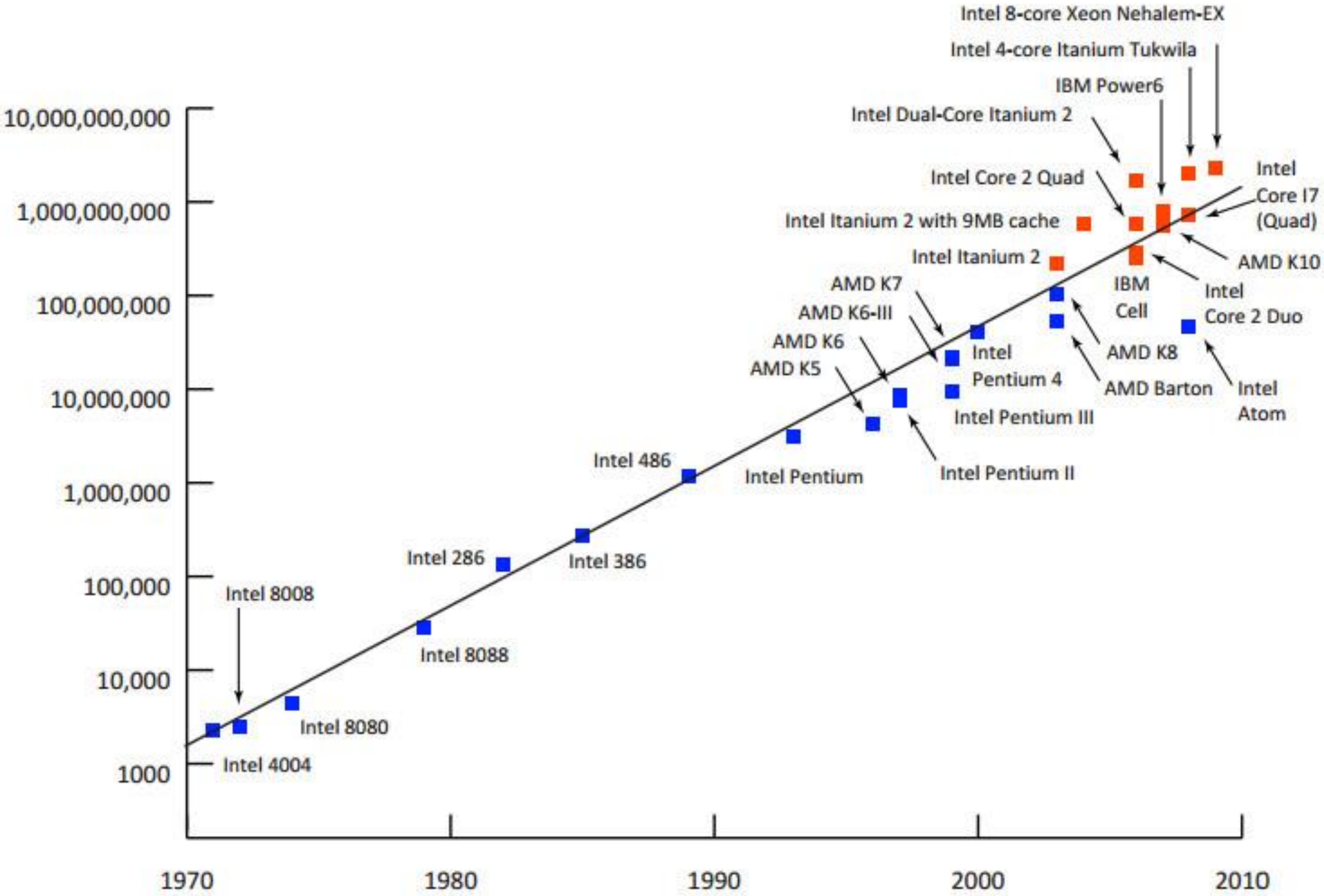
Quantum Computation

(Why Should You Care?)



