UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACHELOR OF ENGINEERING TECHNOLOGY: *ENGINEERING : CIVIL*
SUBJECT	:	**HYDRAULICS 2A**
CODE	:	**HYDCIA2**
ASSESSMENT	:	WINTER EXAMINATION (MAIN PAPER)
DATE		1st JUNE 2018
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40:60
TOTAL MARKS	:	100

ASSESSOR	:	G.K. NKHONJERA
MODERATOR	:	DR EDNAH ONYARI
NUMBER OF PAGES:		PAGES: 19 including the cover page and Annexures.

INSTRUCTIONS :

1. This is a closed-book type of Exam.
2. This paper contains 7 questions. Four (4) in Section A and three (3) in Section B.
3. SECTION A : ANSWER **ALL** QUESTIONS.
   SECTION B : ANSWER **TWO** QUESTIONS ONLY.
4. Make sure that you understand what the question requires before attempting it.
5. Any additional material is to be placed in the answer book and must indicate clearly the question number, your name, and Student number.
5. Where necessary, answers without calculations will not be considered.

SECTION A
ANSWER ALL QUESTIONS

QUESTION 1 [10]

1.1 Define the following terms:

a) Specific gravity. (1)
b) Absolute viscosity. (1)
c) Centre of pressure. (1)

1.2 Two objects of the same volume, one made of wood and the other made of steel, are submerged in water. It is argued, by one of your classmates, that each of the two objects will be subjected to the same buoyancy. Do you agree with these classmates of yours? YES or NO. Explain your answer. (3)

1.3 Explain, in your own words, the difference between the following:

a) Newtonian fluids and Non-Newtonian fluids. (2)
b) Gauge pressure and Atmospheric pressure. (2)

QUESTION 2 [10]

2.1 Consider that you are filling a bucket with water using a garden hose-pipe. You suddenly remember that attaching a nozzle to the hose-pipe increases the discharge velocity of the water but wonders whether this may have any effect on the pressure. If indeed you decide to use the nozzle, state whether the pressure would increase, decrease or remain the same. Explain your answer. (3)

2.2 Given below (**Fig. 2.1**), is an inverted compound manometer tube with a pressure difference between pipes A and B equal to 7.48 kPa, ($P_B - P_A = 7.48kPa$). Pipe A carries freshwater. Vertically below it is another pipe B which carries a liquid with density of 1039 kg/m^3. Given that the specific weight of the oil is 7.85 kN/m^3, calculate the manometer liquid rise h in cm. (7)

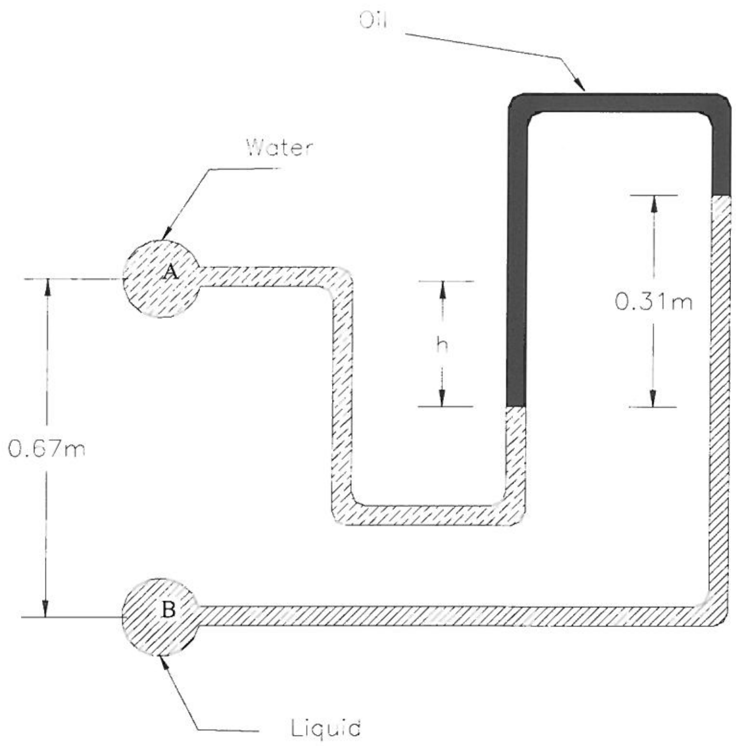


Fig. 2.1

QUESTION 3 [20]

3.1 With respect to open channel flow, describe the following terms.

a) Varied Flow. (1)
b) Hydraulic jump. (1)

3.2 Briefly, describe the difference between subcritical flow and supercritical flow. (2)

3.3 Water flows in a compound channel whose bed slope is 0.002 and whose cross section is as shown in **Fig. 3.2** below. The Manning's coefficient for the concrete channel section, $n = 0.015$ while that for the floodway section is $n = 0.040$. The dimensions of different subsections of this compound channel are also given in the figure. Assuming steady uniform flow, determine the flow rate through the whole channel. (16)

