Chapter 38

6. (a) For the first and second case (labeled 1 and 2) we have

$$eV_{01} = hc/\lambda_1 - \Phi \,, \quad eV_{02} = hc/\lambda_2 - \Phi,$$

from which h and Φ can be determined. Thus,

$$h = \frac{e(V_1 - V_2)}{c\left(\lambda_1^{-1} - \lambda_2^{-1}\right)} = \frac{1.85\,\text{eV} - 0.820\,\text{eV}}{\left(3.00\times10^{17}\ \text{nm/s}\right)\left[\left(300\,\text{nm}\right)^{-1} - \left(400\,\text{nm}\right)^{-1}\right]} = 4.12\times10^{-15}\ \text{eV}\cdot\text{s}.$$

(b) The work function is

$$\Phi = \frac{3(V_2\lambda_2 - V_1\lambda_1)}{\lambda_1 - \lambda_2} = \frac{(0.820\ \text{eV})(400\ \text{nm}) - (1.85\ \text{eV})(300\ \text{nm})}{300\ \text{nm} - 400\ \text{nm}} = 2.27\ \text{eV}.$$

(c) Let $\Phi = hc/\lambda_{max}$ to obtain

$$\lambda_{max} = \frac{hc}{\Phi} = \frac{1240\ \text{eV}\cdot\text{nm}}{2.27\ \text{eV}} = 545\ \text{nm}.$$

7. The initial energy of the photon is (using hc = 1240 eV·nm)

$$E = \frac{hc}{\lambda} = \frac{1240\,\text{eV}\cdot\text{nm}}{0.00400\text{ nm}} = 3.1078\times10^{5}\text{ eV}.$$

Using Eq. 38-11 (applied to an electron), the Compton shift is given by

$$\Delta\lambda = \frac{h}{m_e c}(1-\cos\phi) = \frac{h}{m_e c}(1-\cos 90.0^\circ) = \frac{hc}{m_e c^2} = \frac{1240\,\text{eV}\cdot\text{nm}}{511\times10^{3}\,\text{eV}} = 2.43\text{ pm}$$

Therefore, the new photon wavelength is

$$\lambda' = 4.00\text{ pm} + 2.43\text{ pm} = 6.43\text{ pm}.$$

Consequently, the new photon energy is

$$E' = \frac{hc}{\lambda'} = \frac{1240\,\text{eV}\cdot\text{nm}}{0.00643\,\text{nm}} = 1.9285\times10^{5}\text{ eV}$$

By energy conservation, then, the kinetic energy of the electron must be equal to

$$K_e = \Delta E = E - E' = 3.1078\times10^{5} - 1.9285\times10^{5}\text{ eV} = 1.179\times10^{5}\text{ eV} \approx 1.9\times10^{-14}\text{ J}.$$

9. **THINK** In this problem we solve a special case of the Schrödinger's equation where the potential energy is $U(x) = U_0 =$ constant.

EXPRESS For $U = U_0$, Schrödinger's equation becomes

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 m}{h^2}[E - U_0]\psi = 0.$$

We substitute $\psi = \psi_0 e^{ikx}$.

ANALYZE The second derivative is $\frac{d^2\psi}{dx^2} = -k^2\psi_0 e^{ikx} = -k^2\psi.$ The result is

$$-k^2\psi + \frac{8\pi^2 m}{h^2}[E - U_0]\psi = 0.$$

Solving for k, we obtain

$$k = \sqrt{\frac{8\pi^2 m}{h^2}[E - U_0]} = \frac{2\pi}{h}\sqrt{2m[E - U_0]}.$$

LEARN Another way to realize this is to note that with a constant potential energy $U(x) = U_0$, we can simply redefine the total energy as $E' = E - U_0$, and the Schrödinger's equation looks just like the free-particle case:

$$\frac{d^2\psi}{dx^2} + \frac{8\pi^2 mE'}{h^2}\psi = 0.$$

The solution is $\psi = \psi_0 \exp(ik'x),$ where

$$k'^2 = \frac{8\pi^2 mE'}{h^2} \quad \Rightarrow \quad k = \frac{2\pi}{h}\sqrt{2mE'} = \frac{2\pi}{h}\sqrt{2m(E - U_0)}\ .$$

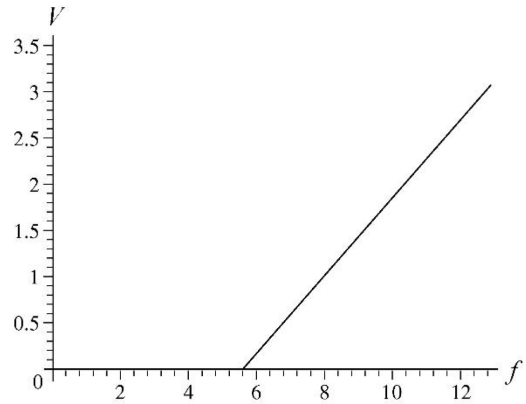
10. We use the uncertainty relationship $\Delta x \, \Delta p \geq \hbar$. Letting $\Delta x = \lambda$, the de Broglie wavelength, we solve for the minimum uncertainty in p:

$$\Delta p = \frac{\hbar}{\Delta x} = \frac{h}{2\pi\lambda} = \frac{p}{2\pi}$$

where the de Broglie relationship $p = h/\lambda$ is used. We use $1/2\pi = 0.080$ to obtain $\Delta p = 0.080p$. We would expect the measured value of the momentum to lie between $0.92p$ and $1.08p$. Measured values of zero, $0.5p$, and $2p$ would all be surprising.

27. (a) We calculate frequencies from the wavelengths (expressed in SI units) using Eq. 38-1. Our plot of the points and the line that gives the least squares fit to the data is shown below. The vertical axis is in volts and the horizontal axis, when multiplied by 10^{14}, gives the frequencies in Hertz.

From our least squares fit procedure, we determine the slope to be 4.14×10^{-15} V·s, which, upon multiplying by e, gives 4.14×10^{-15} eV·s. The result is in very good agreement with the value given in Eq. 38-3.



(b) Our least squares fit procedure can also determine the y-intercept for that line. The y-intercept is the negative of the photoelectric work function. In this way, we find $\Phi = 2.31$ eV.