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IDENTIFIERS	*Arizona State University; Competency Matrix

ABSTRACT

This document consists of a workshop presentation on the development of a new engineering science core curriculum at Arizona State University (ASU). Part 1 presents an overview of the project, which was designed to return a true commonality to the engineering science core and increase understanding of fundamental concepts by reinserting design education into the undergraduate curriculum. Part 2 outlines the four core courses (conservation principles, properties of matter, engineering systems, and conservation principles for continuous media), while part 3 makes comparisons with traditional courses. Part 4 examines learning structures and experiences, while part 5 outlines the implementation of the core courses in chemical engineering at ASU. Part 6 addresses student competencies and levels of learning, while part 7 presents condensed versions of Langford and McNeill's taxonomies of learning. Parts 8, 9, and 10 provide course objectives, daily assignments, and competency matrices for core courses on conservation principles, properties of matter, and engineering systems. (MDM)

NSF / Texas A&M New Engineering Science Core at Arizona State University

Prepared and Presented by*

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Innovation in Engineering Education Program
College of Engineering and Applied Sciences
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** Materials excerpted from Texas A&M presentations*

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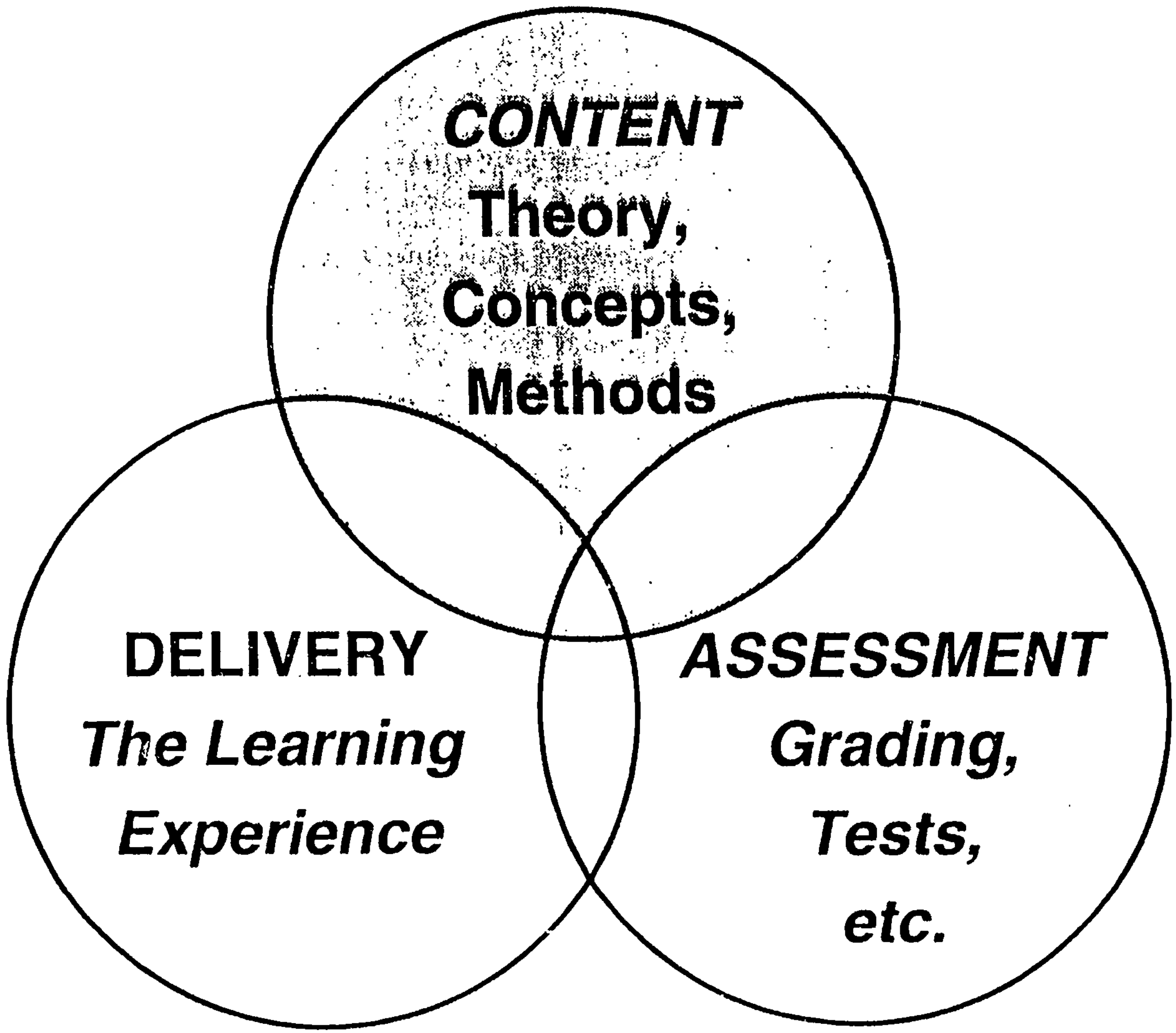
NSF/Texas A&M New Engineering Science Core



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N.B. *of* 13 CHE *Faculty*

Original Texas A&M Goals

1) *Return (?) a true commonality to the engineering science core*
2) *Increase understanding of fundamental concepts by reinserting design education - in particular creative design principles - into the undergraduate curriculum.*

Engineering Department Heads quote: "..students don't know the fundamentals required to begin junior level courses, and ..... don't know how to think through a problem."

Restatement of 1) and 2): Define and present common base of engineering science material in such a way as to effectively promote 'deep learning' of the material for all engineering students.

Original Texas A&M Goals (cont.)

3) Effect efficiencies by decreasing repetition, e.g., units and properties

4) Motivate students !!

5) Design the changes to have minimal impact on the rest of the curriculum.

Goals 1) through 4) have been fairly well accomplished, but 5) is inconsistent with the first four and with any fundamental change in curriculum.

Basic Premises : NSF/A&M Courses

THERE IS A UNIFYING FRAMEWORK FOR ENGINEERING SCIENCE:

CONSERVATION AND ACCOUNTING

- *STUDENTS CAN LEARN ENGINEERING MORE EFFECTIVELY IF THEY ARE AWARE OF THIS COMMON THEME AND STRUCTURE*
- *STUDENTS ARE CAPABLE OF GRASPING AND UNDERSTANDING THE FRAMEWORK EARLY IN THEIR ACADEMIC CAREER*
- *THE BASIC STRUCTURE CAN BE TAUGHT AND LEARNED IN COURSES 1 AND 2 WITH FURTHER MATHEMATICAL SOPHISTICATION DEVELOPED IN COURSES 3 AND 4*

CONCLUSIONS

- *A HANDFUL OF FUNDAMENTAL LAWS ARE OF CENTRAL IMPORTANCE TO ENGINEERING*
- *THESE LAWS ALL FIT A CONSERVATION / ACCOUNTING FRAMEWORK*
- *STRUCTURE THE COURSES AROUND THIS CONSERVATION / ACCOUNTING FRAMEWORK*

NSF/A&M New Engineering Science Core Courses

- *Conservation Principles*
  - *Quantities Which Are Conserved*
    - *Total and Elemental Mass*
    - *Total Energy*
    - *Linear Momentum*
    - *Angular Momentum*
    - *Total Charge*
  - *Quantities Which Are Accounted For*
    - *Entropy (System, Surroundings, Cosmos)*
    - *Species Mass*
    - *Mechanical Energy (Rigid Bodies, Fluids, etc.)*
    - *Thermal Energy*
    - *Electrical Energy*
- *Properties of Matter (Solids, Liquids and Gases)*
- *Engineering Systems (e.g., battery, motor, space antenna)*
- *Conservation Principles for Continuous Media*

COURSE 1: Conservation Principles in Engineering

- The BIG PICTURE of the foundation and structure of all engineering science with applications on a macro scale, e.g., pipe flow.
- Emphasizes the fundamental conservation laws and associated accounting relations
- What seems like a large number of concepts and laws for one course is tractable because they all deal with a single idea, i.e., how we 'count' things !
- Limited to macroscopic, i.e., "large" systems, avoiding complexities of such topics as temperature profiles and stress distributions
- Limited to either
  - finite time periods (=>algebraic equations) or
  - differential time periods (=> ordinary rate equations).

COURSE 2: Properties of Matter

- Supports other three courses and reinforces chemistry and physics while paralleling Course 1
- Discussions on both macroscopic scale and on molecular / atomic scale
- Treats basics, e.g., atomic structure, then various classes of properties, e.g., mechanical, electrical and magnetic, with physical and mathematical models.
- Both predictive and descriptive approaches are explored
- Addresses material properties required for Course 1 (e.g. heat capacities, electrical resistivity, and entropy) and for the complete engineering science core
- Study and understanding of properties placed within the motivational framework of applying conservation laws and second law

  (i.e., Occam's razor + laws = materials' models !)

COURSE 3: Modeling and Behavior of Engineering Systems

- *Builds on foundation structure of Courses 1 and 2 using a wide variety of drill and practice problems plus more complex, diverse and involved systems*
- *Mathematical complexity greater than for Courses 1 and 2 as students are concurrently learning ordinary differential equations*
- *Variety of mass, mechanical, electrical and thermal (and thermo-) dynamics problems on a macroscopic scale*
- *Topics include impedance, kinematics (motion and geometry), power/refrigeration cycles, multi-mode problems (freon filled AC compressor with voltage sources; eddy currents/maglev) plus new topics like system states/variables (order, freedom, decisions on kind of system), linear system response, transient and steady state solutions.*
- *Case studies and strong design content with open-ended problems; recitations include setup for problem by discussing how things work, e.g., level controllers in chemical plants, and what goes wrong if you don't understand the systems.*
- *Reinforcement of Course 1 and 2 concepts and techniques*

COURSE 4: Conservation Principles for Continuous Media

- ***Applications of fundamental concepts to differential-sized systems (in many ways a rerun of Course 1 at microscopic level)***
- ***Problems / applications in solid mechanics, heat transfer, fluid flow and E&M, with extensive use of numerical methods for solution of partial differential equations.***
- ***Mathematical complexity introduced is quite limited; this is possible through a careful problem selection and the use of easy-to-use calculation software***
- ***Presented in a structure that parallels Course 1, including a use of properties that reviews parts of Course 2 material***

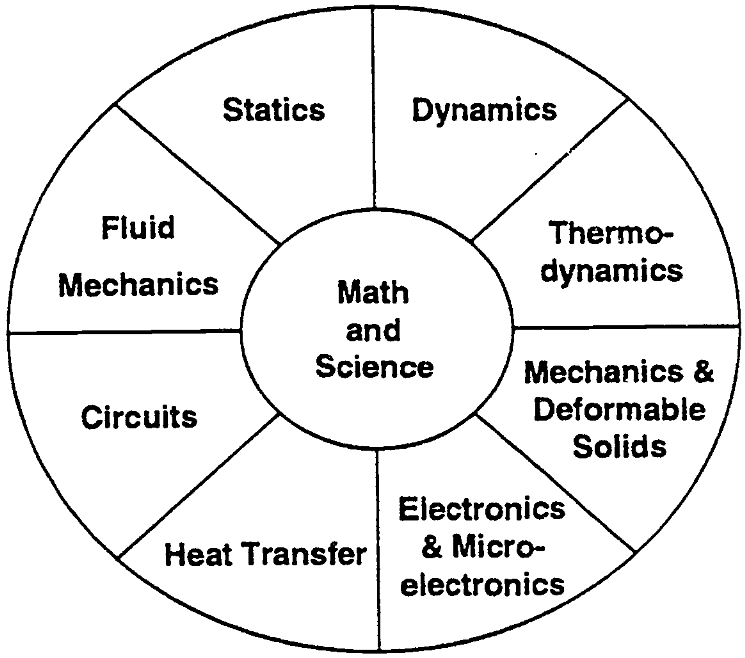
Topic Integration : Courses 1 and 2

Conservation Principles	Properties of Matter
The Fundamental Laws*	Microstructure
Rigid Body Mechanics	Mechanical Properties of Solids
Fluid Mechanics	Mechanical Properties of Fluids and Viscoelastic Materials
Electrical Circuits	Electrical & Magnetic Properties
Thermodynamics	Thermal Properties

*Conservation of ...
- Mass
- Charge
- Linear Momentum
- Angular Momentum
- Energy

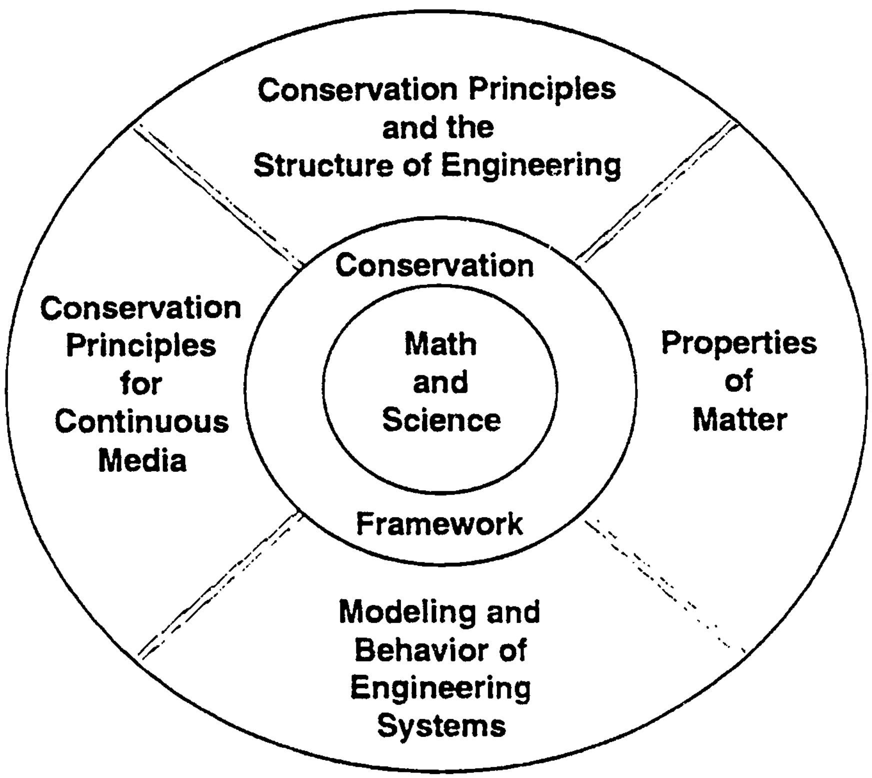
*Accounting for ...
- Entropy
- Species

Another View



Traditional Engineering Core Concept

Note: The new courses are not exact replacements for the content of the indicated traditional courses

