Name: _____

Class: _____

Due Date: _____

E.2 Quantum Physics

Additional HL Understandings

- The photoelectric effect as evidence of the particle nature of light.
- Photons of a certain frequency, known as the threshold frequency, are required to release photoelectrons from the metal.
- Einstein's explanation using the work function and the maximum kinetic energy of the photoelectrons as given by $E_{\max} = hf - \Phi$ where Φ is the work function of the metal.
- Diffraction of particles as evidence of the wave nature of matter.
- Matter exhibits wave-particle duality.
- The de Broglie wavelength for particles as given by $\lambda = \frac{h}{p}$.
- Compton scattering of light by electrons as additional evidence of the particle nature of light.
- Photons scatter off electrons with increased wavelength.
- The shift in photon wavelength after scattering off an electron as given by $\lambda_{\mathrm{f}} - \lambda_{\mathrm{i}} = \Delta\lambda = \frac{h}{m_{\mathrm{e}}c}(1 - \cos\theta)$.

Additional HL Equations

$$E_{\max} = hf - \Phi$$

$$\lambda = \frac{h}{p}$$

$$\lambda_{\mathrm{f}} - \lambda_{\mathrm{i}} = \Delta\lambda = \frac{h}{m_{\mathrm{e}}c}(1 - \cos\theta)$$

If you are interested in learning more about atomic, quantum, and nuclear physics then please read the book *The Quantum Story: A History in 40 Moments* by Jim Baggott.

Also watch all the videos in this website:
https://www.learner.org/series/physics-for-the-21st-century/

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Use your favorite sources to answer the following questions

1. Briefly describe the *photoelectric effect*.

2. About how long does it take for the electrons to leave the metal during the photoelectric effect?

3. Define *critical/threshold frequency*.

4. What will happen to the metal if the intensity of the electromagnetic wave is increased while it is still below the *critical/threshold frequency*? Will the photoelectric effect occur?

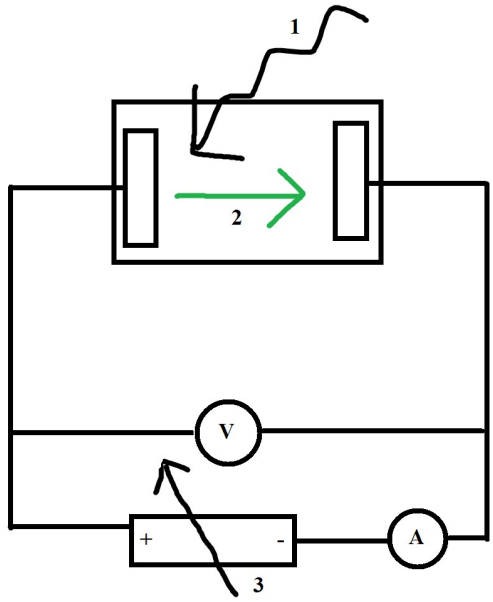
5. What will happen to the electrons if the intensity of the electromagnetic wave is increased while it is above the *critical/threshold frequency*?

6. What is the *work function* φ?

7. Describe the equation given in the IB physics data booklet: $E_{\max} = hf - \varphi$.

8. Draw an $E_{\max}$ vs. incoming frequency graph for three metals. What does the horizontal and vertical intercepts tell us? What does the slope tell us?

9. Describe, step by step, what is happening in the lab setup below.



Step 1:

Step 2:

Step 3:

10. Define *stopping potential/voltage*.

11. From the lab setup from question 9 draw a graph of the *current vs. potential difference across the anode and cathode* with the same incoming frequencies and different intensities.

12. From the lab setup from question 9 draw a graph of the *current vs. potential difference across the anode and cathode* with different incoming frequencies.

13. What is the meaning of *energy is quantized*?

14. State ***two*** experiments in which light behaves as a wave. Do not explain the experiments, just state them.

15. State ***two*** experiments in which light behaves as a particle. Do not explain the experiments, just state them.

16. What is the *de Broglie hypothesis*? What is the equation?

17. Usain Bolt has a mass of 94 kg. He is running with a speed of 9.58 m/s. What is his wavelength?

18. An electron, which has a mass of 9.11×10^{-31} kg, is traveling with a speed of 9.58 m/s. What is its wavelength?

19. Where can we see particles, such as electrons, diffract? In which experiment do electrons diffract?

20. What is the meaning of *wave-particle duality*?

21. Describe the *Compton effect*.