GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam – Spring Semester 2020

Day 1: Radiation Physics & Transport

EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

- Please sign your name on the back of this page—

Georgia Institute of Technology

The George W. Woodruff School of Mechanical Engineering

Nuclear and Radiological Engineering/Medical Physics Program

PhD Qualifying Exam

Spring 2020

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(Your ID Code)

NE Radiation Physics and Transport

(Day 1)

Instructions

1. Use a separate page for each answer sheet using only the front side of the paper. DO NOT write on the back of the answer sheet
2. The **question nuclear and your ID Code** should be shown clearly on each answer sheet
3. **ANSWER 2 OF 3 Questions in each section; you will have answers for 2 Radiation Physics questions and 2 Transport questions**
4. Staple your question sheet to your answer sheet and turn in

Radiation Physics (Answer two out of three questions below)

RP01

The Geiger–Marsden experiments (also called the Rutherford gold foil experiment) were a landmark series of experiments by which scientists discovered that every atom has a nucleus where all of its positive charge and most of its mass is concentrated. They deduced this by measuring how an alpha particle beam is scattered when it strikes a thin metal foil. In this experiment, alpha particles were used to bombard and scatter from a gold foil. What is the minimum energy the alpha particle needs to approach (just touch) the surface of a gold nucleus? HINT: the radius of a proton is approximately1.25fm

RP02

Consider the following beta decay chain.

$$^{210}_{82}Pb \xrightarrow{22\ years} {}^{210}_{83}Bi \xrightarrow{5\ days} {}^{210}_{84}Po$$

A sample contains 20 MBq of $^{210}_{82}Pb$ and 10 MBq of $^{210}_{83}Bi$ at time zero, (a) Calculate the activity of $^{210}_{83}Bi$ at time t = 10 d. (b) If the sample were originally pure $^{210}_{82}Pb$. how old would it have been at time t = 0?

RP03

A neutron is produced when a deuteron absorbs an energetic gamma photon via the reaction of $^{2}\mathrm{H}(\gamma, \mathrm{n})\ ^{1}\mathrm{H}$. Given that the incident photon's energy is 30 MeV and that the $^{2}\mathrm{H}$ nuclide is at rest, (a) estimate the angular distribution of the neutrons w.r.t. the incident gamma photon, and (b) calculate the energy of the neutron if it is emitted in the same direction as that of the incident photon.

<u>Radiation Transport (Answer two out of three questions below)</u>

<u>RT01</u>

(a) Write down the energy and time independent transport equation in a slab of thickness a $(0 \le z \le a)$ in which scattering is isotropic.

(b) Then, derive the P_1 equations starting from your transport equation from part (a) above by assuming the angular flux is linearly anisotropic. Ignore the boundary conditions.

<u>RT02</u>

Given the P_2 equations below show that the continuity of the angular flux moments at an interface is inconsistent with the P_N equations when N is even (2).

$$\frac{\partial \psi_1}{\partial z} + (\sigma - \sigma_s)\psi_0 = S_0$$

$$\frac{2}{3}\frac{\partial \psi_2}{\partial z} + \frac{1}{3}\frac{\partial \psi_0}{\partial z} + (\sigma - \sigma_s f_1)\psi_1 = S_1$$

$$\frac{2}{5}\frac{\partial \psi_1}{\partial z} + +(\sigma - \sigma_s f_2)\psi_2 = S_2$$

<u>RT03</u>

Starting from the integro-differential transport equation, prove that the sum of the transmission probability T and the first-flight collision probability P for an incident flux $\Gamma = 1/2\pi$ impinging on the boundary (∂V) of a volume V is 1, where the escape and collision probabilities are defined as:

$$T = \frac{\oint_{\partial V} ds \int_{\hat{n}^+ \cdot \hat{\Omega} > 0} d\hat{\Omega}\left(\vec{J}^{uc}_{out} \cdot \hat{n}^+\right)}{\oint_{\partial V} ds \int_{\hat{n}^- \cdot \hat{\Omega} > 0} d\hat{\Omega}\left(\hat{\Omega}\Gamma \cdot \hat{n}^-\right)}$$

$$P = \frac{\int_V d\vec{r}\, \phi^{uc}(\vec{r})\sigma(\vec{r})}{\oint_{\partial V} ds \int_{\hat{n}^- \cdot \hat{\Omega} > 0} d\hat{\Omega}\left(\hat{\Omega}\Gamma \cdot \hat{n}^-\right)}$$

J^{uc}_{out} is the uncollided outgoing angular current on the boundary ∂V ad $\phi^{uc}(\vec{r})$ is the uncollided scalar flux at point $\vec{r}$.