Phyx 320
Modern Physics

February 8, 2021

Reading: 37.1 – 37.6

Homework #3 and Reading Reflection Due Tuesday 11:59 pm

Relativity

Asserted that all laws of physics are independent of reference frame

- Implies speed of light is constant

Required us to change our understanding of space and time to be frame dependent

Following this through made us change our definitions of momentum and energy

Makes it impossible to accelerate any object faster than the speed of light

Concluded that there's an energy associated with mass

$$x' = \gamma(x - vt)$$

$$\mathrm{t}' = \gamma(t - \frac{v}{c^2}x)$$

$$p = \gamma_p\, m\, u$$

$$E = mc^2$$

Early Evidence for QM

Around the same time that Relativity was being developed, many observed phenomena could not be explained

Experiments into the nature of atoms did not follow electromagnetism or Newtonian mechanics

Needed a new description of atoms = Quantum Mechanics

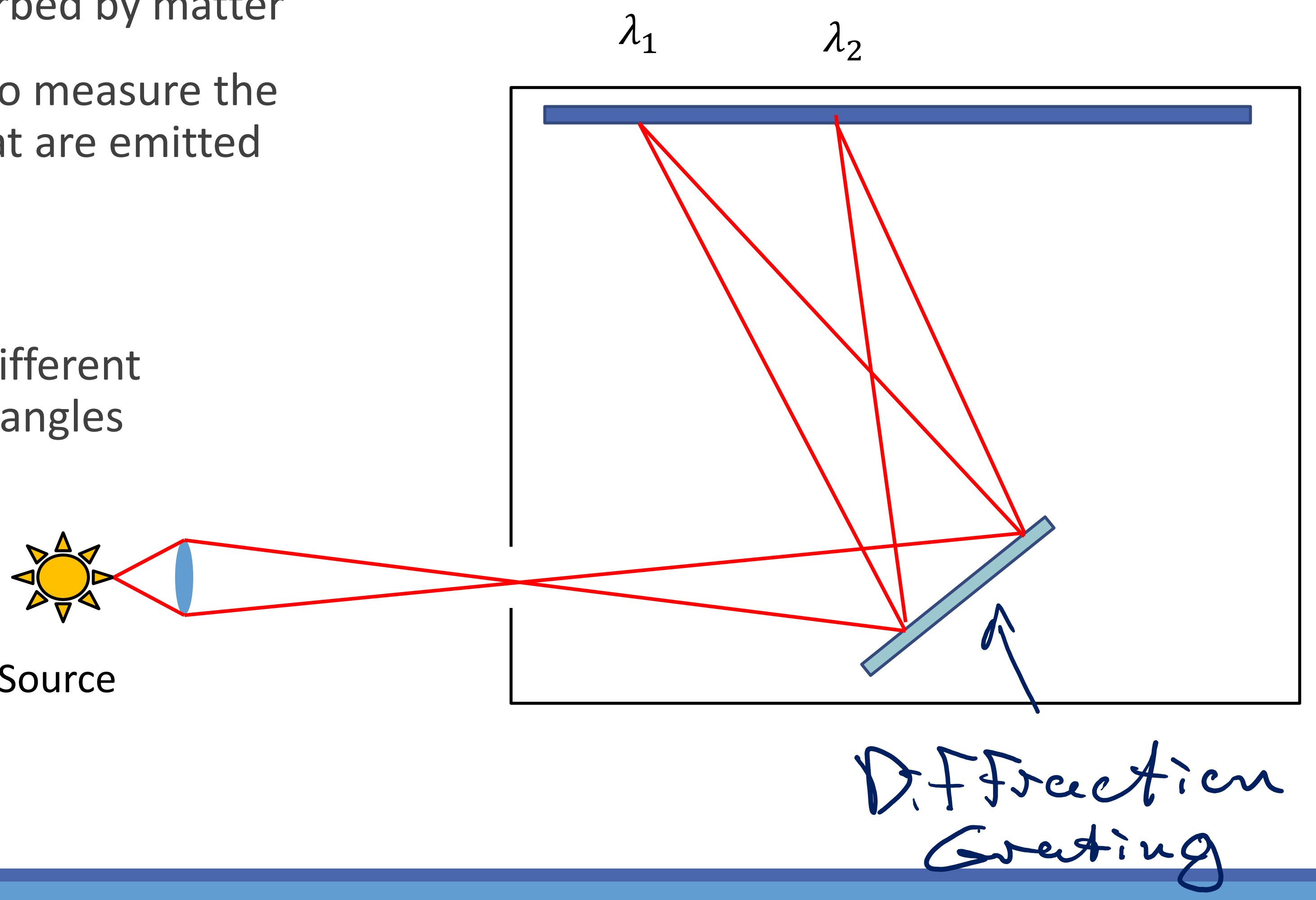
Interaction of Light and Matter

Light can be emitted or absorbed by matter

We can use a spectrometer to measure the collection of wavelengths that are emitted (spectrum)

Wavelength = color of light

Diffraction grating diffracts different wavelength light at different angles



Continuous Emission

Hot objects emit light with a continuous spectrum

- All frequencies emitted at some level

This is how incandescent light bulbs work and why electric heating elements turn red

A spectrometer splits the light into a smoothly varying spectrum

Our eyes see the “average” of the spectrum

$\lambda = 400\ nm$ $\lambda = 700\ nm$

Wavelength

$$c = \lambda f$$

Speed of light

Frequency

Blackbody Radiation

Thermal radiation depends on
- Emissivity
- Surface area
- Temperature

Emissivity is how efficiently the object emits and absorbs

A blackbody is an object that absorbs light perfectly (e=1) implies that it also emits light perfectly

