INDIAN INSTITUTE OF TECHNOLOGY, KHARAGPUR

RP

Date_____ **FN/AN, Time: 2/~~3~~ Hrs., Full Marks** 60 **, Deptt** ME

No. of Students 86 **, Mid/~~End~~ Autumn/~~Spring~~ Semester Examination**___

Sub. No. ME40701|40603 **Sub. Name** Applied Thermo Fluids II

4th **Yr. B.Tech.(H) / ~~B.Arch.(H) / M.Sc.~~/M.Tech(Dual), Instruction**_____

Steam Tables to be provided

1. A steam power plant based on the Rankine cycle with superheat is to be set up in a place where cooling water is available at 30°C. The temperature of the working fluid in the condenser in to be kept at 15°C above the temperature of the incoming cooling water. The quality of steam at turbine exit is to be kept at 0.95 and the temperature of steam entering the turbine should be 500°C. What should be the pressure in the boiler and what is the thermal efficiency of the cycle? Assume an ideal cycle.

   10 marks

2. A drum type boiler operates at a pressure of 80.0 bar. In a simplified model the downcomer and the riser are considered to be vertical pipes of diameter 0.08 m. The downcomer is assumed to contain saturated liquid, while in the riser the working fluid enters as saturated liquid but at the exit the void fraction is 0.25. What is the driving pressure causing natural circulation if the height of the riser is H? Express your answer in terms of H. Assume that the average density in the riser can be approximated by the arithmetic mean of the values at riser top and bottom and use $g = 9.81$ m/s^2. What is the mass flow rate if the total pressure loss in the entire circulation loop can be taken to be equal to the frictional pressure loss when saturated liquid only at boiler pressure, as in the downcomer, flows with the same mass flow rate through a pipe of same diameter as the downcomer and riser but of equivalent length $5H$ and with friction factor $f = 0.001$. Assume that the frictional pressure loss is related to the friction factor by

   $$\Delta p_l = f\frac{L}{D}\frac{\rho V^2}{2}$$

   If the slip factor is 1.6 what is the quality of steam at riser exit? If the heat transfer coefficient, h, is 1500 W/m^{2}K, the combustion products outside the riser are at 1650°C and the riser diameter can be taken to be 0.08 m, what should be the length/height, H, of the riser?

   20 marks

3. What is the four factor formula for the infinite multiplication factor and what do the different factors represent? In a thermal reactor the fuel is a mixture of uranium dioxide, UO_2, which contains depleted uranium with 0.5 percent ^{235}U, and plutonium dioxide, PuO_2, where the plutonium is ^{239}Pu, in the ratio one molecule of PuO_2 for every 19 molecules of UO_2. The moderator is water, H_2O, and there are 5 molecules of water for every atom of fuel, where the uranium and plutonium together constitute fuel. Calculate the value of eta, η, and the

thermal utilization factor, f. Use the data

Substance	σ_c (barns)	σ_f (barns)	ν
^{238}U	2.72	0	–
^{235}U	101	579	2.42
^{239}Pu	270	745	2.91
O	0	0	–
H_2O	0.66	0	–

10 marks

4. In a scattering and absorbing medium, using the continuous slowing-down model, derive an expression for the rate, $q(E)$, at which neutrons are slowing down past energy E per unit volume, if at fission energy E_f, q has the value $q(E_f)$. State any assumptions that you make. Assuming that the cross-sections σ_s and σ_a are independent of the energy E, carry out the integration involved to obtain a simple expression relating $q(E)/q(E_f)$ to E/E_f. Let $\phi(E)\mathrm{d}E$ be the flux of neutrons with energy between E and $E+\mathrm{d}E$. The neutron flux is related to the neutron number density by $\phi(E) = n(E)v$, where $n(E)\mathrm{d}E$ is the number density of neutrons with energy between E and $E+\mathrm{d}E$, the speed, v, is related to the energy, E, by $E = \frac{1}{2}mv^2$. What is the number of neutrons per unit volume with energy in the range $E_2 \leq E \leq E_1$? To make the expressions simpler you may use the notation

$$q = q(E), \quad q_f = q(E_f), \quad k = \frac{\Sigma_a}{\xi(\Sigma_a + \Sigma_s)}$$

If q_f is 10^{16} neutrons/m^{3}s and $E_f = 2.0$ MeV and the slowing down is occurring in a block of graphite, what is the value of q for $E = 1.0$ eV? What is the number density of neutrons which have energy between 10 keV and 20 keV? Graphite has density $\rho = 1.6 \times 10^3$ kg/m^3, atomic mass 12.01 u, absorption cross-sections $\sigma_a = 0.0045$ barns, scattering cross-section $\sigma_s = 4.7$ barns and $\xi = 0.158$. Mass of a neutron = 1.008 665 u. Avogadro number = 6.023×10^{26} kmol^{-1}, 1 barn = 10^{-28} m^2, 1 u = 1.6604×10^{-27} kg and 1 eV = 1.602×10^{-19} J.

20 marks