Course: Engineering Physics
PHY 1701

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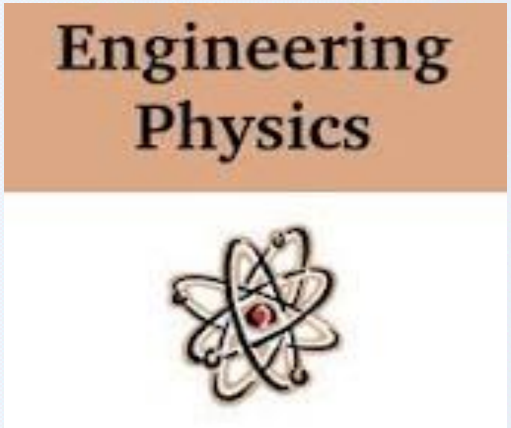
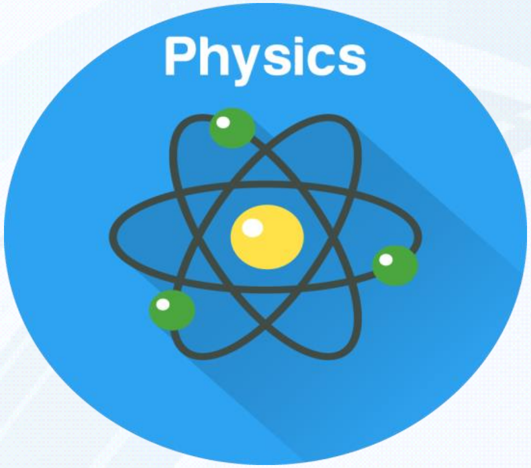
Outline

- **Introduction**
- **Quantum Mechanical Tunneling**



Resources:

Concepts of Modern Physics (Arthur Beiser)
Pages: 215 – 219



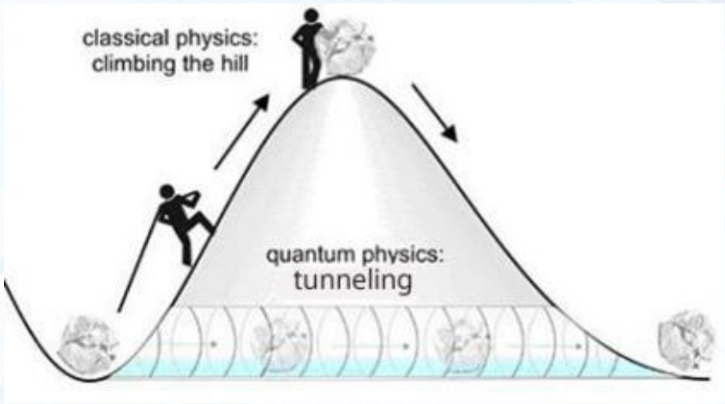
Introduction

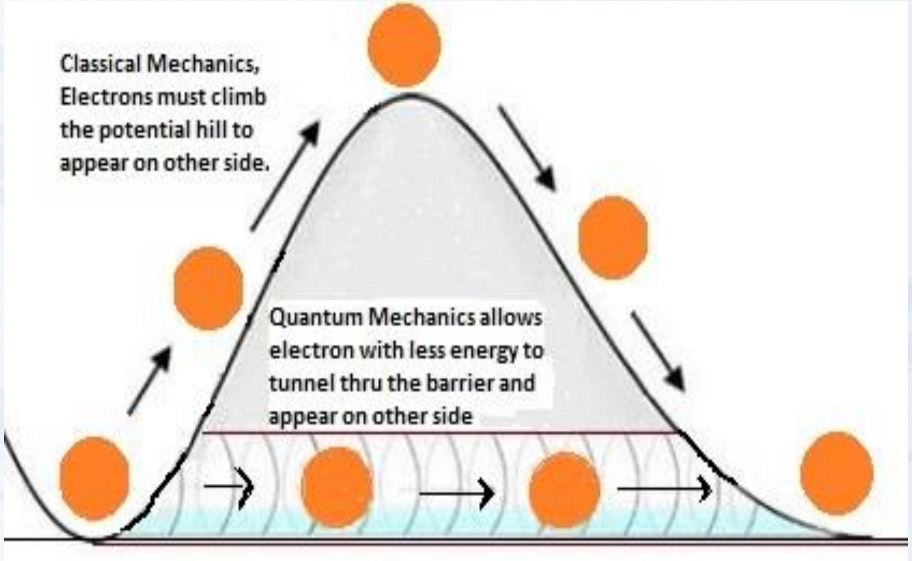
Quantum tunneling refers to the quantum mechanical phenomenon where a particle tunnels through a barrier that it classically could not possible.