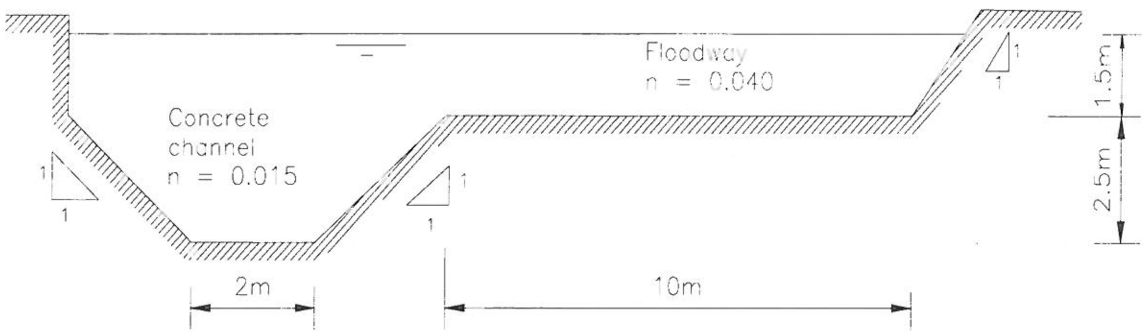


Fig. 3.2

QUESTION 4 [20]

4.1 Water flows through a 550 mm diameter pipe at the end of which there is a reducer connecting to a 300 mm diameter pipe (**Fig. 4.3**). The pressure and the velocity at the entrance to the reducer are 400 kPa and 2.5 m/s respectively. If the friction loss in the reducer is taken as $1.5\frac{V_2^2}{2g}$ (*where* V_2 *is velocity in the smaller pipe*), determine the resultant thrust on the reducer. (7)

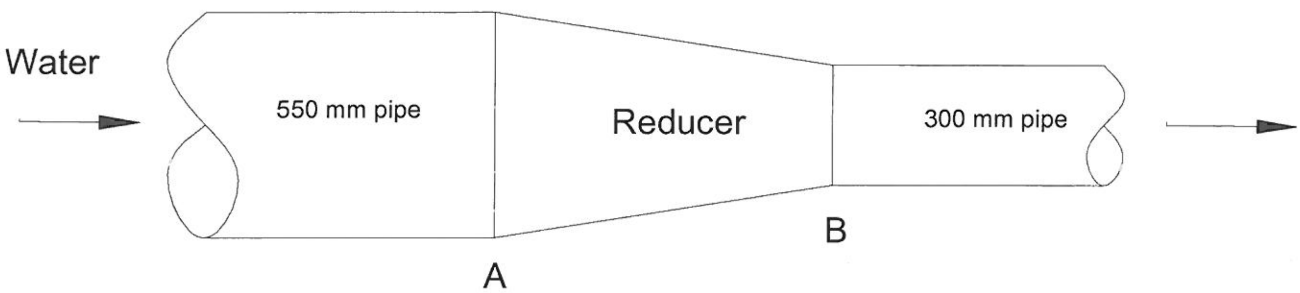


Fig. 4.3

4.2 The gate in the diagram below (**Fig. 4.4**) is 2 m wide and is kept closed, in an inclined position, by means of a counter weight in the form of a concrete block hanging from a cable which passes over a pulley as shown. The concrete itself is completely submerged in water. Assuming friction at the hinge and the pulley being negligible,

a) Determine the tension in the cable. (9)

b) If the density of concrete is taken as 2400 kg/m^3, find the minimum volume of concrete needed to keep the gate closed in an inclined position as shown when the water depth is 5m. (4)

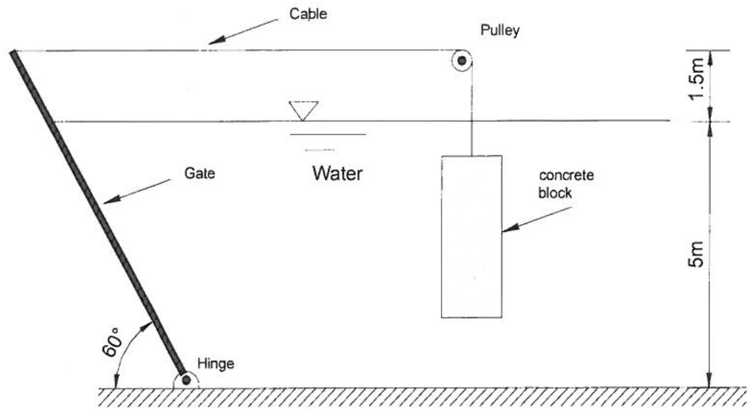


Fig. 4.4

SECTION B
ANSWER TWO QUESTIONS ONLY

QUESTION 5 [20]

You are presented with a water supply pipeline that connects two reservoirs, one a storage reservoir and the other a service reservoir at an elevation 45 m above the storage reservoir. A pump, as shown in **Fig. 5.5**, is installed to deliver 250 l/s of water to the service reservoir. The pump delivers water through a pipe system consisting of a single pipe AB branching at B into two parallel pipes BC and BD. Pipe AB has a length of 4.5 km, diameter of 500 mm and pipe roughness size, $k = 0.25mm$. On the other hand, each of the two parallel pipes BC and BD has a length of 3 km and a pipe roughness size, $k = 0.47mm$. However, their pipe sizes are different. Pipe BC has a diameter of 350 mm and pipe BD a diameter of 300 mm. Assuming all minor losses are negligible, determine:

a) The discharge in BC and BD. (12)
b) The pump delivery head, in metres. (8)

