

Appendix A: Centroids and Area Moments of Inertia

STATICS

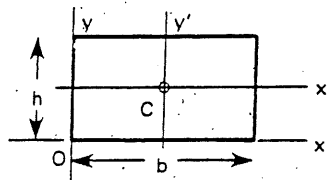
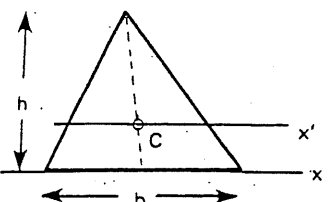
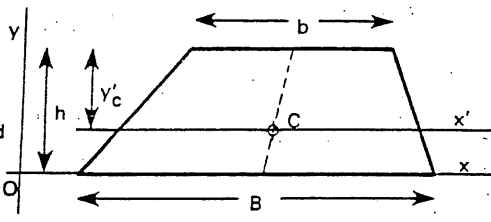
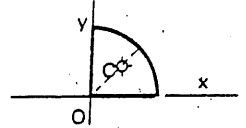
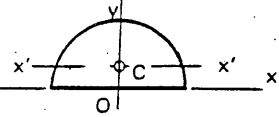
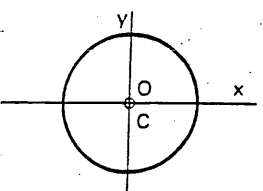
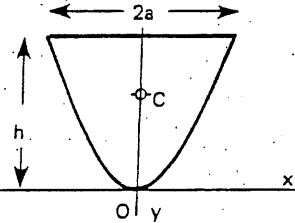
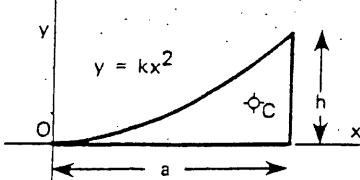
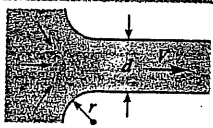
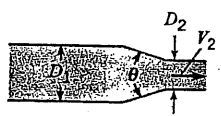
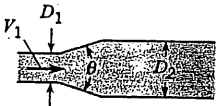
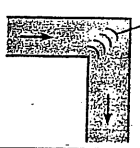
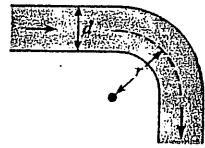
| SHAPE | DIMENSIONS | CENTROID (x_c, y_c) | AREA MOMENT OF INERTIA |
|-----------------------------|---|---|---|
| Rectangle |  | $(\frac{1}{2}b, \frac{1}{2}h)$ | $I_{x'} = (1/12)bh^3$ $I_{y'} = (1/12)hb^3$ $I_x = (1/3)bh^3$ $I_y = (1/3)hb^3$ $J_C = (1/12)bh(b^2 + h^2)$ |
| Triangle |  | $y_c = (h/3)$ | $I_{x'} = (1/36)bh^3$ $I_x = (1/12)bh^3$ |
| Trapezoid |  | $y_c' = \frac{h(2B + b)}{3(B + b)}$ Note that this is measured from the top surface. | $I_{x'} = \frac{h^3(B^2 + 4Bb + b^2)}{36(B + b)}$ $I_x = \frac{h^3(B + 3b)}{12}$ |
| Quarter-Circle, of radius r |  | $((4r/3\pi), (4r/3\pi))$ | $I_x = I_y = (1/16)\pi r^4$ $J_O = (1/8)\pi r^4$ |
| Half Circle, of radius r |  | $(0, (4r/3\pi))$ | $I_x = I_y = (1/8)\pi r^4$ $J_O = \frac{1}{2}\pi r^4$ $I_{x'} = .11r^4$ |
| Circle, of radius r |  | $(0,0)$ | $I_x = I_y = \frac{1}{2}\pi r^4$ $J_O = \frac{1}{2}\pi r^4$ |
| Parabolic Area |  | $(0, (3h/5))$ | $I_x = 4h^3a/7$ $I_y = 4ha^3/15$ |
| Parabolic Spandrel |  | $((3a/4), (3h/10))$ | $I_x = ah^3/21$ $I_y = 3ha^3/15$ |

