CHAPTER 48

SECTIONS AND SHAPES—TABULAR DATA

Joseph E. Shigley
Professor Emeritus
The University of Michigan
Ann Arbor, Michigan

48.1 CENTROIDS AND CENTER OF GRAVITY

When forces are distributed over a line, an area, or a volume, it is often necessary to determine where the resultant force of such a system acts. To have the same effect, the resultant must act at the centroid of the system. The *centroid* of a system is a point at which a system of distributed forces may be considered concentrated with exactly the same effect.

Figure 48.1 shows four weights W_1, W_2, W_4, and W_5 attached to a straight horizontal rod whose weight W_3 is shown acting at the center of the rod. The centroid of this *weight* or *point group* is located at G, which may also be called the *center of gravity* or the *center of mass* of the point group. The total weight of the group is

$$W = W_1 + W_2 + W_3 + W_4 + W_5$$

This weight, when multiplied by the *centroidal distance* $\bar{x}$, must balance or cancel the sum of the individual weights multiplied by their respective distances from the left end. In other words,

$$W\bar{x} = W_1 l_1 + W_2 l_2 + W_3 l_3 + W_4 l_4 + W_5 l_5$$

or

$$\bar{x} = \frac{W_1 l_1 + W_2 l_2 + W_3 l_3 + W_4 l_4 + W_5 l_5}{W_1 + W_2 + W_3 + W_4 + W_5}$$

A similar procedure can be used when the point groups are contained in an area such as Fig. 48.2. The centroid of the group at G is now defined by the two centroidal

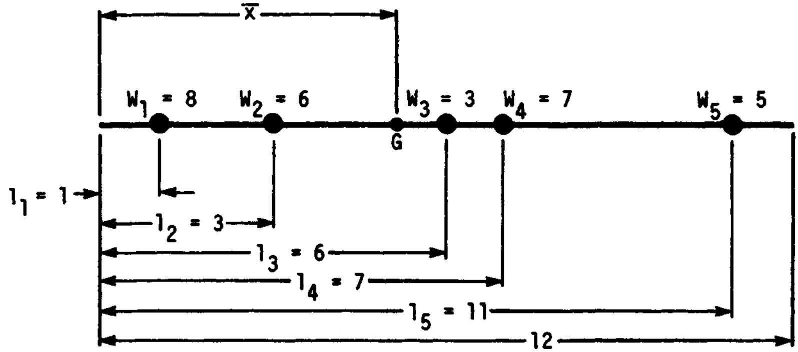


FIGURE 48.1 The centroid of this point group is located at G, a distance of $\bar{x}$ from the left end.

distances $\bar{x}$ and $\bar{y}$, as shown. Using the same procedure as before, we see that these must be given by the equations

$$\bar{x} = \sum_{i=1}^{i=N} A_i x_i \Big/ \sum_{i=1}^{i=N} A_i \qquad \bar{y} = \sum_{i=1}^{i=N} A_i y_i \Big/ \sum_{i=1}^{i=N} A_i \tag{48.1}$$

A similar procedure is used to locate the centroids of a group of lines or a group of areas. Area groups are often composed of a combination of circles, rectangles, triangles, and other shapes. The areas and locations of the centroidal axes for many such shapes are listed in Table 48.1. For these, the x_i and y_i of Eqs. (48.1) are taken as the distances to the centroid of each area A_i.

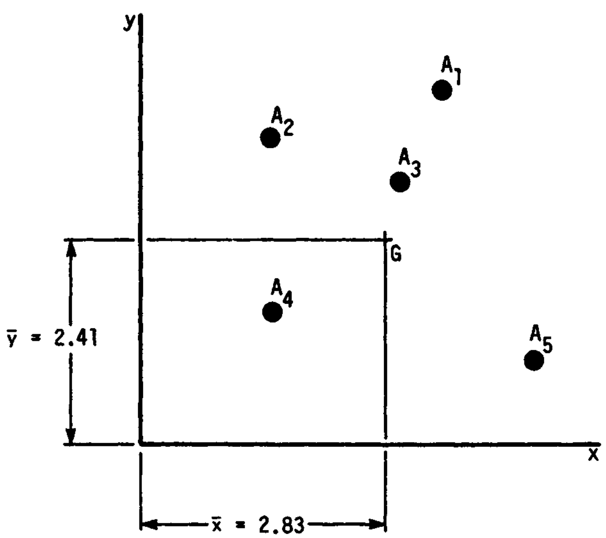
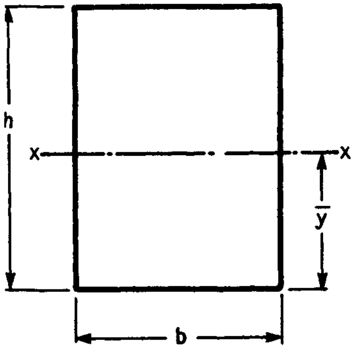


FIGURE 48.2 The weightings and coordinates of the points are designated as A_i (x_i, y_i); they are $A_1 = 0.5(3.5, 4.0)$, $A_2 = 0.5(1.5, 3.5)$, $A_3 = 0.5(3.0, 3.0)$, $A_4 = 0.7(1.5, 1.5)$, and $A_5 = 0.7(4.5, 1.0)$.

TABLE 48.1 Properties of Sections†

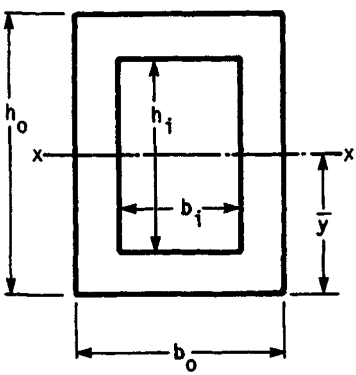
1. Rectangle



$$A = bh \qquad I_x = \frac{bh^3}{12}$$

$$k_x = 0.289\text{h} \qquad \bar{y} = \frac{h}{2}$$

2. Hollow rectangle



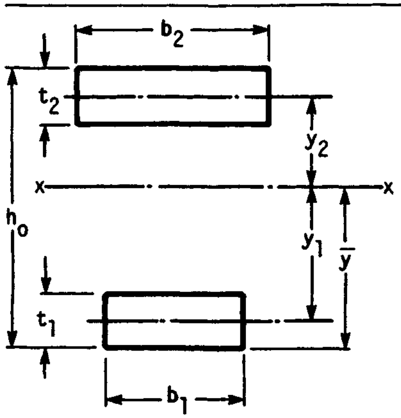
$$A = b_o h_o - b_i h_i$$

$$I_x = \frac{1}{12}(b_o h_o^3 - b_i h_i^3)$$

$$k_x = \left(\frac{I}{A}\right)^{1/2}$$

$$\bar{y} = \frac{h_o}{2}$$

3. Two rectangles



$$A = b_1 t_1 + b_2 t_2$$

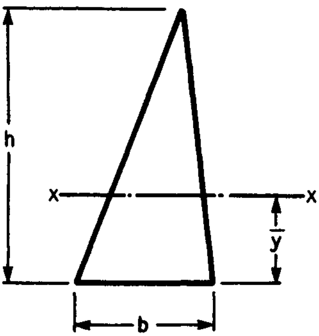
$$I_x = \frac{b_1 t_1^3}{12} + b_1 t_1 y_1^2 + \frac{b_2 t_2^3}{12} + b_2 t_2 y_2^2$$

$$k_x = \left(\frac{I_x}{A}\right)^{1/2}$$

$$\bar{y} = \frac{b_1 t_1^2 + 2b_1 t_2 h_o - b_2 t_2^2}{2(b_1 t_1 + b_2 t_2)}$$

†List of symbols: A = area; I = second area moment about principal axis; J_O = second polar area moment with respect to O; k = radius of gyration; and $\bar{x}$, $\bar{y}$ = centroidal distances.