This plays an essential role in several physical phenomena, such as the nuclear fusion that occurs in main sequence stars like the Sun.

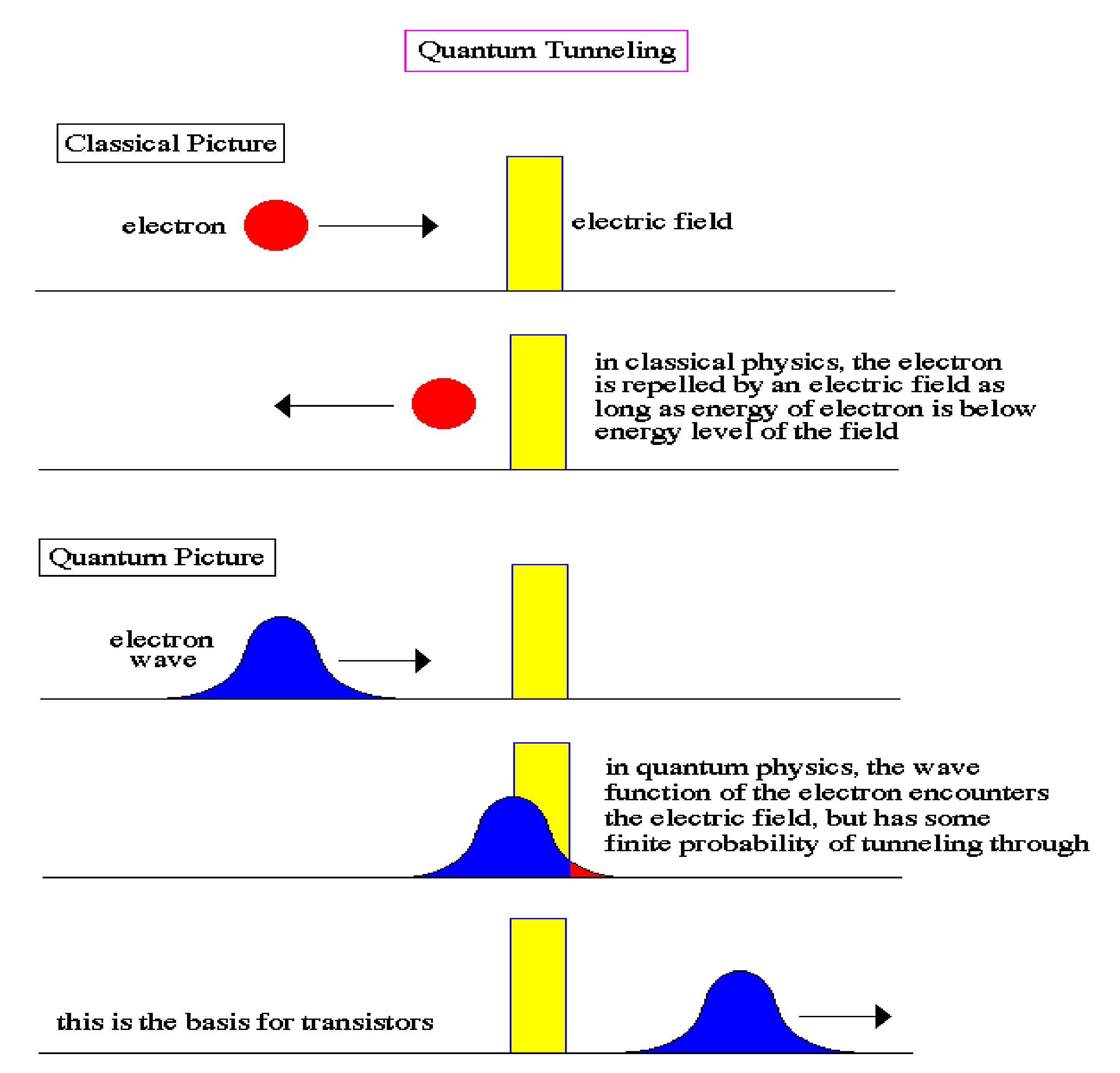
It has important applications to modern devices such as

1. Tunnel diode
2. Quantum computing
3. Scanning tunneling microscope (STM)





Introduction



Introduction

A scanning **tunneling** microscope (STM) is an instrument for imaging surfaces at the atomic level.

