E2.1

$$K = h\nu - w_0$$

$$K = \frac{hc}{\lambda} - w_0$$

$$K = \frac{1240\ eVnm}{589\ nm} - 2.3eV < 0$$

No, this light is not energetic enough. To determine the longest possible wavelength (lowest energy

$$K = \frac{hc}{\lambda_{max}} - w_0 = 0$$

$$\lambda_{max} = \frac{hc}{w_0} = \frac{1240\ eVnm}{2.3eV} = 539\ nm$$

$$\text{or} \quad 5390\ \mathring{A} = \lambda_{max}$$

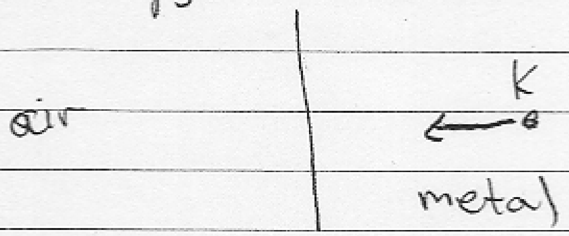
E2.2

$$K = h\nu - w_0$$

a) $K = \frac{hc}{\lambda} - w_0 = \frac{1240\ eVnm}{200\ nm} - 4.2eV$

$$K_{max} = 2.0eV$$

b) Examining Figure 2.2 we see that electrons are actually emitted with all energies. This is complicated and has to do in part with the energy the electron loses as it passes through the metal. Only those right on surface will actually attain the full energy



$$K = \frac{hc}{\lambda} - \omega_0$$

c) $K = eV_0$

$$V_0 = 2\cancel{e}V/\cancel{e} = 2V$$

d) $K = 0 = \frac{hc}{\lambda_{max}} - \omega$ or $\lambda_{max} = \frac{hc}{\omega_0} = \frac{1240 eV\,nm}{4.2 eV}$

$$\lambda_{max} = 2950\,Å$$
$$= 295\,nm$$

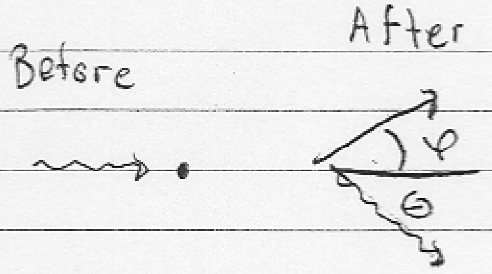
e) Then

$$\frac{\Delta N}{\Delta A\,\Delta t} = \frac{I}{h\nu} = \frac{2.0\,W/m^2}{hc/\lambda} = \frac{2.0 \times W/m^2}{1240\,eV\,nm/200\,nm}$$

$$\frac{\Delta N}{\Delta A\,\Delta t} = 0.322\ \frac{W}{m^2\,eV}$$

$$\frac{\Delta N}{\Delta A\,\Delta t} = 0.2 \times 10^{19}/m^2$$

E2.15:



$$\lambda' - \lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

(1) $E + m_e c^2 = E' + E_e$ (E consv)

(2) $cp = cp'\cos\theta + cp_e\cos\varphi$ (momentum consv i

(3) $0 = -cp'\sin\theta + cp_e\sin\varphi$ (momentum consv in

We wish to determine $\tan\varphi$:

$$cp - cp'\cos\theta = cp_e\cos\varphi$$

$$cp'\sin\theta = cp_e\sin\varphi$$

$$\tan\varphi = \frac{cp'\sin\theta}{cp - cp'\cos\theta}$$

$$\tan\varphi = \frac{\sin\theta}{p/p' - \cos\theta}$$

Using

$$\lambda' - \lambda = \frac{h}{mc}(1 - \cos\theta)$$

$$\frac{\lambda'}{\lambda} - 1 = \frac{hc/\lambda}{m_e c^2}(1 - \cos\theta)$$

$$\frac{\lambda'}{\lambda} = 1 + h\nu / m_e c^2 (1 - \cos\theta)$$

Now $\frac{p}{p'} = \frac{\lambda'}{\lambda}$ so

$$\tan\varphi = \frac{\sin\theta}{[1 + h\nu/m_e c^2 (1 - \cos\theta)] - \cos\theta}$$

$$\boxed{\tan\varphi = \frac{\sin\theta}{1 - \cos\theta} \frac{1}{(1 + h\nu/m_e c^2)}}$$

I would be happy with this

Whenever you see $(1 - \cos\theta)$ appearing as a unit you may find half angles useful because of this formula

$$\cos 2\theta = 1 - 2\sin^2\theta$$

or $\cos\theta = 1 - 2\sin^2\theta/2$

$$2\sin^2\theta/2 = 1 - \cos\theta$$

Then

$$\sin 2\theta = 2\sin\theta\cos\theta \Rightarrow 2\sin\theta/2\,\cos\theta/2 = \sin\theta$$

