3. At a particular temperature, the surface tension of water is 0.073 N/m. Under ideal conditions, the contact angle between glass and water is zero. A student in a laboratory observes water in a glass capillary tube with a diameter of 0.1 mm. What is the theoretical height of the capillary rise?

(A) 0.00020 m
(B) 0.013 m
(C) 0.045 m
(D) 0.30 m

ATH 2/95

1. What is the atmospheric pressure on a planet if the absolute pressure is 100 kPa and the gage pressure is 10 kPa?

(A) 10 kPa
(B) 80 kPa
(C) 90 kPa
(D) 100 kPa

B1P144 6/89

3. 100 g of water are mixed with 150 g of alcohol ($\rho = 790\ \text{kg/m}^3$). What is the specific gravity of the resulting mixture, assuming that the two fluids mix completely?

(A) 0.63
(B) 0.82
(C) 0.86
(D) 0.95

ATH 2/95

4. Kinematic viscosity can be expressed in which of the following units?

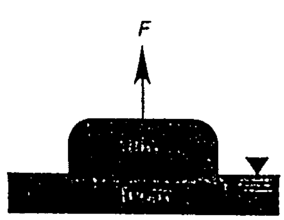
(A) ft^2/sec
(B) sec^2/ft
(C) $lbm\ sec^2/ft$
(D) lbm/sec

5. Which of the following does not affect the rise or fall of liquid in a small-diameter capillary tube?

(A) adhesive forces
(B) cohesive forces
(C) surface tension
(D) viscosity of the fluid

B1P126 6/89

6. The film width in a surface tension experiment is 10 cm. If mercury is the fluid (surface tension = 0.52 N/m), what is the maximum force that can be applied without breaking the membrane? Neglect gravitational force.



(A) 0.1 N
(B) 1.0 N
(C) 2.0 N
(D) 3.4 N

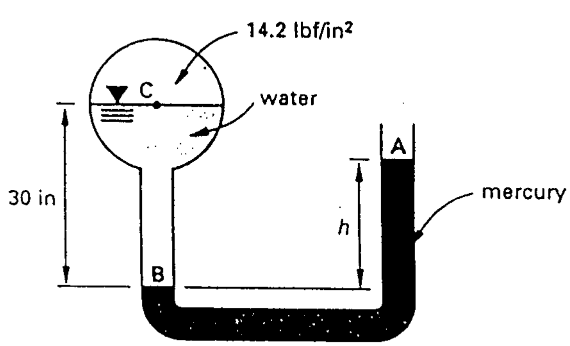
1. What height of mercury column is equivalent to a pressure of 100 psig? The density of mercury is 848 lbm/ft^3.

(A) 2 ft
(B) 4 ft
(C) 11 ft
(D) 17 ft

2. A fluid with a vapor pressure of 0.2 Pa and a specific gravity of 12 is used in a barometer. If the fluid's column height is 1 m, what is the atmospheric pressure?

(A) 9.80 kPa
(B) 11.76 kPa
(C) 101.3 kPa
(D) 117.7 kPa

3. One leg of a mercury U-tube manometer is connected to a pipe containing water under a gage pressure of 14.2 lbf/in^2. The mercury in this leg stands 30 in below the water. What is the height of mercury in the other leg, which is open to the air? The specific gravity of mercury is 13.6.

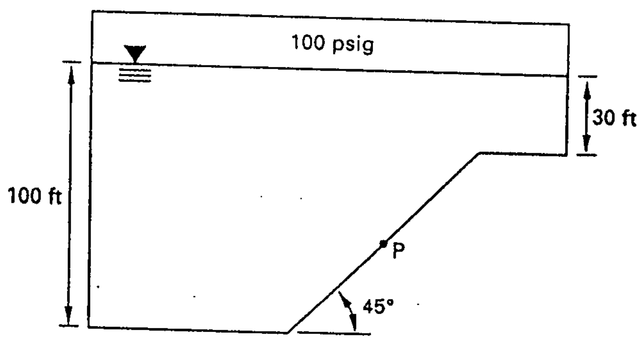


(A) 0.7 ft
(B) 1.5 ft
(C) 2.6 ft
(D) 3.2 ft

4. What is the resultant force on one side of a 10 in diameter vertical circular plate standing at the bottom of a 10 ft pool of water?

(A) 326 lbf
(B) 386 lbf
(C) 451 lbf
(D) 643 lbf

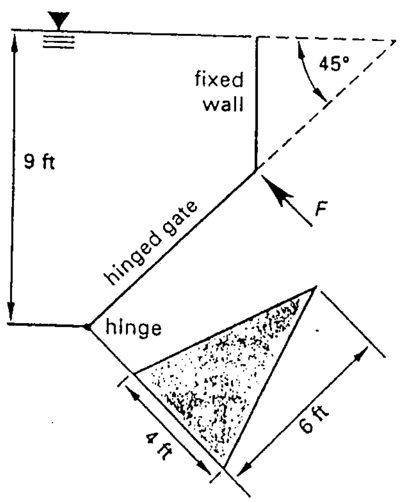
5. A special closed tank with the dimensions shown contains water. If the pressure of the air is 100 psig, what is the pressure at point P, which is located halfway up the inclined wall?



(A) 115 psig
(B) 128 psig
(C) 134 psig
(D) 4060 psig

CA4FP&S#7 1/93

6. A triangular gate with a horizontal base 4 ft long and an altitude of 6 ft is inclined 45° from the vertical with the vertex pointing upward. The hinged horizontal base of the gate is 9 ft below the water surface. What normal force must be applied at the vertex of the gate to keep it closed?



(A) 1430 lbf
(B) 1570 lbf
(C) 1670 lbf
(D) 1720 lbf

DFMP#9 6/87

1. Water flows through a multisectional pipe placed horizontally on the ground. The velocity is 3.0 m/s at the entrance and 2.1 m/s at the exit. What is the pressure difference between these two points? Neglect friction.

(A) 0.2 kPa
(B) 2.3 kPa
(C) 28 kPa
(D) 110 kPa

CA6aFLP&S#41 7/94

2. What is the mass flow rate of a liquid ($\rho = 0.690$ g/cm^3) flowing through a 5 cm (inside diameter) pipe at 8.3 m/s?

(A) 11 kg/s
(B) 69 kg/s
(C) 140 kg/s
(D) 340 kg/s

CA6aFLP&S#44 7/94

3. The mean velocity of 100°F water in a 1.76 in (inside diameter) tube is 5 ft/sec. The kinematic viscosity is $\nu = 7.39 \times 10^{-6}$ ft^2/sec. What is the Reynold's number?

(A) 7.9×10^3
(B) 8.3×10^3
(C) 8.8×10^4
(D) 9.9×10^4

CA18aFMP&S#44 3/94

4. What is the head loss for water flowing through a horizontal pipe if the gage pressure at point 1 is 1.03 kPa, the gage pressure at point 2 downstream is 1.00 kPa, and the velocity is constant?

(A) 3.1×10^{-3} m
(B) 3.1×10^{-2} m
(C) 2.3×10^{-2} m
(D) 2.3 m

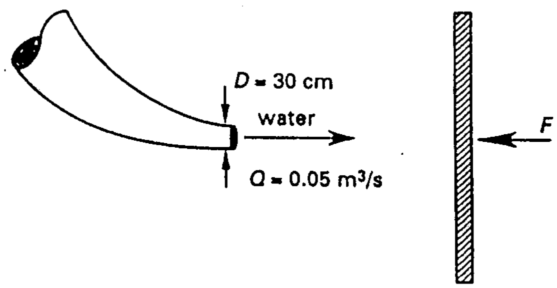
CA6aFLP&S#42 7/94

5. The *hydraulic radius* is

(A) the mean radius of the pipe.
(B) the radius of the pipe bend on the line.
(C) the wetted perimeter of a conduit divided by the area of flow.
(D) the cross-sectional fluid area divided by the wetted perimeter.

B1P131 6/89

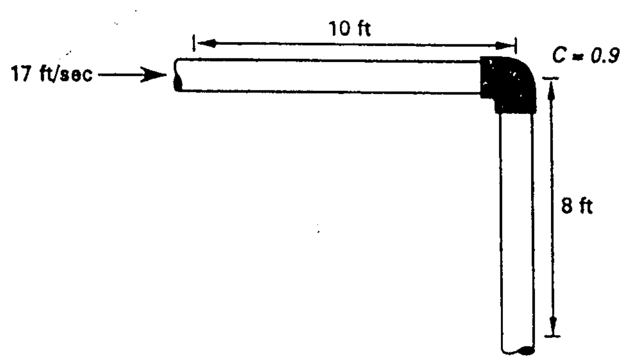
6. What horizontal force is required to hold the plate stationary against the water jet? (All of the water leaves parallel to the plate.)



(A) 17.7 N
(B) 35.4 N
(C) 42.2 N
(D) 67.5 N

B1P139 6/89

7. Water flows with a velocity of 17 ft/sec through 18 ft of cast-iron pipe (specific roughness = 0.00085 ft). The pipe has an inside diameter of 1.7 in. The kinematic viscosity of the water is 5.94×10^{-6} ft^2/sec. The loss coefficient for the standard elbow is 0.9. What percentage of the total head loss is caused by the elbow?



(A) 5.5%
(B) 7.1%
(C) 10%
(D) 18%

CA16FMP&S#6 11/93

1. A 70% efficient pump pumps 60°C water from ground level to a height of 5 m. How much power is used if the flow rate is 10 m^3/s?

