Question 1: Paragraph-Length Response — 10 points

(a)

For indicating that f_B is least and f_C is greatest — **1 point**

For correctly relating the frequency of a photon to the energy of the photon — **1 point**

For indicating that the kinetic energy or speed of an ejected electron is inversely related to the de Broglie wavelength of the electron — **1 point**

For indicating **one** of the following: — **1 point**

- That a greater photon energy or frequency results in a greater kinetic energy for an ejected electron
- That the lowest photon energy or frequency is below the work function or threshold frequency which results in no ejected electron

For a logical, relevant, and internally consistent argument that addresses the required argument or question asked, and follows the guidelines described in the published requirements for the paragraph-length response — **1 point**

Example Response

An electron will be ejected if the incident photon has an energy greater than the work function of the metal. Because no electrons were ejected using f_B, the corresponding photon energy, and, therefore, frequency must be the least. A photon with greater frequency will result in an ejected electron with more kinetic energy; the kinetic energy of an electron is inversely related to the de Broglie wavelength of the electron. Because the de Broglie wavelength of electrons ejected by light of frequency f_A is greater than those ejected by light of frequency f_C, f_A must be less than f_C. Therefore, f_C is the greatest.

Total for part (a) — **5 points**

(b) For **one** of the following: **1 point**

- Correctly relating electron de Broglie wavelength to a correct expression that includes h, m, and v
- Relating kinetic energy to a correct expression that includes momentum and mass

Example Responses

$$\lambda_e = \frac{h}{mv}$$

OR

$$K = \frac{p^2}{2m}$$

For correctly substituting an algebraic expression in terms of λ_e for the electron speed or momentum into a relevant equation for kinetic energy **1 point**

Scoring Note: This point can be earned for substituting a numerical value for electron speed or momentum into a relevant equation for kinetic energy.

Example Responses

$$K = \frac{1}{2}m\left(\frac{h}{m\lambda_e}\right)^2 \quad \textbf{OR} \quad K = \frac{\left(\frac{h}{\lambda_e}\right)^2}{2m}$$

For a correct answer with units **1 point**

Example Response

$K = 5 \times 10^{-19}\ \text{J}$

Example Solution

$$\lambda_e = \frac{h}{p} = \frac{h}{mv}$$

$$v = \frac{h}{m\lambda_e}$$

$$K = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{h}{m\lambda_e}\right)^2$$

$$K = \frac{h^2}{2m\lambda_e^2}$$

$$K = \frac{\left(6.63 \times 10^{-34}\ \text{J} \cdot \text{s}\right)^2}{2\left(9.11 \times 10^{-31}\ \text{kg}\right)\left(6.9 \times 10^{-10}\ \text{m}\right)^2} = 5 \times 10^{-19}\ \text{J}$$

Scoring Note: An answer of $3\ \text{eV}$ also earns the final point.

Total for part (b) **3 points**

(c) For indicating that the work function of Metal 1 is less than the work function of Metal 2 with an attempt at a relevant justification **1 point**

For indicating at least **two** of the following: **1 point**

- The correct relationship between the work function and the difference between hf and $K_{\max}$
- The frequency or energy of the incident photons is the same
- The de Broglie wavelength is inversely related to the energy of the ejected electrons

Example Response

The work function of Metal 1 is less than the work function of Metal 2. When light of the same frequency is incident on both metals, the electron ejected by Metal 1 has a smaller de Broglie wavelength than that of Metal 2, so an electron ejected from Metal 1 has more kinetic energy. The work function is the difference between the photon energy and the maximum kinetic energy. Since the photon energy is the same but the maximum kinetic energy is larger for Metal 1, the difference between the energies, and thus the work function, is smaller for Metal 1.

Total for part (c) 2 points

Total for question 1 10 points