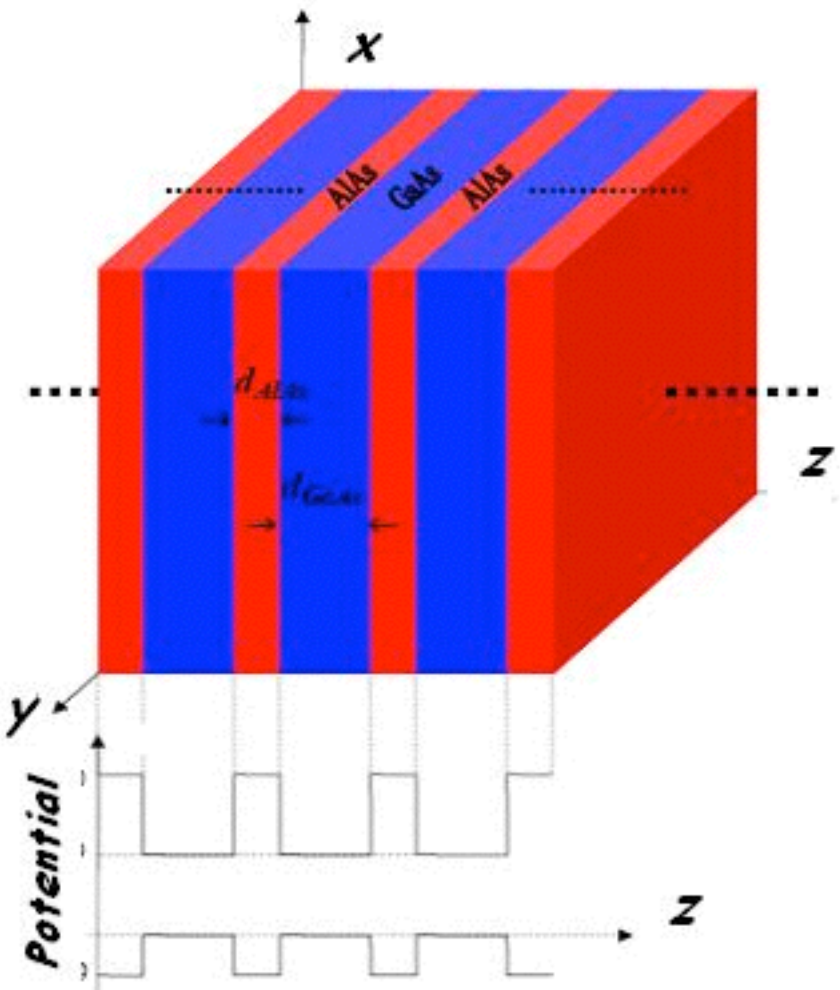
semiconductor junctions/superlattices



http://en.wikipedia.org/wiki/Superlattice

