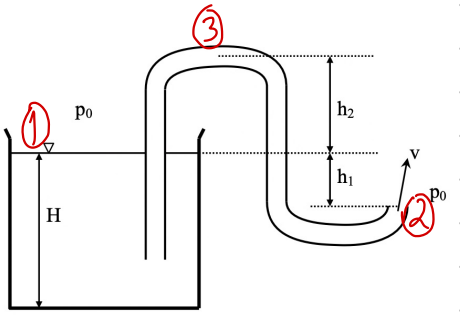
Øving 5

Oppgave 1

Væske strømmer fra et kar via en hevert. Karet er så stort at væskehøyden H kan regnes konstant. Hevertrøret har konstant tverrsnitt. Væsken er inkompressibel med tetthet ρ. Atmosfæretrykket er p_0. Tyngdens akselerasjon er g. Friksjonstap kan neglisjeres.



a) Uttrykk væskens hastighet v gjennom heverten ved de oppgitte størrelser.

b) Bestem den maksimale verdi h_2 kan ha når h_1 og p_0 tenkes gitt, og vi fortsatt skal ha kontinuerlig væskestrøm gjennom heverten.

Sett inn til slutt i svarene:
$h_1 = 3m$, $h_2 = 4m$, $p_0 = 10^5$ Pa (N/m^2) = 1atm., $\rho = 10^3$ kg/m^3, $g = 10$ m/s^2.

a) Bernoulli: Væskeoverflate – utløp

$$\frac{P_1}{\rho} + \frac{V_1^2}{2} + gz_1 = \frac{P_2}{\rho} + \frac{V_2^2}{2} + gz_2$$

$P_1 = P_2 = P_{atm}$, $V_1 = 0$

$$gz_1 = \frac{V_2^2}{2} + gz_2$$

$$V_2^2 = 2g(z_1 - z_2) = 2gh_1$$

$$V_2 = \sqrt{2gh}$$

$$V_2 = \sqrt{2 \cdot 10\ m/s^2 \cdot 3m} = \underline{7{,}75\ m/s}$$

b) Dersom væsken kaviterer dannes det gass => ikke kontinuerlig væskestrøm, da er $p_3 < 0$

Bernoulli: Væskeoverfleden – Toppen av heverten

$P_1 = P_0 = P_{atm}$, $V_1 = 0$, setter $z_1 = 0$ => $z_2 = h_2$

$$\frac{P_0}{\rho} = \frac{P_3}{\rho} + \frac{V^2}{2} + gh_2$$

$$P_3 = P_0 - \left(\frac{V^2}{2} + gh_2\right)\rho = P_0 - \rho g(h_1 + h_2) \geq 0$$

$$h_2 \leq \frac{P_0}{\rho g} - h_1 = \frac{10^5\ \cancel{Pa}}{10^3\ \cancel{kg/m^3} \cdot 10\ \cancel{m/s^2}} - 3m = 7m$$

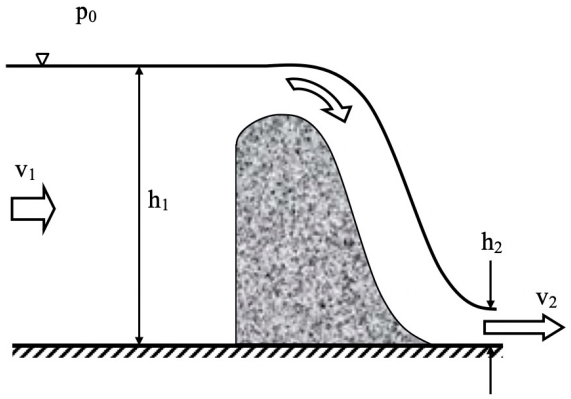
$$\underline{h_2 \leq 7}$$

Oppgave 2

I en overløpsstrømning over en undervannsdemning er det hydrostatiske trykkforhold før og etter (snitt 1 og 2). v_1 og v_2 regnes konstant over sine respektive tverrsnitt. Neglisjèr friksjon, og beregn:

a) v_2
b) Kraft per bredde på demningen.

Bruk $h_1 = 5.0$ m, $h_2 = 0.7$ m, $\rho = 998$ kg/m^3, $g = 9.81$ m/s^s.



a) Bernoulli på væskeoverflaten over h_1 og h_2

$$p_1 = p_2 = p_0$$

$$\frac{p_1}{\rho} + \frac{V_1^2}{2} + gh_1 = \frac{p_2}{\rho} + \frac{V_2^2}{2} + gh_2$$

$$\Rightarrow \underline{V_2^2 = V_1^2 + 2g(h_1 - h_2)}$$

Må finne ett uttrykk for V_1, massebevaring, volumstrømmen av vann er lik over og under demningen (antar steady state)

$$\Rightarrow q_1 = q_2$$

$$V_1 \cdot A_1 = V_2 \cdot A_2$$

$$V_1 = V_2 \cdot \frac{A_2}{A_1} = V_2 \cdot \frac{h_2 \cdot \text{bredde}}{h_1 \cdot \text{bredde}} = V_2 \cdot \frac{h_2}{h_1}$$

$$V_1 = V_2 \cdot \frac{h_2}{h_1}$$

Setter inn i likningen fra bernoulli:

$$V_2^2 = V_2^2 \cdot \left(\frac{h_2}{h_1}\right)^2 + 2g(h_1 - h_2)$$

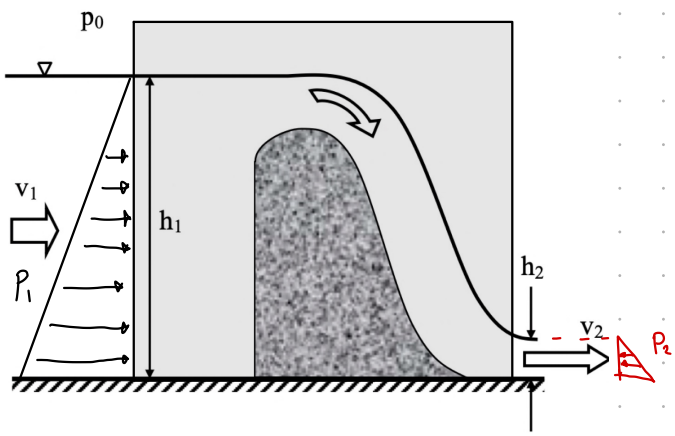
$$V_2^2 - \left(\frac{h_2}{h_1}\right)^2 V_2^2 = 2g(h_1 - h_2)$$

$$V_2^2 = \frac{2g(h_1 - h_2)}{1 - \left(\frac{h_2}{h_1}\right)^2}$$

$$V_2 = \sqrt{\frac{2g(h_1 - h_2)}{1 - \left(\frac{h_2}{h_1}\right)^2}} = \sqrt{\frac{2 \cdot 9{,}81\ \text{m/s}^2 (5\ \text{m} - 0{,}7\ \text{m})}{1 - \left(\frac{0{,}7\ \text{m}}{5\ \text{m}}\right)^2}}$$

$$\underline{\underline{V_2 = 9{,}28\ \text{m/s}}}$$

b) Ser på kontrollvolumet i figuren



Tre krefter virker horisontalt:

- Kontaktkraft fra demningen på vannet, F_k
- Trykkraft fra vannet "før" demningen, på demningen, P_f
- Trykkraft fra vannet "etter" demningen, på demningen, P_e

Newtons 2. lov:

$$\sum F = \dot{m} \cdot a = \Delta(\dot{m}v) = \Delta(\rho q v) = \Delta(\rho A \cdot v^2) = \Delta(\rho \cdot h \cdot b \cdot v^2) = \rho b \left(h_2 v_2^2 - h_1 v_1^2\right)$$

$$F_k + F_f - F_e = F_k + \frac{\rho g b}{2}\left(h_1^2 - h_2^2\right)$$

F_k: vet ikke forlegn

$F_f - F_e$: må defineres i samme retning som akselerasjonen => Positiv mot høyre

- Neglisjerer P_0 på begge sider av demningen

$$P = \frac{F}{A} \Rightarrow F = P \cdot A = P \cdot h \cdot b$$

Average pressure

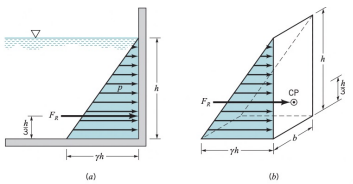


FIGURE 2.19 Pressure prism for vertical rectangular area.

$$P = \frac{\rho g h}{2} \Rightarrow F = \frac{\rho g h^2 \cdot b}{2}$$

$$\Rightarrow F_k + \frac{\rho g b}{2}\left(h_1^2 - h_2^2\right) = \rho b \left(h_2 v_2^2 - h_1 v_1^2\right) \quad / \div b$$

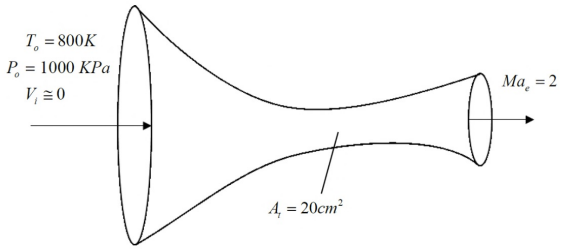
$$\frac{F_k}{b} = \rho\left(h_2 v_2^2 - h_1 v_1^2\right) - \frac{\rho g}{2}\left(h_1^2 - h_2^2\right) \qquad \text{/fra a)} \quad v_1 = v_2 \cdot \frac{h_2}{h_1} = 9{,}28 \cdot \frac{0{,}7}{5} = 1{,}30\ m/s$$

$$\frac{F_k}{b} \cdot 998\ kg/m^3 \left(0{,}7\ m \cdot (9{,}28\ m/s)^2 - 5\ m \cdot (1{,}30\ m/s)^2\right) - \frac{998\ kg/m^3 \cdot 9{,}81\ m/s^2}{2}\left((5\ m)^2 - (0{,}7\ m)^2\right)$$

$$\frac{F_k}{b} = -68252\ N = \underline{-68{,}3\ kN}$$

Vi skulle ha kraften fra vannet på demningen, som er like stor og motsatt rettet => $\underline{\underline{\frac{F_w}{b} = 68{,}3\ kN}}$

Luft går inn i en konvergerende-divergerende dyse, vist i fig, ved 1000 KPa og 800 K med ubetydelig hastighet. Strømmen er jevn, endimensjonal og isentropisk med k =1.4. For en utgang Mach antall Ma= 2 og et innsnevret område på 20 cm^2, bestem (a) innsnevringens betingelser (trykk (MPa) **[A]**, temperatur (K) **[B]**, tetthet (kg/m^3) **[C]**, hastighet (m/s) **[D]**), (b) massestrømningen (kg/s) **[E]** gjennom dysen.



