

# Physics 801: *Nanostructures in Science and Technology*

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## **Exercise 1**

1. Calculate the lowest two energy levels  $E_1$ ,  $E_2$ , and  $E_{QM}=(E_2-E_1)$  for a quantum well of width  $l$ , as shown in Fig. 1.2.2, using the kinetic energy  $E = p^2/2m$  and the de Broglie relation  $p = h/\lambda$  between the momentum  $p$  and the wavelength  $\lambda$ . How small does the width  $l$  have to be in order to have a level spacing  $E_{QM} = 0.025$  eV (which is the thermal energy  $kT$  at room temperature)? Planck's constant  $h = 6.6 \cdot 10^{-34}$  Js, electron mass  $m = 9.1 \cdot 10^{-31}$  kg,  $1$  eV =  $1.6 \cdot 10^{-19}$  J,  $J = \text{kg m}^2/\text{s}^2$ .
2. Calculate the Coulomb  $E_C$  energy for putting a single electron onto a sphere of radius  $r$  embedded in a dielectric with the dielectric constant of silicon ( $\epsilon=12$ ). Use the relation  $E_C = qV$ , where  $q$  is the charge and  $V$  the electrostatic potential (= voltage) of the charged sphere. Use  $V = q/\epsilon r$  (cgs units) or  $V = q/4\pi\epsilon_0\epsilon r$  (SI units). How small does the diameter  $d = 2r$  have to be in order to have a charging energy  $E_C = 0.025$  eV? The charge of an electron is  $e = 4.8 \cdot 10^{-10}$  esu (cgs units),  $1$  eV =  $1.6 \cdot 10^{-12}$  erg (cgs units),  $e^2/4\pi\epsilon_0 = 1.44$  eV nm (SI units).