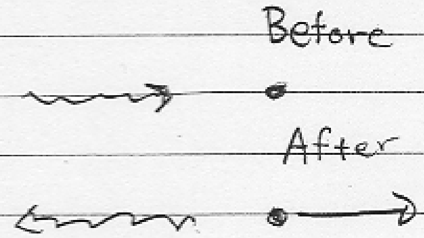
So

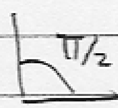
$$\tan\varphi = \frac{2\sin\theta/2\cos\theta/2}{2\sin^2\theta/2}\;\frac{1}{(1+h\nu/m_ec^2)}$$

$$\tan\varphi = \frac{\cot\theta/2}{1+h\nu/m_ec^2}$$

We can check this: If $\theta = \pi$, $\cot\theta/2 = \cot\pi/2 = 0$

then $\tan\varphi = 0$ or $\varphi = 0$





Which agrees ⓦ intuition

Problem 2.16:

$$E + m_e c^2 = E' + E_e$$

$$K = E_e - m_e c^2 = E - E'$$

Using $$\lambda' - \lambda = \frac{h}{m_e c}(1-\cos\theta)$$

$$K = E\left(1 - \frac{E'}{E}\right)$$

we used $$\frac{E'}{E} = \frac{\lambda}{\lambda'}$$ they are inversely propoRtional

So

$$\frac{\lambda'}{\lambda} - 1 = \frac{hc}{m_e c^2 \lambda}(1-\cos\theta)$$

$$\frac{\lambda'}{\lambda} = \frac{h\nu}{m_e c^2}(1-\cos\theta) + 1$$

$$\frac{\lambda}{\lambda'} = \frac{1}{1 + h\nu/mc^2(1-\cos\theta)}$$

Then

$$K = h\nu \left[1 - \frac{1}{\left(1 + \frac{h\nu}{mc^2}(1-\cos\theta)\right)} \right]$$

$$\boxed{K = h\nu \left[\frac{h\nu/mc^2 \, (1-\cos\theta)}{1 + \frac{h\nu}{mc^2}(1-\cos\theta)} \right]}$$

Using the identity shown in 2.15 and the principle that $(1-\cos\theta)$ is "better" expressed in half angles

$$1-\cos\theta = 2\sin^2\theta/2$$

$$\boxed{K = h\nu \left[\frac{2h\nu/mc^2 \, \sin^2\theta/2}{1 + 2h\nu/mc^2 \sin^2\theta/2} \right]}$$

$=$

PE19

(1) $$\lambda' - \lambda = \frac{h}{mc}(1-\cos\theta)$$

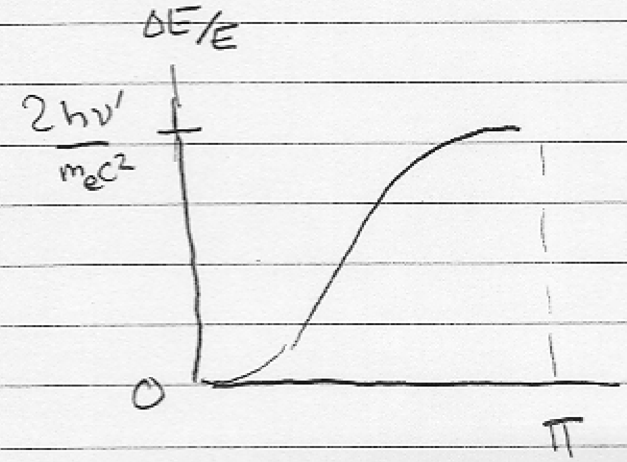
(2) $$\frac{\Delta E}{E} = \frac{E - E'}{E} = 1 - \frac{E'}{E} = 1 - \frac{\lambda}{\lambda'}$$

Dividing by λ' in (1) we have

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

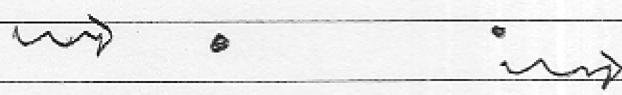
$$\frac{\Delta E}{E} = 1 - \frac{\lambda}{\lambda'} = \frac{hc/\lambda'}{mc^2}(1-\cos\theta)$$

$$\frac{\Delta E}{E} = \frac{h\nu'}{mc^2}(1-\cos\theta)$$



For $\theta = 0$ there is no scattering

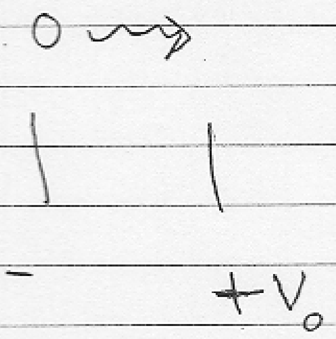
Before: After:



So expect $\Delta E = 0$

E24

The kinetic energy of the electron is



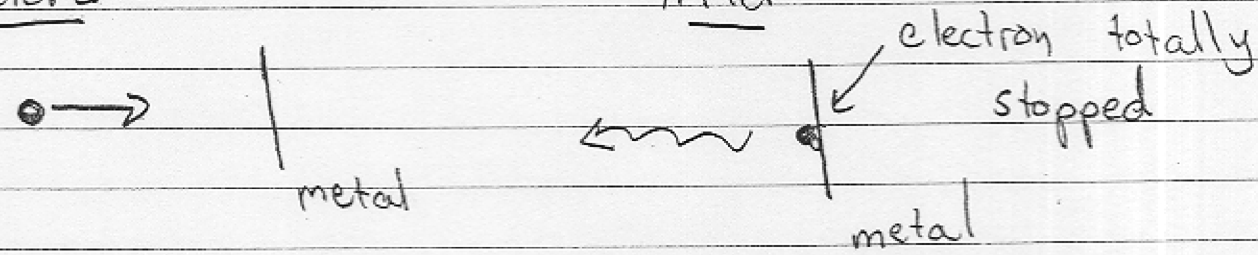
$$K = eV_0$$

All of this kinetic energy goes into producing a photon:

$$K = h\nu_{max} = \frac{hc}{\lambda_{min}}$$

$$\lambda_{min} = \frac{hc}{K} = \frac{hc}{eV_0} = \frac{1240\,\text{eV nm}}{e\left(\frac{V_0}{\text{kV}}\right)\text{kV}}$$

Before | After



$$\lambda_{min} = \frac{1240\,\text{eV} \cdot 10\,\text{Å}}{\text{eV} \cdot 1000\,(V_0/\text{kV})}$$

$$\boxed{\lambda_{min} = 12.4\,\text{Å}/(V_0 \text{ in kV})}$$

For $V = 186\ kV$

$\lambda_{min} = 0.06\ \mathring{A}$

E E2.10

$$\mathcal{P} = (h\nu) \frac{\Delta N}{\Delta t}$$

$$= hc\left(\frac{\nu}{c}\right) \frac{\Delta N}{\Delta t}$$

$$\mathcal{P} = 1240\,eV\,nm \cdot \frac{1}{\lambda} \quad \frac{100}{s}$$

$$= 1240\,eV \cdot nm \ \frac{1}{550nm} \cdot \frac{100}{s}$$

$$\mathcal{P} = 225\,eV/s$$

$$\mathcal{P} = 3.6 \times 10^{-17} \text{ Watts}$$

E2.11

a) The power is the same, thus the shorter wavelength (higher frequency) bulb will emmit fewer higher energy photons to produce the same power

b) $\frac{\Delta N}{\Delta t}_{\text{long}\,\lambda} - \frac{\Delta N}{\Delta t}_{\text{short}\,\lambda}$ = answer = "number of more photons per sec" answer = $\dfrac{P}{h\nu_1} - \dfrac{P}{h\nu_2}$

$= \dfrac{P}{hc/\lambda_1} - \dfrac{P}{hc/\lambda_2}$

answer = $\dfrac{\lambda_1 P}{hc} - \dfrac{\lambda_2 P}{hc} = \dfrac{\lambda_1 P}{hc}(1 - \lambda_2/\lambda_1)$

$= \dfrac{700\,nm\ 40W}{1240\ eV\cdot nm}(1 - 4000/7000)$

answer $= 6 \times 10^{19}$ Hz

Problem 1

a) See Lecture 7. pgs. 5-7

b) //

c) //

d) $E = \gamma mc^2 = mc^2/\sqrt{1-(u/c)^2}$

$cp = \gamma\beta mc^2 = mc^2(-u/c)/\sqrt{1-(u/c)^2}$

E2.13

$E = m_e c^2$ $\quad\quad$ $cp = E = .511\ \mathrm{MeV}$

$h\nu = m_e c^2$ $\quad\quad$ $\boxed{p = 0.511\ \mathrm{MeV}/c}$

$\frac{1}{\lambda} = \frac{\nu}{c} = \frac{m_e c}{h}$

$$\boxed{\lambda = \frac{h}{m_e c} = 0.024\ \mathring{A} = \lambda_c}$$

$\nu = (3 \times 10^8\ \frac{m}{s}) / (0.024\ \mathring{A})$

$$\boxed{\nu = 1.2 \times 10^{20}\ \mathrm{Hz}}$$