Particle nature of light / Photo electric Effect

With our single and double-slit diffraction experiment, we saw that light can behave as a <u>wave</u>. But is this always the case? Can you think of an example when light doesn't behave like a wave? What else could it be?

~~particle~~

To answer this question, let's consider another experiment:

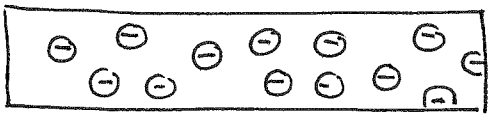
Take a sheet of metal:

what's special about metal?

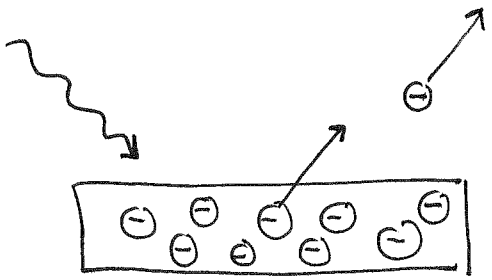
→ conducts electricity... why?

→ "free" electrons .. what do I mean by "free"?

→ not bound to atoms - can move around



Now, what happens if I shine a laser beam onto the metal?



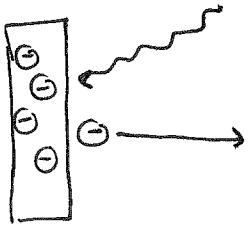
electrons <u>leave</u> the metal!

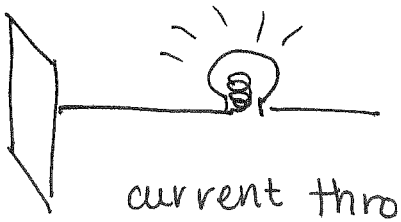
(we can't see or feel this)

If we can't see or feel this, how do we know it's happening?
How could we measure/observe this effect?
What do we know about moving electrons?

→ they generate current

So if we can somehow measure a current, we could find out if electrons are really leaving the metal? Could we design an experiment to do this?





current through wire turns on light bulb!

OK, so how is the light making the electrons leave the metal?

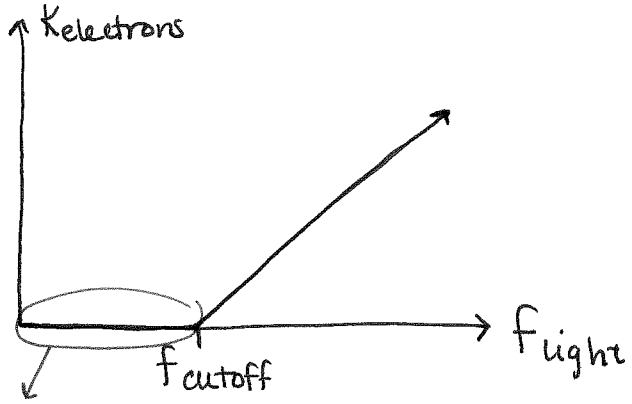
→ delivering energy to the metal
→ energy is transferred to electrons
→ once electrons have enough energy, they break free of metal

Based on our understanding of light, what would happen if:

shine light for long time? (lots of electrons)
" " " very short time? (no electrons)

high frequency (high energy) light? (~~high energy electrons~~ ////////)
low " low " " (have to shine light for longer to release electrons)

What do we actually find?



no electrons!

If we shine light of very low frequency (low energy), we never see electrons, no matter how long we shine light

But this doesn't make any sense! It doesn't agree with our understanding of the wave behavior of light!

How can we resolve this? What's really happening?

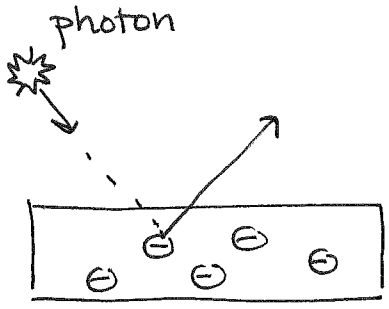
→ light can also behave like a particle

A laser actually emits a stream of photons. A photon is an individual particle of light. These particles have no mass. They only carry energy.

→ Imagine picking up a particle of air. Can you feel it? → No, because the air particle is very light, it has low mass

→ Now imagine picking up a photon. Can you feel it?
→ No, because it has no mass. If you picked up a billion photons, you still couldn't feel it.

Think of a photon as a single packet of energy. Each photon (packet) has a fixed amount of energy.



a single photon transfers its energy to a single electron

if the photon doesn't have enough energy to break the electron out of the metal, no electron is released

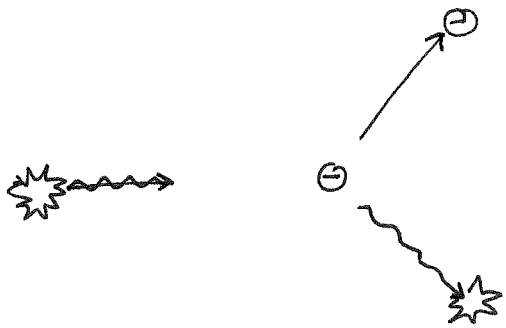
This is called the Photo-electric effect

if the photon has more than enough energy to break out the electron, the electron is released, and it keeps the left over energy

This effect can only be understood by treating light as a particle, NOT as wave.

But maybe this is a fluke, a faulty experiment. Are there other experiments that demonstrate this behavior?

→ Yes. One is <u>compton scattering</u>, where a single photon collides with a single electron



this is analogous to a car crash between a photon (porsche) and an electron (honda). When we describe a car crash, do we treat the cars like waves? → No, we treat them as <u>particles</u>, and that is exactly what we do in this case for light.