Basic Environmental Engineering and Pollution Abatement
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Lecture 10
Tutorial -2

Hello everyone. Now, we will have a tutorial session and now we will solve some numerical problems based on our discussion during last four classes.

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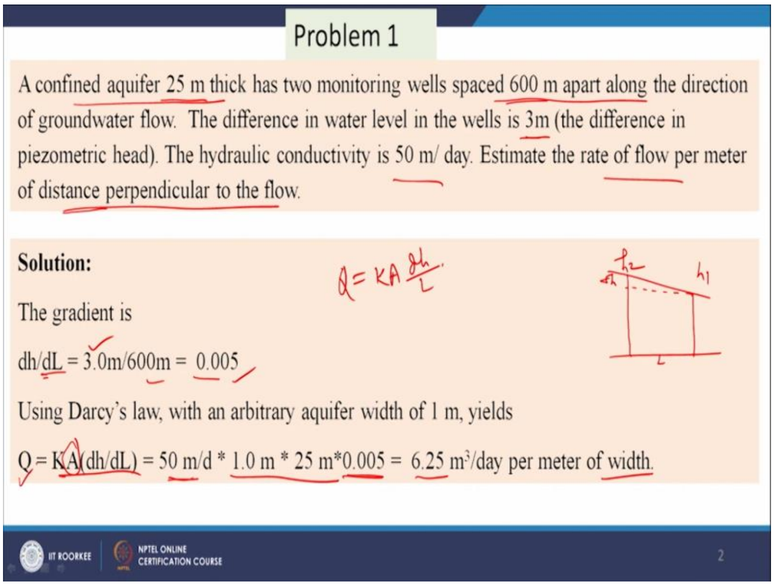

Our first problem statement is a confined aquifer 25 m thick has two monitoring wells spaced 600 m apart along the direction of groundwater flow. The difference in water level in the wells is 3 m. The difference in piezometric head. The hydraulic conductivity is 50 m/d. Estimate the rate of flow per meter of distance perpendicular to the flow.

The gradient is

dh/dL = 3.0m/600m = 0.005

Using Darcy's law, with an arbitrary aquifer width of 1 m, yields

Q = KA(dh/dL) = 50 m/d * 1.0 m * 25 m*0.005 = 6.25 m^3/day per meter of width.

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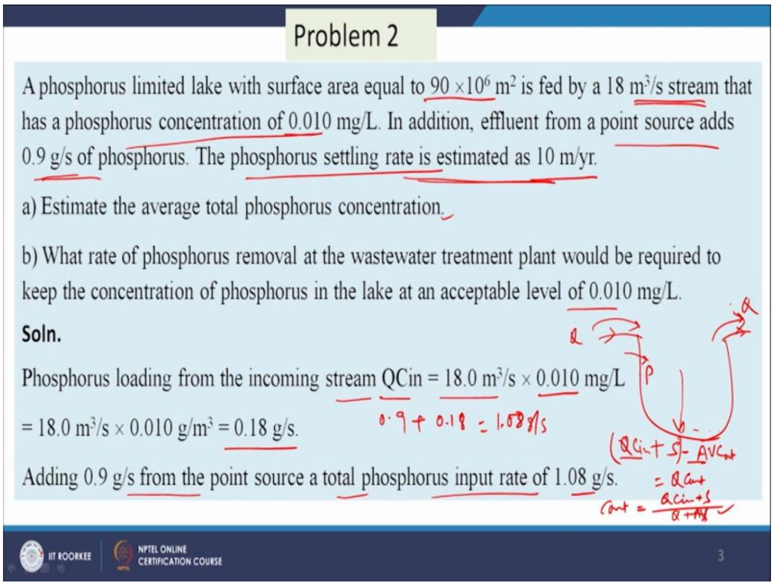

Now, problem number 2. A phosphorous limited lake with surface area equal to $90*10^{-6}$ m^2 is fed by 18 m^3/s stream that has a phosphorous concentration of 0.010 mg/L. In addition, effluent from a point source adds 0.9 g/s of phosphorous. The phosphorous settling rate is estimated as 10 m/y.