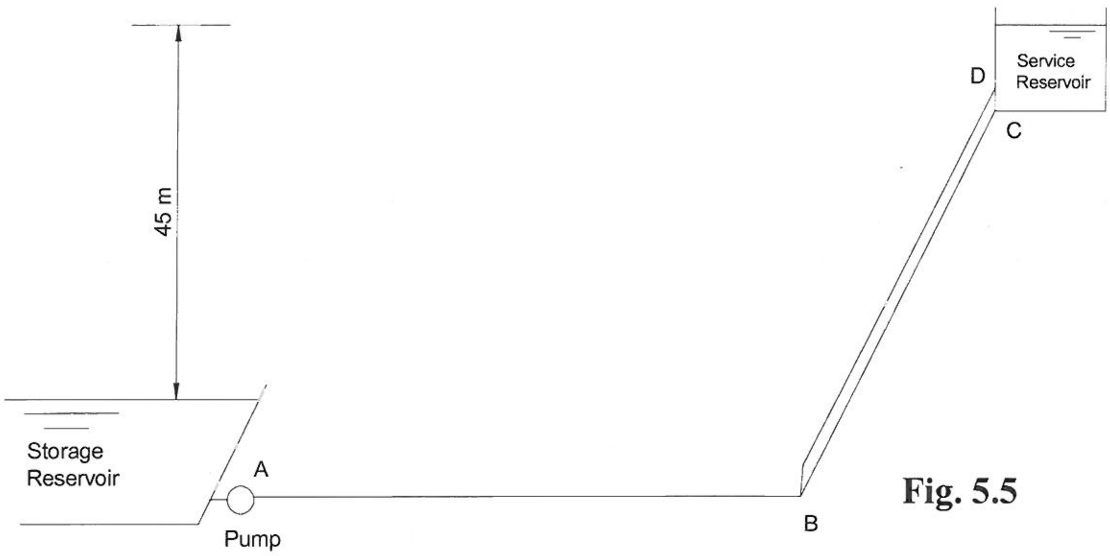


Fig. 5.5

QUESTION 6 [20]

6.1 A trapezoidal channel (**Fig 6.6**) with a bottom width of 5 m, free surface width of 12.2 m, and flow depth of 1.2 m discharges water at a rate of 52.1 m^3/s. The surfaces of the channel are lined with asphalt (n = 0.016). Assuming steady-uniform flow, determine the following:

a) Elevation drop of the channel per km. (8)
b) Froude number for the depth of 1.2 m. (3)
c) Whether flow is supercritical, critical or subcritical. (1)

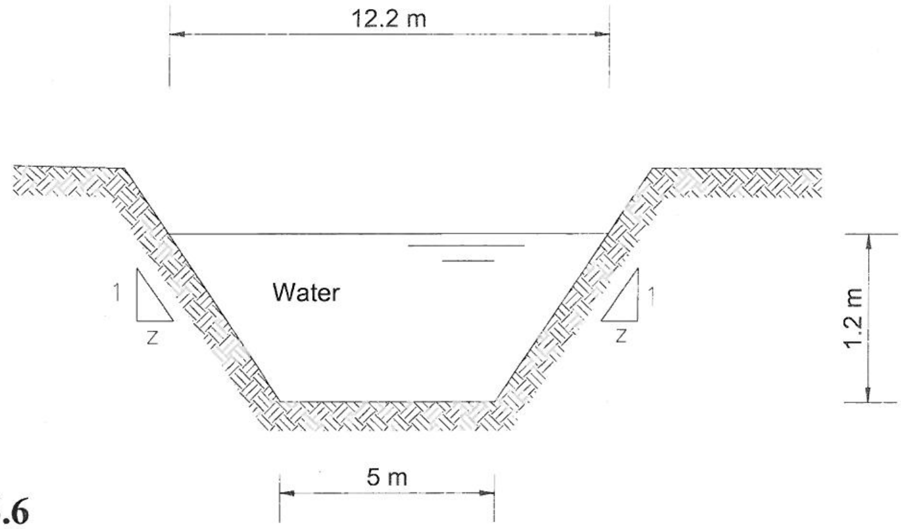


Fig. 6.6

6.2 **Fig. 6.7** below shows a tank of water with a pipe connected to its bottom. A circular gate seals the pipe opening to prohibit flow. To drain the tank, a winch is used to pull the gate open. The diameter of the circular gate is 250 mm. Assuming that the thickness and weight of the gate is negligible, determine the amount of force that the winch cable must exert to open the gate. (8)

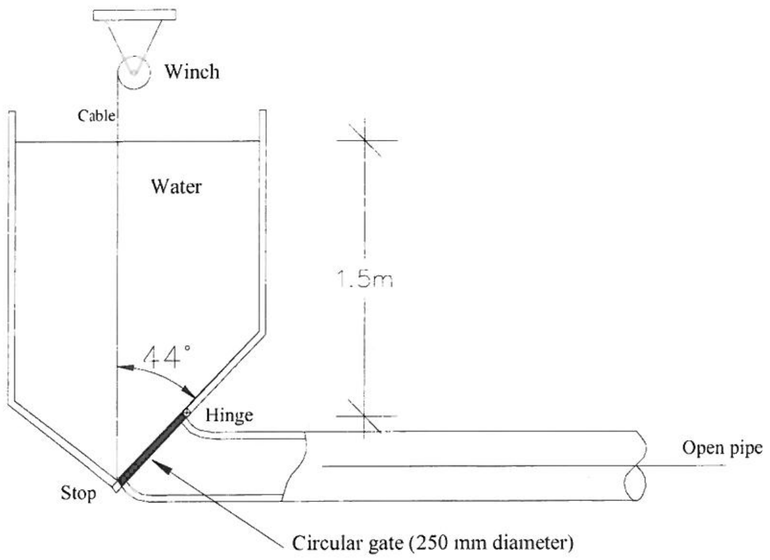


Fig. 6.7

QUESTION 7 [20]

