

Senior Biomedical Design I
APPL697 - Syllabus
Instructor: Robert Dennis (bob@unc.edu)

This course will introduce a series of topics that in some cases apply to design in general and in other cases are more specific to biomedical systems design. The course content is specifically selected to be useful both to students who plan to go into engineering practice with their undergraduate BME degree as well as those students who plan to go on for graduate study and research, working on entrepreneurial biomedical design projects within both industry and academia. The topics covered are:

Biomedical Disinfection & Sterilization
Safety in Design
Industrial Standards and Marks
Regulatory Considerations in Design (FDA and CVM)
Human Interfaces and Universal Design
Concurrent Design
DFX (Design for X), Design Lifecycle, and Robust Design
Mistake-proof design and Design Failure

COURSE STRUCTURE:

Each week you should begin by checking this syllabus on-line for any changes or updates. The most recent version of the syllabus will be maintained at:

<http://www.bme.unc.edu/~bob/classes/senior-design/syllabus-appl697.pdf>

Each week you will be given a reading assignment. I have selected a large number of freely available on-line materials for you to read, and in some cases I have compiled these materials into short chapters and posted them on-line, so that the material will remain more up-to-date (and far less expensive for you) than a text book. Also, there is no single textbook available that contains all of these important topics in enough detail that they would be useful to you as a practicing biomedical engineer.

ASSIGNMENTS and GRADING:

You will begin by reading the assignments each week, followed by a quiz. There may be an additional assignment for you following the quiz. You will complete the quiz and additional assignment and e-mail them to the instructor at bob@unc.edu

Each unit is graded equally and late assignments will be discounted 10%, plus an additional 10% for each week late after the due date. Incomplete or otherwise unsatisfactory work will have a reduced grade at the discretion of the instructor. Final grading at the end of the term will be based upon the overall class distribution and curve. Generally the average grade will be an "A" or "A-", however, it may be lower for the class as a whole if overall performance is lower than expected. Looking at this in a positive light, simply follow this syllabus and turn in the assignments in a timely manner and it is very likely that your final grade will be excellent. Because the assignments are currently under development and may change over time, you will be graded only on the unit that was current when you completed the assignment.

UNIT 1

Biomedical Disinfection and Sterilization (Part 1 of 2)

DUE DATE: This Unit is to be completed by 5:00 pm, 29 August 2008.

The one category of processes that is almost certainly the most pervasive throughout the technical considerations for the manufacturing, design, safety, packaging, maintenance, use, and disposal of biomedical devices and systems are those processes related to cleaning, decontamination, disinfection and sterilization.

Read the following chapter:

<http://www.bme.unc.edu/~bob/classes/senior-design/disinfection-sterilization-chapter.pdf>

QUIZ:

- 1- What is the basis for the rational approach to disinfection and sterilization
- 2- List the three categories in Spaulding's Classification
- 3- Why are there different levels of disinfection recognized by the CDC?
- 4- Why are there so many different processes for achieving disinfection and asepsis
- 5- Define "sterility"
- 6- Define "asepsis"
- 7- This is a class in Biomedical Design, why should you study germ control processes?
- 8- What are the most commonly used processes for achieving disinfection or sterility?
- 9- What forms of ionizing radiation are most commonly used for industrial sterilization?
- 10- What is HEPL, and what is its probable mechanism of action against germs?
- 11- What are the technical problems with using microwave radiation for sterilization?
- 12- What are the major considerations for the use of UV radiation for sterilization?
- 13- Name several methods of sterilization that are currently ineffective or not practical?
- 14- Does autoclaving kill all germs and achieve sterility?
- 15- List two types of pasteurization, and describe each process briefly.
- 16- Why is LTHPGP considered to be safer than EO gas sterilization?
- 17- Which class of polymers is more resistant to damage from ionizing radiation?
- 18- List one class of substances that can not be sterilized by "dry heat sterilization".
- 19- What is an ESCR test?
- 20- How do filters achieve sterility? With what types of substances can they be used?

e-mail your answers to bob@unc.edu

UNIT 2

Biomedical Disinfection and Sterilization (Part 2 of 2)

DUE DATE: This Unit is to be completed by 5:00 pm, 5 September 2008.

