UNIVERSITY OF JOHANNESBURG

PROGRAM	: BENGTECH ENGINEERING: MECHANICAL
SUBJECT	: HYDRAULIC MACHINES 2B
CODE	: HYMMIB2
DATE	: SUPPLEMENTARY EXAMINATION 10 JANUARY 2019
DURATION	: 08:00 – 11:00 AM
WEIGHT	: 60% OF SEMESTER MARK
TOTAL MARKS	: 100 MARKS

Examiner	: MR VT. HASHE
Moderator	: MR S. SIMELANE

INSTRUCTIONS:

1. PLEASE ANSWER ALL QUESTIONS NEATLY
2. SHOW ALL CALCULATIONS
3. ANSWERS WITHOUT UNITS WILL BE PENALIZED
4. NUMBER YOUR ANSWERS STRICTLY ACCORDING TO THE QUESTION

NUMBER OF PAGES : 10 (Including cover page and 6 pages of Annexures)

QUESTION 1

Water at 15°C is to be discharged from a reservoir at a rate of 18 L/s using two horizontal cast iron pipes connected in series and a pump between them. The first pipe is 20 m long and has a 6-cm diameter, while the second pipe is 35 m long and has a 4 cm diameter. The water level in the reservoir is 30 m above the centerline of the pipe. The pipe entrance is sharp-edged, and losses associated with the connection of the pump are negligible. Neglecting the effect of the kinetic energy correction factor, estimate the minimum pumping power to maintain the indicated flow rate.

[35]

QUESTION 2

The initial flow in a pipeline is governed by the inertia pressure. Fig.2 shows a pipe of uniform cross-section and length (L) to convey liquid from a reservoir. The reservoir maintains a constant height of liquid above the pipe connection to a reservoir. The pipe has a valve at its downstream end which is initially closed, and the pressure downstream the valve is constant. When the valve is opened, the difference in piezometric pressure between the ends of the pipeline is applied to the static liquid column in it.

Prove that it will take $t = \frac{L}{V_0(1+K)} \ln(\frac{V_0+V}{V_0-V})$ for the fluid to reach a steady state velocity upon the open on the valve down stream the valve, if V_0 is the steady state velocity and V the unsteady state velocity.

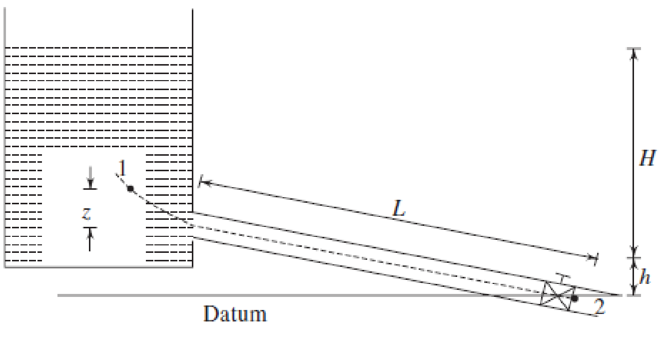


Figure 2

[20]

QUESTION 3

3.1 Fig. 3.1 shows a v-notch installed after a pump in the student laboratory to measure the discharge. Develop an expression to determine the discharge for this application if the theoretical velocity is given by $(2gh)^{1/2}$.

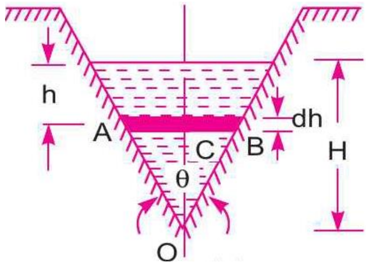


Figure 3.1

3.2 Water flows in a channel whose bottom slope is 0.002 and whose cross section is as shown in Fig. 3.2. The dimensions and the Manning coefficients for the surfaces of different subsections are also given on the figure. Estimate the flow rate through the channel when the flow depth is 3.5 m, as well as the effective Manning coefficient for the channel.

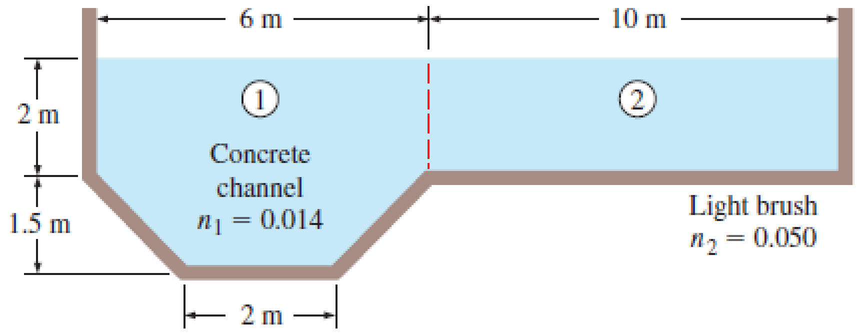


Figure 3.2

[40]

QUESTION 4

The circuit diagram to control a single-acting cylinder is shown in Fig. 4. Describe the control mechanism of this system.

