Screening, trees in a forest, Debye and polymer coils in solution.

Debye considered screening of the energy of interaction (force) between two charged particles, q^+, in a solution that contained ions such as an aqueous salt solution (say Na^+ Cl^-). The screening length, λ, for this situation, scaled with the inverse of the square root of concentration of the salt, $\lambda \sim [NaCl]^{-1/2}$. For particle separations greater than the screening length the two particles did not sense the presence of each other, zero net interaction energy and force. We consider an analogy for this as a forest where the trees in the forest correspond with the salt molecules, and the two charges as two lanterns held by mute campers who want to find each other.

We also consider that the trees do not absorb light at all, but reflect in random directions. Then at a certain separation distance for the two campers, depending on the number density of trees in the forest, the two campers will not be able to find each other quickly since they will only sense a "mean-field" of light, a kind of glowing. The mean field allows the campers to know that the other camper is in the forest but not the direction to walk to find each other. The absence of a field would be complete darkness in the forest. In the analogy, there is no hope of the two campers finding each other in the absence of the mean field (in the dark) while in the presence of the mean field they can search randomly and possibly find each other.

For semi-dilute polymer solutions the mean-field is the interaction parameter χ, which is a mean of the polymer-polymer, polymer-solvent and solvent-solvent interaction energies per lattice site, l_p^3, and per kT. If χ is 0 the systems is athermal and is always miscible since the entropy terms in the Flory-Huggins equation are always negative as is the free energy of mixing. In the presence of a positive mean field, χ, the system will phase separate on cooling, just as the campers will eventually find each other even in a dense forest if they search randomly.

The semi-dilute or concentrated polymer situation differs from the salt solution and charged colloid situation of Debye in that both the "salt" and the "charged colloid" are the same thing for the polymer solution, i.e. polymer chains, in the case of semi-dilute or concentrated polymer solutions. The analogy for the polymer coil depends on identifying 2 chain units from a single chain, A, and labeling all other chain units B. Also, it is probably important to consider that the trees have kinetic energy of their own and move randomly through the solution. So the trees in the forest might become identical "campers" except that only two of the campers have lanterns (since we consider one binary interaction at a time) and we consider that only these two (who come from the same campground) are looking for each other. Also, none of the campers absorb light so they are perfect reflectors in random directions. Again there is a screening length that depends on the concentration of wandering campers (that were trees for the Debye solution). Also, there remains a difference between the presence or absence of light in terms of the possibility of finding each other (phase separation).

The analogy might be closer to polymer chains if a grouping of N campers from the same camp ground were linked together with a rope and if the two campers with lanterns were separated by a number of campers along this rope (long range interaction). Topological problems must be solved by additional dimensions of search, i.e. the roped campers must float in 3-d space and be able to wander in this space. Further, it must be considered that all of the campers in the "forest"

have lanterns that can only be seen by one other camper at a time. Then, a radio homing wave at a certain frequency would probably be a more useful analogy than light for the polymer case.

Then Debye's concept of screening for charged colloids bears some resemblance in analogy to screening in polymer solutions. There are, however, some major differences. An obvious difference is that the campers are joined together by a rope. Also, obvious is that there is a difference between campers screening campers and "trees" screening campers since all of the campers are seeking some other camper from their campground (chain). The basic concept of a screening length that decreases with concentration and a mean field remain similar in the analogy, though the dependence on concentration must be different in detail since the chain scaling changes if screening is present so the concentration dependence changes due to changes in the structure of the coil.