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CONSTRUCTION ESTIMATING REFERENCE DATA

by Ed Sarviel, A.S.P.E.

Craftsman Book Company
6058 Corte del Cedro, Carlsbad, CA 92011

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Introduction

Most construction estimators accumulate tables, man-hour records, and useful data during their entire career. Few ever organize and compile this valuable information into a form that could be used by other estimators. This manual is an attempt to assemble in a convenient form a career's worth of estimating reference data.

The content of the book is limited to estimating reference materials; no dollar costs and very little engineering data are included. If you need engineering, architectural or dollar cost data, many other publications are available. Nowhere in this book do we explain how to compile an estimate. Again, many other books explain estimating procedures.

We generally follow the Uniform Construction Index format to organize the book into sections. If you've used the 16 division UCI system before, you'll have no trouble turning right to the section that has the information you need. For those not familiar with the UCI system, an exhaustive index is provided at the back of this book.

The information you find here falls into four categories: Construction Descriptions, Conversion Tables, Material Tables, and Labor Tables.

Construction Descriptions
It's difficult or impossible to estimate the cost of any work you can't visualize. Consequently, many pages of text and illustrations are included in this book to familiarize you with the work involved. But a much larger volume would be needed to describe all construction work. In fact, a whole library of books would be required. The descriptions included here only highlight information that will be of particular interest when estimating the type of work covered.

Conversion Tables
Every estimator needs to make conversions: from tons to cubic yards; from linear feet to board feet; from bank to loose measure. There's no substitute for the exact conversion table you need, and this manual will most likely have what you're looking for.

Material Tables
Properties of materials are an important subject for every construction estimator: What types of materials are generally available, in what finishes, in what weights, in what sizes? A good, non-technical summary of key materials and how they are used will be found in many sections.

Labor Tables
Most of this book is devoted to man-hour estimating tables, and for good reason. The labor required is a key element in every construction estimate. Because there are so many labor tables in this book, and because labor is such an important part of every estimate, an in-depth explanation of the labor tables is appropriate.

Experienced construction estimators recognize that no two jobs are exactly alike. Labor productivity varies widely from job to job, even if the crew remains the same. Thus, judgement is an essential element in every construction estimate. And judgement will be required when using the labor tables in this manual.

The man-hour tables in this book are **not** based on "ideal" conditions. They assume conditions typical of what most contractors encounter on better planned and managed jobs. The labor productivity indicated in the tables will apply to the extent that these conditions apply to the job you are figuring. Where conditions differ, modification will be necessary.

Specifically, the man-hour tables are based on the following assumptions:

Size of the job is moderate, about what most contractors handling this type of work are accustomed to bidding.

The materials needed are readily available at a storage point relatively close to the point of installation. The materials are service grade and meet generally accepted standards for the type of use intended.

Layout and installation are relatively uncomplicated because the plans and specifications are adequate, access to the work is good, and work done by other trades was done according to the plans and is professional quality.

Labor productivity is fair to good. The crew is experienced in this type of work, motivated to complete the work as required, and is just large enough to get the job done using routine procedures.

Temperature and working conditions do not adversely affect progress of the job.

Tools and equipment appropriate for the job are available and used to best advantage during the course of construction.

Work is professional quality. However, exceptional work involving great detail, decorative materials, custom treatments or unique skills is not considered. Any defects or omissions are remedied before the crew leaves the job site.

Only new construction is involved. Repair, replacement and remodeling-type work often involves problems of limited access, matching of materials, working with non-standard sizes, patching, and control of the construction environment. The tables will be a useful guide to the extent that repair or remodeling work is similar to new construction.

Scope of the Work Described

The man-hour tables in this book will be a useful guide if you can visualize what work is included and what work is excluded from the tasks listed in each table. No man-hour estimate is useful if there is considerable doubt about what the figures actually cover. Most labor tables in this book have a footnote which should clarify the scope of work included. But it would be nearly impossible to describe in detail every element of each man-hour estimate.

It is safe to assume, however, that every task essential to performing the work has been included in the estimate. If the scope of work covered still is not clear, understand that estimates are for the "complete" job and include all of the associated work usually performed along with the named task unless noted otherwise.

But be aware that most tables include work by only one trade classification. This should help you define what is included and excluded from each table. For example, man-hours for installing a cabinet (by a carpenter) would not include the time to stain and seal the cabinet (by a painter).

Two categories of work are specifically included and excluded from the man-hour tables:

Non-productive labor is not included unless noted otherwise. On larger crews it is assumed that the supervisor works along with the crew when not actually directing the work.

Mobilization and demobilization on the site are included. Time usually spent unloading tools, materials and equipment, and preparing to do the work is included in the man-hour estimates. So is time spent reloading tools and equipment at job completion and cleanup of surplus material. Naturally, no travel time or delays off the site are included unless specifically noted.

