Kinetic Molecular Theory

IB PHYSICS | THERMAL PHYSICS

Kinetic Theory of Gases

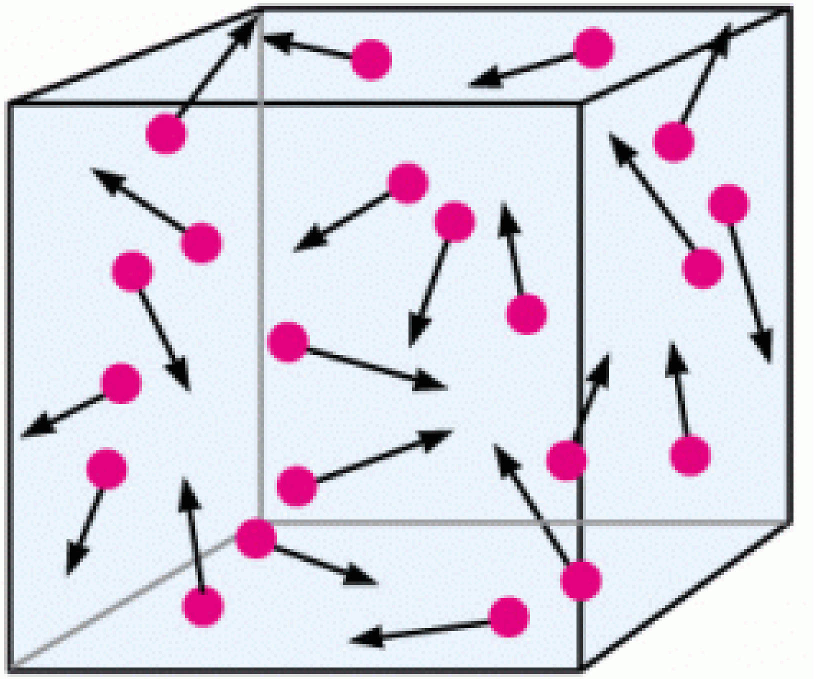
Assumptions:

- Large # of identical molecules
- Volume of molecules is negligible
- Motion is random
- No forces between molecules
- All collisions are elastic

Kinetic Energy is conserved

If these assumptions are true we have an

Ideal Gas



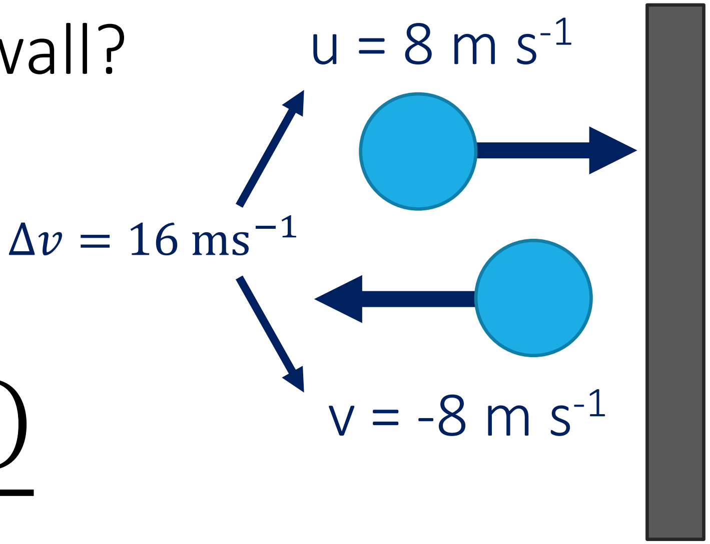
Review of Momentum / Collisions

What is the force of this ball on the wall?

$$Impulse = F\Delta t = \Delta p$$

$$F = \frac{\Delta p}{\Delta t} = \frac{m\Delta v}{\Delta t} = \frac{(5)(16)}{(0.2)}$$

