

JK LAKSHMIPAT UNIVERSITY, JAIPUR

INSTITUTE OF ENGINEERING AND TECHNOLOGY

End Term Examination (Regular/ Backlog), November-December 2015

B. Tech Mechanical Engineering, Semester VII

Roll No.....

COURSE CODE: ME 721

Time: 3 hours

Max. Marks: 100

COURSE TITLE: Fundamentals of Aerodynamics

Instructions to students:

1. Do not write anything other than your roll number on question paper.
 2. Assume suitable data wherever required and mention it clearly.
 3. Writing appropriate units, nomenclature, and drawing neat sketches/schematics/ flow chart wherever, required are an integral part of the answer.
 4. For air $k=1.4$ and $R = 287 \text{ J/kg-k}$
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Q.1A Objective type multiple choice questions

10

- i. Real fluid viscosity is:
 - a. Zero
 - b. Function of time
 - c. Function of coordinate
 - d. Non zero
- ii. Pascal law is valid for:
 - a. For liquid only
 - b. For gases only
 - c. For stationary gases and liquids
 - d. None of the above
- iii. For incompressible fluid:
 - a. Viscosity is constant
 - b. Pressure is a function of temperature
 - c. Density is constant
 - d. None of the above
- iv. Any solid body floats in a fluid due to:
 - a. Its density
 - b. Bouncy effect on the solid
 - c. Center of gravity of solid
 - d. None of the above
- v. Center of pressure of a rectangular surface lies at the depth equal to:
 - a. half of the rectangular surface from free level
 - b. at the bottom of the rectangular surface
 - c. two third depth of the surface from free surface
 - d. none of the above
- vi. The assumption made in derivation of Bernoulli's theorem is:
 - a. Uniform flow
 - b. Non steady flow

- c. Steady flow
 - d. Three dimensional flow
 - vii Flow separation is caused by :
 - a. Reduction of pressure in the direction of flow
 - b. Reduction in boundary layer thickness
 - c. Adverse pressure gradient in the direction of flow
 - d. Positive pressure gradient in the direction of flow
 - viii A normal shock wave is:
 - a. Reversible
 - b. Irreversible
 - c. Isentropic
 - d. None of the above
 - ix Raleigh lines depict:
 - a. Pressure characteristics of the flow
 - b. Heat transfer characteristics of the flow
 - c. Velocity characteristics of the flow
 - d. None of the above
 - x Fanno lines are to check:
 - a. Choking flow in variable cross section duct
 - b. Choking flow in uniform cross section duct
 - c. For any flow in open channel
 - d. None of the above
- Q.2 a. Describe an air foil 10
- b. Describe flow pattern around air foil
- c. Write short note on Fanno lines
- d. Write a short note on flow past cylinder
- Q.3 A box of rectangular base (2m x 2m) contains oil (relative density = 2.0) upto 10
- height of 5 m. Calculate the force on the base and on each side with their line of
- action.
- Q.4A The Mach number at the exit of a combustion chamber is 0.8. The ratio of 10
- stagnation temperature at exit and entry is 3.0. If the pressure and temperature
- of the gas at the exit are 2.5 bar and 1000°C respectively. Determine:
- i. The heat supplied per kg of gas
- ii. The maximum heat that can be supplied to the gas
- If $\gamma = 1.4$ and $C_p = 1.218 \text{ kJ/kg-K}$
- Q.4B Define the following for a flow on flat plate with their expression: 10
- i. Boundary layer rate of growth
- ii. Displacement thickness of boundary layer
- iii. Momentum thickness of boundary layer
- Drag coefficient for laminar and turbulent flow
- Q.5 A circular duct passes 9 kg/s of air at an exit mach number of 0.5. The entry 10
- pressure and temperature are 3 bar and 27°C respectively. The coefficient of
- friction is 0.005. If the Mach number at entry is 0.1. Determine:

- a. Diameter of duct
- b. Stagnation pressure loss

- Q.6 Describe in detail various air foil classification methods with example 10
- OR
- Q.6 Derive pressure coefficient on a cylinder with circular cross section when it is immersed in flowing fluid 10
- Q.7 Describe in detail the geometric factors which affect air foil maximum lift at low speed. 10
- OR
- Q.7 Describe high lift devices at leading and trailing edge of the air foil. 10
- Q.8 If a normal shock wave occurs in the flow of air where $P_1 = 6 \text{ kPa}$, $t_1 = 27^\circ\text{C}$, $V_1 = 1300 \text{ m/s}$. Find Pressure, density, velocity and temperature after shock. 10
- Q.9A A vertical rectangular gate with water on one side has its upper edge at the depth of 3 m from free surface of water. The dimensions of the gate is $2\text{m} \times 1.2 \text{ m}$. Which side of the gate should be vertical and why? Determine the resultant force acting on the gate and location of the center of pressure for this condition. 10
- Q.9B A cylinder 100 mm diameter and 400 mm long is placed in a stream of fluid at 0.5 m/s. the axis of the cylinder is normal to the direction of flow. The density of the fluid is 800 kg/m^3 . The drag force is measured and found to be 30 N. Calculate the drag coefficient at a point on the surface at the pressure is measured at 96 Pa above the ambient level. 10
- OR
- Q.9B Calculate the drag and the power required to tow a smooth flat plate 2 m wide and 20 m long through still water ($\mu = 0.001 \text{ N-s/m}^2$) at 10 m/s. The density of water is 1000 kg/m^3 What would be the drag and the power required if plate was half as long. 10

Table C.3 One-dimensional isentropic relations (for a perfect gas with constant specific heat; $k = 1.4$)†

M	A/A*	P/P ₀	ρ/ρ_0	T/T ₀	M	A/A*	P/P ₀	ρ/ρ_0	T/T ₀
0.00		1.000	1.000	1.000	0.78	1.05	0.669	0.750	0.891
0.01	57.87	0.9999	0.9999	0.9999	0.80	1.04	0.656	0.740	0.886
0.02	28.94	0.9997	0.9999	0.9999	0.82	1.03	0.643	0.729	0.881
0.04	14.48	0.999	0.999	0.9996	0.84	1.02	0.630	0.719	0.876
0.06	9.67	0.997	0.998	0.999	0.86	1.02	0.617	0.708	0.871
0.08	7.26	0.996	0.997	0.999	0.88	1.01	0.604	0.698	0.865
0.10	5.82	0.993	0.995	0.998	0.90	1.01	0.591	0.687	0.860
0.12	4.86	0.990	0.993	0.997	0.92	1.01	0.578	0.676	0.855
0.14	4.18	0.986	0.990	0.996	0.94	1.00	0.566	0.666	0.850
0.16	3.67	0.982	0.987	0.995	0.96	1.00	0.553	0.655	0.844
0.18	3.28	0.978	0.984	0.994	0.98	1.00	0.541	0.645	0.839
0.20	2.96	0.973	0.980	0.992	1.00	1.00	0.528	0.632	0.833
0.22	2.71	0.967	0.976	0.990	1.02	1.00	0.516	0.623	0.828
0.24	2.50	0.961	0.972	0.989	1.04	1.00	0.504	0.613	0.822
0.26	2.32	0.954	0.967	0.987	1.06	1.00	0.492	0.602	0.817
0.28	2.17	0.947	0.962	0.985	1.08	1.01	0.480	0.592	0.810
0.30	2.04	0.939	0.956	0.982	1.10	1.01	0.468	0.582	0.805
0.32	1.92	0.932	0.951	0.980	1.12	1.01	0.457	0.571	0.799
0.34	1.82	0.923	0.944	0.977	1.14	1.02	0.445	0.561	0.794
0.36	1.74	0.914	0.938	0.975	1.16	1.02	0.434	0.551	0.788
0.38	1.66	0.905	0.931	0.972	1.18	1.02	0.423	0.541	0.782
0.40	1.59	0.896	0.924	0.969	1.20	1.03	0.412	0.531	0.776
0.42	1.53	0.886	0.917	0.966	1.22	1.04	0.402	0.521	0.771
0.44	1.47	0.876	0.909	0.963	1.24	1.04	0.391	0.512	0.765
0.46	1.42	0.865	0.902	0.959	1.26	1.05	0.381	0.502	0.759
0.48	1.38	0.854	0.893	0.956	1.28	1.06	0.371	0.492	0.753
0.50	1.34	0.843	0.885	0.952	1.30	1.07	0.361	0.483	0.747
0.52	1.30	0.832	0.877	0.949	1.32	1.08	0.351	0.474	0.742
0.54	1.27	0.820	0.868	0.945	1.34	1.08	0.342	0.464	0.736
0.56	1.24	0.808	0.859	0.941	1.36	1.09	0.332	0.455	0.730
0.58	1.21	0.796	0.850	0.937	1.38	1.10	0.323	0.446	0.724
0.60	1.19	0.784	0.840	0.933	1.40	1.11	0.314	0.437	0.718
0.62	1.17	0.772	0.831	0.929	1.42	1.13	0.305	0.429	0.713
0.64	1.16	0.759	0.821	0.924	1.44	1.14	0.297	0.420	0.707
0.66	1.13	0.747	0.812	0.920	1.46	1.15	0.289	0.412	0.701
0.68	1.12	0.734	0.802	0.915	1.48	1.16	0.280	0.403	0.695
0.70	1.09	0.721	0.792	0.911	1.50	1.18	0.272	0.395	0.690
0.72	1.08	0.708	0.781	0.906	1.52	1.19	0.265	0.387	0.684
0.74	1.07	0.695	0.771	0.901	1.54	1.20	0.257	0.379	0.678
0.76	1.06	0.682	0.761	0.896	1.56	1.22	0.250	0.371	0.672