(A) 80 kW
(B) 220 kW
(C) 700 kW
(D) 950 kW

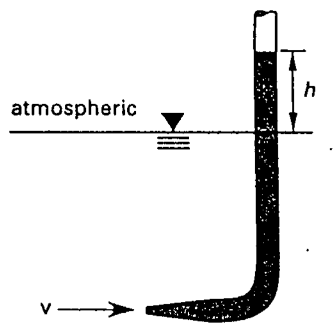
CA6aFLP&S#39 7/94

2. The acoustic velocity in a specific gas depends only on which of the following variables?

(A) c_p, specific heat at constant pressure
(B) k, ratio of specific heats
(C) c_v, specific heat at constant temperature
(D) T, absolute temperature

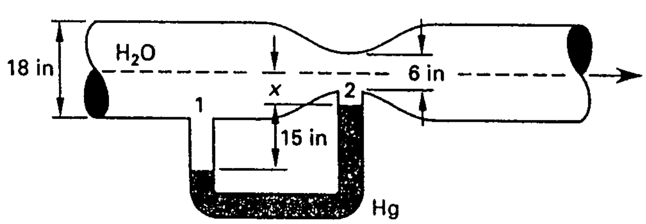
CA6aFLP&S#43 7/94

4. The velocity of the water in the stream is 1.2 m/s. What is the height of water in the pitot tube?



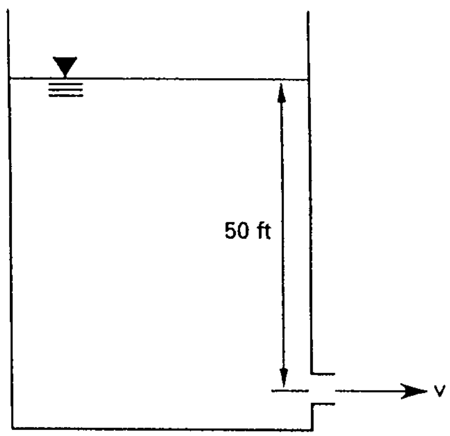
(A) 3.7 cm
(B) 4.6 cm
(C) 7.3 cm
(D) 9.2 cm

5. A venturi meter with a diameter of 6 in at the throat is installed in an 18 in water main. A differential manometer gauge is partly filled with mercury (the remainder of the tube is filled with water) and connected to the meter at the throat and inlet. The mercury column stands 15 in higher in one leg than in the other. Neglecting friction, what is the flow through the meter? The specific gravity of mercury is 13.6.



(A) 3.70 ft^3/sec
(B) 6.29 ft^3/sec
(C) 8.62 ft^3/sec
(D) 10.5 ft^3/sec

6. What is the velocity of water under a 50 ft head discharging through a 1 in diameter round-edged orifice?



(A) 3.6 ft/sec
(B) 9.8 ft/sec
(C) 25 ft/sec
(D) 56 ft/sec

7. A 1:1 model of a torpedo is tested in a wind tunnel according to the Reynolds number criterion. At the testing temperature, $\nu_{air} = 1.41 \times 10^{-5}$ and $\nu_{water} = 1.31 \times 10^{-6}$. If the velocity of the torpedo in water is 7 m/s, what should be the air velocity in the wind tunnel?

(A) 0.6 m/s
(B) 7.0 m/s
(C) 18 m/s
(D) 75 m/s

Problems 8 and 9 refer to the following situation.

A sharp-edged orifice with a 2 in diameter opening is located in the vertical side of a large tank. The coefficient of contraction for the orifice is 0.62, and the coefficient of velocity is 0.98. The orifice discharges under a hydraulic head of 16 ft.

8. What is the minimum diameter of the jet?

(A) 1.24 in
(B) 1.57 in
(C) 2.00 in
(D) 2.54 in

9. What is the velocity at the vena contracta?

(A) 5.54 ft/sec
(B) 10.8 ft/sec
(C) 17.4 ft/sec
(D) 31.5 ft/sec

Problems 10–13 refer to the following situation.

The bottom of a tall tank sits on level ground. The tank is kept filled to a depth of 15 ft, while water discharges at a constant rate through a 0.5 ft diameter hole in the tank side. The center of the hole is 10 ft from the water surface above. The coefficient of velocity for the hole is essentially 1.0.

10. What horizontal distance will the water jet travel before hitting the ground?

(A) 6.5 ft
(B) 7.1 ft
(C) 7.5 ft
(D) 14 ft

11. What is the velocity of the water jet?

(A) 21.9 ft/sec
(B) 25.4 ft/sec
(C) 26.9 ft/sec
(D) 30.6 ft/sec

12. If the hole is represented by a sharp-edged orifice with a coefficient of discharge of 0.61, what will be the rate of discharge?

(A) 2.68 ft^3/sec
(B) 3.04 ft^3/sec
(C) 3.27 ft^3/sec
(D) 3.72 ft^3/sec

13. Assume the orifice can be moved to any point on the side of the tank. What distance below the water surface should the orifice be located such that the horizontal distance traveled by the jet (before hitting the ground) is the greatest?

(A) 7.5 ft
(B) 8.8 ft
(C) 10 ft
(D) 11 ft

14. A 2 m tall, 0.5 m inside diameter tank is filled with water. A 10 cm hole is opened 0.75 m from the bottom of the tank. What is the velocity of the exiting water? Ignore all orifice losses.

(A) 4.75 m/s
(B) 4.80 m/s
(C) 4.85 m/s
(D) 4.95 m/s

1. Reynolds number may be calculated from:

(A) diameter, velocity, and absolute viscosity
(B) diameter, velocity, and surface tension
(C) diameter, density, and kinematic viscosity
(D) diameter, density, and absolute viscosity
(E) characteristic length, mass flow rate per unit area, and absolute viscosity

2. Roughening the leading edge of a smooth sphere will reduce its drag coefficient because

(A) the wake width increases
(B) the separation points move to the front of the sphere
(C) the wake eddies increase
(D) the boundary layer becomes turbulent
(E) Stoke's law becomes applicable

3. What is the hydraulic radius of a rectangular flume 2 feet high and 4 feet wide which is running half full?

(A) 1.33 feet
(B) .33
(C) 8.0
(D) .40
(E) .67

4. Water flows at 10 ft/sec in a 1" inside diameter pipe. What is the velocity if the pipe suddenly increases in diameter to 2"?

(A) 5 ft/sec
(B) 2.5
(C) 40
(D) 20
(E) answer depends on the flow direction

5. What pressure differential exists across a perfect venturi with an area reduction ratio of (3:1) if water is flowing through the throat at 40 fps?

(A) .6 feet of water
(B) 17
(C) 22
(D) 27
(E) 1378

6. If 'L' is defined as the characteristic length, what does the quantity (v^2/Lg) represent?

(A) velocity pressure
(B) Reynolds number
(C) Froude number
(D) total pressure
(E) static pressure

7. Minor losses through valves, fittings, diameter changes, and bends are proportional to

(A) total head
(B) dynamic head
(C) static head
(D) wet head
(E) velocity

8. The horsepower of an ideal pump used to move 2 cfs of water into a tank 50 feet above the pump is most nearly

(A) 2
(B) 11
(C) 290
(D) 1213
(E) 6240

9. A horizontal pipe section 1000 feet long has a total energy loss of 26.2 feet. If the inside pipe diameter is 12 inches and the flow velocity is 10 ft/sec, what is the Darcy-Weisbach friction coefficient?

(A) 0.0170
(B) 0.0080
(C) 0.0017
(D) 0.0002
(E) 0.0008

10. The Reynolds number for a 1-foot diameter sphere moving through a fluid (specific gravity of 1.22, absolute viscosity of 0.00122 lb-sec/ft^2) at 10 ft/sec is approximately

(A) 20
(B) 200
(C) 2,000
(D) 20,000
(E) 200,000

11. Water is flowing in a circular pipe between points 1 and 2. The pressure at point 1 is 16.8 psia. The pressure and velocity at point 2 are 17.2 psia and 6.2 ft/sec, respectively. Points 1 and 2 are at the same elevation. Neglecting friction, what is the velocity at point 1?

(A) 97.8 ft/sec
(B) 9.9
(C) 21.0
(D) 1.52
(E) 4.58

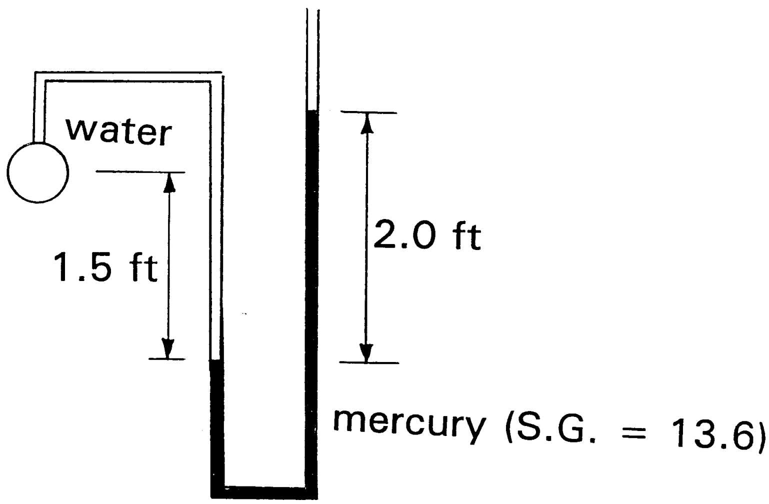
12. The critical depth in a rectangular channel 8 feet wide flowing at a critical velocity of 2 ft/sec is approximately

(A) 0.12 feet
(B) 2.00
(C) 4.00
(D) 0.06
(E) 0.08

13. At a certain section of pipe, water is flowing at a pressure of 80 psi and with a linear velocity of 9 ft/sec. What is the total flow work for 1.5 cubic feet of water which pass that section?

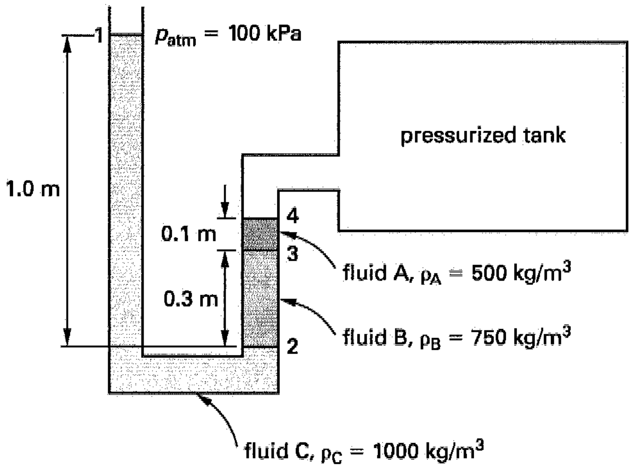
(A) 18,000 ft-lb
(B) 36,000
(C) 120
(D) 12,000
(E) 0

Example: Use the manometer measurements to compute the pressure in the pipe.



