First Semester Examination
Academic Session 2019/2020

December 2019/January 2020

EAP581 – Water Supply Engineering

Duration : 2 hours

Please check that this examination paper consists of **TEN (10)** pages of printed material including appendix before you begin the examination.

Instructions : This paper contains **SIX (6)** questions. Answer **FOUR (4)** questions

All questions must be answered in English.

Each question **MUST BE** answered on a new page.

(1). (a). Nutrient is one of the chemical characteristics in water quality. Excessive nutrient especially nitrogen may pose negative impact to environment particularly to the water body. This nutrient will be converted into simple compound through nitrification and denitrification processes. Explain both processes.

[7 marks]

(b). A sample from a river water was collected and the characteristic of the ion content was carried out. The results for anion and cation analysis are shown in **Table 1** below.

Table 1: The anion and cation analysis

Ca^{2+} = 16 mg/L	HCO_3^- = 54 mg/L
Mg^{2+} = 8 mg/L	SO_4^{2-} = 5 mg/L
Na^+ = 10 mg/L	Cl^- = 20 mg/L
K^+ = 15 mg/L	CO_3^{2-} = 22 mg/L
	NO_3^- = 4 mg/L

Determine the total, carbonate and non-carbonate hardness mg/L as $CaCO_3$.

[10 marks]

(c). Housing scheme consists of 5000 units of terrace houses, each unit has a floor area of 1000 square feet. The building is made up of ordinary construction. Domestic water demand is estimated at 350 litres per capita per day with population equivalent of 5 per unit. With the aid of following information estimate the total flow required. You may use **Tables 2** and **3** to help your estimation.

Table 2: Residential fire flows

Distance between adjacent units (m)	Required fire flow (litre/minute)
> 30.5	1890
9.5 – 30.5	2835 – 3780
3.4 – 9.2	3780 – 5670
< 3.0	5670 – 7560

Table 3: Residential flow duration

Required fire flow (litre/minute)	Duration (hour)
< 3780 (<1000gpm)	4
3780 – 4725 (1000 – 1250 gpm)	5
4725 - 5670 (1250 – 1500 gpm)	6
5670 – 6615 (1500 – 1750 gpm)	7
6615 – 7560 (1750 – 2000 gpm)	8
7560 – 8505 (2000 – 2250 gpm)	9
> 8505 (>2250 gpm)	10

[8 marks]

(2). (a). At a brackish water reverse osmosis (RO) treatment plant, the net pressure is 40 atmospheres. The membrane manufacturer provides that the membrane flux rate coefficient of $1.8x10^{-6}$ sm^{-1}. Compute the flux of water.

[6 marks]

(b). Flotation is an alternative process to sedimentation and this process has gained popularity. Briefly discuss **FIVE (5)** advantages of flotation process with respect to portable water treatment.

[7 marks]

(c). Two sets of jar tests are conducted on raw water containing 30 NTU and an HCO_3^- alkalinity concentration of 40 mg/L expressed as $CaCO_3$. Given the data as shown in **Table 4**, find the optimal pH, optimal coagulant dose and the theoretical amount of alkalinity that would be consumed at the optimal dose.

The reaction occurs when water is added with alum is shown below:

$$Al_2(SO_4)_3.14H_2O + 6HCO_3^- \rightarrow 2Al(OH)_3 + 6CO_2 + 14H_2O + 3SO_4^{2-}$$

Molecular weights of the elements are shown as follows:

Oxygen = 16, sulphur = 32, aluminium = 27, hydrogen =1 and carbon =12

Table 4

Jar Test 1						
Jar	1	2	3	4	5	6
pH	5.0	5.5	6.0	6.5	7.0	7.5
Alum dose (mg/L)	15	15	15	15	15	15
Turbidity (NTU)	14	8	4.5	6.0	9	13
Jar Test 2						
Jar	1	2	3	4	5	6
pH	6.0	6.0	6.0	6.0	6.0	6.0
Alum dose (mg/L)	6	8	12	14	16	18
Turbidity (NTU)	12	10	2.5	4.0	6	13

[12 marks]

(3). Water is treated for a variety of purposes, including removal of pathogenic microorganisms, tastes and odors, color and turbidity, dissolved minerals, and harmful organic materials. In a coagulation treatment process:

(a). Describe how does the surface charge contribute to the destabilization and settling of particles.

[5 marks]

(b). Draw and explain the colloidal electric double layer using the Guoy-Chapman-Stern colloidal model.

[10 marks]

(c). The coagulation involves the addition of chemicals – either hydrolyzing electrolytes or organic polymers. Write down the complete hydrolysis reaction when adding metallic complexes such as aluminum sulfate ($Al2(SO_4)_3$) in the wastewater suspension. List down **FOUR (4)** products of the hydrolysis as an outcome of the polymerization.

[5 marks]

(d). In the sedimentation tank, the settling of particles from the suspension depends on the characteristics of the particles and the concentration of particles in suspension. Explain the terms:

(i). discrete particles

(ii). flocculating particles

(iii). dilute suspensions

(iv). concentrated suspension

[5 marks]

(4). (a). Rapid filtration normally uses granular filter media. Describe **FIVE (5)** properties required for the medium.

