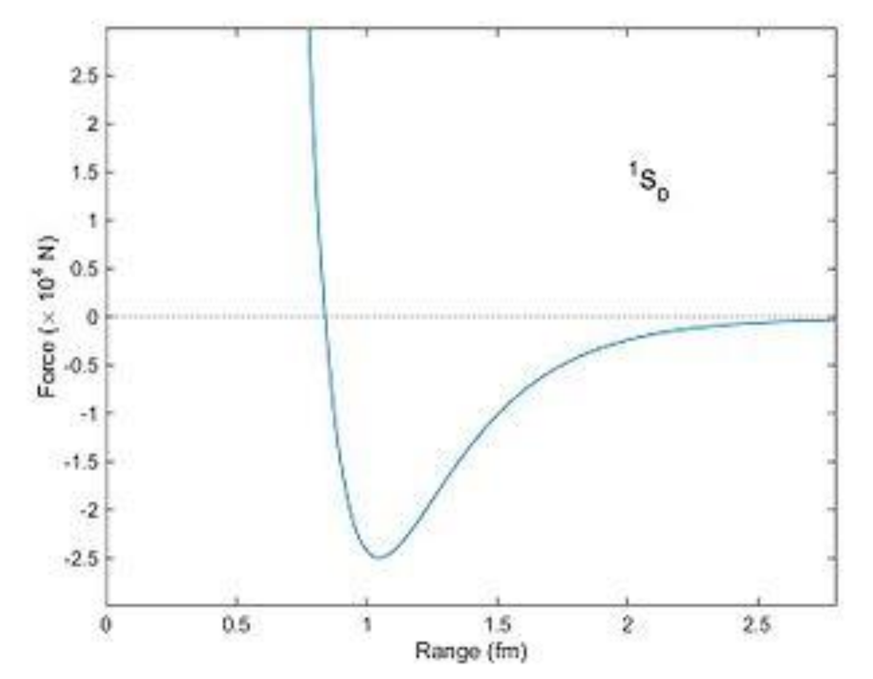
NUCLEAR FORCE

- The nuclear force: is the force that acts between the protons and neutrons of atoms



Force (in units of 10,000 N) between two nucleons as a function of distance . The spins of the neutron and proton are aligned, and they are in the S angular momentum state. The attractive (negative) force has a maximum at a distance of about 1 fm with a force of about 25,000 N. Particles much closer than a distance of 0.8 fm experience a large repulsive (positive) force. Particles separated by a distance greater than 1 fm are still attracted (Yukawa potential), but the force falls as an exponential function of distance.

PROPERTIES OF NUCLEAR FORCE

1. Short range in nature (10^-15m)
2. Electron are unaffected by strong nuclear force
3. It is charge independent and spin symmetric
4. It depends on nuclear spin
5. It is not completely central
6. Nuclear force has a repulsive core

DEUTERON AND 2 NUCLEON SCATTERING EXPERIMENTAL DATA

UNDERSTANDING NUCLEON-NUCLEON INTERACTION

Why Deuteron ?

- A deuteron (^2H nucleus) consists of a neutron and a proton
  (A neutral atom of ^2H is called deuterium.)
- It is the simplest bound state of nucleons and therefore an ideal system for studying the nucleon-nucleon interaction
- Calculate the binding energy of deuteron ?