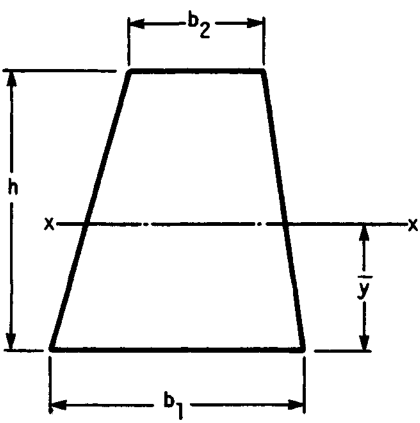
4. Triangle



$$A = \frac{bh}{2} \qquad I_x = \frac{bh^3}{36}$$

$$k = 0.236h \qquad \bar{y} = \frac{h}{3}$$

5. Trapezoid



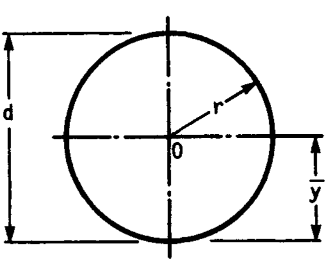
$$A = \frac{h}{2}(b_1 + b_2)$$

$$I_x = \frac{h^3(b_1^2 + 4b_1b_2 + b_2^2)}{36(b_1 + b_2)}$$

$$k_x = \frac{h[2(b_1^2 + 4b_1b_2 + b_2^2)]^{1/2}}{6(b_1 + b_2)}$$

$$\bar{y} = \frac{h(b_1 + 2b_2)}{3(b_1 + b_2)}$$

6. Circle

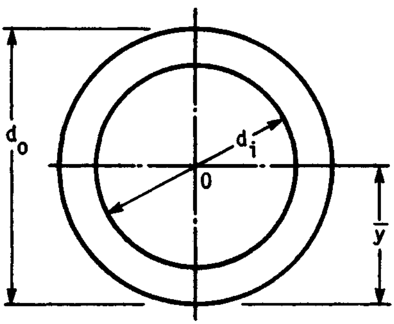


$$A = \pi r^2 = \frac{\pi d^2}{4}$$

$$I = \frac{\pi r^4}{4} = \frac{\pi d^4}{64}$$

$$k = \frac{r}{2} = \frac{d}{4} \qquad \bar{y} = r = \frac{d}{2}$$

7. Hollow circle



$$A = \frac{\pi}{4}(d_o^2 - d_i^2)$$

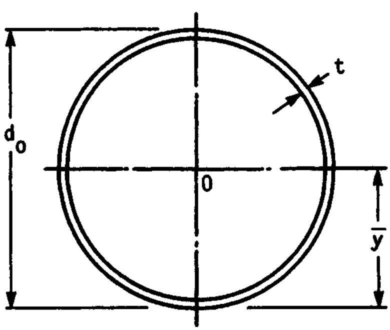
$$I = \frac{\pi}{64}(d_o^4 - d_i^4)$$

$$J_O = \frac{\pi}{32}(d_o^4 - d_i^4)$$

$$k = \frac{1}{4}(d_o^2 + d_i^2)^{1/2}$$

$$\bar{y} = \frac{d_o}{2}$$

8. Thin ring (annulus)

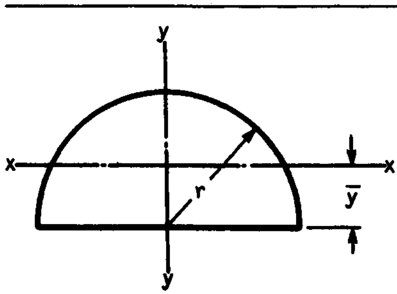


$$A = \pi d_o t \qquad I = \frac{\pi d_o^3 t}{8}$$

$$J_O = \frac{\pi d_o^3 t}{4}$$

$$k = 0.353 d_o \qquad \bar{y} = \frac{d_o}{2}$$

9. Semicircle

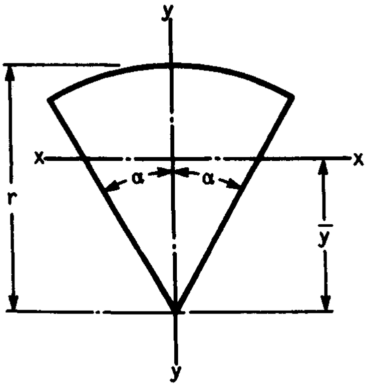


$$A = \frac{\pi r^2}{2} \qquad I_x = 0.1098 r^4$$

$$I_y = \frac{\pi r^4}{8} \qquad k_x = 0.264 r$$

$$k_y = \frac{r}{2} \qquad \bar{y} = 0.424 r$$

10. Circular sector



$$A = \alpha r^2$$

$$I_x = \frac{r^4}{4}\left(\alpha + \sin\alpha\cos\alpha - \frac{16}{9\alpha}\sin^2\alpha\right)$$

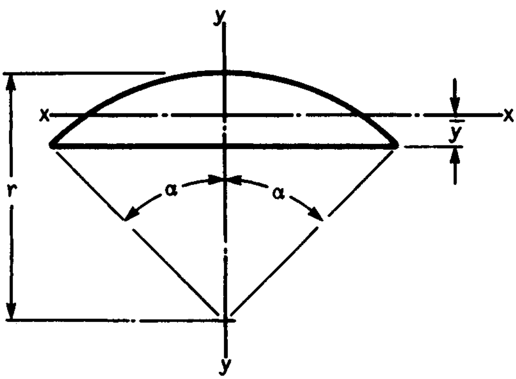
$$I_y = \frac{r^4}{4}(\alpha - \sin\alpha\cos\alpha)$$

$$k_x = \frac{r}{2}\left(1 + \frac{\sin\alpha\cos\alpha}{\alpha} - \frac{16}{9\alpha}\sin^2\alpha\right)^{1/2}$$

$$k_y = \frac{r}{2}\left(\frac{\alpha - \sin\alpha\cos\alpha}{\alpha}\right)^{1/2}$$

$$\bar{y} = \frac{2r\sin\alpha}{3\alpha}$$

11. Circular segment



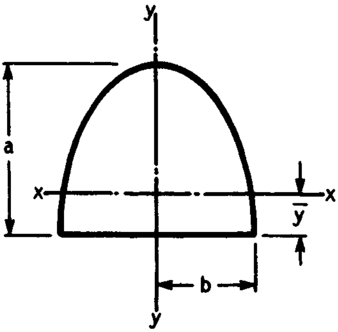
$$A = \frac{r^2}{2}(2\alpha - \sin 2\alpha)$$

$$I_x = r^4\left[\left(\frac{2\alpha - \sin 2\alpha}{8}\right)\left(1 + \frac{2\sin^3\alpha\cos\alpha}{\alpha - \sin\alpha\cos\alpha}\right) - \frac{8\sin^6\alpha}{9(2\alpha - \sin 2\alpha)}\right]$$

$$k_x = \frac{r}{2}\left[1 + \frac{2\sin^3\alpha\cos\alpha}{\alpha - \sin\alpha\cos\alpha} - \frac{64\sin^6\alpha}{9(2\alpha - \sin 2\alpha)^2}\right]^{1/2}$$

$$\bar{y} = \frac{4r\sin^3\alpha}{6\alpha - 3\sin 2\alpha} - r\cos\alpha$$

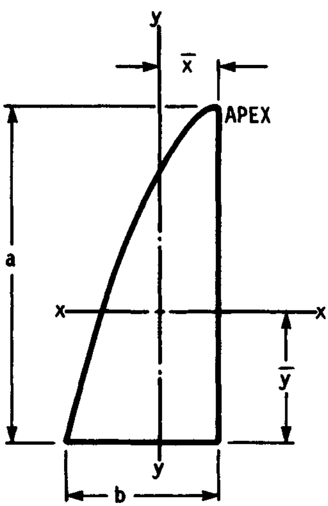
12. Parabola



$$A = \frac{4ab}{3} \qquad I_x = \frac{16a^3b}{175}$$

$$I_y = \frac{4ab^3}{15} \qquad \bar{y} = \frac{a}{5}$$

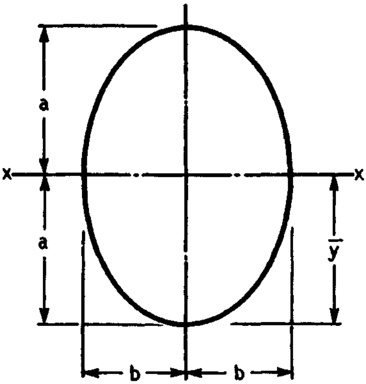
13. Semiparabola



$$A = \frac{2ab}{3} \qquad I_x = \frac{8a^3b}{175}$$

$$I_y = \frac{19ab^3}{480} \qquad \bar{y} = \frac{2a}{5} \qquad \bar{x} = \frac{3b}{8}$$

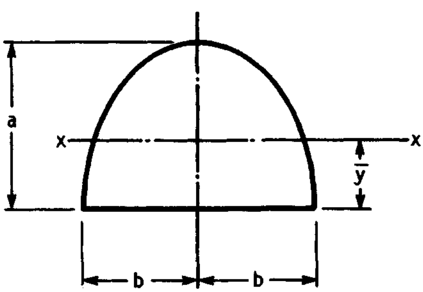
14. Ellipse



$A = \pi ab \qquad I_x = \frac{\pi a^3 b}{4}$

$k_x = \frac{a}{2} \qquad \bar{y} = a$

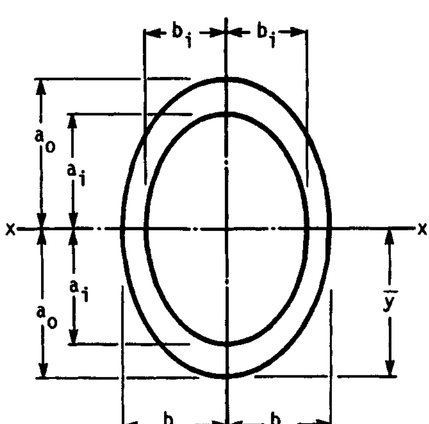
15. Semiellipse



$A = \frac{\pi ab}{2} \qquad I_x = a_3b\left(\frac{\pi}{8} - \frac{8}{9\pi}\right)$

$k_x = \frac{b}{6\pi}(9\pi^2 - 64)^{1/2} \qquad \bar{y} = \frac{4a}{3\pi}$

16. Hollow ellipse

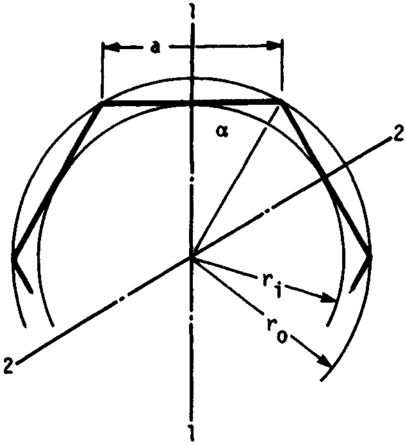


$A = \pi(a_o b_o - a_i b_i)$

$I_x = \frac{\pi(a_o^3 b_o - a_i^3 b_i)}{4}$

$k_x = \frac{1}{2}\left(\frac{a_o^3 b_o - a_i^3 b_i}{a_o b_o - a_i b_i}\right)^{1/2} \qquad \bar{y} = a_o$

17. Regular polygon (*N* sides)

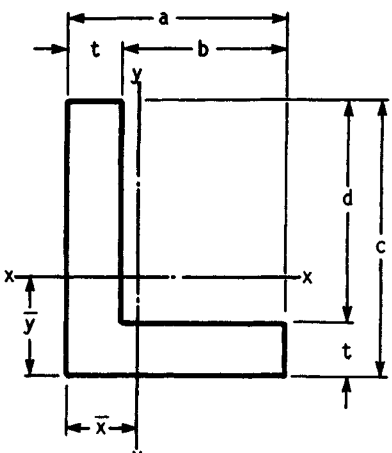


$$A = \frac{Nr_o^2 \sin 2\alpha}{2} = Nr_i^2 \tan \alpha$$

$$I_1 = \frac{A(6r_o^2 - a^2)}{24} \qquad I_2 = \frac{A(12r_i^2 + a^2)}{48}$$

$$k_1 = \left(\frac{6r_o^2 - a^2}{24}\right)^{1/2} \qquad k_2 = \left(\frac{12r_i^2 + a^2}{48}\right)^{1/2}$$