How Accurate are the Tables?

The figures published here are the result of actual observations compiled, interpreted, and verified by professional estimators. This implies an exercise of judgement. And it should be clear to the user that this manual is the product of personal judgement. Crew productivity varies widely. Even the most well-informed, professional judgement can not guarantee that the figures here will apply to the job you are estimating.

In the aggregate the man-hour estimates in this manual will be accurate to within about 20% on most jobs where conditions are similar to the conditions outlined. On most of the remaining jobs the figures will be too high by 20% or more — estimating more man-hours than are actually required. This is intentional, as an estimate slightly too high is better than an estimate slightly too low. Most contractors would agree.

Let's look at an example. This book lists labor installing asphalt strip shingles at 1.5 man-hours per 100 square feet. A skilled shingle specialist working under ideal conditions on a larger job will be able to handle considerably more work than this. You'll hear claims of 200 or more square feet per man-hour. At that rate a two man crew would finish two 1600 square foot roofing jobs in a day. That's an excellent rate. But it's not a rate most estimators should use until they saw their crews produce results like that on several jobs.

Now look at the other extreme. Estimators who have figured asphalt shingles on commercial, better industrial or military jobs claim that 2 to 2.5 man-hours per 100 square feet is a reasonable figure. We don't doubt the validity of these estimates for that type of work.

Most jobs fall between these extremes. Many experienced roofing contractors would insist that their crews can average close to 100 square feet per man-hour. Thus a two man crew would finish that 1600 square foot job in one 8 hour day. That's 33% faster than the 1.5 man-hours listed on page 192 of this manual.

Again, we don't doubt the validity of these figures. But we recognize that they are based on specialized crews working under experienced supervisors and with exactly the right equipment.

To summarize, reasonable estimates for installing asphalt strip shingles may vary from .5 to 2.5 man-hours per square, with most experienced crews producing about 100 square feet per hour.

Why the difference? There are many reasons. The highest and lowest productivity rates vary from the conditions outlined above and probably don't include and exclude the same tasks. Many shinglers can put down 200 square feet of shingles in an hour. But every shingle job involves checking and cleaning the deck, moving tools and materials into place, laying out the job, placing felt and starter strips, some flashing work, making minor repairs and cleanup. All of this should be included in any realistic estimate and is included in the 1.5 hour estimate in this book.

Another difference is the type of work itself — even though the material applied fits the same description. Commercial jobs nearly always receive higher quality workmanship than the typical residential job. Every tradesman worthy of your payroll will give more care and attention to a highly visible roof on a commercial building covered with top quality shingles than a garage roof using strictly standard grade shingles.

Recognize also that an experienced crew working under the direct supervision of an owner-entrepreneur will out-produce less motivated tradesmen on nearly every job. And a crew working on a piecework basis will do its level best to get the job done by quitting time so a return trip isn't necessary the next day.

No single figure will cover all work and a 500 word essay would be needed to describe most common situations. In this book we have selected what we feel are reasonable first approximations for labor productivity. Use these figures when the productivity of the crew is unknown and the exact type of work is not specified. In the case of asphalt strip shingles, 1.5 man-hours was our choice. And that brings us to our final, and most important point.

Every man-hour estimate in this volume is a poor second choice when compared to the figures you develop yourself from the work your crews have handled. Your most reliable guide will always be your own cost records. Where you must supplement your experience with the reference data in this manual, we hope our judgement proves worthy of your trust.

1 general requirements section

Estimating Service

Date	Job No.	LOC.	For
Auth.	Owner	DWG.	Sheet________of______
Est. By	Hrs.	Act. Hrs.	Project

No.	Item and/or Event	Unit	Material Unit $	Cost $	Labor Unit $	Cost $	Extention $

section contents

Tips for Maximizing Productivity

Order materials correctly and issue specific delivery times and places. Make certain that the materials supplier understands the correct amount to be delivered to the proper site at the proper job at the proper time. This avoids delays and extra costs due to incomplete material orders or delivery errors. Keep materials lists up to date. Give your supplier instructions on how piles of materials are to be built up.

Create a flexible material handling system. Because building requires a wide range of materials, flexibility is very important. Most builders have to perform a wide variety of work. Develop systems capable of handling many different types of materials. If possible, anticipate the breakdown of one system and have an alternate ready to avoid delay.

Reduce all materials handling time to a minimum. Storing and moving materials from one site on the job to another can be avoided almost entirely with a good delivery system. Proper materials placement on delivery at the site reduces hand carrying and sorting. Move materials in quantity wherever possible. For example, deliver the lumber package for rough framing to a location predetermined by the supervisor or indicated on the drawings. Stack lumber in the sequence of use with the first material needed on top to eliminate the need for sorting and restacking.

