Hydraulics
Pipes and Pumps FE Training Quiz
12 Sep 2006

1. The hydraulic radius in a conduit containing a flowing liquid is

(A) the mean radius from the center of flow to the wetted side of the conduit

(B) the ratio of the cross-sectional area of the conduit and the wetted perimeter

(C) the ratio of the wetted perimeter and the cross-sectional area of the conduit

(D) the ratio of the cross-sectional area of flow and the wetted perimeter

search in FEref: hydraulic radius
p. 185

Choose D

2. A pipe with a diameter of 2.4 meters is depicted in Figure 1. The pipe is flowing partially full.

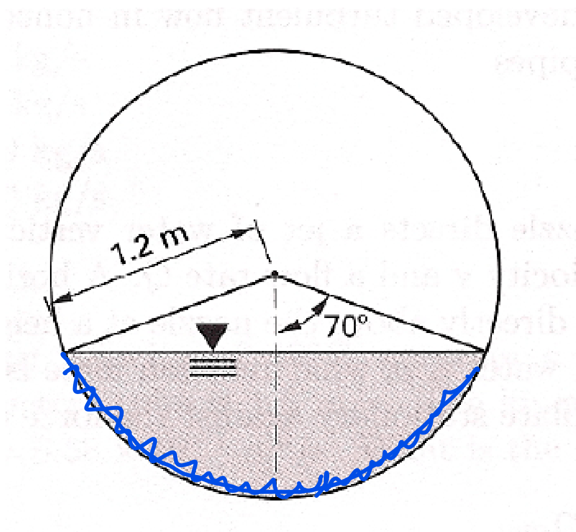


Figure 1: Circular channel flowing partially full.

What is the hydraulic radius of flow in the circular section?

(A) 0.44 m

(B) 0.88 m

(C) 1.30 m

(D) 1.80 m

$$R_h = \frac{A}{P_w}$$

$$P_w = r\phi = 1.2\left(\frac{140\pi}{180}\right) = 2.93\,m$$

$$A = r^2(\phi - \sin\phi)/2 = (1.2)^2\left[\frac{140\pi}{180} - \sin\left(\frac{140\pi}{180}\right)\right] * \frac{1}{2} = 1.295$$

$$R_H = \frac{1.295}{2.93} = 0.442$$

CHOOSE $\underline{A}$

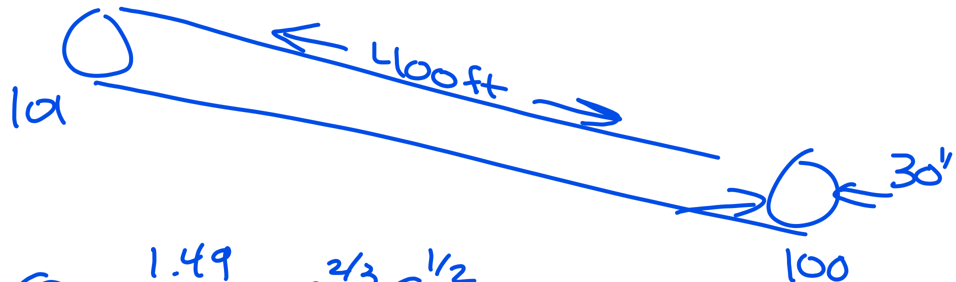
3. A storm sewer (reinforced concrete pipe) is 400-feet long and 30-inches in diameter. The sewer flows full (but not-surcharged) between a personnel access shaft (invert elevation 101.00 feet) and a lift station sump (invert elevation 100.00 feet). Assuming Manning's roughness coefficient is 0.013 for all flow depths, the sewer capacity is about

(A) 4.2 cfs

(B) 9.8 cfs

(C) 20.5 cfs

(D) 32.6 cfs



$$Q_f = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

$$A = \frac{\pi D^2}{4} = \frac{\pi \left(\frac{30}{12}\right)^2}{4} = 4.91$$

$$P_w = \pi D = \pi \left(\frac{30}{12}\right) = 7.85$$

$$R = \frac{4.91}{7.85} = 0.625 \qquad R^{2/3} = 0.731$$

$$S = \frac{1}{400} = 0.0025 \qquad S^{1/2} = 0.05$$

$$Q_f = \frac{1.49}{0.013}(4.91)(0.731)(0.05) = 20.57\ ft^3/s$$

Choose C

4. A smooth concrete channel is depicted in Figure 2. The channel's dimensionless slope in the direction of flow is 0.005. If the flow width at the surface is 2-meters, what is the flow rate in the channel using the Hazen-Williams friction formula?

