MECHANICS OF FLUID II
ASSIGNMENT 2
SUBMISSION DATE: NO LATER THAN 27 JUNE 2024
GOOGLE FORM LINK WILL BE ANNOUNCED IN THE GROUP

Q1.

Consider an incompressible, steady, and viscous air flow between two long and wide parallel plates as shown in Figure Q1. The upper plate is moving in the positive x-direction while the bottom plate moves in the opposite direction. By assuming the flow is in x-direction only, the pressure gradient is insignificant, and the effect of gravity is neglected, derive an expression for fluid velocity $u(y)$. The Navier Stokes equation in the x-direction is given by:

$$\rho\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}\right)=-\frac{\partial \rho}{\partial x}+\rho g_x+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}+\frac{\partial^2 u}{\partial z^2}\right)$$

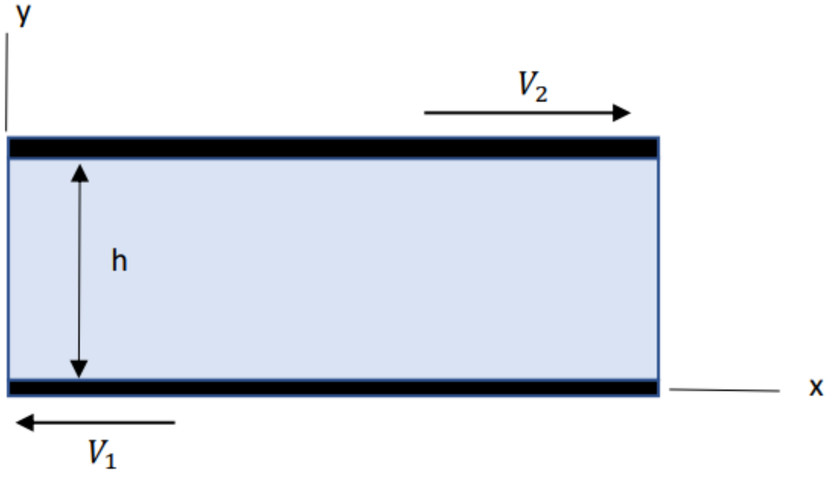

Figure Q1

$$\left[u(y)=\left(\frac{V_2+V_1}{h}\right)y-V_1\right]$$

Q2.

Determine the velocity potential, ϕ from the stream function, ψ as in Eq. Q2 given the flow is non-viscous, two-dimensional, incompressible fluid.

$$\psi = 3+2x-2y+xy \qquad \text{(Eq. Q2)}$$

$$\left[\phi(x)=\frac{1}{2}(x^2-y^2)-2(x+y)\right]$$

Q3.

a) Briefly explain on vortex flow. Give one example of vortex flow in real life phenomena or engineering application. State whether the vortex flow is rotational or irrotational vortex.

b) The flow field associated with a rotating cylinder is shown as in Figure Q3:

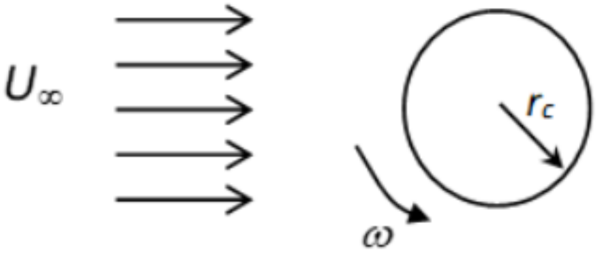

Figure Q3

i) Define the rotating cylinder stream function, determine the doublet strength, μ and derive the radial and tangential velocity components equations.

ii) Derive the circulation, Γ equation in the function of uniform flow, U and cylinder radius, r_c for one stagnation point exists on the cylinder surface. Sketch the flow field and show the stagnation point location.

iii) By aid of a diagram showing the points' location, derive the pressure on the cylinder surface, p_c equation as:

$$p_c = p_\infty + \frac{1}{2}\rho U^2 - \frac{1}{2}\rho\left(-2U^2 \sin\theta + \frac{\Gamma}{2\pi r_c}\right)^2$$

iv) Will the rotating cylinder as Q3(ii) experience a lift or downward force. Briefly explain your answer and state the relevant equation.