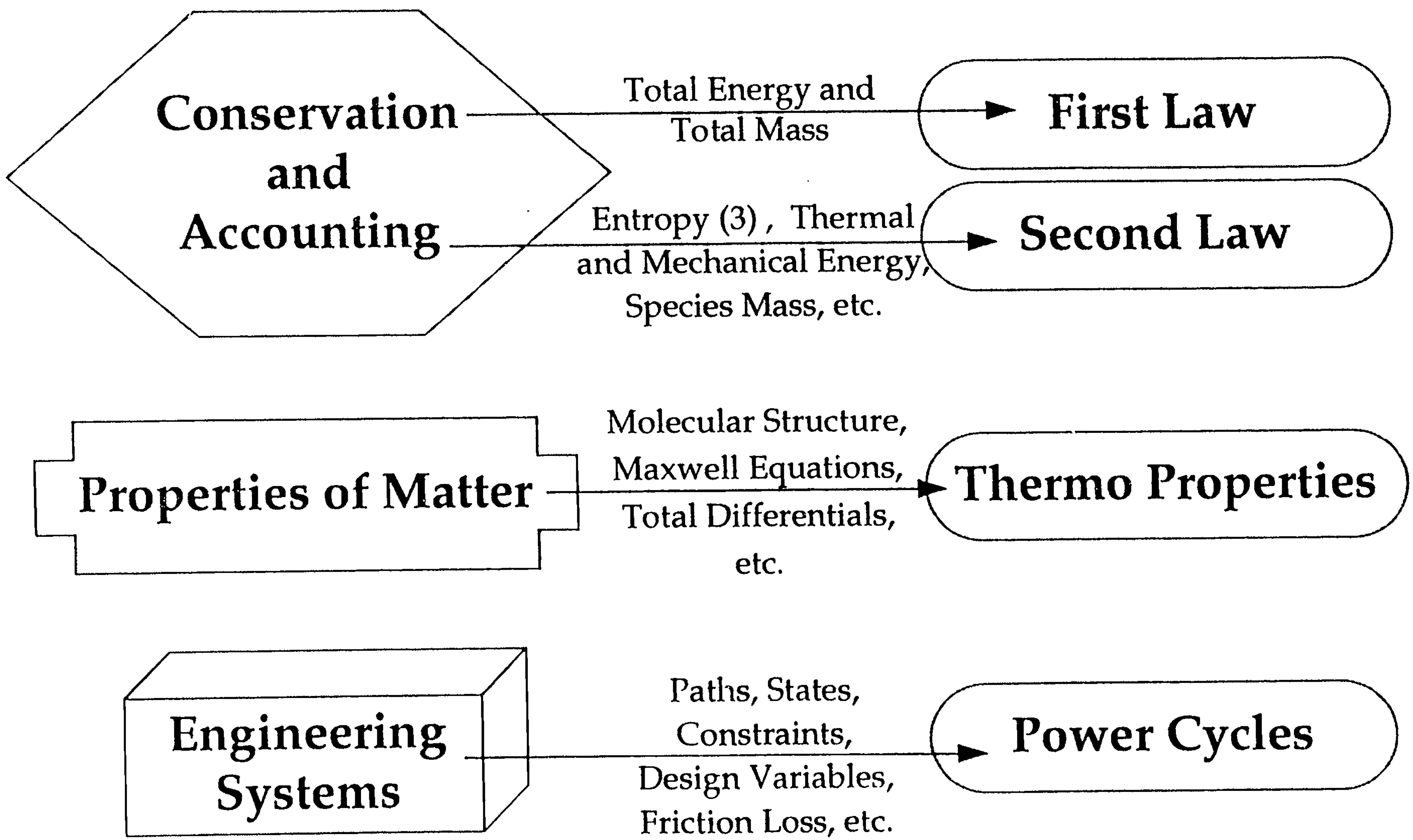


New Engineering Science Core Concept

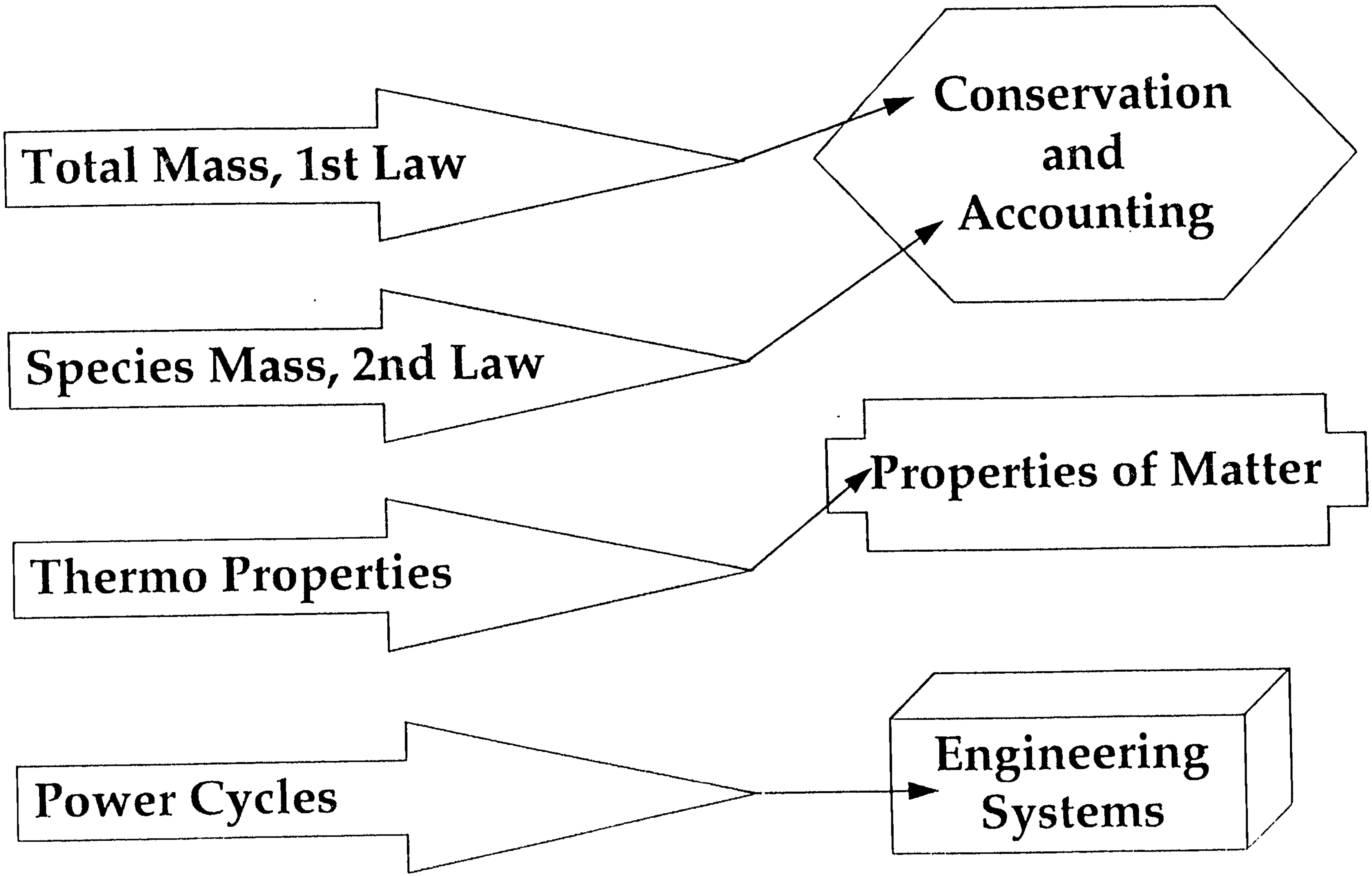
Properties of Matter & Materials Science

Properties of Matter	Materials Science
solids liquids gases	solids
atoms molecules crystals <u>including</u> surfaces crystal defects amorphous	atoms molecules crystals crystal defects amorphous
no processing	some processing
mechanical electromagnetic thermal	mechanical some electromagnetic some thermal
focus on explanation of the behavior of the continuum: descriptive models predictive models	

