Frontiers in Chemical Engineering Education

New Directions and Opportunities – Creating the Future

CCR/NSF Discipline Wide Curriculum Workshops

Workshop II
Content of the Curriculum

My Vision

- An exciting new curriculum that
  - builds on our unique position in engineering
  - attracts the best and brightest undergraduates into our profession
  - is highly valued by industry
  - contains a wealth of fresh, renewable
    - examples
    - laboratories,
    - projects

    contributed and shared by the whole community
  - uses best practices for teaching

Why Cooperate?

- The opportunities/frontiers are too broad for any one or several departments to address effectively
- The costs – time and money – of developing new educational materials are too high for any of us to absorb alone
- The coherence resulting for a joint effort will serve the discipline well
  - Maintain clear identify to the world (potential students, industry, government)
  - Ensure good manpower supply to industry and to our graduate programs

NSF/CCR Curriculum Grant

- The time is right for new curriculum focus
  - Need to incorporate molecular and cellular biology appropriately as underlying science
  - Need to connect students to the many applications of chemical engineering
  - Methods of engaging students in classrooms and laboratories are being reexamined and methods of incorporating new technology for education need to be incorporated
- New curriculum needs to be discipline wide
  - Common core has been a strength of the discipline
  - Richer curriculum results from broad array of examples, texts, modules, ….

Chemical Engineering at the Center

Mathematics

Physics

Computer Science

Structured Fluids

Electrical Engineering

Materials Science

Ceramics Polymers

Microelectronics MEMS

Chemistry

Applied Chemistry

Chemical Engineering

Transportation Energy

Mechanical Engineering

Biochemical Biomedical

Environmental Applications

Biology

Civil Engineering

Chemical engineering has a unique position at the interface between molecular sciences and engineering

Drivers for Change

- Biology represents a new frontier for us as a discipline
  - Advent of molecular biology and its incorporation into biochemistry, genetics, and cell biology make biology a natural science for chemical engineering
- Our close connection with basic science makes our graduates very versatile
  - We have failed to articulate this clearly to our stakeholders
  - We have failed to imbed this in our curriculum
- Our traditional industry has shifted
- Our student base is at risk

Challenges for Our Curriculum

- Need to integrate biology appropriately as a basic science for our discipline
- Need to balance the tension between diversity in research application areas and a coherent, strong core
  - Molecular transformations, quantitative understanding, systems treatment, multiscale analysis
- Need to balance the desire to teach many specific topics vs. using these to educate students for the future
- Need to balance applications with fundamental knowledge, synthesis with analysis
- Need to attract the best and brightest young minds into our discipline
  - Need to project an accurate, exciting image of our discipline to students/employers

The Undergraduate Curriculum is Dynamic

- Historical perspective:
  - Two examples (fill in your own) …
    - Hougen analysis of the chemical engineering curriculum from 1905 to 1965
    - MIT curriculum from 1890 to 2002
- Questions for us:

  What is the core content for the future?

  How do we organize this?

  How do we develop it?

  How do we share it?

NSF/CCR Workshops

- Lead to large NSF proposal to fund development
  - These proposals are for discipline wide efforts
  - Our joint proposal will use talents, time, resources nationally
- Help foster connections between individuals and institutions
- Workshop 1 – Building Blocks of the Future
  - What is the essential ***intellectual*** content of our future educational program
  - Not subject titles or semester blocks
  - Ideas, skills, knowledge, ….
  - Involve individuals deeply interested in undergraduate education
  - Identify specialists for the next workshop

NSF/CCR Workshops

- Workshop 2 – Topic Development
  - Detailed content (knowledge, skills, attributes, …) of the bocks
  - Interconnections among these components
  - Identify gaps and opportunities; disconnected pieces
  - Involve experts in the different topical areas
- Workshop 3 – Integration
  - How do we assemble the components into an exciting, engaging, adaptable educational program?
  - Involve educational experts
  - Plan for proposal to develop curriculum components

Out of the Box Thinking

- Principles:
  - Education is preparation for life: it is more than intellectual development;
  - The value of fundamentals: a technical or professional education should be based on fundamental principles;
  - Excellence and limited objectives: fit to needs of society, fit to concern with science and technology, fit to our unique disciplinary core.

> B.F. Skinner: “Education is what survives when what has been learned has been forgotten.”

Who Are We?

