Introduction to Statics

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Unit 0
Instructions to the Student and Review of Prerequisites

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Frame 0-1

Introduction

Why should you need an instruction manual on how to use a textbook? Because you have probably never used a "programmed text," at least not in a university course.

Like all good engineering projects, this text has been carefully designed, use-tested and re-designed until it worked properly. The concept of facilitating learning has been the governing factor in the design of this material.

The way the book is put together may strike you as a bit unusual and may require a bit of getting used to. To get the greatest benefit from the program you must use it properly. Simply reading the questions and answers will not benefit you greatly. Instead, you must make an active response to each item you are taught. That is because engineering problem solving is a skill acquired through practice.

The steps to successful use of the programs are quite simple.

- Read the information portion of the page.
- Write your answers to the questions.
- Go to the next page to uncover the correct responses and compare your answers to them.
- Continue with the next frame.

Must you write your answers? ☐ Yes ☐ No

Go to the next page to check your answer.

Correct response to preceding frame

Yes, you must write your answers.

Frame 0-2

Writing Your Answers

OK, that was a rather trivial question, but an effective instructional program begins with basic premises and slowly and easily moves to complex relationships, providing opportunity for practice at each step. As you move through the units, some frames will be complete homework problems.

By answering each question you will build the competence and confidence necessary for the fluent use of the subject matter in subsequent courses. If you are required to take additional courses in engineering mechanics such as dynamics and strength of materials these skills will be essential.

Occasionally the correct response will be stated differently than your answer, and when solving problems your equations may be in a different order than ours. If, in your opinion, your answer has the same meaning, you need not worry about the differences between them. Once in a while, you will be told to answer "in your own words." In such a case the response will be rather complicated and you may prefer to merely jot down its main points rather than writing it out in full. By all means, do so, but compare your notes carefully with the correct response to see that you got it all. You will occasionally see the notation "Or equivalent response." You may be the judge of equivalence.

When this book was originally written, there were no personal computers. Our students purchased thousand-page books printed on letter-sized paper. Since this version is distributed as a .PDF file, you have the option of printing it yourself and writing on your print-out. You may, if you choose, read it on your computer screen and write on Engineers' Pad, scratch paper, or old pizza boxes.

Must your answer always match the correct response exactly? ☐ Yes ☐ No

Must you print out this text and write your answers on the pages? ☐ Yes ☐ No

Go to the next page to check your answers.

Correct response to preceding frame

No, you are the judge of the correct answer, and you may use your own words or equations. (Or equivalent response)

No, you don't need to print out the entire textbook.

Frame 0-3

Writing Your Answers and Keeping Permanent Notes

A major problem with programmed texts is the difficulty inherent in review of so many pages. We have attempted to overcome this problem with a separate notebook. When properly completed, the notebook will provide both a concise treatment of the topics covered in the units and an annotated index to them so that when you need to review in depth you will be directed to the appropriate frame. Appropriately, the alphabetic topic index appears at the end of the notebook. By means of this elaborately cross-indexed notebook we feel that we have provided some of the advantages of a reference book without sacrificing the effectiveness of the programs as teaching tools.

You will be instructed to refer to, or to write your answer in, the notebook at the appropriate times.

The Notebook is provided as a .PDF file on our website which you can print as you need it. You should get some sort of binder in which to store and carry the Notebook.

Open your Notebook and read Page 0-1.

When you see the notation (8-23) in the Notebook, it means ________________________ .

You can, of course, print out any individual frame from the text if you want to include additional material in your notebook.

What should you print out before starting work on a unit? ____________________________

Correct response to preceding frame

The notation (8-23) means that the answer will be found in frame 8-23.

Definitely print the notebook pages which are provided. (Or equivalent response)

Frame 0-4

Other Needs

OK, we've established that you need the Notebook pages, and something to write on. As you progress through the course you will be working with equations involving trigonometric and exponential values.

What else should you have on hand while studying?

