CHAPTER 3

EXPERIMENTAL BASIS OF QUANTUM THEORY...

my take!

Let's clean up some details from the historical introduction

- Electron Discovery - multiple experiments by Thompson

\[
\vec{F} = -q\vec{E} - q\vec{v} \times \vec{B}
\]

Presume a negatively charged particle

By adjusting $|E|$ and $|B|$ one can cause "beam" to be undeflected → straight-ahead

* adjust to hit where $\vec{E}=0$; $\vec{B}=0$ beam hit
then \[ qE = qvB \]

\[ \theta = \frac{E}{B} \]

a measure of the velocity

let just the \( E \) field deflect the beam – \( B = 0 \).

[Diagram of electron deflected by electric field with notation for deflection, \( d \)]

uniform acceleration through \( L \) region:

\[ d = \frac{qEL^2}{2mv_0^2} \]

or:

\[ \frac{q}{m} = \frac{2d}{E} \frac{v_0^2}{L^2} \]

\[ \frac{q}{m} \approx \text{known} \]

\[ \frac{q}{m} \approx 2 \times 10^{-11} \text{ C/kg} \]

- He also did \( H^+ \) ions and found \( \frac{q}{m} \approx 10^{-14} \text{ C/kg} \).
- Found charge of \( q \) from bend direction
- Found \( v \) – used later for \( m(v) \) measurements.

Why Thompson? Tubs had been around...

1. Vacuum. Poor vacuums messed up other attempts to see electrostatic deflection

THOMPSON also had a scheme for determining $q$. 

Cloud: water vapor condensed onto dust or other nucleating matter 

creates ions, reduced pressure, drops, which fall 

He counted drops and measured the electrical conductivity of the vapor 

--- crude measurement
"dissatisfied" with Thomson's results,

Robert Millikan

took the idea to an extreme of precision. 1906.

\[ qE = mg \]

\( q \) = total charge on the drop

\( E \) = electric field

\( m \) = mass of drop, measured by watching it fall in viscous medium by measuring speed.

adjust the \( E \) field to counteract gravity

• lots and lots of charges, different on each drop.

• analyzed for a common factor for each charge

\[ \text{the fundamental unit of charge} \]

\( e \) \( \sim \) 1% measurement by him.

then, \( 10^{-3} \) precision.

\[ e = (1.60217733 \pm 0.00000044) \times 10^{-19} \text{ C} \]
BLACK BODY RADIATION

1879  Stefan measured

\[ R_B = \sigma T^4 \]

\( R_B \) - power radiated by blackbody per unit area
\[ \sigma \text{ "radiant emittance"} \]

\( \sigma \) - constant, Stefan's Constant

\[ \sigma = 0.56686 \times 10^{-8} \text{ W/m}^2\text{K}^4 \]

\( T \) - temperature of blackbody, K.

5 years later, Boltzmann showed this thermodynamically

Maxwell had shown that EM radiation produces a pressure

For an energy density of \( u(\lambda, T) \), the total energy density would be

\[ u_{tot}(T) = \int u(\lambda, T) d\lambda \]

\[ u_{tot} = \sigma T^4 \]

\[ \text{radiation pressure proportional} \]

\[ \text{Calculated pressure against a piston:} \]

\[ \text{Pressure} = \sigma T^4 \]
FROM EXPERIMENT:

Energy density

\[ u(\lambda, T) \]

![Graph showing energy density as a function of wavelength \( \lambda \) and temperature \( T \). The graph has three curves labeled HOT, LESS HOT, and EVEN LESS HOT.]

All materials (pretty much -- all blackbodies)

Wilhelm Wien -- early 1880's

two phenomenological results

1. Wien's displacement law...

the peaks of the curves are at different \( \lambda \)

\[ \lambda_{\text{max}} \cdot T = \text{constant} = 2.898 \times 10^3 \text{ m} \cdot \text{K} \]

2. Wien's Radiation law.

From Boltzmann's statistical ideas + assumptions which were not justified

\[ I_{\text{Wien}}(\lambda, T) = b \lambda^5 e^{-a/\lambda T} = b f^3 e^{-a f T} \]

\( a, b, f, \alpha \) to be determined from experiment

→ not a physical theory! Thermodynamics & EM.
Fig. 3.