

Barrel Transverse Shear-Wave Natural Mode Frequencies (Calculated in MKS Units)

Barrel Inputs:		MKS Units	
Vibrational Length (L)	0.685800	meters	
Caliber (d)	0.006706	meters	
Total Barrel Mass (lbm, Kg)	4.020	kg	
Effective Diameter (D)	0.031750	meters	
416R Stainless Steel:			
Elasticity (E)	200.00	Giga Pascals (GN/m^2)	N = kg*m/sec^2
Density (rho)	7750.00	kg/m^3	
Transverse Wave Speed	3054.35	m/sec	
Calculated Values:			
Areal 2nd Mom (I) =	(Pi/32)*[D^4 - d^4]	9.95655E-08	meters^4
Cross-Section Area (A) =	(Pi/4)*[D^2 - d^2]	0.000756411	meters^2
Transverse Shear-Wave Speed	SQRT[G/rho] =	3054.35	meters/second
Flexural rigidity	E*I =	19913.09	kg*m^3/sec^2
	I/A =	0.000131629	meters^2
Mass per unit length	A*rho =	5.8622	kg/meter
	SQRT[E*I/(A*rho)] =	58.2827	m^2/second
Natural frequency constant	SQRT[E*I/(A*rho)]/L^2 =	123.9210	radians/second

Cantilever Beam Mode Frequency Eqn: $\omega(n) = 2 \cdot \pi \cdot f(n) = [a(n)/L^2] \cdot \text{SQRT}[E \cdot I/(A \cdot \rho)]$
[Clamped-Free Ends]

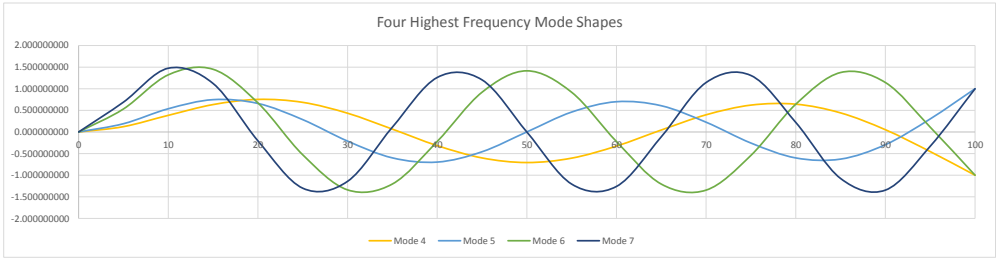
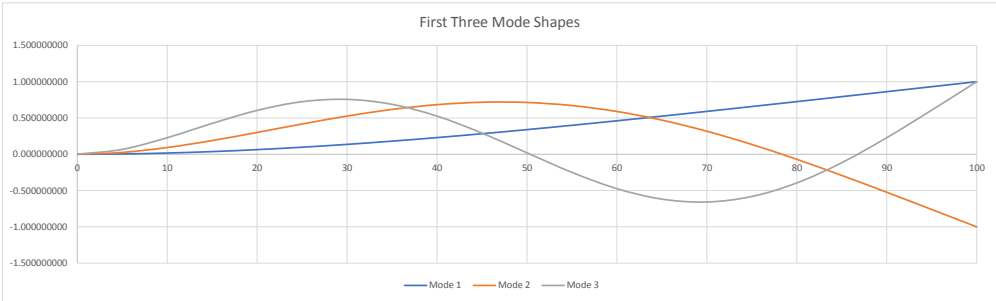
First 7 Transverse Modes:		Mode Frequencies	Mode Frequencies
Mode No. (n)	[a(n) = Lambda(n) Squared]	omega(n) (radians/sec)	f(n) (hertz)
1	3.516015	435.71	69.35
2	22.034492	2730.54	434.58
3	61.697214	7645.58	1216.83
4	120.901916	14982.28	2384.50
5	199.859530	24766.79	3941.76
6	298.555533	36997.29	5888.30
7	416.990786	51673.90	8224.16
(etc.)	[(Pi/2)*(2^n - 1)]^2		

Barrel Natural Mode Shapes Normalized for Unit Amplitude at Muzzle

[Amplitude Envelope of Sinusoidal Vibrations for each Location along Barrel Length (L)]
[Let X = Percent of Barrel Length (L) measured from Receiver Face to Muzzle.]

	Lambda(n) =	1.87510407	4.69409113	7.85475744	10.99554073	14.13716839	17.27875960	20.42035225
	Sigma(n) =	0.734095514	1.018467319	0.999224497	1.000033553	0.999998550	1.000000000	1.000000000
X (percent L)	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7	
0	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	0.000000000	
5	0.004294191	0.025348713	0.067037978	0.123466349	0.191116761	0.532456873	0.690369781	
10	0.016773500	0.092629298	0.228068902	0.385008085	0.537246470	1.321784175	1.474761366	
15	0.036833444	0.188785060	0.424800029	0.633749798	0.747553060	1.450022810	1.122121202	
20	0.063870931	0.301054990	0.604505968	0.753790258	0.659624791	0.673603083	-0.204392958	
25	0.097285808	0.417259094	0.724499863	0.685159226	0.285200206	-0.527892093	-1.300497160	
30	0.136482937	0.526132911	0.756239363	0.433869530	-0.211286962	-1.339389399	-1.141937731	
35	0.180874771	0.617674438	0.688068113	0.065739434	-0.599307290	-1.203451675	0.111745043	
40	0.229884375	0.683469448	0.525924626	-0.315559539	-0.696546857	-0.220235481	1.260357056	
45	0.282948851	0.716965009	0.291744020	-0.600551335	-0.458155657	0.918878162	1.205917424	
50	0.339523113	0.713665832	0.019687588	-0.707118629	0.000851469	1.414390559	0.000036793	
55	0.399083983	0.671233632	-0.249292938	-0.605285383	0.460302042	0.918532839	-1.205802031	
60	0.461134554	0.589475938	-0.473765256	-0.326494931	0.700254532	-0.221200301	-1.260068735	
65	0.525208787	0.470217237	-0.618051292	0.045213331	0.606507222	-1.205802033	-0.110956196	
70	0.590876299	0.317051799	-0.657425954	0.397390753	0.225728893	-1.344991436	1.144123426	
75	0.657747305	0.134983613	-0.581451671	0.621421359	-0.255994882	-0.541193740	1.306563188	
80	0.725477692	-0.070035863	-0.394873741	0.643038066	-0.600445869	0.642040520	0.221231820	
85	0.793774179	-0.291657173	-0.115831701	0.441656182	-0.627580010	1.375139149	-1.075376403	
90	0.862399544	-0.523751781	0.228507453	0.052034576	-0.293997027	1.144122978	-1.344997004	
95	0.931177901	-0.761081475	0.608479988	-0.453590555	0.302093996	0.110957985	-0.330141604	
100	1.000000001	-1.000000004	0.999999691	-0.999996244	1.000037467	-0.999999976	1.000000000	

[Clamped receiver end of barrel is always a transverse vibration node.]
[Transverse Mode Number = Number of Nodes.]



[After Blevins, *Formulas for Natural Frequency and Mode Shape*, 1979]

[For Cantilever Beam with Clamped and Free Ends]