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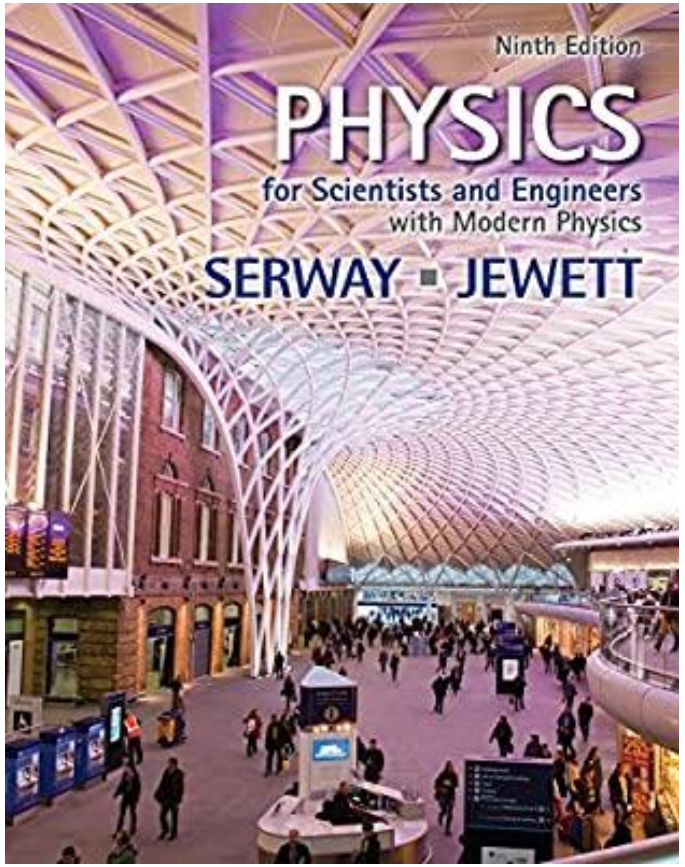
PEN205
MODERN PHYSICS

Introduction

Prof. Dr. H. Gül YAĞLIOĞLU – Dr. Öğr. Üyesi Çağıl KADEROĞLU



SOURCE BOOKS

Physics For Scientists And Engineers
Serway ve Beichner ; Chapters: 39-42

Alternative Sources

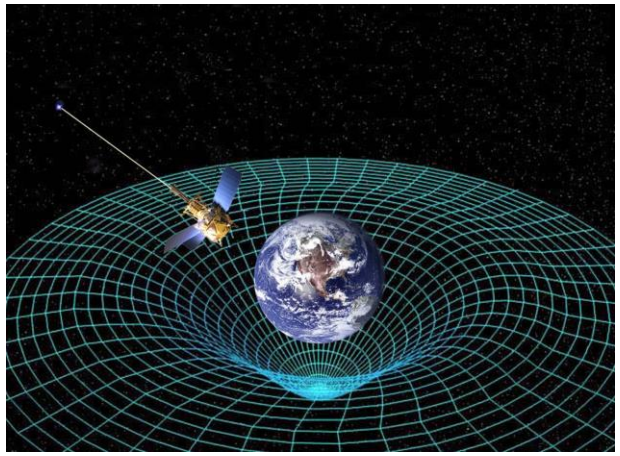
✓ Modern Physics for Scientists and Engineers
S. T. Thornton ve A. Rex ; Chapters: 1-10

- http://galileo.phys.virginia.edu/classes/252/home.html
- https://aklectures.com/subject/modern-physics/special-relativity
- http://www.physics.mcgill.ca/~maloney/260/
- http://bingweb.binghamton.edu/~suzuki/ModernPhysics/0_Introduction.pdf

SCAN ME

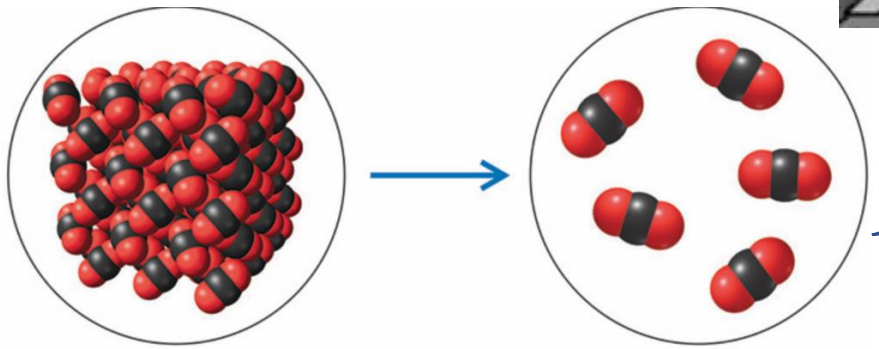
➔ Also search for;
- Other relevant sources
- Videos on YouTube