blue laser diode

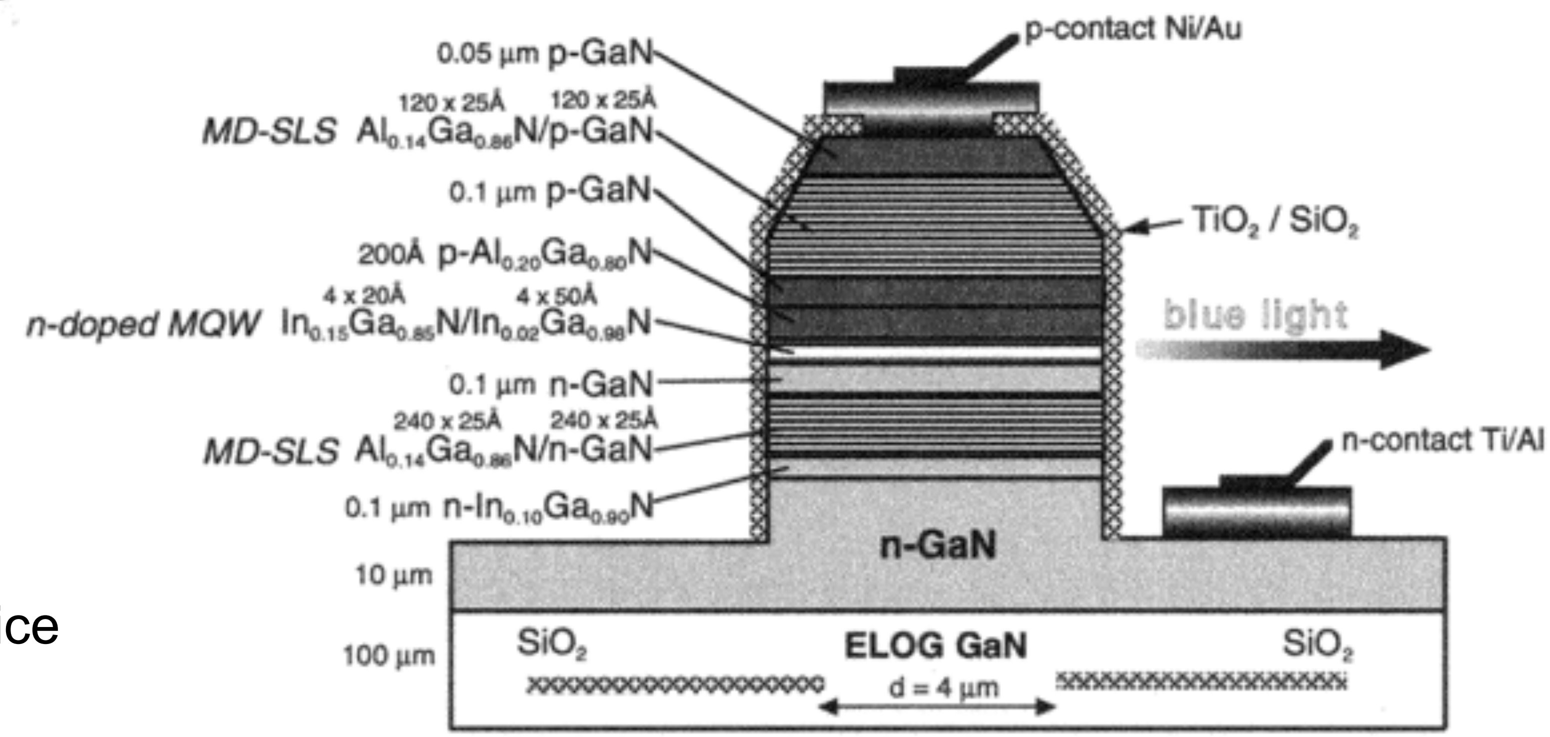
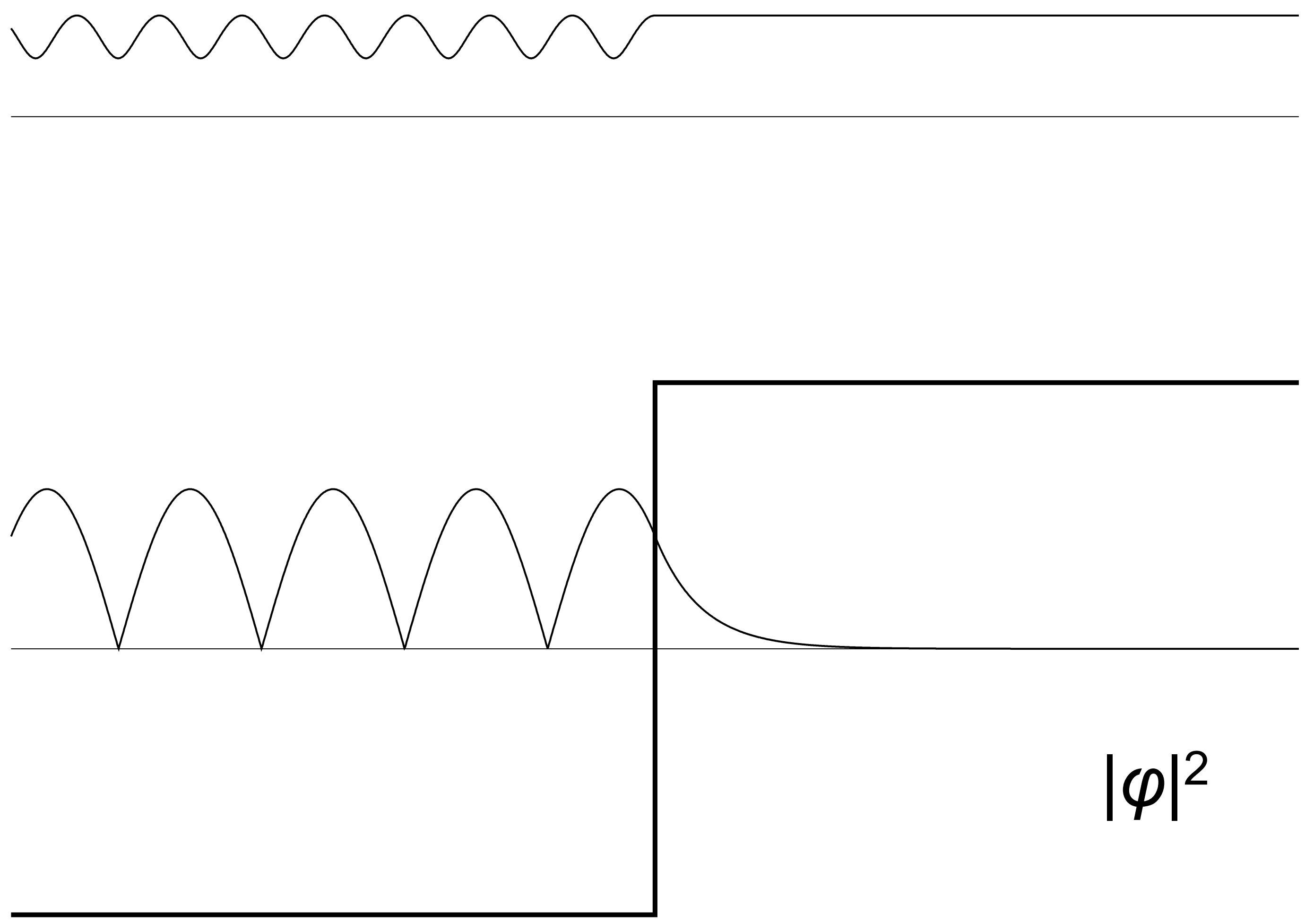