Read the following materials on-line:

http://www.reproline.jhu.edu/english/4morerh/4ip/IP_manual/F_Disinfectants.pdf

<http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5217a2.htm>

<http://www.cdc.gov/OD/OHS/biosfty/bmbl5/sections/AppendixB.pdf>

QUIZ:

- 1- How is superoxidized water made (just a few words, not detailed)?
- 2- Why are ethyl and isopropyl alcohol not considered to be high-level disinfectants?
- 3- What is the least effective alcohol disinfectant?
- 4- What concentration range should be used for ethyl alcohol disinfectant?
- 5- Why are chlorine compounds considered to be high-level disinfectants?
- 6- Why do you need to use a higher concentration of chlorine with unfiltered water?
- 7- What are the disadvantages to using chlorine disinfectants?
- 8- What is the active chemical disinfectant ingredient in Cidex®?
- 9- Is iodine considered a high-level disinfectant?
- 10- Which governmental agencies regulate disinfectants in the United States?
- 11- Does the CDC have regulatory authority over the use of disinfectants?
- 12- Does the CDC make recommendations for the use of disinfectants?
- 13- List the decreasing order of resistance of microorganisms to germicidal agents.
- 14- What infectious agent is a major exception to the list from the above question?
- 15- Define “disinfection”
- 16- What is “space decontamination”?
- 17- What processes are used for space decontamination?

ASSIGNMENT:

Locate a reference or references (printed or on-line) that describe the effect of disinfectants on materials that might be used in the design of biomedical devices or systems. For example, certain disinfectants can damage or destroy certain commonly used materials.

e-mail your answers to bob@unc.edu

UNIT 3

Standards and Marks (Part 1 of 2)

DUE DATE: This Unit is to be completed by 5:00 pm, 12 September 2008.

Design of any commercial or military system is done within the context of “standards”. The number of industrial and military standards is absolutely immense and certainly no one individual can be familiar with all standards, but it is important for any design engineer to have some knowledge of the most important standards that relate to their field and with the U.S. Standards System in general.

Begin by visiting the following web site:

<http://www.standardslearn.org/>

You will go through the ANSI e-Learning courses on this web page. Read each of the short courses on-line by clicking the “syllabus” link on the web page or in this document.

There are 4 courses:

1- **Short Course: Through History with Standards**

A quick overview to demonstrate how standards have evolved over time ([syllabus](#))

2- **Why Standards Matter**

A general introduction to standards and conformity assessment activities ([syllabus](#))

There are several sections, please read each one.

Then take their on-line exam: [Why Standards Matter: Final Exam](#)

Answer each question, then click the link <Check Your Answers> at the bottom

Grade yourself, and send your result to me by e-mail (number correct out of 10)

3- **U.S. Standards System – Today and Tomorrow**

A spotlight on the U.S. national standards system ([syllabus](#))

There are several sections, please read each one.

Take the exam: [Check Your Knowledge: U.S. Standards System - Today and Tomorrow](#)

Answer each question, then click the link <Check Your Answers> at the bottom

Grade yourself, and send your result to me by e-mail (number correct out of 10)

4- **Short Course: Legal Issues in Standard-Setting**

A Simple Review of Antitrust Laws and Patent Policies ([syllabus](#))

ASSIGNMENT:

By searching online, identify at least 5 standards that relate to implantable medical electronic devices.

e-mail copies of your answers to bob@unc.edu

UNIT 4

Standards and Marks (Part 2 of 2)

DUE DATE: This Unit is to be completed by 5:00 pm, 19 September 2008.

