Solutions

Each answer shows the steps, then the **result**.

2.1

- the **lowest frequency** of radiation that will release electrons from the metal

2.2

- the **minimum energy** needed to free an electron from the surface

2.3

- $hf = \Phi + \frac{1}{2}mv_{\max}^2$

2.4

- each photon has energy $hf < \Phi$, so it **cannot supply** enough energy to free an electron (and energy is one-photon-per-electron)

3.1 C

- below threshold, **no electrons** are emitted

3.2

- $\text{KE}_{\max} = hf - \Phi$

$$\text{KE}_{\max} = 3.5 \text{ eV} - 2.0 \text{ eV} = \mathbf{1.5} \text{ eV}$$

3.3

- each electron absorbs **one photon**, so its max KE depends only on the **photon energy (hf)**, set by frequency
- higher intensity means **more photons per second**
- so more electrons per second — a larger current, but the same energy per electron

3.4

- $f_0 = \Phi/h$

$$f_0 = \frac{3.2 \times 10^{-19} \text{ J}}{6.63 \times 10^{-34} \text{ J s}} = \mathbf{4.8 \times 10^{14}} \text{ Hz}$$

3.5

(a) the **Planck constant** h

(b) a line with the **same gradient** (parallel to the first), but shifted to the **right** — a **higher threshold frequency** f_0 (and a more negative y-intercept $-\Phi$)

3.6

(a) the **minimum energy** needed to remove an electron from the surface of the metal

(b) $E = hc/\lambda$

$$E = \frac{(6.63 \times 10^{-34} \text{ J s})(3.00 \times 10^{8} \text{ m s}^{-1})}{410 \times 10^{-9} \text{ m}} = 4.85 \times 10^{-19} \text{ J}$$

$$\frac{4.85 \times 10^{-19}\ \text{J}}{1.60 \times 10^{-19}\ \text{J eV}^{-1}} = \mathbf{3.0}\ \text{eV}$$

(c) $E_{\text{K,max}} = hf - \phi = 3.03\ \text{eV} - 2.3\ \text{eV} = 0.73\ \text{eV} = 1.17 \times 10^{-19}\ \text{J}$

$$v = \sqrt{\frac{2E_{\text{K}}}{m}} = \sqrt{\frac{2 \times 1.17 \times 10^{-19}\ \text{J}}{9.11 \times 10^{-31}\ \text{kg}}} = \mathbf{5.1} \times \mathbf{10^5}\ \text{m s}^{-1}$$

(d) at the threshold all the photon energy goes into escaping: $\lambda_0 = hc/\phi$

$$\lambda_0 = \frac{(6.63 \times 10^{-34}\ \text{J s})(3.00 \times 10^8\ \text{m s}^{-1})}{(2.3)(1.60 \times 10^{-19}\ \text{J})} = 5.4 \times 10^{-7}\ \text{m} = \mathbf{540}\ \text{nm}$$

(e) (i) **no change** — the maximum kinetic energy depends only on the photon energy, i.e. on the wavelength, and one electron absorbs one photon

(ii) the rate **doubles**, because twice as many photons arrive each second and each can free one electron

(f) a wave model says energy arrives continuously and spreads over the surface, so any wavelength should eventually free an electron if you wait long enough or make the light bright enough

- in fact **no** electrons are emitted below the threshold however intense the light, which only makes sense if the energy arrives in whole photons of energy hf