CE443

2005

Ollscoil na hEireann, Gaillimh
National University of Ireland, Galway

FIRST SEMESTER EXAMINATIONS 2005

FOURTH CIVIL AND ENVIRONMENTAL ENGINEERING EXAMINATIONS

SUSTAINABLE ENERGY AND ENVIRONMENTAL SYSTEMS

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Time allowed: **3** hours
Answer **5** questions
Use separate answer books for each section

SECTION A – SUSTAINABLE ENERGY

1. (a) You work for a wind turbine manufacturer and are asked to compare the performance of a number of turbines of different characteristics. What parameter would you use to carry out this comparison and how is the parameter calculated. Why is this parameter important in the design of wind turbines? [4 marks]

(b) Explain with the aid of a diagram how the cross-sectional profile and the pitch of a horizontal axis wind turbine rotor enable it's rotation in a wind flow. [10 marks]

(c) Derive an equation for the mechanical power that a wind turbine rotor can extract from a wind in terms of the pitch of the rotor and its radius. [6 marks]

2. (a) You are employed as an environmental engineer by a city council. The city wishes to increase the sustainable energy contribution to its electricity needs and has decided to construct a hydroelectric facility. The hydro resources available are a sluggish river flowing through the adjacent low-lying countryside, a network of rivers flowing through a valley in the nearby mountains and a large mountain lake located 1,500 m above sea level.
You are asked for advice on the type of facility that would best harness each of the hydro resources. Classify the type of facility you would suggest for each resource, outlining the main features, and describe in detail the type of turbine to be employed in each case including its method of operation and advantages/ disadvantages. [15 marks]

(b) Following discussions, the same city council has also decided to harness the tidal power available within the bay on whose coastline the city is located. The construction of a tidal barrage has been proposed and you are consulted in relation to the best method of power generation from the barrage. Describe the most common methods of power generation including the advantages/ disadvantages of each. [5 marks]

3. (a) Sources of high enthalpy geothermal energy are relatively scarce worldwide and are almost exclusively located along lithospheric plate boundaries. Ireland, therefore, has no such resources but it does have large reservoirs of low enthalpy geothermal energy. Explain two different types of technology which could be used in Ireland to harness low enthalpy geothermal energy. [8 marks]

(b) "Hydrogen fuel is a clean and secure energy resource and the solution to all of our energy problems." Discuss this statement in relation to sustainability. [12 marks]

4. The following diagram is a definition sketch for the analysis of ideal discrete particle settling (Figure Q4). The length, width and depth of the settling zone are L, W, and H, respectively. The influent flow rate is Q.

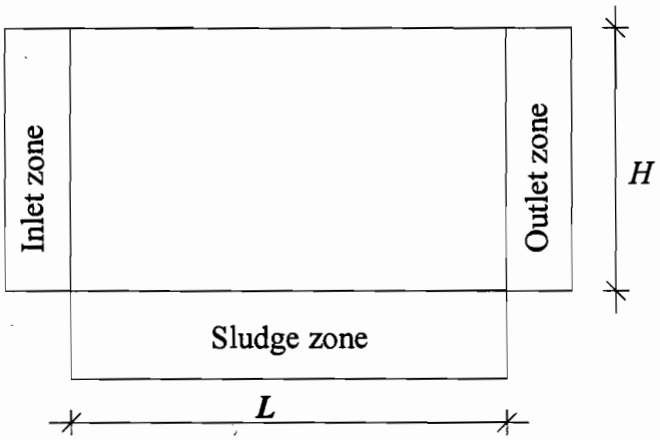

Figure Q4: Definition sketch for the analysis of ideal discrete particle settling

(a) Calculate the critical overflow rate V_C. [5 marks]

(b) Is the depth of the settling zone critical to the design of the settling tank? [2 marks]

(c) If the critical overflow rate is 4 $m^3/m^2 \cdot hr$, the settling tank is treating a wastewater containing particles whose settling velocities are described as given in Table Q4. Calculate the total particle removal efficiency. [6 marks]

Table Q4: Number of particles with different settling velocities in wastewater

Settling velocity, m/hr	**Number of particles, per litre × 10^{-5}**
1	30
2.5	50
4.5	40
6	30

