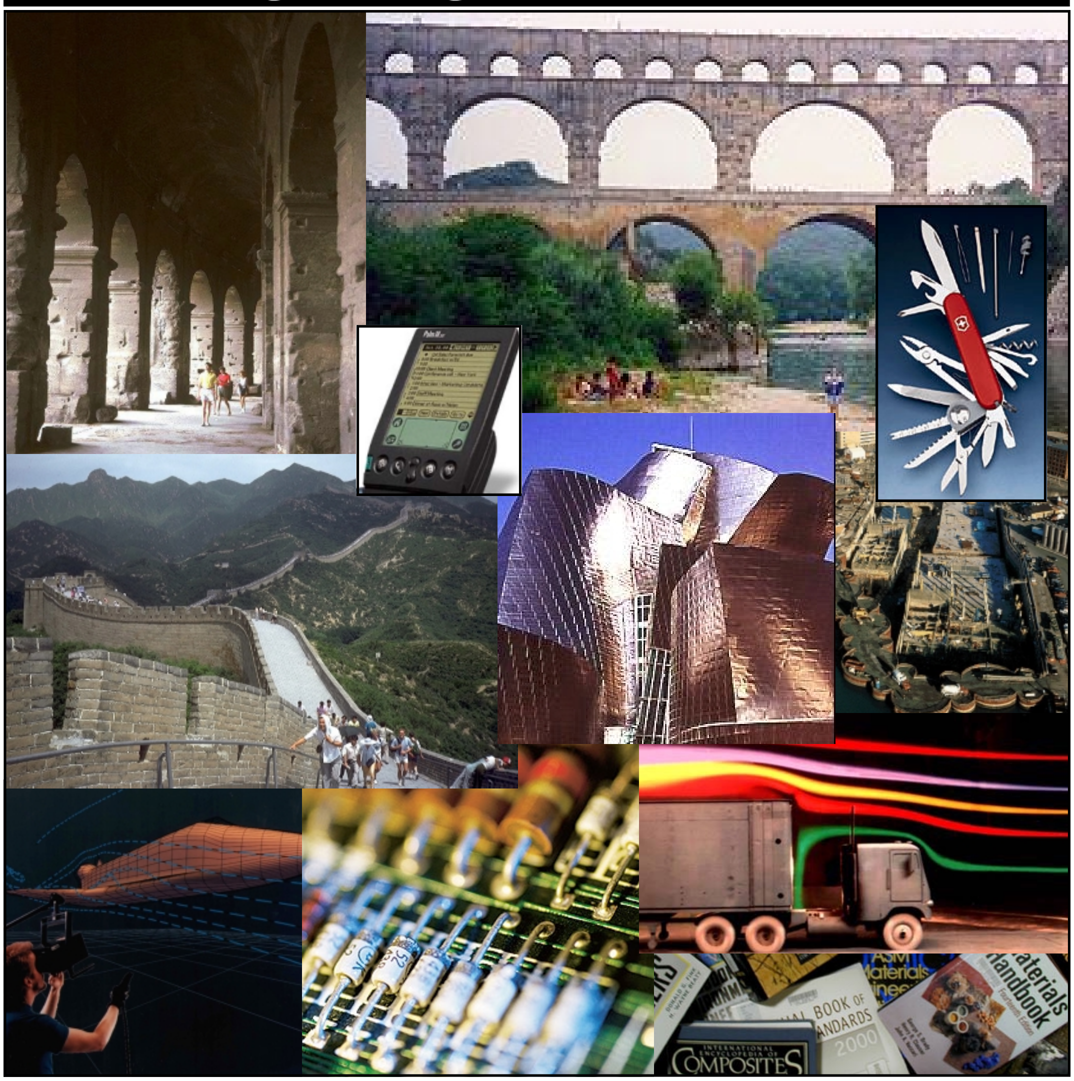
Overview

1

What is Engineering?