You are tasked to select a pump that can deliver water from a dam reservoir to a service reservoir way up the hill as shown in **Fig. 7.9**. The pump station is to be situated 2.5 m above the water level in the dam reservoir. The pump, when running at a constant speed of 1750 rpm, gave the following characteristics as shown in **Table 7.8** below. The only pipe size available for the job is a 150 mm pipe which has a friction coefficient, $f = 0.024$. If this pump were to be used for the job at hand, provide answers for the following questions:

Table 7.8: Pump characteristic data

Discharge (m^3/h)	504	457.2	399.6	309.6	205.2	108	0
Head (m)		24.00	39.00	57.00	69.00	79.00	84.00
NPSH required (m)		6.80	5.30	4.50	3.10	2.60	2.00
Input Power (kW)	90.00	85.00	78.00	67.00	49.00	39.00	25.00

a) Determine the $NPSH_R$, head, discharge and power input at which the pump is operating. (11)

b) Calculate the efficiency at which the pump is operating. (2)

c) If the local atmospheric pressure is 101.4 kPa and the vapour pressure is 7.5 kPa, calculate the NPSH available. (6)

d) State whether the pump is under any threat due to cavitation. (1)

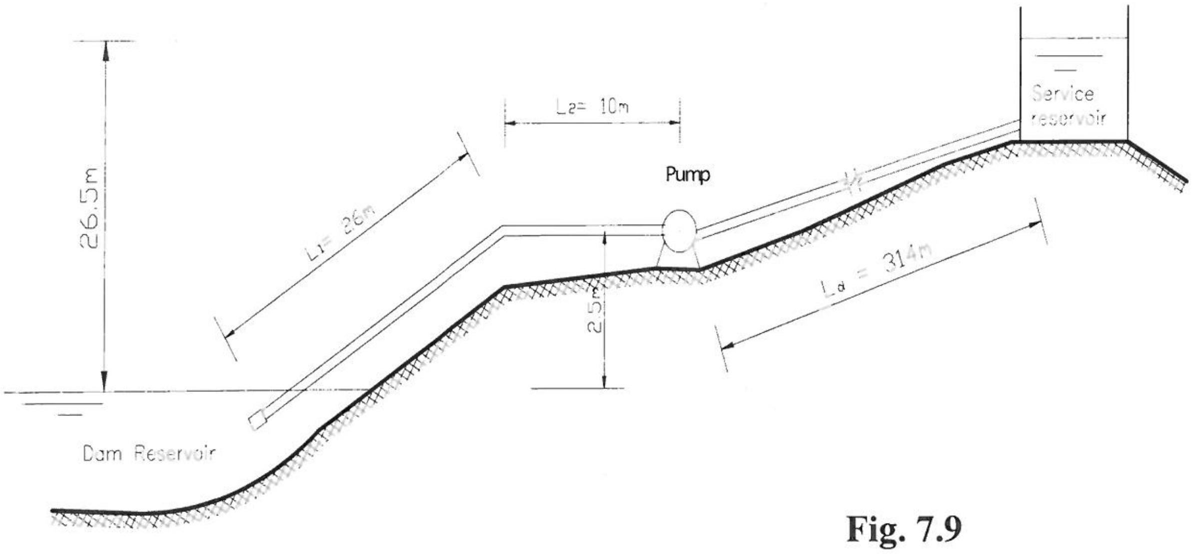


Fig. 7.9

HAPPY WINTER HOLIDAY TO YOU ALL !!!!!

APPENDIX A

FORMULAS

OPEN CHANNEL FORMULAS

$$V = \frac{1}{n} R^{2/3} S^{1/2} = \frac{1}{n} R^{2/3} \left(\frac{h_f}{L} \right)^{1/2}$$

$$V = CR^{1/2} S^{1/2} = CR^{1/2} \left(\frac{h_f}{L} \right)^{1/2}$$

Hydraulic depth, D

$$D = \frac{A}{T}$$

Hydraulic radius, R

$$D = \frac{A}{P}$$

Froude number:

$$N_F = \frac{V}{\sqrt{gD}}$$

Specific energy:

$$E = y + \frac{V^2}{2g}$$

Critical conditions (general):

$$\frac{Q^2 T}{A_c^{\,3} g} = 1$$

Critical conditions (rectangular section):

