Introduction

Mesoscopic system:

intermediate between micro (atomic) and macro scale;

system (device) size $L \lesssim$ characteristic length scales:

l_e = mean free path = average distance between collisions (for an electron)

l_φ = phase coherence length = average distance traveled with "well-defined" Q.M. phase

Phase coherence is destroyed by inelastic scattering (electron-phonon, electron-electron); temperature dependent

$\lambda_F = h/\sqrt{2m^* E_F}$ = Fermi wavelength

Conventional device: $L \gg l_e, l_\varphi, \lambda_F$; diffusive transport

Mesoscopic device: $L < l_e$: ballistic transport

$L < l_\varphi$: phase coherent —"—

$L < \lambda_F$: quantization effects

$\frac{e^2}{C} > k_B T$: single-electron charging effects

In practise: $L <$ 10-100 nm (several!) (depending on details)

Mesoscopic effects to be addressed: [eventually]

- Quantized conductance in quantum point contacts (1988)
- Quantum Hall effect (1980)
- Coulomb blockade, Single Electron Tunneling (1987)
- Giant magnetoresistance (1986)

(Resonant tunneling, Aharonov-Bohm effect, Weak localization, Universal conductance fluctuations, ...)

Type of experiments: mostly transport, i.e., I vs V, i.e., resistance R and conductance G, with ($B \neq 0$) or without ($B = 0$) magnetic field

Physical realization:

- Semiconductors (mostly)
- Low temperature
- Low dimensionality (2DEG, 1D, 0D)

Theoretical "tools":

- Quantum mechanics (only single-particle formalism)
- Solid state physics
- Landauer-Büttiker formalism ("conductance from transmission")

Necessary concepts, to be introduced/repeated

- bandgap, band structure
- chemical potential
- cyclotron radius
- density of states
- diffusion
- Drude conductivity
- effective mass
- (Einstein relation)
- Fermi level, Fermi surface
- Fermi-Dirac distribution, Boltzmann distribution
- gauge
- Hall effect
- (Landau levels)
- linear response
- mean free path
- mobility
- periodic boundary conditions
- Pauli principle
- phase coherence
- scattering mechanisms
- screening
- semiconductors
- spin
- tight-binding model

[Not heard of? Heard of? Familiar with? Working knowledge of?]

New concepts [presumably new]

- Aharonov-Bohm effect
- ballistic transport
- Boltzmann equation
- Coulomb blockade
- edge states
- Giant magnetoresistance
- Landau levels
- Landauer-Büttiker formalism
- Onsager symmetry relations
- Quantum Hall effect
- quantum point contact
- quantum wire
- resonant tunneling
- Shubnikov-de Haas oscillations
- single electron tunneling
- skipping orbits
- Spintronics
- universal conductance fluctuations
- weak localization