Estimate the average total phosphorous concentration. Question number 1 a). And b) part. What rate of phosphorus removal at the wastewater treatment plant would be required to keep the concentration of phosphorus in the lake at an acceptable level of 0.010 mg/L. So, the problem is like this.

Phosphorus loading from the incoming stream QC_{C}in = 18.0 m^3/s × 0.010 mg/L = 0.18 g/s.

Adding 0.9 g/s from the point source a total phosphorus input rate = 0.18+0.9 = 1.08 g/s

The phosphorous settling, the phosphorus is settled here and settling rate is 10 m/yr. So, that we have to calculate, what is the settling rate?

Vs = 10 m/year

= 10/(365 × 24 × 3600) m/s = 3.17 ×10^{-7} m/s

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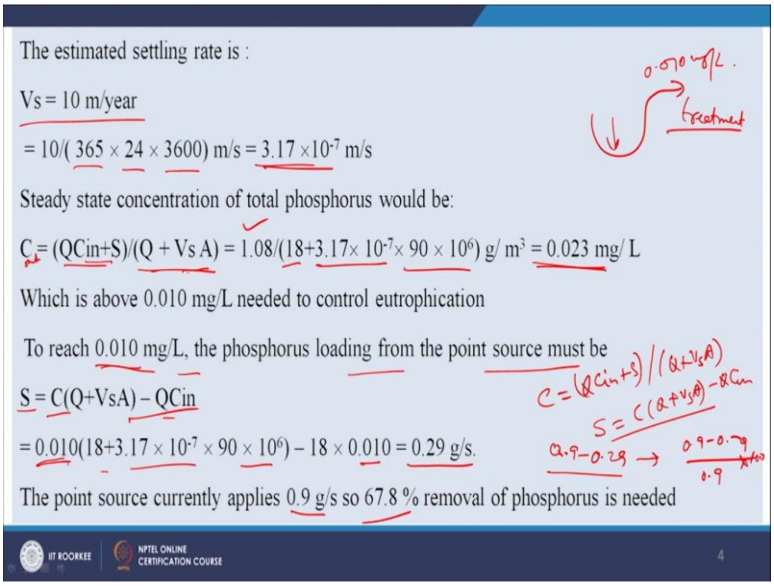

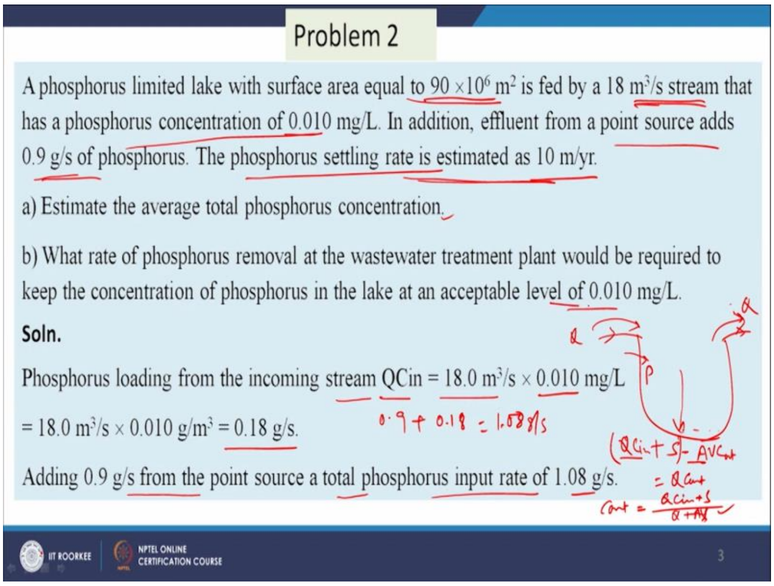

So, steady state concentration of the total phosphorus would be

$$C_{out} = (QC_{in}+S)/(Q + V_s A) = 1.08/(18+3.17\times 10^{-7}\times 90 \times 10^{6})\ g/m^3 = 0.023\ mg/L$$

