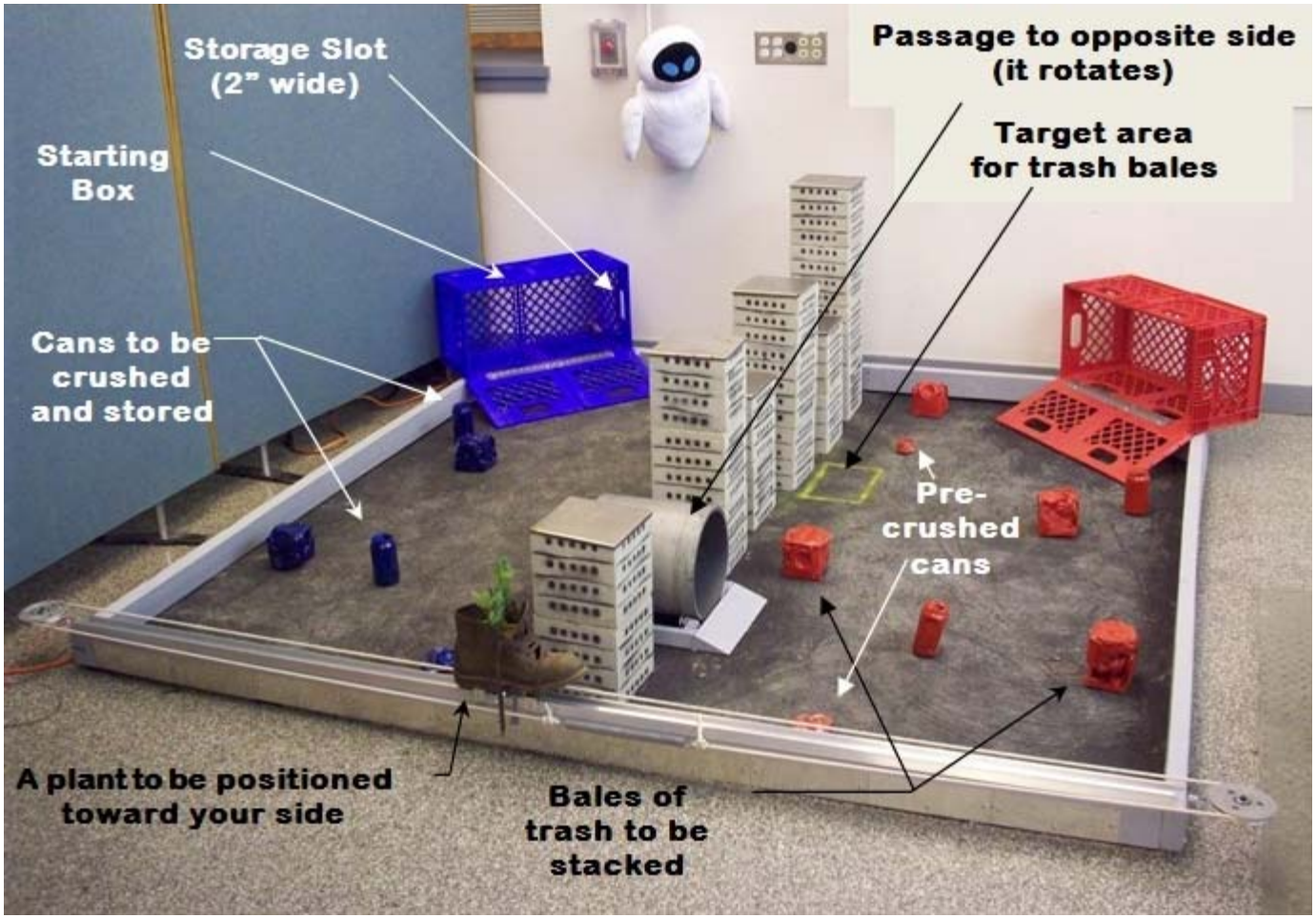
2.007 Design and Manufacturing I
Spring 2009

# 2.007 –Design and Manufacturing I

# Course Introduction

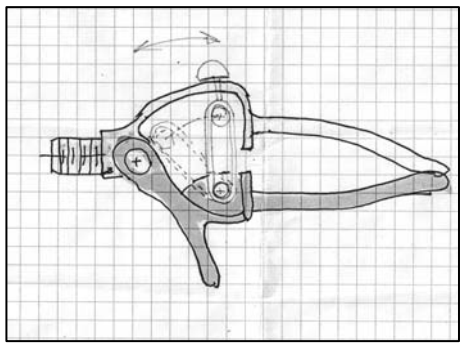


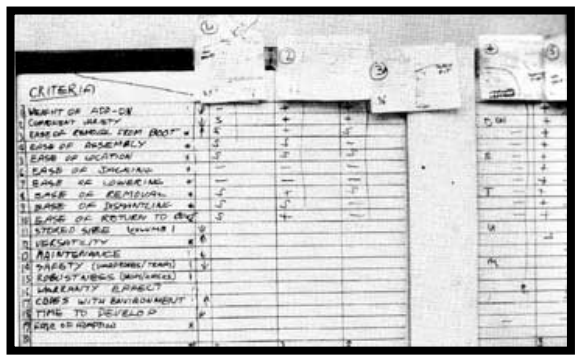

Presented by Dan Frey on 3 FEB 2009

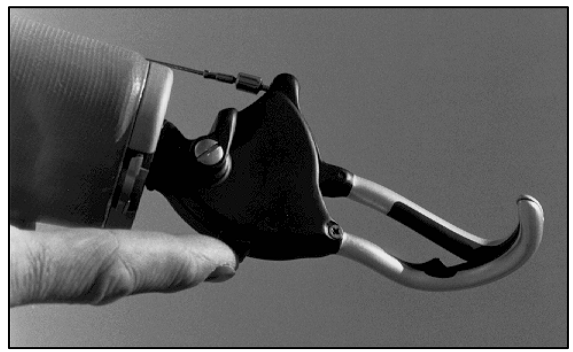
# Today's Agenda

- What is this course about?
- Who are the instructors?
- Course structure, expectations, policy, etc.
- A short overview of "the kit"
- Description of the first milestone
- Introduce this year's contest and new special sections

Engineering design is a systematic process in which designers generate, evaluate, and specify devices, systems, or processes whose form and function achieve objectives while satisfying constraints.





"The knowledge of technical systems or analysis is not sufficient to understand the thought processes that lead to successful synthesis or design."

Dym, C. L., A. M. Agogino, O. Eris, D. D. Frey, and L. J. Leifer, 2005, "Engineering Design Thinking, Teaching, and Learning," *ASEE Journal of Engineering Education* **94**(1):103-120.

"The way we think, a bone is a link; a joint is a bearing; a muscle is an actuator; ligaments and tissues are springs…"
"Superb preparation in good, practical arts -- foundry, forge and machine shop."

- Robert Mann

Informed creative thinking.

- Woodie Flowers

"If you understand people's values better, you can create better products and services for them. That's the future of design."

- Harry West

Design is a passionate process.

