TORQUE DESIGN INFORMATION TABLES

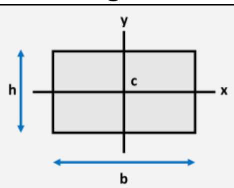
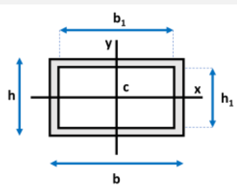
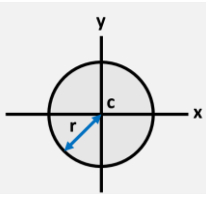
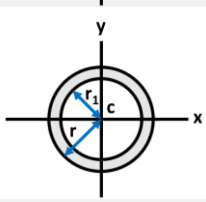
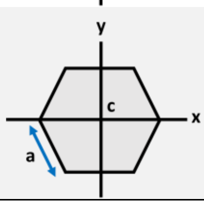
7x7 Strand Stainless Steel Cable Tensile Strength

D (in)	T (lbf)
3/64	270
1/16	480
3/32	920
1/8	1700
5/32	2400
3/16	3700
1/4	6100

12 Strand Spectra Tensile Strength

D (in)	T (lbf)
1/8	1800
3/16	3600
1/4	6000

Material	7075-T6	6061-T6	Delrin	ABS PC
Elastic Modulus (GPa)	71.7	68.9	3	2.64
Tensile Yield (MPa)	462	276	66	56.4
Density (kg/m^3)	2810	2700	1410	1070

Diagram	Area Moment of Inertia
	$I_x = \frac{bh^3}{12} \quad I_y = \frac{b^3 h}{12}$
	$I_x = \frac{bh^3 - b_1 h_1^3}{12} \quad I_y = \frac{b^3 h - b_1^3 h_1}{12}$
	$I_x = I_y = \frac{\pi r^4}{4}$
	$I_x = I_y = \frac{\pi}{4}(r^4 - r_1^4)$
	$I_x = I_y = \frac{5\sqrt{3}}{16} a^4$

TORQUE DESIGN FORMULA SHEET

GEARS

$T = D[dp]$

$[rd] = \frac{T_1+T_2}{2[dp]} + 0.008$

$$\omega_n = \omega_1 \prod_{i=1}^{n/2} -\frac{T_{2i-1}}{T_{2i}}$$

$$\tau_n = \tau_1 \prod_{i=1}^{n/2} -\frac{T_{2i}}{T_{2i-1}}$$

T = teeth
D = diameter
$[dp]$ = diametral pitch
$[cd]$ = center distance
$[rd]$ = recommended distance
ω = angular velocity
i = i^th^ gear (starts at 1)
I = moment of inertia

$$I_{gear} \lesssim \left(\frac{T}{28.7[dp]}\right)^4$$

$$I_{in} = \left(\frac{T_1}{T_2}\right)^2 (I_{out} + I_{G2}) + I_{G1}$$

$$I_{in} \gtrsim I_{out} \prod_{i=1}^{n/2} \left(\frac{T_{2i-1}}{T_{2i}}\right)^2$$

MOTORS

$$t_{spinup} = -\frac{I_{system}\omega_{max}}{\tau_{max}} \ln 0.01$$

$$\omega_{int} = \omega_{max}\left(1 - \frac{\tau_{load}}{\tau_{max}}\right)$$

ROPES

$$F_{T\,load} = F_{T\,in} e^{\mu\theta}$$

μ = coefficient of friction between rope and bar
θ = wrap angle in radians

BELTS

$T = L/p$

$$L \approx 2[cd] + \frac{\pi}{2}(D+d)$$

$$L = 2[cd] + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4[cd]}$$

L = path length
p = pitch
D = large pulley diameter
d = small pulley diameter

ARMS

$$\Delta\theta_{\frac{wrist}{arm}} = \frac{r_{base}}{r_{wrist}} \Delta\theta_{base}$$

$$\Delta\theta_{\frac{wrist}{ground}} = \Delta\theta_{base} - \Delta\theta_{\frac{wrist}{arm}}$$

θ = angle

PROJECTILES

$x = v_{x0}t + x_0$

$$y = -\frac{1}{2}gt^2 + v_{y0}t + y_0$$

$$v_{y0} = v_{x0}\tan(\theta_f) + \frac{gl}{v_{x0}}$$

$$v_{x0} = \sqrt{\frac{gl^2}{2\left(h - \tan(\theta_f)l\right)}}$$

$$\omega_p = \frac{Fr}{I\omega}$$

x = horizontal position
y = vertical position
t = time
v = velocity
g = acceleration due to gravity
θ_f = ending angle
l = horizontal distance to target
h = height of target
ω_p = precessional velocity

TORQUE DESIGN FORMULA SHEET

STATICS	
$V = -\int w\,dx$	x = dimension along the length of the beam w = applied load (weight) V = shear force M = bending moment Q = first moment of area I = area moment of inertia b = section width y = distance to neutral axis
$M = \int V\ dx$	
Q = area above axis of interest * distance from neutral axis to centroid of area	
$\sigma_V = \frac{VQ}{Ib}$	
$\sigma_M = \frac{My}{I}$	

<u>Cascade Elevator Torque Sequence:</u>

$$\tau = m_2 r\left(a_{n+1}\left(\frac{L_1}{L_1 + L_2 + \cdots + L_n}\right) + g\right) + 2m_3 r\left(a_{n+1}\left(\frac{L_1 + L_2}{L_1 + L_2 + \cdots + L_n}\right) + g\right) + \cdots$$
$$+2^{n-1} m_{n+1} r\left(a_{n+1}\left(\frac{L_1 + L_2 + \cdots + L_m}{L_1 + L_2 + \cdots + L_n}\right) + g\right)$$

<u>Gearbox Inertia Sequence (n=6):</u>

$$I_{out} = (I_{in} - I_{G1})\left(\frac{T_2}{T_1}\right)^2\left(\frac{T_4}{T_3}\right)^2\left(\frac{T_6}{T_5}\right)^2 - I_{G2}\left(\frac{T_4}{T_3}\right)^2\left(\frac{T_6}{T_5}\right)^2 - I_{G3}\left(\frac{T_4}{T_3}\right)^2\left(\frac{T_6}{T_5}\right)^2 - I_{G4}\left(\frac{T_6}{T_5}\right)^2 - I_{G5}\left(\frac{T_6}{T_5}\right)^2 - I_{G6}$$