4.2) a) $E_0 = m_0 c^2 = (9.11\times10^{-31}\,kg)(2.998\times10^{8}\,m/s) = 8.188\times10^{-14}$ J.

$1\,eV = 1.602\times10^{-19}$ J.

so: $E_0 = \dfrac{8.188\times10^{-14}\,J}{1.602\times10^{-19}\,\frac{J}{eV}} = 5.11\times10^{5}\,eV = \boxed{511\ keV}$

b) AT $V = \frac{c}{10}$, WE CAN IGNORE RELATIVISTIC EFFECTS, SO:

$$E = \tfrac{1}{2} m_0 V^2 = \tfrac{1}{2} m_0 \left(\tfrac{c}{10}\right)^2 = \tfrac{1}{2}(9.11\times10^{-31}\,kg)\left(\frac{2.998\times10^{8}\,m/s}{10}\right)^2$$

$E = 4.094\times10^{-16}$ J.

$$E = \frac{4.094\times10^{-16}\,J}{1.602\times10^{-19}\,\frac{J}{eV}} = 2.56\times10^{3}\,eV = 2.56\ keV$$

$\boxed{\text{SO A VOLTAGE OF 2.56 KV WILL ACCELERATE ELECTRONS TO } \tfrac{1}{10}c.}$

c) $E = mc^2 - m_0c^2 = \dfrac{m_0 c^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_0 c^2$

$$E = m_0 c^2\left(\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}} - 1\right)$$

$$\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}} - 1 = \frac{E}{m_0 c^2}$$

$$\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}} = \frac{E}{m_0 c^2} + 1 = \frac{E + m_0 c^2}{m_0 c^2}$$

$$\left(1-\frac{v^2}{c^2}\right)^{\frac{1}{2}} = \frac{m_0 c^2}{E + m_0 c^2}$$

$$1 - \frac{v^2}{c^2} = \left[\frac{m_0 c^2}{E + m_0 c^2}\right]^2$$

$$\frac{v^2}{c^2} = 1 - \left[\frac{m_0 c^2}{E + m_0 c^2}\right]^2 = 1 - \left[\frac{511\,\cancel{keV}}{(120+511)\,\cancel{keV}}\right]^2$$

$$\frac{v^2}{c^2} = 0.34418$$

$$\frac{v}{c} = 0.5867$$

$\boxed{v = 0.5867\ c}$

OR

$\boxed{v = 1.759\times10^{8}\ m/s}$

4.3) $KE = mc^2 - m_oc^2 = \dfrac{m_oc^2}{\sqrt{1-\frac{v^2}{c^2}}} - m_oc^2$

$$KE = m_oc^2\left[\underbrace{\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}}} - 1\right]$$

$\Uparrow$

IF $v \ll c$, THEN $\frac{v^2}{c^2} \ll 1$, AND WE HAVE:

$$\left(1-\frac{v^2}{c^2}\right)^{-\frac{1}{2}} \approx 1 - \left(-\frac{1}{2}\right)\frac{v^2}{c^2} = 1 + \frac{1}{2}\frac{v^2}{c^2}$$

SUBSTITUTING BACK IN:

FOR $v \ll c$: $KE \approx m_oc^2\left[\cancel{1} + \frac{1}{2}\frac{v^2}{c^2} - \cancel{1}\right]$

$$KE \approx \frac{1}{2}\frac{m_o\cancel{c^2}v^2}{\cancel{c^2}}$$

$$\boxed{KE \approx \frac{1}{2}m_ov^2}\ \checkmark$$

4.4) CHARACTERISTIC RADIATION: x-ray RADIATION ARISING WHEN AN ENERGETIC ELECTRON COLLIDES w/ A K-SHELL ELECTRON, EXCITING OR IONIZING THE ATOM AND LEAVING A "HOLE" IN THE K-SHELL. THE "CHARACTERISTIC RADIATION" IS RELEASED WHEN THE K-SHELL HOLE IS FILLED BY AN ELECTRON FROM THE L, M, OR N SHELL. THE RELEASED CHARACTERISTIC x-ray PHOTON HAS ENERGY EXACTLY EQUAL TO THE DIFFERENCE IN BINDING ENERGY OF THE EJECTED K-SHELL ELECTRON AND THE L, M, OR N SHELL ELECTRON THAT FILLED THE K-SHELL HOLE.

BREMSSTRAHLUNG RADIATION: EM RADIATION CAUSED WHEN AN ENERGETIC ELECTRON INTERACTS w/ THE POSITIVELY-CHARGED NUCLEUS OF AN ATOM. AS THE NEGATIVELY-CHARGED ELECTRON DECELERATES AS IT PASSES THE NUCLEUS, IT LOSES ENERGY AND EMITS A PHOTON. THE ENERGY OF THE PHOTON EMITTED (THE "BREMSSTRAHLUNG", OR "BREAKING" PHOTON) IS EXACTLY EQUAL TO THE ENERGY LOST BY THE ELECTRON.