Q4.

a) Explain why is it necessary to control the growth of boundary layer on most of bodies and suggest a method in controlling the boundary layer growth.

b) Velocity profile in laminar boundary layer over a flat plate is assumed as

$$u = A\sin(By)$$

where *A* and *B* are constants,

i) determine the velocity profile by applying the appropriate boundary conditions.

ii) derive the boundary layer thickness, δ, and skin friction coefficient, C_f, in term of Reynold number.

$$\left[\delta = \frac{4.795x}{\sqrt{Re}}\ , \qquad C_f = \frac{1.31}{\sqrt{Re}}\right]$$

c) A flat plate 2.0 m long and 1.5 m wide is towed in water (density, ρ= 1000 kg/m^3 and kinematic viscosity, ν = 2 × 10^{-5} m^2/s) in the direction of its length at a speed 15 cm/s. By using formula in Question 4(b) ii), at the trailing edge, determine

i) boundary layer thickness [δ = 0.0784 m]

ii) drag force on both sides of the flat plate [F_D = 0.7222 N]

Q5.

a) List two (2) applications that require knowledge of compressible fluid flow theory in the design and operation of devices commonly encountered in engineering practice.

b) Given the isentropic relations in terms of flow properties ratio as follows:

$$\frac{T_2}{T_1}=\frac{1+\frac{(k-1)}{2}M_1^2}{1+\frac{(k-1)}{2}M_2^2} \qquad \frac{\rho_2}{\rho_1}=\left[\frac{1+\frac{(k-1)}{2}M_1^2}{1+\frac{(k-1)}{2}M_2^2}\right]^{\frac{1}{k-1}}$$

By using continuity equation, show that the ratio of exit area (A_2) to any section in the nozzle (A_1) for the reversible adiabatic one-dimensional flow of a perfect gas in a convergent-divergent nozzle is according to the following correlation:

$$\frac{A_2}{A_1}=\left(\frac{M_1}{M_2}\right)\left[\frac{1+\frac{(k-1)}{2}M_2^2}{1+\frac{(k-1)}{2}M_1^2}\right]^{\frac{k+1}{2(k-1)}}$$

c) The exhaust gases from a rocket engine can be assumed to be one-dimensional isentropic and to behave as a perfect gas with a specific heat ratio, $k=\gamma$ of 1.25. These gases with gas constant, R , of 593.85 J/kg.K are accelerated through a convergent-divergent (CD) nozzle. The mass flow rate through the CD nozzle is 554.23 kg/s. At some point in the CD nozzle where the cross-sectional area of the nozzle is 0.7 m^2, the pressure is 2000 kPa absolute, the temperature is 500°C and the velocity is 181.72 m/s.
By using isentropic table, find:

i) the stagnation pressure (p_0), stagnation temperature (T_0) and stagnation density (ρ_0)

[p_0 = 207.04 kPa, T_0 = 778.57 K, ρ_0 = 4.49 kg/m^3]

ii) the area at the throat (A^*).

[A* = 0.2763 m^3]

If the pressure at some other point in the nozzle is 100 kPa absolute, find the temperature, velocity, and area at this point in the flow.

[T_2 = 424.97 K, V_2 = 1450.43 m/s, A_2 = 1.736 m^2]

Q6.

