Basic Environmental Engineering and Pollution Abatement
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Lecture: 30
Tutorial 6

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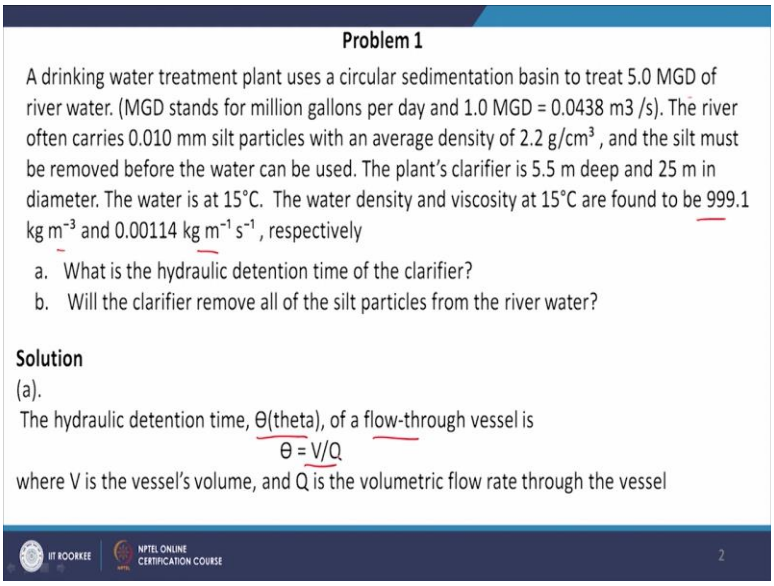

Hello, everyone. Now, we will have a tutorial session and in this class, we will solve some numerical problems based on last four classes.

The problem one, the statement is a drinking water treatment plant uses a circular sedimentation basin to treat 5 MGD of river water. MGD stands for million gallons per day and 1 MGD is equal to 0.0438 m^3/s. The river often carries 0.010 mm silt particles with an average density of 2.2 g/cm^3 and the silt must be removed before the water can be used. The plants clarifier is 5.5-m-deep and 25 m in diameter. The water is at 15 ^oC, the water density and viscosity at 15 ^oC are found to be 999.1 kg/m^3 and 0.00114 kg/m-s respectively.

what is the hydraulic detention time of the clarifier and will the clarifier remove all of the silt particles from the river water? So, these two questions we have to solve.

Now we will see for part one, the hydraulic detention time, the θ of a flow through vessel is

$\theta = V/Q$.

Where V is the volume of the reactor and Q is the volumetric flow rate.

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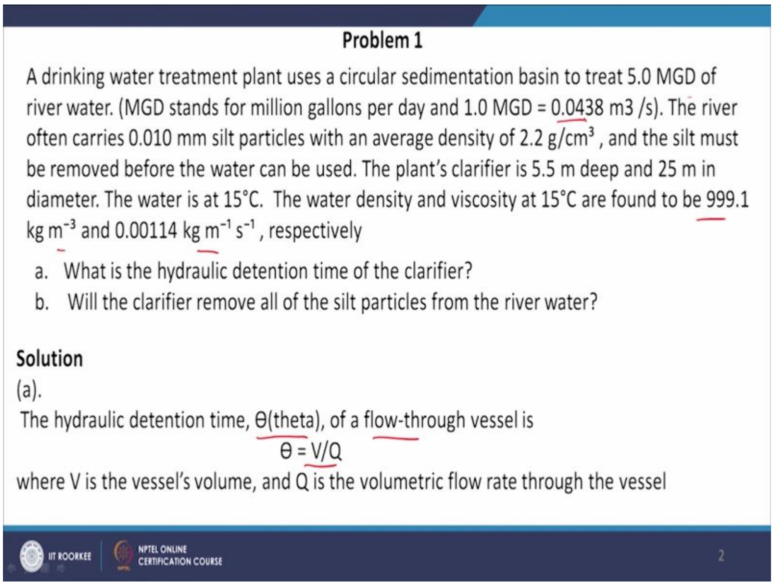

