

1. Determine the force on the support for the 90° elbow shown in Figure 1. The elbow weighs 400 lbs.

a. the pressure head at section (2) is closest to: {Answer 36, 38, 40, 44} ft

b. the force on the support is (express as magnitude and direction):

Answer $F_x = 23.815$ kips \rightarrow or \leftarrow : $F_y = 21.83$ kips \downarrow or \uparrow :

Assume:
 $\alpha = \beta = 1$
 Neglect energy loss and friction.
 Given:

Upstream pressure head (section 1) =	50	ft
Diameter =	3	ft
Q =	80	cfs
Elbow radius =	6	ft

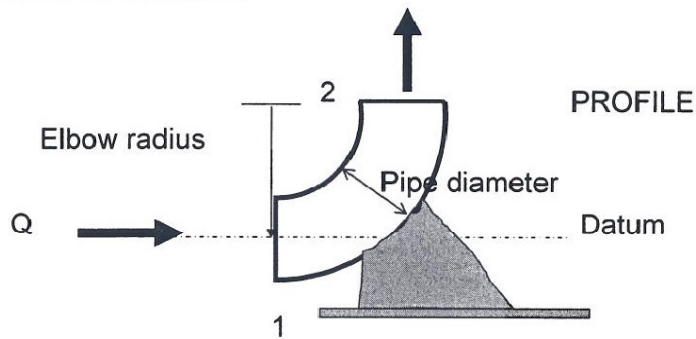
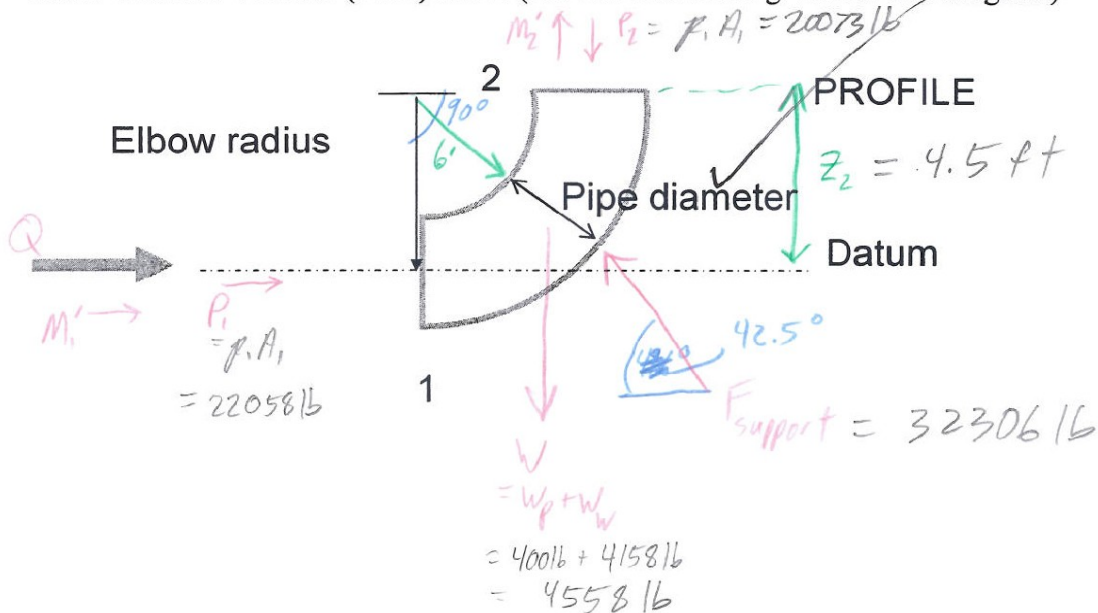


Figure 1.