Two different boundary layer regions will be developed, namely laminar and turbulent, when the flow across any external surfaces. Both flows are highly associated with the drag force on the surface. Calculating the force can be a tedious process when considering both regions. If the flow over a 7-m-long 6-m-wide flat plate surface is 5 m/s at 30°C of atmospheric air,

a) Determine whether the boundary layer is laminar or turbulent.

b) Starting from the Blasius equation, derive the expression for boundary layer thickness, and the local skin friction coefficient for the one-seventh power law. Blasius equation is given by:

$$\tau_0=0.023\rho U^2\left(\frac{\nu}{U\delta}\right)^{\frac{1}{4}}$$

c) Based on your answer in Q6(b), determine the maximum boundary-layer thickness and the drag force on one side of the flat surface.

[δ = 0.143 m, F_D = 2.423 N]

Q7.

a) Briefly explain the formation of the shock wave in compressible flow and its properties across normal shock wave in terms of pressure and temperature.

b) A bullet released from an AK-47 rifle travels at a speed of 460 m/s causing a normal shock wave and passes through stagnation air at a pressure of 100 kPa and temperature of 15°C. By using the normal shock wave table provided in Appendix, determine:

   i) Mach number before the shock wave [$M_1 = 1.35$]
   ii) Mach number after the shock wave [$M_2 = 0.7618$]
   iii) pressure after the shock wave [$P_2 = 195.95$ kPa (abs)]
   iv) temperature after the shock wave [$T_2 = 352.08$ K]
   v) velocity after the shock wave [$V_2 = 286.53$ m/s]
   vi) density after the shock wave [$\rho_2 = 1.939$ kg/m^3]

c) Is it possible for the normal shock wave to occur in a subsonic flow? Justify your answer.

Q8.

a) State two (2) differences between a centrifugal pump and an axial pump.

b) The impeller of a centrifugal pump is powered by a single cylinder internal combustion engine at 2000 rpm. This impeller is designed in such a way that its inlet diameter and width is 45 mm and 15 mm, respectively. This pump is also equipped with a device that straightens the flow at inlet to ensure that the flow enters perpendicular to the impeller leading edge. At exit, the width and diameter of this impeller is 5 mm and 65 mm, respectively. If the relative flow angle at inlet and exit is 40° and 30°, respectively, determine

   i) the flow rate that this pump could deliver [$Q = 8.37\times10^{-3}$ m^3/s]
   ii) the required power to operate this pump [Power = 989 W]
   iii) the actual head across this pump if this pump is rated at 85% efficiency
   [$H_p = 10.24$ m]

Q9.

a) Show that the maximum power of a Pelton wheel can be achieved when the bucket speed, u is half the jet velocity, V_1. Take the power delivered to the Pelton wheel by the jet as

$$P = \rho Q u (V_1 - u)[1 - \cos(\beta_2)]$$

where ρ is fluid density, $Q$is volumetric flowrate and β_2 is bucket deflection angle.

b) A Pelton wheel with two nozzles produces 1MW of output power under an available head of 200 m and rotates at 400 rpm. The turbine efficiency is 75% and the water jet diameter is 80 mm.

   i) Sketch velocity diagram for one of the wheel's jet.
   ii) Calculate the turbine flow rate [$Q = 0.68$ m^3/s]
   iii) Determine the wheel radius for maximum power [$R = 0.81$ m]
   iv) Determine the pressure at the nozzle base if the diameter of the nozzle base is 0.12 m [$P_2 = 1.51$ MPa]

Appendix

Formula

$$\frac{\partial \rho}{\partial t} + u\frac{\partial \rho}{\partial x} + v\frac{\partial \rho}{\partial y} + w\frac{\partial \rho}{\partial z} + \rho\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z}\right) = 0$$

