Share The Future - II

A Working Conference

Sophomore Engineering Curricula -

A Proven, Innovative Approach to

Engineering Science Education

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Objectives of Workshop

- Revisit the idea of a *core* curricula.
- Discuss a proven approach to integrate the engineering science core.
- Discuss ways to apply this framework to develop courses and curricula.

Workshop Overview

- Introductions
- Systems, Conservation & Accounting, and Modeling Paradigm
  - Concepts & Definitions
  - Conservation & Accounting Principles
  - Common Problem Solving Format
  - Example Solutions
- Curricula -- TAMU & RH
- Questions

What's a
Sophomore Engineering Curricula?

An integrated engineering science (and mathematics) curricula taught at the sophomore level.

Advantages of the Systems, Accounting & Modeling Approach

- provides a conceptual framework.
- unifies the presentation of physical laws.
- helps students see links between apparently unrelated topics.
- promotes transfer of learning.
- allows a common problem solving strategy that helps students tackle new problems and apply new concepts.

Group Activity 1

Assuming that there is an engineering science and mathematics core that should be common for all engineering students,

- what would you place in the core in terms of courses or topics, and
- what, if any, common concepts or topics run through all of the core courses?

Is there a core?

?

What's Core Material?

?

What are the themes or threads of the core?

?

What's the Sophomore Engineering Curriculum approach?

A curriculum built on the belief that

- There is a **<u>common engineering science and mathematics *core*</u>** for *all* engineers.
- This **<u>*core* should serve as a foundation</u>** for discipline specific education.
- Both **<u>vertical and horizontal integration</u>** of course material are important.
- Learning can be improved if the *core* is built around **<u>a few key concepts</u>**.

What's Core Material?

Diff. Equations I	Dynamics	Circuits
Fluid Mechanics	Linear Algebra	Statistics
Statics	Thermodynamics	Diff. Equations II
Heat Transfer	System Dynamics	Mechanics of Materials
	Materials	

Sophomore Engineering Curriculum
Content

?

Sophomore Engineering Curriculum

Contents

Free-Body Diagram
Ideal Spring
Dry Friction
Force
F = ma

Ideal Gas Law
Steam Tables
Closed System
Open System
Work & Heat Transfer

Ohm's Law
Node
Current
Voltage
KCL & KVL

Mass Flow
Control Volume
Friction Factor
Newtonian Fluid
Pressure

Sophomore Engineering Curriculum
Common Threads

Constitutive Relations

- **Ohm's Law**
- **Ideal Spring**
- **Dry Friction**
- **Ideal Gas Law**
- **Steam Tables**
- **Friction Factor**
- **Newtonian Fluid**

System

- **Node**
- **Free-Body Diagram**
- **Closed System**
- **Open system**
- **Control Volume**

Interactions with Surroundings

- **Current**
- **Force**
- **Work**
- **Heat Transfer**
- **Mass Flow**

Modeling Assumptions

Physical Constraints

Accounting Equations

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Common Threads

Constitutive Relations

System

Interactions with Surroundings

Modeling Assumptions

Physical Constraints

Accounting Equations

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Common Themes

- Conservation and accounting framework for physical laws
- Problem solving with a common strategy
  - Systems
  - Conservation and accounting concept
  - Modeling

Where did this approach come from?

Where did it come from?

- 1987 - Unified Engineering Science Curriculum Project
  - NSF-funded project at Texas A&M
  - Developed a four-course sequence of sophomore engineering courses (the “20X sequence”):
    - Conservation Principles in Engineering
    - Properties of Matter
    - Modeling/Behavior of Engineering Systems
    - Conservation Principles of Continuous Media
  - http://www-chen.tamu.edu/uesc/

Where did it come from?

- L. Prandtl's fluid mechanics work in the early 1900's.
- Discipline of system dynamics
- Recent calls from physics
  - H. Burkhardt, "System physics: A uniform approach to the branches of classical physics." *Am. J. Phys. 55,* 344-350, 1987.
  - Chapter 1 in H. Fuchs, *The Dynamics of Heat*. Springer-Verlag, 1996.

W. G. Vincenti, *What Engineers Know and How They Know It,* Johns Hopkins Press, 1990.

- "Engineers, unlike physicists, are after useful artifacts and must predict the performance of the objects they design."
- **"Organization according to control-volume ideas is thus not only simpler but brings clearer under-standing of the physical principles common to otherwise disparate situations."**
- "By organizing knowledge according to physical laws rather than known problems, it aids in recognizing a control-volume problem when met in an unfamiliar disguise."

- “Control-volume analysis, by setting up an explicit method of bookkeeping for the various flow quantities, provides such a procedure for the many engineers who must deal with fluid-mechanical devices.”
- **“Control-volume analysis is useful precisely because it provides a framework and method for thinking clearly about a large class of the often confusing problems that arise in engineering design.”**

From Chpt 4, “A Theoretical Tool for Design: Control-Volume Analysis, 1912-1953.”

Concepts & Definitions

- Model
- System
  - Open system
  - Closed system
- Property
  - Intensive property
  - Extensive property
- State of a system
- Process
  - Steady state
  - Finite time
  - Transient
- Interaction
- Accounting Principle
- Conserved Property
- Constitutive Relation

Group Activity 2

- Match the name with the appropriate definition.
- Compare your answers with your team members

Some Concepts Defined

System - any region of space or quantity of matter set aside for analysis

Open system vs. Closed system

Isolated system

Property - any characteristic of a system that can be assigned a numerical value at a specified time without considering the history of the system.

Extensive property vs. Intensive property

Some Concepts Defined

State of a system - complete description of the system in terms of its properties

Process - the means by which a system changes its state.

Steady-state system

Interaction - the transport of an extensive property across a system's boundary.

Conserved property - a property that cannot be generated or consumed.

Accounting Equation for Extensive Property B

$$\frac{dB_{sys}}{dt} = \left[\dot{B}_{in} - \dot{B}_{out} \right] + \left[\dot{B}_{gen} - \dot{B}_{cons} \right]$$

Rate of Accumulation
of *B*
inside the system
at time *t*

Net Transport Rate
of *B*
into the system
at time *t.*

Net Generation Rate
of *B*
inside the system
at time *t*

Accounting Equation for Extensive Property B

$$\frac{d}{dt}B_{sys} = \underbrace{\left[\dot{B}_{in} - \dot{B}_{out}\right]}_{\substack{\text{net rate transported}\\ \text{across the boundary}\\ \text{into the system}}} + \underbrace{\left[\dot{B}_{generated} - \dot{B}_{consumed}\right]}_{\substack{\text{net rate generated}\\ \text{within the system}}}$$

$$= \left[\dot{B}_{net,in}\Big|_{\substack{without\\ mass\ flow}} + \dot{B}_{net,in}\Big|_{\substack{with\\ mass\ flow}}\right] + \left[\dot{B}_{generated} - \dot{B}_{consumed}\right]$$

$$= \left[\dot{B}_{net,in}\Big|_{\substack{without\\ mass\ flow}} + \sum_{in}\dot{m}_i b_i - \sum_{out}\dot{m}_e b_e\right] + \left[\dot{B}_{generated} - \dot{B}_{consumed}\right]$$

Sophomore Engineering Curriculum

Systems & Accounting Framework for Physical Laws

- What's the extensive property?
- How can it be counted?
- How can it be stored in the system?
- How can it be transported?
- How can it be generated or consumed?

Rate of Storage = **Net Transport Rate In** + **Net Generation Rate**

Example

Conservation of

Linear Momentum

Conservation of Linear Momentum

What is linear momentum?

The linear momentum of a particle is the product of the mass of the particle *m* and its velocity **V**. Students already know this definition from physics.

$$\vec{P} = m\vec{V}$$

Conservation of Linear Momentum

How can it be stored in and quantified for a system?

$$\vec{P}_{sys} = \int_{V_{sys}} \vec{V}\, r\, dV$$

$$\vec{P}_{sys} = \sum \vec{P}_j = \sum m_j \vec{V}_j$$

Conservation of Linear Momentum

How can it be transported across the system boundaries?

- External Forces
  - Contact Forces
  - Body Forces
- Mass transport

$$\vec{F}_{external}$$

$$\dot{m}\vec{V}$$

Conservation of Linear Momentum

How can linear momentum be generated or consumed within the system?

Experience has shown that it is impossible to create or destroy linear momentum; hence, we say that ***linear momentum is conserved***.

$$\dot{\vec{P}}_{gen} = \dot{\vec{P}}_{con} = 0$$

Conservation of Linear Momentum (Rate form)

$$\frac{dB_{sys}}{dt} = \left[\dot{B}_{in} - \dot{B}_{out}\right] + \left[\sum_{in}\dot{m}_i b_i - \sum_{out}\dot{m}_e b_e\right] + \left[\dot{B}_{gen} - \dot{B}_{cons}\right]$$

$$\frac{d\vec{P}_{sys}}{dt} = \left[\dot{\vec{P}}_{in} - \dot{\vec{P}}_{out}\right] + \left[\sum_{in}\dot{m}_i \vec{V}_i - \sum_{out}\dot{m}_e \vec{V}_e\right] + \left[\dot{\vec{P}}_{gen} - \dot{\vec{P}}_{cons}\right]$$

0

$$\sum \vec{F}_{external}$$

Conservation of Linear Momentum

$$\vec{P}_{sys} = \int_{V_{sys}} \vec{V} \, r \, dV$$

$$\frac{d\vec{P}_{sys}}{dt} = \sum \vec{F}_{ext} + \left[\sum_{in} \dot{m}_i \vec{V}_i - \sum_{out} \dot{m}_e \vec{V}_e \right]$$

where $\dot{m}$ is the mass flow rate.

Recovering F = ma

$$\frac{d\vec{P}_{sys}}{dt} = \sum \vec{F}_{ext} + \left[\sum_{in} \dot{m}_i \vec{V}_i - \sum_{out} \dot{m}_e \vec{V}_e \right]$$

Closed System

$$\vec{P}_{sys} = m_G \vec{V}_G$$

$$\dot{m} = 0$$

$$\frac{d}{dt}\left(m_G \vec{V}_G\right) = \sum \vec{F}_{ext} \quad \rightarrow \quad m_G \frac{d}{dt}\left(\vec{V}_G\right) = m_G \vec{a}_G = \vec{F}_{net}$$

Group Activity 3

- Match the *extensive property* with its corresponding accounting (or conservation) equation.

