dominant individual wave has $k = k_0$

$$v_p = A k_0^{1/2}$$

$$v_g = \frac{3}{2} A k_0^{1/2}$$

\#18. $\frac{\Delta v}{v} = 0.1\,\% \cancel{\approx} = 0.001$ $\qquad \Delta v = v \times 0.001$

$= 0.03\ m/s$

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

$$\Delta p = m\,\Delta v = 0.05 \times 0.03 = \underline{1.5\times10^{-3}\ kg\,\tfrac{m}{s}}$$

↑ large

$$\Delta x = \frac{\hbar}{2\Delta p} = \underline{5.31\times10^{-32}\ m}$$

↑ Small.

\#19. $K = 1\ MeV = \frac{p^2}{2m} =$ ~~kx~~ $1.6\times10^{-19} \times 1\times10^{6}\ J = \frac{p^2}{2m}$

$$p = 2.32\times10^{-20}\ kg\ \tfrac{m}{s}$$

$$\frac{\Delta p}{p} = 0.05 \Rightarrow \Delta p = \underline{1.16\times10^{-21}\ kg.\tfrac{m}{s}}$$

↑ large.

$$\Delta x \, \Delta p \geq \frac{\hbar}{2}$$

$$\Delta x = \underline{4.56\times10^{-14}\ m}$$

↑ Small

\#22.

$\frac{\Delta p}{p} = 0.01$ $\qquad K = (\gamma - 1)\,mc^2 \Rightarrow \gamma = \frac{K}{mc^2} + 1$

$K = 0.01\ MeV \qquad \gamma = 1.02 \qquad p = \gamma m v$

$K = 1\ MeV \qquad \gamma = 2.96 \qquad p = \gamma m v$

$K = 100\ MeV \qquad \gamma = 197 \qquad p = \gamma m v$

$\gamma_1 = 1.02$ $\quad v = 5.91 \times 10^{7}\,m/s$ $\quad p = 5.49 \times 10^{-23}\ Kg\,\frac{m}{s}$

$\gamma_2 = 2.92$ $\quad v = 2.82 \times 10^{8}\,m/s$ $\quad p = 7.6 \times 10^{-22}\ Kg\,\frac{m}{s}$

$\gamma_3 = 197$ $\quad v = 3 \times 10^{8}\,m/s$ $\quad p = 5.38 \times 10^{-20}\ Kg\,\frac{m}{s}$

$$\underset{\overset{\uparrow}{a}}{\Delta x}\ \Delta p \geq \frac{\hbar}{2}$$

$$a\,(0.01\,p) = \frac{\hbar}{2}$$

$$\boxed{a = \frac{\hbar}{2 \times 0.01\,p}}$$

Proof of equation 5.7 page 154

$$\lambda = \frac{h}{p} = \frac{hc}{pc}$$

$$E^2 = p^2c^2 + \cancel{(mc^2)^2} = (K + mc^2)^2$$

$$= K^2 + 2Kmc^2 + \cancel{(mc^2)^2}$$

$$pc = (K^2 + 2Kmc^2)^{1/2}$$

$$\lambda = \frac{hc}{(K^2 + 2Kmc^2)^{1/2}}$$ but $K = eV$

$$\lambda = \frac{hc}{\sqrt{2Kmc^2}\left(\frac{K}{2mc^2} + 1\right)} = \frac{hc}{\sqrt{2emc^2}\sqrt{V}}\left(\frac{eV}{2mc^2} + 1\right)^{-1/2}$$

$$\frac{hc}{\sqrt{2emc^2}} = \frac{12400\ \text{Å}\cdot\text{eV}}{\sqrt{2 \times 1.6\times10^{-19} \times \frac{0.511\times10^{6}}{1.6\times10^{-19}}}} = 12.27\ \text{Å}\,\text{eV}$$

$$\boxed{\lambda = \frac{12.27}{\sqrt{V}}\left(\frac{eV}{2mc^2} + 1\right)^{-1/2}} \quad (\text{Å})$$

volt