PUMP HYRAULICS FORMULAS

$$h_f = \frac{fLV^2}{2gD}$$

$$h_f = \frac{fLQ^2}{12.1D^5}$$

$$h_m = K\frac{V^2}{2g}$$

$$P_{out} = \rho g Q H$$

$$\eta = \frac{P_{output}}{P_{input}}$$

$$NPSH_A = H_{atm} \pm H_S - H_f - H_v - H_{vap}$$

$$H_{sys} = H_s + H_f$$

Varying pump speed but constant pump size

$$\frac{Q_2}{Q_1} = \frac{N_2}{N_1}$$

$$\frac{H_2}{H_1} = \left(\frac{N_2}{N_1} \right)^2$$

$$\frac{P_{i2}}{P_{i1}} = \left(\frac{N_2}{N_1} \right)^3$$

Varying pump sizes but constant pump speed

$$\frac{Q^2}{T^2 D_c^{\ 3} g} = 1$$ Hydraulic jump: $$\frac{y_2}{y_1} = \frac{1}{2}\left(\sqrt{1+8(N_{F1})^2} - 1\right)$$ $$\frac{q}{g} = y_1 y_2 \left(\frac{y_1 + y_2}{2}\right)$$ $$h_L = \frac{(y_2 - y_1)^3}{4 y_1 y_2}$$	$$\frac{Q_2}{Q_1} = \left(\frac{D_2}{D_1}\right)^3$$ $$\frac{H_2}{H_1} = \left(\frac{D_2}{D_1}\right)^2$$ $$\frac{P_{i2}}{P_{i1}} = \left(\frac{D_2}{D_1}\right)^5$$
MOMENTUM PRINCIPLE $$F = \rho Q (V_2 - V_1)$$ Where, F = momentum force (N) ρ = fluid density (kg/m^3) Q = discharge (m^3/s) V_2 = velocity after change in momentum (m/s) V_1 = initial velocity before change in momentum (m/s)	BOUYANCY AND STABILITY $$BM = \frac{I_G}{\forall}$$ Where: I_G = least 2nd moment of area of the water surface area. $\forall$ = volume of the displaced water.
HYDROSTATICS $$D = \bar{y} + \frac{I}{A\bar{y}}$$ $$P = \rho g h$$ $$F = \bar{P} A$$ Buoyancy: $$BM = \frac{I}{\forall}$$	HYDRODYNAMICS Energy Equation: $$\frac{P_A}{\rho g} + \frac{V_A}{2g} + Z_A = \frac{P_B}{\rho g} + \frac{V_B}{2g} + Z_B + h_L$$

PIPE FLOW

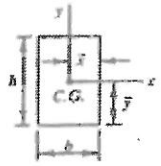
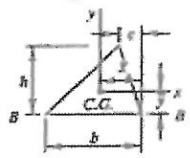
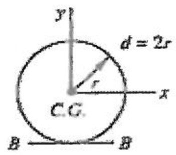
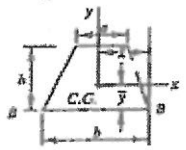
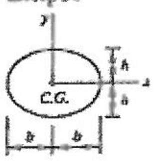
Formula	***Flow Conditions***	***Pipe Conditions***	***Reynolds Number***
$f = \frac{64}{N_R}$	Laminar	Smooth	$N_R < 2000$
$f = \frac{0.3164}{N_R^{1/4}}$	Turbulent	Smooth	$4\times10^4 < N_R < 10^5$
$\frac{1}{\sqrt{f}} = 2.0\log_{10}\left(N_R\sqrt{4f}\right) - 8.0$	Turbulent	Smooth	$5\times10^5 < N_R < 4\times10^7$
$\frac{1}{\sqrt{f}} = 2.0\log_{10}\left(R/k\right) + 1.74$ Or $\frac{1}{\sqrt{f}} = 2.0\log_{10}\left(3.7\, D/k\right)$	Turbulent	Rough	$N_R > 4000$
$h_f = \frac{fLV^2}{2gD}$; $N_R = \frac{\rho VD}{\mu}$	*N_R = Reynolds Number* *k = roughness size* *R = radius of pipe. And D = diameter of pipe.* *V = average velocity.* *μ = dynamic viscosity.*		

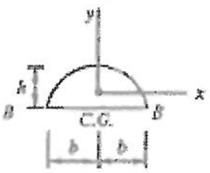
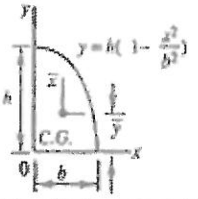
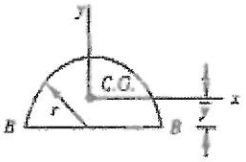
Quadratic equation, $ax^2 + bx + c = 0$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