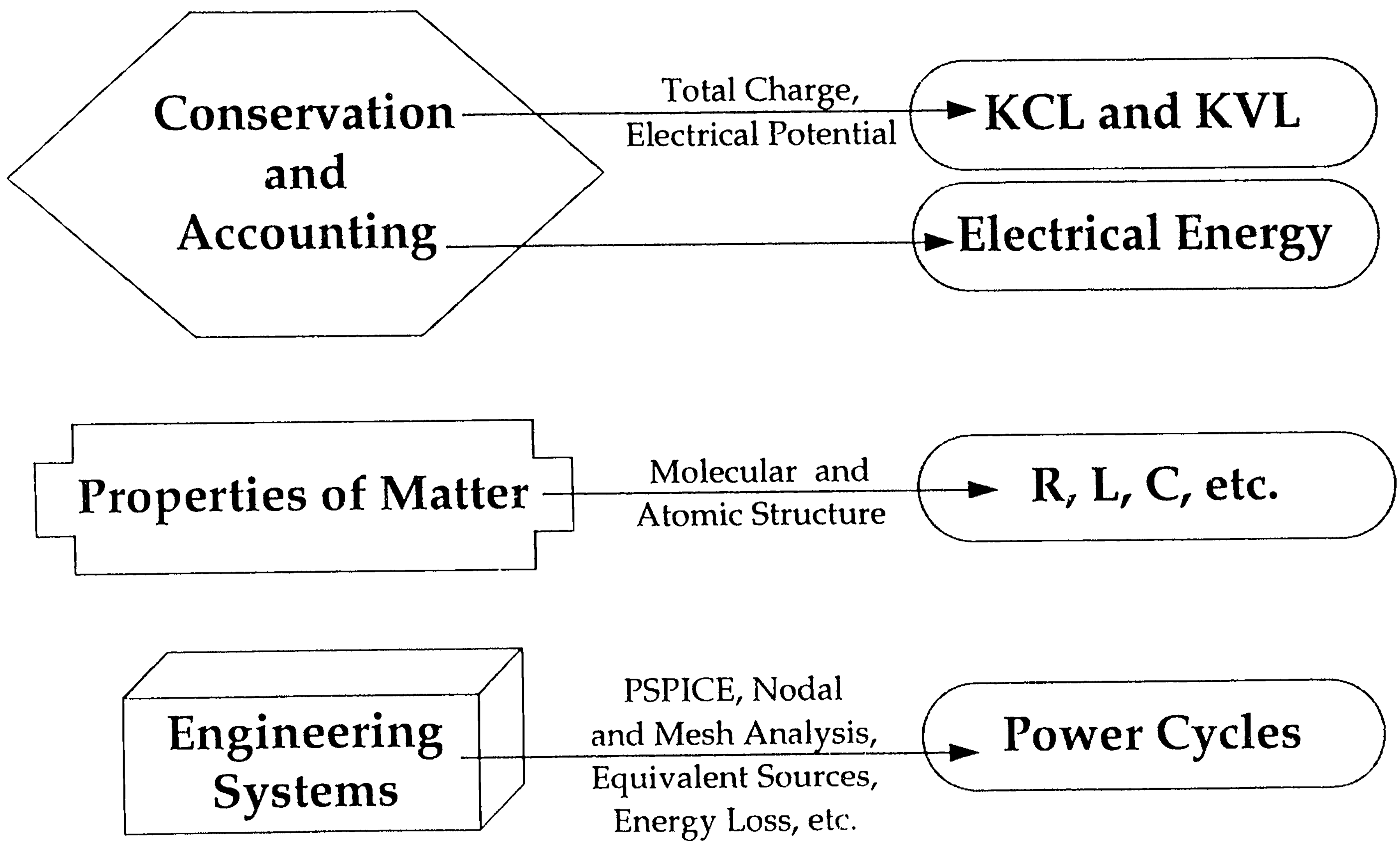
Student View of Thermodynamics



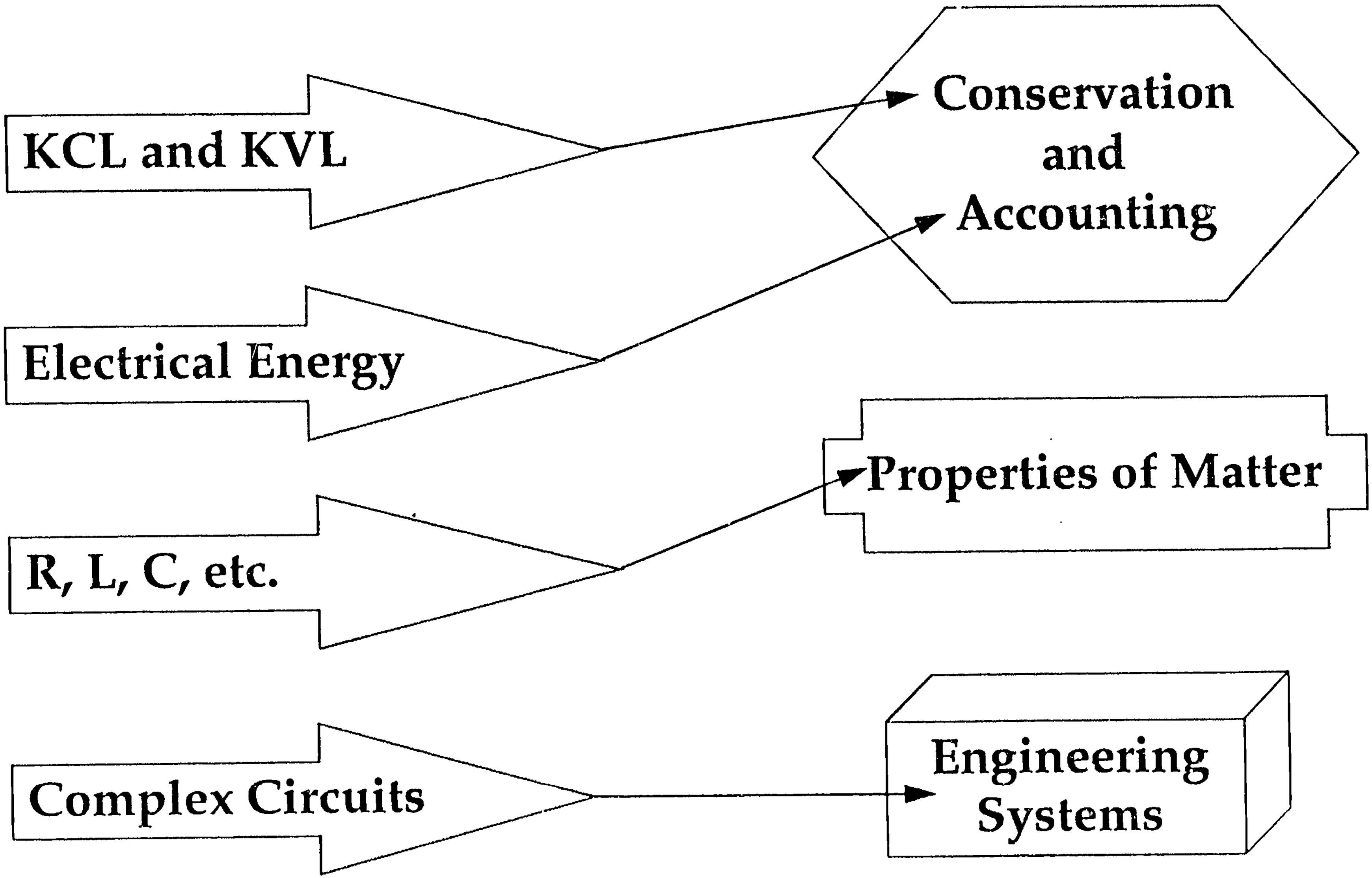
'Mapping' Thermodynamics for Example



Student View of Circuits or Devices

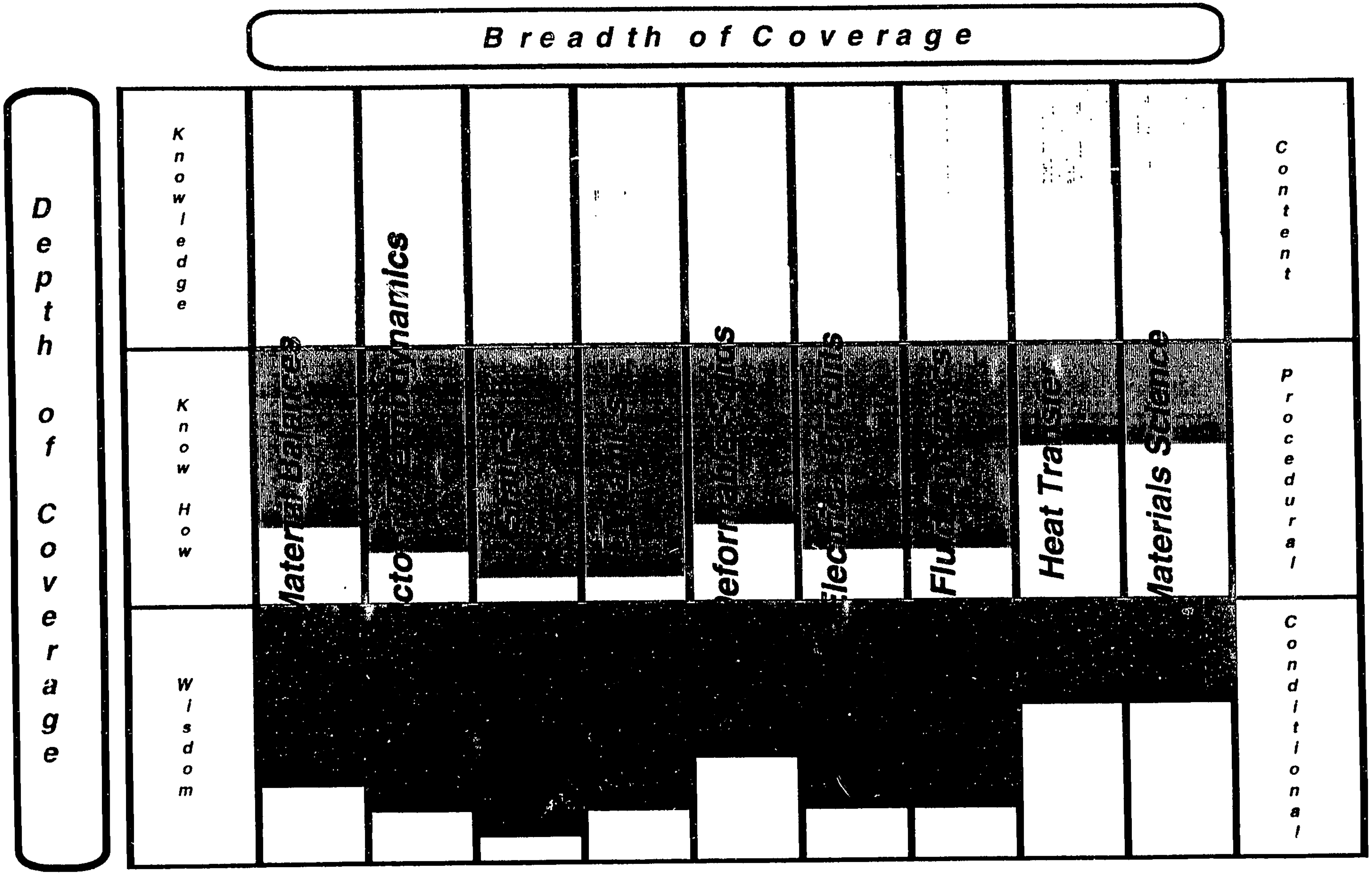


'Mapping' Electrical Circuits for Example



Slide 19

Another Comparison



Percent of Current Courses Covered by NSF/A&M Core Courses

Topic	Material Balances	Introductory Thermodynamics	Mechanics S / DN / DS	Electrical Circuits	Fluid Dynamics	Heat Transfer
Credit Hour	(3)a	(3)	(4)	(3)	(3)	(3)=(19)
NSF/A&M Course						
201 (4) a	70	80	90 / 15 /10	10	55	10
202 (4)	0(10)b	5(20)b	0 / 0 / 20	20	10	10
203 (4)	0	0(5)b	10 / 85 / 0	50	0	0
204 (4)	0	0	0 / 0 / 40	0	15	25
Total(%)	70 d	85 e	100 / 100 / 70	80	80	45
Total(16)	(2.00)a	(2.6)	(3.5)	(2.4)	(2.4)	(1.4)=(14.3)

Notes :

a ***Semester hours credit***

b ***Percentages covered but repetitious***

c ***Primarily Materials Science content***

d ***Primary Deficiencies : psychrometric charts***

e ***Primary Deficiencies : experience with non ideal EOS, generalized correlations, (e.g., van der Waals, Redlich Kwong)***

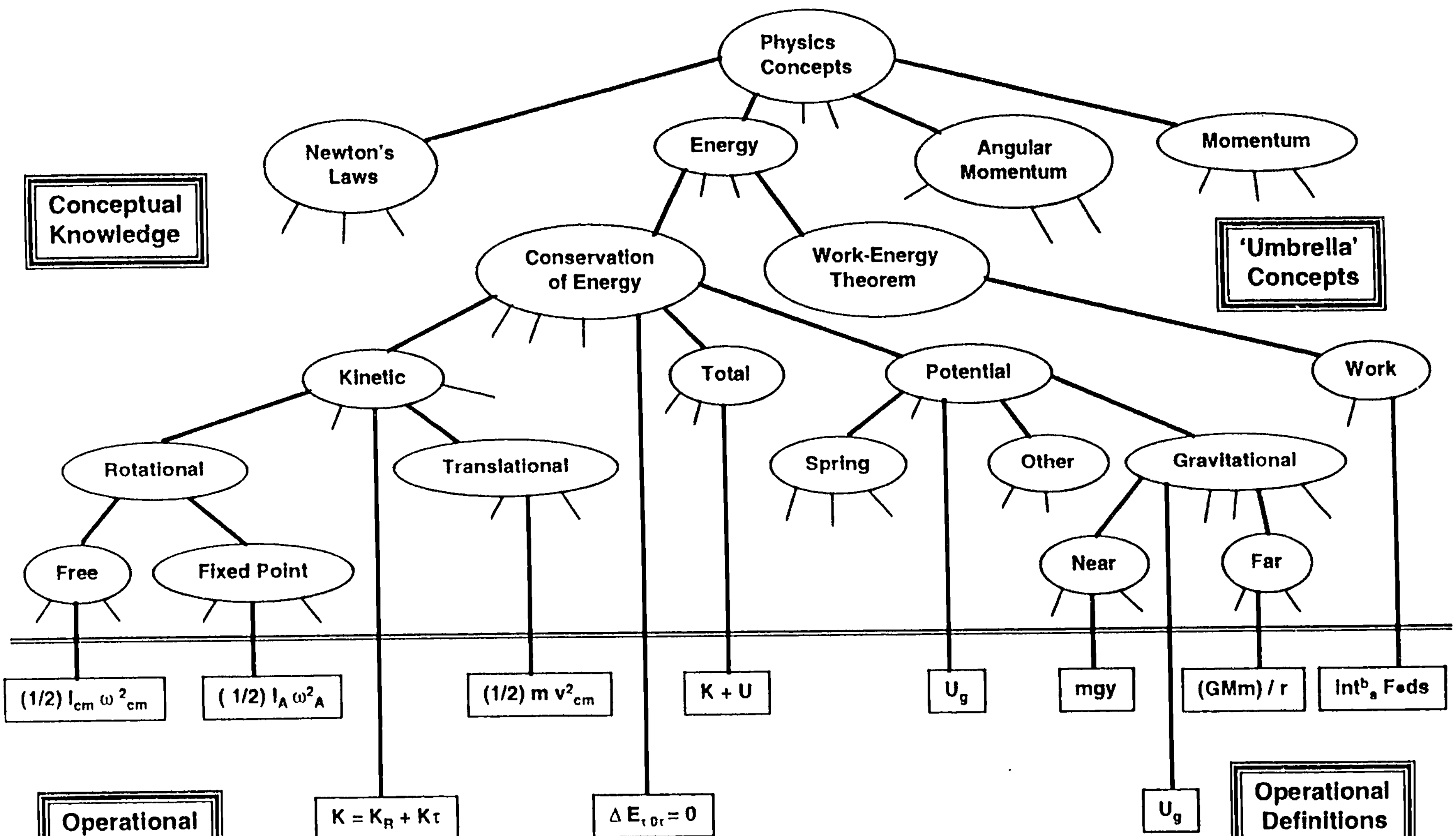
Additional Material not shown in the Topics above : about 50 % of the 202 course, (2) c , and some Process Dynamics / Control

Hierarchical Structures for Students

Hypotheses :

- *For lower level Engineering Science courses (and topics which are assigned primarily at the Knowledge, Comprehension and Analysis Levels of Learning in any course),*
  - *it is the responsibility of the teacher to develop and present hierarchical structures for the content.*
- *A reasonable and appropriate structure, both for the students and for active learning in general,*
  - *can be deduced from a reflective review of the teacher's original, lecture course notes.*

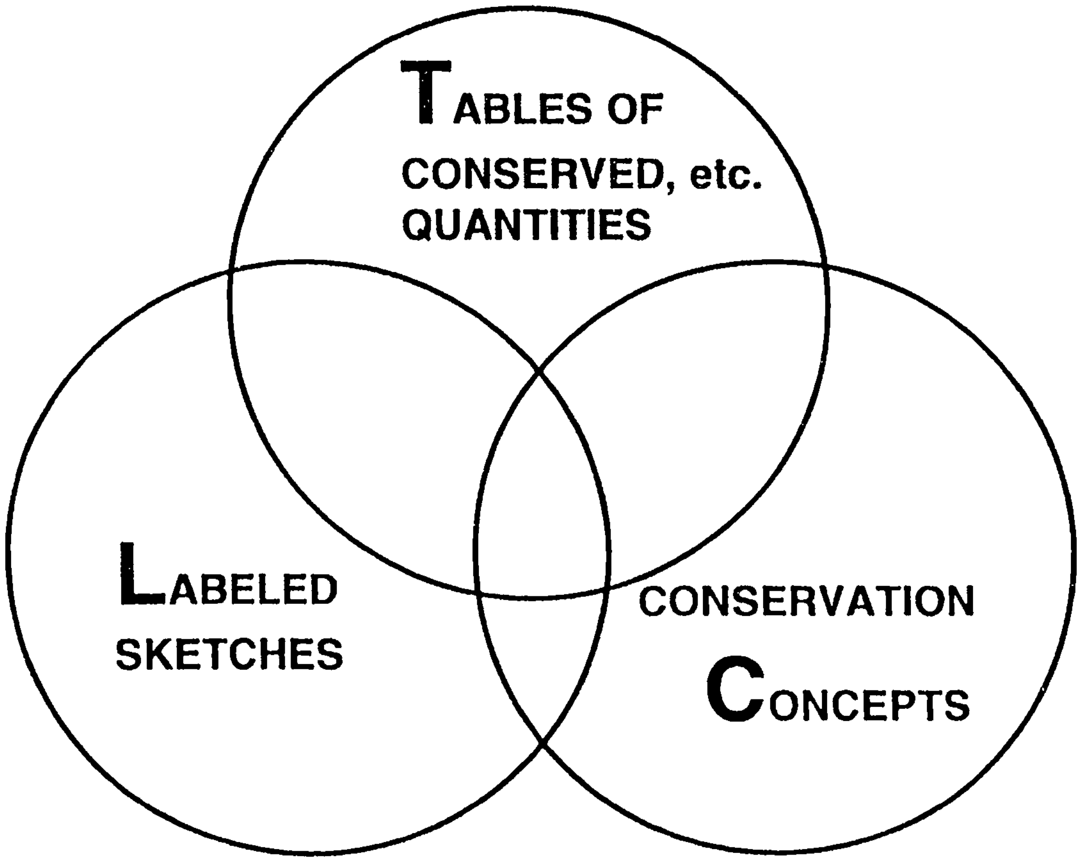
A Hierarchical Structure for Elementary Mechanics



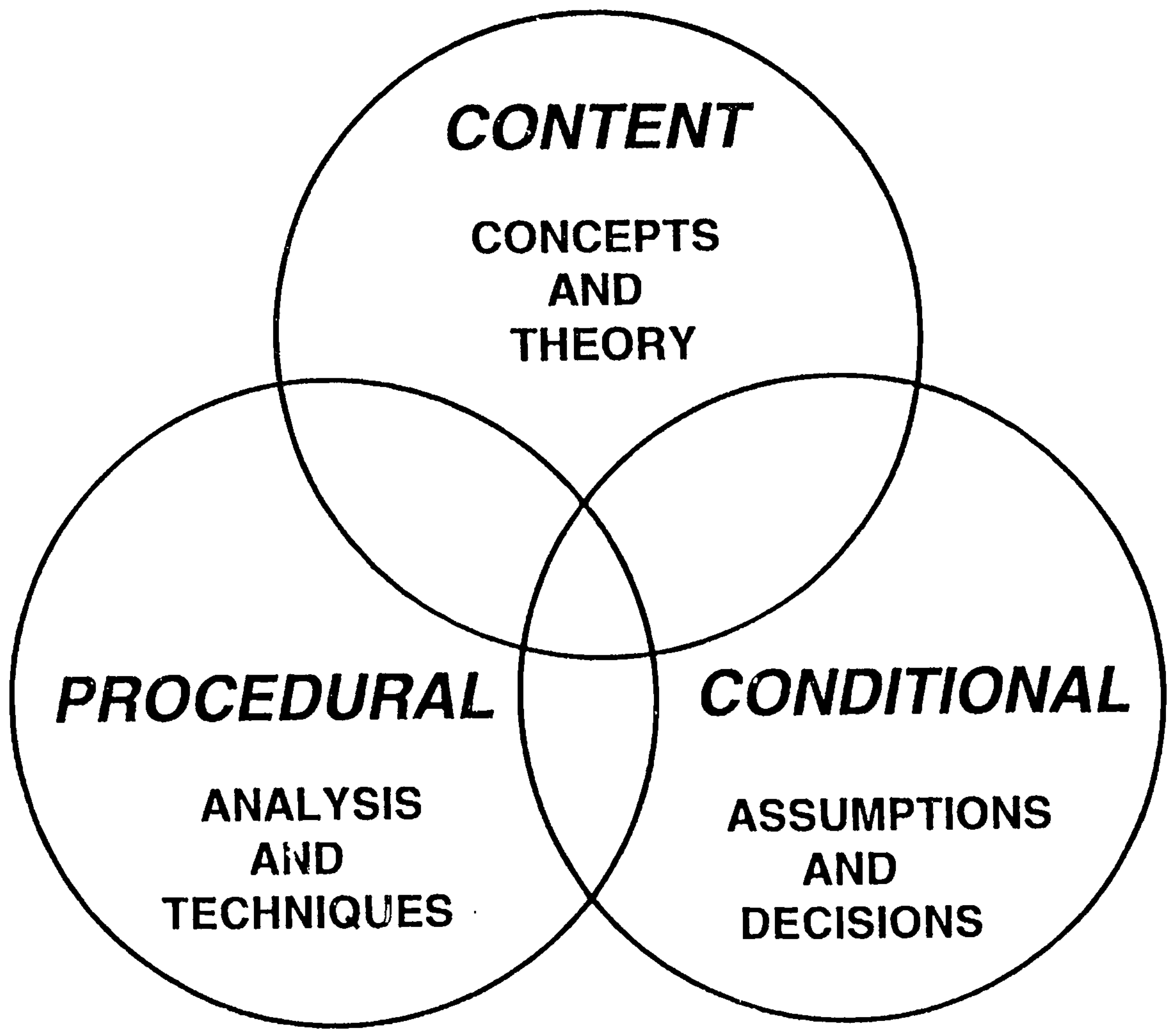
Mestre, Jose P., "Cognitive Aspects of Learning and Teaching Science" [DRAFT],
Pre-College Teacher Enhancement in Science and Mathematics: Status, Issues and Problems

An Organizing Structure for Course 1

Conservation Principles and the Structure of Engineering



Knowledge Types (a structure for Course 3)



Content, Procedural and Conditional

The first type of knowledge (first in the sense of the order we choose to discuss it, not in its supremacy to other forms) is content. Content knowledge includes physics or basic principles of systems. For example, in a pendulum (as in all real systems) linear and angular momentum, and total energy can be accounted for. To do this, an understanding of what energy and momentum are, as well as an understanding of the forces of gravity and air resistance are needed. This knowledge might be labeled content. The content knowledge in this text will build on fundamentals established in your previous courses. The intent is not to introduce vast amounts of content.