Read the following web pages:

<http://en.wikipedia.org/wiki/Standards>

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

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

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

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

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

http://en.wikipedia.org/wiki/Category:Certification_marks

http://en.wikipedia.org/wiki/Product_certification (read only the first 2 sections)

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

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

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

<http://en.wikipedia.org/wiki/Bounding> (read only the first paragraph)

QUIZ:

- 1- Define “standardization”
- 2- Why do people and organizations comply with *de facto* standards?
- 3- Why do people and organizations comply with *de jure* standards?
- 4- True or false: All standards are open for public use.
- 5- List the four levels of standardization.
- 6- Why do industry consortia have an increasing role in creating standards?
- 7- List the 4 categories of standards produced by the ASTM.
- 8- True or False: The ASTM can enforce the standards that it produces.
- 9- What does the National Technology Transfer and Advancement Act require?
- 10- What does ISO stand for, or is it not an acronym at all?
- 11- What 5 things does a certification mark on a product indicate?
- 12- What is a UL Approval?
- 13- What is a CE mark?
- 14- Which of these two is generally required by law: CE or UL mark?
- 15- Can CE or UL charge a fee for the use of their marks on each product?
- 16- Is the GS mark required or voluntary?
- 17- Define “bounding”
- 18- True or False: Military Standards are often used by non-military designers in industry.

e-mail copies of your answers to bob@unc.edu

UNIT 5

FDA (Part 1 of 3)

DUE DATE: This Unit is to be completed by 5:00 pm, 26 September 2008.

The FDA (United States Food and Drug Administration) is often viewed with a mixture of fear, resentment, and annoyance by many who are involved in the design and marketing of biomedical technologies. The mission of the FDA is to protect the public by assuring that approved devices are both safe and effective. Think about it this way: would you want someone to use a medical device on you that had not been thoroughly tested and approved?

Unfortunately some medical device designers spend an inordinate amount of time attempting to avoid (or evade) FDA regulation, and any form of interaction with the FDA. Most medical device designer firms pay special consultants who give advice on strategies for effectively dealing with the FDA. Interestingly, the FDA provides very clear guidelines on their web page, and it is rare indeed to hear of any device designers who have actually spent any time reviewing the materials made available by the FDA. So, to give you a distinct advantage over most medical device designers, you will become familiar with the FDA web page and their guidelines for device design. Please review the following web pages:

<http://www.fda.gov/> (just review the links that are available)

<http://www.fda.gov/cdrh/index.html> (review the available links)

<http://www.fda.gov/oc/combinations/> (review the available links)

<http://www.fda.gov/oc/combinations/overview.html>

<http://www.fda.gov/oc/combinations/faqs.html> (read the FAQs listed below:)

What is a combination product?

What are some examples of combination products?

What are the roles of the Office of Combination Products?

How are combination products assigned for review?

How do I determine which Center will review my combination or non-...

<http://www.fda.gov/orphan/>

<http://www.fda.gov/nanotechnology/>

<http://www.fda.gov/cdrh/devadvice/3132.html>

<http://www.fda.gov/cdrh/consumer/product.html#1>

<http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfTopic/consumer/index.cfm>

(click "Six-Pack abs text link)

<http://www.fda.gov/cdrh/devadvice/> (review the available links)

QUIZ:

- 1- What 8 classes of products are regulated by the FDA (FDA Home page, left side)
- 2- What does CDRH stand for?
- 3- Briefly define "combination product"
- 4- What is an "orphan product?"
- 5- What is the FDA definition of a "medical device"
- 6- Does the FDA provide useful information for consumers of products?
- 7- Can the FDA regulate devices sold for use in exercise and fitness?
- 8- What does IDE stand for?

e-mail copies of your answers to bob@unc.edu

UNIT 6

FDA, CDRH, and CVM (Part 2 of 3)

DUE DATE: This Unit is to be completed by 5:00 pm, 3 October 2008.