FLUIDS–17

Find the pressure in the tank from the manometer readings shown.



(A) 102 kPa (B) 108 kPa (C) 112 kPa (D) 118 kPa

$$p_2 - p_1 = \rho_C g(z_1 - z_2)$$

$$p_3 - p_2 = \rho_B g(z_2 - z_3)$$

$$p_4 - p_3 = \rho_A g(z_3 - z_4)$$

$$p_4 - p_1 = (p_4 - p_3) + (p_3 - p_2) + (p_2 - p_1)$$

$$\begin{aligned} p_4 &= p_1 + g\big(\rho_C(z_1 - z_2) + \rho_B(z_2 - z_3) + \rho_A(z_3 - z_4)\big) \\ &= 100\,000 \text{ Pa} + \left(9.81 \ \frac{\text{m}}{\text{s}^2}\right)\left(\left(1000 \ \frac{\text{kg}}{\text{m}^3}\right)(1 \text{ m})\right. \\ &\quad \left. + \left(750 \ \frac{\text{kg}}{\text{m}^3}\right)(-0.3 \text{ m}) + \left(500 \ \frac{\text{kg}}{\text{m}^3}\right)(0.1 \text{ m})\right) \\ &= 108\,100 \text{ Pa} \quad (108 \text{ kPa}) \end{aligned}$$

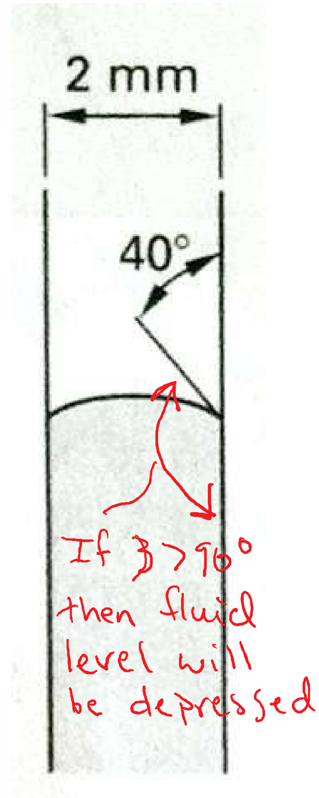
The answer is (B).

A jet aircraft is flying at a speed o f 1700 km/h.

The air temperature is 20°C. The molecular weight of air is 29 g/mol. What is the Mach number of the aircraft?

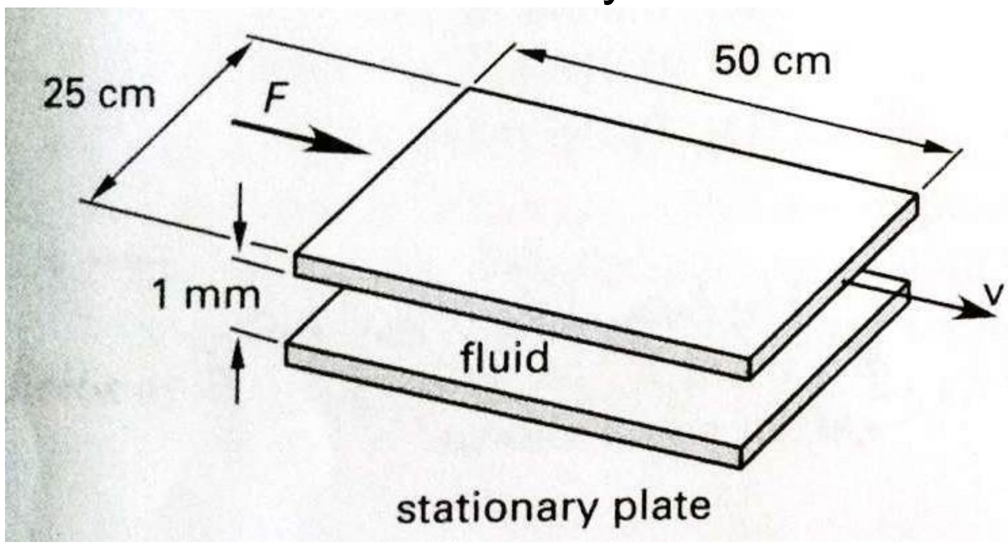
What is the Mach number of a jet of oxygen gas at standard conditions (1 atm and 25°C) with a speed of 450 m/s? (Assume that for oxygen k = 1.40 and R = 0.260 kJ/kg · K.)

A 2 mm (inside diameter) glass tube is placed in a container of mercury. An angle of 40° is measured as illustrated. The density and surface tension of mercury are 13550 kg/m^3 and 37.5 x 10^{-2} N/m, respectively. How high will the mercury rise or be depressed in the tube as a result of

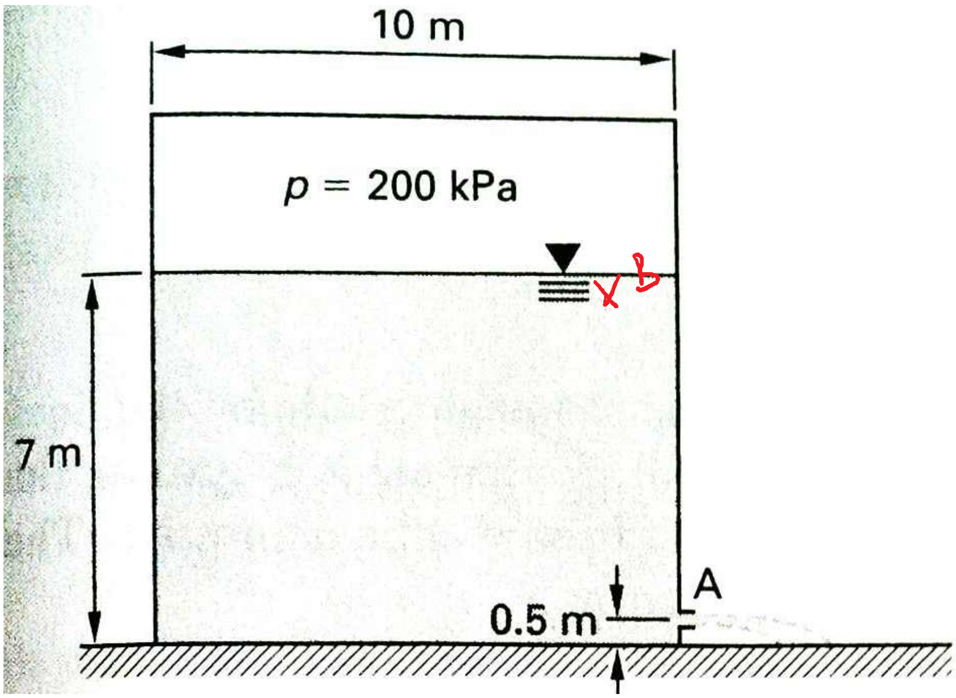


A sliding-plate viscometer is used to measure the viscosity of a Newtonian fluid. A force of 25 N is required to keep the top plate moving at a constant velocity of 5 m/s. What is the viscosity of the fluid?

$\delta =$



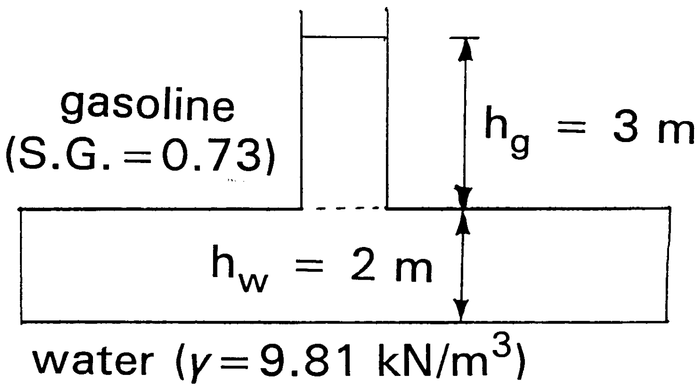
A liquid with a specific gravity of 0.9 is stored in a pressurized, closed storage tank. The tank is cylindrical with a 10 m diameter. The absolute pressure in the tank above the liquid is 200 kPa. What is the initial velocity of a fluid jet when a 5 cm diameter orifice is opened at point A?



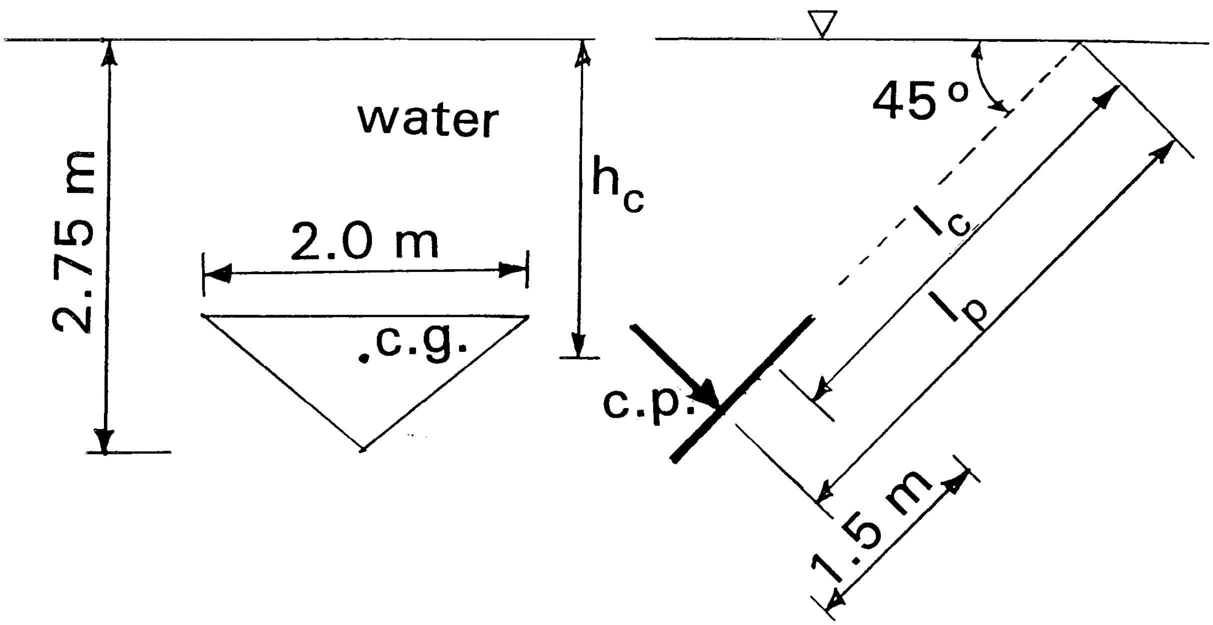
18.6 m/s

Example: What is the pressure 10 feet below the surface of a swimming pool?