Rate Form of Basic Laws

$$\frac{dm_{sys}}{dt} = \sum_{in} \dot{m}_i - \sum_{out} \dot{m}_e \qquad \frac{dq_{sys}}{dt} = \sum_{in} \dot{q}_i - \sum_{out} \dot{q}_e$$

$$\frac{d\vec{P}_{sys}}{dt} = \sum_j \vec{F}_{ext,j} + \left[\sum_{in} \dot{m}_i \vec{V}_i - \sum_{out} \dot{m}_e \vec{V}_e \right]$$

$$\frac{d\vec{L}_{o,sys}}{dt} = \sum_j \vec{M}_{o,j} + \left[\sum_{in} \dot{m}_i \left(\vec{r}_i \times \vec{V}_i \right) - \sum_{out} \dot{m}_e \left(\vec{r}_e \times \vec{V}_e \right) \right]$$

$$\frac{dE_{sys}}{dt} = \dot{Q}_{net,in} + \dot{W}_{net,in} + \left[\sum_{in} \dot{m}_i \left(h_i + \frac{V_i^2}{2} + gz_i \right) - \sum_{out} \dot{m}_e \left(h_e + \frac{V_e^2}{2} + gz_e \right) \right]$$

$$\frac{dS_{sys}}{dt} = \sum_j \frac{\dot{Q}_j}{T_j} + \left[\sum_{in} \dot{m}_i s_i - \sum_{out} \dot{m}_e s_e \right] + \dot{S}_{gen}$$

Sophomore Engineering Curriculum
Problem Solving Format

- Known
- Find
- Given
- Analysis →
  - Strategy
  - Constructing model
  - Solution
- Comments

Typical Questions

•What's the system?

•What properties should we count?

•What's the time interval?

•What are the important interactions?

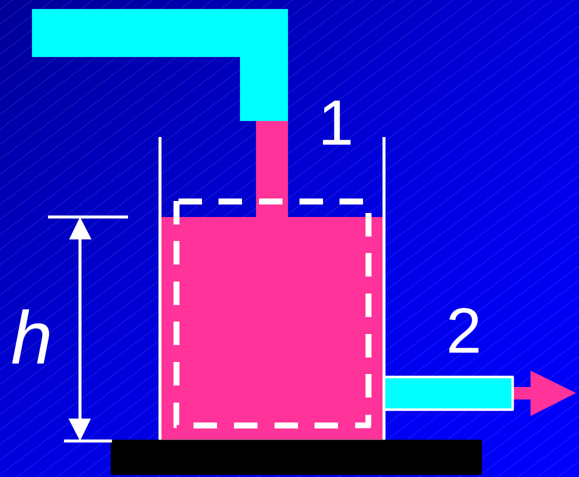
•What are the important constitutive relations?

•How do the basic equations simplify?

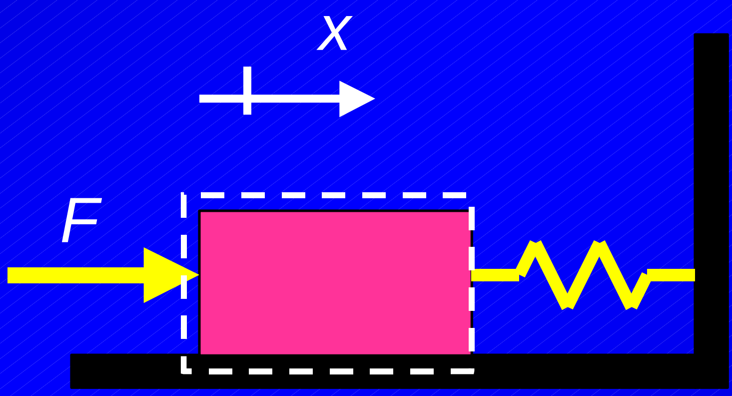
•What are the unknowns?

•How many equations do I need?

Find $h(t)$.

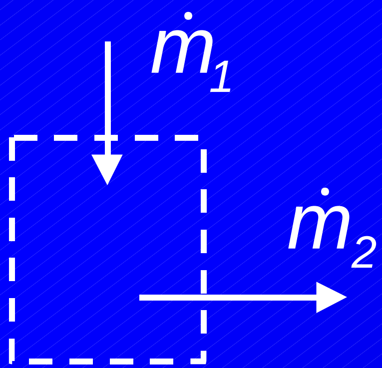


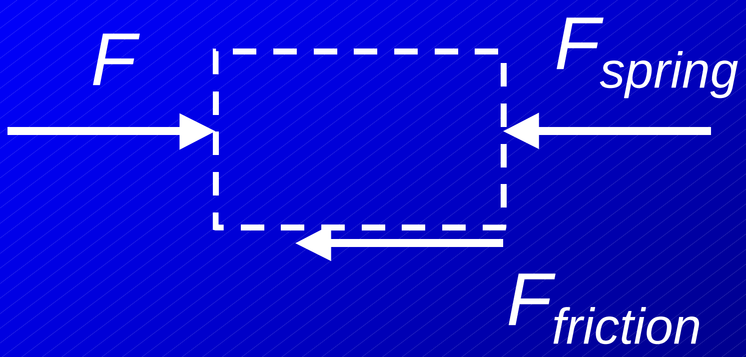
Find $V_x(t)$.



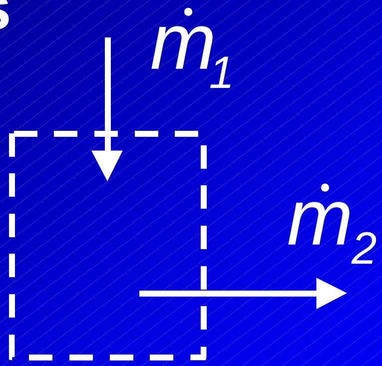
Mass

Linear Momentum

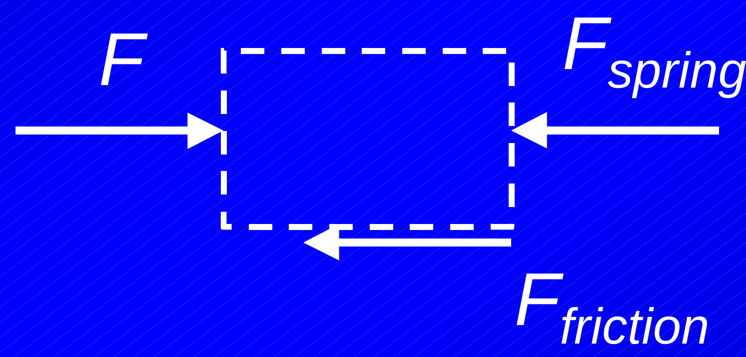




Mass



Linear Momentum



$$\frac{dm_{sys}}{dt} = \dot{m}_1 - \dot{m}_2$$

$$\frac{d}{dt}\left(r A_{tank} h \right) = \dot{m}_1 - C\sqrt{gh}$$

$$\frac{dh}{dt} = \frac{\dot{m}_1}{r A_{tank}} - \frac{C\sqrt{gh}}{r A_{tank}}$$

$$\frac{dP_{x,sys}}{dt} = F - F_{friction} - F_{spring}$$

$$\frac{d}{dt}\left(mV_x \right) = F - m_k mg - kx$$

$$\frac{dV_x}{dt} = \frac{F}{m} - m_k g - \frac{kx}{m}$$

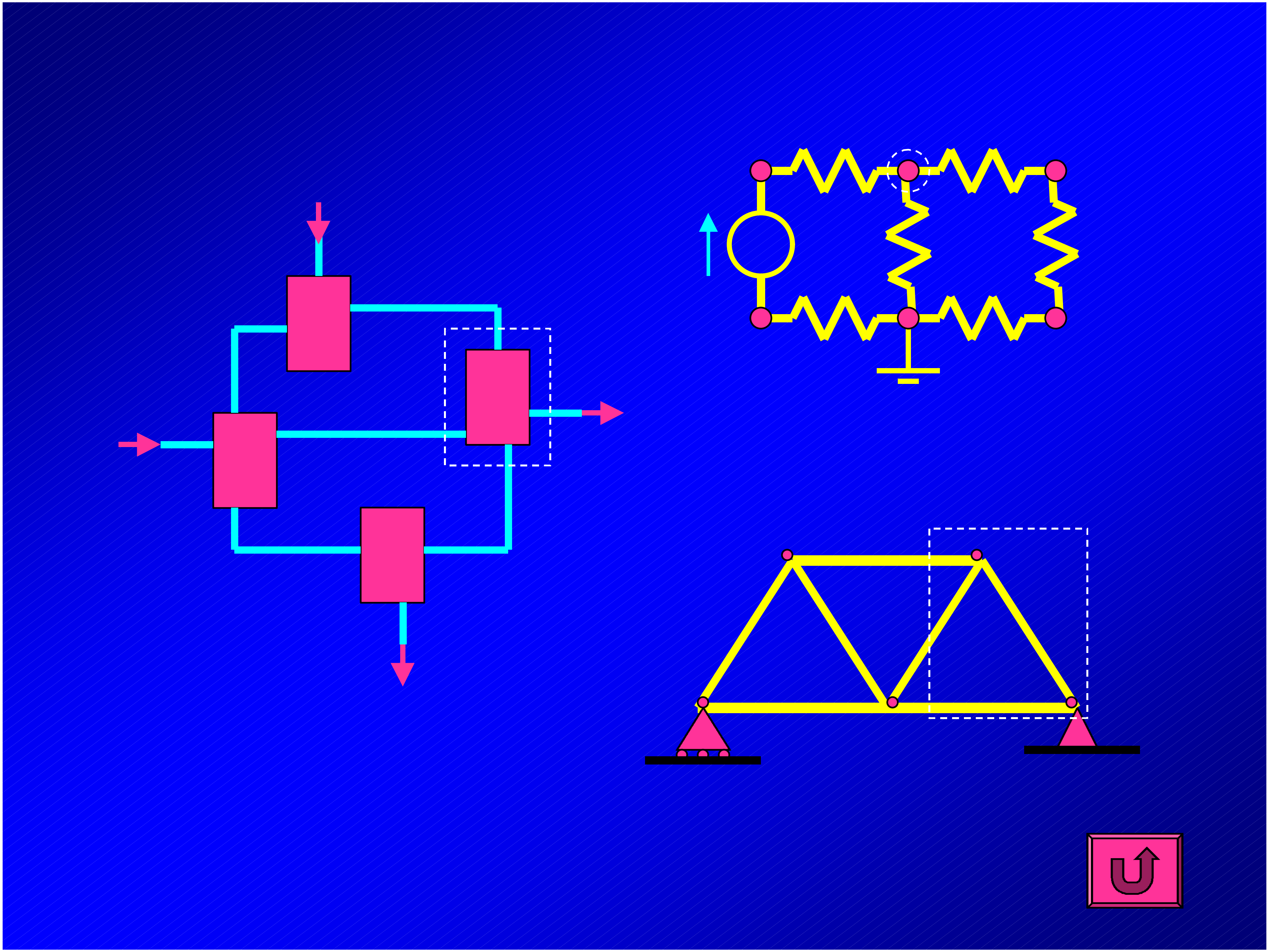
Examples of how students are taught to solve problems

