University of Dhaka
Department of Nuclear Engineering

3rd Year 2nd Semester B.Sc. (Engg.) 2023
Course Code: NE-3204
MATLAB+LabVIEW
Assignment, Submission Date: August 13, 2023

Time: N/a — Full Marks: 30

Answer all questions

1. (a) Calculate the binding energy of isotopes using MATLAB. Beware to subtract binding energy for electrons if you are using atomic masses. **(3)**

   (b) Plot the terms of the semi-empirical mass formula (and compare with experimental data[1]). The formula should include contributions from volume, surface, Coulomb, asymmetry, pairing, and other effects. Please reference the values you use for fitting coefficients. **(10)**

   Note:
   The empirical mass formula is usually given[2] in terms of the binding energy:

   $$B(A, Z) = a_v A - a_s A^{2/3} - a_c \frac{Z(Z-1)}{A^{1/3}} - a_a \frac{(N-Z)^2}{A} + \delta + \eta,$$

   where the coefficients a_i are to be determined (by fitting the mass data) with subscripts v, s, c, and a referring to volume, surface, Coulomb, and asymmetry, respectively. The last but one term represents the pairing effects,

   $$\delta = \left\{(-1)^Z + (-1)^N\right\} \frac{a_P}{A^{1/2}},$$

   where coefficient a_p is also a fitting parameter. The final term, η, is the shell term, positive if N or Z approaches a magic number. A set of values for the five coefficients in the equation is,

   Table 1: A set of values for the fitting coefficients.

a_v/MeV	a_s/MeV	a_c/MeV	a_a/MeV	a_p/MeV
16	18	0.72	23.5	11

   A standard plot might look like the Fig. (1). Note that the discrete data points from the experiment (reference missing) are scatter-plotted. Use the `hold on` command to plot multiple data lines on the same figure.

2. (a) Perform a simulation and study of (i) Range-energy curve for beta particles e.g., in air, polyethylene, aluminum, iron, lead, etc. (ii) Bremsstrahlung fraction-energy curve for beta particles.

   Note:

[1] The data is given as the attachment `binding_energy_per_nucleon.csv`

[2] von Weizsäcker, C. F. (1935). "Zur Theorie der Kernmassen". Zeitschrift für Physik (in German). 96 (7–8): 431–458.

The range $R\,(\mathrm{mg/cm^2})$ for beta particles of maximum energy E is given by the empirical relations (reference missing),

$$R = 412E^{1.265-0.0954\ln E}, 0.01\mathrm{MeV} \le E \le 2.5\mathrm{MeV}$$
$$R = 530\mathrm{E} - 106, E > 2.5\mathrm{MeV}$$

The range of beta particles as a function of energy is plotted for air, polyethylene, aluminum, iron, and lead in Fig. (3). **(10)**

(b) Show that the stopping power for beta particles in sodium iodide due to electronic ionization and radiative loss (bremsstrahlung) equal at ~ 17.5 MeV. **(7)**

Note:

The stopping power for electrons is due to the electronic ionization S_e and radiative loss S_r due to bremsstrahlung (reference missing)

$$S_e(E) = -\frac{dE}{dx} = \frac{2\pi r_e^2 m_e c^2 N z^2 Z}{\beta^2}\left\{\begin{array}{c} \ln\left(\frac{m_e v^2 E}{2I^2(1-\beta^2)}\right) - \ln 2\left(\beta^2 - 1 + 2\sqrt{1-\beta^2}\right) \\ +(1-\beta^2) + \frac{1}{8}\left(1-\sqrt{1-\beta^2}\right) \end{array}\right\}$$

$$S_r(E) = -\left.\frac{dE}{dx}\right|_r = \frac{(z+1)z\rho E}{137 m_e^2 c^4}\left[4\ln\left(\frac{2E}{m_e c^2}\right) - \frac{4}{3}\right]$$

in terms of the atomic number of the projectile z and speed v; r_e is hte classical electron radius; Z and I are the target effective atomic number and the ionization potential, respectively (for NaI, $Z = 45.798$ and $I = 452$ eV). The factor β is given by $\beta = \frac{v}{c} = \sqrt{1 - \frac{1}{\gamma^2}}$.