Heat energy per time

Stefan-Boltzmann constant

$$\frac{Q}{\Delta t} = e\,\sigma\,A\,T^4$$

Emissivity

Surface Area

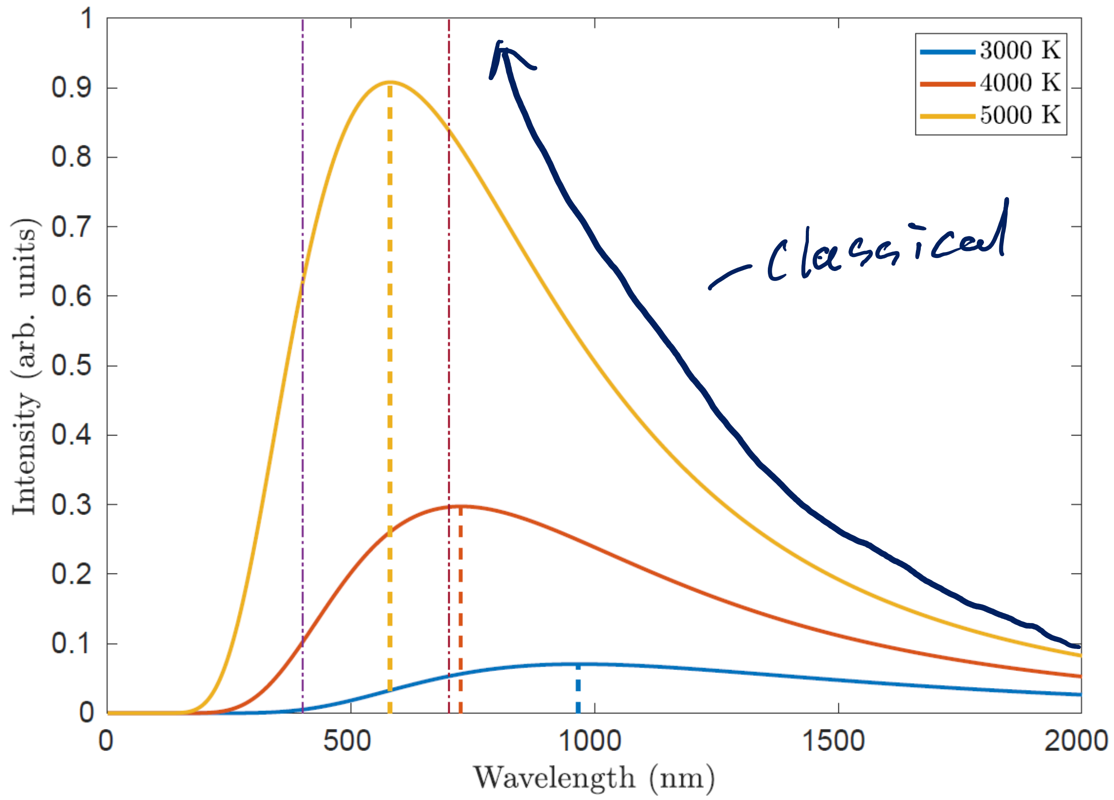
Temperature

Blackbody Radiation

Blackbody (thermal) radiation is at all wavelengths (ultraviolet, visible, infrared)

- Spectrum only depends on temperature of the object
- Hotter objects emit more radiation at all wavelengths
- Higher the temperature the shorter the peak wavelength

No classical explanation



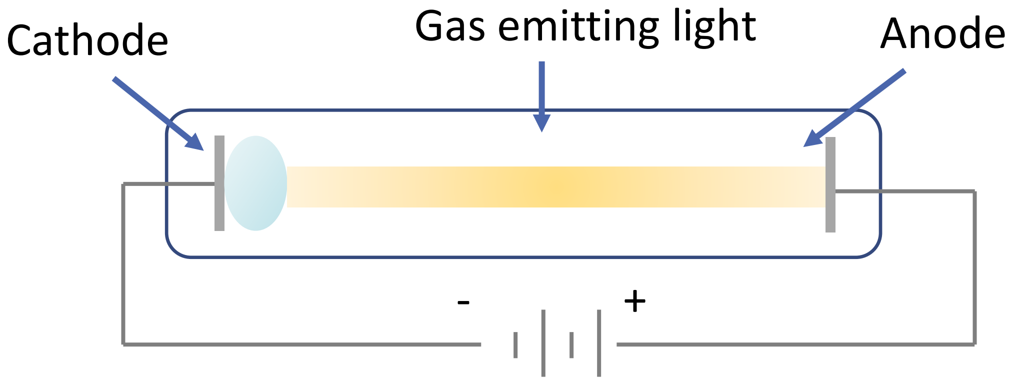
Wein's Law: $\lambda_{peak} = \dfrac{2.90 \times 10^6 \, nm \, K}{T}$

Discrete Spectra

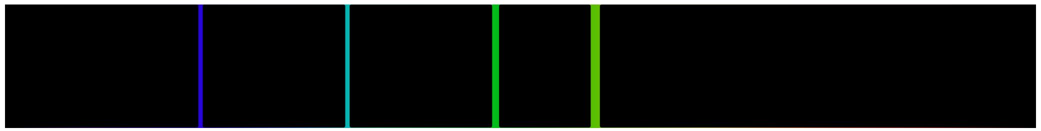
If we put gas in discharge tube, we get a discrete spectrum

- Depends on what element is in the tube
- This is how neon lights and florescent lighting works

Looking at emission spectrum we can know which element is in the tube (elemental fingerprint)



