Howework 1: OM calculations

1. **OM calculation.** Let us consider the elastic scattering of ^{4}He on ^{208}Pb at laboratory energies of 5, 10, 22, 27 and 60 MeV. We plan to analyze this reaction using the optical model (OM). Our optical model potential will consist of a standard Woods-Saxon form, with both real and imaginary parts, and a Coulomb potential generated by a sphere of uniform charge. The OM parameters with the parameters are listed in the table below. Note that the radii of the nuclear part are already absolute radii (not reduced radii).

System	V_0 [MeV]	R_0 [fm]	a_0 [fm]	W_v [MeV]	R_i [fm]	a_i [fm]	r_c [fm]
^{4}He+^{208}Pb	96.44	8.15	0.625	32	7.20	0.42	1.2

   (a) Complete the following table, with the values of the c.m. energy ($E_{\rm cm}$), wavenumbers (k), Sommerfeld parameters (η) and the distance of closest approach for a Coulomb head-on collision (the values at 5 MeV are given for guidance)

$E_{\rm lab}$ (MeV)	$E_{\rm cm}$ (MeV)	k (fm^{-1})	η	r_0 (fm)
5	4.91	0.960	23.1	48.1
10				
22				
27				
60				

   (b) Plot the total real potential (Coulomb and nuclear part). Compare with the estimate:

$$V_b \approx \frac{Z_1 Z_2 e^2}{R_b}; \qquad R_b \approx 1.44(A_1^{1/3} + A_2^{1/3}) \text{ fm}$$

   (c) Introduce the OM parameters in FRESCO and run the calculation at the energies indicated in the first item. For each energy, plot the differential elastic cross section (`fort.201`). Commment on the evolution of this observable with the incident energy, and relate this behaviour with the quantities calculated in the first item.

   (d) Using the information contained in the output file `fort.7`, calculate and plot the modulus of the S-matrix. Commment on the evolution of this observable with the incident energy, and relate this behaviour with the quantities calculated in the first item.

   (e) Using the output file `fort.56`, plot the values of the reaction (third column) and absorption (second column) cross sections as a function of the total angular momentum (note that, since the internal spins are both zero, $J = L$ in this case). Why are they equal in this calculation?

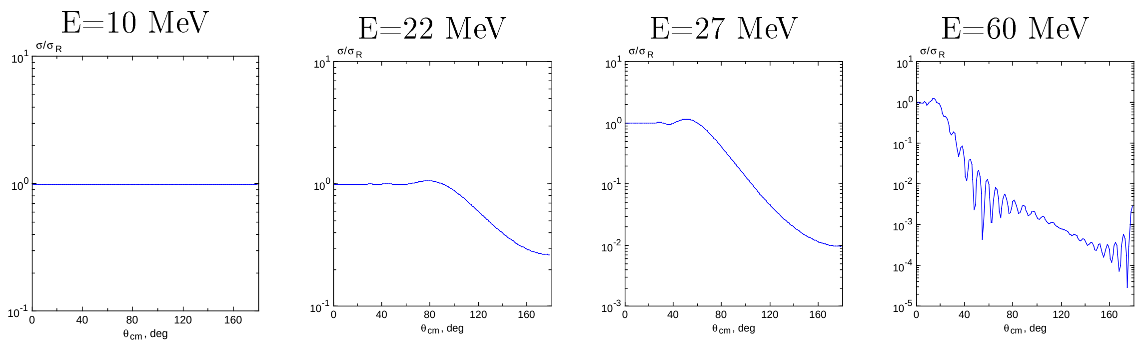

Figure 1: Elastic differential cross sections relative to Rutherford cross section at $E_{\rm lab}$=10, 22, 27 and 60 MeV (from left to right).

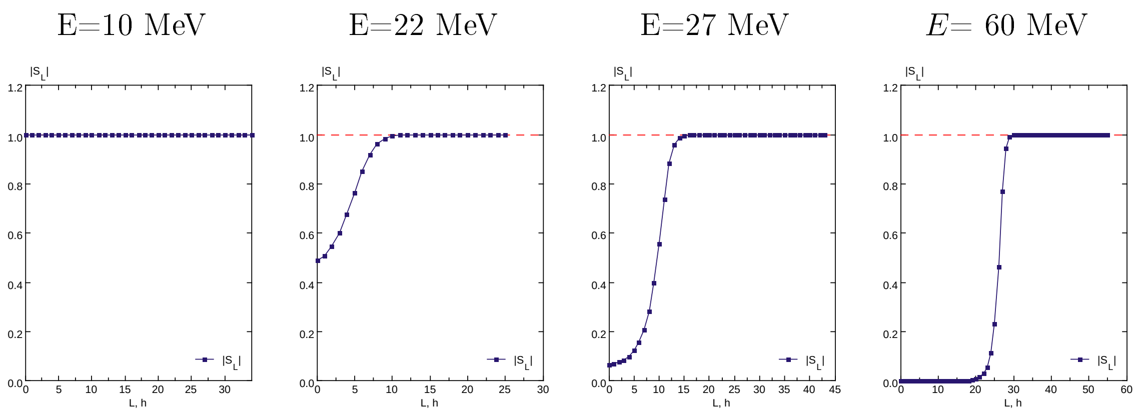

Figure 2: Modulus of the elastic S-matrix as a function of the total orbital angular momentum L for different energies.

(f) At E=27 MeV, the elastic angular distribution displays a typical Fresnel diffraction pattern. A prerequisite for the observation of this pattern is that $L_g \gg 1$ and $\eta \gg 1$. Is this consistent with the value of η calculated in the first item? The grazing angular momentum can be estimated from the condition $|S_L|^2 = 0.5$ ($|S_L| = 0.707$). Calculate this value from the `fort.7` or FRESCO main output

2. SFRESCO **fit**. Fetch the experimental data for the ^{6}He+^{208}Pb reaction at 22 MeV or 27 MeV (you can find them at the EXFOR database: `http://www.nndc.bnl.gov/exfor/exfor.htm`). Using the potential parameters given in the previous exercise, perform an OM calculation for this system, and verify that this calculation fail to reproduce the data. Using the code SFRESCO, perform a parameter search to improve the agreement with the data. To reduce the number of adjustable parameters, fix the values of the real and imaginary radii. From the extracted values of the diffusiveness parameters, what can we conclude regarding the nature of the couplings affecting the elastic scattering?