

ENGINEERING PHYSICS 3D03

DAY CLASS

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DURATION OF EXAMINATION: 3 Hours

McMASTER UNIVERSITY FINAL EXAMINATION

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THIS EXAMINATION PAPER INCLUDES 3 PAGES AND 8 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

Special Instructions:

1. Open Book. All reference material allowed.
2. All hand calculators allowed.
3. Answer **any six (6)** questions.
4. All questions have equal weight.

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1. Using the notation ${}_Z^AX$ write decay equations for alpha, beta(-), beta(+) and gamma decay. Qualitatively sketch a plot of the nuclides on a chart which has N (the number of neutrons in the nucleus) along the x-axis and Z (the number of protons in the nucleus) along the y-axis. Identify those parts of this chart where the nuclides are primarily i) β^- ii) β^+ and iii) α emitters. Using the chart you have drawn state what you expect will be the dominant particles emitted by the nuclides produced from fissioning of U-235 (i.e. the fission product nuclides).
 2. Uranium-235 has a half-life of 700 million years. The current abundance of this nuclide found in nature is 0.71%. Calculate how many billions (10^9) of years ago the concentration of Uranium-235 was 5%. Describe a plausible scenario under which the uranium deposit at Oklo in Gabon, West Africa became a natural fission reactor. Assume this reactor started at the time the U-235 abundance was 5% and operated for 100 million years. If, after 100 million years of operation the U-235 abundance was reduced by 30% of its original value, what would be the current abundance of U-235 in the uranium deposits at Oklo?
 3. Derive the general solution for the neutron flux in a bare finite cylindrical reactor of height H and radius R. If d is the neutron diffusion extrapolation distance, then show that the geometric buckling is given by:

$$B_g^2 = \left(\frac{2.405}{R+d} \right)^2 + \left(\frac{\pi}{H+2d} \right)^2 \bullet$$

Under what conditions can we approximate this buckling to be independent of d .

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4. Assuming two-energy group neutron diffusion equations to describe the neutron flux in a thermal reactor, show that the material buckling for the modified one-group reactor diffusion equation can be expressed as:

$$B_m^2 = \frac{k_\infty - 1}{M_T^2}$$

Define each of the terms appearing in the above equation. For this reactor to be critical what is the relationship between the material buckling and the geometric buckling.

5. A CANDU reactor and a PWR have the following characteristics:

	CANDU	PWR
Core radius [m]	.34	.18
Core Height [m]	6.0	.34
Gross Electrical Power [MW]	1000	1000
Thermal Efficiency [%]	32%	33%
Macroscopic Fission cross-section [cm ⁻¹]	.0053	.07
Recoverable energy from fission [MeV]	189	200

Calculate for the two reactors the average neutron flux in the cores, in units of neutrons/cm²/s, and the thermal power density in MW/m³.

6. A CANDU fuel channel operates at a power of 6000 kW with an inlet temperature of 265°C and a coolant flow through the channel of 27.65 kg/s. If the average specific heat of the coolant is 5.3 kJ/kg/°C what will be the temperature of the coolant leaving the fuel channel. If coolant boiling were to begin at a temperature of 310°C, by how much can the channel power be increased to bring the coolant just to boiling at the exit of the channel?
7. The cost of producing 1 tonne of uranium metal in uranium dioxide fuel for a natural uranium fuelled CANDU and a PWR operating on 5% enriched fuel is shown in the table below. In order to produce one tonne of enriched fuel for a PWR requires 7.2 times more ore be mined and converted to oxide as compared to CANDU fuel.

COST ITEMS	CANDU	PWR
Mining and extraction [\$/kgU]	\$65	\$65
Conversion to UO ₂ [\$/kgU]	\$8	\$16
Enrichment [\$/kgU]	-	\$120
Fabrication [\$/kgU]	\$65	\$275

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What is the cost of producing fuel containing 1 tonne of uranium metal for the two reactors? If the burnup of the CANDU fuel is 8,600 MW-days/tU and the burnup of the PWR fuel is 43,000 MW-days/tU what are the fuelling cost to produce 1 MW-day of thermal energy from the two reactors?

8. Complete fission of 1 gram of U-235 releases approximately 1Mw-day of energy. If a CANDU fuel bundle contains 20 kg of UO_2 and the uranium metal in the fuel contains 0.71 weight % of U-235 what will be the approximate mass of fission products in the fuel after the bundle has produced 100 MW-d of energy. What fraction of the initial U-235 mass in the bundle will be remaining? Assume that the fission energy is produced solely by fission of U-235. Explain why in reality there will be more U-235 remaining in the bundle than the value you calculated.

The End