1. Dimensional analysis: diffusion of a zinc coating

   A very thin zinc coating of thickness δ is diffusing into a thick (relative to the coating) sheet of steel. When they are heated, the zinc diffuses into the steel sheet to make a zinc-iron alloy. For long timescales, the solution to the time-dependent diffusion equation is the "Shrinking Gaussian":

$$C = \frac{\beta}{\sqrt{\pi D t}} \exp\left(-\frac{x^2}{4Dt}\right)$$

   where β is the amount of zinc per unit area, equal to the product of initial concentration of zinc in the coating and coating thickness. Assume that zinc and iron are completely miscible with a uniform diffusion coefficient throughout.

   (a) Write all of the units of all of the dimensions involved (*e.g.* C, β, x, etc.).

   (b) Write the number of dimensions and the number of base units, and use the Buckingham pi theorem to determine the number of dimensionless parameters.

   (c) Construct your dimensionless parameters, keeping at least the concentration C and distance from the center x, and eliminating as many others as possible.

   Note: you *may* have square roots, *i.e.* exponents which are multiples of $\frac{1}{2}$, not just integers.

   (d) Rewrite the Shrinking Gaussian solution above in terms of your new dimensionless parameters, *i.e.* $\pi_C = ...$ Include all coefficients in all parts of the Shrinking Gaussian.

   (e) Draw a graph of this dimensionless solution, labeling the maximum dimensionless concentration and the width (e.g. full width at half maximum).