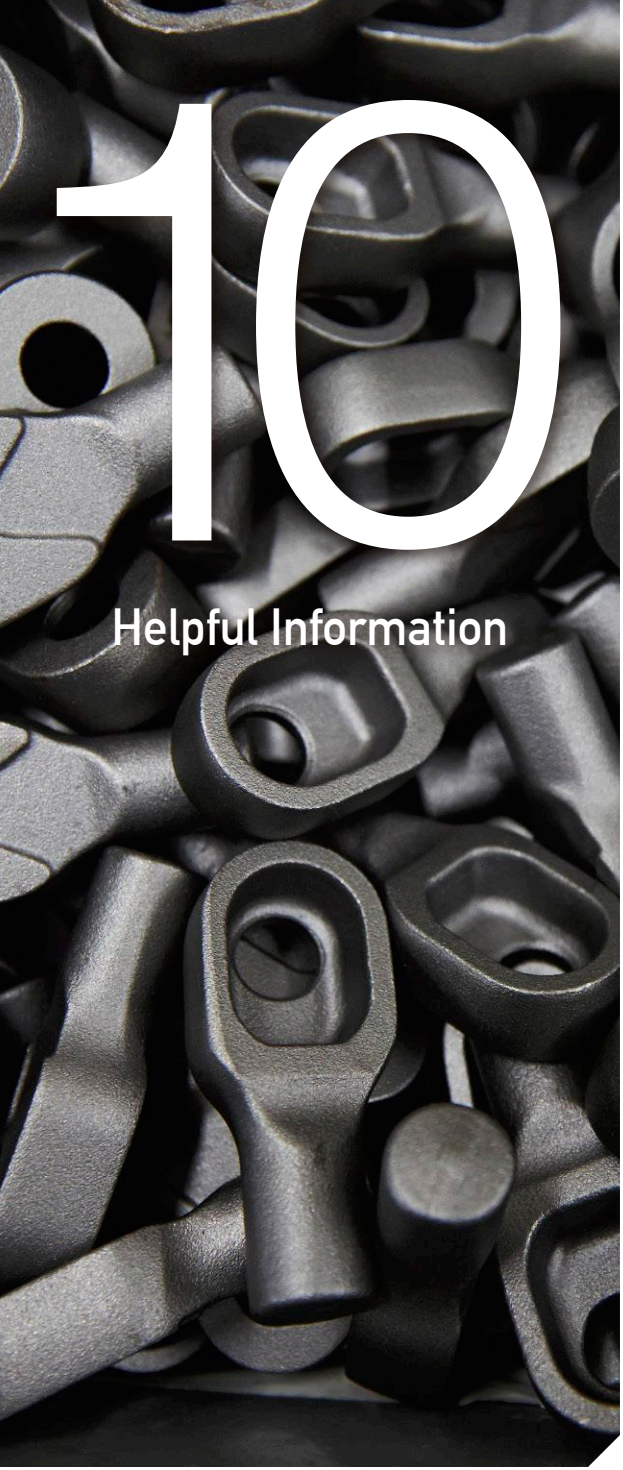


10 Helpful Information

10-1 SI Unit

(1) SI base units 147
(2) SI derived unit 148
(3) SI prefixes 148
(4) Non-SI units which may be used with SI units and their multiples 148

10-2 Characteristic of Material

(1) Physical characteristic of metal material 149
(2) Strength characteristic of plastic 150
(3) Characteristic of special steel 151

10-3 Roughness of Surface

Roughness of Surface 152

10-4 Material Mechanics

(1) Area of plane figure 153
(2) Volume of solid figure 154
(3) Principal moment of inertia and modulus of section 155
(4) Twist of shaft of cross section shape 157
(5) Beam 158
(6) Welding strength 159

10-5 Formula of Electricity

Formula of Electricity 160

10 Helpful Information

10-1 SI Unit

(1) SI base units

The international system of units is based on the seven base units listed table on the right.

SI base units

Base quantity	SI base units	
	Name	Symbol
Length	Meter	m
Mass	Kilogram	kg
Time	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd

10-1 SI Unit

(2) SI derived unit

SI derived units are expressed algebraically in terms of base units. These symbols are obtained by means of the mathematical signs of multiplication and division.

Named units derived from SI units.

Derived quantity	SI derived unit	
	Name	Symbol
Area	Square meter	m^2
Volume	Cubic meter	m^3
Velocity	Meter per second	m/s
Acceleration	Meter per square second	m/s^2
Wave number	Per meter	m^{-1}
Mass density	Kilogram per cubic meter	kg/m^3
Specific volume	Cubic meter per kilogram	m^3/kg

(3) SI prefixes

The multiple can usually be chosen so that the numerical values will be between 0.1 and 1000.

SI prefixes

Factor	Prefix	Symbol
$10^9 = (10^3)^3$	Giga	G
$10^6 = (10^3)^2$	Mega	M
$10^3 = (10^3)^1$	Kilo	k
10^2	Hecto	h
10^1	Deca	da
10^{-1}	Deci	d
10^{-2}	Centi	c
$10^{-3} = (10^3)^{-1}$	Milli	m
$10^{-6} = (10^3)^{-2}$	Micro	μ
$10^{-9} = (10^3)^{-3}$	Nano	n
$10^{-12} = (10^3)^{-4}$	Pico	p

Example of SI derived unit which has

Derived quantity	SI derived unit			
	Special name	Symbol	Expressed in terms of other SI units	Expressed in terms of other SI base units and SI derived unit
Plane angle	radian	rad	–	$m \cdot m^{-1} = 1$
Solid angle	steradian	sr	–	$m^2 \cdot m^{-2} = 1$
Frequency	hertz	Hz	–	s^{-1}
Force	newton	N	–	$m \cdot kg \cdot s^{-2}$
Pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
Energy, work, quantity of heat	joule	J	N•m	$m^2 \cdot kg \cdot s^{-2}$
Power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
Electric charge, quantity of electric	coulomb	C	–	A•s
Electric potential, potential difference, tension electromotive force	volt	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
Capacitance	farad	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
Electric resistance	ohm	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
Magnetic flux	weber	Wb	V•s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
Magnetic flux density	tesla	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$

(4) Non-SI units which may be used with SI units and their multiples

Units used with the SI

Name	Symbol	Definition
Minute	min	1 [min] = 60 [s]
Hour	h	1 [h] = 60 [min] = 3600 [s]
Day	d	1 [d] = 24 [h] = 86400 [s]
Degree	°	$1° = (\pi/180)$ [rad]
Minute	′	$1′ = (1/60)° = (\pi/10800)$ [rad]
Second	″	$1″ = (1/60)′ = (\pi/648000)$ [rad]
Liter	ℓ, L (1)	1 [L] = 1 [dm^3] = 10^{-3} [m^3]
Tonne (2)	t	1 [t] = 10^3 [kg]

Note: 1. The two symbols for the liter are on an equal footing. The CIPM (International Committee of Weights and Measures) will, however, make a survey on the development of the use of the two symbols in order to see if one of the two may be suppressed.
2. Also it is called the metric ton in the English language.

