Lecture – 2

TITLE: A brief history of the development of structure of atom

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Objectives

In this lecture we will go through the chronological development of the Atomic physics.

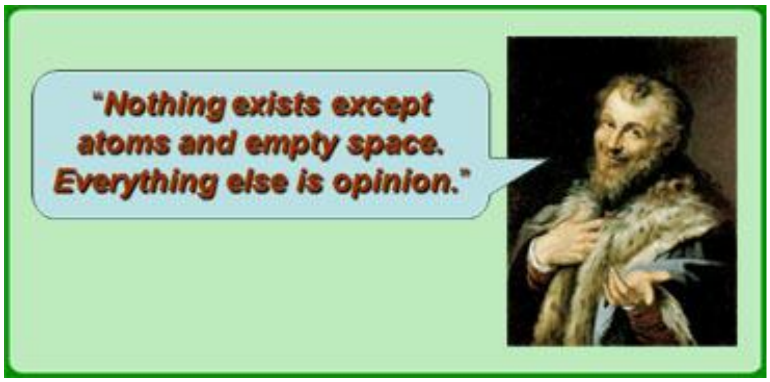
We will find out the thoughts and philosophical minds of ancient scientist

WE will come to know how the observations helped to develop the concept of atom.

Let us start from ancient thoughts of atom around 500 BC.

Ancient History of Atom

- The ancients have hypothecated that matter is made out of atoms for many millennia.
- The word "atom'' comes from the Greek word “a-tomio” which means “uncuttable'' coined by the Greek philosopher Democritus of Adbera (Northern Greece) around 500 B.C.
- Democritus proposed that all material things are composed of extremely small irreducible particles called atoms.



Democritus by Agostino Carracci

(Ref: http://www.intermed.it/liceo/materiali/img)

However, the atomic theory was rejected by Aristotle, and thus, by almost everybody else for the next two millennia.

Aristotle (384 B.C. - 322 B.C.) Greek Philosopher

(Ref: http://space.about.com/od/astronomerbiographies/ig/Aristotle-Pictures-Gallery/Aristotle-from-The-School-of-A.htm)

Development of Concept of Atom (17th through 19th Centuries)

- Robert Boyle (England) extended mathematics to chemistry and revived atomic theory.
- For him chemistry was the science of the composition of substances, not merely an adjunct to the arts of the alchemist or the physician.
- He visualized elements as the indecomposable constituents of material bodies; and made the distinction between mixtures and compounds.
- He further proposed that the elements were ultimately composed of particles of various sorts and sizes, however, they were not to be resolved in any known way.

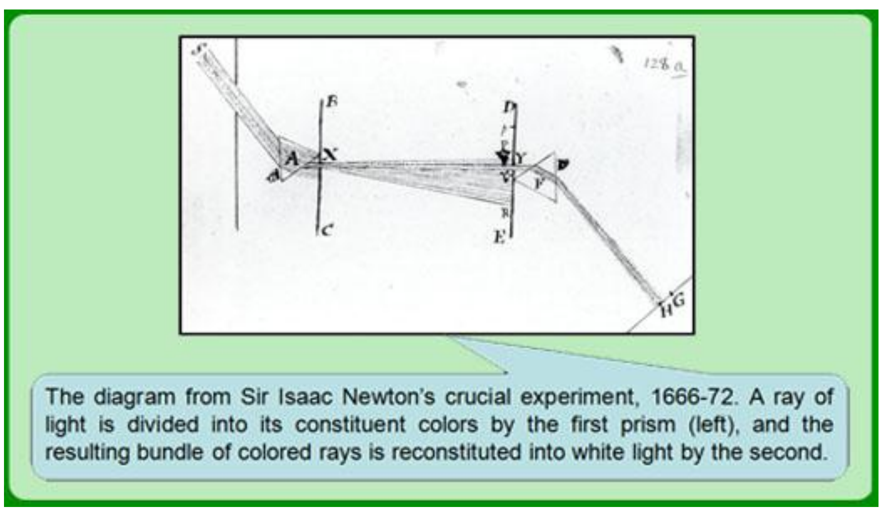
(1627-1691) Robert Boyle (England)

(Ref: http://en.wikipedia.org/wiki/Robert_Boyle)

In 1666:

- Our modern understanding of light and color begins with Isaac Newton from series of experiments that he published in 1672.
- He is the first to understand the rainbow — he refracts white light with a prism, resolving it into its component colors: red, orange, yellow, green, blue and violet.
- This band is called a spectrum. This is the beginning of spectroscopy.