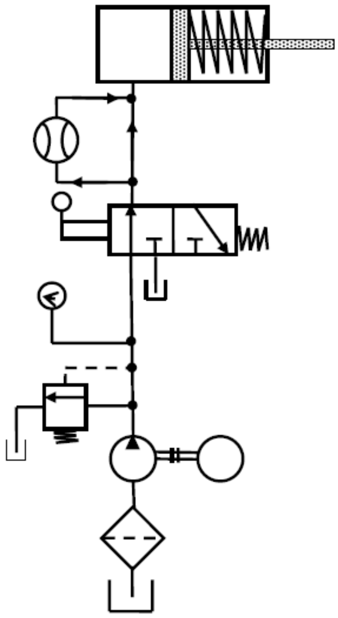


Figure 4

[5]

End

$$\text{Re} = \frac{\rho V_{\text{avg}} D}{\mu}$$

$$\dot{V} = V_{\text{avg}} A_c = \frac{\Delta P \pi D^4}{128 \mu L}$$

$$\Delta P_L = f \frac{L}{D} \frac{\rho V^2}{2} \quad \text{and} \quad h_L = \frac{\Delta P_L}{\rho g} = f \frac{L}{D} \frac{V^2}{2g}$$

$$h_L = K_L \frac{V^2}{2g}$$

$$\frac{1}{\sqrt{f}} = -2.0 \log\left(\frac{\varepsilon/D}{3.7} + \frac{2.51}{\text{Re}\sqrt{f}}\right)$$

$$D_h = \frac{4A_c}{p}$$

$$C_D = \frac{F_D}{\frac{1}{2}\rho V^2 A} \quad \text{and} \quad C_L = \frac{F_L}{\frac{1}{2}\rho V^2 A}$$

$$V_{\text{min}} = \sqrt{\frac{2W}{\rho C_{L,\,\text{max}} A}}$$

$$W = F_L = \tfrac{1}{2} C_{L,\,\text{max}} \rho V_{\text{min}}^2 A$$

$$\text{Amount of fuel} = \frac{m_{\text{fuel}}}{\rho_{\text{fuel}}} = \frac{E_{\text{in}}/\text{HV}}{\rho_{\text{fuel}}}$$

$$V_0 = \frac{a}{n} R_h^{2/3} S_0^{1/2} \quad \text{and} \quad \dot{V} = \frac{a}{n} A_c R_h^{2/3} S_0^{1/2}$$

$$\dot{V}_{\text{rec}} = C_{\text{wd, rec}} \frac{2}{3} b \sqrt{2g} H^{3/2}$$

$$C_{\text{wd, rec}} = 0.598 + 0.0897 \frac{H}{P_w} \quad \text{for} \quad \frac{H}{P_w} \leq 2$$

$$\dot{V} = C_{\text{wd, tri}} \frac{8}{15} \tan\left(\frac{\theta}{2}\right) \sqrt{2g} H^{5/2}$$

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m^3	Specific Heat c_p J/kg·K	Thermal Conductivity k, W/m·K	Thermal Diffusivity α, m^2/s	Dynamic Viscosity μ, kg/m·s	Kinematic Viscosity ν, m^2/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-6}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154