† From Irving Shames, "Mechanics of Fluids," copyright © 1962 by McGraw-Hill, Inc. Used with permission of McGraw-Hill Book Company.

Table C.3 One-dimensional isentropic relations (continued)

M	A/A*	P/P ₀	ρ/ρ_0	T/T ₀	M	A/A*	P/P ₀	ρ/ρ_0	T/T ₀
1.58	1.23	0.242	0.363	0.667	2.30	2.19	0.080	0.165	0.486
1.60	1.25	0.235	0.356	0.661	2.32	2.23	0.078	0.161	0.482
1.62	1.27	0.228	0.348	0.656	2.34	2.27	0.075	0.157	0.477
1.64	1.28	0.222	0.341	0.650	2.36	2.32	0.073	0.154	0.473
1.66	1.30	0.215	0.334	0.645	2.38	2.36	0.071	0.150	0.469
1.68	1.32	0.209	0.327	0.639	2.40	2.40	0.068	0.147	0.465
1.70	1.34	0.203	0.320	0.634	2.42	2.45	0.066	0.144	0.461
1.72	1.36	0.197	0.313	0.628	2.44	2.49	0.064	0.141	0.456
1.74	1.38	0.191	0.306	0.623	2.46	2.54	0.062	0.138	0.452
1.76	1.40	0.185	0.300	0.617	2.48	2.59	0.060	0.135	0.448
1.78	1.42	0.179	0.293	0.612	2.50	2.64	0.059	0.132	0.444
1.80	1.44	0.174	0.287	0.607	2.52	2.69	0.057	0.129	0.441
1.82	1.46	0.169	0.281	0.602	2.54	2.74	0.055	0.126	0.437
1.84	1.48	0.164	0.275	0.596	2.56	2.79	0.053	0.123	0.433
1.86	1.51	0.159	0.269	0.591	2.58	2.84	0.052	0.121	0.429
1.88	1.53	0.154	0.263	0.586	2.60	2.90	0.050	0.118	0.425
1.90	1.56	0.149	0.257	0.581	2.62	2.95	0.049	0.115	0.421
1.92	1.58	0.145	0.251	0.576	2.64	3.01	0.047	0.113	0.418
1.94	1.61	0.140	0.246	0.571	2.66	3.06	0.046	0.110	0.414
1.96	1.63	0.136	0.240	0.566	2.68	3.12	0.044	0.108	0.410
1.98	1.66	0.132	0.235	0.561	2.70	3.18	0.043	0.106	0.407
2.00	1.69	0.128	0.230	0.556	2.72	3.24	0.042	0.103	0.403
2.02	1.72	0.124	0.225	0.551	2.74	3.31	0.040	0.101	0.400
2.04	1.75	0.120	0.220	0.546	2.76	3.37	0.039	0.099	0.396
2.06	1.78	0.116	0.215	0.541	2.78	3.43	0.038	0.097	0.393
2.08	1.81	0.113	0.210	0.536	2.80	3.50	0.037	0.095	0.389
2.10	1.84	0.109	0.206	0.531	2.82	3.57	0.036	0.093	0.386
2.12	1.87	0.106	0.201	0.526	2.84	3.64	0.035	0.091	0.383
2.14	1.90	0.103	0.197	0.522	2.86	3.71	0.034	0.089	0.379
2.16	1.94	0.100	0.192	0.517	2.88	3.78	0.033	0.087	0.376
2.18	1.97	0.097	0.188	0.513	2.90	3.85	0.032	0.085	0.373
2.20	2.01	0.094	0.184	0.508	2.92	3.92	0.031	0.083	0.370
2.22	2.04	0.091	0.180	0.504	2.94	4.00	0.030	0.081	0.366
2.24	2.08	0.088	0.176	0.499	2.96	4.08	0.029	0.080	0.363
2.26	2.12	0.085	0.172	0.495	2.98	4.15	0.028	0.078	0.360
2.28	2.15	0.083	0.168	0.490	3.00	4.23	0.027	0.076	0.357

