Notes From 2013 Qualifying Exam

Detection

Problem 1 – A particle wavelength was given, I believe it was for a neutron, and it was asked to find the corresponding kinetic energy. It may have also included a part B for either a particle or zero rest mass or a relativistic particle. These are both one step solutions.

Non Relativistic Case

$$E = \frac{hc}{\lambda}, h = 4.135x10^{-5}[ev * s], \lambda\ in\ meters, c = 2.9979x10^{8}\frac{meters}{second}$$

Relativistic Case

$$\lambda = \frac{hc}{\sqrt{E_{total}^2 - E_{rest}^2}}$$ -Keep the units consistent, remember $KE = \sqrt{E_{total}^2 - E_{rest}^2}$

Zero Rest Mass, Purely Kinetic Energy

$$\lambda = \frac{hc}{E}$$

Problem 2 - Annihilation of positron-electron pair, calculate resulting energy for two photons. For example a 5 MeV electron with positron at rest:

Conservation of Momentum:

$$P_{e^-} = P_{\gamma 1} + P_{\gamma 2} = \frac{E_1}{C} - \frac{E_2}{C}\ (these\ will\ be\ in\ opposite\ directions)$$

$P_{e^-}C = \sqrt{T_o(T_0 + 2m_oc^2)} = E_1 - E_2$, recall $E^2 = (Pc)^2 + (m_oc^2)^2\ and\ E^2 = (T + m_oc)^2$

Conservation of Energy:

$$(T_o + m_oc^2) + m_oc^2 = E_1 + E_2$$

Solve:

$$6.022\ MeV = E_1 - E_2$$

$$5.49\ MeV = E_1 + E_2$$

$$E_1 = 5.75\ MeV, E_2 = 0.27\ MeV$$

Problem 3 – Activity and production calculations, I don't remember the specific problem but I think it used this equation which is valid for all single production scenarios:

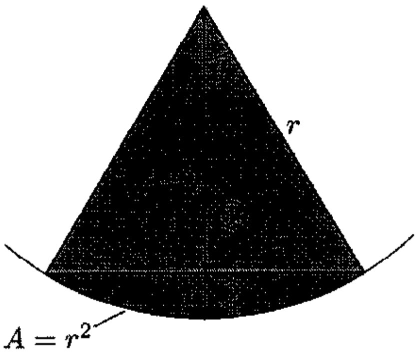
$$\frac{dn}{dt} = -\lambda n + R, \qquad R\ is\ the\ rate\ of\ production\frac{atoms}{time}$$

$$n = n_o e^{-\lambda t} + \frac{R}{\lambda}\left(1 - e^{-\lambda t}\right)$$

$$Yielding\ \alpha(activity) = \alpha_o e^{-\lambda t} + R\left(1 - e^{-\lambda t}\right)$$

$$for\ \alpha_o = 0, R\ will\ be\ maximum\ achievable\ activity$$

Problem 4 – This one I'm really fuzzy on, but it used a beam of alpha particle into specified detector geometry. The cross section was given in the form $\sigma = \frac{x(some\ value)}{steradian}$, I remember using the basic relation below to determine what solid angle corresponded to the detector window after the particle moved through a collimator of some kind. I have no idea what the dimensions were however.



Problem 5 – This was stopping power, $\frac{DE}{Dx}$, related to I believe a deuteron, proton, and alpha particle. The following form was given and some basic questions were asked about how the penetration and energy deposition changed for each particle with speed. It's a pretty basic relationship, so I'll leave this as is. I think Hassanein used to give this on his final exams in 520. I don't know if this was the exact equation so please change as needed. It should be somewhere in Hassanein's 520 notes or homework.

$$\frac{DE}{Dx} = C\left(\frac{Z}{v}\right)^2$$

Materials

Problem 1 – Calculate the $E_{\gamma_{recoil}}$ from an (n,γ) interaction in Fe-56.

$$P_{recoil} = (m_n + m_{atom})V_{recoil} = P_\gamma = \frac{E_\gamma}{C}$$

$$E_{recoil} = \frac{E_\gamma^2}{2(m_n + M_{atom})c^2} = \frac{P_{recoil}^2}{2(m_n + M_{atom})}$$

Problem 2 – Stopping power and range calculation. Given $S = C + KE^{\frac{1}{2}}$. You need to calculate:

$$R = \int \frac{dE}{\frac{dE}{dx}} \; from \; E_i \; to \; 0. \; Therefore \; R = \int \left(\frac{dE}{C + KE^{0.5}}\right)$$

$$R = \frac{2K\sqrt{E} - 2C\ln(C+K\sqrt{E})}{K^2} \; evaluated \; at \; the \; limits \; E_i \; to \; zero$$

E increase -> Range increases

K increases -> Range decreases

C increases -> Range decreases

Problem 3 – Calculating dpa/s given a damage cross section in Fe. Pretty much you need to find the effective energy deposited by the particle given (don't remember) and then use a cut off for displacement, I chose 25 eV I think, and you will get a specified number of displacements per interaction. Now use the cross section and flux given to determine the rate of interaction and likewise the dpa/second.

Use $T_{max} = \frac{4m_1m_2}{(m_1+m_2)^2} E_o$, basic energy transfer here

Problem 4 – Effect on sputtering when changing a host of material properties like surface and bulk binding energy, ion/target mass, velocity, charge, effective charge, etc. There is too much to really sum up in a short solution so I would suggest looking at the Matsunami semi empirical model to get an idea of how these are related. It's page 224 in Nastasi's book.

Thermal Hydraulics

Problem A – Laminar and turbulent profiles along with Reynold's stress.

Problem B – Case of sudden heating solution, application importance to reactor transients.

Problem C – Temperature profile in single phase heat transfer, predict onset of boiling at given heating rate.

Problem D – CVA analysis, loss of coolant or heat sink, what happens?

Problem E – Non-dimensional numbers from field equations and give valid uses for each.

Neutronics

Problem 1 – 2-group equation given with table of values, anyone remember specifics?

Problem 2 – Point kinetics equation given along with heat generation, don't remember the goal here.