TABLE 10.2 LOSS COEFFICIENTS FOR VARIOUS TRANSITIONS AND FITTINGS

| Description | Sketch | Additional Data | K | Source |
|-------------------------------------|---|-----------------|----------------------|--------------|
| Pipe entrance $h_L = K_e V^2/2g$ |  | r/d | K_e | (2)* |
| | | 0.0 | 0.50 | |
| | | 0.1 | 0.12 | |
| | | >0.2 | 0.03 | |
| Contraction |  | D_2/D_1 | K_C | (2) |
| | | | $\theta = 60^\circ$ | |
| | | | $\theta = 180^\circ$ | |
| | | 0.0 | 0.08 | |
| | | 0.20 | 0.08 | |
| | | 0.40 | 0.07 | |
| | | 0.60 | 0.06 | |
| | | 0.80 | 0.06 | |
| | | 0.90 | 0.06 | |
| Expansion |  | D_1/D_2 | K_E | (2) |
| | | | $\theta = 20^\circ$ | |
| | | | $\theta = 180^\circ$ | |
| | | 0.0 | 1.00 | |
| | | 0.20 | 0.30 | |
| | | 0.40 | 0.25 | |
| | | 0.60 | 0.15 | |
| | | 0.80 | 0.10 | |
| 90° miter bend |  | Without vanes | $K_b = 1.1$ | (37) |
| | | With vanes | $K_b = 0.2$ | (37) |
| 90° smooth bend |  | r/d | $K_b = 0.35$ | (5) and (19) |
| | | 1 | 0.19 | |
| | | 2 | 0.16 | |
| | | 4 | 0.21 | |
| | | 6 | 0.28 | |
| | | 8 | 0.32 | |
| | | 10 | 0.32 | |
| Threaded pipe fittings | Globe valve—wide open | $K_v = 10.0$ | | (37) |
| | 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 | $K_b = 0.4$ | | |

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10.5 FLOW AT PIPE IN

FIGURE 10.14 EGL and HGL at a sharp-edged pipe entrance.

FIGURE 10.15 Head losses in a pipe.

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 • 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 | 1230 |
| 15°C | 999 | 9800 | 1.14 × 10 ⁻³ | 1.14 × 10 ⁻⁶ | 1700 |
| 20°C | 998 | 9790 | 1.00 × 10 ⁻³ | 1.00 × 10 ⁻⁶ | 2340 |
| 25°C | 997 | 9781 | 8.91 × 10 ⁻⁴ | 8.94 × 10 ⁻⁷ | 3170 |
| 30°C | 996 | 9771 | 7.97 × 10 ⁻⁴ | 8.00 × 10 ⁻⁷ | 4250 |
| 35°C | 994 | 9751 | 7.20 × 10 ⁻⁴ | 7.24 × 10 ⁻⁷ | 5630 |
| 40°C | 992 | 9732 | 6.53 × 10 ⁻⁴ | 6.58 × 10 ⁻⁷ | 7380 |
| 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 |
| | slugs/ft ³ | lbf/ft ³ | lbf-s/ft ² | ft ² /s | psia |
| 40°F | 1.94 | 62.43 | 3.23 × 10 ⁻⁵ | 1.66 × 10 ⁻⁵ | 0.122 |
| 50°F | 1.94 | 62.40 | 2.73 × 10 ⁻⁵ | 1.41 × 10 ⁻⁵ | 0.178 |
| 60°F | 1.94 | 62.37 | 2.36 × 10 ⁻⁵ | 1.22 × 10 ⁻⁵ | 0.256 |
| 70°F | 1.94 | 62.30 | 2.05 × 10 ⁻⁵ | 1.06 × 10 ⁻⁵ | 0.363 |
| 80°F | 1.93 | 62.22 | 1.80 × 10 ⁻⁵ | 0.930 × 10 ⁻⁵ | 0.506 |
| 100°F | 1.93 | 62.00 | 1.42 × 10 ⁻⁵ | 0.739 × 10 ⁻⁵ | 0.949 |
| 120°F | 1.92 | 61.72 | 1.17 × 10 ⁻⁵ | 0.609 × 10 ⁻⁵ | 1.69 |
| 140°F | 1.91 | 61.38 | 0.981 × 10 ⁻⁵ | 0.514 × 10 ⁻⁵ | 2.89 |
| 160°F | 1.90 | 61.00 | 0.838 × 10 ⁻⁵ | 0.442 × 10 ⁻⁵ | 4.74 |
| 180°F | 1.88 | 60.58 | 0.726 × 10 ⁻⁵ | 0.385 × 10 ⁻⁵ | 7.51 |
| 200°F | 1.87 | 60.12 | 0.637 × 10 ⁻⁵ | 0.341 × 10 ⁻⁵ | 11.53 |
| 212°F | 1.86 | 59.83 | 0.593 × 10 ⁻⁵ | 0.319 × 10 ⁻⁵ | 14.70 |

*Notes: (1) Bulk modulus E_v of water is approximately 2.2 G Pa (3.2×10^5 psi); (2) Water-air surface tension is approximately 7.3×10^{-2} N/m (5×10^{-3} lbf/ft) from 10°C to 50°C.