Figure 10: *A schematic illustration of a blue light emitting laser, where the active layer is a multilayer quantum well structure based on InGaN. AlGaN/GaN modulation-doped strained-layer superlattices (MD-SLSs) are used instead of bulk AlGaN cladding layers to confine the photons. The thicknesses of many of the 743 layers of the device have to be carefully controlled.*

http://www.nobelprize.org/nobel_prizes/physics/laureates/2000/advanced.html

potential step



$$\varphi_<(z) = Ae^{ikz} + Be^{-ikz} \qquad \varphi_>(z) = Ce^{i\tilde{k}z}$$

matching at z=0

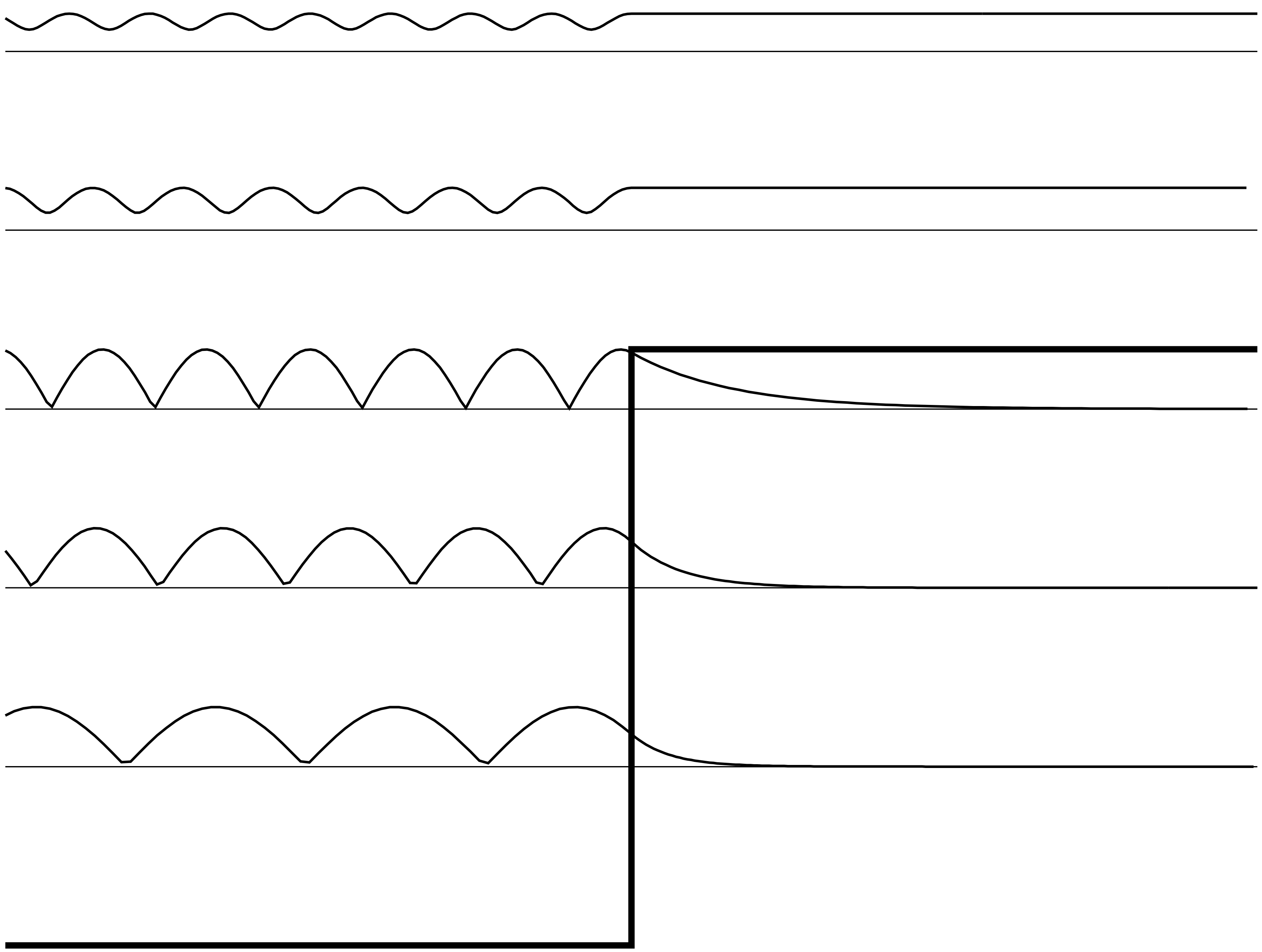
$$\begin{aligned} A + B &= C \\ ik(A - B) &= i\tilde{k}C \end{aligned}$$