Emission Spectrum



Discrete Spectra

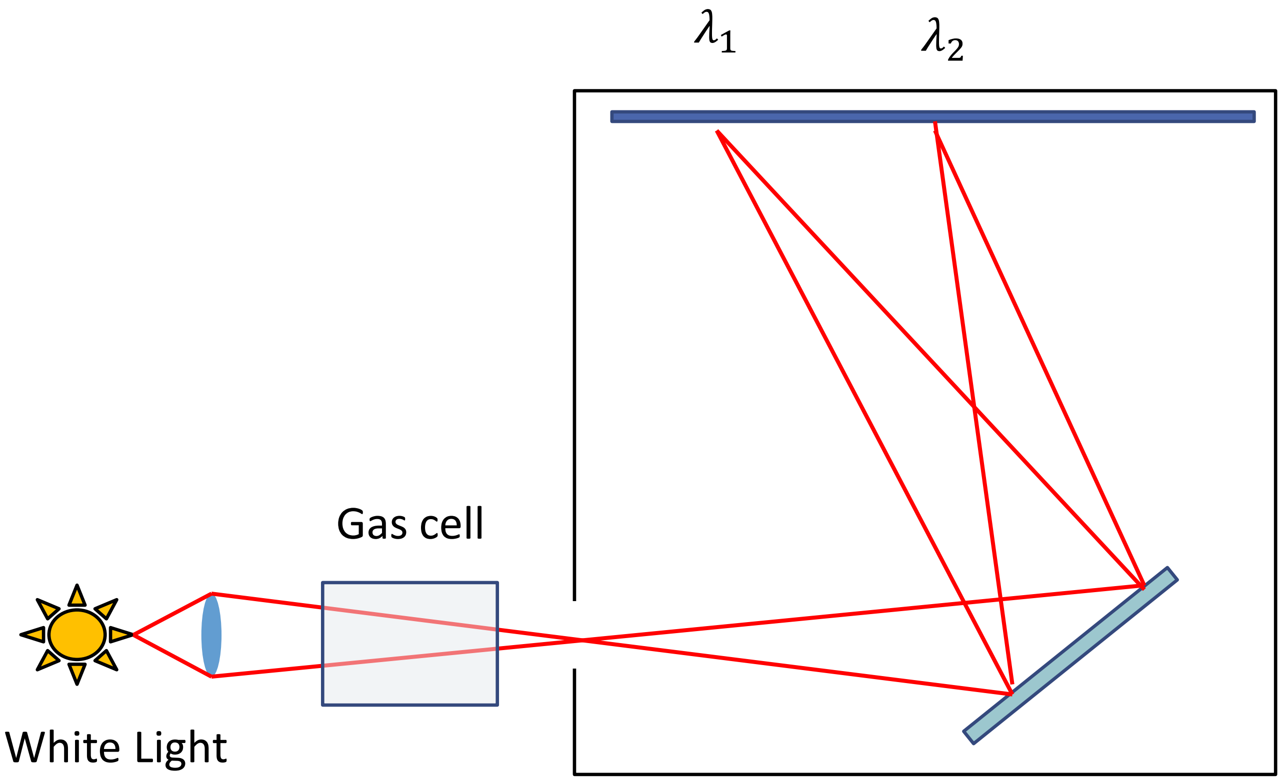
If we send white light through gas, we also get a discrete spectrum

- Depends on what element is in the tube

Every wavelength that is absorbed is also emitted but not every emitted wavelength is absorbed

What causes atoms of different element absorb and emit different, discrete spectra?

