Ch. 4. The Particle Nature of Matter

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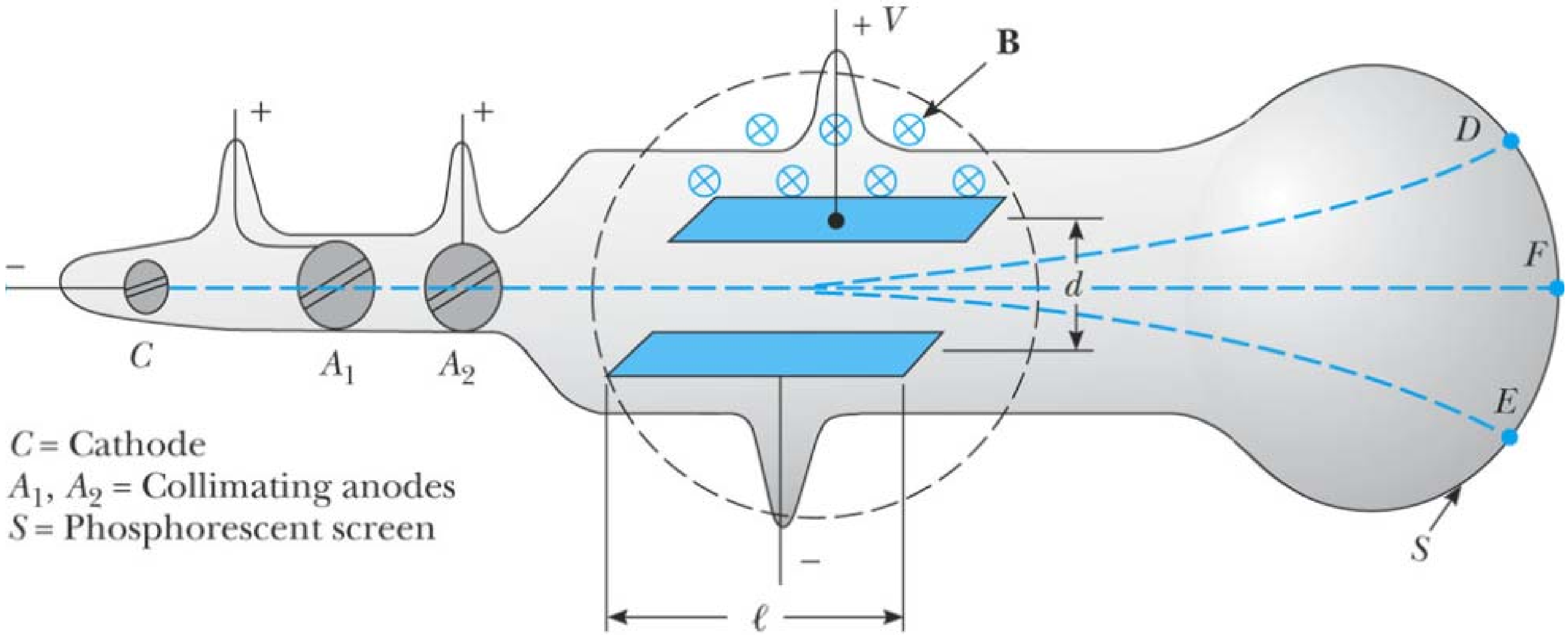
Thomson

Joseph John Thomson (1856-1940)

… he achieved the most brilliant work of his life - an original study of cathode rays culminating in the discovery of the electron, which was announced during the course of his evening lecture to the Royal Institution on Friday, April 30, 1897.

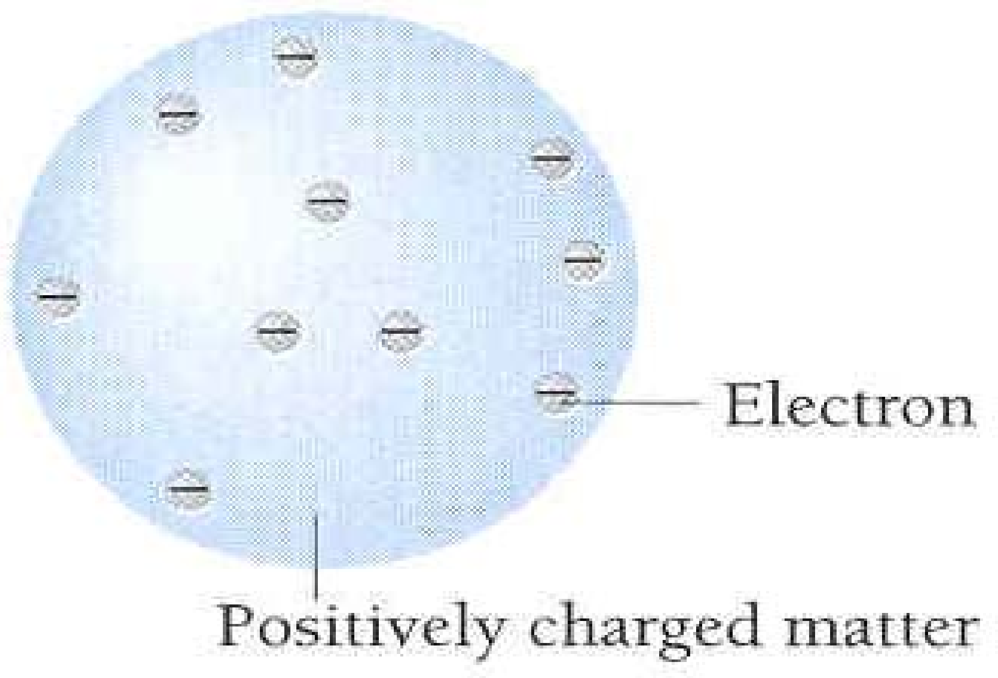
http://nobelprize.org/physics/laureates/1906/thomson-bio.html



+ V
B
+
+
−
D
F
d
E
C
A_1
A_2
S
−
ℓ
C = Cathode
A_1, A_2 = Collimating anodes
S = Phosphorescent screen

Fig. 4-5, p. 111

Thomson의 원자 모델



Millikan

Robert Andrews Millikan
(1868-1953)

The Nobel Prize in Physics 1923

"for his work on the elementary charge of electricity and on the photoelectric effect"

