25.22 (a) The lateral magnification produced by the objective lens of a good compound microscope is closely approximated by $M_1 \approx -L/f_O$, where L is the length of the microscope tube and f_O is the focal length of this lens. Thus, if $L = 20.0 \text{ cm}$ and $M_1 = -50.0$ (inverted image), the focal length of the objective lens is

$$f_O \approx -\frac{L}{M_1} = -\frac{20.0 \text{ cm}}{-50.0} = \boxed{+0.400 \text{ cm}}$$

(b) When the compound microscope is adjusted for most comfortable viewing (with parallel rays entering the relaxed eye), the angular magnification produced by the eyepiece lens is $m_e = 25 \text{ cm}/f_e$. If $m_e = 20.0$, the focal length of the eyepiece is

$$f_e = \frac{25.0 \text{ cm}}{m_e} = \frac{25.0 \text{ cm}}{20.0} = \boxed{+1.25 \text{ cm}}$$

(c) The overall magnification is $m = M_1 m_e = (-50.0)(20.0) = \boxed{-1\,000}$

25.24 **Note**: Here, we need to determine the overall lateral magnification of the microscope, $M = h'_e/h_1$ where h'_e is the size of the image formed by the eyepiece, and h_1 is the size of the object for the objective lens. The lateral magnification of the objective lens is $M_1 = h'_1/h_1 = -q_1/p_1$ and that of the eyepiece is $M_e = h'_e/h_e = -q_e/p_e$. Since the object of the eyepiece is the image formed by the objective lens, $h_e = h'_1$, and the overall lateral magnification is $M = M_1 M_e$.

Using the thin lens equation, the object distance for the eyepiece is found to be

$$p_e = \frac{q_e f_e}{q_e - f_e} = \frac{(-29.0 \text{ cm})(0.950 \text{ cm})}{-29.0 \text{ cm} - 0.950 \text{ cm}} = 0.920 \text{ cm}$$

and the magnification produced by the eyepiece is

$$M_e = -\frac{q_e}{\;} = -\frac{(-29.0 \text{ cm})}{\;} = +31.5$$

The image distance for the objective lens is then

$$q_1 = L - p_e = 29.0 \text{ cm} - 0.920 \text{ cm} = 28.1 \text{ cm}$$

and the object distance for this lens is

$$p_1 = \frac{q_1 f_o}{q_1 - f_o} = \frac{(28.1 \text{ cm})(1.622 \text{ cm})}{28.1 \text{ cm} - 1.622 \text{ cm}} = 1.72 \text{ cm}$$

The magnification by the objective lens is given by

$$M_1 = -\frac{q_1}{p_1} = -\frac{(28.1 \text{ cm})}{1.72 \text{ cm}} = -16.3$$

and the overall lateral magnification is $M = M_1 M_e = (-16.3)(+31.5) = -514$

The lateral size of the final image is

$$h_e' = |q_e| \cdot \theta = (29.0 \text{ cm})(1.43 \times 10^{-3} \text{ rad}) = 4.15 \times 10^{-2} \text{ cm}$$

and the size of the red blood cell serving as the original object is

$$h_1 = \frac{h_e'}{|M|} = \frac{4.15 \times 10^{-4} \text{ m}}{514} = 8.06 \times 10^{-7} \text{ m} = \boxed{0.806\ \mu\text{m}}$$

25.25 Some of the approximations made in the textbook while deriving the overall magnification of a compound microscope are not valid in this case. Therefore, we start with the eyepiece and work backwards to determine the overall magnification.

If the eye is relaxed, the eyepiece image is at infinity $(q_e \to -\infty)$, so the object distance is $p_e = f_e = 2.50 \text{ cm}$, and the angular magnification by the eyepiece is

$$m_e = \frac{25.0 \text{ cm}}{f_e} = \frac{25.0 \text{ cm}}{2.50 \text{ cm}} = 10.0$$

The image distance for the objective lens is then,

$$q_1 = L - p_e = 15.0 \text{ cm} - 2.50 \text{ cm} = 12.5 \text{ cm}$$

and the object distance is $p_1 = \dfrac{q_1 f_o}{q_1 - f_o} = \dfrac{(12.5 \text{ cm})(1.00 \text{ cm})}{12.5 \text{ cm} - 1.00 \text{ cm}} = 1.09 \text{ cm}$

The magnification by the objective lens is $M_1 = -\frac{q_1}{p_1} = -\frac{(12.5\text{ cm})}{1.09\text{ cm}} = -11.5$, and the overall magnification of the microscope is

$$m = M_1 m_e = (-11.5)(10.0) = \boxed{-115}$$

27.3 The wavelength of maximum radiation is given by

$$\lambda_{\max} = \frac{0.289\,8\times10^{-2}\text{ m}\cdot\text{K}}{5\,800\text{ K}} = 5.00\times10^{-7}\text{ m} = \boxed{500\text{ nm}}$$

27.4 The energy of a photon having wavelength λ is $E_\gamma = hf = hc/\lambda$. Thus, the number of photons delivered by each beam must be:

Red Beam:

$$n_R = \frac{E_{total}}{E_{\gamma,R}} = \frac{E_{total}\lambda_R}{hc} = \frac{(2\,500\text{ eV})(690\times10^{-9}\text{ m})}{(6.63\times10^{-34}\text{ J}\cdot\text{s})(3.00\times10^{8}\text{ m/s})}\left(\frac{1.60\times10^{-19}\text{ J}}{1\text{ eV}}\right) = \boxed{1.39\times10^{3}}$$

