AERO2358: Data sheets, tables and charts

Contents

Formulae

Equation of State

$$P = \rho RT \qquad R = \frac{\overline{R}}{\overline{M}}$$

$$h_2 - h_1 = C_P(T_2 - T_1) \qquad e_2 - e_1 = C_V(T_2 - T_1)$$

$$h = e + \frac{P}{\rho} \qquad T_O = T + \frac{V^2}{2C_P} \qquad \gamma = \frac{C_P}{C_V}$$

$$R = C_P - C_V \qquad \frac{R}{C_P} = \frac{\gamma - 1}{\gamma} \qquad \frac{R}{C_V} = \gamma - 1$$

Conservation of Mass

$$\frac{\partial}{\partial t}\iiint_{CV} \rho d\forall + \iint_S \rho \tilde{V} \cdot d\tilde{S} = 0$$

Conservation of Momentum

$$\frac{\partial}{\partial t}\iiint_{CV} \rho \tilde{V} d\forall + \iint_S \tilde{V}\left(\rho \tilde{V} \cdot d\tilde{S}\right) = \sum \tilde{F}$$

$$= \iiint_{CV} \rho \tilde{f}\, d\forall - \iint_S P d\tilde{S} + F_{VISCOUS}$$

Conservation of Energy

$$\frac{d}{dt}(Q - W) = \frac{\partial}{\partial t}\iiint_{CV}\left[\rho\left(e + \frac{V^2}{2}\right)\right]d\forall + \iint_S \left(e + \frac{V^2}{2}\right)\left(\rho \tilde{V} \cdot d\tilde{S}\right)$$

$$= \iiint_{CV} \dot{q}\rho \cdot d\forall + \iint_S P\tilde{V} \cdot d\tilde{S} + \iiint_{CV} \rho\left(\tilde{f} \cdot \tilde{V}\right) \cdot d\forall + \frac{d}{dt}(Q + W)_{VISCOUS}$$

$$\frac{d}{dt}(Q - W) = \frac{\partial}{\partial t}\iiint_{CV}\left[\rho\left(e + \frac{V^2}{2}\right)\right]d\forall + \iint_S \left(h + \frac{V^2}{2}\right)\left(\rho \tilde{V} \cdot d\tilde{S}\right)$$

$$= \iiint_{CV} \dot{q}\rho \cdot d\forall + \iiint_{CV} \rho\left(\tilde{f} \cdot \tilde{V}\right) \cdot d\forall + \frac{d}{dt}(Q + W)_{VISCOUS}$$

Adiabatic Flow

$$\frac{T_O}{T} = 1 + \frac{\gamma - 1}{2} M^2$$

Isentropic Flow

$$a^2 = \frac{dP}{d\rho} = \gamma RT = \frac{\gamma P}{\rho} \qquad P = k\rho^\gamma$$

$$\frac{P_O}{P} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{\gamma}{\gamma - 1}} \qquad \frac{\rho_O}{\rho} = \left(1 + \frac{\gamma - 1}{2} M^2\right)^{\frac{1}{\gamma - 1}}$$

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma - 1}{\gamma}} = \left(\frac{\rho_2}{\rho_1}\right)^{\gamma - 1} \qquad \frac{A}{A^*} = \frac{1}{M}\left[\frac{2}{\gamma + 1}\left(1 + \frac{\gamma - 1}{2} M^2\right)\right]^{\frac{1 + \gamma}{2(\gamma - 1)}}$$

Normal Shock Waves

$$M_2{}^2 = \frac{1 + \left(\frac{\gamma - 1}{2}\right) M_1{}^2}{\gamma M_1{}^2 - \left(\frac{\gamma - 1}{2}\right)} \qquad \frac{\rho_2}{\rho_1} = \frac{V_1}{V_2} = \frac{(\gamma + 1) M_1{}^2}{2 + (\gamma - 1) M_1{}^2}$$

$$\frac{P_2}{P_1} = 1 + \frac{2\gamma}{\gamma + 1}\left(M_1{}^2 - 1\right) \qquad \frac{T_2}{T_1} = \frac{h_2}{h_1} = \left[1 + \frac{2\gamma}{\gamma + 1}\left(M_1{}^2 - 1\right)\right]\left[\frac{2 + (\gamma - 1) M_1{}^2}{(\gamma + 1) M_1{}^2}\right]$$

Oblique Shock Waves

$$\frac{\tan(\beta - \theta)}{\tan\theta} = \frac{2 + (\gamma - 1)(M_1 \sin\beta)^2}{(\gamma + 1)(M_1 \sin\beta)^2} \qquad \cot\theta = \tan\beta\left[\left(\frac{\gamma + 1}{2}\right)\left(\frac{M_1{}^2}{M_1{}^2 \sin^2\beta - 1}\right) - 1\right]$$

Prandtl Meyer Flow

$$\mu = \sin^{-1}\left(\frac{1}{M}\right) \qquad \nu(M) = \sqrt{\frac{\gamma + 1}{\gamma - 1}} \tan^{-1}\sqrt{\frac{\gamma - 1}{\gamma + 1}\left(M^2 - 1\right)} - \tan^{-1}\sqrt{M^2 - 1}$$

Isentropic Flow Properties of a Perfect Gas $\gamma = 1.4$

M	p_0/p	ρ_0/ρ	T_0/T	A/A^*
0.02	1.0003	1.0002	1.0001	28.942
0.04	1.0011	1.0008	1.0003	14.481
0.06	1.0025	1.0018	1.0007	9.6659
0.08	1.0045	1.0032	1.0013	7.2616
0.10	1.0070	1.0050	1.0020	5.8218
0.12	1.0101	1.0072	1.0029	4.8643
0.14	1.0138	1.0098	1.0039	4.1824
0.16	1.0180	1.0128	1.0051	3.6727
0.18	1.0229	1.0163	1.0065	3.2779
0.20	1.0283	1.0201	1.0080	2.9635
0.22	1.0343	1.0244	1.0097	2.7076
0.24	1.0409	1.0290	1.0115	2.4956
0.26	1.0481	1.0341	1.0135	2.3173
0.28	1.0560	1.0397	1.0157	2.1656
0.30	1.0644	1.0456	1.0180	2.0351
0.32	1.0735	1.0520	1.0205	1.9219
0.34	1.0833	1.0588	1.0231	1.8229
0.36	1.0937	1.0661	1.0259	1.7358
0.38	1.1048	1.0738	1.0289	1.6587
0.40	1.1166	1.0819	1.0320	1.5901
0.42	1.1290	1.0905	1.0353	1.5289
0.44	1.1422	1.0996	1.0387	1.4740
0.46	1.1561	1.1092	1.0423	1.4246
0.48	1.1708	1.1192	1.0461	1.3801
0.50	1.1862	1.1297	1.0500	1.3398
0.52	1.2024	1.1407	1.0541	1.3034
0.54	1.2194	1.1522	1.0583	1.2703
0.56	1.2373	1.1643	1.0627	1.2403
0.58	1.2560	1.1768	1.0673	1.2130
0.60	1.2755	1.1898	1.0720	1.1882
0.62	1.2959	1.2034	1.0769	1.1656
0.64	1.3173	1.2176	1.0819	1.1451
0.66	1.3396	1.2322	1.0871	1.1265
0.68	1.3628	1.2475	1.0925	1.1097
0.70	1.3871	1.2633	1.0980	1.0944
0.72	1.4124	1.2797	1.1037	1.0806
0.74	1.4387	1.2967	1.1095	1.0681
0.76	1.4661	1.3143	1.1155	1.0570
0.78	1.4947	1.3325	1.1217	1.0471
0.80	1.5243	1.3514	1.1280	1.0382
0.82	1.5552	1.3709	1.1345	1.0305
0.84	1.5873	1.3910	1.1411	1.0237
0.86	1.6207	1.4118	1.1479	1.0179
0.88	1.6553	1.4333	1.1549	1.0129
0.90	1.6913	1.4555	1.1620	1.0089
0.92	1.7287	1.4784	1.1693	1.0056
0.94	1.7675	1.5020	1.1767	1.0031
0.96	1.8078	1.5264	1.1843	1.0014
0.98	1.8496	1.5515	1.1921	1.0003
1.00	1.8929	1.5774	1.2000	1.0000
1.02	1.9379	1.6041	1.2081	1.0003
1.04	1.9846	1.6316	1.2163	1.0013
1.06	2.0330	1.6599	1.2247	1.0029
1.08	2.0831	1.6891	1.2333	1.0051
1.10	2.1351	1.7191	1.2420	1.0079

