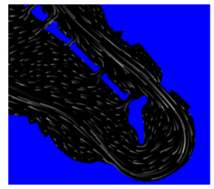
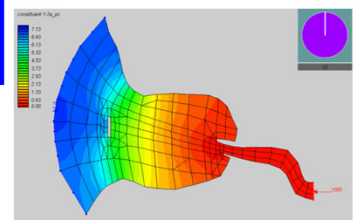
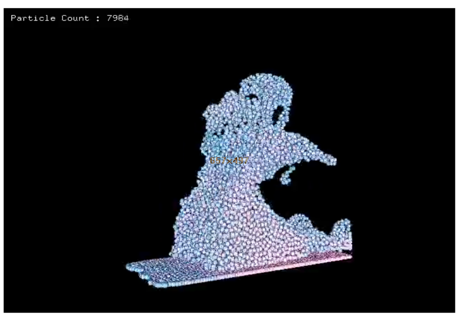
Modeling

- A **model** is a pattern, plan, representation, or description designed to show the main object or workings of an object, system, or concept.
- **Models** may also refer to abstractions, concepts, and theories.

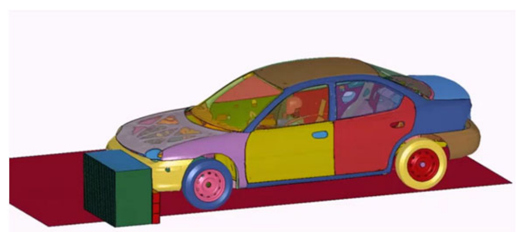
Modeling

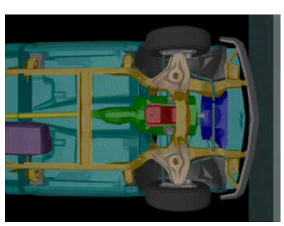
Modeling



Modeling



Modeling

Modeling

- What is a heuristic?
- A heuristic is a plausible or reasonable approach that often proves useful
- We cannot guarantee the efficacy of heuristics
- Modeling is an art rather than a science

Why Models are Important?

- The model is as important as your answer
- You cannot evaluate your answer unless you know the assumptions made in the model
- It is often more important to identify your model than to compare answers

Modeling

- Group Modeling Problem
- Form groups of about three or four people
- Assign one person to be the note taker

Time for Ping-Pong?

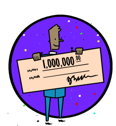
- Take 60 seconds to answer the following question:
- How many ping-pong balls could you fit into this room?

What is your Answer?

- How did you get your answer?
- Did you guess?
- Did you build a model?
- Can you describe your model?

Review of 60 Second Model

- Did you answer “lots” or “hundreds” or “millions”?
- What have you accomplished with your answer?
- Did you develop a predictive model?
- Did you try a volumetric calculation?

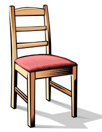


Review of 60 Second Model

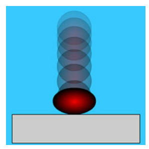
- This is not a completely useless exercise; there is a difference between "some" and "lots"
- If you used a volumetric model, how did you model the room?
- What ***simplifications*** or ***assumptions*** did you make?

Review of 60 Second Model

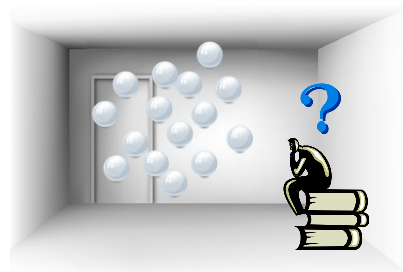
- Did you ignore the furniture?



- Did you account for the irregular shape of the room?
- Did you assume the ping-pong balls could deform?



60 Second Model



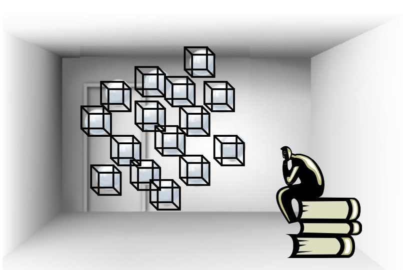
Time for Ping-Pong?

- Take 2 minutes to answer the following question:
- How many ping-pong balls could you fit into this room?

What is your Answer?

- How did you solve the problem this time?
  - Did you refine your 60 second model?
  - Did you change your model?
  - Did you modify your assumptions?
  - Given more resources, did you build a more sophisticated model?

Three Minute Model



Three Minute Model

Assume the following:

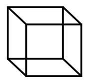
- ***L*** is the length of the room (in.)
- ***W*** is the width of the room (in.)
- ***H*** is the height of the room (in.)
- ***D*** is the diameter of a ping-pong ball (in.)

$$V_{room} = LWH$$

Three Minute Model

- The volume of a ping-pong ball is:

$$V_{ball} = D^3$$



- Therefore the number of ping-pong ball, *n*, can be estimated by:

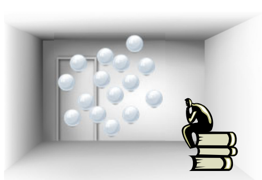
$$n = \frac{V_{room}}{V_{ball}}$$

Three Minute Model

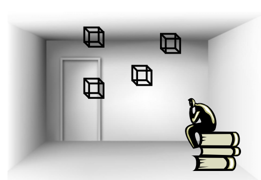
- Therefore the number of ping-pong ball, *n*, can be estimated by:

$$n = \frac{V_{room}}{V_{ball}} \Rightarrow n = \frac{LWH}{D^3}$$

Visual Comparison of the Models



60-second model



3-minute model

What Did We Learn?