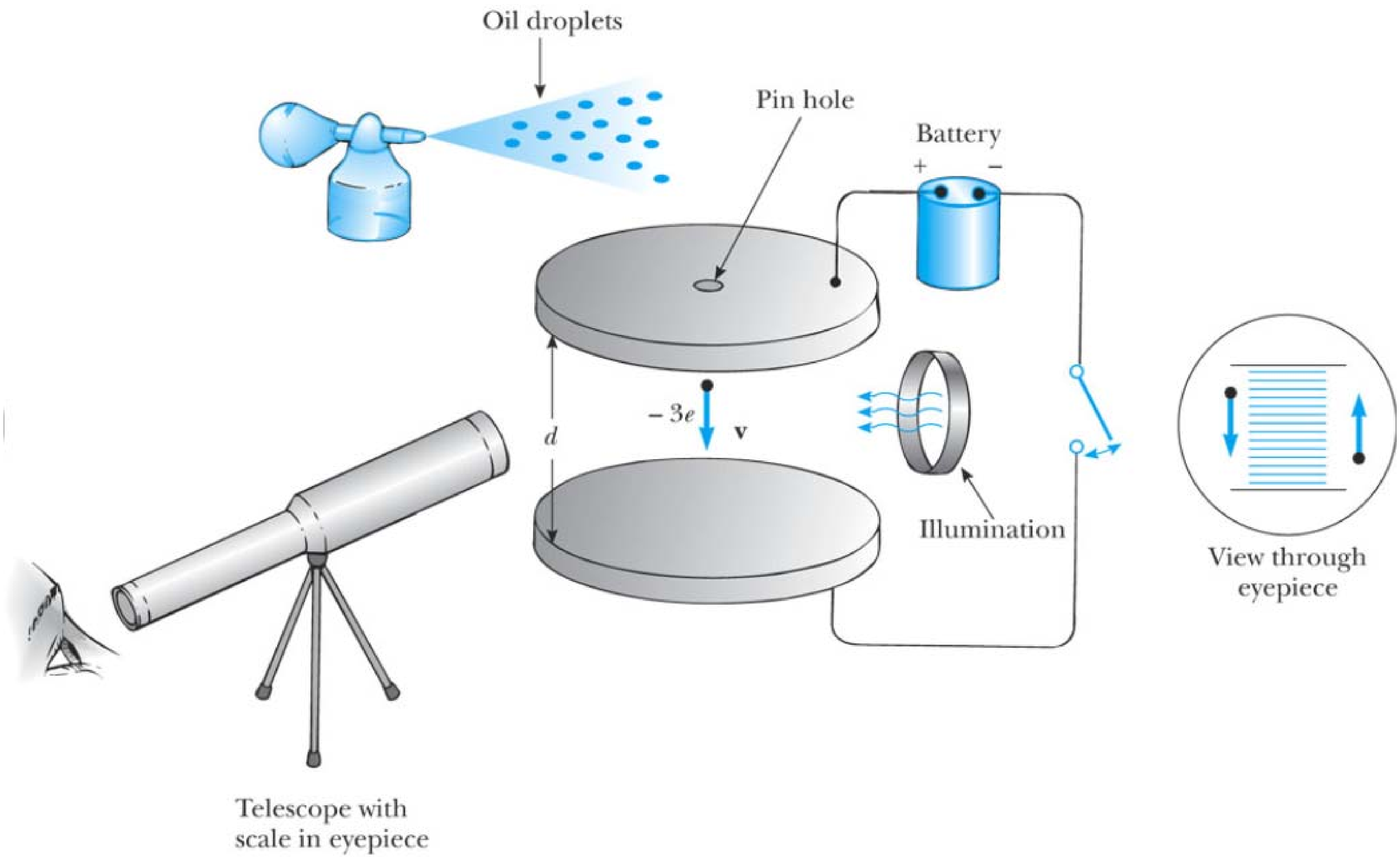
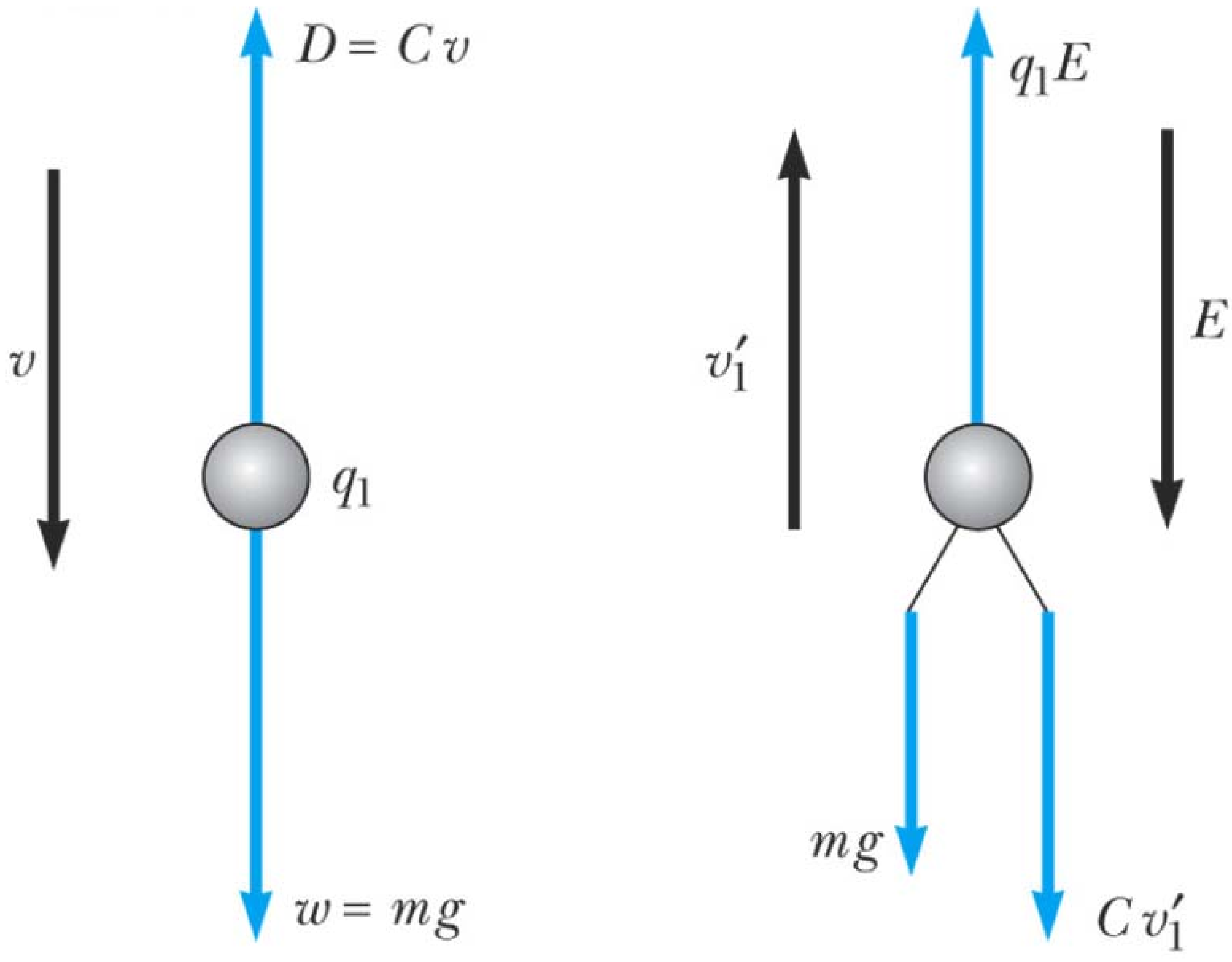

Oil droplets
Pin hole
Battery
+
−
−3e
v
d
Illumination
View through
eyepiece
Telescope with
scale in eyepiece

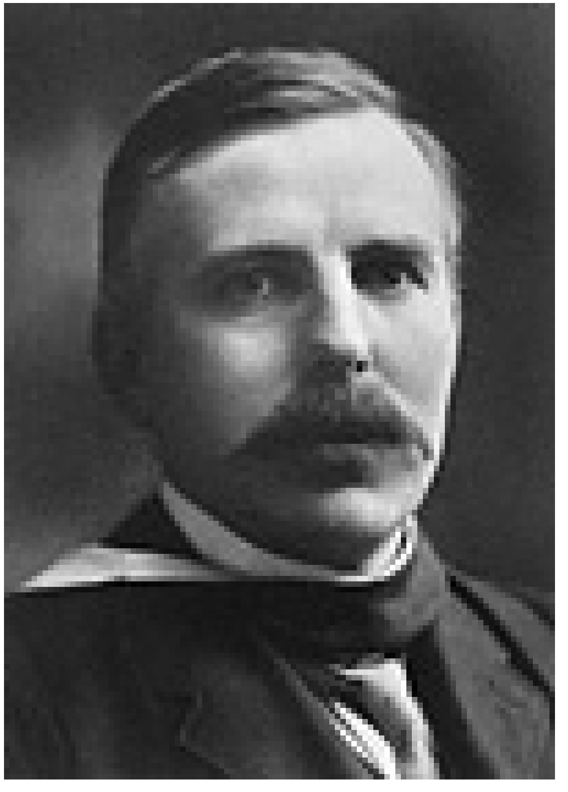
Fig. 4-8, p. 115



(a) Field off (b) Field on

Fig. 4-9, p. 116

Rutherford



Ernest Rutherford (1871-1937)

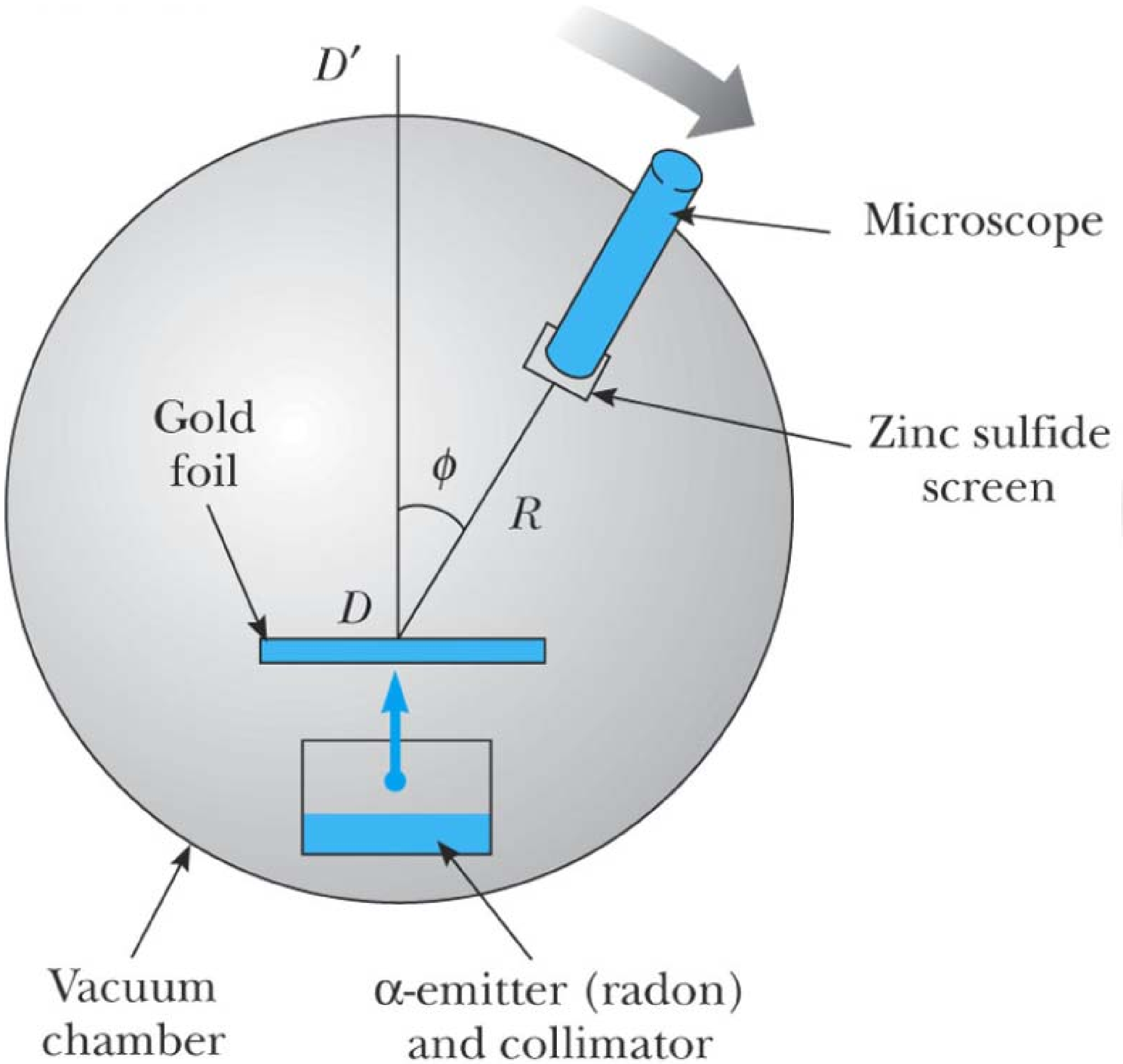

D′
Microscope
Gold
foil
ϕ
R
Zinc sulfide
screen
D
Vacuum
chamber
α-emitter (radon)
and collimator