M	p_0/p	ρ_0/ρ	T_0/T	A/A^*
1.12	2.1890	1.7500	1.2509	1.0113
1.14	2.2449	1.7818	1.2599	1.0153
1.16	2.3028	1.8145	1.2691	1.0198
1.18	2.3628	1.8481	1.2785	1.0248
1.20	2.4250	1.8827	1.2880	1.0304
1.22	2.4894	1.9183	1.2977	1.0366
1.24	2.5560	1.9549	1.3075	1.0432
1.26	2.6251	1.9925	1.3175	1.0504
1.28	2.6967	2.0311	1.3277	1.0581
1.30	2.7707	2.0708	1.3380	1.0663
1.32	2.8474	2.1116	1.3485	1.0750
1.34	2.9269	2.1535	1.3591	1.0842
1.36	3.0091	2.1965	1.3699	1.0940
1.38	3.0942	2.2407	1.3809	1.1042
1.40	3.1823	2.2861	1.3920	1.1149
1.42	3.2734	2.3327	1.4033	1.1262
1.44	3.3678	2.3805	1.4147	1.1379
1.46	3.4654	2.4296	1.4263	1.1501
1.48	3.5665	2.4800	1.4381	1.1629
1.50	3.6710	2.5317	1.4500	1.1762
1.52	3.7792	2.5848	1.4621	1.1899
1.54	3.8911	2.6392	1.4743	1.2042
1.56	4.0068	2.6951	1.4867	1.2190
1.58	4.1266	2.7524	1.4993	1.2344
1.60	4.2504	2.8111	1.5120	1.2502
1.62	4.3785	2.8714	1.5249	1.2666
1.64	4.5110	2.9332	1.5379	1.2836
1.66	4.6479	2.9965	1.5511	1.3010
1.68	4.7896	3.0614	1.5645	1.3190
1.70	4.9360	3.1280	1.5780	1.3376
1.72	5.0874	3.1962	1.5917	1.3567
1.74	5.2439	3.2662	1.6055	1.3764
1.76	5.4057	3.3378	1.6195	1.3967
1.78	5.5729	3.4113	1.6337	1.4175
1.80	5.7458	3.4865	1.6480	1.4390
1.82	5.9244	3.5636	1.6625	1.4610
1.84	6.1091	3.6426	1.6771	1.4836
1.86	6.2998	3.7235	1.6919	1.5069
1.88	6.4970	3.8063	1.7069	1.5308
1.90	6.7006	3.8912	1.7220	1.5553
1.92	6.9111	3.9781	1.7373	1.5804
1.94	7.1284	4.0671	1.7527	1.6062
1.96	7.3530	4.1582	1.7683	1.6326
1.98	7.5849	4.2514	1.7841	1.6597
2.00	7.8244	4.3469	1.8000	1.6875
2.05	8.4581	4.5956	1.8405	1.7600
2.10	9.1447	4.8590	1.8820	1.8369
2.15	9.8881	5.1380	1.9245	1.9185
2.20	10.693	5.4333	1.9680	2.0050
2.25	11.563	5.7457	2.0125	2.0964
2.30	12.504	6.0759	2.0580	2.1931
2.35	13.521	6.4250	2.1045	2.2953
2.40	14.620	6.7937	2.1520	2.4031
2.45	15.806	7.1830	2.2005	2.5168
2.50	17.086	7.5938	2.2500	2.6367

Isentropic Flow Properties of a Perfect Gas $\gamma = 1.4$

M	p_0/p	ρ_0/ρ	T_0/T	A/A^*
2.55	18.466	8.0270	2.3005	2.7630
2.60	19.954	8.4839	2.3520	2.8960
2.65	21.557	8.9652	2.4045	3.0359
2.70	23.283	9.4723	2.4580	3.1830
2.75	25.140	10.006	2.5125	3.3377
2.80	27.138	10.568	2.5680	3.5001
2.85	29.286	11.159	2.6245	3.6707
2.90	31.594	11.780	2.6820	3.8498
2.95	34.073	12.433	2.7405	4.0376
3.00	36.733	13.119	2.8000	4.2346
3.05	39.586	13.839	2.8605	4.4410
3.10	42.646	14.595	2.9220	4.6573
3.15	45.925	15.388	2.9845	4.8838
3.20	49.437	16.219	3.0480	5.1210
3.25	53.196	17.091	3.1125	5.3691
3.30	57.219	18.005	3.1780	5.6286
3.35	61.520	18.961	3.2445	5.9000
3.40	66.117	19.963	3.3120	6.1837
3.45	71.029	21.011	3.3805	6.4801
3.50	76.272	22.108	3.4500	6.7896
3.55	81.868	23.255	3.5205	7.1128
3.60	87.837	24.453	3.5920	7.4501
3.65	94.200	25.706	3.6645	7.8020
3.70	100.98	27.015	3.7380	8.1691
3.75	108.20	28.381	3.8125	8.5517
3.80	115.89	29.807	3.8880	8.9506
3.85	124.07	31.295	3.9645	9.3661
3.90	132.77	32.847	4.0420	9.7990
3.95	142.01	34.465	4.1205	10.250
4.00	151.84	36.151	4.2000	10.719
4.05	162.27	37.908	4.2805	11.207
4.10	173.34	39.739	4.3620	11.715
4.15	185.09	41.644	4.4445	12.243
4.20	197.55	43.628	4.5280	12.792
4.25	210.75	45.692	4.6125	13.362
4.30	224.75	47.839	4.6980	13.955
4.35	239.57	50.072	4.7845	14.571
4.40	255.26	52.392	4.8720	15.210
4.45	271.86	54.804	4.9605	15.873
4.50	289.41	57.310	5.0500	16.562
4.55	307.98	59.912	5.1405	17.277
4.60	327.59	62.614	5.2320	18.018
4.65	348.32	65.418	5.3245	18.786
4.70	370.20	68.328	5.4180	19.583
4.75	393.30	71.346	5.5125	20.408
4.80	417.66	74.477	5.6080	21.264
4.85	443.37	77.722	5.7045	22.150
4.90	470.46	81.086	5.8020	23.067
4.95	499.01	84.571	5.9005	24.017
5.00	529.09	88.182	6.0000	25.000
5.05	560.76	91.921	6.1005	26.017
5.10	594.10	95.792	6.2020	27.070
5.15	629.18	99.799	6.3045	28.158
5.20	666.08	103.95	6.4080	29.283
5.25	704.88	108.24	6.5125	30.447

M	p_0/p	ρ_0/ρ	T_0/T	A/A^*
5.30	745.66	112.67	6.6180	31.649
5.35	788.52	117.26	6.7245	32.891
5.40	833.52	122.00	6.8320	34.175
5.45	880.78	126.90	6.9405	35.500
5.50	930.38	131.97	7.0500	36.869
5.55	982.43	137.20	7.1605	38.282
5.60	1037.0	142.60	7.2720	39.740
5.65	1094.3	148.18	7.3845	41.245
5.70	1154.3	153.94	7.4980	42.797
5.75	1217.2	159.89	7.6125	44.399
5.80	1283.0	166.02	7.7280	46.050
5.85	1352.0	172.35	7.8445	47.753
5.90	1424.2	178.88	7.9620	49.507
5.95	1499.8	185.61	8.0805	51.316
6.00	1578.9	192.55	8.2000	53.180
6.05	1661.6	199.70	8.3205	55.100
6.10	1748.1	207.07	8.4420	57.077
6.15	1838.5	214.66	8.5645	59.114
6.20	1932.9	222.48	8.6880	61.210
6.25	2031.6	230.54	8.8125	63.369
6.30	2134.7	238.84	8.9380	65.590
6.35	2242.4	247.38	9.0645	67.876
6.40	2354.7	256.17	9.1920	70.227
6.45	2471.9	265.21	9.3205	72.646
6.50	2594.2	274.52	9.4500	75.134
6.55	2721.8	284.10	9.5805	77.693
6.60	2854.8	293.95	9.7120	80.323
6.65	2993.5	304.08	9.8445	83.026
6.70	3138.0	314.49	9.9780	85.805
6.75	3288.6	325.20	10.113	88.660
6.80	3445.4	336.20	10.248	91.594
6.85	3608.7	347.51	10.385	94.607
6.90	3778.7	359.13	10.522	97.702
6.95	3955.7	371.06	10.661	100.88
7.00	4139.8	383.32	10.800	104.14
7.05	4331.4	395.91	10.941	107.49
7.10	4530.7	408.83	11.082	110.93
7.15	4737.9	422.10	11.225	114.46
7.20	4953.3	435.72	11.368	118.08
7.25	5177.2	449.70	11.513	121.79
7.30	5409.8	464.05	11.658	125.60
7.35	5651.5	478.76	11.805	129.51
7.40	5902.6	493.86	11.952	133.52
7.45	6163.3	509.34	12.101	137.63
7.50	6433.9	525.22	12.250	141.84
7.55	6714.9	541.50	12.401	146.16
7.60	7006.4	558.19	12.552	150.58
7.65	7308.9	575.30	12.705	155.12
7.70	7622.7	592.83	12.858	159.77
7.75	7948.1	610.80	13.013	164.53
7.80	8285.5	629.22	13.168	169.40
7.85	8635.3	648.08	13.325	174.40
7.90	8997.9	667.40	13.482	179.51
7.95	9373.6	687.19	13.641	184.75
8.00	9762.9	707.45	13.800	190.11