Use the best method of material handling. Find and use the best way of handling the materials for each operation or phase of construction. Methods vary between operations due to differences in materials handled. The best method does not always mean carrying the largest possible quantity with each trip. For example, if a small amount of brick is required for a house, the brick should be packaged so that it can be carried by a two-wheeled handcart rather than a forklift.

Use packaged and unitized materials. This discourages pilferage and materials scattering and helps reduce the total cost of materials. It also tends to speed up production because workmen have no trouble finding the necessary materials when needed. For example, have lumber delivered in banded stacks, have block delivered in pallet-sized units, and use boxes for tools and equipment when possible.

Reduce interdependency of men and machines. Provide holding or storage facilities so workmen can continue their operations without being delayed by waiting for other men or machines. For example, when material is raised with a forklift, have a storage platform on the roof so the man below does not have to wait for the man above to deposit each piece and return to take the next piece.

Schedule for continuous flow of production and materials. Schedule production so there is minimum distance between jobsites. A diagram may help determine the best schedule. Certain crews must make several trips to each jobsite. The need for scheduling an even flow of materials and production should be obvious. Schedules must include time for both production and material delivery. For example, assume lumber to be used in the construction of two houses will be delivered to the jobsites in one truck. The material can be unloaded much faster and placed in the proper locations with a minimum of travel if the houses are adjacent to each other.

Use good housekeeping. Whenever possible, use unitized and packaged material to keep good material together. Be certain that material is not scattered around the jobsite and susceptible to damage by vehicles and weather. Separate waste material from usable material. This allows easier equipment movement around each site.

Make full use of equipment. Use the right kind of equipment for each job. Keep equipment operating near its maximum capacity to provide the largest possible benefit. But don't overextend the capacity of equipment. Make sure operators are familiar with each piece of equipment. Consider equipment use when scheduling all work involving equipment. This keeps equipment working on productive jobs and helps eliminate conflicts. For example, don't use a large capacity front-end loader for carrying lumber around a jobsite. Don't try to use a small loader to dig an entire basement. Remember that your goal is to keep every piece of equipment working all during every work day. No builder can do this, but keep it in mind when buying equipment. Don't buy equipment that is going to stand idle much of the time. Nearly anything you need only occasionally will be available at an equipment rental yard. Your success as a builder is not measured by the value of the equipment parked in your yard or on jobsites each night. Your success is in the profit you make on each job and at the end of each year.

Use multipurpose equipment. Equipment flexibility depends on the size of the operation and the type of construction done. In a large organization, specific uses of equipment can be justified. But builders with a smaller volume must be able to perform a variety of operations with each major piece of equipment. To keep equipment operating continuously, you need equipment that can perform several types of operations. For example, a front-end loader with backhoe can be used for small excavation work and for lifting and carrying materials. It can also be used for pulling tool wagons and equipment such as concrete mixers around the jobsite. A belt conveyor used for positioning gravel in the basement can also carry shingles to the roof.

Use simple low-cost jigs and equipment. Job fabricated jigs and simple tools can greatly reduce materials handling. For example, build a plywood ladder out of 2'' x 6'' lumber for moving plywood to the first and second floors. Make a simple chute out of plywood for positioning gravel in the basement for slab base.

Select equipment carefully. When considering the purchase of equipment, compare annual savings produced by the equipment with the annual cost of the equipment. In determining equipment cost, consider the initial price, capital costs, repair costs and operating costs.

Set up a maintenance program. Good maintenance extends equipment life and reduces equipment down time. If equipment is to operate properly when needed, it must be maintained.

Reduce worker fatigue. Good material handling reduces worker fatigue and allows operations to be performed better and faster. This is especially important when heavy, bulky or a large number of items must be moved. For example, transporting concrete block to the basement can be exhausting work. Many masonry jobs are 30% or more materials handling. Be especially alert to reduce double handling when heavy materials are involved. Try to get materials delivered close to the point of use and at the same height if possible. This reduces fatigue and can significantly improve production late in the day and during warm weather.

Increase safety awareness. Good materials handling methods reduce on-the-job injuries and cut lost time. Time lost due to injury normally costs more than a good materials handling program. For example, place a waste box on each job to avoid rehandling and stepping on discarded materials. This also highlights waste and scrap material accumulation by putting it where everybody can see it.

