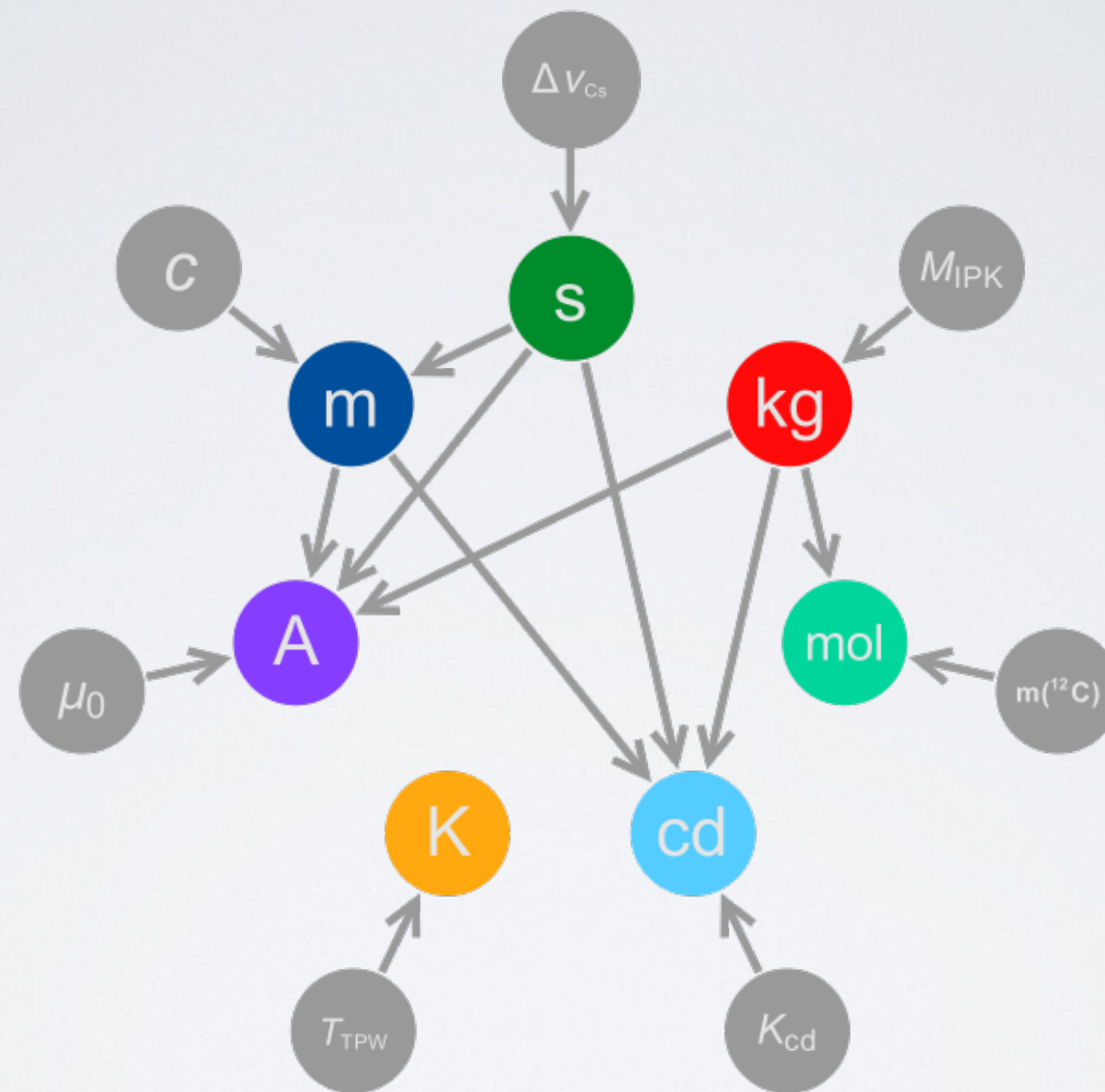


FUNDAMENTAL UNITS



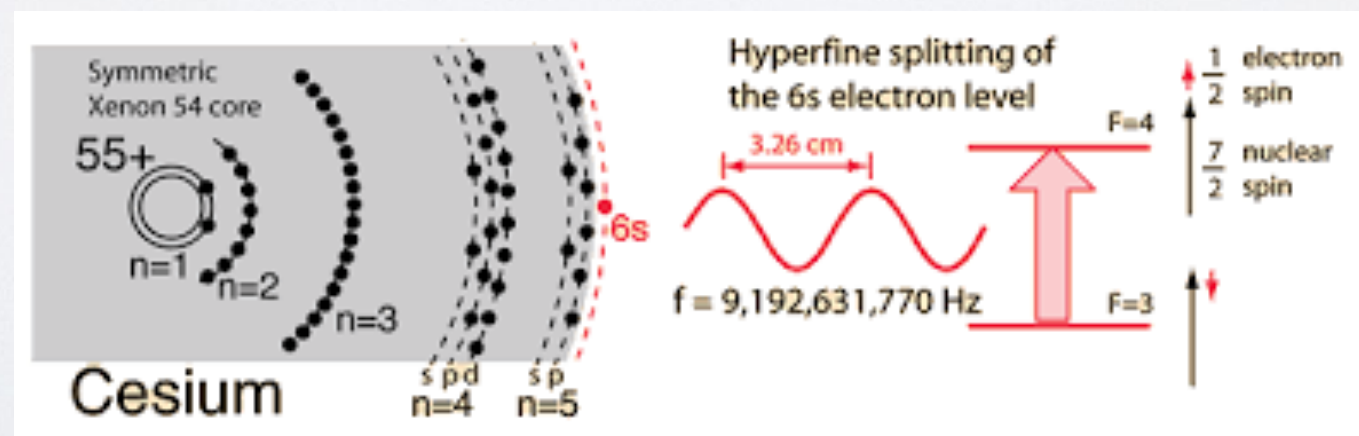
Just for fun...