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1. Determine the head loss, given the kind and size of pipe and the flow rate.
2. Determine the flow rate, given the head, kind, and size of pipe.
3. Determine the size of pipe needed to carry the flow, given the kind of pipe, head, and flow rate.

In the first type of problem, the Reynolds number and k_s/D are first computed and then f is read from Fig. 10.8, after which the head loss is obtained by the use of Eq. (10.22).

$$Re_f^{1/2} = \frac{D^{3/2}}{v} \left(\frac{2gh_f}{L} \right)^{1/2}$$

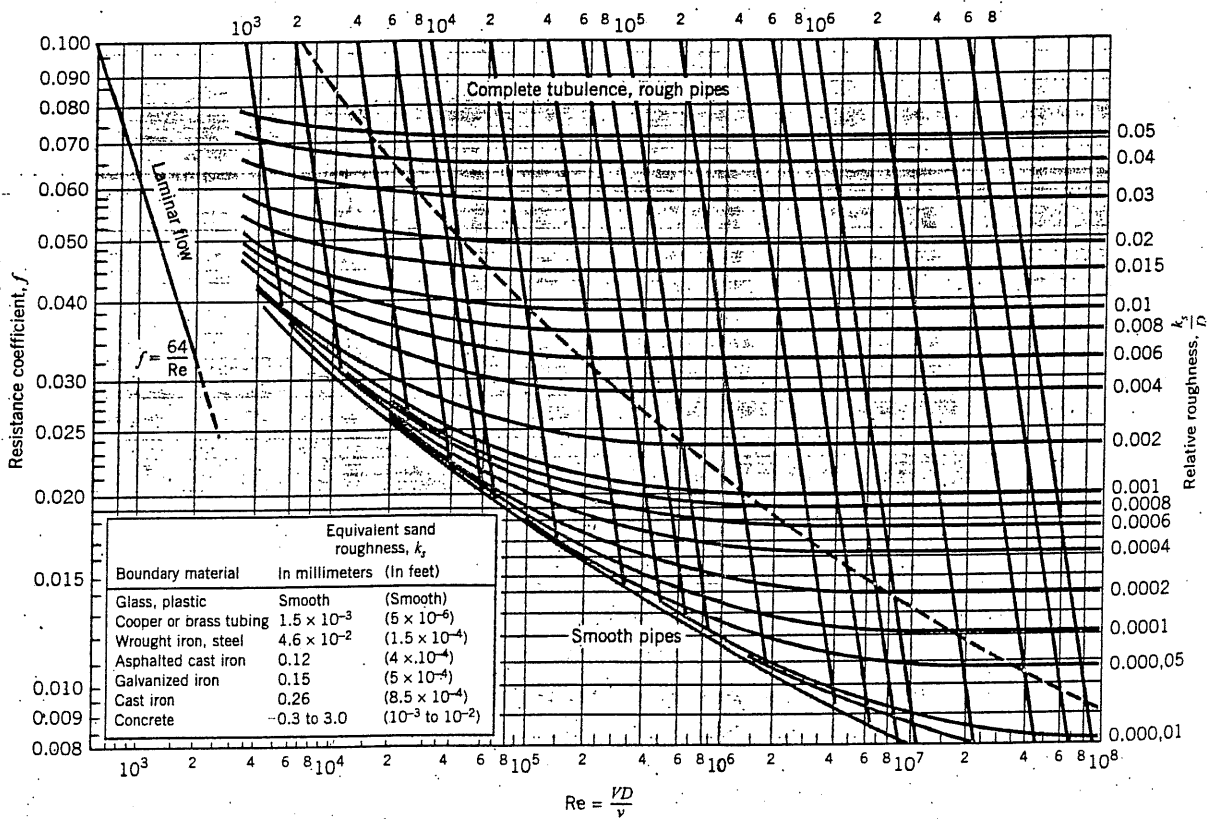


FIGURE 10.8
Resistance coefficient f versus Re . Reprinted with minor variations. [After Moody (29). Reprinted with permission from the A.S.M.E.]

FIGURE 10.9
Relative roughness k_s/D versus Re for various kinds of pipes. [After Moody (29). Reprinted with permission from the A.S.M.E.]