Read the following web pages:

<http://www.fda.gov/cdrh/devadvice/> (review the available links)

<http://www.fda.gov/cdrh/devadvice/overview.html>

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

<http://www.accessdata.fda.gov/scripts/cdrh/cfdocs/cfpd/315.cfm> (exemptions)

<http://www.fda.gov/cdrh/devadvice/pma/userfees.html> (Just the first 2 tables)

<http://www.evtoday.com/FDA%20Articles/March2003.html> (off-label use)

http://en.wikipedia.org/wiki/Off-label_use

QUIZ:

- 1- What are the basic regulatory requirements for medical devices in the U.S.
- 2- What does GMP stand for? What does GLP stand for?
- 3- Does the FDA regulate and enforce GMP in the United States?
- 4- Which classes of devices may be exempt from Premarket Notification 510(k)?
- 5- Give a specific example of a cardiovascular device that is exempt from 510(k)
- 6- Under what conditions is dental floss exempt from FDA 510(k) submission?
- 7- What are the characteristics of a class III device?
- 8- What is a PMA? What class of devices require a PMA?
- 9- What is the standard fee for a PMA?
- 10- What is Quality System Regulation?
- 11- What types of firms are required to list medical devices on form FDA-2892?
- 12- How would you define “off-label” use of a medical device?

e-mail copies of your answers to bob@unc.edu

FALL BREAK (week ending October 19, 2007)

No reading assignment during the week of Fall Break

UNIT 7

FDA, CDRH, and CVM (Part 3 of 3)

DUE DATE: This Unit is to be completed by 5:00 pm, 10 October 2008.

Read the following web pages:

<http://www.fda.gov/cdrh/devadvice/> (review the available links from the last unit)

<http://www.fda.gov/cdrh/devadvice/3122.html>

<http://www.fda.gov/cdrh/devadvice/312.html>

<http://www.fda.gov/cdrh/devadvice/33.html>

<http://www.fda.gov/cdrh/devadvice/351.html>

<http://www.fda.gov/cvm/default.html> (review available links)

<http://www.fda.gov/cvm/aboutcvm.html> (review available links)

<http://www.fda.gov/cvm/regofdevices.htm>

<http://www.fda.gov/cvm/aboutbeg.htm>

QUIZ:

- 1- What is an “IVD”?
- 2- What are the three steps to obtaining marketing Clearance from CDRH?
- 3- What are the three Premarket requirements?
- 4- What are the postmarket requirements?
- 5- Is advertising essentially the same as labeling?
- 6- What is “MDR”?
- 7- If your facility uses an FDA approved device which results in a death:
 - a. Are you required to report the death?
 - b. To whom do you make the report?
 - c. Within what time period are you required to make the report?

- 8- What does “CVM” stand for, and what do they regulate?

For devices intended exclusively for veterinary use:

- 9- Do manufacturers of veterinary devices need to register or list their devices?
- 10- What agency has regulatory oversight for veterinary devices in the United States?
- 11- Who is responsible for ensuring that veterinary devices are safe and effective?
- 12- Is it possible that some devices could be used for both animals and humans?
- 13- What is the “Green Book”?

e-mail copies of your answers to bob@unc.edu

BREAK: 17 October 2008: no assignment due.

UNIT 8

Design Control (Part 1 of 1)

DUE DATE: This Unit is to be completed by 5:00 pm, 24 October 2008.

One way that the FDA regulates and ensures the quality of medical devices is to require that medical device designers and manufacturers employ “design control”. This is done as a part of the FDA’s Quality System Regulation activities. Basically, *design control* is a way to verify that the design is regularly evaluated during development to ensure that the system will perform the intended function, and a way to incorporate corrections to the design as early as possible in the development and testing process. This is a kind of formal feedback mechanism within the design process, and in practice it is a very good thing to do, whether or not the FDA actually requires it.