10 Helpful Information

10-2 Characteristic of Material

(1) Physical characteristic of metal material

Element	Symbol	Specific gravity	Fusing point [C]	Longitudinal elastic coefficient E [N/mm²]
Zinc	Zn	7.113 (25°)	419.5	–
Argon	Ar	0.00178	−189.4	–
Aluminum	AL	2.699	660	61782
Sulfur	S	2.07	119	77473
Uranium	U	19.07	1132.3	166713
Chlorine	CL	0.00321	−101	–
Cadmium	Cd	8.65	320.9	54917
Potassium	K	0.86	63.7	–
Gallium	Ga	5.907	29.78	–
Calcium	Ca	1.55	838	21575~26478
Gold	Au	19.32	1063	80415
Silver	Ag	10.49	960.8	70608~77473
Chromium	Cr	7.19	1875	–
Silicon	SI	2.33 (25°)	1410	10787
Germanium	Ge	5.323 (25°)	937	–
Cobalt	Co	8.85	1495	205940
Samarium	Sm	7.49	1072	54917
Zirconium	Zr	6.489	1852	94144
Mercury	Hg	13.546	−38.36	–
Tin	Sn	7.29	231.9	41188~45111
Tungsten	W	19.3	3410	34323
Carbon	C	2.25	3727	4903
Titanium	TI	4.507	1668	115718
Nitrogen	N	0.00125	−209	
Iron	Fe	7.87		
Copper	Cu	8.96	1083	107873
Sodium	Na	0.9712	97.82	–
Lead	Pb	11.36	327.4	13729
Nickel	NI	8.902 (25°)	1453	205940
Neodymium	Nd	7	1019	–
Platinum	Pt	21.45	1769	147100
Vanadium	V	6.1	1900	127486~137293
Barium	Ba	3.5	714	–
Fluorine	F	0.001696	−219.6	–
Plutonium	Pu	19~19.72	640	98067
Beryllium	Be	1.848	1277	27459~30401
Magnesium	Mg	1.74	650	44130
Manganese	Mn	7.43	1245	156906
Molybdenum	Mo	10.22	2610	411879
Lithium	LI	0.534	180.5	–
Phoshorus	P	1.83	44.25	–

Alloy name	Specific gravity	Fusing point [C]	Longitudinal elastic coefficient E [N/mm²]	Transuerse elastic coefficient G [N/mm²]
Duralumin	2.79	Approx. 650	Approx. 68647	26478
Super mild steel	7.856~7.861	1500	205940	79434
Hard steel	7.836~7.846	1390~1420	204959	81984
High carbon steel	7.81	1335~1450	196133~202017	80415~81395
Cast steel	7.84	1410~1470	205940	76982
Alminum bronze	7.6	1040	109834	–
Phosphorus bronze	8.78	1000	109834	–
German silver	8.3~8.7	950~1180	107873	39227
Berylium copper	8.2	864~ 955	1108151	–
Chrome steel	Approx. 7.84	–	201036~210843	–
Chrome-Stainless steel	7.6~7.75	1510~1532	202998~207901	–
Silicon steel	7.6~7.8	1430~1530	216727~220650	–
Nickel-Chrome steel	7.8	1450~1510	203978	–
White metal	7.38	240~ 355	52171	–

10-2 Helpful Information Characteristic of Material

(2) Strength characteristic of plastic

Model	Code	Specific gravity	Elongation [%]	Longitudinal elastic coefficient E [N/mm²]	Tensile strength [N/mm²]	Bending strength [N/mm²]
Thermoplasticity						
Polyethylene	PE					
Low density (LD)		0.91～0.925	90～ 800	96.1～ 260.9	3.9～ 15.7	–
Medium density (MD)		0.926～0.94	50～ 600	171.6～ 377.6	7.8～ 24.5	33.3～ 48.1
High density (HD)		0.941～0.965	20～1300	411.9～ 1235.6	20.6～ 38.2	–
Polypropylene	PP	0.90～0.91	200～ 700	1098.3～ 1549.5	29.4～ 38.2	41.2～ 54.9
Vinyl chloride resin (Hard)	PVC	1.30～1.58	40～ 80	2402.6～ 4118.8	41.2～ 52.0	68.6～109.8
Tetrafluoride ethylene	PTFE	2.14～2.20	200～ 400	398.1	13.7～ 34.3	–
ABS resin	ABS					
Shock resistance (H1)		1.03～1.06	5.0～ 25	2059.4～ 3089.1	45.1～ 52.0	75.5～ 89.2
With fiberglass		1.23～1.36	2.5～ 3.0	4050.1～ 7219.8	58.8～130.4	109.8 ～185.3
Polycarbonate	PC					
No packing		1.2	100 ～130	2059.4～ 3383.3	54.9～ 65.7	93.2
With fiberglass		1.24～1.52	0.9～ 5.0	3432.3～11909.8	82.4～171.6	116.7～219.7
Polyacetal	POM					
Homopolymerization		1.42	25～ 75	3569.6	68.6	97.1
With homopolymerization fiberglass		1.56	2～ 7	6864.7	54.9～ 75.5	–
Copolymerization		1.41	40～ 75	2814.5	60.8	89.2
With copolymerization fiberglass		1.61	3	8580.8	127.5	192.2
Nylon 6		1.12～1.14	200dry～300	–	68.6～ 81.4	–
Nylon 6 with fiberglass		1.35～1.42	3	5491.7～ 9953.7	171.6 ～ 89.2	164.8 dry
Nylon 6,6		1.13～1.15	60dry～300	–	82.4～ 75.5	116.7～42.2
Nylon 6,6 with fiberglass		1.38	4dry～5	–	164.8 ～185.3	281.5 dry
Nylon 12		1.01～1.02	300	1235.6	54.9～ 63.7	–
Polymide with fiberglass	PI	1.9	1 or less	19564.3	185.3	340.3
Plastic of cellulose						
Cellulose acetate	CA	1.22～1.34	6.0～ 7.0	451.1～ 2745.9	12.7～ 61.8	13.7～109.8
Cellulose acetate butylete	CAB	1.15～1.22	50～100	1372.9～ 1716.2	17.7～ 47.1	27.5～ 61.8