- Alex Slocum

# Mechanical Design

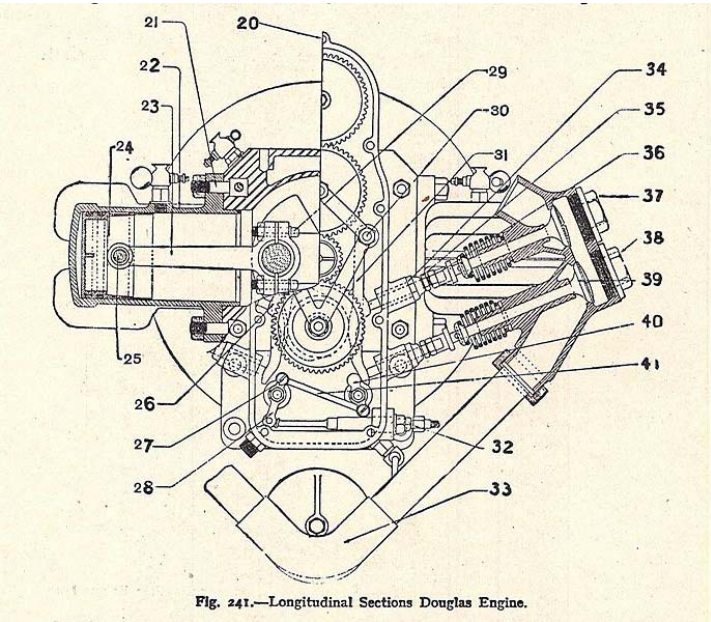
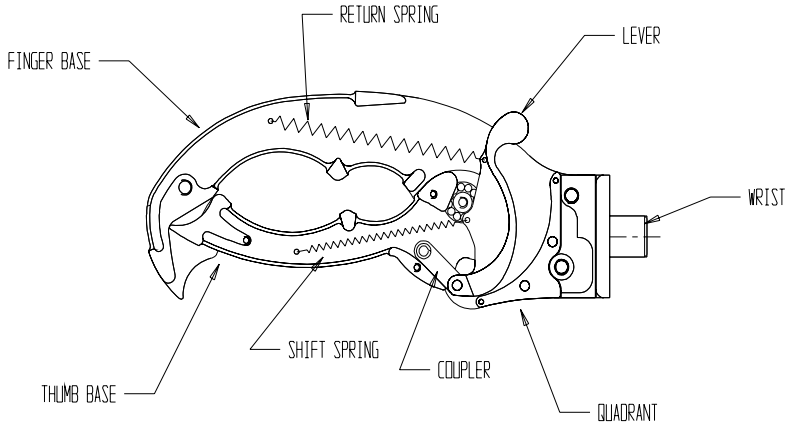
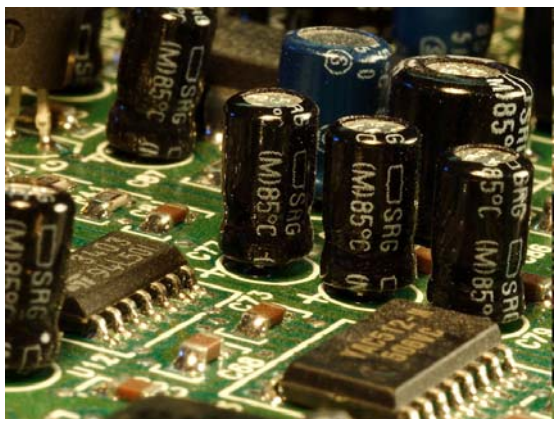
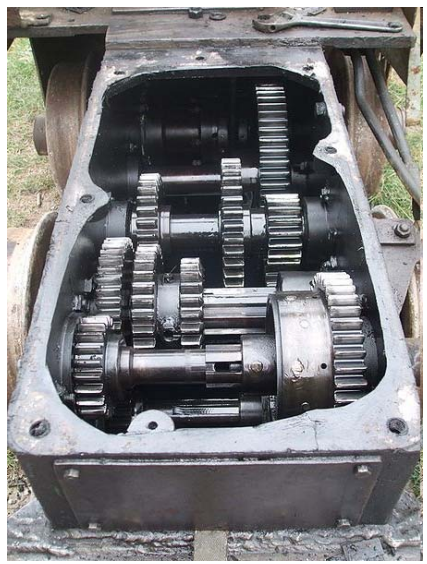


Fig. 241.—Longitudinal Sections Douglas Engine.



Courtesy of TRS Inc. Used with permission.





Images from Wikimedia Commons, http://commons.wikimedia.org, and PD Photo, http://pdphoto.org

# Introductions

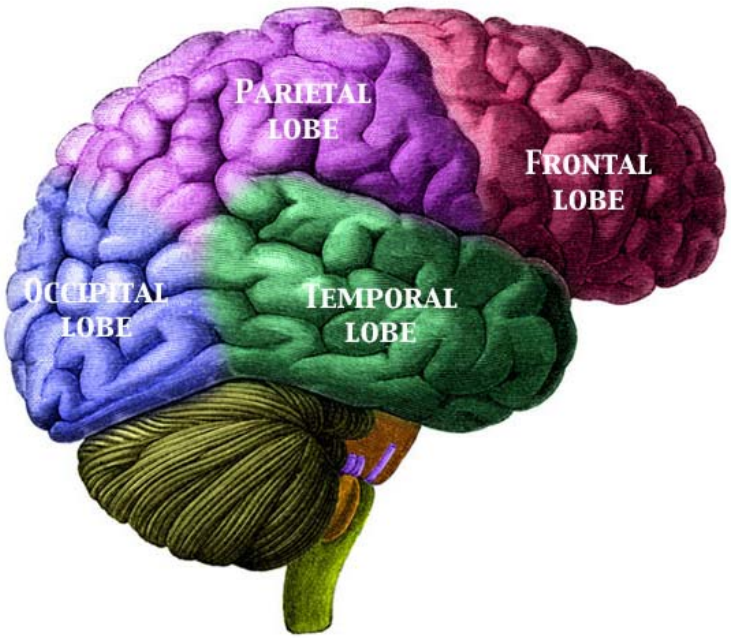
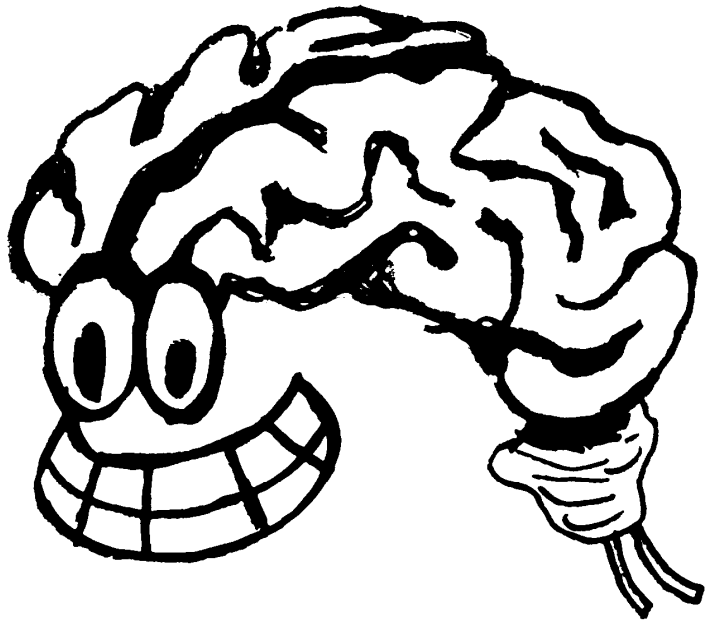



Image courtesy of Camazine on Wikimedia Commons.

This is your brain.



This is your brain on design!