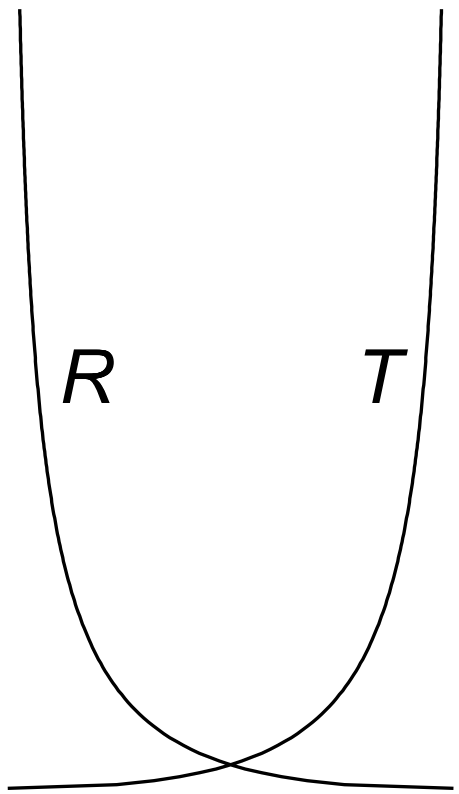
$$\begin{aligned} C/A &= \frac{2k}{k + \tilde{k}} \\ B/A &= \frac{k - \tilde{k}}{k + \tilde{k}} \end{aligned}$$

reflection and transmission

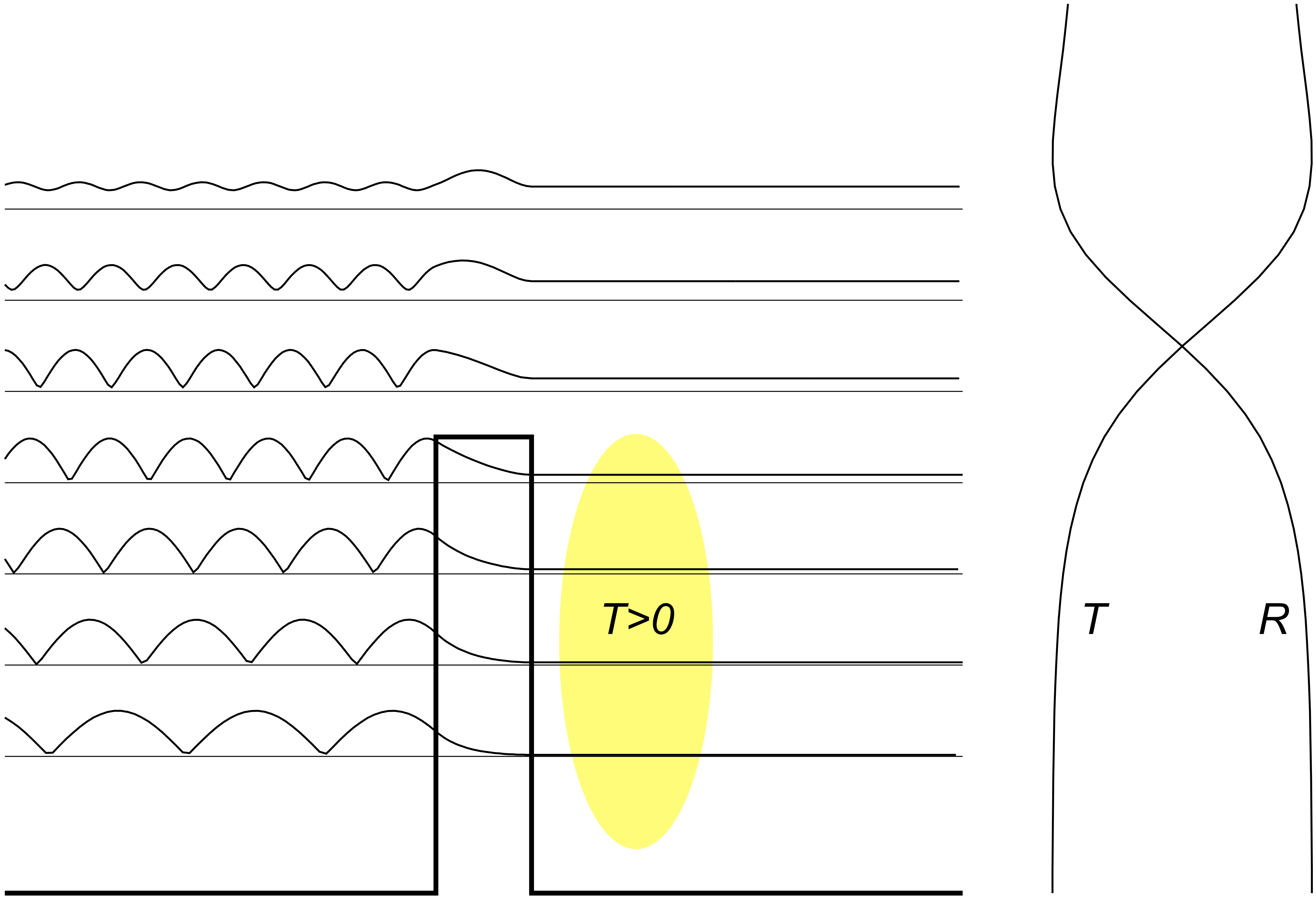
$$R = \left| \frac{k - \tilde{k}}{k + \tilde{k}} \right|^2$$

$$T = \frac{4k\tilde{k}}{(k+\tilde{k})^2} \text{ for } E > V_0, \text{ otherwise } = 0$$