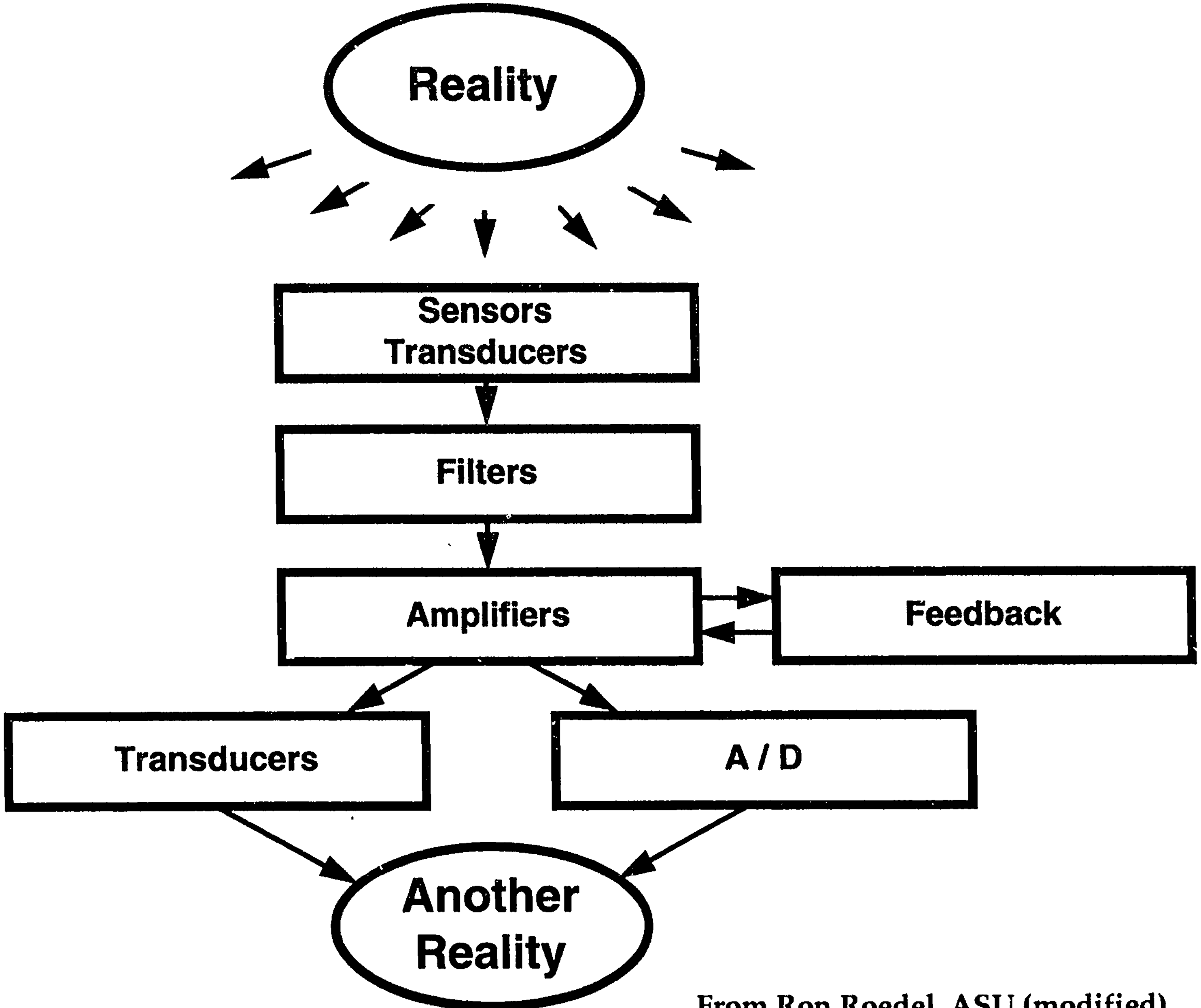
The second, and most common knowledge type in this text, is procedural. Procedural knowledge includes the process or methodology which you apply to understand systems. For example, to apply the content knowledge that angular momentum is conserved in the pendulum, you must determine the forces acting on the system. This can be done best by drawing a free-body diagram. There is a procedure, or correct way, to draw a free-body diagram, if one does not possess such procedural knowledge it will be difficult to apply content knowledge.

The third type of knowledge contained in this course is conditional. Conditional knowledge is used to decide when various methodologies are applicable. For example, if a point on the pendulum is fixed to the Earth, you must decide if the Earth should be assumed fixed, rotating about its axis, or hurling through space.

This course will emphasize te development of procedural and conditional knowledge by providing practice in the design and analysis of complex devices. The objective is to allow you to gain some of the experience necessary to make important engineering decisions about the design and analysis of complex processes. The text will also reinforce knowledge for understanding why a system behaves as it does, and to make design decisions based on desired behavior.

Everett, Louis J.,
Understanding Engineering Systems Via Conservation, *1992, McGraw-Hill, New York*

Another Structure



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From Ron Roedel, ASU (modified)

Learning Experiences Defined

- *... NOT the same as the content with which a course deals NOR the activities performed by the teacher*
- *Learning takes place through the active behavior of the student; it is what the student does that the student learns, NOT what the teacher does.*
- *This means that the teacher must have some understanding of the kinds of interests and background the students have so that she can make some prediction as to the likelihood that a given situation will bring about a reaction from the student; and, furthermore, will bring about the kind of reaction which is essential to the learning desired.*

Organizing Learning Experiences

Learning experiences must be organized to reinforce each other. Their relationship over time and from one area to another must be considered; often referred to as vertical and horizontal relationships.

- ***CONTINUITY***

  the vertical reiteration or recurring emphasis of major curriculum elements, themes or organizing threads

- ***SEQUENCE***

  increasing the breadth and depth of vertical reiteration

- ***INTEGRATION***

  the horizontal relationship of curriculum experiences (i.e., with the objective of allowing the student to develop a unified view)

General Principles in Selecting Learning Experiences

- *the learning experience must provide the student with an opportunity to practice the kind of behavior implied by the objective*
- *the student must derive some satisfaction from exhibiting the kind of behavior implied by the objectives*
- *the learning experience must be within the range of possibility for the students involved*
- *there are many particular experiences that can be used to attain the same educational objectives*
- *the same learning experience will usually bring about several outcomes*

ASU / CHE Implementation (only 3 of 4 NSF/A&M Courses)

CHE Introductory Courses

3 Material Balances

3 CHE Thermodynamics I

ASU Engineering Science Core (Partial)

3 Statics

3 Dynamics (*)

3 Deformable Solids

3 Materials Science (*)

3 Circuits

4 Devices

---

19 CR (total required for CHE)

(*) Not taken by Chemical Engineers

NSF/A&M New Engineering Science Core Courses

4 Conservation Principles

Quantities Conserved

Total & Elemental Mass,
Total Energy,
Linear & Angular Momentum,
Total Charge

Quantities Accounted For

Species Mass, Entropy,
Electrical Energy,
Mechanical Energy, etc.

4 Properties of Matter

Solids, Liquids and Gases

4 Engineering Systems

---

12 CR (N.B. Includes Introductory Fluids)

"What Should We Expect From Education?"

- Knowledge -- enables us to understand what we learn in relationship to what we already know
- Know-How -- enables us to do, it puts knowledge to work
- Wisdom -- the ability to decide what is important and what is not
- Character -- a combination of Knowledge, Know-How and Wisdom, coupled with motivation

honesty, initiative, curiosity, truthfulness, integrity, cooperativeness, ability to work alone, ability to work in a group, self esteem (from Covey, 7 Habits of Highly Effective People ...)

Tribus, Myron C. , Total Quality Management in Schools of Engineering and of Business

Tribus, Myron C. , Quality Management in Education, 1993

*Stages of Knowledge**

- *You do not know that you do not know (unconscious incompetent)*
- *You know that you do not know (conscious incompetent)*
- *You know that you know (conscious competent)*
- *You do not know that you know (unconscious competent)*

*Mr. House - Hewlett Packard

Stages of Knowledge

Relating Awareness and Competence Levels

Competence (Level of Learning)

Self - Awareness (Degree of Internalization)	Low	High
High	2 You know that you do not know (Conscious Incompetence)	3 You know that you know (Conscious Competence)
Low	1 You do not know that you do not know (Unconscious Incompetence)	4 You do not know that you know (Unconscious Competence)

'Conscious Competence - The Mark of a Competent Instructor', *Personnel Journal*, July, 1979, pp. 538-539

Evaluation of Educational State

- Learning Outcomes Translated into Competencies
  - set by course instructor
  - statements of what topics are to be covered
- Levels of Learning (or Degrees of Internalization)
  - characterizations of the different types of learning possible for the learning outcomes
  - defined by the activities done by student and teacher
  - Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (for example)
- Competency Matrix
  - shows relationship between learning outcomes and levels of learning or degrees of internalization

One View of Levels of Learning

- **Knowledge**

  I have basic information,
  but cannot explain it to others.

- **Comprehension / Understanding**

  I understand and can explain this information
  to others (requires knowledge).

- **Application**

  I can apply this concept or information to
  different situations
  (requires knowledge and comprehension).

One View of Levels of Learning (Continued)

- *Analysis & Synthesis*

  I can play with the concept, break it apart and create new variations (requires knowledge and comprehension).

- *Evaluation*

  Having gone through the preceding states, I have a deep appreciation for this concept (requires knowledge, comprehension, application, and analysis & synthesis).

Competency Matrix

- *A 'snap shot' of a person's level of learning for a variety of concepts or skills*
- *An L matrix of concepts to be learned*
  versus
  stages (or levels) of learning
- *The matrix is filled out by person being evaluated*
- *It must be constructed by the person responsible for (1) establishing the course objectives, and (2) designing both the learning experiences and assessment instruments required to achieve the course objectives.*

Sample Evaluation Matrix

Instructions for filling in the matrix

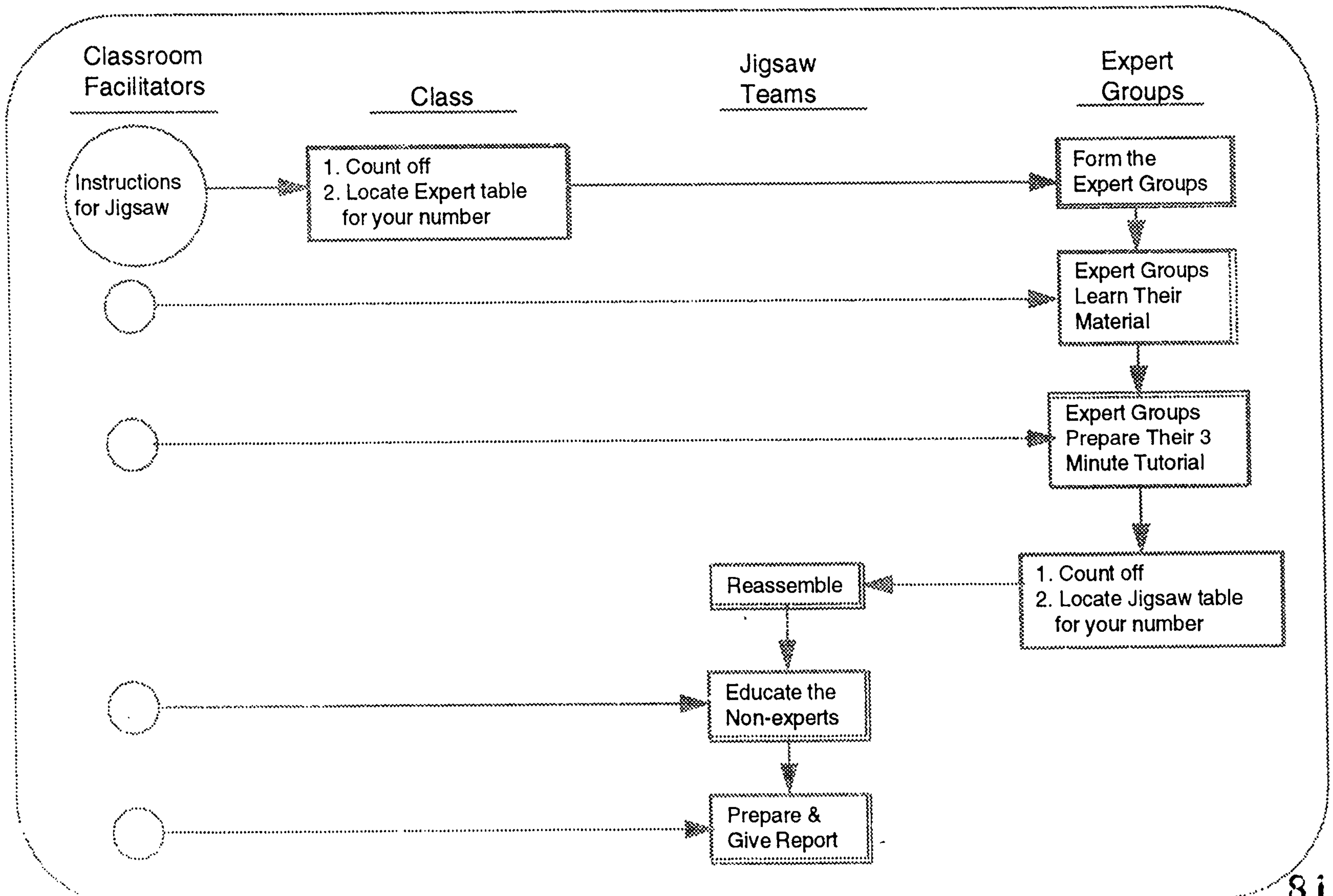
a. **For each competency area darken the row up to and including the column which indicates your current level of learning for the competency. You can refer to the following pages to assist you in understanding the meaning of these levels of learning.**

b. **If you do not know or recognize a competency area then you only blank the first column (Before Knowledge)**

c. **Each time you re-evaluate your state of learning for a competency, if your level of learning has increased then move the bar farther to the right using a different color or pattern to fill in the column(s).**

Competency Category	Competencies	Before Knowledge	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
Cooperative Learning	Code of Cooperation							
	Face to Face Interaction							
	Individual Accountability							
	Jigsaw							
	Structure Before Task							
	Structured Controversy							
Teams	Gatekeeper							
	Storming							
	Team Diversity							
	Team Member							
Assessment	Competency Matrix							
	Grades							
	Knowledge							
	Know-How							
	Stages of Learning							

Levels of Learning Jigsaw



Forming 'Expert' Groups (3 minutes)

- *Count off within room*
- *Depending on your number you will read the material in the Appendix*
  - *1's read about Knowledge , Receiving*
  - *2's read about Comprehension , Responding*
  - *3's read about Application , Evaluation . Valuing*
  - *4's read about Analysis , Synthesis , Valuing*
- *Look around the room until you see where the numbered expert tables are located*
- *All the 1's will get up and move to Table 1; all the 2's will get up and move to Table 2; etc.*

Becoming an 'Expert ' (30 minutes)

- Read the material which you will find at your expert table (or may be delivered to your expert table).
- Discuss the reading with your expert team members to reach consensus on meaning and Importance of the various ideas.
- As a team develop a three minute tutorial which you can use to teach other members of the class about your level or degree
- As an aid in preparing your table's tutorial, prepare a class assignment which could be used to demonstrate your table's LoL.
  - *If your group has become experts in either Knowledge, Comprehension, or Application, prepare an assignment on:*

    ✓ ______________________
  - *If your group has become experts in either Analysis, Synthesis, or Evaluation, prepare an assignment on:*

    ✓ ______________________

Forming Jigsaw Groups (3 minutes)

- *Count off within expert groups starting at 1*
- *Look around the room until you see where the various numbered tables are located*
- *All the 1's will get up and move to Table 1; all the 2's will get up and move to Table 2; etc.*
- *If there is no table for your number let the course facilitator know and she will assign you to a jigsaw group*

Presenting the Tutorial (35 minutes)

- ***The three minute tutorials for EACH type should be delivered in the following sequence: (30 minutes)***
  - *Receiving*
  - *Knowledge*
  - *Responding*
  - *Comprehension*
  - *Application*
  - *Analysis*
  - *Valuing (delivered by either fifth team member or the person who did not do Analysis*
  - *Evaluation*
- ***It is a good idea to check each other to ensure that everyone is learning the material to at least the Knowledge LoL and Receiving DoL***
- ***After all tutorials have been delivered spend a few moments in clarification (5 minutes)***

Reporting Out (25 minutes)

- *Using the examples generated in the Expert Groups as starting points, develop an integrated, consistent example showing how the various learning levels could be demonstrated (15 minutes)*
- *Outline the example on the overhead slides provided*
- *One group, selected at random (the presenter also selected at random) will present their example as a basis for workshop discussion (10 minutes or until interest wanes, or everyone has to leave, whichever comes first)*
- *Turn in transparencies used in report so copies for the workshop can be made.*

Knowledge (Information)

Process verbs:		
define	memorize	record
label	name	relate
list	read	repeat
listen	recall	view

How do I know I have reached this level?
I recall information? I bring to mind the appropriate material at the appropriate time? I have been exposed to the information and I can respond to questions, tasks, etc.

