So you're going to be an engineer

by don herold

ILLUSTRATED BY THE AUTHOR

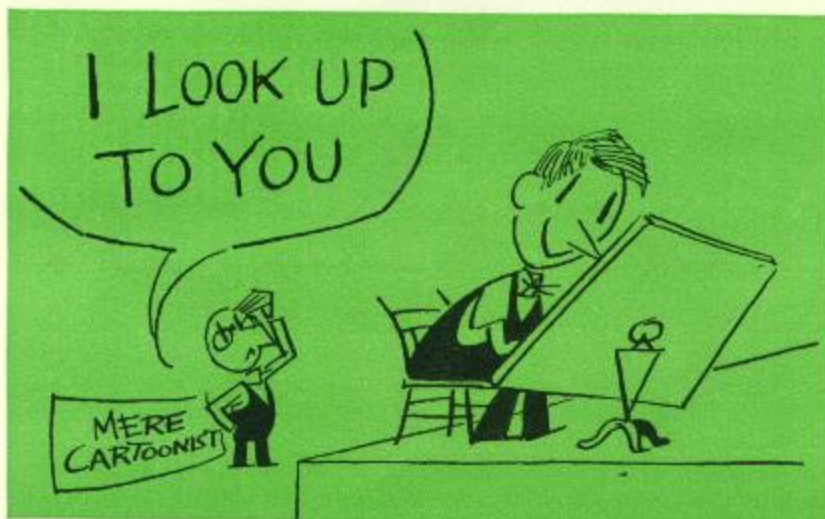**S**O, you've decided to be an engineer.

Well, that means you're going to make a lot of the rest of us look lazy, sleepy, sloppy, inexact and unimaginative.

(Yes, engineers have imagination. In my opinion, a guy who can dream up a bridge, a road or a modern industrial machine is more of a poet than most poets.)
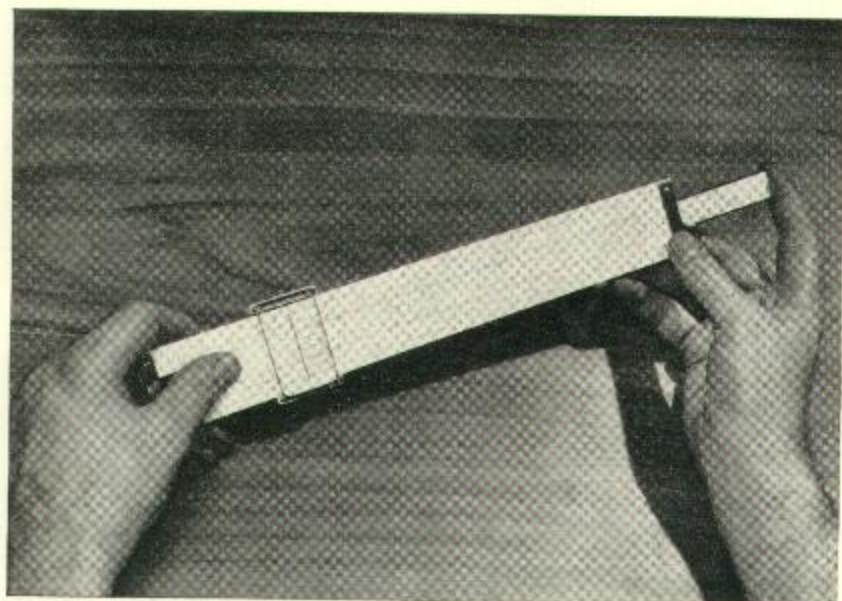
You've chosen a pip of a profession. The world looks to engineers, and looks up to 'em. Engineers have designed such things as the Eiffel Tower, Boulder Dam, the Hudson Tunnel, Chevrolets and Fords, B-29's, safety razors, popsicles, roller coasters, washing machines, kiddie cars and skyscrapers—and I was going to say the Grand Canyon, but I guess that Nature did that.

Every engineer and scientist needs tools and equipment. (I'm telling you!) You'll need them within a few hours after you hit college and keep on needing them until they triangulate you for a pine box.

The tools you use will have to be absolutely dependable and precise—to within a ten-thousandth of a cat's whisker. There is no just "dumb luck" calculation in an engineer's life.

YOUR SLIDE RULE

First thing on your engineering shopping list is a slide rule.