MAIN SUBJECTS of THIS CLASS

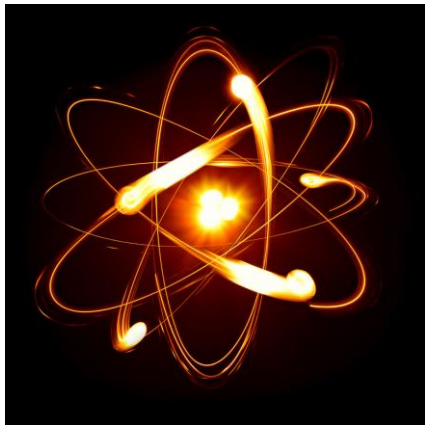


1. Relativity

2. Quantum Mechanics

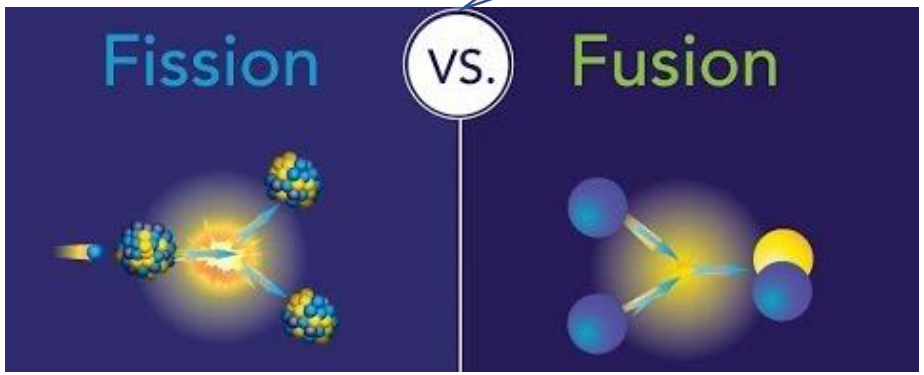


4. Molecules and Solids

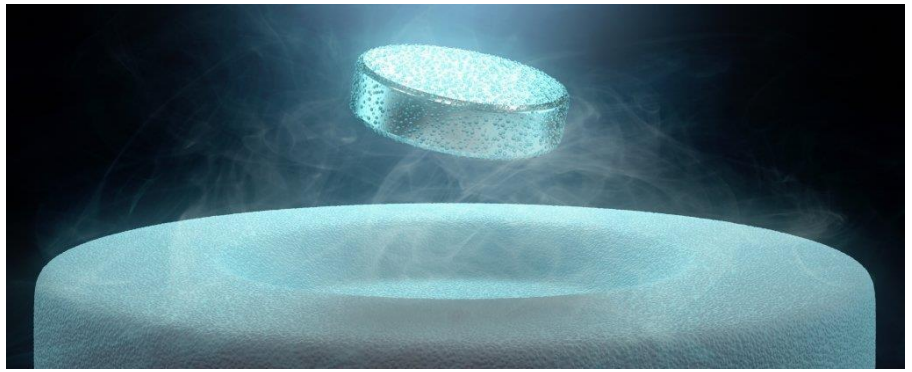


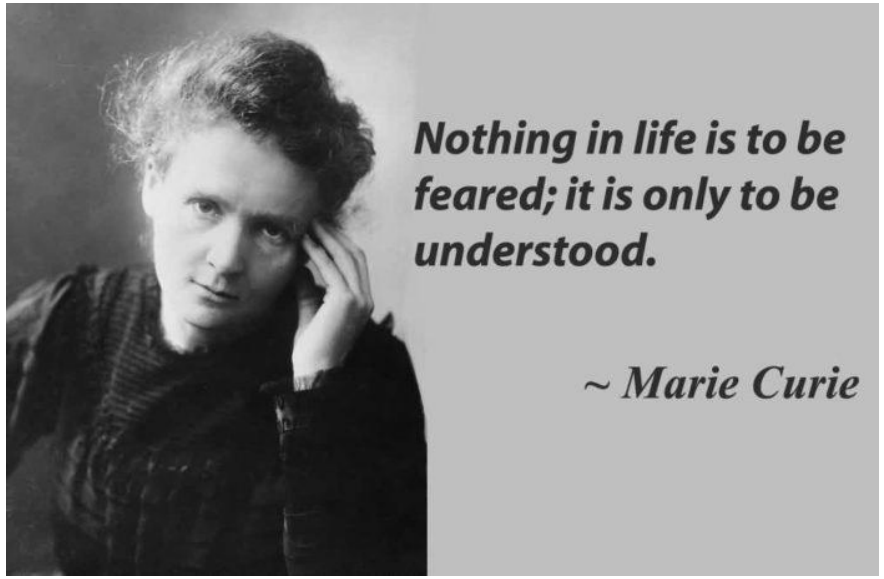
3. Atom Physics

5. Properties of Nuclei
6. Nuclear Fission & Fussion



7. Superconductivity





You should repeat / remember classical mechanics, electricity and magnetism courses to be successful in this course.

Your interest in the topics of the lesson and your research at other times will bring you one step closer to understanding the universe.

What are the standards of mass and length in SI unit system?

Why do we need standards for units?

Meter (1983): the distance traveled by light in vacuum during a time of 1/299 792 458 second.

Kilogram (2019): New definition according to Planck's constant...

What do we understand from MODERN PHYSICS?

How is it different from CLASSICAL PHYSICS?

Classical Physics :

- devoleped before 20th century
- Deals with matter → speed << speed of light, size >> atom
- it is still valid today, but its scope is insufficient for our understanding of nature

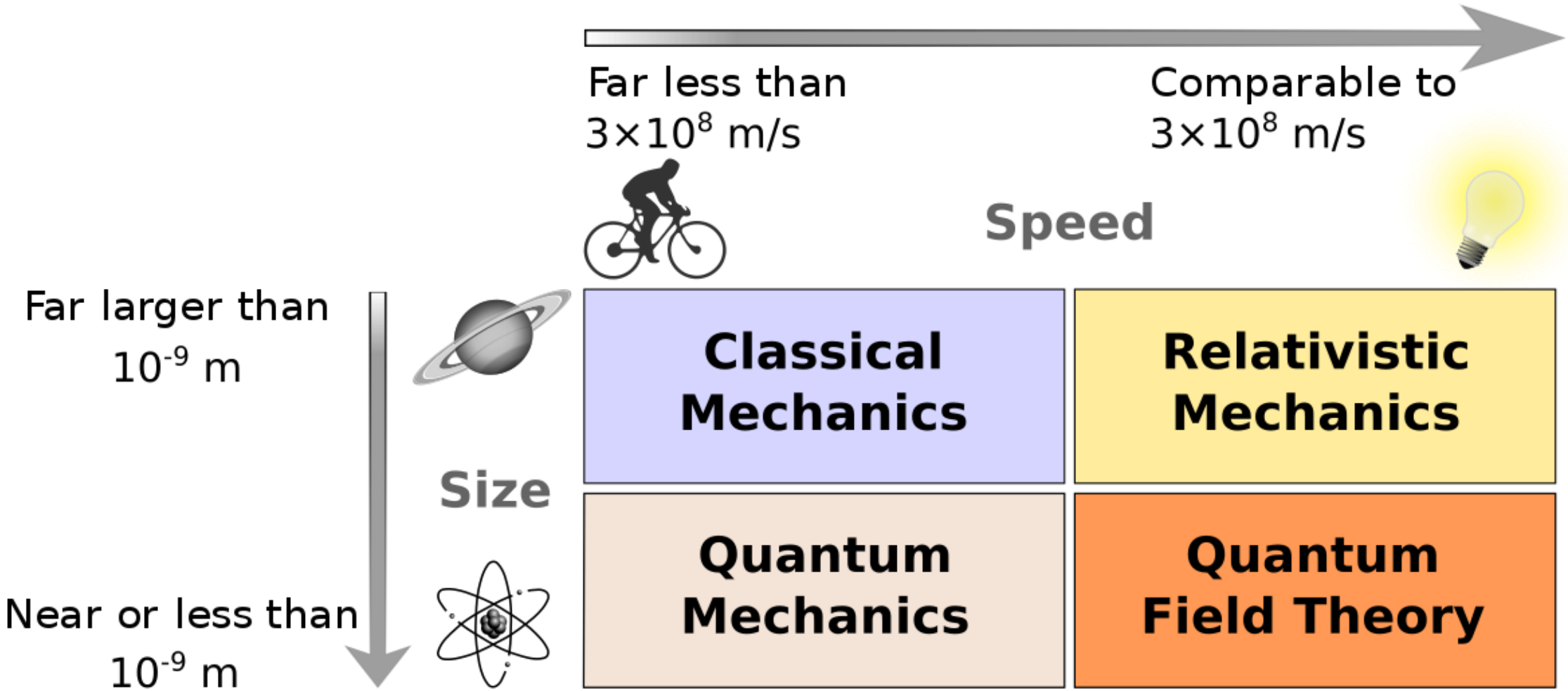
Mechanics (Galileo, Newton)
Electromagnetism (Maxwell)
Thermodynamics
Kinetic Theory of Gases
Waves and Particles
Conservation Principles and Fundamental Forces
Atom Theory