Which is above 0.010 mg/L needed to control eutrophication

To reach 0.010 mg/L, the phosphorus loading from the point source must be

$$S = C(Q+V_sA) - QC_{in}$$

$$= 0.010(18+3.17 \times 10^{-7} \times 90 \times 10^{6}) - 18 \times 0.010 = 0.29\ g/s.$$

The point source currently applies 0.9 g/s so 67.8 % removal of phosphorus is needed

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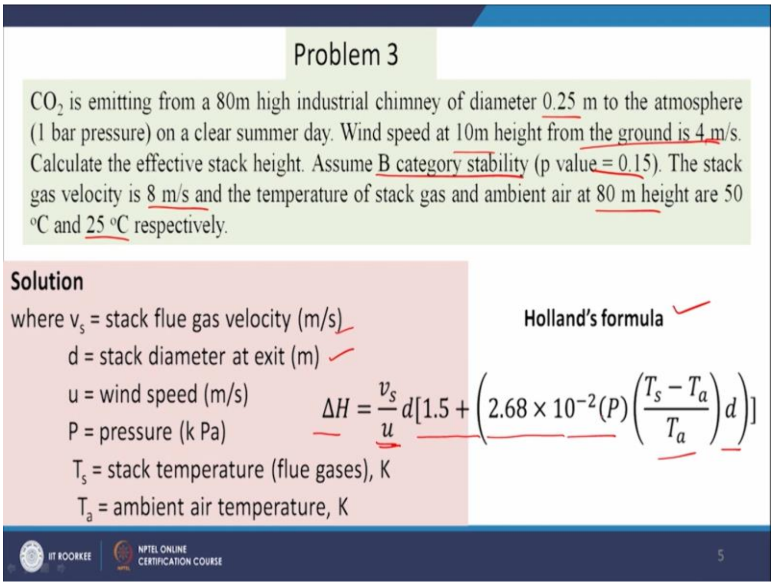

So, problem 3. CO_2 is emitting from a 80 m high industrial chimney of diameter 0.2 m to the atmosphere, that 1 bar pressure on a clear summer day. Wind speed at 10 m height from the ground is 4 m/s. Calculate the effective stack height. Assume B category stability p value is 0.15. The stack gas velocity is 8 m/s and the temperature of stack gas and ambient air at 80 m height are 50 °C and 25 °C, respectively.

So, these are the given condition. So, we have to calculate the stack height. So, how we can do that? So, we know that Holland's formula

$$\Delta H = \frac{v_s}{u} d[1.5 + \left(2.68 \times 10^{-2}(P)\left(\frac{T_s - T_a}{T_a}\right)d\right)]$$

Where: v_s = stack velocity(m/s); d=stack diameter(m); u=wind speed(m) P=Atmospheric pressure (k Pa), mill bars; T_s = stack gas temperature (K); T_a = air temperature(K)

$$u_2 = u_1\left(\frac{z_2}{z_1}\right)^p$$

$$u_2 = 4 \times \left(\frac{80}{10}\right)^{0.15} = 5.464\ \frac{m}{s}$$

$$\Delta H = \left(\frac{8 \times 0.25}{5.464}\right)\left[1.5 + \left(2.68 \times 10^{-2} \times 10^2 \times \left(\frac{323 - 298}{323}\right) \times 0.25\right)\right] = 0.568\ m$$