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial \rho}{\partial x} + g_x + \nu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right)$$

$$u = \frac{\partial \psi}{\partial y} = \frac{\partial \phi}{\partial x} \qquad v_r = \frac{1}{r}\frac{\partial \psi}{\partial \theta} = \frac{\partial \phi}{\partial r}$$

$$v = -\frac{\partial \psi}{\partial x} = \frac{\partial \phi}{\partial y} \qquad v_\theta = -\frac{\partial \psi}{\partial r} = \frac{1}{r}\frac{\partial \phi}{\partial \theta}$$

$$\psi = U_\infty y \qquad \psi = \frac{\Gamma}{2\pi}\ln r$$

$$\psi = \frac{q}{2\pi}\theta \qquad \psi = -\frac{\mu \sin\theta}{r}$$

$$p_1 + \frac{1}{2}\rho V_1{}^2 + \rho g h_1 = p_2 + \frac{1}{2}\rho V_2{}^2 + \rho g h_2$$

Formula Q4-Q5

Von Karman momentum integral equation

$$\tau_0 = \rho U_\infty^2 \frac{d\theta}{dx}$$

Momentum thickness equation

$$\theta = \int_0^\delta \frac{u}{U_\infty}\left(1 - \frac{u}{U_\infty}\right)dy$$

Isentropic Flow Table for γ = 1.25

M	T_o/T	P_o/P	ρ_o/ρ	c_o/c	A/A^*
0.00	1.00000	1.00000	1.00000	1.00000	
0.02	1.00005	1.00025	1.00020	1.00002	29.43617
0.04	1.00020	1.00100	1.00080	1.00010	14.72802
0.06	1.00045	1.00225	1.00180	1.00022	9.82973
0.08	1.00080	1.00401	1.00320	1.00040	7.38391
0.10	1.00125	1.00627	1.00501	1.00062	5.91909
0.12	1.00180	1.00903	1.00722	1.00090	4.94478
0.14	1.00245	1.01231	1.00984	1.00122	4.25077
0.16	1.00320	1.01610	1.01286	1.00160	3.73196
0.18	1.00405	1.02041	1.01630	1.00202	3.32997
0.20	1.00500	1.02525	1.02015	1.00250	3.00975
0.22	1.00605	1.03062	1.02442	1.00302	2.74903
0.24	1.00720	1.03652	1.02911	1.00359	2.53293
0.26	1.00845	1.04297	1.03423	1.00422	2.35118
0.28	1.00980	1.04997	1.03978	1.00489	2.19642
0.30	1.01125	1.05753	1.04577	1.00561	2.06327
0.32	1.01280	1.06566	1.05219	1.00638	1.94769
0.34	1.01445	1.07437	1.05906	1.00720	1.84660
0.36	1.01620	1.08367	1.06639	1.00807	1.75759
0.38	1.01805	1.09357	1.07418	1.00898	1.67877
0.40	1.02000	1.10408	1.08243	1.00995	1.60862
0.42	1.02205	1.11522	1.09116	1.01096	1.54593
0.44	1.02420	1.12700	1.10037	1.01203	1.48968
0.46	1.02645	1.13943	1.11007	1.01314	1.43905
0.48	1.02880	1.15254	1.12027	1.01430	1.39335
0.50	1.03125	1.16633	1.13098	1.01550	1.35201
0.52	1.03380	1.18082	1.14221	1.01676	1.31454
0.54	1.03645	1.19603	1.15397	1.01806	1.28052
0.56	1.03920	1.21198	1.16626	1.01941	1.24960
0.58	1.04205	1.22869	1.17911	1.02081	1.22147
0.60	1.04500	1.24618	1.19252	1.02225	1.19587
0.62	1.04805	1.26447	1.20650	1.02374	1.17258
0.64	1.05120	1.28359	1.22107	1.02528	1.15138
0.66	1.05445	1.30356	1.23624	1.02686	1.13210
0.68	1.05780	1.32440	1.25203	1.02849	1.11460
0.70	1.06125	1.34613	1.26844	1.03017	1.09874
0.72	1.06480	1.36880	1.28550	1.03189	1.08439
0.74	1.06845	1.39242	1.30322	1.03366	1.07146
0.76	1.07220	1.41703	1.32161	1.03547	1.05984
0.78	1.07605	1.44265	1.34069	1.03733	1.04946