Normal Shock Properties $\gamma = 1.4$

M_1	p_2/p_1	ρ_2/ρ_1	T_2/T_1	p_{02}/p_{01}	p_{02}/p_1	M_2
1.00	1.00000	1.00000	1.00000	1.00000	1.89293	1.00000
1.02	1.04713	1.03344	1.01325	0.99999	1.93790	0.98052
1.04	1.09520	1.06709	1.02634	0.99992	1.98442	0.96203
1.06	1.14420	1.10092	1.03931	0.99975	2.03245	0.94445
1.08	1.19413	1.13492	1.05217	0.99943	2.08194	0.92771
1.10	1.24500	1.16908	1.06494	0.99893	2.13285	0.91177
1.12	1.29680	1.20338	1.07763	0.99821	2.18513	0.89656
1.14	1.34953	1.23779	1.09027	0.99726	2.23877	0.88204
1.16	1.40320	1.27231	1.10287	0.99605	2.29372	0.86816
1.18	1.45780	1.30693	1.11544	0.99457	2.34998	0.85488
1.20	1.51333	1.34161	1.12799	0.99280	2.40750	0.84217
1.22	1.56980	1.37636	1.14054	0.99073	2.46628	0.82999
1.24	1.62720	1.41116	1.15309	0.98836	2.52629	0.81830
1.26	1.68553	1.44599	1.16566	0.98568	2.58753	0.80709
1.28	1.74480	1.48084	1.17825	0.98268	2.64996	0.79631
1.30	1.80500	1.51570	1.19087	0.97937	2.71359	0.78596
1.32	1.86613	1.55055	1.20353	0.97575	2.77840	0.77600
1.34	1.92820	1.58538	1.21624	0.97182	2.84438	0.76641
1.36	1.99120	1.62018	1.22900	0.96758	2.91152	0.75718
1.38	2.05513	1.65494	1.24181	0.96304	2.97981	0.74829
1.40	2.12000	1.68966	1.25469	0.95819	3.04924	0.73971
1.42	2.18580	1.72430	1.26764	0.95306	3.11980	0.73144
1.44	2.25253	1.75888	1.28066	0.94765	3.19149	0.72345
1.46	2.32020	1.79337	1.29377	0.94196	3.26431	0.71574
1.48	2.38880	1.82777	1.30695	0.93600	3.33823	0.70829
1.50	2.45833	1.86207	1.32022	0.92979	3.41327	0.70109
1.52	2.52880	1.89626	1.33357	0.92332	3.48942	0.69413
1.54	2.60020	1.93033	1.34703	0.91662	3.56667	0.68739
1.56	2.67253	1.96427	1.36057	0.90970	3.64501	0.68087
1.58	2.74580	1.99808	1.37422	0.90255	3.72445	0.67455
1.60	2.82000	2.03175	1.38797	0.89520	3.80497	0.66844
1.62	2.89513	2.06526	1.40182	0.88765	3.88658	0.66251
1.64	2.97120	2.09863	1.41578	0.87992	3.96928	0.65677
1.66	3.04820	2.13183	1.42985	0.87201	4.05305	0.65119
1.68	3.12613	2.16486	1.44403	0.86394	4.13791	0.64579
1.70	3.20500	2.19772	1.45833	0.85572	4.22383	0.64054
1.72	3.28480	2.23040	1.47274	0.84736	4.31083	0.63545
1.74	3.36553	2.26289	1.48727	0.83886	4.39890	0.63051
1.76	3.44720	2.29520	1.50192	0.83024	4.48804	0.62570
1.78	3.52980	2.32731	1.51669	0.82151	4.57825	0.62104
1.80	3.61333	2.35922	1.53158	0.81268	4.66952	0.61650
1.82	3.69780	2.39093	1.54659	0.80376	4.76185	0.61209
1.84	3.78320	2.42244	1.56173	0.79476	4.85524	0.60780
1.86	3.86953	2.45373	1.57700	0.78569	4.94970	0.60363
1.88	3.95680	2.48481	1.59239	0.77655	5.04521	0.59957
1.90	4.04500	2.51568	1.60792	0.76736	5.14178	0.59562
1.92	4.13413	2.54633	1.62357	0.75812	5.23940	0.59177
1.94	4.22420	2.57675	1.63935	0.74884	5.33808	0.58802
1.96	4.31520	2.60695	1.65527	0.73954	5.43782	0.58437
1.98	4.40713	2.63692	1.67132	0.73021	5.53860	0.58082
2.00	4.50000	2.66667	1.68750	0.72087	5.64044	0.57735
2.05	4.73625	2.74002	1.72855	0.69751	5.89963	0.56906
2.10	4.97833	2.81190	1.77045	0.67420	6.16537	0.56128
2.15	5.22625	2.88231	1.81322	0.65105	6.43766	0.55395
2.20	5.48000	2.95122	1.85686	0.62814	6.71648	0.54706

Normal Shock Properties $\gamma = 1.4$

M_1	p_2/p_1	ρ_2/ρ_1	T_2/T_1	p_{02}/p_{01}	p_{02}/p_1	M_2
2.25	5.73958	3.01863	1.90138	0.60553	7.00182	0.54055
2.30	6.00500	3.08455	1.94680	0.58329	7.29368	0.53441
2.35	6.27625	3.14897	1.99311	0.56148	7.59205	0.52861
2.40	6.55333	3.21190	2.04033	0.54014	7.89691	0.52312
2.45	6.83625	3.27335	2.08846	0.51931	8.20828	0.51792
2.50	7.12500	3.33333	2.13750	0.49901	8.52614	0.51299
2.55	7.41958	3.39187	2.18746	0.47928	8.85048	0.50831
2.60	7.72000	3.44898	2.23834	0.46012	9.18131	0.50387
2.65	8.02625	3.50468	2.29015	0.44156	9.51862	0.49965
2.70	8.33833	3.55899	2.34289	0.42359	9.86240	0.49563
2.75	8.65625	3.61194	2.39657	0.40623	10.2127	0.49181
2.80	8.98000	3.66355	2.45117	0.38946	10.5694	0.48817
2.85	9.30958	3.71385	2.50672	0.37330	10.9326	0.48469
2.90	9.64500	3.76286	2.56321	0.35773	11.3022	0.48138
2.95	9.98625	3.81062	2.62064	0.34275	11.6784	0.47821
3.00	10.3333	3.85714	2.67901	0.32834	12.0610	0.47519
3.05	10.6863	3.90246	2.73833	0.31450	12.4500	0.47230
3.10	11.0450	3.94661	2.79860	0.30121	12.8455	0.46953
3.15	11.4096	3.98961	2.85982	0.28846	13.2475	0.46689
3.20	11.7800	4.03150	2.92199	0.27623	13.6559	0.46435
3.25	12.1563	4.07229	2.98511	0.26451	14.0708	0.46192
3.30	12.5383	4.11202	3.04919	0.25328	14.4921	0.45959
3.35	12.9263	4.15072	3.11422	0.24252	14.9199	0.45735
3.40	13.3200	4.18841	3.18021	0.23223	15.3542	0.45520
3.45	13.7196	4.22511	3.24715	0.22237	15.7949	0.45314
3.50	14.1250	4.26087	3.31505	0.21295	16.2420	0.45115
3.55	14.5363	4.29570	3.38391	0.20393	16.6956	0.44925
3.60	14.9533	4.32962	3.45373	0.19531	17.1556	0.44741
3.65	15.3763	4.36267	3.52451	0.18707	17.6221	0.44565
3.70	15.8050	4.39486	3.59624	0.17919	18.0951	0.44395
3.75	16.2396	4.42623	3.66894	0.17166	18.5745	0.44231
3.80	16.6800	4.45679	3.74260	0.16447	19.0603	0.44073
3.85	17.1263	4.48657	3.81723	0.15760	19.5526	0.43921
3.90	17.5783	4.51559	3.89281	0.15103	20.0513	0.43774
3.95	18.0363	4.54387	3.96936	0.14475	20.5565	0.43633
4.00	18.5000	4.57143	4.04688	0.13876	21.0681	0.43496
4.05	18.9696	4.59829	4.12535	0.13303	21.5861	0.43364
4.10	19.4450	4.62448	4.20479	0.12756	22.1106	0.43236
4.15	19.9263	4.65002	4.28520	0.12233	22.6416	0.43113
4.20	20.4133	4.67491	4.36657	0.11733	23.1790	0.42994
4.25	20.9063	4.69919	4.44891	0.11256	23.7228	0.42878
4.30	21.4050	4.72286	4.53221	0.10800	24.2731	0.42767
4.35	21.9096	4.74595	4.61648	0.10364	24.8298	0.42659
4.40	22.4200	4.76847	4.70171	9.9481E-02	25.3930	0.42554
4.45	22.9363	4.79044	4.78792	9.5501E-02	25.9626	0.42453
4.50	23.4583	4.81188	4.87509	9.1698E-02	26.5387	0.42355
4.55	23.9863	4.83280	4.96322	8.8062E-02	27.1212	0.42260
4.60	24.5200	4.85321	5.05233	8.4586E-02	27.7101	0.42168
4.65	25.0596	4.87313	5.14240	8.1263E-02	28.3055	0.42079
4.70	25.6050	4.89258	5.23343	7.8086E-02	28.9073	0.41992
4.75	26.1563	4.91156	5.32544	7.5047E-02	29.5156	0.41908
4.80	26.7133	4.93010	5.41842	7.2140E-02	30.1303	0.41826
4.85	27.2763	4.94820	5.51236	6.9359E-02	30.7514	0.41747
4.90	27.8450	4.96587	5.60727	6.6699E-02	31.3790	0.41670
4.95	28.4196	4.98314	5.70315	6.4153E-02	32.0130	0.41595