18. Angle



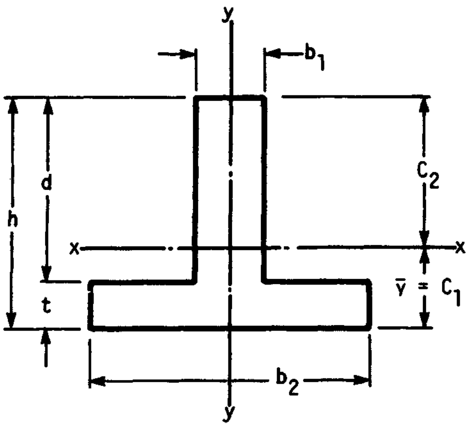
$$A = t(a + d)$$

$$\bar{y} = \frac{c^2 + bt}{2(a + d)} \qquad \bar{x} = \frac{a^2 + dt}{2(a + d)}$$

$$I_x = \frac{1}{3}[t(c - \bar{y})^3 + a\bar{y}^3 - b(\bar{y} - t)^3]$$

$$I_y = \frac{1}{3}[t(a - \bar{x})^3 + c\bar{x}^3 - d(\bar{x} - t)^3]$$

19. T section



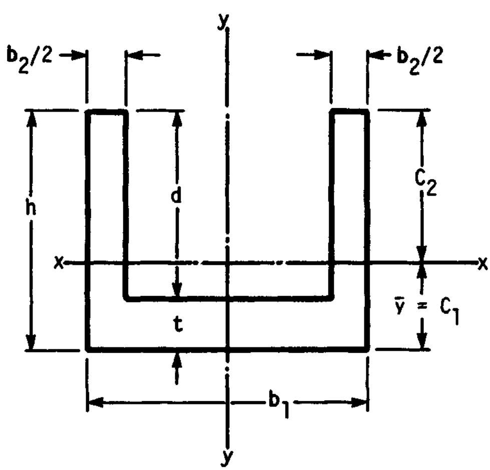
$$A = b_1 t + b_2 d$$

$$\bar{y} = \frac{b_1 t^2 + 2 b_2 t d + b_2 d^2}{2A}$$

$$I_x = \frac{b_1 c_1^3 - (b_1 - b_2)(c_1 - t)^3 + b_2 c_2^3}{3}$$

$$I_y = \frac{t b_1^3 + d b_2^3}{12}$$

20. U Section



$$A = b_1 t + b_2 d$$

$$\bar{y} = \frac{b_1 t^2 + 2 b_2 t d + b_2 d^2}{2A}$$

$$I_x = \frac{b_1 c_1^3 - (b_1 - b_2)(c_1 - t)^3 + b_2 c_2^3}{3}$$

$$I_y = \frac{h b_1^3 - d(b_1 - b_2)^3}{12}$$

Equations (48.1) can easily be solved on an ordinary calculator using the Σ key twice, once for the denominator and again for the numerator. The equations are also easy to program. Practice these techniques using the data and results in Figs. 48.1, 48.2, and 48.3.

By substituting integration signs for the summation signs in Eqs. (48.1), we get the more general form of the relations as

$$\bar{x} = \frac{\int x'\,dA}{\int dA} \qquad \bar{y} = \frac{\int y'\,dA}{\int dA}$$

These reduce to

$$\bar{x} = \frac{1}{A}\int x'\,dA \qquad \bar{y} = \frac{1}{A}\int y'\,dA \tag{48.2}$$

where x' and y' = coordinate distances to the centroid of the element dA. These equations can be solved by

- Finding expressions for x' and y' and then performing the integration analytically.
- Approximate integration using the routines described in the programming manual of your programmable calculator or computer.
- Using numerical integration routines described in Chap. 4.

48.2 SECOND MOMENTS OF AREAS

The expression $A\bar{x} = \int x'dA$ from Eqs. (48.2) is a *first moment of an area.* A *second moment of an area* is obtained when the element of area is multiplied by the square of a distance to some stated axis. Thus the expressions

$$\int x^2\,dA \qquad \int y^2\,dA \qquad \int r^2\,dA \tag{48.3}$$

are all second moments of areas. Such formulas resemble the equation for *moment of inertia,* which is

$$\int \rho^2\,dm \tag{48.4}$$

where ρ = distance to some axis and dm = an element of mass. Because of the resemblance, Eqs. (48.3) are often called the equations for moment of inertia too, but this is a misnomer because an area cannot have inertia.

We can find the second moment of an area about rectangular axes by using one of the formulas

$$I_x = \int y^2\,dA \qquad I_y = \int x^2\,dA \tag{48.5}$$

Example 1. Find the second moment of area of the rectangle in Fig. 48.4 about the x axis.

Solution. Select an element of area dA such that it is everywhere y units from x. Substituting appropriate terms into Eqs. (48.5) gives

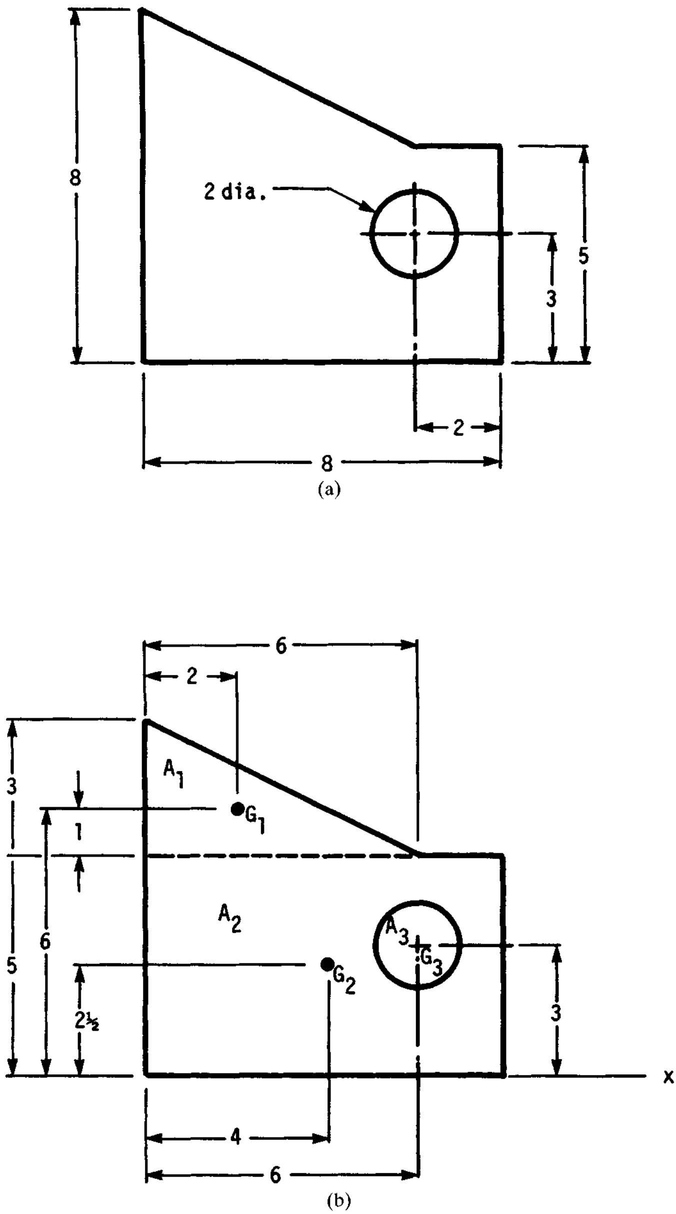


FIGURE 48.3 A composite shape consisting of a rectangle, a triangle, and a circular hole. The centroidal distances are found to be $\bar{x} = 3.47$ and $\bar{y} = 3.15$.

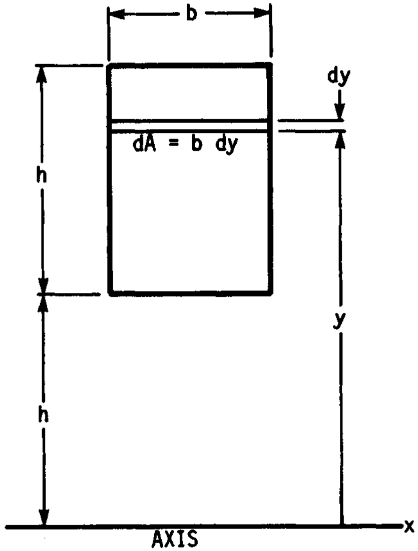


FIGURE 48.4 Second area moment of a rectangle.

$$I_x = \int y^2\,dA = \int_h^{2h} y^2 b\,dy = \frac{by^3}{3}\bigg|_h^{2h} = \frac{7bh^3}{3}$$

The *polar second moment of an area* is the second moment taken about an axis *normal to the plane* of an area. The equation is

$$J = \int \rho^2\,dA \tag{48.6}$$

Example 2. Find the polar second moment of the area of a circle about its centroidal axis.

Solution. Let the radius of the circle be r. Define a thin elemental ring of thickness $d\rho$ at radius ρ. Then $dA = 2\pi\rho\,d\rho$. We now have

$$J = \int \rho^2\,dA = \int_0^r \rho^2(2\pi\rho)\,d\rho = 2\pi\frac{\rho^4}{4}\bigg|_0^r = \frac{\pi r^4}{2}$$

48.2.1 Radius of Gyration

If we think of the second moment of an area as the total area times the square of a fictitious distance, then

$$I_x = \int y^2\,dA = k_x^2 A \qquad \text{or} \qquad k_x = \sqrt{\frac{I_x}{A}} \tag{48.7}$$

In polar form,

$$J_z = \int \rho^2\,dA = k_z^2 A \qquad \text{or} \qquad k_z = \sqrt{\frac{J_z}{A}} \tag{48.8}$$

In each case, k is called the *radius of gyration.*

48.2.2 Transfer Formula

In Fig. 48.5, suppose we know the second moment of the area about x to be I_x. We can find the second moment of the area about some new axis that is parallel to the old using the transfer formula. Thus the second moment of the area in Fig. 48.5 about the x' axis is

$$I' = I_G + d^2 A \tag{48.9}$$

where I_G = second moment about the centroidal axis and d = transfer distance. Using this formula and the second moments from Table 48.1 makes it possible to compute the second moments of sections made up of a combination of shapes. The procedure has much in common with the example in Fig. 48.3.

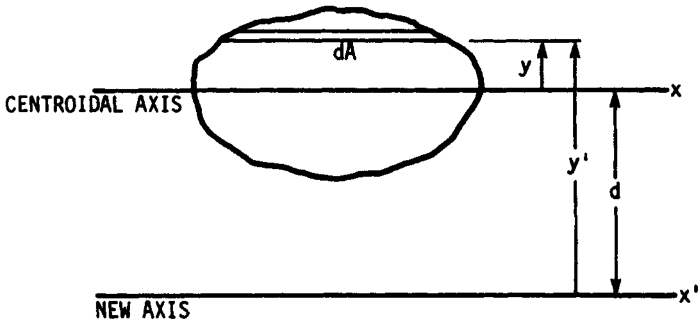


FIGURE 48.5 Use of the transfer formula.