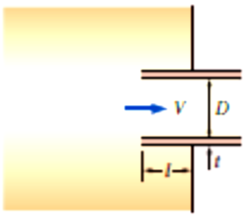
PHYSICAL PROPERTIES OF TAP WATER AT 1 ATMOSPHERE

Temperature T [ºC]	Density ρ [kg.m^{-3}]	Dynamic viscosity μ [kg.m^{-1}s^{-1}]	Surface tension σ [N.m^{-1}]	Vapour pressure head $p/\rho g$ [m]	Bulk modulus of elasticity K [MN.m^{-2}]
0	999.9	1.792 x 10^{-3}	0.0762	0.06	2040
5	1000.0	1.519 x 10^{-3}	0.0754	0.09	2060
10	999.7	1.308 x 10^{-3}	0.0748	0.12	2110
15	999.1	1.14 x 10^{-3}	0.0741	0.17	2140
20	998.2	1.005 x 10^{-3}	0.0736	0.25	2200
25	997.1	0.894 x 10^{-3}	0.0726	0.33	2220
30	995.7	0.801 x 10^{-3}	0.0718	0.44	2230
35	994.1	0.723 x 10^{-3}	0.071	0.58	2240
40	992.2	0.656 x10^{-3}	0.0701	0.76	2270
45	990.2	0.599 x 10^{-3}	0.0692	0.98	2290
50	988.1	0.549 x 10^{-3}	0.0682	1.26	2300
60	983.2	0.469 x 10^{-3}	0.0668	2.03	2280
70	977.8	0.406 x 10^{-3}	0.065	3.2	2250
80	971.8	0.357 x 10^{-3}	0.063	4.86	2210
90	965.3	0.317 x 10^{-3}	0.0612	7.18	2160
100	958.4	0.284 x 10^{-3}	0.0594	10.33	2070

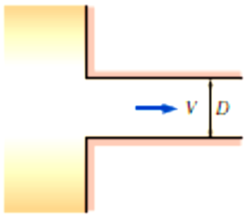
Loss coefficients K_L of various pipe components for turbulent flow (for use in the relation $h_L = K_L V^2/(2g)$, where V is the average velocity in the pipe that contains the component)*

Pipe Inlet

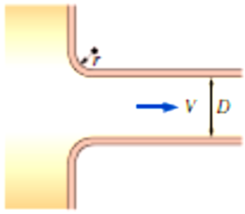
Reentrant: $K_L = 0.80$
($t \ll D$ and $l \approx 0.1D$)



Sharp-edged: $K_L = 0.50$

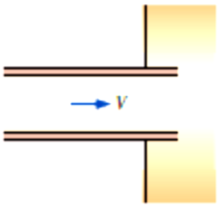


Well-rounded ($r/D > 0.2$): $K_L = 0.03$
Slightly rounded ($r/D = 0.1$): $K_L = 0.12$
(see Fig. 8–39)

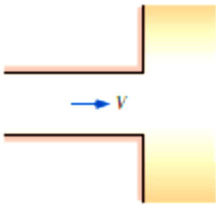


Pipe Exit

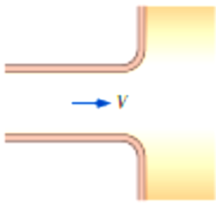
Reentrant: $K_L = \alpha$



Sharp-edged: $K_L = \alpha$



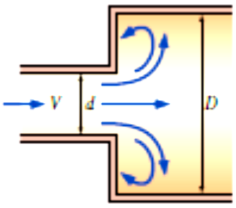
Rounded: $K_L = \alpha$



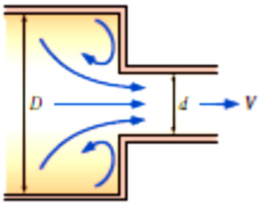
Note: The kinetic energy correction factor is $\alpha = 2$ for fully developed laminar flow, and $\alpha \approx 1.05$ for fully developed turbulent flow.

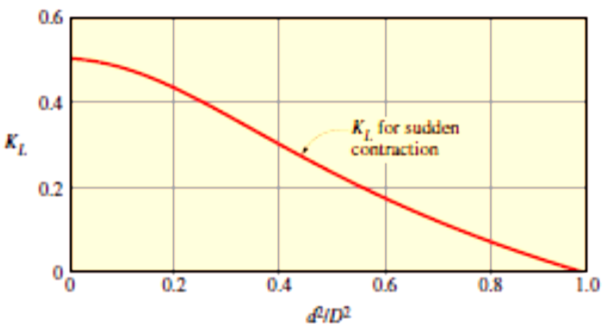
Sudden Expansion and Contraction (based on the velocity in the smaller-diameter pipe)

Sudden expansion: $K_L = \alpha\left(1 - \frac{d^2}{D^2}\right)^2$



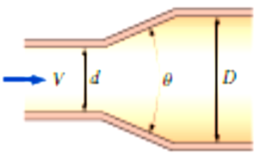
Sudden contraction: See chart.