Solution:

Show Control Volume (FBD) here! (20% of marks are given for this diagram)



$$A_p = \frac{\pi}{4} (3\text{ft})^2 = \underline{7.07 \text{ft}^2}$$

$$w_p = \underline{400 \text{lb}}$$

$$h_{1-2} \approx \emptyset$$

$$\frac{p_1}{\gamma} = 50'$$

$$Q = 80 \text{ cfs}$$

$$\text{radius} = 6'$$

$$V_{\text{pipe}} = A_p(r)(\theta^{\text{rad}}) = 7.07(6)\left(\frac{\pi}{2}\right) = \underline{66.6 \text{ft}^3}$$

$$W_w = 66.6 \text{ft}^3 (62.4 \frac{\text{lb}}{\text{ft}^3}) = \underline{4158 \text{lb}}$$

$$V_1 = V_2 = \frac{Q}{A} = \frac{80 \frac{\text{ft}^3}{\text{s}}}{7.07 \text{ft}^2} = \underline{11.32 \text{ft/s}}$$

$$P_1 = p_1 A_1 = 50(62.4)(7.07) = \underline{22058 \text{lb}}$$

Impulse-Mom

x-direction

$$\Sigma F_x = \cancel{PQV_{2x}} - \cancel{PQV_{1x}}$$

$$-N_x + P_1 A_1 = -PQV_1$$

$$(7.07) 50(62.4) + (1.94)(80)(11.32) = N_x$$

$$N_x = \underline{23815 \text{lb} \leftarrow}$$

y-direction

$$\Sigma F_y = \cancel{PQV_{2y}} - \cancel{PQV_{1y}}$$

$$N_y - P_2 = PQV_2$$

$$N_y = (1.94)(80)(11.32) + 20073$$

$$N_y = \underline{21830 \text{lb} \uparrow}$$

Energy Bal

$$\frac{P_1}{\gamma} + z_1 + \frac{V_1^2}{2g} = \frac{P_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + h_{1-2}$$

$$50' = \frac{P_2}{62.4} + 4.5' \rightarrow P_2 = 2839 \text{ psf}$$

$$P_2 = P_2 A_2 = 2745(7.07) = \underline{20073 \text{lb}}$$

$$N = \sqrt{N_x^2 + N_y^2} = \underline{32306 \text{lb}}$$

$$\theta = \tan^{-1}\left(\frac{21168}{23815}\right) = \underline{42.5^\circ \searrow}$$

Force of water on support

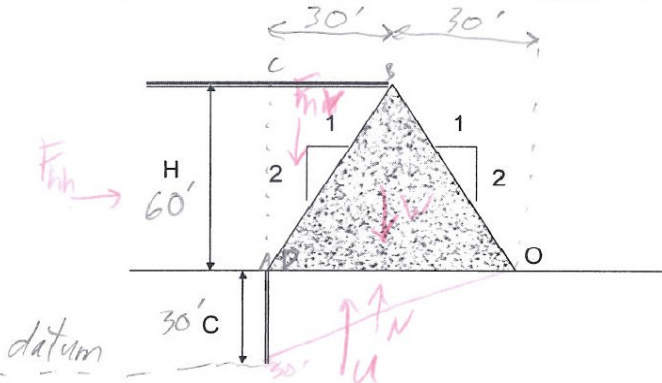
$$F_{w \rightarrow \text{sup}} = \underline{31863 \text{lb}}$$

$$F_{w \rightarrow \text{sup}} \theta = 42.5^\circ \searrow$$

2. For the concrete dam in Figure 2 with a seepage barrier of length C:
 a) Determine the Factors of Safety against sliding and overturning.
 b) Will there be any tension in the foundation?

Assume: the specific weight of concrete = 150 lbs/ft³
 Neglect: ice, silt and earthquake forces.

H	60	ft
Friction factor at the base =	$\mu = 0.7$	
C	30	ft



$$F_{hh} = \frac{1}{2} \gamma H^2 = 112.32 \text{ K} \rightarrow$$

$$F_{hv} = \gamma A_{ABC} = 0.5(30)(60)(\gamma) = 56.16 \text{ K} \downarrow$$

a centroid ABC

$$W = \frac{1}{2} \gamma_c = 0.5(60)(60)(150) = 270 \text{ K} \downarrow$$

$$\phi_A = 60' + 30' = 90'$$

$$\phi_O = 30'$$

$$\Delta\phi = (-60')$$

$$\phi_D = \phi_A + \Delta\phi \left(\frac{S_D}{S_E} \right) = 90' + (-60') \left(\frac{60}{120} \right) = 60'$$

$$S_e = 2(30) + 60 = 120' \quad \frac{h}{\gamma} = \phi_D - h_{20} = 60 - 30 = 30'$$

$$U = 0.5(30)(60)(1)(62.4) = 56160 \text{ lb} \uparrow$$

Figure 2.
 Circle the closest answer here!