Normal Shock Properties $\gamma = 1.4$

M_1	p_2/p_1	ρ_2/ρ_1	T_2/T_1	p_{02}/p_{01}	p_{02}/p_1	M_2
5.00	29.0000	5.00000	5.80000	6.17163E-02	32.6535	0.41523
5.10	30.1783	5.03257	5.99660	5.71513E-02	33.9537	0.41384
5.20	31.3800	5.06367	6.19709	5.29659E-02	35.2797	0.41252
5.30	32.6050	5.09338	6.40144	4.91260E-02	36.6315	0.41127
5.40	33.8533	5.12178	6.60968	4.56005E-02	38.0091	0.41009
5.50	35.1250	5.14894	6.82180	4.23614E-02	39.4124	0.40897
5.60	36.4200	5.17492	7.03779	3.93833E-02	40.8414	0.40791
5.70	37.7383	5.19979	7.25767	3.66431E-02	42.2962	0.40690
5.80	39.0800	5.22360	7.48143	3.41200E-02	43.7768	0.40594
5.90	40.4450	5.24642	7.70907	3.17950E-02	45.2831	0.40503
6.00	41.8333	5.26829	7.94059	2.96509E-02	46.8152	0.40416
6.10	43.2450	5.28927	8.17599	2.76723E-02	48.3730	0.40333
6.20	44.6800	5.30939	8.41528	2.58448E-02	49.9566	0.40254
6.30	46.1383	5.32871	8.65845	2.41558E-02	51.5660	0.40179
6.40	47.6200	5.34726	8.90550	2.25936E-02	53.2011	0.40107
6.50	49.1250	5.36508	9.15643	2.11476E-02	54.8620	0.40038
6.60	50.6533	5.38221	9.41126	1.98080E-02	56.5486	0.39972
6.70	52.2050	5.39868	9.66996	1.85663E-02	58.2610	0.39909
6.80	53.7800	5.41452	9.93255	1.74144E-02	59.9991	0.39849
6.90	55.3783	5.42977	10.1990	1.63450E-02	61.7630	0.39791
7.00	57.0000	5.44444	10.4694	1.53515E-02	63.5526	0.39736
7.10	58.6450	5.45858	10.7436	1.44279E-02	65.3680	0.39683
7.20	60.3133	5.47220	11.0218	1.35686E-02	67.2092	0.39632
7.30	62.0050	5.48533	11.3038	1.27686E-02	69.0761	0.39583
7.40	63.7200	5.49799	11.5897	1.20233E-02	70.9687	0.39536
7.50	65.4583	5.51020	11.8795	1.13286E-02	72.8871	0.39491
7.60	67.2200	5.52199	12.1732	1.06804E-02	74.8313	0.39447
7.70	69.0050	5.53336	12.4707	1.00754E-02	76.8012	0.39405
7.80	70.8133	5.54435	12.7722	9.51020E-03	78.7969	0.39365
7.90	72.6450	5.55496	13.0775	8.98193E-03	80.8183	0.39326
8.00	74.5000	5.56522	13.3867	8.48783E-03	82.8655	0.39289
8.50	84.1250	5.61165	14.9911	6.44918E-03	93.4876	0.39121
9.00	94.3333	5.65116	16.6927	4.96386E-03	104.754	0.38980
9.50	105.125	5.68504	18.4915	3.86636E-03	116.663	0.38860
10.00	116.500	5.71429	20.3875	3.04475E-03	129.217	0.38758
10.50	128.458	5.73970	22.3807	2.42217E-03	142.414	0.38669
11.00	141.000	5.76190	24.4711	1.94506E-03	156.256	0.38592
11.50	154.125	5.78142	26.6587	1.57557E-03	170.740	0.38525
12.00	167.833	5.79866	28.9435	1.28662E-03	185.869	0.38466
12.50	182.125	5.81395	31.3255	1.05859E-03	201.642	0.38414
13.00	197.000	5.82759	33.8047	8.77092E-04	218.058	0.38368
13.50	212.458	5.83979	36.3812	7.31484E-04	235.118	0.38326
14.00	228.500	5.85075	39.0548	6.13796E-04	252.822	0.38289
14.50	245.125	5.86063	41.8257	5.18007E-04	271.170	0.38256
15.00	262.333	5.86957	44.6938	4.39529E-04	290.161	0.38226
15.50	280.125	5.87768	47.6591	3.74835E-04	309.797	0.38199
16.00	298.500	5.88506	50.7217	3.21193E-04	330.076	0.38174
16.50	317.458	5.89179	53.8814	2.76471E-04	350.998	0.38152
17.00	337.000	5.89796	57.1384	2.38991E-04	372.565	0.38131
17.50	357.125	5.90361	60.4926	2.07426E-04	394.775	0.38113
18.00	377.833	5.90881	63.9440	1.80718E-04	417.630	0.38095
18.50	399.125	5.91361	67.4926	1.58020E-04	441.127	0.38079
19.00	421.000	5.91803	71.1385	1.38649E-04	465.269	0.38065
19.50	443.458	5.92213	74.8816	1.22051E-04	490.055	0.38051
20.00	466.500	5.92593	78.7219	1.07775E-04	515.484	0.38039

One dimensional flow with heat addition $\gamma =$ 1.4

M	p/p^*	T/T^*	ρ/ρ^*	p_0/p_0^*	T_0/T_0^*
0.02	2.3987	0.0023	1042.3	1.2675	0.0019
0.04	2.3946	0.0092	261.00	1.2665	0.0076
0.06	2.3880	0.0205	116.32	1.2647	0.0171
0.08	2.3787	0.0362	65.688	1.2623	0.0302
0.10	2.3669	0.0560	42.250	1.2591	0.0468
0.12	2.3526	0.0797	29.519	1.2554	0.0666
0.14	2.3359	0.1069	21.842	1.2510	0.0895
0.16	2.3170	0.1374	16.859	1.2461	0.1151
0.18	2.2959	0.1708	13.443	1.2406	0.1432
0.20	2.2727	0.2066	11.000	1.2346	0.1736
0.22	2.2477	0.2445	9.192	1.2281	0.2057
0.24	2.2209	0.2841	7.817	1.2213	0.2395
0.26	2.1925	0.3250	6.747	1.2140	0.2745
0.28	2.1626	0.3667	5.898	1.2064	0.3104
0.30	2.1314	0.4089	5.213	1.1985	0.3469
0.32	2.0991	0.4512	4.652	1.1904	0.3837
0.34	2.0657	0.4933	4.188	1.1822	0.4206
0.36	2.0314	0.5348	3.798	1.1737	0.4572
0.38	1.9964	0.5755	3.469	1.1652	0.4935
0.40	1.9608	0.6151	3.188	1.1566	0.5290
0.42	1.9247	0.6535	2.945	1.1480	0.5638
0.44	1.8882	0.6903	2.736	1.1394	0.5975
0.46	1.8515	0.7254	2.552	1.1308	0.6301
0.48	1.8147	0.7587	2.392	1.1224	0.6614
0.50	1.7778	0.7901	2.250	1.1141	0.6914
0.52	1.7409	0.8196	2.124	1.1059	0.7199
0.54	1.7043	0.8469	2.012	1.0979	0.7470
0.56	1.6678	0.8723	1.912	1.0901	0.7725
0.58	1.6316	0.8955	1.822	1.0826	0.7965
0.60	1.5957	0.9167	1.741	1.0753	0.8189
0.62	1.5603	0.9358	1.667	1.0682	0.8398
0.64	1.5253	0.9530	1.601	1.0615	0.8592
0.66	1.4908	0.9682	1.540	1.0550	0.8771
0.68	1.4569	0.9814	1.484	1.0489	0.8935
0.70	1.4235	0.9929	1.434	1.0431	0.9085
0.72	1.3907	1.0026	1.387	1.0376	0.9221
0.74	1.3585	1.0106	1.344	1.0325	0.9344
0.76	1.3270	1.0171	1.305	1.0278	0.9455
0.78	1.2961	1.0220	1.268	1.0234	0.9553
0.80	1.2658	1.0255	1.234	1.0193	0.9639
0.82	1.2362	1.0276	1.203	1.0157	0.9715
0.84	1.2073	1.0285	1.174	1.0124	0.9781
0.86	1.1791	1.0283	1.147	1.0095	0.9836
0.88	1.1515	1.0269	1.121	1.0070	0.9883
0.90	1.1246	1.0245	1.098	1.0049	0.9921
0.92	1.0984	1.0212	1.076	1.0031	0.9951
0.94	1.0728	1.0170	1.055	1.0017	0.9973
0.96	1.0479	1.0121	1.035	1.0008	0.9988
0.98	1.0236	1.0064	1.017	1.0002	0.9997
1.00	1.0000	1.0000	1.000	1.0000	1.0000
1.02	0.9770	0.9930	0.9838	1.0002	0.9997
1.04	0.9546	0.9855	0.9686	1.0008	0.9989
1.06	0.9327	0.9776	0.9542	1.0017	0.9977
1.08	0.9115	0.9691	0.9406	1.0031	0.9960
1.10	0.8909	0.9603	0.9277	1.0049	0.9939