Gasskonstanten av luft er 0.287 kJ/kg.k. Ved halsen på dysen Ma = 1, for en ideell gass med k = 1,4 fra isentropisk strøm av en ideell gass graf.

Bruk tabellene i denne nettlenken: http://www.cchem.berkeley.edu/cbe150a/isentropic_flow.pdf. Rund sifrene til to desimaler.

Se lenger ned

a) Finner verdier i tabellen, for $k = \gamma = 1{,}4$, $Ma = 1$:

Ma	P/P_o	T/T_o	A/A^*
1.00	0.5283	0.8333	1.0000

[A] $\frac{P}{P_o} = 0{,}5283 \Rightarrow P = 0{,}5283 \cdot P_o = 0{,}5283 \cdot 1000\ kPa = 5283\ kPa = \underline{0{,}53\ MPa}$

[B] $\frac{T}{T_o} = 0{,}8333 \Rightarrow T = 0{,}8333 \cdot 800K = \underline{666{,}64K}$

[C] $\frac{\rho}{\rho_o} = \frac{P/RT}{P_o/RT_o} = \frac{P}{P_o} \cdot \frac{T_o}{T} = \frac{0{,}5283}{0{,}8333} = 0{,}6340$

$\Rightarrow \rho = 0{,}6340 \cdot \rho_o = 0{,}6340 \cdot \frac{P_o}{R \cdot T_o} = 0{,}6340 \cdot \frac{1000 \cdot kPa}{0{,}287\ kJ/kg \cdot K \cdot 800K} = \underline{2{,}76\ kg/m^3}$

[D] Fra læreboka: $c = \sqrt{RTk}$

C er ikke lyshastigheten

$V = \sqrt{RTk} = \sqrt{0{,}287 \cdot 10^3\ J/kg \cdot K \cdot 666{,}64K \cdot 1{,}4} = \underline{517{,}55\ m/s}$

b) [E] $\dot{m} = \rho A V = 2{,}76\ kg/m^3 \cdot 20(10^{-2})^2\ m^2 \cdot 517{,}55\ m/s$

$\underline{\dot{m} = 2{,}86\ kg/s}$

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A*	M	P/P_0	T/T_0	A/A*
0.00	1.0000	1.0000	Infinite	0.35	0.9188	0.9761	1.7780
0.01	0.9999	1.0000	57.8738	0.36	0.9143	0.9747	1.7358
0.02	0.9997	0.9999	28.9421	0.37	0.9098	0.9733	1.6961
0.03	0.9994	0.9998	19.3005	0.38	0.9052	0.9719	1.6587
0.04	0.9989	0.9997	14.4815	0.39	0.9004	0.9705	1.6234
0.05	0.9983	0.9995	11.5914	0.40	0.8956	0.9690	1.5901
0.06	0.9975	0.9993	9.6659	0.41	0.8907	0.9675	1.5587
0.07	0.9966	0.9990	8.2915	0.42	0.8857	0.9659	1.5289
0.08	0.9955	0.9987	7.2616	0.43	0.8807	0.9643	1.5007
0.09	0.9944	0.9984	6.4613	0.44	0.8755	0.9627	1.4740
0.10	0.9930	0.9980	5.8218	0.45	0.8703	0.9611	1.4487
0.11	0.9916	0.9976	5.2992	0.46	0.8650	0.9594	1.4246
0.12	0.9900	0.9971	4.8643	0.47	0.8596	0.9577	1.4018
0.13	0.9883	0.9966	4.4969	0.48	0.8541	0.9559	1.3801
0.14	0.9864	0.9961	4.1824	0.49	0.8486	0.9542	1.3595
0.15	0.9844	0.9955	3.9103	0.50	0.8430	0.9524	1.3398
0.16	0.9823	0.9949	3.6727	0.51	0.8374	0.9506	1.3212
0.17	0.9800	0.9943	3.4635	0.52	0.8317	0.9487	1.3034
0.18	0.9776	0.9936	3.2779	0.53	0.8259	0.9468	1.2865
0.19	0.9751	0.9928	3.1123	0.54	0.8201	0.9449	1.2703
0.20	0.9725	0.9921	2.9635	0.55	0.8142	0.9430	1.2549
0.21	0.9697	0.9913	2.8293	0.56	0.8082	0.9410	1.2403
0.22	0.9668	0.9904	2.7076	0.57	0.8022	0.9390	1.2263
0.23	0.9638	0.9895	2.5968	0.58	0.7962	0.9370	1.2130
0.24	0.9607	0.9886	2.4956	0.59	0.7901	0.9349	1.2003
0.25	0.9575	0.9877	2.4027	0.60	0.7840	0.9328	1.1882
0.26	0.9541	0.9867	2.3173	0.61	0.7778	0.9307	1.1767
0.27	0.9506	0.9856	2.2385	0.62	0.7716	0.9286	1.1656
0.28	0.9470	0.9846	2.1656	0.63	0.7654	0.9265	1.1552
0.29	0.9433	0.9835	2.0979	0.64	0.7591	0.9243	1.1451
0.30	0.9395	0.9823	2.0351	0.65	0.7528	0.9221	1.1356
0.31	0.9355	0.9811	1.9765	0.66	0.7465	0.9199	1.1265
0.32	0.9315	0.9799	1.9219	0.67	0.7401	0.9176	1.1179
0.33	0.9274	0.9787	1.8707	0.68	0.7338	0.9153	1.1097
0.34	0.9231	0.9774	1.8229	0.69	0.7274	0.9131	1.1018

