P30 Unit C UA pt C: Quantum Physics

1.

Evidence light is a wave	Evidence light is a particle	Evidence of wave-particle duality
refraction	Compton Effect	reflection
diffraction & interference		Photoelectric Effect
polarization		Debroglie Matter Waves

2. $P = \frac{W}{t}$ (P ← Power, W ← work, t ← time)

$0.004\,W = \frac{W}{12.0\,s}$

$W = 0.048\,J$

$\Delta E = 0.048\,J$ ← total energy in beam of light

$\Delta E = \frac{hc}{\lambda}$

$\Delta E = \frac{(6.63\times10^{-34}\,Js)(3\times10^{8}\,m/s)}{(532\times10^{-9}\,m)}$

$\Delta E = 3.739\times10^{-19}\,J$ ← Energy in one photon

$\#\text{ of photons} = \frac{\text{total energy in many photons}}{\text{energy in one photon}}$

$\#\text{ of photons} = \frac{0.048\,J}{3.739\times10^{-19}\,J} = \underline{\underline{1.28\times10^{17}\text{ photons}}}$

3. $V = \frac{\Delta E}{q}$

$8.5\times10^{3}\,V = \frac{\Delta E}{1.6\times10^{-19}\,C}$

$\Delta E = 1.36\times10^{-15}\,J$

$\Delta E = hf$

$1.36\times10^{-15}\,J = (6.63\times10^{-34}\,Js)\,f$

$f = \underline{\underline{2.05\times10^{18}\,Hz}}$

4. Change ① → Increase the incident frequency of the light. A high frequency photon will have more energy, more energy can overcome the work function of the metal, causing it to release an electron and create current.

4.(cont.) Change (B) → Choose a metal with a lower work function. A smaller work function means the metal takes less of the photon's energy, allowing for more to release the electron.

5. Light with a smaller wavelength than 520nm in this experiment is above the threshold frequency (f_0). Any photon with a frequency higher than the threshold emits an electron.

As frequency increases, electrons produced have more kinetic energy, but the current does not increase. Current is a measure of amount of charge passing a point per second. High frequency means high energy, but not more charge, so the current does not change.

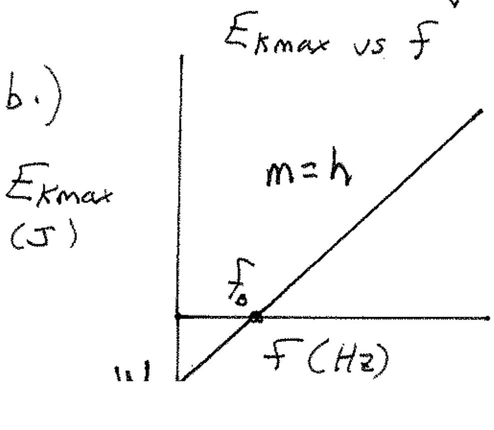
6. a)

E_{Kmax} (J)	f of incident light (Hz)
1.8×10^{-20}	5.77×10^{14} Hz
8.5×10^{-20}	6.82×10^{14} Hz
1.2×10^{-19}	7.50×10^{14} Hz
1.5×10^{-19}	7.89×10^{14} Hz

*Sample calculations: $V = \frac{\Delta E}{q}$ $\quad 0.11V = \frac{\Delta E}{1.6\times10^{-19}J}$ $\quad \Delta E = 1.76\times10^{-20}J = \underline{1.8\times10^{-20}J}$

$v = f\lambda$ $\quad (3\times10^{8}\frac{m}{s}) = f(520\times10^{-9}m)$ $\quad f = \underline{5.77\times10^{14}Hz}$

b.)



h = slope = 6.0×10^{-34} Js

f_0 = x-int = 5.5×10^{14} Hz

W = negative of y-int = 3.3×10^{-19} J

7. $E_{photon} = E_{metal} + E_{electron}$

$$hf = hf_0 + qV_{stop}$$

$$(6.63\times10^{-34}Js)(5.85\times10^{15}Hz) = (6.63\times10^{-34}Js)f_0 + (1.6\times10^{-19}C)(12.8V)$$

$$f_0 = \underline{\underline{2.76\times10^{15}Hz}}$$

8. $p = \frac{h}{\lambda}$ for photons of light. p is inversely proportional to λ, so more momentum comes from a smaller λ.

∴ use low λ light (violet).

9. a.) $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}Js}{14.2\times10^{-12}m} = \underline{\underline{4.67\times10^{-23}Ns}}$

b.) $\Delta\lambda = \frac{h}{mc}(1-\cos\theta)$

$\Delta\lambda$ = increase in wavelength.

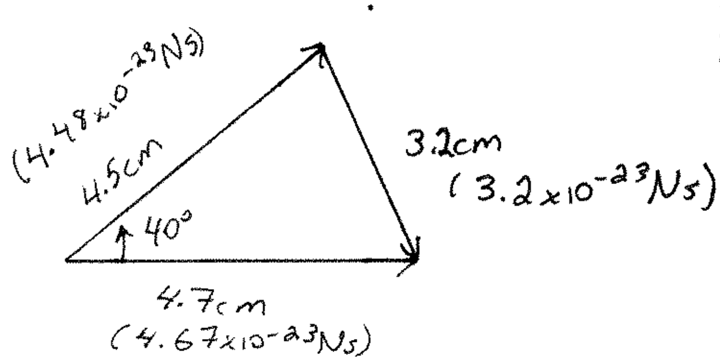
$$\Delta\lambda = \frac{(6.63\times10^{-34}Js)(1-\cos(40°))}{(9.11\times10^{-31}kg)(3\times10^{8}m/s)} = 5.6755\times10^{-13}m$$

$$\lambda_{final} = 14.2\times10^{-12}m + 5.6755\times10^{-13}m = \underline{\underline{1.48\times10^{-11}m}}$$

c.) $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}Js}{1.48\times10^{-11}m} = \underline{\underline{4.48\times10^{-23}Ns}}$

d.) Using a conservation of momentum 2D Vector Analysis (scale diagram)

$p = \underline{\underline{3.2\times10^{-23}Ns}}$



10. $p = mv$

$p = (15\,kg)(29.17\,m/s)$

$p = 437.5\ kg\,m/s$

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

$437.5\ kg\,m/s = \frac{6.63\times10^{-34}\ Js}{\lambda}$

$\lambda = \underline{\underline{1.5\times10^{-36}\ m}}$