THE SI UNITS

The Second?



The second is the duration of 9,192,631,770 periods of oscillation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 isotope...

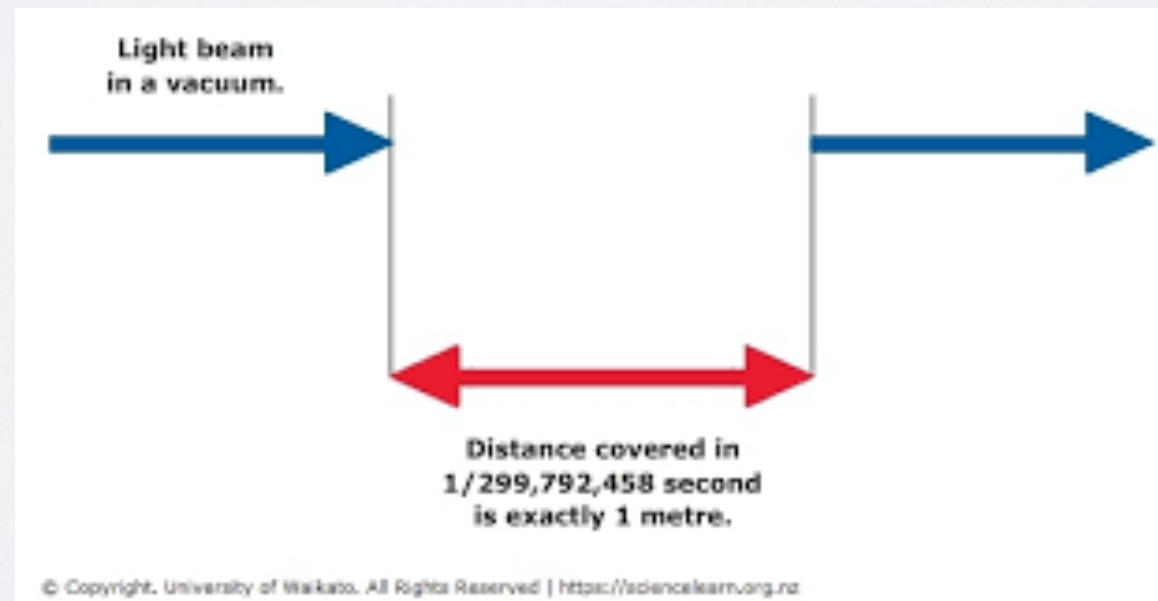


THE SI UNITS

The Meter?



The meter is the length of the path travelled by light in vacuum during a time interval of $1/299\,792\,458$ of a second.



THE SI UNITS

The Kilogram?

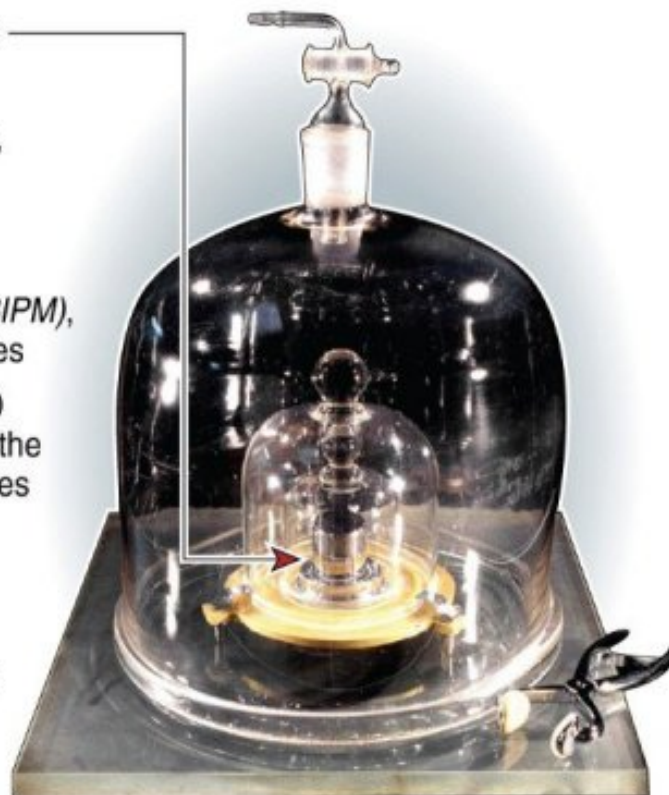
The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

The kilogramme prototype

The kilogramme is officially defined by a lump of metal stored in a vault in France for more than 120 years under the International System of Units (SI)

The International prototype

- ▶ Manufactured in 1889
- ▶ Made up of 90% platinum, and 10% iridium
- ▶ Kept in a vault at the International Bureau of Weights and Measures (BIPM), along with six official copies
- ▶ The basis of more than 80 copies distributed around the world as national prototypes
- ▶ Steam-cleaned under strict guidelines on a regular basis
- ▶ The last remaining base unit measured against a specific material artefact