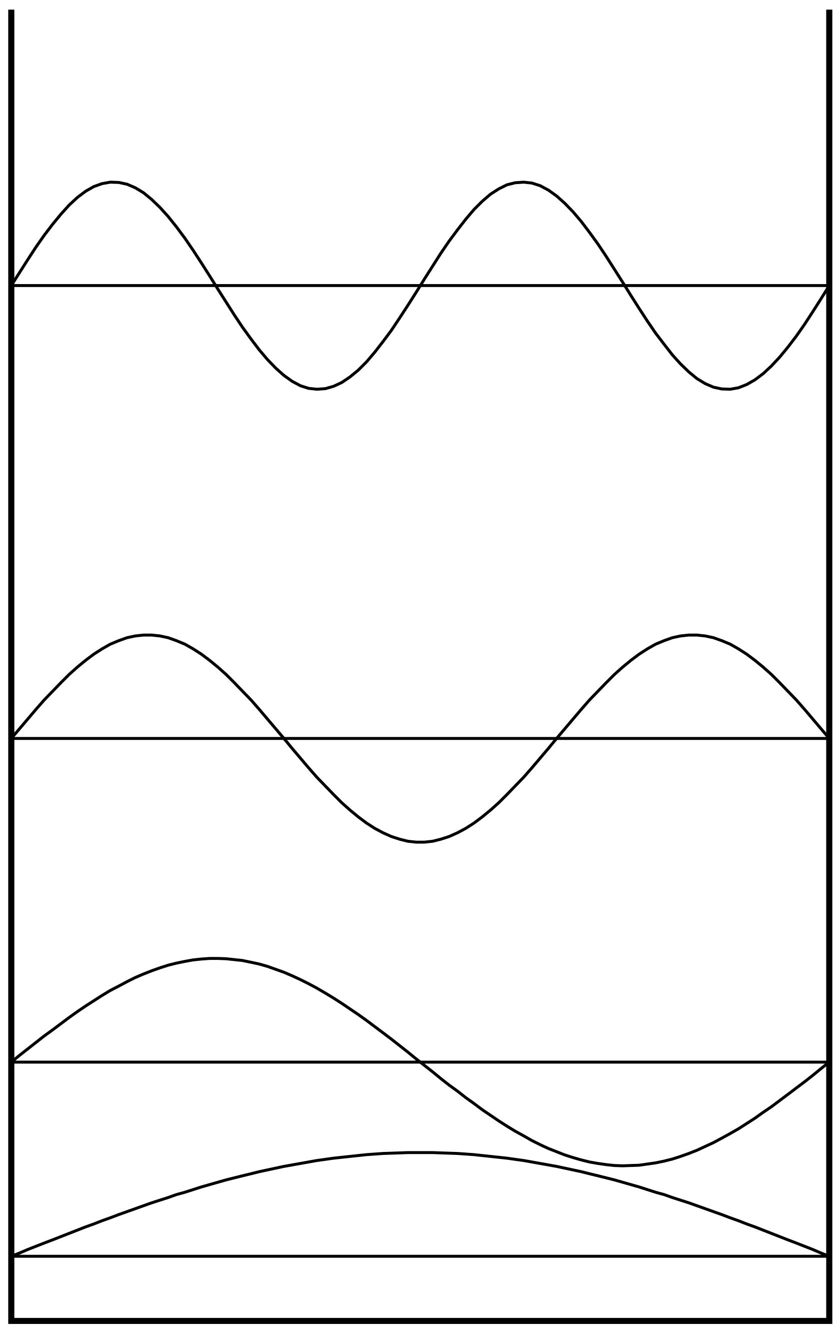




tunneling



particle in a box



boundary conditions ⇒ **quantization**

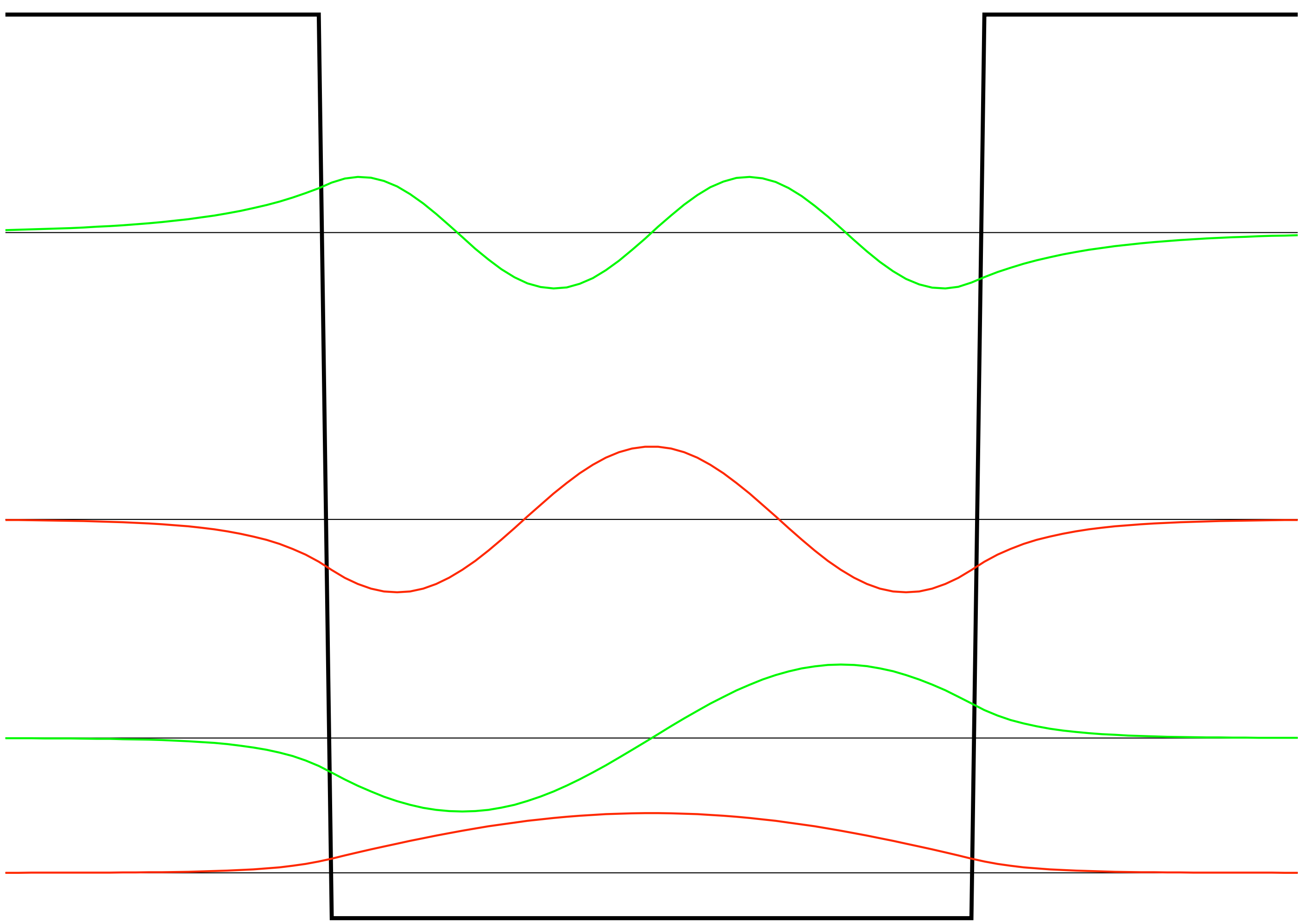
$$E_n = \frac{\hbar^2}{2m}\left(\frac{n\pi}{L_z}\right)^2$$

$$\varphi_n(z) = \sqrt{\frac{2}{L_z}}\,\sin\left(\frac{n\pi\, z}{L_z}\right)$$