- Molecular transformations
- Multiscale understanding
- Systems view
- Quantitative approach

We need to build on these while maintaining

- Well defined, common core
- Close, active connection with science
- Relevance to industry

Workshop 1 – Common Themes

- Biology is a foundation science
- Agreement that the need for change goes beyond biology
  - Diversity of employment
  - Public perception
  - Recognition of molecular-level understanding
  - Competition for best students
- Need to engage enabling sciences in change
- Infuse curriculum with contemporary examples that integrate principles of chemical engineering
- Chemical engineering involves analysis, design, and synthesis

Common Themes continued

- Need to articulate to freshmen the intellectual challenges and professional opportunities
- Chemical engineering includes multi-scale descriptions of materials and phenomena
- Agreement on the desired attributes of the chemical engineering graduate
  - Experience in labs
  - Communication skills
  - Problem solving skills
  - Etc …
- Curriculum should be designed for flexibility

Building Blocks – Areas of Agreement

- The enabling sciences are:
  - biology
  - chemistry
  - physics
  - math
- There is a core set of chemical engineering principles
- Molecular level design is a new core principle
- Chemical engineering contains both product & process design
- There is a need for 1st year chemical engineering experience

Building Blocks

- Proposals
  - case study learning
  - vertical integration
  - molecular-level design as an organizing principle
  - single-room learning
- Other Ideas
  - benefits of alternative terminology in curriculum revitalization
  - student as a customer (or partner, employer as partner, participant, constituent, ally)

Discussion after the Report

- "Employers, students, and alumni are important voices in curriculum revitalization"
- Regarding biology
  - We should state explicitly that biology is a full enabling science.
  - What do we mean when we say, "biology"? We need to elaborate components of biology that are most important to the curriculum – quantitative, e.g. cellular, molecular, biochemistry, genetics, microbiology (+ -)
  - Hard work will be required to integrate biology fully into the curriculum

