Phyx 320
Modern Physics

February 19, 2021

Reading: 38.1 – 38.4

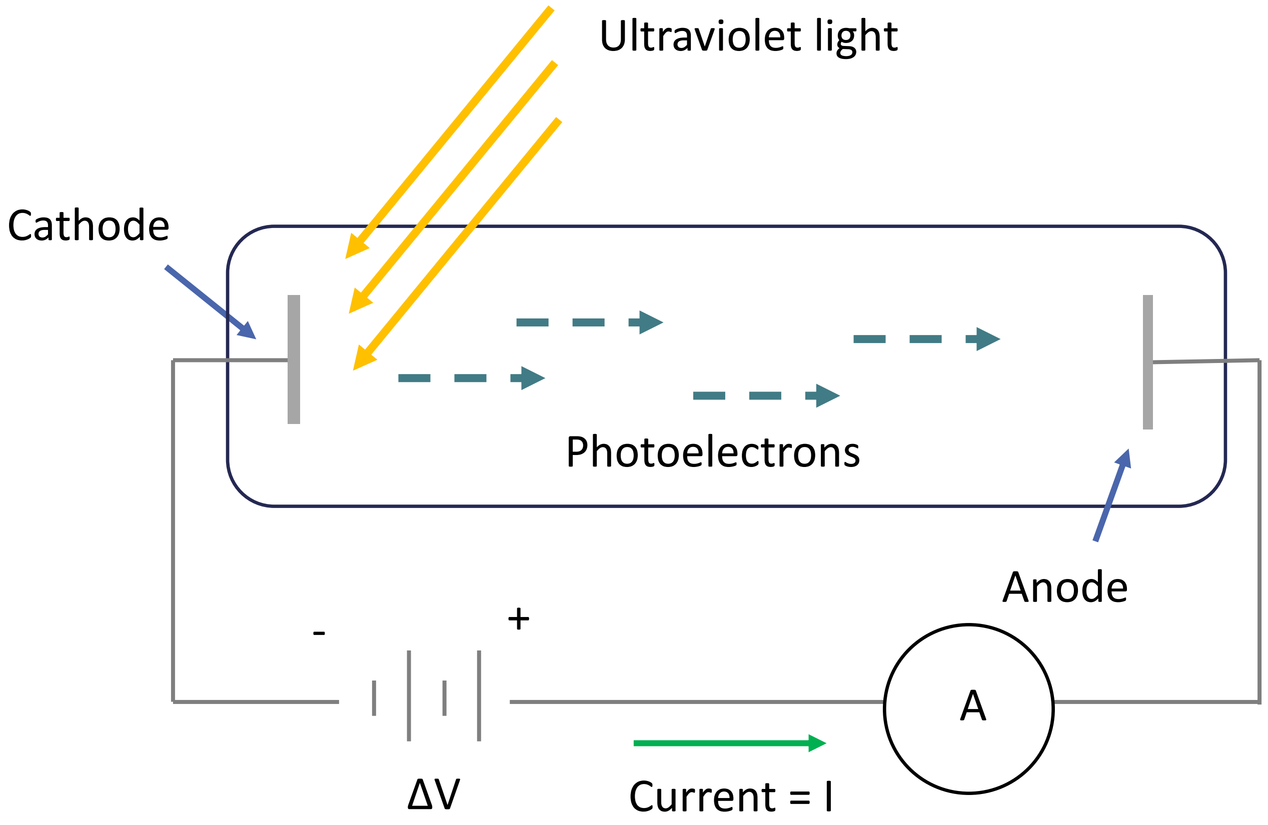
Homework #5 and Reading Reflection Next Next Tuesday 11:59 pm

Photoelectric Effect

Light can cause electrons to be ejected from metals

Found that the energy of a photon is $E = hf$ where f is the frequency of light and $h = 6.63 \times 10^{-34} J\ s$ is Planck's constant

