Second Semester Examination
2020/2021 Academic Session

July/August 2021

EAH225 – Hydraulics

Duration : 3 hours

Please ensure that this examination paper contains **NINE (9)** printed pages before you begin the examination.

Instructions: This paper contains **SIX (6)** questions. Answer any **FIVE (5)** questions.

All questions **MUST BE** answered on a new page.

1. (a). Water is flowing at 0.05 m^3/s through a 20 cm diameter asphalt cast iron pipe. If the water temperature is 20°C, kinematic viscosity v =1x10^{-6} m^2/s and equivalent sand roughness for asphalt cast iron = 0.12 mm, calculate the head loss per kilometer of pipe.

[5 marks]

(b). A 300 mm diameter horizontal pipe carrying water with a flow rate of 0.4 m^3/s is suddenly enlarged to a 600 mm diameter pipe. If the pressure in the smaller pipe is 125 kN/m^2, calculate:

i) head loss due to the sudden enlargement

ii) pressure in the larger pipe

[5 marks]

(c). A pipe 6 cm in diameter, 1000 m long and with f = 0.018 is connected in parallel between two points M and N with another pipe 8 cm in diameter, 800 m long and having f = 0.020. A total discharge of 20 L/s enters the parallel pipes through division at M to rejoin at N. Calculate the division of discharge in the two pipes.

[10 marks)

2. (a). A syphon of diameter 20 cm connects two reservoirs having a difference in elevation (water level) of 20 m. The length of the syphon is 500 m and the summit (syphon) is 3 m above the water level in the upper reservoir. The length of the pipe from upper reservoir to the summit (syphon) is 100 m. Determine the discharge through the syphon and pressure at the summit (syphon). Neglect minor losses and given coefficient of friction, f = 0.005.

[10 marks]

(b). A partially submerged body is towed in water. The resistance (*R*) to its motion depends on the density (ρ), the viscosity (μ) of water, length (*l*) of the body, velocity (*v*) of the body and the acceleration due to gravity (*g*). Show that the resistance to the motion can be expressed in the form as shown below.

$$R = \rho L^2 V^2 \phi \left[\left(\frac{\mu}{\rho V L} \right) \cdot \left(\frac{lg}{V^2} \right) \right].$$

[10 marks]

3. (a). A 7.2 m high and 15 m long spillway discharges 94 m^3/s of discharge under a head of 2 m. If a 1:9 scale model of this spillway is to be constructed, determine the model dimensions, head over spillway and model discharge. If the model experiences a force of 7500 N (764.53 kgf), determine force on the prototype.

[10 marks]

(b). A reaction turbine works at 450 rpm under a head of 115 m. The diameter of the inlet is 1.20 m and the flow area is 0.4 m^2. At the inlet the absolute relative velocities make angle of 20° and 60° respectively with the tangential velocity. Determine the power developed and hydraulic efficiency. Assume the velocity of whirl at the outlet to be zero.

[10 marks]

4. A 1 in 20 model of a naval ship having a submerged surface area of 5 m^2 and length of 8 m has a total drag of 20 N when towed through water at a velocity of 1.5 m/s. Calculate the total drag on the prototype when moving at the corresponding velocity. Use the relation $F_f = \frac{1}{2} C_f \rho A V^2$ for calculating the skin (frictional) resistance. The value of C_f is given by $C_f = \frac{0.0735}{(R_e)^{1.5}}$. Take kinematic viscosity of water as 0.01×10^{-4} m^2/s and density of water as 1000 kg/m^3.

[20 marks]

5. (a). Consider the compound channel given in **Figure 1** as a composite section. The Manning's roughness coefficients are given as n_1, n_2 and n_3 where the channel is smooth earth; naturally made channel with tall grasses and reeds; and stones and weeds respectively. The channel bed slope for the whole channel is 0.5% and consider all side slopes as 1:1.