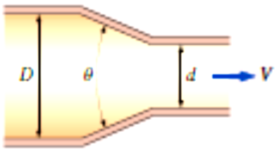


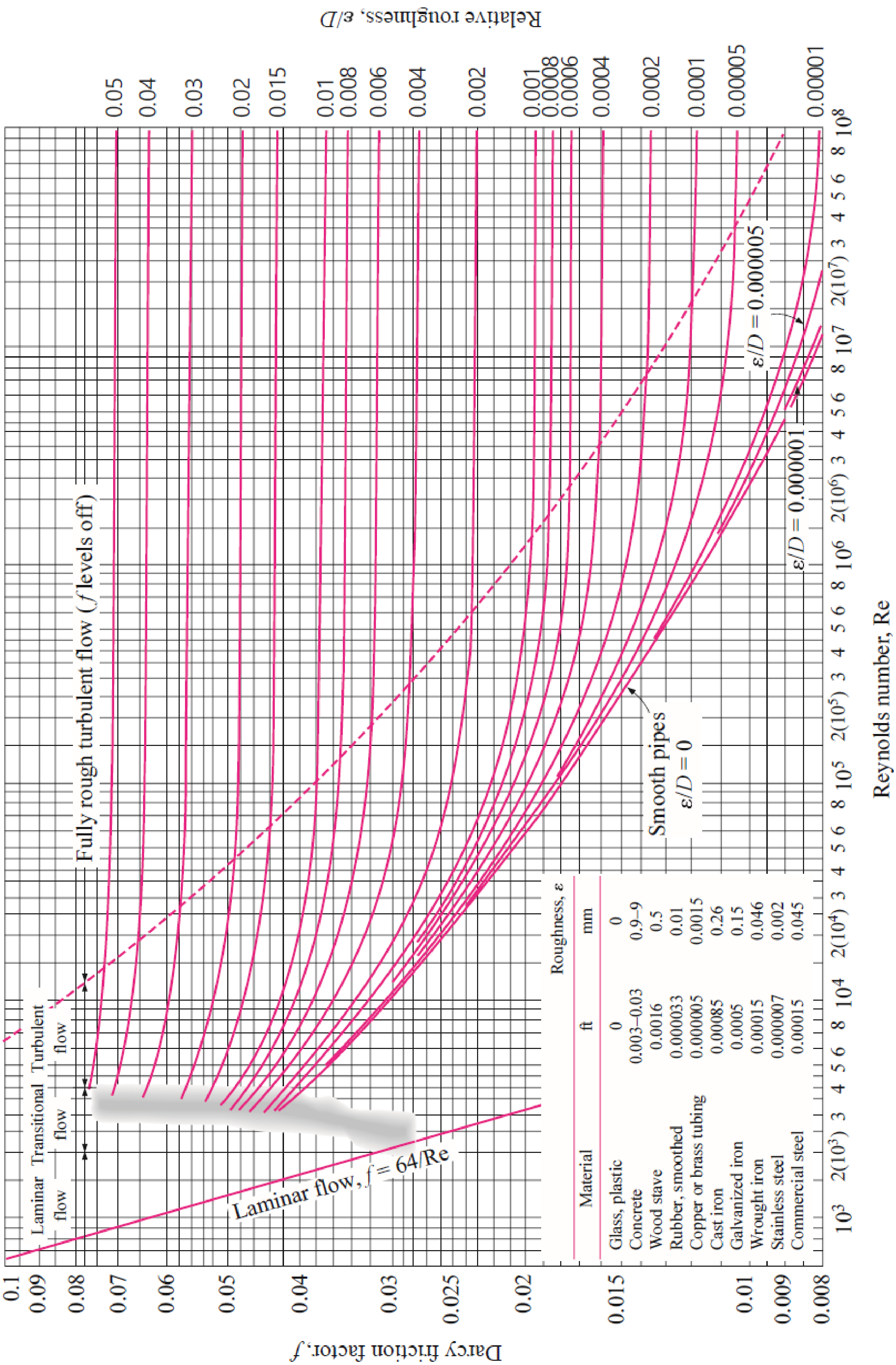
Gradual Expansion and Contraction (based on the velocity in the smaller-diameter pipe)

Expansion (for $\theta = 20°$):
$K_L = 0.30$ for $d/D = 0.2$
$K_L = 0.25$ for $d/D = 0.4$
$K_L = 0.15$ for $d/D = 0.6$
$K_L = 0.10$ for $d/D = 0.8$



Contraction:
$K_L = 0.02$ for $\theta = 30°$
$K_L = 0.04$ for $\theta = 45°$
$K_L = 0.07$ for $\theta = 60°$




Relative roughness, ε/D
Darcy friction factor, f
Reynolds number, Re
Fully rough turbulent flow (f levels off)
Laminar flow
Transitional flow
Turbulent flow
Laminar flow, f = 64/Re
Smooth pipes ε/D = 0
ε/D = 0.000001
ε/D = 0.000005
Roughness, ε
Material
ft
mm
Glass, plastic 0 0
Concrete 0.003–0.03 0.9–9
Wood stave 0.0016 0.5
Rubber, smoothed 0.000033 0.01
Copper or brass tubing 0.000005 0.0015
Cast iron 0.00085 0.26
Galvanized iron 0.0005 0.15
Wrought iron 0.00015 0.046
Stainless steel 0.000007 0.002
Commercial steel 0.00015 0.045

