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$$p_{\text{abs}} = p_{\text{gage}} + p_{\text{atm}} \qquad g = 9.81\ \boldsymbol{m/s^2}$$

Ideal Gas Law: $p = \rho R T$

$$\tau = \mu \frac{dV}{dy} \qquad E_v = -\frac{dp}{d\mathcal{V}/\mathcal{V}} = \frac{dp}{d\rho/\rho} \qquad F_\sigma = \sigma L \qquad \gamma = \rho g \qquad S = \frac{\gamma_{\text{fluid}}}{\gamma_{\text{water}}} = \frac{\rho_{\text{fluid}}}{\rho_{\text{water}}}$$

Hydrostatics:

$$\frac{dp}{dz} = -\gamma \qquad F_B = \gamma \mathcal{V}_D \qquad GM = \frac{I_{00}}{\mathcal{V}} - CG \qquad p_1 + \sum_{\text{down}} \gamma_i h_i - \sum_{\text{up}} \gamma_i h_i = p_2$$

$$y_{cp} = y_c + \frac{I_{xx,c}}{y_c A}, \bar{p} = \gamma h_c, F_p = \gamma h_c A \qquad \text{RM} = \gamma \mathcal{V} GM \alpha$$

$$\text{Re} = \frac{VD}{\nu} = \frac{4\dot{m}}{\pi D \mu} \qquad D_h = 4R_h = \frac{4 \times \text{section area}}{\text{wetted perimeter}}$$

Euler's Equation: $-\frac{\partial}{\partial \ell}(p + \gamma z) = \rho a_\ell$ Rotating flows: $p + \gamma z - \rho \frac{\omega^2 r^2}{2} = C$

Bernoulli Equation: $p + \gamma z + \rho \frac{V^2}{2} = C$

$$a_t = \frac{\partial V}{\partial t} + V\frac{\partial V}{\partial s} \qquad a_n = \frac{V^2}{r} \qquad \omega = 2\Omega = \left(\frac{\partial w}{\partial y} - \frac{\partial v}{\partial z}\right)\mathbf{i} + \left(\frac{\partial u}{\partial z} - \frac{\partial w}{\partial x}\right)\mathbf{j} + \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)\mathbf{k} = \nabla \times V$$

$$\boldsymbol{a} = \frac{\boldsymbol{\partial V}}{\boldsymbol{\partial t}} + \boldsymbol{V}.\boldsymbol{\nabla V}, \quad \boldsymbol{\nabla} = \mathbf{i}\frac{\boldsymbol{\partial}}{\boldsymbol{\partial}\mathbf{x}} + \mathbf{j}\frac{\boldsymbol{\partial}}{\boldsymbol{\partial}\mathbf{y}} + \mathbf{k}\frac{\boldsymbol{\partial}}{\boldsymbol{\partial}\mathbf{z}}, \quad a_x = \frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z},$$

$$a_y = \frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z}, \qquad a_z = \frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z}$$

$$\frac{d}{dt}\int_{\text{cv}} \rho\, d\mathcal{V} + \int_{\text{cs}} \rho \boldsymbol{V} \cdot d\boldsymbol{A} = 0 \qquad \frac{d}{dt}M_{\text{cv}} = \sum \dot{m}_i - \sum \dot{m}_o \qquad \dot{m} = \int_A \rho V\, dA \qquad Q = \int_A V\, dA = \overline{V}A$$

$$\sum_{\text{cs}} \boldsymbol{F} = \frac{d}{dt}\int_{\text{cv}} \boldsymbol{v}\rho\, d\mathcal{V} + \int_{\text{cs}} \boldsymbol{v}\rho \boldsymbol{V} \cdot d\boldsymbol{A} \qquad \sum_{\text{cs}} \boldsymbol{F} = \frac{d}{dt}\int_{\text{cv}} \boldsymbol{v}\rho\, d\mathcal{V} + \sum_{\text{cs}} \dot{m}_o \boldsymbol{v}_o - \sum_{\text{cs}} \dot{m}_i \boldsymbol{v}_i$$

$$\sum_{\text{cs}} \boldsymbol{M} = \frac{d}{dt}\int_{\text{cv}} \rho(\boldsymbol{r} \times \boldsymbol{v})\, d\mathcal{V} + \sum_{\text{cs}} \boldsymbol{r}_o \times (\dot{m}_o \boldsymbol{v}_o) - \sum_{\text{cs}} \boldsymbol{r}_i \times (\dot{m}_i \boldsymbol{v}_i) \qquad \dot{Q} - \dot{W}_s = \sum_{\text{cs}} \dot{m}_o\left(\frac{V_o^2}{2} + h_o + gz_o\right) - \sum_{\text{cs}} \dot{m}_i\left(\frac{V_i^2}{2} + h_i + gz_i\right)$$

