OU Condensed Matter Physics

Physics you can touch.

Well, more than in astrophysics, high energy and all those other fields…

The Department of Physics and Astronomy has 29 faculty in four major areas of research:

- Astrophysics
- Atomic, Molecular and Chemical Physics
- High Energy Physics
- Solid State and Applied Physics.

A.k.a. Condensed Matter Physics

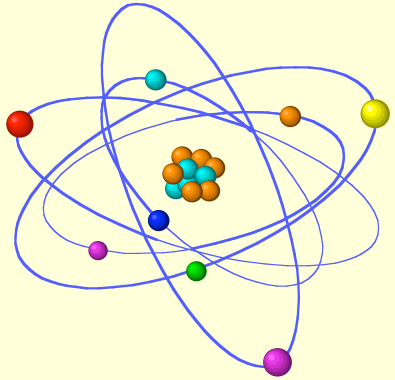
What is this condensed matter stuff?

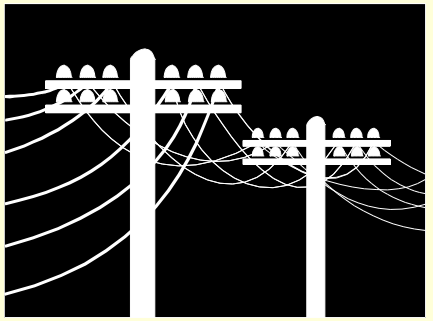
Who does it?

What does it involve?

Goal of Condensed Matter Physics:

Given all the properties of individual atoms, be able to predict or explain the properties of dense collections of atoms.





A copper atom is not a conductor.

10^23 copper atoms do conduct.

Formerly known as solid state physics, condensed matter physics includes liquids, gels, plastics, glasses and suspensions.

High Energy Theory:

"Given our one universe, what is H?"

Condensed matter theory:

"Given H, what is possible in our universe?"

$$H = \sum_{j=1}^{N} \frac{p_j^2}{2m_j} + \frac{1}{2} K \sum_{i \neq j} \frac{q_i q_j}{|\vec{r}_i - \vec{r}_j|^2} + \frac{1}{2} G \sum_{i \neq j} \frac{m_i m_j}{|\vec{r}_i - \vec{r}_j|^2}$$

$$H\Psi = E\Psi$$

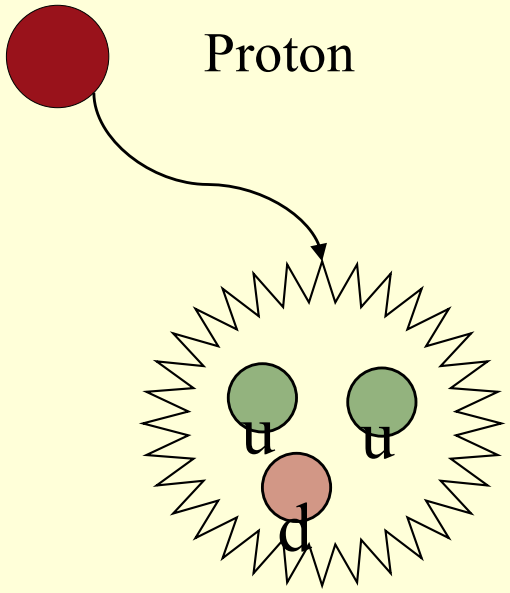
So far answers include:

- Superconductors
- Superfluids
- ferromagnets
- liquids, solids, vapors
- glasses and amorphous solids
- quantum Hall effect
- Topological insulators
- Topological superconductors
- "Strange" metals...

A difference in perspective:

High Energy:

- At "long times" we see integer charges.
- At short times we see exotic particles and fractional charges.