A.3. Isentropic flow of a perfect gas ($\gamma = 1.4$)

M	M^*	T/T_0	p/p_0	A/A^*	F/F^*	A_p/A^*p_0
0.00	0.000	1.000	1.000	∞	∞	∞
0.05	0.0548	0.999	0.998	11.592	9.158	11.571
0.10	0.1094	0.998	0.993	5.822	4.624	5.781
0.15	0.1640	0.996	0.984	3.910	3.132	3.849
0.20	0.218	0.992	0.973	2.964	2.400	2.882
0.25	0.272	0.987	0.957	2.403	1.973	2.301
0.30	0.326	0.982	0.939	2.035	1.698	1.912
0.35	0.378	0.976	0.918	1.778	1.509	1.634
0.40	0.431	0.969	0.895	1.590	1.375	1.424
0.45	0.483	0.961	0.870	1.448	1.276	1.261
0.50	0.534	0.952	0.843	1.339	1.203	1.129
0.55	0.585	0.943	0.814	1.255	1.147	1.022
0.60	0.635	0.933	0.784	1.188	1.105	0.932
0.65	0.684	0.922	0.753	1.135	1.073	0.855
0.70	0.732	0.910	0.721	1.094	1.049	0.789
0.75	0.779	0.898	0.688	1.062	1.031	0.731
0.80	0.825	0.886	0.656	1.038	1.018	0.681
0.85	0.870	0.874	0.623	1.020	1.009	0.636
0.90	0.914	0.860	0.591	1.009	1.004	0.596
0.95	0.958	0.847	0.559	1.002	1.001	0.560
1.00	1.000	0.833	0.528	1.000	1.000	0.528
1.10	1.081	0.805	0.468	1.008	1.003	0.472
1.20	1.158	0.776	0.412	1.030	1.011	0.425
1.30	1.231	0.747	0.361	1.066	1.022	0.385
1.40	1.300	0.718	0.314	1.115	1.034	0.350
1.50	1.364	0.689	0.272	1.176	1.048	0.320
1.60	1.425	0.661	0.235	1.250	1.063	0.294
1.70	1.482	0.634	0.202	1.337	1.078	0.271
1.80	1.536	0.607	0.174	1.439	1.093	0.250
1.90	1.586	0.581	0.149	1.555	1.108	0.232
2.00	1.633	0.555	0.128	1.687	1.123	0.215
2.25	1.737	0.497	0.0865	2.096	1.156	0.181
2.50	1.826	0.444	0.0585	2.637	1.187	0.154
2.75	1.900	0.398	0.0397	3.337	1.213	0.133
3.00	1.964	0.357	0.027	4.234	1.236	0.115
3.50	2.064	0.289	0.013	6.789	1.274	0.089
4.00	2.138	0.238	0.00658	10.719	1.303	0.0706
4.50	2.194	0.198	0.00346	16.562	1.325	0.057
5.00	2.236	0.166	0.00189	25.000	1.341	0.047

A.4. Normal shocks in a perfect gas ($\gamma = 1.4$)

