PROBLEM 1 – 6 points

[2 points] (a) Do we have any evidence that light acts like a wave? If so, provide two examples of experiments, or situations, which can only be explained in terms of light acting as a wave.

Yes, we do – there was a whole sequence of experiments throughout the 19^{th} century that could only be explained in terms of light acting as a wave. Situations which can be explained in terms of light acting as a wave include:

- **Diffraction from a single slit**
- **Interference from a double slit**
- **Thin-film interference**

[2 points] (b) Do we have any evidence that light acts like it is made of particles? If so, provide two examples of experiments, or situations, which can only be explained in terms of light acting as particles.

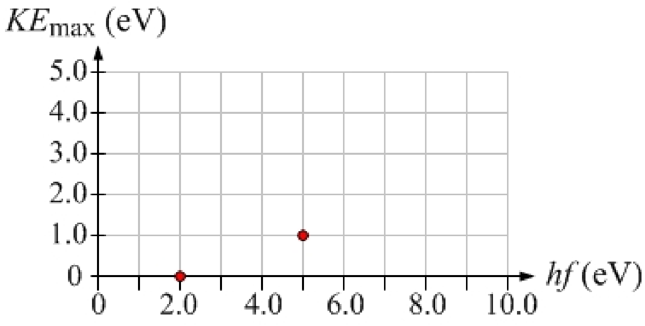
Yes, we do. One example is the photo-electric effect, for which Albert Einstein won the Nobel prize in physics for his explanation of light acting as particles. Electrons are emitted from metal surfaces through single photon – single electron interactions. A second example is the Compton effect, which is an elastic collision between a photon and an electron.

[2 points] (c) Do we have any evidence that things we generally think of as particles (such as electrons, protons, or neutrons) can exhibit wave properties? If so, provide one example.

Yes, we do. One very practical application is an electron microscope, in which electrons are used to image tiny objects. Another example is double-slit interference of electrons. A third example is neutron diffraction, which is used to study crystal structures.

PROBLEM 2 – 15 points

The graph shows two values of the maximum kinetic energy of electrons emitted when light of a certain intensity shines on a particular metal plate, as a function of the energy of the photons in the light. When the photon energy is 2.0 eV, no electrons are emitted (so KE_{max} = 0). When the photon energy is 5.0 eV, the maximum kinetic energy of emitted electrons is 1.0 eV.



[3 points] (a) Calculate the work function (in eV) of this particular metal.