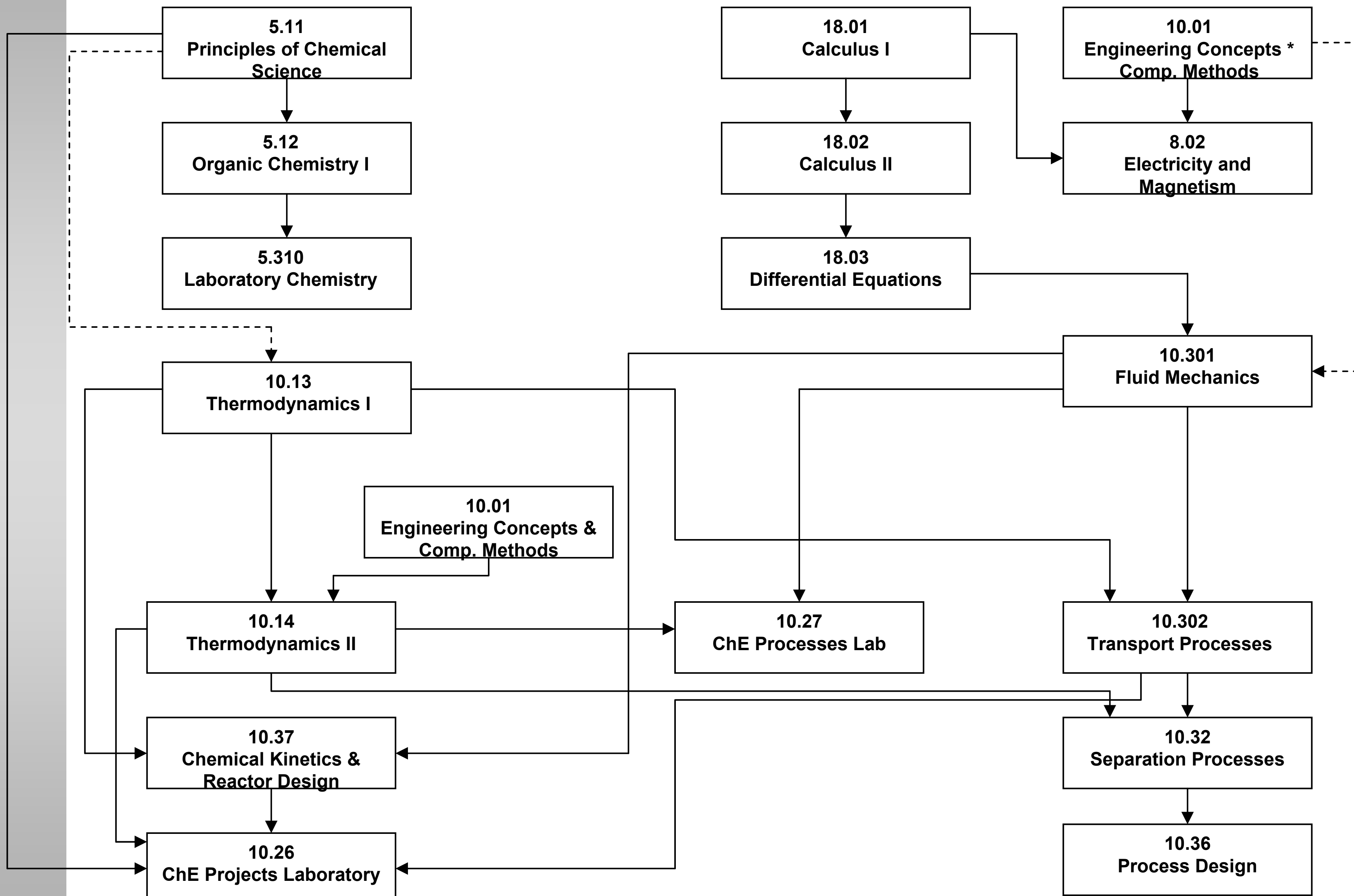
Nature of Change

- While several models were proposed, from a case-study-driven curriculum to perturbations of existing programs, several themes emerged:
  - critical need for better and more relevant examples that can be embedded into courses
  - need for integrating examples that cross boundaries between courses
  - stronger links/integration of the enabling sciences (biology, chemistry, mathematics, physics) with curriculum to relate molecular structure to properties and function

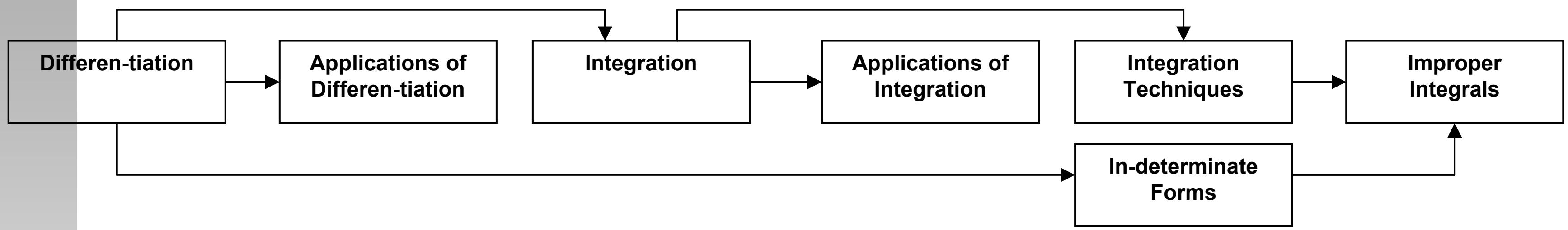
Workshop II

- Curriculum components
- Interconnections
  - The following slides illustrate interconnected modules for the MIT curriculum in 1987.
  - This is an illustration ONLY. It is old enough so that no one should take it seriously as a model for the discussion in the workshop.