Fig. 4-10, p. 120

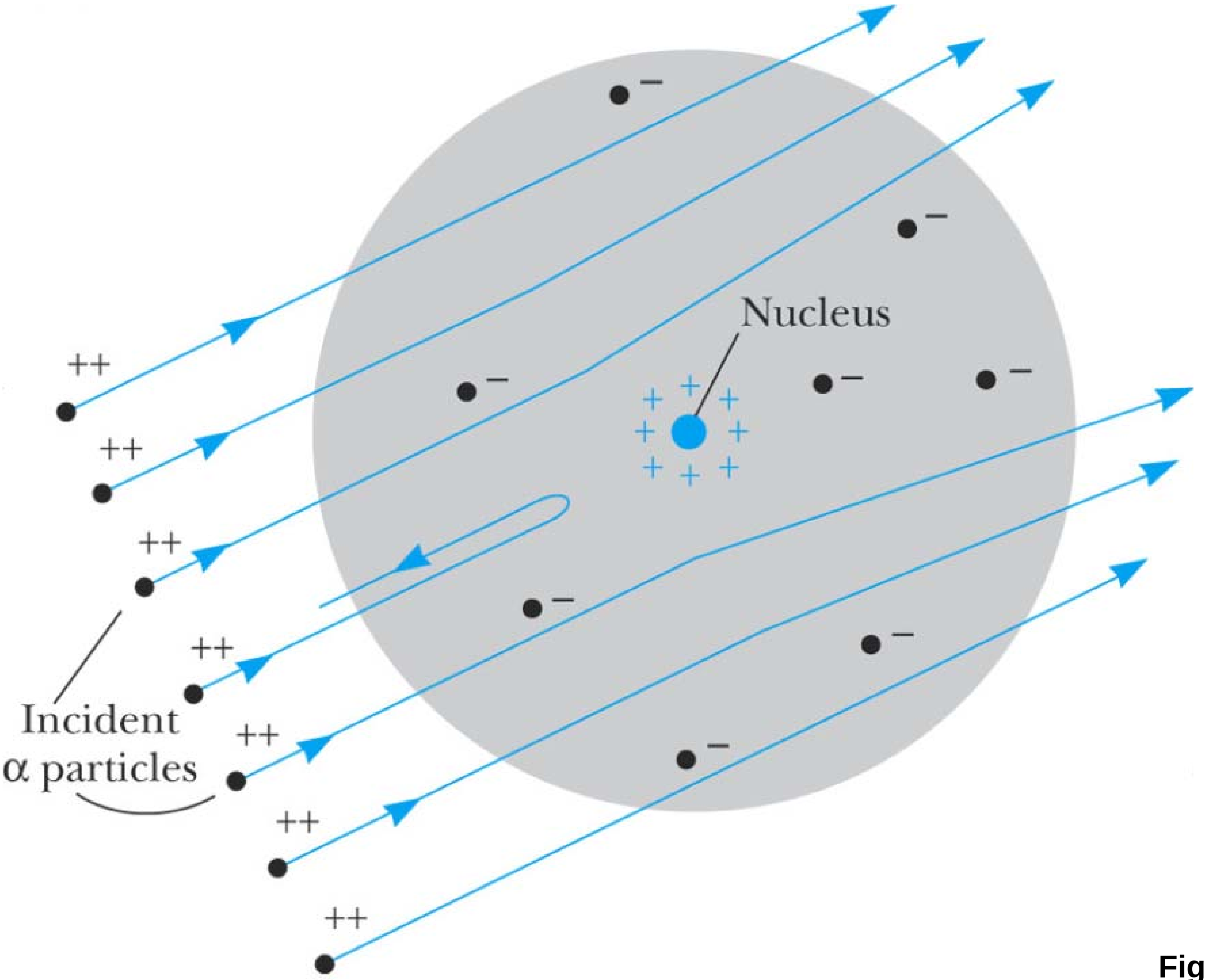
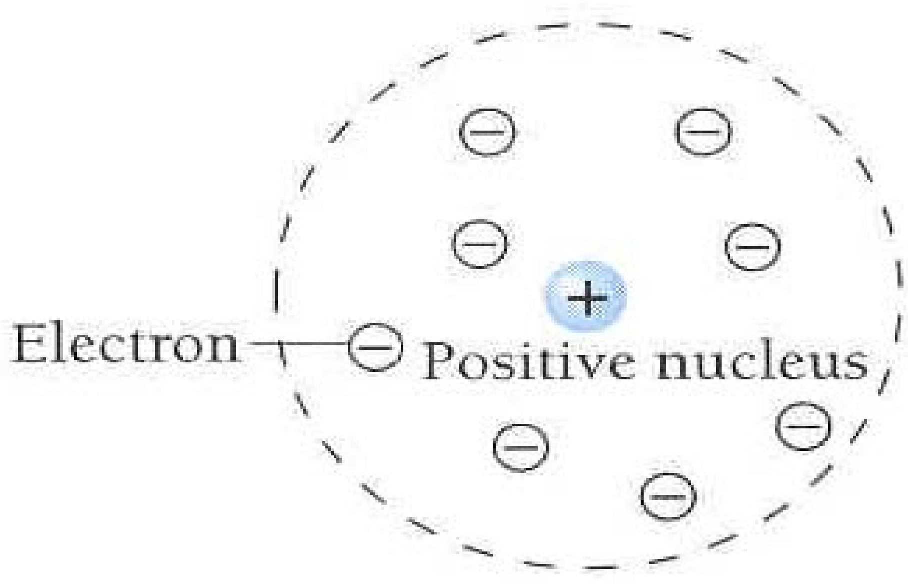
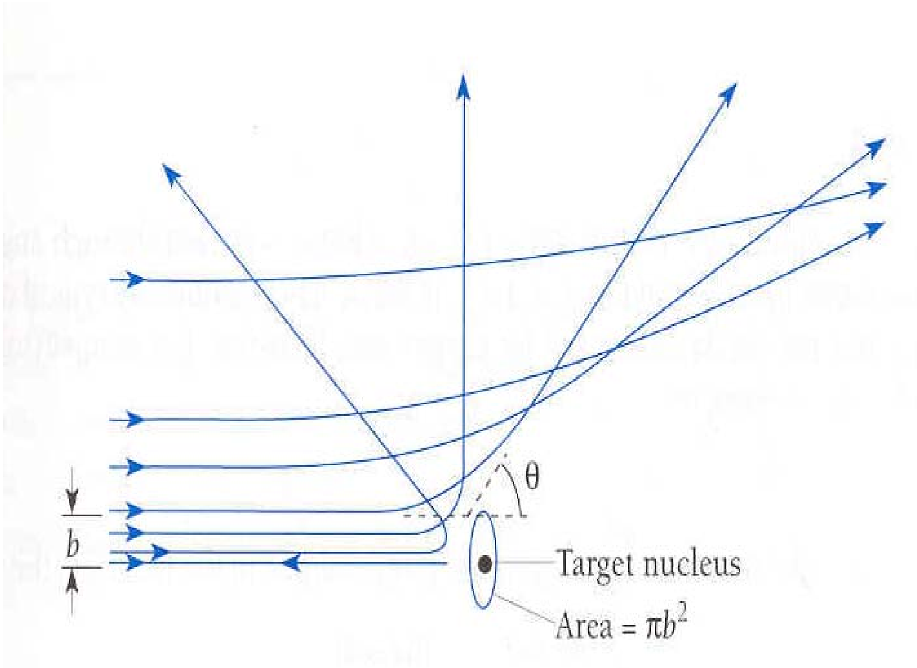
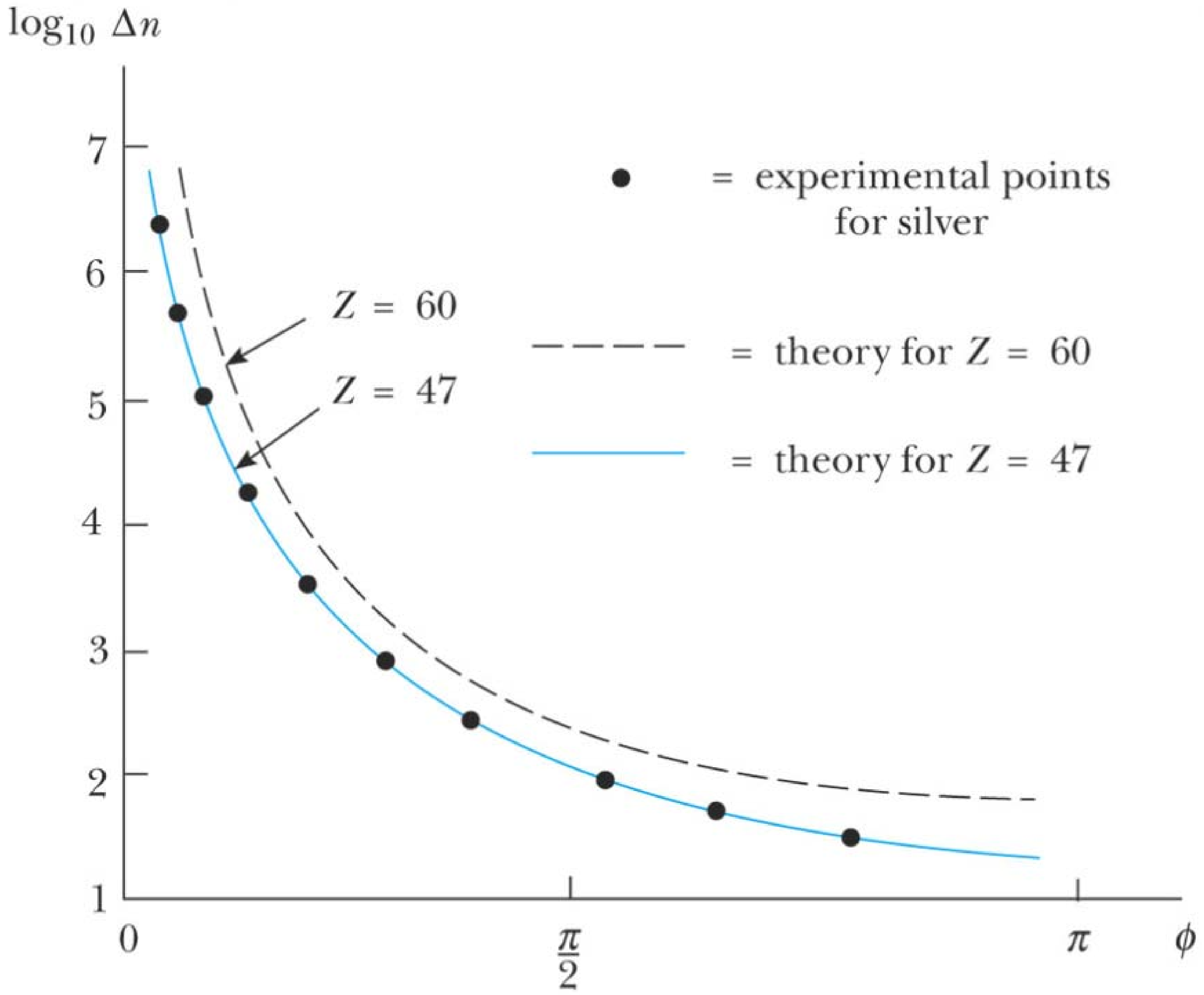