An engineer without a slide rule is like a slide trombonist without a slide trombone. You'll be eating and sleeping with your slide rule as long as you live.

There are various types of slide rules. They start with the simplest, original Mannheim type. This rule has been the basis for all the improvements and more elaborate scales that Keuffel & Esser have added since, on the *Polyphase*, the *Log Log Duplex Trig* and *Decitrig* and the *Log Log Duplex Vector* rules. Here again your professor will advise you what to get. Most profs today are recommending the *Log Log Duplex Trig* or *Decitrig* to their students because these babies will handle exponential equations.

My nickel's worth is this: whatever type of slide rule you buy, be sure it is a good one. An almost good slide rule is like an almost good egg. It is possible for a manufacturer to stamp out slide rules like cookies, but it really takes aches and pains to turn out a good

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DRAWING INSTRUMENTS

Just as a bride gets a kick out of starting matrimony with a chest of the best darned silverware on earth—expecting it to last her all her married life—you can get a boot out of starting your engineering career with a set of the best darned drawing instruments on earth—which will last you all your engineering life. Next to your slide rule, this is one of the earliest principal investments you'll probably have to make as a freshman.

You can look at them in their case, and dream of the bridges, dams, tunnels and ships that may come to life through their use.

It's a fact that a really good set of drawing instruments simply can't be cheap. Something for nothing ain't. But if you buy a set made by a manufacturer with a fine reputation, you can count on getting what you pay for. If he makes several grades, as he is sure to, you can safely gauge the quality by the price.

Like good slide rules, good drawing instruments aren't just thrown together. They're a job for genuine craftsmen—they're precision instruments for lifelong precision performance.

The best are made of rolled nickel silver. The nickel content insures the necessary hardness and wearing qualities of the joints and

WOBBLY CIRCLES
SIMPLY DON'T GO
IN ENGINEERING
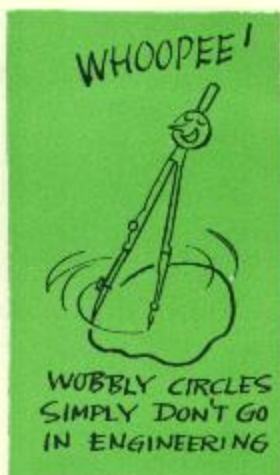
moving parts. The joints mean a lot (as whose joints don't?). The accuracy of the instruments depends on them. If the joints of a compass wobble, you'll draw a wobbly circle. That is, if the joints of a compass don't move in the same plane, the points of the instrument won't meet exactly. You'll get eccentric circles, which don't go in engineering.

The best pens are made of high carbon steel, stainless steel or high speed steel. The right steel wears; soft steel does not.

MISCELLANEOUS DRAFTING TOOLS

You'll need a T-square too, most likely, and even your T-square might as well be a thoroughbred right from the start. A T-square leads a hard life (it gets dropped, stepped on, wrenched and kicked around, alas, alas) and it ought to be built for hardship.

You can get one that is all wood and nothing else, but there are
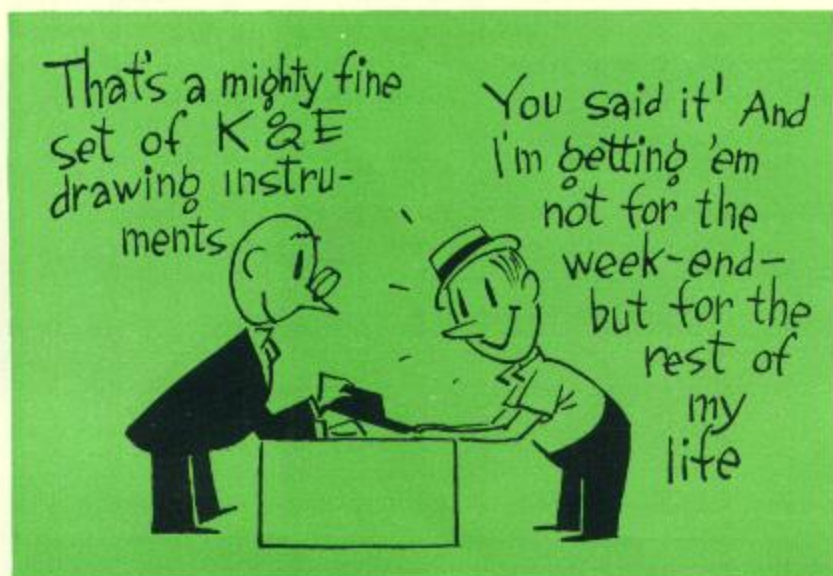
other kinds that are better. One that is wood but has transparent edges is better because it lets you see a full quarter inch of the work below the line you are drawing. And best of all is the kind with patented transparent edges. The patented feature is: that the transparent edge is a little thinner than the wood center—that is, it is very slightly raised above the drawing surface. The advantage of this is a double-header. First, the transparent edge rides free and keeps more transparent. Secondly, the tip of your ruling pen is not in contact with the ruling edge. This defies capillary attraction with its ink blobs and smudges which are enough to make any engineer cuss like a buccaneer.

