The hotter the object, the shorter the wavelength:

- kitchen stove burner glows reddishly and glows in the infrared (we feel it as heat)
- molten metal glows red and yellow
- the sun is yellow
- really hot plasma gives off X-rays and gamma rays

Increasing temperature
decreasing wavelength

->Clicker question

The exact relationship between intensity and wavelength could not be predicted with classical physics. Planck postulated that a hot object emits radiation in 'chunks' of E=hf and derived a formula which works great. This is why h is called Planck's constant. Einstein then expanded Planck's hypothesis and used it to explain the photoelectric effect.

$$I_T(\lambda) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

You will learn about this formula in physics 203 (or 333).

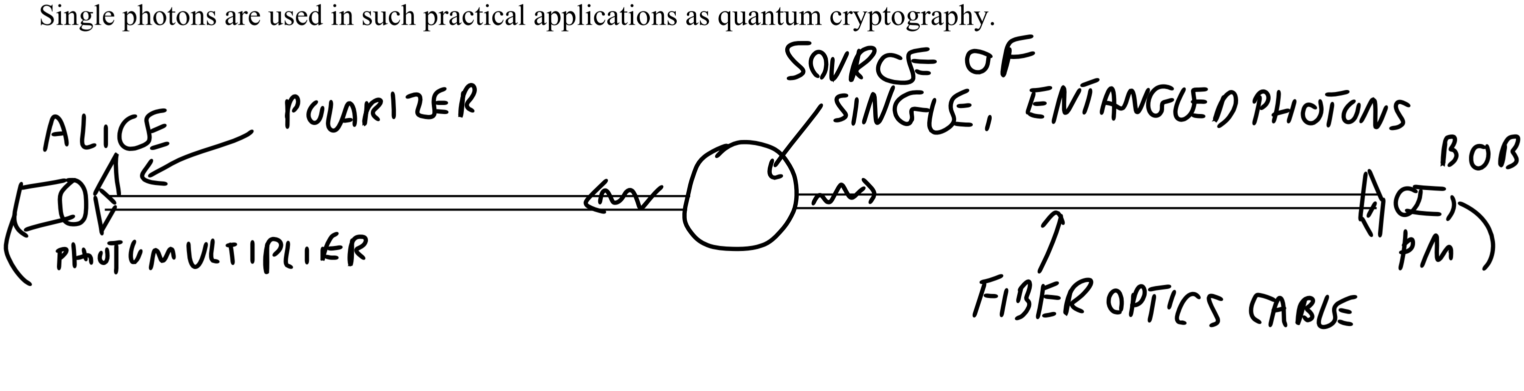
Let's review the historical evidence for the photon picture:

- black body radiation spectrum can be explained by assuming that radiation is emitted by the black body in little chunks, or quanta, with energy E=hf. (Planck)
- the photoelectric effect can be explained by assuming that radiation is always made up of these quanta
- the Compton effect can be explained by assuming that photons are actual (massless) particles, carrying momentum and energy

Modern picture: today, we have technology to create, detect and manipulate single photons.

A photomultiplier is a device for detecting single photons (see slide in the clicker questions). The photon knocks out an electron via photoelectric effect, this electron is then accelerated towards another metal surface where it hits hard enough to knock out a bunch of electrons, which are then accelerated towards the next surface, etc... the resulting avalanche gives a measurable current even for just one photon.
Since not all photons will knock out an electron, not all photons will be detected, but enough will. (<30% efficiency with visible light).

Single photons are used in such practical applications as quantum cryptography.



Polarization of photons

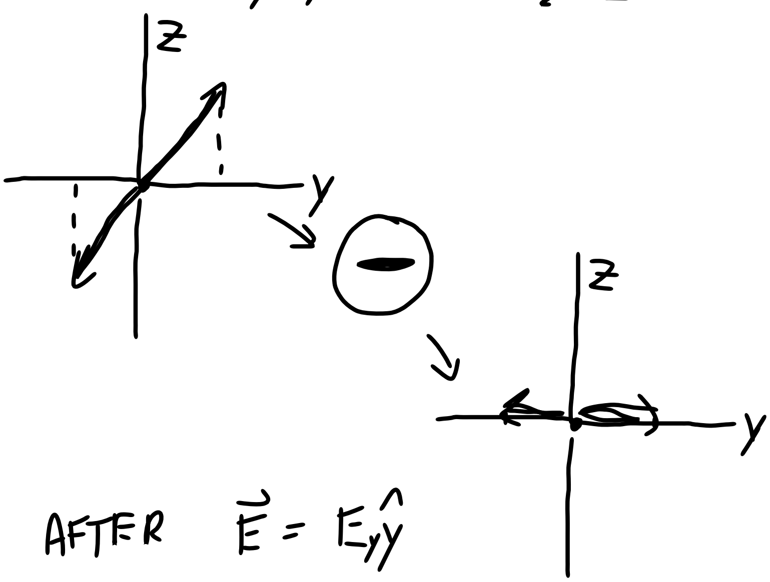
EM waves have polarization, so photons much have it too. We want to make sure that the photon picture is consistent with such phenomena as the workings of a polarizer.

-> demo with (polarizing) sun glasses

How does this work with electromagnetic radiation? recall that we had

$$\vec{E}(x,t) = \vec{E}\cos\left(2\pi\left(ft - x/\lambda\right)\right)$$

$$\vec{E} = E_y\hat{y} + E_z\hat{z}$$ linearly polarized light



No matter what the incident light is,
only the horizontaly polarized components of
light make it through.

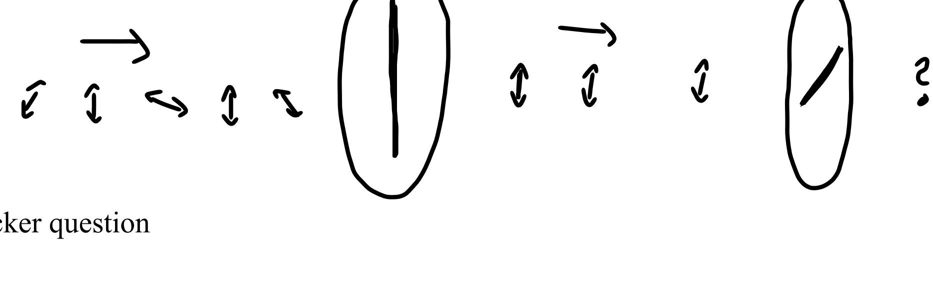
ie: we can decompose all electric fields into vertical
and horizonal componets. The vertical gets 'eaten'
by the polarizer.

AFTER $\vec{E} = E_y\hat{y}$

-> clicker question

The first pair of polarizing sun glasses cuts the intensity in 1/2 (gets rid of one component and leaves the other one). After passing the glasses, the light has only one component (call it y). Now, we can rotate the other pair so that either its direction is the same (all the light goes through) or perpendicular (no light goes through) or in-between.

What if we try to think about this with single photons?
A bunch of photons are incident on a polarizer. Only those polarized in that direction will go through.
Now, let them go through a second polarizer, at 45 degs to the first one.



-> clicker question