M_x	M_y	P_y/P_x	T_y/T_x	P_{0y}/P_{0x}	P_{0y}/P_x
1.00	1.000	1.000	1.000	1.000	1.893
1.05	0.953	1.119	1.033	0.999	2.008
1.10	0.912	1.245	1.065	0.999	2.133
1.12	0.896	1.297	1.077	0.998	2.185
1.14	0.882	1.349	1.090	0.997	2.239
1.16	0.868	1.403	1.103	0.996	2.294
1.18	0.855	1.458	1.115	0.995	2.350
1.20	0.842	1.513	1.128	0.993	2.407
1.22	0.829	1.569	1.140	0.991	2.466
1.24	0.818	1.627	1.153	0.988	2.526
1.26	0.807	1.686	1.166	0.985	2.587
1.28	0.796	1.745	1.178	0.983	2.650
1.30	0.786	1.805	1.191	0.979	2.714
1.32	0.776	1.866	1.203	0.976	2.778
1.34	0.766	1.928	1.216	0.972	2.844
1.36	0.757	1.991	1.229	0.967	2.911
1.38	0.748	2.055	1.242	0.963	2.979
1.40	0.739	2.120	1.255	0.958	3.049
1.42	0.731	2.186	1.267	0.953	3.119
1.44	0.723	2.253	1.281	0.947	3.192
1.46	0.716	2.320	1.294	0.942	3.264
1.48	0.708	2.389	1.307	0.936	3.338
1.50	0.701	2.458	1.320	0.929	3.413
1.52	0.694	2.529	1.333	0.923	3.489
1.54	0.687	2.600	1.347	0.916	3.567
1.56	0.681	2.672	1.361	0.907	3.645
1.58	0.675	2.746	1.374	0.903	3.725
1.60	0.668	2.820	1.388	0.895	3.805
1.70	0.641	3.205	1.458	0.856	4.224
1.75	0.628	3.406	1.495	0.834	4.443
1.80	0.616	3.613	1.532	0.813	4.669
1.85	0.605	3.826	1.569	0.790	4.902
1.90	0.595	4.045	1.608	0.767	5.142
2.00	0.577	4.500	1.687	0.721	5.641
2.50	0.513	7.125	2.137	0.499	8.526
3.00	0.475	10.333	2.679	0.328	12.061
3.50	0.451	14.125	3.315	0.213	16.242
4.00	0.435	18.500	4.047	0.138	21.068
4.50	0.423	23.548	4.875	0.0917	26.539
5.00	0.415	29.000	5.800	0.0617	32.634

A.5. Initial Mach number as function of oblique shock wave angles and deflections ($\gamma = 1.4$)

σ/δ	2	3	4	5	10	15	20	25	30
15	4.232	4.457	4.718	5.031	8.823				
20	3.132	3.251	3.385	3.536	4.734	9.830			
25	2.505	2.582	3.667	2.757	3.382	4.697	14.925		
30	2.100	2.158	2.217	2.280	2.681	3.348	4.900		
35	1.824	1.869	1.915	1.962	2.253	2.678	3.424	5.454	
40	1.624	1.662	1.698	1.738	1.965	2.275	2.748	3.635	6.812
45	1.475	1.507	1.541	1.575	1.767	2.015	2.359	2.905	4.055
50	1.362	1.391	1.422	1.453	1.625	1.837	2.115	2.515	3.198
55	1.276	1.305	1.334	1.363	1.526	1.718	1.959	2.287	2.788
60	1.211	1.240	1.270	1.300	1.460	1.645	1.870	2.165	2.582
65	1.165	1.195	1.227	1.257	1.425	1.615	1.840	2.125	2.520
70	1.135	1.169	1.204	1.240	1.426	1.635	1.878	2.187	2.608
75	1.125	1.165	1.208	1.252	1.478	1.733	2.035	2.418	2.970

A.6. Initial and final Mach numbers and deflections from normal shock tables ($\gamma = 1.4$)