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A*	M	P/P_0	T/T_0	A/A*
0.70	0.7209	0.9107	1.0944	1.05	0.4979	0.8193	1.0020
0.71	0.7145	0.9084	1.0873	1.06	0.4919	0.8165	1.0029
0.72	0.7080	0.9061	1.0806	1.07	0.4860	0.8137	1.0039
0.73	0.7016	0.9037	1.0742	1.08	0.4800	0.8108	1.0051
0.74	0.6951	0.9013	1.0681	1.09	0.4742	0.8080	1.0064
0.75	0.6886	0.8989	1.0624	1.10	0.4684	0.8052	1.0079
0.76	0.6821	0.8964	1.0570	1.11	0.4626	0.8023	1.0095
0.77	0.6756	0.8940	1.0519	1.12	0.4568	0.7994	1.0113
0.78	0.6691	0.8915	1.0471	1.13	0.4511	0.7966	1.0132
0.79	0.6625	0.8890	1.0425	1.14	0.4455	0.7937	1.0153
0.80	0.6560	0.8865	1.0382	1.15	0.4398	0.7908	1.0175
0.81	0.6495	0.8840	1.0342	1.16	0.4343	0.7879	1.0198
0.82	0.6430	0.8815	1.0305	1.17	0.4287	0.7851	1.0222
0.83	0.6365	0.8789	1.0270	1.18	0.4232	0.7822	1.0248
0.84	0.6300	0.8763	1.0237	1.19	0.4178	0.7793	1.0276
0.85	0.6235	0.8737	1.0207	1.20	0.4124	0.7764	1.0304
0.86	0.6170	0.8711	1.0179	1.21	0.4070	0.7735	1.0334
0.87	0.6106	0.8685	1.0153	1.22	0.4017	0.7706	1.0366
0.88	0.6041	0.8659	1.0129	1.23	0.3964	0.7677	1.0398
0.89	0.5977	0.8632	1.0108	1.24	0.3912	0.7648	1.0432
0.90	0.5913	0.8606	1.0089	1.25	0.3861	0.7619	1.0468
0.91	0.5849	0.8579	1.0071	1.26	0.3809	0.7590	1.0504
0.92	0.5785	0.8552	1.0056	1.27	0.3759	0.7561	1.0542
0.93	0.5721	0.8525	1.0043	1.28	0.3708	0.7532	1.0581
0.94	0.5658	0.8498	1.0031	1.29	0.3658	0.7503	1.0621
0.95	0.5595	0.8471	1.0021	1.30	0.3609	0.7474	1.0663
0.96	0.5532	0.8444	1.0014	1.31	0.3560	0.7445	1.0706
0.97	0.5469	0.8416	1.0008	1.32	0.3512	0.7416	1.0750
0.98	0.5407	0.8389	1.0003	1.33	0.3464	0.7387	1.0796
0.99	0.5345	0.8361	1.0001	1.34	0.3417	0.7358	1.0842
1.00	0.5283	0.8333	1.0000	1.35	0.3370	0.7329	1.0890
1.01	0.5221	0.8306	1.0001	1.36	0.3323	0.7300	1.0940
1.02	0.5160	0.8278	1.0003	1.37	0.3277	0.7271	1.0990
1.03	0.5099	0.8250	1.0007	1.38	0.3232	0.7242	1.1042
1.04	0.5039	0.8222	1.0013	1.39	0.3187	0.7213	1.1095