What do I do at this level?
I read material, listen to lectures, watch videos, take notes and I am able to pass a test of knowledge on the subject area. I learn the vocabulary of the competency area, i.e., the terminology. I learn the conventions used.

How will the teacher know I am at this level?
The teacher will provide opportunities (either orally or in written tests), regardless of complexity, that can be answered through simple recall of previously learned material.

What does the teacher do at this level?
The teacher directs, tells, shows, identifies, examines the information necessary at this level.

What are typical ways I can demonstrate my knowledge?
1. Define technical terms by giving their attributes, properties or relations.
2. Recall the major facts about a particular subject.
3. List the characteristic ways of treating and presenting ideas (i.e., list conventions associated with the subject).
4. Name the classes, sets, divisions, and arrangements which are regarded as fundamental for a given subject field or problem.
5. List the criteria used to judge facts, principles, and ideas.
6. Describe the method(s) of inquiry or techniques and procedures used in a particular field of study.
7. List the relevant principles and generalizations.
8. Fill in the blank.

Modifications by B. McNeill of David Langford's definitions of Levels of Learning in *Total Quality Learning Handbook*, Langford Quality Education and B. Bloom et al. *Taxonomy of Educational Objectives*, Longmans, Green and Co. 1956.

Comprehension / Understanding

Process verbs:

describe	identify	report	tell
explain	locate	restate	work
express	recognize	review	

How do I know I have reached this level?
I comprehend and understand what is being communicated and make use of the ideas but without relating them to other ideas or material. I may not yet understand the fullest meaning. I understand what others are discussing concerning this idea. This level requires Knowledge.

What do I do at this level?
I successfully work assignments in which the appropriate approach is evident either because of material in the problem statement or because of the problem's relative location in the book to the appropriate method. I translate information into my own words (translation from one level of abstraction to another. I translate symbolic information (e.g., tables, commas, diagrams, graphs, mathematical formulas, etc.) into verbal forms, and vice versa. I interpret or summarize communications (written/graphical/oral). I determine implications, consequences, corollaries , effects, etc. which are extensions of trends or tendencies beyond the given data.

How will the teacher know I am at this level?
The teacher will often ask questions or give tests that can be answered by merely restating or reorganizing material in a rather literal (clearly stating the facts or primary meaning of the material) manner to show that I understand the essential meaning, e.g., give the ideas in your own words.

What does the teacher do at this level?
The teacher demonstrates, works problems, listens, questions, compares, contrasts, and examines the information and your knowledge of it.

What are typical ways I can demonstrate or can show on my own my comprehension and understanding.
1. Read Comprehension level problems, know what is being asked for, and successfully work the problems.
2. Clearly chronicle the process used in working the problem.
3. Clearly describe the results of working the problem.
4. Draw conclusions (interpret trends) from the results of solving the problem.
5. Compare/contrast two different problems (i.e., what things are the same? / what things are different?)
6. Restate and idea, theory, or principle in your own words.

Modifications by B. McNeill of David Langford's definitions of Levels of Learning in *Total Quality Learning Handbook*, Langford Quality Education and B. Bloom et al. *Taxonomy of Educational Objectives*, Longmans, Green and Co. 1956.

Application (Thinking)

Process verbs:		
apply	illustrate	practice
demonstrate	interpret	recognize
employ	operate	

How do I know I have reached this level?

I have the ability to recognize the need to use an idea, method, concept, principle, or theory without being told to use it, i.e., I have the ability to use ideas, methods, concepts, principles and theories in new situations. I know and comprehend the information and can apply it to a new situation. I also have the ability to recognize when a certain task, project, theory or concept is beyond my current competency. Application requires having Knowledge and Comprehension.

What do I do at this level?

I work problems for which the solution method is not immediately evident or obvious. I take knowledge that has been learned at the Knowledge and Comprehension levels of learning and apply it to new situation. I solve problems on my own and make use of other techniques. This requires not only knowing and comprehending information, but deep thinking about the usefulness of this information and how it can be used to solve new problems that I create or identify.

How will the teacher know I am at this level?

I will show the teacher through my work that I am involved in problem solving in new situations with minimal identification or prompting of the appropriate rules, principles, or concepts by the teacher. The teacher will be able to ask general questions like, How much protection from the sun is enough? and I will know how to attack the problem.

What are the typical ways I can demonstrate or show, on my own, my application of Knowledge and Comprehension?

1. Solve problems which require recognition of the appropriate concepts, theories, solution techniques, etc.
2. Apply the laws of mathematics, chemistry, physics, and engineering to practical situations.
3. Work *project type* problems.

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Analysis (Thinking)

Process verbs:

break apart	examine
break down	explain

How do I know I have reached this level?
I can explain *why*. I can examine, methodically, ideas, concepts, writing etc. and separate into parts or basic principles. I have the ability to break down information into component parts in order to make organization of the whole clear. Work at this level requires having Knowledge and Comprehension levels of learning (application is not required).

What do I do at this level?
I analyze results by breaking concepts, ideas, theories, equations, etc. apart. I can explain the logical interconnections of the parts and can develop detailed cause and effect chains.

What does the teacher do at this level?
The teacher probes, guides, observes, and acts as a resource.

What are typical questions I can pose for myself to answer which will demonstrate or show my Analysis level of learning?

1. Why did this (result) happen?
2. What reasons does she give for her conclusions?
3. Does the evidence given support the hypothesis, the conclusion?
4. Are the conclusions supported by facts, opinions, or analysis of the results?
5. What are the causal relationships between the results for the whole and the parts?
6. What are the unstated assumptions?

Modifications by B. McNeill of David Langford's definitions of Levels of Learning in *Total Quality Learning Handbook*, Langford Quality Education and B. Bloom et al. *Taxonomy of Educational Objectives*, Longmans, Green and Co. 1956.

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Synthesis (Thinking)

Process verbs:			
arrange	construct	manage	propose
assemble	create	organize	set up
collect	design	plan	write
compose	formulate	prepare	

How do I know I have reached this level?

I have the ability to put together parts and elements into a unified organization or whole which requires original, creative thinking. I recognize new problems and develop new tools to solve them. I create my own plans, models, and/or hypotheses for finding solutions to problems. This level of learning requires Knowledge, Comprehension, Application and Analysis levels of learning.

What do I do at this level?

put ideas together to create something. This could be a physical object, a process, a design method, a communication, or even a set of abstract relations (i.e., mathematical models). I produce reports, (written/oral) which create a desired effect (e.g., information acquisition, acceptance of a point of view, continued support, etc.) in the reader (listener). I generate project plans, I propose designs, I formulate hypotheses based on the analysis of pertinent factors. I am able to generalize from a set of axioms, principles.

How will the teacher know I am at this level?

I show that I can combine ideas into a statement, plan, product, etc., that is new for me; e.g., I can develop a program that includes the best parts of each of those ideas

What does the teacher do as this level?

The teacher reflects, extends, analyses, and evaluates.

Wh t are the typical questions I can answer which will demonstrate or show my Synthesis?

1. Can I create a project plan?
2. Can I develop a model?
3. Can I propose a design?

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Appreciation / Evaluation (Wisdom)

Process verbs:

appraise	judge
choose	predict (quality)
compare	rate value
estimate (quality)	select
evaluate	

How do I know I have reached this level?

I have the ability to judge and appreciate the value of ideas, procedures and methods using appropriate criteria. To work at this level requires having achieved Knowledge, Comprehension, Application, Analysis and Synthesis levels of learning.

What do I do at this level?

I make value judgments based on certain considerations such as usefulness, effectiveness, and so on. Based on information gained through application, analysis ,and synthesis I can rationally select a process, a method, a model, a design, etc. from among a set of possible processes, methods, models, designs, etc. I evaluate competing plans of action before actually starting the planned work. I evaluate work based on internal standards of consistency, logical accuracy and the absence of internal flaws (e.g., I can certify if design feasibility has been demonstrated in a report). I evaluate work based on external standards of efficiency, cost, utility to meet particular ends (e.g., I can certify that design quality has been demonstrated in a report).

How will the teacher know I am at this level?

I can demonstrate that I can make a judgment about something using some criteria or standard for making the judgment.

What does the teacher do at this level?

The teacher clarifies, accepts, harmonizes, aligns, and guides.

What are typical statements and questions I can respond to which will demonstrate or show my appreciation/evaluation?

1. I can evaluate an idea in terms of ...
2. For what reasons do I favor...
3. Which policy do I think would result in the greatest good for the greatest number?
4. Which of these models i.e., modeling approaches is the best for my current needs. How does this report show that the design is feasible? How does this report show the quality of the design?

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Affective (Character) Traits

What are some affective traits?

Ability to work alone	*Curiosity*	*Interest*
Ability to work in teams	*Honesty*	*Self Esteem*
Attention	*Initiative*	*Truthfulness*
Cooperativeness	*Integrity*	

What questions can I ask myself to determine if I am exhibiting these characteristics?

1. *Do I come to class (meetings) prepared?*
2. *Do I come to class (meetings) on time?*
3. *Do I seek out material on a subject beyond what is suggested by the instructor?*
4. *Do I admit when I do not know something?*
5. *Do I talk about class subjects with my friends during informal gatherings.*
6. *Do I help others when they are having difficulties?*
7. *Do I invest the time expected working on the class (meetings)?*
8. *Do I do the work I say I will do and have it done when I say I will have it done?*
9. *Do I know I can solve problems?*

Course 1 : Conservation Principles

- *Course Objectives* 1
- *Daily Assignments (Topics, Reading, etc.)* 2 - 9
- *Competency Matrix* 10

COURSE 1 :
CONSERVATION PRINCIPLES IN ENGINEERING

COURSE OBJECTIVES

By the end of this course, the student should be able to:

1. list the physical quantities that are conserved and those that can be accounted for;

2. state the general conservation laws for those properties that are conserved and state the general accounting balances for the properties which are not conserved.

3. For a specific engineering problem:

   a. identify an appropriate system, surroundings and time period based on a verbal or written description of the problem or a visual observation of the physical system;

   b. identify the quantities to be conserved and those that can be accounted for in the system and surroundings;

   c. construct the appropriate conservation laws and accounting balances;

   d. delineate the specifications and data required for the model if the number of independent equations is to equal the number of unknowns;

   e. make appropriate assumptions, but retain the important elements of the problem;

   f. state whether the model is descriptive or predictive;

   g. solve the resulting equations which describe the model;

   h. discuss the phys[illegible] relevance of the numerical values for the solution and the physical relevance of the problem in general;

   i. state the distinction between the mathematical model and the physical reality the model attempts to describe;

In addition, the student should:

4. develop a cooperative attitude towards learning;

5. take an active role in her or his education;

6. strive for continuous improvement.

Course 1 : Conservation Principles in Engineering

1. TOPIC : **Introduction** READ : Series Editor's Preface, pps iii-iv Chapter 1 , pps 3 - 5	M / 24 / AUG FOR M / 24 / AUG
R1. RECITATION : **Introduction (Cont.) , "Fun Math Test"** 2. TOPIC : **The Big Picture : Accounting Concept** STUDY Chapter 2 , pps 6 - 14 QUESTIONS 1, 2, 9 and 13 (pp 27)	T / 25 / AUG FOR W / 26 / AUG
3. TOPIC : **The Big Picture : Conservation** STUDY Chapter 2 , pps 14 - 22 PROBLEMS 1, 2, 3 and 5 (pps 28 - 29)	F / 28 / AUG FOR F / 28 / AUG
4. TOPIC : **Conservation Principles** STUDY : Chapter 2 , pps 22 - 27 PROBLEMS 4, 6, 7 and 11 (pps 29 - 31)	M / 31 / AUG FOR M / 31 / AUG
R2. RECITATION : **TBA**	T / 1 / SEP
5. TOPIC : **Conservation of Mass** STUDY : Chapter 3 , pps 33 , 35 - 42 QUESTIONS 1, 4, 8 and 11 (pps 68 - 69) * **SUBMIT** Homework Assignments 2 , 3 and 4	W / 2 / SEP FOR W / 2 / SEP ON W / 2 / SEP
6. TOPIC : **The Rate Equation (Mass)** STUDY Chapter 3 , pps 43 - 49 PROBLEMS 1, 2, and 4 (pps 69 - 70)	F / 4 / SEP FOR F / 4 / SEP

R3. RECITATION : **TBA**	T / 8 / SEP
7. TOPIC : **Complex Mass Balances** STUDY Chapter 3 , pps 49 - 57 PROBLEMS 3 (pp 70) * **SUBMIT** Homework Assignments 5 and 6	W / 9 / SEP FOR W / 9 / SEP ON W / 9 / SEP
8. TOPIC : **Density , Flow Rates** STUDY Chapter 3 , pps 57 - 62 PROBLEMS 5 (pp 70)	F / 11 / SEP FOR F / 11 / SEP
9. TOPIC : **Chemical Reactions , Closed and Open Systems** STUDY Chapter 3 , pps 62 - 68 : PROBLEMS 6 (pp 70 - 71)	M / 14 / SEP FOR M / 14 / SEP
R4. RECITATION : **TBA**	T / 15 / SEP
10. TOPIC : **Conservation of Charge** STUDY Chapter 4 , pps 76 - 88 QUESTIONS 1, 2, 5 and 6 (pp 98) PROBLEMS 1 and 2 (pps 99-100) * **SUBMIT** Homework Assignments 7, 8 and 9	W / 16 / SEP FOR W / 16 / SEP ON W / 16 / SEP
11. TOPIC : **The Rate Equation (Charge), Kirchoff's Law** STUDY Chapter 4 , pps 88 - 98 PROBLEMS 4, 5 and 6 (pps 100-102)	F / 18 / SEP FOR F / 18 / SEP

12. TOPIC : **Conservation of Linear Momentum** STUDY Chapter 5 , pps 105 - 115 QUESTIONS 1, 3, 9 and 12 (pps 128-129) PROBLEMS 1 (pp 129)	M / 21 / SEP FOR M / 21 / SEP
R5. RECITATION : **Exam 1 , Chapters 1 - 4**	ON T / 22 / SEP
13. TOPIC : **Newton's Laws of Motion** STUDY Chapter 5 , pps 115 - 118 PROBLEMS 2, 3 and 4 (pps 129-130) * **SUBMIT** Homework Assignments 10 and 11	W / 23 / SEP FOR W / 23 / SEP ON W / 22 / SEP
14. TOPIC : **Special Cases , Reference Frame** STUDY Chapter 5 , pps 118 - 128 PROBLEMS 5 and 6 (pp 131)	F / 25 / SEP FOR F / 25 / SEP
15. TOPIC : **Conservation of Angular Momentum - Particles** STUDY Chapter 6 , pps 134 - 142 (thru EQ 6-10) QUESTIONS 1, 4, 8 and 11 (pps 179 - 180)	M / 28 / SEP FOR M / 28 / SEP
R6. RECITATION : **TBA**	T / 29 / SEP
16. TOPIC : **Angular Momentum - Rigid Bodies** STUDY Chapter 6 , pps 149 - 152 , 157 - 166 , Evans Supplement (4 pps) PROBLEMS 1 and 2 (pp 180) * **SUBMIT** Homework Assignments 14 and 15	W / 30 / SEP FOR W / 30 / SEP ON W / 30 / SEP
17. TOPIC : **Conservation of Angular Momentum - Rigid Bodies** STUDY Chapter 6 , pps 166 - 168 (thru ex. 6-8); 176 - 177 (6.9, and REVIEW 1-4, 6 - 8); and 178 - 179 PROBLEMS 3 and 4 (pps 180 - 181)	F / 2 / OCT FOR F / 2 / OCT

