How to Use
Biological Process Engineering
in Class

Biological Process Engineering is a book with a different flavor. This book is different because of the following attributes:

1. systems approach
2. design oriented
3. full range of biological applications completely integrated
4. extensive tables of values
5. many worked examples
6. 373 new problems
7. marginal notes

1. Systems Approach. The Systems chapter 1 is a little hard for the students to comprehend. Expect them to be confused and discouraged. Let them know that the first chapter lays the foundation for the other chapters, and that they will feel better about the approach once they see it used a little more in the rest of the chapters. Let them know, also, that once a systems diagram can be drawn, the problem is essentially solved; the rest of the problem becomes one of determining details. Help them to be patient; they probably haven't seen these concepts before; they are certainly not familiar with them. Assist them to know the most important material and be able to select important material from the details. Important stuff is generally given in the list of lecture highlights in another file on this web site.

Thereafter, be sure to point out the various systems diagrams in the other chapters when you come to them. In particular, note Tables 2.1.1, 3.1.1, and 4.1.1 that compare the three transport processes of fluid flow, heat transfer, and mass transfer with a systems viewpoint.

One thing to note to the students is that resistance limits flow, but also gives a path for flow to occur. Capacity is usually seen in parallel with resistance, and inertia is hardly seen at all. The difference between an ideal effort source and an ideal flow source is that the flow from an effort source is determined by external resistance; external resistance has no effect on flow from a flow source. Both sources may vary in magnitude, but the variation comes from the source, not the external components. Illustrate this with the ac power source in the wall outlet.

Another good thing to mention is the electrical mnemonic helper: "ELI the ICE man." Voltage (E) leads current (I) by 90^o in inductance (L) and current leads voltage by 90^o in capacitance (C). The same holds true for general inertia and capacity. Illustrate this with atmospheric temperature. The minimum heat flow (sunlight) in the northern hemisphere occurs in December; the minimum temperatures are in January or February. Therefore, the flow variable leads the effort variable. Thus, this must be a system involving capacity. Because the phase angle is not 90^o, there must be resistance involved, also.

2. Design Orientation. The book is design oriented. There are simple design flow charts at appropriate places near the end of the chapters. These are there to help students understand steps to be taken.

More than that, however, such techniques as iteration are introduced and illustrated. This can be an important technique in design.

Comments at the ends of the worked examples are meant to give a practical bent to these problems. If a solution is unrealistic, I have tried to say so. Not all engineering calculations work out perfectly, and the students should be able to see that it happens to professors, too. Students should be expected to begin developing engineering judgment, and that only happens when they stand back and ask if an answer is reasonable.

I usually begin the course by asking students to tell me why they are solving problems, why they have to write reports, and to give characteristics of the readers of their reports. I want them to realize that, in addition to their idealisms, that their mortgage payments and their family's welfare depend on them doing a good job. Characteristics include: busy, demanding, hard-to-please, and maybe nontechnical. They need to keep these things in mind as they complete design assignments throughout the course.

I give three design assignments in the course: one at the end of fluid flow, one after heat transfer, and one after mass transfer. Applications areas for these design projects are environment, medicine, and biotechnology. The pairing of transport process with applications area changes from year to year. These design projects are the same as I would have given as a full semester design project, but I only give them about 10 days to do each. I figure that they'd wait until about 10 days before they are due at the end of the semester, anyway. By this means, I give them repeated practice at approaching engineering designs – some figure it out right away, others take 2 reports. All seem to know how to do it the third time.

Biological Process Engineering was written with this in mind. The tabled material is quite extensive, but not enough for these projects. I intended to do it this way.

Once I assigned a project that required design of the ventilation system for a BL-4 biosecure building with several laboratories included. One group gave me a report ion which they had designed an extra bathroom in the building. I penalized them for this. Now, this was probably the first time any teacher had ever marked them down for giving extra effort. I justified my actions this way: the way the project was worded, the U.S. government was asking for bids. To put extra in their solution meant that someone in the government would have to justify spending money on something not within the specifications. In addition, the engineers would be cutting their own throats. They were giving away their services by providing this extra design for free; it would be better to state that a bathroom was necessary, and that they could design the bathroom with additional contract money. The students listened and understood.

This same project involved HEPA filters, and all groups but one specified a HEPA filter 99.97% efficient, according to manufacturers' specifications. One group specified a 99.99% efficient filter. I criticized this as a mistake, because, I said, the contract agent will know that manufacturers specify 99.97%, not 99.9%, and if the engineers couldn't get this simple fact right, then they would be questioned about whether they could get the rest of the design right.

Well, the group sent me a letter, as if to the contract officer, stating that, indeed, they had found one manufacturer's literature that gave an efficiency of 99.9%. They were specifying filters from that manufacturer.

