Appendix

Table A-1. Description of Unknowns and Equations Needed to Solve Problems 1-8 to 1-11

Prob. No	*Assumptions/ Specifications*	*Unknowns*	*Equation Name*	*Equation*	*Modified Equation*	*Solution Type*
1-8	No Minor losses	h_f, f, V or Q	Energy	$Z_1 - Z_2 = h_f$	no modification	Direct
	Fully Rough Turbulent Flow		Colebrook-White	$1/f^{0.5} = 1.14 + 2\log_{10}(d/k_s)$	$f = 1/[1.14 + 2\log_{10}(d/k_s)]^2$	
	Use Darcy-Weisbach Method		Darcy-Weisbach	$h_f = fLV^2/(2gd)$	$V = [2gdh_f/(fL)]^{0.5}$	
	Use Colebrook-White Method					
1-9	No Minor losses	h_f, f, R_e, V or Q	Energy	$Z_1 - Z_2 = h_f$	no modification	Trial and
	Use Darcy-Weisbach Method		Swamee and Jain	$f = 0.25/\{\log_{10}[k_s/(3.7d) + 5.74/\mathrm{R}_e^{0.9}]\}^2$	no modification	Error
	Use Swamee and Jain Method		Darcy-Weisbach	$h_f = fLV^2/(2gd)$	$V = [2gdh_f/(fL)]^{0.5}$	
			Reynolds	$\mathrm{R}_e = Vd\rho/\mu$	no modification	
1-10	No Minor losses	h_f, R, S, Q	Energy	$Z_1 - Z_2 = h_f$	no modification	Direct
	Use Hazen-Williams Method		Hazen-Williams	$Q = 0.85C_H R^{0.63} S^{0.54} A$	no modification	
			Hydraulic Radius	$R = d/4$	no modification	
			Slope of EGL	$S = h_f/L$	no modification	
1-11	Include Minor losses	h_f, h_{mi}, R_e, f, V or Q	Energy	$Z_1 - Z_2 = h_f + h_{mi}$	no modification	Trial and
	Use Darcy-Weisbach Method		Swamee and Jain	$f = 0.25/\{\log_{10}[k_s/(3.7d) + 5.74/\mathrm{R}_e^{0.9}]\}^2$	no modification	Error
	Use Swamee and Jain Method		Darcy-Weisbach	$h_f = fLV^2/(2gd)$	no modification	
			Reynolds	$\mathrm{R}_e = Vd\rho/\mu$	no modification	
			Minor Loss	$h_{mi} = K'[V^2/(2g)]$	no modification	

Note that in the minor loss equation of Problem 1-11, K' is the sum of minor loss coefficients K_e and K_{ex}.

Table A-2. Description of Unknowns and Equations Needed to Solve Problem 1-12 to 1-14

Prob. No	*Assumptions/ Specifications*	*Unknowns*	*Equation Name*	*Equation*	*Modified Equation*	*Solution Type*
1-12	Include Minor losses	h_f, h_{mi}, h_p, R_e, f, P	Energy	$Z_1 - Z_2 = h_f + h_{mi} - h_p$	no modification	Trial and Error
	Use Darcy-Weisbach Method		Swamee and Jain	$f = 0.25/\{log_{10}[k_s/(3.7d) + 5.74/R_e^{0.9}]\}^2$	no modification	
	Use Swamee and Jain Method		Darcy-Weisbach	$h_f = fLV^2/(2gd)$	$V = [2\,gdh_f/(fL)]^{0.5}$	
			Reynolds	$R_e = Vd\rho/\mu$	no modification	
			Minor Loss	$h_{mi} = K'[V^2/(2g)]$	no modification	
			Power	$P = \Upsilon h_p Q$	no modification	
1-13	No Minor losses	h_f, f, R_e, d	Energy	$Z_1 - Z_2 = h_f$	no modification	Trial and Error
	Use Darcy-Weisbach Method		Swamee and Jain	$f = 0.25/\{\log_{10}[k_s/(3.7d) + 5.74/R_e^{0.9}]\}^2$	no modification	
	Use Swamee and Jain Method		Darcy-Weisbach	$h_f = fLV^2/(2gd)$	$d = K(LQ^2/h_f)^{0.2}; K = [8f/(g\pi^2)]^{0.2}$	
			Reynolds	$R_e = Vd\rho/\mu$	no modification	
1-14	Include Minor losses	h_f, h_{mi}, R_e, f, d	Energy	$Z_1 - Z_2 = h_f + h_{mi}$	no modification	Trial and Error
	Use Darcy-Weisbach Method		Swamee and Jain	$f = 0.25/\{\log_{10}[k_s/(3.7d) + 5.74/R_e^{0.9}]\}^2$	no modification	
	Use Swamee and Jain Method		Darcy-Weisbach	$h_f = fLV^2/(2gd)$	no modification	
			Reynolds	$R_e = Vd\rho/\mu$	no modification	
			Minor Loss	$h_{mi} = K'[V^2/(2g)]$	no modification	