The chunk of metal is under triple lock-and-key in Sevres, France

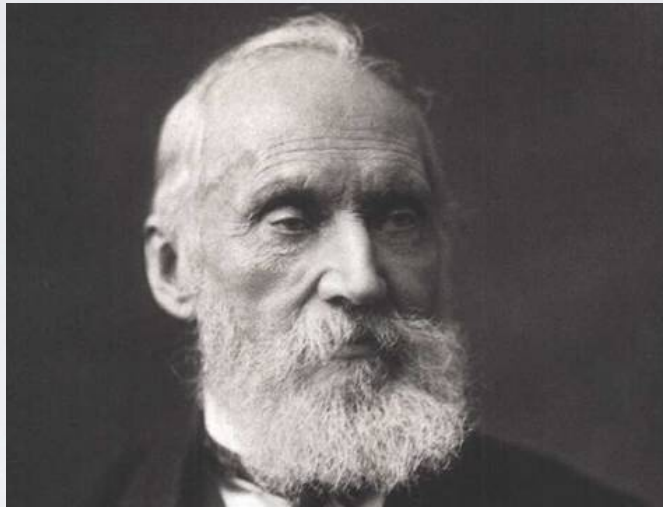


HOT OFF THE PRESS...

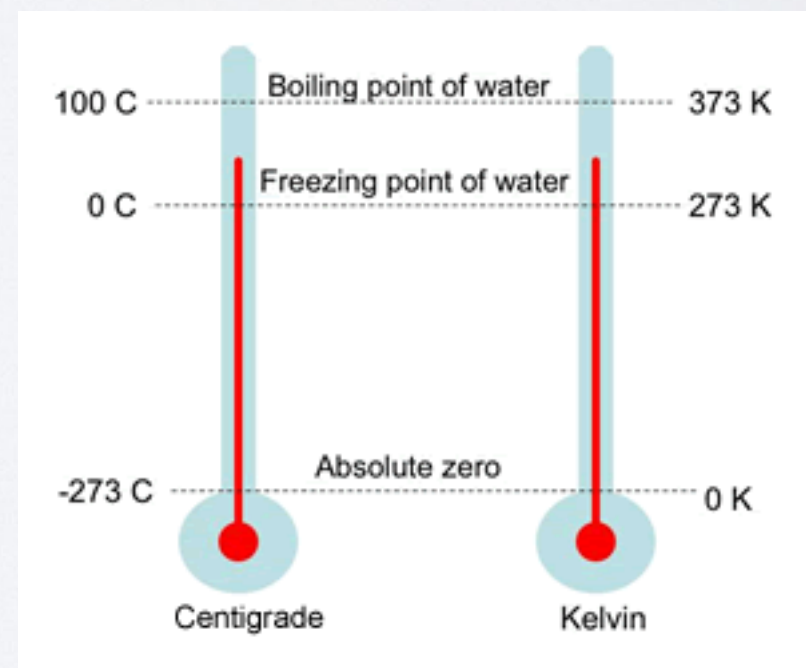
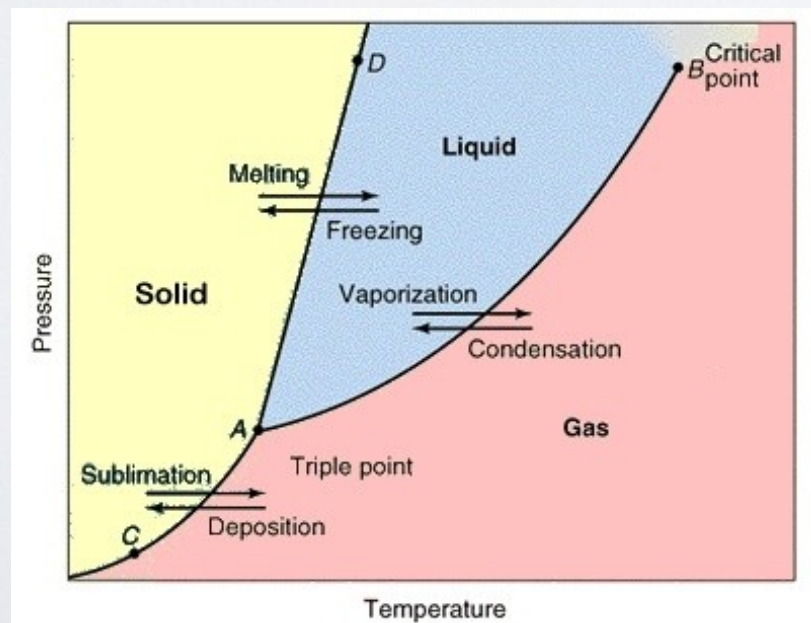
- In 2018 the new "kilogram" will be adopted at the 26th General Conference on Weights and Measures -- a kilogram that is not defined by an object or a physical mass, but by a physical constant: the Planck's constant. The highly precise continuously measuring Planck balance, developed by the German university Technische Universität Ilmenau, operates on the principle of electromagnetic force compensation. Simply put, a weight on the one side is to be balanced by electrical force on the other. This electrical force is inextricably linked with the Planck's constant and can be directly referred to the new kilogram definition. As this balance is the first self-calibrating instrument of its kind, masses determined as reference or standard masses for calibrating scales and balances are no longer required. Another advantage of the Planck balance is its wide measuring range covering a range from milligrams to one kilogram. At the end of the year the first prototype of the balance will be available and ready for use.

THE SI UNITS

The Kelvin?



The kelvin, unit of thermodynamic temperature, is the fraction $1/273.16$ of the thermodynamic temperature of the triple point of water.