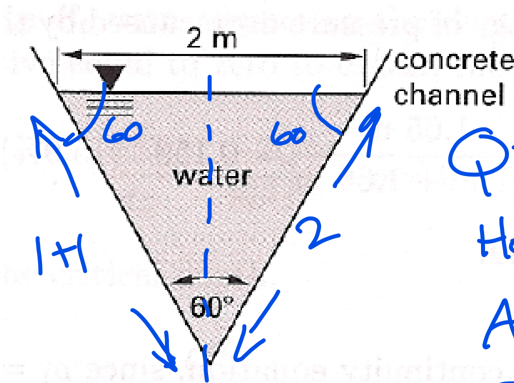


Figure 2: Triangular channel.

(A) 0.8 m^3/s

(B) 1.3 m^3/s

(C) 6.8 m^3/s

(D) 9.8 m^3/s

$C_H = 130$ (p 297)

$Q = 0.849 C A R_H^{0.63} S^{0.54}$

Heron's

$A = \frac{\sqrt{3}}{4} s^2 = 1.732 m^2$

$P_w = 4m$

$R_H = \frac{1.732}{4} = 0.433$

$R_H^{0.63} = 0.590$

$S = 0.005$ $S^{0.54} = 0.0572$

$Q = 0.849(130)(1.732)(0.590)(0.0572)$
$= 6.45 m^3/s$ Choose C

5. Water is pumped from a lake with a pipe inlet at elevation 200-meters to a reservoir with elevation 205-meters. The pipeline from the lake to the reservoir is 300-meters long, cast-iron, with 0.3-meter inside diameter. The flow rate in the pipe is 1.25 m^3/sec. The kinematic viscosity of water is $1 \times 10^{-6}\ m^2/sec$. The roughness height for cast iron is $e = 0.25\ mm$. Using the Darcy-Weisbach friction loss model, the pipe head loss is approximately

$$h_f = f \frac{L}{D} \frac{V^2}{2g}$$

(A) 300 m

(B) 310 m

(C) 320 m

(D) 330 m

$$\frac{L}{D} = 1000$$

$$V = \frac{Q}{A} = \frac{Q4}{\pi D^2} = \frac{1.25(4)}{\pi (0.3)^2} = 17.683$$

$$\frac{\varepsilon}{D} = \frac{0.25 \cdot 10^{-3}}{0.3} = 0.00083$$

$$\frac{V^2}{2g} = \frac{(17.683)^2}{2(9.8)} = 15.95$$

$$f = 0.019$$

$$Re = \frac{VD}{\nu} = \frac{(17.683)(0.3)}{1 \cdot 10^{-6}} = 4{,}800{,}000$$

$$h_f = (0.019)(1000)(15.95) = 311 m$$

choose B

6. The pressure drop over 15 m of 2-cm-diameter galvanized iron pipe (roughness height = 0.25mm) is measured to be 60 kPa. If the pipe is horizontal, estimate the flow rate of water. ($\nu = 10^{-6} m^2/sec$)

(A) 6.82 L/s

(B) 2.18 L/s

(C) 0.682 L/s

(D) 0.218 L/s

$$h_f = f \frac{L}{D} \frac{V^2}{2g} \qquad V = \frac{Q}{A}$$

$$\frac{\Delta p}{\rho g} = h_f = \frac{60 \cdot 10^3 \text{ Pa}}{9800 \text{ N/m}^3} = 6.12 \text{ m}$$

$$\frac{\varepsilon}{D} = \frac{0.00025}{0.02} = 0.0125$$

$$Re = \frac{V(0.02)}{10^{-6}} \qquad \frac{L}{D} = \frac{15}{0.02} = 750$$

V	Re	f	$\frac{V^2}{2g}$	h_f	
1	20,000	0.044	$5.1 \cdot 10^{-2}$	1.68	too low
2	40,000	0.042	$2.04 \cdot 10^{-1}$	6.42	too high
1.95	39,000	0.042	$1.94 \cdot 10^{-1}$	6.112	close enough

$$Q = 1.95 \frac{(0.02)^2 \pi}{4} = 0.000612 \text{ m}^3/\text{s}$$

$0.612 \frac{L}{s}$

choose C

7. What is the power requirement of an 85% efficient pump that transports $0.04 m^3/sec$ of water if it increases the pressure from 200 kPa to 1200 kPa?