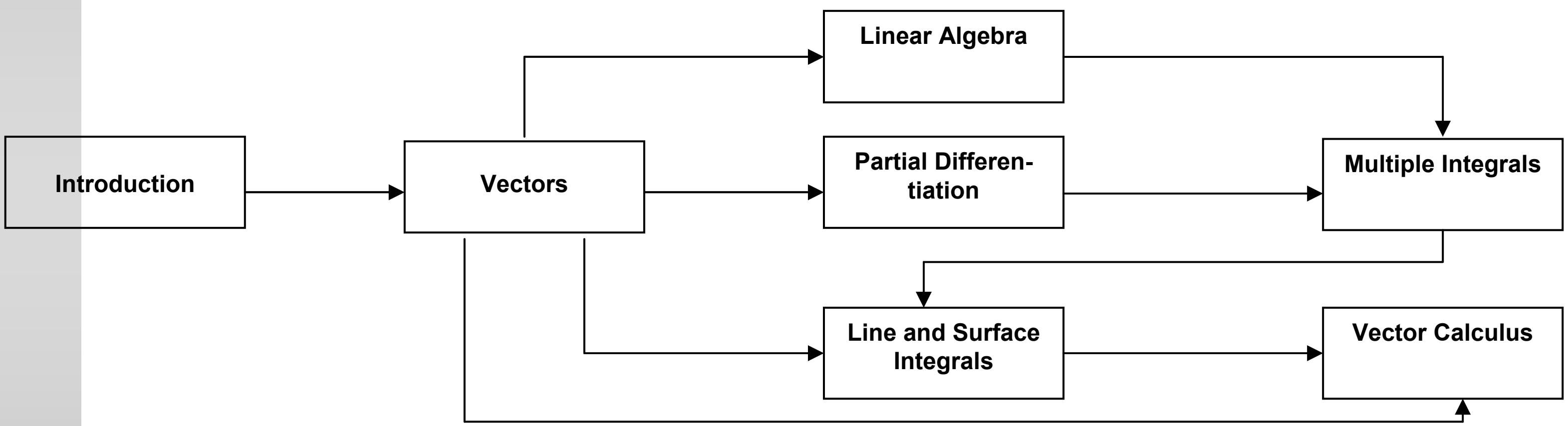
Chemical Engineering Core Curriculum



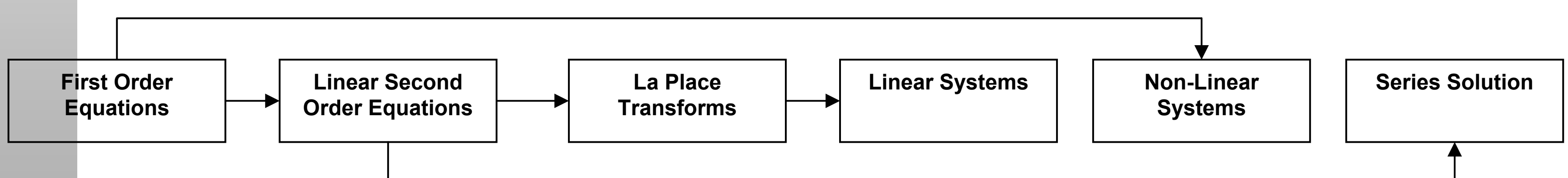
18.01 Calculus I



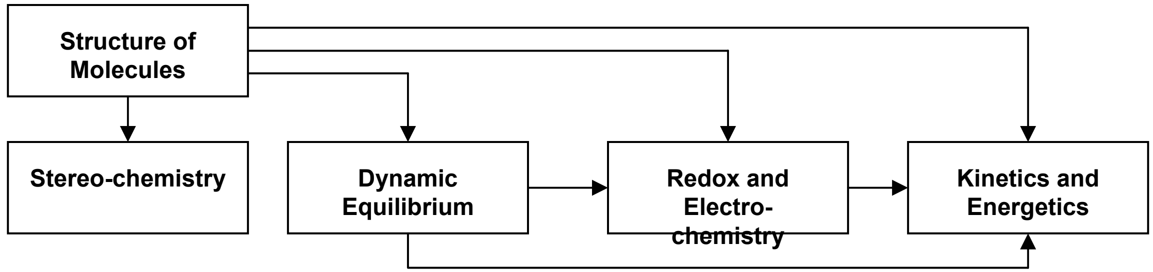
18.02 Calculus II



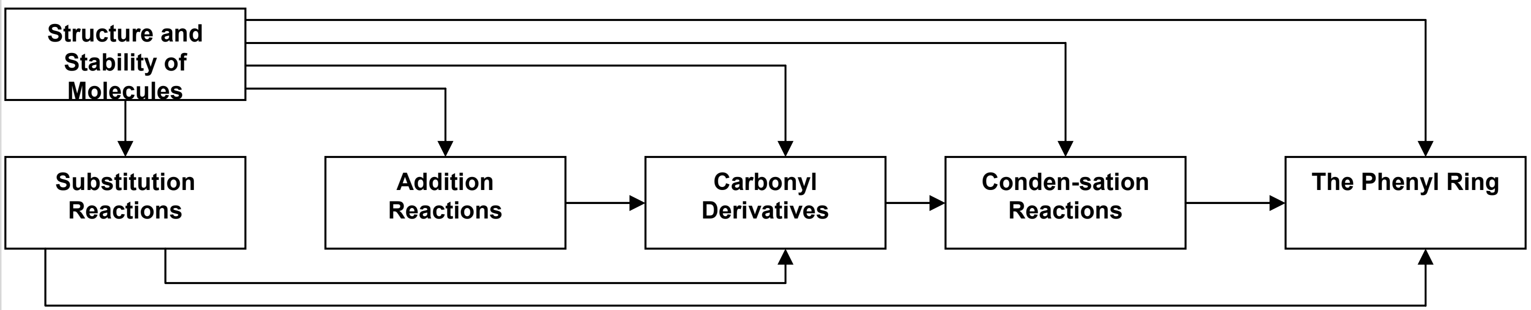