$$\boxed{F = 400\ \text{N}}$$



m = 5 kg

$\Delta t = 0.2\ \text{s}$

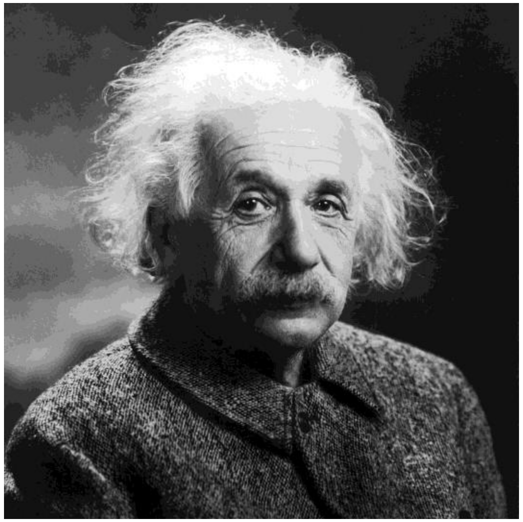
Pressure

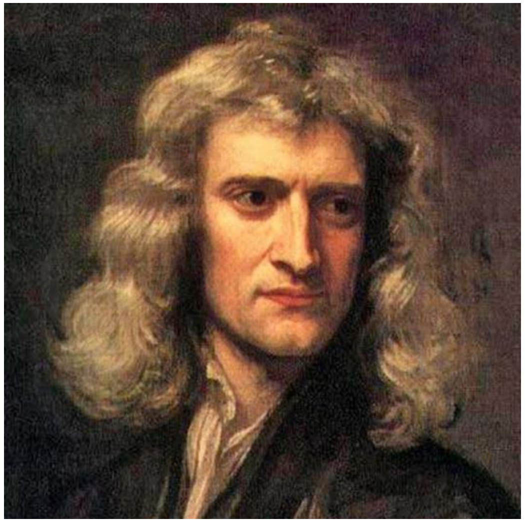
When many molecules collide with the sides of a container it is measured as **pressure**

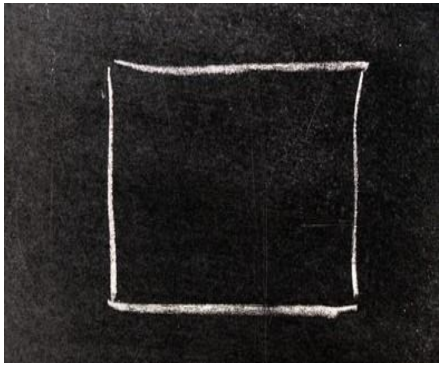
Quantity	Symbol	Unit
Force	F	$[\mathrm{N}]$
Area	A	$[\mathrm{m}^2]$
Pressure	p	$[\mathrm{N\ m}^{-2}] = [\mathrm{Pa}]$ Pascal

$$p = \frac{F}{A}$$

A brief interlude…







$$\frac{N}{m^2} = Pa$$

Units of Pressure

There are several different units used to measure pressure of a gas

1 atm = 101,325 Pa = 760 Torr = 760 mm Hg

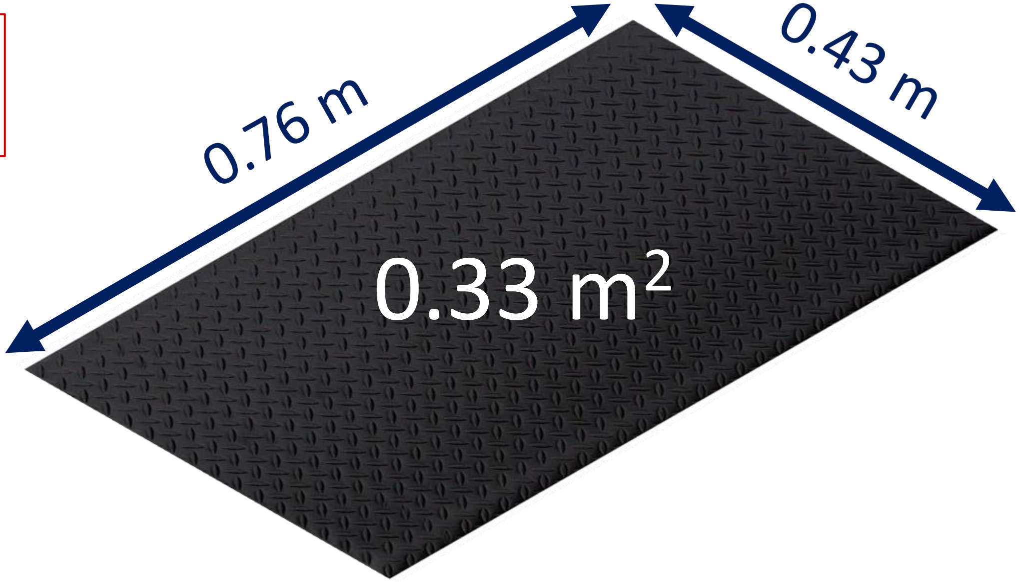
100 kPa *is a pretty good approximation*

Atmospheric Pressure

What is the force from atmospheric pressure on this doormat?