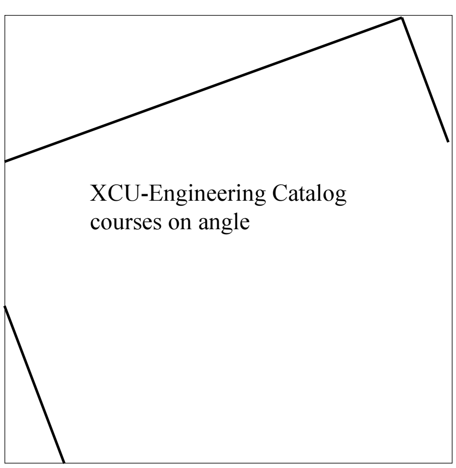


1 Overview

"Engineering...
the art or science...
...of practical application
of the knowledge of
pure sciences...

...physics, chemistry, etc.,...

...as in engines, bridges,
buildings, mines,
chemical plants,
and the like."



What is engineering?

A simple answer might be designing and building things. Not an inaccurate definition, but not a very complete definition either. The Random House College Dictionary says it's "the art or science of making practical application of the knowledge of pure sciences, as physics, chemistry, etc., as in the construction of engines, bridges, buildings, mines, chemical plants, and the like." The "science" part we might have guessed; but "art"? Does this mean that there's more to engineering than science and mathematics? Absolutely! Is there yet more to the meaning of engineering? Absolutely!

Ordinarily we think that, to become an effective engineer, all we need to do is master the science and mathematics of the discipline—statics, thermodynamics, digital circuits, reactor design.

Certainly, if we look at course offerings in university catalogs in, say, a department of mechanical engineering, these would be the listings that we would find.

But such courses relate only to the technical aspects of engineering. And engineering is far from being purely technical.

Recall the word "art" in the dictionary definition.

So, what is engineering?

Engineering is a way of thinking.

It's the practice of solving multi-parameter problems using mathematics, science, and technology as tools. But within the constraints of many other things—some economic, some aesthetic, some cultural, some political. And where these tools are inadequate, engineering is the creation of new tools.

1 Overview

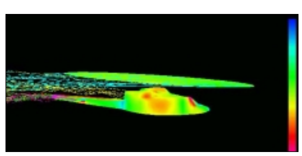
"Is there more to engineering than science and mathematics?"

Engineering is invention.

Engineers develop new devices, materials, or processes to meet the needs that existing technology does not address. Sometimes invention means finding new ways to combine and use existing technologies.

Engineering is measurement and estimation.

River flow, noise in communication systems, and the failure parameters of automobile tires—to name a few—require measurement.



How does one make these measurements?

How accurate must they be?

What variability will they have?
How can we characterize this variability?

These are engineering questions.

Engineering is approximation.

When the mathematics and science that relate to a problem are too complex to apply, progress requires approximations, simplifications, and, sometimes, intelligent guesses. But what are appropriate approximations, simplifications, and guesses?

That's part of engineering.

photo from book
"Environmental Geology"
how many tires?
Westley California

Engineering is modeling and simulation.

To confirm that an idea or design will work, engineers must experiment with a scale model or computer simulation—perhaps an airplane or a chemical processing column.

Then they must determine how to apply the results to full-sized versions.

1 Overview

"Developing a balance between form and function can be a very rewarding part of engineering."

Engineering is...

...a way of thinking.
...invention.
...measurement & estimation.
...approximation.
...modeling and simulation.
...communication.
...politics.
...money.
...art.

Engineering is communication.

ask mjk-designs

ask mjk-collaboration

ask mjk-ops manual draft

Selling designs, collaborating on projects, and writing operation manuals are all a part of engineering.

Engineering is politics.

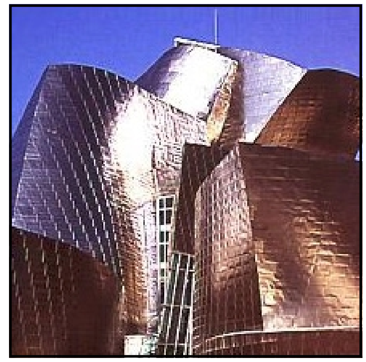
The best technical solution to a problem may be impractical because of political or social objections. Engineers must develop compromises that satisfy functional and societal constraints.

ask MJK about photo to show
• Engineers agreeing
- shaking hands
- smiling with execs?