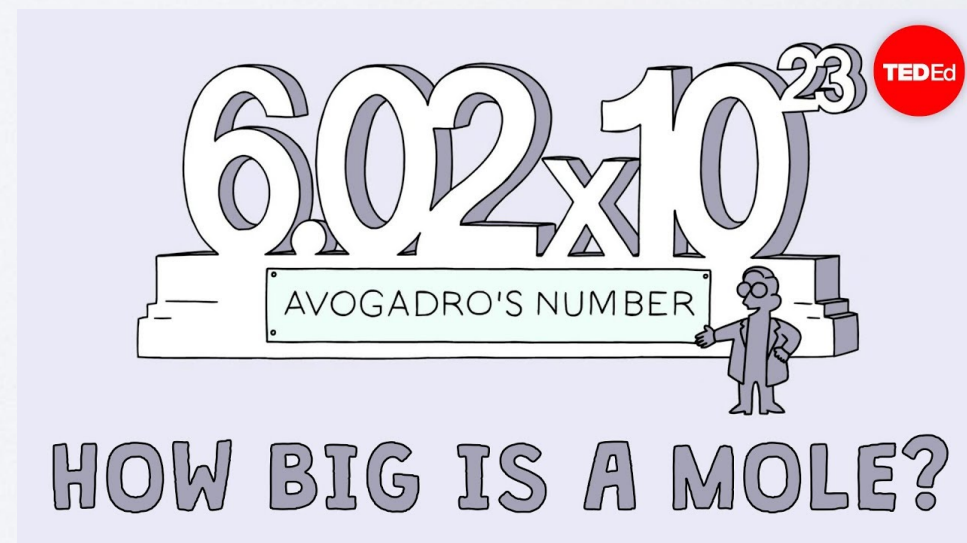
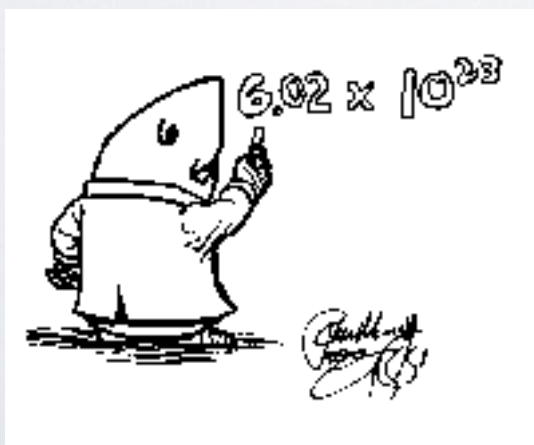
THE SI UNITS

The Mole?

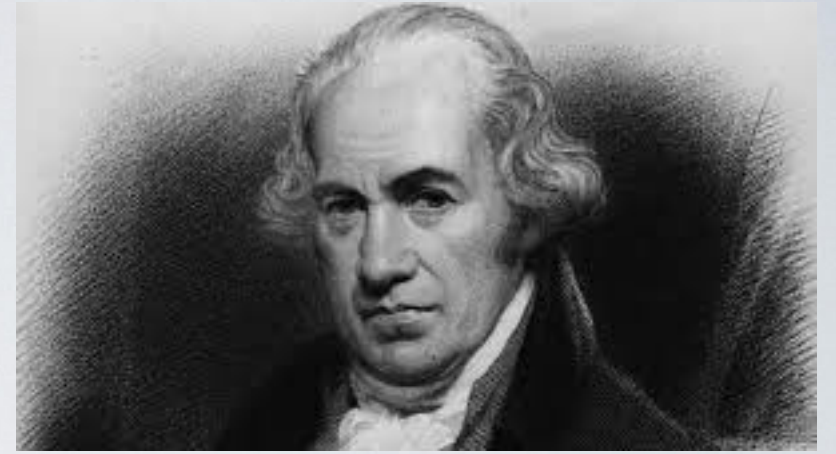


1. The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of the carbon 12 isotope; its symbol is "mol."

2. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.



JAMES WATT



- Watt is the unit of power (symbol: W). The watt unit is named after James Watt, the inventor of the steam engine. One watt is defined as the energy consumption rate of one joule per second.
- $1\text{ W} = 1\text{ J} / 1\text{ s}$. One watt is also defined as the current flow of one ampere with voltage of one volt.

JAMES PRESCOTT JOULE



- The joule (symbol: J) is a derived unit of energy in the International System of Units. It is equal to the energy transferred to (or work done on) an object when a force of one newton acts on that object in the direction of its motion through a distance of one metre (1 newton metre or $\text{N}\cdot\text{m}$)

ISAAC NEWTON



- The newton (symbol: N) is the International System of Units (SI) derived unit of force. It is named after Isaac Newton in recognition of his work on classical mechanics, specifically Newton's second law of motion.
- $F = m \cdot a$?

ISAAC NEWTON



- So Force is really....

$$F = m.a$$

$$\text{Newton} = \text{Kg} \cdot (\text{m/s}^2)$$

JAMES PRESCOTT JOULE



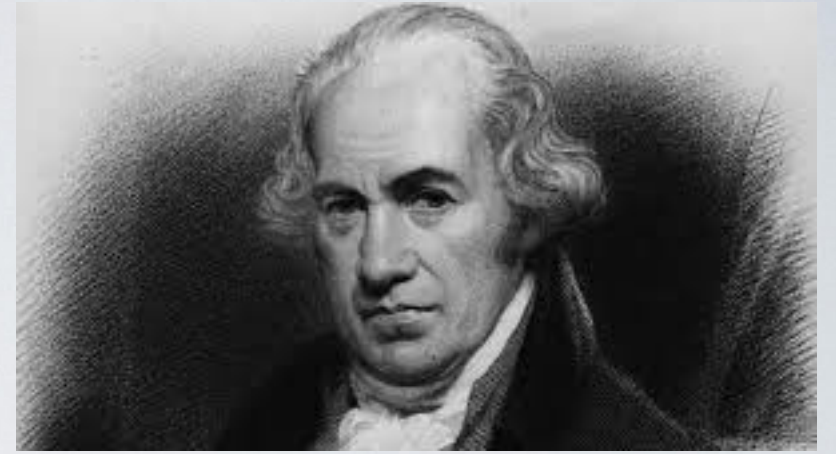
- Kinetic Energy = $\frac{1}{2} . m . V^2$

Potential Energy = $m . g . h$

Work Done = $F . d = Nm = (mass . a) meters = ?$

-

JAMES WATT



- Power = Joules / second

So (Kg.m²/s²) / s

$$\text{Power} = \text{Kg} \cdot \frac{\text{m}^2}{\text{s}^3}$$

HOW HEAVY IS AIR?