Molar mass, gas constant, and ideal-gas specfic heats of some substances

Substance	Molar Mass M, kg/kmol	Gas Constant R, kJ/kg · K*	Specific Heat Data at 25°C		
			c_p, kJ/kg · K	c_v, kJ/kg · K	$k = c_p/c_v$
Air	28.97	0.2870	1.005	0.7180	1.400
Ammonia, NH_3	17.03	0.4882	2.093	1.605	1.304
Argon, Ar	39.95	0.2081	0.5203	0.3122	1.667
Bromine, Br_2	159.81	0.05202	0.2253	0.1732	1.300
Isobutane, C_4H_{10}	58.12	0.1430	1.663	1.520	1.094
n-Butane, C_4H_{10}	58.12	0.1430	1.694	1.551	1.092
Carbon dioxide, CO_2	44.01	0.1889	0.8439	0.6550	1.288
Carbon monoxide, CO	28.01	0.2968	1.039	0.7417	1.400
Chlorine, Cl_2	70.905	0.1173	0.4781	0.3608	1.325
Chlorodifluoromethane (R-22), $CHClF_2$	86.47	0.09615	0.6496	0.5535	1.174
Ethane, C_2H_6	30.070	0.2765	1.744	1.468	1.188
Ethylene, C_2H_4	28.054	0.2964	1.527	1.231	1.241
Fluorine, F_2	38.00	0.2187	0.8237	0.6050	1.362
Helium, He	4.003	2.077	5.193	3.116	1.667
n-Heptane, C_7H_{16}	100.20	0.08297	1.649	1.566	1.053
n-Hexane, C_6H_{14}	86.18	0.09647	1.654	1.558	1.062
Hydrogen, H_2	2.016	4.124	14.30	10.18	1.405
Krypton, Kr	83.80	0.09921	0.2480	0.1488	1.667
Methane, CH_4	16.04	0.5182	2.226	1.708	1.303
Neon, Ne	20.183	0.4119	1.030	0.6180	1.667
Nitrogen, N_2	28.01	0.2968	1.040	0.7429	1.400
Nitric oxide, NO	30.006	0.2771	0.9992	0.7221	1.384
Nitrogen dioxide, NO_2	46.006	0.1889	0.8060	0.6171	1.306
Oxygen, O_2	32.00	0.2598	0.9180	0.6582	1.395
n-Pentane, C_5H_{12}	72.15	0.1152	1.664	1.549	1.074
Propane, C_3H_8	44.097	0.1885	1.669	1.480	1.127
Propylene, C_3H_6	42.08	0.1976	1.531	1.333	1.148
Steam, H_2O	18.015	0.4615	1.865	1.403	1.329
Sulfur dioxide, SO_2	64.06	0.1298	0.6228	0.4930	1.263
Tetrachloromethane, CCl_4	153.82	0.05405	0.5415	0.4875	1.111
Tetrafluoroethane (R-134a), $C_2H_2F_4$	102.03	0.08149	0.8334	0.7519	1.108
Trifluoroethane (R-143a), $C_2H_3F_3$	84.04	0.09893	0.9291	0.8302	1.119
Xenon, Xe	131.30	0.06332	0.1583	0.09499	1.667

* The unit kJ/kg · K is equivalent to kPa · m³/kg · K. The gas constant is calculated from $R = R_u/M$, where R_u = 8.31447 kJ/kmol · K is the universal gas constant and M is the molar mass.

Source: Specific heat values are obtained primarily from the property routines prepared by The National Institute of Standards and Technology (NIST), Gaithersburg, MD.

From Chow (1959).

Wall Material	*n*
A. Artificially lined channels	
Glass	0.010
Brass	0.011
Steel, smooth	0.012
Steel, painted	0.014
Steel, riveted	0.015
Cast iron	0.013
Concrete, finished	0.012
Concrete, unfinished	0.014
Wood, planed	0.012
Wood, unplaned	0.013
Clay tile	0.014
Brickwork	0.015
Asphalt	0.016
Corrugated metal	0.022
Rubble masonry	0.025
B. Excavated earth channels	
Clean	0.022
Gravelly	0.025
Weedy	0.030
Stony, cobbles	0.035
C. Natural channels	
Clean and straight	0.030
Sluggish with deep pools	0.040
Major rivers	0.035
Mountain streams	0.050
D. Floodplains	
Pasture, farmland	0.035
Light brush	0.050
Heavy brush	0.075
Trees	0.150

* The uncertainty in *n* can be ± 20 percent or more.