"The mind is a system of organs of computation, designed by natural selection to solve the kinds of problems our ancestors faced…" Steven Pinker

# (pre)History of Engineering Design

Stone tools >>1,000,000 BC

Fire >500,000 BC

Spears circa 400,000 BC

Sewing circa 23,000 BC

Spear thrower 14,000 BC

Domestication of sheep 9,000 BC

Permanent settlement and irrigation 7,000 BC

Copper circa 6,000 BC

Division of labor 5,000 BC

Images from Wikimedia Commons, http://commons.wikimedia.org

# Three Brains in One

- Reptilian Complex
  - digestion, reproduction, circulation, breathing, "fight or flight" response
- Limbic System
  - houses primary centers of emotion
  - hippocampus -- important aspects of long term memory
- Neocortex
  - processing senses
  - logic
  - language
  - motor control

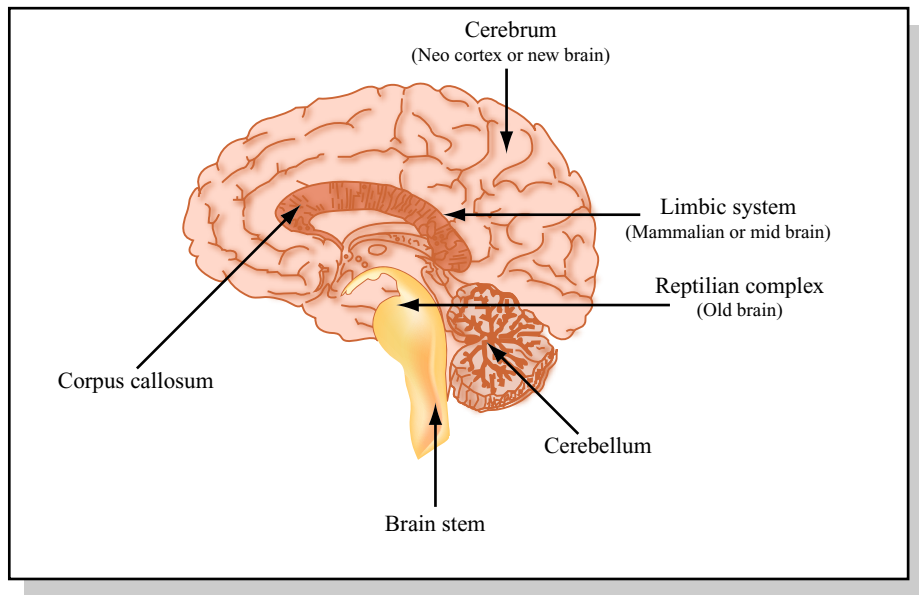



Figure by MIT OpenCourseWare.

# Neocortex

- 2mm thick
- 6 layers
- About the size of a newspaper (unfolded)
  - So it has to be wrinkled up to fit in the skull
- About $3 \times 10^{10}$ neurons
- About 1000 synapses per neuron
- Each neuron capable of 200 cycles / sec
  - 5 million times slower than a computer

# Visual Cortex

Image courtesy NASA.

About ⅓ of the cerebral cortex.

Retina – a 2½-D data stream
~ a million nerve fibers

The fiber pathways are two-way… They carry as much information down from higher conceptual areas as from lower sensory areas...

**Pinker, Steven, 1997, *How the Mind Works*, Norton & Co, New York.**

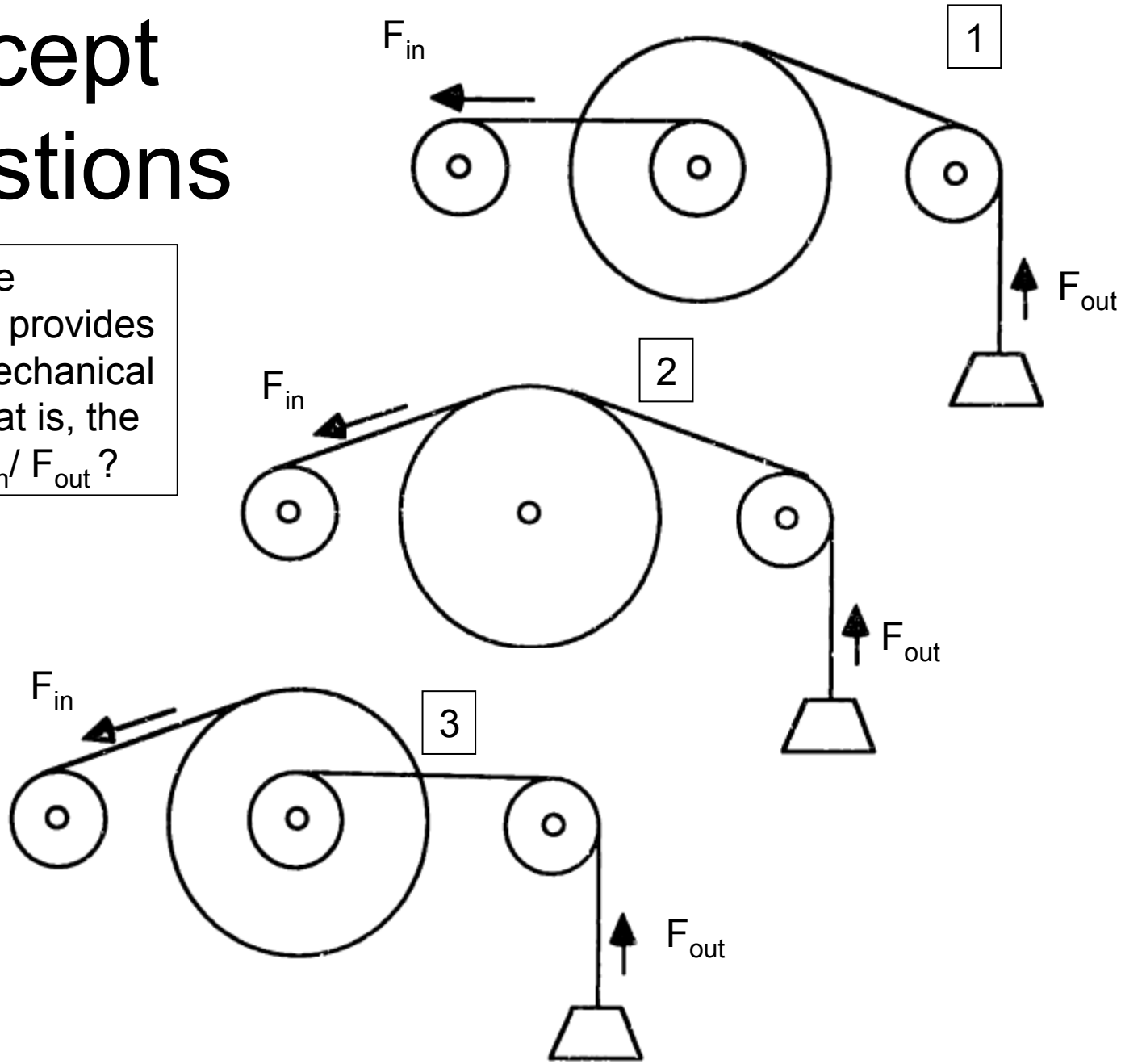
# Really Seeing

- "…focused attention is needed …"*
- You cannot assume that information flowing into your brain via your senses will be attended to; it may be ignored completely
- It also true in engineering

*Rensink, R. A., 2002, "Change Detection," *Annual Review of Psychology,* **53**:4245-277.

# Concept Questions

Which of these arrangements provides the highest mechanical advantage, that is, the lowest ratio $F_{in}/ F_{out}$ ?