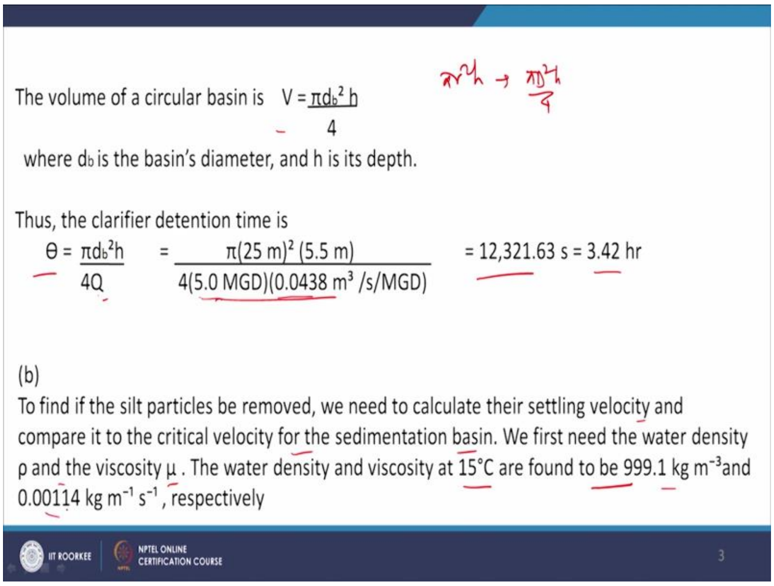

The volume of a circular basin it is $V = \pi r^2 h = \pi d_b^2 h/4$

where d_b is the diameter of the basin and h is the height. And then, what will be the theta value? Thus, the clarifier detention time is

$$\theta = \frac{\pi d_b^2 h}{4Q} = \frac{\pi(25\text{m})^2(5.5\text{m})}{4(5.0\text{ MGD})(0.0438\text{m}^3/\text{s/MGD})} = 12321.63\text{ s} = 3.42\text{ hr}$$

And in part two, we have to verify whether all particles will be settled or not, that means we need to calculate the terminal settling velocity of the particles.

And to find the silt particles to be removed, we need to calculate the settling velocity and compare it to the critical velocity for the sedimentation basin. And we first need the water density rho and the viscosity mu which are provided. In this case, the water density and viscosity at 15 degrees centigrade are found to be 999.1 kg per meter cube and 0.00114 kg per meter per second, respectively it is given.

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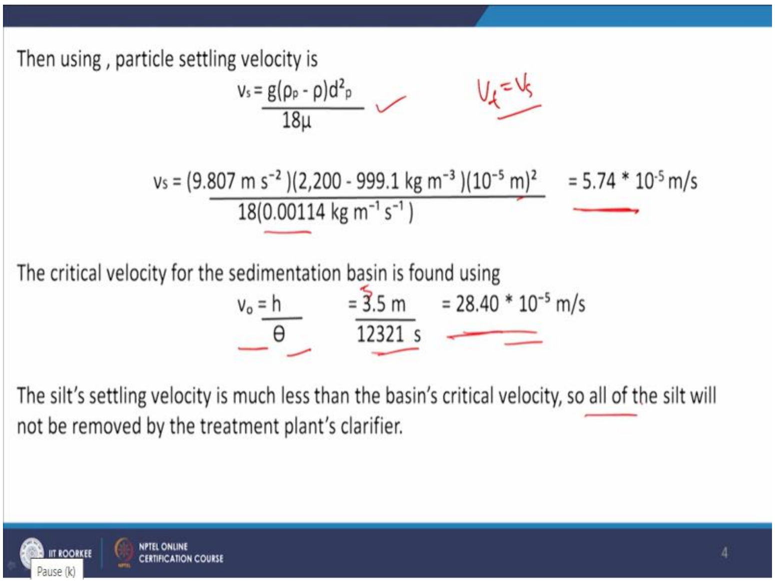

