Setting some parameters

```
ClearAll[R, Mn, Edeut, Vzero]
e = N[10^-4];
hbarc = 198;
R = 1.93/hbarc;
Mn = 940.;
Edeut = 2.225;
```

Solving transcendental equation to get the square well height in MeV

```
Vzero = Vzero /. FindRoot[
    Cot[√Mn (Vzero - Edeut)/R] == -√(Edeut/(Vzero - Edeut)), {Vzero, 20}]
```

```
Out[478]=
38.9882
```

Defining the square well potential

```
Vtotal[r_] = If[r < R, -Vzero, 0];
potplot = Plot[Vtotal[r], {r, 0, 3 R}, PlotStyle -> Red]
```

```
Out[480]=
```

```
```
Solving the Schrödinger equation numerically for the bound state

\begin{verbatim}
In[496]:= normali = 0.75 10^4;
(* Normalization factor for the wavefunction *)
crap = NDSolve[
  \{-1/\[Mn] u''[r] + (V_{total}[r] + E_{deut}) u[r]\} == 0,
  u[\[epsilon]] == \[epsilon], u'[\[epsilon]] == 1\}, u, \{r, \[epsilon], 5 R\};
BSplot = Plot[Evaluate[normali (u[r] /. crap)],
  \{r, \[epsilon], 5 R\}, Frame -> True, PlotStyle -> Green]
\end{verbatim}

Out[497]=

Scattering states: Finding the scattering length

Let’s first plot the wavefunction at zero energy
\texttt{k = 0; normali = 0.75 \times 10^4;}
\texttt{(* Normalization factor for the wavefunction *)}
\texttt{crap = NDSolve\left\{\left(-\frac{1}{Mn} u''[r] + V_{total}[r] - k^2\right) u[r]\right\} = 0,}
\texttt{u[\epsilon] = \epsilon, u'[\epsilon] = 1\right\}, u, \{r, \epsilon, 20 \text{ R}\};
\texttt{scattplot = Plot[Evaluate[normali (u[r] /. crap)],}
\texttt{\{r, \epsilon, 5 \text{ R}\}, Frame -> True, PlotStyle -> Blue} \bigg]
\texttt{Out[491] =}

\texttt{Now let's get the scattering length using method described in class}
\texttt{ClearAll[crapA, rtest, Deriv, atest, ascatt];}
\texttt{ascatt := Module\left\{\text{atest}\right\},}
\texttt{crapA = NDSolve\left\{\left(-\frac{1}{Mn} u''[r] + V_{total}[r] u[r]\right) \right\} = 0,}
\texttt{u[\epsilon] = \epsilon, u'[\epsilon] = 1\right\}, u, \{r, \epsilon, 20 \text{ R}\};
\texttt{rtest = 4 \text{ R};}
\texttt{Deriv = D((u[r] /. crapA), r) /. r -> rtest;}
\texttt{atest = (rtest - ((u[r] /. crapA) /. r -> rtest) / Deriv) \bigg]}
\texttt{Recall that experimentally a = 5.4 \text{ fm}}
\texttt{ascatt[[1]] \text{ hbarc}}
\texttt{Out[494] = 5.26039}
The nucleons in the deuteron live most of the time outside of the range of the potential that binds them!