Factor of safety against sliding = $\{ < 1, 1 - 1.5, 1.5 - 2, > 2 \}$ (Safe), (Unsafe)

Factor of safety against overturning = $\{ < 1, 1 - 1.25, 1.25 - 1.5, > 1.5 \}$ (Safe), (Unsafe)

Tension in base: (Yes) (No)

Solution:

Force ID	$F_x \rightarrow +$	$F_y \uparrow +$	Moment arm	+Moment uprighting	-Moment overturning
Hydro Horizontal	112.32 K		$\frac{60}{3} = 20'$		2246.4 K-ft
" Vertical		(-56.16 K)	$30 + \left(\frac{2(30)}{3}\right) = 50'$	2808 K-ft	
weight Dam		(-270 K)	30'	8100 K-ft	
U		56.16 K	$\frac{2(60)}{3} = 40'$		2246.4 K-ft
SUM			Σ	10908 K-ft	4493 K-ft

$$N = 213.8 \text{ K}$$

$$F_{fmax} = 150 \text{ K}$$

$$x_N = 30.0$$

w/in middle 1/3

$$\Sigma = -270$$

$$N = 270$$

$$N = W - U = 213.8 \text{ K}$$

$$a N = 149.66 \text{ K} \sim 150 \text{ K}$$

$$x_N = \frac{A - P}{N} = 30.0$$

$$F_{os OT} = \frac{\Sigma +}{\Sigma} = 2.428$$

$$F_{os slid} = \frac{\mu N}{\Sigma F_x} = \frac{150}{112.32} = 1.34$$

3. a) Determine the operating point and efficiency for two pumps operating in parallel as shown in Figure 3 for the pump curve in Figure 4.

b) Will the pump cavitate?

The pump curve is attached.

Given: $K_{ps} = 1$;

$K_{pd} = 4$.

Wet Well Level = 100 ft

Reservoir Level = 135 ft

Circle the closest answer below:

$Q_o = \{ 1.0, 1.1, 1.4, 1.6, 2.0 \}$ cfs

$H_o = \{ 35, 39, 40, 45, 47 \}$ ft

Efficiency in % =

40

48

75

80

Cavitation: (Yes) (No)



PLAN OF PUMPS IN PARALLEL

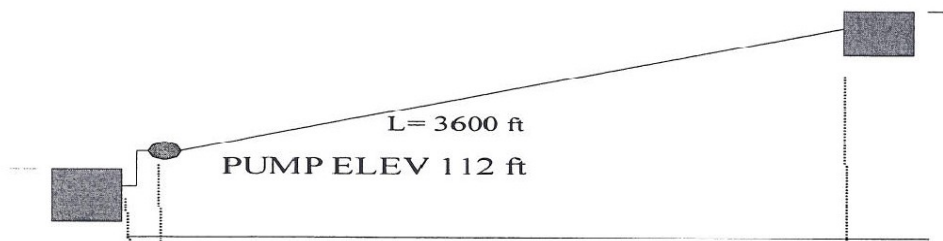


Figure 3.

Q_d	Q_s	H_{st}	$h_{Ls} = \frac{Q_s^2}{K_{ps}}$	$h_{Ld} = \frac{4(Q_d)^2}{K_{pd}}$	$H_{sys} = H_{st} + h_{Ls} + h_{Ld}$	Q_d	Q_s	h_{Ls}	h_{Ld}	H_{sys}
1	0.5	35'	0.25	4	39.25	1.8	0.9	0.81	12.16	48.77
1.1	0.55	35	0.303	4.84	40.14	1.7	0.85	0.723	12.16	47.3
1.2	0.6	35	0.36	5.76	41.12					
1.3	0.65	35	0.423	6.76	42.18					
1.4	0.7	35	0.49	7.84	43.33					
1.5	0.75	35	0.563	9	44.56					
1.6	0.8	35	0.64	10.24	45.88					