48.2.3 Principal Axes

Sometimes we encounter the integral

$$I_{xy} = \int xy\, dA \tag{48.10}$$

which is called the *product moment of an area.* This integral can be either positive or negative because x and y can have positive or negative values.

If one of the axes of an area, say y, is an axis of symmetry, then every element of area dA located by a positive x will have a twin, symmetrically located, having a corresponding negative x. These will sum to zero in the integration, and so the product moment is always zero when either x or y is an axis of symmetry. Since I_{xy} can be either positive or negative, there must be some orientation of rectangular axes where $I_{xy} = 0$. The two axes corresponding to this zero position are called the *principal axes.* If such axes intersect at the centroid of a section, then they are called the *centroidal principal axes.*

48.3 PREFERRED NUMBERS AND SIZES

The recommendations given in this section are not intended to be used as rules for design, since there are none. And even if rules were specified, there would be many occasions when designers would have to deviate from them, because other more pressing considerations may be present.

48.3.1 Preferred Numbers

A set of characteristic values that are to be distributed over a specified range for machines or products can be best obtained using a set of *preferred numbers.* Examples are the horsepower ratings of electric motors, the capacities of presses, or the speeds of a truck transmission. The preferred number system is internationally standardized (ISO3) and is described as the Renard, or R, series. This series is shown in Table 48.2. Some of the interesting characteristics are

TABLE 48.2 Preferred Numbers

First choice R5	Second choice R10	Third choice R20	Fourth choice R40
1			
			1.06
		1.12	
			1.18
	1.25		
			1.32
		1.4	
			1.5
1.6			1.7
		1.8	
			1.9
	2		
			2.12
		2.24	
			2.36
2.5			2.65
		2.8	
			3
	3.15		
			3.35
		3.55	
			3.75
4			4.25
		4.5	
			4.75
	5		
			5.3
		5.6	
			6
6.3			6.7
		7.1	
			7.5
	8		
			8.5
		9	
			9.5
10			

SOURCE: British standard PD 6481-1977.

1. The series can be applied to any value because it can be increased or decreased by powers of 10.
2. The R10 series contains all the R5 values; the R20 series contains all the R10 values; etc.
3. The preferred numbers can be multiplied, divided, or raised to a power by a single number, and the result, even if slightly rounded, is still a preferred number.
4. The number $3.15 \cong \pi$ in R10 and up means that the diameter, area, and circumference of a circle are also preferred numbers in view of the previous characteristic.

Preferred numbers are based on logarithmic interpolation and are given by

$$x_i = x_s \left(\frac{x_l}{x_s}\right)^{i/n+1} \tag{48.11}$$

where x_l = largest number
x_s = smallest number
x_i = ith interpolated number
i = interpolation number
n = number of interpolations

The results should be appropriately rounded.

48.3.2 Preferred Sizes

Table 48.3 provides a list of preferred sizes for linear measurement in SI units. Note that these sizes are not the same as preferred numbers because of the convenience

TABLE 48.3 Preferred Metric Sizes in Millimeters

1st choice	2nd choice	3rd choice	1st choice	2nd choice	3rd choice	1st choice	2nd choice	3rd choice	1st choice	2nd choice	3rd choice
1	1.1	1.3	10	11	13	100	115	102	200	210	205
1.2	1.4	1.5	12	14	15	105	125	108	220	230	215
1.6	1.8	1.7	16	18	17	110	135	112	240	250	225
2	2.2	1.9	20	22	19	120	145	118	260	270	235
2.5	2.8	2.1	25	28	21	130	155	122	280	290	245
3	3.5	2.4	30	32	23	140	165	128	300	310	255
4	4.5	2.6	35	38	24	150	175	132	320	330	265
5	5.5	3.2	40	42	26	160	185	138	340	350	275
6	6.5	3.8	45	48	34	170	195	142	360	370	285
8	7	4.2	50	52	36	180		148	380	390	295
10	9	4.8	55	58	44	190		152	400†		305
		5.2	60	62	46	200		158			315
		5.8	65	68	54			162			325
		6.8	70	72	56			168			335
		7.5	75	78	64			172			345
		8.5	80	85	66			178			355
		9.5	90	95	74			182			365
			100		76			188			375
					82			192			385
					88			198			395
					92						
					98						

†Continued similarly above 400 mm.
SOURCE: British standard PD 6481-1977.

and simplicity of whole numbers for sizes of things. Preferred sizes in fractions of inches are listed in Table 48.4.

48.4 SIZES AND TOLERANCES OF STEEL SHEETS AND BARS

The dimensions and tolerances of steel products in this section are given in U.S. Customary System (USCS) units. Multiply inches by 25.4 to get the units of millimeters.

48.4.1 Sheet Steel

The *Manufacturer's Standard Gauge* for iron and steel sheets specifies a gauge number based on the weight per square foot. Remember, the gauge size is based on *weight,* not thickness. Steel products having thicknesses of $\frac{1}{4}$ in and over are called *plates* or *flats,* depending on the width.

The weights and equivalent thicknesses of carbon steel sheets are shown in Table 48.5. Standard widths and lengths available depend on the gauge sizes. Most are also available in coils, but steel warehouses may not stock all sizes.

Tables 48.6 to 48.11 provide the thickness tolerances for various grades of steel sheets. Except as noted, the tables apply to both coils and cut lengths. The width ranges are from *over* the lower limit up to and *including* the upper limit.

48.4.2 Bar Steel

When hot-rolled bars are machined on centers, it is necessary to allow for straightness as well as for the size and out-of-round tolerances in selecting the diameter (see Table 48.12). Tolerances for cold-finished bars are given in Tables 48.13, 48.14, and 48.15.

TABLE 48.4 Preferred Sizes in Fractions of Inches†

$\frac{1}{64}$	$\frac{1}{2}$	$2\frac{1}{4}$	5	$9\frac{1}{2}$	15
$\frac{1}{32}$	$\frac{9}{16}$	$2\frac{1}{2}$	$5\frac{1}{4}$	10	$15\frac{1}{2}$
$\frac{1}{16}$	$\frac{5}{8}$	$2\frac{3}{4}$	$5\frac{1}{2}$	$10\frac{1}{2}$	16
$\frac{3}{32}$	$\frac{11}{16}$	3	$5\frac{3}{4}$	11	$16\frac{1}{2}$
$\frac{1}{8}$	$\frac{3}{4}$	$3\frac{1}{4}$	6	$11\frac{1}{2}$	17
$\frac{5}{32}$	$\frac{7}{8}$	$3\frac{1}{2}$	$6\frac{1}{2}$	12	$17\frac{1}{2}$
$\frac{3}{16}$	1	$3\frac{3}{4}$	7	$12\frac{1}{2}$	18
$\frac{1}{4}$	$1\frac{1}{4}$	4	$7\frac{1}{2}$	13	$18\frac{1}{2}$
$\frac{5}{16}$	$1\frac{1}{2}$	$4\frac{1}{4}$	8	$13\frac{1}{2}$	19
$\frac{3}{8}$	$1\frac{3}{4}$	$4\frac{1}{2}$	$8\frac{1}{2}$	14	$19\frac{1}{2}$
$\frac{7}{16}$	2	$4\frac{3}{4}$	9	$14\frac{1}{2}$	20

†See also ANSI standard Z17.1-1973, Preferred Numbers.

TABLE 48.5 Gauge Sizes of Carbon Steel Sheets

Gauge no.	Thickness, in†	Weight, lb/ft²‡	Gauge no.	Thickness, in†	Weight, lb/ft²‡
7	0.1793	7.500	23	0.0269	1.125
8	0.1644	6.875	24	0.0239	1.000
9	0.1494	6.250	25	0.0209	0.875
10	0.1345	5.625	26	0.0179	0.750
11	0.1196	5.000	27	0.0164	0.6875
12	0.1046	4.375	28	0.0149	0.625
13	0.0897	3.750	29	0.0135	0.5625
14	0.0747	3.125	30	0.0120	0.500
15	0.0673	2.812	31	0.0105	0.4375
16	0.0598	2.500	32	0.0097	0.4062
17	0.0538	2.250	33	0.0090	0.375
18	0.0478	2.000	34	0.0082	0.3438
19	0.0418	1.750	35	0.0075	0.3125
20	0.0359	1.500	36	0.0067	0.2812
21	0.0329	1.375	37	0.0064	0.2656
22	0.0299	1.250	38	0.0060	0.250

†Multiply the thickness in inches by 25.4 to get the thickness in millimeters.
‡Multiply the weight in pounds per square foot by 4.88 to get the mass in kilograms per square meter (SI units).

TABLE 48.6 Thickness Tolerances for Hot-Rolled Carbon Sheets†

Thickness, in	Width, in					
	12–20	20–40	40–48	48–60	60–72	72 up
0.0449–0.0508	5	5	5			
0.0509–0.0567	5	5	6	6	7	
0.0568–0.0709	6	6	6	7	7	
0.0710–0.0971	6	7	7	7	8	8
0.0972–0.1799	7	7	8	8	8	8
0.1800–0.2299	7	8	9			

†Tolerances are plus or minus and in mils (1 mil = 0.001 in). This table applies only to coils.
SOURCE: Ref. [48.1], Sec. 5, Aug. 1979.

TABLE 48.7 Thickness Tolerances for Hot-Rolled Alloy Steel Sheets†

Thickness, in	Width, in					
	24–32	32–40	40–48	48–60	60–72	72–80
0.0568–0.0709	6	6	6	7	7	
0.0710–0.0821	7	7	7	7	8	8
0.0822–0.0971	7	8	8	8	9	9
0.0972–0.1799	8	9	10	10	11	12
0.1800–0.2299	9	9	10			

†Tolerances are plus or minus and in mils (1 mil = 0.001 in).
SOURCE: Ref [48.1], Sec. 5, Aug. 1979.