M	T_0/T	P_0/P	ρ_0/ρ	a_0/a	A/A^*
2.48	1.76880	17.31385	9.78847	1.32996	3.08970
2.50	1.78125	17.93182	10.06699	1.33463	3.16327
2.52	1.79380	18.57249	10.35371	1.33933	3.23889
2.54	1.80645	19.23666	10.64888	1.34404	3.31663
2.56	1.81920	19.92518	10.95272	1.34878	3.39653
2.58	1.83205	20.63890	11.26547	1.35353	3.47866
2.60	1.84500	21.37873	11.58739	1.35831	3.56307
2.62	1.85805	22.14558	11.91872	1.36310	3.64981
2.64	1.87120	22.94040	12.25973	1.36792	3.73896
2.66	1.88445	23.76419	12.61068	1.37275	3.83056
2.68	1.89780	24.61797	12.97185	1.37761	3.92469
2.70	1.91125	25.50278	13.34351	1.38248	4.02141
2.72	1.92480	26.41971	13.72595	1.38737	4.12079
2.74	1.93845	27.36989	14.11947	1.39228	4.22288
2.76	1.95220	28.35447	14.52437	1.39721	4.32777
2.78	1.96605	29.37466	14.94095	1.40216	4.43552
2.80	1.98000	30.43168	15.36954	1.40712	4.54620
2.82	1.99405	31.52682	15.81045	1.41211	4.65990
2.84	2.00820	32.66140	16.26402	1.41711	4.77669
2.86	2.02245	33.83678	16.73059	1.42213	4.89663
2.88	2.03680	35.05435	17.21050	1.42717	5.01983
2.90	2.05125	36.31558	17.70412	1.43222	5.14635
2.92	2.06580	37.62196	18.21181	1.43729	5.27628
2.94	2.08045	38.97503	18.73394	1.44238	5.40971
2.96	2.09520	40.37638	19.27090	1.44748	5.54672
2.98	2.11005	41.82768	19.82307	1.45260	5.68741
3.00	2.12500	43.33060	20.39087	1.45774	5.83187
3.02	2.14005	44.88690	20.97470	1.46289	5.98018
3.04	2.15520	46.49839	21.57498	1.46806	6.13245
3.06	2.17045	48.16693	22.19214	1.47324	6.28878
3.08	2.18580	49.89443	22.82662	1.47845	6.44926
3.10	2.20125	51.68290	23.47889	1.48366	6.61400
3.12	2.21680	53.53435	24.14938	1.48889	6.78310
3.14	2.23245	55.45091	24.83859	1.49414	6.95668
3.16	2.24820	57.43475	25.54699	1.49940	7.13483
3.18	2.26405	59.48810	26.27508	1.50468	7.31768
3.20	2.28000	61.61327	27.02336	1.50997	7.50534
3.22	2.29605	63.81264	27.79236	1.51527	7.69793
3.24	2.31220	66.08867	28.58259	1.52059	7.89556
3.26	2.32845	68.44387	29.39461	1.52593	8.09836
3.28	2.34480	70.88087	30.22896	1.53127	8.30646
3.30	2.36125	73.40233	31.08622	1.53664	8.51998

TABLE B.2 Properties of Air at Atmospheric Pressure

Temperature T (°C)	*Density* ρ (kg/m^3)	*Viscosity* μ (N·s/m^2)	*Kinematic viscosity* ν (m^2/s)	*Velocity of sound* c (m/s)
−50	1.582	1.46×10^{-5}	0.921×10^{-5}	299
−30	1.452	1.56	1.08×10^{-5}	312
−20	1.394	1.61	1.16	319
−10	1.342	1.67	1.24	325
0	1.292	1.72	1.33	331
10	1.247	1.76	1.42	337
20	1.204	1.81	1.51	343
30	1.164	1.86	1.60	349
40	1.127	1.91	1.69	355
50	1.092	1.95	1.79	360
60	1.060	2.00	1.89	366
70	1.030	2.05	1.99	371
80	1.000	2.09	2.09	377
90	0.973	2.13	2.19	382
100	0.946	2.17	2.30	387
200	0.746	2.57	3.45	436
300	0.616	2.93×10^{-5}	4.75×10^{-5}	480