Example: The tank of water has a 3-m column of gasoline (S.G. = 0.73) above it. Atmospheric pressure is 101 kPa. Compute the pressure on the bottom of the tank.

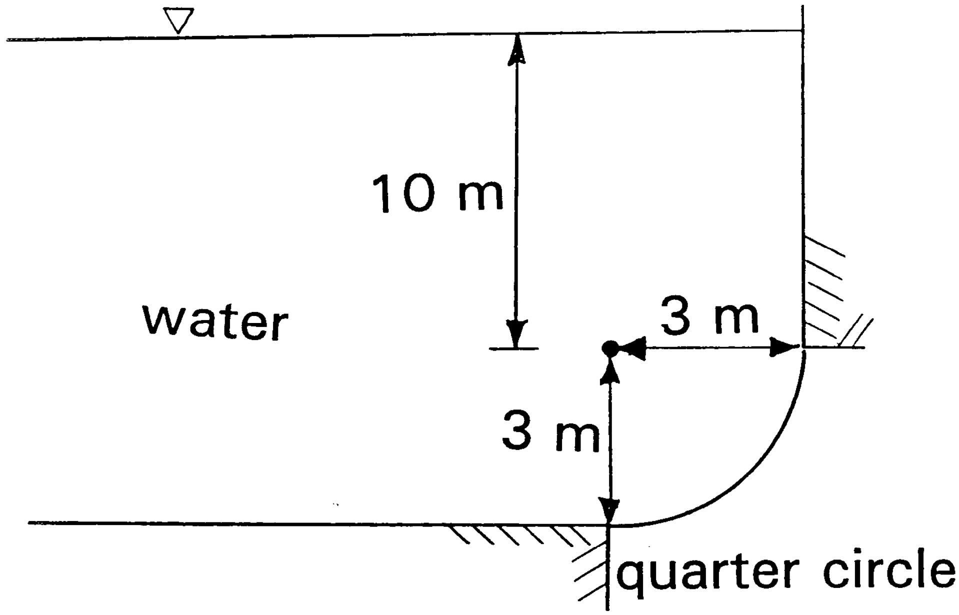


Example: Compute the magnitude and location of the resultant force.

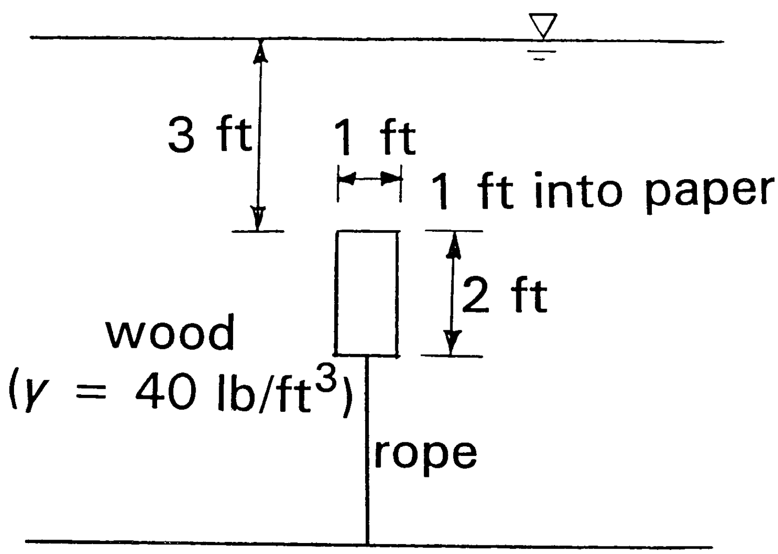


moment of inertia $I_c = bh^3/36$

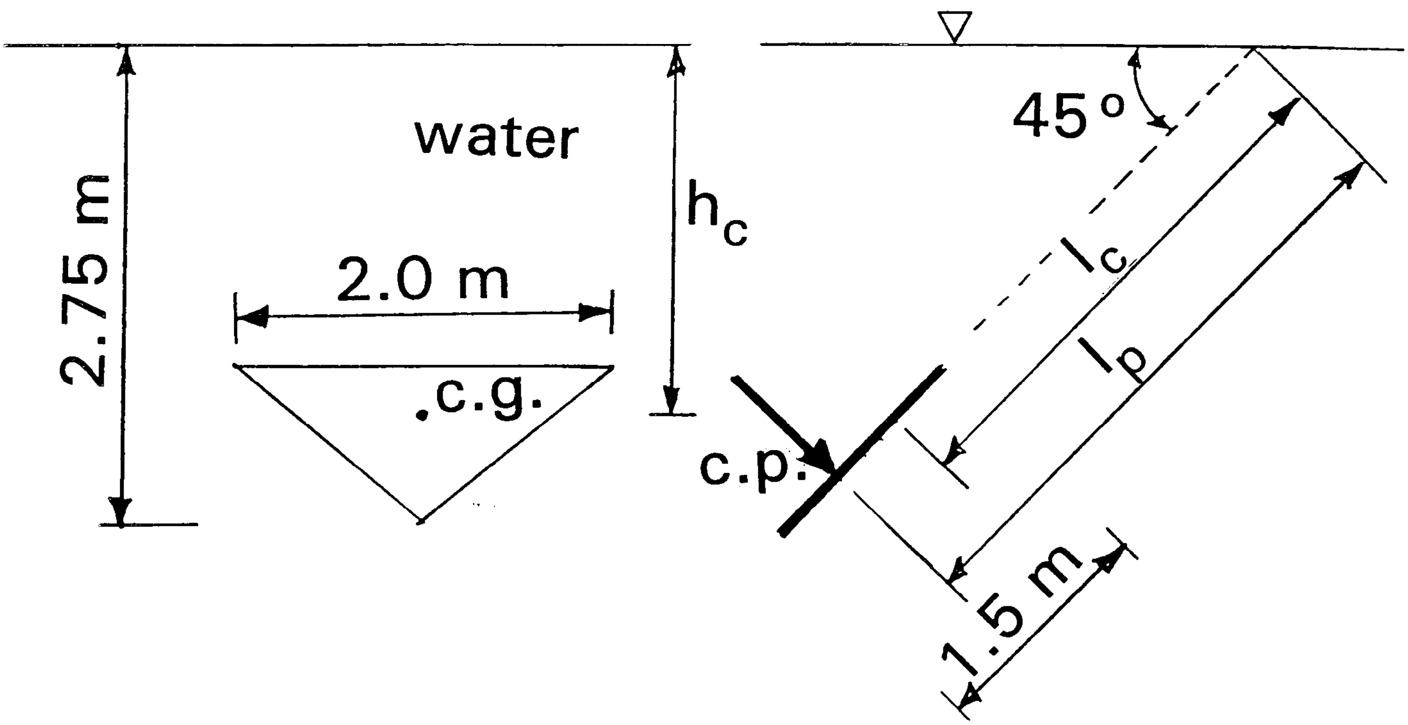
Example: Compute the force on the curved corner for a unit width.



Example: Compute the force in the rope.

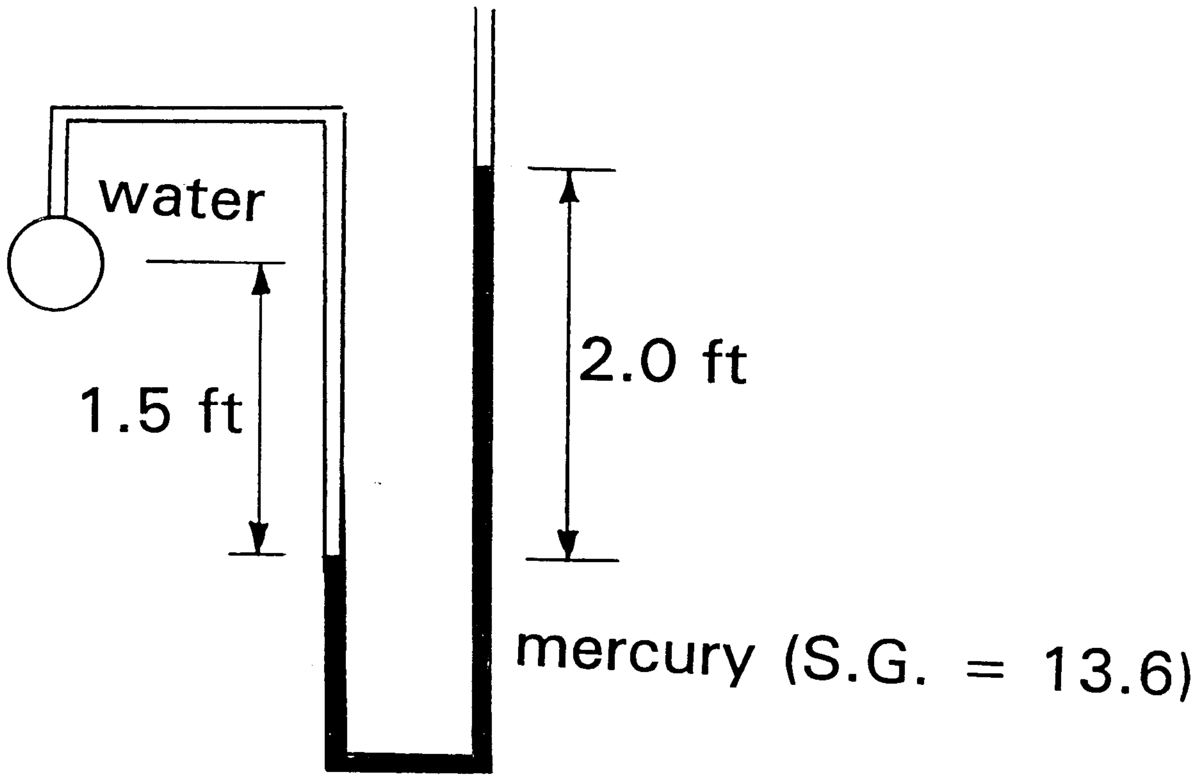


Example: Compute the magnitude and location of the resultant force.



moment of inertia $I_c = bh^3/36$

Example: Use the manometer measurements to compute the pressure in the pipe.