Light now seen as discrete particles instead of continues wave



Double-slit Experiment

Let's revisit the double slit experiment but with the photon picture

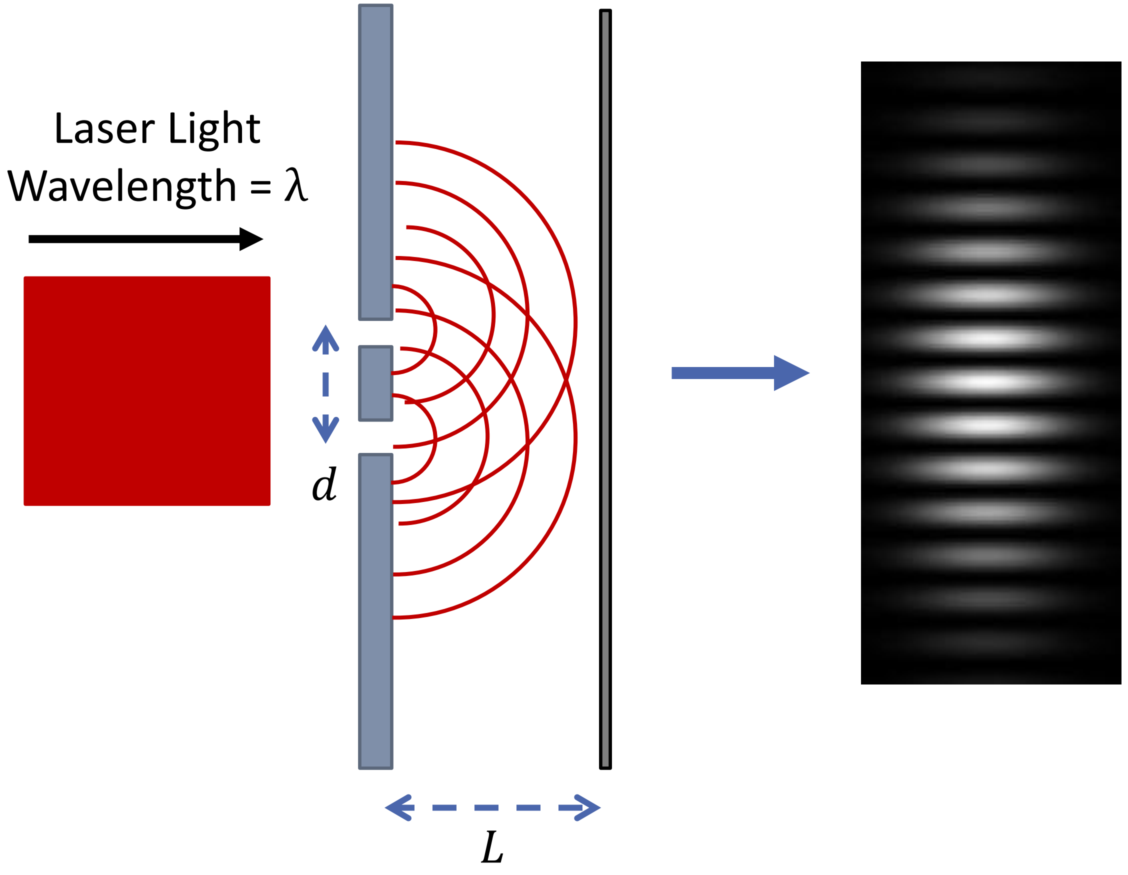
Set up coherent laser light shining through two small slits

The interference pattern is then imaged on a screen and we find multiple peaks

Peaks separated by $\Delta y = \frac{\lambda L}{d}$

Wave model of light describes this observation perfectly

Each slit is seen as a point source which interfere at the screen



Double-slit Experiment

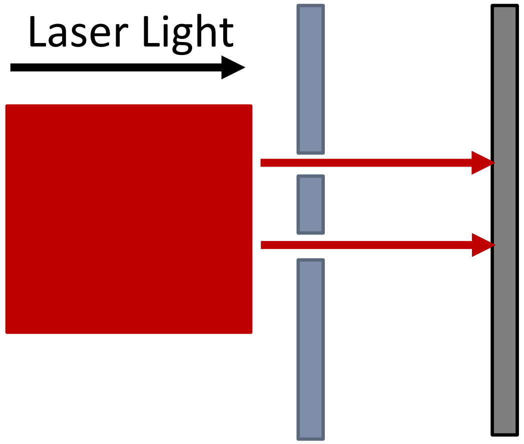
Let’s run this experiment with low light and a detector that’s sensitive to single photons