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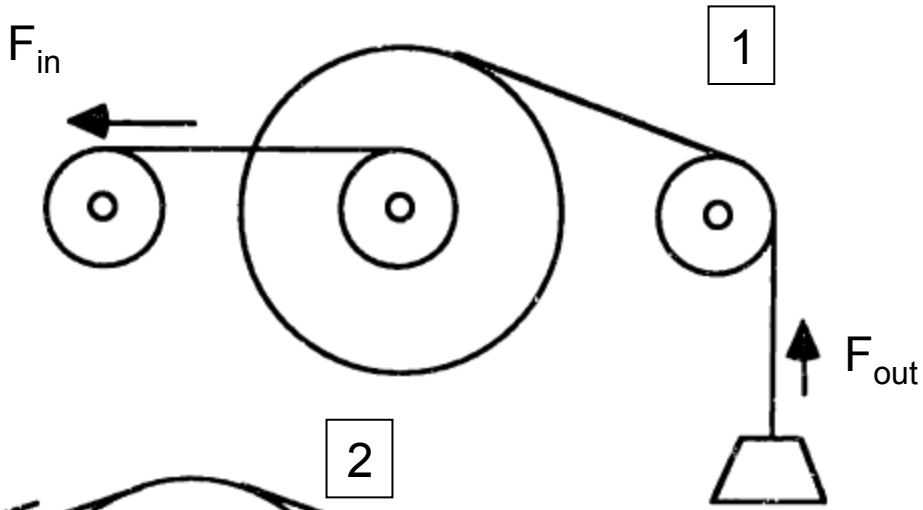
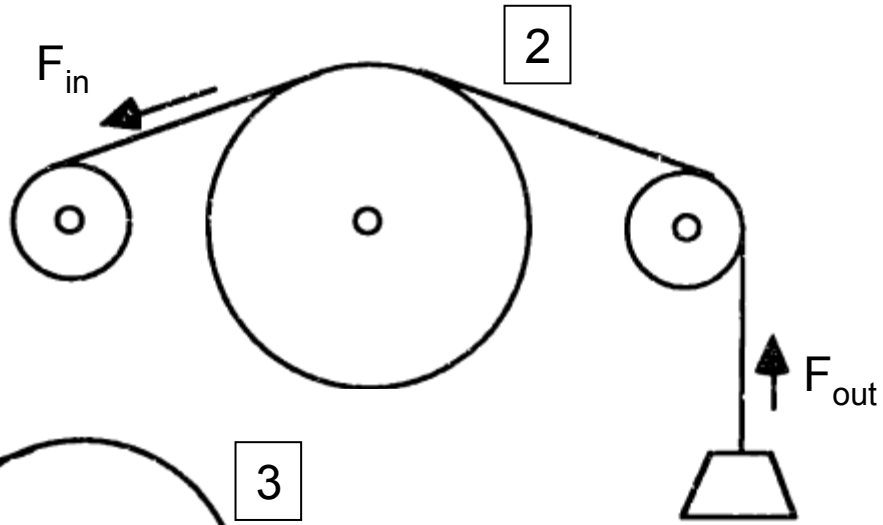
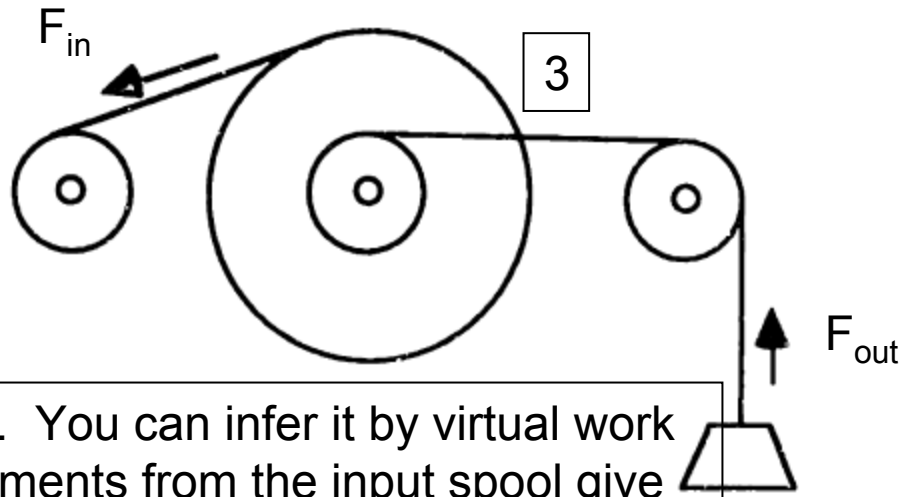



The answer is 3. You can infer it by virtual work -- large displacements from the input spool give only small displacements onto the output spool

# Bloom's Taxonomy of Educational Objectives

| Educational Objective | Associated Action Verbs |
|---|---|
| 5. Synthesis | Design, invent, propose |
| 6. Evaluation | Judge, critique, justify |
| 4. Analysis | Predict, model, derive |
| 3. Application | Calculate, solve |
| 2. Comprehension | Explain, paraphrase |
| 1. Knowledge | List, recite |

# Learning Objectives

After taking this subject students should be able to:

- Generate, analyze, and refine the design of electro-mechanical devices making use of physics and mathematics
- For common machine elements including fasteners, joints, springs, bearings, gearing, clutches, couplings, belts, chains, and shafts
  - Describe the function of the element
  - List common uses in mechanical systems and give examples
  - Analyze its performance and failure modes
  - Describe how they are manufactured and the implications of the alternatives
  - Select an element for a specific use based on information such as that typically available in a manufacturer's catalog
- Apply experimentation and data analytic principles relevant to mechanical design
  - Consider the effects of geometric variation on a design
  - …
- Communicate a design and its analysis (written, oral, and graphical forms)
  - Read and interpret mechanical drawings of systems with moderate complexity
  - …

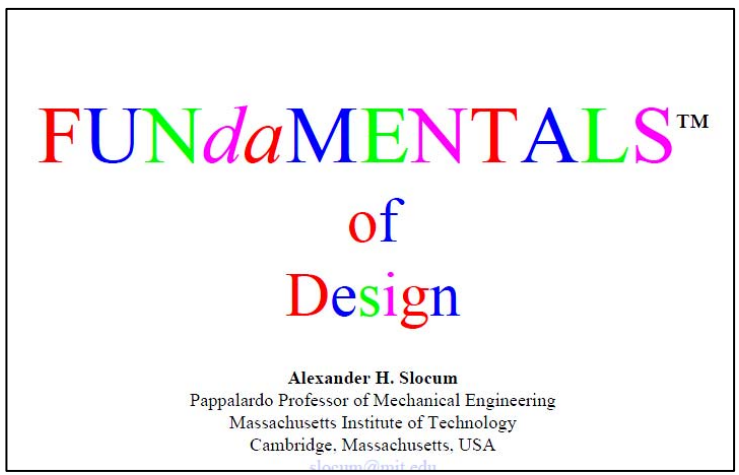
# Sources of Content

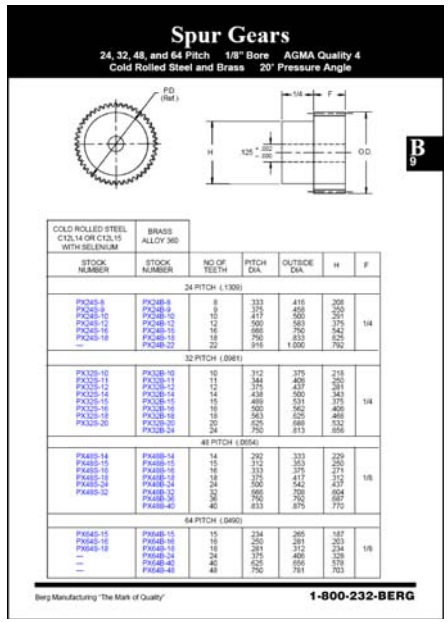

Shigley, Joseph E., Charles R. Mischke, and Richard G. Budynas. *Mechanical Engineering Design.* Boston, MA: McGraw-Hill, 2003.