TABLE 48.8 Thickness Tolerances for Hot-Rolled High-Strength Steel Sheets†

Thickness, in	Width, in					
	12–15	15–20	20–32	32–40	40–48	48–60
0.0710–0.0821	6	7	7	7	7	7
0.0822–0.0971	6	7	7	8	8	8
0.0972–0.1799	7	8	8	9	10	10
0.1800–0.2299	7	8	9	9	10	

†Tolerances are plus or minus and in mils (1 mil = 0.001 in).
SOURCE: Ref. [48.1], Sec. 5, Aug. 1979

TABLE 48.9 Thickness Tolerances for Cold-Rolled Carbon Steel Sheets†

Thickness, in	Width, in			
	2–12	12–15	15–72	72 up
0.0142–0.0194	2	2	2	
0.0195–0.0388	3	3	3	3
0.0389–0.0567	4	4	4	4
0.0568–0.0709	5	5	5	5
0.0710–0.0971	5	5	5	6
0.0972–0.1419	....	5	6	7

†Tolerances are plus or minus and in mils (1 mil = 0.001 in).
SOURCE: Ref [48.1], Sec. 5, Aug. 1979.

TABLE 48.10 Thickness Tolerances for Cold-Rolled Alloy Steel Sheets†

Thickness, in	Width, in					
	24–32	32–40	40–48	48–60	60–70	70–80
0.0195–0.0313	3	3	3	3		
0.0314–0.0508	4	4	4	4	5	
0.0509–0.0567	5	5	5	5	6	
0.0568–0.0709	5	5	5	6	6	
0.0710–0.0821	5	6	6	6	7	7
0.0822–0.0971	6	7	7	8	9	9
0.0972–0.1419	7	8	9	10	10	11
0.1420–0.1799	8	9	10	10	11	12
0.1800–0.2299	8	9	10			

†Tolerances are plus or minus and in mils (1 mil = 0.001 in).
SOURCE: Ref. [48.1], Sec. 5, Aug. 1979.

TABLE 48.11 Thickness Tolerances for Cold-Rolled High-Strength Steel Sheets†

Thickness, in	Width, in					
	2–12	12–15	15–24	24–32	32–40	40–48
0.0142–0.0194	2	2	2	2	2	2
0.0195–0.0388	3	3	3	3	3	3
0.0389–0.0567	4	4	4	4	4	4
0.0568–0.0709	5	5	5	5	5	5
0.0710–0.0971	6	5	5	5	6	6
0.0972–0.1419	....	5	6	6	6	6
0.1419 up	....	6	6	7	7	7

†Tolerances are plus or minus and in mils (1 mil = 0.001 in).
SOURCE: Ref. [48.1], Sec. 5, Aug. 1979.

TABLE 48.12 Machining Allowances for Hot-Rolled Carbon Steel Bars for Turning on Centers†

Diameter, in	Allowance, in	Diameter, in	Allowance, in
To $\frac{7}{8}$	0.025	$2\frac{1}{2}$ to $3\frac{1}{2}$	0.090
$\frac{7}{8}$ to 1	0.028	$3\frac{1}{2}$ to $4\frac{1}{2}$	0.115
1 to $1\frac{1}{8}$	0.031	$4\frac{1}{2}$ to $5\frac{1}{2}$	0.140
$1\frac{1}{8}$ to $1\frac{1}{4}$	0.034	$5\frac{1}{2}$ to $6\frac{1}{2}$	0.165
$1\frac{1}{4}$ to $1\frac{3}{8}$	0.037	$6\frac{1}{2}$ to $8\frac{1}{4}$	0.209
$1\frac{3}{8}$ to $1\frac{1}{2}$	0.040	$8\frac{1}{4}$ to $9\frac{1}{2}$	0.240
$1\frac{1}{2}$ to 2	0.053	$9\frac{1}{2}$ to 10	0.253
2 to $2\frac{1}{2}$	0.065		

†Size range is from over the lower limit up to and including the upper limit; the allowances are on the *radius*.
SOURCE: Ref. [48.1].

TABLE 48.13 Size Tolerances for Cold-Drawn Carbon Steel Bars†

Size and shape, in	Carbon range, percent			
	To 0.28	0.28–0.55	To 0.55‡	Over 0.55§
Rounds:				
To 1½	2	3	4	5
1½ to 2½	3	4	5	6
2½ to 4	4	5	6	7
Hexagons:				
To ¾	2	3	4	6
¾ to 1½	3	4	5	7
1½ to 2½	4	5	6	8
2½ to 3⅛	5	6	7	9
Squares:				
To ¾	2	4	5	7
¾ to 1½	3	5	6	8
1½ to 2½	4	6	7	9
2½ to 4	6	8	9	11
Flats				
To ¾	3	4	6	8
¾ to 1½	4	5	8	10
1½ to 3	5	6	10	12
3 to 4	5	6	10	12
4 to 6	8	10	12	20
Over 6	13	15		

†Includes tolerances for bars that have been annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. The table *does not* include tolerances for bars that are spheroidize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing. Size range and carbon range are from over the lower limit up to and including the upper limit. Tolerances are minus and are in mils (1 mil = 0.001 in).

‡Stress relieved or annealed after cold finishing.

§Quenched and tempered or normalized and tempered before cold finishing.

¶These tolerances apply to *both* the widths and thickness of flats.

SOURCE: Ref. [48.1].

TABLE 48.14 Size Tolerances for Cold-Finished, Turned, and Polished Carbon Steel Round Bars†

Diameter, in	Carbon range, percent			
	To 0.28	0.28–0.55	To 0.55‡	Over 0.55§
To 1½	2	3	4	5
1½ to 2½	3	4	5	6
2½ to 4	4	5	6	7
4 to 6	5	6	7	8
6 to 8	6	7	8	9
8 to 9	7	8	9	10
Over 9	8	9	10	11

†Includes tolerances for bars that have been annealed, spheroidize annealed, normalized, normalized and tempered, or quenched and tempered before cold finishing. The table *does not* include tolerances for bars that are spheroidize annealed, normalized, normalized and tempered, or quenched and tempered after cold finishing. Size range and carbon range are from over the lower limit up to and including the upper limit. Tolerances are minus and are in mils (1 mil = 0.001 in).

‡Stress relieved or annealed after cold finishing.

§Quenched and tempered or normalized and tempered before cold finishing.

SOURCE: Ref. [48.1].

TABLE 48.15 Size Tolerances for Ground and Polished Carbon Steel Rounds Prefinished by Cold Drawing or by Turning†

Diameter, in	Prefinish	
	Cold drawn	Turned
To 1½	1	1
1½ to 2½	1.5	1.5
2½ to 3	2	2
3 to 4	3	3
4 to 6		4‡
Over 6		5‡

†Size range is from over the lower limit up to and including the upper limit. Tolerances are minus and in mils (1 mil = 0.001 in).

‡Increase this tolerance by 1 mil if the steels have a sulfur content under 0.08 percent or if they are thermally treated.

SOURCE: Ref. [48.1].

48.4.3 Pipe and Tubing

The outside diameter of pipe having a nominal size of 12 in or smaller is larger than the nominal size. The difference between pipe and tubing is that pipe is intended to be used in piping systems; also, tubing has an outside diameter the same as the nominal size. See Table 48.16 for pipe sizes.

TABLE 48.16 Dimensions and Weights for Threaded and Coupled Pipe

Nominal size, in	Outside diameter, in	Wall thickness, in	Weight,† lb/ft	Weight class	Schedule no.
⅛	0.405	0.068	0.24	STD	40
		0.095	0.32	XS	80
¼	0.540	0.088	0.42	STD	40
		0.119	0.54	XS	80
⅜	0.675	0.091	0.57	STD	40
		0.126	0.74	XS	80

TABLE 48.16 Dimensions and Weights for Threaded and Coupled Pipe (*Continued*)

Nominal size, in	Outside diameter, in	Wall thickness, in	Weight,† lb/ft	Weight class	Schedule no.
½	0.840	0.109	0.85	STD	40
		0.147	1.09	XS	80
		0.294	1.72	XXS	
¾	1.050	0.113	1.13	STD	40
		0.154	1.48	XS	80
		0.308	2.44	XXS	
1	1.315	0.133	1.68	STD	40
		0.179	2.18	XS	80
		0.358	3.66	XXS	
1¼	1.660	0.140	2.28	STD	40
		0.191	3.02	XS	80
		0.382	5.22	XXS	
1½	1.900	0.145	2.73	STD	40
		0.200	3.66	XS	80
		0.400	6.41	XXS	
2	2.375	0.154	3.68	STD	40
		0.218	5.07	XS	80
		0.436	9.03	XXS	
2½	2.875	0.203	5.82	STD	40
		0.276	7.73	XS	80
		0.552	13.70	XXS	
3	3.500	0.216	7.62	STD	40
		0.300	10.33	XS	80
		0.600	18.57	XXS	
3½	4.000	0.226	9.20	STD	40
		0.318	12.63	XS	80
4	4.500	0.237	10.89	STD	40
		0.337	15.17	XS	80
		0.674	27.58	XXS	
5	5.563	0.258	14.81	STD	40
		0.375	21.09	XS	80
		0.750	38.61	XXS	
6	6.625	0.280	19.18	STD	40
		0.432	28.89	XS	80
		0.864	53.14	XXS	
8	8.625	0.277	25.55		30
		0.322	29.35	STD	40
		0.500	43.90	XS	80
		0.875	72.44	XXS	
10	10.750	0.279	32.75		
		0.307	35.75		30
		0.365	41.85	STD	40
		0.500	55.82	XS	60
12	12.750	0.330	45.45		30
		0.375	51.15	STD	
		0.500	66.71	XS	

†This is the weight of threaded pipe including the coupling.
SOURCE: ASTM standard A53, Table X3. A greater range of sizes together with SI equivalents is given in ANSI standard B36.10-1979.

TABLE 48.17 Decimal Equivalents of Wire and Sheet-Metal Gauges in Inches

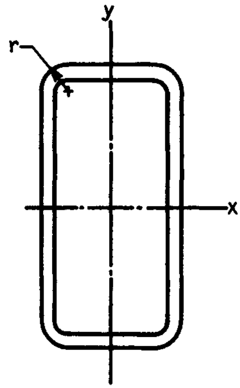
Always specify the name of the gauge when gauge numbers are used.