$$(101{,}325\ N\ m^{-2})(0.33\ m^{2})$$

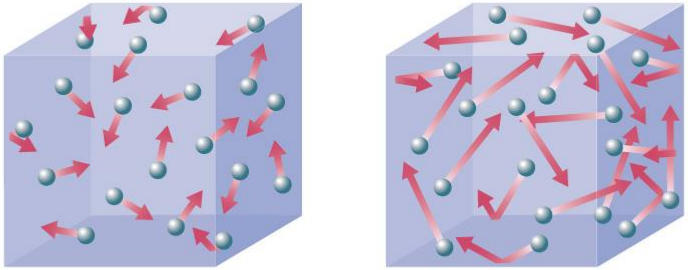
$$\boxed{F = 33{,}100\ N}$$



Temperature Review

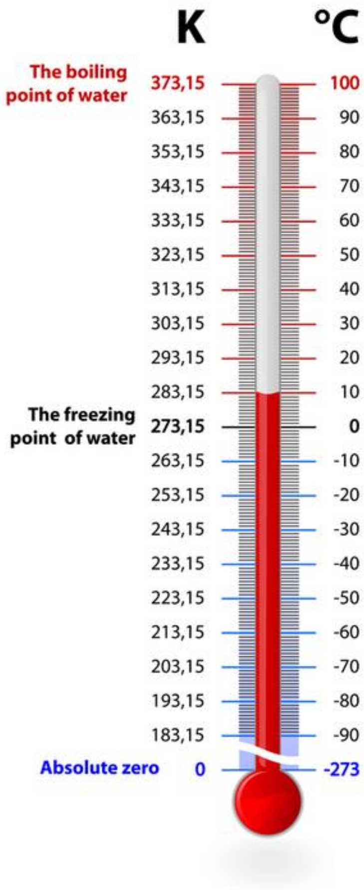
Measure of how hot or cold something feels

Temperature is the average kinetic energy of the molecules of a substance



Kelvin Scale (K)