APPENDIX B

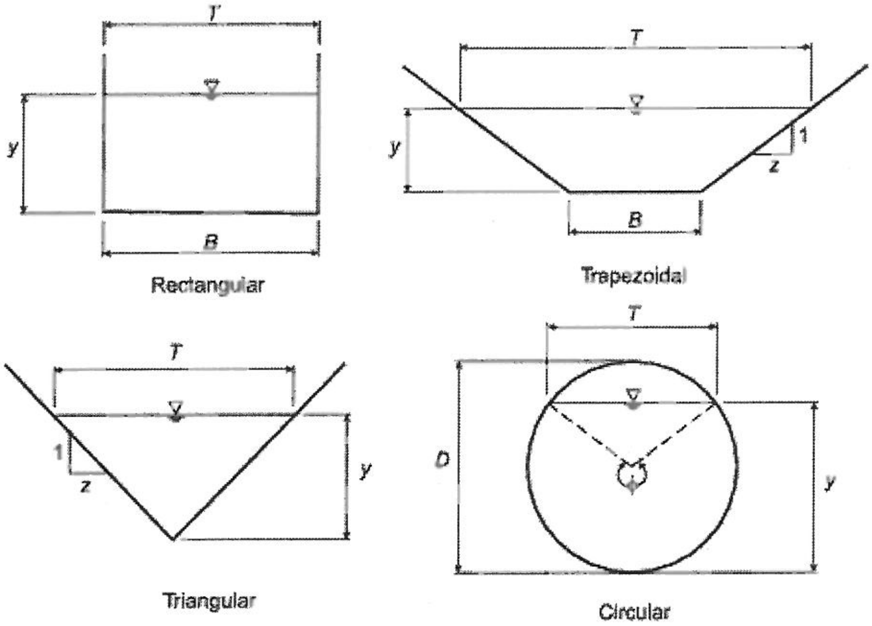
GEOMETRICAL PROPERTIES OF COMMON SHAPES

Shape	Area	Centroid	Moment of Inertia About the Neutral x-Axis
Rectangle 	bh	$\bar{x} = \frac{1}{2}b$ $\bar{y} = \frac{1}{2}h$	$I_0 = \frac{1}{12}bh^3$
Triangle 	$\frac{1}{2}bh$	$\bar{x} = \frac{b+c}{3}$ $\bar{y} = \frac{h}{3}$	$I_0 = \frac{1}{36}bh^3$
Circle 	$\frac{1}{4}\pi d^2$	$\bar{x} = \frac{1}{2}d$ $\bar{y} = \frac{1}{2}d$	$I_0 = \frac{1}{64}\pi d^4$
Trapezoid 	$\frac{h(a+b)}{2}$	$\bar{y} = \frac{h(2a+b)}{3(a+b)}$	$I_0 = \frac{h^3(a^2+4ab+b^2)}{36(a+b)}$
Ellipse 	πbh	$\bar{x} = b$ $\bar{y} = h$	$I_0 = \frac{\pi}{4}bh^3$

Shape	Area	Centroid	Moment of Inertia About the Neutral x-Axis
Semi-ellipse 	$\frac{\pi}{2}bh$	$\bar{x} = b$ $\bar{y} = \frac{4h}{3\pi}$	$I_0 = \frac{(9\pi^2 - 64)}{72\pi}bh^3$
Parabolic section 	$\frac{2}{3}bh$	$\bar{y} = \frac{2}{5}h$ $\bar{x} = \frac{3}{8}b$	$I_0 = \frac{8}{175}bh^3$
Semicircle 	$\frac{1}{2}\pi r^2$	$\bar{y} = \frac{4r}{3\pi}$	$I_0 = \frac{(9\pi^2 - 64)r^4}{72\pi}$

APPENDIX C

OPEN CHANNEL CROSS SECTIONS



Channel Shape	*Area, A*	*Wetted Perimeter, P*	*Hydraulic Radius, R*	*Top Width, T*	*Hydraulic depth, D*
Rectangular	By	$B+2y$	$\frac{By}{B+2y}$	B	y
Trapezoidal	$By+zy^2$	$B+2y\sqrt{1+z^2}$	$\frac{By+zy^2}{B+2y\sqrt{1+z^2}}$	$B+2zy$	$\frac{By+zy^2}{B+2zy}$
Triangular	zy^2	$2y\sqrt{1+z^2}$	$\frac{zy}{2\sqrt{1+z^2}}$	$2zy$	$\frac{y}{2}$
Circular (*ϕ in radians*)	$\frac{D^2(\phi-\sin\phi)}{8}$	$\frac{D\phi}{2}$	$\frac{D}{4}\left(1-\frac{\sin\phi}{\phi}\right)$	$D\frac{\sin\phi}{2}$	$\frac{D(\varphi-\sin\varphi)}{4\sin\varphi}$

Pump Characteristic Curves (APPENDIX D)

