Name____

Physics 111 Quiz #7, March 7, 2025

Please show all work, thoughts and/or reasoning to receive partial credit. The quiz is worth 10 points total, and all parts may not be of equal weight.

I affirm that I have carried out my academic endeavors with full academic honesty.

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Photoelectric absorption of photons of light in the body is the primary mechanism responsible for the generation of a medical "x-ray" photograph of the body. The primary absorber of x-rays in the body are bone and soft tissue with work functions $\phi_{bone} = 20eV$ and $\phi_{ST} = 5eV$ respectively.

1. If x-rays are incident on bone with a wavelength $0.1nm$, what is their energy in eV and J?

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34}Js \times 3 \times 10^{8}\frac{m}{s}}{0.1 \times 10^{-9}m} = 1.99 \times 10^{-15}J$$

$$E = 1.99 \times 10^{-15}J \times \frac{1eV}{1.6 \times 10^{-19}J} = 1.24 \times 10^{4}eV$$

2. Suppose that x-rays are incident on bone in the body at a rate of $1 \times 10^{15}s^{-1}$. What is the intensity of the x-ray beam of photons on a $1cm^2$ piece of bone?

$$S = \frac{Energy}{time \cdot area} = \frac{1 \times 10^{15}s^{-1} \times 1.99 \times 10^{-15}J}{1cm^2 \times \left(\frac{1m}{100cm}\right)^2} = 1.99 \times 10^{4}\frac{W}{m^2}$$

3. What stopping voltage would be needed to stop ejected electrons from bone?

$$K = eV_{stop} = \frac{hc}{\lambda} - \phi = 1.24 \times 10^{4}eV - 20eV = 1.23810^{4}eV$$

$$V_{stop} = 1.23810^{4}V$$

4. Using relativistic ideas, what is the speed of the ejected electrons from bone, expressed as a fraction of the speed of light.

$$K = eV_{stop} = (\gamma - 1)mc^2 \rightarrow \gamma = \frac{K}{mc^2} + 1 = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} \rightarrow v = \sqrt{1 - \frac{1}{\gamma^2}}c$$

$$\gamma = \frac{K}{mc^2} + 1 = \frac{1.23810^4 eV}{511000 \frac{eV}{c^2} c^2} + 1 = 1.024317$$

$$v = \sqrt{1 - \frac{1}{\gamma^2}}c = \sqrt{1 - \frac{1}{(1.024317)^2}}c = 0.21c$$

5. X-rays are a form of what's termed "ionizing radiation." This means that when they interact with materials, they produce electrons and positive ions. In the body, it takes roughly between $25eV$ to $50eV$ to cause a double strand break in the DNA of bone. Would an ejected electron from an x-ray incident on bone be able to damage the DNA in bone? Explain your answer.

   Since the energy of the ejected electron is $1.24 \times 10^4 eV$, which is approximately three orders of magnitude greater than the energy needed to bread bonds in DNA the ejected electron will have more than enough energy do disrupt the function of DNA.