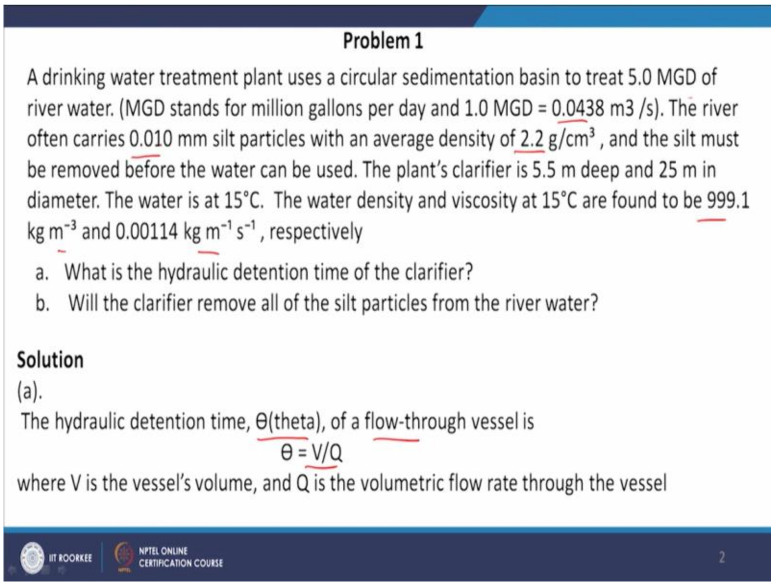

So, we will be putting these values in our expression of V_t or V_s. Vs is settling velocity or V_t is terminal settling velocity both are same. In different cases you might have seen different abbreviation. So, both are same V_t and V_s.

$$v_s = \frac{(9.807\ m\ s^{-2})(2{,}200 - 999.1\ kg\ m^{-3})(10^{-5}\ m)^2}{18(0.00114\ kg\ m^{-1} s^{-1})} = 5.74 \times 10^{-5}\ m/s$$

And the critical velocity for the sedimentation basin can be found by using this V_o.

$V_o = h/\theta = 3.5m/12321s = 28.40*10^{-5}$ m/s

Now, we see the silt settling velocity is much less than the basin critical velocity. Therefore, it can be concluded that all particles will not settle.

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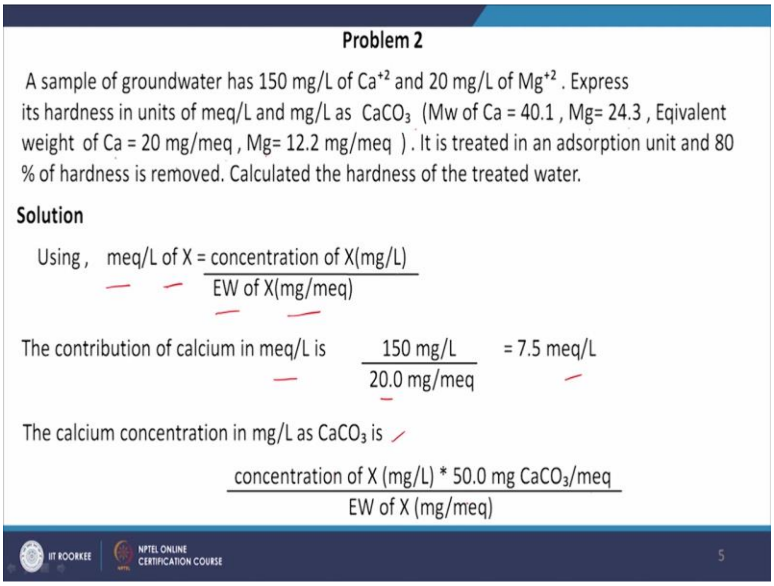

Now, problem number two, the statement is a sample of groundwater has 150 mg/L of calcium^{2+} and 20 mg/L of magnesium^{2+}. Express its hardness in units of meq/L and mg/L as calcium carbonate $CaCO_3$? Molecular weight of calcium 40.1 and magnesium 24.3, equivalent weight of calcium 20 mg/meq and for magnesium it is 12.2 mg/meq. It is treated in an absorption unit and 80 % hardness is removed. Calculate the hardness of the treated water?