Engineering is money.

Design, construction, operation, and maintenance all cost money! Realistic cost projections are essential to any engineering project.

Engineering is art.



The best designs are not only functional but also aesthetically pleasing.

Developing a balance between form and function can be a very rewarding part of engineering.

And, since engineering problems rarely have single solutions, creativity and imagination play a large role in engineering.

Notice, our descriptions don't even mention the technical aspects of engineering.

Nor do they mention the various fields of engineering. Yet, they still accurately reflect what is engineering.

The descriptions apply to all of engineering.

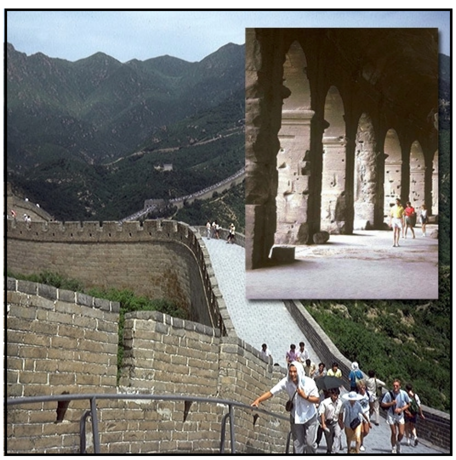
Most certainly, math and science are the foundations on which engineers build their ideas and designs.

But math and science are only limited tools in the practice of engineering.

1 Overview

"Engineering is both very old and very new."

"We still marvel at engineering accomplishments that are thousands of years old,



But engineering as an academic discipline is not that old."

sodium carbonate

MJK antique cloth dying

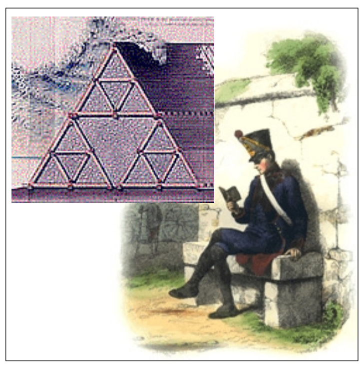
MJK leather tanning

MJK food preserving

Engineering is both very old and very new. We still marvel at engineering accomplishments that are thousands of years old—the pyramids of Egypt, the Great Wall of China. But engineering as an academic discipline is not that old.

Probably the first schools for engineering were created in France: L'Ecole des Ponts et Chaussees (bridges and roads) in 1747...

...and L'Ecole du Genie de Mezieres (military engineering) in 1748.



In the U.S. it was only in the late 19th century that scientists thought it would be useful to provide engineers with a better theoretical understanding of their art. So schools of engineering were created. But, first you were an engineer; then you were a student.

Not exactly the way the profession works today.

Chemical engineering, although "practiced" for 2000 years through making clothing dyes, through tanning leather, through preserving food, became an academic discipline only in the late 1800s.

At that time, in England, soda ash (alkali), used extensively in the glass industry, was being produced by the Le Blanc process which released hydrochloric acid, sulfur, and chlorine gas into the atmosphere.

Hazardous waste was such a problem that the government dispatched teams of alkali inspectors to review the chemical plants.

PHOTO of English pollution

George Davis, an alkali inspector was observing a revolution in the techniques of production of soda ash and potash. He realized that, for progress to continue, it would be necessary to blend the backgrounds of applied chemists with those of mechanical engineers.

In 1880 he proposed the creation of a society for "chemical engineers". To illustrate the content of this new field, he gave a series of twelve lectures on chemical operations that attracted attention in the U.S.

PHOTO of
• George Davis
• or First Society of Chemical Engineers

So much attention, that in 1888 a chemistry professor at MIT, Lewis Norton, established "Course X"—the first four-year undergraduate program in chemical engineering. Voila! An academic engineering discipline was born.

1 Overview

"The development of reliable, safe, cost-effective, aesthetic, useful products is the ultimate goal of the engineer."