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A^*	M	P/P_0	T/T_0	A/A^*
1.40	0.3142	0.7184	1.1149	1.75	0.1878	0.6202	1.3865
1.41	0.3098	0.7155	1.1205	1.76	0.1850	0.6175	1.3967
1.42	0.3055	0.7126	1.1262	1.77	0.1822	0.6148	1.4070
1.43	0.3012	0.7097	1.1320	1.78	0.1794	0.6121	1.4175
1.44	0.2969	0.7069	1.1379	1.79	0.1767	0.6095	1.4282
1.45	0.2927	0.7040	1.1440	1.80	0.1740	0.6068	1.4390
1.46	0.2886	0.7011	1.1501	1.81	0.1714	0.6041	1.4499
1.47	0.2845	0.6982	1.1565	1.82	0.1688	0.6015	1.4610
1.48	0.2804	0.6954	1.1629	1.83	0.1662	0.5989	1.4723
1.49	0.2764	0.6925	1.1695	1.84	0.1637	0.5963	1.4836
1.50	0.2724	0.6897	1.1762	1.85	0.1612	0.5936	1.4952
1.51	0.2685	0.6868	1.1830	1.86	0.1587	0.5910	1.5069
1.52	0.2646	0.6840	1.1899	1.87	0.1563	0.5884	1.5187
1.53	0.2608	0.6811	1.1970	1.88	0.1539	0.5859	1.5308
1.54	0.2570	0.6783	1.2042	1.89	0.1516	0.5833	1.5429
1.55	0.2533	0.6754	1.2116	1.90	0.1492	0.5807	1.5553
1.56	0.2496	0.6726	1.2190	1.91	0.1470	0.5782	1.5677
1.57	0.2459	0.6698	1.2266	1.92	0.1447	0.5756	1.5804
1.58	0.2423	0.6670	1.2344	1.93	0.1425	0.5731	1.5932
1.59	0.2388	0.6642	1.2422	1.94	0.1403	0.5705	1.6062
1.60	0.2353	0.6614	1.2502	1.95	0.1381	0.5680	1.6193
1.61	0.2318	0.6586	1.2584	1.96	0.1360	0.5655	1.6326
1.62	0.2284	0.6558	1.2666	1.97	0.1339	0.5630	1.6461
1.63	0.2250	0.6530	1.2750	1.98	0.1318	0.5605	1.6597
1.64	0.2217	0.6502	1.2836	1.99	0.1298	0.5580	1.6735
1.65	0.2184	0.6475	1.2922	2.00	0.1278	0.5556	1.6875
1.66	0.2151	0.6447	1.3010	2.01	0.1258	0.5531	1.7016
1.67	0.2119	0.6419	1.3100	2.02	0.1239	0.5506	1.7160
1.68	0.2088	0.6392	1.3190	2.03	0.1220	0.5482	1.7305
1.69	0.2057	0.6364	1.3283	2.04	0.1201	0.5458	1.7451
1.70	0.2026	0.6337	1.3376	2.05	0.1182	0.5433	1.7600
1.71	0.1996	0.6310	1.3471	2.06	0.1164	0.5409	1.7750
1.72	0.1966	0.6283	1.3567	2.07	0.1146	0.5385	1.7902
1.73	0.1936	0.6256	1.3665	2.08	0.1128	0.5361	1.8056
1.74	0.1907	0.6229	1.3764	2.09	0.1111	0.5337	1.8212

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A^*	M	P/P_0	T/T_0	A/A^*
2.10	0.1094	0.5313	1.8369	2.45	.6327 E-1	0.4544	2.5168
2.11	0.1077	0.5290	1.8529	2.46	.6229 E-1	0.4524	2.5403
2.12	0.1060	0.5266	1.8690	2.47	.6133 E-1	0.4504	2.5640
2.13	0.1043	0.5243	1.8853	2.48	.6038 E-1	0.4484	2.5880
2.14	0.1027	0.5219	1.9018	2.49	.5945 E-1	0.4464	2.6122
2.15	.1011 E+0	0.5196	1.9185	2.50	.5853 E-1	0.4444	2.6367
2.16	.9956 E-1	0.5173	1.9354	2.51	.5762 E-1	0.4425	2.6615
2.17	.9802 E-1	0.5150	1.9525	2.52	.5674 E-1	0.4405	2.6865
2.18	.9649 E-1	0.5127	1.9698	2.53	.5586 E-1	0.4386	2.7117
2.19	.9500 E-1	0.5104	1.9873	2.54	.5500 E-1	0.4366	2.7372
2.20	.9352 E-1	0.5081	2.0050	2.55	.5415 E-1	0.4347	2.7630
2.21	.9207 E-1	0.5059	2.0229	2.56	.5332 E-1	0.4328	2.7891
2.22	.9064 E-1	0.5036	2.0409	2.57	.5250 E-1	0.4309	2.8154
2.23	.8923 E-1	0.5014	2.0592	2.58	.5169 E-1	0.4289	2.8420
2.24	.8785 E-1	0.4991	2.0777	2.59	.5090 E-1	0.4271	2.8688
2.25	.8648 E-1	0.4969	2.0964	2.60	.5012 E-1	0.4252	2.8960
2.26	.8514 E-1	0.4947	2.1153	2.61	.4935 E-1	0.4233	2.9234
2.27	.8382 E-1	0.4925	2.1345	2.62	.4859 E-1	0.4214	2.9511
2.28	.8251 E-1	0.4903	2.1538	2.63	.4784 E-1	0.4196	2.9791
2.29	.8123 E-1	0.4881	2.1734	2.64	.4711 E-1	0.4177	3.0073
2.30	.7997 E-1	0.4859	2.1931	2.65	.4639 E-1	0.4159	3.0359
2.31	.7873 E-1	0.4837	2.2131	2.66	.4568 E-1	0.4141	3.0647
2.32	.7751 E-1	0.4816	2.2333	2.67	.4498 E-1	0.4122	3.0938
2.33	.7631 E-1	0.4794	2.2538	2.68	.4429 E-1	0.4104	3.1233
2.34	.7512 E-1	0.4773	2.2744	2.69	.4362 E-1	0.4086	3.1530
2.35	.7396 E-1	0.4752	2.2953	2.70	.4295 E-1	0.4068	3.1830
2.36	.7281 E-1	0.4731	2.3164	2.71	.4229 E-1	0.4051	3.2133
2.37	.7168 E-1	0.4709	2.3377	2.72	.4165 E-1	0.4033	3.2440
2.38	.7057 E-1	0.4688	2.3593	2.73	.4102 E-1	0.4015	3.2749
2.39	.6948 E-1	0.4668	2.3811	2.74	.4039 E-1	0.3998	3.3061
2.40	.6840 E-1	0.4647	2.4031	2.75	.3978 E-1	0.3980	3.3377
2.41	.6734 E-1	0.4626	2.4254	2.76	.3917 E-1	0.3963	3.3695
2.42	.6630 E-1	0.4606	2.4479	2.77	.3858 E-1	0.3945	3.4017
2.43	.6527 E-1	0.4585	2.4706	2.78	.3799 E-1	0.3928	3.4342
2.44	.6426 E-1	0.4565	2.4936	2.79	.3742 E-1	0.3911	3.4670