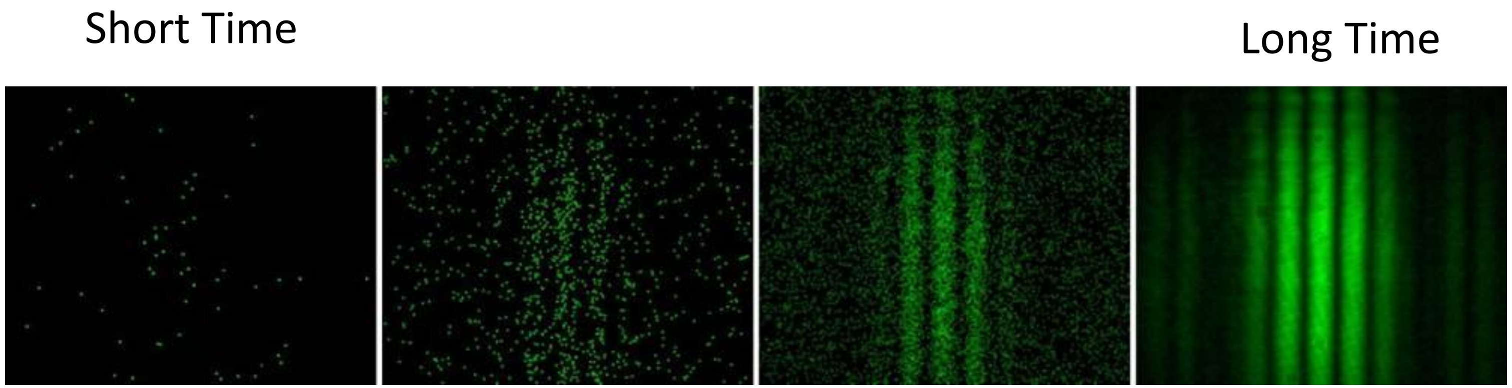
Particle picture would say we shouldn’t see any interference just two peaks at location of slits

But what still see interference pattern after a long time

Implies that each photon travels through both slits and interferes with itself

Detected at screen as single particles





Photon Model of Light

Light is made of individual particles called photons

Photons are massless and travel at the speed of light in vacuum

Each photon has an energy of $E = hf$

Photons travel as waves but are detected as particles

The superposition of many photons yields a classical EM wave

$$E_\gamma = hF$$

$$E_{beam} = NhF$$

$$P = \frac{dE}{dt}$$

constant

$$= \frac{d}{dt}\left[NhF\right]$$

$$= hF\frac{dN}{dt}$$

Number per time rate $= R$

$$P = hFR$$

Matter Waves

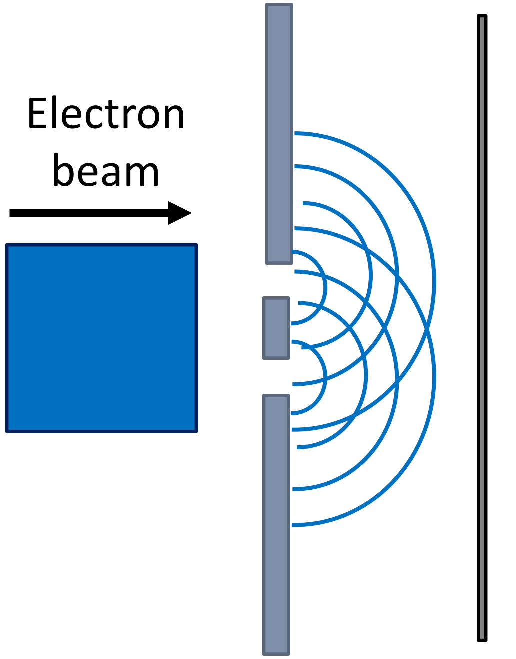
If light is a particle and a wave, can this also be true for matter?