***Table A-3.* Description of Unknowns and Equations Needed to Solve Problem 1-15**

Prob. No	*Assumptions/ Specifications*	*Unknowns*	*Equation Name*	*Equation*	*Modified Equation*	*Solution Type*
1-15	Include Minor losses	h_f, h_{mi}, h_p, R_e, f, V or Q	Energy	$Z_1 - Z_2 = h_f + h_{mi} - h_p$	no modification	Trial and Error
	Use Darcy-Weisbach Method		Swamee and Jain	$f = 0.25/\{\log_{10}[k_s/(3.7d) + 5.74/R_e^{0.9}]\}^2$	no modification	
	Use Swamee and Jain Method		Darcy-Weisbach	$h_f = fLV^2/(2gd)$	no modification	
			Reynolds	$R_e = Vd\rho/\mu$	no modification	
			Minor Loss	$h_{mi} = K'[V^2/(2g)]$	no modification	
			Pump Performance	$h_p = 20 - 4{,}713Q^2$	no modification	

Note that in the minor loss equation of Problem 1-15, K' is the sum of minor loss coefficients K_e, K_{ex}, K_b, and K_v.

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***Table A-4.* Description of Unknowns and Equations Needed to Solve Problem 1-16**

Prob. No	*Assumptions/Specifications*	*Unknowns*	*Equation Name*	*Equation*	*Modified Equation*	*Solution Type*
1-16	No Minor losses	h_{f1}, h_{f2}, h_{f3}	Energy Eq. 1	$Z_1 = E_j + h_{f1}$	$h_{f1} = Z_1 - E_j$	Trial and Error
	Use Darcy-Weisbach Method	V_1 or Q_1	Energy Eq. 2	$Z_2 = E_j + h_{f2}$ (if $Z_2 > E_j$)	$h_{f2} = Z_2 - E_j$ (if $Z_2 > E_j$)	
	f = constant	V_1 or Q_2	Energy Eq. 2	$E_j = Z_2 + h_{f2}$ (if $Z_2 < E_j$)	$h_{f2} = E_j - Z_2$ (if $Z_2 < E_j$)	
		V_1 or Q_3	Energy Eq. 3	$E_j = Z_3 + h_{f3}$	$h_{f3} = E_j - Z_3$	
		E_J	Darcy-Weisbach Eq. 1	$h_{f1} = fL_1V_1^2/(2gd_1)$	$V_1 = [2gd_1h_{f1}/(fL_1)]^{0.5}$	
			Darcy-Weisbach Eq. 2	$h_{f2} = fL_2V_2^2/(2gd_2)$	$V_2 = [2gd_2h_{f2}/(fL_2)]^{0.5}$	
		V_2 or Q_2	Darcy-Weisbach Eq. 3	$h_{f3} = fL_3V_3^2/(2gd_3)$	$V_3 = [2gd_3h_{f3}/(fL_3)]^{0.5}$	
			Continuity Eq. 1	$Q_1 + Q_2 = Q_3$ (if $Z_2 > E_j$)	Net$Q = Q_1 + Q_2 - Q_3 = 0$ (if $Z_2 > E_j$)	
			Continuity Eq. 1	$Q_1 = Q_2 + Q_3$ (if $Z_2 < E_j$)	Net$Q = Q_1 - Q_2 - Q_3 = 0$ (if $Z_2 < E_j$)	