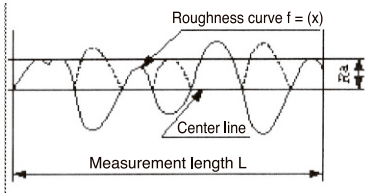
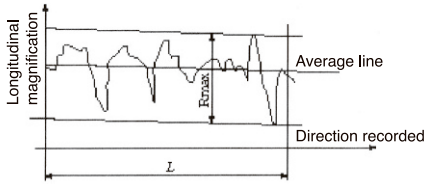
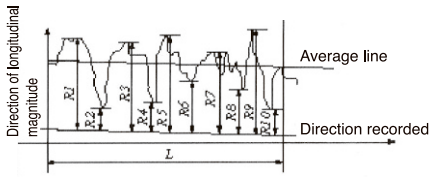
Model	Code	Specific gravity	Elongation [%]	Longitudinal elastic coefficient E [N/mm²]	Tensile strength [N/mm²]	Bending strength [N/mm²]
Thermosetting						
Phenol resin	PF					
Molding with organism		1.34～1.45	0.4～0.8	5491.7～11669.9	34.3～ 61.8	48.1～ 96.1
Molding mineral		1.45～2.00	0.2～0.5	6864.7～20594.0	31.4～ 52.0	48.1～ 96.1
Molding with fiberglass		1.69～1.95	0.2	13042.8～22653.4	34.3～127.5	68.6～411.9
Urea resin	UF					
Molding with α-cellulose		1.47～1.52	0.5～1.0	6864.7～10297.0	38.2～ 89.2	68.6～123.6
Epoxy resin	EP					
No molding		1.11～1.40	3～6	2402.6	27.5～ 89.2	91.2～144.2
Molding with fiberglass		1.6～2.0	4	20868.6	68.6～137.3	68.6～411.9
Unsaturation polyester resin	UP					
No molding		1.11～1.46	5 or less	2059.4～ 4393.4	41.2～ 89.2	58.8～157.9
Brimix molding	(BMC)	1.65～2.30	0.5	6864.7～17161.6	20.6～68.6	48.1～137.3
Melanin resin	MF					
Molding with α-cellulose		1.47～1.52	0.6～0.9	8237.6～ 9610.5	48.1～89.2	68.6～109.8
Silicon resin	SI					
Molding with fiberglass		1.80～1.90	–	–	27.5～45.1	68.6～ 96.1
Polyurethane	PUR					
Molding		1.10～1.50	100～1000	686.5～ 6864.7	1.0～68.6	4.9～ 31.4
Thermoplasticity		1.05～1.25	100～650	686.5～ 2402.6	31.4～57.9	4.9～ 61.8

1N=0.101972kgf
1kgf=9.80665N

(3) Characteristic of special steel

Classification	Symbol	Heat treatment [°C]	Yielding point or bearing force [N/mm²]	Tensile strength [N/mm²]	Elongation [%]	Contraction [%]	Hardness [HB]	Hardness [HRC]
General structural steel (JIS G3101)	SS400	–	More than 215	400~510	More than 21	–	–	–
Machine structural carbon steel (JIS 4051)	S25C	Annealing	–	–	–	–	121~156	–
	S30C	Hardening / Annealing	More than 355	More than 540	More than 23	More than 57	152~212	–
	S35C	Normalizing	More than 305	More than 510	More than 23	–	149~207	–
		Annealing	–	–	–	–	126~163	–
		Hardening / Tempering	More than 390	More than 570	More than 22	More than 55	167~235	–
	S45C	Normalizing	More than 345	More than 570	More than 20	–	167~229	–
		Annealing	–	–	–	–	137~170	–
		Hardening / Tempering	More than 490	More than 690	More than 17	More than 45	201~269	–
	S50C	Normalizing	More than 365	More than 610	More than 18	–	179~235	–
		Annealing	–	–	–	–	143~187	–
		Hardening / Tempering	More than 540	More than 740	More than 15	More than 40	212~277	–
	S55C	Normalizing	More than 390	More than 650	More than 15	–	183~255	–
		Annealing	–	–	–	–	149~192	–
		Hardening / Tempering	More than 590	More than 780	More than 14	More than 35	229~285	–
Carbon tool steel (JIS 4401)	SK3	Hardening / Tempering	–	More than 850	–	–	–	More than 63
	SK4	Hardening / Tempering	–	More than 770	–	–	–	More than 61
	SK5	Hardening / Tempering	–	–	–	–	–	More than 59
Chrome steel (JIS 4104)	SCr415	Hardening / Tempering	–	More than 780	More than 15	More than 40	217~302	–
	SCr420	Hardening / Tempering	–	More than 830	More than 14	More than 35	235~321	–
	SCr440	Hardening / Tempering	More than 785	More than 930	More than 13	More than 45	269~331	–
Chromium-molybdenum steel (JIS 4105)	SCM415	Hardening / Tempering	–	More than 830	More than 16	More than 40	235~321	–
	SCM420	Hardening / Tempering	–	More than 930	More than 14	More than 40	262~352	–
	SCM435	Hardening / Tempering	–	More than 930	More than 15	More than 50	269~331	–
	SCM440	Hardening / Tempering	–	More than 980	More than 12	More than 45	285~352	–
	SCM455	Hardening / Tempering	–	More than 1030	More than 12	More than 40	302~363	–

10-3 Roughness of Surface

Type symbol	Symbol	How to determine	Explanation
Center line average roughness	Ra	Turn back roughness curve from center line, and express the value by [μm] of area got from roughness curve and center line, divided by length L. Generally to read directly average line roughness measurement.	
Max. height	Rmax	Sectional curve, to get max. height of part extracted standard length L and to express by [μm]. To extract just standard length from part without extraordinary high mountain and deep valley recognized as scar.	 L: Standard length Rmax: Max. height of the part to
Ten points average height	Rz	For the part just extracted standard length from sectional curve to express the difference between average of height of mountaintop from max. to the fifth and average of height of bottom from most deep to the fifth by [μm]	 R1, R3, R5, R7, R9 : height of mountain top from Max. to the fifth R2, R4, R6, R8, R10 : height of bottom from most deep to the fifth $Rz = \frac{(R1 + R3 + R5 + R7 + R9) - (R2 + R4 + R6 + R8 + R10)}{5}$

10 Helpful Information

10-4 Material Mechanics

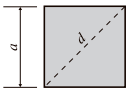
(1) Area of plane figure

a. Square

$A = a^2$

$a = \sqrt{A}$

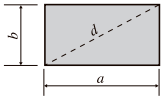
$d = a\sqrt{2}$



b. Rectangle

$A = ab$

$d = \sqrt{a^2+b^2}$

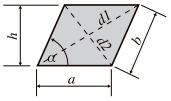


c. Parallelogram

$A = ah = ab\sin\alpha$

$d1 = \sqrt{(a+h\cot\alpha)^2+h^2}$

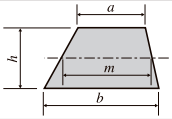
$d2 = \sqrt{(a-h\cot\alpha)^2+h^2}$



d. Trapezoid

$A = \frac{a+b}{2}h = mh$

$m = \frac{a+b}{2}$

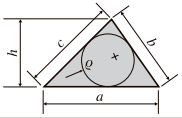


e. Triangle

$A = \frac{ah}{2} = \varrho s$

$= \sqrt{s(s-a)(s-b)(s-c)}$

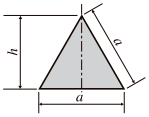
$s = \frac{a+b+c}{2}$



f. Equilateral triangle

$A = \frac{a^2}{4}\sqrt{3}$

$h = \frac{a}{2}\sqrt{3}$



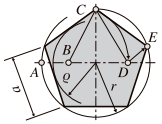
g. Equilateral pentagon

$A = \frac{5}{8}r^2\sqrt{10+2\sqrt{5}}$

$a = \frac{1}{2}r\sqrt{10-2\sqrt{5}}$

$\varrho = \frac{1}{4}r\sqrt{6+2\sqrt{5}}$

Drawing: $\overline{AB} = 0.5r, \overline{BC} = \overline{BD}, \overline{CD} = \overline{CE}$