- Density of Air?
- How heavy is the air in the room?
- How fast is the air 'moving'?

HOW FAST IS AIR?

- In physics, you can examine certain properties of molecules of an ideal gas as they zip around. For instance, you can calculate the average kinetic energy (and speed) of each molecule with a very simple equation:

$$KE_{avg} = \frac{3}{2}kT$$

- where k is Boltzmann's constant,

$$1.38 \times 10^{-23} \text{ joules per kelvin (J/K),}$$

- and T is the temperature in kelvins. And because you can determine the mass of each molecule if you know which gas you're dealing with, you can figure out the molecules' speeds at various temperatures.

HOW FAST IS AIR?

$$KE_{avg} = \frac{3}{2}kT$$

- Now plug in the numbers:

$$KE_{avg} = \frac{3}{2}(1.38 \times 10^{-23} \text{ J/K})(301 \text{ K}) \approx 6.23 \times 10^{-21} \text{ J}$$

- The average molecule has a kinetic energy of

$$6.23 \times 10^{-21} \text{ joules.}$$

- The molecules are pretty small — what speed does this correspond to?
Well, you know that $KE = (1/2)mv^2$ where m is the mass and v is the velocity.
Therefore,

$$v = \sqrt{\frac{2KE}{m}}$$

HOW FAST IS AIR?

- Air is mostly nitrogen, and each nitrogen atom has a mass of about

$$14.0 \text{ u} = 2.32 \times 10^{-26} \text{ kg}$$

- (you can figure that one out yourself by finding the mass of a mole of nitrogen and dividing by the number of atoms in a mole, N_A). In air, nitrogen molecules form molecules comprising two nitrogen atoms, so the mass of these molecules is

$$28.0 \text{ u} = 4.65 \times 10^{-26} \text{ kg.}$$

- You can plug in the numbers to get...

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2(6.23 \times 10^{-21} \text{ J})}{(4.65 \times 10^{-26} \text{ kg})}} \approx 518 \text{ m/s}$$

- 1,160 mph !!! ... Faster than the speed of sound!! = mach 1.5!!

WHAT ACTUALLY IS PRESSURE?

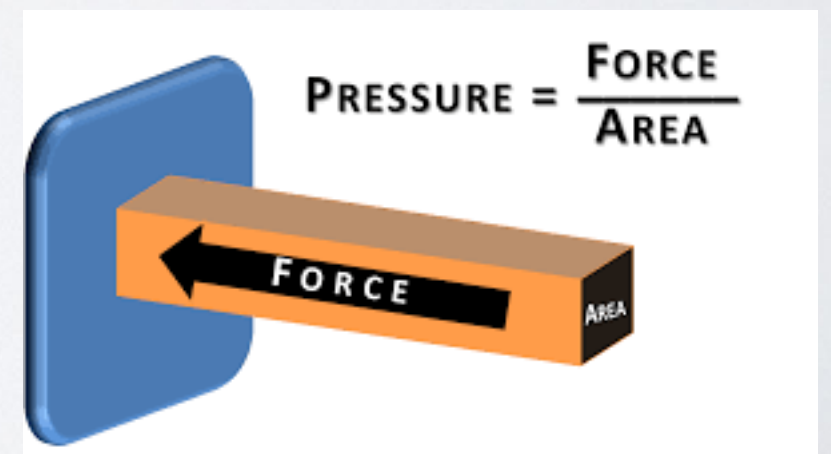
- Pressure (symbol: p or P) is the force applied perpendicular to the surface of an object per unit area over which that force is distributed. Gauge pressure (also spelled gage pressure) is the pressure relative to the ambient pressure. Various units are used to express pressure.

- $\text{Pressure} = (\text{Kg} \cdot \text{m} / \text{s}^2) / \text{m}^2$

$$\text{Pressure} = \text{Kg} / (\text{m} \cdot \text{s}^2)$$

- Notice that $\text{Pressure} \times \text{Volume} = \text{N} / \text{m}^2 \times \text{m}^3$

