City & Guilds

9210-103
Level 6 Graduate Diploma in Engineering
Hydraulics and hydrology

Sample Paper

You should have the following for this examination
- one answer book
- ordinary graph paper
- pen, pencil, ruler

Work sheet booklets are attached
- Worksheet WSQ3
- Worksheet WSQ7
- Worksheet WSQ9

General instructions
- This examination paper is of **three hours** duration.
- This examination paper contains **nine** questions in **two** sections.
- Answer **five** questions with at least selecting **two** questions from each section.
- All questions carry equal marks. The maximum marks for each section within a question are given against that section.
- An electronic, non-programmable calculator may be used, but the candidate **must** show clearly the steps prior to obtaining final numerical values.
- Drawing should be clear, in good proportion and in pencil. Do **not** use red ink.

Section A

1 a) Describe an experiment to determine the Darcy friction coefficient f for a circular pipe where,

$$h_f = \frac{4fl}{d}\frac{v^2}{2g}$$

using an arrangement of piezo metric tubes. (8 marks)

b) A pipeline of length 1 km and Darcy friction coefficient f equal to 0.012, which is, connected to a reservoir discharges into the atmosphere at a level 50 m below the surface level in the reservoir. The diameter of the pipeline is 200 mm for a length of 400 m from the reservoir and enlarges to 300 mm for the remainder of the pipeline. Assuming the head loss at entry to the pipeline from the reservoir as $0.5\,\frac{v^2}{2g}$ and the loss at enlargement as $\frac{(v1 - v2)^2}{2g}$, determine the discharge at the lower end of the pipeline. (12 marks)

2 a) Briefly describe the difference between reaction turbines (Francis type Turbines) and impulse turbines (Pelton Wheel type turbines) indicating what head conditions (with regard to low, medium and high supply heads) would favour each type.) (8 marks)

b) A double-jet Pelton Turbine has each nozzle of diameter 50 mm and velocity coefficient C_v equal to 0.92. It is fed from a reservoir with surface elevation 300 m above the centre of nozzles, through a pipeline of length 2 km, diameter 300 mm and Darcy friction coefficient f equal to 0.008. The wheel diameter is 1.0 m. and the bucket speed is 0.46 of the jet speed. Assuming the hydraulic efficiency (the efficiency of converting power available at the jets to shaft power) as 80 %, calculate

i) The power available at the shaft in kw (4 marks)

ii) The speed of the turbine in revolutions per minute (RPM) (4 marks)

iii) The overall efficiency of the system (efficiency of converting reservoir head to shaft head). Neglect loss of head at entry to the pipeline from the reservoir. (4 marks)

3 a) For a channel carrying water at constant discharge Q, show that critical flow conditions prevail when $\frac{Q^2B}{gA^3} = 1$ where B is the width at free surface and A is the cross-sectional area covered with water. (6 marks)

b) A channel with irregular cross-section carries a constant discharge of 75.0 m^3/s. Manning, s roughness coefficient for the channel is 0.02.

The shape of the cross-section is given by the following table:

Depth from the bottom of channel bed (m)	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Free surface Width (m)	3.0	5.0	6.0	8.0	9.0	9.0	10.0	11.0	13.0	14.0	14.5
Wetted Perimeter (m)	2.0	6.0	8.0	12.0	13.5	15.0	19.0	19.5	22.0	24.0	25.0
Cross-sectional area (m^2)	0	3.5	8.5	15.25	23.5	32.5	42.5	53.0	65.5	78.5	92.5

For the given condition, determine;

i) The critical depth. (7 marks)

ii) The critical slope. (7 marks)