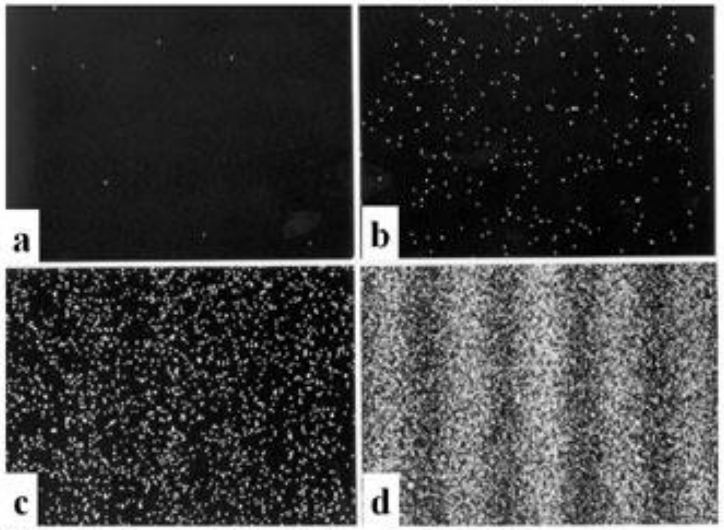
De Broglie proposed that if matter is described by a wave, then its wavelength must depend on its momentum

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

Double slit experiment shows the same interference when electrons are used instead of light

Matter is also a wave!





Single-electron Build-up of Interference Pattern

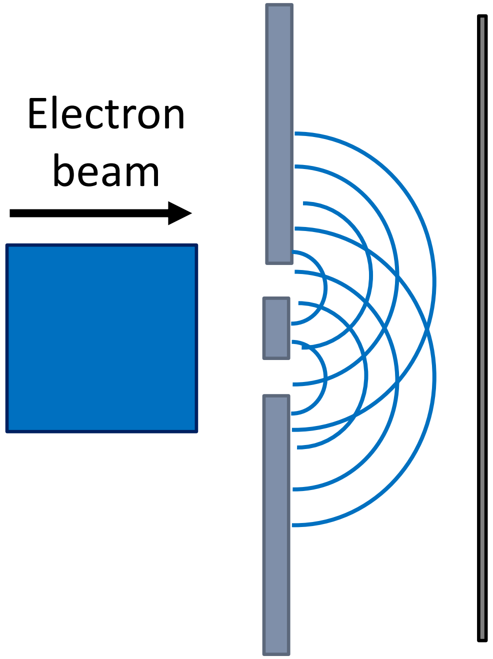
Matter Waves

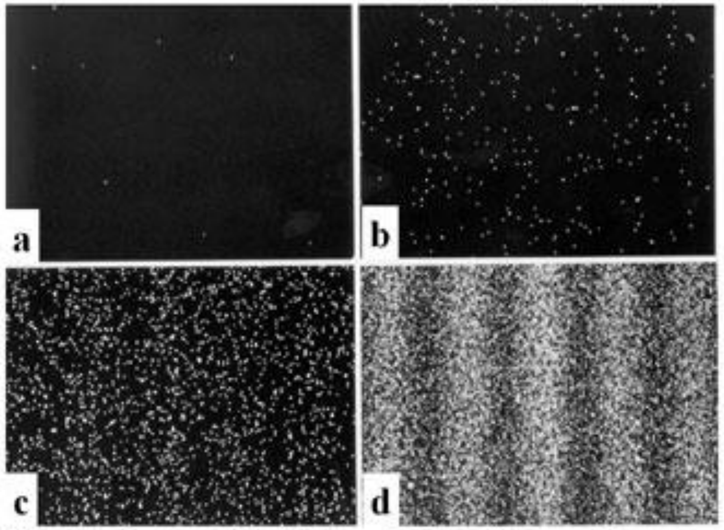
Light and matter are detected as individual particles

However, they move through the world as probability waves

- Where wave has maximum means, we have maximum probability to measure a particle