M	p/p^*	T/T^*	ρ/ρ^*	p_0/p_0^*	T_0/T_0^*
1.12	0.8708	0.9512	0.9155	1.0070	0.9915
1.14	0.8512	0.9417	0.9039	1.0095	0.9887
1.16	0.8322	0.9320	0.8930	1.0124	0.9856
1.18	0.8137	0.9220	0.8826	1.0157	0.9823
1.20	0.7958	0.9118	0.8727	1.0194	0.9787
1.22	0.7783	0.9015	0.8633	1.0235	0.9749
1.24	0.7613	0.8911	0.8543	1.0279	0.9709
1.26	0.7447	0.8805	0.8458	1.0328	0.9668
1.28	0.7287	0.8699	0.8376	1.0380	0.9624
1.30	0.7130	0.8592	0.8299	1.0437	0.9580
1.32	0.6978	0.8484	0.8225	1.0497	0.9534
1.34	0.6830	0.8377	0.8154	1.0561	0.9487
1.36	0.6686	0.8269	0.8086	1.0629	0.9440
1.38	0.6546	0.8161	0.8021	1.0701	0.9391
1.40	0.6410	0.8054	0.7959	1.0777	0.9343
1.42	0.6278	0.7947	0.7900	1.0856	0.9293
1.44	0.6149	0.7840	0.7843	1.0940	0.9243
1.46	0.6024	0.7735	0.7788	1.1028	0.9193
1.48	0.5902	0.7629	0.7736	1.1120	0.9143
1.50	0.5783	0.7525	0.7685	1.1215	0.9093
1.52	0.5668	0.7422	0.7637	1.1315	0.9042
1.54	0.5555	0.7319	0.7590	1.1419	0.8992
1.56	0.5446	0.7217	0.7545	1.1527	0.8942
1.58	0.5339	0.7117	0.7502	1.1640	0.8892
1.60	0.5236	0.7017	0.7461	1.1756	0.8842
1.62	0.5135	0.6919	0.7421	1.1877	0.8792
1.64	0.5036	0.6822	0.7383	1.2002	0.8743
1.66	0.4940	0.6726	0.7345	1.2131	0.8694
1.68	0.4847	0.6631	0.7310	1.2264	0.8645
1.70	0.4756	0.6538	0.7275	1.2402	0.8597
1.72	0.4668	0.6445	0.7242	1.2545	0.8549
1.74	0.4581	0.6355	0.7210	1.2692	0.8502
1.76	0.4497	0.6265	0.7178	1.2843	0.8455
1.78	0.4415	0.6176	0.7148	1.2999	0.8409
1.80	0.4335	0.6089	0.7119	1.3159	0.8363
1.82	0.4257	0.6004	0.7091	1.3324	0.8317
1.84	0.4181	0.5919	0.7064	1.3494	0.8273
1.86	0.4107	0.5836	0.7038	1.3669	0.8228
1.88	0.4035	0.5754	0.7012	1.3849	0.8185
1.90	0.3964	0.5673	0.6988	1.4033	0.8141
1.92	0.3895	0.5594	0.6964	1.4222	0.8099
1.94	0.3828	0.5516	0.6940	1.4417	0.8057
1.96	0.3763	0.5439	0.6918	1.4616	0.8015
1.98	0.3699	0.5364	0.6896	1.4821	0.7974
2.00	0.3636	0.5289	0.6875	1.5031	0.7934
2.05	0.3487	0.5109	0.6825	1.5579	0.7835
2.10	0.3345	0.4936	0.6778	1.6162	0.7741
2.15	0.3212	0.4770	0.6735	1.6780	0.7649
2.20	0.3086	0.4611	0.6694	1.7434	0.7561
2.25	0.2968	0.4458	0.6656	1.8128	0.7477
2.30	0.2855	0.4312	0.6621	1.8860	0.7395
2.35	0.2749	0.4172	0.6588	1.9634	0.7317
2.40	0.2648	0.4038	0.6557	2.0451	0.7242
2.45	0.2552	0.3910	0.6527	2.1311	0.7170
2.50	0.2462	0.3787	0.6500	2.2218	0.7101

One dimensional flow with heat addition $\gamma =$ 1.4

M	p/p^*	T/T^*	ρ/ρ^*	p_0/p_0^*	T_0/T_0^*
2.55	0.2375	0.3669	0.6474	2.3173	0.7034
2.60	0.2294	0.3556	0.6450	2.4177	0.6970
2.65	0.2216	0.3448	0.6427	2.5233	0.6908
2.70	0.2142	0.3344	0.6405	2.6343	0.6849
2.75	0.2071	0.3244	0.6384	2.7508	0.6793
2.80	0.2004	0.3149	0.6365	2.8731	0.6738
2.85	0.1940	0.3057	0.6346	3.0014	0.6685
2.90	0.1879	0.2969	0.6329	3.1359	0.6635
2.95	0.1820	0.2884	0.6312	3.2768	0.6586
3.00	0.1765	0.2803	0.6296	3.4245	0.6540
3.05	0.1711	0.2725	0.6281	3.5790	0.6495
3.10	0.1660	0.2650	0.6267	3.7408	0.6452
3.15	0.1612	0.2577	0.6253	3.9101	0.6410
3.20	0.1565	0.2508	0.6240	4.0871	0.6370
3.25	0.1520	0.2441	0.6228	4.2721	0.6331
3.30	0.1477	0.2377	0.6216	4.4655	0.6294
3.35	0.1436	0.2315	0.6205	4.6674	0.6258
3.40	0.1397	0.2255	0.6194	4.8783	0.6224
3.45	0.1359	0.2197	0.6183	5.0984	0.6190
3.50	0.1322	0.2142	0.6173	5.3280	0.6158
3.55	0.1287	0.2088	0.6164	5.5676	0.6127
3.60	0.1254	0.2037	0.6155	5.8173	0.6097
3.65	0.1221	0.1987	0.6146	6.0776	0.6068
3.70	0.1190	0.1939	0.6138	6.3488	0.6040
3.75	0.1160	0.1893	0.6130	6.6314	0.6013
3.80	0.1131	0.1848	0.6122	6.9256	0.5987
3.85	0.1103	0.1805	0.6114	7.2318	0.5962
3.90	0.1077	0.1763	0.6107	7.5505	0.5937
3.95	0.1051	0.1722	0.6100	7.8820	0.5914
4.00	0.1026	0.1683	0.6094	8.2268	0.5891
4.05	0.1002	0.1645	0.6087	8.5853	0.5869
4.10	0.0978	0.1609	0.6081	8.9579	0.5847
4.15	0.0956	0.1573	0.6075	9.3451	0.5827
4.20	0.0934	0.1539	0.6070	9.7473	0.5807
4.25	0.0913	0.1506	0.6064	10.165	0.5787
4.30	0.0893	0.1473	0.6059	10.599	0.5768
4.35	0.0873	0.1442	0.6054	11.049	0.5750
4.40	0.0854	0.1412	0.6049	11.516	0.5732
4.45	0.0836	0.1383	0.6044	12.000	0.5715
4.50	0.0818	0.1354	0.6039	12.502	0.5698
4.55	0.0800	0.1326	0.6035	13.023	0.5682
4.60	0.0784	0.1300	0.6030	13.563	0.5666
4.65	0.0767	0.1274	0.6026	14.122	0.5651
4.70	0.0752	0.1248	0.6022	14.702	0.5636
4.75	0.0736	0.1224	0.6018	15.302	0.5622
4.80	0.0722	0.1200	0.6014	15.923	0.5608
4.85	0.0707	0.1177	0.6010	16.567	0.5594
4.90	0.0693	0.1154	0.6007	17.232	0.5581
4.95	0.0680	0.1132	0.6003	17.921	0.5568
5.00	0.0667	0.1111	0.6000	18.634	0.5556
5.05	0.0654	0.1090	0.5997	19.371	0.5543
5.10	0.0641	0.1070	0.5994	20.133	0.5532
5.15	0.0629	0.1051	0.5990	20.920	0.5520
5.20	0.0618	0.1032	0.5987	21.734	0.5509
5.25	0.0606	0.1013	0.5985	22.575	0.5498