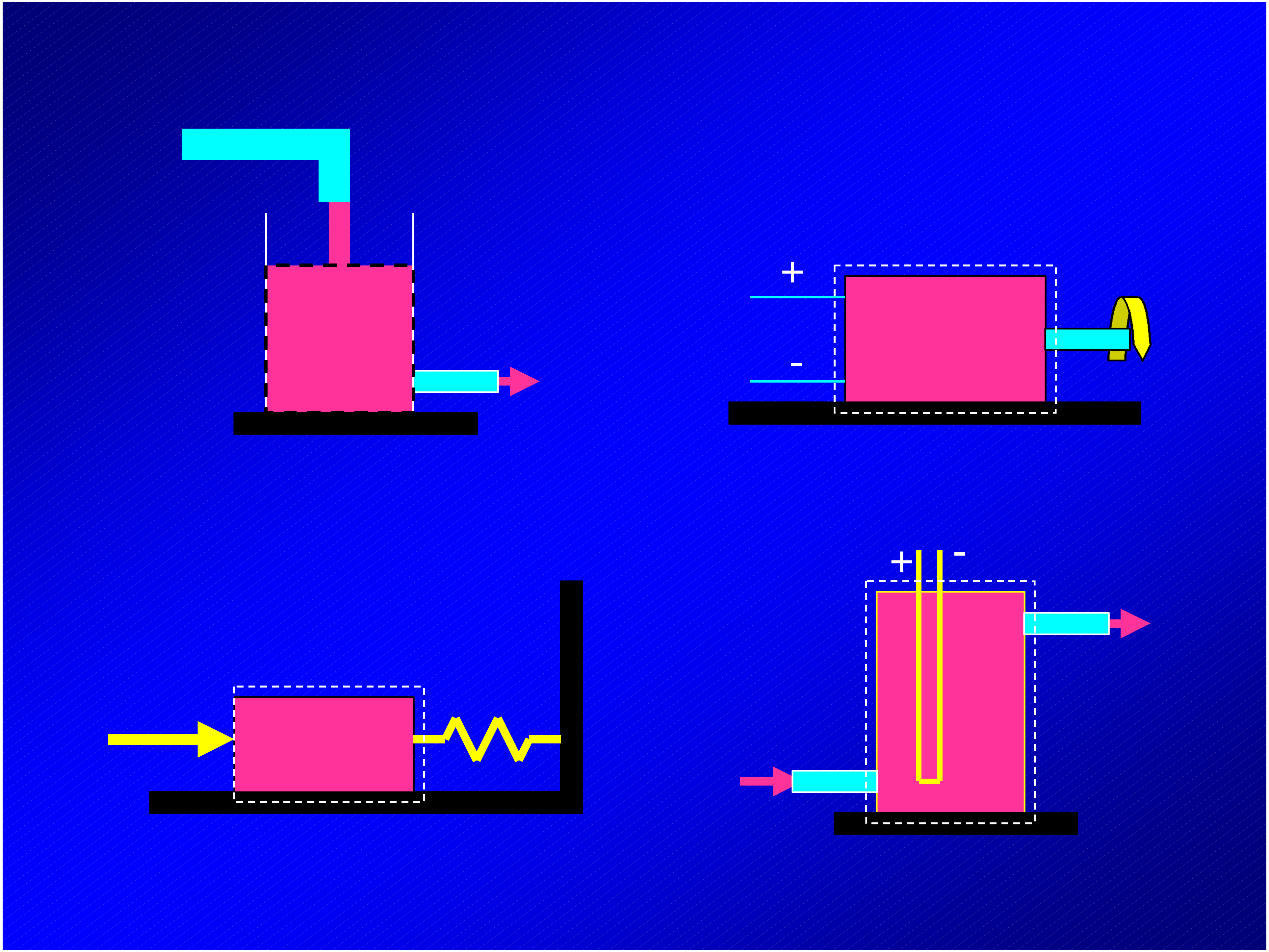
Heat Engine Performance

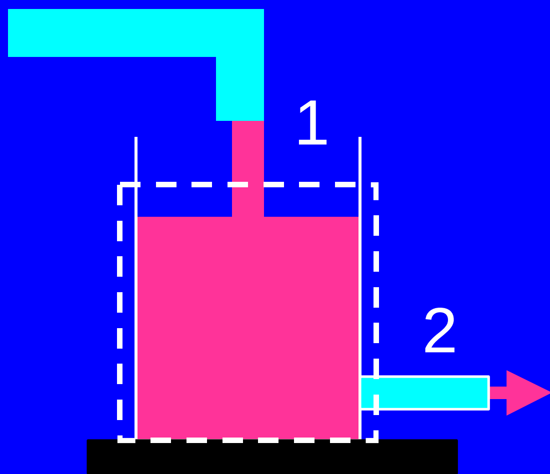
Monkeys on a Rope

Colliding Train Cars

Grain Conveyor Belt



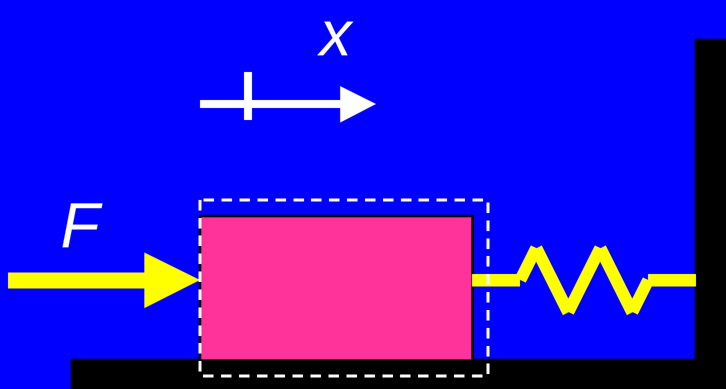




$$\frac{dm_{sys}}{dt} = \dot{m}_1 - \dot{m}_2$$

$$\frac{d}{dt}\left(rA_{tank}h\right) = \dot{m}_1 - C\sqrt{gh}$$

$$\frac{dh}{dt} = \frac{\dot{m}_1}{rA_{tank}} - \frac{C\sqrt{gh}}{rA_{tank}}$$



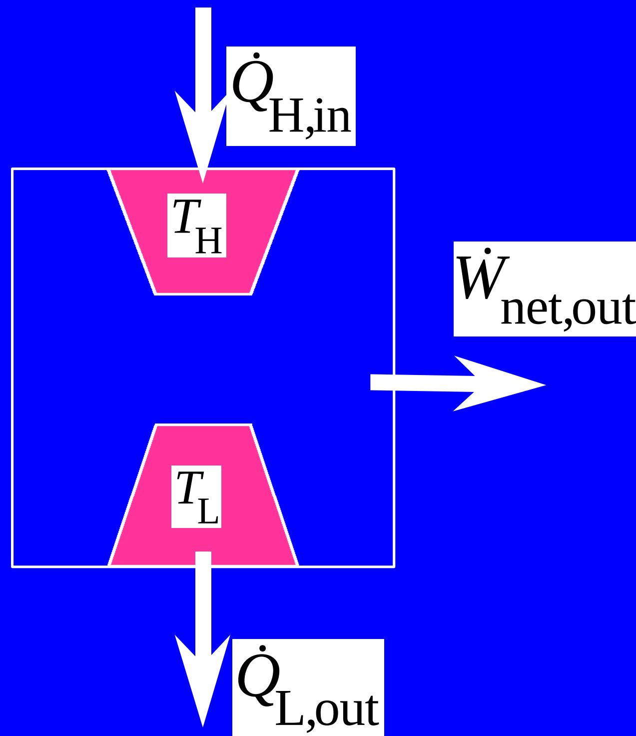
$$\frac{dP_{x,sys}}{dt} = F - m_k mg - kx$$

$$\frac{d}{dt}\left(mV_x\right) = F - m_k mg - kx$$

$$m\frac{dV_x}{dt} = \frac{F - m_k mg - kx}{m}$$

Example - Carnot Cycle Revisited

What is the maximum thermal efficiency of a steady-state heat engine that receives energy by heat transfer at a surface temperature T_H and rejects energy by heat transfer at a surface temperature T_L?



Analysis

What's the system?

What properties should we count?

What is the time interval?

What are the important interactions?

$$\frac{dE_{sys}}{dt} \overset{0,SS}{=} \dot{Q}_{net,in} + \dot{W}_{net,in}$$

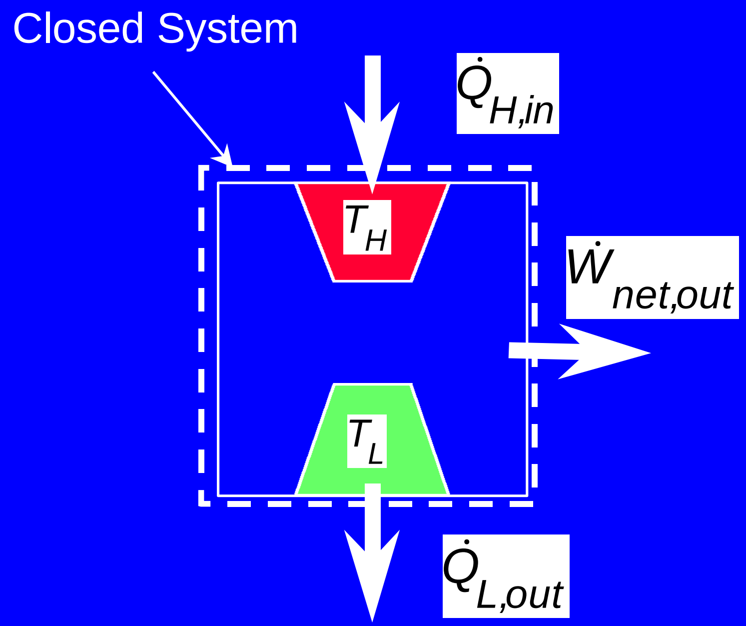
$$0 = \left[\dot{Q}_{H,in} - \dot{Q}_{L,out}\right] - \dot{W}_{net,out}$$

$$\dot{W}_{net,out} = \dot{Q}_{H,in} - \dot{Q}_{L,out}$$

$$\frac{dS_{sys}}{dt} \overset{0,SS}{=} \sum_j \frac{\dot{Q}_j}{T_j} + \dot{S}_{gen}$$