Name of gauge (principal use) / Gauge Number	American or Brown & Sharpe (nonferrous sheet and rod)	Birmingham or Stubs iron wire (tubing, ferrous strip, flat wire, and spring steel)	United States Standard (ferrous sheet and plate, 480 lb/ft)	Manufacturers Standard (ferrous sheet)	Steel wire or Washburn & Moen (ferrous wire except music wire)	Music wire (music wire)	Stubs steel wire (steel drill rod)	Twist drill (twist drills and drill steel)
7/0	....	....	0.500	....	0.490 0			
6/0	0.580 0	....	0.468 75	....	0.461 5	0.004		
5/0	0.516 5	....	0.437 5	....	0.430 5	0.005		
4/0	0.460 0	0.454	0.406 25	....	0.393 8	0.006		
3/0	0.409 6	0.425	0.375	....	0.362 5	0.007		
2/0	0.364 8	0.380	0.343 75	....	0.331 0	0.008		
0	0.324 9	0.340	0.312 5	....	0.306 5	0.009		
1	0.289 3	0.300	0.281 25	....	0.283 0	0.010	0.227	0.228 0
2	0.257 6	0.284	0.265 625	....	0.262 5	0.011	0.219	0.221 0
3	0.229 4	0.259	0.25	0.239 1	0.243 7	0.012	0.212	0.213 0
4	0.204 3	0.238	0.234 375	0.224 2	0.225 3	0.013	0.207	0.209 0
5	0.181 9	0.220	0.218 75	0.209 2	0.207 0	0.014	0.204	0.205 5
6	0.162 0	0.203	0.203 125	0.194 3	0.192 0	0.016	0.201	0.204 0
7	0.144 3	0.180	0.187 5	0.179 3	0.177 0	0.018	0.199	0.201 0
8	0.128 5	0.165	0.171 875	0.164 4	0.162 0	0.020	0.197	0.199 0
9	0.114 5	0.148	0.156 25	0.149 5	0.148 3	0.022	0.194	0.196 0
10	0.101 9	0.134	0.140 625	0.134 5	0.135 0	0.024	0.191	0.193 5
11	0.090 74	0.120	0.125	0.119 6	0.120 5	0.026	0.188	0.191 0
12	0.080 81	0.109	0.109 357	0.104 6	0.105 5	0.029	0.185	0.189 0

13	0.071 96	0.095	0.093 75	0.089 7	0.091 5	0.031	0.182	0.185 0
14	0.064 08	0.083	0.078 125	0.074 7	0.080 0	0.033	0.180	0.182 0
15	0.057 07	0.072	0.070 312 5	0.067 3	0.072 0	0.035	0.178	0.180 0
16	0.050 82	0.065	0.062 5	0.059 8	0.062 5	0.037	0.175	0.177 0
17	0.045 26	0.058	0.056 25	0.053 8	0.054 0	0.039	0.172	0.173 0
18	0.040 30	0.049	0.05	0.047 8	0.047 5	0.041	0.168	0.169 5
19	0.035 89	0.042	0.043 75	0.041 8	0.041 0	0.043	0.164	0.166 0
20	0.031 96	0.035	0.037 5	0.035 9	0.034 8	0.045	0.161	0.161 0
21	0.028 46	0.032	0.034 375	0.032 9	0.031 7	0.047	0.157	0.159 0
22	0.025 35	0.028	0.031 25	0.029 9	0.028 6	0.049	0.155	0.157 0
23	0.022 57	0.025	0.028 125	0.026 9	0.025 8	0.051	0.153	0.154 0
24	0.020 10	0.022	0.025	0.023 9	0.023 0	0.055	0.151	0.152 0
25	0.017 90	0.020	0.021 875	0.020 9	0.020 4	0.059	0.148	0.149 5
26	0.015 94	0.018	0.018 75	0.017 9	0.018 1	0.063	0.146	0.147 0
27	0.014 20	0.016	0.017 187 5	0.016 4	0.017 3	0.067	0.143	0.144 0
28	0.012 64	0.014	0.015 625	0.014 9	0.016 2	0.071	0.139	0.140 5
29	0.011 26	0.013	0.014 062 5	0.013 5	0.015 0	0.075	0.134	0.136 0
30	0.010 03	0.012	0.012 5	0.012 0	0.014 0	0.080	0.127	0.128 5
31	0.008 928	0.010	0.010 937 5	0.010 5	0.013 2	0.085	0.120	0.120 0
32	0.007 950	0.009	0.010 156 25	0.009 7	0.012 8	0.090	0.115	0.116 0
33	0.007 080	0.008	0.009 375	0.009 0	0.011 8	0.095	0.112	0.113 0
34	0.006 305	0.007	0.008 593 75	0.008 2	0.010 4	....	0.110	0.111 0
35	0.005 615	0.005	0.007 812 5	0.007 5	0.009 5	....	0.108	0.110 0
36	0.005 000	0.004	0.007 031 25	0.006 7	0.009 0	....	0.106	0.106 5
37	0.004 453	....	0.006 640 625	0.006 4	0.008 5	....	0.103	0.104 0
38	0.003 965	....	0.006 25	0.006 0	0.008 0	....	0.101	0.101 5
39	0.003 531	....	.....	......	0.007 5	....	0.099	0.099 5
40	0.003 145	....	.....	......	0.007 0	....	0.097	0.098 0

SOURCE: **Reynolds Metals Co., Richmond, Virginia.**

TABLE 48.18 Properties of Square and Rectangular Structural Steel Tubing†



Size, in	Weight, lb/ft	Area A, in²	Radius‡ r, in	I_x, in⁴	I_y, in⁴
2 × 2 × 3/16	4.32	1.27	3/8	0.668	
1/4	5.41	1.59	1/2	0.766	
3 × 2 × 3/16	5.59	1.64	3/8	1.24	0.977
1/4	7.11	2.09	1/2	2.21	1.15
3 × 3 × 3/16	6.87	2.02	3/8	2.60	
1/4	8.81	2.59	1/2	3.16	
5/16	10.58	3.11	5/8	3.58	
4 × 2 × 3/16	6.87	2.02	3/8	3.87	1.29
1/4	8.81	2.59	1/2	4.69	1.54
5/16	10.58	3.11	5/8	5.32	1.71
4 × 3 × 3/16	8.15	2.39	3/8	5.23	3.34
1/4	10.51	3.09	1/2	6.45	4.10
5/16	12.70	3.73	5/8	7.45	4.71
4 × 4 × 3/16	9.42	2.77	3/8	6.59	
1/4	12.21	3.59	1/2	8.22	
5/16	14.83	4.36	5/8	9.58	
3/8	17.27	5.08	3/4	10.7	
1/2	21.63	6.36	1	12.3	
5 × 3 × 1/4	12.21	3.59	1/2	11.3	5.05
5/16	14.83	4.36	5/8	13.2	5.85
3/8	17.27	5.08	3/4	14.7	6.48
1/2	21.63	6.36	1	16.9	7.33
5 × 4 × 1/4	13.91	4.09	1/2	14.1	9.98
5/16	16.96	4.98	5/8	16.6	11.7
3/8	19.82	5.83	3/4	18.7	13.2

TABLE 48.18 Properties of Square and Rectangular Structural Steel Tubing† (*Continued*)

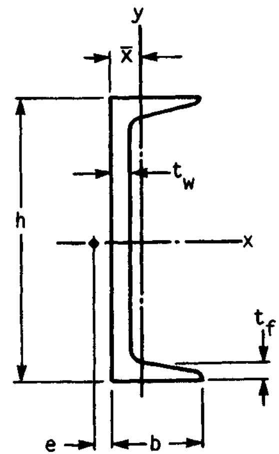
Size, in	Weight, lb/ft	Area A, in^2	Radius‡ r, in	I_x, in^4	I_y, in^4
$5 \times 5 \times \frac{1}{4}$	15.62	4.59	$\frac{1}{2}$	16.9	
$\frac{5}{16}$	19.08	5.61	$\frac{5}{8}$	20.1	
$\frac{3}{8}$	22.37	6.58	$\frac{3}{4}$	22.8	
$\frac{1}{2}$	28.43	8.36	1	27.0	
$6 \times 3 \times \frac{1}{4}$	13.91	4.09	$\frac{1}{2}$	17.9	6.00
$\frac{5}{16}$	16.96	4.98	$\frac{5}{8}$	21.1	6.98
$\frac{3}{8}$	19.82	5.83	$\frac{3}{4}$	23.8	7.78
$6 \times 4 \times \frac{1}{4}$	15.62	4.59	$\frac{1}{2}$	22.1	11.7
$\frac{5}{16}$	19.08	5.61	$\frac{5}{8}$	26.2	13.8
$\frac{3}{8}$	22.37	6.58	$\frac{3}{4}$	29.7	15.6
$\frac{1}{2}$	28.43	8.36	1	35.3	18.4
$6 \times 6 \times \frac{1}{4}$	19.02	5.59	$\frac{1}{2}$	30.3	
$\frac{5}{16}$	23.34	6.86	$\frac{5}{8}$	36.3	
$\frac{3}{8}$	27.48	8.08	$\frac{3}{4}$	41.6	
$\frac{1}{2}$	35.24	10.4	1	50.5	
$8 \times 4 \times \frac{5}{16}$	23.34	6.86	$\frac{5}{8}$	53.9	18.1
$\frac{3}{8}$	27.48	8.08	$\frac{3}{4}$	61.9	20.6
$\frac{1}{2}$	35.24	10.4	1	75.1	24.6
$8 \times 6 \times \frac{5}{16}$	27.59	8.11	$\frac{5}{8}$	72.4	46.4
$\frac{3}{8}$	32.58	9.58	$\frac{3}{4}$	83.7	53.5
$\frac{1}{2}$	42.05	12.4	1	103.	65.7
$8 \times 8 \times \frac{5}{16}$	31.84	9.36	$\frac{5}{8}$	90.9	
$\frac{3}{8}$	37.69	11.1	$\frac{3}{4}$	106.	
$\frac{1}{2}$	48.85	14.4	1	131.	
$\frac{5}{8}$	59.32	17.4	$1\frac{1}{4}$	153.	

†Size expressed by outside dimensions and wall thickness; other sizes are available (see Ref. [48.2]).
‡Tolerance is three times the wall thickness.

Seamless mechanical steel tubing is available in a great range of sizes, from about $\frac{3}{16}$ in outside diameter with a wall thickness of no. 24 gauge B and W up to a wall thickness of 1 in and an outside diameter of 12 in or over. Welded tubing is made from strip steel, either hot rolled with a bright finish or cold rolled. Tubing is also available cold drawn and may be obtained with a high-quality inside finish for certain applications.

The wall thickness of tubing is usually specified in gauge sizes or in fractions of an inch when USCS units are used. The tolerances of tubing are generally specified for the outside diameter and the wall thickness. This means that the inside diameter takes all the variation. However, tubing can be ordered using an inside-diameter specification.