EVEN A "T" SQUARE CAN HAVE CLASS

Then come the odds and ends—the *triangles, protractors* and *curves*. They come in various qualities, but here again the main thing is to get them from a good manufacturer.

Drawing boards, too. You'll likely have to get one. They come with or without battens to reinforce them underneath. The battens make the board heavier, and you'll probably go for the lighter kind. If you wish, you can get a surface material to cover the board with. K&E make one called *Laminene* which is as smooth as glass and wonderful as a base for your drawing or tracing paper, and is easy to keep clean, too. I've had the same drawing board for about a quarter of a century, and I love it almost as much as I do Mrs. Herold.

SCALES

Until you get over being a layman, you'll probably call a scale a "scale rule." I still do. A scale is a basic drafting tool on which something little usually represents something bigger. Maybe, for example, when 1/4 inch stands for 1 foot. Anyway, you use it for measuring or laying off distances or dimensions which represent proportionately larger distances or dimensions. You'll depend a lot on good scales. The best professional scale is the boxwood type with white facings and "engine divided" graduations. (Remember what I said above about slide rules?)

I'M GOING TO LOOK INTO THIS MATTER OF A CAT'S WHISKER

Then there's the sort that is made entirely of plastic. They cost a bit less, and you get what you pay for. And there's the hardwood type that is merely printed.

There's the flat type of scale, with two or four bevels, and the triangular one, with six faces, chosen by most colleges because they are more useful. Some scales are graduated for civil engineering drafting, divided 10, 20, 30 (and so forth) feet to the inch; others for mechanical engineers or architects, divided $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$ inch, and so on, to the foot. Besides, there are special scales that are sometimes used by mechanical engineers (known as ratio scales) that are $\frac{1}{8}$ size ($1\frac{1}{2}$ in. = 1 ft.), $\frac{1}{4}$ size (3 in. = 1 ft.), $\frac{1}{2}$ size (6 in. = 1 ft.) and suchlike. This is a lot of detail, but your professor will help clear up the mud.

DRAWING PAPER, TRACING PAPER, TRACING CLOTH

I've about covered the tools you're likely to need right away—all except the materials you'll be drawing on. You'll most likely launch your drafting career on opaque drawing paper. You'll feel more at home on this at first because you can scratch around and blunder and erase and re-draw to your heart's content without ruining a lot of more expensive paper.

In engineering and commercial drafting rooms, the sharks make practically all their drawings on transparent tracing paper or trac-

DON'T BE ASHAMED TO SCRIBBLE AND TEAR UP, AT FIRST

ing cloth. And a good deal of work is done on these in colleges today. But the chances are, you'll start off on a non-transparent paper.

Nevertheless, there are a coupla things about tracing papers and cloths worth knowing. There are a number of kinds of both of them. My own choice of tracing paper would be the kind called *Albanene*, every time. That's what my engineering friends all tell me, too. And they also swear by a tracing cloth called *Phoenix*. It's moisture-proof, they say, and it scares away what they call "ghosts."

And then, while we're on this subject, there's a wonderful new development called *Stabilene*. That's a tracing cloth made out of glass fibers, that just won't change its dimensions one iota, come rain or shine or hot or cold. It's very important for work of certain kinds. But there isn't room for the whole story here.

REPRODUCTIONS

If you're going to be an engineer, you gotta reproduce. I mean, you can't hand an original drawing around to all the people who have to read it and work with it, any more than an author of a book can pass his original manuscript around to the entire public. Reproductions are to the engineer what the printed book is to the author. Good reproductions that are clear and easily read are needed. And it takes good drawings and good materials to make 'em.

