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Master of Nuclear Engineering 1st year 2nd Semester Examination, 2018

Subject: Reactor Thermal Hydraulics

Time: Three hours **Full marks: 100**

Use separate answer scripts for each part

Part I (*answer all questions*)

1 (a) Two infinite plates are placed parallel to each other, with the upper plate moving at a speed of 10 m/s and the bottom plate stationery. The height of the channel is 5 cm. Comment on whether the flow is laminar or turbulent, and calculate the shear stress at the upper and lower plates if $\mu = 0.44$ kg/m.s and $\rho = 1$ g/cm^3. 5

(b) Explain how fuel pin arrangement affects power density of the core. Hence, calculate the core-averaged values of volumetric heat generation rate in the fuel for an infinite triangular array for a linear power rating of 17.8 KW/m and fuel rod pitch of 12.6 mm. 7

(c) What is the significance of Hydrodynamic and Thermal Boundary Layer? How can these be related? 3

2 (a) Derive the general heat conduction equation for plate fuel elements and the fuel cladding. 10

(b) Consider a steady state viscous flow in a circular tube of radius R. State the expressions for pressure drop in the developing flow region and the fully developed flow region of the boundary layer, and the assumptions made. 5

3. Show that for the maximum temperature limit and symmetric boundary conditions linear heat rating is greater for an annular fuel pin compared to a solid fuel pin. 10

4. Consider an incompressible, viscous flow in a channel of diameter D. Assume heat transfer due to conduction only and also assume the material properties to be temperature independent. Derive a dimensionless form of the relevant mass, momentum and energy conservation equations considering appropriate dimensionless parameters. 10

Part-II

1. (a) Why the released energy due to β decay of fission products are non-recoverable? 3

(b) Consider a CANDU reactor have the following specifications-

Core power (MWth)	% of power deposited in fuel rods	Fuel assemblies/core	Assembly lateral spacing (mm)	Fuel rods/assembly	Fuel rod length (mm)	Fuel rod diameter (mm)
2140	95	4560	280 (square pitch)	37	480	13.1

Determine-

(i) Equivalent core diameter and core length. 6

(ii) Average core power density. 2

(iii) Core-wide average linear heat generation rate of a fuel rod. 2

(iv) Core-wide average heat flux at the interface between the rod and the coolant. 2

2. (a) What do you mean by microscopic and macroscopic fission cross section? 2

(b) What is the role of pressuriser in a PWR primary coolant circuit? 3

(c) Obtain an expression for the power requirements of a PWR pump in terms of the flow rate. 2

(d) For a heavy-water moderated reactor with uniform distribution of enriched UO_2 fuel in a cylindrical reactor core, calculate the power generated in a fuel rod located half-way between the centreline and the outer boundary. The salient parameters for the core are as follows- 8

Core diameter (m)	Core height (m)	Fuel pellet outside diameter (m)	Maximum thermal-neutron flux (neutrons/cm^{2}s)
2.44	6.10	0.01524	10^{13}

Assume- Bessel function $J_0\,(1.202) = 0.6719$ and $q'''(\mathrm{W/m^3}) = 7.27\times 10^{-6}\phi$

3. (a) Briefly discuss about the different phases of fuel-coolant interaction during severe accident scenario in a nuclear reactor. 5

(b) Derive an analytical expression for the expansion work done during a FCI scenario by assuming coolant and fuel expanded as one system in thermal equilibrium adiabatically and isentropically 15

Or

4. Derive the energy conservation equation across the surface of discontinuity within a control volume. Assume the jump in the kinetic energy and stress work are negligible. 20