Modern Physics:

- physics of 20th century and later
- very small and very big objects, energy, …

Nature of Light
Relativity
Quantum Physics
Atom Physics

Classification of physics as the function of matter's size and speed…



At the end of the 19th century, it was thought that all the laws of physics were known;

Newton's Mechanics

Maxwell's electricity and magnetism

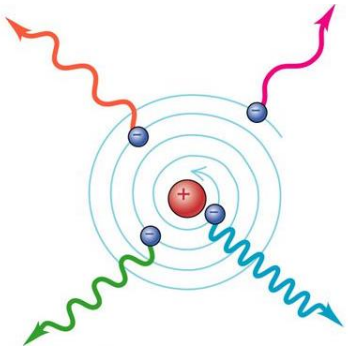
Thermodynamics (Carnot, Boyle, Bernoulli, etc…)

Optics (Ibn al-Haytham, Newton, ..)

Motion of the planets (Kepler)

But Newton's laws were insufficient to explain atomic level phenomena… **WHAT WAS THE PROBLEM WITH CLASSICAL PHYSICS?**

1897- Thomson discovered electron



- Orbiting electron → accelerating charge
- Accelerating charge → emits electromagnetic waves → lose energy

↓

According to classical physics, the electron must emit a continuous radiation and must fall on the nucleus in a spiral way.

↓

Atom collapses → there would be no matter and the universe

Birth of Modern Physics

The era of Modern Physics started by;

- 1900 → Max Planck's discovery of the role of energy quantization in blackbody radiation.
- 1905 → Einstein's special theory of relativity

Architechs of Modern Physics

Fifth International Congress of Physics held in 1927 by the Solvay Institute in Brussels

1. A. Piccard
2. E. Henriot
3. P. Ehrenfest
4. E. Herzen
5. Th. de Donder
6. E. Schroedinger
7. E. Verschaffelt
8. W. Pauli
9. W. Heisenberg
10. R.H. Fowler
11. L. Brillouin
12. P. Debye
13. M. Knudsen
14. W.L. Bragg
15. H.A. Kramers
16. P.A.M. Dirac
17. A.H. Compton
18. L.V. de Broglie
19. M. Born
20. N. Bohr
21. I. Langmuir
22. M. Planck
23. M. Curie
24. H.A. Lorentz
25. A. Einstein
26. P. Langevin
27. C.E. Guye
28. C.T.R. Wilson
29. O.W. Richardson

The way going to Modern Physics…

$$\vec{\nabla}\cdot\vec{E}=0 \qquad \vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}$$

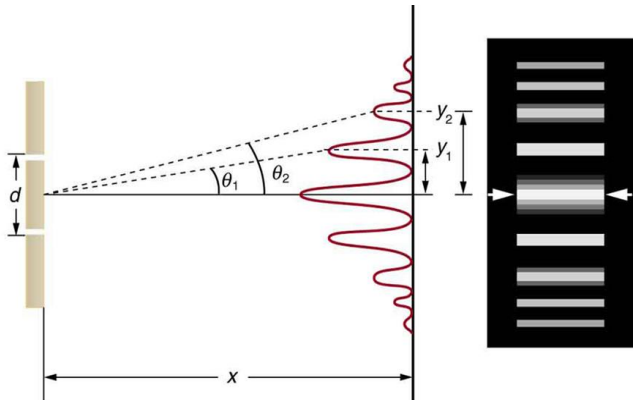
$$\vec{\nabla}\cdot\vec{B}=0 \qquad \vec{\nabla}\times\vec{B}=\frac{1}{c^2}\frac{\partial\vec{E}}{\partial t}$$

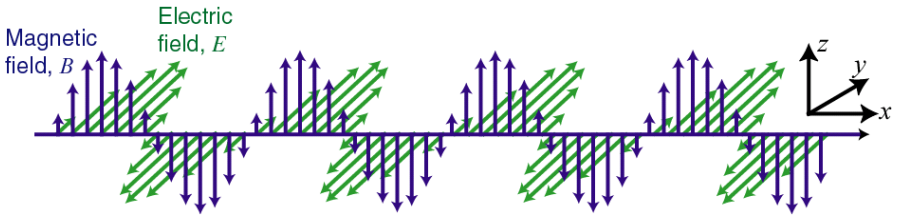
Maxwell → light is in a wave form

$c = 3.00 \times 10^8$ m/s ; speed of light

According to these formulas, an object with mass (m) can not travel at light speed

Young's double slit experiment → light is a wave

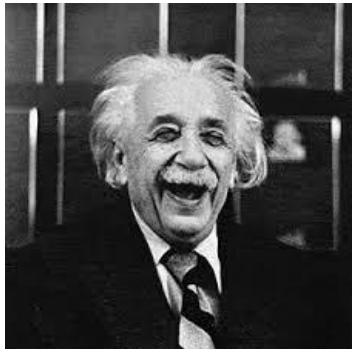




The electric field, the magnetic field, and the propagation direction are all perpendicular.

Most of the waves needs a medium to propogate in.