Aside from the fact that specifying one specific manufacturer's product was not a good idea when so many other sources were available, I sent the group back a letter, as if from the contract officer, in which I acknowledged the correctness of their figures. In the letter I then went on to say that in the meantime, the contract had been given to another group, and I wished them well in future endeavors. They easily got the point: they had won the battle, but lost the war. The contract wasn't theirs.

Anyway, <u>Biological Process Engineering</u> also includes enough hardware information that the students are introduced to means to implement their design solutions. They will have to consult manufacturers' information, but they will know enough to understand what is being offered.

3. <u>Biological Applications</u>. The challenge for teachers of biological engineering undergraduate courses is to make them broad enough for everyone, no matter what their applications interest, to feel that the course is worthwhile. We have had that same challenge, and <u>Biological Process Engineering</u> is the product of that challenge. There are examples from environment, medicine, biotechnology, agriculture, and others. Often the principles are the same despite disparate applications. For instance, moving herbicides past the hydrophobic cuticle layer in plants, and moving drugs transcutaneously past the hydrophobic stratum corneum in humans illustrate the same principle. These are described in successive statements in the book. Let the students see the similarities, and let them decide which example illustrates the point best to them.

4. <u>Extensive Tables of Values</u>. The intention was to give enough entries that the student would either find the values she or he needed or at least be able to estimate the needed value. Be sure to emphasize that tabled values are usually averages, and that they do not represent the entire population. If there is much variation, then students will have to extend tabled values sometimes quite a bit. They <u>may</u> then be able to see why extreme precision is not usually warranted.

I am particularly proud of Table 4. This is a table of conversions among different measures of concentration. You won't see another table like this anywhere. Even some of the few similar entries in the <u>Handbook of Chemistry and Physics</u> are incorrect. There are some corrections for my table, too.

5. <u>Many worked examples</u>. These examples are meant to illustrate, not just the applications of the materials presented in the preceding sections, but also analysis and design related to biological systems. I have noticed in other books that the exact choices of equations and constants is not clear. They seem to be clear until one tries to use them. I tried to solve this problem for students by example.

Not all of the calculations worked out very neatly the first time. When they didn't, I decided not to rework the example, but to use it to illustrate the judgment that must be applied to every biological engineering problem. If the answer was not realistic, I told the student that it wasn't, and said what should be done about it. If precision is not warranted, I said that, too. If there were some independent means to check the solution, I tried to include that as well.

6. <u>New Problems</u>. The problems at the ends of the chapters have been obtained indirectly from journals, trade magazines, and friends. Some are similar to other <u>problems</u> you see in other texts, but most are not. One reason that there are so many problems is that I wanted to give instructors the choice of similar types of problems with different applications areas. Thus, an instructor in a biomedical engineering course may choose to assign only those problems dealing with medicine or physiology. Someone with a biotech course may want to assign problems on bioreactors and microbes.

Students must understand that many of these problems do not have unique answers; that it is the process of arriving at an answer that is more important than the answer itself. Thus, students should learn to make choices and to justify these choices when they submit their work.

7. <u>Marginal Notes</u>. Students really like these. They make it easier to find material in the text, especially when the thorough index is consulted to find the page where <u>something</u> may be found. The publisher did not want to include these because they would have been too expensive. I checked back with students to see how important marginal notes really were. They confirmed that they were extremely well liked. It took some negotiating with the publisher to include them.

The instructor can use the marginal notes as a key to summarize materials in the reading. Although some marginal notes point to materials not as important as others, this is another way to separate details from more important generalizations.

There is too much material in the book to be covered in one semester's worth of lectures. Nonetheless, this book can be covered in one semester if you assign readings to be completed before class. Expect the students to have done their homework. Don't let students get away with not reading their assignments, or you will lose control of the class. I go over important points in the reading. After this summary, I ask for questions. If no questions then I let the class go.

The number of details in the book can be daunting, both for students and for the instructor. You need not know all about the details. I didn't before I wrote the book, but many of my friends helped me fill in the holes. The point is, keep your eye on the main points, and help the student identify what the main points are. If students ask about details which you know nothing about, admit that, and expound with details from examples you do know. That way, you will enrich the class with your own specialized knowledge.

Many of us first learned transport processes with a mathematical approach. Yet, if we admit it, we probably didn't learn transport very easily. If you wish to supplement this book with mathematics, by all means try it. However, I have had students, strangers, come up to me, thank me for writing this book, and tell me that the approach in Biological Process Engineering is an easy way to learn transport when they didn't know anything about it before.

There is a solutions manual for the problems. It is available from John Wiley, but they won't admit it. Thus, qualified instructors can get it from me. The solutions manual can make your job a lot easier, and again, keep you from having to become an expert in problems you are not sure of yourself.

Errata, and supplements when available, can be found on my University of Maryland web page, http://www.bioe.umd.edu/artjohnson/. Be sure to let the students know about this, and check it often yourself. As changes are made, they will appear here.