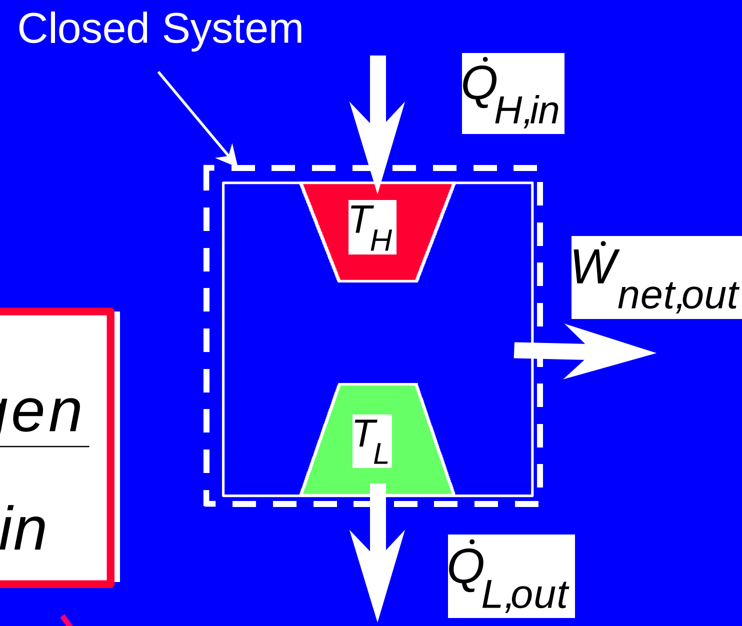
$$0 = \left[\frac{\dot{Q}_{H,in}}{T_H} - \frac{\dot{Q}_{L,out}}{T_L}\right] + \dot{S}_{gen}$$

$$\dot{Q}_{L,out} = \dot{Q}_{H,in}\left(\frac{T_L}{T_H}\right) + T_L \dot{S}_{gen}$$



$$\dot{W}_{net,out} = \dot{Q}_{H,in} - \left[\dot{Q}_{H,in}\frac{T_L}{T_H} + T_L \dot{S}_{gen}\right]$$

$$h = \frac{\dot{W}_{net,out}}{\dot{Q}_{H,in}} = \left[1 - \frac{T_L}{T_H}\right] - \frac{T_L \dot{S}_{gen}}{\dot{Q}_{H,in}}$$



$$h = \frac{\dot{W}_{net,out}}{\dot{Q}_{H,in}} = \left[1 - \frac{T_L}{T_H}\right] - \frac{T_L \dot{S}_{gen}}{\dot{Q}_{H,in}}$$

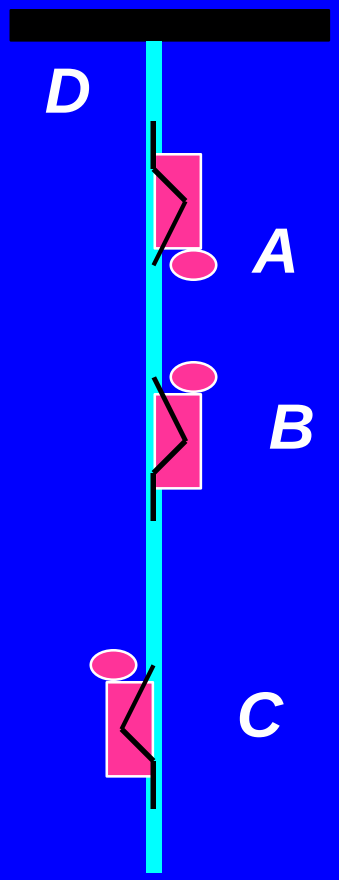
$$h\Big|_{max} = \left[1 - \frac{T_L}{T_H}\right]$$

$$\frac{T_L \dot{S}_{gen}}{\dot{Q}_{H,in}} \geq 0$$

Example - Monkeys on a Rope

Three monkeys *A, B, and C* with masses of 10, 12, and 8 kg, respectively, are climbing up and down the rope suspended from point *D*. At the instant shown in the figure, *A* is descending the rope with an acceleration of 1.6 m/s^2, and *C* is pulling himself up with an acceleration of 0.9 m/s^2. Monkey *B* is climbing up with a constant speed of 0.6 m/s.

Determine the tension *T* in the rope at *D,* in newtons.



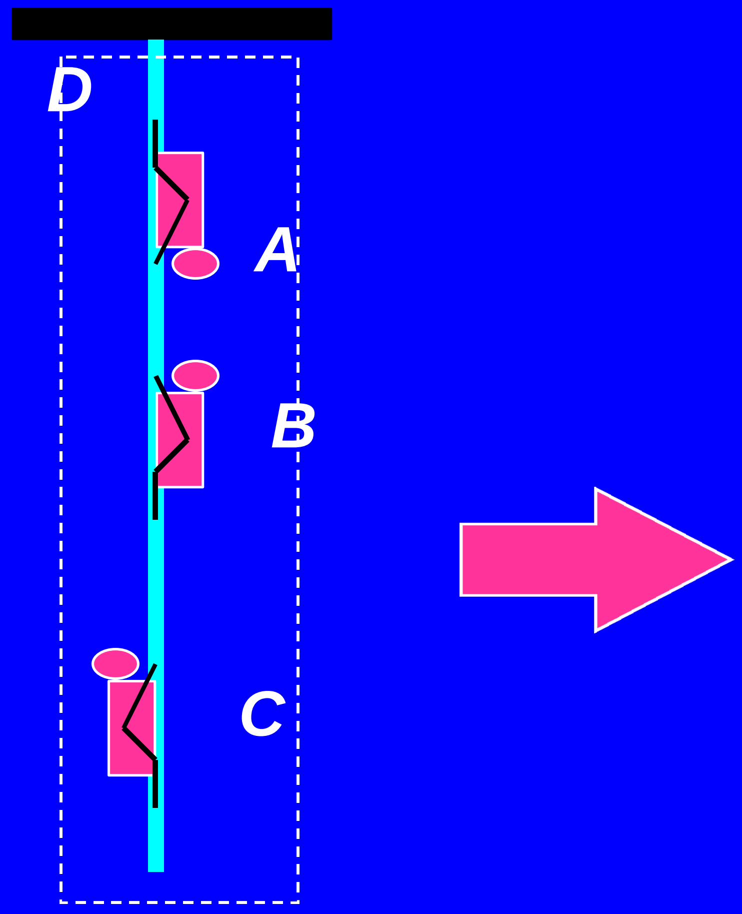
Analysis

What's the system?

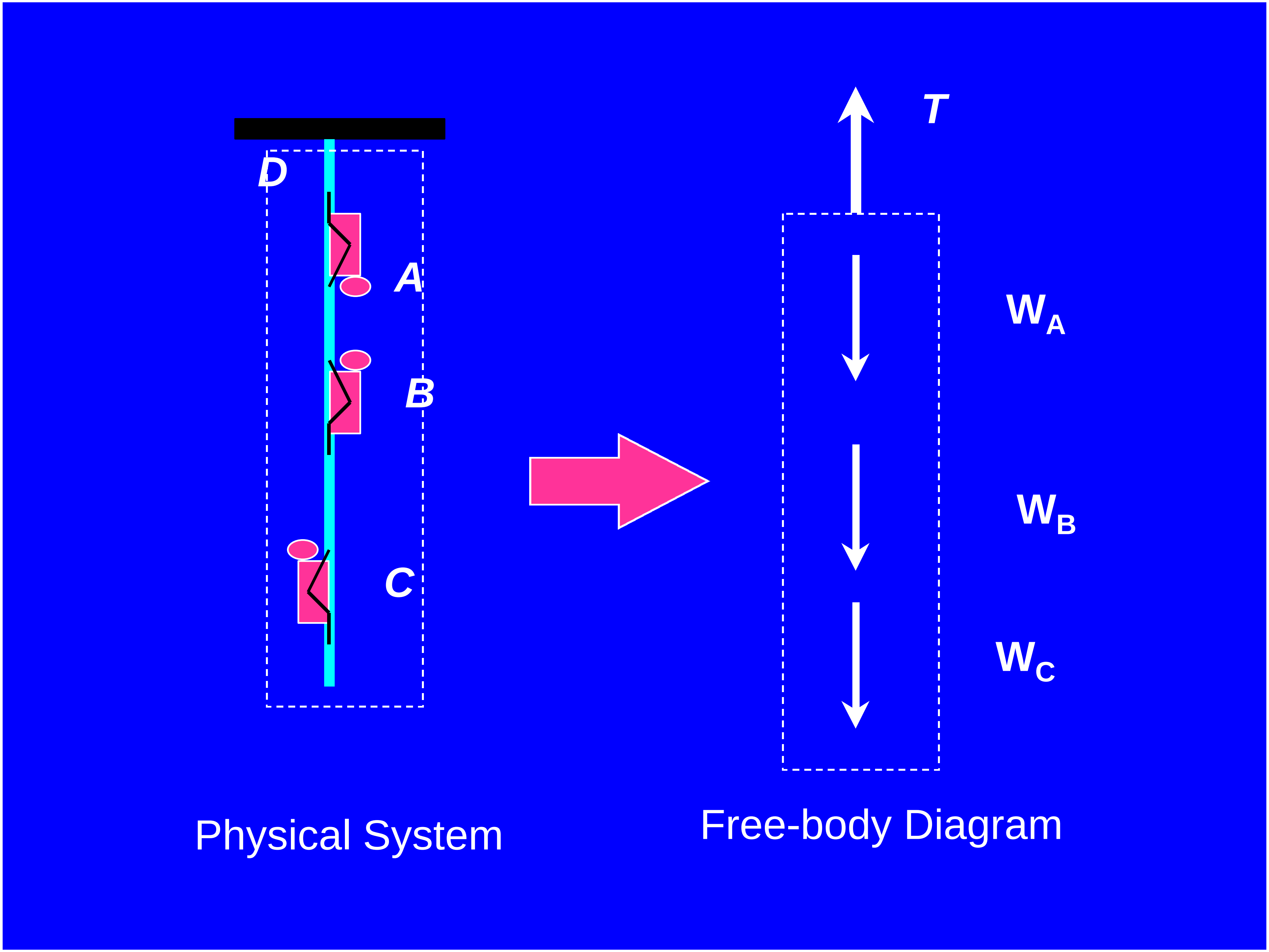
What properties should we count?

What is the time interval?

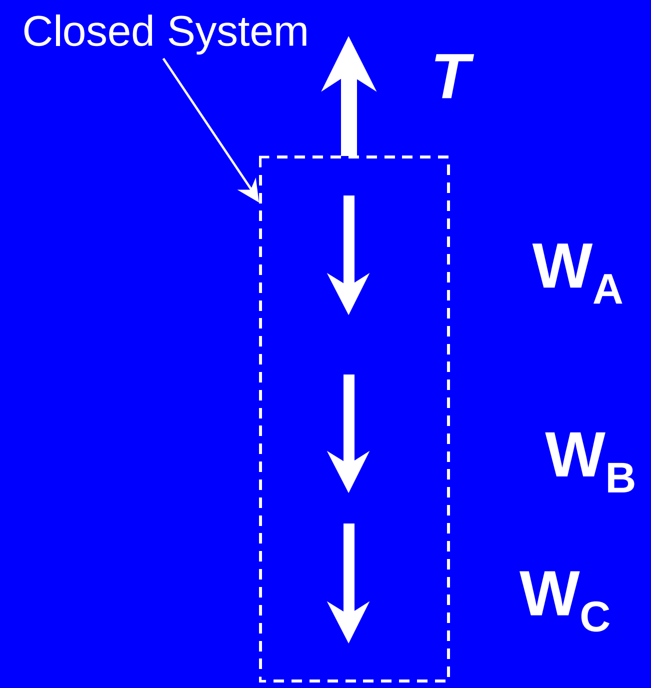
What are the important interactions?