Don't let the work expand to fill the time available. Most tradesmen can drag out a task until it is completed just at quitting time. If your crews begin carrying tools back to the truck an hour before quitting time and spend the last 15 minutes waiting in the truck for four o'clock to arrive, you have a problem. If you don't do any other scheduling, schedule the last hour of each day. Make sure each lead man has a list of productive work that can be put off until some job is finished just before the end of the day. If nothing else, the crew can spend the time maintaining tools, cleaning up the jobsite or moving materials to where they will be needed the next day. Likewise, make it your policy that work begins at the beginning of the work day. Some employees arrive at work with the intention of spending the first half hour drinking coffee, eating a roll and discussing last night's T.V. programs or the morning news. An employee who needs a half hour to get ready to go to work should arrive at the job a half hour early.

Use the lowest paid workers to haul materials. If you look at most building tasks carefully, you will discover that about 40% of the work does not require highly skilled labor. Most crews should be one half laborers or apprentices, and the laborers or apprentices should do nearly all the materials handing. A single laborer can often supply materials to two craftsmen working in different trades. For example, if you have a one man finish carpentry crew and a one man painting crew on the job, a single laborer may be able to mix paint for the painter when he is not helping the carpenter carry doors and hardware. Every crew of two or more men on most jobs should include a laborer or trainee to handle materials.

Don't waste valuable materials. Good material handling policy requires that carpenters take the time to pick up and use every sound piece of lumber over 11 inches long. There are probably 500 places in a home where a 12 inch 2 x 4 or 2 x 6 can be used. At $500 per thousand board feet, a 2 x 6 twelve inches long is worth 50 cents. Even at a cost of $20 per hour, it is worth a minute of a carpenter's time to pick up a 12 inch 2 x 6. At $500 per thousand board feet, stud material costs considerably more than the labor required to install or repair it. All scrap material is not waste material. Educate supervisors on the differences: scrap is what is left over after some material has been installed; waste material has no value for its original intended use. Scrap materials are waste only if they can not be used economically somewhere else on the job. Separate scrap and waste and encourage crews to go to the scrap pile when they need bits and pieces to complete a job.

Instruct your staff. Show your entire staff the importance of the materials handling systems that you develop. Everyone should assist in putting these systems into use. Workmen should be trained in the correct methods for handling materials.

Encourage your supervisors to "microschedule." Some of the most effective planning on a residential job is done by lead men and foremen who have the appropriate materials available before the need arises. As each task is finished, the skilled craftsmen should be able to go directly to the next task. The tools and materials should be prepositioned to where they are needed and the lead man should have thought out just how the work will be done. This type of planning pleases many craftsmen and frees them to be nearly 100% productive. Once that task is progressing smoothly, the lead man should begin to think about preparing for the next task. This is scheduling on a very small and very personal scale. Many crew leaders do it instinctively. Every leader should "microschedule" for high productivity.

Use the smallest crew that can get the job done. There is a tendency to have more people available to do the work than are really needed. Job foremen often feel that they need more men or could get the job done better if they had a larger crew. This is especially true where the work is unpleasant or the working conditions difficult. Make it clear to your foremen that they are to use the smallest crew size that will get the job done on time. This means that for many jobs only one man will be assigned. Seldom will you need a seven man carpentry crew, for example.

There are several reasons for using the smallest crew possible. Delays occur on every job. There are many reasons why the work can't go forward temporarily. Many times, it is expedient to drag out the work until quitting time for the day. There are just about the same number of these delays on a given job when a small crew is working as when a large crew is working. But where there are more men, there are more manhours wasted during the delay. Unfortunately, your lead man, foreman or superintendent may not realize how much time is nonproductive. Look at your jobs through the eyes of an industrial engineer. Spot time lost due to unnecessary delay.

Building Material Weights per Volume

Asbestos 110-120 lbs. per C.F.
Brick
- Common 2½" x 4" x 8¼", 5.4 lbs. each; 2.7 tons per 1000
- Fire, standard 9" x 4½" x 2½", 7.0 lbs. each; 3.5 tons per 1000
- Hard 2¼" x 4¼" x 8½", 6.48 lbs. each; 3.24 tons per 1000
- Paving 2¼" x 4" x 8½", 6.75 lbs. each; 3.37 tons per 1000
- Paving 3¼" x 4" x 8½", 8.75 lbs. each; 4.37 tons per 1000
- Soft 2¼" x 4" x 8¼", 4.32 lbs. each; 2.6 tons per 1000

Cement bag 94 lbs. each; bbl. weighs 376 lbs.
Clay
- Dry 63-95 lbs. per C.F.; 1700-2295 lbs. per C.Y.
- Fire 130 lbs. per C.F.; 3510 lbs. per C.Y.
- Wet 120-140 lbs. per C.F.; 2970-3200 lbs. per C.Y.

Concrete 138 lbs. per C.F.; 3726 lbs. per C.Y.
- Cinder concrete 112 lbs. per C.F.
- Gravel and limestone concrete 150 lbs. per C.F.
- Trap-rock concrete 155 lbs. per C.F.