$$\frac{\partial \rho}{\partial t} + \boldsymbol{\nabla}.(\rho \boldsymbol{V}) = 0, \quad \text{Incompressible flow: } \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0$$

$$\frac{p_1}{\gamma} + \alpha_1 \frac{V_1^2}{2g} + z_1 + h_p = \frac{p_2}{\gamma} + \alpha_2 \frac{V_2^2}{2g} + z_2 + h_t + h_L \qquad h_L = \sum_{\text{pipes}} f\frac{L}{D}\frac{V^2}{2g} + \sum_{\text{components}} K\frac{V^2}{2g}$$

$$\dot{W}_p = \gamma Q h_p \qquad \dot{W}_t = \gamma Q h_t \qquad \dot{W}_s = \dot{W}_p / \eta_p \qquad \dot{W}_s = \eta_t \dot{W}_t$$

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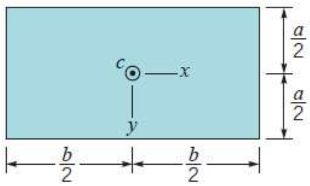


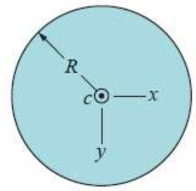
$A = ba$

$I_{xc} = \frac{1}{12} ba^3$

$I_{yc} = \frac{1}{12} ab^3$

$I_{xyc} = 0$

(*a*) Rectangle

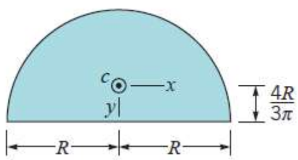


$A = \pi R^2$

$I_{xc} = I_{yc} = \frac{\pi R^4}{4}$

$I_{xyc} = 0$

(*b*) Circle



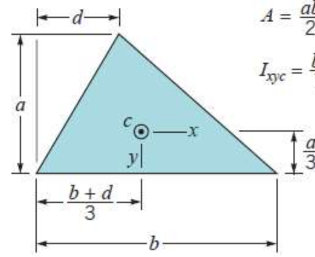
$A = \frac{\pi R^2}{2}$

$I_{xc} = 0.1098R^4$

$I_{yc} = 0.3927R^4$

$I_{xyc} = 0$

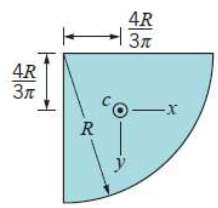
(*c*) Semicircle



$A = \frac{ab}{2}$ $I_{xc} = \frac{ba^3}{36}$

$I_{xyc} = \frac{ba^2}{72}(b - 2d)$

(*d*) Triangle

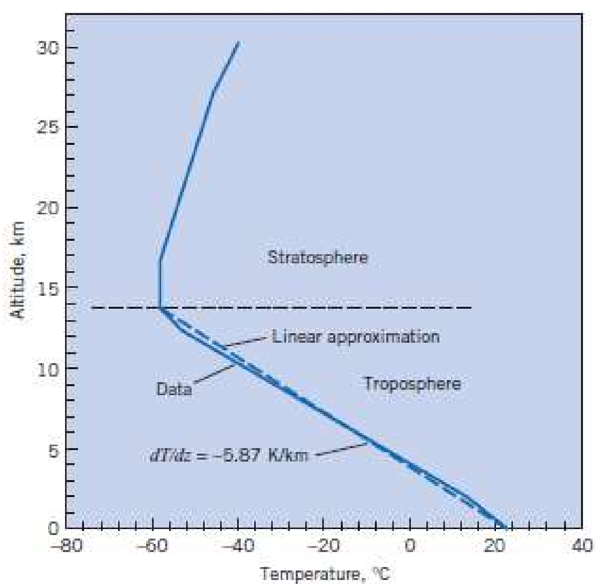


$A = \frac{\pi R^2}{4}$

$I_{xc} = I_{yc} = 0.05488R^4$

$I_{xyc} = -0.01647R^4$

(*e*) Quarter circle



Pressure Variation in the Troposphere $T = T_0 - \alpha(z - z_0)$

$$p = p_0 \left[\frac{T_0 - \alpha(z - z_0)}{T_0} \right]^{g/\alpha R}$$

Pressure Variation in the Lower Stratosphere $p = p_0 e^{-(z - z_0)g/RT}$

Swamee and Jain Relations:

$$Q = -2.22\, D^{5/2} \sqrt{gh_f/L} \log\left(\frac{k_s}{3.7\, D} + \frac{1.78\, \nu}{D^{3/2} \sqrt{gh_f/L}} \right)$$

$$D = 0.66 \left[k_s^{1.25} \left(\frac{LQ^2}{gh_f} \right)^{4.75} + \nu Q^{9.4} \left(\frac{L}{gh_f} \right)^{5.2} \right]^{0.04}$$