TABLE 48.19 Properties of American Standard Channels†



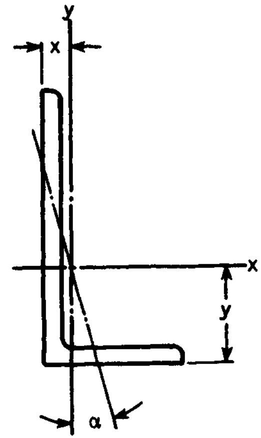
Designation	Area A, in^2	t_w, in	b, in	t_f, in	D, in	$\bar{x}$, in	e, in	I_x, in^4	I_y, in^4
C 3 × 4.1	1.26	0.170	1.410	0.273	...	0.436	0.461	1.66	0.197
3 × 5	1.47	0.258	1.498	0.273	...	0.438	0.392	1.85	0.247
3 × 6	1.76	0.356	1.596	0.273	...	0.455	0.322	2.07	0.305
C 4 × 5.4	1.59	0.184	1.584	0.296	...	0.457	0.502	3.85	0.319
4 × 7.25	2.13	0.321	1.721	0.296	$\frac{5}{8}$	0.459	0.386	4.59	0.433
C 5 × 6.7	1.97	0.190	1.750	0.320	...	0.484	0.552	7.49	0.479
5 × 9	2.64	0.325	1.885	0.320	$\frac{5}{8}$	0.478	0.427	8.90	0.632

C 6 × 8.2	2.40	0.200	1.920	0.343	5/8	0.511	0.599	13.1	0.693
6 × 10.5	3.09	0.314	2.034	0.343	5/8	0.499	0.486	15.2	0.866
6 × 13	3.83	0.437	2.157	0.343	5/8	0.514	0.380	17.4	1.05
C 7 × 9.8	2.87	0.210	2.090	0.366	5/8	0.540	0.647	21.3	0.968
7 × 12.25	3.60	0.314	2.194	0.366	5/8	0.525	0.538	24.2	1.17
7 × 14.75	4.33	0.419	2.299	0.366	5/8	0.532	0.441	27.2	1.38
C 8 × 11.5	3.38	0.220	2.260	0.390	3/4	0.571	0.697	32.6	1.32
8 × 13.75	4.04	0.303	2.343	0.390	3/4	0.553	0.604	36.1	1.53
8 × 18.75	5.51	0.487	2.527	0.390	3/4	0.565	0.431	44.0	1.98
C 9 × 13.4	3.94	0.233	2.433	0.413	3/4	0.601	0.743	47.9	1.76
9 × 15	4.41	0.285	2.485	0.413	3/4	0.586	0.682	51.0	1.93
9 × 20	5.88	0.448	2.648	0.413	3/4	0.583	0.515	60.9	2.42
C 10 × 15.3	4.49	0.240	2.600	0.436	3/4	0.634	0.796	67.4	2.28
10 × 20	5.88	0.379	2.739	0.436	3/4	0.606	0.637	78.9	2.81
10 × 25	7.35	0.526	2.886	0.436	3/4	0.617	0.494	91.2	3.36
10 × 30	8.82	0.673	3.033	0.436	3/4	0.649	0.369	103	3.94
C 12 × 20.7	6.09	0.282	2.942	0.501	7/8	0.698	0.870	129	3.88
12 × 25	7.35	0.387	3.047	0.501	7/8	0.674	0.746	144	4.47
12 × 30	8.82	0.510	3.170	0.501	7/8	0.674	0.618	162	5.14
C 15 × 33.9	9.96	0.400	3.400	0.650	1	0.787	0.896	315	8.13
15 × 40	11.8	0.520	3.520	0.650	1	0.777	0.767	349	9.23
15 × 50	14.7	0.716	3.716	0.650	1	0.798	0.583	404	11.0

†The designation is the channel depth and the unit weight in pounds per foot: D = diameter of maximum flange fastener, and e = location of shear center.

SOURCE: Ref. [48.2]. All the sizes listed here are generally available in aluminum alloys. For these, the unit weight is obtained by multiplying the area by 0.829.

TABLE 48.20 Properties of Angles†



Size, in	w, lb/ft	Area A, in²	y, in	I_x, in⁴	x, in	I_y, in⁴	Tan α
L 2 × 2 × 1/8	1.65	0.484	0.546	0.190	0.546	0.190	1.000
× 3/16	2.44	0.715	0.569	0.272	0.569	0.272	1.000
× 1/4	3.19	0.938	0.592	0.348	0.592	0.348	1.000
× 5/16	3.92	1.15	0.614	0.416	0.614	0.416	1.000
× 3/8	4.7	1.36	0.636	0.479	0.636	0.479	1.000
L 2½ × 2 × 3/16	2.75	0.809	0.764	0.509	0.514	0.291	0.631
× 1/4	3.62	1.06	0.787	0.654	0.537	0.372	0.626
× 5/16	4.5	1.31	0.809	0.788	0.559	0.446	0.620
× 3/8	5.3	1.55	0.831	0.912	0.581	0.514	0.614
L 2½ × 2½ × 3/16	3.07	0.902	0.694	0.547	....	....	1.000
× 1/4	4.10	1.19	0.717	0.703	....	....	1.000
× 5/16	5.00	1.46	0.740	0.849	....	....	1.000
× 3/8	5.9	1.73	0.762	0.984	....	....	1.000

L 3 × 2 × 3/16	3.07	0.902	0.970	0.842	0.470	0.307	0.446
L 3 × 2 × 1/4	4.1	1.19	0.993	1.09	0.493	0.392	0.440
× 5/16	5.0	1.46	1.02	1.32	0.516	0.470	0.435
× 3/8	5.9	1.73	1.04	1.53	0.539	0.543	0.428
L 3 × 2½ × 3/16	3.39	0.996	0.888	0.907	0.638	0.577	0.688
× 1/4	4.5	1.31	0.911	1.17	0.661	0.743	0.684
× 3/8	6.6	1.92	0.956	1.66	0.706	1.04	0.676
L 3 × 3 × 3/16	3.71	1.09	0.820	0.962	....	....	1.000
× 1/4	4.9	1.44	0.842	1.24	....	....	1.000
× 5/16	6.1	1.78	0.865	1.51	....	....	1.000
× 3/8	7.2	2.11	0.888	1.76	....	....	1.000
× 1/2	9.4	2.75	0.932	2.22	....	....	1.000
L 3½ × 2½ × 1/4	4.9	1.44	1.11	1.80	0.614	0.777	0.506
× 5/16	6.1	1.78	1.14	2.19	0.637	0.939	0.501
× 3/8	7.2	2.11	1.16	2.56	0.660	1.09	0.496
L 3½ × 3 × 1/4	5.4	1.56	1.04	1.91	0.785	1.30	0.727
× 5/16	6.6	1.93	1.06	2.33	0.808	1.58	0.724
L 3½ × 3 × 3/8	7.9	2.30	1.08	2.72	0.830	1.85	0.721
L 3½ × 3½ × 1/4	5.8	1.69	0.968	2.01	....	....	1.000
× 5/16	7.2	2.09	0.990	2.45	....	....	1.000
× 3/8	8.5	2.48	1.01	2.87	....	....	1.000
L 4 × 3 × 1/4	5.8	1.69	1.24	2.77	0.736	1.36	0.558
× 5/16	7.2	2.09	1.26	3.38	0.759	1.65	0.554
× 3/8	8.5	2.48	1.28	3.96	0.782	1.92	0.551
× 1/2	11.1	3.25	1.33	5.05	0.827	2.42	0.543
L 4 × 3½ × 1/4	6.2	1.81	1.16	2.91	0.909	2.09	0.759
× 5/16	7.7	2.25	1.18	3.56	0.932	2.55	0.757
× 3/8	9.1	2.67	1.21	4.18	0.955	2.95	0.755
× 1/2	11.9	3.50	1.25	5.32	1.00	3.79	0.750

TABLE 48.20 Properties of Angles† (*Continued*)

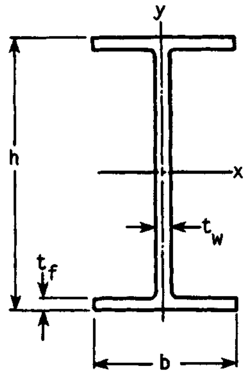
Size, in	w, lb/ft	Area A, in²	y, in	I_x, in⁴	x, in	I_y, in⁴	Tan α
L 4 × 4 × 1/4	6.6	1.94	1.09	3.04	....	....	1.000
× 5/16	8.2	2.40	1.12	3.71	....	....	1.000
× 3/8	9.8	2.86	1.14	4.36	....	....	1.000
× 1/2	12.8	3.75	1.18	5.56	....	....	1.000
L 4 × 4 × 5/8	15.7	4.61	1.23	6.66	....	....	1.000
× 3/4	18.6	5.44	1.27	7.67	....	....	1.000
L 5 × 3 × 1/4	6.6	1.94	1.66	5.11	0.657	1.44	0.371
× 5/16	8.2	2.40	1.68	6.26	0.681	1.75	0.368
× 3/8	9.8	2.86	1.70	7.37	0.704	2.04	0.364
× 1/2	12.8	3.75	1.75	9.45	0.750	2.58	0.357
L 5 × 3½ × 5/16	8.7	2.56	1.59	6.60	0.838	2.72	0.489
× 3/8	10.4	3.05	1.61	7.78	0.861	3.18	0.486
× 1/2	13.6	4.00	1.66	9.99	0.906	4.05	0.479
× 3/4	19.8	5.81	1.75	13.9	0.996	5.55	0.464
L 5 × 5 × 5/16	10.3	3.03	1.37	7.42	....	....	1.000
× 3/8	12.3	3.61	1.39	8.74	....	....	1.000
× 1/2	16.2	4.75	1.43	11.3	....	....	1.000
× 3/4	23.6	6.94	1.52	15.7	....	....	1.000
× 7/8	27.2	7.98	1.57	17.8	....	....	1.000
L 6 × 3½ × 5/16	9.8	2.87	2.01	10.9	0.763	2.85	0.352
× 3/8	11.7	3.42	2.04	12.9	0.787	3.34	0.350