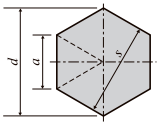
h. Equilateral hexagon

$A = \frac{3}{2}a^2\sqrt{3}$

$d = 2a$

$= \frac{2}{\sqrt{3}}s \approx 1.155s$

$s = \frac{\sqrt{3}}{2}d \approx 0.866d$



i. Equilateral octagon

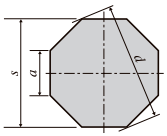
$A = 2as \approx 0.83s^2$

$= 2s\sqrt{d^2+s^2}$

$a = s\times\tan 22.5^\circ \approx 0.415s$

$s = d\times\cos 22.5^\circ \approx 0.924d$

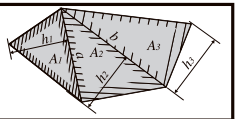
$d = \frac{s}{\cos 22.5^\circ} \approx 1.083s$



j. Polygon

$A = A_1+A_2+A_3$

$= \frac{ah_1+bh_2+bh_3}{2}$

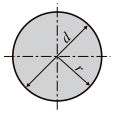


k. Circle

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

$\approx 0.785d^2$

$U = 2\pi r = \pi d$

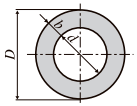


l. Annulus ring

$A = \frac{\pi}{4}(D^2-d^2)$

$= \pi(d+b)b$

$b = \frac{D-d}{2}$



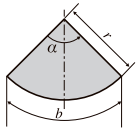
m. Sector

$A = \frac{\pi}{360^\circ}r^2\alpha = \frac{\widehat{\alpha}}{2}r$

$= \frac{br}{2}$

$b = \frac{\pi}{180^\circ}r\alpha$

Formula1 —— $\widehat{\alpha} = \frac{\pi}{180^\circ}\alpha$ α = Circular measure ofα (rad)



n. Arch shape

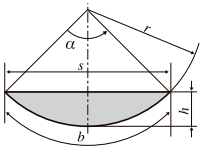
$s = 2r\sin\frac{\alpha}{2}$

$A = \frac{h}{6s}(3h^2+4s^2) = \frac{r^2}{2}(\widehat{\alpha}-\sin\alpha)$

$r = \frac{h}{2}+\frac{s^2}{8h}$

$h = r(1-\cos\frac{\alpha}{2}) = \frac{s}{2}\tan\frac{\alpha}{4}$

Segment For$\widehat{\alpha}$see formula1 of sector.



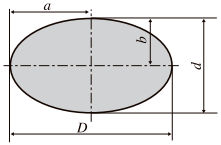
o. Ellipse

$A = \frac{\pi}{4}Dd = \pi ab$

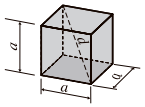
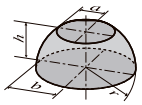
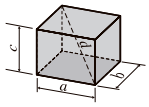
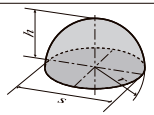
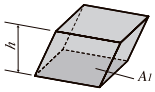
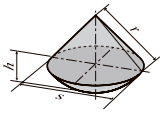
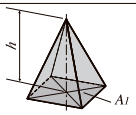
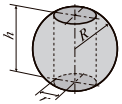
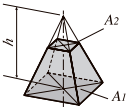
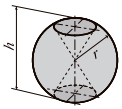
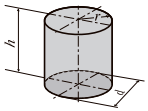
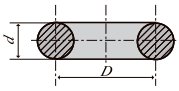
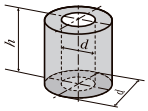
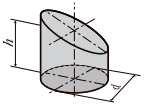
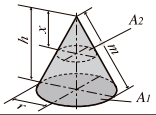
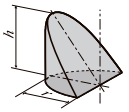
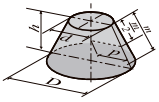
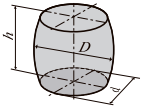
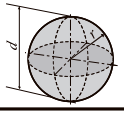
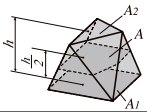
$U \approx \pi\frac{D+d}{2}$

$= \pi(a+b)\left[1+\frac{1}{4}\lambda^2+\frac{1}{64}\lambda^4+\frac{1}{256}\lambda^6+\right.$

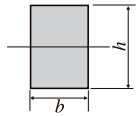
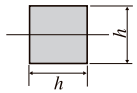
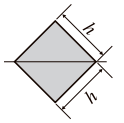
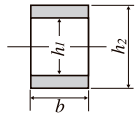
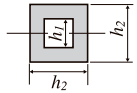
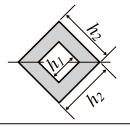
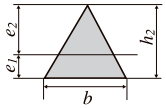
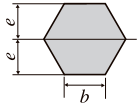
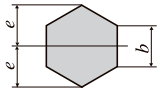
$\left.\frac{25}{16384}\lambda^8+\cdots\cdots\right]$, here$\lambda = \frac{a-b}{a+b}$



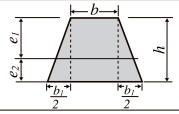
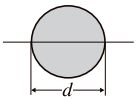
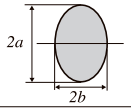
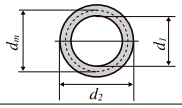
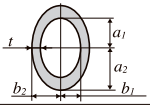
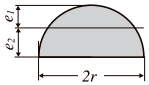
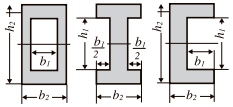
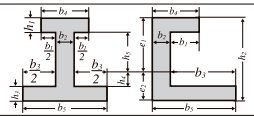
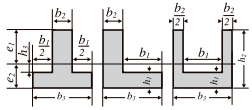
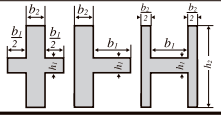
(2) Volume of solid figure

