1. Consider two particles in three spatial dimensions interacting via a very weak spherically-symmetric attractive potential $V(r)$. Show that if the potential is sufficiently weak, there is no bound state. What about two spatial dimensions; must there be a bound state for any attractive potential? And what about one spatial dimension?

2. Calculate the mean-square radius $r$ of a Cooper pair under the approximation where the momentum-space matrix elements of the interaction are $V_{kk'} = -V/L^3$ for $h^2k^2/2m < E_F + \hbar \omega_D$ and $h^2(k')^2/2m < E_F + \hbar \omega_D$ and $V_{kk'} = 0$ otherwise (i.e., that the interaction matrix elements are nonzero and constant only in the narrow region above the Fermi surface). You should be able to write your answer in terms of $\hbar$, the Fermi velocity $v_F$, and the binding energy $E$ of the Cooper pair.

   a. Find a solution to the Lond equation that has cylindrical symmetry and applies outside a line core. In cylindrical polar coordinates, we want a solution of
   
   \[ B - \lambda^2 \nabla^2 B = 0 \]
   that is singular at the origin and for which the total flux is the flux quantum:
   
   \[ 2\pi \int_0^\infty d\rho \rho B(\rho) = \Phi_0, \]
   where $\Phi_0 = 2\pi \hbar c/2e \approx 2.0678 \times 10^{-7}$ gauss-cm$^2$. The equation is in fact valid only outside the normal core of radius $\xi$.
   b. Show that the solution has the limits
   
   \[ B(\rho) \approx (\Phi_0/2\pi\lambda^2) \ln(\lambda/\rho), \quad (\xi \ll \rho \ll \lambda) \]
   \[ B(\rho) \approx (\Phi_0/2\pi\lambda^2)(\pi \lambda/2\rho)^{1/2} \exp(-\rho/\lambda), \quad (\rho \gg \lambda) \]
   In a Type II superconductor ($\xi \gg \lambda$), an externally applied magnetic field can penetrate the superconductor, but the magnetic field is confined to these very narrow flux tubes where the superconducting state (i.e., the Cooper pair) is broken. Outside the flux tube, the material behaves like an ordinary superconductor and expels magnetic field.