Norton, Robert L. *Design of Machinery.* Boston, MA: McGraw-Hill, 2004.

Pugh, Stuart. *Total Design: Integrated Methods for Successful Product Engineering.* Reading, MA: Addison-Wesley, 1991.

*Machinery's Handbook*. New York, NY: Industrial Press, 2008.

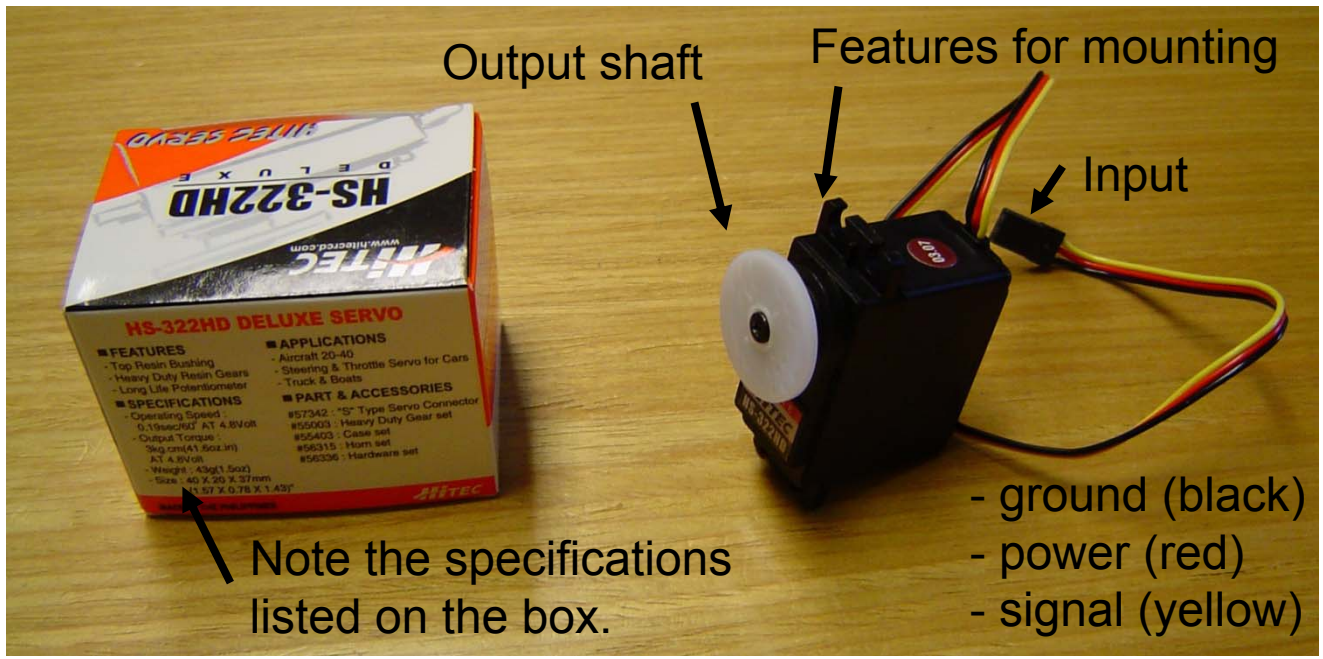




Courtesy of W. M. Berg, Inc. Used with permission.

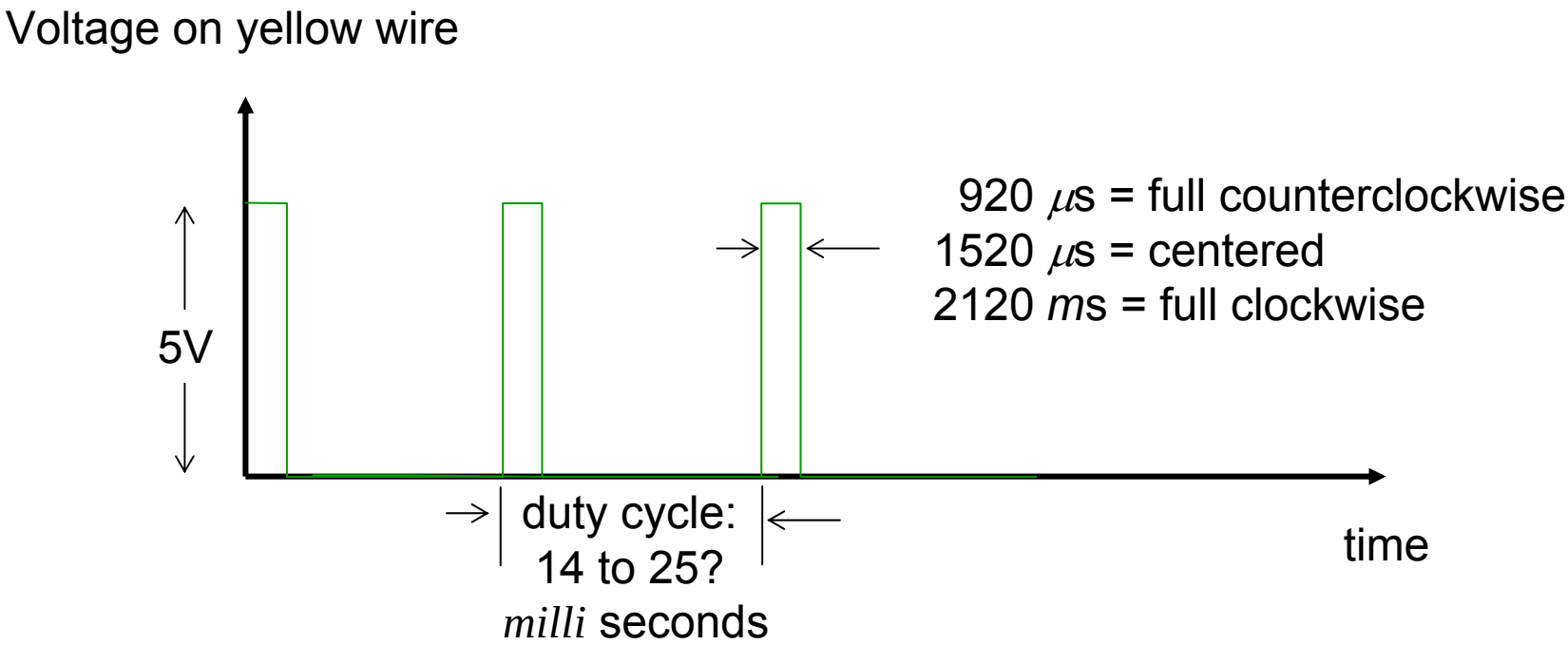
# Servo Motors

- Actuators that attain and hold a commanded position
- The type that are commonly used in radio controlled cars and planes