Physical System


D
A
B
C
T
W_A
W_B
W_C
Physical System
Free-body Diagram

$$\frac{d\vec{P}_{sys}}{dt} = \sum_j \vec{F}_{ext,j}$$



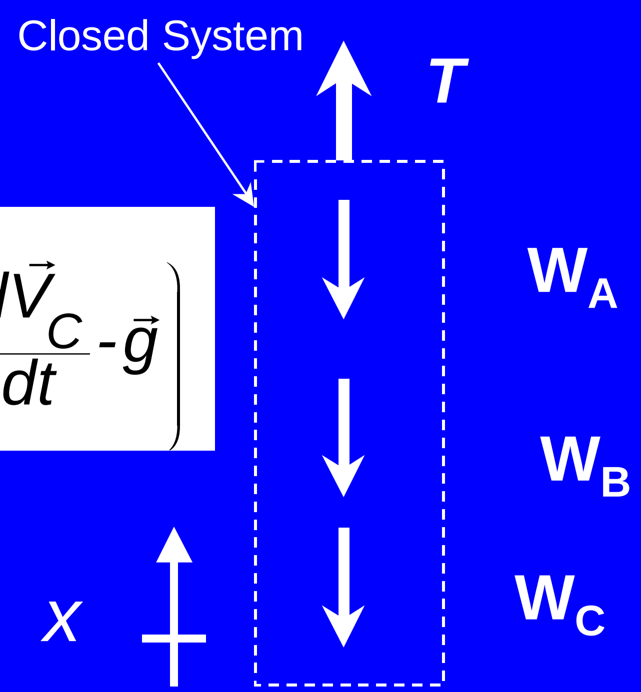
$$\sum_j \vec{F}_{ext,j} = \vec{W}_A + \vec{W}_B + \vec{W}_C + \vec{T}$$

$$\vec{P}_{sys} = m_A\vec{V}_A + m_B\vec{V}_B + m_C\vec{V}_C$$

$$\frac{d}{dt}\left(m_A\vec{V}_A + m_B\vec{V}_B + m_C\vec{V}_C\right) = \vec{W}_A + \vec{W}_B + \vec{W}_C + \vec{T}$$

$$m_A\left(\frac{d\vec{V}_A}{dt}\right) + m_B\left(\frac{d\vec{V}_B}{dt}\right) + m_C\left(\frac{d\vec{V}_C}{dt}\right) = m_A\vec{g} + m_B\vec{g} + m_C\vec{g} + \vec{T}$$

$$\vec{T} = m_A\left(\frac{d\vec{V}_A}{dt}-\vec{g}\right) + m_B\left(\frac{d\vec{V}_B}{dt}-\vec{g}\right) + m_C\left(\frac{d\vec{V}_C}{dt}-\vec{g}\right)$$



$$\begin{aligned} T &= (10\ \mathrm{kg})[-1.6+9.81]\left(\frac{\mathrm{m}}{\mathrm{s}^2}\right) + (12\ \mathrm{kg})[0+9.81]\left(\frac{\mathrm{m}}{\mathrm{s}^2}\right) + (8\ \mathrm{kg})[0.9+9.81]\left(\frac{\mathrm{m}}{\mathrm{s}^2}\right) \\ &= 82.1\mathrm{N} + 117.7\ \mathrm{N} + 85.6\ \mathrm{N} \end{aligned}$$

$$T = 285.4\ \mathrm{N}$$

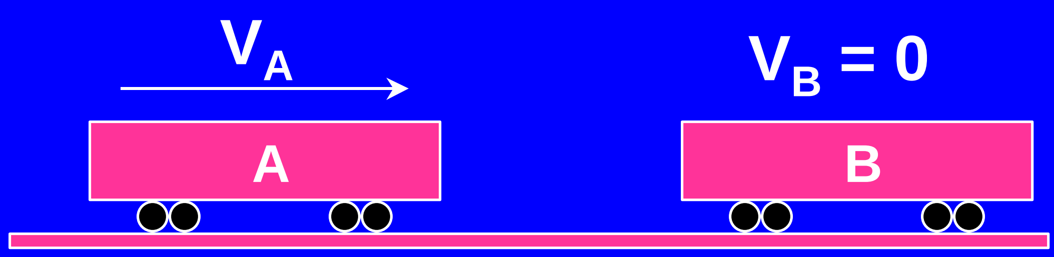
Examples - Rail Cars on the Move

A 45-Mg railroad car moving with a velocity of 3 km/h is to be coupled to a 25-Mg car which is at rest.

Determine

(a) the final velocity of the coupled cars

(b) the average impulsive force acting on each car if the coupling is completed in 0.3 s.



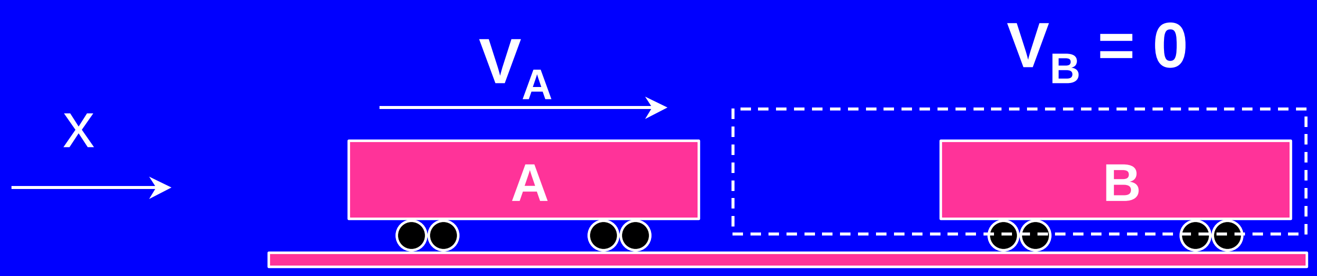
Part (a) - Final velocity after coupling

System: Assume an **open**, **moving system**.

Initially it contains car *B* only and finally it contains both cars.

Property:

$$\frac{d\vec{P}_{sys}}{dt} = \sum_j \vec{F}_{ext,j} + \sum_{in} \dot{m}_i \vec{V}_i - \sum_{out} \dot{m}_e \vec{V}_e$$



Conservation of Linear Momentum (x-direction)

$$\frac{dP_{sys,x}}{dt} = \dot{m}_i V_{x,i}$$

Integrate over time interval t_1 to t_2.

$$\int_{t_1}^{t_2} \left(\frac{dP_{sys,x}}{dt} \right) dt = \int_{t_1}^{t_2} \left(\dot{m}_i V_{x,i} \right) dt$$

1 - Initial state

2 - Final state

$$P_{sys,x,2} - P_{sys,x,1} = m_A V_{A,1}$$

$V_{B,1} = 0$

$$\left(m_A + m_B \right) V_{AB,2} - m_B V_{B,1} = m_A V_{A,1}$$

0

$$V_{AB,2} = \frac{m_A V_{A,1}}{m_A + m_B}$$

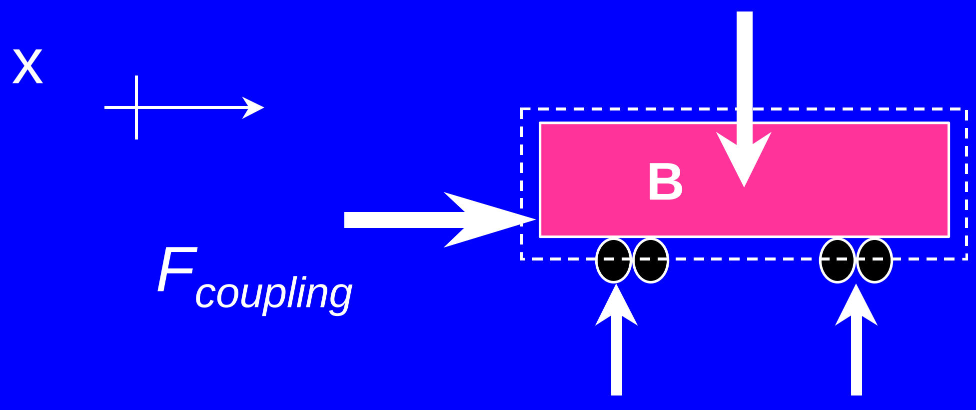
Part (b) Coupling Force

System: Assume a **closed system** that only contains car *B* throughout the process. This system moves with car *B*.

Property:

$$\frac{d\vec{P}_{sys}}{dt} = \sum_j \vec{F}_{ext,j} + \sum_{in} \dot{m}_i \vec{V}_i - \sum_{out} \dot{m}_e \vec{V}_e$$

0



Conservation of Linear Momentum (x-direction)

$$\frac{dP_{sys,x}}{dt} = F_x$$

Integrate over time interval t_1 to t_2.

$$\int_{t_1}^{t_2} \left(\frac{dP_{sys,x}}{dt} \right) dt = \int_{t_1}^{t_2} F_x \, dt$$

1 - Initial state

2 - Final state

$$P_{sys,x,2} - P_{sys,x,1} = F_{x,avg} \Delta t$$

$V_{B,1} = 0$

$$m_B V_{B,2} - m_B V_{B,1} = F_{x,avg} \Delta t \quad (m_B V_{B,1} \rightarrow 0)$$

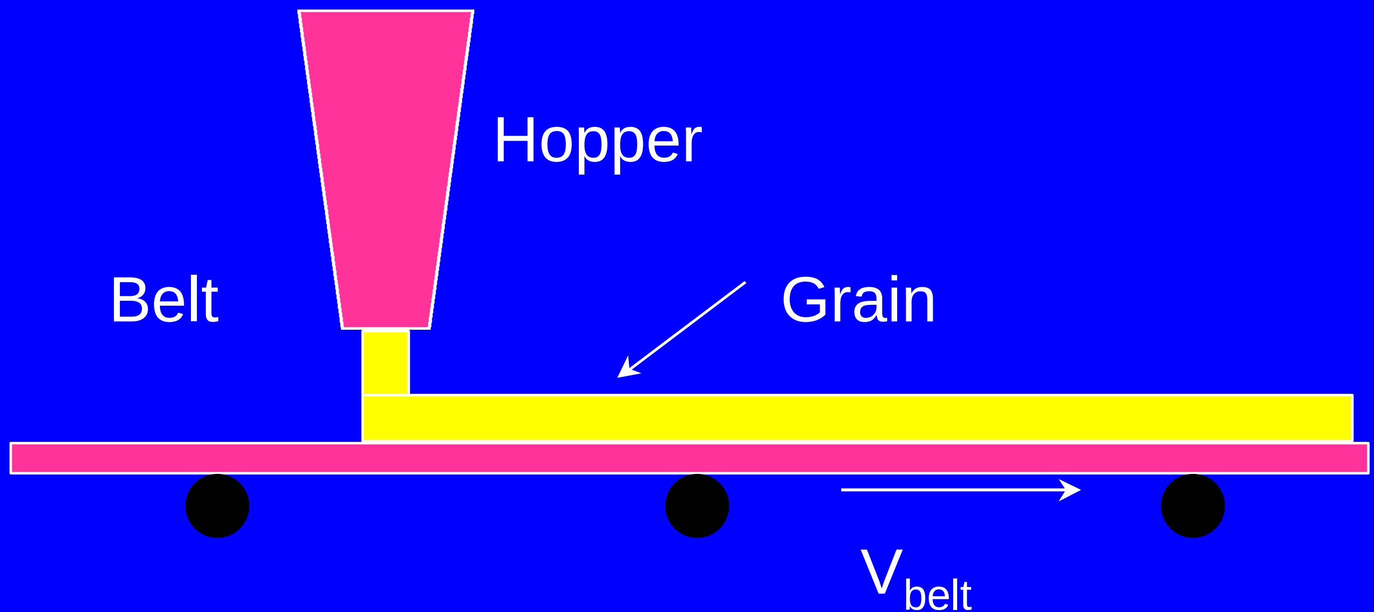
$V_{B,2} = V_{AB,2}$ from part (a)