18. TOPIC : **Conservation of Energy** STUDY Chapter 7 , pps 184 - 195 QUESTIONS 1, 4, 5 and 6 (pp 239)	M / 5 / OCT FOR M / 5 / OCT
R7. RECITATION : **TBA**	T / 6 / OCT
19. TOPIC : **Energy in Transition** READ Chapter 7 , pps 196 - 209 PROBLEMS 1, 2 and 3 (pps 240 - 241) * **SUBMIT** Homework Assignments 16, 17, and 18	W / 7 / OCT FOR W / 7 / OCT ON W / 7 / OCT
20. TOPIC : **Mechanical and Thermal Energy** STUDY Chapter 7 , pps 209 - 217 PROBLEMS 4, 5 and 6 (pps 241 - 242)	F / 9 / OCT FOR F / 9 / OCT
********* HARVEST MOON ***********	ON S / 11 / OCT
21. TOPIC : **Electrical Energy** STUDY Chapter 7 , pps 217 - 238 QUESTIONS 12 and 23 (pps 239 - 240) PROBLEMS 7, 8 and 9 (pps 242 - 243)	M / 12 / OCT FOR M / 12 / OCT
R8. RECITATION : **TBA**	T / 13 / OCT
22. TOPIC : **Second Law of Thermodynamics** READ Chapter 8 , pps 246 - 262 QUESTIONS 2 and 8 (pp 263) PROBLEMS 1 and 2 (pps 264 - 265) **and** Supplements # 1 and # 2 * **SUBMIT** Homework Assignments 19 , 20 and 21	W / 14 / OCT FOR W / 14 / OCT ON W / 14 / OCT
23. TOPIC : **Particle Statics** STUDY Chapter 9 , pps 271 - 277 QUESTIONS 1, 8, 9 and 10 (pps 322 - 323)	F / 16 / OCT FOR F / 16 / OCT

24. TOPIC : **Rigid Body Statics** READ Chapter 9 , pps 277 - 283 PROBLEMS 2 and 3 (pp 234)	M / 19 / OCT FOR M / 19 / OCT
R9. RECITATION : **Exam 2 , Chapters 5 - 8**	T / 20 / OCT
25. TOPIC : **Rigid Bodies (Cont.)** STUDY Chapter 9 , pps 283 - 293 PROBLEMS 6 (pps 325 - 326) **and** Supplement # 3 * **SUBMIT** Homework Assignments 22 , 23 and 24	W / 21 / OCT FOR W / 21 / OCT ON W / 21 / OCT
26. TOPIC : **Analysis of Structures** STUDY Chapter 9 , pps 294 - 314 PROBLEMS 5 (pp 325) **and** Supplement # 4 , # 5, and # 6	F / 23 / OCT FOR F / 23 / OCT
27. TOPIC : **Analysis of Machines** STUDY Chapter 9 , pps 314 - 322 PROBLEMS Supplement # 7 (Evans !)	M / 26 /OCT FOR M / 26 /OCT
R10. RECITATION : **TBA**	T / 27 / OCT
28. TOPIC : **Particle Kinematics** STUDY Chapter 10 , pps 328 - 343 QUESTIONS 7 , 8, 10 and 12 (pps 399) PROBLEMS 1 (pp 400) * **SUBMIT** Assignments 25, 26 and 27	W / 28 / OCT FOR W / 28 / OCT ON W / 28 / OCT
29. TOPIC : **Rigid Body Kinematics** STUDY Chapter 10 , pps 343 - 357 PROBLEMS 2 (pp 400)	F / 30 / OCT FOR F / 30 / OCT

30. TOPIC : **Particle Dynamics (Kinetics)** STUDY Chapter 10 , 357 - 374 PROBLEMS Supplement # 8	M / 2 / NOV FOR M / 2 / NOV
R11. RECITATION : **TBA**	T / 3 / NOV
31. TOPIC : **Rigid Body Dynamics (Kinetics)** STUDY Chapter 10 , pps 374 - 387 , 396 - 398 READ Chapter 10 , pps 387 - 396 PROBLEMS (Evans !) * **SUBMIT** Homework Assignments 28, 29 and 30	W / 4 / NOV FOR W / 4 / NOV ON W / 4 / NOV
32. TOPIC : **Pressure Distribution in Static Fluids** REVIEW Chapter 5 , pps 120 - 124 STUDY Chapter 11 , pps 403 - 414 QUESTIONS 1, 3, 6 and 8 (p 442) PROBLEMS 1 and 2 (p 443)	F / 6 / NOV FOR F / 6 / NOV
33. TOPIC : **Forces on Submerged Areas , Buoyancy** READ Chapter 11 , pps 414 - 440 QUESTIONS 9 and 13 (PPS 442 - 443) PROBLEM 3, 4, 5 and 6 (pps 443 - 445)	M / 9 / NOV FOR M / 9 / NOV
R12. RECITATION : **Exam 3 , Chapters 9 - 10**	T / 10 / NOV
34. TOPIC : **Fluid Dynamics** REVIEW Chapter 5 , pps 124 - 126 STUDY Chapter 12 , pps 448 - 459 QUESTIONS 1 and 3 (pp 506) PROBLEMS 1 and 2 (pp 507) * **SUBMIT** Homework Assignments 31, 32 and 33	F / 13 / NOV FOR F / 13 / NOV ON F / 13 / NOV

35. TOPIC : **Flow in Pipes and Other Closed Conduits** STUDY Chapter 12 , pps 459 - 479 PROBLEMS 3 and 4 (pp 507)	M / 16 / NOV FOR M / 16 / NOV
R13. RECITATION : **TBA**	T / 17 / NOV
36. TOPIC : **Miscellaneous Topics , Measurement of Flow** READ Chapter 12 , pps 479 - 490 PROBLEMS 5, 6 and 7 (pps 507 - 508) * **SUBMIT** Homework Assignments 34 and 35	W / 18 / NOV FOR W / 18 / NOV ON W / 18 / NOV
37. TOPIC : **Forces Associated with Fluid Systems** READ Chapter 3 , pp 126 STUDY Chapter 12 , pps 490 - 505 PROBLEMS Supplement #9, #10, and #11	F / 20 / NOV FOR F / 20 / NOV
38. TOPIC : **Source Transformation, Superposition** READ Chapter 13 , pps 513 - 527 STUDY Chapter 13 , pps 527 - 532 QUESTIONS 9, 13 (pp 552) PROBLEMS 1 (pp 552)	M / 23 / NOV FOR M / 23 / NOV
R14 RECITATION : **Exam 4, Chapters 11 - 12**	T / 24 / NOV
39. TOPIC : **Nodal and Mesh Analysis, Thevenin Circuit and Maximum Power Transfer** STUDY Chapter 13 , pps 533 - 551 PROBLEMS 5 and 7 (pp 554) * **SUBMIT** Homework Assignments 36 and 37	W / 25 / NOV FOR W / 25 / NOV ON W / 25 / NOV

40. TOPIC : **Inductance and Capacitance Revisited** REVIEW Chapter 14 , pps 556 - 563 QUESTIONS 5, 6, 11 and 12 (pp 552) PROBLEMS 1 and 2 (pps 577 - 578)	M / 30 / NOV FOR M / 30 / NOV
R15. RECITATION : **TBA**	T / 31 / NOV
41. TOPIC : **More on Entropy and the Second Law** STUDY Chapter 16 , pps 674 - 687 QUESTIONS 3, 4 and 13 (pps 693 - 694) PROBLEMS 1 and 9 (N.B. Chapter 15, pps 668 - 669) * **SUBMIT** Homework Assignments 38, 39 and 40	W / 2 / DEC FOR W / 2 / DEC ON W / 2 / DEC
42. TOPIC : **Power Cycles** STUDY Chapter 17 , pps 695 - 714 QUESTIONS 1 (pp 722) PROBLEMS 4 (pp 724 - 725)	F / 4 / DEC FOR F / 4 / DEC
43. TOPIC : **Refrigeration Cycles** STUDY Chapter 17 , pps 714 - 722 PROBLEMS 5 (pp 725)	M / 7 / DEC FOR M / 7 / DEC
R16. RECITATION : **Exam 5 , Chapters 13 , 14 , 16 and 17** * **SUBMIT** Homework Assignments 41, 42 and 43	T / 8 / DEC ON T / 8 / DEC
44. TOPIC : **PERSPECTIVES AGAIN ! (or a Tour !)**	W / 9 / DEC
45. **FINAL EXAM** 7:40 AM - 9:30 AM , ECG 238	ON M / 14 / DEC

Learning Outcomes	Competency Category	Competencies	Knowledge	Comprehension / Understanding	Application	Analysis	Synthesis	Appreciation / Evaluation
		Course 1 : Conservation Principles in Engineering						
		Conservation Principles and the Structure of Engineering ECE 394 A REVIEW						
	System Definition I Selection	Labeled Sketches						
		System or Free body Diagram						
		Surroundings						
		Time Period						
		Data (Nature)						
		Specifications (Human)						
		Parameters (Shared)						
		Coordinate System (Motion Easy?)						
		Required						
		Assumptions						
		Defining Relationships (Constraints)						
	Analysis of a Mathematical Model	Variables (All)						
		Equations						
		Data (Nature)						
		Specifications (Human)						
		Parameters (Shared)						
		Initial Conditions (include t0)						
		Remaining Unknowns						
	Conservation Concepts	Total Mass						
		Elemental Mass						
		Total Charge						
		Linear Momentum						
		Angular Momentum						
		Total Energy						
		Entropy (Cosmos, A)						
	Accounting Concepts	Species Mass (A)						
		Moles (A)						
		Plus Charge						
		Minus Charge						
		Electrical Energy (A,D)						
		Mechanical Energy (A,D)						
		Mechanical Energy (Particles, A,D)						
		Mechanical Energy (Rigid Bodies, A,D)						
		Mechanical Energy (Fluid Flow, A, I)						
		Entropy (System, A)						
		Entropy (Surroundings, A)						
		Entropy Generation (Irreversibility)						
	Other	Extensive Properties						
		Intensive Properties						
		Tables for Extensive Properties						
		KCL						
		KVL						

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Course 2 : Properties of Matter

- Course Objectives 1 - 5
- Daily Assignments (Topics, Reading, etc.) 6 - 9
- Competency Matrix 10 - 15

COURSE OBJECTIVES

By the end of this course the student should:

- Appreciate the importance of materials in the practice of engineering
- Understand the fundamental chemical, mechanical and thermal structure of matter and the key distinguishing features of solid, liquid and gas
- Understand the critical need for materials' properties in the application of conservation and accounting principles
- Appreciate the scope and diversity of materials' behavior
- Understand how to relate the structure of matter to its properties through models and be able to develop simple structure-property relationships
- Understand the distinction between a *model* and *physical reality*
- Understand the distinction between *descriptive* and *predictive* models
- Be able to critically evaluate the validity/usefulness of alternative models

In addition, the student should:

- Develop a cooperative attitude in learning
- Take an active role in her/his education
- Strive for continuous improvement

SUMMARY OF OBJECTIVES

Atomic / Molecular Structure

- RECALL SIMPLE MODELS FOR ATOMIC ORBITALS, AND UNDERSTAND THE DISTINCTION BETWEEN OUR MODELS AND PHYSICAL REALITY. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY:

  (1) SKETCHING REASONABLE PICTORIAL REPRESENTATIONS OF s, p, d AND spd HYBRID ATOMIC ORBITALS, AND
  (2) EXPLAINING IN WORDS THE DIFFERENCES BETWEEN THE MODEL SUGGESTED BY THE SKETCH, THE MATHEMATICAL MODEL FOR AOs, AND THE RELATIONSHIP TO PHYSICAL REALITY

- UNDERSTAND THE NATURE OF MOLECULAR BONDING. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY:

  (1) DEVELOPING QUALITATIVE MODELS OF MOLECULAR ORBITALS IN SIMPLE MOLECULES USING THE LCAO-MO MODEL TO GIVE MO ENERGIES AND MO WAVEFORMS
  (2) SKETCHING REASONABLE PICTORIAL REPRESENTATIONS OF THE MOs SHOWING DIRECTIONALITY OF BONDING AND SHARING OF ELECTRON DENSITY
  (3) ESTIMATING RESONANCE ENERGIES FOR THE GROUND STATE
  (4) DETERMINING WHETHER THE CARBONIUM ION, THE NEUTRAL OR THE CARBANION IN THEIR RESPECTIVE GROUND STATES ARE MOST STABLE

- UNDERSTAND HOW SYMMETRY CAN SIMPLIFY THE PROBLEM OF MO DETERMINATION. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY:

  (1) IDENTIFYING PLANES OF SYMMETRY INHERENT TO THE ATOMIC ORBITALS IN A GIVEN MOLECULE
  (2) IDENTIFYING APPROPRIATE "GROUP SYMMETRY ORBITALS" BASED ON THE SYMMETRY PLANES
  (3) SOLVING FOR MO ENERGIES AND WAVEFORMS BY CONSIDERING THE SYMMETRY TYPES SEPARATELY - SINCE ORBITALS OF UNLIKE SYMMETRY CANNOT INTERACT!

- UNDERSTAND THE BASIS FOR THE LENNARD-JONES TYPE DIAGRAM. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY RATIONALIZING IN WORDS THE SHAPE OF THE DIAGRAM, AND BY EXPLAINING HOW THE DIAGRAM RELATES QUANTITATIVELY AND QUALITATIVELY TO THE LCAO-MO MODEL.

- UNDERSTAND THAT THE STABILITY/REACTIVITY OF A MOLECULE IS A FUNCTION OF ITS ELECTRON ENERGY CONFIGURATION. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY DETERMINING, FOR A GIVEN MOLECULAR ELECTRONIC STRUCTURE:

  (1) POSSIBLE MODES FOR EXCITATION TO HIGHER ENERGY STATES AND DE-EXCITATION TO LOWER ENERGY STATES
  (2) THE ENERGY TRANSFERRED IN THE PROCESS(ES)
  (3) WHETHER OR NOT THE MOLECULES IN THE EXCITED STATES ARE STABLE

- UNDERSTAND HOW TO BUILD A SOLID'S ELECTRON ENERGY DIAGRAM BASED ON THE PRINCIPLES WE HAVE LEARNED IN THE LCAO-MO METHODOLOGY. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY SKETCHING SCHEMATIC CONTINUUM "BAND" DIAGRAMS WHICH ARE CONSISTENT WITH DISCRETE LCAO-MO MODELS.