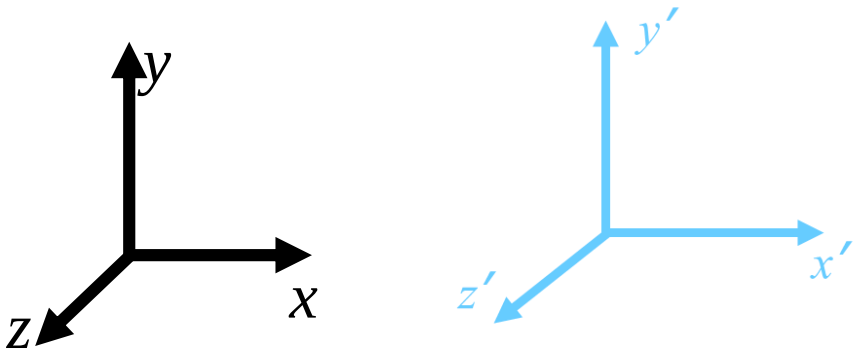
Michelson-Morley (1887) tried to measure the earth's velocity with respect to eather. Aether was thought to be the medium that fills all the space and light travels in!!



Einstein's Special Relativity

A Little Summary of Einstein's Special Relativity

The speed of light *c* is a constant in any frame
The speed of light can not be exceeded.
Time passes at a rate that depends on the object's velocity



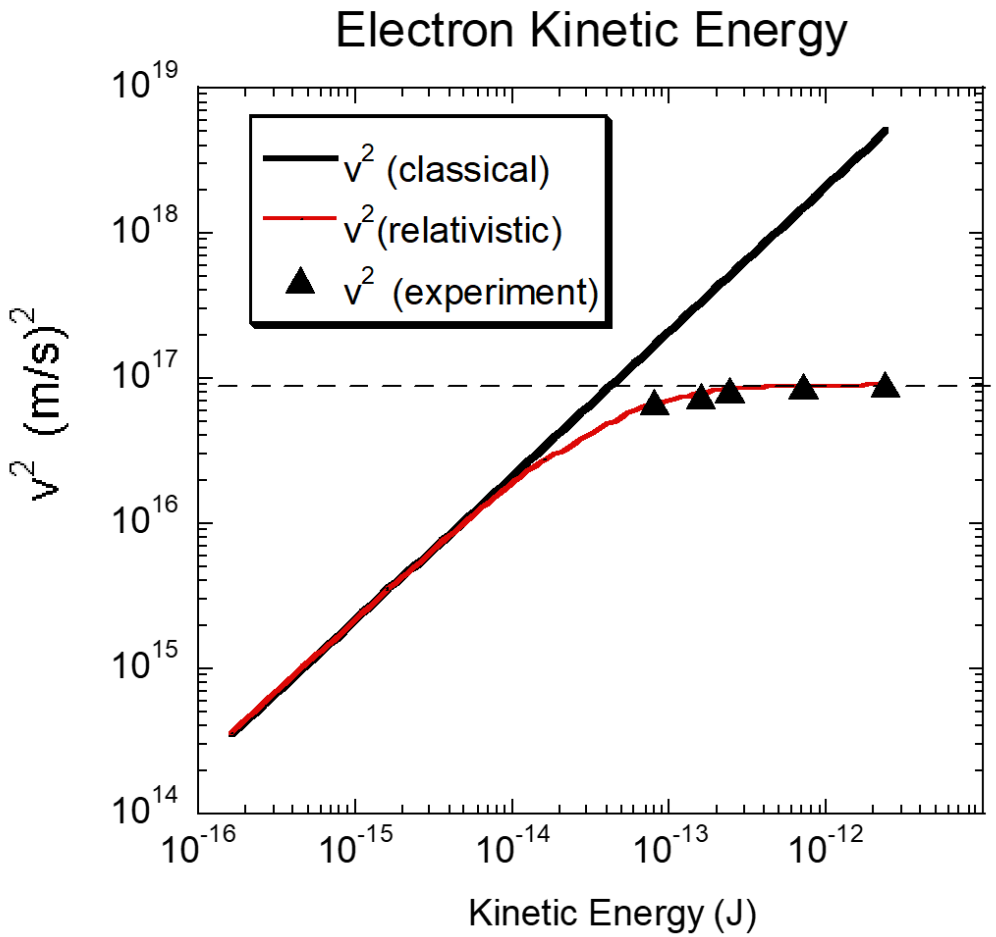
One frame has a velocitv v with respect to the other

Without SR

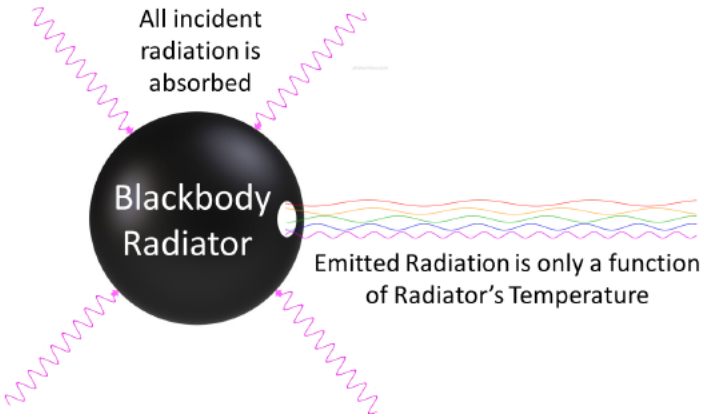
$$x' = x - vt$$
$$y' = y$$
$$z' = z$$
$$t' = t$$

With SR

$$x' = \frac{x - vt}{\sqrt{1 - v^2/c^2}}$$
$$y' = y$$
$$z' = z$$
$$t' = \frac{t - vx/c^2}{\sqrt{1 - v^2/c^2}}$$



Black Body Radiation



A blackbody is a theoretical body which absorbs all colors when it is cool.

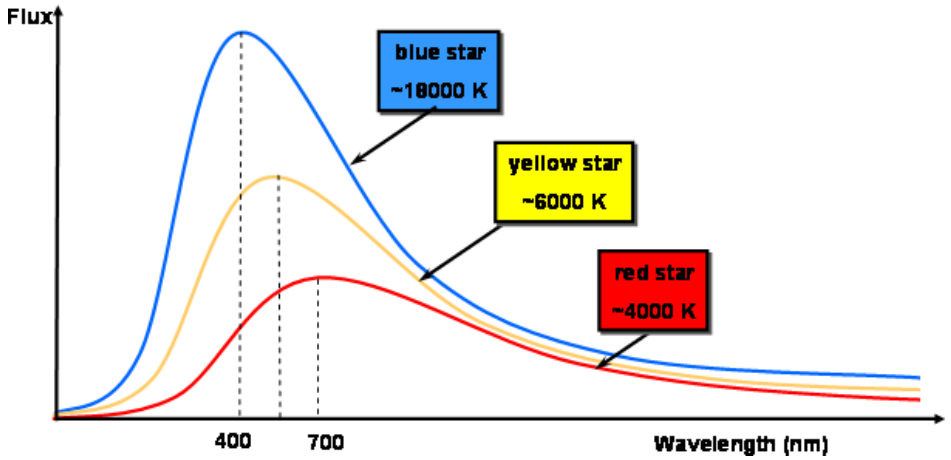
It is a hypothetical object which is a "perfect" absorber over all wavelengths.