discrete energies
zero-point energy
increasing number of nodes

symmetry of potential
symmetry of solutions (density)
even/odd eigenfunctions

finite potential well



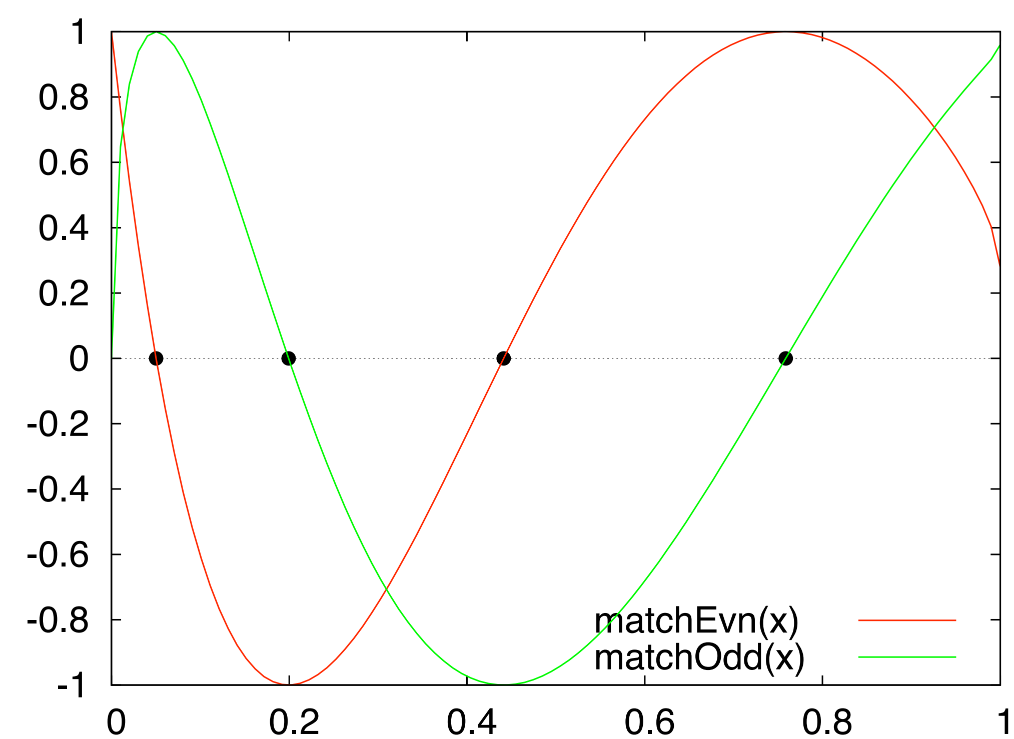
$B\,e^{+\kappa z}$ $\quad A\cos kz$ $\quad +B\,e^{-\kappa z}$