Sir Isaac Newton (1642-1726)



The diagram from Sir Isaac Newton's crucial experiment, 1666-72. A ray of light is divided into its constituent colors by the first prism (left), and the resulting bundle of colored rays is reconstituted into white light by the second.

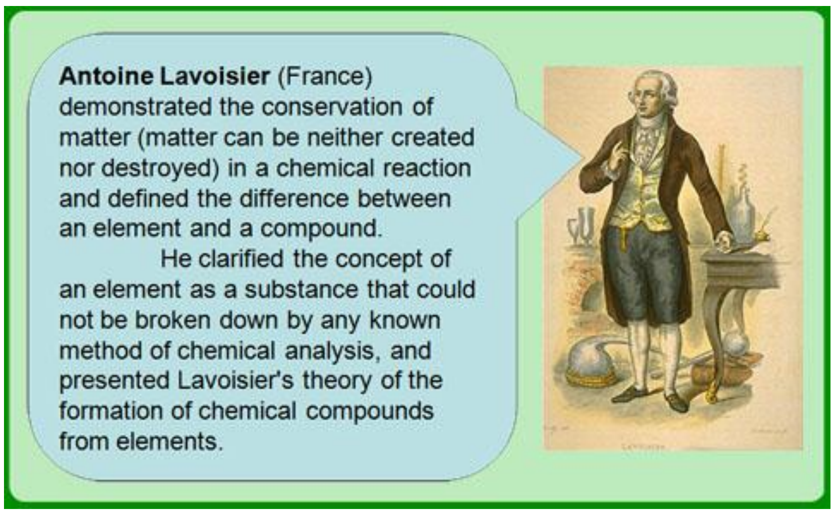
(Ref: http://www.webexhibits.org/colorart/bh.html)

In 1749:

- Thomas Melvill(e) described how he had used a prism to observe a flame colored by various salts.
- He reported that a yellow line was always seen at the same place in the spectrum; this was derived from the sodium which was present as an impurity in all his salts.
- He is known as the father of Flame Emission Spectroscopy.

(Ref: http://en.wikipedia.org/wiki/Thomas_Melvill)

In 1777:



In 1780:

Charles Coulomb (France) described the force between two electric charges with a mathematical formula as given in Equation – 2.1, which looked very much like Newton's law of gravity:

$$F = K\frac{q_1 q_2}{r^2}$$

Equation – 2.1

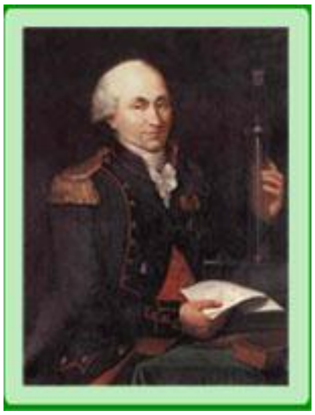
Here, F is the force

K is a constant

q_1 and q_2 are two charges

r is the distance between them.

This force is attractive when charges q_1 and q_2 have opposite signs and repulsive when the charges have the same sign.



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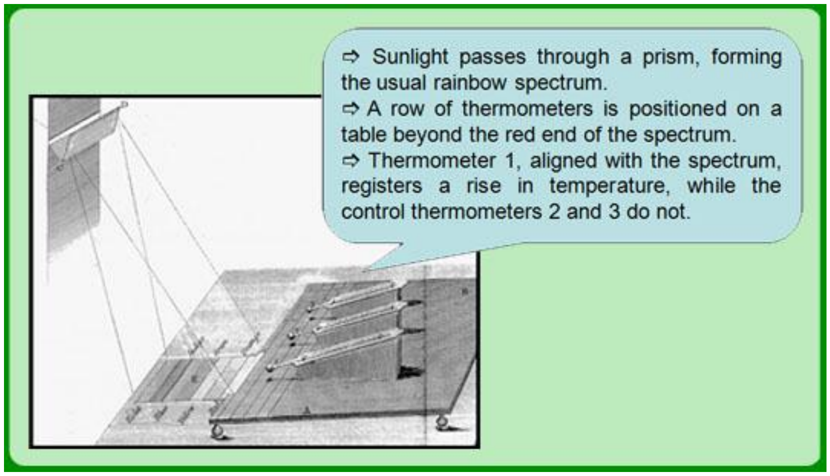
In 1800:

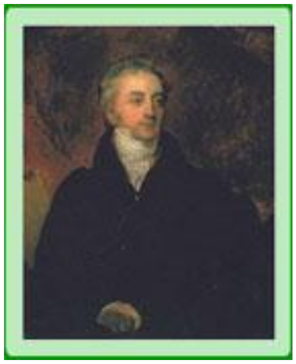
William Herschel discovers the Infrared Light.

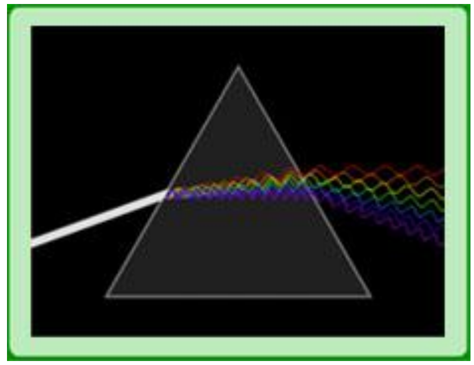


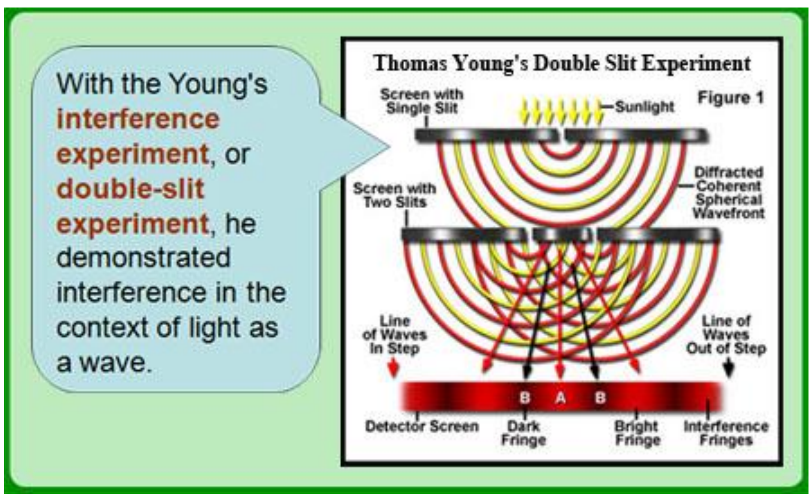
His experimental setup for the detection of invisible solar radiation

In 1801:

Thomas Young established the wave theory of light.







In 1802:

William Wollaston discovers the Solar Absorption Lines.

- Wollaston was the first to employ a narrow slit rather than a circular aperture, or pinhole, prior to the prism.
- With the slit positioned parallel to the refracting edge of the prism, he was able to observe a number of black lines in the solar spectrum as shown in the Figure – 2.1.
- He surmised that these lines were the boundaries between the primary colors of the rainbow. He labeled several of the strong lines (A-E) and even some of the weaker ones with lower case letters.

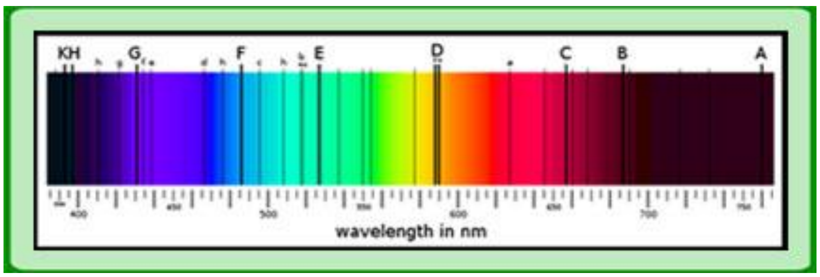


Figure – 2.1

But Wollaston's interest was in the colors themselves, and not the dark lines, so he let the matter drop.

