Answers to Exercise 3.2
Photoelectric Effect

1. Classical physics suggests that light behaves as a wave.

   If light behaved only as a wave, its energy would be increased by increasing the intensity of the light. If this were the case, the current measured would increase steadily as the intensity of light shone on the surface increased, and there would be no threshold frequency.

   The fact that there is a threshold frequency indicates that the light energy is "packaged" into particles of light (which we call photons). When one photon of light hits the surface, it can excite an electron out of its atom <u>only if the energy of the photon is high enough</u>.

   Increasing the intensity of the light increases the number of photons but does not increase the energy of any individual photon. Thus, above the threshold frequency, increasing the intensity of the light increases the <u>number</u> of electrons ejected from the surface but does not affect the kinetic energy of any of the electrons.

   Einstein's photon hypothesis suggests that the energy of a photon of light is directly proportional to the frequency of the light ($E = h\nu$). Thus, increasing the frequency of the light increases the kinetic energy of the ejected electrons. It also explains the existence of a threshold frequency *(see paragraph three)*.

2. The stopping potential is the electrochemical potential* that must be applied to stop the current generated by the flow of electrons in a photoelectric effect experiment. It measures the energy carried by each electron (i.e. the energy "leftover" after the photon excited the electron out of an atom).

   * *You learned about electrochemical potential in Chemistry 30 (or equivalent course) in the electrochemistry topic. Potential is measured in volts (V) where 1 V = 1 J/C. In turn, a coulomb (C) is a quantity of electrons. So, potential is the energy carried by a specific number of electrons and is directly related to the energy carried by each electron.*

3. When light shone on a sample results in ejection of electrons, each photon excites a single electron out of a single atom. This requires a certain amount of energy (the threshold energy). Any "leftover" energy from the photon is transferred to the electron as kinetic energy.

Since you were not given any energies, begin by converting the wavelengths into energies.

Step 1: Calculate the energy of the light source (λ = 200. nm)

$$\boldsymbol{E_{photon} = h\nu} \qquad \textit{and} \qquad \boldsymbol{c = \nu\lambda}$$

$$\boldsymbol{E_{photon} = \frac{hc}{\lambda} = \frac{\left(6.626070\times10^{-34}\frac{J}{Hz}\right)\left(2.997925\times10^{8}\frac{m}{s}\right)}{200.nm} \times \frac{1Hz}{1\frac{1}{s}} \times \frac{10^{9}nm}{1m} = 9.93\times10^{-19}J}$$

Step 2: Calculate the threshold energy for lanthanum (i.e. the energy corresponding to a photon with λ = 376 nm). This is the energy required to excite an electron from an atom of lanthanum.

$$\boldsymbol{E_{threshold} = h\nu} \qquad \textit{and} \qquad \boldsymbol{c = \nu\lambda}$$

$$\boldsymbol{E_{threshold} = \frac{hc}{\lambda} = \frac{\left(6.626070\times10^{-34}\frac{J}{Hz}\right)\left(2.997925\times10^{8}\frac{m}{s}\right)}{376nm} \times \frac{1Hz}{1\frac{1}{s}} \times \frac{10^{9}nm}{1m} = 5.28\times10^{-19}J}$$

Step 3: Calculate the difference between the energy of a photon (Step 1) and the energy required to excite an electron from lanthanum (Step 2). This gives the electron's maximum kinetic energy.

$$E_k = E_{photon} - E_{threshold} = (9.93\times10^{-19}J) - (5.28\times10^{-19}J) = 4.65\times10^{-19}J$$

Step 4: Check your work

Does your answer seem reasonable? Are sig. fig. correct?