Fig. 4-11, p. 121

Rutherford의 원자 모델



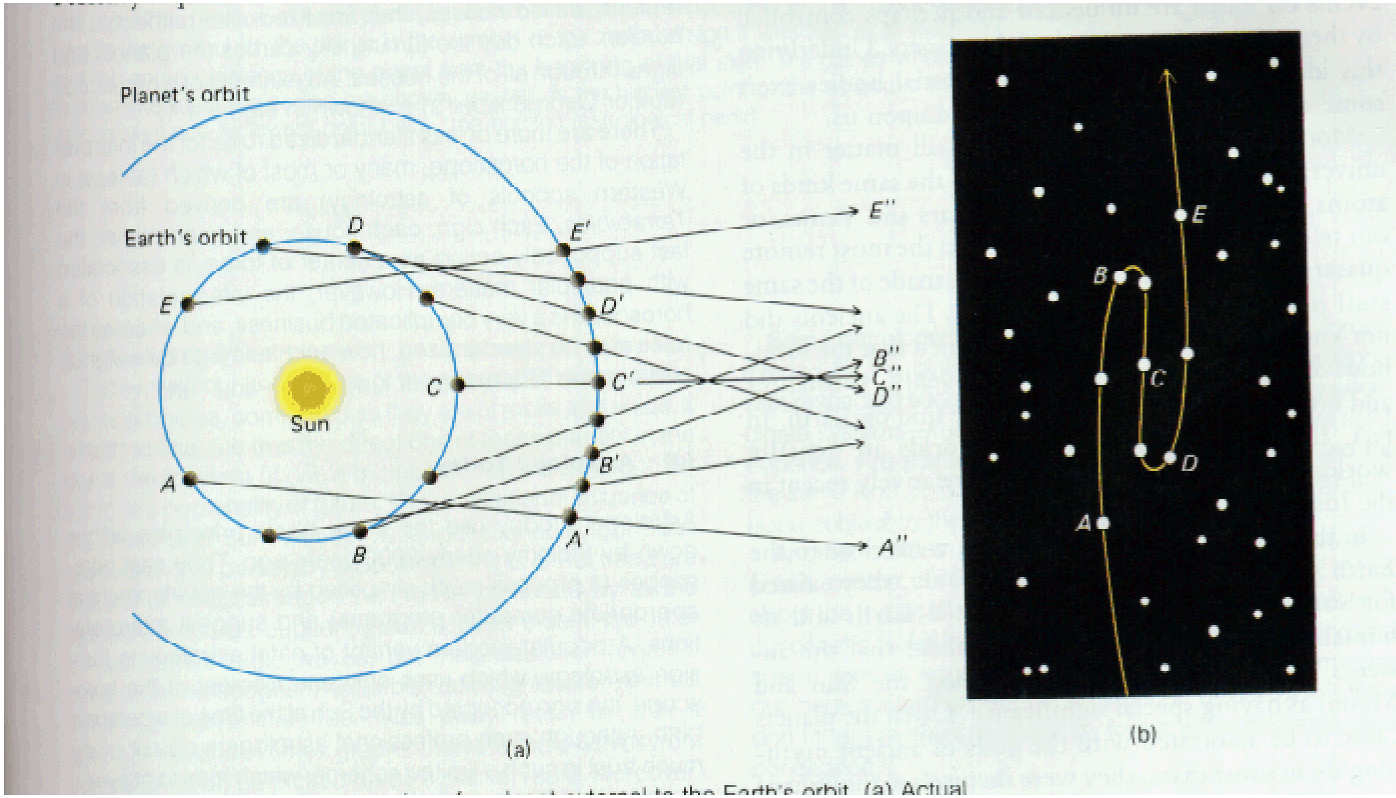

θ
b
Target nucleus
Area = πb²



log10 Δn
7
6
5
4
3
2
1
0
π/2
π
φ
= experimental points for silver
Z = 60
Z = 47
= theory for Z = 60
= theory for Z = 47