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End of the Silicon Technology

- End of Moore’s law (~10 years)
- Slowing down of Moore’s law
- Limitation to silicon-based computing
- Overheating and quantum mechanical effects
- Uncertainty principle: You don’t know where the electron is

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Quantum Computers

theinquirer.net

- Replacement for classical computers
- Solve problems that are infeasible for classical computers
- Simulate quantum environments
- Factoring large integers
- Combinatorial optimization problems
- Major problem: Docoherence, noise, loss of information

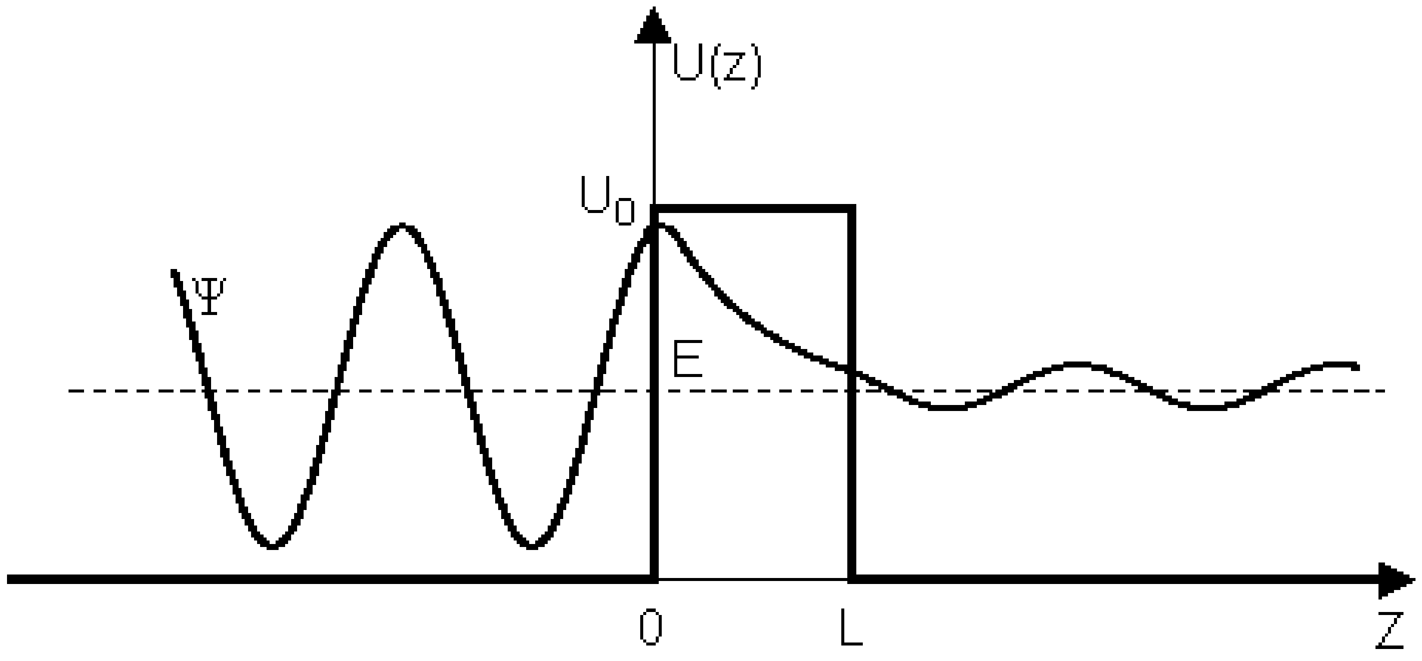
Internship

physics.umbc.edu

- Kevin Huang, junior at Centennial High School
- Professor Kestner
- University of Maryland, Baltimore County
- Quantum Information in Department of Physics
- Interest in developing physical devices which exploit quantum mechanical phenomena
- **Project: Joint measurement on two qubits without revealing the individual state of either qubit**
- **Application in error-tolerant encoding of multiple physical qubits**

Tasks

- Transmission of matter wave across a rectangular barrier



ntmdt.com

Boundary Conditions

Both ψ and $\frac{d\psi}{dx}$ must be continuous at the boundaries joining separate regions. There will be four such equations.