YOU GOTTA REPRODUCE

There's quite a variety of reproduction processes. One kind has come tremendously to the front in recent years. It is the dry diazo, ammonia developing process that gives positive line prints (not negative like blueprints) on paper, cloth or film. That description sounds like a big mouthful, but K&E just call them *Helios* prints.

Another handy trick a lot of people don't know about is the making of new tracings from pencil originals by photographic and similar processes. It's a matter of minutes and saves hours of tracing by hand.

Now we come to one or two things you may or may not actually meet in college. But you'll want to know them eventually, so you might as well have a knock-down to them right now.

DRAFTING MACHINES

One of these is the drafting machine. No, this isn't a contraption that will do your work while you go fishing. But modern drafting rooms, where they have been used, wouldn't be without them. They are taught and used in some college classes. You may even use one in your freshman year.

WONDER IF I
COULD GET
ONE OF
THOSE TO
DRAW MY
CARTOONS
FOR ME?
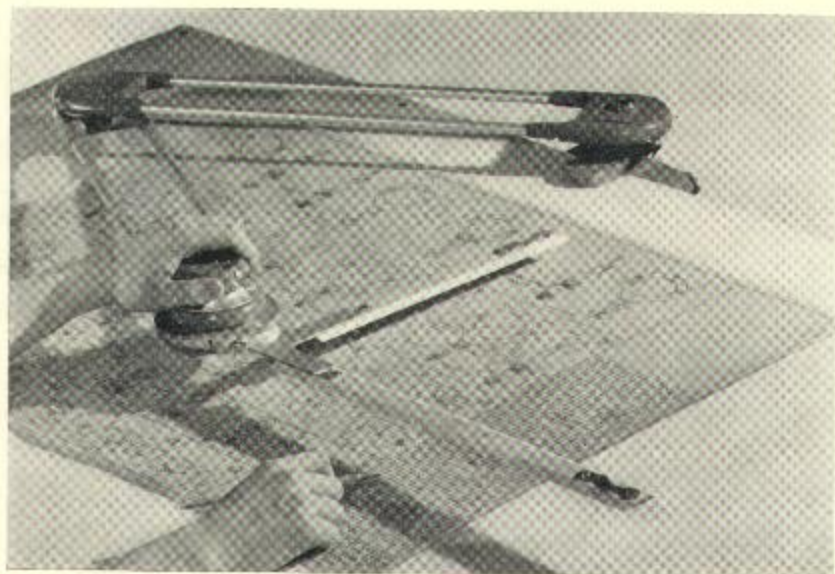
The big idea is, it permits you to move a rule all over a drafting board and the rule stays parallel to its original position. The best model works on the principle of enclosed drums and steel bands. The accuracy depends on the precision of the radii of the drums, if I am not too stuffy.

Comparing a drafting machine with a T-square, triangles and a protractor is like comparing power navigation with sailing. But if you haven't got an engine, you have to use a sail.

LETTERING

Every engineer ought to learn how to letter pretty well, so that what he writes will be neat and readable. Here again is an art that has to be learned the hard way first.

But later on, you will want the luxury—no, it isn't even a luxury any longer—of what might be called "controlled" lettering. There are two main types of this. One is done with stencils. The other is done with guides or templates on which the letters or numbers or even graphical symbols (mapping, electrical, welding and so on) are grooved. K&E's outfit is called *Leroy*, and it consists of the guides and a little device which has one arm with which you trace the grooves and another arm with a little pen which draws the same letters a short distance away, clear of the guide. This is by far the
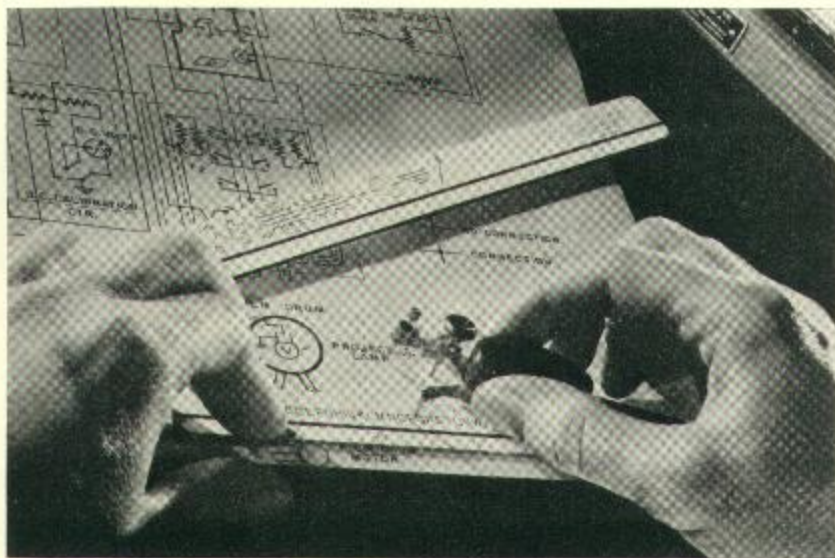
most practical method of lettering, because you can see what you're doing. There's no risk of smudges or blobs, because the pen itself never touches the guide. The beauty of this kind of lettering is that it takes no skill, and is always the same, whoever does it. It has become so popular in recent years that it is a "must" in literally thousands of drafting rooms.