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In 1803:

John Dalton (England) formulated the modern version of the atomic theory. In his model:

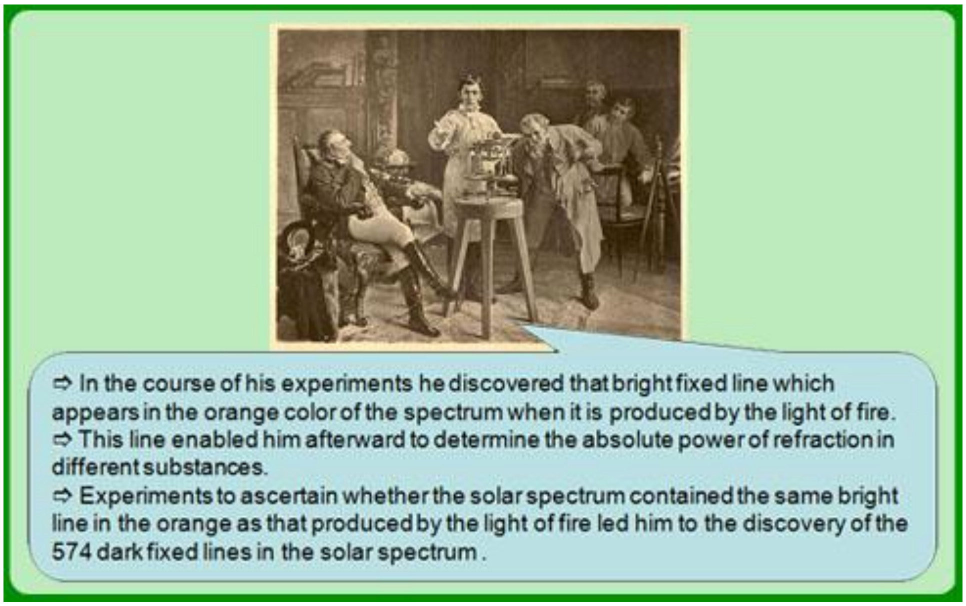
- Matter is made up of small indivisible particles, called atoms.
- All atoms in a given chemical element are exactly alike, while the atoms of different elements differ by atomic weight.
- Atoms can neither be created nor destroyed.
- A chemical reaction is just a simple rearrangement of atoms and the same number of atoms must be present before and after the reaction.

In 1814:

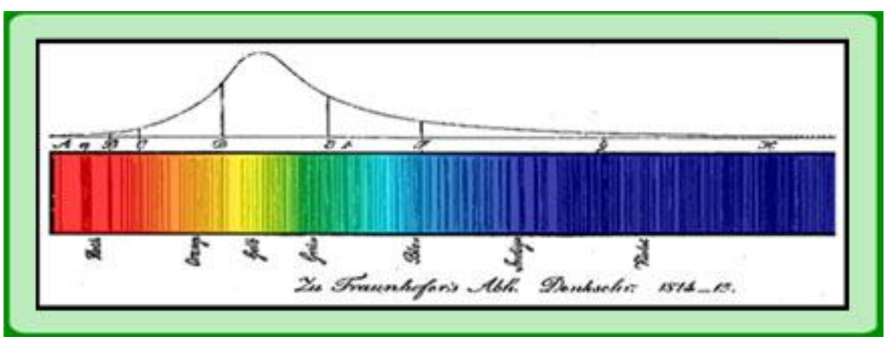
Joseph von Fraunhofer observes the solar spectral lines using an early version of the spectroscope.

In 1821:

Joseph von Fraunhofer builds the first diffraction grating, composed of 260 close parallel wires.



In 1814, Fraunhofer invented the spectroscope.



Solar spectrum with Fraunhofer lines as it appears visually

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In 1827:

Sir David Brewster produces absorption spectra in a laboratory.

He contributed in many ways in the field of optics:

- The laws of light polarization by reflection and refraction, and other quantitative laws of phenomena.
- Experiments on the absorption of light. In this line of investigation, the prime importance belongs to the discovery of the connection between the refractive index and the polarizing angle; biaxial crystals, and the production of double refraction by irregular heating.