Fig. 4-12, p. 123

태양과 행성 – No Problem



Dilemma

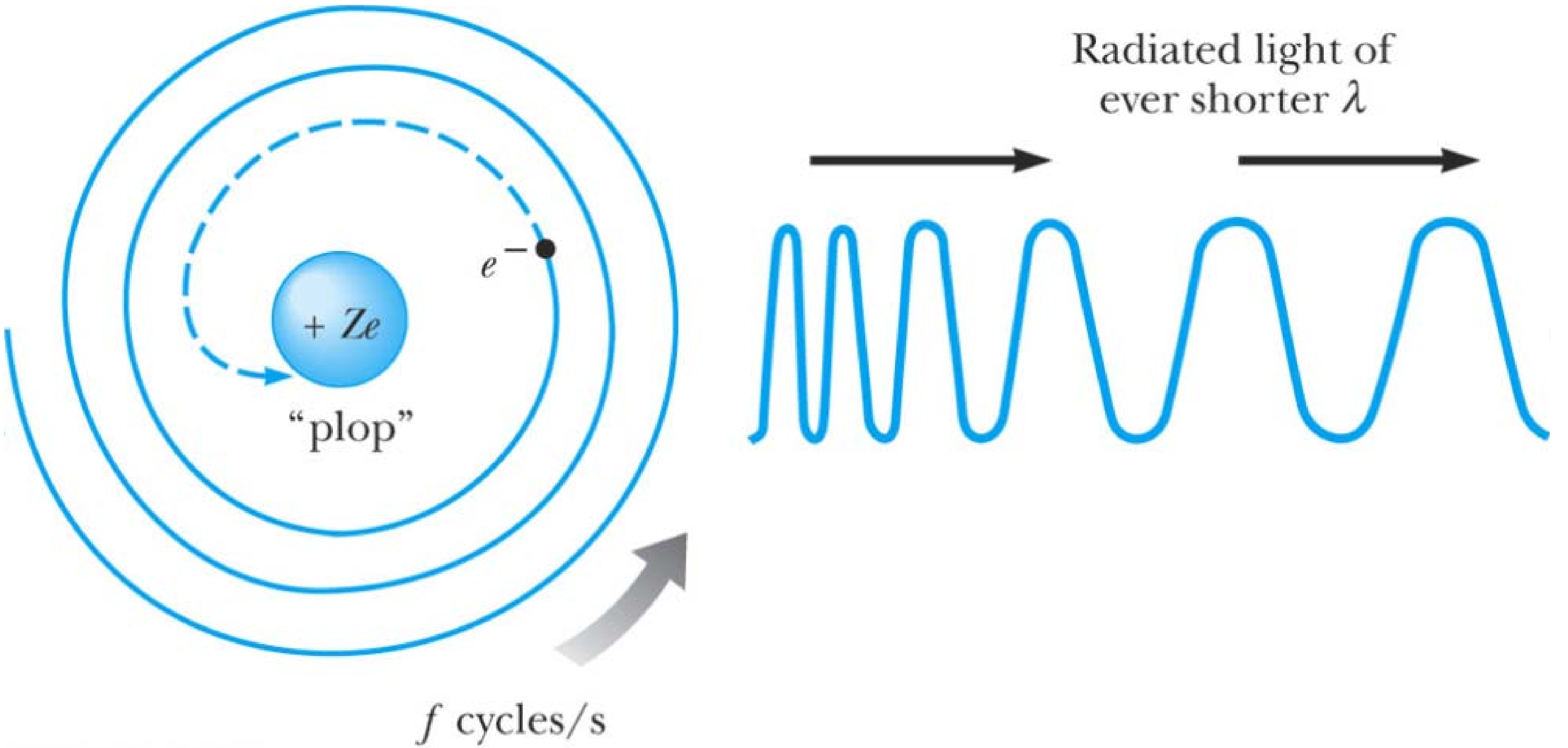


Fig. 4-21, p. 131

왜? - Maxwell's Equations

$$\vec{\nabla}\cdot\vec{D}=\rho$$

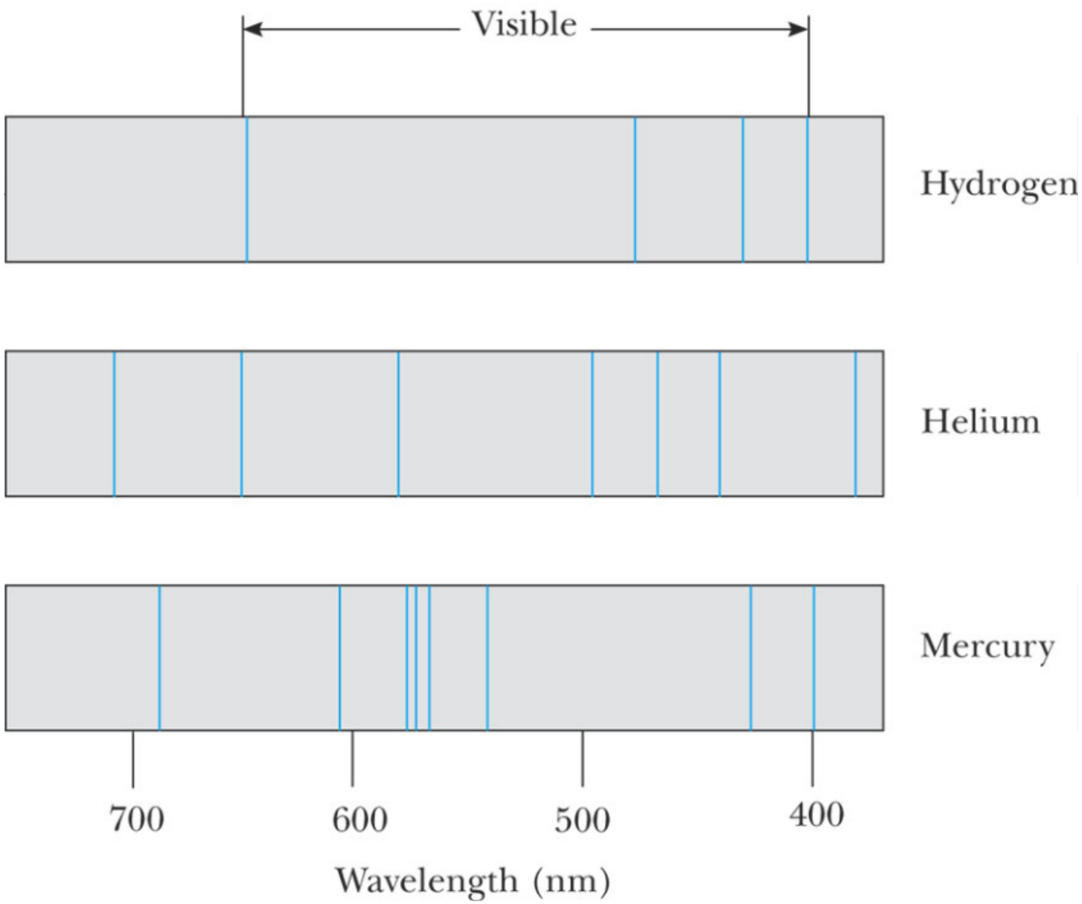
$$\vec{\nabla}\cdot\vec{B}=0$$

$$\vec{\nabla}\times\vec{E}=-\frac{\partial\vec{B}}{\partial t}$$

$$\vec{\nabla}\times\vec{H}=\vec{J}+\frac{\partial\vec{D}}{\partial t}$$

cf. $\vec{D}=\varepsilon\vec{E},\quad \vec{B}=\mu\vec{H}$

Oh, My God…



$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Fig. 4-15, p. 127

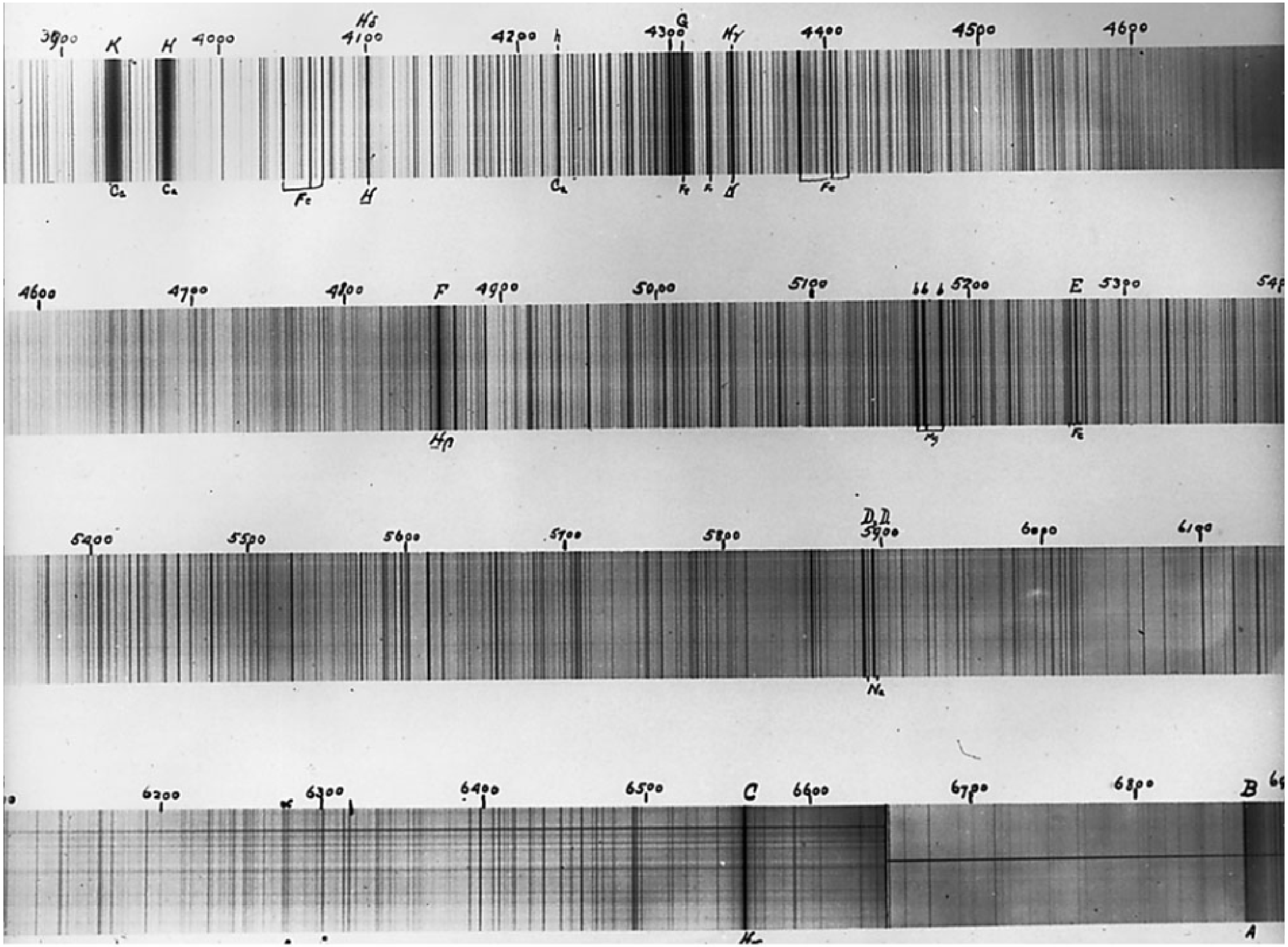

3900
K
H
4000
4100
4200
4300
G
4400
4500
4600
Ca
Ca
Fe
H
Ca
Fe
Fe
4600
4700
4800
F
4900
5000
5100
5200
E
5300
Hβ
Fe
5400
5500
5600
5700
5800
D D
5900
6000
6100
Na
6200
6300
6400
6500
C
6600
6700
6800
B
A