Leroy Lettering has made history. When we Americans licked the Japs, we used a *Leroy* set to prepare the surrender document to which they appended their John Hashimotos that day aboard the "Mighty Mo."

By the way, K&E also make a "non-professional" lettering set called *Doric*, which works on the *Leroy* Lettering principle. It is an excellent job for student use. You might ask your college bookstore to let you see one.

GRAPH PAPER FORMS

Graph paper forms, too, are worth a paragraph, if you are still reading. (I'm still writing.) These have several main uses: for plotting engineering or scientific or business data (such as showing the variations in the price of cheese since 1863); as a guide for sketching or drawing, etc. The selection is a bit confusing and alarming at first, what with all the available square and rectangular section forms,

the logarithmic and semi-logarithmic forms, the reciprocal forms and the specials like electrical, polar co-ordinate, trigonometric and so on. You'll get the instinct for choosing the ones you need, and there are good guides to their use to help you choose.

PLANIMETERS

Another ingenious little gimmick with which you'll want to make friends sooner or later is the planimeter. What it does is to measure the area of any shape or form you want. You simply run a tracer point round the periphery and then read the distance the measuring wheel has gone while you weren't watching it. You may need one for doing things like measuring drainage areas, or computing excavations or evaluating indicator diagrams. But you can imagine that it has got to be mighty accurate, or you'll be way off in your areas.

SURVEYING INSTRUMENTS

That brings us out into the great outdoors.

Let's talk about surveying for the moment.

Somebody has defined it as "the art of finding out where something is or putting it exactly where it ought to be." Maybe it's a science instead of an art, for its middle name is accuracy. Lin Yutang, in seeking to define the difference between Americans and Chinese,
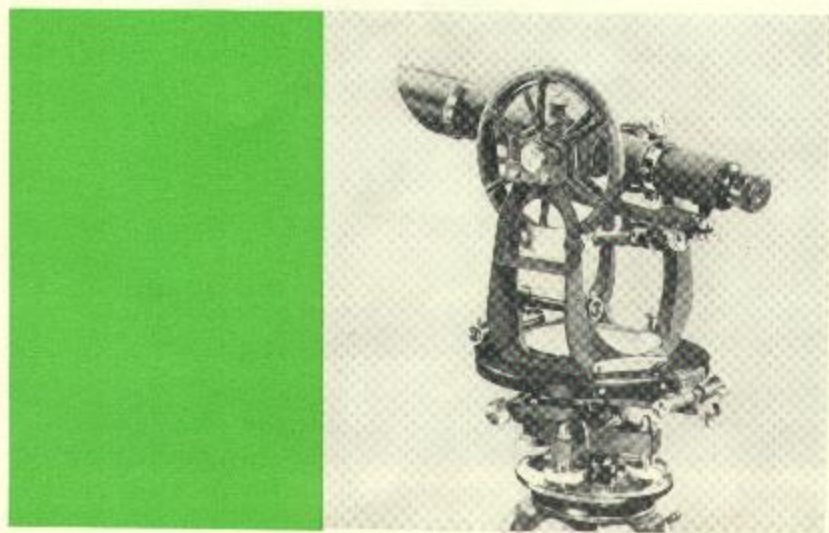
says that the American engineers will build a tunnel through a mountain, starting from both ends, and meet in the middle to within ⅜ths of an inch, while the Chinese will start at both ends and both crews will go clear through the mountain, and thus get two tunnels. No kidding, American engineers have actually hit it that close, and such feats are more or less commonplace with the skilled man using the right instruments. Yes sir, you've picked a real profession! But whether you're building tunnels or dams or airplanes or machinery, you can't hope for much if your surveying instruments aren't just the way they ought to be, no matter how hot you are, yourself.