Download and read the following document:

<http://www.fda.gov/cdrh/comp/designgd.pdf> or <http://www.fda.gov/cdrh/comp/designgd.html>

QUIZ:

- 1- What are the competitive advantages of having written design controls?
- 2- T/F: Design controls are part of the comprehensive quality system of a product?
- 3- T/F: Design control applies to the entire life of a product, throughout production?
- 4- Define “design validation”
- 5- Define “concurrent engineering”
- 6- Which classes of devices are required by the FDA to have design controls?
- 7- Define “quality” within the context of design control.
- 8- List some key elements of a Design & Development Plan.
- 9- What is the difference between a “concept document” and “design input”?
- 10- Define “specification” within the context of design control.
- 11- Define “design output” within the context of design control.
- 12- Production Specifications include ... (list at least 8)
- 13- Other Descriptive materials include ...
- 14- Define “Design Review” within the context of design control.
- 15- T/F: Formal design reviews should be planned to detect problems very early.
- 16- When selecting reviewers, what three factors should be considered?
- 17- Define “validation” within the context of design control.
- 18- Define “verification” within the context of design control.
- 19- List examples of verification methods and activities
- 20- What problems are caused by “hidden assumptions”?
- 21- List a few of the important considerations for validation methods.
- 22- “Design Transfer” is the translation of the design device into _____.
- 23- What are the two principle administrative elements in controlling design changes?
- 24- Define “DHF” within the context of design control.
- 25- Who is the primary beneficiary of the design history file?

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UNIT 9

Safety and Reliability (Part 1 of 2)

DUE DATE: This Unit is to be completed by 5:00 pm, 31 October 2008.

Design safety is arguably *the* most important factor in any design. Please read the following summary of design guidelines for safe, error-resistant medical devices:

Eleven keys to designing error-resistant medical devices:

<http://www.devicelink.com/mddi/archive/02/05/004.html>

Many organizations have general safety standards that must be followed. Military systems (including all biomedical devices used by the military) must also follow these safety standards. Briefly review the following document:

MIL-STD-882D:

<http://www.safetycenter.navy.mil/instructions/osh/milstd882d.pdf>

QUIZ:

- 1- Because of FDA regulations of medical devices, safety features are generally mandated on all approved biomedical devices. This is not so true of all consumer products, especially older products or those that have been damaged, are incomplete, or have been modified, and it is definitely not true for research devices and prototypes. Review carefully the eleven keys to error-resistant design and then look around in your environment to find a device or system that violates one or more of these design guidelines. Briefly describe this device and the violations that you can see.
- 2- The second reading, MIL-STD-882D, is a military standard document. It is very different, much more formal, and in most ways much more general in nature than the eleven guidelines for error-resistant medical devices. What are the main points of similarity between these two documents?

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UNIT 10

Safety and Reliability (Part 2 of 2)

DUE DATE: This Unit is to be completed by 5:00 pm, 7 November 2008.

Vast resources are expended each year to increase the safety of medical devices, drugs, automobiles, aircraft, and many consumer products. However, there is some controversy as to whether or not the inclusion of safety features actually reduces the number of injuries or deaths because people are thought to exhibit a behavior known as “[risk compensation](#)”. This behavior results in what is known as “[the Peltzman Effect](#)”. These are of course psychological phenomena, and as such for them to occur the individual in question must *perceive* an alteration in the risk or safety of a device or situation. So, for the design engineer, safety is an issue that must be considered both within the details of the system design, as well as in the perception of the device or system by the end user. The end user’s perception will ultimately define their real behavior. One way of looking at this is that safety should be engineered deeply into all medical devices, but not necessarily advertised externally. People invariably play with “safety needles”...