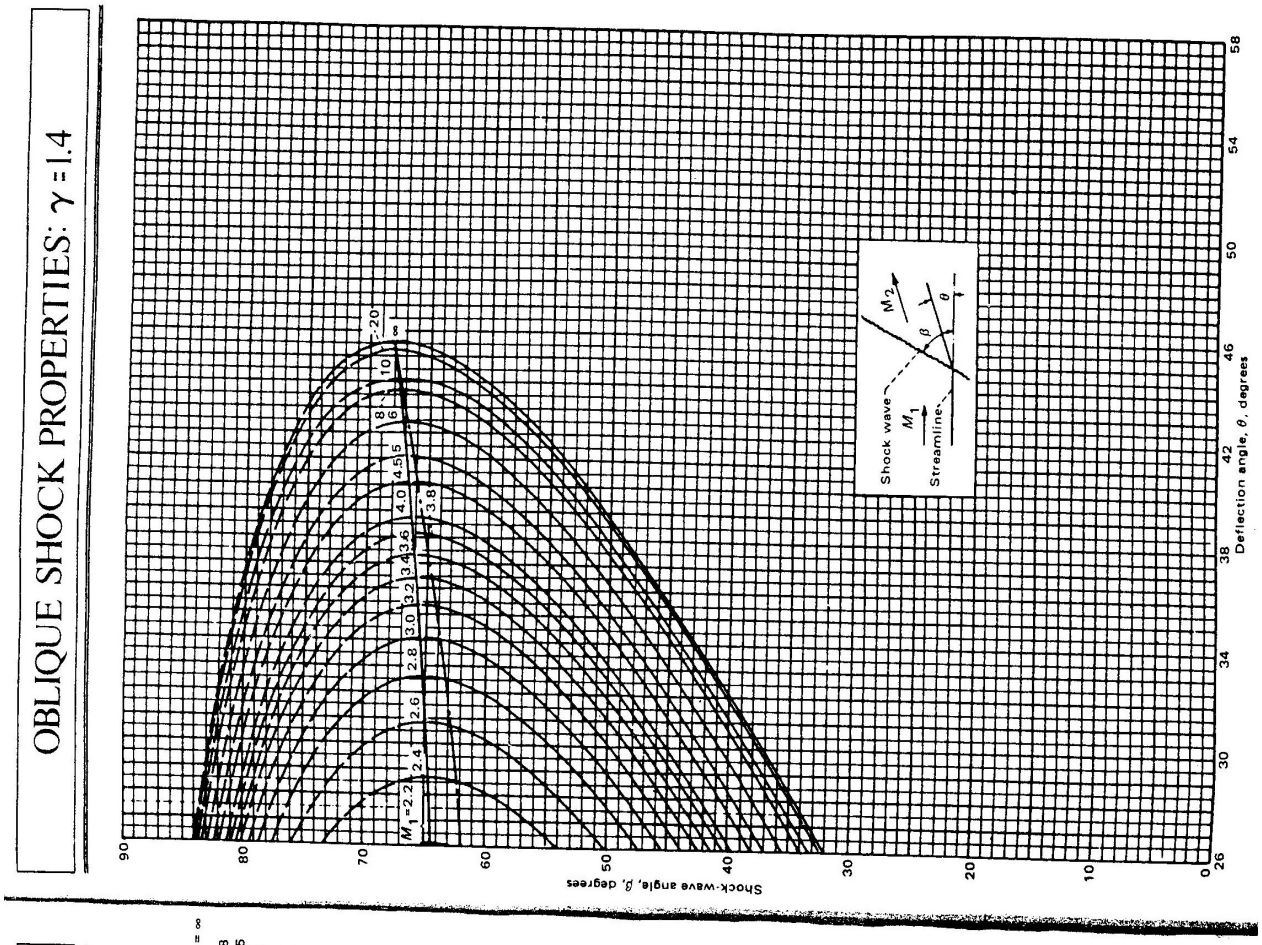
M	p/p^*	T/T^*	ρ/ρ^*	p_0/p_0^*	T_0/T_0^*
5.30	0.0595	0.0995	0.5982	23.444	0.5487
5.35	0.0584	0.0977	0.5979	24.341	0.5477
5.40	0.0574	0.0960	0.5976	25.268	0.5467
5.45	0.0564	0.0943	0.5974	26.224	0.5457
5.50	0.0554	0.0927	0.5971	27.211	0.5447
5.55	0.0544	0.0911	0.5969	28.230	0.5438
5.60	0.0534	0.0896	0.5966	29.281	0.5429
5.65	0.0525	0.0881	0.5964	30.364	0.5420
5.70	0.0516	0.0866	0.5962	31.482	0.5411
5.75	0.0508	0.0852	0.5959	32.634	0.5403
5.80	0.0499	0.0838	0.5957	33.822	0.5394
5.85	0.0491	0.0824	0.5955	35.046	0.5386
5.90	0.0483	0.0811	0.5953	36.308	0.5378
5.95	0.0475	0.0798	0.5951	37.607	0.5371
6.00	0.0467	0.0785	0.5949	38.946	0.5363
6.05	0.0459	0.0772	0.5947	40.324	0.5356
6.10	0.0452	0.0760	0.5945	41.744	0.5349
6.15	0.0445	0.0748	0.5943	43.205	0.5342
6.20	0.0438	0.0737	0.5942	44.708	0.5335
6.25	0.0431	0.0726	0.5940	46.256	0.5328
6.30	0.0424	0.0714	0.5938	47.848	0.5322
6.35	0.0418	0.0704	0.5937	49.486	0.5315
6.40	0.0411	0.0693	0.5935	51.170	0.5309
6.45	0.0405	0.0683	0.5933	52.902	0.5303
6.50	0.0399	0.0673	0.5932	54.683	0.5297
6.55	0.0393	0.0663	0.5930	56.514	0.5291
6.60	0.0387	0.0653	0.5929	58.395	0.5285
6.65	0.0381	0.0644	0.5928	60.329	0.5280
6.70	0.0376	0.0634	0.5926	62.315	0.5274
6.75	0.0370	0.0625	0.5925	64.356	0.5269
6.80	0.0365	0.0616	0.5923	66.452	0.5264
6.85	0.0360	0.0608	0.5922	68.605	0.5259
6.90	0.0355	0.0599	0.5921	70.815	0.5254
6.95	0.0350	0.0591	0.5920	73.085	0.5249
7.00	0.0345	0.0583	0.5918	75.414	0.5244
7.05	0.0340	0.0575	0.5917	77.804	0.5239
7.10	0.0335	0.0567	0.5916	80.257	0.5234
7.15	0.0331	0.0559	0.5915	82.774	0.5230
7.20	0.0326	0.0552	0.5914	85.356	0.5225
7.25	0.0322	0.0544	0.5913	88.004	0.5221
7.30	0.0317	0.0537	0.5912	90.720	0.5217
7.35	0.0313	0.0530	0.5910	93.505	0.5213
7.40	0.0309	0.0523	0.5909	96.361	0.5208
7.45	0.0305	0.0516	0.5908	99.287	0.5204
7.50	0.0301	0.0509	0.5907	102.29	0.5200
7.55	0.0297	0.0503	0.5906	105.36	0.5197
7.60	0.0293	0.0496	0.5905	108.51	0.5193
7.65	0.0289	0.0490	0.5905	111.74	0.5189
7.70	0.0286	0.0484	0.5904	115.05	0.5185
7.75	0.0282	0.0478	0.5903	118.43	0.5182
7.80	0.0278	0.0472	0.5902	121.90	0.5178
7.85	0.0275	0.0466	0.5901	125.45	0.5175
7.90	0.0272	0.0460	0.5900	129.09	0.5171
7.95	0.0268	0.0455	0.5899	132.81	0.5168
8.00	0.0265	0.0449	0.5898	136.62	0.5165

