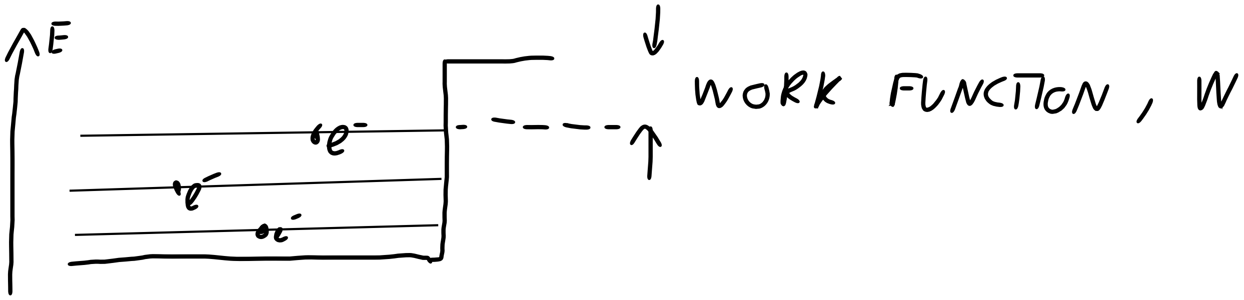
The photoelectric effect: Take two parallel metal plates separated by vacuum. Connect with a wire. Now shine light on one metal plate: electrons are ejected, allowing current to flow!

See the simulation, play in on: Sodium, V=0, blue light. Demonstrate that as the intensity goes up and down, the current increases and decreases (linearly in intensity).

How does this work?

We can imagine electrons in a metal like a bunch of electrons in a box (Drude model).



If the energy of an electron could be increased by at least W, this electron could escape.

How does light add energy to the electrons?

-> clicker question

So, electrons could leave even in classical theory. And it makes sense that greater intensity makes more electrons and therefore more current.

What about frequency?
-> clicker question
Since the intensity is independent of frequency, we should get a current at lower frequencies, too.
Instead, the experiment shows that current abruptly stops below a certain frequency (above a certain wavelength).

Moreover, we can measure the energy of the electrons coming out by putting on a retarting potential (Millican's experiment). (Show how the retarding potential stops electrons from reaching the anode)

-> Clicker question
(demonstrate that answer E does not happen. Can't give more energy to the electrons by cranking up the power.)

Finally, we can see that increasing the frequency of the light increases the retarding potential: we get more energetic electrons with higher frequency but not with higher intensity.

What is going on? Einstein's fix is that energy from light cannot be absorbed in any amount, but only in little indivisible packets: photons.

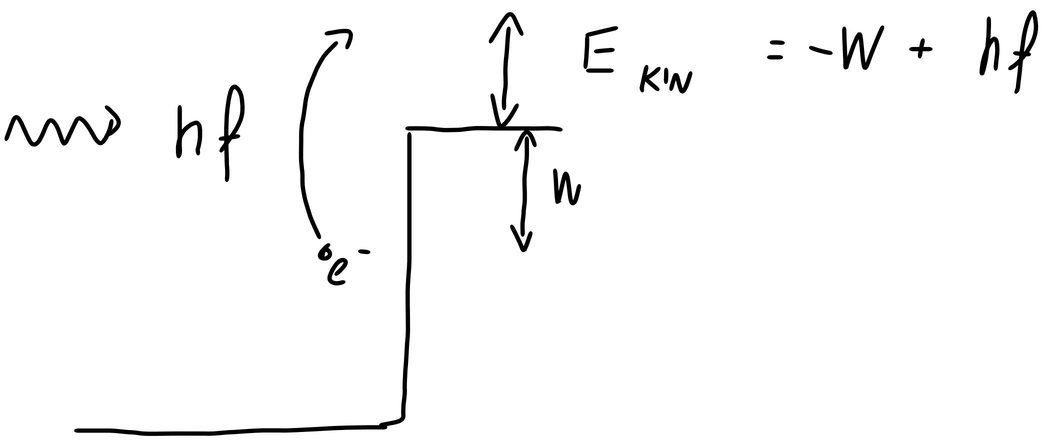
$$E_{PHOTON} = hf = \frac{hc}{\lambda}$$

This does not explain how the energy is delivered to the electrons, but it does constrain how electron receive it:
- an electron can absorb one photon at a time.

(and chances of absorbing 2 are low, since there are not that many photons to go around)

-> clicker question
-> clicker question

So, higher frequency means more energy per photon and therefore electrons ejected with more energy from the metal, capable of overcoming a greater retarding potential - show it in the simulation



Note that with higher frequency you get a bigger current, because photons can now free electrons with lower initial energy

On the left, the photons don't have enough energy to free electrons from deeper in.
On the right, they do.

More on this in Tutorial 7 and in the next lecture.