M_x	M_y	σ	M_1	δ	M_2
1.00	1.00	15	3.863	0	3.863
1.05	0.953	15	4.057	1.11	3.972
1.10	0.912	15	4.250	2.09	4.081
1.20	0.842	15	4.636	3.70	4.278
1.30	0.786	15	5.023	4.97	4.515
1.40	0.739	15	5.409	5.989	4.723
1.50	0.701	15	5.795	6.811	4.922
2.00	0.577	15	7.727	9.26	5.775
2.50	0.513	15	9.659	10.40	6.402
3.00	0.475	15	1.591	11.02	6.857
1.00	1.00	30	2.000	0	2.000
1.05	0.953	30	2.100	1.96	2.027
1.10	0.912	30	2.200	3.71	2.059
1.20	0.842	30	2.400	6.72	2.131
1.30	0.786	30	2.600	9.15	2.208
1.40	0.739	30	2.800	11.13	2.288
1.50	0.701	30	3.000	12.77	2.368
2.00	0.577	30	4.000	17.78	2.728
2.50	0.513	30	5.000	20.17	3.006
3.00	0.475	30	6.000	21.48	3.210
1.00	1.00	45	1.414	0	1.414
1.05	0.953	45	1.485	2.30	1.405
1.10	0.912	45	1.555	4.45	1.403
1.20	0.842	45	1.697	8.30	1.409
1.30	0.786	45	1.838	11.58	1.427
1.40	0.739	45	1.980	14.38	1.452
1.50	0.701	45	2.121	16.76	1.482
2.00	0.577	45	2.828	24.44	1.644
2.50	0.513	45	3.535	28.30	1.785
3.00	0.475	45	4.243	30.46	1.893
1.00	1.00	60	1.154	0	1.154
1.05	0.953	60	1.212	2.04	1.124
1.10	0.912	60	1.270	4.02	1.100
1.20	0.842	60	1.385	7.76	1.065
1.30	0.786	60	1.501	11.19	1.044
1.40	0.739	60	1.616	14.29	1.033
1.50	0.701	60	1.732	17.07	1.029
2.00	0.577	60	2.309	26.99	1.060

(Contd.)

M_1	M_2	α	M_1	δ	M_2
2.50	0.513	60	2.887	32.54	1.113
3.00	0.475	60	3.464	35.82	1.160
1.00	1.00	75	1.035	0	1.035
1.05	0.953	75	1.087	1.19	0.993
1.10	0.912	75	1.139	2.39	0.955
1.20	0.842	75	1.242	4.77	0.895
1.30	0.786	75	1.345	7.10	0.848
1.40	0.739	75	1.449	9.36	0.812
1.50	0.701	75	1.553	11.52	0.783
2.00	0.577	75	2.071	20.55	0.709
2.50	0.513	75	2.588	26.77	0.687
3.00	0.475	75	3.106	30.94	0.683

 A.7. Flow of a perfect gas with friction (Fanno line, $\gamma = 1.4$)