Quantum mechanical treatment of deuteron

- Considering nucleon-nucleon potential as a three-dimensional square well,

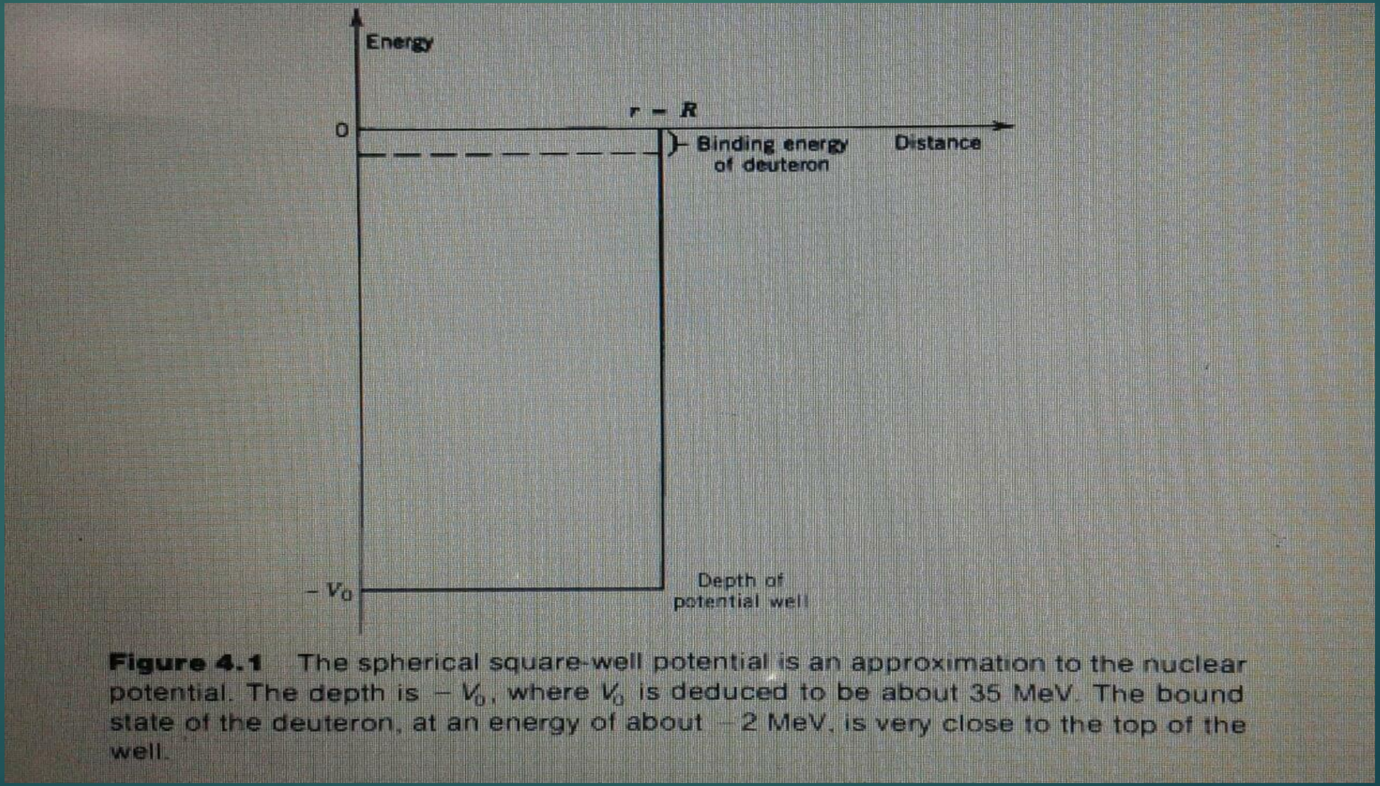


Figure 4.1 The spherical square-well potential is an approximation to the nuclear potential. The depth is $-V_0$, where V_0 is deduced to be about 35 MeV. The bound state of the deuteron, at an energy of about -2 MeV, is very close to the top of the well.

Quantum mechanical treatment of deuteron(cont.)