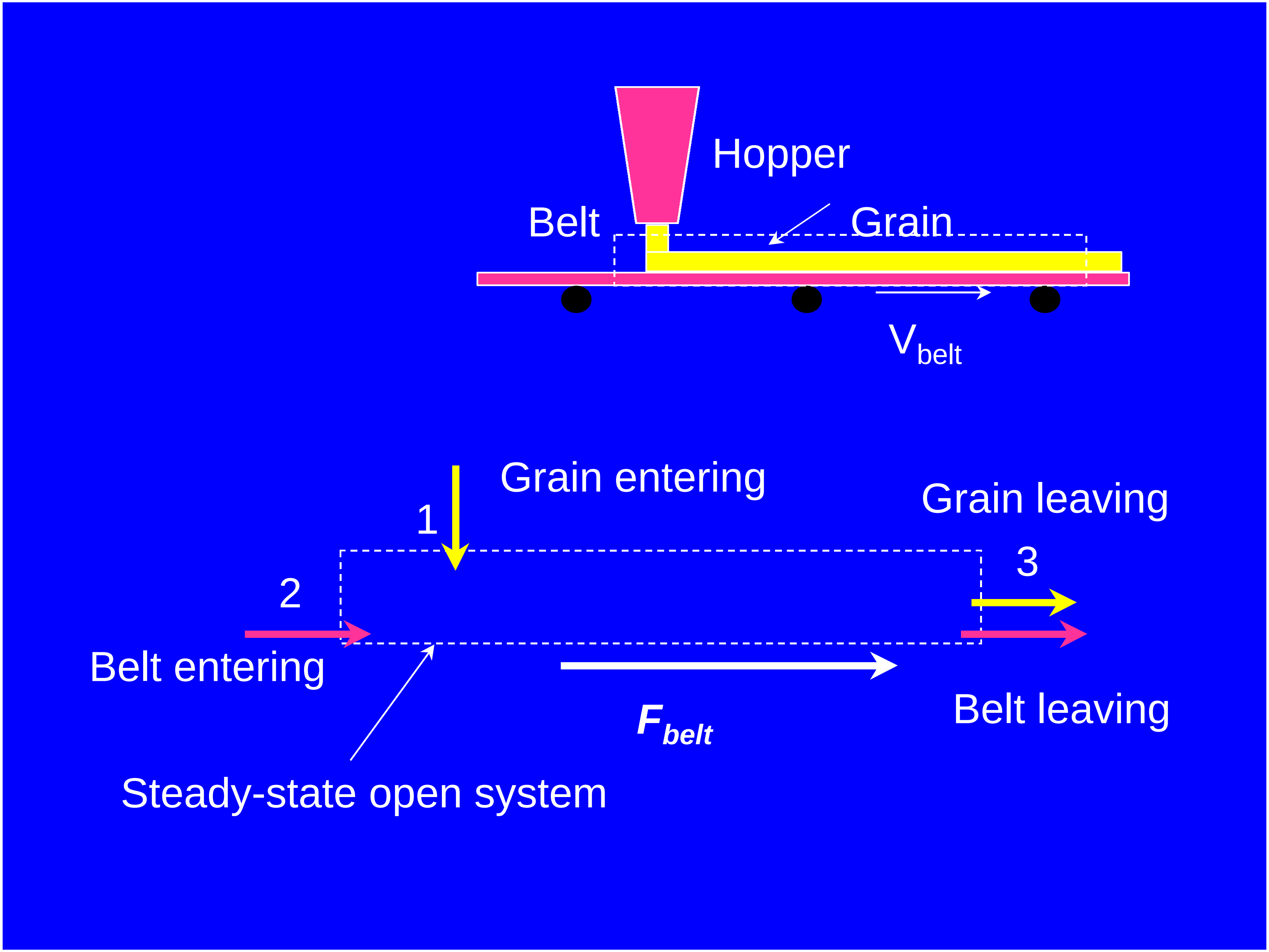
$$F_{x,avg} = \frac{m_B V_{B,2}}{\Delta t}$$

Example - Conveyor Belt

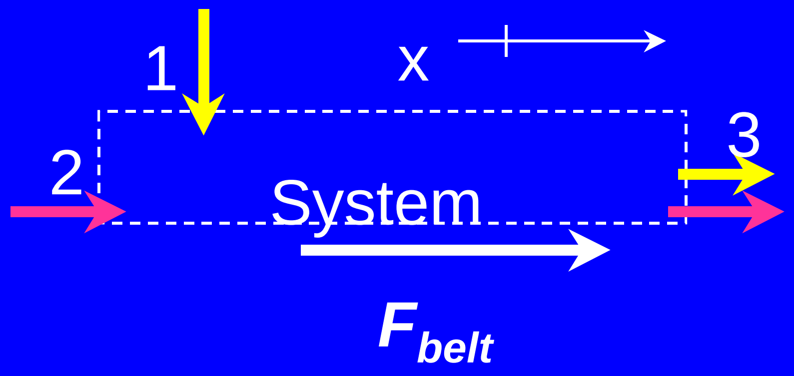
Grain falls from a hopper onto a conveyor belt at the rate of 200 kg/min. The conveyor belt carries the grain away at a constant velocity of 2 m/s.

Determine the force on the belt required to keep the belt moving at a constant speed.




Hopper
Belt
Grain
V_{belt}
Grain entering
1
Grain leaving
3
2
Belt entering
F_{belt}
Belt leaving
Steady-state open system

Conservation of mass
for this system.



$$\frac{dm_{sys}}{dt} = \dot{m}_{grain,1} + \dot{m}_{belt,2} - \dot{m}_{belt,3} - \dot{m}_{grain,3}$$

$$m_{sys} = m_{belt,sys} + m_{grain,sys}$$

0, SS

$$\frac{dm_{belt,sys}}{dt} = \dot{m}_{belt,2} - \dot{m}_{belt,3}$$

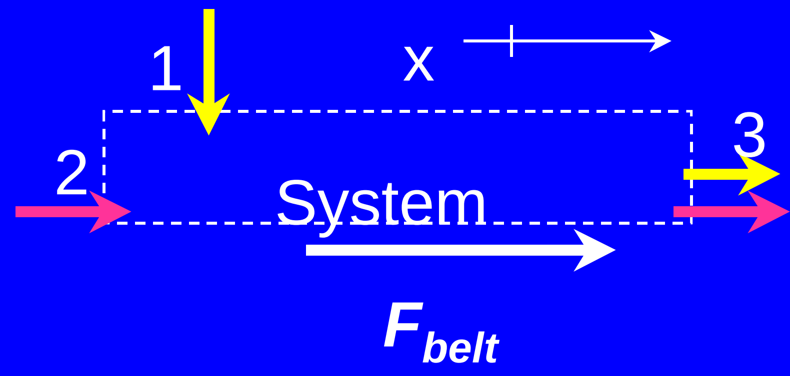
0, SS

$$\frac{dm_{grain,sys}}{dt} = \dot{m}_{grain,1} - \dot{m}_{grain,3}$$

$$\dot{m}_{belt,2} = \dot{m}_{belt,3}$$

$$\dot{m}_{grain,1} = \dot{m}_{grain,3}$$

Conservation of Linear Momentum for this system. (X-direction)



0, SS

$$\frac{dP_{x,sys}}{dt} = \sum_j F_{x,ext,j} + \sum_{in} \dot{m}_i V_{x,i} - \sum_{out} \dot{m}_e V_{x,e}$$

$$0 = F_{belt} + \dot{m}_{grain,1} V_{x,grain,1} + \dot{m}_{belt,2} V_{x,belt,2} - \dot{m}_{belt,3} V_{x,belt,3} - \dot{m}_{grain,} V_{x,grain,3}$$

$$0 = F_{belt} + \dot{m}_{grain}\left(V_{x,grain,1} - V_{x,grain,3}\right) + \dot{m}_{belt}\left(V_{x,belt,2} - V_{x,belt,3}\right)$$

0 0

$$F_{belt} = \dot{m}_{grain} V_{x,grain,3} = \dot{m}_{grain} V_{belt}$$

End of Examples

Implications for curricula and courses

- Can be used as a way to integrate existing courses if instructors work together.
- Can be used as basis for *new* curricula based on *system, conservation and accounting, and modeling paradigm.*

Texas A&M - College Station

Sophomore Curriculum

History of Conservation Principles at TAMU

- 1987 NSF funded a program to unify the Undergraduate Engineering Sciences
- Developed the four sophomore courses (the 20X sequence) comprising "all" the engineering science needed by "all" majors.
- The FC, in response to feedback, modified the material to form 5 courses

Current TAMU Structure

- ENGR 211(3) - Conservation Principles and the Structure of Engineering - Statics and Dynamics
- ENGR 212 (3) - Conservation Principles and the Structure of Engineering - Thermo/Fluid Dynamics
- ENGR 213 (3) - Properties of Materials
- ENGR 214(3) - Conservation Principles of Continuous Media
- ENGR 215 (3) - Principles and Application of Electrical Engineering

Rose-Hulman

Sophomore Engineering Curricula

What is the Rose-Hulman Sophomore Engineering Curriculum?

An eight-course sequence that integrates core material in engineering science and mathematics.

- Designed for all engineering majors.
- Developed by a multi-disciplinary faculty team.
- Taught since 1995-1996.
- Required of all electrical, computer, and mechanical engineering students.

What's our Core?