All objects with a temperature above absolute zero (0 K, -273.15 ^{o}C) emit energy in the form of EM radiation.

So at a constant temperature, black body also emits EM radiation (black body radiation).

Blackbodies are interesting because their optical properties are independent of the material and only depend on the temperature.

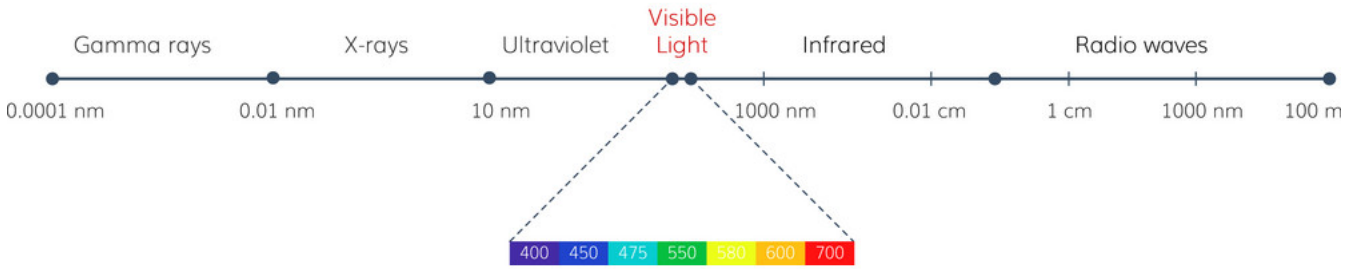
Stars can be thought as black bodies and their temperatures can be determined by looking at their radiation

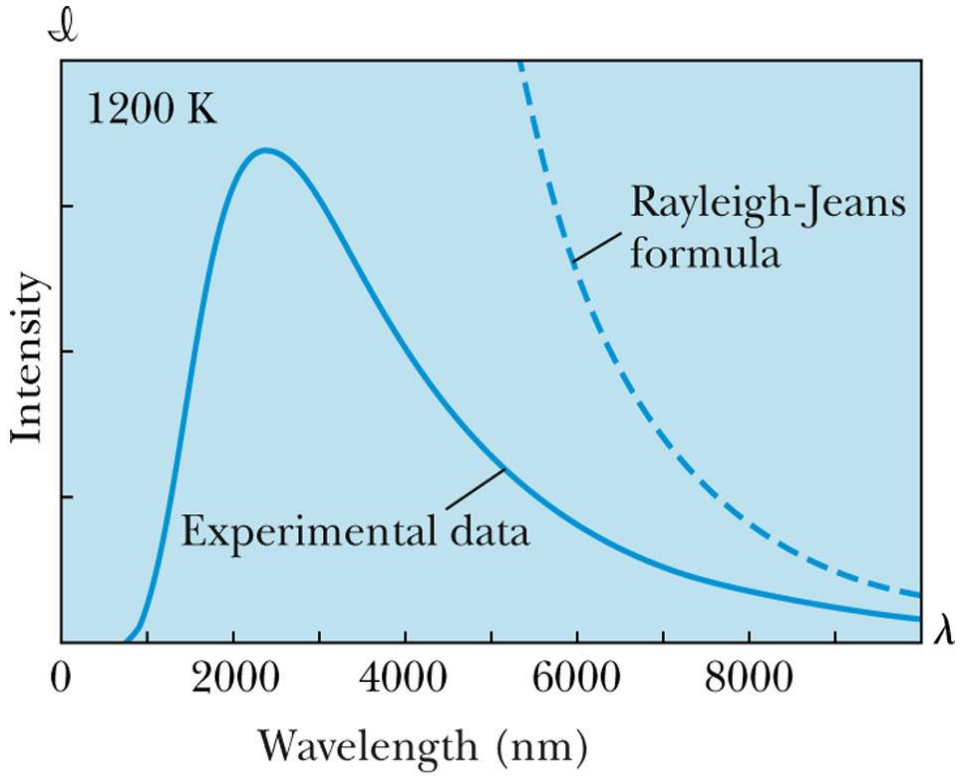


Rayleigh-Jeans (1905)→ used classical theories of electromagnetism and thermodynamics to plot the black body spectrum

Rayleigh-Jeans Formula

$$\mathcal{I}(\lambda,T) = \frac{2\pi ckT}{\lambda^4}$$





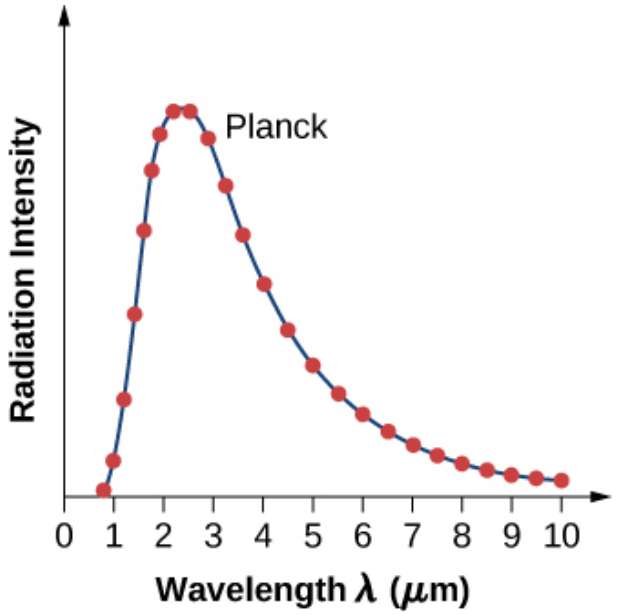
This worked at longer wavelengths but deviates badly at short ones.
This problem became known as the ultraviolet catastrophe and was one of the many effects classical physics couldn't explain.