So, it is given, already we have discussed that in equivalent by liter of any substance that is X

$$\frac{\text{meq}}{\text{L}}\text{ of X} = \frac{\text{concentration of X}(\frac{\text{mg}}{\text{L}})}{\text{EW of X}(\frac{\text{mg}}{\text{meq}})}$$

The contribution of calcium in meq/L is = (150 mg/L)/(20.0 mg/meq) = 7.5 meq/L

So, the calcium concentration in mg/L as calcium carbonate $CaCO_3$ is

$$= \frac{\text{concentration of X}(\frac{\text{mg}}{\text{L}}) * 50.0 \text{ mg CaCO}_3/\text{meq}}{\text{EW of X}(\frac{\text{mg}}{\text{meq}})}$$

$$\frac{\left(150\frac{\text{mg}}{\text{L}}\right) * 50.0 \text{ mg CaCO}_3/\text{meq}}{(20\frac{\text{mg}}{\text{meq}})} = 375\frac{\text{mg}}{\text{L}} \text{ as CaCO}_3$$

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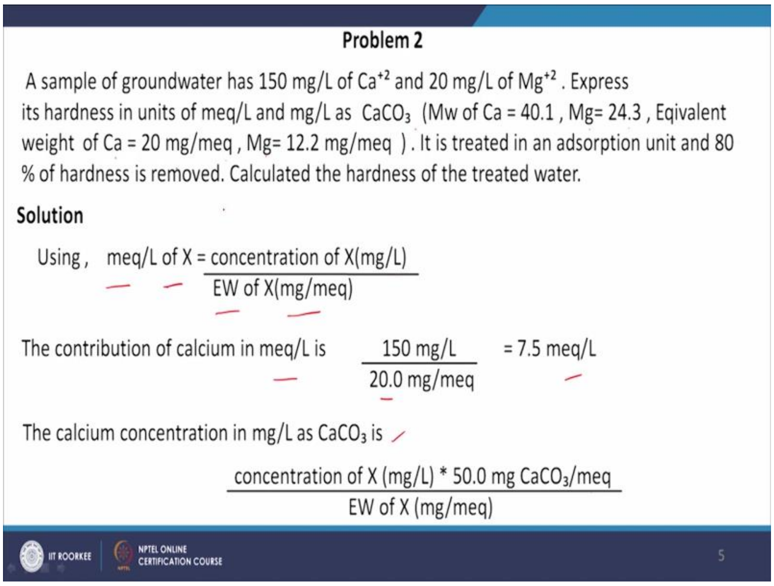

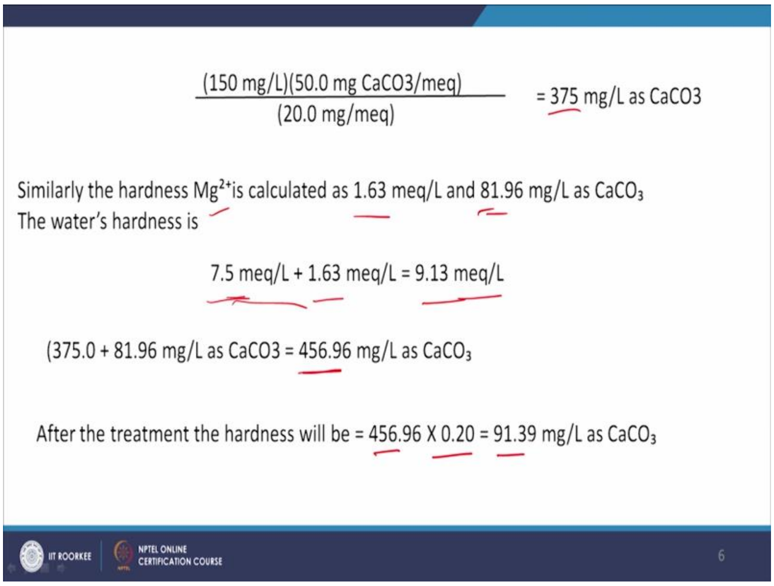

Similarly, for hardness due to magnesium^{2+}, we can calculate the same expression. Here, we have concentration is equal to 20 mg/L.

Similarly the hardness $Mg^{2+}$is calculated as 1.63 meq/L and 81.96 mg/L as $CaCO_3$

Now, if we take the total hardness, 1 is due to calcium and other is due to magnesium.