Run this through many particles leads to a classical wave





Single-electron Build-up of Interference Pattern

Quantization of Energy

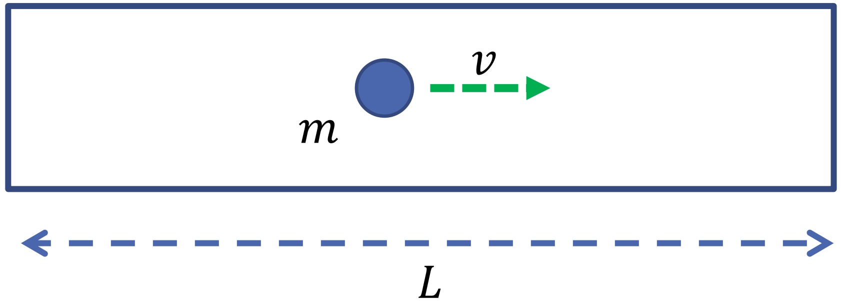
The wave nature of matter also changes their possible energies

Let's put a particle in a box and calculate its energy

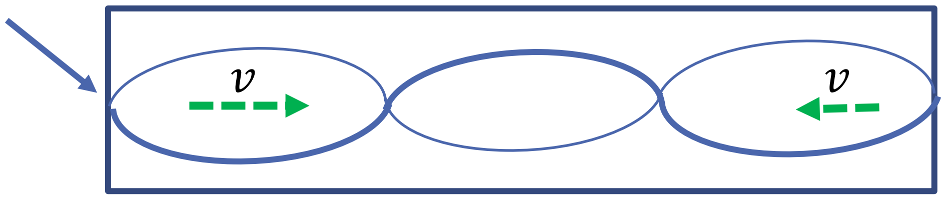
Classically any energy can be in box

$$E = \frac{1}{2} m\, v^2$$

What wavelengths are allowed?

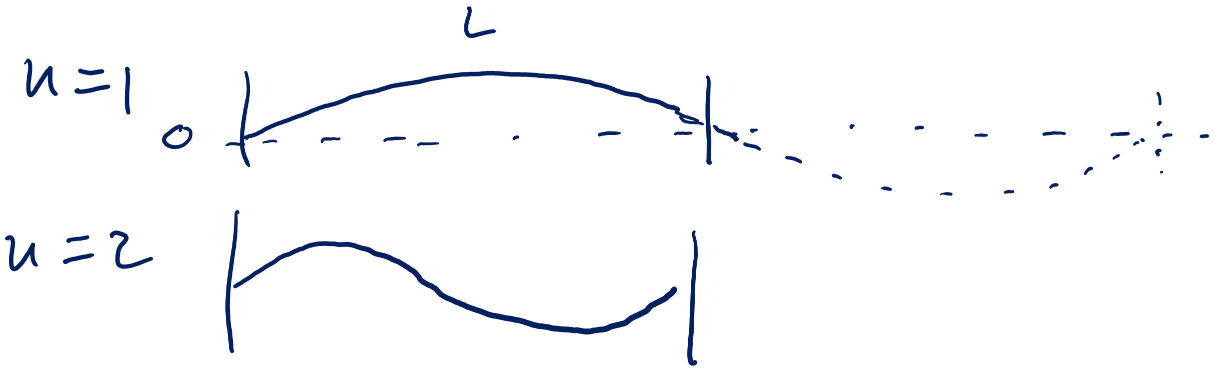


Perfect reflection
= wave zero



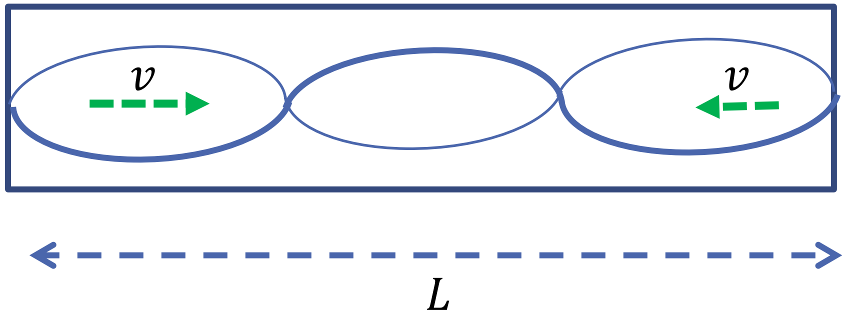
$$\lambda = \frac{h}{mv} = \frac{2L}{n}$$

$$n = 1, 2, 3, \ldots$$



Quantization of Energy

What's the allowed energies of these particles?