a. Cube	$V = a^3$ $A_0 = 6a^2$ $d = \sqrt{3}a$		k. Spherical zone	$V = \frac{\pi}{6}h(3a^2+3b^2+h^2)$ $A_m = 2\pi rh$ $A_0 = \pi(2rh+a^2+b^2)$	
b. Rectangular parallelepiped	$V = abc$ $A_0 = 2(ab+ac+bc)$ $d = \sqrt{a^2+b^2+c^2}$		l. Spherical crown	$V = \frac{\pi}{6}h(\frac{3}{4}s^2+h^2)$ $= \pi h^2(r-\frac{h}{3})$ $A_m = 2\pi rh$ $= \frac{\pi}{4}(s^2+4h^2)$	
c. Parallelepiped	$V = A_1 h$		m. Cube part of it cut	$V = \frac{2}{3}\pi r^2 h$ $A_0 = \frac{\pi}{2}r(4h+s)$	
d. Pyramid	$V = \frac{A_1 h}{3}$		n. Globe with hollow cylinder	$V = \frac{\pi}{6}h^3$ $A_0 = 2\pi h(R+r)$	
e. Pyramid of head cut	$V = \frac{h}{3}(A_1+A_2+\sqrt{A_1A_2})$ $\approx h+\frac{A_1+A_2}{2}$		o. Globe with hollow circular cone	$V = \frac{2}{3}\pi r^2 h$ $A_0 = 2\pi(h+\sqrt{r^2-\frac{h^2}{4}})$	
f. Circular cylinder	$V = \frac{\pi}{4}d^2h$ $A_m = 2\pi rh$ $A_0 = 2\pi r(r+h)$		p. Torus	$V = \frac{\pi^2}{4}Dd^2$ $A_0 = \pi^2 Dd$	
g. Hollow cylinder	$V = \frac{\pi}{4}h(D^2-d^2)$		q. Circular cylinder cut diagonally	$V = \frac{\pi}{4}d^2h$	
h. Circular cone	$V = \frac{\pi}{3}r^2h$ $A_m = \pi rm$ $A_0 = \pi r(r+m)$ $m = \sqrt{h^2+r^2}$ $A_2 : A_1 = x^2 : h^2$		r. Hoof shape	$V = \frac{2}{3}r^2h$ $A_m = 2rh$ $A_0 = A_m + \frac{\pi}{2}r^2 + \frac{\pi}{2}r\sqrt{r^2+h^2}$	
i. Circular cylinder of head cut	$V = \frac{\pi}{12}h(D^2+Dd+d^2)$ $A_m = \frac{\pi}{2}m(D+d) = 2\pi pm$ $m = \sqrt{(\frac{D-d}{2})^2+h^2}$		s. Barrel shape	$V \approx \frac{\pi}{12}h(2D^2+d^2)$	
j. Globe	$V = \frac{4}{3}\pi r^3 = \frac{1}{6}\pi d^3$ $\approx 4.189r^3$ $A_0 = 4\pi r^2 = \pi d^2$		t. Angular base	$V = \frac{h}{6}(A_1+A_2+4A)$ *This formula can be used for volume calculation of globe and part of globe.*	

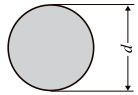
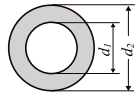
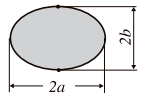
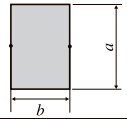
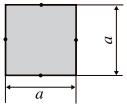
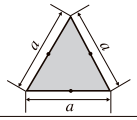
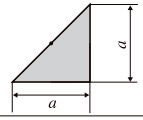
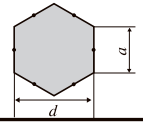
(3) Principal moment of inertia and modulus of section-1

Cross section shape	Area of cross section shape $A[cm^2]$	Principal moment of inertia $Ix[cm^4]$	Modulus of section $Z[cm^3]$	Radius of gyration: k $k^2[cm^2]$
a. 	bh	$\frac{1}{12}bh^3$	$\frac{1}{6}bh^2$	$\frac{1}{12}h^2$
b. 	h^2	$\frac{1}{12}h^4$	$\frac{1}{6}h^3$	$\frac{1}{12}h^2$
c. 	h^2	$\frac{1}{12}h^4$	$\frac{\sqrt{2}}{12}h^3$	$\frac{1}{12}h^2$
d. 	$b(h_2-h_1)$	$\frac{1}{12}b(h_2^3-h_1^3)$	$\frac{1}{6}\frac{b(h_2^3-h_1^3)}{h_2}$	$\frac{1}{12}\frac{h_2^3-h_1^3}{h_2-h_1}$
e. 	$h_2^2-h_1^2$	$\frac{1}{12}(h_2^4-h_1^4)$	$\frac{1}{6}\frac{h_2^4-h_1^4}{h_2}$	$\frac{1}{12}(h_2^2+h_1^2)$
f. 	$h_2^2-h_1^2$	$\frac{1}{12}(h_2^4-h_1^4)$	$\frac{\sqrt{2}}{12}\frac{h_2^4-h_1^4}{h_2}$	$\frac{1}{12}(h_2^2+h_1^2)$
g. 	$\frac{1}{2}bh$	$\frac{1}{36}bh^3$	$Z_1=\frac{1}{24}bh^2$ $Z_2=\frac{1}{12}bh^2$ $e_1=\frac{2}{3}h,\quad e_2=\frac{1}{3}h$	$\frac{1}{18}h^2$
h. 	$\frac{3\sqrt{3}}{2}b^2=2.60b^2$	$\frac{5\sqrt{3}}{16}b^4=0.5413b^4$	$Z=\frac{5}{8}b^3=0.625b^3$ $e=\frac{\sqrt{3}}{2}b=0.866b$	$\frac{5}{24}b^2$
i. 	$\frac{3\sqrt{3}}{2}b^2=2.60b^2$	$\frac{5\sqrt{3}}{16}b^4=0.5413b^4$	$\frac{5\sqrt{3}}{16}b^3=0.5413b^3$ $e=b$	$\frac{5}{24}b^2$