Determine the total discharge of the composite section using:

i) Pavlovskii method.

ii) Hortons' method

[14 marks]

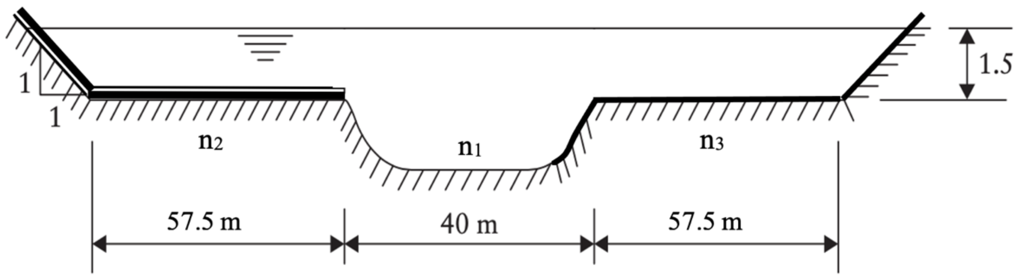


Figure 1

(b). A hydraulic jump is situated in a 4.25 m wide rectangular channel. The discharge in the channel is 7.2 m^3/s, and the depth upstream of the jump is 0.22 m. Determine:

i) the depth downstream of the jump,

ii) the upstream and downstream Froude numbers, and

iii) the head loss in the jump

[6 marks]

6. The measure of energy relative to the bottom of an open channel is termed as specific energy. Consider a 6.5 m wide rectangular channel with a discharge of 22.5 m^3/s flowing through a depth of 1.85 m. Determine:

i) The specific energy head.

ii) The critical depth and the corresponding minimum specific energy.

iii) The type of flow.

iv) The alternate depth (use trial and error method).

v) The specific energy for 5 different depths; and draw the specific energy diagram for the given discharge. Sketch the corresponding values on the graph.

[20 marks]

APPENDIX 1

TABLE 1 – Values for Mannings' Coefficient

Values for Manning's *n*	
Channel Description	***n***
Glass, copper, plastic, or other smooth surface	0.010
Smooth, unpainted steel, planed wood	0.012
Painted steel or coated cast iron	0.013
Smooth asphalt, common clay drainage tile, trowel-finished concrete, glazed brick	0.013
Uncoated cast iron, black wrought iron pipe, vitrified clay sewer tile	0.014
Brick in cement mortar, float-finished concrete, concrete pipe	0.015
Formed, unfinished concrete, spiral steel pipe	0.017
Smooth earth	0.018
Clean excavated earth	0.022
Corrugated metal storm drain	0.024
Natural channel with stones and weeds	0.030
Natural channel with light brush	0.050
Natural channel with tall grasses and reeds	0.060
Natural channel with heavy brush	0.100

Equivalent Roughness (N_{eq}) – Horton's Method

$$\sum A_i = A = A\frac{\sum\left(n_i^{3/2}P_i\right)}{n^{3/2}P}$$

$$n = \frac{\left(\sum n_i^{3/2}P_i\right)^{2/3}}{P^{2/3}} \qquad (4.35)$$

Equivalent Roughness (N_{eq}) – Total Discharge Method

$$\mathbf{n_{eq}} = \sqrt{\frac{\sum \mathbf{n_i^2\,P_i}}{\sum \mathbf{P_i}}}$$

Equivalent Roughness (N_{eq}) – Pavlovskii method

$$n_c = \sqrt{\frac{\sum_1^N (P_N n_N^2)}{P}} = \sqrt{\frac{P_1 n_1^2 + P_2 n_2^2 + \cdots + P_N n_N^2}{P}}$$

