WASTE WATER TREATMENT FACILITIES

Introduction:

Due to the recent water source contamination, the town of East Rutherford, NJ needs a new wastewater treatment facility. The town has asked you for assistance in solving some of the problems involved with the design of the facility.

REQUIREMENT 1:

Flow Equalization

Wastewater does not flow into a municipal wastewater treatment plant at a constant rate; the flow rate varies from hour to hour, reflecting the daily water-use patterns of the area served. On the other hand, a wastewater treatment plant works best when designed to handle a (nearly) constant inflow-rate. A solution to this dilemma is the construction of a Flow Equalization Basin (FEB). This is a tank designed to collect and store wastewater, from which the wastewater is then pumped into the treatment plant at a constant rate. The level of wastewater in the FEB will therefore vary throughout the day. Your task is to design an efficient FEB, taking into account such factors as size, cost, ease of construction and repair, and safety margins.

A. Table 1 shows readings of wastewater flow from the town, into the FEB, taken at one-hour intervals, over a 24-hour period. Using this data, determine the constant flow rate at which the wastewater should be pumped out of the FEB and into the treatment plant. Also, determine the required volume of the FEB. Provide a graph of the amount of wastewater in the FEB at time t.

B. What concerns would you point out to the East Rutherford City Engineer about your confidence in your answers in parts A and B? Discuss what other considerations should be included in the design of your FEB.

C. Design a rectangular FEB for the sewage flow using the following constraints:

Provide a ___ percent excess capacity for unexpected flow variations.

The height of the FEB must be ___ meters deep.

The cost associated with constructing the equalization basin is a function of the length and width of the basin, and is described by the function: $c(w,l) = _ \cdot l^2 + _ \cdot w + _ \cdot l \cdot w$.

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Table 1: Sewage Flow Data			
Hour	**Flow(m^3/sec)**	**Hour**	**Flow(m^3/sec)**
0000		1200	
0100		1300	
0200		1400	
0300		1500	
0400		1600	
0500		1700	
0600		1800	
0700		1900	
0800		2000	
0900		2100	
1000		2200	
1100		2300	

REQUIREMENT 2:

Fluid Flow Through a Pipe

The velocity of fluid in a pipe depends on how far the fluid is from the wall of the pipe. For fluid flow in a circular pipe, the function that describes the velocity of the fluid is given by

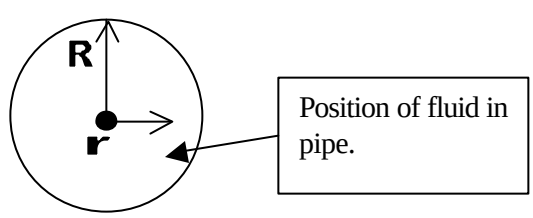
$$v(r) = \mathbf{a} \cdot \left(\mathbf{1} - \frac{r^2}{\mathbf{R}^2} \right)$$

r is the location of the fluid in the pipe measured as a radius of fluid from the center of the pipe.

v(r) is the velocity of the fluid as a function of its location in the pipe measured in m/sec

R is the radius of the pipe in meters, a constant

a is a constant



A. Compare and discuss the velocities of the fluid at the wall of the pipe and at the center of the pipe. Give a physical interpretation of the meaning of your answers.

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B. The flow rate (in $m^3/\sec$) may be calculated as follows:

$$Q = 2\pi \int_0^R v(r) \cdot r \cdot dr$$

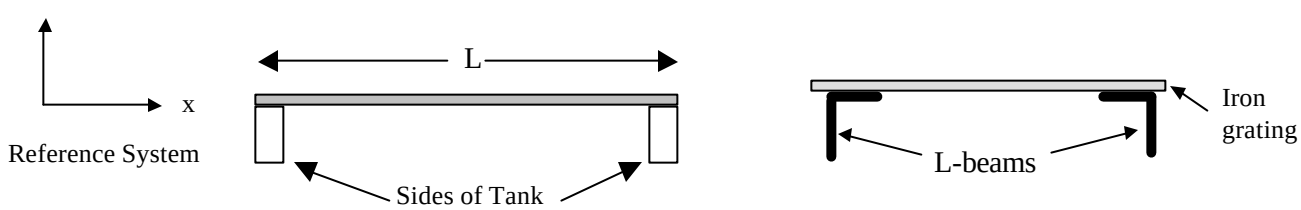
where ***v(r)*** is the velocity function for a circular pipe as above. Using the flow rate you calculated in Requirement 1, part A, and given $a =$ ____, determine the radius of the pipe needed to carry the flow of wastewater between the FEB and the treatment plant. Explain your results and discuss why you don't want a smaller/larger pipe?

REQUIREMENT 3:

Designing an Inspection Catwalk

The wastewater treatment personnel require a catwalk to cross over the equalization basin you designed in Requirement 1 (see sketch below). The catwalk will be used by 3 person inspection teams who take readings of the wastewater in the FEB. It is estimated that each of the personnel will weigh no more than ____ pounds.

(Not to Scale) Side View of Catwalk **End Cross-Section View of the Catwalk**



For a fixed length and beam material, the chief factor in determining the vertical deflection of a beam comes from the Moment of Inertia (**I**). The Moment of Inertia is defined as the sum of the products of each elementary area of the cross-section of the **L-Beam** multiplied by the square of the distance of that area from the assumed axis of rotation. Each **L-Beam** size has an associated Moment of Inertia specification. The Water Treatment personnel have **L-Beams** with the following specifications:

L-Beam	**I** (in.^{4}) Spec:	Cost ($/l ft)

The differential equation that models the vertical deflection of a beam, from the "Handbook of Engineering Fundamentals," is given by

$$\mathbf{EI}\,\frac{d^2 y}{dx^2} = M(x) \quad \text{with Initial Conditions:} \quad y(0) = 0\text{, and} \quad y'\left(\frac{L}{2}\right) = 0\,.$$

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$$M(x) = \frac{1}{2}\int_0^x \mathbf{P}dx\ ,\quad 0 \le x \le \frac{\mathbf{L}}{2}$$

x is the distance, in inches, along the catwalk.

M(x) is the bending moment in inch/pounds, *x* inches from the side of the FEB.

y(x) is the vertical deflection of the L-beam in inches, *x* inches from the side of the FEB.

E is the modulus of elasticity of the material **E = 29,000,000 lbs/in** ^{2} for this beam.

P is the concentrated load in pounds per L-beam.

L is the length of the L-beam.

A. Explain the physical meaning of the two given initial conditions. Discuss the reasonableness of the initial conditions?

B. Given a maximum possible load (3-person inspection team), determine the maximum vertical deflection of the catwalk.

C. What must our moment of inertia be if we allow the catwalk to deflect no more than one and one-half inches? Why might we wish to allow such a deflection?

FINAL REQUIREMENT:

Complete and submit your findings no later than the beginning of class, 27 April 1998. Prepare a one page (single spaced, 12 cpi) memorandum to the East Rutherford City Engineer that summarizes your findings and recommendations. Provide Analytical and Mathematical Support (graphs, tables, calculations) as enclosures for each requirement where appropriate.