PUMP SELECTION USING CHARACTERISTIC CURVES

Design Discharge, Q = ____________

Operating Head, H = ____________

Efficiency, η = ____________

Power Input P = ____________

$NPSH_R$ = ____________

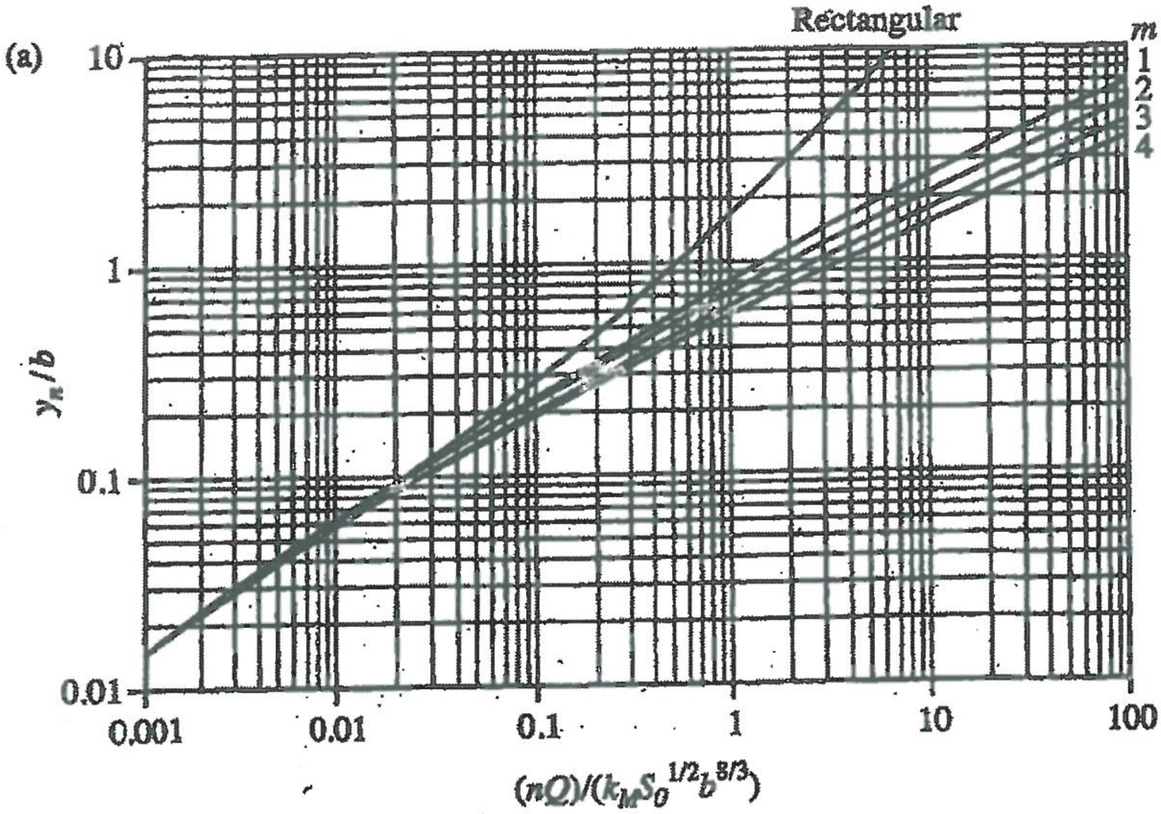
APPENDIX E

PIPE MATERIAL AND THEIR ROUGHNESS SIZES

Pipe Material	e (mm)	e (ft)
Brass	0.0015	0.000005
Concrete		
Steel forms, smooth	0.18	0.0006
Good joints, average	0.36	0.0012
Rough, visible form marks	0.60	0.002
Copper	0.0015	0.000005
Corrugated metal (CMP)	45	0.15
Iron (common in older water lines, except ductile or DIP, which is widely used today)		
Asphalt lined	0.12	0.0004
Cast	0.26	0.00085
Ductile; DIP—cement mortar lined	0.12	0.0004
Galvanized	0.15	0.0005
Wrought	0.045	0.00015
Polyvinyl chloride (PVC)	0.0015	0.000005
Polyethylene, high density (HDPE)	0.0015	0.000005
Steel		
Enamel coated	0.0048	0.000016
Riveted	0.9 ~ 9.0	0.003–0.03
Seamless	0.004	0.000013
Commercial	0.045	0.00015