Crushed stone 100 lbs. per C.F.; 2700 lbs. per C.Y.
Gravel 95 lbs. per C.F.; 2565 lbs. per C.Y.
Hydrated lime 40 lbs. per C.F.
Mortar 103 lbs. per C.F.
Plaster of paris 98 lbs. per C.F.
Reinforced concrete 150 lbs. per C.F.
Sand
- Dry 97-117 lbs. per C.F.; 2619-3159 lbs. per C.Y.
- Wet 120-140 lbs. per C.F.; 3240-3780 lbs. per C.Y.

Shingles, bundles 24" long, 20" wide, 10" high weighs 50 lbs. Approximately 250 per bundle
Slag 1755-1890 lbs. per C.Y.; 65-70 lbs. per C.F.
Slag concrete 135 lbs. per C.F.
Stone riprap 65 lbs. per C.F.; 1755 lbs. per C.Y.

Live Load Allowances
Minimum Uniformly Distributed Live Loads

Occupancy or Use	Live Load in Lbs. Per S.F.
Apartments (see Residential)	
Assembly halls and other places of assembly	
Fixed seats	60
Movable seats	100
Balcony (exterior)	100
Bowling alleys, poolrooms, etc.	75
Corridors	
First floor	100
Other floors, same as occupancy served	
Dance halls, dining rooms and restaurants	100
Dwellings (see Residential)	
Garages (passenger cars)	100
Floors shall be designed to carry 150% of the maximum wheel load anywhere on the floor.	
Grandstands (see Reviewing stands)	
Gymnasiums, main floors and balconies	100
Hospitals	
Operating rooms	60
Private rooms	40
Wards	40
Hotels (see Residential)	
Libraries	
Reading rooms	60
Stack rooms	150
Manufacturing	125
Marquees	75
Office buildings	
Offices	80
Lobbies	100
Residential	
Multifamily houses	
Private apartments	40
Public rooms	100
Corridors	60

Live Load Allowances (Continued)
Miminum Uniformly Distributed Live Loads

Occupancy or Use	Live Load in Lbs. Per S.F.
Dwellings	
First floor	40
Second floor and habitable attics	30
Uninhabitable attics	20
Hotels	
Guest rooms	40
Public rooms	100
Corridors serving public rooms	100
Public corridors	60
Private corridors	40
Reviewing stands and bleachers	100
Schools	
Classrooms	40
Corridors	100
Sidewalks, vehicular driveways, and yards subject to trucking	250
Skating rinks	100
Stairs, fire escapes, and exitways	100
Storage warehouse	
Light	125
Heavy	250
Stores	
Retail	
First-floor, rooms	100
Upper floors	75
Wholesale	125
Theaters	
Aisles, corridors and lobbies	100
Orchestra floors	60
Balconies	60
Stage floors	150
Yards and terraces, pedestrian traffic	100

Dead Loads — Approximate Weights per Square Foot

Roof or Ceiling Type	Pounds
Roofs	
Asphalt, felt and gravel (3-5 ply built-up)	5 - 6½
Asphalt, felt and slag (3-5 ply built-up)	4½-5½
Composition 3-ply	1
Concrete, cinder (per inch thickness)	9
Concrete, nailing (per inch thickness)	8
Corrugated aluminum (.024″ thick)	½
Corrugated asbestos (¼″-3/8″ thick)	3 - 4½
Corrugated iron-steel (20-18 gauge)	2 - 3
Gypsum slab (per inch thickness)	8
Sheathing boards (1″ WP, Spr., Hmlk.)	2½ - 3
Shingles, asbestos	3 - 6
Ceilings	
Gypsum lath and plaster (3/8″ plus 1/2″ thick)	5½
Lath and ¾″ plaster	8
Suspended metal lath and plaster	10
Gypsum board (½″ thick)	2

Inch Fractions to Decimal Equivalents

1/32 = .03125	5/32 = .15625	9/32 = .28125	13/32 = .40625
1/16 = .0625	3/16 = .1875	5/16 = .3125	7/16 = .4375
3/32 = .09375	7/32 = .21875	11/32 = .34375	15/32 = .46875
1/8 = .125	1/4 = .250	3/8 = .375	1/2 = .500
17/32 = .53125	21/32 = .65625	25/32 = .78125	29/32 = .90625
9/16 = .5625	11/16 = .6875	13/16 = .8125	15/16 = .9375
19/32 = .59375	23/32 = .71875	27/32 = .84375	31/32 = .96875
5/8 = .625	3/4 = .750	7/8 = .875	1 =1.0000

Building Material Weights Per Square Foot

Block, creosoted wood, 3″	15.00
Boards, fiber insulating	
1″	1.50
¾″	1.10
½″	0.80
Ceiling, wood	
¾″	2.50
⅝″	1.80
½″	1.40
⅜″	1.10
Copper, sheet	1.00
Lead, sheet	4.00 to 8.00
Plywood	
¼″	0.70
5/16″	1.00
⅜″	1.10
Shingles	
Asphalt	2.00 to 3.00
Wood	2.50
Slate	10.00
Tile, plain	9.00 to 12.00
Tin, painted	1.00
Zinc, sheet	1.00 to 2.00

Use these figures when determining dead loads on floors and roofs.