$$\lambda = \frac{h}{mv} = \frac{2L}{n} \qquad n = 1, 2, \ldots$$

$$v = n\left(\frac{h}{2mL}\right)$$

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

$$= \frac{1}{2}m\left(n\,\frac{h}{2mL}\right)^2$$

$$= n^2\left(\frac{h^2}{8mL^2}\right) \qquad n = 1, 2, 3, \ldots$$

$$E_0 = \frac{h^2}{8mL^2}$$

quantum numbers

Quantization of Energy

By putting a particle in a box, the energy is quantized

Energy:

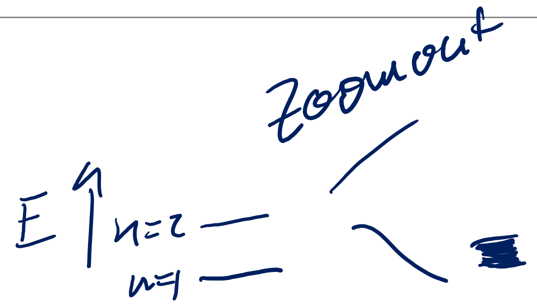
$$E = \frac{n^2 h^2}{8mL^2}$$

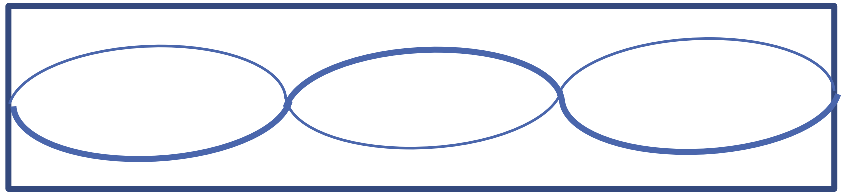
Quantum number:

n = (number of nodes)-1

Ground state is what we call the lowest energy state

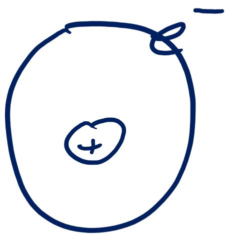
$$E_0 = \frac{h^2}{8mL^2}$$





nodes = 4

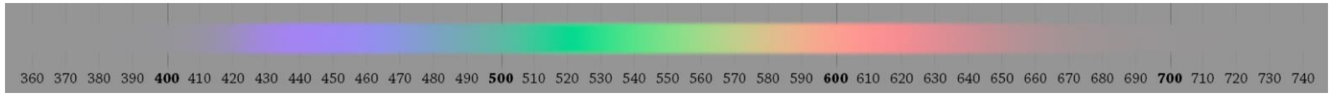
n = 3



Quiz 4 Solutions

The Sun is at a temperature of 5,778 K. Human eyes are sensitive to light with wavelength between 380 to 750 nm. Below is a rendering of colors at corresponding wavelengths.

1. If we treat the sun as a blackbody, what peak wavelength does it emit at? What color does this correspond to?
2. For the Lyman series (m=1) emission of hydrogen, what n corresponds a wavelength of 97.26 nm?



1. $T = 5{,}778\ K$

$$\lambda_{peak} = \frac{2.90 \times 10^{6}\ nm\ K}{T}$$

$$= 502\ nm$$

2. $$\lambda = \frac{\lambda_0}{\frac{1}{m^2} - \frac{1}{n^2}} \leftarrow \lambda_0 = 91.18\ nm$$

$m = 1$

Quiz ~~3~~ 4 Solutions

2. $$\lambda = \frac{\lambda_0}{\frac{1}{m^2} - \frac{1}{n^2}}$$

$\lambda_0 = 91.18\,nm$

$m = 1$

$\lambda = 97.26\,nm$

$$\lambda\left(1 - \frac{1}{n^2}\right) = \lambda_0$$

$$\frac{1}{n^2} = 1 - \frac{\lambda_0}{\lambda}$$

$$n = \frac{1}{\sqrt{1 - \frac{\lambda_0}{\lambda}}} = 3.995$$

must be integer

$$\boxed{n = 4}$$

Homework Questions

Homework Questions

Homework Questions

Homework Questions