Effective stack height = 80 +0.568 m = 80.568 m

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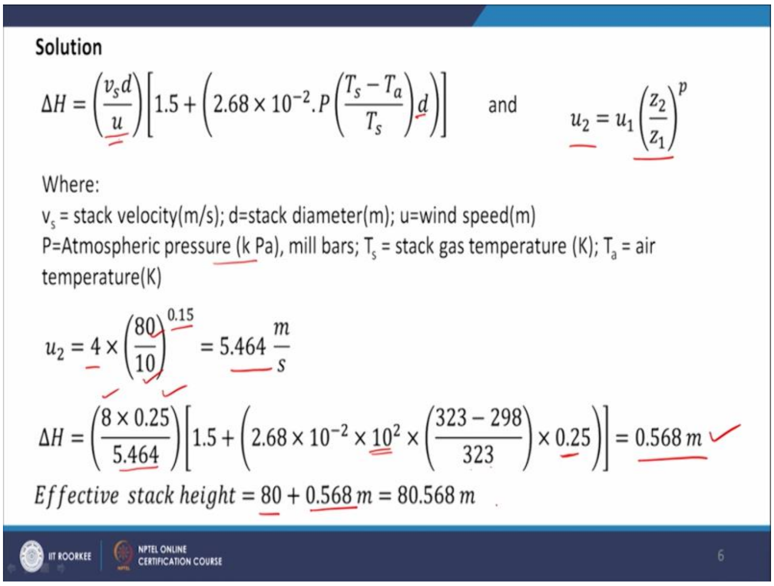

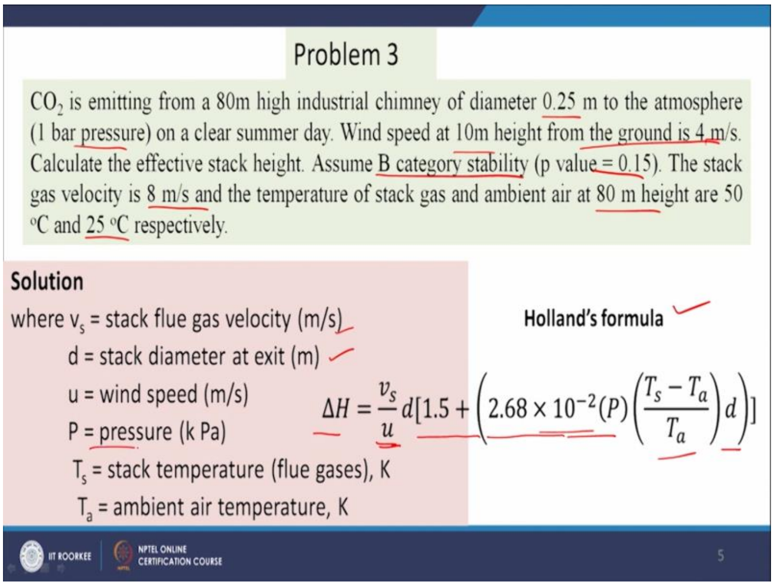

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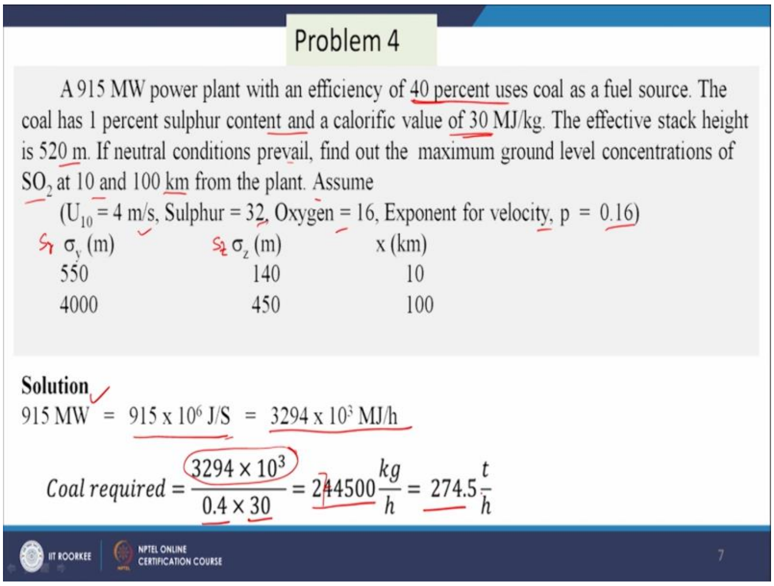