Fig. 4-18, p. 128

Bohr

Niels Henrik David Bohr
(1885-1962)

Niels Bohr Institute Group Photo 1960

Bohr's Atom Model

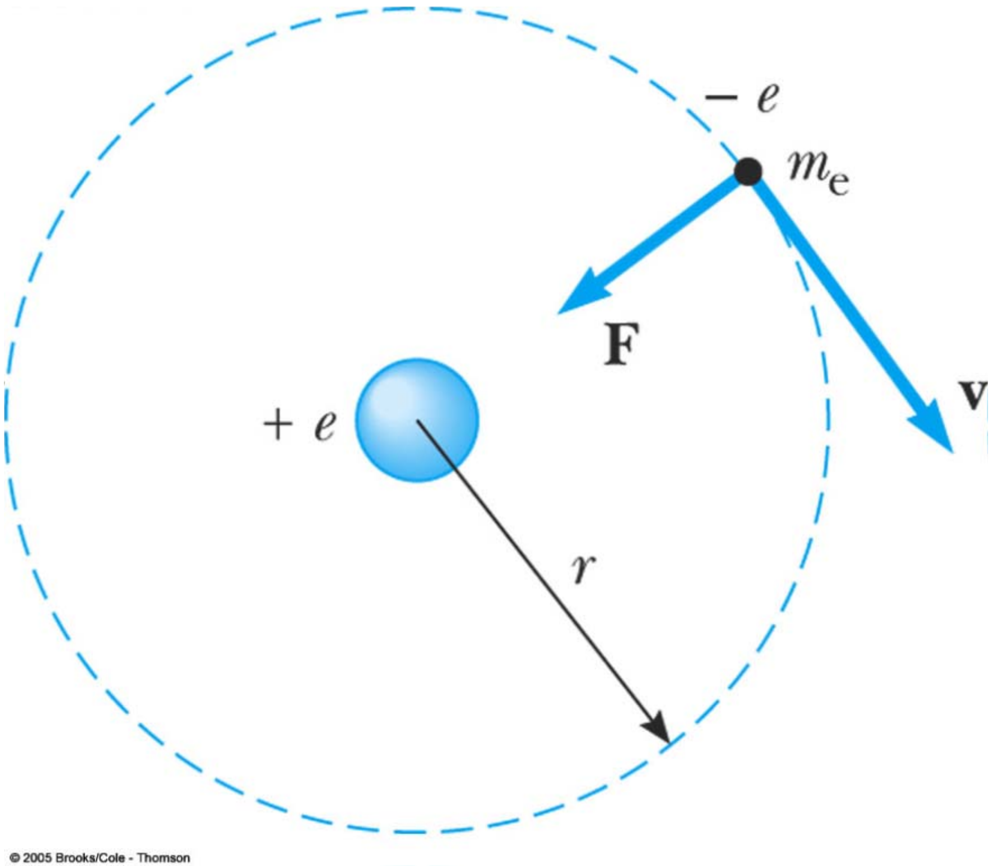


Fig. 4-22, p. 132

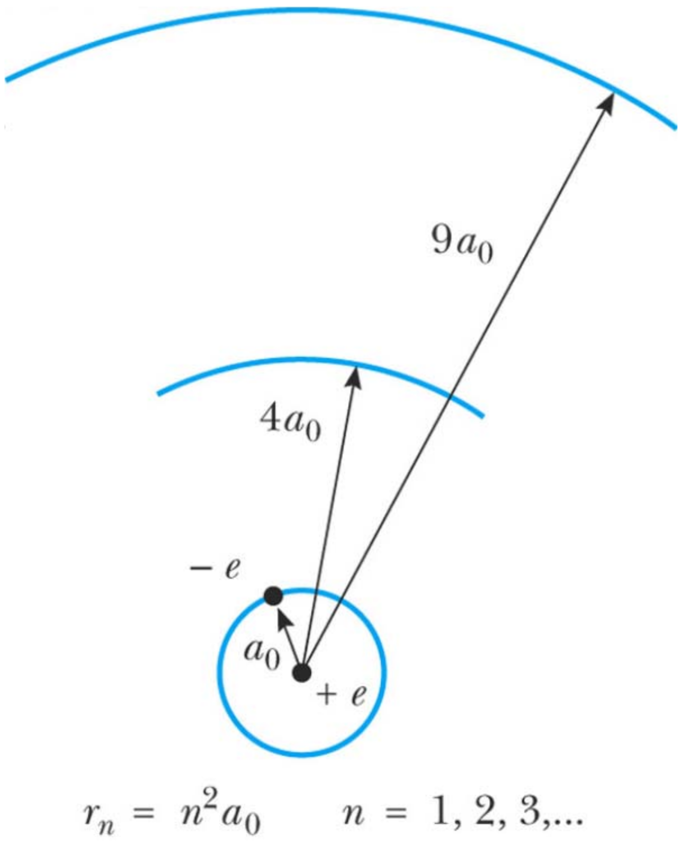
$$m_e v r = n\hbar \quad (n = 1, 2, 3, \ldots)$$

$$\left(\hbar = \frac{h}{2\pi}\right)$$

$$E = K + U = \frac{1}{2} m_e v^2 - k\frac{e^2}{r} = -k\frac{e^2}{2r}$$

$$\left(\because \frac{ke^2}{r^2} = \frac{m_e v^2}{r}\right)$$

Bohr's Atom Model

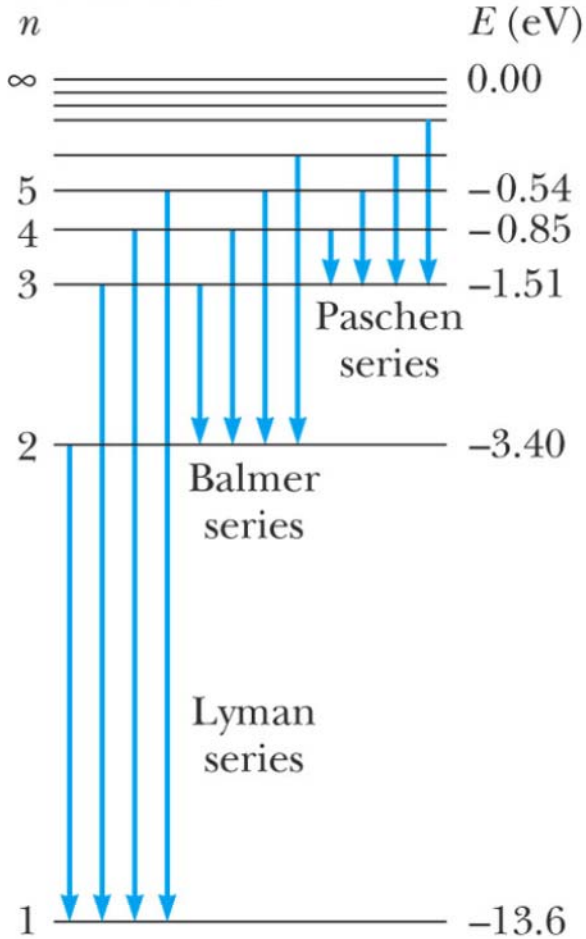


$$r_n = \frac{n^2\hbar^2}{m_e k e^2} \qquad n = 1, 2, 3, \ldots$$

$$a_o \equiv r_1 = \frac{\hbar^2}{m_e k e^2} = 0.529\,\mathring{A} \quad \text{Bohr radius}$$

Fig. 4-23, p. 133

Bohr's Atom Model



$$E_n = -\frac{ke^2}{2a_o}\left(\frac{1}{n^2}\right) = -\frac{13.6}{n^2}\text{eV} \qquad n = 1, 2, 3, \ldots$$

$$E_i - E_f = hf$$

$$\frac{1}{\lambda} = \frac{f}{c} = \frac{ke^2}{2a_o hc}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Fig. 4-24, p. 134