Table 10.5 LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

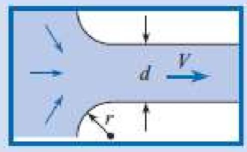
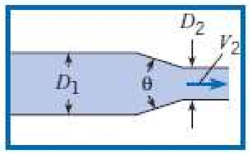
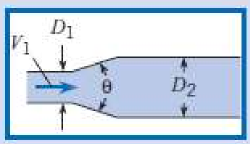
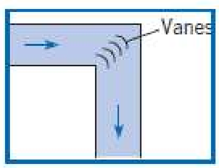
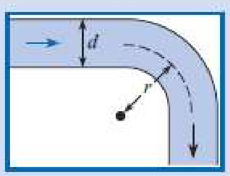
Description	Sketch	Additional Data		K	Source
Pipe entrance		r/d		K_e	(10)†
$h_L = K_e V^2/2g$		0.0		0.50	
		0.1		0.12	
		>0.2		0.03	
Contraction			K_C	K_C	
$h_L = K_C V_2^2/2g$		D_2/D_1	$\theta = 60°$	$\theta = 180°$	(10)
		0.00	0.08	0.50	
		0.20	0.08	0.49	
		0.40	0.07	0.42	
		0.60	0.06	0.27	
		0.80	0.06	0.20	
		0.90	0.06	0.10	
Expansion			K_E	K_E	
$h_L = K_E V_1^2/2g$		D_1/D_2	$\theta = 20°$	$\theta = 180°$	(9)
		0.00		1.00	
		0.20	0.30	0.87	
		0.40	0.25	0.70	
		0.60	0.15	0.41	
		0.80	0.10	0.15	
90° miter bend		Without vanes	$K_b = 1.1$		(15)
		With vanes	$K_b = 0.2$		(15)
90° smooth bend		r/d			(16) and (9)
		1	$K_b = 0.35$		
		2	0.19		
		4	0.16		
		6	0.21		
		8	0.28		
		10	0.32		
Threaded pipe fittings	Globe valve—wide open			$K_v = 10.0$	(15)
	Angle valve—wide open			$K_v = 5.0$	
	Gate valve—wide open			$K_v = 0.2$	
	Gate valve—half open			$K_v = 5.6$	
	Return bend			$K_b = 2.2$	
	Tee				
	Straight-through flow			$K_t = 0.4$	
	Side-outlet flow			$K_t = 1.8$	
	90° elbow			$K_b = 0.9$	
	45° elbow			$K_b = 0.4$	

Table 10.4 EQUIVALENT SAND-GRAIN ROUGHNESS, (k_S), FOR VARIOUS PIPE MATERIALS

Boundary Material	k_s, Millimeters	k_s, Inches
Glass, plastic	Smooth	Smooth
Copper or brass tubing	0.0015	6×10^{-5}
Wrought iron, steel	0.046	0.002
Asphalted cast iron	0.12	0.005
Galvanized iron	0.15	0.006
Cast iron	0.26	0.010
Concrete	0.3 to 3.0	0.012–0.12
Riveted steel	0.9–9	0.035–0.35
Rubber pipe (straight)	0.025	0.001

