Phys 112 2019

Lecture 37

Weds / Thurs : Lab - prelabs

Fri: HW by 5pm

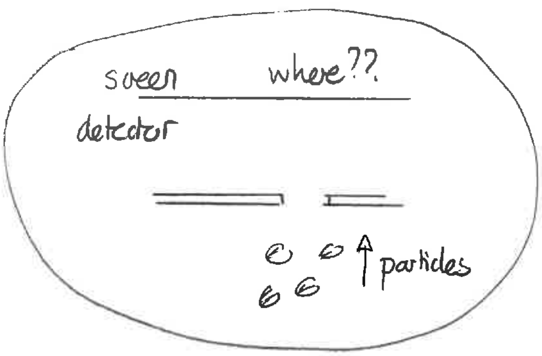
Supp 126, 127, 128, 129, 130

Ch 28 Quest 26, 38

Ch 28 Prob 61

Particles and Waves

Various double-slit and other interference experiments indicate that particles can have a wave-like nature. Quantum physics describes this situation via:

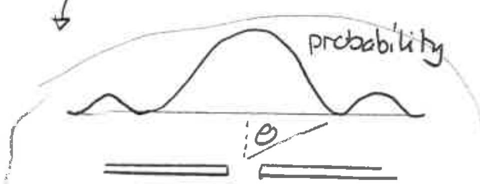


→ Associate wave with particles. Wavelength of wave

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

→ Use wave physics to calculate intensities on screen (just as for optics)

Then: probability is proportional to intensity



minima at θ_p s.t.

$$a \sin\theta_p = p\lambda$$

Note that the wave / wavelength is not

1) related to the electrons spatial size
2) a picture of how the electron moves

It simply provides a tool for determining the results of various experiments.

Evidence for such behavior includes:

1) <u>particle interference experiments</u>

- neutrons + double slit
- C_{60} molecules
- Molecules with 10 000 AMU.

2) <u>Scattering of electrons off crystals</u>

<u>PhET</u> Electron diffraction

- fire electrons at medium intensity
- small separation - observe pattern
- lowe velocity - observe pattern

This suggests bright + dark fringes that can be described by interference of waves associated with the electrons

<u>Demo:</u> Electron diffraction images

3) <u>Electron microscopy</u>

One can attain small wavelengths with electrons and use these for high resolution microscopy since the wavelength can be much smaller than optical wavelengths. Diffraction limitations will therefore be less of an issue than with visible light

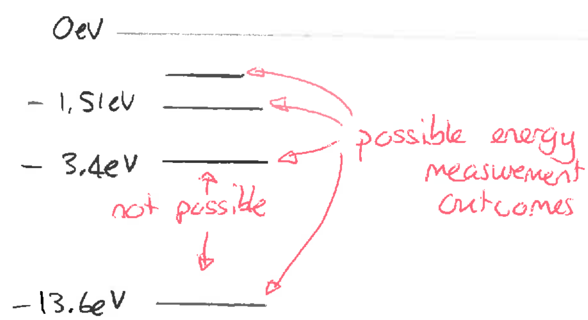
<u>Demo</u> Wikipedia Images

Energy quantization

It eneges generally in quantum theory that the possible energies of a system can only assume discrete values. We say that such energies are quantized. For example, when quantum theory is applied to the hydrogen atom the possible energies are:

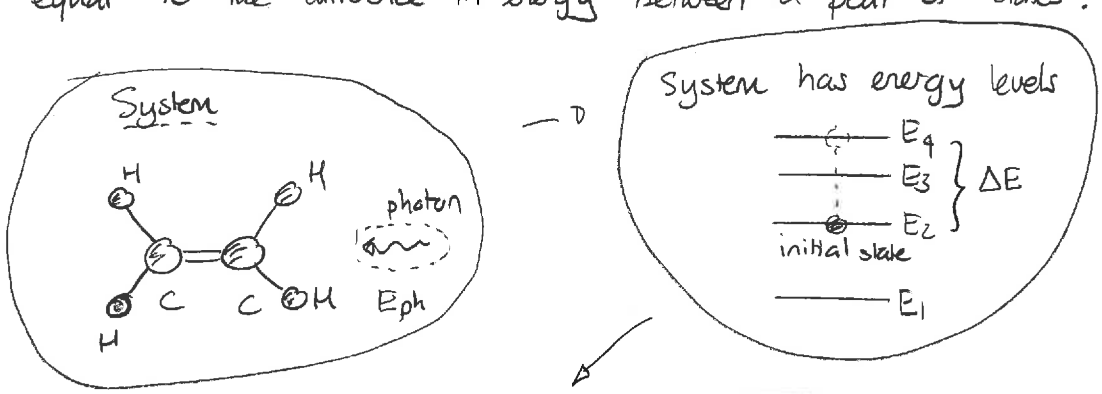
$$-13.6\,eV, \; -3.4\,eV, \; -1.51\,eV, \; \ldots$$

We can depict these via a ladder. The meaning of this is that if the energy were measured the result could only be one of these values and nothing between.



This situations occurs with all atomic and molecular systems as well as solids in bulk.

Then an additional feature to this is that if the energy of the atom is to change it can only change by particular discrete amounts. Thus a photon which is absorbed by the atom must have an energy exactly equal to the difference in energy between 'a pair of' states. Schematically:



If Eph = difference in energy between initial state + possible final state then photon is absorbed

The same applies for emitting a photon. In general

> If a system absorbs or emits a photon with energy E_{photon} then the change in system energy ΔE_{system} must satisfy
>
> 1) $\Delta E_{system} = E_{photon}$
>
> 2) be equal to the difference between two energy levels of the system.

Then using $E_{photon} = \frac{hc}{\lambda}$ we get that the possible wavelengths of emitted or absorbed light satisfy

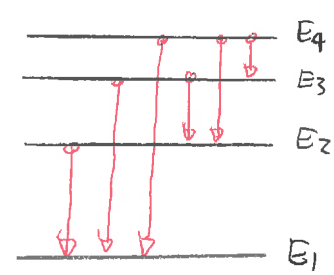
$$\Delta E_{system} = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E_{system}}$$

Since there are only discrete possibilities for ΔE_{system}:

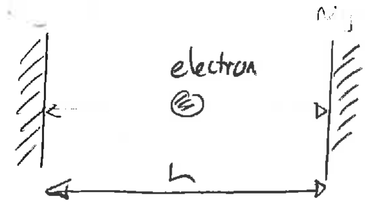
> Quantized energies in material systems imply that the spectrum of emitted or absorbed light consists of discrete wavelengths

Quiz 1 — 20% → 60%

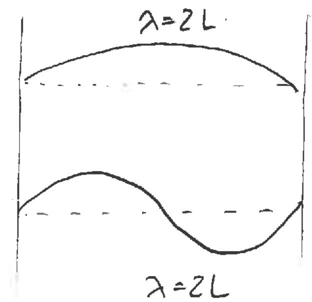
The diagram lists a system with four levels and thus six possible energy transitions. This would give six possible wavelengths of emitted light.



Particle in a box



In some situations particles are trapped inside a region and are effectively free to move inside the region. Quantum physics requires that we associated a wave with such a particle. But the waves must be accommodated within the box. There are only certain possible wavelengths that can do so. We get:



Restricted set of possible λ ⇒ Restricted set of possible v ⇒ Restricted set of possible $E = \frac{1}{2}mv^2$

A detailed analysis gives:

> Consider a particle of mass m in a one-dimensional box of length L. The possible energies are:
>
> $$E_n = \frac{h^2}{8mL^2} n^2$$
>
> where $n = 1, 2, 3, \ldots$

Quiz 2