature is consistent with Kelvin scale definition!

Definitions match exactly if:

$$\text{constant}_2 = \frac{8.31 \text{ J/mol·K}}{6.02 \times 10^{23}} \begin{array}{l} \leftarrow \text{call this } R \\ \leftarrow \text{this is } N_A \end{array}$$

IDEAL GAS LAW



$$P = \text{const} \cdot \overset{\text{molecular density}}{\frac{N}{V}} \cdot \overset{\text{avg. kinetic energy per molecule}}{E^{kin}_{avg}}$$

$$\Downarrow$$

$$PV = \underset{\text{\# moles}}{n} \cdot \underset{8.31 \frac{J}{mol \cdot K}}{R} \cdot T$$

Tells us how much force a gas exerts on the wall