Then problem number 4. A 915 MW power plant with an efficiency of 40% uses coal as a fuel source. The coal has 1 % sulphur content and a calorific value of 30 MJ/kg. The effective stack height is 520 m. If neutral conditions prevail, find out the maximum ground water concentrations of SO_2 at 10 and 100 km from the plant.

Assume that U_{10} that is wind speed at 10 m height is equal to 4 m/s. Sulphur molecular weight is 32, Oxygen 16. Exponent for velocity is equal to 0.16. And σ_y and σ_z or Sy Sz, we have also discussed in the previous class. And this is our different distance, if you consider the Sy, Sz values are given. So, now, we have to calculate the concentration of the pollutants that is SO_2.

915 MW = 915 x 10^6 J/S = 3294 x 10^3 MJ/h

$$\text{Coal required} = \frac{3294 \times 10^3}{0.4 \times 30} = 274500 \frac{\text{kg}}{\text{h}} = 274.5 \frac{\text{t}}{\text{h}}$$

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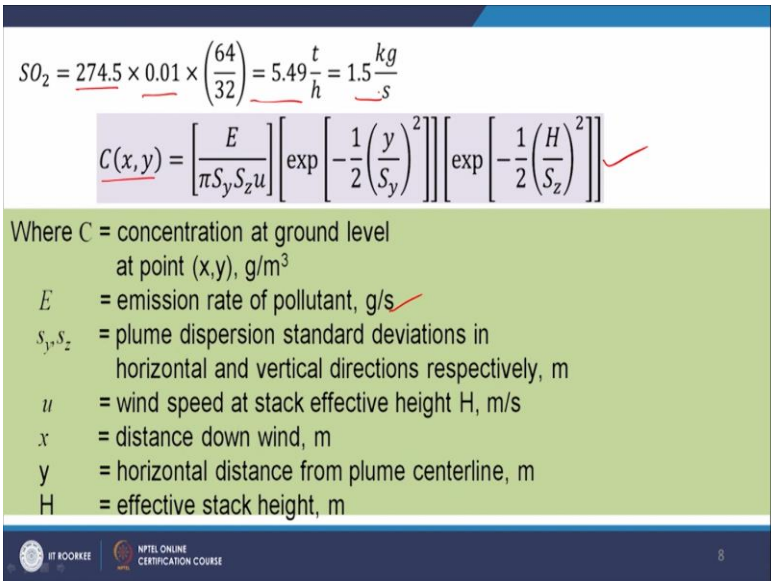

We can calculate the concentration of SO_2 by using this formula.

$$C(x, y) = \left[\frac{E}{\pi S_y S_z u}\right]\left[\exp\left[-\frac{1}{2}\left(\frac{y}{S_y}\right)^2\right]\right]\left[\exp\left[-\frac{1}{2}\left(\frac{H}{S_z}\right)^2\right]\right]$$

$$SO_2 = 274.5 \times 0.01 \times \left(\frac{64}{32}\right) = 5.49\frac{t}{h} = 1.5\frac{kg}{s}$$