The water's hardness is 7.5 meq/L + 1.63 meq/L = 9.13 meq/L

(375.0 + 81.96 mg/L as CaCO3 = 456.96 mg/L as $CaCO_3$

After the treatment the hardness will be = 456.96 X 0.20 = 91.39 mg/L as $CaCO_3$

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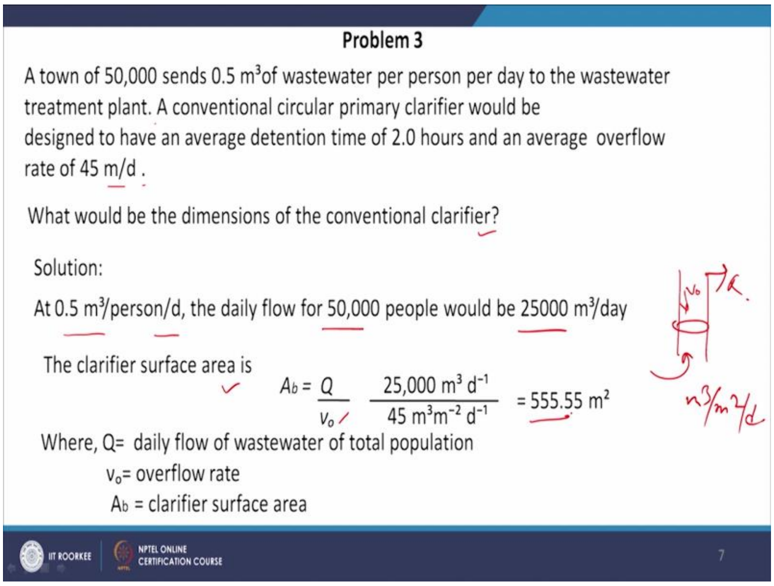

Now problem number three, the statement is a town of 50,000 sends 0.5 m^3 of wastewater per person per day to the wastewater treatment plant. A conventional circular primary clarifier would be designed to have an average detention time of 2 hours and an average overflow rate of 45 m/d. What would be the dimensions of the conventional clarifier? That we have to calculate.

So, you see here in this case at 0.5 m^3/person/day, the daily flow for 50,000 people would be 25000 m^3/day.

The clarifier surface area that will be volumetric flow rate divided by velocity.

$A_b = Q/V_o = (25000\ m^3/d)/(45\ m^3/\ m^2\text{-}d) = 555.55\ m^2$

So, V_o is overflow rate, A_b is the clarifier surface area and Q daily flow of wastewater of total population. So, now we have to get the dimension.

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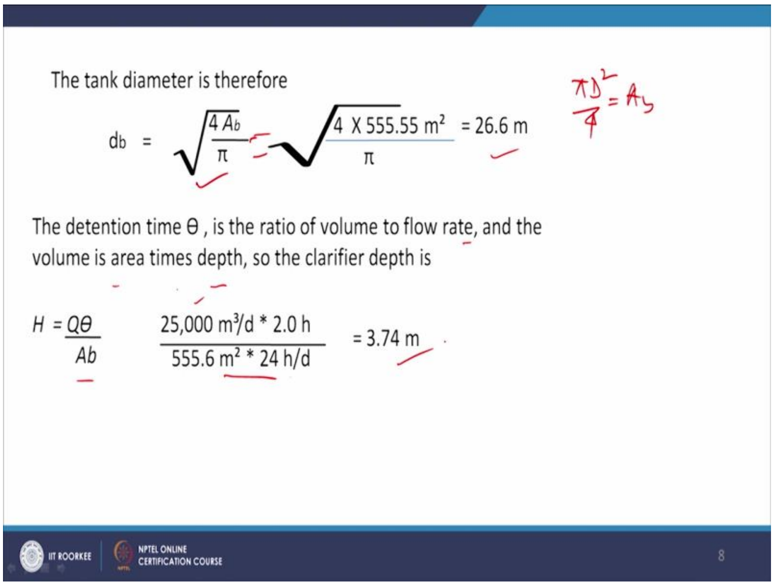

The tank diameter is therefore

$$d_b = \sqrt{\frac{4 * A_b}{\pi}} = \sqrt{\frac{4 * 555.55 m^2}{\pi}} = 26.6 \text{ m}$$

The detention time θ is the ratio of volume to flow rate and the volume is area times the depth.So, we need to determine the dimension.So, diameter as well as the height we have to calculate.

$$H = \frac{Q\theta}{A_b} = \frac{25000 m^3/d * 2.0 \text{ h}}{555.6 m^2 * 24 \text{ h/d}} = 3.74 \text{ m}$$