Some things to consider about this example:

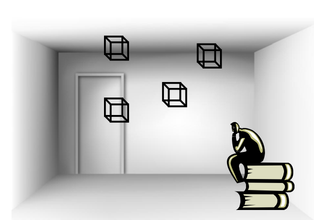
- A "rough" answer is better than no answer
- A model is a partial not a complete representation
- The design of a model depends on the constraints
- A symbolic representation is "clean" and powerful
- An explicit model is an indispensable tool for solving problems

The Real World and the Model World

- What is the connection between the two?
- How do we get from one to the other?
- Why does the model world have no windows?
- Does it matter what color the walls are?
- Are there doors and windows in the model world?

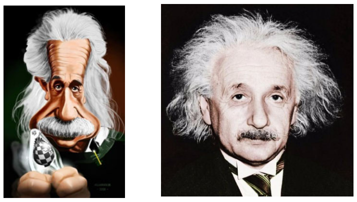
The Real World and the Model World

- The room is the ***real*** world
- The ***model*** world is likely more like this:



The Real World and the Model World

A model is like a caricature



- Certain features are emphasized at the expense of other features
- Identify aspects of the ***real*** world that are relevant

Occam's Razor

William of Occam was a 14th century English philosopher who propounded the heuristic:

"entia non sunt multiplicanda praeter necessitatem"

http://en.wikipedia.org/wiki/William_of_Ockham

Occam's Razor

William of Occam was a 14th century English philosopher who propounded the heuristic:

"entities should not be multiplied beyond necessity".

"All other things being equal, the simplest solution is the best."

http://en.wikipedia.org/wiki/Occam's_Razor

Occam's Razor

- You should eliminate all unnecessary information relating to a problem
- Occam was reputed to have a sharp, cutting mind - thus this heuristic is called:

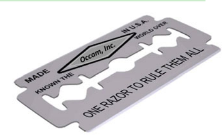
Occam's Razor

Occam's Razor

Think of the model world connected to the real world by a passage guarded by a mythical customs officer with Occam's razor.

Occam's Razor

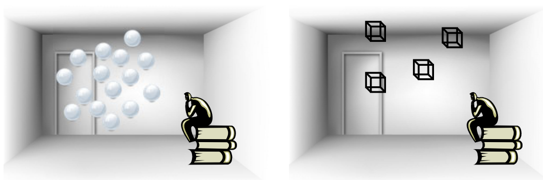
A "bad" model is either:



Using the razor too little
(letting irrelevant details in the model)

Using the razor too much
(cutting essential features of the real world)

Occam's Razor



- How do we reach a balance?
  - Should the furniture be in the model?
  - Is the cube a good model of the ball?

Occam's Razor

- There are no hard-and-fast rules
- We do have some guidelines:
  - The objective of the model
  - Constraints on resources

- How do we apply these guidelines to the ping-pong ball problem?

Time for Ping-Pong?

What is the "best" answer to the question:

How many ping-pong balls could you fit into this room?

Considerations for "Best" Model?

- Define the problem
- What are your objectives?
- Should we measure the room more accurately?
- Fill the room up with ping-pong balls and count them?
- Thinking of the "best" answer is equivalent to making a wish list of things you would like to have in your model world
- "***Musts***" and "***Wants***"

Upper and Lower Bounds of the Model

- Suppose you model a ping-pong ball as a sphere instead of a cube:

$$V_{ball} = \frac{\pi D^3}{6}$$

- Suppose the balls are packed so that are no air gaps (***upper bound***):

$$n = \frac{6LWH}{\pi D^3}$$

Upper and Lower Bounds of the Model

- If you compare the upper bound to the lower bound:

$$\frac{Upper}{Lower} = \frac{6}{\pi}$$

- This is a ratio of nearly 2

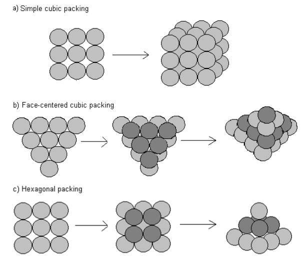
Comparing Assumptions

- The room is shaped like a box
- The ping-pong ball is assumed to be a cube
- Furniture in the room is ignored
- Windows and door spaces are ignored

Which assumptions should we relax?

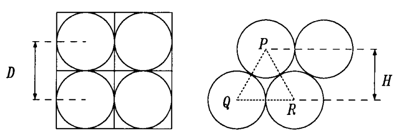
Packing Spheres

- A more "realistic" representation of the ping-pong balls

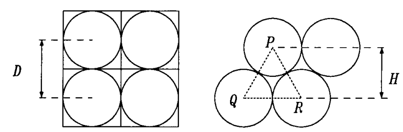


Packing Spheres

- A more "realistic" representation of the ping-pong balls



Packing Spheres



$H/D = \sin 60^{o}$ $H=0.866D$

- The distance between the center of two balls is reduced by nearly 14%

What Did We Learn?

- You should risk making "***back of the envelope***" calculations and recognize when they are appropriate
- Match model resolution with available resources
- Awareness of assumptions
- Power of symbolic representation
- "***Looking Back***" is a good heuristic for problem solving, but it is ***vital*** for learning

Modeling

Questions?