Correct response to preceding frame

I'd say a "scientific" model pocket calculator of some sort. (When these programs were originally written, we'd have suggested a good slide rule.) You might consider using an accessory program on your computer, but I think I'd prefer to use the same device on the practice work in the units that I would be using in class on quizzes and exams.

Did you also remember that you'll need a pen or pencil?

Frame 0-5

Topics to Cover and Course Schedules

This text is organized in units and blocks of units which may be omitted or re-combined to fit the needs of a specific engineering degree.

We have ordered the topics in a way which we think expedites learning. At times this has resulted in an order of presentation or approach that departs from tradition. These departures are particularly evident in the early units on forces and vectors, in the late treatment of couples and resultants, and in the units on friction.

We have included all of the topics which we consider to be part of a complete basic course in Statics. If you are using this book as part of a combined course, as a review, or as a short summary, your instructor may skip one or more topics. Your instructor may also shuffle some material. Your instructor should provide you with some sort of course calender.

If you are a typical engineering student, you don't want to study topics which will not appear on the course examinations.

In your own words, how should you decide which units to work, and in what order?

____

____ .

Correct response to preceding frame

The course administrator should provide a detailed outline and schedule.

Frame 0-6

Other Essential Stuff

You need to keep records of you progress in the Notebook so you can review your progress.

Your Instructor also needs to keep records of your progress. To do so, he or she needs your help. To help, you will probably need the information below.

Copy the information below from your course handout or class notes so that you can reinforce your memory through practice.

Instructor's name: ____

Instructor's office address: ____

Instructor's email address: ____

Course number for Statics: _______________

Your Section number (if applicable): ______________

Instructor's grading scale: _______________________________________

____

Anything really weird about the course administration: _____________

____

Correct response to preceding frame

The course administrator should provide a detailed outline and schedule.

Frame 0-7

Transition

As engineers we have our own ways of writing numbers which we use when communicating with other engineers. We also have to read information provided by scientists and sales people, and to provide numerical information to managers and production people.

In this next section we will take a short look at several ways of expressing numerical results.

Go to the next frame.

Correct response to preceding frame

No response

Frame 0-8

Scientific Notation

You have probably encountered scientific notation before in several courses.

In scientific notation, a number is written with one digit to the left of the decimal point and the real size of the number is expressed by multiplying the significant digits by a power of ten.

Thus 45379 in scientific notation is 4.5379×10^4 or alternatively $4.5379(10^4)$ or 4.5379E4

Express the following in scientific notation:

`0.00341 =` ________________________

`3,721,332.7 =` ________________________

Correct response to preceding frame

$0.00341 = 3.41 \times 10^{-3}$ or $3.41(10^{-3})$ or 3.41E-3

$3{,}721{,}332.7 = 3.7213327 \times 10^{6}$ or $3.7213327(10^{6})$ or 3.7213327E6

We prefer the " $\times 10^{x}$ " format, but you are free to use either of the others

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Frame 0-9

Engineering Notation

Engineers typically use what you might consider a modified scientific notation. In engineering notation the exponents are in 3's.

For example, in engineering notation a force of 37,400 pounds would be expressed as 37.4×10^{3} or described as 37.4 kilopounds or 37.4 kips. A cost estimate of $17,400,000 would typically be expressed as $\$17.4 \times 10^{6}$ or described as 17.4 megabucks.

Express the following in engineering notation:

32,000 psi = ________________ psi

0.071 square inches = ________________ square inches

Correct response to preceding frame

`32,000 psi = 32 x 10^3 psi`

$32{,}000 \text{ psi} = 32 \times 10^{3} \text{ psi}$

$0.071 \text{ square inches} = 71 \times 10^{-3} \text{ square inches}$

Frame 0-10

American Versus European Punctuation of Numbers

As everyone says, we work and live in a global economy. In America we use a “period” as a decimal point, and tend to use “commas” to make numbers easier to read.