18.03 Differential Equations



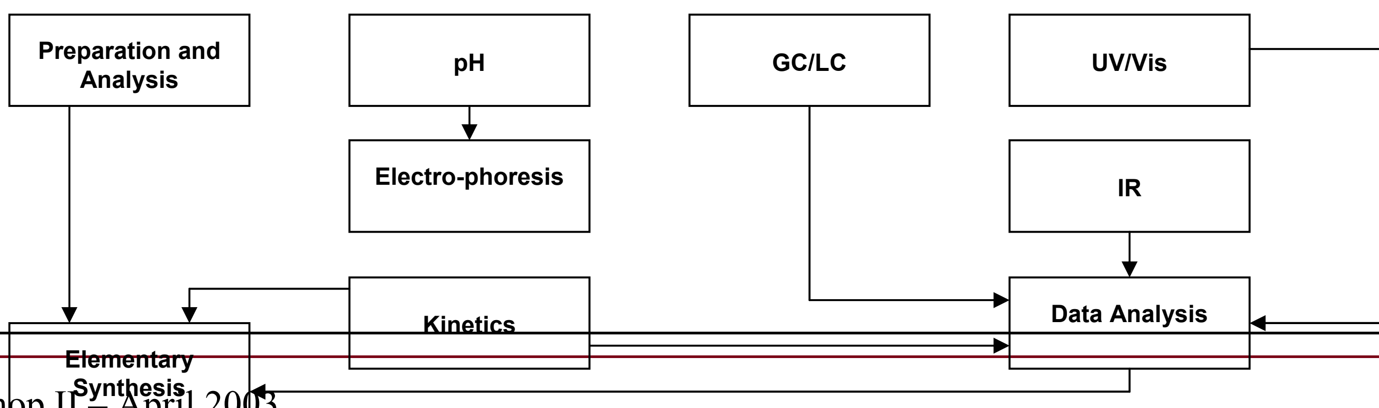
5.11 Principles of Chemical Science



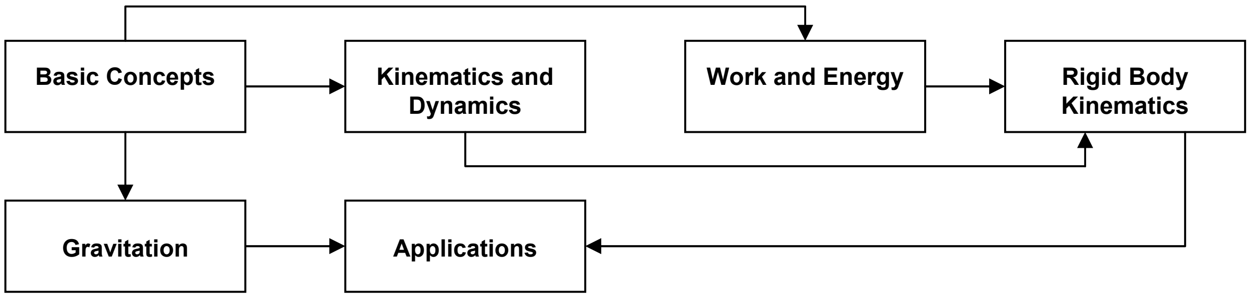
5.12 Organic Chemistry I



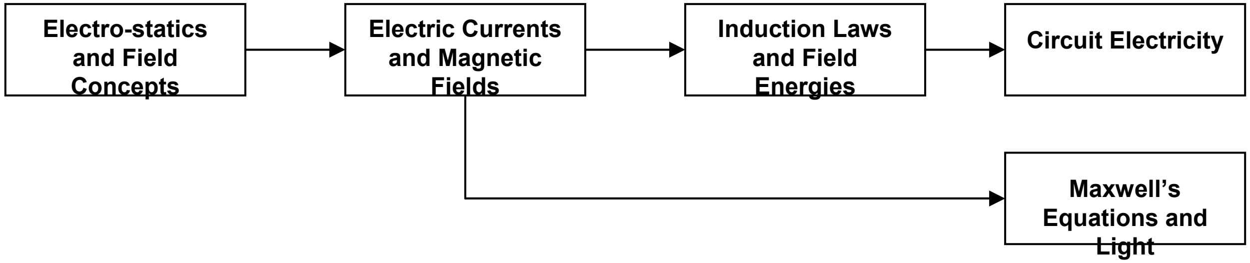