$B\,e^{+\kappa z}$ $\quad A\sin kz$ $\quad -B\,e^{-\kappa z}$

matching

$$\begin{aligned} A\cos kL/2 &= Be^{-\kappa L/2} \\ -kA\sin kL/2 &= -\kappa Be^{-\kappa L/2} \end{aligned}$$

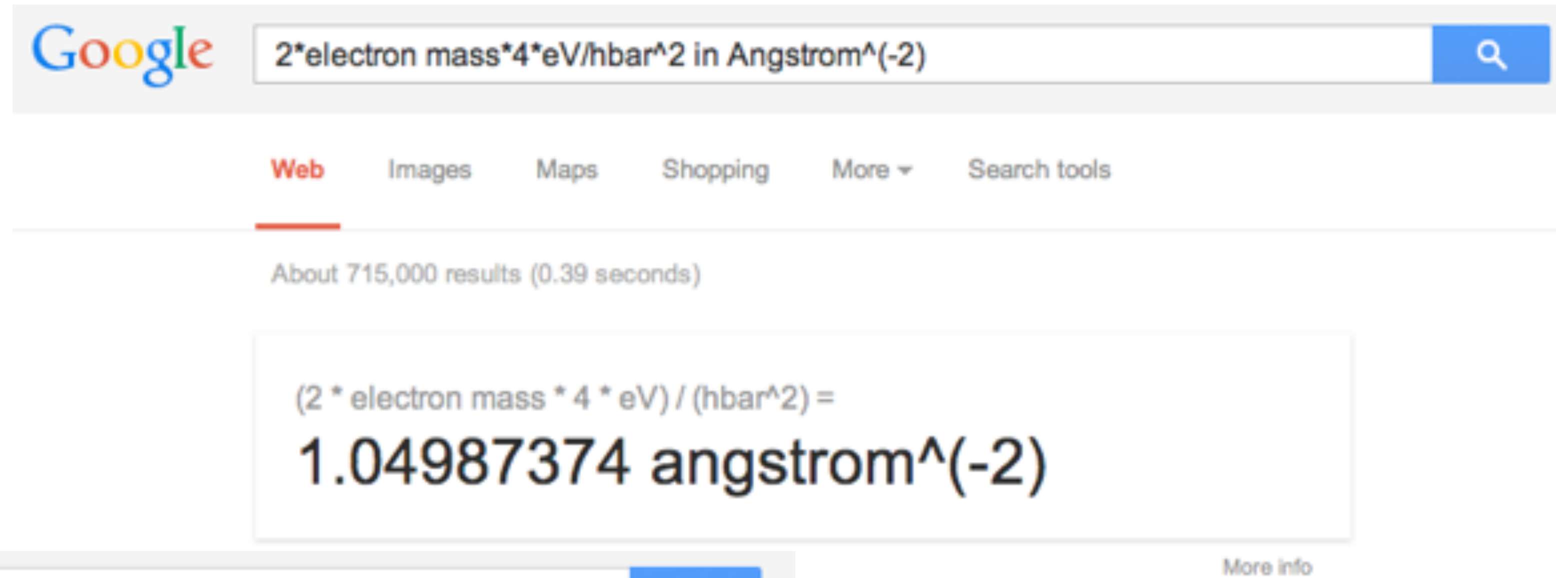
$$\begin{aligned} A\sin kL/2 &= -Be^{-\kappa L/2} \\ kA\cos kL/2 &= \kappa Be^{-\kappa L/2} \end{aligned}$$