1.
$$Ae^{ikx_0} + Be^{-ikx_0} = Ce^{ilx_0} + De^{-ilx_0}$$

2.
$$Ce^{il(x_0+d)} + De^{-il(x_0+d)} = Fe^{ik(x_0+d)}$$

3.
$$ikAe^{ikx_0} - ikBe^{-ikx_0} = ilCe^{ilx_0} - ilDe^{-ilx_0}$$

4.
$$ilCe^{il(x_0+d)} - ilDe^{-il(x_0+d)} = ikFe^{ik(x_0+d)}$$

From equations 2 and 4, we have:

$$C = \frac{1}{2}\left(1 + \frac{k}{l}\right) Fe^{i(k-l)(x_0+d)}$$

$$D = \frac{1}{2}\left(1 - \frac{k}{l}\right) Fe^{i(k+l)(x_0+d)}$$

From equations 1 and 3:

$$\left(1 + \frac{k}{l}\right) Ae^{ikx_0} + \left(1 - \frac{k}{l}\right) Be^{-ikx_0} = 2 * \frac{1}{2}\left(1 + \frac{k}{l}\right) Fe^{i(k-l)(x_0+d)} * e^{ilx_0}$$

$$\left(1 - \frac{k}{l}\right) Ae^{ikx_0} + \left(1 + \frac{k}{l}\right) Be^{-ikx_0} = 2 * \frac{1}{2}\left(1 - \frac{k}{l}\right) Fe^{i(k+l)(x_0+d)} * e^{-ilx_o}$$

Simplifying:

$$Ae^{ikx_0} + \left(\frac{l-k}{l+k}\right) Be^{-ikx_0} = Fe^{i[k(x_0+d)-ld]}$$

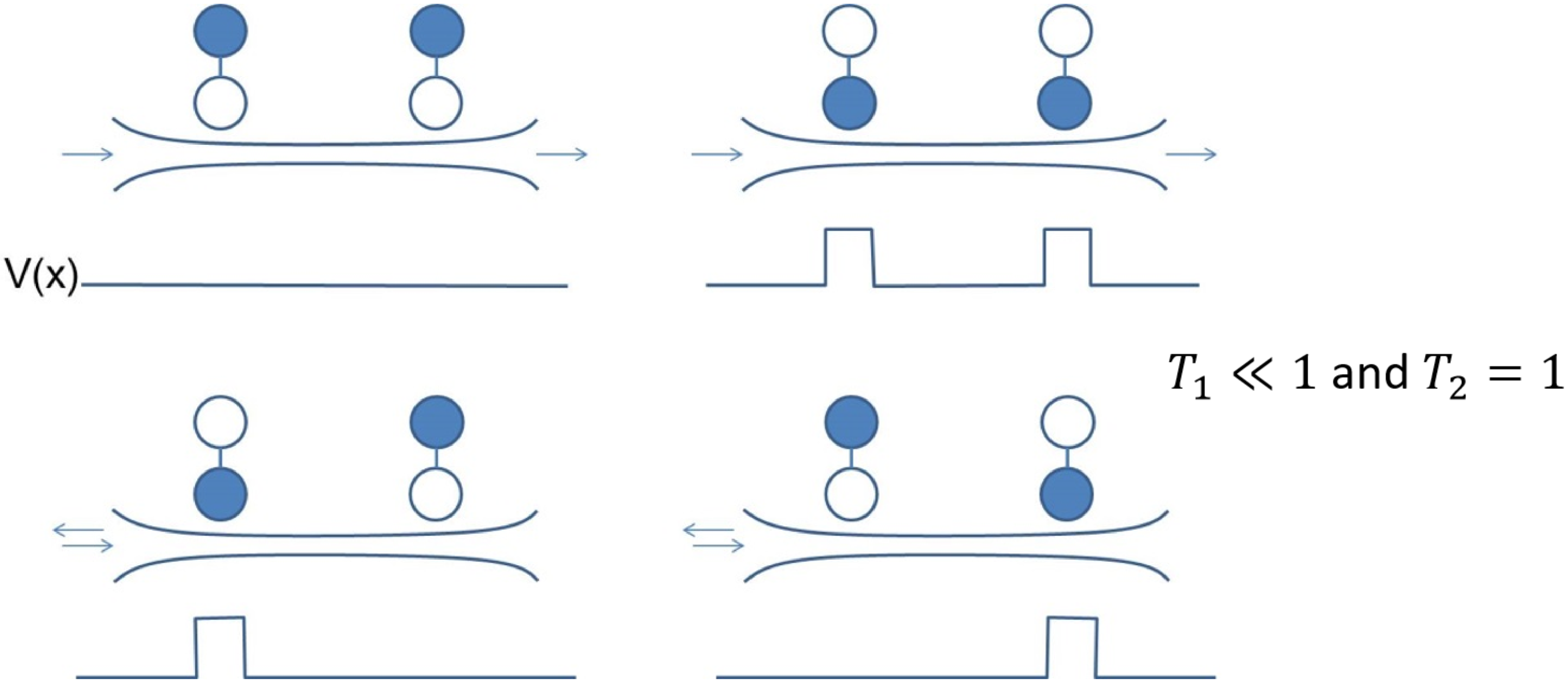


Figure 1: Double-quantum-dot charge qubits capacitively coupled to a conductance channel create a scattering potential that depends on the joint state of the qubits. Open (shaded) circles here represent empty (charged) dots, but Pauli blocking can be used to translate the idea to spin qubits.