Its development in 1981 earned its inventors, Gerd Binnig and Heinrich Rohrer (at IBM Zürich), the Nobel Prize in Physics in 1986.

Quantum Mechanical Tunneling

The phenomenon of tunneling, which has no counterpart in classical physics, is an important consequence of quantum mechanics.

Consider a particle with energy E in the inner region of a one-dimensional potential well V(x). (A potential well is a potential that has a lower value in a certain region of space than in the neighbouring regions.)

In classical mechanics, if $E < V$ (the maximum height of the potential barrier), the particle remains in the well forever; if $E > V$, the particle escapes.

Quantum Mechanical Tunneling

In quantum mechanics, the situation is not so simple.

The particle can escape even if its energy E is below the height of the barrier V , although the probability of escape is small unless E is close to V .

In that case, the particle may tunnel through the potential barrier and emerge with the same energy E.

Quantum Mechanical Tunneling

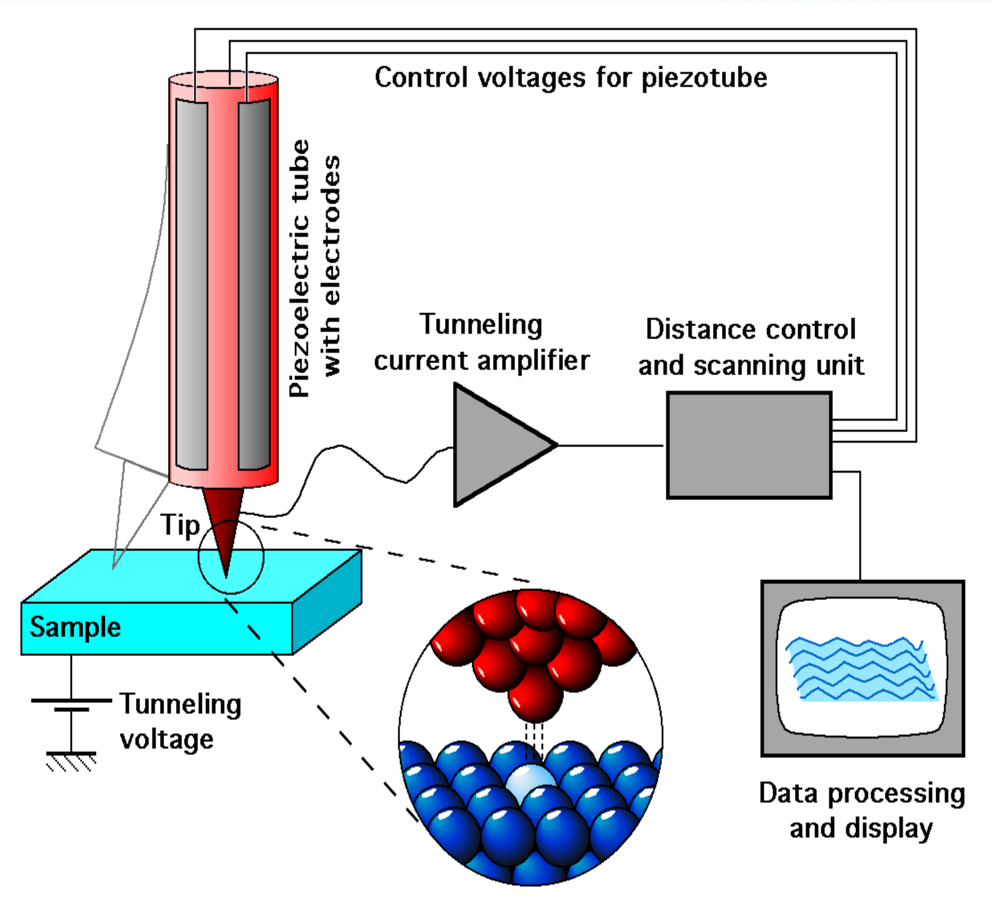
From the definition of k_1 and k_2, we have

$$\left(\frac{k_2}{k_1}\right)^2 = \frac{2\mathrm{m}(\mathrm{U}-\mathrm{E})/\hbar^2}{2\mathrm{mE}/\hbar^2} = \frac{\mathrm{U}}{\mathrm{E}} - 1$$