[7 marks]

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(b). A layer of filter has a flow rate of 2 litres/m^2s with a concentration of suspended impurities of 50 mg/L (density 1003 kg/m^3). The concentration of impurities at the time was 0.02 m^3/m^3 of sand bed and the rate parameters for λ_0=10 m^{-1}, ϕ=22 mm^{-1}, and the initial porosity was 0.4. Calculate the volumetric proportion of deposited impurities one hour later at that position of the filter. The following equations may be useful to facilitate your calculation:

$$\lambda = \lambda_0 + c\sigma - \frac{\phi\sigma^2}{f_0 - \sigma}$$

$$\frac{\partial\sigma}{\partial t} = \lambda V_w C$$

[6 marks]

(c). A horizontal sedimentation tank has a capacity of 2 million gallon per day (MGD), retention time of 3.5 hour and a surface loading of 1.2 m/hour. The tank is designed with length:breadth ratio of 4:1. Calculate the dimensions of the tank and the length of the outlet weir. Sketch the diagram of the outlet weir based on your design.

[12 marks]

(5). (a). After being disinfected, treated water will be stored in a tank before being distributed to the consumer. A good water distribution system is required to supply enough water pressure and safe water to drink. With the help of sketches, describe **THREE (3)** types of water distribution system.

[10 marks]

(b). **Figure 1** shows a water reticulation system. Estimate the flow rate in each pipeline using Hardy-Cross Method and Hazen-William formula up to two iterations. Adopt Hazen-William coefficient, C, as 100. Use initial flowrate of 150 litres per second (L/s) from point D to A. The lengths and diameters for pipes AB, BC, CD, and AD are as follows:

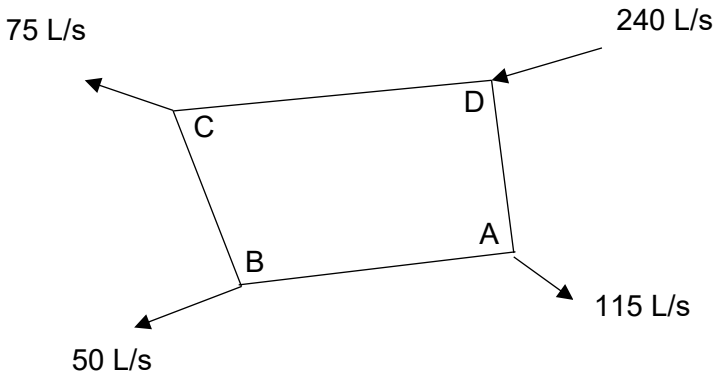

Figure 1: Water reticulation system

Pipe AB: length = 900 m and diameter = 250 mm

Pipe BC: length = 650 m and diameter = 200 mm

Pipe CD: length = 950 m and diameter = 200 mm

Pipe AD: length = 550 m and diameter = 250 mm

[15 marks]

(6). (a). A lake has the following characteristics:

Volume = 60, 000 m^3
Mean depth = 5.5 m
Inflow = outflow = 9, 000 m^3/d
Temperature = 28 °C

The lake receives the input of a pollutant from two sources: a slaughterhouse with a discharge of 40 kg/d, and the inflow stream that has a concentration of 12 mg/L. If the pollutant decays at the rate of 0.25/d at 20 °C (θ = 1.05),

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(i). Sketch the system

(ii). Compute the assimilation factor

(iii). Determine the steady state concentration

[13 marks]

(b). (i). Explain **THREE (3)** main functions of the National Water Services Commission.

[6 marks]

(ii). Based on **Regulation 89 (Disconnection of water supply)**, a licensed water supplier may **disconnect** the supply of water to a consumer if he fails to settle the amount for the water supplied. Describe other **THREE (3)** legitimate reasons or circumstances does the licensed water supplier have the right to do so towards the consumer.

[6 marks]

APPENDIX

Equations related to water supply:

$F=18C(A)^{0.5}$

$$P_n = P_i + nI$$

$$P_n = P_i\left(1+\frac{i}{100}\right)^n$$

$$P_n = P_i + n(I+m)$$

$$P_n = P_i\left(1+\frac{(1-k}{100}\right)^n$$

$$G = \left(\frac{P}{\mu\forall}\right)^{1/2}$$

$$P = \frac{1}{2}C_d\rho A\vee^3$$

$$P = \rho Qgh$$

$$h_L = KQ^2$$

$$\frac{d_1}{d_2} = \frac{1}{2}\left[\left(1-8F^2\right)^{1/2}-1\right]$$

$$F = \frac{V_1}{(gd_1)^{1/2}}$$

$$\mathrm{Re} = \frac{\rho vd}{\mu}$$

$$\Delta H = [(v_1^2 + 5v_2^2 + 4v_3^2)/2g] + \text{normal channel friction}$$

$$h = \frac{nv_1^2 + (n-1)v_2^2}{2g}$$

$$v_s = \frac{gd^2(\rho_s - \rho_w)}{18\mu}$$

$$t = \frac{2\pi H}{Q}\int_{R1}^{R2} rdr = \frac{\pi\left(R_2^2 - R_1^2\right)H}{Q}$$

$$V_s = \frac{Q}{A}$$

$$D = V_s t$$

$$L = \frac{0.2Q}{HV_s}$$

$$H = \frac{1128\times10^9}{d^{4.87}}\left[\frac{Q}{100}\right]^{1.85}$$

$$\Delta = -\frac{\Sigma H}{N\sum\frac{H}{Q_a}}$$

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$$H_L = \frac{10.67}{D^{4.87}} L \left[\frac{Q}{C}\right]^{1.85}$$

$$H_L = \frac{12.25 \times 10^9}{D^{4.87}} L \left[\frac{Q}{C}\right]^{1.85}$$

$$k(T) = k(20)\theta^{T-20}$$

$$V\frac{dc}{dt} = W(t) - Qc - kVc - vA_s c$$

$$c = \frac{W}{Q + kV = vA_s}$$

$$c = \frac{1}{a}W$$

$$a = Q + kV + vA_s$$

$$Accumulation = V\frac{dc}{dt}$$

$$Loading = Qc_{in}(t)$$

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