"When you approach a bridge in your car, you drive over it.

You have complete trust in the engineering and construction of the bridge."

In this course we are going to explore engineering. But this exploration will not be the traditional "overview" of engineering disciplines.

Yes, a few lectures will focus on specific areas of engineering—like chemical engineering and civil engineering. But others will address the tools and techniques that all engineers need to have in their arsenal of skills—approximation, statistics, modeling.

And, yet, other chapters will demonstrate how science, technology, creativity, budget, and teamwork must be integrated to develop products.

The development of reliable, safe, cost-effective, aesthetic, useful products is the ultimate goal of the engineer. This course is a first step toward understanding how to get there.

Before we begin, let's talk a bit about how the engineering profession really works.

If you go to a doctor with a pain in your side and he tells you that you need an operation, what do you do? Most probably you would get a "second opinion". That is, you don't entirely trust the first doctor's judgement.

When you approach a bridge in your car what do you do? You drive over it. Why? Why don't you get out of your car to inspect it, or ask who built and designed it to ensure that it's safe?

The answer is, you have complete trust in the engineering and construction of the bridge.

In a few remarkable instances, e.g., the Tacoma Narrows bridge in 1940, your trust would not have been warranted.

But in the vast majority of cases, what has been "engineered" is safe.

With so many engineers—some not as good as others—working on so many engineering projects, how could this enviable record be achieved? The answer is self-regulation and self-imposed standards.

We all laugh when we hear of self-regulation: the tobacco industry keeping cigarettes from children, or the entertainment industry setting sex and violence limits on its productions. But in engineering, it works. People's lives are at stake, and the profession takes fierce pride in setting standards and regulations that are safe.

The professional engineering societies—ASCE, AICHE, ASME, IEEE, and others—play a significant role in this process.

When you want to build an outdoor deck, what size post do you use?

Look it up in the Standard Handbook for Civil Engineers.

Depending on the load, the height of the deck, the type of wood for the deck post, you will find an answer that has been verified. If the answer is 6" x 6", you can be sure that 6" x 6" is adequate. And this figure has already taken into consideration variations in materials.

1 Overview

XCU-nut and bolt

"The engineering community certifies its engineers– especially when public safety is involved."

Rivet patterns for holding together steel beams, sand/cement ratios for concrete, diameter of wire to carry electricity, chimney heights for fireplaces—these data have all been assembled by professional engineering societies in conjunction with public agencies to define acceptable practice. So, the importance of these societies is not to be underestimated.

When you go to a hardware store to buy a nut and bolt to fasten together something at home, you pick up a cute little plastic package with what you think you need. And, you assume that your purchase will do the job.

If you really want to be certain, you could order a nut and bolt from a machinery supply house and specify exactly what you need in terms of an ASTM (American Society for Materials and Testing) standard or a military specification.

You have no idea how many parameters can be specified for a simple nut or bolt. If you're curious about how many standards there are for all the materials we use today, you can buy the current year's ASTM standards manual—75 volumes at a cost of about $6,000.

The engineering community also certifies its engineers—especially when public safety is involved.

In these cases, an engineering degree does not make you an engineer. First, through a series of exams, you must demonstrate your theoretical competence. Usually you take these exams near the end of your undergraduate years.

Then, some years later, after having created a portfolio of projects you have worked on, you can apply to take the second half of the certification process—a lengthy design problem. If you pass, you may attach the letters P.E. to your name—Professional Engineer. These letters certify you to sign off of on designs and construction projects. And, of course, there are many kinds of P.E.s—each having his area of expertise.

ask MJK about photo to show
• ENGINEER'S STAMP PE

The impact of engineering on society is tremendous, so sometimes small, subtle improvements are vastly important.

Consider sulfuric acid production.

ask mjk-sulfuric acid prod

ask mjk-fertilizer plant

ask mjk-sulf acid pix

Sulfuric acid is used in fertilizers, car batteries, and metal processing. You've probably barely even heard of sulfuric acid. But in 1995 the U.S. produced 50 million tons—not pounds, but tons— of sulfuric acid with a market price of about $42/ton.

