

**THIS QUESTION PAPER MUST BE HANDED-IN TO
THE INVIGILATOR AT THE END OF THE
EXAMINATION**

CRANFIELD UNIVERSITY

Examination

**SCHOOL OF ENERGY, ENVIRONMENT AND AGRIFOOD
WATER & WASTEWATER ENGINEERING
MSc / PgD / PgC
MTech IN WATER PROCESSES**

PHYSICAL PROCESSES

Friday 22 January 2016: 13.00 – 15.30

Open Note

INSTRUCTIONS TO CANDIDATES:

Attempt **all** questions in Section A.

Attempt **one question only** from Section B.

Start each answer on a separate page.

Candidates are allowed a non-programmable calculator
and 1 x A4 file of material and personal notes.

Candidates may also have a copy of Metcalf and Eddy or Droste

SECTION A (COMPULSORY)

Question A-1 – Compulsory

A practical session resulted in the following data being obtained for some jar test experiments using ballasted coagulation. The data shows the residual turbidity after sedimentation or flotation for three different ballasting agents compared against a control experiment where no ballast has been added to the system. Each experiment has been repeated three times using the same dosing conditions and the same settlement or flotation time.

Magnetite ballasted settled turbidity (NTU)		
1	2	3
1.1	1.2	1.5
Floating beads floated turbidity (NTU)		
1	2	3
1.7	4.5	2.9
Sand ballasted settled turbidity (NTU)		
1	2	3
0.2	0.3	0.5
Control settled turbidity (NTU)		
1	2	3
0.9	1.6	1.2

From the data and your experience from the practical sessions, answer the following questions:

- a) What is the mean residual turbidity for each of the systems?
[3 marks]
- b) What experimental reasons might explain the differences observed between the mean residual turbidity for the sand, magnetite and floating beads compared to the control system?
[14 marks]
- c) What are the process advantages of using a ballasting agent for solid-liquid separation processes?
[4 marks]
- d) What are the disadvantages of using a ballasting agent for solid-liquid separation processes?
[4 marks]

[Total 25 marks]

Question A-2 – Compulsory

- a) Based on the sludge settling characteristics of activated sludge in the table and the information below, calculate the required surface area of the secondary clarifier tank.

Mixed liquor suspended solids (MLSS) mg/L	Settling velocity (m/hr)
1000	6.2
2000	5.8
3000	4.5
4000	3
5000	1.4
6000	0.8
7000	0.5
8000	0.3
9000	0.2
10000	0.1
11000	0.05
12000	0.01
13000	0.01
14000	0.01

A flow of 15,000 m³/day

$\alpha = 0.3$

Required solids concentration in the underflow = 11,500 mg/L

MLSS concentration in the activated sludge = 4,000 mg/L

[15 marks]

- b) The sludge characteristics at the WWTWs change throughout the year, calculate the required recycle ratio needed in order to maintain the operation of the clarifier for new sludge A, based on the surface area calculated above. The underflow solids concentration is kept at 11,500 mg/L and the MLSS concentration is still 4,000 mg/L.

Sludge A

Mixed liquor suspended solids (MLSS) mg/L	Settling velocity (m/hr)
1000	4.2
1500	3.9
4200	2.2
4800	1.8
5500	1.6
6100	1
6600	0.9
8100	0.5
8900	0.4
12000	0.1
15000	0.1

[10 marks]

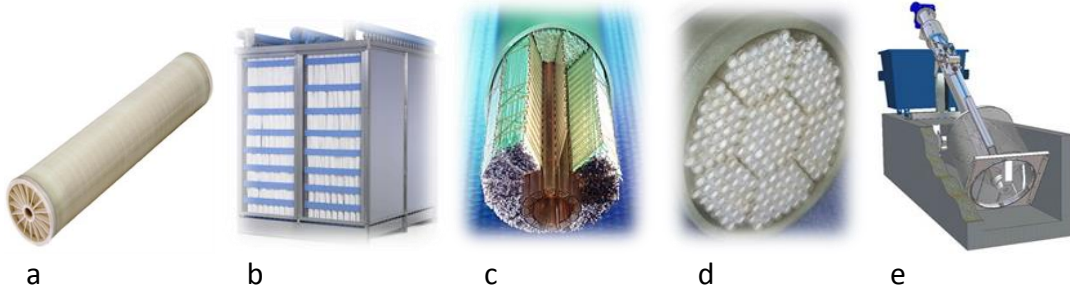
[Total 25 marks]