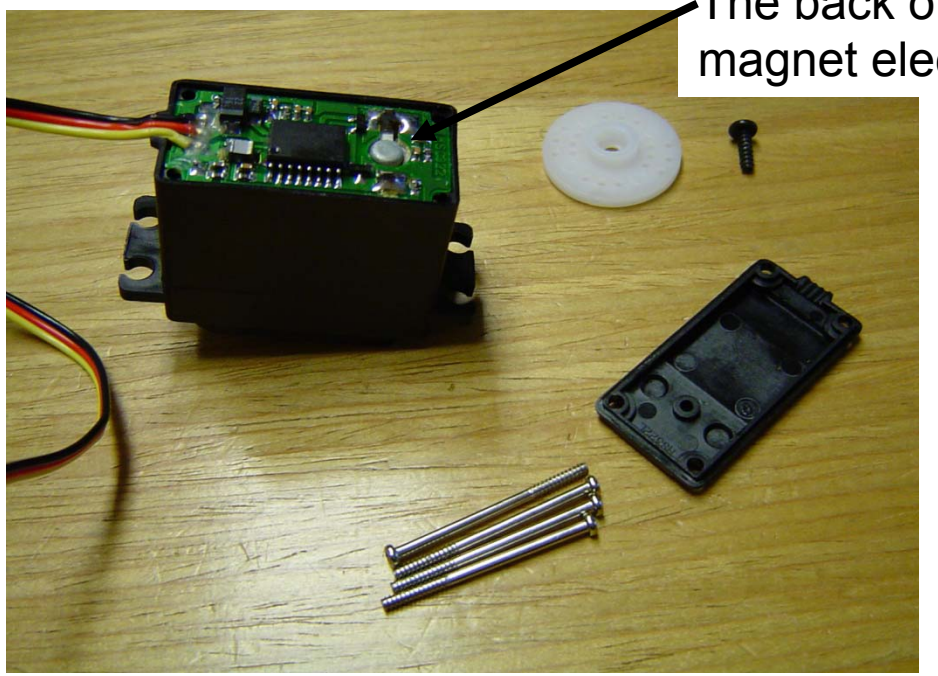
# Pulse Width Modulation (PWM)

- The duration of the pulse is interpreted as a commanded position



# Electronics Within the Servo

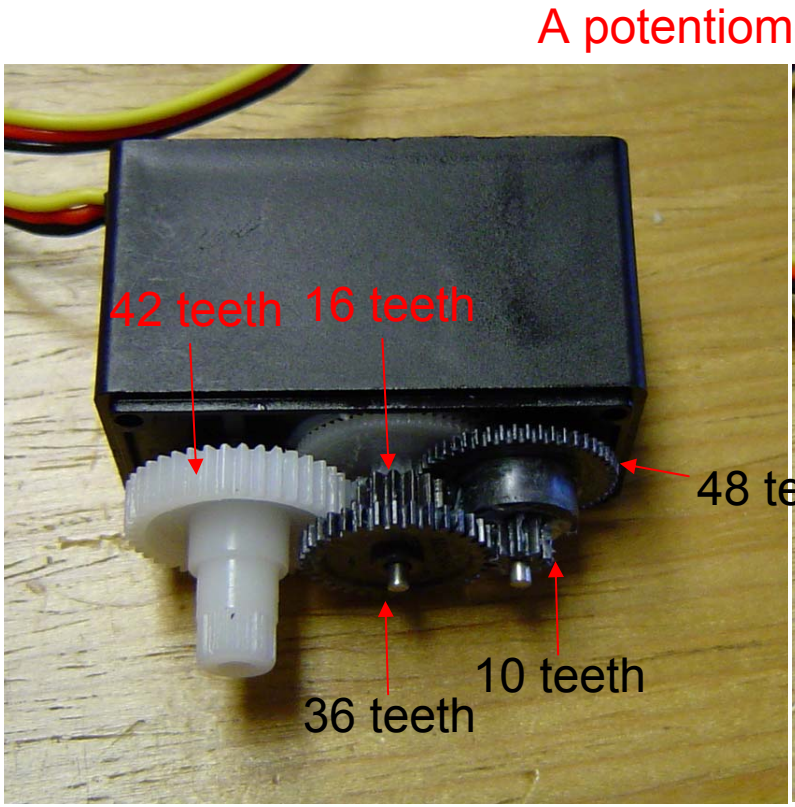
- Receive the commanded position
- Sense the position of the output shaft
- Supply voltage to the motor (either polarity) depending on the error

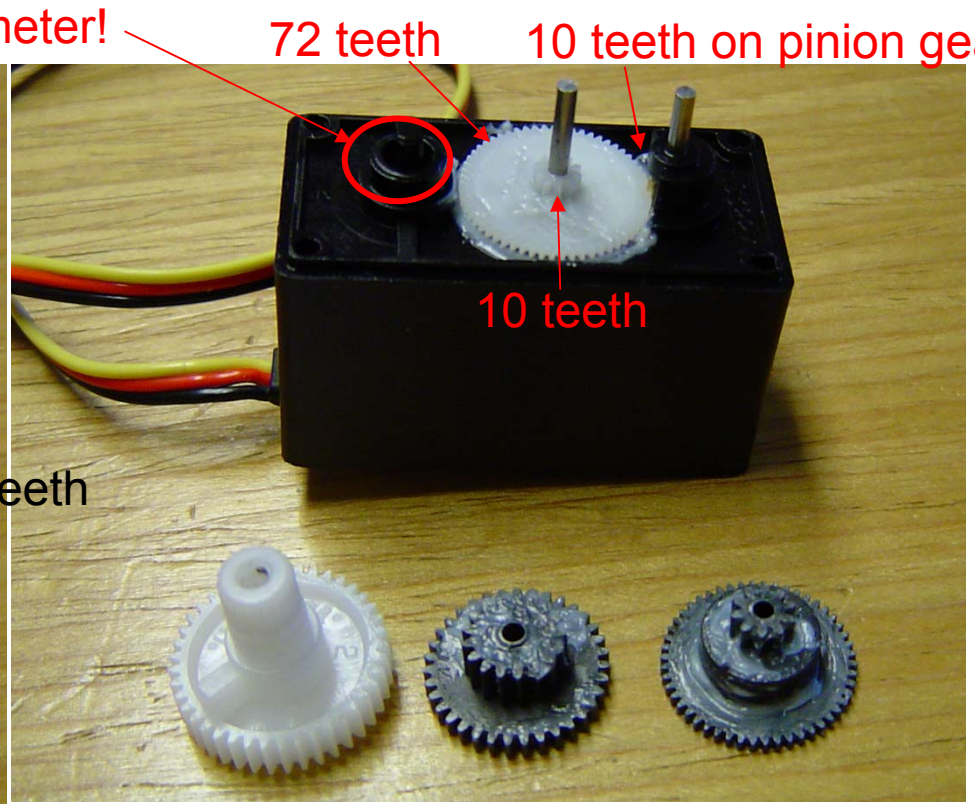


# Reduction Gears

- Given the rated output shaft speed, what is the approximate motor shaft speed in rpm?