For an American example, take the number $13,429,721.52

In Europe the practice is to use a comma for the decimal and spaces as spaces to increase readability.

The number above would be printed in Europe as $13 429 721,52

Neither punctuation is “wrong” and you might encounter either in any place.

Mark the following with an A or an E to designate the usage:

2.007 is ______ 0,037 is ______ 32,421 is _______

Correct response to preceding frame

`2.007` is **A**   `0,037` is **E**

`32,421` is **Anyone's guess**. I'd look at other numbers on the same page before making use of it.

Frame 0-11

Transition

In general, we try to teach, not preach, in this book, but I'm going to insert a warning here.

When we say that engineering mechanics is a set of skills, we mean that it is a set of things you will ***do*** without be told when you encounter a mechanics problem.

One of the reasons you have (probably) been forced to take statics is that faculty who teach later courses expect us to teach you to express numbers as an engineer would. Proper use of significant figures is a major part of that.

Failure to write results correctly may cause your superiors to mutter "This kid still has a lot to learn!" - or worse --- and they'll put part of the blame on me.

Turn to the next frame.

Correct response to preceding frame

No response

Frame 0-12

Significant Figures

We will deal first with the technique of “rounding off” an answer to a problem to a designated number of significant figures. This is probably a review of things you were taught in science or math classes.

Any of the digits from 1 to 9 appearing in a number is a *significant figure*. An 0 is significant unless it is simply being used to show the position of the decimal point.

Examples:

The number 351 has 3 significant figures.
The number 7 has 1 significant figure.
The number 0.0002 has 1 significant figure.
The number 230.0002 has 7 significant figure.
The number 3 071,5 has 5 significant figures.

How many significant figures are in the numbers below?

`521.7` _________

`23.456` _________

`0.0775` _________

`3,220` (in European punctuation) _________

`3,220` (in American punctuation) _________

Correct response to preceding frame

521.7		4 significant figures
23.456		5 significant figures
0.0775		3 significant figures
3,220	(in European punctuation)	4 significant figures
3,220	(in American punctuation)	probably 3 significant figures

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Frame 0-13

Significant Figures

One of the advantages to the use of engineering and scientific notation is that we can, and should, make all of the numbers significant.

How many significant figures are in the numbers below?

3.41×10^{-3} ________

3.7213327×10^{6} ________

3.4100×10^{-4} _________

3×10^{5} _________

Correct response to preceding frame

3.41×10^{-3} 3 significant figures
3.7213327×10^{6} 8 significant figures
3.4100×10^{-4} 5 significant figures
3×10^{5} 1 significant figure

Frame 0-14

Significant Figures

Often, or perhaps I should say "usually," our calculators do not give us the correct number of significant figures for a numeric answer. We must "round off" an answer to a problem to a desired number of significant figures.

You probably remember that to round off a number to ***n*** significant figures you follow the following rules:

Look at the n+1th figure -

- If the n+1th figure is 0 through 4 you just drop all figures to the right.
- If this figure is from 6 through 9, you increase the nth figure by 1 and drop all figures to the right.
- If this figure is 5 and the 5 is followed by 1 through 9, you increase the nth figure by 1 and drop all figures to the right.
- If this figure is 5 and the 5 is followed by 0, round the nth figure to the nearest even number.
- If your calculator drops to below the required number of figures, add 0s to the right of the number.

Examples:

To 3 significant figures

```
A = 31.55 rounds to A = 31.6
X = 3,153.27 feet rounds to X = 3,150 feet
Y = 7 meters rounds to Y = 7.00 meters
s = 5,527 psi rounds to s = 5,530 psi (or 5,53 in European notation)
```

Round the following to 3 significant figures:

B = 3.14159 ___________   R = 2500 rpm ___________

Y = 25.666666 meters ___________   N = 2 ____________

F = 32.57 pounds __________ R_x = 517.5003 Newtons ___________

Correct response to preceding frame

B = 3.14   R = 2500 rpm   Y = 25.7   N = 2.00
F = 32.6 pounds R_x = 518 Newtons

Frame 0-15

Significant Figures

In engineering we try to relate theoretical problem solutions to "the real world."