Correspondence Principle – Classical Limit

$h \to 0$ or $n \to \infty$: Classical limit

Example

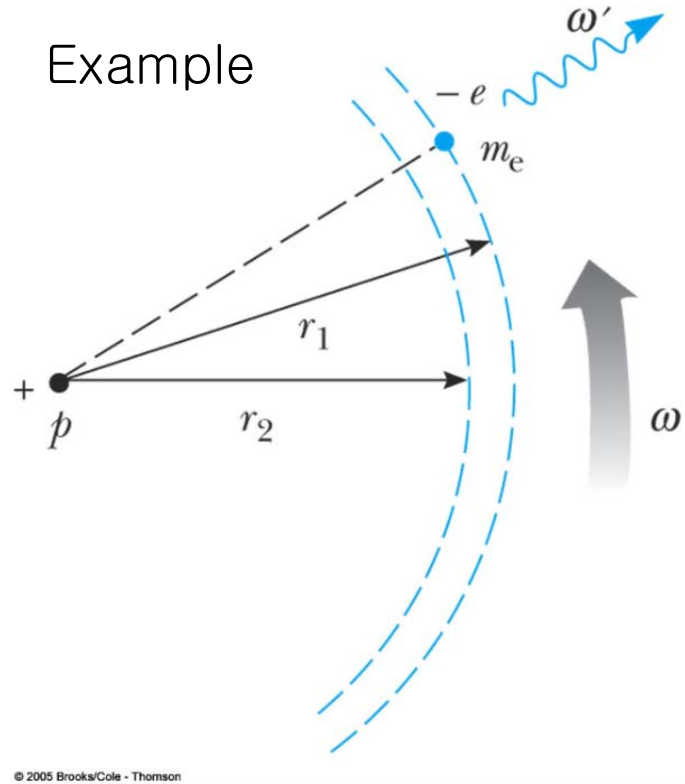


Fig. 4-26, p. 140

Franck-Hertz Experiment

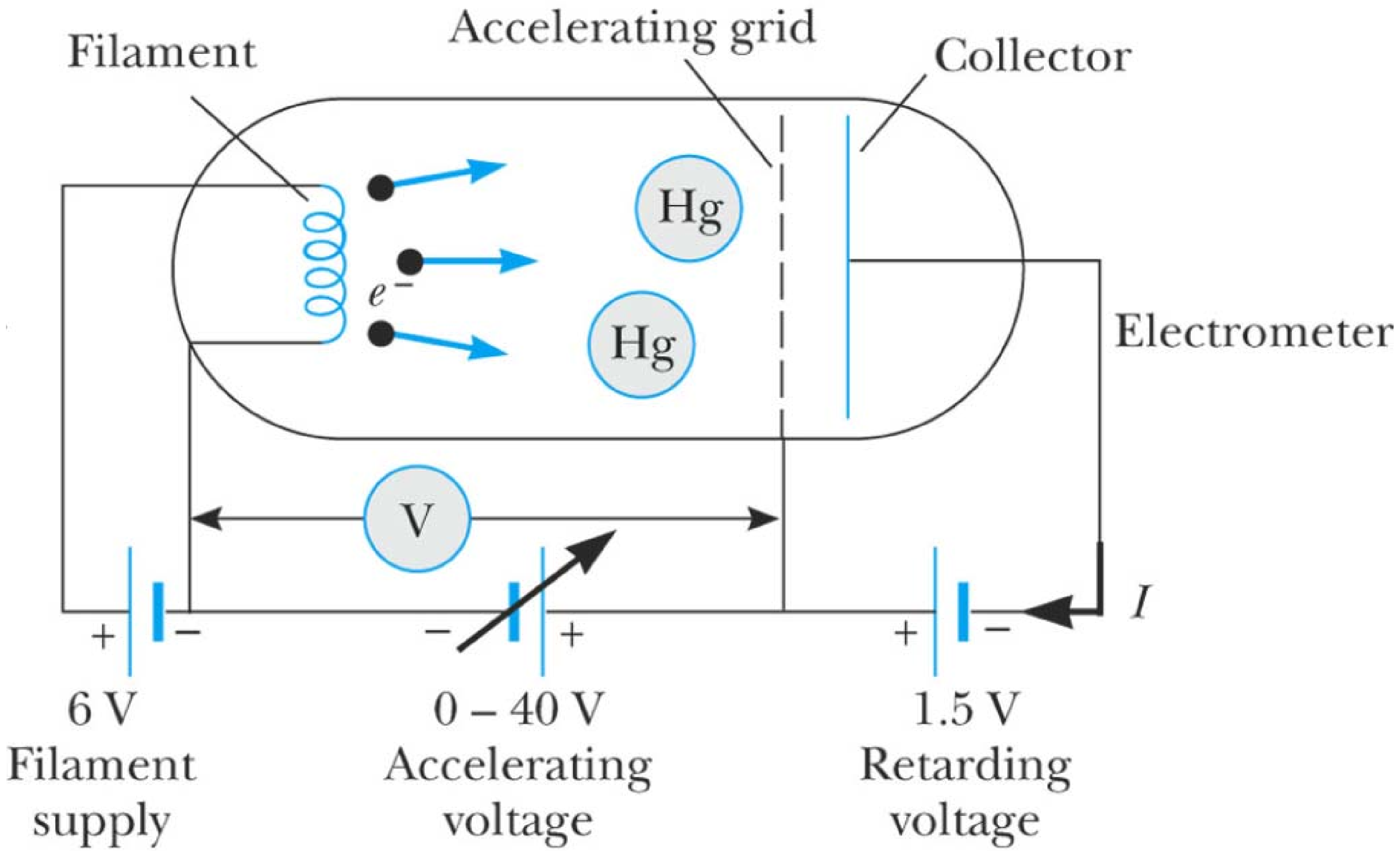
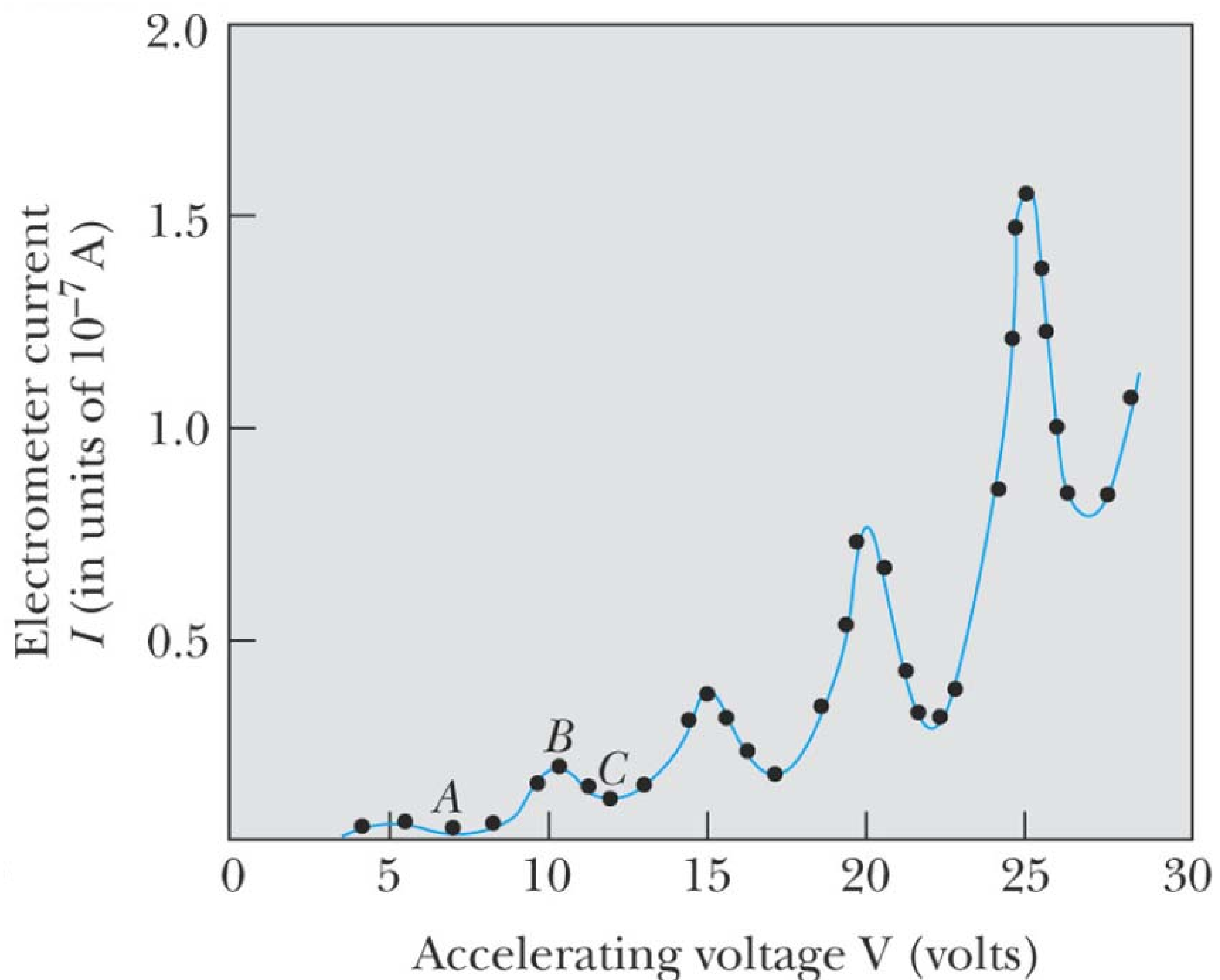


Fig. 4-27, p. 141



Electrometer current
I (in units of 10^{-7} A)
2.0
1.5
1.0
0.5
A
B
C
0
5
10
15
20
25
30
Accelerating voltage V (volts)

Fig. 4-28, p. 142

Ch. 5. Matter Waves

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De Broglie

Louis de Broglie (1892-1987)

De Broglie

Light		*Electron*
파동(전자파: Maxwell)으로 알았는데, 입자의 성질도(Einstein)!!!	→	입자(Thomson)로 아는데, 파동의 성질도? (뭐의 파동인가는 모르겠지만…)