If you, as an engineer, could improve the efficiency of sulfuric acid production by only 1%, the value of that improvement would be $20 million per year. That's not small change. And we're talking about a small improvement in producing just one chemical.

1 Overview

"In engineering things add up quickly because the quantities are so large."

"One of the intriguing things about engineering is uncertainty."

Consider another example.

Have you ever noticed that cars of different sizes have a different number of lug nuts holding their wheels to the axle?

Some really, really small cars have as few as three. Some large trucks may have twenty. Why do you suppose there is so much variation? Aesthetics?

3 wheels and lug nuts
- one small
- one medium
- one semi

No. Larger vehicles need more bolts to distribute the increased load.

Suppose you could develop a design that would use one fewer bolt, yet be just as safe. What's that worth?

Well, vehicle production in the U.S. is about 10 million per year, so the saving would be 40 million nuts and bolts per year. At $0.50 per set, that's another $20 million.

In engineering things add up quickly because the quantities are so large.

One of the intriguing things about engineering is uncertainty. Although we all like to have perfect answers to everything, in engineering it's not possible. There are variations in materials, variations in construction quality, variations in environmental conditions; these all have to be taken into account by the engineer.

It is not possible, for example, to design an absolutely safe bridge or a zero-defects space shuttle. What is possible, however, is to design a fairly safe bridge or space shuttle. The difference between the two goals has to do with assumptions.

The Golden Gate bridge would probably collapse if its lanes were filled with military tanks and subjected to a 100 mph wind. So, it's not absolutely safe.

diff shot of Golden Gate bridge...generic, do not show traffic, just spans

The bridge could have been built to take such a load, but its cost would have probably been 10 times as high. So the engineering question is how much of an atypical situation should one design for?

In fact, in 1987 San Francisco celebrated the 50th anniversary of the Golden Gate Bridge by blocking all automotive traffic and allowing pedestrians to stroll along its length.

So many people took part in this event, that the characteristic arch of the roadway disappeared.

Officials very quickly carried out calculations to decide if the bridge could handle this unusual circumstance.

It could.

1 Overview

"Uncertainty and variability lead engineers to the study of probability and statistics."

The problem with designing for zero defects or absolute safety is that enormous resources—weight, size ,money—can be spent for very, very rare occurrences.

Consider that a fuel valve could fail on the space shuttle. That would be catastrophic. So you design the shuttle with a backup valve. But, what if both the primary and the backup valve were to fail simultaneously, do you design for a third valve? When do you stop?

Risk or failure vs. cost becomes the issue. If a 0.1% increase in reliability doubles the cost of a project, how one does address this factor.

So the characteristics of uncertainty and variability must be well understood by the engineer.

Uncertainty and variability lead engineers to the study of probability and statistics—areas of study we will not ignore in this course.

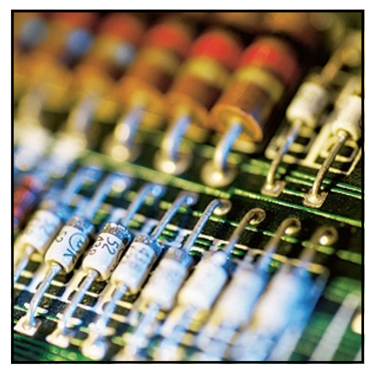
Uncertainty and variability occur in more than just structures. It's a very large issue in manufacturing processes.

Temperature changes, flow rates, instabilities can alter the purity and quality of many products: gasoline, polymers, silicon crystals.

ask MJK about photo to show
• new devices
• new combinations

When you buy a computer you can specify the speed of the CPU: 300MHz, 600MHz, 800MHz. Since the same material is used in each processor, why not simply sell the higher speed CPUs?

The answer is variability. The chip manufacturers would love to make only 800MHz CPUs. But because of manufacturing variations, not all the chips work at 800MHz. (In fact, some don't work at all.)



Each chip is tested at different speeds. The highest speed at which it works is the label it gets. Since, not that large a fraction operate correctly at the highest speed, the higher speed chips are disproportionately more expensive.