(A) 4.8 kW

(B) 14.2 kW

(C) 34.0 kW

(D) 47.1 kW

$$h_p = \frac{\Delta p}{\gamma} = \frac{1000\,kPa}{9800} = 102.04\,m$$

$$P = \frac{Q\gamma h}{\eta}$$

$\gamma = 9800$

$\eta = 0.85$

$$P\ \frac{(0.04)(9800)(102.04\,m)}{0.85}$$

$= 4.7 \cdot 10^4\ W$

$= 47\ kW$

choose D

8.) A water supply system draws from a river at an elevation of 800-feet and delivers the water to a storage reservoir at elevation 820-feet. The supply pipeline is a 1000-foot long, 10-inch diameter, cast iron pipe. Minor losses, entrance, and exit losses are neglected. A single pump with the pump characteristic curve in Figure 3 is used to fill the reservoir.

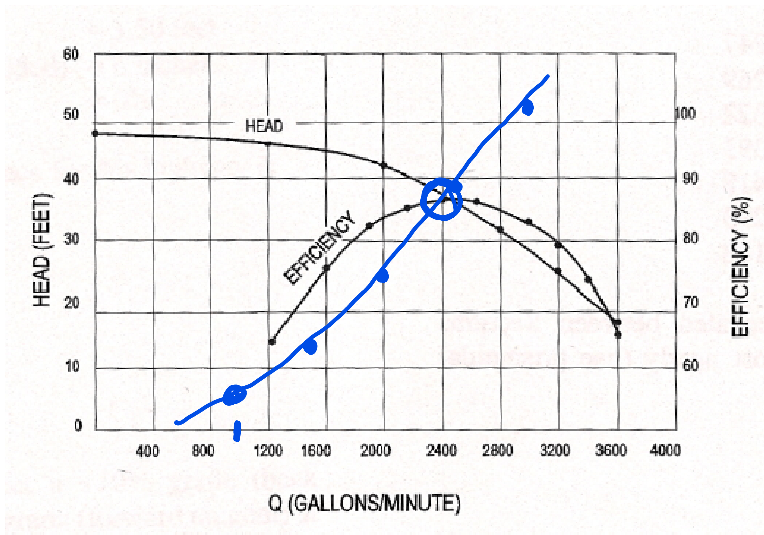


Figure 3: Pump characteristic curve

The system characteristics for the water supply are listed in Table 1.

Table 1: Pumped-Storage System Performance Characteristics.

Discharge (gpm)	System Loss (feet)	Pumping Head (feet)
1,000	6.2	47
1,500	14.0	45
2,000	24.9	44
2,500	39.0	34
3,000	52.6	28

The operating point of the pump station is about

(A) 1450 gpm

(B) 1875 gpm

(C) 2400 gpm

(D) 2800 gpm

9. The electric power supplied to the pump to lift the water at the operating point is about[1].

(A) 10.0 kilowatts

(B) 15.0 kilowatts

(C) 20.0 kilowatts

(D) 25.0 kilowatts

$$P = \frac{Q \gamma h}{\eta}$$

$= 2400 \text{gpm} \sim 6.422 \text{ ft}^3/\text{s}$

$\gamma = 62.4 \text{ lb}/\text{ft}^3$

$h = 37 \text{ ft}$

$\eta = 0.85$

$$= \frac{(6.422)(62.4)(37)}{0.85}$$

$$= 17443 \frac{\text{ft} \cdot \text{lbs}}{\text{s}} * \frac{1 \text{ watt}}{6.737 \frac{\text{ft} \cdot \text{lb}}{\text{s}}}$$

$= 23.649 \cdot 10^3 \text{ W}$

$= 24 \text{ kW}$

Choose D

[1] The efficiency on the pump curve is the wire-to-water efficiency