One dimensional flow with friction $\gamma = 1.4$

M	T/T^*	p/p^*	ρ/ρ^*	p_0/p_0^*	$4fL^*/D$	M	T/T^*	p/p^*	ρ/ρ^*	p_0/p_0^*	$4fL^*/D$
0.02	1.1999	54.770	45.645	28.942	1778.4	1.12	0.9593	0.8745	0.9116	1.011	1.382E-02
0.04	1.1996	27.382	22.825	14.481	440.35	1.14	0.9524	0.8561	0.8988	1.015	1.819E-02
0.06	1.1991	18.251	15.220	9.6659	193.03	1.16	0.9455	0.8383	0.8865	1.020	2.298E-02
0.08	1.1985	13.684	11.418	7.2616	106.72	1.18	0.9386	0.8210	0.8747	1.025	2.814E-02
0.10	1.1976	10.944	9.1378	5.8218	66.922	1.20	0.9317	0.8044	0.8633	1.030	3.364E-02
0.12	1.1966	9.1156	7.6182	4.8643	45.408	1.22	0.9247	0.7882	0.8524	1.037	3.943E-02
0.14	1.1953	7.8093	6.5333	4.1824	32.511	1.24	0.9178	0.7726	0.8418	1.043	4.547E-02
0.16	1.1939	6.8291	5.7200	3.6727	24.198	1.26	0.9108	0.7574	0.8316	1.050	5.174E-02
0.18	1.1923	6.0662	5.0879	3.2779	18.543	1.28	0.9038	0.7427	0.8218	1.058	5.820E-02
0.20	1.1905	5.4554	4.5826	2.9635	14.533	1.30	0.8969	0.7285	0.8123	1.066	6.483E-02
0.22	1.1885	4.9554	4.1694	2.7076	11.596	1.32	0.8899	0.7147	0.8031	1.075	7.161E-02
0.24	1.1863	4.5383	3.8255	2.4956	9.3865	1.34	0.8829	0.7012	0.7942	1.084	7.850E-02
0.26	1.1840	4.1851	3.5347	2.3173	7.6876	1.36	0.8760	0.6882	0.7856	1.094	8.550E-02
0.28	1.1815	3.8820	3.2857	2.1656	6.3572	1.38	0.8690	0.6755	0.7773	1.104	9.259E-02
0.30	1.1788	3.6191	3.0702	2.0351	5.2993	1.40	0.8621	0.6632	0.7693	1.115	9.974E-02
0.32	1.1759	3.3887	2.8818	1.9219	4.4467	1.42	0.8551	0.6512	0.7615	1.126	1.069E-01
0.34	1.1729	3.1853	2.7158	1.8229	3.7520	1.44	0.8482	0.6396	0.7540	1.138	1.142E-01
0.36	1.1697	3.0042	2.5684	1.7358	3.1801	1.46	0.8413	0.6282	0.7467	1.150	1.215E-01
0.38	1.1663	2.8420	2.4367	1.6587	2.7054	1.48	0.8344	0.6172	0.7397	1.163	1.288E-01
0.40	1.1628	2.6958	2.3184	1.5901	2.3085	1.50	0.8276	0.6065	0.7328	1.176	1.361E-01
0.42	1.1591	2.5634	2.2115	1.5289	1.9744	1.52	0.8207	0.5960	0.7262	1.190	1.433E-01
0.44	1.1553	2.4428	2.1145	1.4740	1.6915	1.54	0.8139	0.5858	0.7198	1.204	1.506E-01
0.46	1.1513	2.3326	2.0261	1.4246	1.4509	1.56	0.8071	0.5759	0.7135	1.219	1.579E-01
0.48	1.1471	2.2313	1.9451	1.3801	1.2453	1.58	0.8004	0.5662	0.7074	1.234	1.651E-01
0.50	1.1429	2.1381	1.8708	1.3398	1.0691	1.60	0.7937	0.5568	0.7016	1.250	1.724E-01
0.52	1.1384	2.0519	1.8024	1.3034	0.9174	1.62	0.7869	0.5476	0.6958	1.267	1.795E-01
0.54	1.1339	1.9719	1.7391	1.2703	0.7866	1.64	0.7803	0.5386	0.6903	1.284	1.867E-01
0.56	1.1292	1.8975	1.6805	1.2403	0.6736	1.66	0.7736	0.5299	0.6849	1.301	1.938E-01
0.58	1.1244	1.8282	1.6260	1.2130	0.5757	1.68	0.7670	0.5213	0.6796	1.319	2.008E-01
0.60	1.1194	1.7634	1.5753	1.1882	0.4908	1.70	0.7605	0.5130	0.6745	1.338	2.078E-01
0.62	1.1143	1.7026	1.5279	1.1656	0.4172	1.72	0.7539	0.5048	0.6696	1.357	2.147E-01
0.64	1.1091	1.6456	1.4836	1.1451	0.3533	1.74	0.7474	0.4969	0.6648	1.376	2.216E-01
0.66	1.1038	1.5919	1.4421	1.1265	0.2979	1.76	0.7410	0.4891	0.6601	1.397	2.284E-01
0.68	1.0984	1.5413	1.4032	1.1097	0.2498	1.78	0.7345	0.4815	0.6555	1.418	2.352E-01
0.70	1.0929	1.4935	1.3665	1.0944	0.2081	1.80	0.7282	0.4741	0.6511	1.439	2.419E-01
0.72	1.0873	1.4482	1.3320	1.0806	0.1721	1.82	0.7218	0.4668	0.6467	1.461	2.485E-01
0.74	1.0815	1.4054	1.2994	1.0681	0.1411	1.84	0.7155	0.4597	0.6425	1.484	2.551E-01
0.76	1.0757	1.3647	1.2686	1.0570	0.1145	1.86	0.7093	0.4528	0.6384	1.507	2.616E-01
0.78	1.0698	1.3261	1.2395	1.0471	9.17E-02	1.88	0.7030	0.4460	0.6344	1.531	2.680E-01
0.80	1.0638	1.2893	1.2119	1.0382	7.23E-02	1.90	0.6969	0.4394	0.6305	1.555	2.743E-01
0.82	1.0578	1.2542	1.1858	1.0305	5.59E-02	1.92	0.6907	0.4329	0.6267	1.580	2.806E-01
0.84	1.0516	1.2208	1.1609	1.0237	4.23E-02	1.94	0.6847	0.4265	0.6230	1.606	2.868E-01
0.86	1.0454	1.1889	1.1373	1.0179	3.10E-02	1.96	0.6786	0.4203	0.6193	1.633	2.929E-01
0.88	1.0391	1.1583	1.1148	1.0129	2.18E-02	1.98	0.6726	0.4142	0.6158	1.660	2.990E-01
0.90	1.0327	1.1291	1.0934	1.0089	1.45E-02	2.00	0.6667	0.4082	0.6124	1.688	3.050E-01
0.92	1.0263	1.1011	1.0730	1.0056	8.91E-03	2.05	0.6520	0.3939	0.6041	1.760	3.197E-01
0.94	1.0198	1.0743	1.0535	1.0031	4.82E-03	2.10	0.6376	0.3802	0.5963	1.837	3.339E-01
0.96	1.0132	1.0485	1.0348	1.0014	2.06E-03	2.15	0.6235	0.3673	0.5890	1.919	3.476E-01
0.98	1.0066	1.0238	1.0170	1.0003	4.95E-04	2.20	0.6098	0.3549	0.5821	2.005	3.609E-01
1.00	1.0000	1.0000	1.0000	1.0000	0.0E+00	2.25	0.5963	0.3432	0.5756	2.096	3.738E-01
1.02	0.9933	0.9771	0.9837	1.0003	4.59E-04	2.30	0.5831	0.3320	0.5694	2.193	3.862E-01
1.04	0.9866	0.9551	0.9681	1.0013	1.77E-03	2.35	0.5702	0.3213	0.5635	2.295	3.983E-01
1.06	0.9798	0.9338	0.9531	1.0029	3.84E-03	2.40	0.5576	0.3111	0.5580	2.403	4.099E-01
1.08	0.9730	0.9133	0.9387	1.0051	6.58E-03	2.45	0.5453	0.3014	0.5527	2.517	4.211E-01
1.10	0.9662	0.8936	0.9249	1.0079	9.94E-03	2.50	0.5333	0.2921	0.5477	2.637	4.320E-01