4.5) a) IONIZATION IS THE EJECTION OF AN ELECTRON FROM AN ATOM. IN ORDER TO EJECT THE ELECTRON, THE INCIDENT RADIATION MUST HAVE SUFFICIENT ENERGY TO OVERCOME THE BINDING ENERGY OF THE ELECTRON. THE SMALLEST BINDING ENERGY AMONG ATOMS HAVING SMALLER ATOMIC #S IS THAT OF HYDROGEN'S SINGLE ELECTRON, w/ BINDING ENERGY 13.6 eV. WITH LESS ENERGY THAN 13.6 eV, RADIATION CAN'T IONIZE MUCH OF ANYTHING.

b) IONIZATION = EJECTION OF ELECTRON FROM AN ATOM

EXCITATION = BUMPING AN ELECTRON TO A HIGHER ENERGY LEVEL, BUT WITHOUT IONIZING THE ATOM.

4.6) $\lambda = 4$ TO 400×10^{-9} m.

b) $E = h\nu \qquad \nu = \frac{c}{\lambda}$

$$E_1 = \frac{hc}{\lambda_1} = \frac{(6.626\times10^{-34}\ \text{J}\cdot\cancel{\text{s}})(2.998\times10^{8}\ \cancel{\text{m}}/\cancel{\text{s}})}{4\times10^{-9}\ \cancel{\text{m}}}$$

$$E = \frac{4.9662\times10^{-17}\ \cancel{\text{J}}}{1.602\times10^{-19}\ \cancel{\text{J}}/\text{eV}} = 310\ \text{eV}$$

FLIPPED

$$E_2 = \frac{hc}{\lambda_2} = 3.1\ \text{eV}$$

SO ENERGY IS BETWEEN: $\boxed{3.1 \text{ AND } 310 \text{ eV}}$.

a) $$\nu_1 = \frac{c}{\lambda_1} = \frac{2.998\times10^{8}\ \cancel{\text{m}}/\text{s}}{4\times10^{-9}\ \cancel{\text{m}}} = 7.5\times10^{16}\ \text{Hz}$$

$$\nu_2 = \frac{c}{\lambda_2} = \frac{2.998\times10^{8}\ \cancel{\text{m}}/\text{s}}{400\times10^{-9}\ \cancel{\text{m}}} = 7.5\times10^{14}\ \text{Hz}$$

SO FREQUENCY IS BETWEEN: $\boxed{7.5\times10^{14} \text{ AND } 7.5\times10^{16}\ \text{Hz}}$

c) SOME ULTRAVIOLET LIGHT IS IONIZING, IF $E > 13.6\ eV$

WHAT IS THE FREQUENCY OF LIGHT WHEN IT BECOMES IONIZING?

$$E = h\nu = 13.6\ eV$$

$$\nu = \frac{(13.6\ \cancel{eV})\left(1.602\times10^{-19}\ \frac{J}{eV}\right)}{\left(6.626\times10^{-34}\ J\cdot s\right)}$$

$$\nu = 3.28\times10^{15}\ Hz$$

SO WHEN $\nu > 3.28\times10^{15}\ Hz$, ULTRAVIOLET LIGHT IS IONIZING.

4.8) a) $\frac{N}{N_0} = e^{-\mu\Delta x}$

$$.005 = e^{-\mu\Delta x}$$

$$\ln(.005) = -\mu\Delta x$$

$$\Delta x = -\frac{\ln(.005)}{\mu}$$

$$\boxed{\Delta x \approx \frac{5.3}{\mu}}$$

4.11) $\lambda = 8.9\times10^{-2}\ \cancel{Å}\ \frac{.1\times10^{-10}\ meters}{1\ \cancel{Å}}$

$\lambda = 8.9\times10^{-12}\ m$

$\lambda = \frac{c}{\nu}$

$\nu = \frac{c}{\lambda}$

$\nu = 3.3685\times10^{19}\ Hz$

$$h\nu = \frac{\left(6.626\times10^{-34}\ \cancel{J}\cdot\cancel{s}\right)\left(3.3685\times10^{19}\ \frac{cyc}{\cancel{s}}\right)}{1.602\times10^{-19}\ \frac{J}{eV}}$$

$$h\nu = 139.32\ keV$$

$$E' = \frac{h\nu}{1 + (1-\cos\theta)\frac{h\nu}{m_0c^2}}$$

$$E' = \frac{139.32\ keV}{1 + \left[1-\cos(2\pi)\right]\frac{139.3\ \cancel{keV}}{511\ \cancel{keV}}}$$

$$E' = 135.8\ keV$$

SO DETECTOR SHOULD ACCEPT PHOTONS FROM $\boxed{135.8\ \text{TO}\ 139.3\ keV}$