a) $10^2$ rpm  b) $10^3$ rpm  c) $10^4$ rpm  d) $10^5$ rpm



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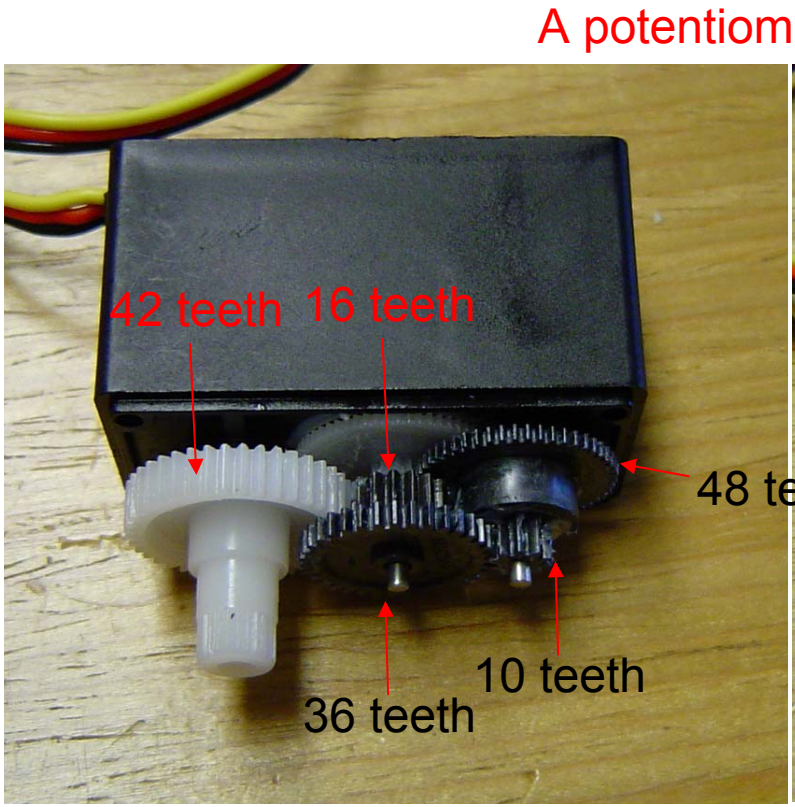
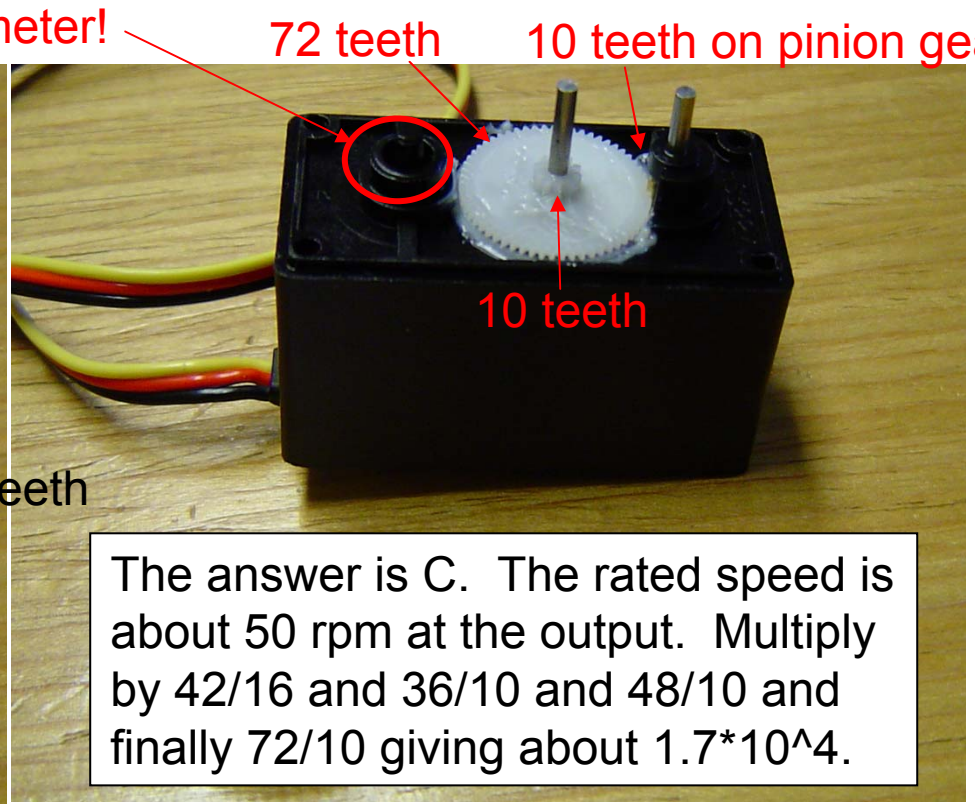


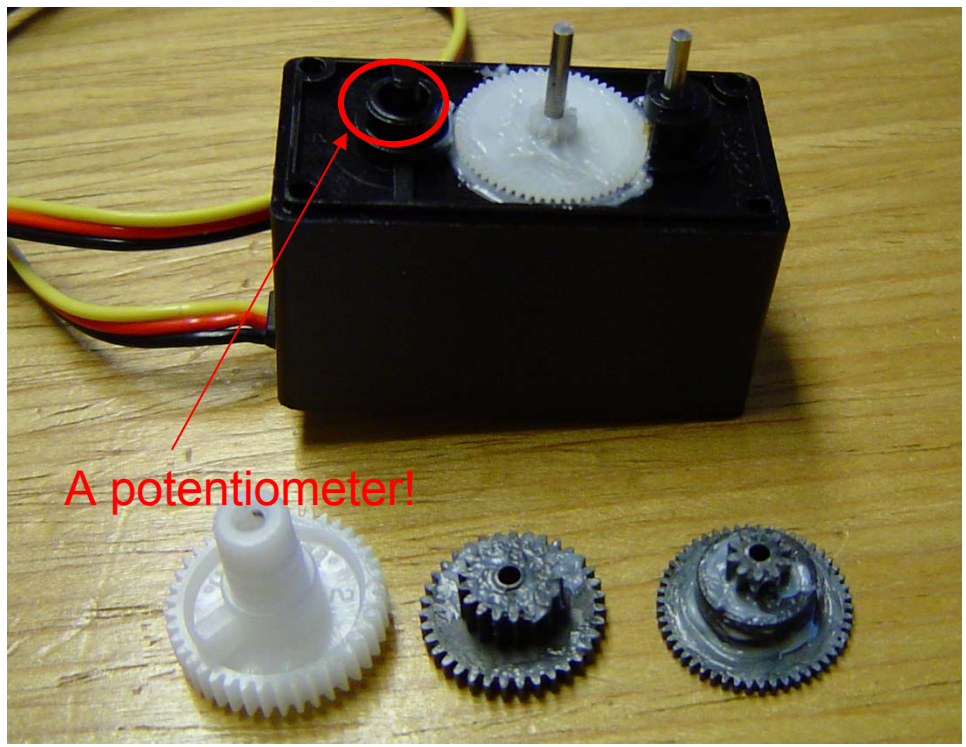




The answer is C. The rated speed is about 50 rpm at the output. Multiply by 42/16 and 36/10 and 48/10 and finally 72/10 giving about 1.7*10^4.

# Changing the System

- What if I snipped the wires leading to the potentiometer and placed a fixed resistor across the terminals that was equal to the resistance of the potentiometer when it's in the middle position?

a) The motor would work to maintain the center position of the output shaft regardless of the input signal
b) The motor would back-drive freely regardless of the input signal
c) The motor would turn as far clockwise as possible when the stick is displaced one direction and as far counter-clockwise as possible when the stick is displaced the other direction