In actual practice, there is a limit to the accuracy with which the data for a problem can be measured, and to which actual products can be produced.

We will leave any detailed consideration of the philosophical aspects of Accuracy-Precision-Significance to your Physics courses and details of the applied aspects to your laboratory and measurements instructors, but a short consideration is needed here.

The photo below shows a digital caliper being used to measure the length of an AA battery.

The number displayed is 50.1 mm.

How many significant figures are shown? ___________

Can you guess the next significant digit? ☐ Yes ☐ No

By US Standards, 1 inch is exactly 25.4 mm.

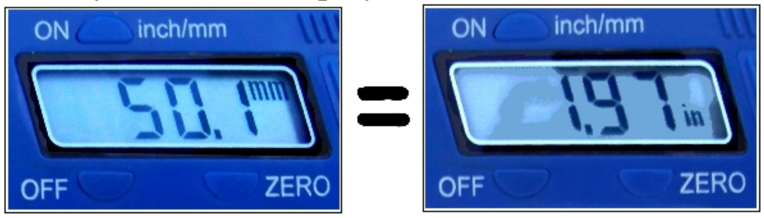
What is the length of the battery in inches? __________________

What would number would you expect to be displayed if the caliper is reset to measure the length in inches?

____

Correct response to preceding frame

3 significant figures
No, you cannot guess the next one
If I divide 50.1 by 25.4, my calculator displays 1.972440945, which "rounds" to 1.97



Frame 0-16

Significant Figures

In "the real world" many common measuring instruments provide readings as three significant figures. If a bar of aluminum undergoes a temperature change of 100 Fahrenheit degrees, its dimensions will change by about 0.13 percent.

For these, and other reasons, engineers often work to three significant figures. We will adopt that practice in this book.

Before "rounding off," you should perform calculations to the maximum accuracy of your calculator.

A cylinder is measured and found to have a diameter of 3.72 inches and a length of 5.61 inches. Calculate the volume and report your answer to the number of significant figures adopted for this text.

V = ______________________________ in^3

Correct response to preceding frame

$V = 61.0\ in^3$

Frame 0-17

Systems of Units

In this course we will work in two systems of units: *American Customary Units* (ACU)and *Système Internationale d'Unités* (SI). *Système Internationale d'Unités* is French for "International System of units." These are the systems in which most engineering mechanics work is done.

In American Customary Units (ACU) we typically measure:

- Distance in feet, inches, yards, and miles.
- Time in hours, minutes, and seconds.
- Force in pounds, or occasionally tons.
- Volume in cubic inches or feet, or quarts and gallons.
- Mass in slugs.

In SI we typically measure:

- Distance in meters, millimeters, and kilometers.
- Time in hours, minutes, and seconds.
- Force in Newtons.
- Volume in cubic meters or centimeters and liters.
- Mass in kilograms, or occasionally metric tons.

Cross out the units in the following list which are not appropriate for use in this course:

Pounds force	Pounds mass	Poundals
Kilograms force	Dynes	Kilometers
Cubits	Bushels	Barrels

Correct response to preceding frame

We shall ***not*** use:

Pounds mass	Poundals	Kilograms force	Dynes

(all these are actually used in some much older works in mechanics)

Cubits	Bushels	Barrels

(some of these are still used in other branches of engineering)

Frame 0-18

Transition

We will find later that there is a bit of a conundrum involving mass-weight-force relationships, and we will return to that in an early unit.

SI is sometimes referred to as "the metric system." Actually there have been a whole bunch of "metric" systems in the past, and traces of some may still linger in older books or specific design applications. SI is a set of measurements and standards officially adopted by international treaties for engineering work. It is the world standard.