APPENDIX F

OPEN CHANNEL DESIGN, NORMAL DEPTH



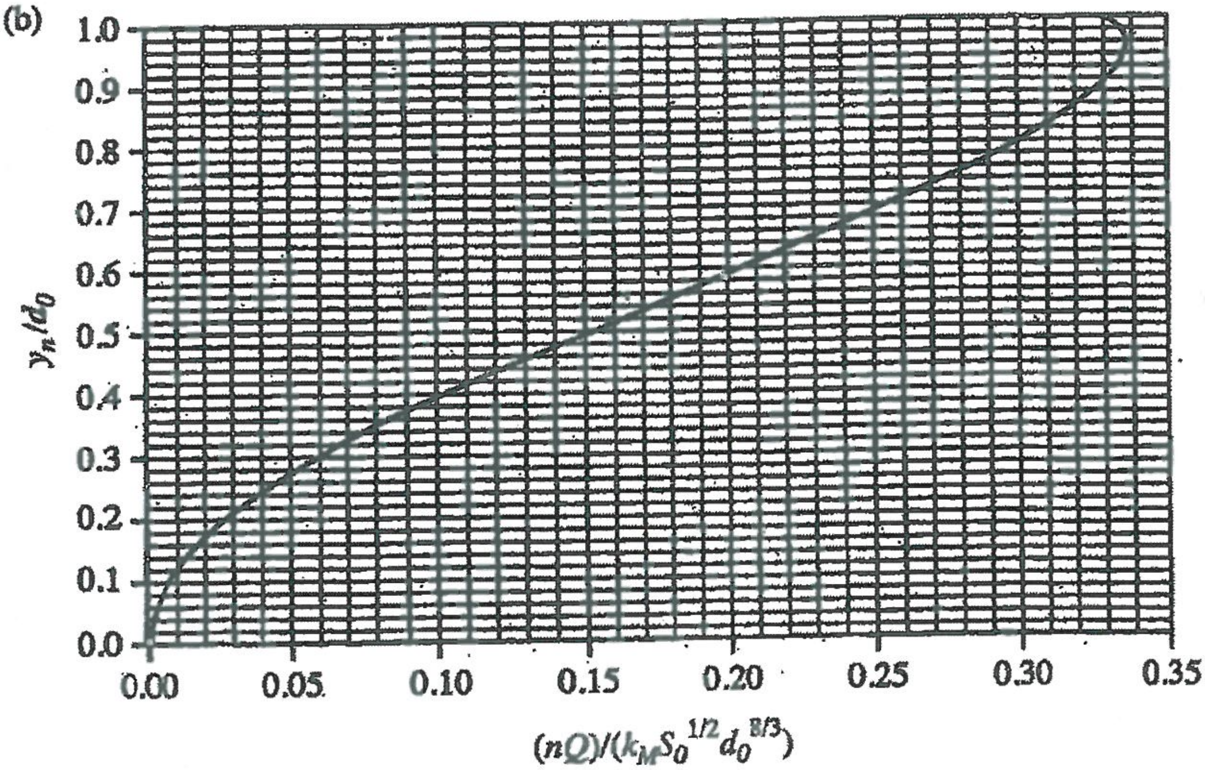


Figure 6.4 Normal depth solution procedure: (a) trapezoidal channels (m = side slope) and (b) circular channels (d_0 = diameter)

APPENDIX G

OPEN CHANNEL DESIGN, CRITICAL DEPTH

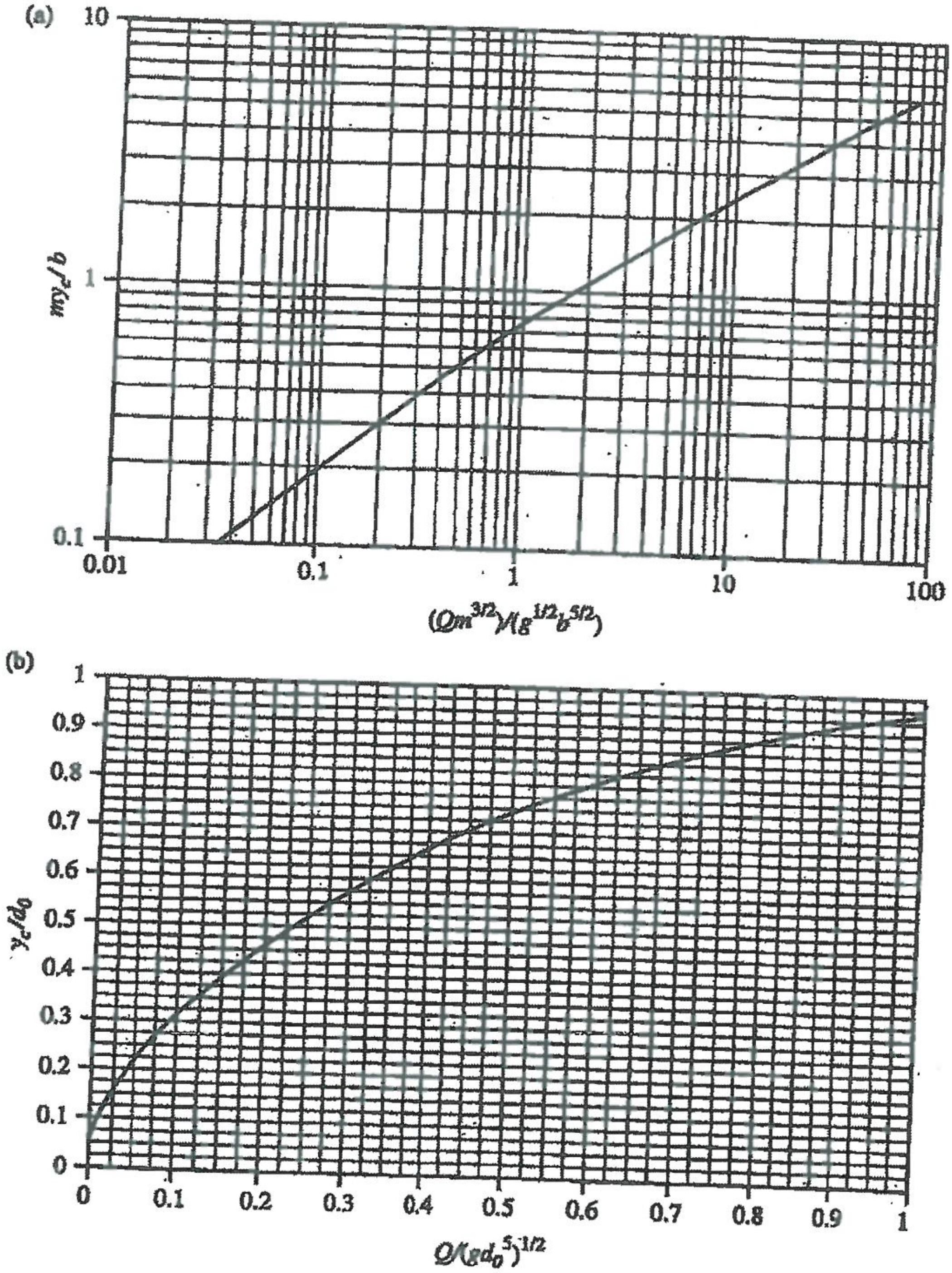


Figure 6.9 Critical depth solution procedure: (a) trapezoidal channels and (b) circular channels