SECTION B

Attempt one question only from Section B (B-1 or B-2)

Question B-1

Part i



Identify which of the above:

- i Contain(s) a number of HF modules
- ii Is/are used for treating surface waters in drinking water production
- iii Operate(s) from in-to-out with respect to the flow of water
- iv Is the usual technology used for membrane desalination
- v Does not contain a membrane
- vi Fit(s) inside a pressure vessel
- vii Is/are used in immersed MBR plants
- viii Is/are planar in configuration
- ix Is/are cylindrical in configuration
- x Is/are used in sidestream MBRs

[15 marks]

NB There may be more than one answer

Part 2

Water flows at a rate of 5 MLD through 4 stacks of 60 membrane modules, each module having an area of 35 m². They are backflushed with permeate at a flux of 35 LMH every 10 minutes for 30s. The TMP over the course of the cycle ranges from 0.06 to 0.28 bar.

- a) Which of the above operations could be a CEB? [1 mark]
- b) What is the operating (or gross) flux of this process in LMH? [4 marks]
- c) What is the net flux of the process? [4 marks]
- d) What is the mean net permeability of the process [3 marks]
- e) Given the information available and the above calculated parameters, what sort of membrane technology is this likely to be an example of and why? [10 marks]

Part 3

Define the following terms (acronyms), as applied to membrane technology:

- i. CIP
- ii. SAD
- iii. CF
- iv. PDT
- v. CT

[5 marks]

Which of these relates directly to (a) blower energy consumption, (b) membrane integrity, and (c) chemical usage?

[3 marks]

What is the main fundamental difference between ED or FO, and RO or NF?

[5 marks]

Attempt one question only from Section B (B-1 or B-2)

Question B-2

Question

- (A) Describe the ideal characteristics of a filter grain used in depth filtration of drinking water. Explain your choices.

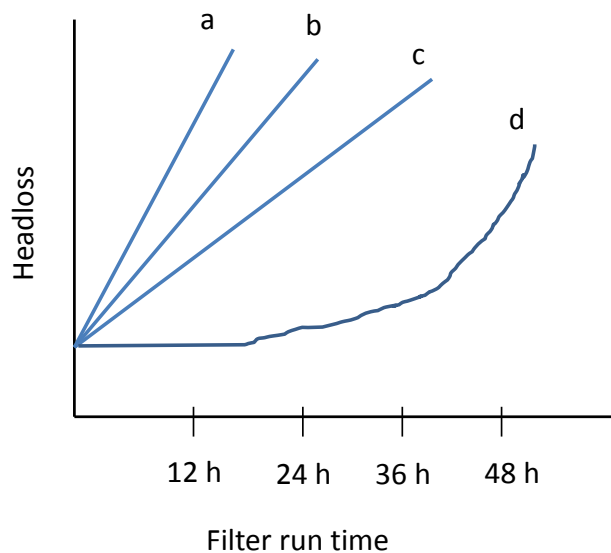
[10 marks]

- (B) Calculate the minimum fluidisation velocity for a typical down flow mono-media sand filter as used for drinking water treatment. What change in velocity would be required if the bed had to expand by 15% assuming an operational bed depth of 0.8 m?

Sand grain size 0.5 mm,
Specific gravity of sand media is 2.6,
Porosity = 0.25
 $\alpha = 0.2$

[20 marks]

- (C) A series of filter runs were operated that resulted in the following headloss profiles with filter run time. Explain what might be happening with respect to the upstream coagulant dosing for lines a, b, c and d.



[10 marks]

(D) What information does the normalised starting headloss (NSH) tell us and how can we use this information to diagnose what might be happening in a filter? You may use diagrams to help you explain in your answer.

What practical steps might we take in order to confirm the NSH observations?

[10 marks]

[Total 50 marks]