When the electron with an orbital magnetic moment ~~interact with~~ ($\vec{\mu}_L$) interact with an external magnetic field $\vec{B}$, the corresponding change in energy would $+\vec{\mu}_L \cdot \vec{B}$. With detail calculation it is found that some of the energy levels remain undisturbed and some of the energy levels get shifted by an amount of $\pm \mu_B B$ (magnetic energy).

Zeeman effect:

When a hydrogen atom is placed in an ~~uni~~ external uniform magnetic field, its energy levels get shifted. This energy shift is known as the Zeeman effect.

~~If the intrinsic spin motion of the electron is ignored,~~

Apart from the ~~mag~~ orbital motion of the electron, it has an intrinsic spin motion. This will give rise to spin magnetic moment of the electron and this spin magnetic moment can also interact with the external magnetic field.

The Zeeman effect without the ~~spi~~ spin of the electron is called the normal Zeeman effect. When the spin of the electron is considered, we get what is called the anomalous Zeeman effect. Here we are going to focus only on normal zeeman effect.

The new energy levels of hydrogen atom in presence of the external magnetic fied is given by

$$E_{nlm} = E_n + m \mu_B B \text{ , where}$$

$E_n$ = energy of n th level in absence of external magnetic field,

$\mu_B$ → Bohr magneton,

B → external magnetic field

m → magnetic quantum number.

The energy expression does not depend on the orbital quantum number l.

For each l, the total no of m = (2l+1).

So, when a hydrogen atom is placed in a uniform magnetic field, each level with angular momentum l will split into (2l+1) equally spaced levels (as shown in the figure ~~below~~ in next page), where the spacing is given by $\Delta E = \mu_B B$; the spacing is independent of l. This equidistant splitting of the levels is known as normal zeeman effect.

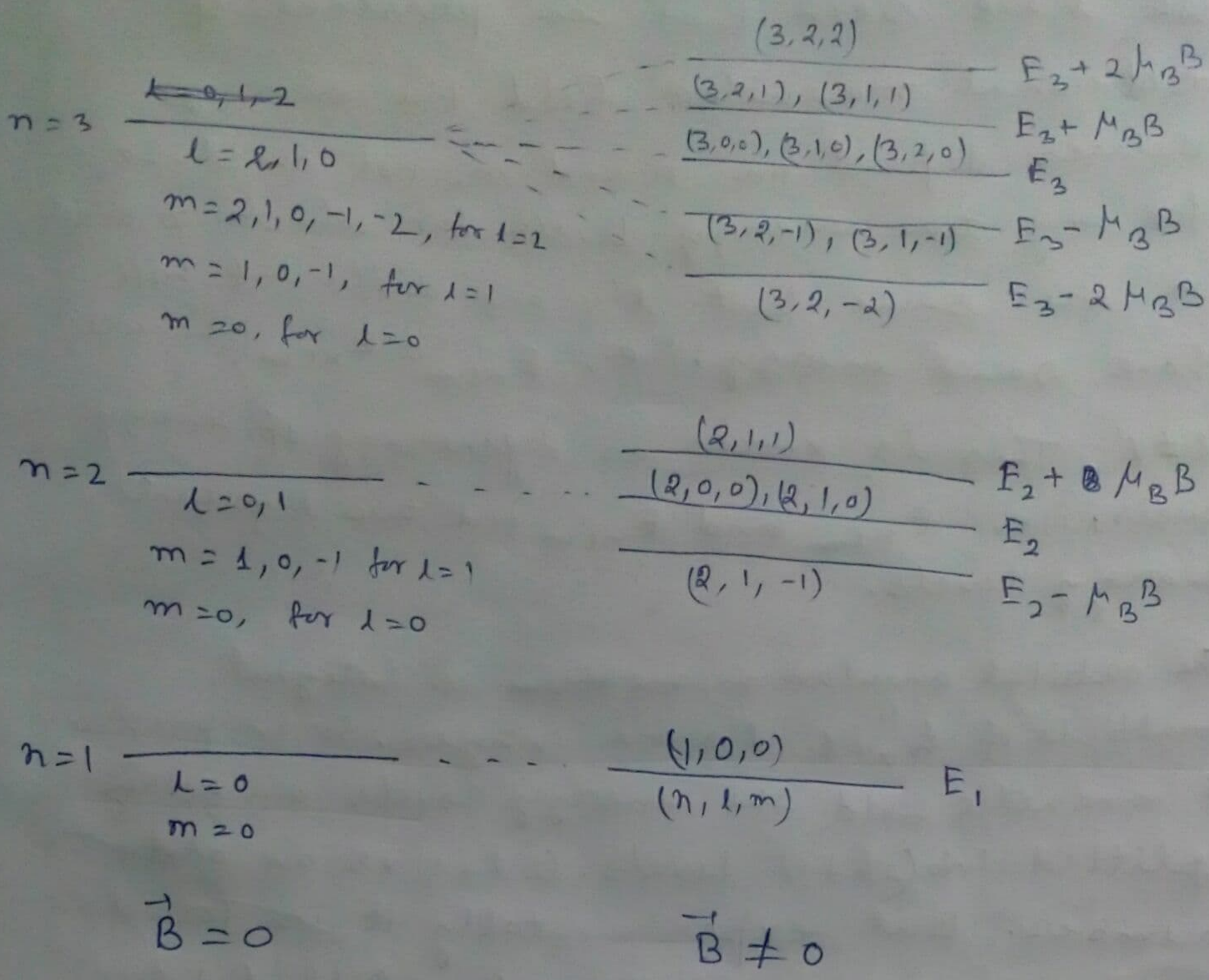


Fig: Normal Zeeman effect in hydrogen. In left, when $B = 0$, the energy levels are degenerate with respect to $l$ and $m$. When $B \neq 0$, the degeneracy with respect to $m$ is removed, but the degeneracy with respect to ~~is removed~~ $l$ persists.

# Degeneracy:

The energy levels which were earlier denoted $E_n$ are now denoted as $E_{nlm}$ where

$n \rightarrow$ principal quantum number,

$l \rightarrow$ orbital " " and

$m \rightarrow$ magnetic quantum number.

We have seen that in presence of external magnetic field the energy values depend on $n$ and $m$, not on $l$. So for any two energy levels for which $n$ and $m$ are same but $l$'s are different will have same energy, i.e., $E_{nlm} = E_{nl'm}$, where $l \neq l'$. This is known as degeneracy of energy levels, i.e., $E_{nlm}$ and $E_{nl'm}$ are two degenerate energy levels.

The orbital angular momentum is integral multiple of $\hbar$, i.e., $l$'s are integer. So in presence of magnetic field the energy levels are getting splitted into $(2l+1)$ levels. $(2l+1)$ is an odd number. But experimentally it is found that the energy levels get splitted into an even number of levels. This indicates that the angular ~~momentum~~ momentum ~~must~~ must be ~~an~~ half-integer ~~inftead~~ instead of integer. This disagreement is due to the simplifying assumption where the spin of the electron was ignored. Lifting of all the energy levels in presence of a nonuniform magnetic field is called anomalous zeeman effect. In this case the Skin angular momentum of electron is also considered.