Quantum mechanics is fundamentally different from classical mechanics.

One might think that we should start classical mechanics and then "quantize" it to reach quantum mechanics. The could work, and historically, the founders of quantum mechanics are inspired by some formulation of classical mechanics. However, conceptually, this is completely the opposite.

Quantum mechanics is more fundamental than classical mechanics. One can derive classical mechanics from quantum mechanics, not the other way around. In fact, quantum mechanics is the most fundamental we know. It governs everything we have observed so far.

This maybe a good time to distinguish basic mechanics with their applications. Basic mechanics are about the basic rules of writing down physics laws. Examples of basic rules in classical mechanics include F=ma, and least action principle, etc. They applies no matter what kind of force or system is under consideration. At the same time, physics is not just about basic rules. We have to apply these rules to describe nature. A good way of organizing this is to classify natural phenomena according the fundamental interaction involved. Therefore, for example, we have theory of gravity. The classical theory of gravity include Newton's theory and Einstein's general relativity. We don't have a complete theory of quantum gravity yet. Another example is electromagnetism. Classical theory of electromagnetism is summarized by Maxwell's equations. We have a very well developed quantum electrodynamics (QED).

We will start with the basic rules of quantum mechanics, using the simplest examples. Then we will move on to more advanced applications.

Notice that this is not quite the historical path through which quantum mechanics is developed. Unfortunately, our first encounters with quantum phenomena, in hydrogen atom, blackbody radiations, are in quite complicated systems.
Quantum Mechanics

<table>
<thead>
<tr>
<th>Quantum Mechanics</th>
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<td>(</td>
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<tr>
<td>( {0_i} ) : a set of #s dep. on how this state is made.</td>
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<table>
<thead>
<tr>
<th>Classical Mechanics</th>
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<tbody>
<tr>
<td>( x, \dot{x} ) or ( x, p )</td>
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<tr>
<td>any function of ( x, p )</td>
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**observable:** \( \hat{x}, \hat{p}, \text{spin} \) ...

**measurement:** \( |1\rangle \rightarrow |1'\rangle \)

**time evolution:** \( |1\rangle (t) \)

**theory predicts:** probability of \( |1\rangle (t) \)

\[
\downarrow \text{measurement} \\
|1'\rangle 
\]

\( x(t), \ p(t) \)
Because classical mechanics does not work!

- Stern-Gerlach exp.

- beam of unpolarized Ag atom

Ag atom has magnetic moment \( \mu \propto \hat{S} \)

Interaction energy \( \mathcal{V} = -\hat{\mu} \cdot \hat{B} \)

Classically \( M_z = \mu \cos \theta \)

Ag unpolarized \( \rightarrow \theta \) random

However, exp results show \( \mu \) take two discrete values. Or,

\[ S_z = \pm \frac{\hbar}{2} \text{ only}!! \]

\[ \hbar = 6.5822 \times 10^{-16} \text{ eV s}^{-1} \]
- Double slit
  - \( \rightarrow \) \( \rightarrow \) 
  electron beam 
  (can be one electron at a time)

- More along the actual history

  - Photo electric effect
    - Einstein
    - \( E_{\text{electron}} = h\nu - E_{\text{threshold}} \)
    - \( \nu \); frequency of photon independent of intensity

  - Black body radiation
    - Planck
    - photon, energy \( h\nu \)

  - Hydrogen atom
    - Bohr
    - why stable energy levels