M	p/p^*	$c/c^* = \rho^*/\rho$	T/T^*	p_0/p_0^*	F/F^*	$4fL_{max}/D$
0.00	∞	0	1.200	∞	∞	∞
0.05	21.903	0.0547	1.199	11.592	9.158	280.02
0.10	10.944	0.1094	1.197	5.822	4.624	66.922
0.12	9.116	0.131	1.1965	4.864	3.875	45.408
0.14	7.809	0.153	1.195	4.182	3.343	32.511
0.16	6.829	0.175	1.194	3.673	2.947	24.198
0.18	6.066	0.196	1.192	3.278	2.642	18.543
0.20	5.455	0.218	1.1905	2.963	2.400	14.533
0.25	4.355	0.272	1.185	2.403	1.973	8.483
0.30	3.619	0.3257	1.178	2.035	1.698	5.299
0.35	3.092	0.379	1.171	1.778	1.509	3.453
0.40	2.696	0.431	1.163	1.590	1.375	2.308
0.45	2.386	0.483	1.153	1.448	1.276	1.566
0.50	2.138	0.534	1.143	1.340	1.203	1.069
0.52	2.052	0.555	1.138	1.303	1.178	0.917
0.54	1.972	0.575	1.134	1.270	1.157	0.787
0.56	1.897	0.595	1.129	1.240	1.138	0.673
0.58	1.828	0.615	1.124	1.213	1.120	0.576
0.60	1.763	0.635	1.119	1.188	1.105	0.491
0.65	1.618	0.684	1.106	1.135	1.073	0.325
0.70	1.493	0.732	1.093	1.094	1.049	0.208
0.75	1.385	0.779	1.078	1.062	1.031	0.127
0.80	1.289	0.825	1.064	1.038	1.018	0.072
0.85	1.205	0.870	1.048	1.020	1.0097	0.0363
0.90	1.129	0.914	1.0327	1.009	1.004	0.0145
0.95	1.061	0.958	1.0165	1.002	1.001	0.0033
1.00	1.000	1.000	1.000	1.000	1.000	0.000
1.20	0.804	1.158	0.932	1.030	1.011	0.0336
1.50	0.606	1.365	0.827	1.176	1.048	0.136
1.60	0.557	1.425	0.794	1.250	1.063	0.172
1.70	0.513	1.483	0.760	1.338	1.078	0.208
1.80	0.474	1.536	0.728	1.439	1.0935	0.242
1.90	0.439	1.586	0.697	1.555	1.108	0.274
2.00	0.408	1.633	0.667	1.687	1.123	0.305
2.50	0.292	1.826	0.533	2.637	1.187	0.432
3.00	0.218	1.964	0.428	4.235	1.237	0.522
3.50	0.1685	2.064	0.348	6.789	1.274	0.586
4.00	0.134	2.138	0.286	10.719	1.303	0.633
4.50	0.108	2.194	0.237	16.562	1.325	0.667
5.00	0.0894	2.236	0.200	25.000	1.342	0.691

A.8. Flow of a perfect gas with heat transfer (Rayleigh line $\gamma = 1.4$)

M	p/p^*	p_0/p_0^*	T/T^*	T_0/T_0^*	$c/c^* = \rho^*/\rho$
0.00	2.400	1.268	0.000	0.000	0.000
0.05	2.392	1.266	0.0143	0.0119	0.00598
0.10	2.367	1.259	0.056	0.0468	0.0237
0.12	2.353	1.255	0.079	0.0667	0.0339
0.14	2.336	1.251	0.107	0.089	0.0458
0.16	2.317	1.246	0.137	0.115	0.0593
0.18	2.296	1.241	0.1708	0.143	0.0744
0.20	2.273	1.235	0.2066	0.1735	0.091
0.25	2.207	1.218	0.304	0.257	0.138
0.30	2.131	1.198	0.409	0.3468	0.192
0.35	2.048	1.178	0.514	0.439	0.251
0.40	1.961	1.157	0.615	0.529	0.314
0.45	1.870	1.135	0.708	0.614	0.378
0.50	1.778	1.114	0.790	0.691	0.444
0.52	1.741	1.106	0.819	0.720	0.470
0.54	1.704	1.098	0.847	0.747	0.497
0.56	1.668	1.090	0.872	0.772	0.523
0.58	1.632	1.083	0.896	0.796	0.549
0.60	1.596	1.075	0.917	0.819	0.574
0.65	1.508	1.058	0.961	0.868	0.637
0.70	1.424	1.043	0.993	0.908	0.697
0.75	1.343	1.030	1.014	0.940	0.755
0.80	1.266	1.019	1.025	0.964	0.810
0.85	1.193	1.011	1.028	0.981	0.862
0.90	1.125	1.045	1.0245	0.992	0.911
0.95	1.060	1.001	1.0146	0.998	0.957
1.00	1.000	1.000	1.000	1.000	1.000
1.20	0.796	1.0194	0.912	0.978	1.146
1.50	0.578	1.122	0.753	0.909	1.301
1.60	0.523	1.176	0.702	0.884	1.340
1.70	0.475	1.240	0.654	0.859	1.375
1.80	0.433	1.316	0.609	0.836	1.405
1.90	0.396	1.405	0.567	0.814	1.431
2.00	0.363	1.503	0.529	0.794	1.455
2.50	0.246	2.222	0.378	0.710	1.538
3.00	0.176	3.424	0.280	0.654	1.588
3.50	0.132	5.328	0.214	0.616	1.619
4.00	0.1025	8.227	0.168	0.589	1.641
4.50	0.0818	12.502	0.135	0.569	1.656
5.00	0.0667	18.634	0.111	0.555	1.667