American units are sometimes mistakenly called "English units." There are several cases in which American and English sizes are actually different.

Go to the next frame.

Correct response to preceding frame

No response

Frame 0-19

Conversion of Units

In these units we will usually ask you to work problems only within a system of units, not to switch between them.

We will assume that you already know (OK, have "memorized") the basic conversion factors within both ACU and SI. For example, 1 foot = 12 inches, 1 meter = 1000 millimeters, 1 minute = 60 seconds, and 1 mile = 5280 feet

As you move through the units you will find you "know" other conversions, such as 1 in. = 25.4 mm pretty well.

We encourage you to use a formal, algebraic, written units conversion process in most cases. This is not because we like formality, but because it decreases the likelihood of mistakes.

Example: Convert 75 miles per hour to meters per second

$$\left(\frac{75\ \cancel{\text{miles}}}{\cancel{\text{hour}}}\right)\left(\frac{1\ \cancel{\text{hour}}}{60\ \cancel{\text{minutes}}}\right)\left(\frac{1\ \cancel{\text{minute}}}{60\ \text{seconds}}\right)\left(\frac{5280\ \cancel{\text{feet}}}{1\ \cancel{\text{mile}}}\right)\left(\frac{0.305\ \text{meters}}{1\ \cancel{\text{foot}}}\right) = 3.36\ \text{m/s}$$

OK, your turn. Use the algebraic process to convert 45 feet per second to kilometers per hour.

`45 fps = ________ kph`

Correct response to preceding frame

$$\left(\frac{45\ \cancel{\text{feet}}}{\cancel{\text{second}}}\right)\left(\frac{60\ \cancel{\text{seconds}}}{1\ \cancel{\text{minute}}}\right)\left(\frac{60\ \cancel{\text{minutes}}}{1\ \text{hour}}\right)\left(\frac{0.305\ \cancel{\text{meters}}}{1\ \cancel{\text{foot}}}\right)\left(\frac{1\ \text{kilometer}}{1000\ \cancel{\text{meters}}}\right) = 49.4\ \text{kph}$$

Frame 0-20

Transition

We expect you to remember some basic mathematics. It's not our job to teach you these skills, but we feel it is only fair to warn you of our expectations.

The next few frames are a Skill Inventory.

If you can solve these problems you should be in good shape. If not, you should do a review of the topics to prevent embarrassment.

Go to the next frame.

Correct response to preceding frame

No response

Frame 0-21

Solution of Simultaneous Equations

You will be working a lot of problems in two dimensions, and a good number in three dimensional space.

In 3-D a single body may have nine equations in nine unknowns, and a complex structure may be composed of many bodies. Fortunately, by using the techniques of engineering mechanics we seldom have to deal with simultaneous solution of more than three equations in three unknowns.

Test yourself on the following problem:

Find A, B and C from this set of equations.

$$A - \frac{2}{3}B - \frac{4}{13}C = 0$$

$$-8000 + 8B + \frac{48}{13}C = 0$$

$$-4B + \frac{36}{13}C = 0$$

A = ____________

B = ____________

C = ____________

Correct response to preceding frame

A = 667, B = 600, C = 867

My solution:

I'd start by using the third equation to find B in terms of C.

$$C = \left[\frac{4\,(13)}{36}\right] B$$

Substituting this in the second equation, I get:

$$-8000 + 8\,B + \frac{48}{13}\left[\frac{4\,(13)}{36}\right] B = 0 \quad \text{so } [8 + 192/36\ B] = 8000 \text{ and } B = 600$$

Then C = 867

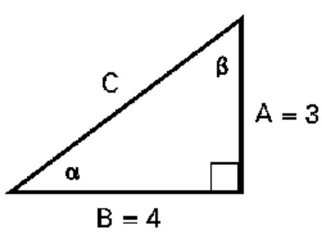
From the first equation, $A = \frac{2}{3}B + \frac{4}{13}C = 667$

Frame 0-22

Mathematics of Triangles

Throughout mechanics the mathematics of the ***measuration of trigons*** plays an important role. We'll make a quick review of a few essentials.

