Chronology of QM

Max Planck (1901)
Black-body radiation

\[ E = nh\nu, \quad n = 0, 1, 2, \ldots \]

\[ h = 6.62618 \times 10^{-34} \text{ Js} \]
Planck's constant

Einstein (1905)
Photoelectric effect

\[ hv = W + KE \]
Bohr (1913)  
Hydrogen atom

\[ U = \frac{m_e M_N}{m_e + M_N} \]

Assumption: \[ \mu V r = n \hbar \]
\[ \hbar = \frac{\hbar}{2\pi} \]

\[ \Rightarrow \quad E_n = - \frac{\mu_e e^4}{2\hbar^2} \frac{Z^2}{n^2} \quad \frac{\mu_e e^4}{2\hbar^2} = 13.6 \text{ ev} \]

\[ r_n = n^2 a_0 \]
\[ a_0 = \frac{\hbar^2}{\mu_e e^2} \approx 0.5 \text{ Å} \]
Sommerfeld (1915)
extended Bohr's model to include elliptical orbits, more general (integrable) systems.

Einstein (1918)
Critique of Bohr-Sommerfeld quantization rules — they only work for integrable systems, e.g., not for three-body problem.

Gutzwiller (1970) solved Einstein's chaotic systems.

Compton (1923)
Compton scattering

\[ p = \frac{h}{\lambda} \]
\[ E = h\nu \]
\[ p = \frac{h}{\lambda} \] 
\( E = hv \) \{ photon \}

Waves behave like particles

\[ p = \frac{h}{\lambda} \] \{ electron \}

\underline{de Broglie (1923)}

Particles behave like waves!

Explains Bohr's quantization of angular momentum:

\[ \hbar v r = n \frac{\hbar}{\lambda} \]

\[ p r = n \hbar \]

\[ \frac{\hbar r}{\lambda} = n \hbar \]

\[ \Rightarrow \ h \lambda = 2\pi r \]

Standing waves
Heisenberg (1925)
matrix mechanics
uncertainty principle
$\Delta x \Delta p_x \geq \hbar$

Schrödinger (1925)
wave mechanics

Dirac (1927)
shows approaches of H. & Sch.
are equivalent.

Born, Bohr & Heisenberg (late 1920s)
Copenhagen interpretation
QM = probabilistic theory

Objections to Einstein et al.