Successful Engineering

- To be a successful engineer, you must be **effective** - put your efforts where they need to be placed and do your work both thoroughly and accurately.
- To be a successful engineer, you must be **efficient** - do your work without wasting resources (time, energy, money, etc.).

Solving Problems

- In some ways, solving a problem is like driving a car.
- Driving without navigation sometimes leads directly to the destination.
- Driving without navigation sometimes leads to a dead end.
- Driving without navigation increases the likelihood that you will arrive too late.

Solution Steps

Plan
- Make assumptions.
- Visualize the system.
- Identify governing principle(s).
- Write generic equations.

Execute
- Write specific equations.
- Solve mathematically.
- Validate.
“Everything should be made as simple as possible - but no simpler.”

– Albert Einstein

Solution Steps

Plan
• Make assumptions.
• Visualize the system.
• Identify governing principle(s).

Execute
• Write generic equations.
• Write specific equations.
• Solve mathematically.
• Validate.

Fundamental Principles

• Laws of thermodynamics
• Kepler’s laws (astronomy)
• Newton’s laws (force & motion)
• Fourier’s law (heat conduction)
• Einstein’s law of mass-energy equivalence
• Etc.
Solving Problems

2 Where do your efforts need to be placed so that you can be effective and efficient? On the job, your employer will tell you what is needed and expect you to take it from there. As a student, you should try to understand your weaknesses (for example, time management, weak test-taking skills or weak understanding of certain concepts from mathematics or physics). By practicing, studying and asking for help, you can strengthen any weakness.

3 In addition to the ability to apply and manipulate equations, engineers must PLAN what they do. No significant engineering achievement occurs without detailed planning. You may prefer to “get ‘er done” as fast as possible, but that is not how engineers build things. Such things as computers, mobile phones, cars, aircraft, ships, buildings, highways, wastewater treatment facilities, satellites, assembly lines, oil refineries, power plants, turbines, compressors, etc., all require the efforts of large engineering teams. The team must try to anticipate all of the environments that a system will experience during its expected lifetime. They must try to design and manufacture systems to survive all of those. When engineers fail, their organization loses money and people may be injured. To be a successful engineer, you must learn to plan ahead.
The solution to almost every engineering problem involves all of the steps shown here. The first several steps are part of formulating a plan, and the remaining steps are part of executing that plan. An error in any of these steps can invalidate the entire solution. So, it is important that you become adept at every one of these steps. You have what it takes to do that. But how can you do that? There is only one way to become adept at the steps involved in solving an engineering problem, and that is to practice, practice, practice.

To begin to analyzing a system, we must make assumptions about the system. The purpose of making assumptions is to simplify the problem so that the mathematical steps involved in executing the plan are as easy as possible. (We tend to make fewer errors when we do easier mathematics.) But our assumptions must also insure that the information we wish to obtain from solving the problem is contained in the problem’s solution. If you want to understand how long it will take a block sliding on a flat plane to come to rest, you must assume that there is friction between the block and the plane. If you assume that there is no friction, then applying Newton’s laws will tell you that the block will slide forever, which is not a realistic answer. When we assume the absence of friction, we lose the ability to find the answer we need. In that case, as the saying goes, we have “thrown the baby out with the bath water.”

The importance of assumptions is summarized in the famous saying on this slide.
Once we have made assumptions, we should always visualize the system in question. In this course, we will usually do this by drawing a sketch called a free-body diagram or FBD. To draw an appropriate figure requires that we correctly visualize what the text is saying.

The final step in planning a solution is deciding which fundamental principle of physics governs the system’s behavior. In school, this is usually very easy. Since each problem is related to a specific course and perhaps also to a specific chapter in a book, the appropriate principle is usually obvious.

There are many, many governing principles in physics. In this course, the governing principle will always be some form of Newton’s first law. But in real life, identifying the appropriate physical principle can be a difficult task.

The first step in executing the plan is to find the generic equations associated with the governing physical principle. These are usually very easy to find, because we study them in class and they are contained in the textbook.

The next step is to apply the generic equations to the system at hand to generate specific equations for that system. To do this successfully, we must clearly understand every aspect of the system and every term in the generic equations. We must also clearly identify what quantities are known, or “given,” and what quantities we are asked to find.
In writing specific equations, it helps to keep in mind two things. The first is that the number of equations should equal the number of unknowns in the equations. (Otherwise, it is highly unlikely that we will be able to solve the equations.) After writing each specific equation, we can stop to count the total number of equations and the total number of unknowns. If there are more unknowns than equations, we must find more equations. The second thing to remember is that at least one of the specific equations that we write must contain the variable whose value we are asked to find. Otherwise, even if we solve the equations, our solution will not tell us what we want to know.

Once we have a set of specific equations, we have reduced the problem to mathematics. The next step is to solve the equations using such things as calculus, trigonometry, geometry, algebra and arithmetic, as needed. The final step in executing the plan is to validate the result. Is it reasonable? Can we check it by solving the equations in another way? It is a mistake to assume that the first solution is correct, because it usually is not. We do not always perform these steps in the order shown. Sometimes we find in one step that we must return to a previous step and revise it. But to arrive at a correct solution, we will almost always need to perform every one of these steps.