(3) Principal moment of inertia and modulus of section-2

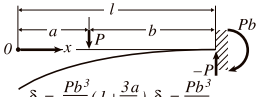
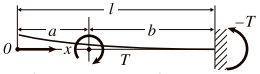
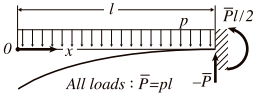
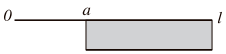
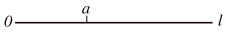
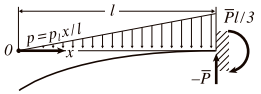
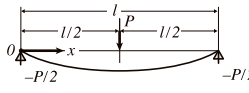
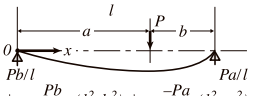
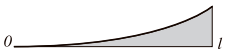
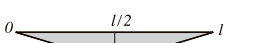
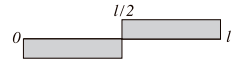
Cross section shape	Area of cross section shape $A[cm^2]$	Principal moment of inertia $Ix[cm^4]$	Modulus of section $Z[cm^3]$	Radius of gyration: k $k2[cm^2]$
j. 	$h\left(b+\frac{b_1}{2}\right)$	$\frac{6b^2+6bb_1+b_1^2}{36(2b+b_1)}h^3$	$Z=\frac{6b^2+6bb_1+b_1^2}{12(3b+2b_1)}h^2$ $e=\frac{1}{3}\frac{3b+2b_1}{2b+b_1}h$ $e=h-e_1$	$\frac{6b^2+6bb_1+b_1^2}{18(2b+b_1)^2}h^2$
k. 	$\frac{\pi}{4}d^2$	$\frac{\pi}{64}d^4$	$\frac{\pi}{32}d^3$	$\frac{\pi}{16}d^2$
l. 	πab	$\frac{\pi}{4}a^3b$	$\frac{\pi}{4}a^2b$	$\frac{1}{4}a^2$
m. 	$\frac{\pi}{4}(d_2^2-d_1^2)$	$\frac{\pi}{64}(d_2^4-d_1^4)$	$\frac{\pi}{32}\frac{d_2^4-d_1^4}{d_2}$ $\fallingdotseq 0.8d_m^2t$ $\left(When\ \frac{t}{d_m}\ is\ very\ small\right)$	$\frac{1}{16}(d_2^2+d_1^2)$
n. 	$\pi(a_2b_2-a_1b_1)$	$\frac{\pi}{4}(a_2^3b_2-a_1^3b_1)$	$\frac{\pi}{4a^2}(a_2^3b_2-a_1^3b_1)$ $\fallingdotseq\frac{\pi}{4}a_2(a_2+3b_2)t$	$\frac{1}{4}\frac{a_2^3b_2-a_1^3b_1}{a_2b_2-a_1b_1}$
o. 	$\frac{\pi}{2}r^2$	$\left(\frac{\pi}{8}-\frac{8}{9\pi}\right)r^4$ $=0.1098r^4$	$Z_1=0.1908r^3$ $Z_2=0.2587r^3$ $e_1=0.5756r$ $e_2=0.4244r$	$\frac{9\pi^2-64}{36\pi^2}r^2$ $=0.0697r^2$
p. 	$b_2h_2-b_1h_1$	$\frac{1}{12}(b_2h_2^3-b_1h_1^3)$	$\frac{1}{6}\frac{b_2h_2^3-b_1h_1^3}{h_2}$	$\frac{1}{12}\frac{b_2h_2^3-b_1h_1^3}{b_2h_2-b_1h_1}$
q. 	$b_1h_1+b_2h_2$ $+b_3h_3$	$\frac{1}{3}(b_4e_1^3-b_1h_5^3$ $+b_5e_2^3-b_3h_4^3)$	$e_2=\frac{b_2h_2^2+b_3h_3^2+b_1h_1(2h_2-h_1)}{2(b_1h_1+b_2h_2+b_3h_3)}$	
r. 	$b_1h_1+b_2h_2$	$\frac{1}{3}(b_3e_2^3-b_1h_3^3$ $+b_2e_1^3)$	$e_2=\frac{b_1h_1^2+b_2h_2^2}{2(b_1h_1+b_2h_2)}$ $e_1=h_2-e_2$	$\frac{1}{3}\frac{b_3e_2^3-b_1h_3^3+b_2e_1^3}{b_1h_1+b_2h_2}$
s. 	$b_1h_1+b_2h_2$	$\frac{1}{12}(b_1h_1^3+b_2h_2^3)$	$\frac{1}{6}\frac{b_1h_1^3+b_2h_2^3}{h_2}$	$\frac{1}{12}\frac{b_1h_1^3+b_2h_2^3}{b_1h_1+b_2h_2}$

(4) Twist of shaft of cross section shape

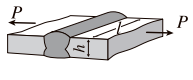
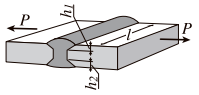
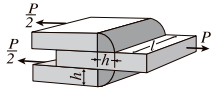
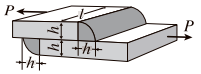
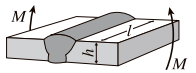
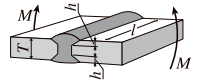
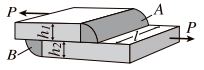
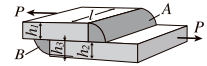
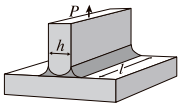
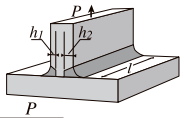
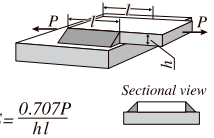
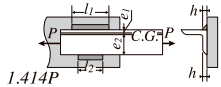
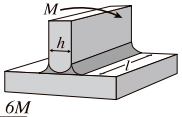
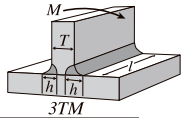
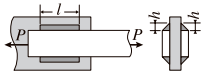
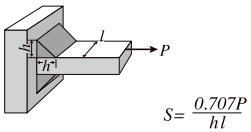
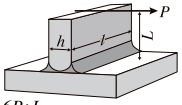
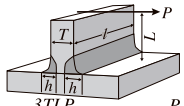
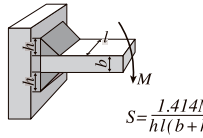
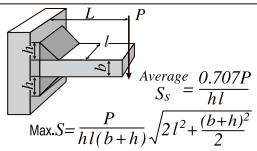
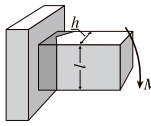
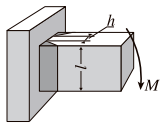
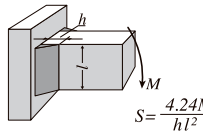
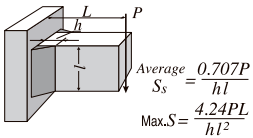
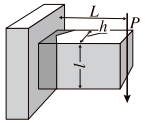
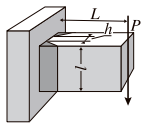
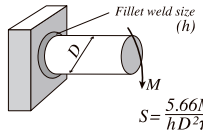
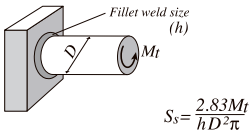
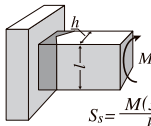
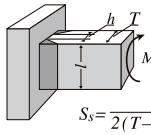
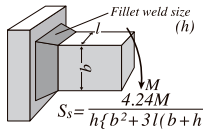
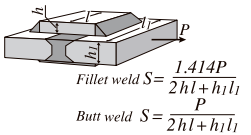
Cross section shape	Polar moment of inertia $Ip[cm^4]$	Max sharing stress $\tau\ max\ [kg/cm^2]$	Twisting angleθ against length l $\theta[rad]$
a. 	$\frac{\pi d^4}{32}$	$\frac{16T}{\pi d^3}$ (Outer corner)	$\frac{32}{\pi d^4}\ \frac{Tl}{G}$
b. 	$\frac{\pi (d_2^4-d_1^4)}{32}$	* $\frac{16d_2T}{\pi(d_2^4-d_1^4)}$ (Outer corner)	$\frac{32}{\pi(d_2^4-d_1^4)}\ \frac{Tl}{G}$
c. 	$\frac{\pi a^3b^3}{a^2+b^2}$	$\frac{T}{\pi ab^2}$	$\frac{a^2+b^2}{\pi a^3b^3}\ \frac{Tl}{G}$
d. 	k_3ab^3 k_3 Following table	$\frac{1}{k_1}\ \frac{T}{ab^2}$ k_1 Following table	$\frac{1}{k_3}\ \frac{Tl}{ab^3G}$ k_3 Following table
e. 	$0.1041a^4$	$\frac{T}{0.208a^3}$	$\frac{7.114}{a^4}\ \frac{Tl}{G}$
f. 	$\frac{a^4}{46.2}$	$\frac{20T}{a^3}$	$\frac{80}{\sqrt{3}\ a^4}\ \frac{Tl}{G}$
g. 	$\frac{a^4}{38.3}$	$\frac{17.58T}{a^3}$	$\frac{38.3}{a^4}\ \frac{Tl}{G}$
h. 	$1.04a^4$	$\frac{4.61T}{Ad}=5.32\frac{T}{d^3}$ $d=\sqrt{3}a$ $A=\frac{3}{2\sqrt{3}}d^2=0.866d^2$	$\frac{7.52}{Ad^2}\ \frac{Tl}{G}$ A=Cross section