Table A-5. Description of Unknowns and Equations Needed to Solve Problem 1-17

Prob. No	*Assumptions/Specifications*	*Unknowns*	*Equation Name*	*Equation*	*Modified Equation*	*Solution Type*
1-17	No Minor losses	h_{f1}, h_{f2}, h_{f3}, h_{f4}, h_{f5}	Energy Eq. 1	$E_A + h_p = E_{J1} + h_{f1}$	$E_{J1} = E_A + h_p - h_{f1}$	Trial and Error
	Use Darcy-Weisbach Method	V_1 or Q_1	Energy Eq. 2	$E_{J1} = E_{J2} + h_{f2}$	$h_{f2} = E_{J1} - E_{J2}$	
		V_1 or Q_2	Energy Eq. 3	$E_{J1} = E_{J3} + h_{f3}$	$h_{f3} = E_{J1} - E_{J2}$	
		V_1 or Q_3	Energy Eq. 4	$E_{J2} = E_B + h_{f4}$	$h_{f4} = E_{J2} - E_B$	
		V_1 or Q_4	Energy Eq. 5	$E_{J2} = E_C + h_{f5}$	$h_{f5} = E_{J2} - E_C$	
		V_1 or Q_5	Darcy-Weisbach Eq. 1	$h_{f1} = fL_1V_1^2/(2gd_1)$	no modification	
		E_{J1}, E_{J2}	Darcy-Weisbach Eq. 2	$h_{f2} = fL_2V_2^2/(2gd_2)$	$V_2 = [2gd_2h_{f2}/(fL_2)]^{0.5}$	
		h_p	Darcy-Weisbach Eq. 3	$h_{f3} = fL_3V_3^2/(2gd_3)$	$V_3 = [2gd_3h_{f3}/(fL_3)]^{0.5}$	
			Darcy-Weisbach Eq. 4	$h_{f4} = fL_4V_4^2/(2gd_4)$	$V_4 = [2gd_4h_{f4}/(fL_4)]^{0.5}$	
			Darcy-Weisbach Eq. 5	$h_{f5} = fL_5V_5^2/(2gd_5)$	$V_5 = [2gd_5h_{f5}/(fL_5)]^{0.5}$	
			Continuity Eq. 1	$Q_1 = Q_4 + Q_5$	no modification	
			Continuity Eq. 2	$Q_1 = Q_2 + Q_3$	no modification	
			Pump Characteristic	$h_p = 60 - 10Q_1^2$	no modification	

Note that only **one** of the two continuity equations listed in Problem 1-16 can be used; an IF statement can also be used.

Table A-6. Description of Unknowns and Equations Needed to Solve Problem 1-18

Prob. No	*Assumptions/ Specifications*	*Unknowns*	*Equation Name*	*Equation*	*Modified Equation*	*Solution Type*
1-18	No Minor losses	h_{f1}, h_{f2}, h_{f3}, h_{f4}, h_{f5}	Energy Eq. 1	$E_A + h_p = E_{J1} + h_{f1}$	$E_{J1} = E_A + h_p - h_{f1}$	Trial and Error
	Use Darcy-Weisbach Method	V_1 or Q_1	Energy Eq. 2	$E_{J1} = E_{J2} + h_{f2}$	$h_{f2} = E_{J1} - E_{J2}$	
	f = constant	V_1 or Q_2	Energy Eq. 3	$E_{J1} = E_{J3} + h_{f3}$	$h_{f3} = E_{J1} - E_{J2}$	
		V_1 or Q_3	Energy Eq. 4	$E_{J2} = E_B + h_{f4}$	no modification	
		V_1 or Q_5	Energy Eq. 5	$E_{J2} = E_C + h_{f5}$	$h_{f5} = E_{J2} - E_C$	
		E_{J1}, E_{J2}	Darcy-Weisbach Eq. 1	$h_{f1} = fL_1V_1^2/(2gd_1)$	no modification	
		h_p	Darcy-Weisbach Eq. 2	$h_{f2} = fL_2V_2^2/(2gd_2)$	$V_2 = [2gd_2h_{f2}/(fL_2)]^{0.5}$	
		d_4	Darcy-Weisbach Eq. 3	$h_{f3} = fL_3V_3^2/(2gd_3)$	$V_3 = [2gd_3h_{f3}/(fL_3)]^{0.5}$	
			Darcy-Weisbach Eq. 4	$h_{f4} = fL_4V_4^2/(2gd_4)$	no modification	
			Darcy-Weisbach Eq. 5	$h_{f5} = fL_5V_5^2/(2gd_5)$	$V_5 = [2gd_5h_{f5}/(fL_5)]^{0.5}$	
			Continuity Eq. 1	$Q_1 = Q_4 + Q_5$	no modification	
			Continuity Eq. 2	$Q_1 = Q_2 + Q_3$	no modification	
			Pump Characteristic	$h_p = 60 - 10Q_1^2$	no modification	