Read the following web pages, and browse the links under “See Also” in some cases:

<http://en.wikipedia.org/wiki/Safety>

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

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

<http://en.wikipedia.org/wiki/Life-critical>

<http://www.kidsindanger.org/> (just review this web page briefly)

<http://www.kidsindanger.org/programs/test/resources.pdf>

http://en.wikipedia.org/wiki/Inherent_safety (read the links under “See Also”)

<http://en.wikipedia.org/wiki/Fail-safe>

<http://en.wikipedia.org/wiki/Interlock>

<http://en.wikipedia.org/wiki/Poka-Yoke>

http://en.wikipedia.org/wiki/Error-tolerant_design

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

<http://en.wikipedia.org/wiki/Reliability>

http://en.wikipedia.org/wiki/Reliability_engineering (just review this briefly)

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

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

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

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

QUIZ:

- 1- List at least 10 common safety measures that could be used with a product.
- 2- What does FMEA stand for?
- 3- What is a “life critical system”?
- 4- Why might it not be such a good Idea to advertise a medical device as “Absolutely safe and error proof”?
- 5- What behaviors have you noticed in yourself or others when they *perceive* that an object is unusually safe, or unusually dangerous?

e-mail copies of your answers to bob@unc.edu

UNIT 11

Human Interface and Human Factors Design (Part 1 of 1)

DUE DATE: This Unit is to be completed by 5:00 pm, 14 November 2008.

"Do it by design"

Read one of these two documents (they are the same, one is just a *.PDF file):

<http://www.fda.gov/cdrh/humfac/doi.html> (do it by design)

or

<http://www.fda.gov/cdrh/humfac/doi.pdf>

Briefly look at the following on Human Interface & Universal design principles:

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

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

<http://en.wikipedia.org/wiki/Usability>

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

<http://en.wikipedia.org/wiki/Ergonomics>

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

QUIZ:

Choose any device or system in your environment for the following exercise. The simpler the better (try to avoid choosing something too complex). Objects such as simple cooking implements or tools are suitable, for example. Based on your readings, what is wrong with this object or system from a human factors perspective, and how would you change the design to correct or improve the human factors aspect of the design?

e-mail copies of your answers to bob@unc.edu

UNIT 12
Ethics (Part 1 of 1)

DUE DATE: This Unit is not required.

I thought you would be interested to know that there is a Code of Ethics for Engineers. It is short (2 pages) and at the very least it is worth knowing that it exists. You should take a minute to look at it.

The NSPE code of ethics for engineers is posted at the following web site:

<http://www.mtengineers.org/pd/NSPECodeofEthics.pdf>

QUIZ:

No quiz for this unit

e-mail copies of your answers to bob@unc.edu

UNIT 13

DFx, Product Lifecycle (Part 1 of 1)

DUE DATE: This Unit is not required.

Although this material is not required for your grade, it is certainly worth looking at for a few minutes.

"DFx" means Design For (something), which includes Design for Assembly, Design for Environment, Design for Manufacturing, Design for Maintainability, and there are many others. Generally this topic relates to the design for the life cycle of the product (assembly, manufacturing, some area of use, maintenance and repair, and eventual decommissioning which can mean disassembly, disposal, recycling, up-cycling, etc.). Some European countries are beginning to require considerations for end-of-life management of items that are imported, and most now have restrictions on hazardous substances such as lead and cadmium that they want to avoid putting into their landfills.

Restriction of Hazardous Substances Directive (RoHS):

<http://en.wikipedia.org/wiki/RoHS>

DFM, DFA,

Design for Environment:

<http://www.pre.nl/ecodesign/?gclid=CNjdi8fq-I4CFQdEFQodDk2eDg>

<http://www.pre.nl/ecodesign/ecodesign.htm>

http://www.pre.nl/life_cycle_assessment/default.htm

http://www.pre.nl/life_cycle_assessment/life_cycle_assessment.htm

http://www.pre.nl/life_cycle_assessment/impact_assessment.htm

http://www.pre.nl/life_cycle_assessment/life_cycle_inventory.htm

<http://www.pre.nl/eco-it/eco-it.htm>

http://www.pre.nl/eco-indicator99/eco-indicator_application.htm

http://www.pre.nl/links/ecodesign_links.htm (review available links)

QUIZ:

No quiz for this unit

e-mail copies of your answers to bob@unc.edu