Max Planck found the solution to get rid of this UV catastrophe

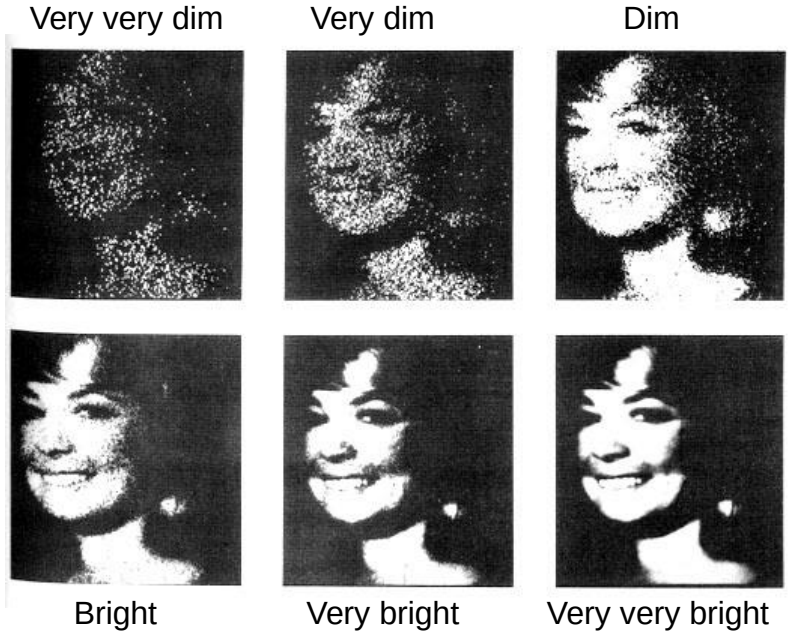
He considered the light as particles!!

$$E_\lambda = \frac{8\pi hc}{\lambda^5} \times \frac{1}{\exp(hc/kT\lambda) - 1}.$$

The value of Planck's constant is defined as $6.62607015 \times 10^{-34}$ J.s



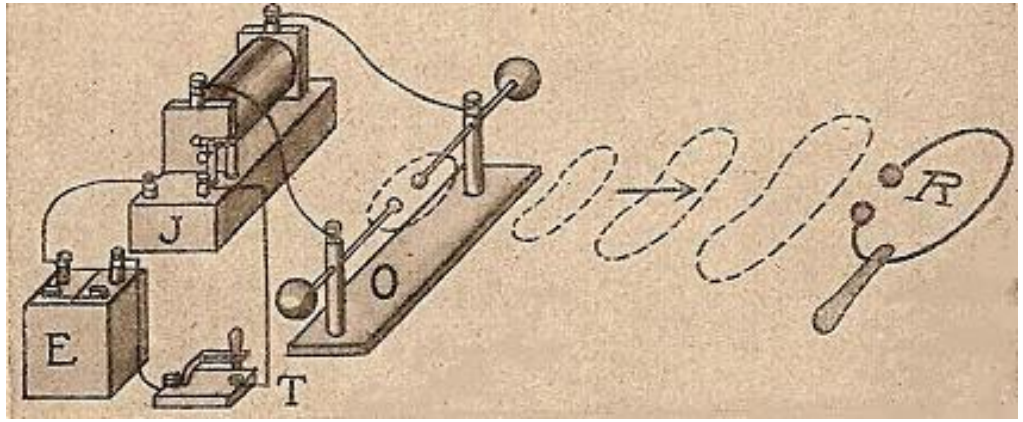
Experiments proved Planck !!
Classical physics is not valid for back-body…



Photographs taken in dimmer light look grainier showing that light is made of photons !!

Photoelectric Effect

1887 → Heinrich Hertz → when UV light shines on two metal electrodes with a voltage applied across them, the light changes the voltage.



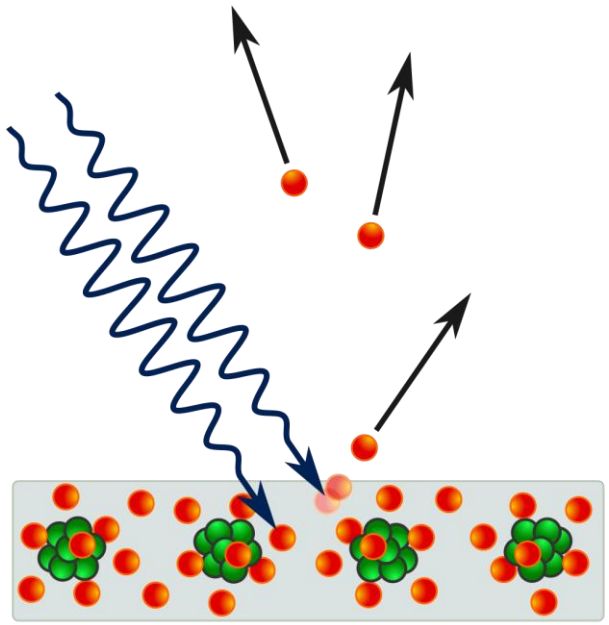
Production and reception of EM waves

sparks created when ultraviolet light was used were stronger than when visible light was used

1902 → Phillip Lenard → demonstrated that electrically charged particles are liberated from a metal surface when it is illumunated.

the kinetic energy of electrons emitted increased with the frequency of radiation used

formulated by Einstein in 1905.



Light falls on a metal surface → electrons may fly out from the surface

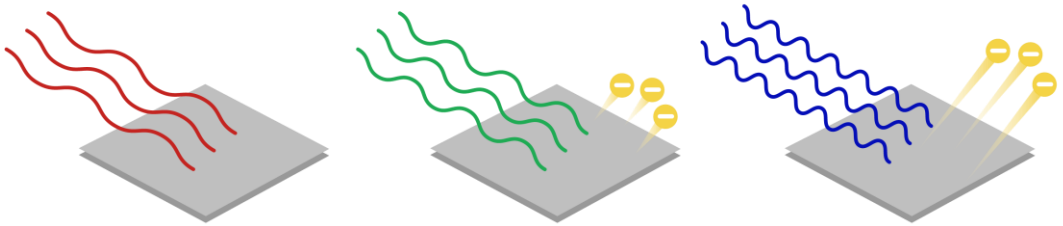
Emitted electrons called as Photoelectrons

Based on the wave model of light;

light amplitude increase → kinetic energy of emitted photoelectrons increase
frequency increase → measured current increase

But experiment results said that ;