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A*	M	P/P_0	T/T_0	A/A*
2.80	.3685 E-1	0.3894	3.5001	3.15	.2177 E-1	0.3351	4.8838
2.81	.3629 E-1	0.3877	3.5336	3.16	.2146 E-1	0.3337	4.9304
2.82	.3574 E-1	0.3860	3.5674	3.17	.2114 E-1	0.3323	4.9774
2.83	.3520 E-1	0.3844	3.6015	3.18	.2083 E-1	0.3309	5.0248
2.84	.3467 E-1	0.3827	3.6359	3.19	.2053 E-1	0.3295	5.0727
2.85	.3415 E-1	0.3810	3.6707	3.20	.2023 E-1	0.3281	5.1210
2.86	.3363 E-1	0.3794	3.7058	3.21	.1993 E-1	0.3267	5.1697
2.87	.3312 E-1	0.3777	3.7413	3.22	.1964 E-1	0.3253	5.2189
2.88	.3263 E-1	0.3761	3.7771	3.23	.1936 E-1	0.3240	5.2685
2.89	.3213 E-1	0.3745	3.8133	3.24	.1908 E-1	0.3226	5.3186
2.90	.3165 E-1	0.3729	3.8498	3.25	.1880 E-1	0.3213	5.3691
2.91	.3118 E-1	0.3712	3.8866	3.26	.1853 E-1	0.3199	5.4201
2.92	.3071 E-1	0.3696	3.9238	3.27	.1826 E-1	0.3186	5.4715
2.93	.3025 E-1	0.3681	3.9614	3.28	.1799 E-1	0.3173	5.5234
2.94	.2980 E-1	0.3665	3.9993	3.29	.1773 E-1	0.3160	5.5758
2.95	.2935 E-1	0.3649	4.0376	3.30	.1748 E-1	0.3147	5.6286
2.96	.2891 E-1	0.3633	4.0763	3.31	.1722 E-1	0.3134	5.6820
2.97	.2848 E-1	0.3618	4.1153	3.32	.1698 E-1	0.3121	5.7358
2.98	.2805 E-1	0.3602	4.1547	3.33	.1673 E-1	0.3108	5.7900
2.99	.2764 E-1	0.3587	4.1944	3.34	.1649 E-1	0.3095	5.8448
3.00	.2722 E-1	0.3571	4.2346	3.35	.1625 E-1	0.3082	5.9000
3.01	.2682 E-1	0.3556	4.2751	3.36	.1602 E-1	0.3069	5.9558
3.02	.2642 E-1	0.3541	4.3160	3.37	.1579 E-1	0.3057	6.0120
3.03	.2603 E-1	0.3526	4.3573	3.38	.1557 E-1	0.3044	6.0687
3.04	.2564 E-1	0.3511	4.3989	3.39	.1534 E-1	0.3032	6.1260
3.05	.2526 E-1	0.3496	4.4410	3.40	.1512 E-1	0.3019	6.1837
3.06	.2489 E-1	0.3481	4.4835	3.41	.1491 E-1	0.3007	6.2419
3.07	.2452 E-1	0.3466	4.5263	3.42	.1470 E-1	0.2995	6.3007
3.08	.2416 E-1	0.3452	4.5696	3.43	.1449 E-1	0.2982	6.3600
3.09	.2380 E-1	0.3437	4.6132	3.44	.1428 E-1	0.2970	6.4198
3.10	.2345 E-1	0.3422	4.6573	3.45	.1408 E-1	0.2958	6.4801
3.11	.2310 E-1	0.3408	4.7018	3.46	.1388 E-1	0.2946	6.5409
3.12	.2276 E-1	0.3393	4.7467	3.47	.1368 E-1	0.2934	6.6023
3.13	.2243 E-1	0.3379	4.7920	3.48	.1349 E-1	0.2922	6.6642
3.14	.2210 E-1	0.3365	4.8377	3.49	.1330 E-1	0.2910	6.7266