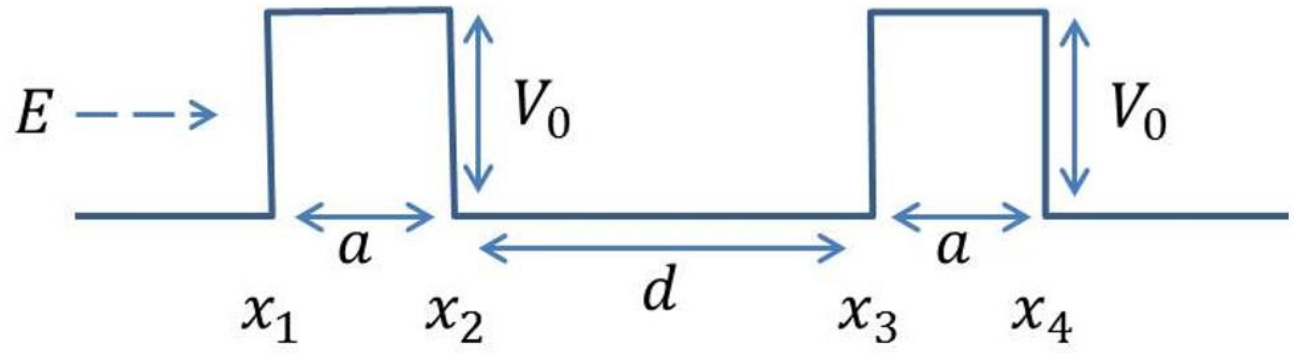
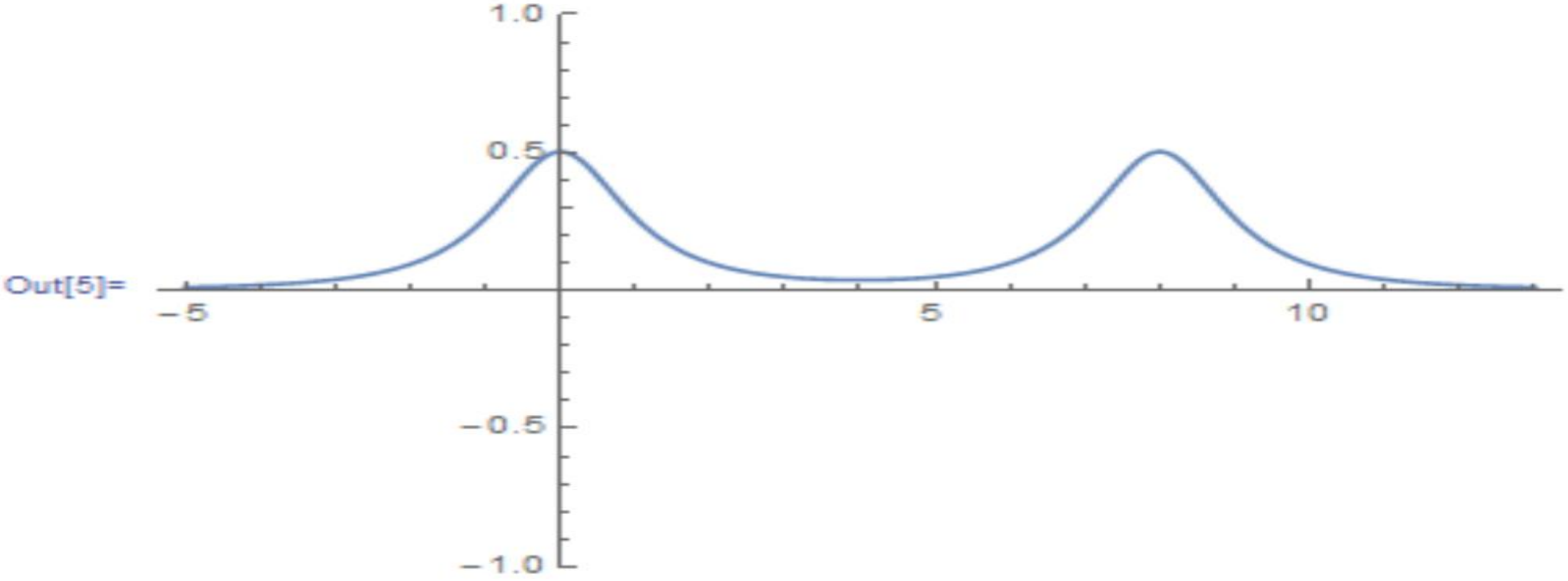
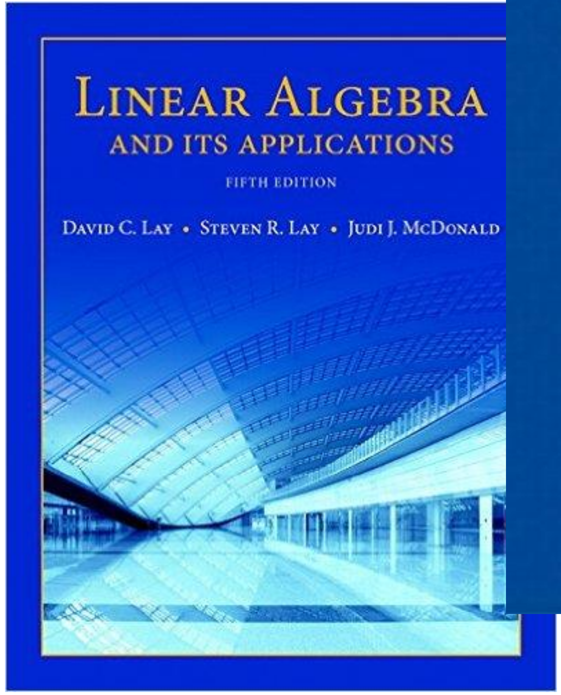


Figure 2: Square barrier model.

$$V(x) = V_1(x) + V_2(x) = \frac{\delta e}{e}\frac{e^2}{4\pi\epsilon}\left(\frac{1}{\sqrt{x^2+l'^2}} - \frac{1}{\sqrt{x^2+l^2}} + \frac{1}{\sqrt{(x-d)^2+l'^2}} - \frac{1}{\sqrt{(x-d)^2+l^2}}\right)$$