Absorption Spectrum



Balmer Series

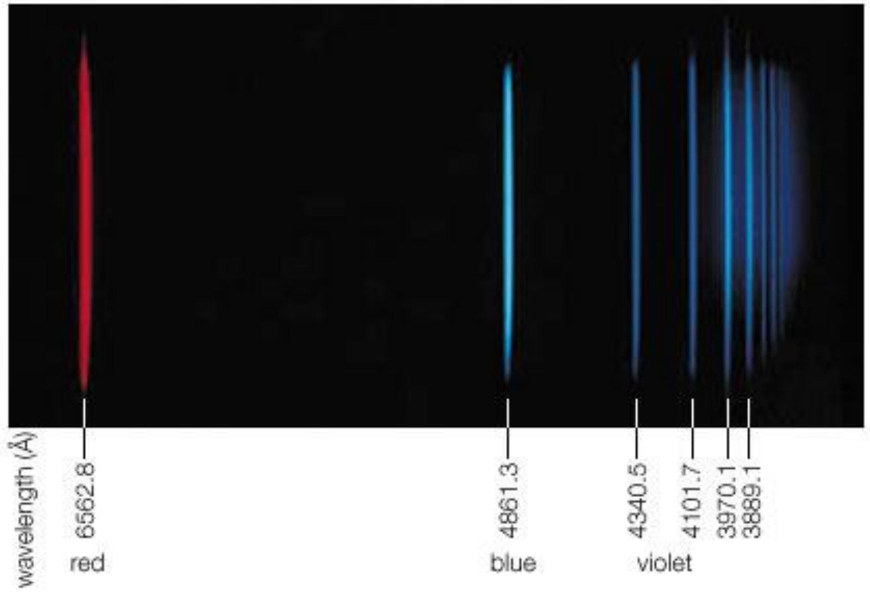
When looking at hydrogen Balmer realized that the spectrum could be described by an empirical law:

$$\lambda = \frac{91.18\ nm}{\frac{1}{2^2} - \frac{1}{n^2}}$$

$$n = 3, 4, 5, \ldots$$

Discrete Series

Emission spectrum of Hydrogen



Balmer Series

With more sophisticated measurements, more groups of emission lines were found.

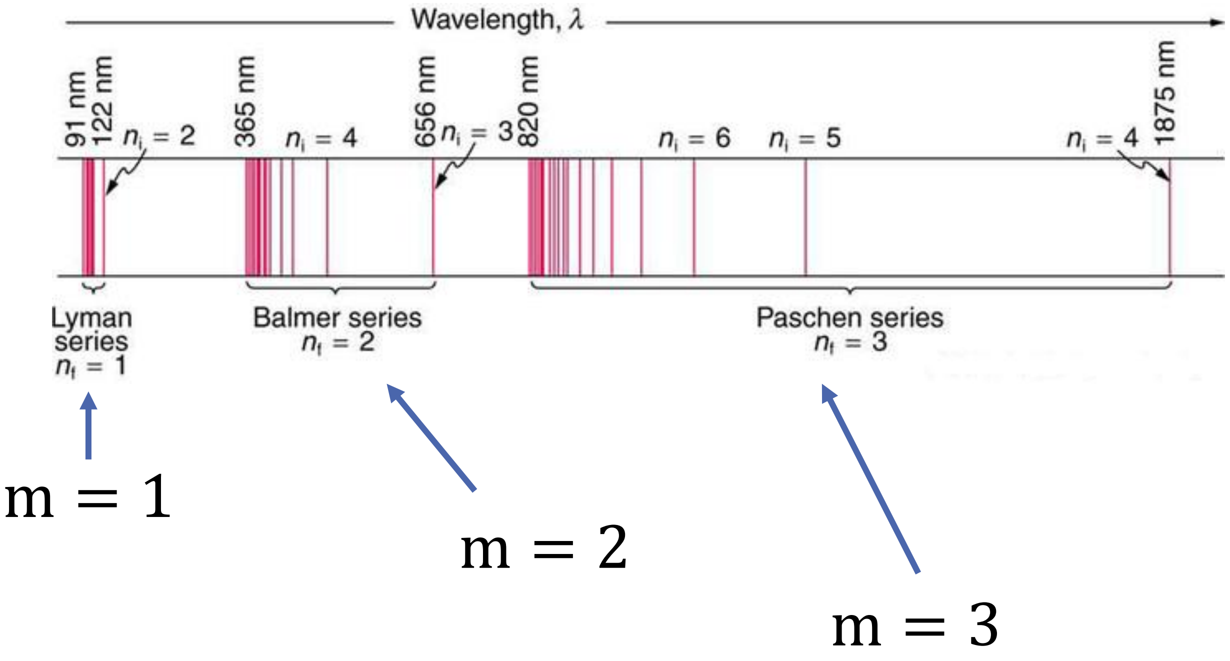
Balmer's result was generalized to:

$$\lambda = \frac{91.18\,nm}{\frac{1}{m^2} - \frac{1}{n^2}}$$

$$\mathrm{m} = 1, 2, 3, \ldots$$

$$\mathrm{n} = m + 1, m + 2, \ldots$$

Emission spectrum of Hydrogen



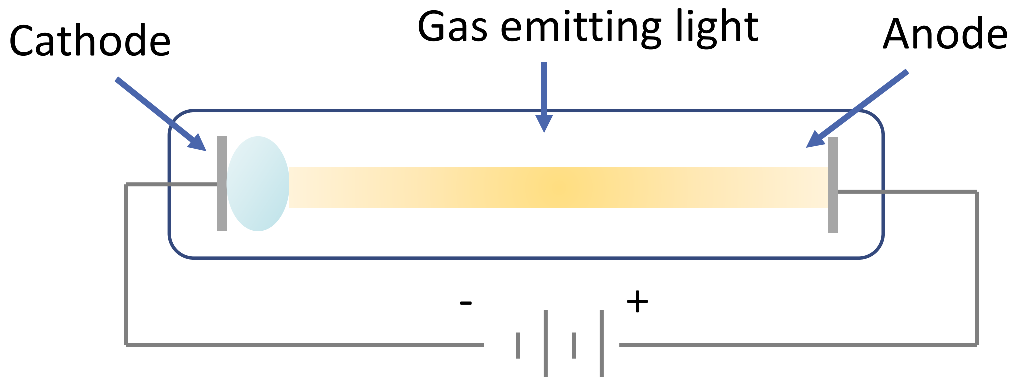
Cathode Rays

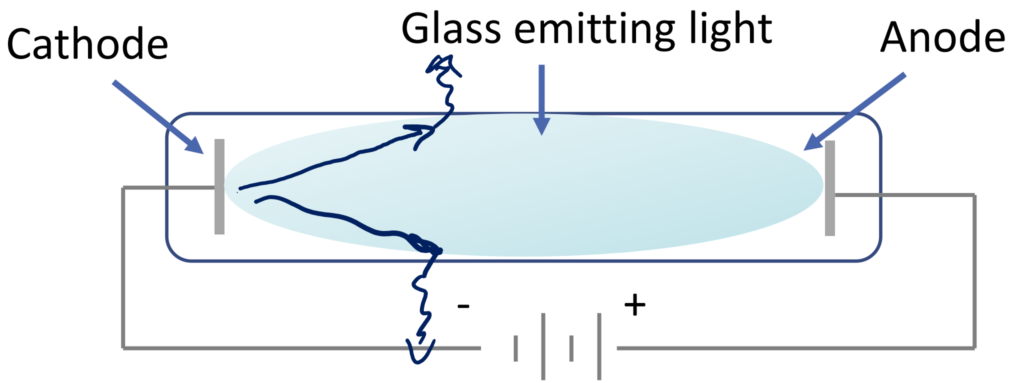
As vacuum technology got better, experimenters found that a discharge tube with no gas (vacuum) still emits light

Some sort of rays were emitted by the cathode (named cathode rays)

