List of practicals in Nuclear and Particle Physics (DSE-II) in Scilab.

1) **Nuclear Radius.** Plot nuclear radii as a function of its atomic mass number. That is plot R vs A. Since nucleon density is constant over the nucleus (nucleon are uniformly distributed over the nucleus) $\boldsymbol{R = R_0 A^{1/3}}$. Take R_0 = 1.2 fm.
2) **Nuclear Charge Distribution.** Plot the following nuclear charge distribution: $\boldsymbol{\rho = \rho_0 e^{-\ln(2)\left(\frac{r}{R}\right)^2}}$. That is plot **ρ/ρ₀** with **r**, r given in units of R, the mean nuclear radius; $R_0\ A^{1/3}$.
3) **Nuclear Form Factor**. Evaluate the nuclear form factor F(q) based on the above charge distribution, $\boldsymbol{\rho = \rho_0 e^{-\ln(2)\left(\frac{r}{R}\right)^2}}$. Plot the form factor F(q) as a function of q; where q is the change in momentum due to scattering, $\boldsymbol{F(q) = \frac{4\pi}{q}\int \sin(qr')\rho(r')r'dr'}$.
4) **Mass Parabola.** The minimum atomic number in the mass parabola is given by $\boldsymbol{z_{\min} \simeq \frac{A}{2}\left(1 + \frac{1}{4}A^{\frac{2}{3}}\frac{a_c}{a_{sym}}\right)^{-1}}$. Plot z_{min} vs A. Take a_c = 0.72 MeV and a_{sym} = 23 MeV. Do you find z_{min} ~ A/2 for small A and < A/2 for large A?
5) **Semi-Empirical Mass Formula.** Plot B/A vs A for any Z. (Say Z = 56) $\boldsymbol{B = a_v A - a_s A^{\frac{2}{3}} - a_c Z(Z-1)A^{-\frac{1}{3}} - \frac{a_{sym}(A-2Z)^2}{A} + \delta}$. Take a_v = 15.5 MeV, a_s = 16.8 MeV, a_c = 0.72 MeV, a_{sym} = 23 MeV, a_p = 34 MeV and δ = 0 for odd A, $\delta = a_p A^{-3/4}$ for even N, even Z and $\delta = -\ a_p A^{-3/4}$ for odd N, odd Z. Plot separately: a. volume terms only, b. volume + surface terms, c. volume + surface + coulomb terms, and finally d. volume +surface + coulomb + symmetry terms.
6) **Nuclear Potential Energy.** Plot V assuming a point nucleus and assuming uniform spherical charge distribution. $\boldsymbol{V_{pc} = -\frac{Ze^2}{4\pi\epsilon_0}\frac{1}{r}}$. $\boldsymbol{V_{sph} =}$

$-\frac{Ze^2}{4\pi\epsilon_0}\frac{1}{R}\left\{\frac{3}{2}-\frac{1}{2}\left(\frac{r}{R}\right)^2\right\}$. For convenience treat $\frac{e^2}{4\pi\epsilon_0}=1$ and chose scale of r in suitable range of R.

7) **Range of Force.** Plot Range of a force R vs mass of its carrier particle m_xc^2. $\boldsymbol{R=c\Delta t=\frac{hc}{2\pi m_x c^2}=\frac{197.3\ MeV.fm}{m_x c^2}}$.

8) **Mean radius squared**. Plot mean of radius squared vs A, (i.e. expectation value of radius squared vs A) for the nucleus, assuming nucleus as a uniform charged sphere. $\boldsymbol{<r^2>=\frac{3}{5}R^2=\frac{3}{5}R_0^2A^{\frac{2}{3}}}$.

9) **Gaussian Probability Distribution.** Plot the Gaussian probability distribution for a standard deviation σ = 0.01 and mean μ = 0.1. $\boldsymbol{P=\frac{1}{\sqrt{2\pi\sigma^2}}e^{-\frac{(x-\mu)^2}{2\sigma^2}}}$.

10) **Kinetic energy of alpha particle.** Plot Kinetic energy of alpha particle T_α vs mass number A. Assume Q value is 5 MeV. $\boldsymbol{T_\alpha=Q\left(1-\frac{4}{A}\right)}$.

11) **Neutrino Mass.** Plot variation in Q if $m_\nu c^2$ varies between 0.01 to 0.08 MeV. $\boldsymbol{Q=0.782\ MeV-m_\nu c^2}$. For the decay n $\rightarrow$ p + e^- + anti-ν.

12) **Power radiated by accelerated charge.** Plot power radiated (P) by an electric dipole of unit strength, depicted by the following relation, vs frequency, ω. $\boldsymbol{P=\frac{1}{12\pi\epsilon_0}\frac{\omega^4}{c^3}d^2}$.

13) **Scattering Cross Section.** Plot Rutherford differential scattering cross section vs sine of scattering angle, θ. $\boldsymbol{\sigma_{diff}=\frac{d\sigma}{d\Omega}=\left(\frac{zZe^2}{4\pi\epsilon_0}\right)^2\left(\frac{1}{4T_a}\right)^2\frac{1}{\sin^4\frac{\theta}{2}}}$. Use KE of alpha particle = T_a = 10 MeV. Use Gold nucleus for Z.

14) **Fusion Reaction.** Plot plasma Debye length L_D vs particle concentration n. Take n in units of 10^{27} /m^3. Mean KE per particle = 10 keV. T at the order of 10^8 K. $\boldsymbol{L_D=\frac{4\pi\epsilon_0}{e^2}\sqrt{\frac{kT}{4n}}}$.

15) Synchrotron Condition. Plot ν (frequency) vs B (magnetic field) for protons at radius r = 0.25 m. $\boldsymbol{\nu = \frac{eBc^2}{2\pi}\sqrt{e^2r^2B^2c^2 + m^2c^4}}$.