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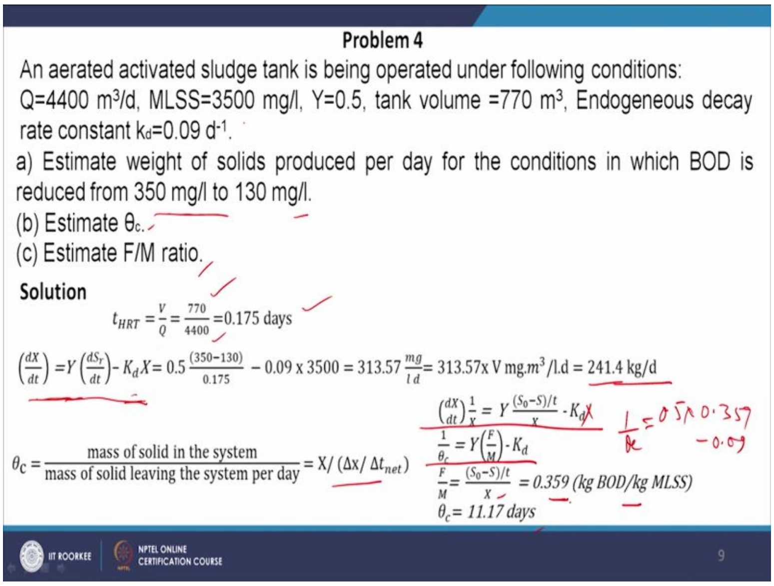

Problem four. The statement is, an aerated activated sludge tank is being operated under following conditions Q is equal to 4400 m^3/d, MLSS 3500 mg/L, Y equal to 0.5, tank volume equal to 770 m^3, Endogenous decay rate constant k_d is equal to 0.09 per day. So, estimate weight of solids produced per day for the conditions in which BOD is reduced from 350 mg/L to 130 mg/L. Part b, estimate θ_c that is cell residence time and part c, estimate F/M ratio?

So, now, the first we have to weight of solids produced per day for the conditions in which BOD is reduced from 350 mg per liter to 130 mg per liter. So, we need to calculate dx/dt that

$$\frac{dX}{dt} = Y\left(\frac{ds_r}{dt}\right) - K_d X$$

And in this case, we will be putting the values 0.5 into Y value is given. So, this expression we can get this value here, S_o minus S by t into X. So, that value we are putting here and we need the value of t. So, t we have to calculate by this expression. So, HRT hydraulic retention time that is V by Q that is 770 divided by 4400 that is equal to 0.175 days.

Now, we will be putting those values here. So, 0.5 into this expression which we have used that is this one. So, Y equal to 0.5 into 350 minus 130 divided by t 0.175 minus K_d which we are getting here that is equal to 0.09 into 3500. So, by solving these expressions, we are getting dx by dt that is equal to 313.57 mg per liter per day.

So, then if we want to convert it into kg per day, so, we have to multiply it with the volume of the reactor. So, 313.57 into V mg per meter cube per liter per day. So, that it is converting to 241.4 kg per day. And the first part we are getting now, now, we have to estimate the theta c value. So, theta c value we know the expression is this one, theta c is equal to x by del x by del t net. So, 1 by theta c into this 1 by theta c equal to Y into F by M minus K_d. Now, F by M we can calculate by this formula, so minus s by t by capital X. So, that is equal to 0.359 kg BOD by kg MLSS.

We will be putting these value 350 minus 130 divided by 0.175 this is and then X, X is the MLSS 3500. So, if we put the value will be 0.359 kg BOD per kg MLSS. So, this expression will put it here, here we can get 1 by theta c equal to 0.5 into F by M we are getting 0.359 minus K_d, K_d equal to 0.09. So, by solving these expressions we will be getting the theta c will equal to 11.17 days.

