Mon: Warm Up 14 (D2L)

Tues: Discussion /quiz

Quantum Physics

The physics which we have encountered so far is all Newtonian, or classical physics. The key ideas here are that the state of an physical system can be described in terms of the motion (position and velocity) of all its constituents. This uses the basic ideas of force and acceleration to address questions about motion. It emerges that for some situations the Newtonian framework gives predictions that are inconsistent with experimental observations.

An alternative to this, quantum physics, was initially developed in the early 20^{th} century. Quantum physics:

1) is a general framework that can in principle be applied to any physical situation

2) does not use the concepts of force and acceleration as classical physics does

3) offers a very different (to classical physics) formalism for describing physical situations.

Quantum physics is generally most powerful when describing small scale phenomena. Some examples include:

1) atomic + molecular structure and dynamics. Interactions of such atoms and molecules with light/electromagnetic fields (e.g. NMR)

2) properties of solids (e.g. electrical conductivity) – superconductors, semiconductors

3) light – photons and lasers

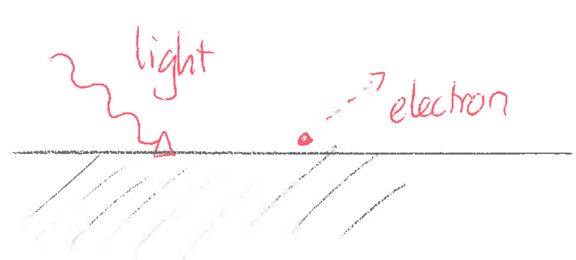
4) fundamental particles – CERN etc...

The term quantum arises because unlike classical physics, some measurable quantities can only assume discrete values. We will encounter this later.

Photoelectric effect

One of the first phenomena to reveal a discrete nature of physical quantities had to do with the emission of electrons from certain metals by incident light. This is called the photoelectric effect

Demo: PhET Photoelectric Effect
- simply shine violet light + observe electrons
- increase λ → slower electrons → no electrons
- now increase intensity



Observations: See p 989-993

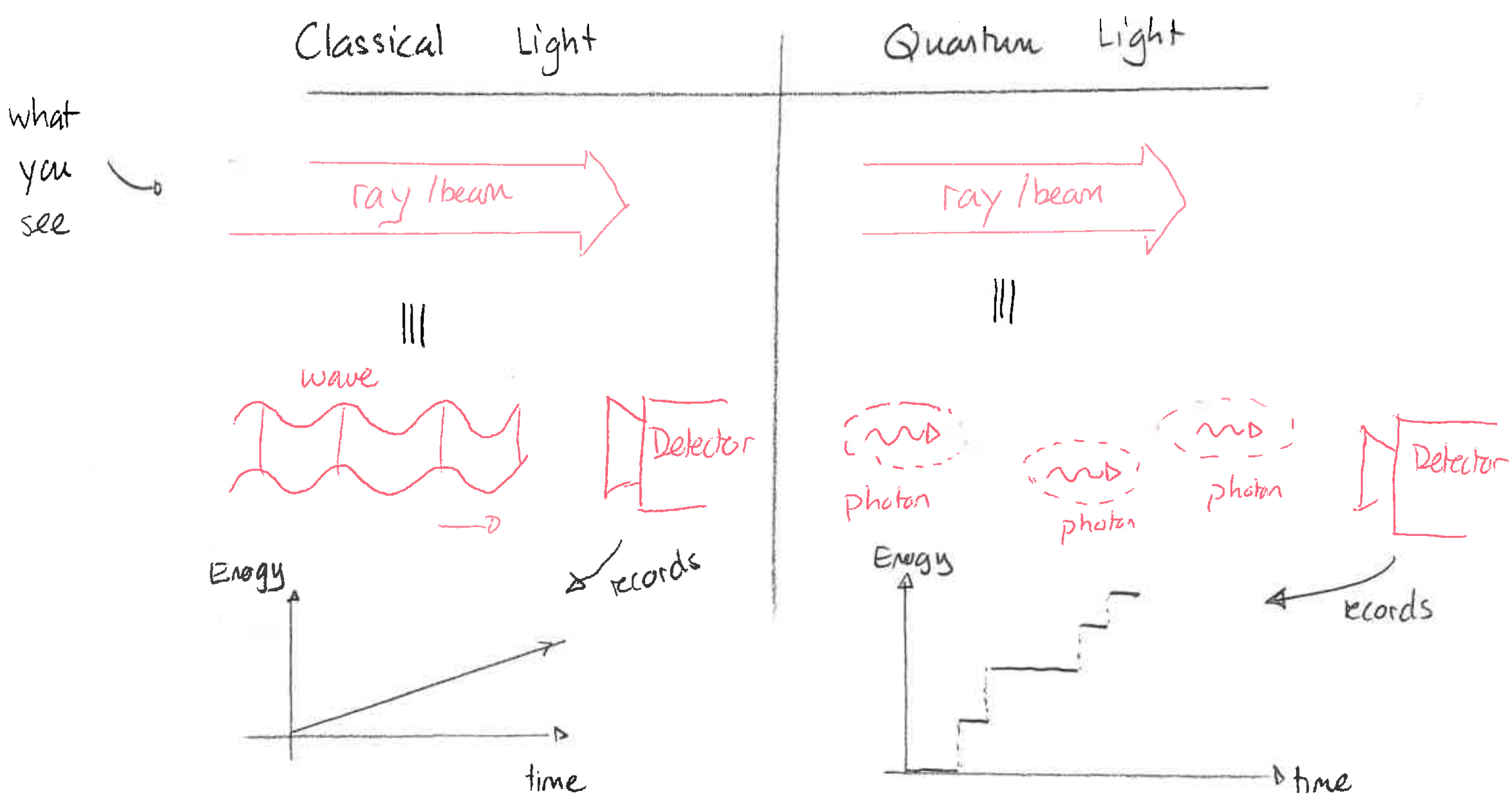
1) if wavelength is too large, no electrons emitted
2) if wavelength small enough, electrons are emitted
3) if electrons are emitted then <u>intensity</u> describes <u>rate of emission</u>