Mechanical Structure

- COMMUNICATE IN THE LANGUAGE OF THE CRYSTALLOGRAPHER, AS DEMONSTRATED BY:

  (1) THE ABILITY TO USE A LATTICE AND A BASIS TO DESCRIBE A GIVEN LATTICE STRUCTURE
  (2) THE ABILITY TO USE MILLER INDICES TO DESCRIBE LATTICE POSITIONS, DIRECTIONS AND CRYSTAL PLANES

- UNDERSTAND THAT THE POSSIBLE CRYSTAL LATTICE TYPES ARE LIMITED TO ALLOWABLE SYMMETRY TYPES. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY BEING ABLE TO IDENTIFY THE KEY TRANSLATIONAL, REFLECTION AND ROTATIONAL SYMMETRY TYPES IN A GIVEN LATTICE

- CALCULATE THE DENSITY OF A SOLID GIVEN ITS STRUCTURE AND LATTICE PARAMETER(S)

- UNDERSTAND THE RELATIONSHIP BETWEEN MECHANICAL STRUCTURE AND BONDING IN A CRYSTAL. THE STUDENT WILL DEMONSTRATE THIS UNDERSTANDING BY:

  (1) EXPLAINING IN WORDS HOW BONDING DIFFERENCES LEAD TO CLOSE-PACKED *vs.* LOOSELY-PACKED CRYSTALS AND IDENTIFYING WHICH ELEMENTS SHOULD CRYSTALLIZE IN EACH
  (2) PREDICTING CRYSTAL STRUCTURE IN IONIC SOLIDS

- UNDERSTAND THE USE OF PHASE DIAGRAMS IN ENGINEERING. GIVEN A PHASE DIAGRAM AND SPECIFIED CONDITIONS AND BULK COMPOSITION, THE STUDENT SHOULD BE ABLE TO:

  (1) DETERMINE THE NUMBER AND TYPE (solid sol'n, liquid sol'n, solid compound, *etc.*) OF PHASES PRESENT AND THEIR COMPOSITIONS
  (2) CALCULATE THE RELATIVE AMOUNTS OF EACH PHASE PRESENT
  (3) JUDGE WHETHER OR NOT THE PHASE DIAGRAM CAN BE APPLIED IN A GIVEN PROCESSING SITUATION

Surface Structure

- COMMUNICATE IN THE LANGUAGE OF THE SURFACE CRYSTALLOGRAPHER, AS DEMONSTRATED BY:

  (1) THE ABILITY TO USE A LATTICE AND A BASIS TO DESCRIBE A GIVEN SURFACE STRUCTURE
  (2) THE ABILITY TO USE MILLER INDICES TO DESCRIBE CRYSTAL PLANES

- CALCULATE THE SURFACE DENSITY OF A SOLID SURFACE GIVEN ITS BULK (3D) STRUCTURE, MILLER INDICES AND LATTICE PARAMETER(S)

- UNDERSTAND BOND-BREAKING MODELS FOR SURFACE ENERGIES AND BE ABLE TO DEMONSTRATE THIS UNDERSTANDING THROUGH CALCULATION OF SURFACE ENERGY FOR A SPECIFIED SURFACE (BULK CRYSTAL STRUCTURE AND MILLER INDEXED SURFACE)

- UNDERSTAND HOW LENNARD-JONES POTENTIAL MODELS OF BULK CRYSTALS PROVIDE NECESSARY PARAMETERS FOR THE BOND BREAKING MODELS, AND DEMONSTRATE THIS UNDERSTANDING BY ADOPTING THE CORRECT PARAMETER WHEN GIVEN A QUANTITATIVE MODEL AND KNOWLEDGE OF THE CRYSTAL STRUCTURE

Course 2 : Properties of Matter

Date(s)	In-class Topic / Activity	Advance Reading	Advance Work
8/23-8/25	**Part I - MOTIVATION AND PERSPECTIVES**		
8/23	Paradigm Shifts		
8/25	Motivation: Materials and Innovation	P: Chapter 1 (all) WB: Total Quality Learning	
8/26-10/8	**Part II - THE FUNDAMENTAL STRUCTURE OF MATTER**		
8/26	• Properties, Specifications and Variables • Modeling and the Role of Models	P: Chapter 2 (all)	WB: Modeling
8/27	• Electronic Structure of Atoms • A simple model for molecular structure: LCAO-MO	P: Chapter 3 (all)	WB: LCAO-MO
8/30	• LCAO-MO application • Relative stability • Resonance stabilization		WB: Relative Stability and Resonance
9/1	• Symmetry • Use of symmetry to simplify LCAO-MO calculations		WB: Symmetry
9/2	• Molecular bonding dynamics • L-J diagrams • Molecular excitation, de-excitation and dissociation • Photoemission demo	P: p. 59 pp. 349-350	WB: Molecular Bonding Dynamics
9/3	• Solid electronic structure	P: pp. 62-66	WB: Relationship of L-J diagrams to solids
9/6	*NO CLASS*: Labor day		
9/8	• Models to visualize solid structure • Crystal structure	P: Chapter 4, pp. 77-94	WB: Crystal Structure Determination
9/9	• Analysis of mechanical structure		WB: bcc lattice example

9/10	• Bonding and crystal structure • Metallic, ionic and covalent solids	P: pp. 102-107	WB: Bonding and Crystal Structure
9/13	• Miller indices	P: pp. 107-110	WB: Some Interesting Properties of Miller Indices
9/15	• X-ray diffraction		WB: X-ray Diffraction
9/16	• Solubility and Phase Diagrams • Lever rule *vs.* conservation	P: pp. 95-102	WB: Solid Solution Behavior
9/17	• More phase diagrams		
9/20	• General rules for interpretation of phase diagrams		
9/22	• Surface structure • Miller indices revisited • Surface density	P: Chapter 5 (all)	WB: Surface structure
9/23	• Scanning force microscopies		WB: AFM
9/24	• Surface energy • Binding energy • Bond breaking models		WB: Surface energy
9/27	• Thermal structure models • Translational, rotational and vibrational molecular energies	P: Chapter 6 (all) pp. 153-157	WB: Molecular Energies of Gases
9/29	• Vibrational modes and the Hooke's Law model	P: pp. 158-161	
9/30	***QUIZ #1: Atomic, Mechanical and Surface Structure***		
10/1	• Entropy • Configurational Entropy • Equilibrium concentration of defects in solids	P: pp. 161-166	WB: Randomness and Allowed Configurations
10/4	• Permutations and entropy	P: pp. 167-169	WB: Permutations, Combinations, Entropy
10/6	• Diffusion • Diffusion mechanisms in solids	P: pp. 169-178	WB: Diffusion Mechanisms - Jigsaw Exercise
10/7	• Fick's First Law of diffusion • Fick's 2nd Law of diffusion • T-dependence of diffusivity	P: pp. 179-189	WB: Fick's Law of Diffusion
10/8	• Application of diffusion		WB: Diffusion Problems

10/11-29	**Part III - MECHANICAL PROPERTIES OF SOLIDS AND LIQUIDS**		
10/11	• Elasticity and Plasticity • Mechanical testing: stress-strain behavior • Model's for Young's Modulus	P: Chapter 7 pp. 193-217	WB: Elasticity and Plasticity: Basics
10/13	• Poisson's ratio • Models for Poisson's ratio	P: pp. 218-224	WB: Poisson's Ratio
10/14	***QUIZ #2: Thermal Structure***		
10/15	• Non-linear responses and models	P: pp. 225-239	WB: Power Law Model and Other Models
10/18	• Mechanical Properties of Fluids • Kinetic Theory of Gases Model for Pressure	P: Chapter 8 pp. 245-251	WB: Mechanical Properties of Fluids
10/20	• Kinetic Theory of Gases Model for Gas Viscosity	P: pp. 251-256	WB: Viscosity
10/21	• Design Problem: Rock Concert at Sun Devil Stadium		
10/22	• Newtonian and non-Newtonian fluid behavior • Models for non-Newtonian behavior	P: pp. 257-266	WB: Viscosity (continued)
10/25	• Surface tension	P: pp. 266-269	WB: Surface Tension
10/27	• Viscoelastic behavior • Glassy, leathery, rubbery, rubbery flow and viscous flow • The Challenger accident	P: Chapter 9 pp. 273-279 pp. 285-296	WB: Time Dependent Models for Complex Materials
10/28	• Problem-solving session		
10/29	• Spring-dashpot models for viscoelastic response	P: pp. 279-285	WB: Complex Materials
11/1-12/3	**Part IV - ELECTRICAL AND MAGNETIC PROPERTIES**		
11/1	• Electrical properties • Energy Band models	P: Chapter 10 pp. 299-304	WB: Energy Band Theory
11/3	• Electron Gas model	P: pp. 304-309	WB: The Classical Treatment of an "Electron Gas"

11/4	*QUIZ #3: Mechanical Properties of Solids and Liquids*		
11/5	• Conductors and Insulators • Charge carriers • Conductivity • Mobility	P: pp. 309-312	WB: Conductors and Insulators
11/8	• Semiconductors • Intrinsic behavior	P: pp. 313-319	WB: Semiconductors
11/10	• Dopants • Extrinsic behavior: n and p-type		
11/11	*NO CLASS*: Veterans' Day		
11/12	• Models for semiconductor conductivity		
11/15	• Semiconductor junctions • Diodes and photo-diodes		WB: Junctions. Diodes. Transistors
11/17	• Transistors		
11/18	• Problem solving session		
11/19	• Superconductors • Dielectrics	P: pp. 319-327	WB: Superconductors Dielectrics
11/22	• Magnetic Properties • Dipoles. magnetization. domains	P: Chapter 11 pp. 335-344	
11/24	• Hall effect	P: p. 345	
11/25 - 26	*NO CLASS*: Thanksgiving Recess		
11/29	• Curie Temperature	P: pp. 345-346	
12/1	• Magnetic *vs.* electrical properties		
12/2	*QUIZ #4: Electrical and Magnetic Properties*		
12/3	• Perspectives: The Big Picture		
12/6	• Thought Exercise: Different Physics = Different Materials Properties?		
12/8	• Review: An Intriguing Demonstration		

Competency	Knowledge	Know-How	Process Learning			
			Wisdom			
	Information	Understanding	Application	Analysis	Synthesis	Evaluation
General						
Modeling						
Implicit Assumptions						
Occam's Razor						
Constraints						
Specifications						
Extensive Properties						
Intensive Properties						
Fundamental Structure II: Molecular & Bonding Structure						
Atomic Orbitals						
LCAO-MO Model						
LCAO-MO Methodology						
Bonding MOs						
Non-bonding MOs						
Anti-bonding MOs						
Molecular Orbital Energies						
Molecular Orbital Waveforms						
Electronic Configurations						
Relative Stability						
Resonance						
Resonance Energy						
Symmetry Types						
Symmetry in LCAO-MO						
Excitation / De-excitation						
Lennard-Jones Model						
Energy Band Diagrams						

Competency		Process Learning				
	Knowledge	Know-How	Wisdom			
	Information	Understanding	Application	Analysis	Synthesis	Evaluation
Fundamental Structure II: Mechanical Structure						
Crystal Structure						
Crystal Lattice						
Basis						
Translation Vectors						
Unit Cell						
Primitive Unit Cell						
Symmetry in Solids						
Bravais Lattices						
Nearest Neighbors						
Packing Fraction						
Density						
Miller Indices						
X-ray Diffraction						
Metallic Bonding						
Ionic Bonding						
Covalent Bonding						
Vacancies						
Substitutional Impurities						
Interstitial Impurities						
Frenkel Defects						
Schottkey Defects						
Line Defects (dislocations)						
Solid Solutions						
Partial Miscibility						
Phase Diagrams						
Lever-rule *vs.* Conservation						
Eutectics						
Allotropism						

Competency	Knowledge	Know-How	Process Learning			
			Wisdom			
	Information	Understanding	Application	Analysis	Synthesis	Evaluation
Fundamental Structure III: Surface Structure						
Surface Structure						
Surface Lattice						
Basis						
Translation Vectors						
Unit Cell						
Primitive Unit Cell						
Nearest Neighbors						
Surface Packing Fraction						
Surface Density						
Miller Indices						
Surface Energy						
Dangling Bonds						
Bond Breaking Models						
Binding Energy						
Fundamental Structure IV: Thermal Structure						
Allowed Modes of Motion						
Translational Energies						
Rotational Energies						
Vibrational Energies						
Continuum *vs.* Discrete Models						
Electromagnetic Spectrum						
Hooke's Law Model						
Configurational Entropy						
Randomness						
Allowed Configurations						
Permutations						
Equilibrium Defect Concentrations						
Diffusion						
Diffusion Mechanisms						
Fick's 1st Law						
Fick's 2nd Law						
Microscopic Diffusivity Models						

Competency		Process Learning				
	Knowledge	Know-How	Wisdom			
	Information	Understanding	Application	Analysis	Synthesis	Evaluation
Mechanical Properties of Solids						
Mechanical Testing						
Stress						
Strain						
Engineering Stress-strain curves						
True Stress-strain curves						
Elastic Response						
Plastic Response						
Proportional Limit						
Young's Modulus						
Yield Point						
Yield Strength						
Ultimate Strength						
Fracture Strength						
Tension						
Stress						
Shear						
Poisson's Ratio						
Bulk Modulus						
Theoretical Models for Mechanical Properties						
Empirical Models for Mechanical Properties						
Semi-empirical Models for Mechanical Properties						

	Process Learning					
	Knowledge	Know-How	Wisdom			
Competency	Information	Understanding	Application	Analysis	Synthesis	Evaluation
Mechanical Properties of Fluids						
Kinetic Theory of Gases						
Molecular model for Pressure						
Mean molecular velocity						
Mean Free Path						
Collision Frequency						
Ideal Gas Equation of State						
Bulk Modulus for a fluid						
Viscosity						
Molecular model for Viscosity						
Newtonian fluids						
non-Newtonian fluids						
Turbulent flow						
Laminar flow						
Boundary layer						
Speed of sound through fluids						
Surface Tension						
Time-Dependent Mechanical Behavior: Solids and Fluids						
Visco-elastic behavior						
Temperature-dependent behavior						
Strain rate dependent behavior						
Dashpot-spring models for viscoelastic response						
Creep						
Fatigue						

Competency	Process Learning					
	Knowledge	Know-How	Wisdom			
	Information	Understanding	Application	Analysis	Synthesis	Evaluation
Electrical Properties of Materials						
Energy band models						
Energy band gap						
Fermi Energy						
Fermi distribution						
Conductors						
Insulators						
Semiconductors						
Free Electron Gas Model						
Resistivity & Conductivity						
Mobility						
Charge carriers						
Doping: acceptors & donors						
Carrier concentrations						
p-type and n-type semiconductors						
p-n junctions						
Diode performance						
Transistor performance						
Dielectrics						
Dielectric strength						
Superconductivity						

Course 3 : Engineering Systems

- Course Objectives 1
- Daily Assignments (Topics, Reading, etc.) 2 - 8
- Competency Matrix 9 - 13

COURSE 3 :
MODELING AND BEHAVIOR OF ENGINEERING SYSTEMS

COURSE OBJECTIVES

By the end of this course, the student should be able to:

1. Differentiate between the three types of knowledge: content, procedural, and conditional.
2. Demonstrate the ability to make important engineering decisions about the design and analysis of complex processes.
3. Model multidiscipline and highly complex single discipline systems.
4. Differentiate between symptoms of a "problem" and the root cause of a "problem".
5. Model vs. reality.
6. Reading and interpreting a problem by extracting important information and ignoring unimportant details.
7. Demonstrate the ability to understand systems as opposed to solving problems.
8. Properly execute thoughts and ideas.
9. Determine system extent.