a / b	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0	8.0	10.0	∞
k1	0.208	0.231	0.246	0.258	0.267	0.282	0.292	0.298	0.307	0.312	0.333
k2	1.000	0.859	0.759	0.766	—	0.745	0.743	—	0.743	0.743	0.743
k3	0.141	0.196	0.229	0.249	0.263	0.281	0.291	0.298	0.307	0.312	0.333

(5) Beam

Beam (elastic curve)	 $\delta_0=\frac{Pb^3}{3EI}\left(1+\frac{3a}{2b}\right),\delta_a=\frac{Pb^3}{3EI}$ $\phi_0=\phi_a=-\frac{Pb^2}{2EI}$	 $\delta_0=\frac{-Tb^2}{2EI}\left(1+\frac{2a}{b}\right),\delta_a=\frac{-Tb^2}{2EI}$ $\phi_0=\phi_a=\frac{Tb}{EI}$	 All loads : $\bar{P}=pl$ $\delta_0=\frac{\bar{P}l^3}{8EI},\phi_0=\frac{-\bar{P}l^2}{6EI}$
M (bending moment)	 $M_0=0,\ M_a=0,\ M_l=Pb$	 $M_0=0,\ M_{a+}=M_l=-T$	 $M_0=0,\ M_l=\frac{\bar{P}l}{2}$
F (shearing force)	 $F_0=0$ $\quad F_l=P$	 $F=0(\text{const.})$	 $F_0=0$ $\quad F_l=P$
Some formula	$0\sim a$: $\delta=\frac{Pb^3}{3EI}\left[1+\frac{3(a-x)}{2b}\right]$ $M=0,\ F=0$ $a\sim l$: $\delta=\frac{Pb^3}{3EI}\left[1-\frac{3(a-x)}{2b}+\frac{(x-a)^3}{2b^3}\right]$ $M=Pb(x-a)/l$ $F=P$	$0\sim a$: $\delta=\frac{-Tb^2}{2EI}\left[1+\frac{2(a-x)}{b}\right]$ $M=0,\ F=0$ $a\sim b$: $\delta=\frac{-T}{2EI}(l-x)^2$ $M=-T$ $F=0$	$0\sim l$: $\delta=\frac{\bar{P}l^3}{8EI}\left(1-\frac{4x}{3l}+\frac{x^4}{3l^4}\right)$ $\phi=\frac{-\bar{P}l^2}{6EI}\left(1-\frac{x^3}{l^3}\right)$ $M=\frac{\bar{P}x^2}{2l}$ $F=\frac{\bar{P}x}{l}$
Beam (elastic curve)	 All loads : $\bar{P}=p_l l/2$ $\delta_0=\frac{\bar{P}l^3}{15EI},\phi_0=\frac{-\bar{P}l^2}{12EI}$	 $\phi_0=\frac{Pl^2}{16EI},\phi_l=-\frac{Pl^2}{16EI}$ $\delta_{max}=\frac{Pl^3}{48EI}\ ;x=\frac{l}{2}$	 $\phi_0=\frac{Pb}{6EIl}\left(l^2-b^2\right),\phi_l=\frac{-Pa}{6EI}\left(l^2-a^2\right)$ $\delta_a=\frac{Pa^2b^2}{3EIl},\ \phi_a=\frac{-Pab(a-b)}{3EIl}$ $\delta_{max}=\frac{Pb(l^2-b^2)^{3/2}}{9\sqrt{3}EIl}\ x=\left[(l^2-b^2)/3\right]^{1/2}$
M (bending moment)	 $M_0=0$ $\quad M_l=Pl/3$	 $M_0=0$ $\quad M_l=0$ $M_{max}=M_{l/2}=Pl/4$	 $M_0=0$ $\quad M_l=0$ $M_a=-Pab/l$
F (shearing force)	 $F_0=0$ $\quad F_l=P$	 $F_0=-P/2$ $\quad F_l=P/2$	 $F_0=-Pb/l$ $\quad F_l=Pa/l$
Various formula	$0\sim l$: $\delta=\frac{\bar{P}l^3}{15EI}\left(1-\frac{5x}{4l}+\frac{x^5}{4l^5}\right)$ $\phi=\frac{-\bar{P}l^2}{12EI}\left(1-\frac{x^4}{l^4}\right)$ $M=\frac{\bar{P}x^3}{3l^2}$ $F=\frac{\bar{P}x^2}{l^2}$	$0\sim l/2$: $\delta=\frac{Pl^3}{48EI}\left(\frac{3x}{l}-\frac{4x^3}{l^3}\right)$ $\phi=\frac{Pl^2}{16EI}\left(1-\frac{4x^2}{l^2}\right)$ $M=-Px/2$ $F=-P/2$	$0\sim a$: $\delta=\frac{Pbx}{6EIl}\left[2l(l-x)-b^2-(l-x)^2\right]$ $M=-Pbx/l$ $F=-Pb/l$ $a\sim l$: $\delta=\frac{Pa(l-x)}{6EIl}\left[2lb-b^2-(l-x)^2\right]$ $M=-Pa(l-x)/l$ $F=Pa/l$