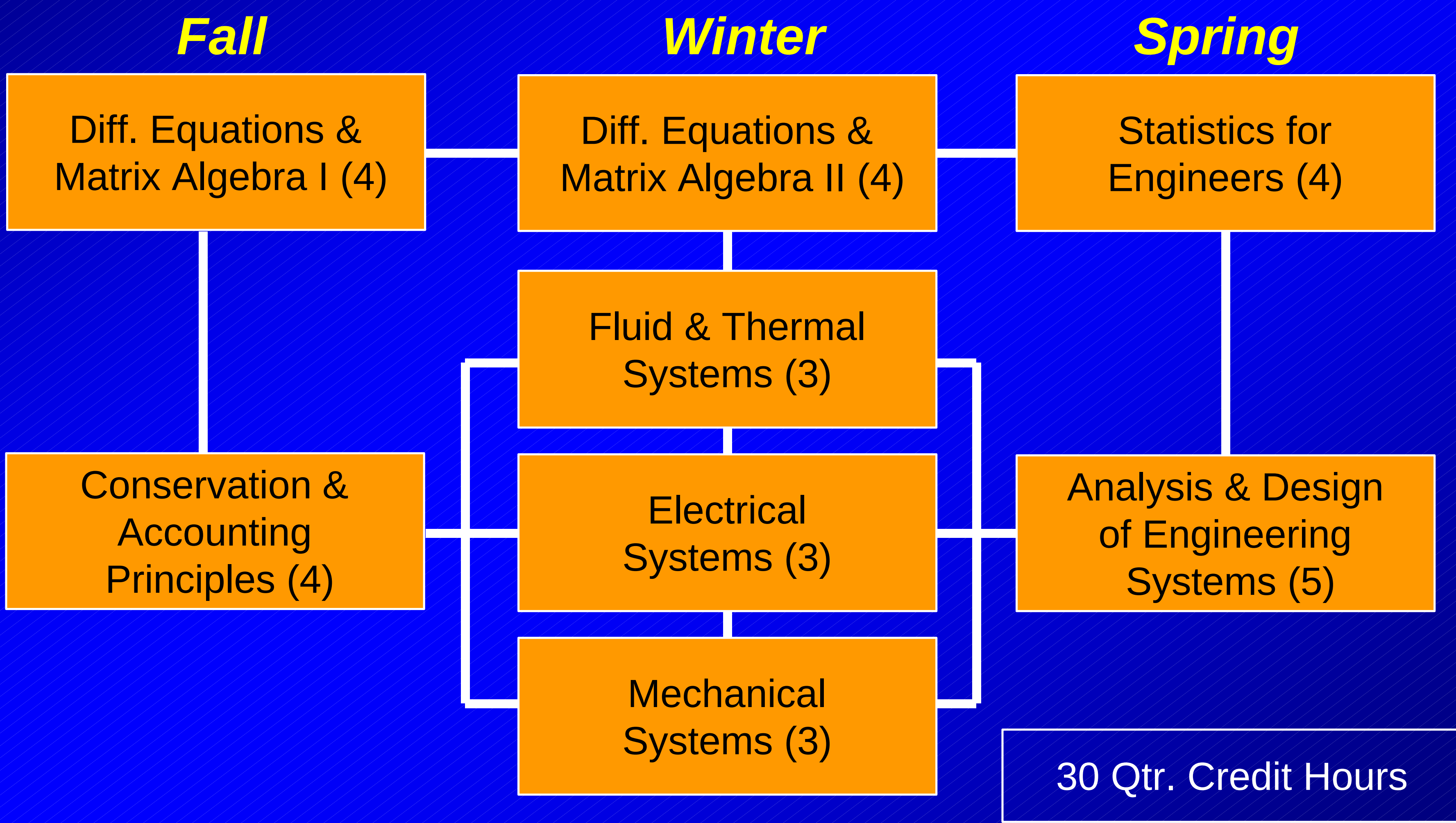
Diff. Equations I	**Dynamics**
Fluid Mechanics	**Circuits**
Thermodynamics	**Diff. Equations II**
Statistics	**System Dynamics**

Matrix Algebra

32 Qtr. Credit Hours

Sophomore Engineering Curriculum

Our New Approach



Sophomore Engineering Curriculum
Advantages for Students

- Participate in a <u>coordinated curriculum</u> that consciously stresses the links between engineering science and mathematics.
- Provide a <u>common foundation</u> of engineering science and mathematics knowledge for future learning.
- Learn to apply a <u>common framework for problem solving</u> based upon an understanding of the conservation and accounting principles.
- Learn to handle <u>open-ended problems</u>.
- Work with <u>multi-discipline problems</u>.
- <u>Learn cooperatively</u> and <u>work in teams</u>.
- Use <u>computer technology across the curriculum</u>.

Sophomore Engineering Curriculum
A Brief History

Fall 1993

- Foundation Coalition funded by NSF.

1993-1994

- Institute considered various ideas for Sophomore Curriculum (Friday afternoon meetings)

Summer 1994

- Workshops on teaming, active learning, curriculum design. (Approximately 4 days total)
- Multidisciplinary faculty team developed overall framework for SEC. (12 faculty)

Sophomore Engineering Curriculum
A Brief History

1994-1995

- Met with departments and finalized proposal.
- Proposal for pilot approved by Institute.
- Required by electrical and computer engineering department.

Summer 1995

- Team of 12 faculty and 3 students developed detailed curriculum material for eight courses.

Sophomore Engineering Curriculum
A Brief History

1995-1996

- Offered RH/FC SEC for first time to 90 students
- Rose-Hulman required students to purchase a laptop computer.

1996-1997

- Adopted by mechanical engineering department for Fall 1998.

2000-2001

- Currently taken by 220-230 mechanical, electrical, and computer engineering students.

Sophomore Engineering Curriculum
Curriculum Structure

FALL Quarter . . . . .8 Credit Hours

MA 211 - Applied Mathematics I (4)

ES 201 - Conservation & Accounting Principles (4)

WINTER Quarter . . . . 13 Credit Hours

MA 213 - Applied Mathematics III (4)

ES 202 - Fluid & Thermal Systems (3)

ES 203 - Electrical Systems (3)

ES 204 - Mechanical Systems (3)

SPRING Quarter. . . . . 9 Credit Hours

MA 223 - Engineering Statistics (4)

ES 205 - Analysis & Design of Engineering Systems (5)