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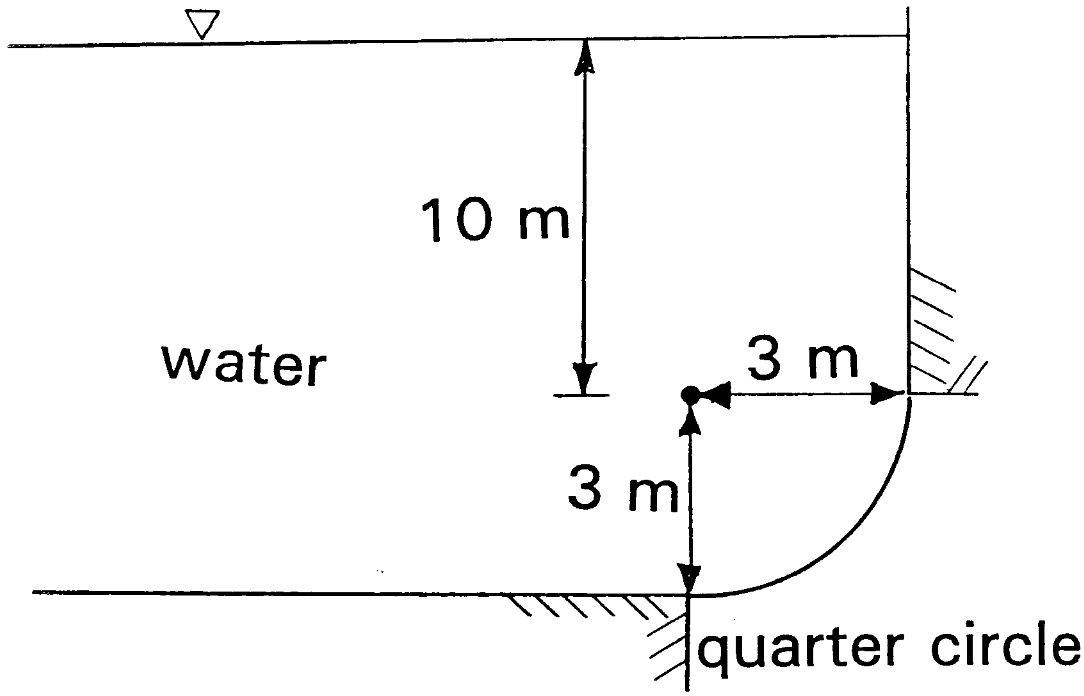
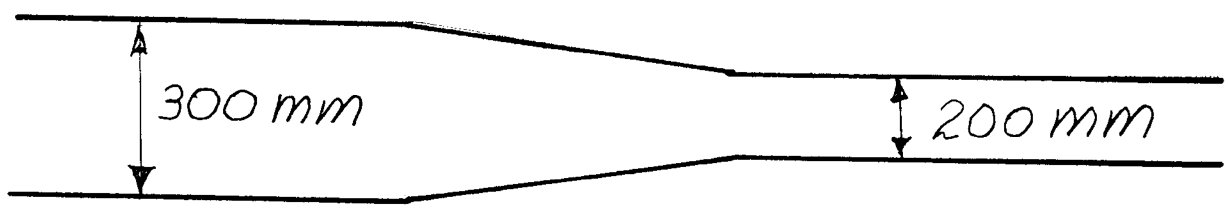


Example: Three kN/s of water flows through the pipeline reducer. Determine the flow rate and velocity in the 300 mm and 200 mm pipes.



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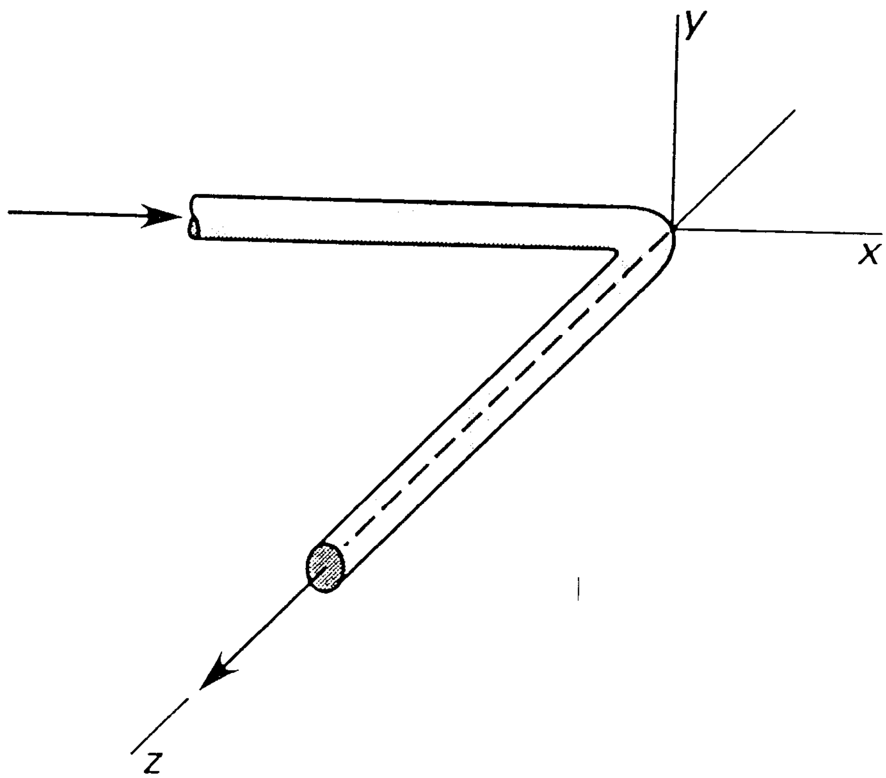
Example: Water is flowing at 0.884 m^3/s through a 15 cm diameter pipe, that has a 90° bend. What is the reaction on the water in the z-direction in the bend?



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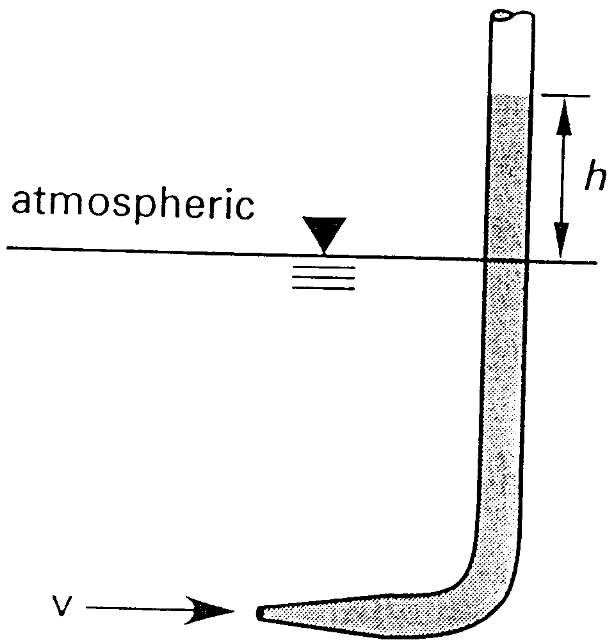
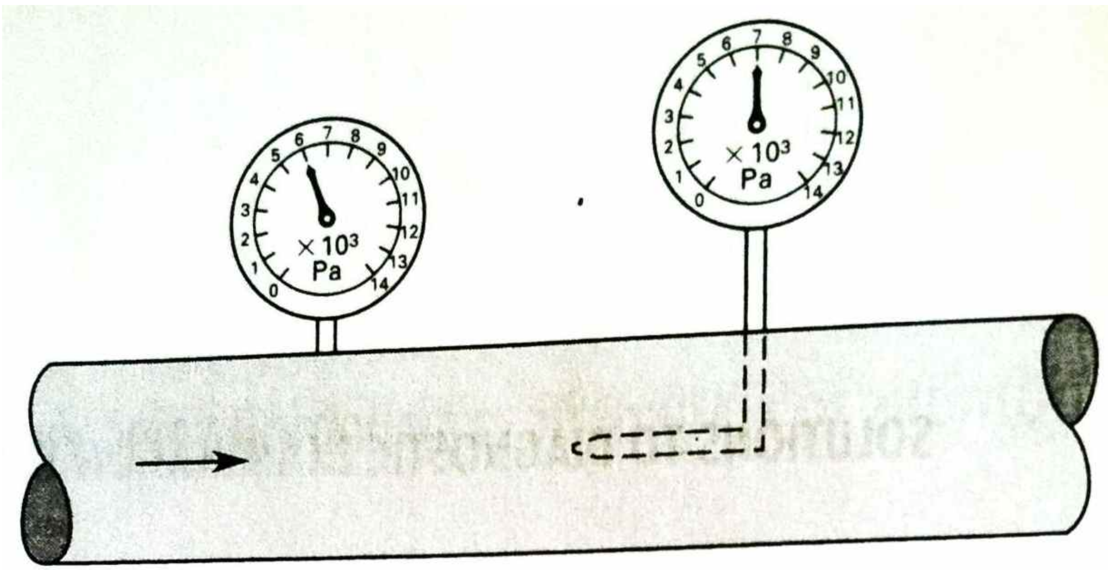
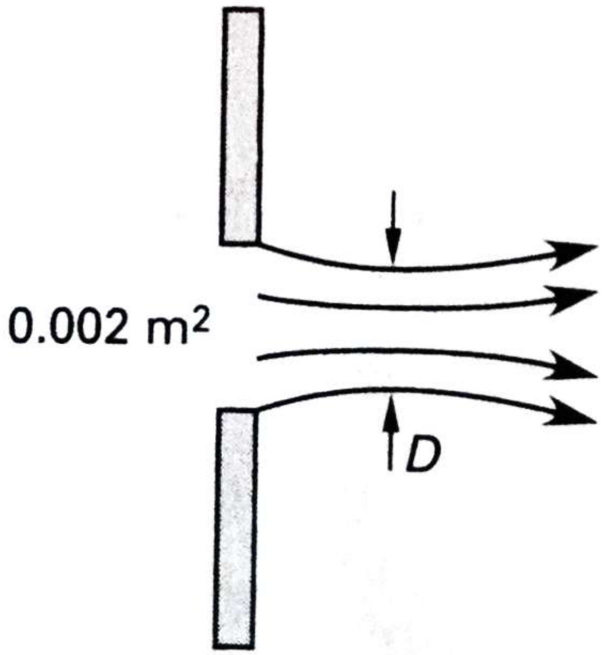
Example: The height of water in the pitot tube is measured to be 7.3 cm. What is the velocity at that point in the flow.