(6) Welding strength

 $S=\frac{P}{hl}$	 $S=\frac{P}{(h_1+h_2)l}$	 $S=\frac{0.707P}{hl}$	 $S=\frac{0.707P}{hl}$
 $S=\frac{6M}{lh^2}$	 $S=\frac{3TM}{lh(3T^2-6Th+4h^2)}$	 The stress of A and B is equal $S=\frac{1.414P}{(h_1+h_2)l}$	 $A: S=\frac{1.414P}{(h_1+h_2)l}$ $B: S=\frac{1.414Ph_2}{h_3l(h_1+h_2)}$
 $S=\frac{P}{hl}$	 $S=\frac{P}{(h_1+h_2)l}$	 $S=\frac{0.707P}{hl}$	 $S=\frac{1.414P}{h(l_1+l_2)}$ $l_1=\frac{1.414Pe_2}{Shb}$; $l_2=\frac{1.414Pe_1}{Shb}$
 $S=\frac{6M}{lh^2}$	 $S=\frac{3TM}{lh(3T^2-6Th+4h^2)}$	 $S=\frac{0.354P}{hl}$	 $S=\frac{0.707P}{hl}$
 $S=\frac{6P\cdot L}{lh^2}$ $S_s=\frac{P}{lh}$	 $S=\frac{3TLP}{lh(3T^2-6Th+4h^2)}$, $S_s=\frac{P}{2lh}$	 $S=\frac{1.414M}{hl(b+h)}$	 Average $S_s=\frac{0.707P}{hl}$ Max.$S=\frac{P}{hl(b+h)}\sqrt{2l^2+\frac{(b+h)^2}{2}}$
 $S=\frac{6M}{hl^2}$	 $S=\frac{3M}{hl^2}$	 $S=\frac{4.24M}{hl^2}$	 Average $S_s=\frac{0.707P}{hl}$ Max.$S=\frac{4.24PL}{hl^2}$
 $S=\frac{6PL}{hl^2}$ $S_s=\frac{P}{hl}$	 $S=\frac{3PL}{hl^2}$ $S_s=\frac{P}{2hl}$	 $S=\frac{5.66M}{hD^2\pi}$	 $S_s=\frac{2.83M_t}{hD^2\pi}$
 $S_s=\frac{M(3l+1.8h)}{h^2l^2}$	 $S_s=\frac{M}{2(T-h)(l-h)h}$	 $S_s=\frac{4.24M}{h\{b^2+3l(b+h)\}}$	 Fillet weld $S=\frac{1.414P}{2hl+h_1l_1}$ Butt weld $S=\frac{P}{2hl+h_1l_1}$

10-5 Formula of Electricity

Formula of Electricity-1

Relation between frequency and cycle	$f = \frac{1}{T}\ [Hz]$
Relation between instantaneous magnitude and effective value of electric current	$I = \sqrt{i^2\ Average}\ \ [A]$
Relation of effective value of sine wave current	$I = \frac{1}{\sqrt{2}}\ Im\ [A]$
Ohm's law	$I = \frac{E}{R}\ [A]$
Relation of magnitude between voltage and current of inductive circuit	$I = \frac{E}{\omega L} = \frac{E}{X_L}\ [A]$
Relation of magnitude between voltage and current of capacitance circuit	$I = \frac{E}{\frac{1}{\omega C}} = \frac{E}{X_C}\ [A]$
Impedance of LR straight circuit	$Z = \sqrt{R^2 + \omega^2 L^2}\ [\Omega]$
Impedance of RC straight circuit	$Z = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}\ [\Omega]$
Composite reactance of LC straight circuit	$X = \omega L - \frac{1}{\omega C} = (X_L - X_C)\ \ [\Omega]$
Impedance of LRC straight circuit	$Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}\ \ [\Omega]$
Resonance frequency	$f_0 = \frac{1}{2\pi\sqrt{LC}}\ [Hz]$
Voltage expansion of series resonance	$\frac{E_L}{E} = \frac{\omega_0 L}{R} \qquad \frac{E_C}{E} = \frac{1}{\omega_0 CR}$
Voltage expansion of parallel resonance	$\frac{I_L}{I_0} = \frac{I_C}{I_0} = \frac{\omega L}{R} = \frac{1}{\omega CR}$
Inductive reactance expressed by symbolic method	$\dot{I} = \frac{\dot{E}}{j\omega l} = -j\frac{\dot{E}}{\omega L}\ [A]$
Capacitive reactance expressed by symbolic method	$\dot{I} = \frac{\dot{E}}{-j\frac{1}{\omega C}} = j\frac{\dot{E}}{\frac{1}{\omega C}}\ [A]$
LRC impedance expressed by symbolic method	$\dot{Z} = R + j(\omega L - \frac{1}{\omega C})\ [\Omega]$
Admittance	$\dot{Y} = \frac{1}{Z} = g + jb = (\frac{R}{R^2+X^2} - j\frac{X}{R^2+X^2})\ [\Omega]$
Resonance frequency in case coil with resistance	$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}\ [Hz]$

Formula of Electricity-2

Parallel condition of impedance bridge	$\dot{Z}_1\dot{Z}_4 = \dot{Z}_2\dot{Z}_3$
Electricity of AC circuit	$P = EI\cos\phi \ [W]$
Power factor	$\cos\phi = \frac{P}{EI} = \frac{EI\cos\phi}{EI} = \frac{R}{Z}$
Relation of volt-ampere, effective power and reactive power	$EI = \sqrt{(EI\cos\phi)^2 + (EI\sin\phi)^2} \ [VA]$
Calculation of AC electric power by symbolic method	$\dot{E}\dot{I}' = (E_1 + jE_2)(I_1 - jI_2)$ $= (P_a + jP_r) \ [W, Var]$ $\dot{E}'\dot{I} = (E_1 - jE_2)(I_1 + jI_2)$ $= (P_a - jP_r) \ [W, Var]$
Balanced three phase AC voltage	$e_a = \sqrt{2}E\sin\omega t \ [V]$ $e_b = \sqrt{2}E\sin(\omega t - \frac{2\pi}{3}) \ [V]$ $e_c = \sqrt{2}E\sin(\omega t - \frac{4\pi}{3}) \ [V]$
Symbolic method expression of balanced three phase AC	$\dot{E}_a = E \ [V]$ $\dot{E}_b = E(-\frac{1}{2} - j\frac{\sqrt{3}}{2}) \ [V]$ $\dot{E}_c = E(-\frac{1}{2} + j\frac{\sqrt{3}}{2}) \ [V]$
Relation between phase voltage and line voltage of balanced three phrases Y- connection	$E_l = \sqrt{3}E_s \ [V]$
Relation between line circuit and phase current of balanced three Δ-connection	$I_l = \sqrt{3}I_s \ [A]$
Effective electric power of balanced three phase AC current	$P_a = \sqrt{3}E_lI_l\cos\phi = 3E_sI_s\cos\phi \ [W]$
Reactive electric power of balanced three phase AC current	$P_r = \sqrt{3}E_lI_l\sin\phi \ [Var]$
Apparent power of balanced three phase AC current	$VA = \sqrt{3}E_lI_l \ [VA]$