Area and Volume Conversions

Area of a square = length x breadth or height.
Area of a rectangle = length x breadth or height.
Area of a triangle = base x ½ altitude.
Area of parallelogram = base x altitude.
Area of trapezoid = altitude x ½ the sum of parallel sides.
Area of trapezium = divide into two triangles, total their areas.
Circumference of circle = diameter x 3.1416.
Circumference of circle = radius x 6.283185.
Diameter of circle = circumference x .3183.
Diameter of circle = square root of area x 1.12838.
Radius of a circle = circumference x .159155.
Area of a circle = half diameter x half circumference.
Area of a circle = square of diameter x .7854.
Area of a circle = square of circumference x .07958.
Area of a sector of circle = length of arc x ½ radius.
Area of a segment of circle = area of sector of equal radius minus area of a triangle, when the segment is less, and plus area of triangle, when segment is greater than the semi-circle.
Area of circular ring = sum of the diameter of the two circles x difference of the diameter of the two circles and that product x .7854.
Side of square that shall equal area of circle = diameter x .8862.
Side of square that shall equal area of circle = circumference x .2821.
Diameter of circle that shall contain area of a given square = side of square x 1.1284.
Side of inscribed equilateral triangle = diameter x .86.
Side of inscribed square = diameter x .7071.
Side of inscribed square = circumference x .225.
Area of ellipse = product of the two diameters x .7854.
Area of a parabola = base x 2/3 of altitude.
Area of a regular polygon = sum of its sides times perpendicular from its center to one of its sides divided by 2.
Surface of cylinder or prism = area of both ends plus length and times circumference.
Surface of sphere = diameter x circumference.
Solidity of sphere = surface x 1/6 diameter.
Solidity of sphere = cube of diameter x .5236.
Solidity of sphere = cube of radius x 4.1888.
Solidity of sphere = cube of circumference x .016887.
Diameter of sphere = cube root of solidity x 1.2407.
Diameter of sphere = square root of surface x .56419.
Circumference of sphere = square root of surface x 1.772454.
Circumference of sphere = cube root of solidity x 3.8978.
Contents of segment of sphere = (height squared plus three times the square of radius of base) x (height x .5236).
Contents of a sphere = diameter x .5236.
Side of inscribed cube of sphere = radius x 1.1547.
Side of inscribed cube of sphere = square root of diameter.
Surface of pyramid or cone = circumference of base x ½ of the slant height plus area of base.
Contents of pyramid or cone = area of base x ⅓ altitude.
Contents of frustum of pyramid or cone = sum of circumference at both ends x ½ slant height plus area of both ends.
Contents of frustum of pyramid or cone = multiply areas of two ends together and extract square root. Add to this root the two areas and x ⅓ altitude.
Contents of a wedge = area of base x ½ altitude.

Square Measure

1 square centimeter	0.1550 square inch
1 square decimeter	0.1076 square feet
1 square meter	1.196 square yard
1 acre	3.954 square rods
1 hectare	2.47 acres
1 square kilometer	0.386 square mile
1 square inch	6.452 square centimeters
1 square foot	9.2903 square decimeters
1 square yard	0.8361 square meter
1 square rod	0.259 acre
1 acre	0.4047 hectare
1 square mile	2.59 square kilometers
144 square inches	1 square foot
9 square feet	1 square yard
30¼ square yards	1 square rod
40 square rods	1 rood
4 roods	1 acre
640 acres	1 square mile

Square Tracts of Land

Acres	Length of One Side of Square Tract, L.F.	Area S.F.
1/10	66.0	4,356
1/8	73.8	5,445
1/6	85.2	7,260
1/4	104.4	10,890
1/3	120.5	14,520
1/2	147.6	21,780
3/4	180.8	32,670
1	208.7	43,560
1½	255.6	65,340
2	295.2	87,120
2½	330.0	108,900
3	361.5	130,680
5	466.7	217,800

Linear Conversions

1 centimeter	0.3937 inches
1 inch	2.54 centimeters
1 decimeter	3.937 inches or 0.328 foot
1 foot	3.048 decimeters
1 meter	39.37 inches or 1.0936 yards
1 yard	0.9144 meter
1 dekameter	1.9884 rods
1 rod	0.5029 dekameter
1 kilometer	0.62137 mile
1 mile	1.6093 kilometers