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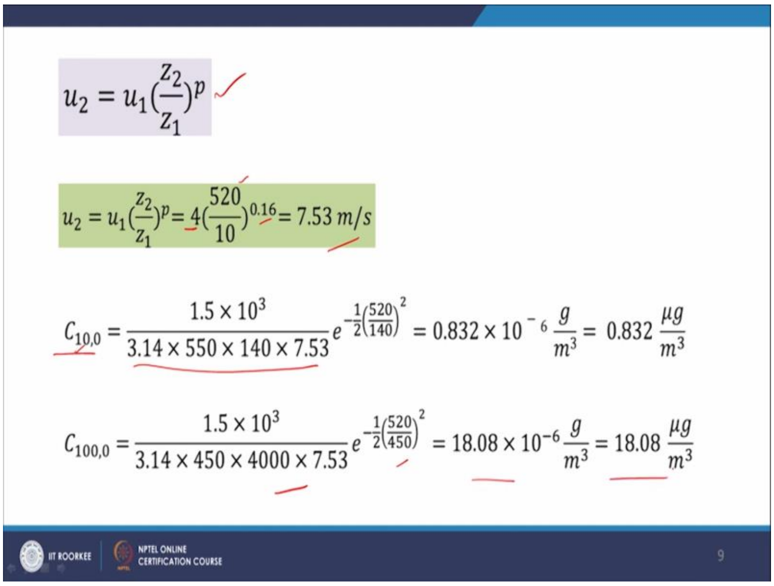

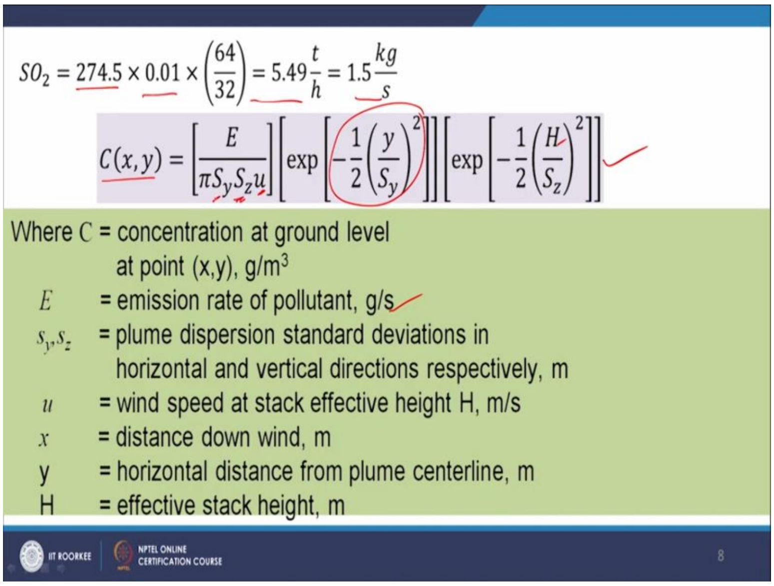

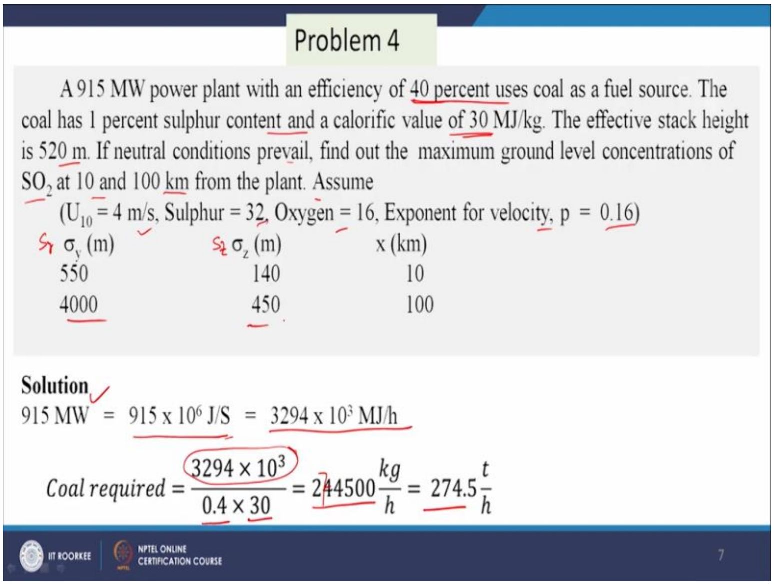

And we need to calculate the value of u_2

$$u_2 = u_1\left(\frac{z_2}{z_1}\right)^p$$

$$u_2 = u_1\left(\frac{z_2}{z_1}\right)^p = 4\left(\frac{250}{10}\right)^{0.16} = 7.53\ m/s$$