L $6 \times 4 \times \frac{3}{8}$	12.3	3.61	1.94	13.5	0.941	4.90	0.446
$\times \frac{1}{2}$	16.2	4.75	1.99	17.4	0.987	6.27	0.440
$\times \frac{5}{8}$	20.0	5.86	2.03	21.1	1.03	7.52	0.435
$\times \frac{3}{4}$	23.6	6.94	2.08	24.5	1.08	8.68	0.428
L $6 \times 6 \times \frac{3}{8}$	14.9	4.36	1.64	15.4	....	....	1.000
$\times \frac{1}{2}$	19.6	5.75	1.68	19.9	....	....	1.000
$\times \frac{5}{8}$	24.2	7.11	1.73	24.2	....	....	1.000
$\times \frac{3}{4}$	28.7	8.44	1.78	28.2	....	....	1.000
$\times \frac{7}{8}$	33.1	9.73	1.82	31.9	....	....	1.000
$\times 1$	37.4	11.0	1.86	35.5	....	....	1.000
L $7 \times 4 \times \frac{3}{8}$	13.6	3.98	2.37	20.6	0.870	5.10	0.340
$\times \frac{1}{2}$	17.9	5.25	2.42	26.7	0.917	6.53	0.335
$\times \frac{3}{4}$	26.2	7.69	2.51	37.8	1.01	9.05	0.324
L $8 \times 4 \times \frac{1}{2}$	19.6	5.75	2.86	38.5	0.859	6.74	0.267
$\times \frac{3}{4}$	28.7	8.44	2.95	54.9	0.953	9.36	0.258
$\times 1$	37.4	11.0	3.05	69.6	1.05	11.6	0.247
L $8 \times 6 \times \frac{1}{2}$	23.0	6.75	2.47	44.3	1.47	21.7	0.558
$\times \frac{3}{4}$	33.8	9.94	2.56	63.4	1.56	30.7	0.551
$\times 1$	44.2	13.0	2.65	80.8	1.65	38.8	0.543
L $8 \times 8 \times \frac{1}{2}$	26.4	7.75	2.19	48.6	....	....	1.000
$\times \frac{5}{8}$	32.7	9.61	2.23	59.4	....	....	1.000
$\times \frac{3}{4}$	38.9	11.4	2.28	69.7	....	....	1.000
$\times \frac{7}{8}$	45.0	13.2	2.32	79.6	....	....	1.000
$\times 1$	51.0	15.0	2.37	89.0	....	....	1.000
$\times 1\frac{1}{8}$	56.9	16.7	2.41	98.0	....	....	1.000

†Size is the length of each leg and the thickness; unit weight for steel is *w*.

SOURCE: Ref. [48.2]. Angles up to 6 in inclusive are also available in aluminum alloys. For these, the unit weight is obtained by multiplying the area by 0.829. Sizes in structural steel larger than those listed are available on special order.

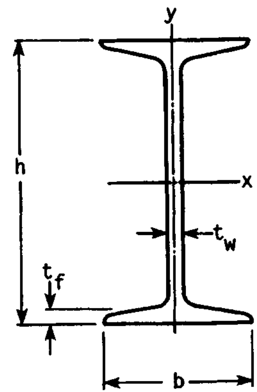
TABLE 48.21 Properties of W Shapes†



Designation	Area A, in^2	h, in	t_w, in	b, in	t_f, in	I_x, in^4	I_y, in^4
W 4 × 13	3.83	4.16	0.280	4.060	0.345	11.3	3.86
W 5 × 16	4.68	5.01	0.240	5.000	0.360	21.3	7.51
5 × 19	5.54	5.15	0.270	5.030	0.430	26.2	9.13
W 6 × 9	2.68	5.90	0.170	3.940	0.215	16.4	2.19
6 × 12	3.55	6.03	0.230	4.000	0.280	22.1	2.99
6 × 16	4.74	6.28	0.260	4.030	0.405	32.1	4.43
6 × 15	4.43	5.99	0.230	5.990	0.260	29.1	9.32
6 × 20	5.87	6.20	0.260	6.020	0.365	41.4	13.3
6 × 25	7.34	6.38	0.320	6.080	0.455	53.4	17.1
W 8 × 10	2.96	7.89	0.170	3.940	0.205	30.8	2.09
8 × 13	3.84	7.99	0.230	4.000	0.255	39.6	2.73
8 × 15	4.44	8.11	0.245	4.015	0.315	48.0	3.41
8 × 18	5.26	8.14	0.230	5.25	0.330	61.9	7.97
8 × 21	6.16	8.28	0.250	5.27	0.400	75.3	9.77
8 × 24	7.08	7.93	0.245	6.495	0.400	82.8	18.3
8 × 28	8.25	8.06	0.285	6.535	0.465	98.0	21.7
8 × 31	9.13	8.00	0.285	7.995	0.435	110	37.1
8 × 35	10.3	8.12	0.310	8.020	0.495	127	42.6
8 × 40	11.7	8.25	0.360	8.070	0.560	146	49.1
8 × 48	14.1	8.50	0.400	8.110	0.685	184	60.9
8 × 58	17.1	8.75	0.510	8.220	0.810	228	75.1
8 × 67	19.7	9.00	0.570	8.280	0.935	272	88.6
W 10 × 12	3.54	9.87	0.190	3.960	0.210	53.8	2.18
10 × 15	4.41	9.99	0.230	4.000	0.270	68.9	2.89
10 × 17	4.99	10.11	0.240	4.010	0.330	81.9	3.56
10 × 19	5.62	10.24	0.250	4.020	0.395	96.3	4.29
W 10 × 22	6.49	10.17	0.240	5.75	0.360	118	11.4
10 × 26	7.61	10.33	0.260	5.770	0.440	144	14.1
10 × 30	8.84	10.47	0.300	5.810	0.510	170	16.7
W 10 × 33	9.71	9.73	0.290	7.960	0.435	170	36.6
10 × 39	11.5	9.92	0.315	7.985	0.530	209	45.0
10 × 45	13.3	10.10	0.350	8.020	0.620	248	53.4

†The designation is the nominal depth, and the unit weight for steel is in pounds per foot. Larger sizes are available from W 10 × 49 to W 36 × 300. See Ref. [48.2]. Some of the sizes 8 in and under are available in aluminum alloys which are then called H sections.

TABLE 48.22 Properties of S Shapes†



Designation		Area A, in^2	h, in	t_w, in	b, in	t_f, in	D, in	I_x, in^4	I_y, in^4
S	3 × 5.7	1.67	3.00	0.170	2.330	0.260	...	2.52	0.455
	3 × 7.5	2.21	3.00	0.349	2.509	0.260	...	2.93	0.586
S	4 × 7.7	2.26	4.00	0.193	2.663	0.293	...	6.08	0.764
	4 × 9.5	2.79	4.00	0.326	2.796	0.293	...	6.79	0.903
S	5 × 10	2.94	5.00	0.214	3.004	0.326	...	12.3	1.22
	5 × 14.75	4.34	5.00	0.494	3.284	0.326	...	15.2	1.67
S	6 × 12.5	3.67	6.00	0.232	3.332	0.359	...	22.1	1.82
	6 × 17.25	5.07	6.00	0.465	3.565	0.359	$\frac{5}{8}$	26.3	2.31
S	7 × 15.3	4.50	7.00	0.252	3.662	0.392	$\frac{5}{8}$	36.7	2.64
	7 × 20	5.88	7.00	0.450	3.860	0.392	$\frac{5}{8}$	42.4	3.17

TABLE 48.22 Properties of S Shapes† (*Continued*)

Designation	Area A, in^2	h, in	t_w, in	b, in	t_f, in	D, in	I_x, in^4	I_y, in^4
S 8 × 18.4	5.41	8.00	0.271	4.001	0.426	$\frac{3}{4}$	57.6	3.73
8 × 23	6.77	8.00	0.441	4.171	0.426	$\frac{3}{4}$	64.9	4.31
S 10 × 25.4	7.46	10.00	0.311	4.661	0.491	$\frac{3}{4}$	124	6.79
10 × 35	10.3	10.00	0.594	4.944	0.491	$\frac{3}{4}$	147	8.36
S 12 × 31.8	9.35	12.00	0.350	5.000	0.544	$\frac{3}{4}$	218	9.36
12 × 35	10.3	12.00	0.428	5.078	0.544	$\frac{3}{4}$	229	9.87
S 12 × 40.8	12.0	12.00	0.462	5.252	0.659	$\frac{3}{4}$	272	13.6
12 × 50	14.7	12.00	0.687	5.477	0.659	$\frac{3}{4}$	305	15.7
S 15 × 42.9	12.6	15.00	0.411	5.501	0.622	$\frac{3}{4}$	447	14.4
15 × 50	14.7	15.00	0.550	5.640	0.622	$\frac{3}{4}$	486	15.7
S 18 × 54.7	16.1	18.00	0.461	6.001	0.691	$\frac{7}{8}$	804	20.8
18 × 70	20.6	18.00	0.711	6.251	0.691	$\frac{7}{8}$	926	24.1
S 20 × 66	19.4	20.00	0.505	6.255	0.795	$\frac{7}{8}$	1190	27.7
20 × 75	22.0	20.00	0.635	6.385	0.795	$\frac{7}{8}$	1280	29.8
S 20 × 86	25.3	20.30	0.660	7.060	0.920	1	1580	46.8
20 × 96	28.2	20.30	0.800	7.200	0.920	1	1670	50.2
S 24 × 80	23.5	24.00	0.500	7.000	0.870	1	2100	42.2
24 × 90	26.5	24.00	0.625	7.125	0.870	1	2250	44.9
24 × 100	29.3	24.00	0.745	7.245	0.870	1	2390	47.4

†The designation is the nominal depth and the unit weight for steel is in pounds per foot; D = diameter of maximum flange fastener.

SOURCE: Ref. [48.2]. Many of the sizes in this table up to and including 12 in are also available in aluminum alloys. Multiply the area by 0.829 to get the weight of these shapes.

48.5 WIRE AND SHEET METAL

Gauge sizes of wire and sheet metal of both ferrous and nonferrous materials are tabulated in Table 48.17. The use of SI units is simpler for such products because it is easier to express thicknesses directly in millimeters.

48.6 STRUCTURAL SHAPES

An assortment of various shapes used in structural steel works and their sizes and properties are tabulated in Tables 48.18 to 48.22. These are probably the most useful sizes for machine-design purposes, but other sizes are available or can be obtained on special order. Generally, aluminum shapes are available in a larger range of sizes, especially the smaller ones.

REFERENCES

48.1 *Steel Products Manual,* American Iron and Steel Institute, Washington, D.C.

48.2 *Manual of Steel Construction,* American Institute of Steel Construction, Inc., Chicago, Illinois.