The top instrument in surveying is the transit. Of all instruments of any kind in general use that you can think of, the transit is about the most accurate. And it is exceedingly versatile in its accomplishments. It's used for establishing level lines, for measuring vertical or horizontal angles, and for measuring approximate distances, by means of its stadia hairs and a leveling rod. Its lesser brother, the level, is for level lines only. And then there's its other relative, the alidade and plane table, used for topographical mapping. If it ever falls to your lot to buy or specify any of these extremely vital instruments, always take into account what you know of the manufacturer and his reputation when you are looking for quality, accuracy, reliability and long life. I'm not mentioning any names, but you may sense vaguely what outfit I'm talking about.

TAPES

And speaking of measuring, (was I?) I want to throw in a word about tapes, steel and woven measuring tapes. Each kind has its purpose. The steel ones are, of course, used for accuracy. Here, what counts is legibility and wear. There's nothing clearer or better than a white background with bold, black numbers and graduations on it. Engineers swear by *Wyteface*. Tapes are made in a variety of lengths and in all the different forms of graduation you'll ever need.

FIELD BOOKS

One buddy you'll have to have is a good Field Book in which to record your notes. It should be one you can use outdoors in all weathers and that will last forever, or thereabouts. The best ones are stitched with non-rusting wire and will open right back, cover to cover, without cracking. The paper should be waterproofed.

I've been trying in as gentlemanly a way as possible through these pages to hint you should give real consideration now and forever to Keuffel & Esser as the makers of all your engineering and drafting equipment.

Here's a company that is over 80 years old, and getting more alive every year. They have been through three wars and won most elegant wreaths of laurel for the things they developed and built for the armed forces in all three fracases—things like periscopes, range and height finders, to mention a few. There is hardly a major piece of engineering, from the Panama Canal to the Brooklyn Bridge, backwards and forward, in which K&E products have not played an important part.

K&E have a big factory, with many workers who have been with them for years, some for generations, and who have inherited the skills and the devotion which go into making a line of fine, first class precision engineering instruments and materials. K&E products are known and respected from coast to coast and all over the world. The K&E catalog has been called the handbook of the industry.

MUST HAVE BEEN SOMETHING WRONG WITH MY TRANSIT

THE FINALE

As I said at the opening of this lecture, yours isn't a hit or miss profession. It's gotta be hit every time. You can't afford to have it any other way. It has happened once in a while that a bridge has fallen down or a building sagged or collapsed. Not often—but who knows, maybe the instruments used had something to do with it.

Anyway, you owe it to yourself to attach to yourself the best equipment you can possibly get. Second rate stuff is like shoes that don't fit—and you know what those can do to your feet.

So pick your manufacturer, and stick to him. Find out something about him. Learn what he makes, how long he's been at it, and what his rep is.

*　　*　　*

You may want to toss away what I've written here, but Keuffel & Esser Co. have craftily put some valuable stuff in the following pages which make it a reference book that you simply can't afford to throw away. —d.h.

DON'T THROW THIS VOLUME AWAY UNTIL YOU HAVE LOOKED FURTHER

UNITS OF MEASUREMENT
with Conversion Factors

U. S. SYSTEM

METRIC SYSTEM

Length

1 mile = 5280 feet
1 yard =   3 feet
1 foot =   12 inches

1 kilometer = 1000 meters
1 meter   =   10 decimeters
1 decimeter =   10 centimeters
1 centimeter =   10 millimeters
1 millimeter = 1000 microns (μ)
1 micron   = 1000 millimicrons (mμ)
1 millimicron =   10 angstroms (A)

Surveyor's or Gunter's Measure

1 mile = 8 furlongs = 80 chains
1 chain = 100 links = 66 feet
1 rod   = 5½ yards = 16½ feet

Nautical Measure

1 nautical mile = 6080* feet
1 fathom   =   6 feet

1 mile   = 1.609* kilometers
1 meter = 39.37 inches
1 yard   = 0.914* meter
1 foot   = 0.3048* meter
1 inch   = 2.54* centimeters

