Mon: HW1 by 5pm NOW WEDS

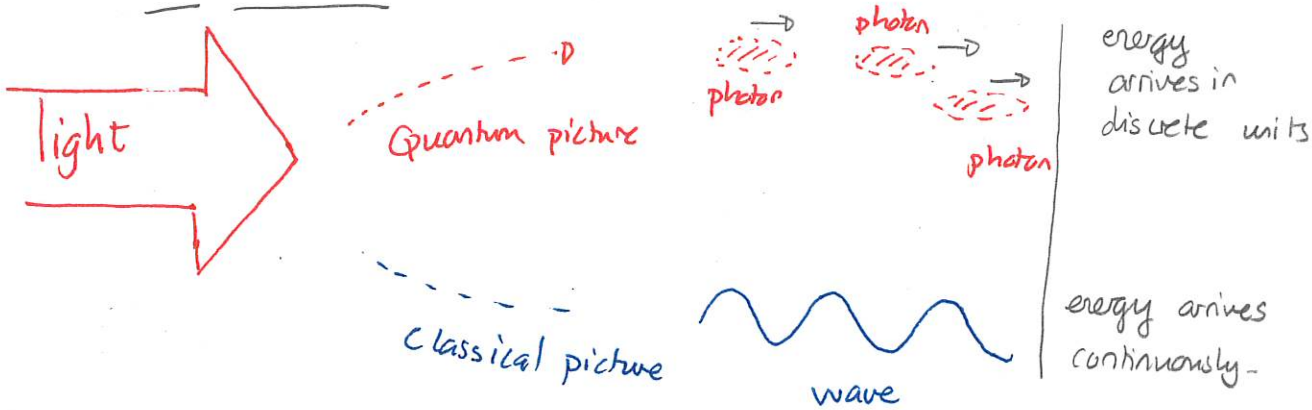
↳ HW academic integrity

Weds: Read 3.6

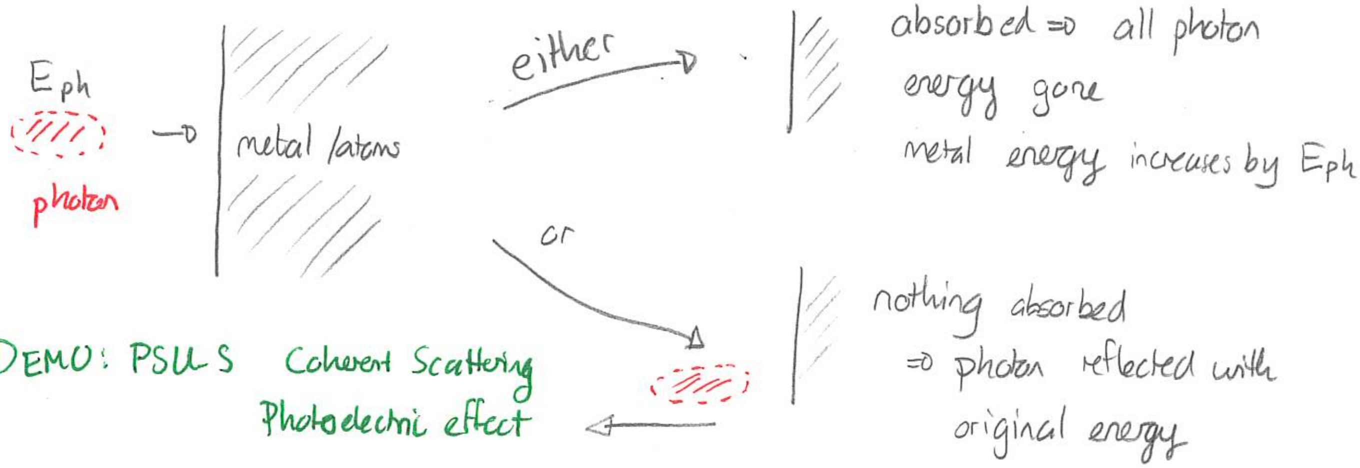
Photons

The photoelectric effect could be described with two assumptions:

1) Light and any other electromagnetic radiation arrives in discrete pieces or quanta. These are called photons. A fundamental property of a photon is that it is indivisible.