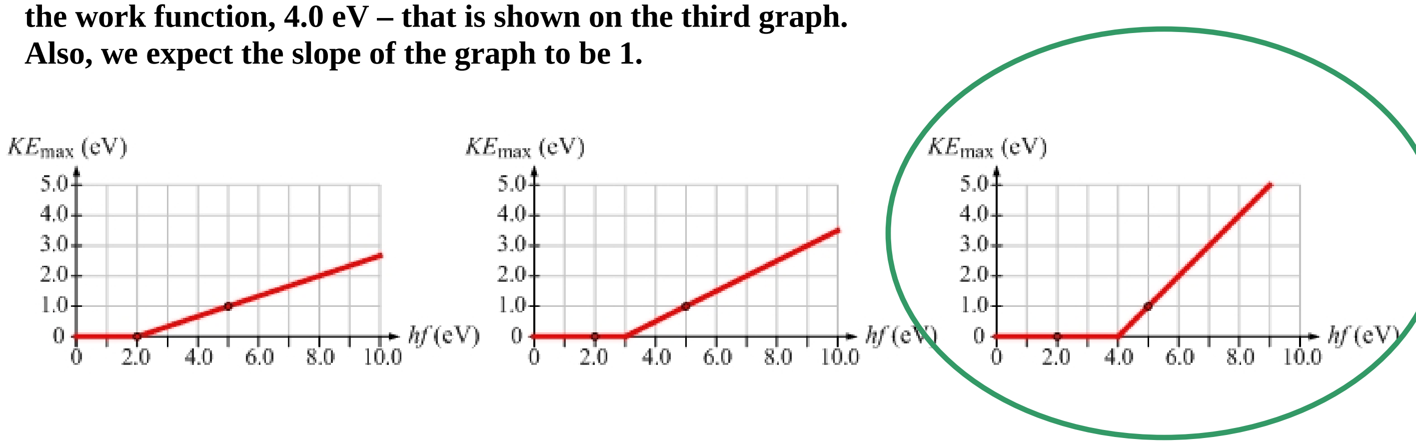
$$hf = W_0 + KE_{max}$$

$$W_0 = hf - KE_{max} = 5.0\text{ eV} - 1.0\text{ eV} = 4.0\text{ eV}$$

[2 points] (b) Circle the graph below that correctly shows the relationship between the maximum energy of emitted electrons and the energy of the photons in the incident light.

[2 points] (c) Justify your answer to part (b).

The smallest photon energy that will cause electrons to be emitted is an energy equal to the work function, 4.0 eV – that is shown on the third graph.
Also, we expect the slope of the graph to be 1.



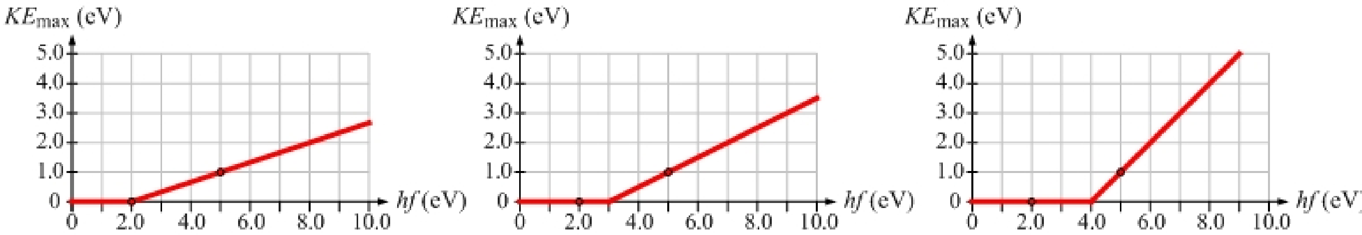
[2 points] (d) With the photon energy held constant at 5.0 eV, the intensity of light shining on the metal is now doubled. The maximum kinetic energy of emitted electrons is now…

[ ] more than 1.0 eV [**X**] still 1.0 eV [ ] less than 1.0 eV

Doubling the intensity doubles the number of photons incident on the metal. We expect to get double the number of electrons emitted, but each electron is emitted by a single photon, so the electrons don't come off with any more (or less energy) – the photon energy is the same.

PROBLEM 2 (continued)

For your reference, we show the three graphs from part (b) again.



We now replace the original plate by a different metal plate with a larger work function, and again plot a graph of the maximum kinetic energy of emitted electrons as a function of the energy of the incident photons (using the original intensity of light).

[2 points] (e) The slope of the new graph, compared to the slope of the correct graph in (b), is …

[ ] smaller [**X**] equal [ ] larger

The equation is $KE_{\max} = hf - W_0$, so graphing $KE_{\max}$ vs. hf gives a slope of 1, still.

[2 points] (f) For the new metal plate, the value of the maximum kinetic energy of emitted electrons when the incident photons have an energy of 5.0 eV is …

[ ] more than 1.0 eV [ ] still 1.0 eV

[**X**] less than 1.0 eV, and possibly no electrons are emitted at all

With a larger work function, there is less energy left over for the kinetic energy of the electrons. If the work function is more than 5.0 eV, no electrons will be admitted at all.

[2 points] (g) Are we going to observe electrons emitted from the new metal plate when the photons have an energy of 2.0 eV?

[**X**] Definitely not [ ] Yes, for certain [ ] Possibly – we can't be sure

We didn't have any emitted at 2.0 eV with the original plate. Increasing the work function means we need even more energy to remove electrons, so we certainly won't get any emitted at 2.0 eV with an even larger work function.