Area

1 square mile = 640 acres
1 acre   =   10 square chains
1 acre   = 43,560 square feet
1 square inch = 1.273* circular inches
1 circular inch = 1,000,000 circular mils

1 square kilometer = 100 hectares
1 hectare   = 100 ares
1 are   = 100 centares
1 centare   =   1 square meter

1 square mile = 2.590* square kilometers
1 square yard = 0.8361* square meter
1 square foot = 0.0929* square meter
1 square inch = 6.452* square centimeters
1 acre   = 0.4047* hectare

Volume

1 acre-foot = 43,560 cubic feet
1 cord   =   128 cubic feet
1 board foot = 144 cubic inches
1 cubic yard =   0.7646* cubic meter
1 cubic foot =   0.02832* cubic meter
1 cubic inch = 16.39* cubic centimeters

Capacity—Volume of Liquids

1 U.S. gallon   = 8.345* pounds of water   1 liter = 1000* cubic centimeters
1 U.S. gallon   = 231 cubic inches
1 cubic foot   = 7.481* U.S. gallons
1 Imperial gallon = 1.2* U.S. gallons

1 U.S. gallon = 3.785* liters
1 quart   = 0.9463* liter
1 liter   = 61.02* cubic inches

* Indicates an approximate value.

Weight or Mass

1 short ton = 2000 pounds	1 metric ton = 1000 kilograms
1 long ton = 2240 pounds	1 kilogram = 1000 grams
1 pound = 16 ounces	1 gram = 1000 milligrams

$$1 \text{ short ton} = 907.18^* \text{ kilograms}$$
$$1 \text{ pound} = 0.4536^* \text{ kilogram}$$

Angular Measurement

1 circumference	= 360 degrees
1 degree	= 60 minutes
1 minute	= 60 seconds
1 circumference	= 6.2832* radians
1 radian (ρ)	= 57.2958* degrees
1 quadrant	= 90 degrees
1 quadrant	= 1600 mils
1 quadrant	= 100 grads
1 grad	= 100 grad minutes
1 grad minute	= 100 grad seconds
1 circumference	= 3.14159* diameters

Temperature

$$x \text{ degrees F} = \frac{x-32}{1.8} \text{ degrees C}$$

$$y \text{ degrees C} = (1.8y + 32) \text{ degrees F}$$

$$\text{Absolute zero} = -459.72°F = -273.18°C$$

PHYSICS, Some Formulas, Units and Equivalents

Uniform Velocity

$$(\text{velocity}) \; v = \frac{d \; (\text{distance})}{t \; (\text{time})}$$

1 mile per hour = 88 feet per minute
1 nautical mile per hour = 1 knot = 1.1516 miles per hour
Velocity of light = 186,300* miles per second

Uniform Acceleration

$$(\text{acceleration}) \; a = \frac{v_2 \; (\text{velocity, final}) - v_1 \; (\text{velocity, initial})}{t \; (\text{time, elapsed})}$$

Standard acceleration due to gravity (g.) = 32.174* feet per second
per second = 980.7* centimeters per second per second

Force

$$(\text{force}) \; F = \text{mass} \times \text{acceleration} = ma = \frac{W \; (\text{weight})}{g.} \, a$$

1 gram weight = 980.7* dynes
1 pound weight = 32.17* poundals
1 pound weight = 453.6* grams weight

* Indicates an approximate value.

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Pressure

1 atmosphere = 14.7* pounds per sq. in.
1 atmosphere = 29.92* inches mercury
1 atmosphere = 33.9* feet of water
1 atmosphere = 760 millimeters of mercury

Work and Energy

Mechanical

1 erg = 1 dyne-centimeter
1 gram-centimeter = 980.7* ergs
1 kilogram-meter = 7.233 foot-pounds
1 horsepower sec. = 550 foot-pounds

Thermal

1 British thermal unit = 778* foot-pounds
1 British thermal unit = 252* gram-calories
1 foot-pound = 0.3239* gram-calorie
1 gram-calorie = 0.4269* kilogram-meter

Electrical

1 joule = 10^7 ergs
1 watt-second = 1 joule
1 foot-pound = 1.356* joules

Power

1 horsepower = 550 foot-pounds per second
1 horsepower = 2545 BTU per hour
1 horsepower = 746* watts
1 kilowatt = 1.341 horsepower

ALGEBRA, Some Formulas

Quadratic

If $ax^2 + bx + c = 0$, then $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

Binomial

$$(a \pm b)^n = a^n \pm na^{n-1}b + \frac{n(n-1)}{2!}a^{n-2}b^2 \pm \frac{n(n-1)(n-2)}{3!}a^{n-3}b^3 + \ldots$$

Arithmetic and Geometric Progression

If n = the number of terms, a = the first term, l = the last term, d = the common difference, s = the sum of n terms, r = the common ratio.