Variability strikes again.

1 Overview

"ENGINEERING...

IF IT MOVES, IT'S MECHANICAL.

IF IT DOESN'T MOVE, IT'S CIVIL.

IF YOU CAN FEEL IT, BUT CAN'T SEE IT, IT'S ELECTRICAL.

IF YOU CAN SMELL IT, IT'S CHEMICAL."

"IN THIS COURSE WE WILL FOCUS ON LEARNING HOW TO APPROACH AND SOLVE ENGINEERING PROBLEMS."

What about the engineering disciplines themselves? What types of problems or situations do the various engineers deal with? That can be fully answered in this very paragraph.

If it moves, it's mechanical engineering. If it doesn't move, it's civil engineering. If you can feel it but can't see it, it's electrical engineering. If you can smell it, it's chemical engineering. That's it. All other branches of engineering are just combinations of these.

And, you will pleased to learn that, unlike physics, there is only one important parameter in all of engineering. It's symbol is $$$. There you have it: a two paragraph synopsis of engineering.

As we suggested earlier, in this course we will focus on learning how to approach and solve engineering problems. We will delve into some technical topics like statics and digital circuits—what most people identify as the "substance" of engineering—but we will use those concepts primarily as contexts in which to approach problems.

Engineering is so much more than science and technology. In this course we hope to make you realize that.

The course has several objectives: to get rid of students who shouldn't be in engineering; and to encourage students who should.

Let me explain. As a student enters college he or she is asked to decide on a major: engineering, or non-engineering.

How could a student possibly know?

Yet a student will make the decision to proceed with an engineering program.

Engineering curricula typically begin with math, chemistry, and physics. In fact, for almost two years, a student may not see a real engineering course. For some students, math, chemistry, and physics may **not** be most appealing.

So, after a year and half they say "If this is engineering, it's not for me." Well, math, chemistry, and physics are **not** engineering; but many students don't realize it.

That's one of the goals of the present course: to show you what engineering is **really** about.

photo of college students
either in class or in library.
lots of them
are they engineering or
not?

There's a second group of students who may like math, chemistry, and physics, and are quite content with their curricula.

But, then, as juniors they begin to take serious engineering courses. And some discover they don't like them. It requires a new way of thinking. No definitive answers.

Engineering is not for them.

Well, making that discovery two-thirds of the way through a student's undergraduate program serves no one.

That's the other goal of this course: to help students make more-informed decisions much earlier in their academic careers.

1 Overview

"Engineering is a many faceted discipline.

We hope that, if engineering is right for you, you'll discover that in this course."

So, what **is** this course about?

From a substantive perspective, this course—through lectures, laboratories, and projects—introduces some of the technology and science of engineering:

1. Strength/Behavior of Materials (Materials Science)

2. Statics/Structures (Civil, Mechanical Engineering)

3. Uncertainty, Statistics, Measurement (all branches of engineering)

4. Robotics (Mechanical Engineering)

5. Digital Logic/Circuitry (Computer, Electrical Engineering)

6. Separation Processes (Chemical Engineering)

7. Diffusion, Heat Transfer (Mechanical, Chemical Engineering)

But, substance isn't everything.—especially in engineering.

There's also the "process"—what an engineer actually does to ply his trade. And we address that, as well, in this course. From this process point of view, the course consists of the following:

1. Communication
    a) Proposal Presentation (oral)
    b) Development of Assembly/Construction plans
    c) Reporting of Laboratory Results/Interpretation
    d) Presentation of Research Synthesis (written)

2. Project Development
    a) Time/Team Management
    b) Design
    c) Construction
    d) Testing

3. Experimentation
    a) Measurement
    b) Application of Principles
    c) Interpretation/Presentation of data

4. Tools
    a) Approximation
    b) Statistics
    c) Computer Software
        i) Simulation
        ii) Spreadsheet/Presentation
        iii) Graphics/Drawing

Engineering is a many faceted discipline.

We hope that, if engineering is right for you, you'll discover that in this course.