5.310 Laboratory Chemistry



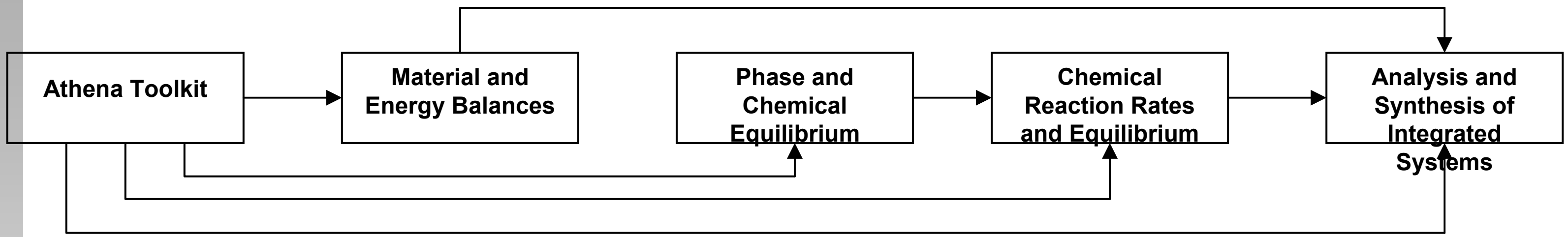
8.01 Mechanics



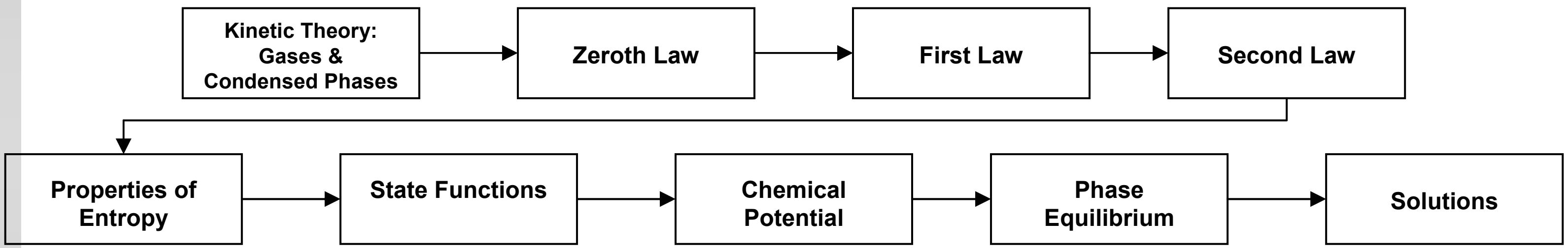
8.02 Electricity and Magnetism



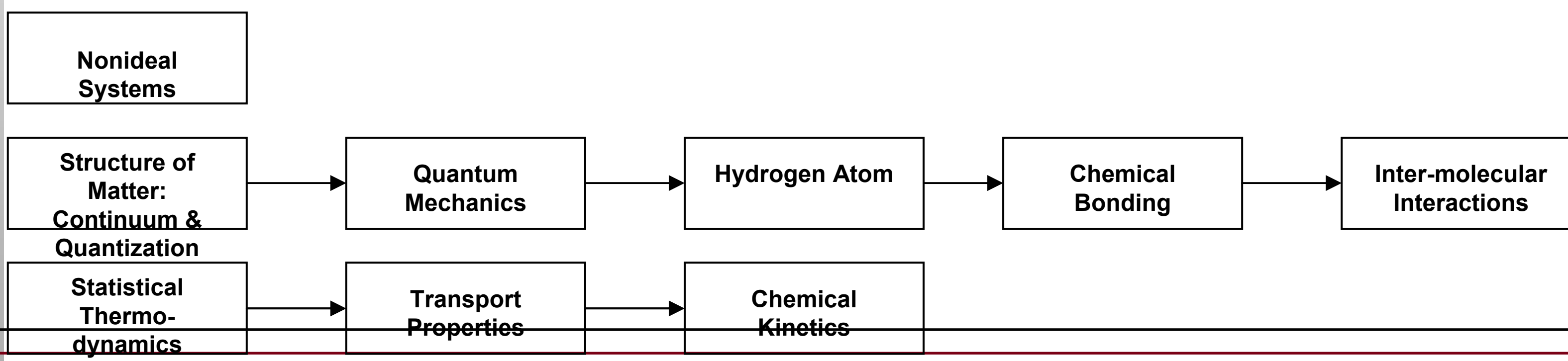
10.01 Engineering Concepts and Computer Methods