The density of air flowing in a duct is 1.15 kg/m^3. A pitot tube is placed in the duct as shown. The static pressure in the duct is measured with a wall tap and pressure gage. Use the gage readings to determine the velocity of the air.



Water flows out of a tank at 12.5 m/s from an orifice located 9m below the surface. The cross-sectional area of the orifice is 0.002 m^2, and the coefficient of discharge is 0.85. What is the diameter D, at the vena contracta?



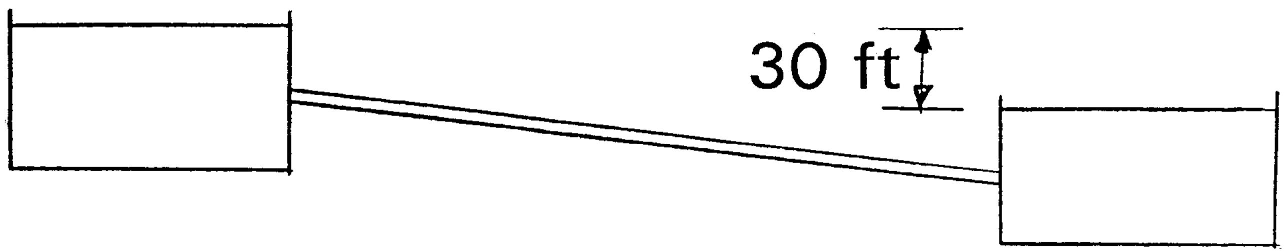
4.8 cm

A nuclear submarine is capable of a top underwater speed of 65 km/h. How fast would a 1/20 scale model of the submarine have to be moved through a testing pool filled with seawater for the forces on the submarine and model to be dimensionally similar?

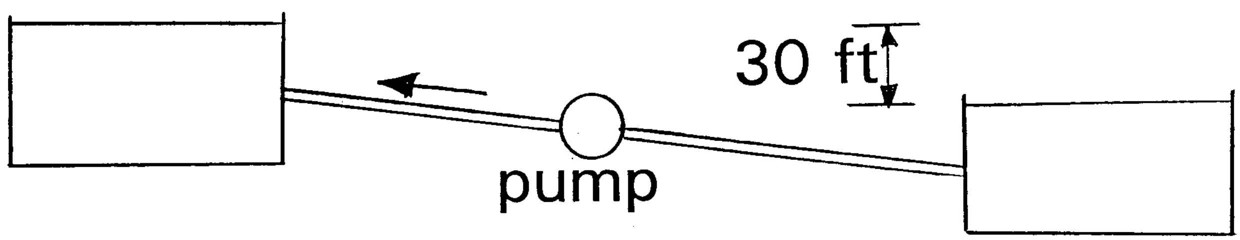
360 m/s

Darcy-Weisbach Example: For a discharge (Q) of 1.0 ft^3/s, compute the head loss in 1,500 feet of new 6-inch diameter cast iron pipe (ϵ = 0.00085 ft). Assume a water temperature of 60° F.

Example: A 6-inch diameter 500 ft long steel pipe (ϵ = 0.00015 ft) conveys flow between two reservoirs which have a difference in water surface elevation of 30 ft. The pipe exit and entrance are square edge. Compute the flow rate.



Example: - Assume a pump is added to the previous example and the flow direction is reversed. What pump head is required for a discharge of 2.0 cfs.



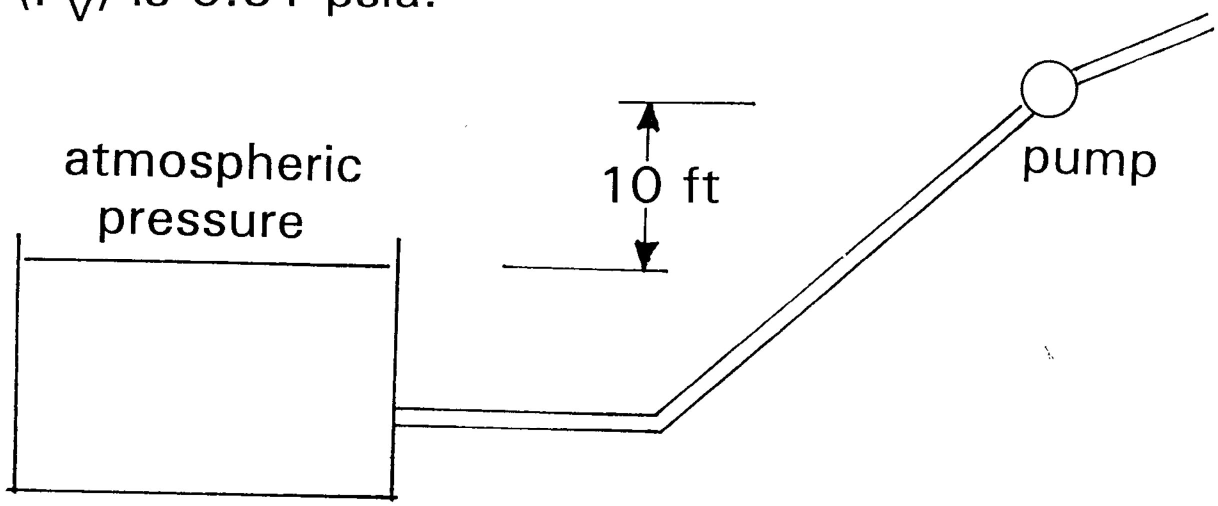
Example: Determine the horsepower required for the pump of the previous problem, assuming the pump efficiency is 75%.

$Q = 2.0 \text{ ft}^3/\text{s}$

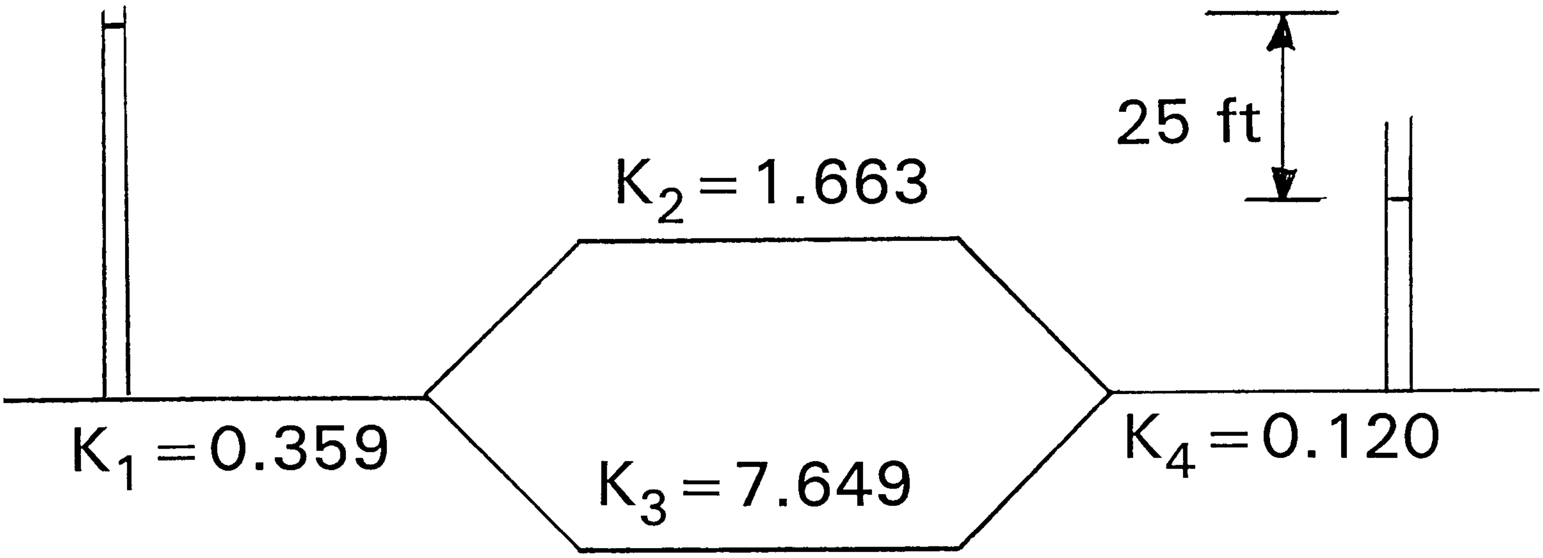
$h_p = 58.2 \text{ ft}$

$\eta = 0.75$

Example: Compute the discharge rate that causes the pressure to drop to vapor pressure. The pipe between the reservoir and pump has a length of 1,000 ft, diameter of 3 feet, and friction factor (f) of 0.02. Neglect minor losses. For a water temperature of 80°F , the vapor pressure (P_V) is 0.51 psia.