Blue Beam: $$n_B = \frac{E_{total}}{E_{\gamma,B}} = \frac{E_{total}\lambda_B}{hc} = \frac{(2\,500\text{ eV})(420\times10^{-9}\text{ m})}{(6.63\times10^{-34}\text{ J}\cdot\text{s})(3.00\times10^{8}\text{ m/s})}\left(\frac{1.60\times10^{-19}\text{ J}}{1\text{ eV}}\right) = \boxed{845}$$

27.5 $$E = hf = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\text{ J}\cdot\text{s})(3.00\times10^{8}\text{ m/s})}{\lambda}\left(\frac{1.00\text{ eV}}{1.60\times10^{-19}\text{ J}}\right)f$$

which yields $E = \frac{1.24\times10^{-6}\text{ m}\cdot\text{eV}}{\lambda}$

(a) $E = \frac{1.24\times10^{-6}\text{ m}\cdot\text{eV}}{5.00\times10^{-2}\text{ m}} = \boxed{2.49\times10^{-5}\text{ eV}}$

(b) $E = \frac{1.24\times10^{-6}\text{ m}\cdot\text{eV}}{500\times10^{-9}\text{ m}} = \boxed{2.49\text{ eV}}$

(c) $E = \frac{1.24\times10^{-6}\text{ m}\cdot\text{eV}}{5.00\times10^{-9}\text{ m}} = \boxed{249\text{ eV}}$

27.8 The energy entering the eye each second is

$$\mathcal{P} = I \cdot A = \left(4.0\times10^{-11}\ \text{W/m}^2\right)\left[\frac{\pi}{4}\left(8.5\times10^{-3}\ \text{m}\right)^2\right] = 2.3\times10^{-15}\ \text{W}$$

The energy of a single photon is

$$E_\gamma = \frac{hc}{\lambda} = \frac{\left(6.63\times10^{-34}\ \text{J}\cdot\text{s}\right)\left(3.00\times10^{8}\ \text{m/s}\right)}{500\times10^{-9}\ \text{m}} = 3.98\times10^{-19}\ \text{J}$$

so the number of photons entering the eye in $\Delta t = 1.00\ \text{s}$ is

$$N = \frac{\Delta E}{E_\gamma} = \frac{\mathcal{P}\cdot(\Delta t)}{E_\gamma} = \frac{\left(2.3\times10^{-15}\ \text{J/s}\right)(1.00\ \text{s})}{3.98\times10^{-19}\ \text{J}} = \boxed{5.7\times10^{3}}$$

27.14 (a) The energy of the incident photons is

$$E_\gamma = \frac{hc}{\lambda} = \frac{\left(6.63\times10^{-34}\ \text{J}\cdot\text{s}\right)\left(3.00\times10^{8}\ \text{m/s}\right)}{400\times10^{-9}\ \text{m}}\left(\frac{1\ \text{eV}}{1.60\times10^{-19}\ \text{J}}\right) = 3.11\ \text{eV}$$

For photo-electric emission to occur, it is necessary that $E_\gamma \geq \phi$. Thus, of the three metals given, $\boxed{\text{only lithium}}$ will exhibit the photo-electric effect.

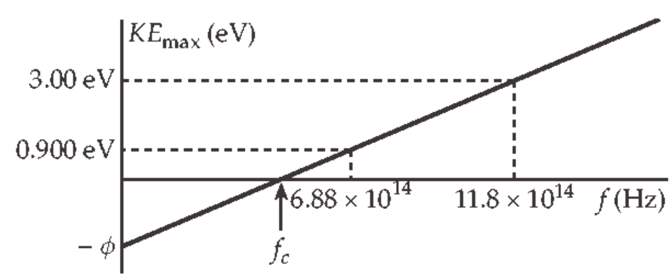
(b) For lithium, $KE_{\text{max}} = \dfrac{hc}{\lambda} - \phi = 3.11\ \text{eV} - 2.30\ \text{eV} = \boxed{0.81\ \text{eV}}$

27.17 The two light frequencies allowed to strike the surface are

$$f_1 = \frac{c}{\lambda_1} = \frac{3.00\times10^{8}\ \text{m/s}}{254\times10^{-9}\ \text{m}} = 11.8\times10^{14}\ \text{Hz}$$

and $$f_2 = \frac{3.00\times10^{8}\ \text{m/s}}{436\times10^{-9}\ \text{m}} = 6.88\times10^{14}\ \text{Hz}$$

The graph you draw should look somewhat like that given at the right.



The desired quantities, read from the axis intercepts of the graph line, should agree within their uncertainties with

$$f_c = \boxed{4.8\times10^{14}\ \text{Hz}} \text{ and } \phi = \boxed{2.0\ \text{eV}}$$

27.30 (a) $\Delta\lambda = \lambda_C(1-\cos\theta) = (0.002\,43\text{ nm})(1-\cos 37.0°) = \boxed{4.89\times10^{-4}\text{ nm}}$

(b) The wavelength of the incident x-rays is

$$\lambda_0 = \frac{hc}{(E_\gamma)_0} = \frac{(6.63\times10^{-34}\text{ J}\cdot\text{s})(3.00\times10^{8}\text{ m/s})}{(300\text{ keV})(1.60\times10^{-16}\text{ J/keV})}\left(\frac{1\text{ nm}}{10^{-9}\text{ m}}\right) = 4.14\times10^{-3}\text{ nm}$$

so the scattered wavelength is $\lambda = \lambda_0 + \Delta\lambda = 4.63\times10^{-3}\text{ nm}$

The energy of the scattered photons is then

$$E_\gamma = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34}\text{ J}\cdot\text{s})(3.00\times10^{8}\text{ m/s})}{(4.63\times10^{-3}\text{ nm})(10^{-9}\text{ m/1 nm})}\left(\frac{1\text{ keV}}{1.60\times10^{-16}\text{ J}}\right) = \boxed{268\text{ keV}}$$