$l = a + (n-1)d$ $\qquad\qquad$ $s = \tfrac{1}{2}n(a + l)$

$l = ar^{n-1}$ $\qquad\qquad$ $s = a\dfrac{r^n - 1}{r - 1}$

* Indicates an approximate value.

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$$\sin (A \pm B) = \sin A \cos B \pm \cos A \sin B$$
$$\cos (A \pm B) = \cos A \cos B \mp \sin A \sin B$$

$$\tan (A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A \tan B} \qquad \cot (A \pm B) = \frac{\cot A \cot B \mp 1}{\cot B \pm \cot A}$$

$$\sin A + \sin B = 2 \sin \tfrac{1}{2}(A+B) \cos \tfrac{1}{2}(A-B)$$
$$\sin A - \sin B = 2 \cos \tfrac{1}{2}(A+B) \sin \tfrac{1}{2}(A-B)$$
$$\cos A + \cos B = 2 \cos \tfrac{1}{2}(A+B) \cos \tfrac{1}{2}(A-B)$$
$$\cos A - \cos B = -2 \sin \tfrac{1}{2}(A+B) \sin \tfrac{1}{2}(A-B)$$
$$\sin 2A = 2 \sin A \cos A$$
$$\cos 2A = \cos^2 A - \sin^2 A = 1 - 2 \sin^2 A = 2 \cos^2 A - 1$$

$$\tan 2A = \frac{2 \tan A}{1 - \tan^2 A} \qquad \cot 2A = \frac{\cot^2 A - 1}{2 \cot A}$$

$$\sin \tfrac{1}{2}A = \pm .7071 \sqrt{1 - \cos A} \qquad \cos \tfrac{1}{2}A = \pm .7071 \sqrt{1 + \cos A}$$

$$\tan \tfrac{1}{2}A = \frac{1 - \cos A}{\sin A} = \frac{\sin A}{1 + \cos A} = \frac{1}{\cot \tfrac{1}{2}A}$$

Solution of Oblique Triangles

Angles A, B and C. Sides opposite a, b and c respectively.

$$A + B + C = 180°$$

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

$$a^2 = b^2 + c^2 - 2bc \cos A$$
$$\tfrac{1}{2}(A+B) = 90° - \tfrac{1}{2} C \qquad \cos A = \frac{-a^2 + b^2 + c^2}{2bc}$$

$$\tan \tfrac{1}{2}(A-B) = \frac{a-b}{a+b} \times \tan \tfrac{1}{2} (A+B)$$

$$A = \tfrac{1}{2}(A+B) + \tfrac{1}{2}(A-B) \qquad B = \tfrac{1}{2}(A+B) - \tfrac{1}{2}(A-B)$$

$$\text{Area} = \tfrac{1}{2}bc \sin A = \frac{a^2 \sin B \sin C}{2 \sin A}$$

$$= \sqrt{s(s-a)(s-b)(s-c)} \text{ when } s = \tfrac{1}{2}(a+b+c)$$

These are some trade marks to look for to make sure you are getting genuine K&E products:

K+E ®

K&E®

POLYPHASE® Slide Rules

LOG LOG DUPLEX TRIG and DECITRIG® Slide Rules

LOG LOG DUPLEX VECTOR® Slide Rules

MINUSA® Drawing Instruments

PARAGON® Drawing Instruments

ANVIL Drawing Instruments

MERCURY® Drawing Instruments

LAMINENE Drawing Board Surface Material

PARAGON® Scales

ALBANENE® Tracing Paper

PHOENIX® Tracing Cloth

STABILENE Glass Cloth

HELIOS® Dry Diazo Reproduction Materials

PARAGON® Drafting Machines

LEROY® Lettering Equipment

DORIC Lettering Equipment

PARAGON Surveying Instruments

WYTEFACE Steel and Woven Tapes

K+E