A right trigon with one side 4 units long and one 3 units long is shown below. Complete the equations.



C = ____________________

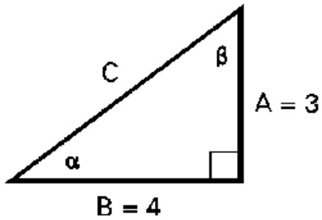
sin α = ____________________

tan α = ____________________

cos α = ____________________

sin β = ____________________

Correct response to preceding frame



$$C = \sqrt{A^2 + B^2} = 5$$

$$\sin \alpha = \frac{3}{5}$$

$$\tan \alpha = \frac{3}{4}$$

$$\cos \alpha = \frac{4}{5}$$

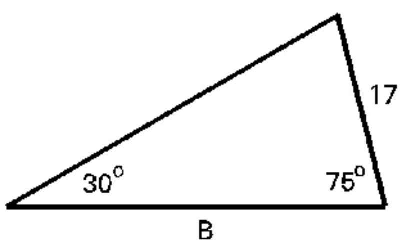
$$\sin \beta = \cos \alpha = \frac{4}{5}$$

Frame 0-23

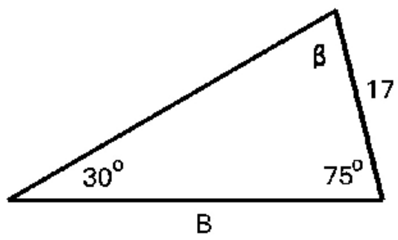
Mathematics of Triangles

We will very frequently work with right triangles, but other sorts will also appear.

Find the length of side B of the triangle below.



Correct response to preceding frame



Since the sum of the interior angles of a triangle is 180°

$\beta = 180 - 30 - 75 = 75°$

Using the Law of Sines,

$$\frac{B}{\sin \beta} = \frac{17}{\sin 30}$$

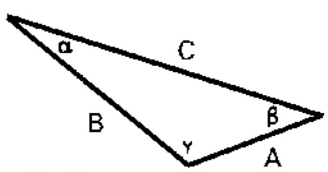
B = 32. 8

Frame 0-24

Mathematics of Triangles

My mention of the Law of Sines should stir your memories of another law.

Find side C of the triangle below.



$\gamma = 120°$

A = 30 units

B = 49.3 units

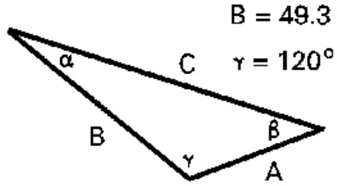
C = __________

What is a ***trigon***? ______________________ (You can find it in a dictionary if you can not guess.)

What is the mathematics of the ***measuration of trigons*** commonly called?

_______________ _________________

Correct response to preceding frame



A = 30 units

B = 49.3 units

$\gamma = 120°$

By Law of Cosines

$$C^2 = A^2 + B^2 - 2AB\cos\gamma$$

C = 69. 4 units

Trigon is an archaic name for a triangle, and the mathematics of triangles is ***trigonometry***.

Frame 0-25

Conclusion

Got the hang of it? Good.

You've gone through a lot of pages for such a simple set of ideas, but pages are cheap if you are reading this on a digital device.

As far as study time is concerned, suit your own needs. A programmed text allows you to learn at your own pace, not at that of a lecturer or a video.

Go fast or slow. Do half a unit at one sitting or take on several.

A good place to interrupt your work is at a frame marked "Preview" or "Transition." Such a frame signals the presentation of a new idea. At such points we sometimes offer an estimate how much more time it will take to finish the next section. Of course "your actual mileage may vary," but you can develop your own correction factor.

You are now ready for Unit 1.