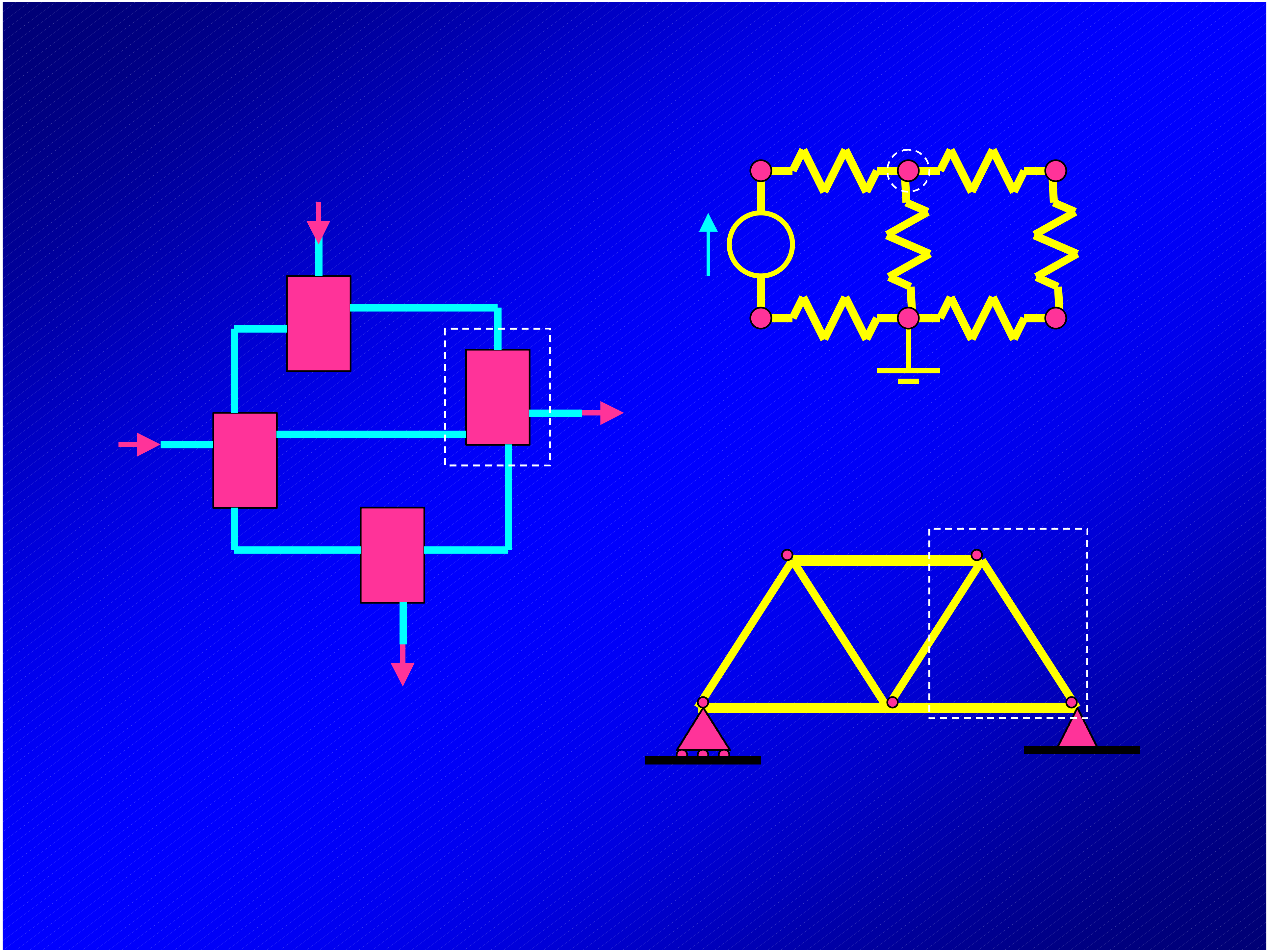
TOTAL CREDITS . . . . 30 Credit Hours

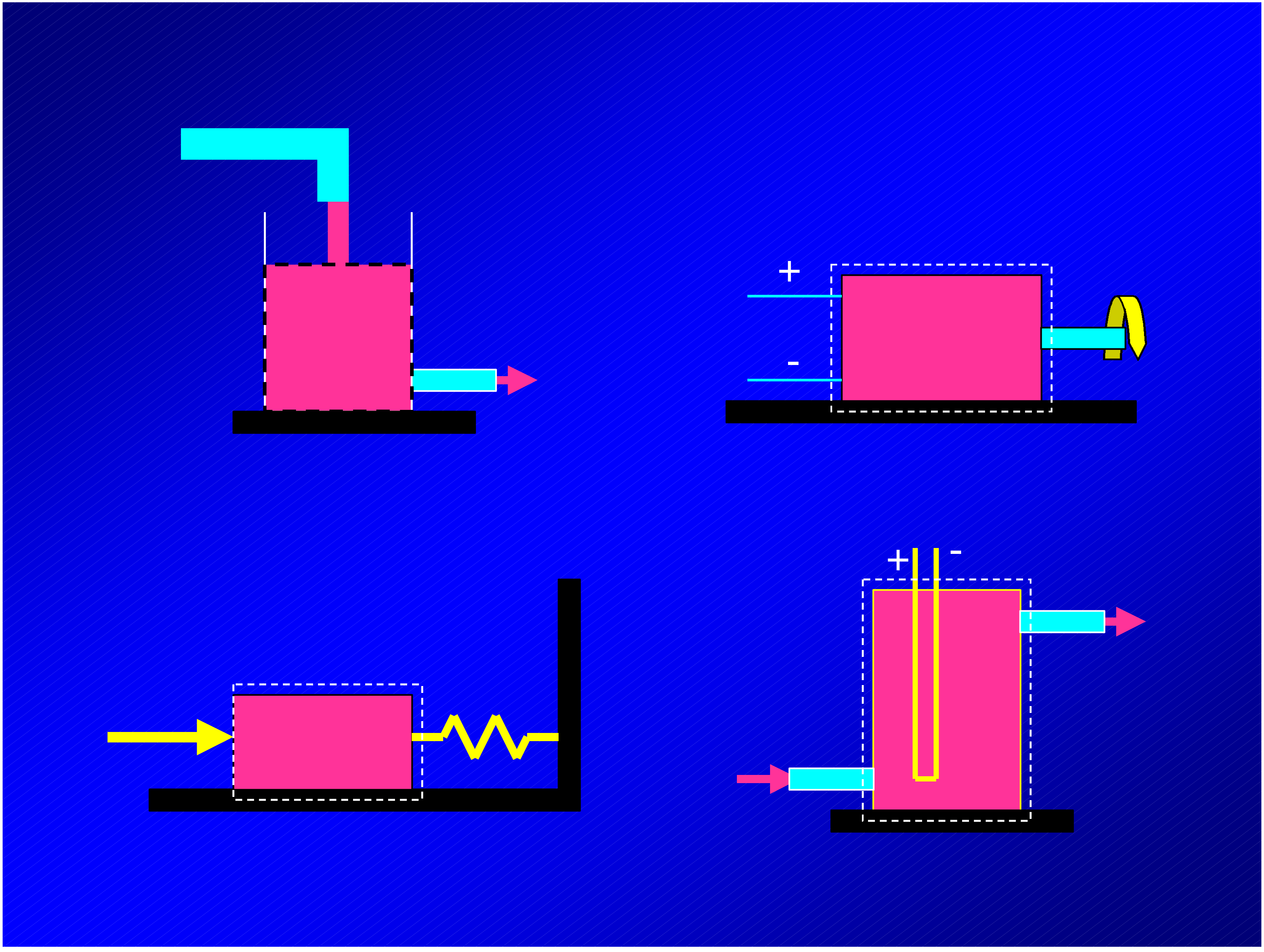
ES 201
Conservation & Accounting Principles

Fall Quarter - 4 credits

Conservation & Accounting Principles

- Basic Systems, Accounting, and Modeling Concepts
- Laws
  - Conservation Laws: Mass, Charge, Energy, Linear & Angular Momentum
  - Accounting Principle: Entropy
- Simple open and closed systems





ES 202
Fluid & Thermal Systems

Winter Quarter - 3 credits

Shared 3-hr Laboratory

Fluid & Thermal Systems

- Thermodynamic Properties
  - Pure simple compressible substances
  - Gases: ideal gas & Z-Chart
  - Solids/Liquids: incompressible substance
- Applications to Open and Closed Systems
- Simple Cycles

Fluid & Thermal Systems

- Dimensional Analysis
- Mechanical Energy Equation
  - Bernoulli Equation
  - Pipe Flow of Incompressible Fluids
  - Pump/Turbine Efficiencies
- Lift and Drag
- Hydrostatics

Fluid & Thermal Systems

<u>Laboratory Experiences</u>

Lab 1 - Dimensional Analysis

Lab 2 - Torricelli's Principle, Friction Factors, Water-Wall Exhibit

Lab 3 - Back-pressure steam turbine

ES 203
Electrical Systems

Winter Quarter - 3 credits

Shared 3-hr Laboratory

Electrical Systems

- Circuit Elements
- Kirchhoff's Laws
- Equivalent circuits and Voltage and current dividers
- Operational amplifiers
- First, second, and higher order circuits
- Transient and steady-state behavior
- AC circuits and power

ES 204
Mechanical Systems

Winter Quarter - 3 credits

Shared 3-hr Laboratory

ES204 - Mechanical Systems

- More Kinematics
  - Normal-Tangential coordinates
  - Radial - Transverse coordinates
  - Dependent motion
  - Relative motion
  - Rigid bodies
- Impacts (coefficient of restitution)

Mechanical Systems (cont.)

- Use Working Model, Maple, Concept maps
- Three labs
- Immediate application to kinetics problems
- Combination problems

Assessment - Is it worse?

- Year 2 - Gave 17 identical multiple choice and 1 identical workout problem to ES204 and to dynamics students
  - 4 ES204 sections/3 professors
  - 5 Dynamics sections/3 professors
- Year 3 - Gave identical finals to ES204 and to dynamics students (20 multiple choice, 3 workout)
  - 4 ES204 sections/2 professors
  - 5 Dynamics/3 professors

Year 2 - Multiple Choice

Prob. #	First Assessment			Second Assessment		
	SEC - ES204	Dynamics	Difference	SEC - ES204	Dynamics	Difference
1	45.7	43.0	2.7	40.2	32.0	8.2
2	24.7	48.6	-23.9	56.3	61.0	-4.7
3	88.9	90.8	-2.0	94.3	94.0	0.3
4				87.4	81.0	6.4
5	80.2	45.8	34.5	71.3	56.0	15.3
6	72.8	66.9	5.9	82.8	79.0	3.8
7	91.4	62.7	28.7	82.8	76.0	6.8
8	59.3	47.2	12.1	57.5	55.0	2.5
9	87.7	85.2	2.4	87.4	94.0	-6.6
10	74.1	28.9	45.2	78.2	49.0	29.2
11	95.1	95.8	-0.7	90.8	93.0	-2.2
12	48.1	33.8	14.3	46.0	57.0	-11.0
13				96.6	98.0	-1.4
14	92.6	88.0	4.6	90.8	95.0	-4.2
15	90.1	80.3	9.8	66.7	63.0	3.7
16				62.1	54.0	8.1
17	61.7	52.1	9.6	50.6	79.0	-28.4
18	45.7	39.4	6.2	41.4	47.0	-5.6
19				9.2	47.0	-37.8
20	71.6	44.4	27.2	63.2	56.0	7.2

*Workout problems**

Year 2			
Prob. #	**SEC - ES204**	**Dynamics**	**Difference**
1	33.3	23.3	10

Year 3			
Prob. #	**SEC - ES204**	**Dynamics**	**Difference**
1	35.8	17	19.8
2	70.1	22	48.1
3	46	6	40

* Essentially an “A” solution

ES 205

Analysis & Design of Engineering Systems

Spring Quarter - 5 credits

3-hr Laboratory

ES205 - Analysis & Design of Engineering Systems

- Pre-vibrations/controls
- Mechanical, Electrical , Electro-mechanical, Hydraulic, Fluid, Thermal systems
- Governing differential equations
- System Response
- System identification

Systems Concepts in ES205

- Modeling of system elements
- Equations of motion
  - Natural frequency, Damping ratio, Static gain
  - 2nd order matrix form, state space form
- Transfer functions
- Free response
  - log decrement

Systems Concepts in ES205 (cont.)

- Forced Response
  - Step input
    - performance specifications
  - Harmonic input
    - Frequency response plots
  - General periodic forcing
    - Fourier Series
- Simulink,Matlab and Maple

Analysis & Design of Engineering Systems

Laboratory

- Introduction to the design process.
- Teams of students study and develop *design specifications*** for products.
- Includes written and oral presentations.

**S. Pugh. *Total Design*, Addison Wesley, 1991.

K. T. Ulrich and S. D. Eppinger. *Product Design and Development*, McGraw-Hill, 1995.

Mathematics Sequence

- Differential Equations & Matrix Algebra I
- Differential Equations & Matrix Algebra II
- Statistics for Engineers

Sophomore Engineering Curriculum
Mathematics

- Stresses Linear Structures
  - systems of algebraic equations (Ax=b)
  - 1st & 2nd order differential equations
  - systems of differential equations
  - Laplace transforms
  - Fourier series
  - linearization
- Applications of Statistics
- Students have laptops with access to MAPLE, MATLAB, and MINITAB.

Differential Equations & Matrix Algebra I

- Basic Matrix Algebra
  - systems of linear equations (algebraic and geometrical viewpoints)
  - least squares
  - eigenvalues and eigenvectors
- Differential Equations
  - Review of first-order de’s
  - Second-order linear de’s with constant coefficients (homogeneous and non-homogeneous cases)
- Introduction to Complex Arithmetic

Differential Equations & Matrix Algebra II

- Laplace Transforms
- Systems of First-Order Linear DE's
  - solution using Laplace transforms
  - investigation of solution structure determined by eigensystems.
- Phase Portrait Analysis and Stability of Critical Points for Systems of Equations
- Approximation of Functions
  - Taylor and Fourier series

Statistics for Engineers

- Introductory course in statistical data analysis emphasizing
  - hypothesis testing
  - analysis of variance
  - quality control charts
  - simple and multiple regression
  - simple experimental designs
- Computer Tools: MINITAB and Excel

Sophomore Engineering Curriculum
Assessment Activities

- Standard Rose-Hulman Course Evaluation
- Feedback from Student Council
- ES201 / MA211 Course Survey
- Focus Groups
- Sample EIT/FE Exam
- Comparison of performance on standard final exam test questions.
- Anecdotal information from upper-division courses.
- Sophomore surveys
- Survey of graduating seniors

Student Comments after Completing the SEC

Student A

"ES201 was an excellent foundation to start on. A solid handle on this class is a must for success in the following classes. All classes were connected to this class."

Student Comments

Student B

“The sophomore curriculum has won me over. At first, I thought it was a complete waste of time. Then during winter quarter I saw the importance of it. Now, I am glad to have gone through it. The book didn’t help much, it was vague and made the class more difficult.”

Student Comments

Student C

"I was very pessimistic about the course (ES205) at the beginning of the quarter. This course defeated every pessimistic premise I had before it was completed. This course brought all the engineering disciplines together and, at the very least, made this skeptical EE a believer in the SEC. Not only was the course an eye-opener, but it also enhanced my ability to solve general complex-system problems regardless of what discipline they came from.?

Thank You !

For further information about Sophomore Engineering Curricula -----

Check the Foundation Coalition Web Site --

http://www.foundationcoalition.org

Contact Don Richards --

http://www.rose-hulman.edu/~richards

donald.e.richards@rose-hulman.edu