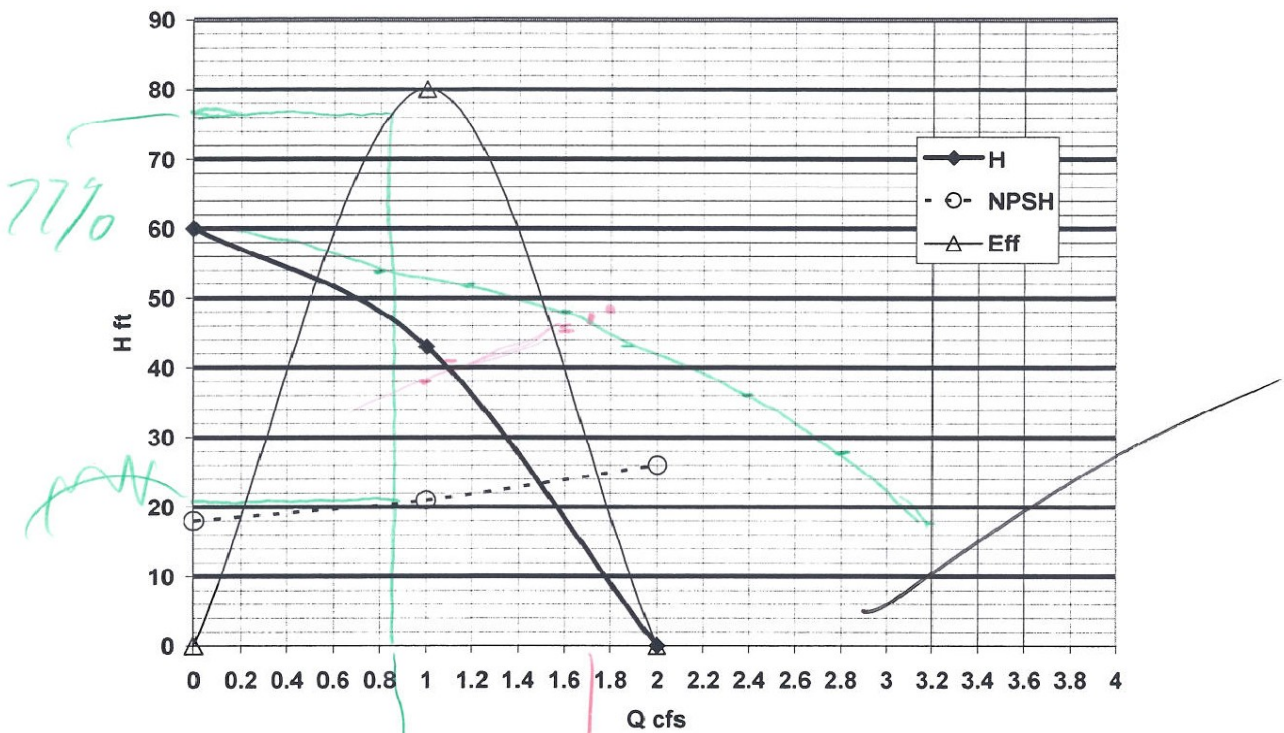
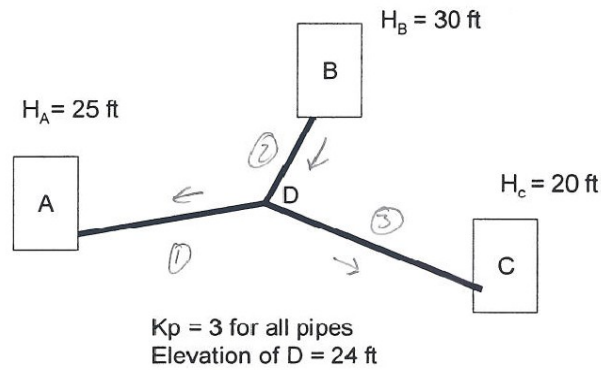


Figure 4. [4 marks will be allocated for the completion of this diagram]

4. In the three reservoir problem illustrated below, the value of H_D is closest to:

{ 28, 26, 25, 24 } ft



10

Assume $H_D = \frac{30 + 25 + 20}{3} = 25$

Figure 5.

Pipe	Det	K_p	ΔH (ft)	Q (cfs)	Res	H (ft)
1	-	3	0	0	A	25
2	-	3	5	1.291	B	30
3	-	3	(-5)	-1.291	C	20
			$\Sigma = \phi$			

$\Delta H = H_{res} - H_D$
 $Q = \sqrt{\frac{\Delta H}{K_p}}$