$$\mathrm{Re}\, f^{1/2} = \frac{D^{3/2}}{\nu}(2gh_f/L)^{1/2}$$

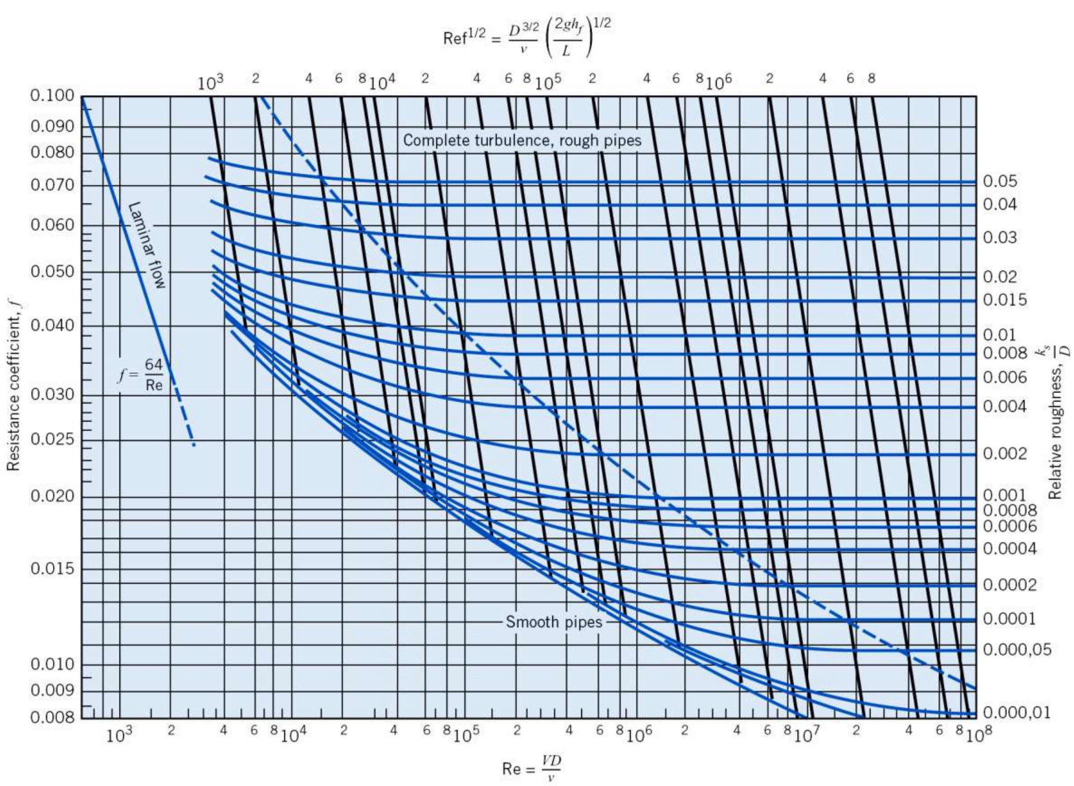


Table A.3 MECHANICAL PROPERTIES OF AIR AT STANDARD ATMOSPHERIC PRESSURE				
Temperature	Density	Specific Weight	Dynamic Viscosity	Kinematic Viscosity
	kg/m^3	N/m^3	$N \cdot s/m^2$	m^2/s
−20°C	1.40	13.70	1.61×10^{-5}	1.16×10^{-5}
−10°C	1.34	13.20	1.67×10^{-5}	1.24×10^{-5}
0°C	1.29	12.70	1.72×10^{-5}	1.33×10^{-5}
10°C	1.25	12.20	1.76×10^{-5}	1.41×10^{-5}
20°C	1.20	11.80	1.81×10^{-5}	1.51×10^{-5}
30°C	1.17	11.40	1.86×10^{-5}	1.60×10^{-5}
40°C	1.13	11.10	1.91×10^{-5}	1.69×10^{-5}
50°C	1.09	10.70	1.95×10^{-5}	1.79×10^{-5}
60°C	1.06	10.40	2.00×10^{-5}	1.89×10^{-5}
70°C	1.03	10.10	2.04×10^{-5}	1.99×10^{-5}
80°C	1.00	9.81	2.09×10^{-5}	2.09×10^{-5}
90°C	0.97	9.54	2.13×10^{-5}	2.19×10^{-5}
100°C	0.95	9.28	2.17×10^{-5}	2.29×10^{-5}
120°C	0.90	8.82	2.26×10^{-5}	2.51×10^{-5}
140°C	0.85	8.38	2.34×10^{-5}	2.74×10^{-5}
160°C	0.81	7.99	2.42×10^{-5}	2.97×10^{-5}
180°C	0.78	7.65	2.50×10^{-5}	3.20×10^{-5}
200°C	0.75	7.32	2.57×10^{-5}	3.44×10^{-5}

Table A.5 APPROXIMATE PHYSICAL PROPERTIES OF WATER* AT ATMOSPHERIC PRESSURE					
Temperature	Density	Specific Weight	Dynamic Viscosity	Kinematic Viscosity	Vapor Pressure
	kg/m^3	N/m^3	$N \cdot s/m^2$	m^2/s	N/m^2 abs
0°C	1000	9810	1.79×10^{-3}	1.79×10^{-6}	611
5°C	1000	9810	1.51×10^{-3}	1.51×10^{-6}	872
10°C	1000	9810	1.31×10^{-3}	1.31×10^{-6}	1,230
15°C	999	9800	1.14×10^{-3}	1.14×10^{-6}	1,700
20°C	998	9790	1.00×10^{-3}	1.00×10^{-6}	2,340
25°C	997	9781	8.91×10^{-4}	8.94×10^{-7}	3,170
30°C	996	9771	7.97×10^{-4}	8.00×10^{-7}	4,250
35°C	994	9751	7.20×10^{-4}	7.24×10^{-7}	5,630
40°C	992	9732	6.53×10^{-4}	6.58×10^{-7}	7,380
50°C	988	9693	5.47×10^{-4}	5.53×10^{-7}	12,300
60°C	983	9643	4.66×10^{-4}	4.74×10^{-7}	20,000
70°C	978	9594	4.04×10^{-4}	4.13×10^{-7}	31,200
80°C	972	9535	3.54×10^{-4}	3.64×10^{-7}	47,400
90°C	965	9467	3.15×10^{-4}	3.26×10^{-7}	70,100
100°C	958	9398	2.82×10^{-4}	2.94×10^{-7}	101,300