(d) The sludge volume index (*SVI*) is always used to evaluate the settling property of activated sludge flocs and one experiment with the following procedures was conducted to test the *SVI*: (1) 1 litre mixed liquid was taken from the aeration tank and the mixed liquid had a biomass concentration of 3000 mg SS/l; (2) The mixed liquid was added to a graduated cylinder and was allowed to settle for 30 minutes; (3) After 30 minutes, the settled sludge volume was 750 ml. Calculate the SVI and evaluate the settling property of activated sludge flocs. [5 marks]

(e) If the influent flow rate Q = 4000 m^3/hr and the hydraulic retention time (*HRT*) for the settling tank is 2 hours, calculate the volume of the settling tank. [2 marks]

5. A 10 m diameter single-stage trickling filter contains conventional cross-flow plastic packing at a depth of 5 meters. Primary effluent, with the characteristics given in Table Q5, is applied to the filter. The specific surface area of the packing is 200 m^2/m^3.

Table Q5: Primary effluent wastewater characteristics

Item	**Unit**	**Value**
Flow rate	m^3/d	4000
BOD	mg/l	120
TSS	mg/l	80
TKN	mg/l	25

(a) Is the "trickling filter" process the same as the filter used for drinking water purification? Why? [3 marks]

(b) The trickling filter process and the rotating biological contactor process (RBC) are attached-growth processes. Describe how aeration is fulfilled in both processes if they are applied to treat wastewater aerobically. [5 marks]

(c) Calculate the volumetric BOD loading rate and calculate the specific TKN loading rate that is based on the surface area of the biofilm media. [4 marks]

(d) Calculate the hydraulic loading rate. [2 marks]

(e) Why can complete nitrification be achieved in low-rate trickling filters and not in high-rate filters? [3 marks]

(f) What are the advantages of moving-medium attached-growth systems over stationary-medium systems? [3 marks]

6. For an A^2O process removing nutrients from wastewater (Figure Q6), V_1, V_2 and V_3 are volumes of the anaerobic, anoxic and aerobic zones, respectively; X_1, X_2 and X_3 are biomass concentrations in the three zones, respectively. The influent wastewater flow rate is Q_i and biomass in the influent is negligible; the sludge return ratio is R; Q_w is the flow rate of waste sludge, which is decanted from the secondary clarifier with the biomass concentration of X_w; The biomass concentration in the effluent is X_e.

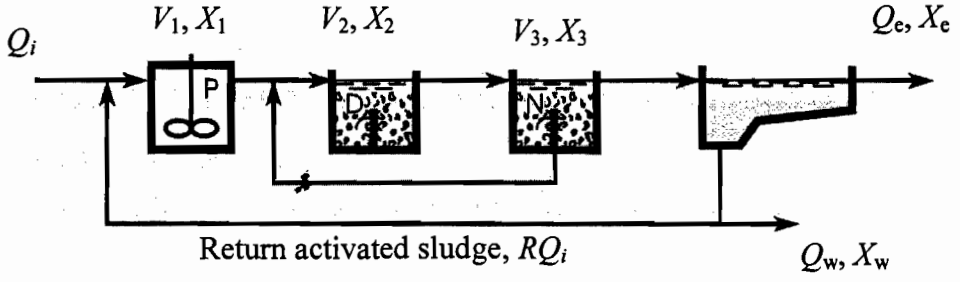

Figure Q6: Sketch diagram of an A^2O (Anaerobic-anoxic-oxic) process.

(a) Calculate Q_e (the flow rate of effluent). [2 marks]

(b) Calculate the sludge retention time (SRT) of the system at the steady state. [3 marks]

(c) Explain the purpose of the internal recycle which delivers wastewater from the aeration zone to the anoxic zone. [2 marks]

(d) Explain the purpose of sludge return from the secondary clarifier to the inlet of the anaerobic zone. [2 marks]

(e) Explain the mechanism of biological phosphorus removal. [3 marks]

(f) Describe two problems in the A^2O process. [3 marks]

(g) The kinetics of the denitrification process is expressed as:

$$r_{V,S} = \frac{\mu_{\max} XS}{Y_{\max}(K_s + S)} \frac{S_{NO_3-N}}{S_{NO_3-N} + K_{NO_3-N}} \frac{K_{O_2}}{K_{O_2} + S_{O_2}}$$

How does the equation reveal the influence of dissolved oxygen concentrations on the denitrification kinetics? [3 marks]

(h) The A^2O system is designed as a plug-flow reactor. Please list two advantages of a plug-flow aeration tank over a perfect complete-mix aeration tank. [2 marks]