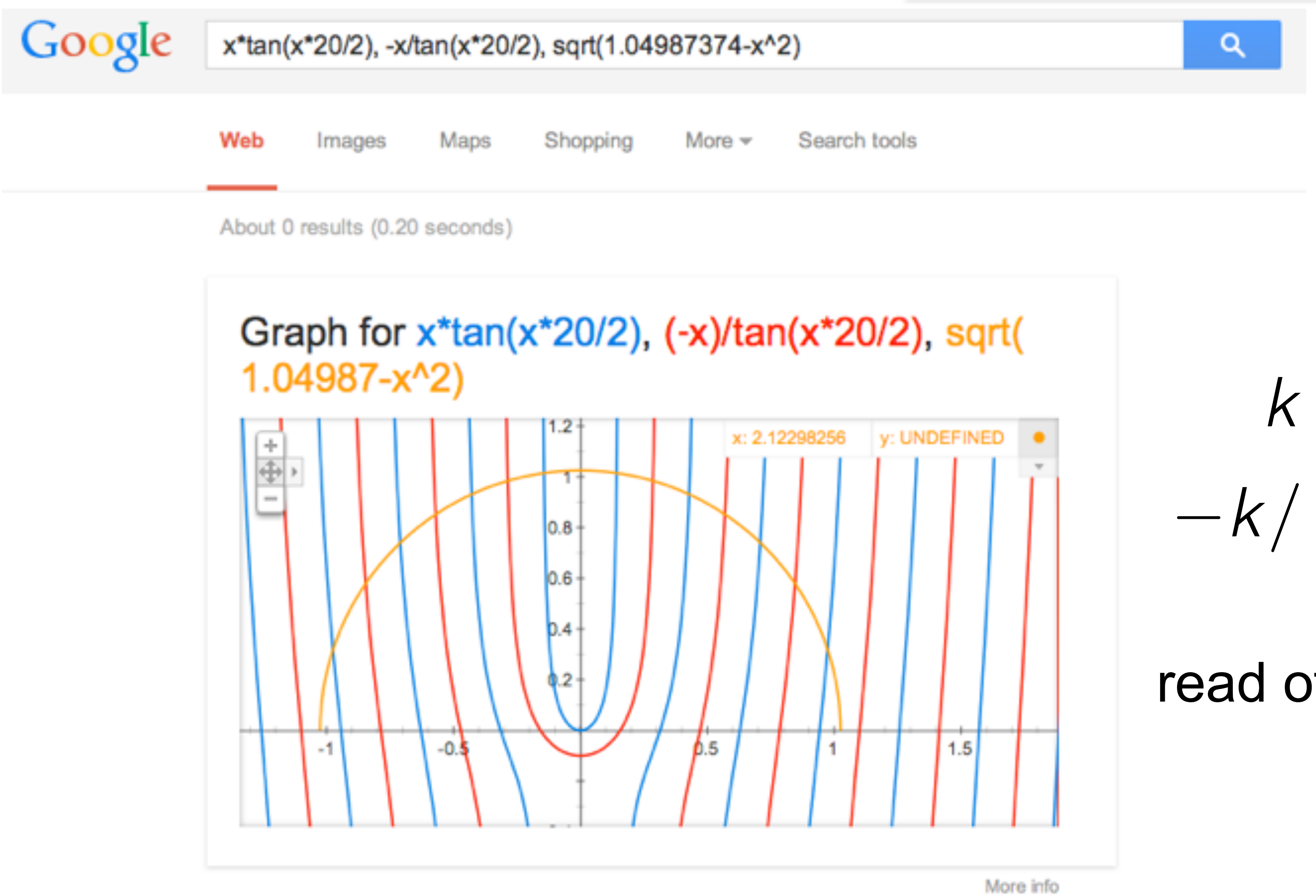


solution by Google

L = 20 Å, V_0 = 4 eV, work in Å

$$\kappa = \sqrt{2mV_0/\hbar^2 - k^2}$$





$$k \tan(kL/2) = \kappa$$

$$-k/\tan(kL/2) = \kappa$$

read off solutions k_n

typical units

h = 6.626068 10^{-34} Js
m_{el} = 9.109382 10^{-31} kg
e = 1.602176 10^{-19} C

http://physics.nist.gov/cuu/Constants/index.html

$$E = \frac{\hbar^2 k^2}{2m_{el}}$$

why use Å and eV?

1 Å = 10^{-10} m
1 eV = 1.602176 10^{-19} J

E [in J] = 6.10 10^{-39} (k [in m^{-1}])^2

E [in eV] = 3.81 (k [in Å^{-1}])^2

```
from math import pi
hbar  = 1.0546e-34      # h/2pi in Js
me    = 9.1094e-31      # electron mass in kg
e     = 1.6022e-19      # electron charge in C

const=hbar**2/(2*me)    # print(const) --> 6.10457966496e-39
L = 1e-9                # in m (1 nm = 10 \AA)
k1=pi/L
E1=const*k1**2          # ground-state energy --> 6.024979e-20 J

const=hbar**2/(2*me)/(1e-10**2*e) # print(const) --> 3.81012337097
L = 10                  # in \AA
k1=pi/L
E1=const*k1**2          # ground-state energy --> 3.760441e-01 eV
```