One dimensional flow with friction $\gamma =$ 1.4

M	T/T^*	p/p^*	ρ/ρ^*	p_0/p_0^*	$4fL^*/D$
2.55	0.5216	0.2832	0.5430	2.7630	0.4425
2.60	0.5102	0.2747	0.5385	2.8960	0.4526
2.65	0.4991	0.2666	0.5342	3.0359	0.4624
2.70	0.4882	0.2588	0.5301	3.1830	0.4718
2.75	0.4776	0.2513	0.5262	3.3377	0.4809
2.80	0.4673	0.2441	0.5225	3.5001	0.4898
2.85	0.4572	0.2373	0.5189	3.6707	0.4983
2.90	0.4474	0.2307	0.5155	3.8498	0.5065
2.95	0.4379	0.2243	0.5123	4.0376	0.5145
3.00	0.4286	0.2182	0.5092	4.2346	0.5222
3.05	0.4195	0.2124	0.5062	4.4410	0.5296
3.10	0.4107	0.2067	0.5034	4.6573	0.5368
3.15	0.4021	0.2013	0.5007	4.8838	0.5437
3.20	0.3937	0.1961	0.4980	5.1210	0.5504
3.25	0.3855	0.1911	0.4955	5.3691	0.5569
3.30	0.3776	0.1862	0.4931	5.6286	0.5632
3.35	0.3699	0.1815	0.4908	5.9000	0.5693
3.40	0.3623	0.1770	0.4886	6.1837	0.5752
3.45	0.3550	0.1727	0.4865	6.4801	0.5809
3.50	0.3478	0.1685	0.4845	6.7896	0.5864
3.55	0.3409	0.1645	0.4825	7.1128	0.5918
3.60	0.3341	0.1606	0.4806	7.4501	0.5970
3.65	0.3275	0.1568	0.4788	7.8020	0.6020
3.70	0.3210	0.1531	0.4770	8.1691	0.6068
3.75	0.3148	0.1496	0.4753	8.5517	0.6115
3.80	0.3086	0.1462	0.4737	8.9506	0.6161
3.85	0.3027	0.1429	0.4721	9.3661	0.6206
3.90	0.2969	0.1397	0.4706	9.7990	0.6248
3.95	0.2912	0.1366	0.4691	10.250	0.6290
4.00	0.2857	0.1336	0.4677	10.719	0.6331
4.05	0.2803	0.1307	0.4663	11.207	0.6370
4.10	0.2751	0.1279	0.4650	11.715	0.6408
4.15	0.2700	0.1252	0.4637	12.243	0.6445
4.20	0.2650	0.1226	0.4625	12.792	0.6481
4.25	0.2602	0.1200	0.4613	13.362	0.6516
4.30	0.2554	0.1175	0.4601	13.955	0.6550
4.35	0.2508	0.1151	0.4590	14.571	0.6583
4.40	0.2463	0.1128	0.4579	15.210	0.6615
4.45	0.2419	0.1105	0.4569	15.873	0.6646
4.50	0.2376	0.1083	0.4559	16.562	0.6676
4.55	0.2334	0.1062	0.4549	17.277	0.6706
4.60	0.2294	0.1041	0.4539	18.018	0.6734
4.65	0.2254	0.1021	0.4530	18.786	0.6762
4.70	0.2215	0.1001	0.4521	19.583	0.6790
4.75	0.2177	0.0982	0.4512	20.408	0.6816
4.80	0.2140	0.0964	0.4504	21.264	0.6842
4.85	0.2104	0.0946	0.4495	22.150	0.6867
4.90	0.2068	0.0928	0.4487	23.067	0.6891
4.95	0.2034	0.0911	0.4480	24.017	0.6915
5.00	0.2000	0.0894	0.4472	25.000	0.6938
5.05	0.1967	0.0878	0.4465	26.017	0.6961
5.10	0.1935	0.0862	0.4458	27.070	0.6983
5.15	0.1903	0.0847	0.4451	28.158	0.7004
5.20	0.1873	0.0832	0.4444	29.283	0.7025
5.25	0.1843	0.0818	0.4437	30.447	0.7045
5.30	0.1813	0.0803	0.4431	31.649	0.7065
5.35	0.1785	0.0790	0.4425	32.891	0.7085
5.40	0.1756	0.0776	0.4419	34.175	0.7104
5.45	0.1729	0.0763	0.4413	35.500	0.7122
5.50	0.1702	0.0750	0.4407	36.869	0.7140
5.55	0.1676	0.0738	0.4401	38.282	0.7158
5.60	0.1650	0.0725	0.4396	39.740	0.7175
5.65	0.1625	0.0713	0.4391	41.245	0.7192
5.70	0.1600	0.0702	0.4385	42.797	0.7208
5.75	0.1576	0.0690	0.4380	44.399	0.7224
5.80	0.1553	0.0679	0.4375	46.050	0.7240
5.85	0.1530	0.0669	0.4371	47.753	0.7255
5.90	0.1507	0.0658	0.4366	49.507	0.7270
5.95	0.1485	0.0648	0.4361	51.316	0.7284
6.00	0.1463	0.0638	0.4357	53.180	0.7299
6.05	0.1442	0.0628	0.4352	55.100	0.7313
6.10	0.1421	0.0618	0.4348	57.077	0.7326
6.15	0.1401	0.0609	0.4344	59.114	0.7340
6.20	0.1381	0.0599	0.4340	61.210	0.7353
6.25	0.1362	0.0590	0.4336	63.369	0.7366
6.30	0.1343	0.0582	0.4332	65.590	0.7378
6.35	0.1324	0.0573	0.4328	67.876	0.7390
6.40	0.1305	0.0565	0.4324	70.227	0.7402
6.45	0.1287	0.0556	0.4321	72.646	0.7414
6.50	0.1270	0.0548	0.4317	75.134	0.7425
6.55	0.1253	0.0540	0.4314	77.693	0.7437
6.60	0.1236	0.0533	0.4310	80.323	0.7448
6.65	0.1219	0.0525	0.4307	83.026	0.7458
6.70	0.1203	0.0518	0.4304	85.805	0.7469
6.75	0.1187	0.0510	0.4301	88.660	0.7479
6.80	0.1171	0.0503	0.4298	91.594	0.7489
6.85	0.1156	0.0496	0.4294	94.607	0.7499
6.90	0.1140	0.0489	0.4292	97.702	0.7509
6.95	0.1126	0.0483	0.4289	100.88	0.7519
7.00	0.1111	0.0476	0.4286	104.14	0.7528
7.05	0.1097	0.0470	0.4283	107.49	0.7537
7.10	0.1083	0.0463	0.4280	110.93	0.7546
7.15	0.1069	0.0457	0.4277	114.46	0.7555
7.20	0.1056	0.0451	0.4275	118.08	0.7564
7.25	0.1042	0.0445	0.4272	121.79	0.7572
7.30	0.1029	0.0439	0.4270	125.60	0.7580
7.35	0.1017	0.0434	0.4267	129.51	0.7589
7.40	0.1004	0.0428	0.4265	133.52	0.7597
7.45	0.0992	0.0423	0.4262	137.63	0.7604
7.50	0.0980	0.0417	0.4260	141.84	0.7612
7.55	0.0968	0.0412	0.4258	146.16	0.7620
7.60	0.0956	0.0407	0.4256	150.58	0.7627
7.65	0.0945	0.0402	0.4253	155.12	0.7634
7.70	0.0933	0.0397	0.4251	159.77	0.7642
7.75	0.0922	0.0392	0.4249	164.53	0.7649
7.80	0.0911	0.0387	0.4247	169.40	0.7656
7.85	0.0901	0.0382	0.4245	174.40	0.7662
7.90	0.0890	0.0378	0.4243	179.51	0.7669
7.95	0.0880	0.0373	0.4241	184.75	0.7675
8.00	0.0870	0.0369	0.4239	190.11	0.7682


OBLIQUE SHOCK PROPERTIES: γ = 1.4
Shock-wave angle, β, degrees
Deflection angle, θ, degrees
Shock wave
Streamline
M1
M2
β
θ
M1 = ∞
Weak shock wave
Strong shock wave
Sonic limit (M2 = 1)

Prandtl-Meyer Function and Mach angle $\gamma = 1.4$

M	ν	μ
1.00	0.00	90.000
1.02	0.13	78.635
1.04	0.35	74.058
1.06	0.64	70.630
1.08	0.97	67.808
1.10	1.34	65.380
1.12	1.74	63.234
1.14	2.16	61.306
1.16	2.61	59.550
1.18	3.07	57.936
1.20	3.56	56.443
1.22	4.06	55.052
1.24	4.57	53.751
1.26	5.09	52.528
1.28	5.63	51.375
1.30	6.17	50.285
1.32	6.72	49.251
1.34	7.28	48.268
1.36	7.84	47.332
1.38	8.41	46.439
1.40	8.99	45.585
1.42	9.57	44.767
1.44	10.15	43.983
1.46	10.73	43.230
1.48	11.32	42.507
1.50	11.91	41.810
1.52	12.49	41.140
1.54	13.09	40.493
1.56	13.68	39.868
1.58	14.27	39.265
1.60	14.86	38.682
1.62	15.45	38.118
1.64	16.04	37.572
1.66	16.63	37.043
1.68	17.22	36.530
1.70	17.81	36.032
1.72	18.40	35.549
1.74	18.98	35.080
1.76	19.56	34.624
1.78	20.15	34.180
1.80	20.73	33.749
1.82	21.30	33.329
1.84	21.88	32.921
1.86	22.45	32.523
1.88	23.02	32.135
1.90	23.59	31.757
1.92	24.15	31.388
1.94	24.71	31.028
1.96	25.27	30.677
1.98	25.83	30.335
2.00	26.38	30.000
2.05	27.75	29.196
2.10	29.10	28.437
2.15	30.43	27.718
2.20	31.73	27.036

M	ν	μ
2.25	33.02	26.388
2.30	34.28	25.771
2.35	35.53	25.184
2.40	36.75	24.624
2.45	37.95	24.090
2.50	39.12	23.578
2.55	40.28	23.089
2.60	41.41	22.620
2.65	42.53	22.170
2.70	43.62	21.738
2.75	44.69	21.324
2.80	45.75	20.925
2.85	46.78	20.541
2.90	47.79	20.171
2.95	48.78	19.815
3.00	49.76	19.471
3.05	50.71	19.139
3.10	51.65	18.819
3.15	52.57	18.509
3.20	53.47	18.210
3.25	54.35	17.920
3.30	55.22	17.640
3.35	56.07	17.368
3.40	56.91	17.105
3.45	57.73	16.849
3.50	58.53	16.602
3.55	59.32	16.361
3.60	60.09	16.128
3.65	60.85	15.901
3.70	61.60	15.680
3.75	62.33	15.466
3.80	63.04	15.258
3.85	63.75	15.055
3.90	64.44	14.857
3.95	65.12	14.665
4.00	65.78	14.478
4.05	66.44	14.295
4.10	67.08	14.117
4.15	67.71	13.943
4.20	68.33	13.774
4.25	68.94	13.609
4.30	69.54	13.448
4.35	70.13	13.290
4.40	70.71	13.137
4.45	71.27	12.986
4.50	71.83	12.840
4.55	72.38	12.696
4.60	72.92	12.556
4.65	73.45	12.419
4.70	73.97	12.284
4.75	74.48	12.153
4.80	74.99	12.025
4.85	75.48	11.899
4.90	75.97	11.776
4.95	76.45	11.655

M	ν	μ
5.00	76.92	11.537
5.10	77.84	11.308
5.20	78.73	11.087
5.30	79.60	10.876
5.40	80.43	10.672
5.50	81.24	10.476
5.60	82.03	10.287
5.70	82.80	10.104
5.80	83.54	9.928
5.90	84.26	9.758
6.00	84.96	9.594
6.10	85.63	9.435
6.20	86.29	9.282
6.30	86.94	9.133
6.40	87.56	8.989
6.50	88.17	8.850
6.60	88.76	8.715
6.70	89.33	8.584
6.80	89.89	8.457
6.90	90.44	8.333
7.00	90.97	8.213
7.10	91.49	8.097
7.20	92.00	7.984
7.30	92.49	7.873
7.40	92.97	7.766
7.50	93.44	7.662
7.60	93.90	7.561
7.70	94.34	7.462
7.80	94.78	7.366
7.90	95.21	7.272
8.00	95.62	7.181
9.00	99.32	6.379
10.00	102.3	5.739
11.00	104.8	5.216
12.00	106.9	4.780
13.00	108.7	4.412
14.00	110.2	4.096
15.00	111.5	3.823
16.00	112.7	3.583
17.00	113.7	3.372
18.00	114.6	3.185
19.00	115.5	3.017
20.00	116.2	2.866
21.00	116.9	2.729
22.00	117.5	2.605
23.00	118.0	2.492
24.00	118.6	2.388
25.00	119.0	2.292
26.00	119.5	2.204
27.00	119.9	2.123
28.00	120.2	2.047
29.00	120.6	1.976
30.00	120.9	1.910
31.00	121.2	1.849
32.00	121.5	1.791