When these rays hit the glass, they caused it to emit green light

Used in old TVs and computer monitors



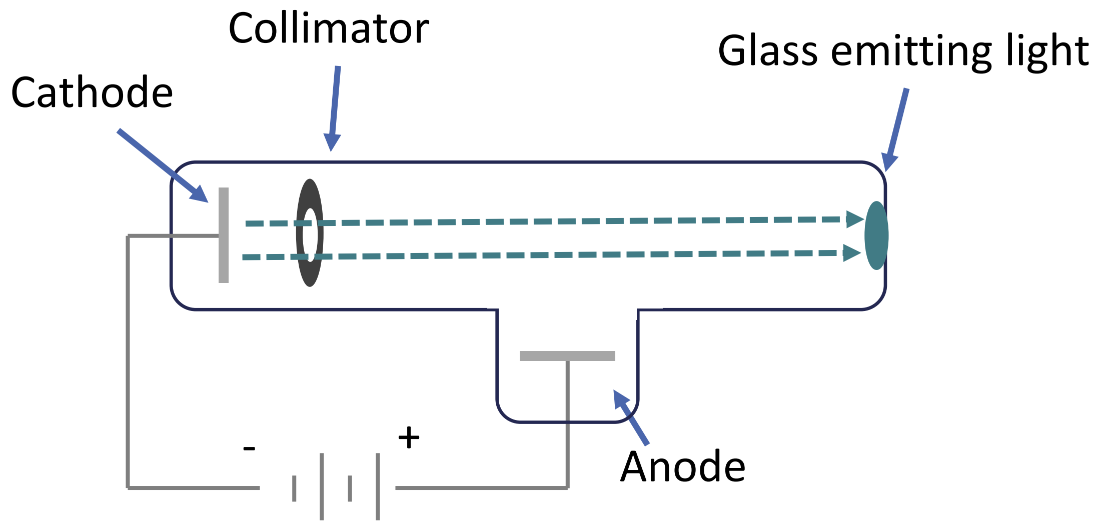


Crookes Tube

Crookes added a collimator to form a beam of cathode rays

Found that the rays did not depend on cathode material

Early version of a particle accelerator



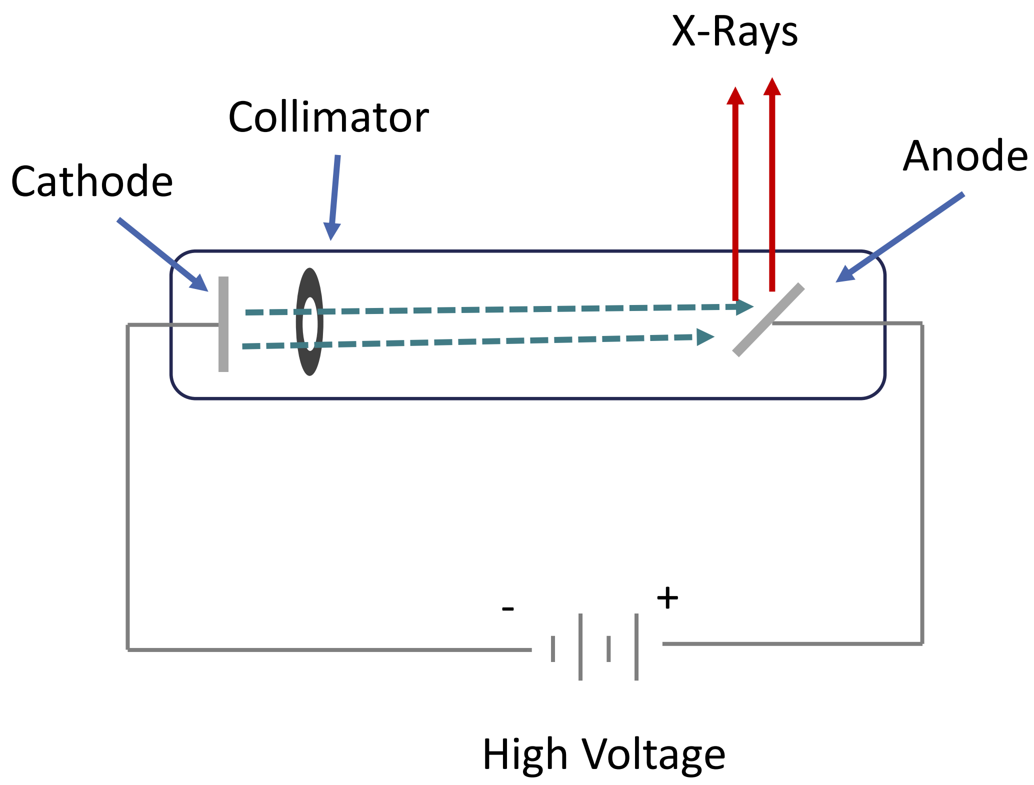
X-Rays

Röntgen decided to increase the voltage and let the cathode rays strike the anode in vacuum