TABLE D.2 Normal-Shock Flow

M_1	M_2	p_2/p_1	T_2/T_1	p_{02}/p_{01}
1.00	1.000	1.000	1.000	1.000
1.02	.9805	1.047	1.013	1.000
1.04	.9620	1.095	1.026	.9999
1.06	.9444	1.144	1.039	.9997
1.08	.9277	1.194	1.052	.9994
1.10	.9118	1.245	1.065	.9989
1.12	.8966	1.297	1.078	.9982
1.14	.8820	1.350	1.090	.9973
1.16	.8682	1.403	1.103	.9961
1.18	.8549	1.458	1.115	.9946
1.20	.8422	1.513	1.128	.9928
1.22	.8300	1.570	1.141	.9907
1.24	.8183	1.627	1.153	.9884
1.26	.8071	1.686	1.166	.9857
1.28	.7963	1.745	1.178	.9827
1.30	.7860	1.805	1.191	.9794
1.32	.7760	1.866	1.204	.9758
1.34	.7664	1.928	1.216	.9718
1.36	.7572	1.991	1.229	.9676
1.38	.7483	2.055	1.242	.9630
1.40	.7397	2.120	1.255	.9582
1.42	.7314	2.186	1.268	.9531
1.44	.7235	2.253	1.281	.9476
1.46	.7157	2.320	1.294	.9420
1.48	.7083	2.389	1.307	.9360
1.50	.7011	2.458	1.320	.9298
1.52	.6941	2.529	1.334	.9233
1.54	.6874	2.600	1.347	.9166
1.56	.6809	2.673	1.361	.9097
1.58	.6746	2.746	1.374	.9026
1.60	.6684	2.820	1.388	.8952
1.62	.6625	2.895	1.402	.8877
1.64	.6568	2.971	1.416	.8799
1.66	.6512	3.048	1.430	.8720
1.68	.6458	3.126	1.444	.8640
1.70	.6405	3.205	1.458	.8557
1.72	.6355	3.285	1.473	.8474
1.74	.6305	3.366	1.487	.8389
1.76	.6257	3.447	1.502	.8302
1.78	.6210	3.530	1.517	.8215
1.80	.6165	3.613	1.532	.8127
1.82	.6121	3.698	1.547	.8038
1.84	.6078	3.783	1.562	.7948
1.86	.6036	3.870	1.577	.7857
1.88	.5996	3.957	1.592	.7765
1.90	.5956	4.045	1.608	.7674
1.92	.5918	4.134	1.624	.7581
1.94	.5880	4.224	1.639	.7488
1.96	.5844	4.315	1.655	.7395
1.98	.5808	4.407	1.671	.7302
2.00	.5774	4.500	1.688	.7209

TABLE D.2 Normal-Shock Flow (*continued*)