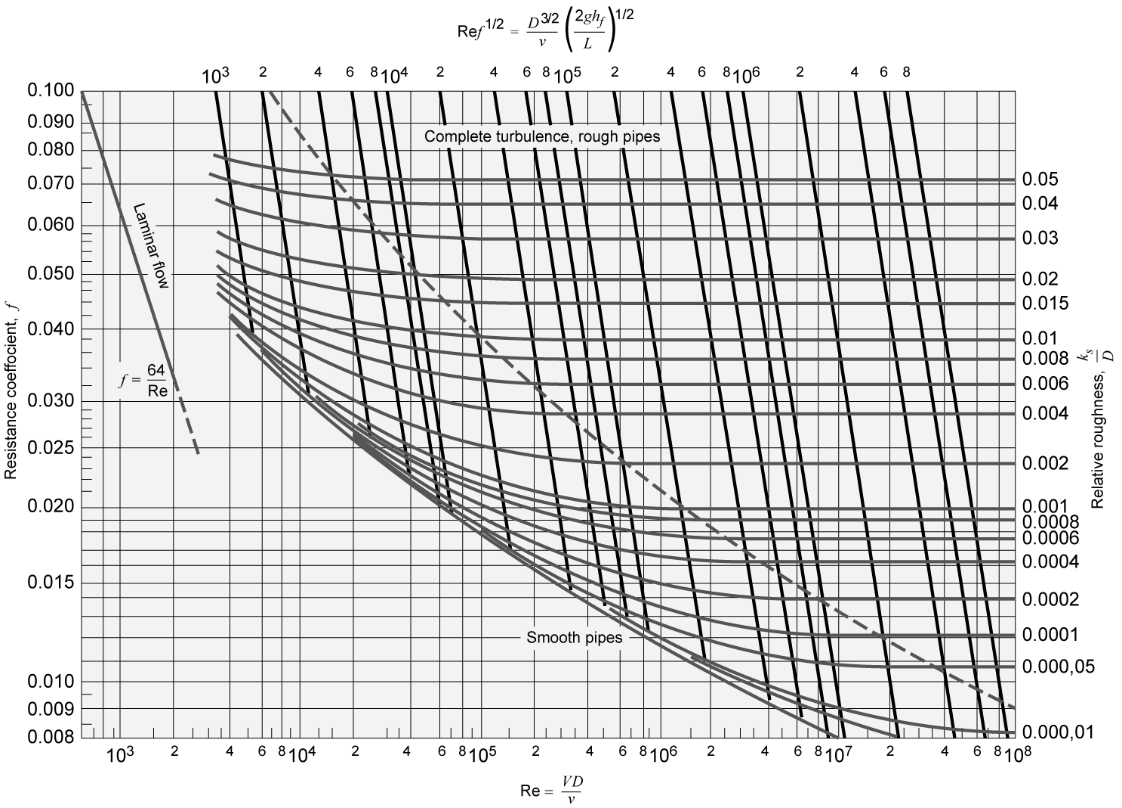
Equivalent Roughness (N_{eq}) – Lotter Method

$$n_c = \frac{PR^{5/3}}{\sum_1^N \left(\frac{P_N R_N^{5/3}}{n_N}\right)} = \frac{PR^{5/3}}{\frac{P_1 R_1^{5/3}}{n_1} + \frac{P_2 R_2^{5/3}}{n_2} + \cdots + \frac{P_N R_N^{5/3}}{n_N}}$$

Equivalent Roughness (N_{eq}) – Colebach method

$$n_c = \left(\frac{\sum_1^N (A_N n_N^{1.5})}{A}\right)^{2/3} = \frac{(A_1 n_1^{1.5} + A_2 n_2^{1.5} + \cdots + A_N n_N^{1.5})^{2/3}}{A^{2/3}}$$

APPENDIX 2



Resistance coefficient *f* versus Re (Source: ASME)

APPENDIX 3

Given

Head loss due to expansion:

$$h_e = \left(\frac{V_1 - V_2}{2g}\right)^2$$

before expansion = after expansion

$$\frac{p_1}{w} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{w} + \frac{V_2^2}{2g} + z_2 + h_e$$

Power equation:

$$P = \frac{wQh}{1000} kW$$

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