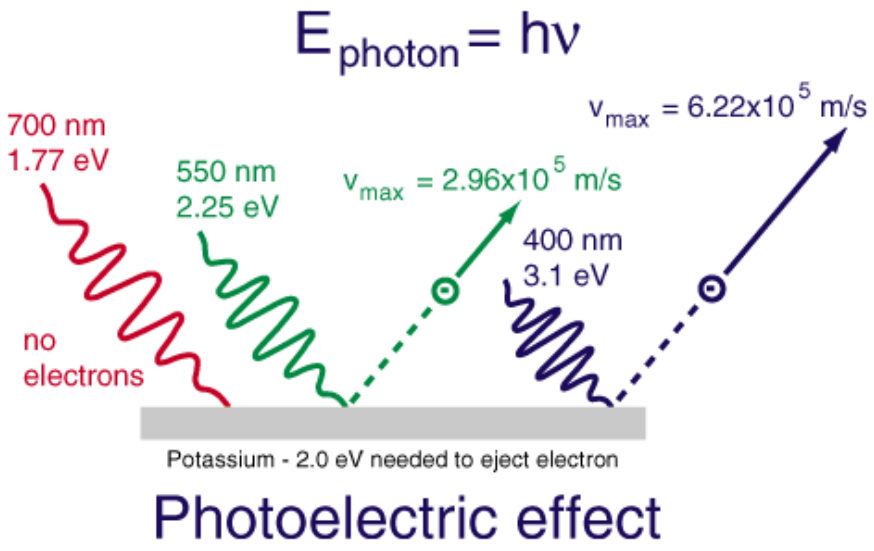
Increasing light amplitude → increased the current
Increasing frequency → kinetic energy increase



it occurs when the light exceeds a threshold frequency. → *COLOR is important*

Einstein proposed that light behaved like a stream of particles called *photons* with an energy of E=*hv*

PE can not be explained by the classical elecromagnetic theory !!!



In Einstein's theory of light;

Each particle of light, or photon, contains a fixed amount of energy, or quantum, that depends on the light's frequency.

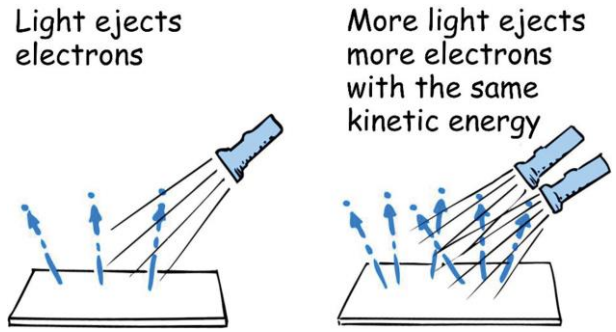
Photons are energy packages of light.
Photons are the quantums of light.
They have zero mass, zero charge, and a velocity that is always c.

Energy of each photon → E=*hν*

h is the Planck's constant that Max Planck derived from his black body radiation theory.

What happens when the photon has greater energy than the threshold energy required to break an electron from surface?

This extra energy turns into the kinetic energy of the electron ☺

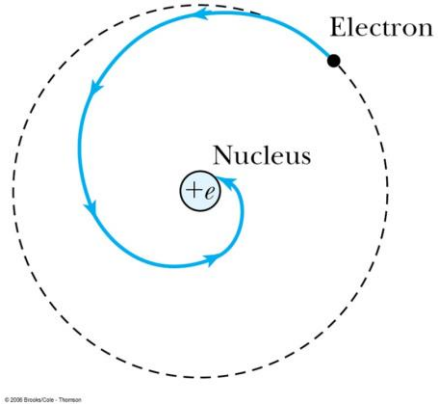


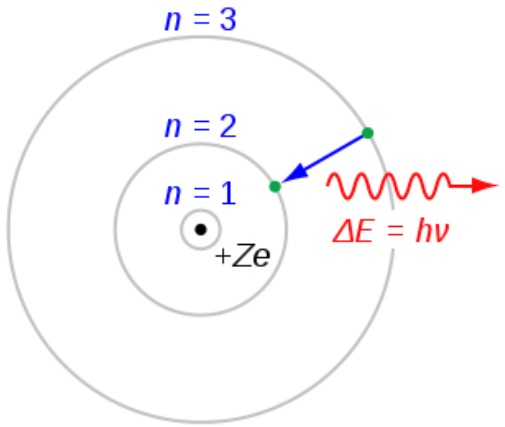
$$h\nu = w + KE$$

w is the energy required to bump an electron (work function), if the photon has less energy than w, no electron is emitted.

Going back to this problem…

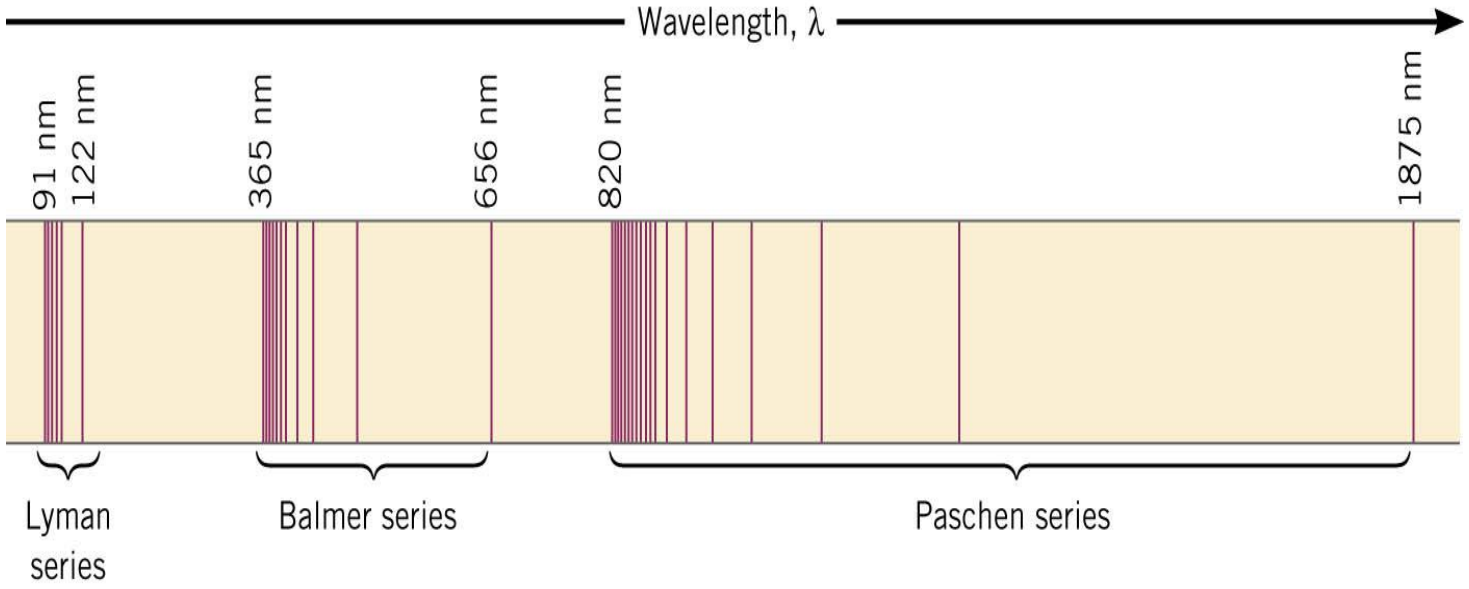
→ Bohr's Quantization Condition is the answer!