Condensed Matter

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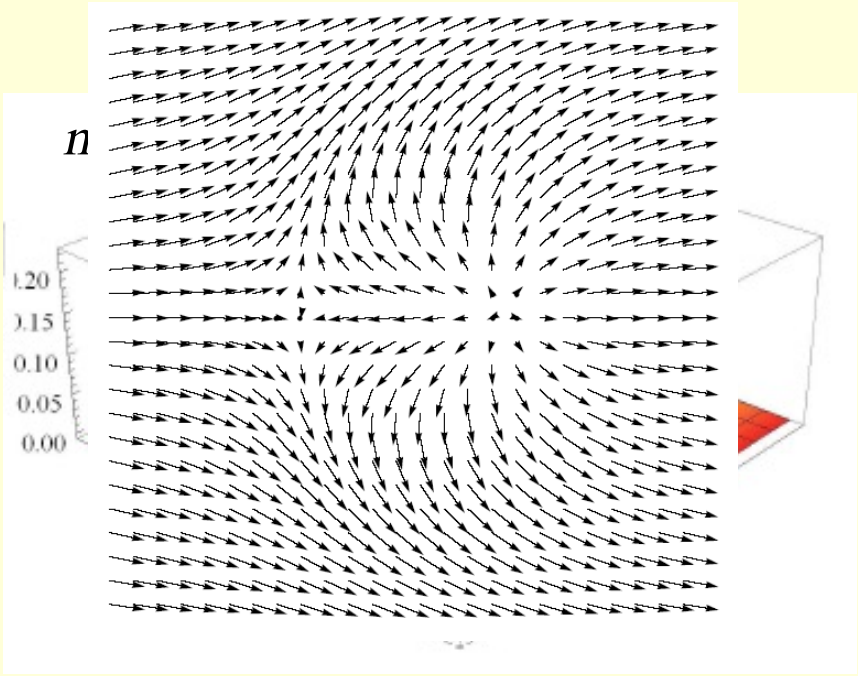


Where are the "Frontiers of Physics?"

Very small: Look for smaller particles

(Reductionism)

Very large: Look at the night sky

(Cosmology)

A frontier is a boundary: there are many unexplored frontiers:

- Nanotechnology: the crossover between the classical and quantum world.
- Nonequilibrium dynamics
- Designer materials: creating structures that never existed in nature.
- Low temperatures: examing matter at energies that never existed before.

What are some current topics of research in Condensed Matter Physics?

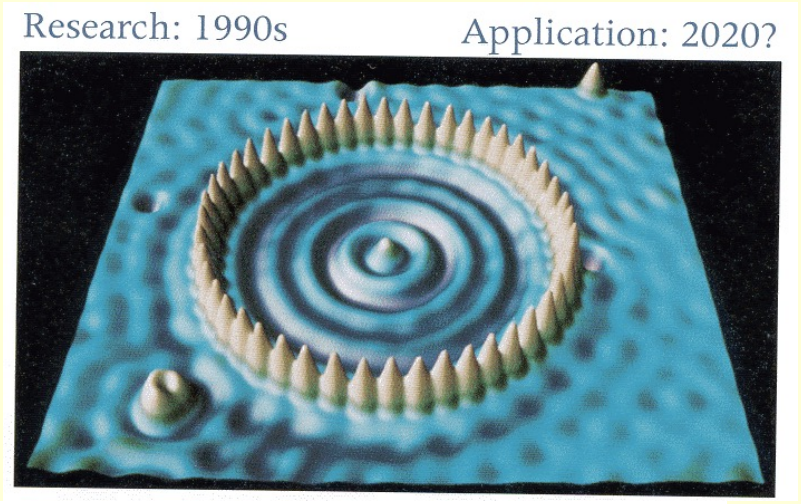
- Semiconductor electronics
- Semiconductor lasers
- Optical storage materials
- Electro-optical computing
- Quantum Computing
- Quantum Communication
- High temperature superconductors
- Biomaterials
- Strange metals
- Micromachines
- Nonequilibrium phenomena
- Fullerenes and Nanotubes
- Topological insulators and superconductors.
- Weyl metals

What do you need to know to do CMP?

