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TRANSPORT IN SMALL STRUCTURES
Transport in Disordered and Ultra Small Structures

- **Perfect crystalline materials**
  - Bloch oscillations

- **“Small” degree of disorder**
  - Scattering, mobility, velocity-field relations

- **“Large” disorder**
  - Localized states, band tails
  - Hopping conduction

- **Very small structures**
  - Mesoscopic systems
  - Quantized transport

Transport formalism is different for different regimes

Jaspreet Singh
Coherent Transport: No Scattering

Resonant tunneling transport: Double barriers have resonant states in the well. Tunneling probability is energy dependent.
Coherent Transport: Double Barrier Tunneling

Resonant tunneling transport: Tunneling probability is energy dependent. Current-voltage relation will show peaks and valleys.
Coherent Transport: Double Barrier Tunneling

Resonant tunneling transport: Current-voltage relation shows negative resistance, bistable points Microwave applications, simplified logic circuits.
Coherent Transport: Quantum Interference Devices

Electron waves flowing along two paths can interfere.

Constructive interference: ON;
Destructive interference: OFF
Disordered materials: Solar cells, display electronics, … Electron wavefunctions are not Bloch states
Disordered materials: E-k picture is not valid. States fall in localized (in space) and extended states.
Disordered materials: Conduction occurs by hopping in localized states.
Disordered materials: Various hopping processes in localized states.
1. Thermal excitation to the extended states
2. Nearest state hopping
3. Variable range hopping
Mesoscopic Structures:
Transmission-reflection approach to transport.
Single electron transport.
Conductance is quantized.
Transport in Small Structures: Coulomb Blockade

Mesoscopic Structures: Capacitance is so small that each electron creates a voltage shift greater than the thermal energy.
Transport in Small Structures: Coulomb Blockade

Mesoscopic Structures: At low temperatures the current-voltage relation shows non-linear behavior.

\[ T \geq T_0 \]

\[ T < T_0 = \frac{928.5 \text{ K}}{\text{C(aF)}} \]

Current, I

Voltage, V

80 mV/C(aF)