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A*	M	P/P_0	T/T_0	A/A*
3.50	.1311 E-1	0.2899	6.7896	3.85	.8060 E-2	0.2522	9.3661
3.51	.1293 E-1	0.2887	6.8532	3.86	.7951 E-2	0.2513	9.4513
3.52	.1274 E-1	0.2875	6.9172	3.87	.7844 E-2	0.2503	9.5372
3.53	.1256 E-1	0.2864	6.9819	3.88	.7739 E-2	0.2493	9.6237
3.54	.1239 E-1	0.2852	7.0471	3.89	.7635 E-2	0.2484	9.7110
3.55	.1221 E-1	0.2841	7.1128	3.90	.7532 E-2	0.2474	9.7990
3.56	.1204 E-1	0.2829	7.1791	3.91	.7431 E-2	0.2464	9.8877
3.57	.1188 E-1	0.2818	7.2460	3.92	.7332 E-2	0.2455	9.9771
3.58	.1171 E-1	0.2806	7.3135	3.93	.7233 E-2	0.2446	10.0672
3.59	.1155 E-1	0.2795	7.3815	3.94	.7137 E-2	0.2436	10.1581
3.60	.1138 E-1	0.2784	7.4501	3.95	.7042 E-2	0.2427	10.2496
3.61	.1123 E-1	0.2773	7.5193	3.96	.6948 E-2	0.2418	10.3420
3.62	.1107 E-1	0.2762	7.5891	3.97	.6855 E-2	0.2408	10.4350
3.63	.1092 E-1	0.2751	7.6595	3.98	.6764 E-2	0.2399	10.5289
3.64	.1076 E-1	0.2740	7.7305	3.99	.6675 E-2	0.2390	10.6234
3.65	.1062 E-1	0.2729	7.8020	4.00	.6586 E-2	0.2381	10.7188
3.66	.1047 E-1	0.2718	7.8742	4.01	.6499 E-2	0.2372	10.8148
3.67	.1032 E-1	0.2707	7.9470	4.02	.6413 E-2	0.2363	10.9117
3.68	.1018 E-1	0.2697	8.0204	4.03	.6328 E-2	0.2354	11.0093
3.69	.1004 E-1	0.2686	8.0944	4.04	.6245 E-2	0.2345	11.1077
3.70	.9903 E-2	0.2675	8.1691	4.05	.6163 E-2	0.2336	11.2069
3.71	.9767 E-2	0.2665	8.2443	4.06	.6082 E-2	0.2327	11.3068
3.72	.9633 E-2	0.2654	8.3202	4.07	.6002 E-2	0.2319	11.4076
3.73	.9500 E-2	0.2644	8.3968	4.08	.5923 E-2	0.2310	11.5091
3.74	.9370 E-2	0.2633	8.4739	4.09	.5845 E-2	0.2301	11.6115
3.75	.9242 E-2	0.2623	8.5517	4.10	.5769 E-2	0.2293	11.7147
3.76	.9116 E-2	0.2613	8.6302	4.11	.5694 E-2	0.2284	11.8186
3.77	.8991 E-2	0.2602	8.7093	4.12	.5619 E-2	0.2275	11.9234
3.78	.8869 E-2	0.2592	8.7891	4.13	.5546 E-2	0.2267	12.0290
3.79	.8748 E-2	0.2582	8.8695	4.14	.5474 E-2	0.2258	12.1354
3.80	.8629 E-2	0.2572	8.9506	4.15	.5403 E-2	0.2250	12.2427
3.81	.8512 E-2	0.2562	9.0323	4.16	.5333 E-2	0.2242	12.3508
3.82	.8396 E-2	0.2552	9.1148	4.17	.5264 E-2	0.2233	12.4597
3.83	.8283 E-2	0.2542	9.1979	4.18	.5195 E-2	0.2225	12.5695
3.84	.8171 E-2	0.2532	9.2817	4.19	.5128 E-2	0.2217	12.6801

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A*	M	P/P_0	T/T_0	A/A*
4.20	.5062 E-2	0.2208	12.7916	4.55	.3247 E-2	0.1945	17.2767
4.21	.4997 E-2	0.2200	12.9040	4.56	.3207 E-2	0.1938	17.4228
4.22	.4932 E-2	0.2192	13.0172	4.57	.3168 E-2	0.1932	17.5699
4.23	.4869 E-2	0.2184	13.1313	4.58	.3129 E-2	0.1925	17.7181
4.24	.4806 E-2	0.2176	13.2463	4.59	.3090 E-2	0.1918	17.8674
4.25	.4745 E-2	0.2168	13.3622	4.60	.3053 E-2	0.1911	18.0178
4.26	.4684 E-2	0.2160	13.4789	4.61	.3015 E-2	0.1905	18.1693
4.27	.4624 E-2	0.2152	13.5965	4.62	.2978 E-2	0.1898	18.3218
4.28	.4565 E-2	0.2144	13.7151	4.63	.2942 E-2	0.1891	18.4755
4.29	.4507 E-2	0.2136	13.8345	4.64	.2906 E-2	0.1885	18.6303
4.30	.4449 E-2	0.2129	13.9549	4.65	.2871 E-2	0.1878	18.7862
4.31	.4393 E-2	0.2121	14.0762	4.66	.2836 E-2	0.1872	18.9433
4.32	.4337 E-2	0.2113	14.1984	4.67	.2802 E-2	0.1865	19.1015
4.33	.4282 E-2	0.2105	14.3215	4.68	.2768 E-2	0.1859	19.2608
4.34	.4228 E-2	0.2098	14.4456	4.69	.2734 E-2	0.1852	19.4212
4.35	.4174 E-2	0.2090	14.5706	4.70	.2701 E-2	0.1846	19.5828
4.36	.4121 E-2	0.2083	14.6965	4.71	.2669 E-2	0.1839	19.7456
4.37	.4069 E-2	0.2075	14.8234	4.72	.2637 E-2	0.1833	19.9095
4.38	.4018 E-2	0.2067	14.9513	4.73	.2605 E-2	0.1827	20.0746
4.39	.3968 E-2	0.2060	15.0801	4.74	.2573 E-2	0.1820	20.2409
4.40	.3918 E-2	0.2053	15.2099	4.75	.2543 E-2	0.1814	20.4084
4.41	.3868 E-2	0.2045	15.3406	4.76	.2512 E-2	0.1808	20.5770
4.42	.3820 E-2	0.2038	15.4724	4.77	.2482 E-2	0.1802	20.7469
4.43	.3772 E-2	0.2030	15.6051	4.78	.2452 E-2	0.1795	20.9179
4.44	.3725 E-2	0.2023	15.7388	4.79	.2423 E-2	0.1789	21.0902
4.45	.3678 E-2	0.2016	15.8735	4.80	.2394 E-2	0.1783	21.2637
4.46	.3633 E-2	0.2009	16.0092	4.81	.2366 E-2	0.1777	21.4384
4.47	.3587 E-2	0.2002	16.1459	4.82	.2338 E-2	0.1771	21.6144
4.48	.3543 E-2	0.1994	16.2837	4.83	.2310 E-2	0.1765	21.7916
4.49	.3499 E-2	0.1987	16.4224	4.84	.2283 E-2	0.1759	21.9700
4.50	.3455 E-2	0.1980	16.5622	4.85	.2255 E-2	0.1753	22.1497
4.51	.3412 E-2	0.1973	16.7030	4.86	.2229 E-2	0.1747	22.3306
4.52	.3370 E-2	0.1966	16.8449	4.87	.2202 E-2	0.1741	22.5128
4.53	.3329 E-2	0.1959	16.9878	4.88	.2177 E-2	0.1735	22.6963
4.54	.3288 E-2	0.1952	17.1317	4.89	.2151 E-2	0.1729	22.8811