- Classical Mechanics
- Electricity and Magnetism
- Statistical Mechanics
- Thermodynamics
- Quantum Mechanics

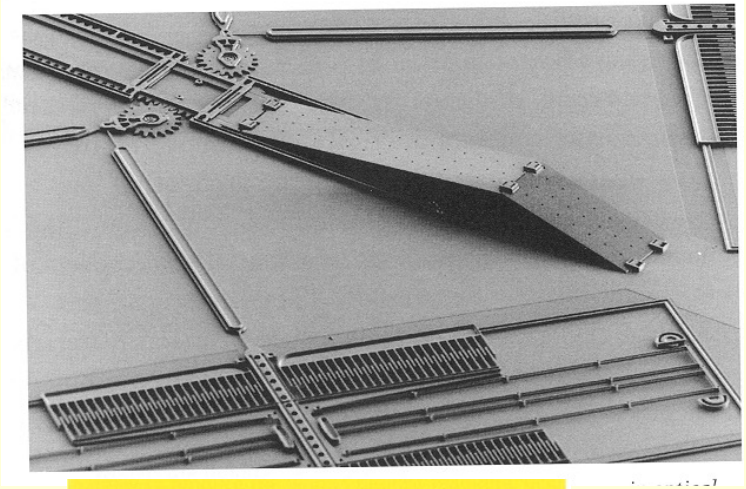
Condensed matter requires a knowledge
of all the fundamental subjects in Physics.

In addition, it has the advantage of being closely tied
to experiments, and
and to applications.



Electron Corral

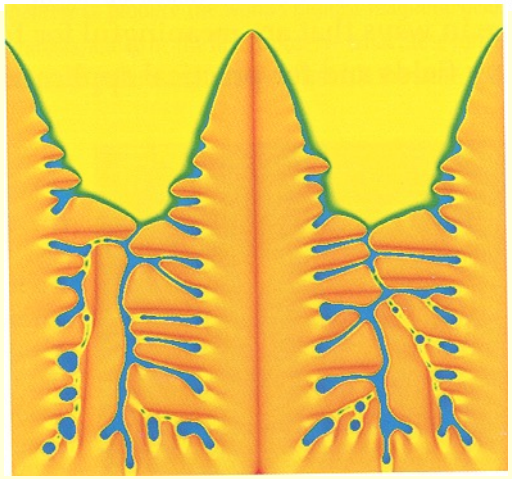
size: 14nm



Micro-machines

Gear size:

50 microns



Nonequilibrium crystal growth of metals with impurities.

How important is Condensed Matter to Physics?

Nobel Prizes in Physics since 2000:

- 2000: Semiconductor heterostructures used in high-speed- and opto-electronics
- 2003: Superconductivity and Superfluidity.
- 2007: Giant magneto-resistance.
- 2009: CCD cameras and fiber optics.
- 2010: Two dimensional graphene
- 2014: Light emitting diodes
- 2016: Topological properties in condensed matter
- 2018: Optical tweezers and chirped pulse lasers
- 2021: Disorder in statistical mechanics and the replica trick
- 2023: Attosecond pulses of light to study of electron dynamics in matter

Who does condensed matter physics?

Industrial Physicists:

- Research Labs (AT&T, IBM, GM)
- Production Scientists (TI, Intel)

Government labs:

- National Inst. Standards and Tech.
- Naval Research Lab, JPL
- Sandia, Livermore.

Academic Researchers:

- Professors
- Technicians and Postdocs

Over 70% of career physicists are in CMP.

Grand Challenges in CMP

1. How do complex phenomena emerge from simple ingredients?
2. What is the physics of life?
3. What happens far from equilibrium and why?
4. What new discoveries await us in the nano-world?
5. How will the information technology revolution be extended?

-- National Academy of Studies, "Condensed Matter and Materials Physics: The Science of the World Around Us," (NA Press 2007)

Personal View of CM Research

Condensed matter physics consists mostly of:

- Discovering *materials,*
- Determining the *properties* of materials, new and old,
- Discovering the properties of *structures* of materials.
- Blurring the line between materials and structures.