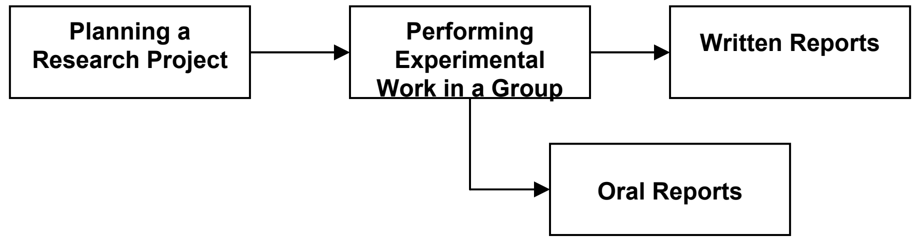
10.13 Thermodynamics I



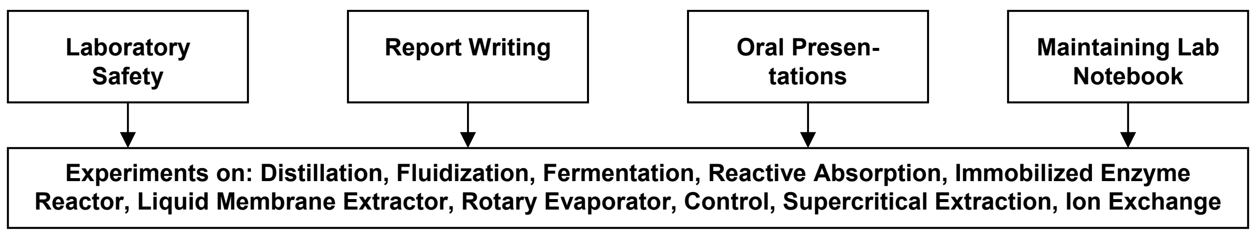
10.14 Thermodynamics II



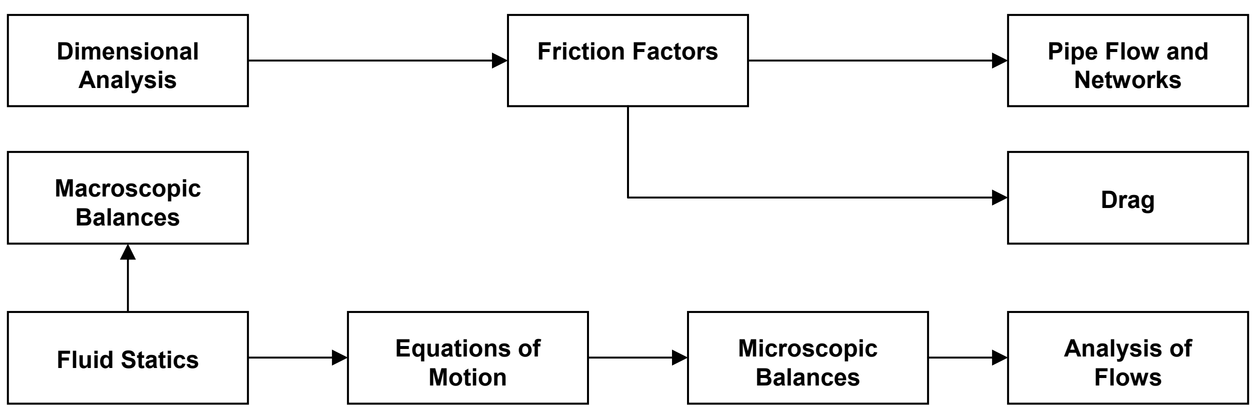
10.26 Chemical Engineering Projects Laboratory



