3. (30 pts.) An electron in a long organic molecule used in a dye laser behaves approximately like a particle confined to a one-dimensional box of length 5.00 nm.

a. (5 pts.) What is the second-longest possible wavelength for the electron when it is confined to this box?

b. (5 pts.) What is the corresponding kinetic energy?

c. (5 pts.) What is the third-longest possible wavelength for the electron when it is confined to this box?

d. (5 pts.) What is the corresponding kinetic energy?

e. (10 pts.) What is the wavelength of the photon emitted when the electron makes a transition from the state in part (c) to the state in part (a)?

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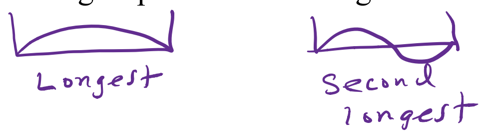

$$L = 2\left(\frac{\lambda_2}{2}\right) \Rightarrow \lambda_2 = \frac{2L}{2} = \boxed{5.00\ nm}$$

b. (5 pts.) What is the corresponding kinetic energy?

$$p = \frac{h}{\lambda} = \frac{6.626 \times 10^{-34}\ J\cdot s}{5.00 \times 10^{-9}\ m} = 1.325 \times 10^{-25}\ kg\ m/s$$

$$E_2 = \frac{1}{2}mv^2 = \frac{p^2}{2m} = \frac{(1.325 \times 10^{-25}\ kg\ m/s)^2}{2(9.11 \times 10^{-31}\ kg)} =$$

$$E_2 = 9.64 \times 10^{-21}\ J = 0.0602\ eV$$

c. (5 pts.) What is the third-longest possible wavelength for the electron when it is confined to this box?

$$\lambda_3 = \frac{2L}{3} = 3.33\ nm$$

d. (5 pts.) What is the corresponding kinetic energy?

$$p = \frac{h}{\lambda_3} = \frac{6.626 \times 10^{-34}\ J\cdot s}{3.33\ nm} = 1.99 \times 10^{-25}\ kg\ m/s$$

$$E_3 = \frac{p^2}{2m} = 2.17 \times 10^{-20}\ J = 0.135\ eV$$

e. (10 pts.) What is the wavelength of the photon emitted when the electron makes a transition from the state in part (c) to the state in part (a)?

$$\Delta E = E_3 - E_2 = 0.135\ eV - 0.0602\ eV = 0.0752\ eV$$

Then $\Delta E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{\Delta E} = \frac{1240\ eV\cdot nm}{0.0752\ eV} = 16{,}500\ nm$