2) When light interacts with matter then each photon is either absorbed entirely or it is not absorbed at all



DEMO: PSUS Coherent Scattering

Photoelectric effect

Quantitative predictions then follow from

> Consider electromagnetic radiation with frequency f. Then the energy of a single photon is
>
> $$E_{ph} = hf$$
>
> where
>
> $$h = 6.63 \times 10^{-34}\ J\cdot s.$$
>
> is Planck's constant

Quiz 1 33% – 75%

Here we use

$$E_{ph} = hf$$

$$c = \lambda f \Rightarrow f = c/\lambda$$

$$\boxed{E_{ph} = \frac{hc}{\lambda}}$$

Thus we have that the photon picture predicts

Source	freq	wavelength	photon energy	
red	lower	higher	lower	→ Each individual energy piece smaller "dime"
blue	higher	lower	higher	→ Each piece larger "quarter"

The discrete nature of light can be revealed by applying light to a photodetector

DEMO: * Show PMT tube.

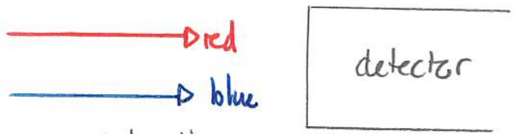
* Show signal output
* Ted Baldwin YT video

We can compare classical + quantum descriptions of light in various situations

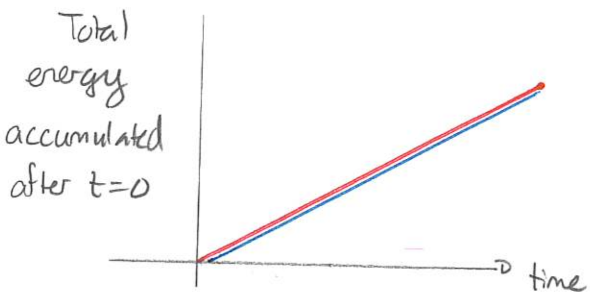
Classical	Quantum (Photon)
energy arrives and accumulates continuously	energy arrives and accumulates in discrete step

Classical

energy arrives and accumulates continuously

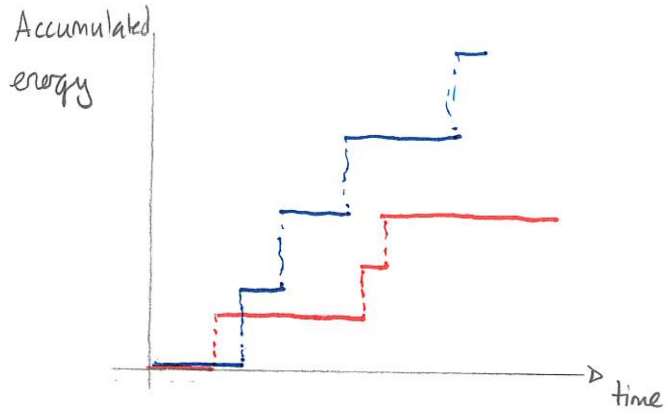


same intensity



Quantum (Photon)

energy arrives and accumulates in discrete step



Multiple photons

In general a source of light may produce more than one photon per second. Then the power of the source is determined by adding the energy of the photons produced every second.

Quiz 2 ~80%

We can then determined the power produced by the source via

$$\text{Power} = (E_{ph}) \times (\text{number of photons produced per second})$$

1 Laser photons

A diode laser produces red light with wavelength 650 nm. The laser power is 8.0 mW. Initially, all the light produced by the laser is incident upon a detector.

a) Determine the energy of a single photon.

b) Determine the number of photons that arrive at the detector in 1.0 ms.

c) How long would one have to wait for an additional 2000 photons to arrive?

One can reduce the number of photons that arrive at the detector by placing an attenuator between the laser and the detector.

d) Suppose that we only wanted about 20 photons to arrive in 1.0 ms. What fraction of the photons would the attenuator have to ~~absorb~~ transmit?

Answer: a) $E_{ph} = hf = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\,J\cdot s \times 3.0\times10^{8}\,m/s}{650\times10^{-9}\,m}$

$= 3.06\times10^{-19}\,J$

b) The energy delivered in 1.0 ms is $E_{total} = Pt$

$= 8.0\times10^{-3}\,W \times 1.0\times10^{-3}\,s$

$= 8.0\times10^{-6}\,J$

The number of photons is:

$E_{total}/E_{ph} = \frac{8.0\times10^{-6}\,J}{3.06\times10^{-19}\,J} = 2.6\times10^{13}$

c) the energy in these is $E_{total} = 2000\times E_{ph} = 6.1\times10^{-16}\,J$

then $P = E/t \Rightarrow t = E/P = \frac{6.1\times10^{-16}\,J}{8\times10^{-3}\,W} = 7.6\times10^{-14}\,s$

d) It transmits $20/2.6\times10^{13} = 7.7\times10^{-13}$

Quiz3 20% - 60%

This illustrates the fact that in ordinary situations, source produce a very large number of photons each second We would not usually expect to observe their discrete nature.

DEMO: ~~Ted Baldwin~~ ?