The approximate transmission probability is

$$T = e^{-2k_2L}$$

Scanning Tunneling Microscope



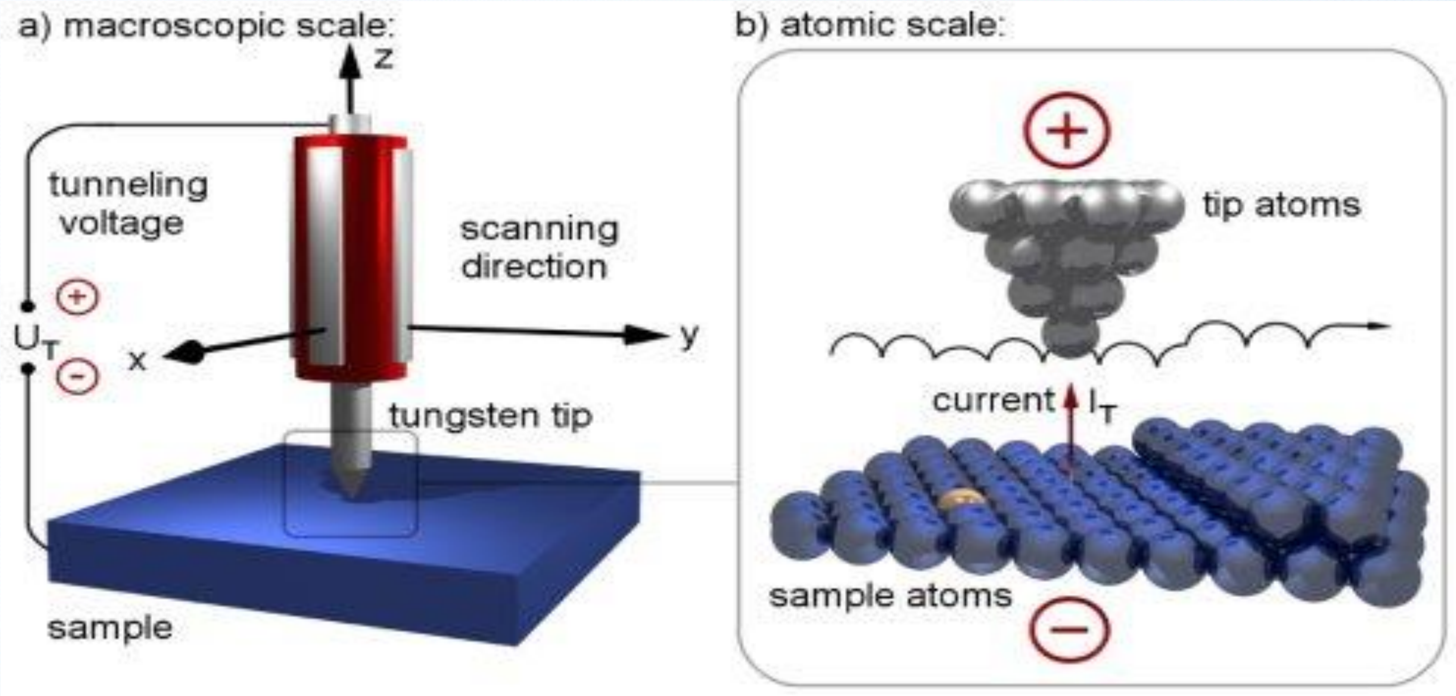
Schematic view of STM

The STM is based on the concept of quantum tunneling.

When a conducting tip is brought very near to the surface to be examined, a bias applied between the two can allow electrons to tunnel through the vacuum between them.

The resulting *tunneling current* is a function of tip position, applied voltage, and the local density of states of the sample

Scanning Tunneling Microscope



Tunneling is a functioning concept that arises from quantum mechanics. Classically, an object hitting an impenetrable barrier will not pass through. In contrast, objects with a very small mass, such as the electron, have wavelike characteristics which permit such an event, referred to as tunneling.