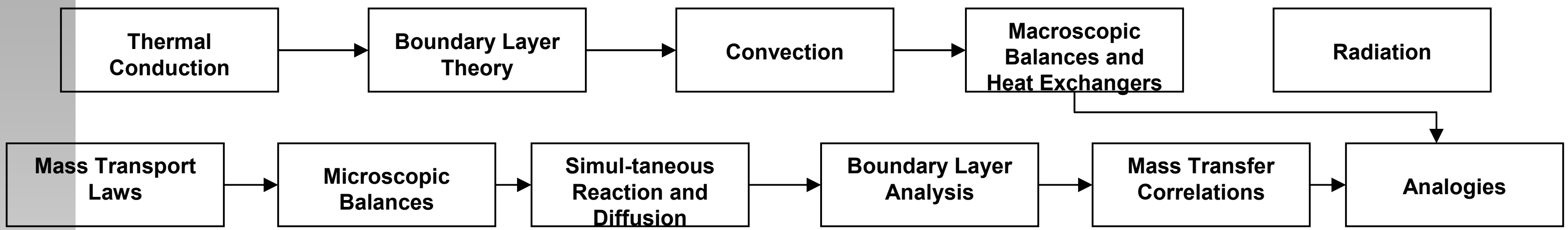
10.27 Chemical Engineering Processes Laboratory



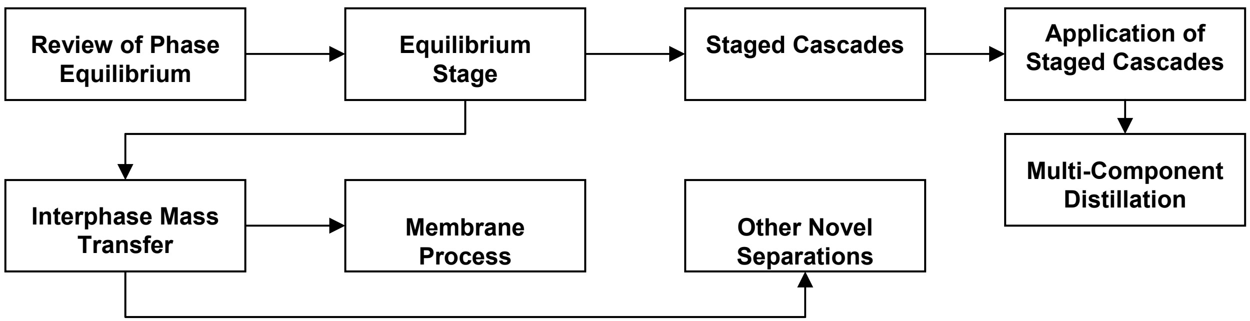
10.301 Fluid Mechanics



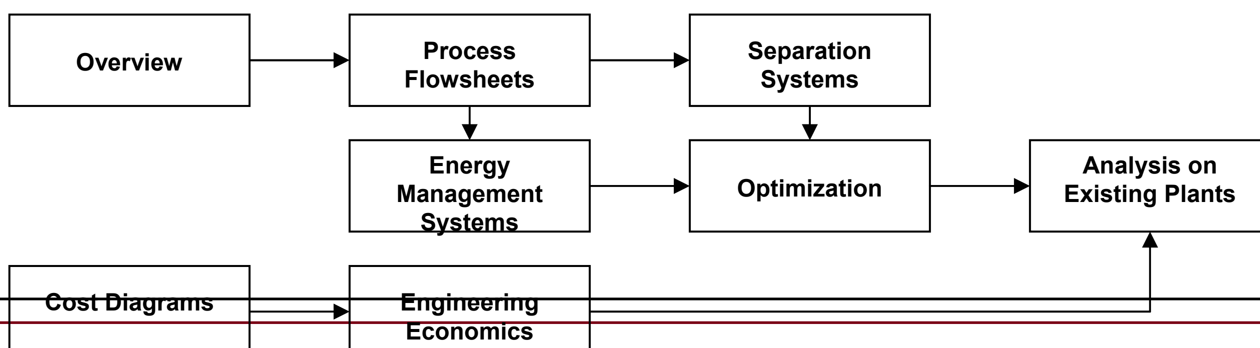
10.302 Transport Processes



10.32 Separation Processes



10.36 Process Design



10.37 Chemical Kinetics and Reactor Design