4 a) For a rectangular channel on level bed developing a hydraulic jump, show that the initial depth d_1 and the sequent depth d_2 can be expressed by the equation

$$d_2 = \sqrt{\frac{d_1^2}{4} + \frac{2q^2}{gd_1}} - \frac{d_1}{2}$$

Where, q is the discharge per unit width of the channel. (8 marks)

b) Water is released from a reservoir into a rectangular channel of width 3.5 m through a vertical sluice gate, which spans the entire width of the channel. The free surface level in the reservoir is 12 m above the bottom of the sluice, which is the same as the bed level of the channel at entry. Neglect any contraction effects and energy loss at the sluice. Indicating any assumptions, you make.

i) Show that a hydraulic jump may be formed when the sluice opening is 1.5 m. and indicate the conditions required downstream for a Hydraulic jump to form. (5 marks)

ii) Calculate the tail water depth required for a hydraulic jump to form immediately downstream of the sluice. (3 marks)

iii) Calculate the loss of energy in N-m/s at the hydraulic jump. (4 marks)

5 a) Derive expressions for the following, in terms of mass density ρ, velocity v, coefficient of viscosity η, linear dimension l or d and gravitational acceleration g as relevant

i) Inertia force (2 marks)

ii) Viscous force F (given by F = η (dv/dl) x A where η is coefficient of viscosity, dv/dl is velocity gradient and A is area) (2 marks)

iii) Gravity force. (2 marks)

b) Show that in hydraulic model studies, the dimensionless numbers that are applicable to relate model values to prototype values in situations where gravity force predominates and viscous force predominates are respectively Froude Number $\frac{V}{\sqrt{gd}}$ and Reynold's Number $\frac{pVd}{\eta}$, where, v, d, ρ and η are respectively mean velocity, linear dimension (depth or pipe diameter), mass density and coefficient of viscosity. (6 marks)

c) i) Calculate the discharge to be maintained in the model to simulate a prototype discharge of 20 m^3/s. (4 marks)

ii) Calculate the mean velocity at the bottom of the prototype spillway corresponding to a velocity of 1.5 m/s measured in the model. (4 marks)

Section B

6 a) Explain the difference between the following in the context of Groundwater Hydrology.

i) Confined aquifer and unconfined aquifer. (2 marks)

ii) Artesian well and flowing well. (2 marks)

iii) Infiltration and ground water recharge. (2 marks)

iv) Saturated zone and unsaturated zone. (2 marks)

b) The flow of groundwater in an unconfined aquifer between two boundaries with constant heads H_0 and H_1 distant L between them, when the aquifer is receiving a constant recharge of q may be approximated to the following equation in consistent units ;

$$h^2 = H_0^2 - \frac{(H_0^2 - H_1^2)x}{L} + \left(\frac{qx}{K}\right)(L - x)$$

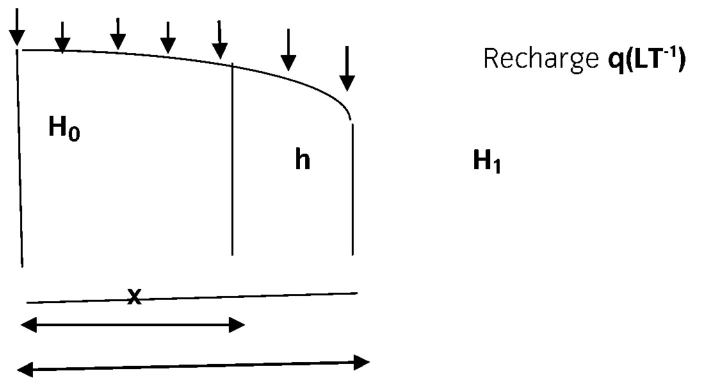
Where h is the height of water table above a horizontal impermeable base at a distance x from the boundary of constant head H_0, q is the recharge in dimensions LT^{-1} and K is the coefficient of permeability. Constant heads H_0 and H_1 are reckoned with the horizontal base of the aquifer as datum as indicated in the accompanying figure. When H_0 = 12 m; H_1 = 5 m; L = 1 km; q = 5 mm/day; K = 25.0 m/day, determine

i) The maximum height of water table above the impermeable base. (4 marks)

ii) The value of x corresponding to the maximum height of water table. (4 marks)

iii) The discharge per metre width of aquifer at boundary of constant head H_1. (4 marks)

The figure for this question is shown below,



7 a) Explain the functions of the following in a reservoir,

i) Sluices. (2 marks)

ii) Spillways. (2 marks)

iii) Dead storage. (2 marks)

iv) Radial gates. (2 marks)

b) The design inflow for a reservoir is given by the hydrograph in the following table.