Example: Compute the discharge in each pipe. Neglect minor losses.



$$h_L = KQ^2$$

$$K = f\left(\frac{L}{D}\right)\left(\frac{1}{2gA^2}\right)$$

Pipe	L(feet)	D(inch)	A(ft^2)	f	K=f(L/D)(1/2gA^2)
1	3,000	16	1.396	0.020	0.359
2	3,000	12	0.785	0.022	1.663
3	2,000	8	0.349	0.020	7.649
4	1,000	16	1.396	0.020	0.120

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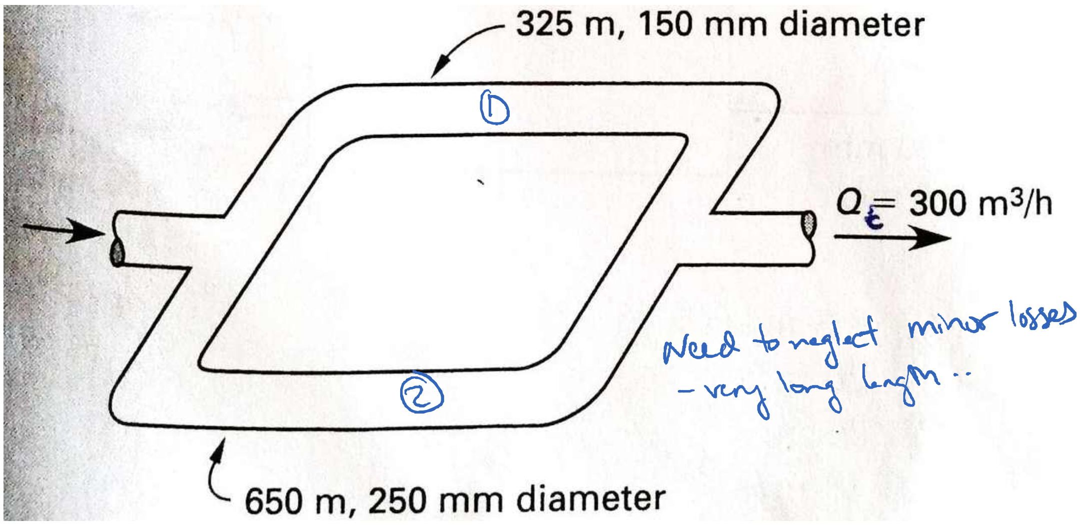
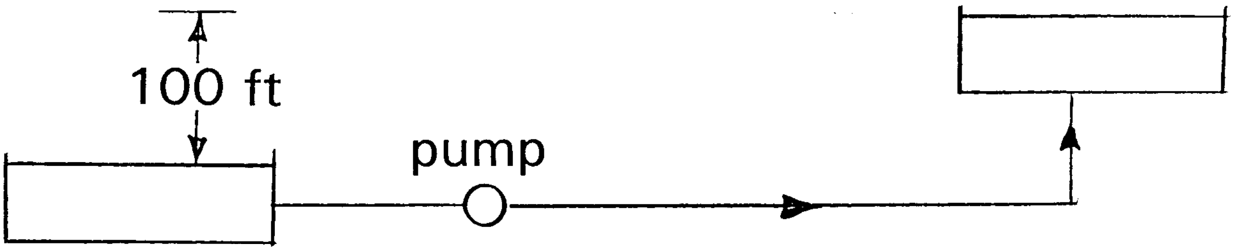
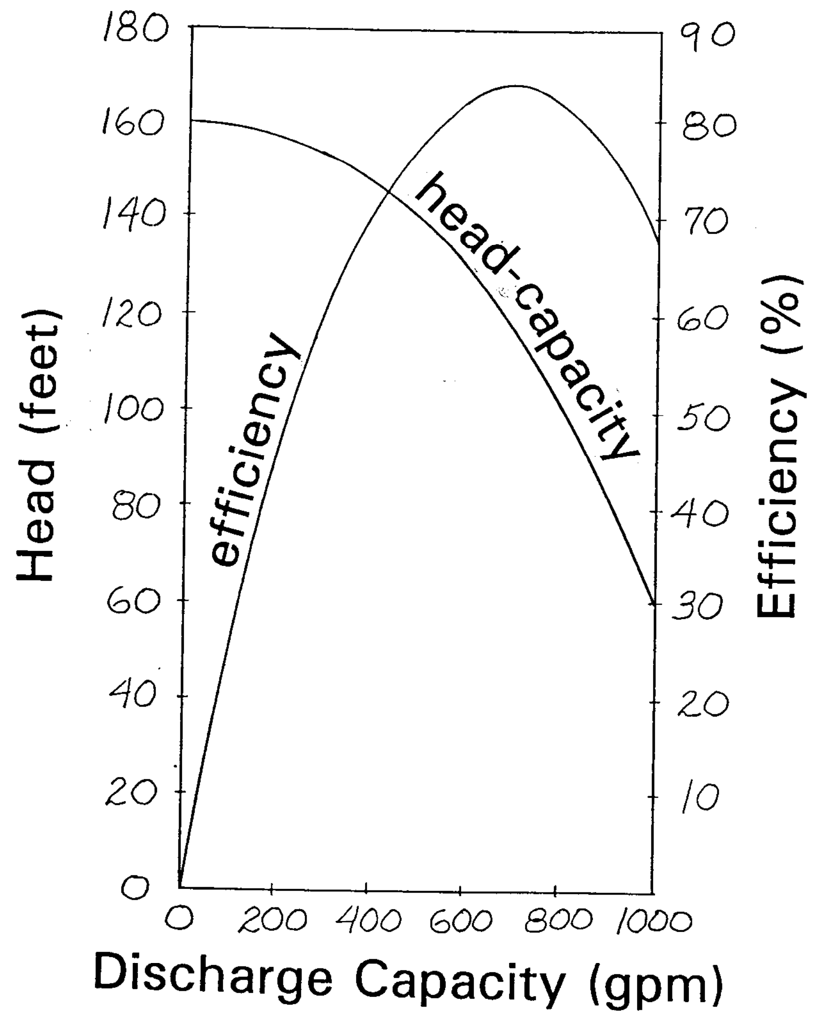
The Darcy friction factor for both of the pipes shown is 0.024. The total flow rate is 300 m³/h. What is the flow rate through the 250 mm pipe?



<u>EXAMPLE</u>: Two reservoirs are connected by a 850 feet long 6-inch diameter pipe ($f = 0.020$). A pump with the given characteristic curves is used to lift water from one reservoir to the other. Determine the discharge rate.





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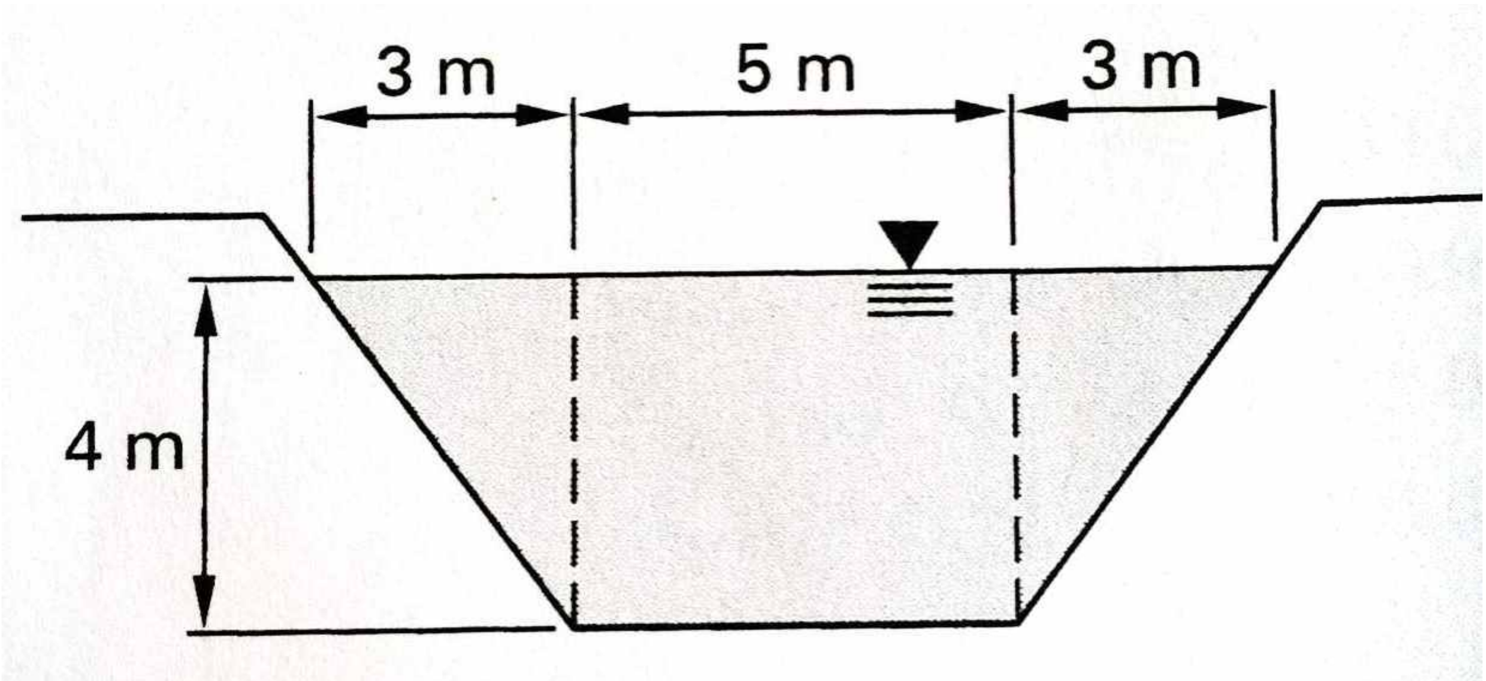
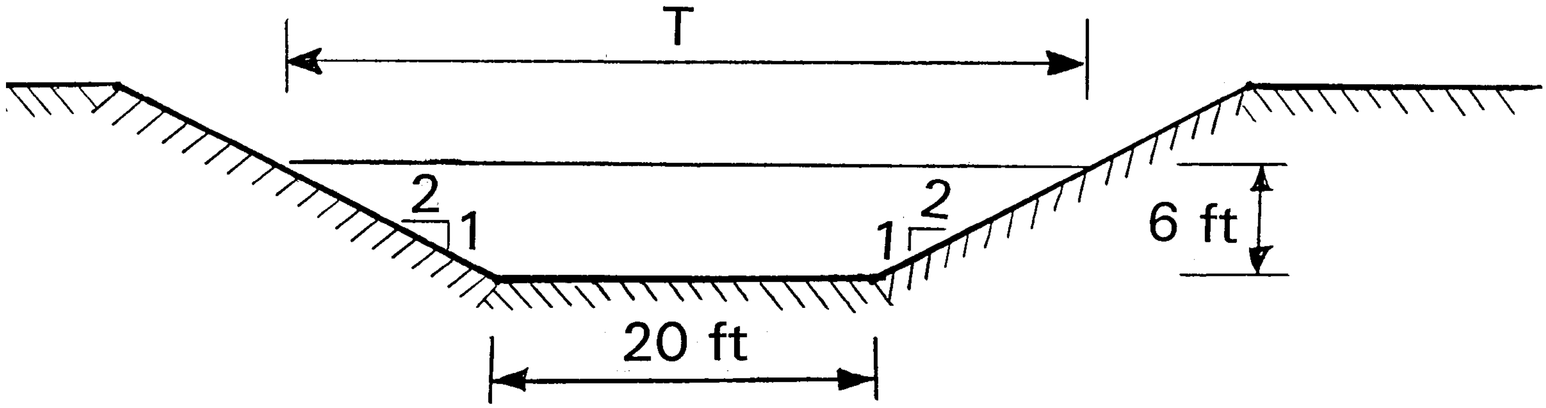
What is the hydraulic radius of the trapezoidal irrigation canal shown?