Isentropic Flow Tables

γ = **1.4**

M	P/P_0	T/T_0	A/A*	M	P/P_0	T/T_0	A/A*
4.90	.2126 E-2	0.1724	23.0671	5.25	.1419 E-2	0.1536	30.4467
4.91	.2101 E-2	0.1718	23.2545	5.26	.1403 E-2	0.1531	30.6840
4.92	.2076 E-2	0.1712	23.4431	5.27	.1387 E-2	0.1526	30.9229
4.93	.2052 E-2	0.1706	23.6331	5.28	.1372 E-2	0.1521	31.1634
4.94	.2028 E-2	0.1700	23.8243	5.29	.1356 E-2	0.1516	31.4054
4.95	.2004 E-2	0.1695	24.0169	5.30	.1341 E-2	0.1511	31.6491
4.96	.1981 E-2	0.1689	24.2109	5.31	.1326 E-2	0.1506	31.8943
4.97	.1957 E-2	0.1683	24.4061	5.32	.1311 E-2	0.1501	32.1411
4.98	.1935 E-2	0.1678	24.6027	5.33	.1297 E-2	0.1497	32.3896
4.99	.1912 E-2	0.1672	24.8007	5.34	.1282 E-2	0.1492	32.6397
5.00	.1890 E-2	0.1667	25.0000	5.35	.1268 E-2	0.1487	32.8914
5.01	.1868 E-2	0.1661	25.2007	5.36	.1254 E-2	0.1482	33.1448
5.02	.1847 E-2	0.1656	25.4027	5.37	.1240 E-2	0.1478	33.3998
5.03	.1825 E-2	0.1650	25.6062	5.38	.1227 E-2	0.1473	33.6565
5.04	.1804 E-2	0.1645	25.8110	5.39	.1213 E-2	0.1468	33.9148
5.05	.1783 E-2	0.1639	26.0172	5.40	.1200 E-2	0.1464	34.1748
5.06	.1763 E-2	0.1634	26.2249	5.41	.1187 E-2	0.1459	34.4365
5.07	.1742 E-2	0.1628	26.4339	5.42	.1174 E-2	0.1454	34.6999
5.08	.1722 E-2	0.1623	26.6444	5.43	.1161 E-2	0.1450	34.9650
5.09	.1703 E-2	0.1618	26.8563	5.44	.1148 E-2	0.1445	35.2318
5.10	.1683 E-2	0.1612	27.0696	5.45	.1135 E-2	0.1441	35.5003
5.11	.1664 E-2	0.1607	27.2843	5.46	.1123 E-2	0.1436	35.7705
5.12	.1645 E-2	0.1602	27.5005	5.47	.1111 E-2	0.1432	36.0425
5.13	.1626 E-2	0.1597	27.7182	5.48	.1099 E-2	0.1427	36.3162
5.14	.1608 E-2	0.1591	27.9373	5.49	.1087 E-2	0.1423	36.5917
5.15	.1589 E-2	0.1586	28.1579	5.50	.1075 E-2	0.1418	36.8690
5.16	.1571 E-2	0.1581	28.3800	5.51	.1063 E-2	0.1414	37.1480
5.17	.1553 E-2	0.1576	28.6036	5.52	.1052 E-2	0.1410	37.4288
5.18	.1536 E-2	0.1571	28.8287	5.53	.1040 E-2	0.1405	37.7113
5.19	.1518 E-2	0.1566	29.0552	5.54	.1029 E-2	0.1401	37.9957
5.20	.1501 E-2	0.1561	29.2833	5.55	.1018 E-2	0.1397	38.2819
5.21	.1484 E-2	0.1555	29.5129	5.56	.1007 E-2	0.1392	38.5699
5.22	.1468 E-2	0.1550	29.7441	5.57	.9961 E-3	0.1388	38.8597
5.23	.1451 E-2	0.1545	29.9767	5.58	.9853 E-3	0.1384	39.1513
5.24	.1435 E-2	0.1540	30.2109	5.59	.9748 E-3	0.1379	39.4448