$$C_{10,0} = \frac{1.5\times10^3}{3.14\times550\times140\times7.53} e^{-\frac{1}{2}\left(\frac{520}{140}\right)^2} = 0.832\times10^{-6}\ \frac{g}{m3} = 0.832\ \frac{\mu g}{m^3}$$

$$C_{100,0} = \frac{1.5\times10^3}{3.14\times450\times4000\times7.53} e^{-\frac{1}{2}\left(\frac{520}{450}\right)^2} = 18.08\times10^{-6}\ \frac{g}{m^3} = 18.08\ \frac{\mu g}{m^3}$$

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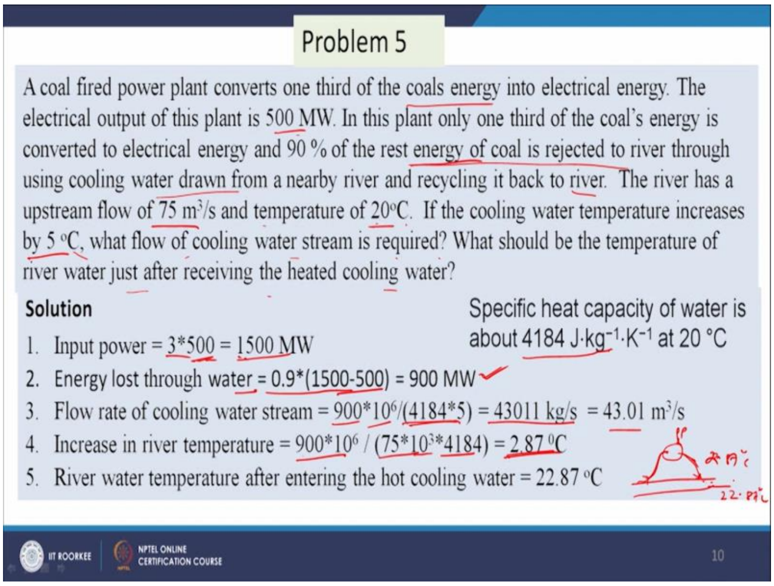

Now, problem number 5. A coal fired power plant converts one third of the coals energy into electrical energy. The electrical output of this plant is 500 MW. In this plant only one third of the coals energy is converted to electrical energy and 90% of the rest energy of coal is rejected to river through using cooling water drawn from a nearby river and recycling it back to river. The river has a upstream flow of 75 m^3/s and temperature of 20 ^oC. If the cooling water temperature increases by 5 20 ^oC, what flow of cooling water stream is required? What should be the temperature of river water just after receiving the heated cooling water?

Input power = 3*500 = 1500 MW

Energy lost through water = 0.9*(1500-500) = 900 MW

Specific heat capacity of water is about 4184 $J \cdot kg^{-1} \cdot K^{-1}$ at 20 °C

Flow rate of cooling water stream = $900*10^6/(4184*5)$ = 43011 kg/s = 43.01 m^3/s