The Brewster Stereoscope, 1849

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Discovery of Subatomic Particles

In 1832:

Michael Faradey showed that chemical changes occur when electricity is passed through an electrolyte. He stated that electricity is made up of particles called Atoms of Electricity.

In 1891:

Later, G. J. Stoney suggested the name "Electron", fundamental unit of electric charge, to describe the atoms of electricity, Michael Faraday's 1832 experiment.

In 1897:

In 1897, J. J. Thomson determined the charge/mass as given in Equation – 2.2 ratio of these cathode ray particles "electrons" and found the value of

$$e/m = 1.76 \times 10^{11}\ Coulomb/Kg$$

Equation – 2.2

In 1849:

Leon Foucault noticed that Fraunhofer's D line in the Sun corresponded with the bright yellow-orange line in lamps as shown in Figure – 2.2. To show that the two lines matched, he passed sunlight through the arc of a lamp in order to view the superimposed spectra. To his surprise, he found that the absorption lines in the solar spectrum became stronger. Additional experiments using carbon arc lamps showed that a given medium could produce either emission of absorption lines.

Emission spectrum for sodium, showing the D line

Figure – 2.2

In Mid 1850's:

Faradey studied electrical discharge in partially evacuated tubes, known as "Cathode Ray Discharge Tubes".

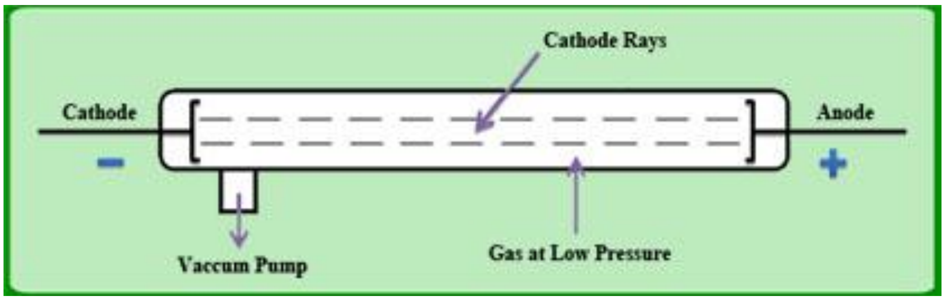


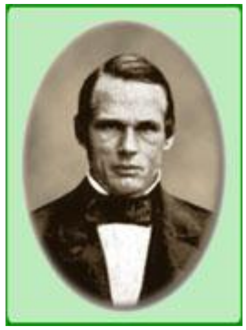
Figure – 2.3

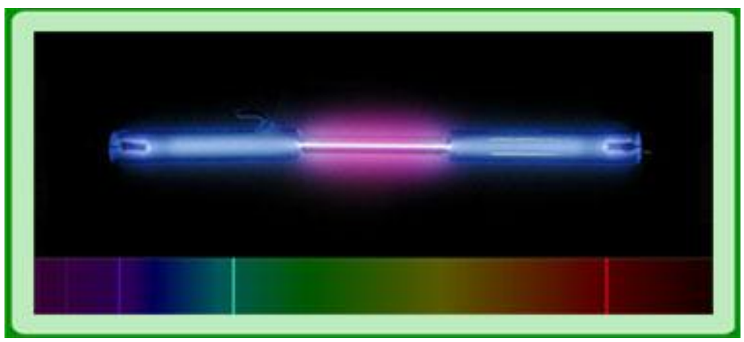
Conclusions drawn from these experiments, as shown in Figure – 2.3 are:

- Cathode Rays start from cathode and move towards anode.
- The behavior of cathode rays is similar to negatively charged particles, so cathode rays consist of negative charge particle called "electrons".
- Cathode rays ionize the gas through which they pass.

In 1853:

Anders Angström measures the hydrogen spectral lines.





Hydrogen Spectra

- The Swedish physicist Anders Jonas Ångström presented similar theories about gases having spectra in his work: Optiska Undersökningar to the Royal Swedish Academy of Sciences
- He pointed out that the electric spark yields two superposed spectra. Ångström postulated that an incandescent gas emits luminous rays same as those it can absorb — a fundamental principle of spectrum analysis.