2.13 m

Geometric Elements of Channel Section

example: trapezoidal section



top width $T =$

flow area

wetted perimeter

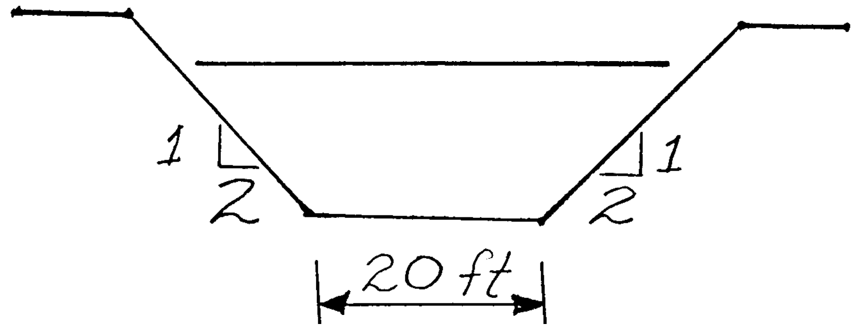
hydraulic radius

hydraulic depth

Example: Compute the discharge in a concrete ($n = 0.015$) channel with the previous cross-section and slope of 0.10%.

Example: Compute the normal depth and velocity.

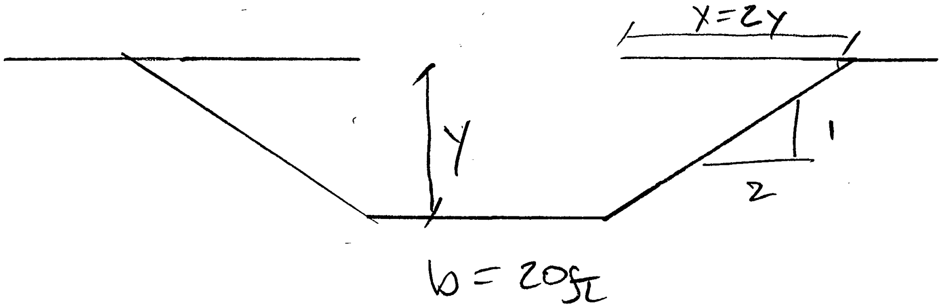
$Q = 400$ cfs
$S = 0.0016$
$n = 0.025$



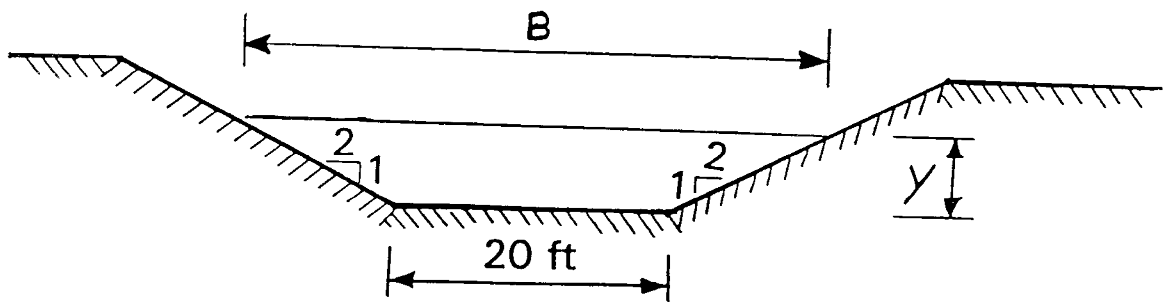
$Q = 400 \frac{ft^3}{s}$ $\quad Y_c = ?$

$S = 0.0016$

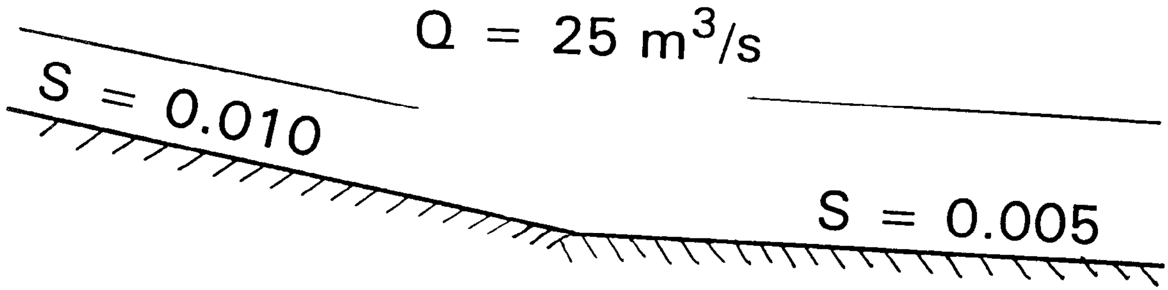
$n = 0.025$



Example: Compute the critical depth and velocity for Q = 400 cfs.



Example: A rectangular concrete ($n = 0.013$) channel with a bottom width of 12 meters abruptly changes from a slope of 0.010 to a slope of 0.005. A discharge of 25 m^3/s is flowing in the channel. Determine whether a hydraulic jump occurs.

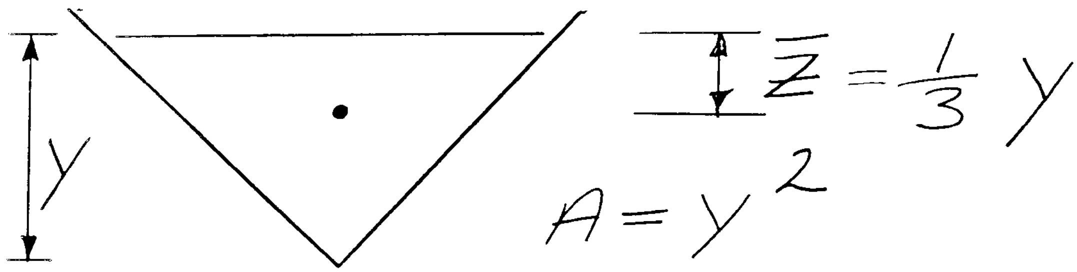


<u>Example</u>: A 15-ft wide rectangular channel has a roughness coefficient (n) of 0.~~0~~015 and bottom slope of 0.0015. The channel discharges into a river which may reach a stage of 10-feet above the channel bottom during floods. For a design discharge of 500 cfs, calculate y_n, y_c, and the distance from the channel outlet to the location where normal depth occurs.

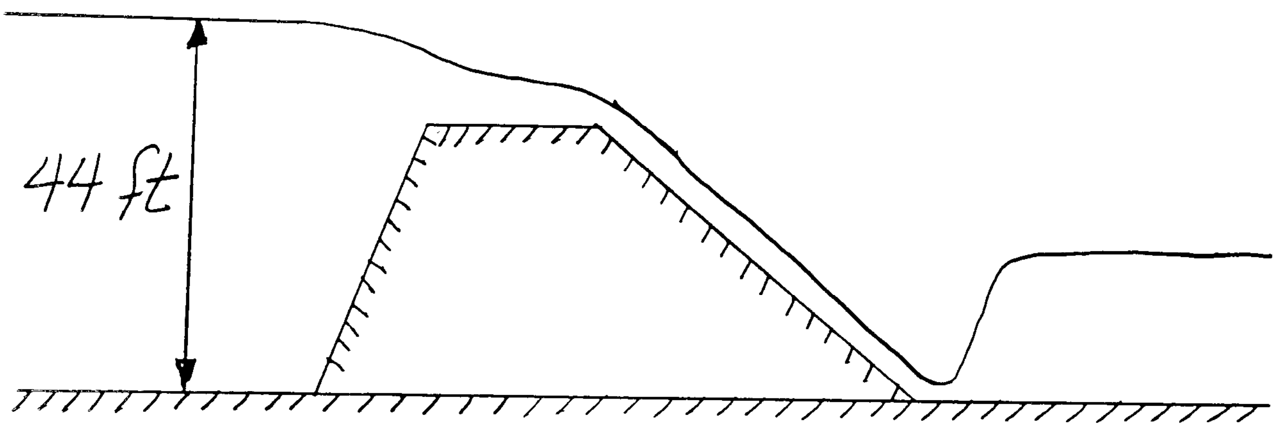
<u>normal depth</u>

<u>critical depth</u>

<u>Example</u>: A hydraulic jump occurs in a triangular flume having side slopes of 1:1. The flow rate is 0.45 m^3/s and the depth before the jump is 0.30 m. Compute the depth after the jump.



Example: Estimate the flow depth in the downstream channel and the energy loss in the hydraulic jump at the foot of the 100-ft wide rectangular broad crested spillway for a discharge of 2,130 cfs.



Compute the depth (Y1) at the toe of the spillway:

Compute the sequent depth:

Compute the energy loss in the hydraulic jump:

Example: A 50 acre watershed in Brazos County has a curve number (CN) of 86. Compute the direct runoff volume to result from a design storm with a recurrence interval of 50 years and duration of 24 hours.