The electrons move in certain allowed, "stationary" orbits or states in which they *do not radiate.*

The electron in a high energy state can make a transition to a lower energy state by emitting a photon whose energy was the difference in energies of these two states, $h\nu = E_i - E_f$



Bohr's model works for Hydrogen

But not for other atoms!

Fortunately we have SCHRODINGER ☺

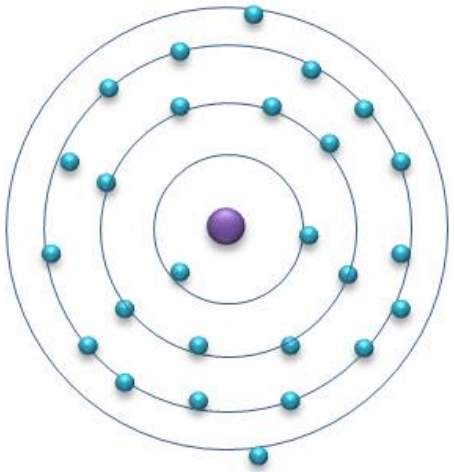
Light acts like a particle…

Does a particle act like a wave?

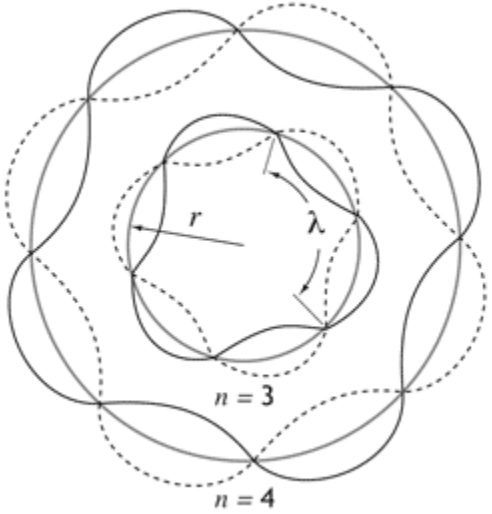
Louis V. de Broglie answered it in 1923

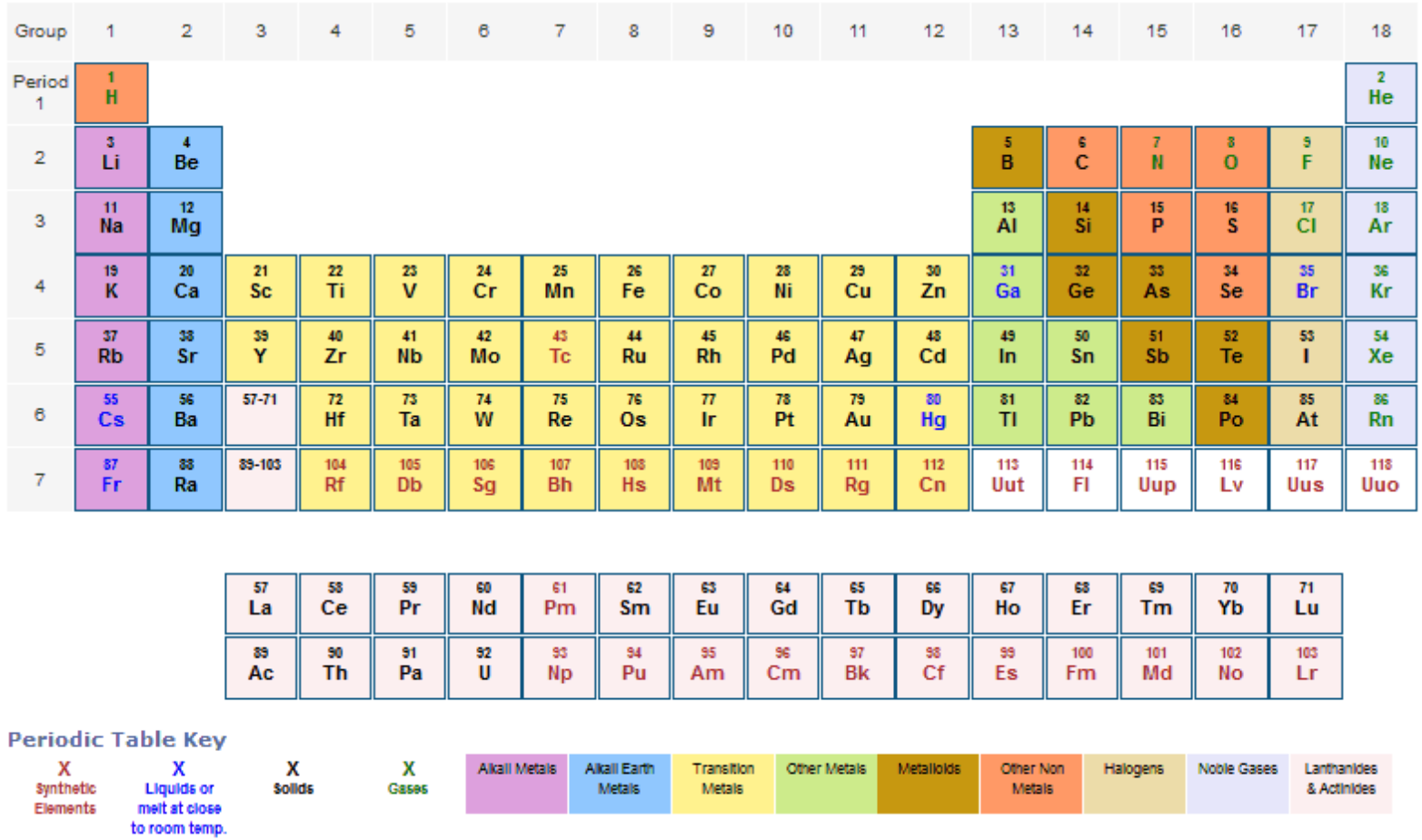
Particles have wave properties similar to light.
The wavelength of the particle wave is called **de Broglie wavelength**

$$\lambda = \frac{h}{p}$$



Bohr to *de Broglie*





Who first designed the periodic table?

Is there a relationship between periodic table and quantum theory ?