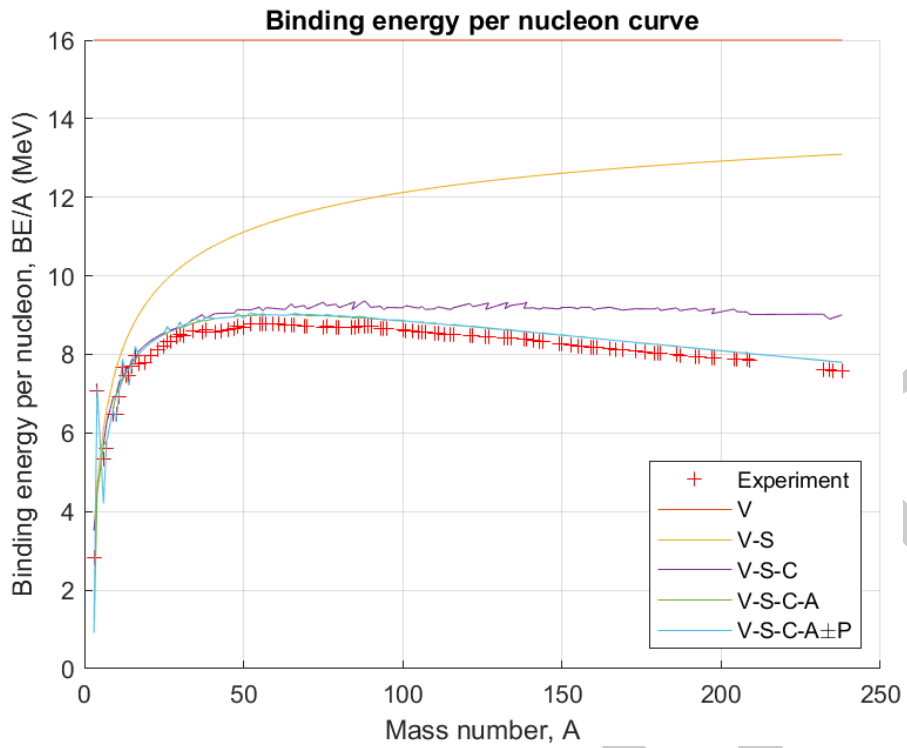

Figure 1: The contributions to B/A from various terms of the semi-empirical mass formula.

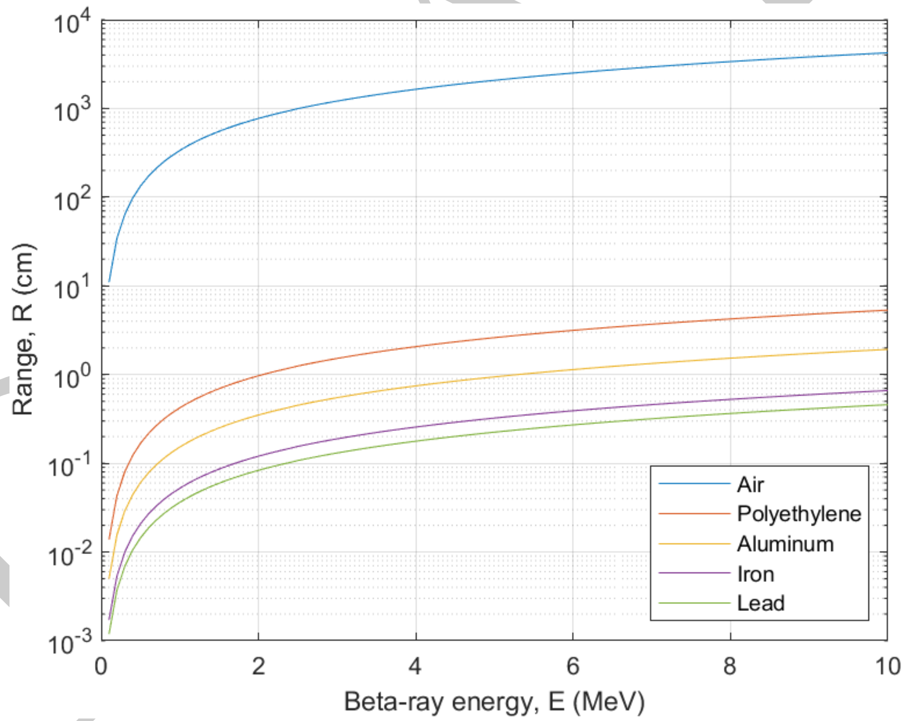

Figure 2: The range of beta particles as a function of energy.

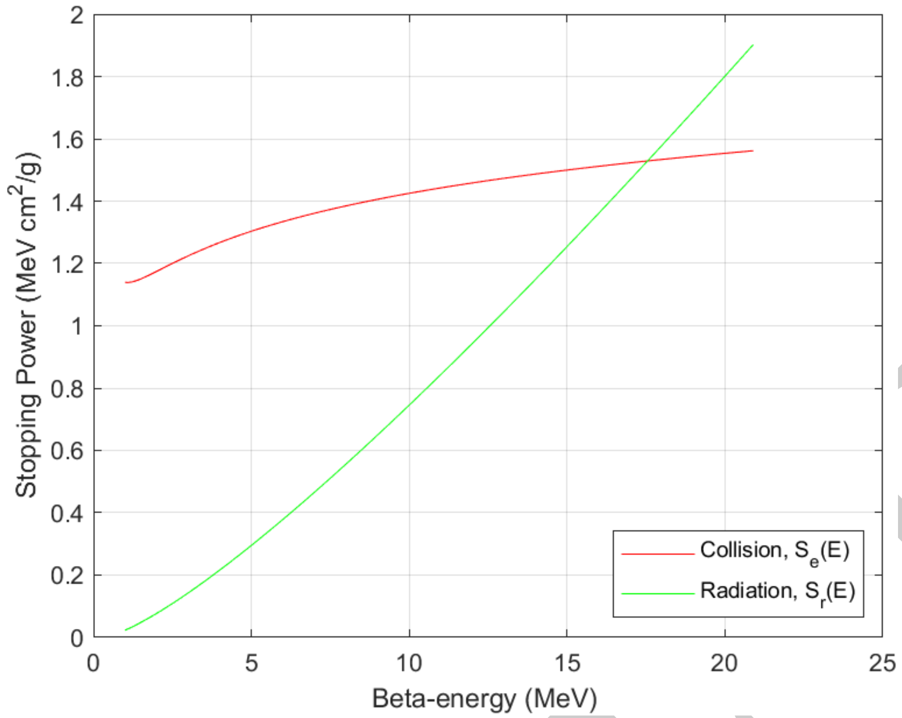

Figure 3: Stopping power for beta particles in sodium iodide (NaI).