Time hr	0	6	12	18	24	30	36	42
Design inflow (m^3/s)	11	16	28	45	31	20	14	12

The storage and outflow characteristics of the reservoir are as given below

Elevation (m)	Storage($10^6 m^3$)	Outflow(m^3/s)
200.0	3.9	0
201.0	4.5	11.25
202.0	5.6	67.5
202.5	6.1	101.25
203.0	6.7	140.6

When the water level in the reservoir is at elevation 200.0 m (which is also the crest level of the spillway), the design inflow starts entering the reservoir. Determine the water surface elevation at time 6hr and 12 hr from the commencement of the design inflow.

You may assume the equation ,

$$\frac{(I_1 + I_2)\Delta t}{2} + \left(S_1 + \frac{Q_1 \Delta t}{2}\right) = \left(S_2 + \frac{Q_2 \Delta t}{2}\right)$$

Where I, Q and S refer to inflow, outflow and storage respectively with suffixes 1 and 2 indicating values at the beginning and end of a time stepΔt.

A graphical method based on a plot of $\left(S + \frac{Q\Delta t}{2}\right)$ Vs Elevation is suggested.

Indicate any assumptions you make. (12 marks)

8 a) Briefly describe the following to bring out their meaning and relevance in the context of rainfall analysis.

i) Time of concentration. (2 marks)

ii) Hyetograph. (2 marks)

iii) Infiltration Capacity. (2 marks)

b) Intensity-duration-return period relationship (for rainfall) for a rain gauge station within a small catchment at the downstream end is given by the relationship $I = 1.25\ XD^{-Y}$ where, I is the intensity of rainfall in cm/hr and D is the duration of rainfall in minutes. X and Y are constants for the catchment for different values of return period. For a return period of 50 years, X = 90.2 and Y = 0.625. The runoff coefficient and area of this catchment are respectively 0.45 and 3.25 km^2. From tracer studies, it was established that it takes 15 minutes for rainfall from the region of the catchment remotest from the gauging station to reach the gauging station. Estimate the discharge at the gauging station for a return period of 50 years, indicating any assumptions you make. (14 marks)

9 a) Explain what is meant by 'The one-hour unit hydrograph' for a catchment. (3 marks)

b) Explain the practical use of unit hydrographs. (3 marks)

c) The following data represent the stream flow for a river resulting from gauged rainfall of uniform intensity 5.0 cm/hr lasting for 0.25 hr. The stream flow is measured using the staff gauge and flow-rating curve. Rainfall is measured using a continuous recording rain gauge. The θ-index for the catchment is 8.0 mm/hr. During the period of the above rainfall, the base flow may be assumed to be constant a10 m^3/s.

Time from commencement of Rainfall (hr)	0	0.25	0.5	0.75	1.00	1.25	1.50
Gauged stream flow m^3/s	10.0	22.0	45.0	83.0	97.0	95.0	87.5

Time from commencement of rainfall (hr)	1.75	2.00	2.25	2.50	2.75	3.00
Gauged stream flow m^3/s	75.0	63.5	50.5	38.0	27.0	10.0

Determine

i) The half-hour unit hydrograph of one cm net rainfall for the catchment (9 marks)

ii) The maximum stream runoff discharge (gauged stream flow discharge) resulting from uniform intensity gauged rainfall of 5.0 cm/hr lasting for half hour assuming that θ-index value and base flow remain constant. (5 marks)