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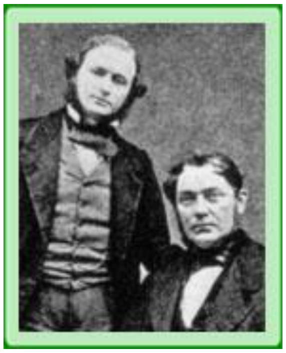
In 1860:

Gustav Kirchhoff and Robert Bunsen develop the Bunsen-Kirchhoff spectroscope that uses both a slit and a collimator. Figure – 2.4 shows the first spectroscope.



Gustav Kirchhoff (left) and Robert Bunsen (right)

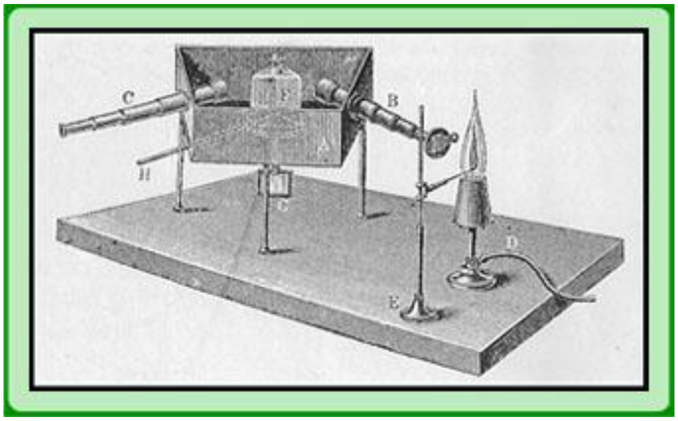


Figure – 2.4

In 1861:

Bunsen and Kirchhoff performed experiments.

Conclusion: “The dark lines in the solar spectrum, observed by Wollaston and Fraunhofer, arise due to the absorption of light by gases in the solar atmosphere that are cooler than those emitting the light”.

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In 1860:

Gustav Kirchhoff develops his spectral laws and the black body problem.

Kirchhoff's three laws of spectroscopy

- A hot solid object produces light with a continuous spectrum.
- A hot tenuous gas produces light with spectral lines at discrete wavelengths (i.e. specific colors) which depend on the energy levels of the atoms in the gas.
- A hot solid object surrounded by a cool tenuous gas (i.e. cooler than the hot object) produces light with an almost continuous spectrum which has gaps at discrete wavelengths depending on the energy levels of the atoms in the gas.

In 1862:

Anders Angström observes hydrogen in the spectra of the Sun.

In 1868:

Anders Angström publishes a compilation of all the visible lines in the solar spectral.

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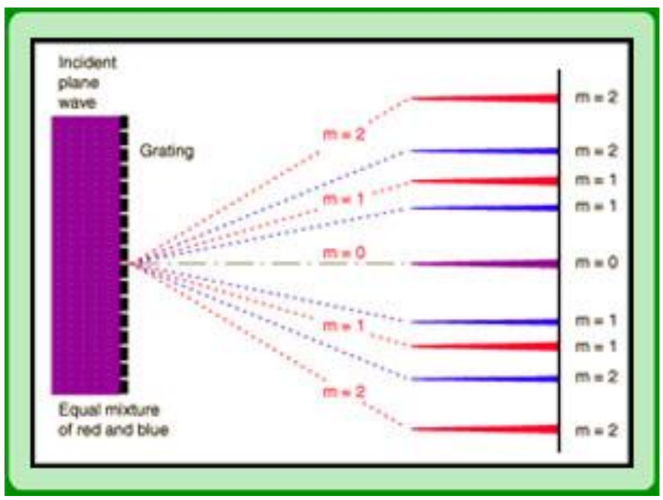
In 1882:

The beginning of a new era in the analysis of the spectra.

- Rowland constructed a ruling grating and published a photographic map of solar spectrum.
- Angstrom introduced a convenient unit of length, ten millionths of a millimeter, known as Angstrom unit as given in Equation – 2.3.

$$1\overset{o}{\mathrm{A}} = 10^{-8}cm = 10^{-10}m$$

Equation – 2.3



Diffraction Grating

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Recap

In this lecture we have gone through the chronological development of the concept of Atom.

Various philosophical thoughts and experimental observations helped to put them together and provided the basic understanding of light and matter.

In the next lecture we will find out the need for quantization of light and matter.