If we assume that it requires a certain energy to eject an electron from a metal then classical physics, which states that energy = intensity × time, would predict that we could eject an electron with any wavelength. We can just by adjusting the intensity supply any energy that we need.

This was first successfully explained by Einstein, who assume that the energy provided by the incident light arrives in discrete (quantized) packages. These were eventually called photons.

Photons

Consider two possible models of light



Demo: PE Effect – show photons in "Options.

We now provide the crucial properties of photons:

1) a single photon has energy

$$\boxed{E_{photon} = hf = \frac{hc}{\lambda}}$$

where f = frequency of light

$h = 6.6 \times 10^{-34}$ J·s (Planck's constant)

2) A photon cannot be split or subdivided. Two photons will not combine into a single photon.

Photons have a discrete nature and can be counted. Suppose that the total energy in a beam of light is E_{total}. Then

$$E_{total} = N E_{photon}$$

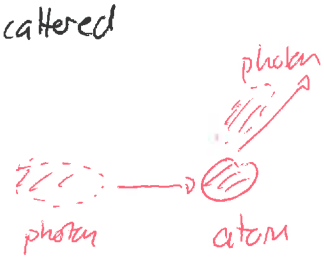
where N = number of photons

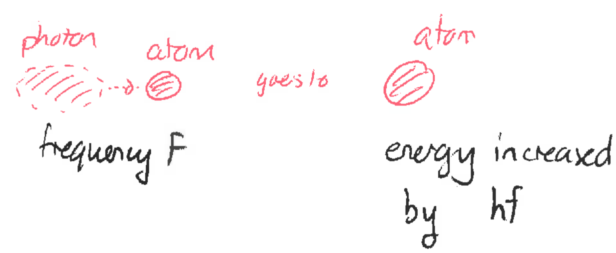
E_{photon} = energy of single photon.

Quiz 1 80%

3) When interacting with an atom or matter, a photon is either

a) scattered OR b) absorbed





Quiz 2

Example: A laser emits light with wavelength 632.8×10^{-9} m. The laser power is 1.0 mW. Determine

a) energy per photon

b) number of photons emitted per second.

Answer: a) $E_{photon} = hf = hc/\lambda$

$$= \frac{6.6 \times 10^{-34}\ J \cdot s \times 3.0 \times 10^{8}\ m/s}{632.8 \times 10^{-9}\ m}$$

$$= 3.13 \times 10^{-19}\ J.$$

b) Total energy in time T is $E_{total} = PT$

Then $E_{total} = N E_{photon}$

$$\Rightarrow N E_{photon} = PT$$

$$\Rightarrow N = \frac{PT}{E_{photon}}$$

$$= \frac{1.0 \times 10^{-3}\ W \times 1.0\ s}{3.13 \times 10^{-19}\ J}$$

$$\Rightarrow N = 3.2 \times 10^{15} \text{ per second.}$$