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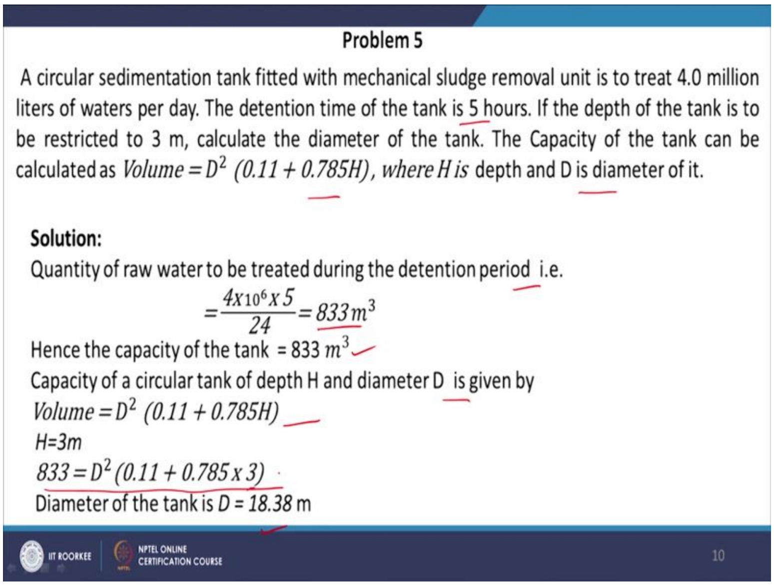

Now, problem five. Statement is, a circular sedimentation tank fitted with mechanical sludge removal unit is to treat 4 million liters of water per day. The detention time of tank is 5 hours if the depth of the tank is to be restricted to 3 meter, calculate the diameter of the tank the capacity of the tank can be calculated as volume = D^2 (0.11 + 0.785H), where H is depth and D is diameter of it.

So, quantity of raw water to be treated during the detention period that is

$= (4*10^6*5)/24 = 833\ m^3$

Hence the capacity of the tank = 833 m^3 and capacity of a circular tank of depth H and D is given by, volume = D^2 (0.11 + 0.785*H)

H = 3 m

$833 = D^2 (0.11 + 0.785*3)$

Diameter of the tank is 18.38 m.

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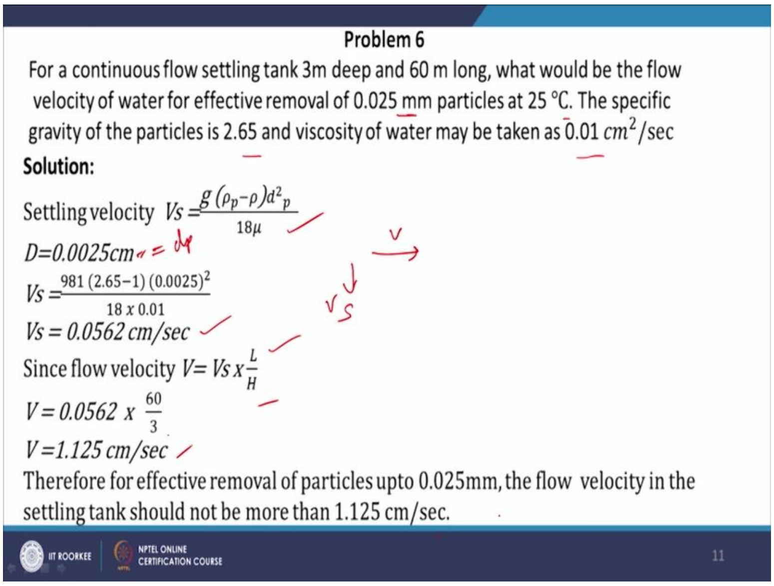

Now, problem number six. Statement is for a continuous flow settling tank 3 m deep and 60 m long, what would be the flow velocity of water for effective removal of 0.025 mm particles at 25 ^oC? The specific gravity of the particle is 2.65 and viscosity of water may be taken as 0.01 cm^2/s.

So, again we will be assuming that Stokes law is applicable or Laminar Flow Zone and Settling velocity is given for this zone

$$v_s = \frac{g\,(\rho_p - \rho)d_p^2}{18\mu}$$

D = 0.0025 cm

$$v_s = \frac{981\,(2.65 - 1)\,(0.0025)^2}{18\ x\ 0.01}$$

Vs = 0.0562 cm/sec

Since flow velocity V= Vs* L/H

V = 0.0562* 60/3

V =1.125 cm/sec

Therefore, for effective removal of particles up to 0.025 millimeter the flow velocity in the settling tank should not be more than 1.125 cm/sec. So, we have solved all the six problems and up to this in this class. Thank you very much for your presence.