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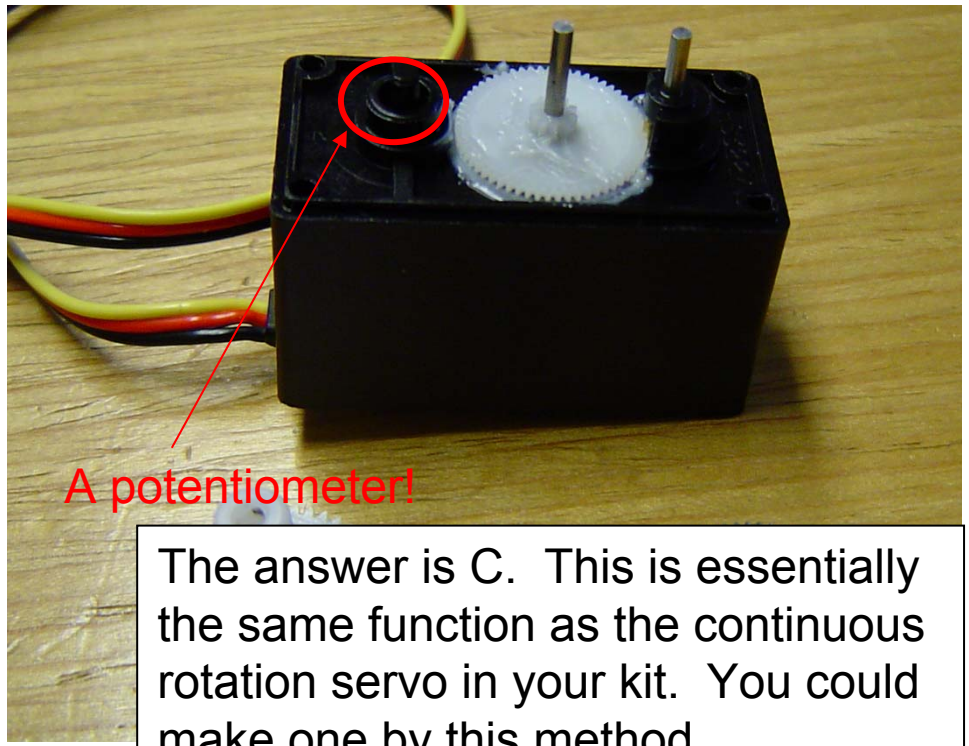
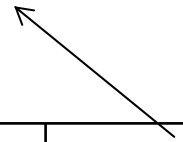



The answer is C. This is essentially the same function as the continuous rotation servo in your kit. You could make one by this method.

# Grading

More detailed breakdown will be provided by your section instructor.



| | |
|---|---|
| Lab Section (Design Notebook, etc.) | 50% |
| Exams (2 exams at 15% each) | 30% |
| Homework (4 assignments at 5% each) | 20% |

# MIT Grading Policy

- A - Exceptionally good performance, demonstrating a *superior* understanding of the subject matter, a foundation of extensive knowledge, and a skillful use of concepts and/or materials.
- B - Good performance, demonstrating capacity to use the appropriate concepts, a *good* understanding of the subject matter, and an ability to handle the problems and materials encountered in the subject.
- C - Adequate performance, demonstrating an *adequate* understanding of the subject matter, an ability to handle relatively simple problems, and adequate preparation for moving on to more advanced work in the field.

There is no curve in 2.007

# Collaboration

- We encourage you to work together and learn from one another
- What you submit should be your own work
- Acknowledge the contribution of others
- The course policy handout lays out many examples

# Time Required

- This subject is 12 units
- 3-4-5
- 3 hours of “lectures”
- 4 hours of “lab”
- 5 hours outside of scheduled class time
  - Reading
  - Doing homework
  - Studying for exams
  - Designing at home
  - Peer group meetings

# Computers and Software

- We will use computers a lot
  - Solid modeling (Solidworks)
  - Analysis (e.g., MathCad 14, Excel, etc.)
  - Embedded programming (PBASIC)
- We recommend a laptop for 2.007
- You can also use Mechanical Engineering computing facilities
- The laptop loaner program might help some people too

# Lab Sessions

- A critical element of the course
- Hands-on activities to support
  - Learning the content
  - Advancing your design projects
- You must keep a design notebook to document your work

# This Year's Theme

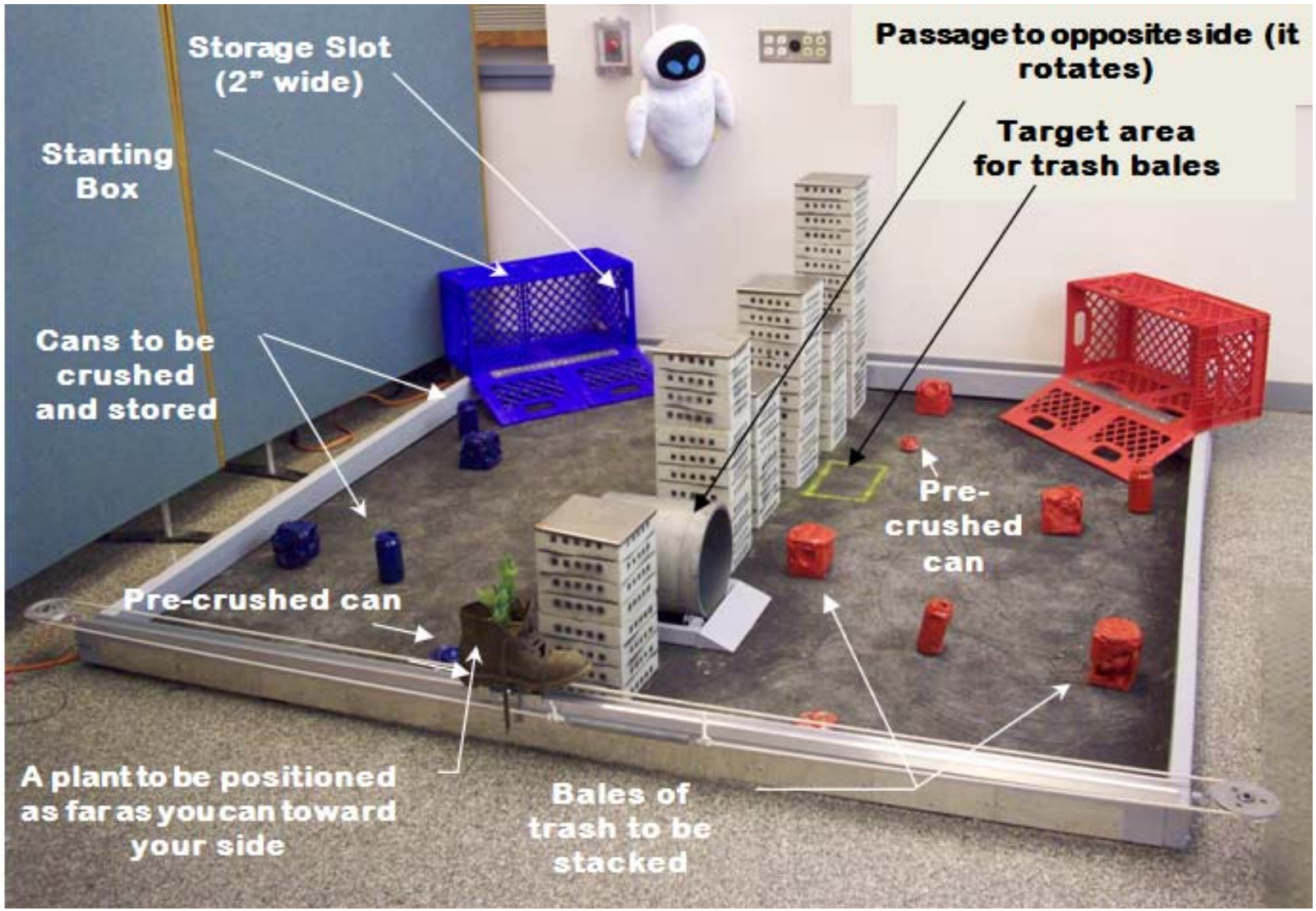
- Post apocalyptic world
- Cityscape covered with trash
- Robot has a home and collections
- Crushing and stacking

Images removed due to copyright restrictions. Please see Stanton, Andrew. *Wall-E*. Pixar Animation Studios, 2008.

- Pursuit of a plant
- Interesting obstacles

http://movies.apple.com/movies/us/games/walle/walle-h.ref20080630.mov

# This Year's Contest



# Next Steps

- No lab sessions this week
- Next class session is Thursday 5 FEB right here
- Communicate your preferences regarding lab sections -- assignments will be final by Friday
- If you are in the “regular” sections, get your kit and begin to explore