M_1	M_2	p_2/p_1	T_2/T_1	p_{02}/p_{01}
2.30	.5344	6.005	1.947	.5833
2.32	.5321	6.113	1.965	.5745
2.34	.5297	6.222	1.984	.5658
2.36	.5275	6.331	2.002	.5572
2.38	.5253	6.442	2.021	.5486
2.40	.5231	6.553	2.040	.5401
2.42	.5210	6.666	2.059	.5317
2.44	.5189	6.779	2.079	.5234
2.46	.5169	6.894	2.098	.5152
2.48	.5149	7.009	2.118	.5071
2.50	.5130	7.125	2.138	.4990
2.52	.5111	7.242	2.157	.4991
2.54	.5092	7.360	2.177	.4832
2.56	.5074	7.479	2.198	.4754
2.58	.5056	7.599	2.218	.4677
2.60	.5039	7.720	2.238	.4601
2.62	.5022	7.842	2.259	.4526
2.64	.5005	7.965	2.280	.4452
2.66	.4988	8.088	2.301	.4379
2.68	.4972	8.213	2.322	.4307
2.70	.4956	8.338	2.343	.4236
2.72	.4941	8.465	2.364	.4166
2.74	.4926	8.592	2.386	.4097
2.76	.4911	8.721	2.407	.4028
2.78	.4896	8.850	2.429	.3961
2.80	.4882	8.980	2.451	.3895
2.82	.4868	9.111	2.473	.3829
2.84	.4854	9.243	2.496	.3765
2.86	.4840	9.376	2.518	.3701
2.88	.4827	9.510	2.540	.3639
2.90	.4814	9.645	2.563	.3577
2.92	.4801	9.781	2.586	.3517
2.94	.4788	9.918	2.609	.3457
2.96	.4776	10.06	2.632	.3398
2.98	.4764	10.19	2.656	.3340
3.00	.4752	10.33	2.679	.3283
3.02	.4740	10.47	2.703	.3327
3.04	.4729	10.62	2.726	.3172
3.06	.4717	10.76	2.750	.3118
3.08	.4706	10.90	2.774	.3065
3.10	.4695	11.05	2.799	.3012
3.12	.4685	11.19	2.823	.2960
3.14	.4674	11.34	2.848	.2910
3.16	.4664	11.48	2.872	.2860
3.18	.4654	11.63	2.897	.2811
3.20	.4643	11.78	2.922	.2762
3.22	.4634	11.93	2.947	.2715
3.24	.4624	12.08	2.972	.2668
3.26	.4614	12.23	2.998	.2622
3.28	.4605	12.38	3.023	.2577

TABLE D.2 Normal-Shock Flow (*continued*)

M_1	M_2	p_2/p_1	T_2/T_1	p_{02}/p_{01}
3.30	.4596	12.54	3.049	.2533
3.32	.4587	12.69	3.075	.2489
3.34	.4578	12.85	3.101	.2446
3.36	.4569	13.00	3.127	.2404
3.38	.4560	13.16	3.154	.2363
3.40	.4552	13.32	3.180	.2322
3.42	.4544	13.48	3.207	.2382
3.44	.4535	13.64	3.234	.2243
3.46	.4527	13.80	3.261	.2205
3.48	.4519	13.96	3.288	.2167
3.50	.4512	14.13	3.315	.2129
3.52	.4504	14.29	3.343	.2093
3.54	.4496	14.45	3.370	.2057
3.56	.4489	14.62	3.398	.2022
3.58	.4481	14.79	3.426	.1987
3.60	.4474	14.95	3.454	.1953
3.62	.4467	15.12	3.482	.1920
3.64	.4460	15.29	3.510	.1887
3.66	.4453	15.46	3.539	.1855
3.68	.4446	15.63	3.568	.1823
3.70	.4439	15.81	3.596	.1792
3.72	.4433	15.98	3.625	.1761
3.74	.4426	16.15	3.654	.1731
3.76	.4420	16.33	3.684	.1702
3.78	.4414	16.50	3.713	.1673
3.80	.4407	16.68	3.743	.1645
3.82	.4401	16.86	3.772	.1617
3.84	.4395	17.04	3.802	.1589
3.86	.4389	17.22	3.832	.1563
3.88	.4383	17.40	3.863	.1536
3.90	.4377	17.58	3.893	.1510
3.92	.4372	17.76	3.923	.1485
3.94	.4366	17.94	3.954	.1460
3.96	.4360	18.13	3.985	.1435
3.98	.4355	18.31	4.016	.1411
4.00	.4350	18.50	4.047	.1388