Increase in river temperature = $900*10^6$ / $(75*10^3*4184)$ = 2.87 ^0C

River water temperature after entering the hot cooling water = 22.87 ^oC

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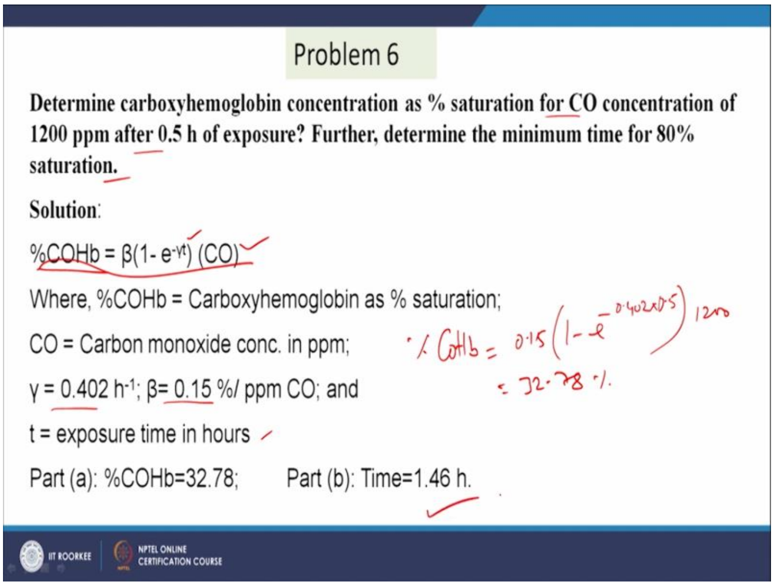

Now, problem number 6. Determine carboxyhemoglobin concentration as percentage saturation for carbon monoxide concentration of 1200 ppm after 0.5 h of exposure. Further, determine the minimum time for 80% saturation. So, we know some empirical relationship to find out the concentration of carboxyhemoglobin in the blood.

$$\%COHb = \beta(1- e^{-\gamma t}) (CO)$$

Where, %COHb = Carboxyhemoglobin as % saturation;

CO = Carbon monoxide conc. in ppm;

$\gamma = 0.402\ h^{-1}$; $\beta = 0.15$ %/ ppm CO; and

t = exposure time in hours

Part (a): %COHb=32.78;   Part (b): Time=1.46 h.

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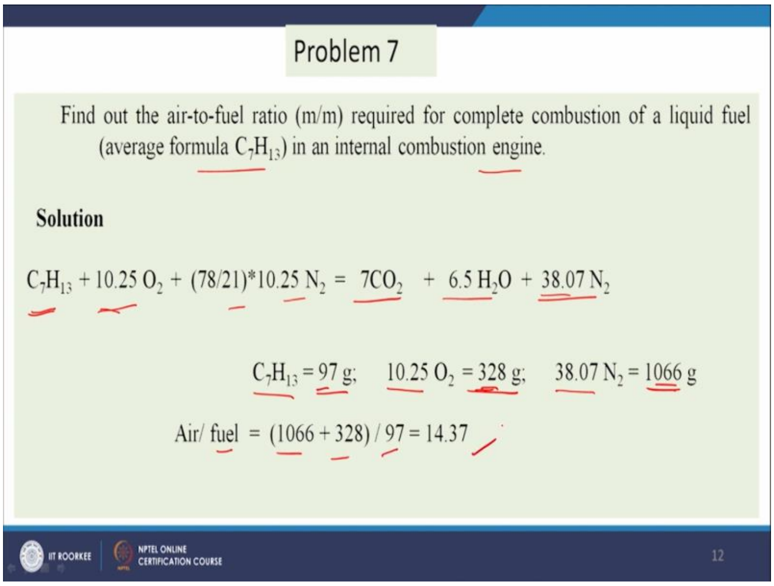

Now, problem number 7. Find out the air to fuel ratio required for complete combustion of a liquid fuel (average formula C7 H13) in an internal combustion engine.

$C_7H_{13} + 10.25\ O_2 + (78/21)*10.25\ N_2 = 7CO_2 + 6.5\ H_2O + 38.07\ N_2$

C_7H_{13} = 97 g; $10.25\ O_2$ = 328 g; $38.07\ N_2$ = 1066 g

Air/ fuel = (1066 + 328) / 97 = 14.37

Thank you very much for your patience.