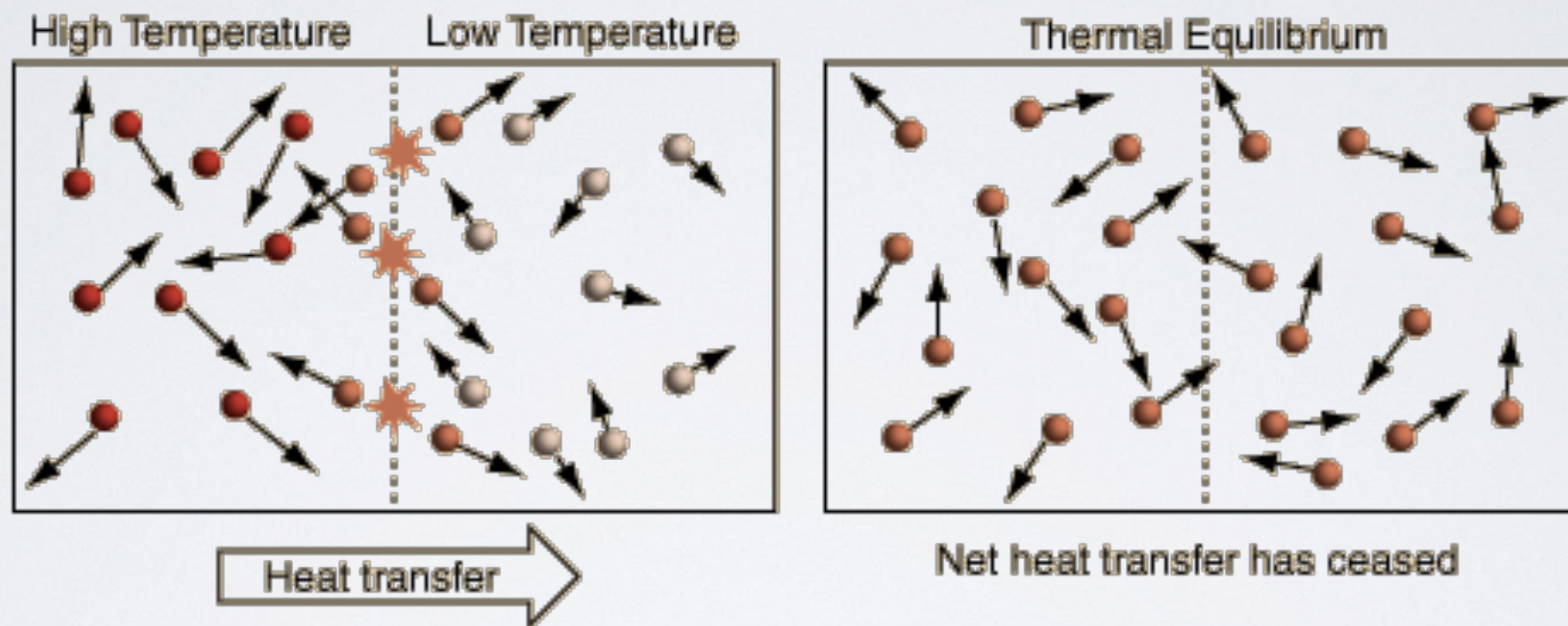
$$\text{Pressure} \times \text{Volume} = \text{Nm} = \text{Torque} = \text{Energy}$$



WHAT ABOUT TEMPERATURE?

- Heat?
- The degree or intensity of heat present in a substance or object, especially as expressed according to a comparative scale and shown by a thermometer or perceived by touch.

WHAT ABOUT TEMPERATURE?



Heat, Energy and Temperature?

- Temperature and heat are related to thermal energy.
- Temperature is a measure of the average kinetic energy of all the atoms or molecules in an object.
- Temperature is measured in Kelvin, Celsius, Fahrenheit, Rankine – We use Kelvin...

Heat

- Heat is defined as the flow of thermal energy from an object of one temperature to an object of another temperature.
- Heat is a form of energy.
- Heat is measured in Joules.

Heat Transfer

- Heat is often defined as energy in transit or the flow of energy. Thermal energy is the energy itself.
- There are 3 types of Heat Transfer that we need to consider:
- These are :
- Conduction, Convection and Radiation...



Conduction

Thermal energy can be transferred from one substance to another when they are in direct contact. The moving molecules of one material can increase the energy of the molecules of the other. Heat can also travel along a material as one molecule transfers energy to a neighbouring one.



Convection

When heat is transferred by the circulation of fluids due to density changes induced by heating, then the process is known as free or natural convective heat transfer.

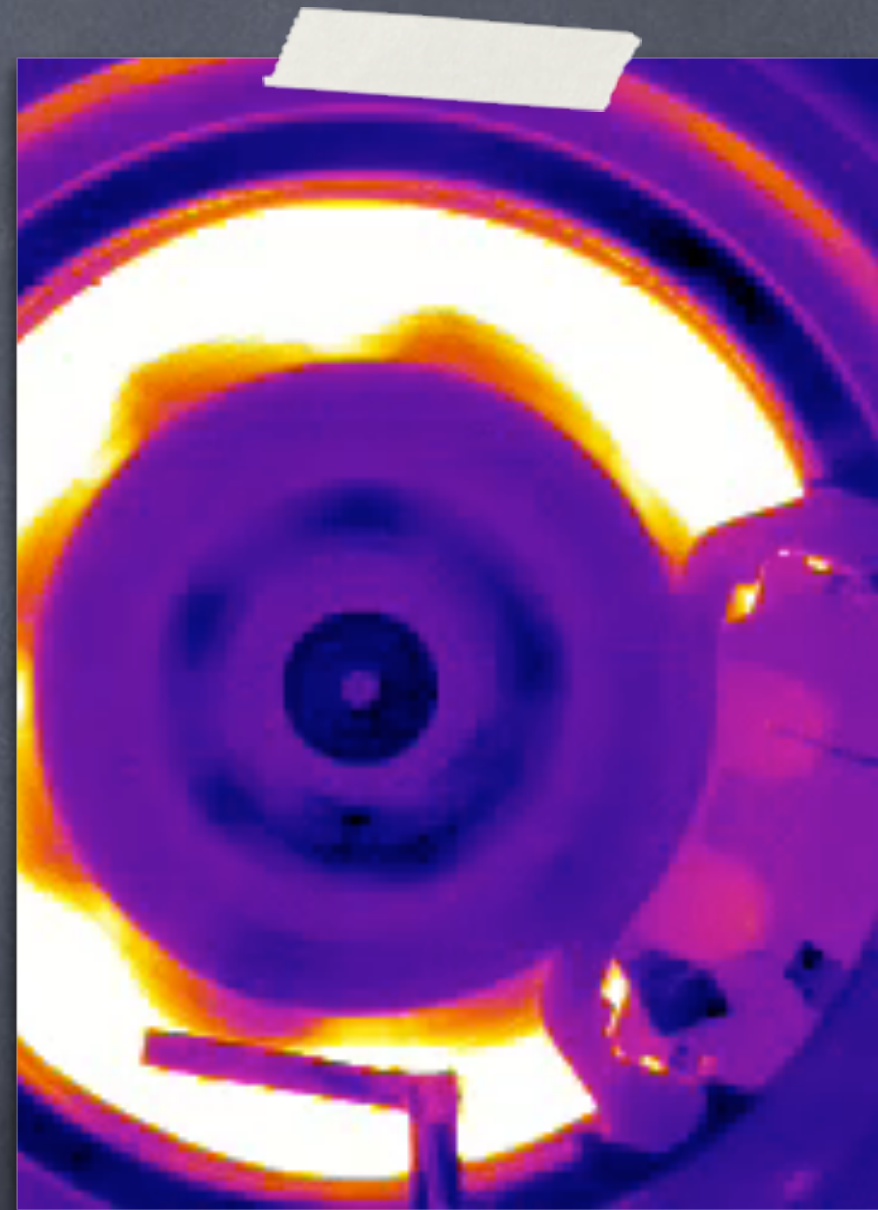
Familiar examples are the upward flow of air due to a fire or hot object and the circulation of water in a pot that is heated from below.