Absolute Temperature



Average Kinetic Energy

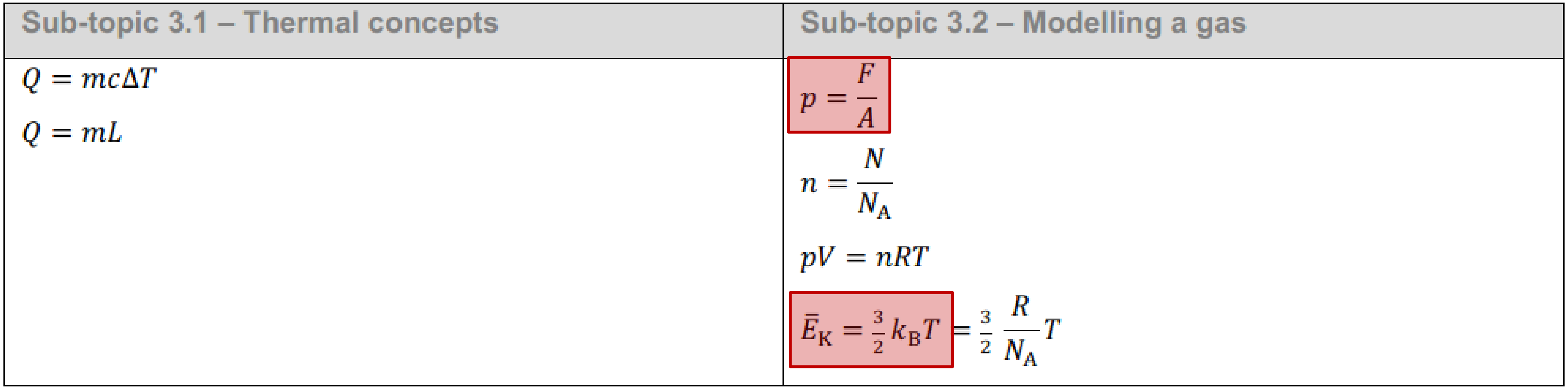
$$\bar{E}_K = \frac{3}{2} k_B T$$

$k_B \rightarrow Boltzmann's\ constant$

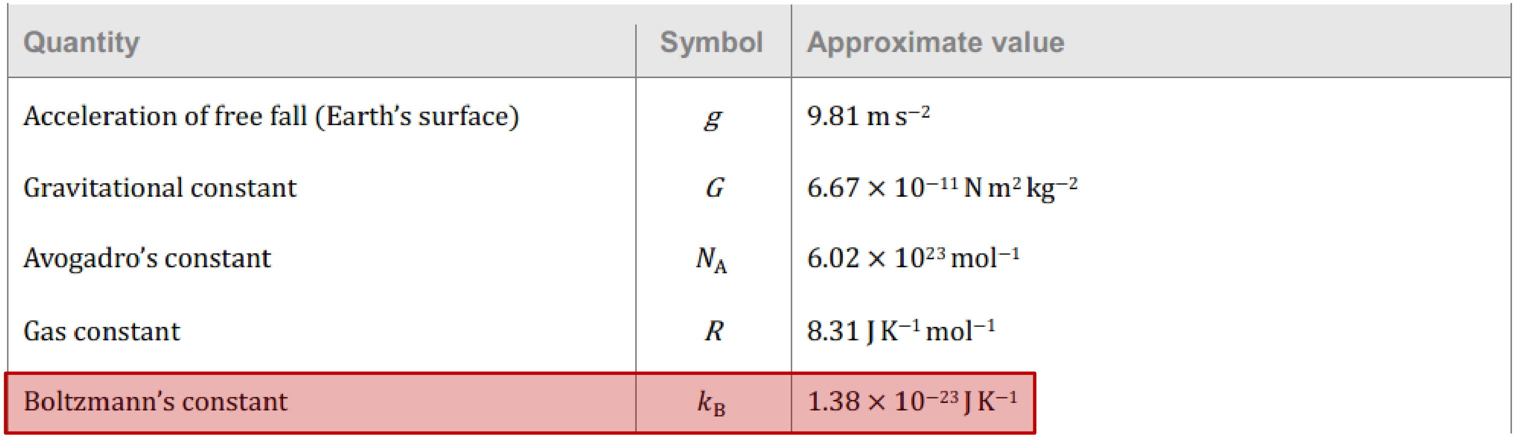
$k_B = 1.38 \times 10^{-23}\ J\ K^{-1}$

Quantity	Symbol	Unit
Average Kinetic Energy	$\bar{E}_K$	[J]
Absolute Temperature	T	[K]

IB Physics Data Booklet



Sub-topic 3.1 – Thermal concepts	Sub-topic 3.2 – Modelling a gas
$Q = mc\Delta T$ $Q = mL$	$p = \frac{F}{A}$ $n = \frac{N}{N_A}$ $pV = nRT$ $\bar{E}_K = \frac{3}{2}k_B T = \frac{3}{2}\frac{R}{N_A}T$



Quantity	Symbol	Approximate value
Acceleration of free fall (Earth's surface)	g	$9.81\ \mathrm{m\ s^{-2}}$
Gravitational constant	G	$6.67 \times 10^{-11}\ \mathrm{N\ m^2\ kg^{-2}}$
Avogadro's constant	N_A	$6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
Gas constant	R	$8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$

Try This | 1

Calculate the average translational kinetic energy of molecules in the air at 27°C

$k_B = 1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$

$T = 27°\mathrm{C} + 273 = 300\ \mathrm{K}$

$$\bar{E}_k = \frac{3}{2} k_B T = \frac{3}{2}(1.38 \times 10^{-23})(300)$$

$$\boxed{\bar{E}_k = 6.21 \times 10^{-21}\ \mathrm{J}}$$

What is Kinetic Energy?

$$\bar{E}_K = \frac{3}{2}k_B T$$

$k_B \rightarrow Boltzmann's\ constant$

$k_B = 1.38 \times 10^{-23}\ J\ K^{-1}$

$$\bar{E}_K = \frac{1}{2}mv^2$$

Try This | 2

Calculate the average speed for oxygen molecules at 0°C.
(the mass of an oxygen molecule is 5.32×10^{-26} kg)

$m = 5.32 \times 10^{-26}\ \mathrm{kg}$
$k_B = 1.38 \times 10^{-23}\ \mathrm{J\ K^{-1}}$
$T = 0°\mathrm{C} + 273 = 273\ \mathrm{K}$

$$\bar{E}_k = \frac{3}{2}k_B T = \frac{1}{2}mv^2$$

$$\frac{3}{2}(1.38 \times 10^{-23})(273) = \frac{1}{2}(5.32 \times 10^{-26})v^2$$

$$5.62 \times 10^{-21}\ \mathrm{J} = \frac{1}{2}(5.32 \times 10^{-26})v^2$$

$$\boxed{\boldsymbol{v = 461\ \mathrm{ms}^{-1}}}$$

Which molecules move faster?

H_2 gas at 23°C

1

H

1.01

$$\bar{E}_k = \frac{1}{2}mv^2$$

If the gases have the same kinetic energy (temp), the lighter one must be moving faster

O_2 gas at 23°C

8

O

16.00

Lesson Takeaways

- ☐ I can describe the conditions necessary for a substance to be considered an ideal gas
- ☐ I can define pressure with appropriate fundamental and derived units
- ☐ I can relate average molecular kinetic energy with absolute temperature
- ☐ I can calculate the average molecule speed for a molecule at a certain temperature
- ☐ I can discuss how the mass of a molecule changes its overall speed at a given temperature