- For a 3 dmensional squre well potential

$V(r) = -V_o$ for $r < R$

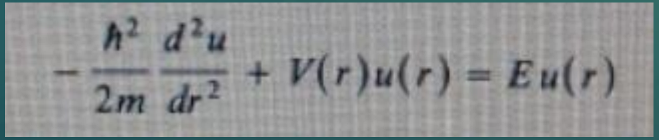
$= o$ for $r > R$

where r – separation between neutron and proton

R – diameter of deuteron

- If we define the radial part of Ψ(r) as u(r)/r, then

We can write the schrodinger eqn for the sysytem

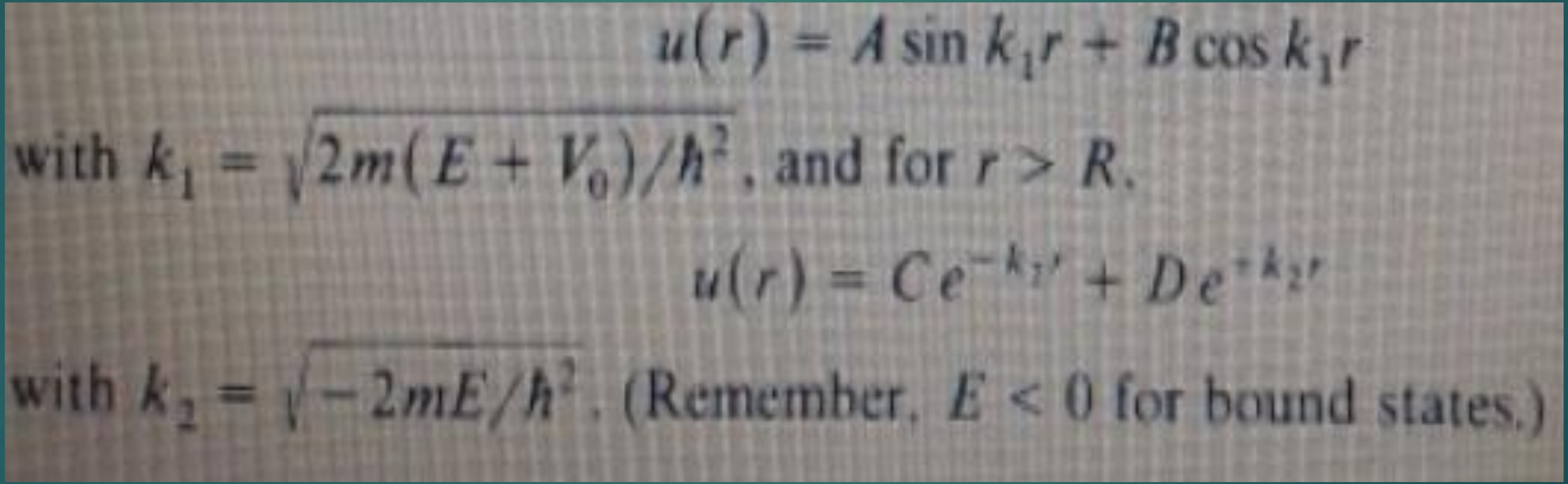


$$-\frac{\hbar^2}{2m}\frac{d^2u}{dr^2}+V(r)u(r)=Eu(r)$$

Quantum mechanical treatment of deuteron(cont.)

- The solutions can be written,

  for r < R



$$u(r) = A\sin k_1 r + B\cos k_1 r$$

with $k_1 = \sqrt{2m(E + V_0)/\hbar^2}$, and for $r > R$,

$$u(r) = Ce^{-k_2 r} + De^{+k_2 r}$$

with $k_2 = \sqrt{-2mE/\hbar^2}$. (Remember, $E < 0$ for bound states.)

Quantum mechanical treatment of deuteron(cont.)

- The deuteron wave function is shown the graph below.

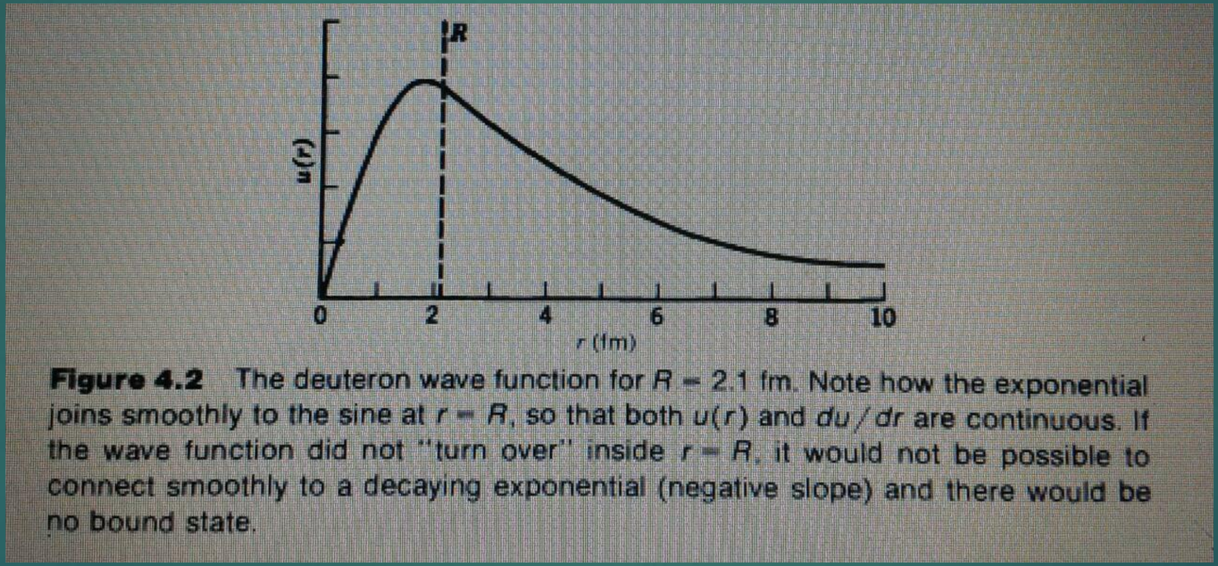


Figure 4.2 The deuteron wave function for $R = 2.1$ fm. Note how the exponential joins smoothly to the sine at $r = R$, so that both $u(r)$ and du/dr are continuous. If the wave function did not "turn over" inside $r = R$, it would not be possible to connect smoothly to a decaying exponential (negative slope) and there would be no bound state.

- The weak binding means that Ψ(r) is just barely able to "turn over" in the well so as to connect at r = R with the negative slope of the decaying exponential.

Quantum mechanical treatment of deuteron(cont.)

- Applying the continuity conditions on u and du/dr at r = R,

  we obtain

$$\boxed{k_1 \cot k_1 R = -k_2}$$

This transcendental equation gives a relationship between Vo and R.

- Solving above Equation numerically the result is **Vo = 35 MeV.**
- This is actually quite a reasonable estimate of the strength of the nucleon-nucleon potential, even in more complex nuclei.