Forced Convection

In forced heat convection, transfer of heat is due to movement in the fluid which results from many other forces, such as (for example) a fan or pump.

Forced Convection is the main process of heat transfer for an automotive radiator and also for brake cooling.



Radiation

This has nothing to with...

Bombs

Fission

Fusion

Marie Curie

Power Stations

Uranium 238

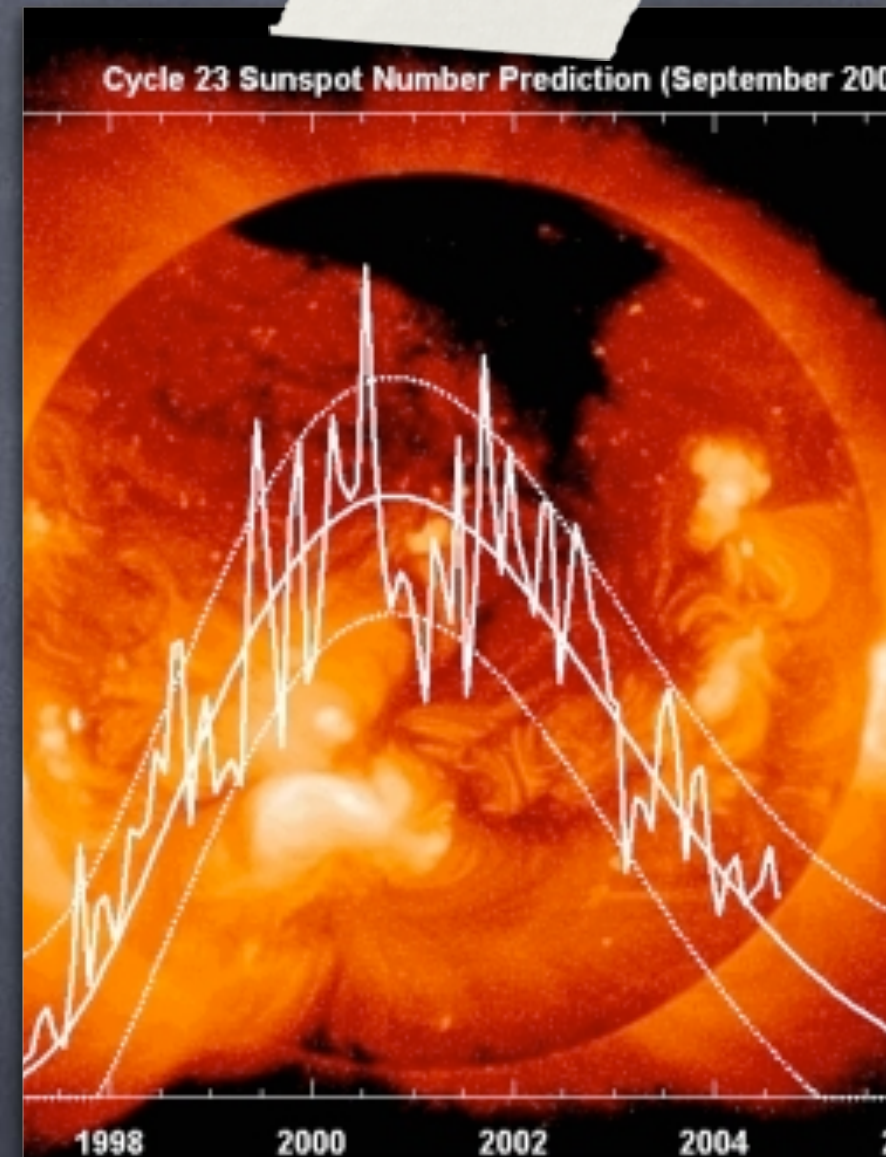
Atomic Decay

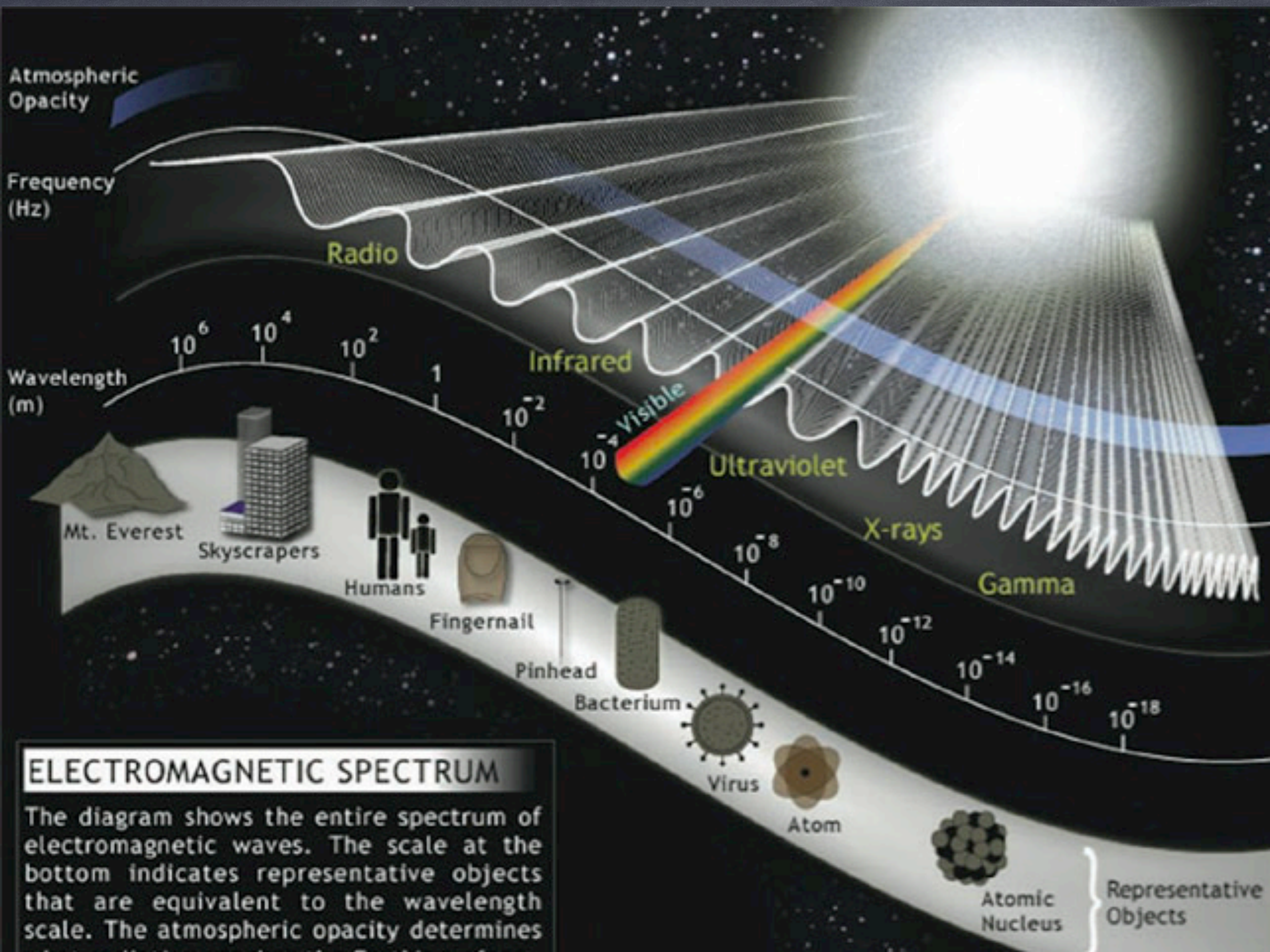


Radiation – Heat Transfer

A warm or hot object gives off infrared electromagnetic radiation, which can be absorbed in another object, heating it up.

Transfer of heat by radiation travels at the speed of light and goes great distances, even in a vacuum. We are heated from the Sun through radiation transfer of heat.





WHAT ABOUT MASS?

THE HIGGS BOSON

THE HUNT CONTINUES...

Although we have now found the **Higgs boson**, there's still a lot we **don't know** about it. The only way to find out those things is to make more Higgs bosons and examine them.

We do know

The Higgs is its **own** antiparticle

Most particles have an antimatter version. Some other bosons, such as the photon and Z boson are also their own antiparticles

It has **zero** electric charge and **zero** spin

The Higgs decays into **W and Z bosons** at roughly the rate predicted by the Standard Model

This is important because it shows that the Higgs gives the bosons their mass

After the Higgs decays into a W or Z boson, those particles also decay into particle pairs

For example, when a Higgs decays into a pair of Z bosons, these can go on to decay into pairs of leptons (electrons, muons, and taus) and anti-leptons. Z bosons can also decay into quarks and antiquarks

The LHC looks for this sequence of decay products

A muon is a sort of 'heavy' electron

The Higgs decays into **photons** at roughly the rate predicted

Photons are their own anti-particles

We would like to know

Does the Higgs **self-interact** in the way it is expected to?

This is how the Higgs would give 'itself' mass

How long does the Higgs '**live**' before it decays?

Does it decay into **quarks and leptons** at the rate we expect?

This would tell us whether the Higgs gives these particles mass too (there is some evidence that this is the case)

Is the Higgs really a **fundamental particle**, or is it made of something we haven't seen yet?

Does the Higgs particle give mass to **Dark Matter**?

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EXPERIMENT TIME!