Volume Conversions

1 cubic centimeter	0.061 cubic inch
1 cubic inch	16.39 cubic centimeters
1 cubic decimeter	0.0353 cubic foot
1 cubic foot	28.317 cubic decimeters
1 cubic yard	0.7646 cubic meter
1 stere	0.2759 cord
1 cord	3.624 steres
1 liter	0.908 dry quarts or 1.0567 liquid quarts
1 dry quart	1.101 liters
1 liquid quart	.09463 liter
1 dekaliter	2.6417 gallons or 1.135 pecks
1 gallon	0.3785 dekaliter
1 peck	0.881 dekaliter
1 hektoliter	2.8375 bushels
1 bushel	0.3524 hektoliter

Length Conversion Tables for English to Metric Systems

Inches Centimeters Feet Meters Yards Meters Miles Kilometers	Kilometers / Miles	Miles / Kilometers	Meters / Yards	Yards / Meters	Meters / Feet	Feet / Meters	Centimeters / Inches	Inches / Centimeters
1	0.62	1.61	1.09	0.91	3.28	0.30	0.39	2.54
2	1.24	3.22	2.19	1.83	6.56	0.61	0.79	5.08
3	1.86	4.83	3.28	2.74	9.84	0.91	1.18	7.62
4	2.49	6.44	4.37	3.66	13.12	1.22	1.57	10.16
5	3.11	8.05	5.47	4.57	16.40	1.52	1.97	12.79
6	3.73	9.66	6.56	5.49	19.68	1.83	2.36	15.24
7	4.35	11.27	7.66	6.40	22.97	2.13	2.76	17.73
8	4.97	12.87	8.75	7.32	26.25	2.44	3.15	20.32
9	5.59	14.48	9.84	8.23	29.53	2.74	3.54	22.86
10	6.21	16.09	10.94	9.14	32.81	3.05	3.93	25.40
20	12.43	32.19	21.87	18.29	65.62	6.10	7.87	50.80
30	18.64	48.28	32.31	27.43	98.42	9.14	11.81	76.20
40	24.85	64.37	43.74	36.58	131.23	12.19	15.75	101.60
50	31.07	80.47	54.68	45.72	164.04	16.24	19.68	127.00
60	37.28	96.56	65.62	54.86	196.85	18.29	23.62	152.40
70	43.50	112.65	76.55	64.00	229.66	21.34	27.56	177.80
80	49.71	128.75	87.49	73.15	262.47	24.38	31.50	203.20
90	55.92	144.34	98.42	82.80	295.28	27.43	35.43	228.60
100	62.14	160.94	109.36	91.44	328.08	30.48	39.37	254.00

Example: 2 inches = 5.08 cm

Basic Metric Length Relationships

One Unit (Below) Equals	Millimeters	Centimeters	Meters	Kilometers
Millimeter (mm)	1.	0.1	0.001	0.000,001
Centimeter (cm)	10.	1.	0.01	0.000,01
Meters	1,000.	100.	1.	0.001
Kilometer (km)	1,000,000.	100,000.	1,000.	1.

Weight[1] Conversion Tables for English to Metric Systems

Number	Metric Ton / Short Ton	Short Ton / Metric Ton	Kilograms / Pounds	Pounds / Kilograms	Grams / Ounces	Ounces / Grams
1	1.10	0.91	2.20	0.46	0.04	28.4
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.84	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.18	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.47	1984.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	188.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0

Example: Convert 28 pounds to kilograms.
28 pounds = 20 pounds + 8 pounds
From the tables: 20 pounds = 9.07 kg and 8 pounds = 3.63 kilograms
Therefore, 28 pounds = 9.07 kg + 3.63 kg = 12.70 kg

[1]The weights used for the English system are avoirdupois (common) weights. The short ton is 2,000 pounds. The metric ton is 1,000 kilograms.

Volume Conversion Tables for English to Metric Systems

Cubic Meters Cubic Yards Cubic Feet	Cubic Feet To:		Cubic Yards To:		Cubic Meters To:	
	Cubic Yards	Cubic Meters	Cubic Feet	Cubic Meters	Cubic Feet	Cubic Yards
1	0.037	0.028	27.0	0.76	35.3	1.31
2	0.074	0.057	54.0	1.53	70.6	2.62
3	0.111	0.085	81.0	2.29	105.9	3.92
4	0.148	0.113	108.0	3.06	141.3	5.23
5	0.185	0.142	135.0	3.82	176.6	6.54
6	0.212	0.170	162.0	4.59	211.9	7.85
7	0.259	0.198	189.0	5.35	247.2	9.16
8	0.296	0.227	216.0	6.12	282.5	10.46
9	0.333	0.255	243.0	6.88	317.8	11.77
10	0.370	0.283	270.0	7.65	353.1	13.07
20	0.741	0.566	540.0	15.29	706.3	26.16
30	1.111	0.850	810.0	22.94	1059.4	39.24
40	1.481	1.133	1080.0	30.58	1412.6	52.82
50	1.852	1.416	1350.0	38.23	1765.7	65.40
60	2.222	1.700	1620.0	45.87	2118.9	78.48
70	2.592	1.982	1890.0	53.52	2472.0	91.56
80	2.962	2.265	2160.0	61.16	2825.2	104.63
90	3.333	2.548	2430.0	68.81	3178.3	117.71
100	3.703	2.832	2700.0	76.46	3531.4	130.79