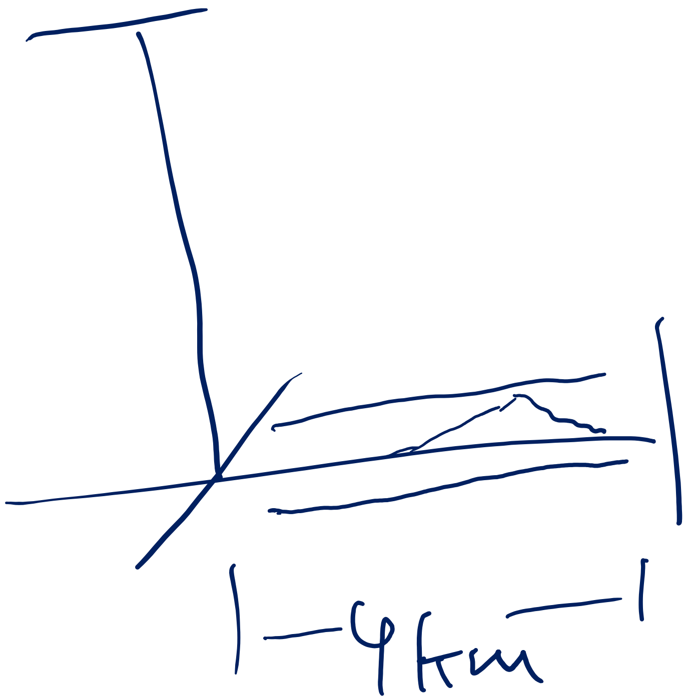
Produced x-rays for the first time

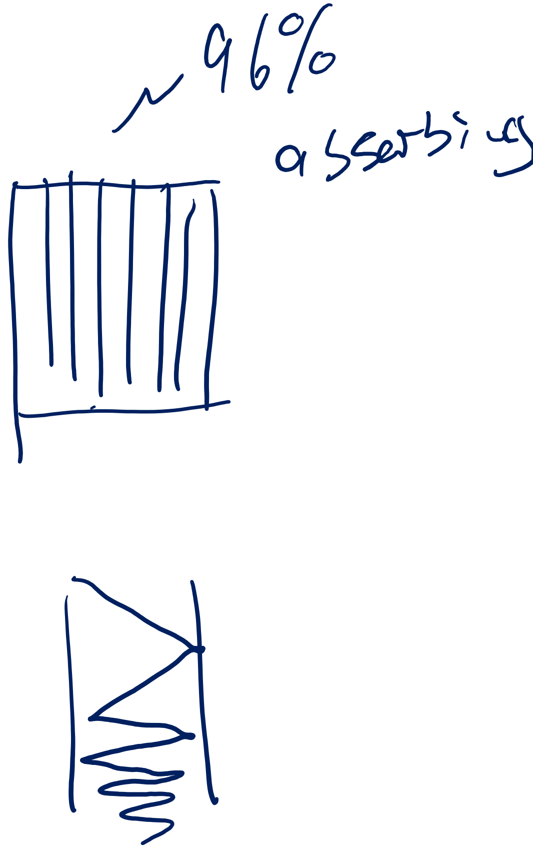
Found that they pass through most material and traveled in straight lines

20 years later, it was shown that x-rays are EM waves with wavelengths of 0.01 nm – 10 nm



Homework Questions





Homework Questions

$\longrightarrow$

$0.999c$

$m_p = 1.673 \times 10^{-27}\ kg$

MeV

$h = c = 1$

Natural Units

Homework Questions

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