Realistic Effects



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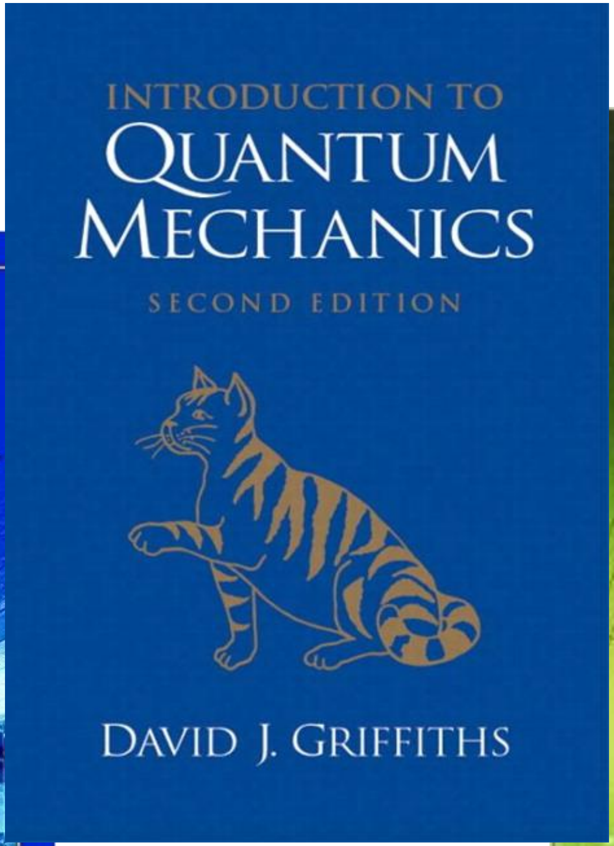

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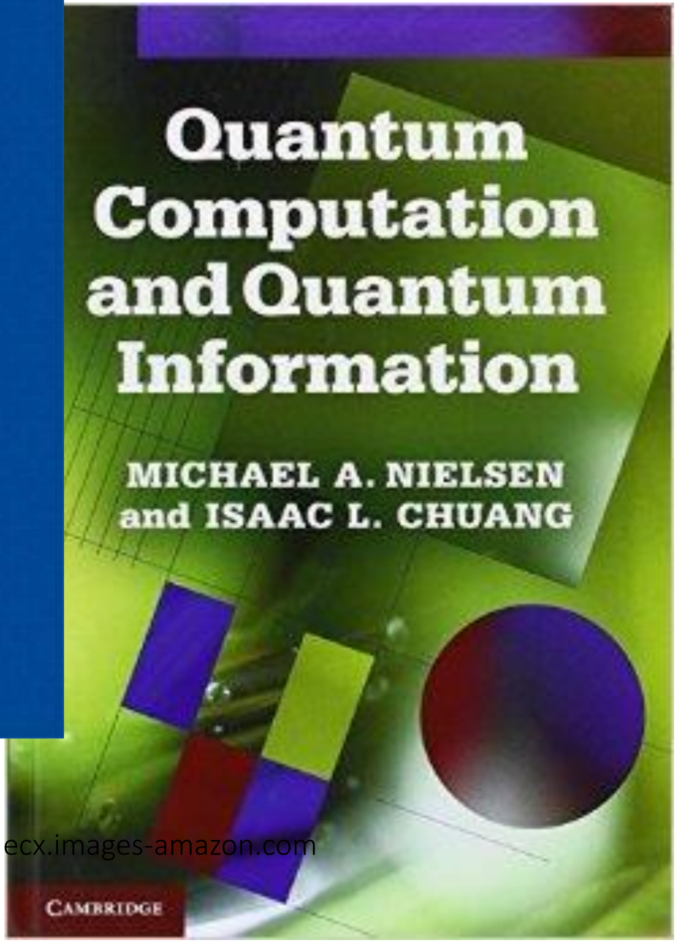

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