Example: 3 cubic yards = 81.0 cubic feet.
Volume: The cubic meter is the only common dimension used for measuring the volume of solids in the metric system.

Conversion Factors

(°C. x 9/5) + 32 = °F.
(°F — 32) x 5/9 = °C.
Liter x 1.05671 = U.S. quarts
Quarts x .946333 = liters
Liters x 61.025 = cubic inches
Gallons x 231 = cubic inches
Kilograms x 2.2046 = pounds
Pounds x 453.59 = grams
Ounces (avdp) x 28.35 = grams
Kilowatts x 1.341 = horsepower
Horsepower x 746 = watts
1 atmosphere = 33.899 feet of water at 39 1°F
1 atmosphere = 760 mm. of mercury
1 atmosphere = 14.7 pounds per square inch
1 cubic foot water = 62.37 pounds @ 60°F
1 cubic inch water = 0.036 pounds@ 60°F
Cubic meters x 35.314 = cubic feet
Cubic feet x 0.02832 = cubic meters
Centistokes x density = centipoises
Pounds/gallon at 20°C. = specific gravity at 20/20°C. x 8.3216
1 centimeter = 0.3937 inches
1 inch = 2.540 centimeter

Cubic Measure

1,728 cubic inches	1 cubic foot
128 cubic feet	1 cord wood
27 cubic feet	1 cubic yard
40 cubic feet	1 ton shipping
2,150.42 cubic inches	1 standard bushel
268.8 cubic inches	1 standard gallon dry
231 cubic inches	1 standard gallon liquid
1 cubic foot	About 4/5 of a bushel
1 Perch	A mass 16½ feet long, 1 foot high and 1½ feet wide, containing 24-2/3 cubic feet.

Miscellaneous

3 inches	1 palm
4 inches	1 hand
6 inches	1 span
18 inches	1 cubit
21.8 inches	Bible cubit
2½ feet	1 military pace

Fractions of an Inch

Inch	1/16	1/8	3/16	1/4	5/12	3/8	7/16	1/2
Centimeters	0.16	0.32	0.48	0.64	0.79	0.95	1.11	1.27
Inch	9/16	5/8	11/16	3/4	13/16	7/8	15/16	1
Centimeters	1.43	1.59	1.75	1.91	2.06	2.22	2.38	2.54

Units of Centimeters

Centimeters	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Inches	0.04	0.08	0.12	0.16	0.20	0.24	0.28	0.31	0.35	0.39

Surveyor's Measure

7.92 inches	1 link
25 links	1 rod
4 rods	1 chain
10 square chains or 160 square rods	1 acre
640 acres	1 square mile
36 square miles or 6 miles square	1 township

Weight Conversions

1 gram	0.03527 ounce
1 ounce	18.35 grams
1 kilogram	2.2046 pounds
1 pound	0.4536 kilogram
1 metric ton	0.98421 English ton
1 English ton	1.016 metric ton

Time Conversion Factors

Man-Hours to Minutes		Man-Days to Hours	
Fractional Man-Hours	Minutes Equivalent	Fractional Man-Days	Man-Hours Equivalent
.04	2.4	.1	48 min.
.05	3.0	.2	1 hr. 36 min.
.06	3.6	.3	2 hr. 24 min.
.07	4.2	.4	3 hr. 12 min.
.08	4.8	.5	4 hr.
.09	5.6	.6	4 hr. 48 min.
.10	6.0	.7	5 hr. 36 min.
.15	9.0	.8	6 hr. 24 min.
.20	12.0	.9	7 hr. 12 min.
.25	15.0		
.30	18.0		
.40	24.0		
.50	30.0		
.60	36.0		
.70	42.0		
.80	48.0		
.90	56.0		
1.00	60.0		

Basic Metric Weight Relationships

One Unit (Below) Equals	Grams	Kilograms	Metric Ton
Gram (gm)	1.	0.001	0.000,001
Kilogram (kg)	1,000.	1.	0.001
Metric ton	1,000,000.	1,000.	1.

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