Ch 27

27.10

The net force exerted on the electron (of charge q_e moving with velocity $\vec{v}$) is $\vec{F} = q_e(\vec{E}+\vec{v}\times\vec{B})$. For the electron to undergo no acceleration $\vec{F} = 0$, and so $\vec{E} + \vec{v} \times \vec{B} = 0$, which requires $E = |\vec{v} \times \vec{B}| = vB \sin\theta$. Plug in $E = 1000\,\mathrm{V/m}$, $B = 20.0 \times 10^{-2}\,\mathrm{T}$, and $\theta = 90.0°$ to obtain

$$v = \frac{E}{B\sin\theta} = \frac{1000\,\mathrm{V/m}}{(20.0 \times 10^{-2}\,\mathrm{T})(\sin 90.0°)} = 5.00 \times 10^3\,\mathrm{m/s}\,.$$

27.15

An electron in the beam enters the crossing electric and magnetic field with $v_x = E/B$ [see Chapter 19). The time it takes for the electron to pass through the E-field in between the parallel plates of length L is $t = L/v_x$, during which it is being accelerated in the y-direction by the electric field at the rate of of $a_y = F_E/m_e = eE/m_e$. So as it emerges from the E-field the x-component of its velocity remains v_x, while the y-component increases from zero to

$$v_y = a_y t = \left(\frac{eE}{m_e}\right)\left(\frac{L}{v_x}\right)\,.$$

Thus $\tan\theta = v_y/v_x = (eE/m_e)(L/v_x)/v_x$, or $e/m_e = v_x^2 \tan\theta/EL$. Now, If $v_x \gg v_y$. then $\tan\theta \approx \theta$ (as $\theta \ll 1$), whereupon

$$\frac{e}{m_e} = \frac{v_x^2\tan\theta}{EL} \approx \frac{v_x^2\theta}{EL} = \frac{(E/B)^2\theta}{EL} = \frac{E\theta}{B^2L}\,,$$

where we used $v_x = E/B$ again.

27.22

From the hint we know that we must use relativistic approach. The KE of the electron as it emerges from the accelerating potential V is $\mathrm{KE} = eV$, which is the difference between its rest energy $\mathrm{E}_0 = m_e c^2$ and the total energy $\mathrm{E} = \gamma m_e c^2$, where $\gamma = 1/\sqrt{1 - v^2/c^2}$, with v its final speed:

$$\mathrm{KE} = eV = \mathrm{E} - \mathrm{E}_0 = (\gamma - 1) m_e c^2 .$$

Solve for γ:

$$\gamma = \frac{eV}{m_e c^2} + 1 = \frac{e \cdot 1.00 \times 10^6\ \mathrm{V}}{0.5109 \times 10^6\ \mathrm{eV}} + 1 = 2.9573 ,$$

where we noted that $1\, e \cdot \mathrm{V} \equiv 1\, \mathrm{eV}$. Thus

$$v = c\sqrt{1 - \frac{1}{\gamma^2}} = (2.998 \times 10^8\ \mathrm{m/s})\sqrt{1 + \frac{1}{(2.9573)^2}} = 2.82 \times 10^8\ \mathrm{m/s} .$$

27.29

X-ray diffraction by crystals satisfy the Bragg equation, Eq. (27.3): $2d \sin\theta_m = m\lambda$. Here d is the spacing between adjacent atomic planes, θ_m is the angle at which the m-th order reflection of the beam occurs, and λ is the wavelength of the incident beam. The first-order reflection angle θ_1 then satisfies

$$\sin\theta_1 = \left.\frac{m\lambda}{2d}\right|_{m=1} = \frac{\lambda}{2d} .$$

Plug in $d = 0.303\ \mathrm{nm}$ and $\lambda = 0.090\ \mathrm{nm}$, and solve for θ_1:

$$\theta_1 = \sin^{-1}\frac{\lambda}{2d} = \sin^{-1}\left[\frac{0.090\ \mathrm{nm}}{2(0.303\ \mathrm{nm})}\right] = 8.5^\circ .$$