Course 3 : Modeling and Behavior of Engineering Systems

1. TOPIC : **Introduction : Knowledge Types, System I Model Characteristics** STUDY : Chapter 1 OUTLINE AND SUMMARIZE : Chapter 1 PROBLEMS 26 and 27 (pps 21 - 22)	W / 20 / JAN FOR W / 20 / JAN
R1. RECITATION : **TBA**	R / 21 / JAN
2. TOPIC : **System Concepts : System I Model Variables, Impedance** STUDY : Chapter 2 , pps 25 - 40 OUTLINE AND SUMMARIZE : Chapter 2	F / 22 / JAN FOR F / 22 / JAN
3. TOPIC : **System Concepts : Order, Degrees of Freedom, Constraints** STUDY : Chapter 2 , pps 40 - 60 PROBLEMS 1, 2, 3, 4 and 5 (pp 59)	M / 25 / JAN FOR M / 25 / JAN
4. TOPIC : **Mechanical Systems : Free Body Diagrams, Friction** STUDY : Chapter 3 , pps 61 - 80 PROBLEMS 3 and 7 (pp 139) * **SUBMIT** Homework Assignments 1, 2 and 3	W / 27 / JAN FOR W / 27 / JAN ON W / 27 / JAN
R2. RECITATION : **TBA**	R / 28 / JAN
5. TOPIC : **Mechanical Systems : Attachments, Springs, Dampers** STUDY : Chapter 3 , pps 80 - 104 PROBLEMS 10 and 15 (pps 141 - 143)	F / 29 / JAN FOR F / 29 / JAN

6. TOPIC : **Problem Session** PROBLEMS 18 and 26 (pps 143 - 147)	M / 1 / FEB FOR M / 1 / FEB
7. TOPIC : **Mechanical Systems : Position, Velocity, Acceleration** STUDY : Chapter 3 , pps 104 - 110 PROBLEMS 25 and 38 (pps 147 - 152) * **SUBMIT** Homework Assignments 4, 5, and 6	W / 3 / FEB FOR W / 3 / FEB ON W / 3 / FEB
R3. RECITATION : **TBA**	R / 4 / FEB
8. TOPIC : **Mechanical Systems : Rigid Body Contact, Ropes and Pulleys** STUDY : Chapter 3 , pps 110 - 122 PROBLEMS 40 and 42 (pps 152 - 154)	F / 5 / FEB FOR F / 5 / FEB
9. TOPIC : **Problem Session** PROBLEMS 45 and 28 (pps 147 - 155)	M / 8 / FEB FOR M / 8 / FEB
10. TOPIC : **Mechanical Systems : Angular Velocity** STUDY : Chapter 3 , pps 122 - 130 PROBLEMS 32 and 41 (pps 149 - 154) * **SUBMIT** Homework Assignments 7, 8 and 9	W / 10 / FEB FOR W / 10 / FEB ON W / 10 / FEB
R4. RECITATION : **TBA** 11. TOPIC : **Mechanical Systems : Kinetics** STUDY : Chapter 3 , pps 130 - 139 PROBLEMS 47 (p 155)	R / 11 / FEB F / 12 / FEB FOR F / 12 / FEB

12. TOPIC : **Problem Session**		M / 15 / FEB
13. TOPIC : **TBA**		W / 17 / FEB
* **SUBMIT** Homework Assignments 10 and 11	ON	W / 17 / FEB
R5. RECITATION : **EXAM 1**	ON	R / 18 / FEB
14. TOPIC : **Electrical Systems : Resistive Circuits**		F / 19 / FEB
STUDY : Chapter 4 , pps 159 - 162 PROBLEMS 1 and 2 (p 198)	FOR	F / 19 / FEB
15. TOPIC : **Electrical Systems : Capacitive Circuits**		M / 22 / FEB
STUDY : Chapter 4 , pps 162 - 169 PROBLEMS 3 and 4 (p 200)	FOR	M / 22 / FEB
16. TOPIC : **Problem Session**		W / 24 / FEB
PROBLEMS 5 (p 200)	FOR	W / 24 / FEB
* **SUBMIT** Homework Assignments 14 and 15	ON	W / 24 / FEB
R6. RECITATION : **TBA**		R / 25 / FEB
17. TOPIC : **Electrical Systems : Magnetic Fields, Force Generation, Voltage Induction**		F / 26 / FEB
STUDY : Chapter 4 , pps 169 - 179 PROBLEMS 6 (p 200)	FOR	F / 26 / FEB

18. TOPIC : **Electrical Systems : Inductor Circuits** STUDY : Chapter 4 , pps 179 - 189 PROBLEMS 11 (p 201) * **SUBMIT** DESIGN PROJECT NO. 1	M / 1 / MAR FOR M / 1 / MAR ON M / 1 / MAR
19. TOPIC : **Problem Session** PROBLEMS 12 (p 201) * **SUBMIT** Homework Assignments 16, 17 and 18	W / 3 / MAR ON W / 3 / MAR
R7. RECITATION : **Student Presentations (Problems 5, 6, 11, 12))**	R / 4 / MAR
20. TOPIC : **Electrical Systems :** **Electrical Impedance Relations** STUDY : Chapter 4 , pps 189 - 195 PROBLEMS 13 (p 201)	F / 5 / MAR FOR F / 5 / MAR
21. TOPIC : **Electrical Systems : Equivalent Circuits** STUDY : Chapter 4 , pps 195 - 198 PROBLEMS 7 and 9 (odd no. teams) 8 and 10 (even no. teams)	M / 8 / MAR FOR M / 8 / MAR
22. TOPIC : **Student Presentations (Problems 7, 8, 9, 10)** * **SUBMIT** Homework Assignments 19, 20 and 21	W / 10 / MAR ON W / 10 / MAR
R8. RECITATION : **PROCESS CHECK**	R / 11 / MAR
23. TOPIC : **Fluid Thermal Systems : Fluid Flow,** **Thermo Properties, Equilibrium** STUDY : Chapter 5 , pps 203 - 218	F / 12 / MAR FOR F / 1[illegible] / MAR

****** SPRING BREAK ******	M / 15 / MAR TO F / 19 / MAR
24. TOPIC : **Fluid Thermal Systems : Heat, Work, Entropy, Heat Engines and Pumps** STUDY : Chapter 5 , pps 218 - 233 * **SUBMIT** Tank Design Project	M / 22 / MAR FOR M / 22 / MAR ON M / 22 / MAR
25. TOPIC : **Problem Session** PROBLEMS Supplemental Homework # 1	W / 24 / MAR FOR W / 24 / MAR
R9. RECITATION : **EXAM II**	R / 25 / MAR
26. TOPIC : **Fluid Thermal Systems : Efficiency, Carnot and Rankine Cycles** STUDY : Chapter 5 , pps 233 - 243 PROBLEMS Supplemental Homework #'s 2,3,4 and 5	F / 26 / MAR FOR F / 26 / MAR
27. TOPIC : **Fluid Thermal Systems : Irreversibility and Availability** STUDY : Chapter 5 , pps 243 - 245	M / 29 / MAR FOR M / 29 / MAR
28. TOPIC : **Problem Session** PROBLEMS Supplemental Homework #'s 6,7,8,9 and 10 * **SUBMIT** Homework Assignments 25 and 26	W / 31 / MAR FOR W / 31 / MAR ON W / 31 / MAR
R10. RECITATION : **TBA**	R / 1 / APR
29. TOPIC : **Multiple Discipline : Electro-Mechanical Machines** STUDY : Chapter 6 , pps 251 - 255	F / 2 / APR FOR F / 2 / APR

30. TOPIC : **Multiple Discipline : Hydraulic Machines**		M / 5 / APR
STUDY : Chapter 6 , 255 - 261	FOR	M / 5 / APR
31. TOPIC : **Problem Session**		W / 7 / APR
* **SUBMIT** Homework Assignment 28	ON	W / 7 / APR
R11. RECITATION : **TBA**		R / 8 / APR
32. TOPIC : **Multiple Discipline : Multi Domain Problems**		F / 9 / APR
STUDY : Chapter 6 , pps 266 - 274 PROBLEM Chapter 6, Supplemental HW 1	FOR	F / 9 / APR
33. TOPIC : **Multiple Discipline : Operational Amplifiers**		M / 12 / APR
STUDY : Chapter 6 , pps 261 - 266 PROBLEMS 1, 2, 3, and 4 (pp 277)	FOR	M / 12 / APR
34. TOPIC : **Operational Amplifiers (Continued)**		W / 14 / APR
R12. RECITATION : **Competency Work Session**	ON	R / 15 / APR
35. TOPIC : **Sensors and Transducers; Reality to Reality**		F / 16 / APR
STUDY : Class Handout	FOR	F / 16 / APR
* **SUBMIT** Homework Assignment 32	ON	F / 16 / APR

36. TOPIC : **Team # 9 Presentation** Example 6.2 , "A Hydraulic Acutator"		M / 19 / APR
37. TOPIC : **Team # 4 Presentation** Example 6.3 , "A Moderately Strong Hydraulic Actuator"		W / 21 / APR
R13. RECITATION : **Competency Work Session**		R / 22 / APR
38. TOPIC : **Team # 5 Presentation** Chapter 6, Supplemental Homework Problem		F / 23 / APR
* **SUBMIT** Homework Assignment 33	ON	F / 23 / APR
39. TOPIC : **Team # 6 Presentation** Example 6.6 , "A System With Feedback Constraints"		M / 26 / APR
40. TOPIC : **Team # 8 Presentation** Example 6.7 , "An Electric Hoist"		W / 28 / APR
R14 RECITATION : **INTEL General Manager Presentation**	ON	R / 29 / APR
41. TOPIC : **Team # 7 Presentation** Problem 17 (pp 280) "A DC Motor With Multiple Viscous Friction"		F / 30 / APR
42. TOPIC : **Team # 3 Presentation** Problem 15 (pp 280) "Matching a Motor to a Load"		M / 3 / MAY
43. TOPIC : **Team # 2 Presentation** Example 3.27, "A Slider Crank Mechanism, Internal Combustion Engine"		W / 5 / MAY
44. **FINAL EXAM** 7:40 AM - 9:30 AM , ECG 238 **Individual Opportunities ONLY!**		W / 12 / MAY

Learning Outcomes	Competency Category	Competencies	Knowledge	Comprehension / Understanding	Application	Analysis	Synthesis	Appreciation / Evaluation
		Course 3 : Modeling and Behavior of Engineering Systems						
		Course 1 : Conservation Principles in Engineering REVIEW						
	System Definition / Selection	Labeled Sketches						
		System or Free body Diagram						
		Surroundings						
		Time Period						
		Data (Nature)						
		Specifications (Human)						
		Parameters (Shared)						
		Coordinate System (Motion Easy?)						
		Required						
		Assumptions						
		Defining Relationships (Constraints)						
	Analysis of a Mathematical Model	Variables (All)						
		Equations						
		Data (Nature)						
		Specifications (Human)						
		Parameters (Shared)						
		Initial Conditions (Include t0)						
		Remaining Unknowns						
	Conservation Concepts	Total Mass						
		Elemental Mass						
		Total Charge						
		Linear Momentum						
		Angular Momentum						
		Total Energy						
		Entropy (Cosmos, A)						
	Accounting Concepts	Species Mass (A)						
		Moles (A)						
		Plus Charge						
		Minus Charge						
		Electrical Energy (A,D)						
		Mechanical Energy (A,D)						
		Mechanical Energy (Particles, A,D)						
		Mechanical Energy (Rigid Bodies, A,D)						
		Mechanical Energy (Fluid Flow, A, I)						
		Entropy (System, A)						
		Entropy (Surroundings, A)						
		Entropy Generation (Irreversibility)						
	Other	Extensive Properties						
		Intensive Properties						
		Tables for Extensive Properties						
		KCL						
		KVL						
	Knowledge Types	Content (Concepts)						
		Procedural (Know-How)						
		Conditional (Decisions)						
	Mathematical Models / Variable Types	Inputs						
		Outputs						
		Disturbances						
		Degrees of Freedom						
		Order						
		Auxiliary Variables (DOF-Order)						
		Constraints						
	Mathematical Model / System Variables	Effort						
		Flow						
		Impedance						
		Interrelationships (Independence)						
		Power						
		State						

Learning Outcomes	Competency Category	Competencies	Knowledge	Comprehension / Understanding	Application	Analysis	Synthesis	Appreciation / Evaluation
Course 3 : Modeling and Behavior of Engineering Systems								
	Friction	Freebody Diagrams						
		• Single Body						
		• Multiple Bodies						
		Static (Dry)						
		• Limits						
		• Impending Motion						
		• Known Direction (Magnitude?)						
		• Known Force (Direction?)						
		Dynamic (Dry?)						
		• Known Direction (Magnitude?)						
		• Known Force (Direction?)						
		Viscous (Fluid)						
		• Rigid Body Motion						
		• Bearings, etc.						
		• Dampers or Dashpots						
		Springs (Force, Mechanical Energy)						
	Static Analysis of Structures: Trusses and Frames Only	System or Freebody Diagram						
		• Joint (Truss and LM Only)						
		• Member						
		• Section						
		• Structure						
		Attachments and Connections						
		Friction						
		Ropes and Pulleys						
		Springs (Force Only)						
		Tension / Compression (3rd Law)						
	Rigid Body Motion	Freebody diagram						
		Dynamic Friction (Dry)						
		Viscous Friction						
		Springs (Force, Mech. Energy)						
		Specifying Motion (Function of t)						
		• Acceleration, Velocity, Pos.						
		Method of Special Points						
		• Known and Unknown Points						
		• Contact Points						
		•• Permanent						
		•• Temporary, No Slip						
		•• Temporary, With Slip						
		• Number of Constraints						
		Method of Vector Loops						
		Angular Velocity						
		• Inertial Reference						
		• Painted Line on Body						
		• Right Hand Rule						
		• Adding Angular Velocities						
		Angular Momentum Conservation						
		• Intertial Reference Frame						
		• Moving Point (Fixed W/CG)						
		• About the Center of Gravity						
		• Moments (RHR, Cross Product)						
		Multiple Rigid Bodies (Additive)						
		Linear Momentum, Mech. Energy						

Learning Outcomes	Competency Category	Competencies	Knowledge	Comprehension / Understanding	Application	Analysis	Synthesis	Appreciation / Evaluation
Course 3 : Modeling and Behavior of Engineering Systems								
	Electrical Circuits / Electrical Energy Accounting	Degrees of Freedom						
		Order						
		Circuit Elements						
		Resistors						
		• Two Possible Flows						
		• Defining Relationship						
		• Energy Dissipation (to?)						
		• Time Response, V and I						
		• Impedance Relationship						
		•• High/Low Frequency						
		Capacitors						
		• Defining Relationship						
		• Energy Storage/Release						
		• Time Response, V and I						
		• Switching Capacitive Loads						
		• Steady State Response						
		• Impedance Relationship						
		•• High/Low Frequency						
		Inductors						
		• Defining Relationship						
		• Energy Storage/Release						
		• Time Response, V and I						
		• Switching Inductive Loads						
		• Steady State Response						
		• Impedance Relationship						
		•• High/Low Frequency						
		• External/Internal Magnetic Fields						
		•• Vector Representation, RHR						
		•• Magnetic Fluxes						
		•• External Forces						
		• Self Induction						
		• Mutual Induction						
		•• Modeling Induced Voltage						
		• Transformers						
		• DC Induction Machines						
		•• External Forces						
		•• External Torques						
		•• Torque/Current Relationships						
		•• Induced Volt./Angular Velocity						
		•• Total Energy Equation						
		Equivalent Impedances						
		Voltage Sources						
		Current Sources						
		Equivalent Sources (Transformation)						
		Diodes						
		Photodiodes						
		Transistors						
		Switches						
		Operational Amplifiers						
		• Function (Reality-Reality)						
		• Circuit Isolation						
		• Open Loop Response						
		• Feedback Elements						
		• Summer						
		• Integrator						
		• Differentiator						
		Sensors						
		• Function (Reality-Reality)						
		• Types						

Learning Outcomes	Competency Category	Competencies	Knowledge	Comprehension / Understanding	Application	Analysis	Synthesis	Appreciation / Evaluation
Course 3 : Modeling and Behavior of Engineering Systems								
	Fluid Systems	Fluid Statics/Hydraulics						
		Fluid Dynamics						
		* Mechanical Energy Accounting						
		Steady State Flow						
		* Turbulent						
		* Laminar						
		* Conservation of Mass						
		Power Sources						
		* Pumps (liquids)						
		Compressors (gasses)						
		* Other						
		Friction Losses						
		* Conduit						
		** Equivalent Diameter						
		** Contraction						
		** Expansion						
		** Elbows						
		** Tees						
		** Pumps/Compressors						
		Flow Measurement						
		* Orifices						
		* Venturi						
		* Level Measurement						
		* Other Devices/Methods						
		Hydraulic Actuators						

Learning Outcomes	Competency Category	Competencies	Knowledge	Comprehension / Understanding	Application	Analysis	Synthesis	Appreciation / Evaluation
		Course 3 : Modeling and Behavior of Engineering Systems						
	Thermal Systems / Thermodynamics	State						
		State Functions						
		Gibbs Phase Rule						
		Paths						
		* Isothermal						
		* Isobaric						
		* Isometric						
		* Adiabatic						
		* Isentropic						
		* Polytropic						
		* Reversible						
		* Irreversible						
		** Causes of Irreversibility						
		* Other Paths						
		Path Functions						
		* Work						
		* Heat						
		* Entropy Generation						
		Equilibrium						
		Phase Diagrams (Liquid/Vapor)						
		* P - T						
		* P - V						
		* Other						
		Pure Component Property Determination						
		* Graphical						
		* Tabular						
		** Single Interpolation						
		** Double Interpolation						
		* Equation of State						
		** Perfect Gas						
		** Ideal Gas						
		** Incompressible Liquid						
		** Real Fluids						
		* Two Phase Mixtures						
		Thermodynamic Cycles						
		* Carnot						
		** Essential Elements (6)						
		** Power						
		** Refrigeration						
		** Heat Pump						
		* Other Cycles						
		Thermodynamic Efficiency						
		*Theoretical Maximum						
		* Thermal						
		* Isentropic						
		* Mechanical						
		* Other Efficiencies						
		Availability						
		* Property						
		* Closed System						
		* Open System						