Light

$$E = hf = pc$$

$$p = \frac{h}{\lambda}$$

Electron

$$\lambda = \frac{h}{p}$$

$$f = \frac{E}{h}$$

$$p = \gamma m v$$

$$E^2 = p^2c^2 + m^2c^4 = \gamma^2 m^2 c^4$$

$$n\lambda = 2\pi r \qquad n = 1, 2, 3, \ldots$$

$$m_e v r = n\hbar$$

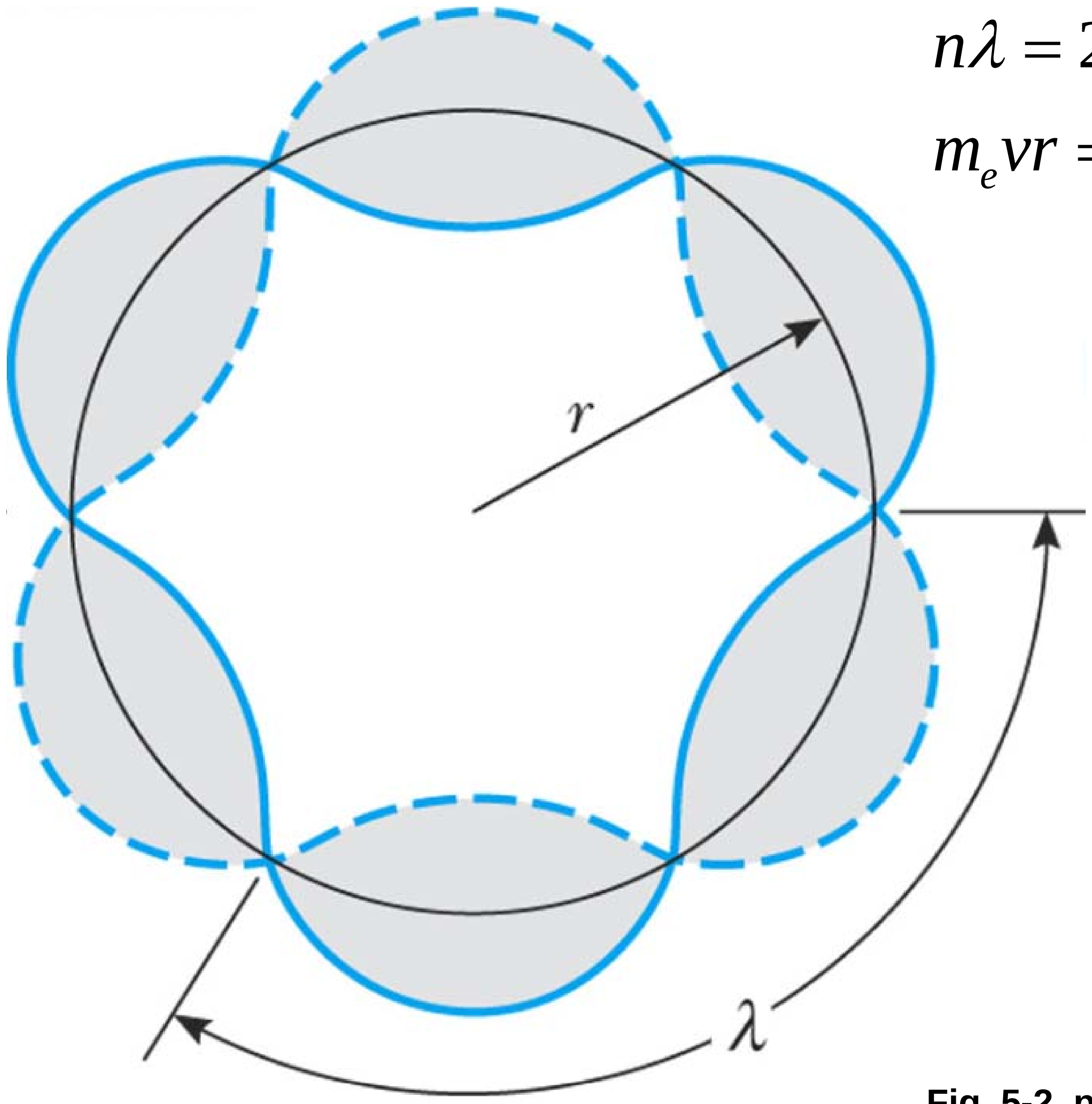
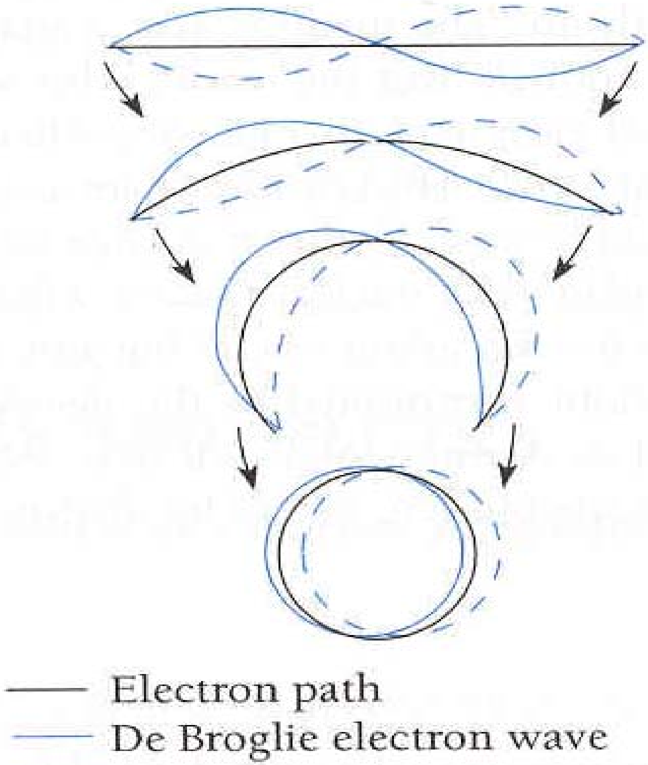
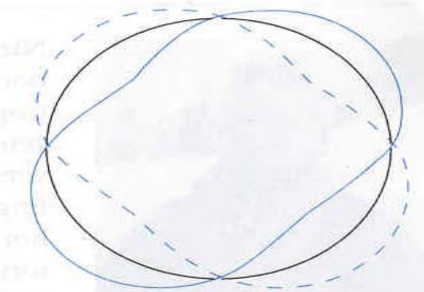
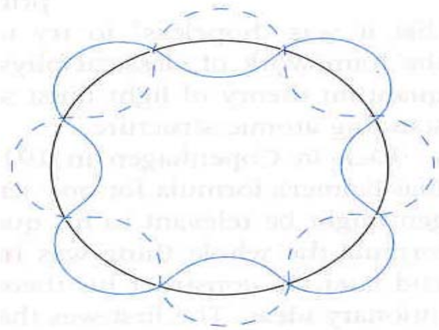


Fig. 5-2, p. 153

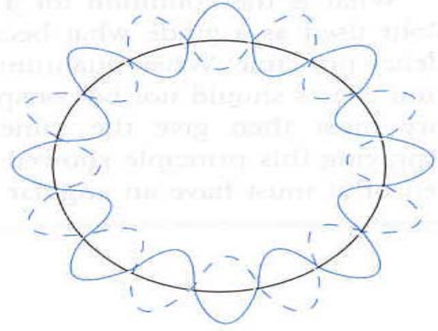

Electron path
De Broglie electron wave



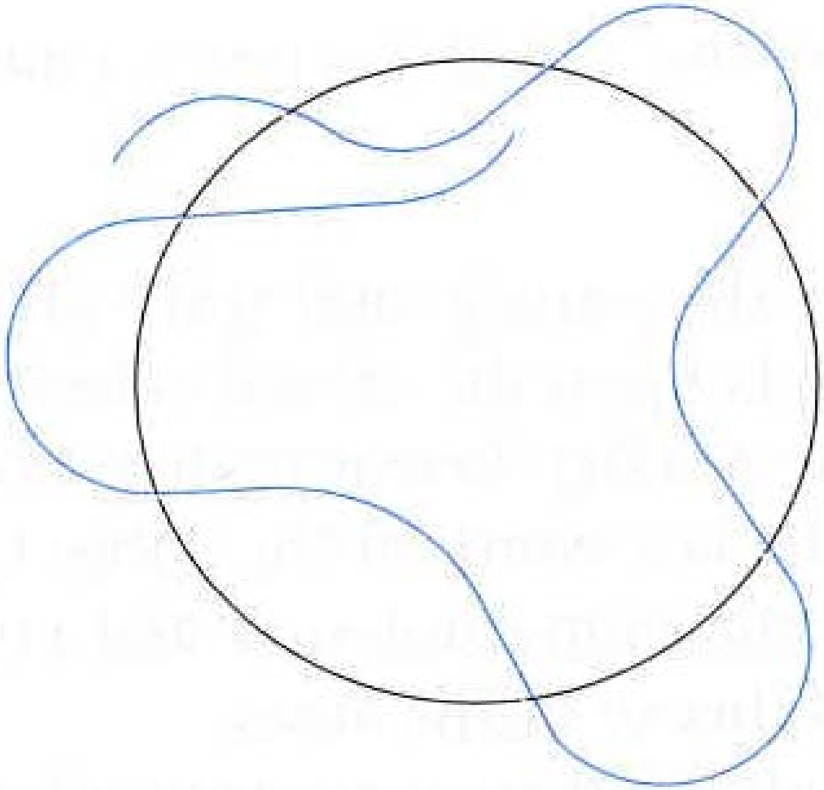
Circumference = 2 wavelengths

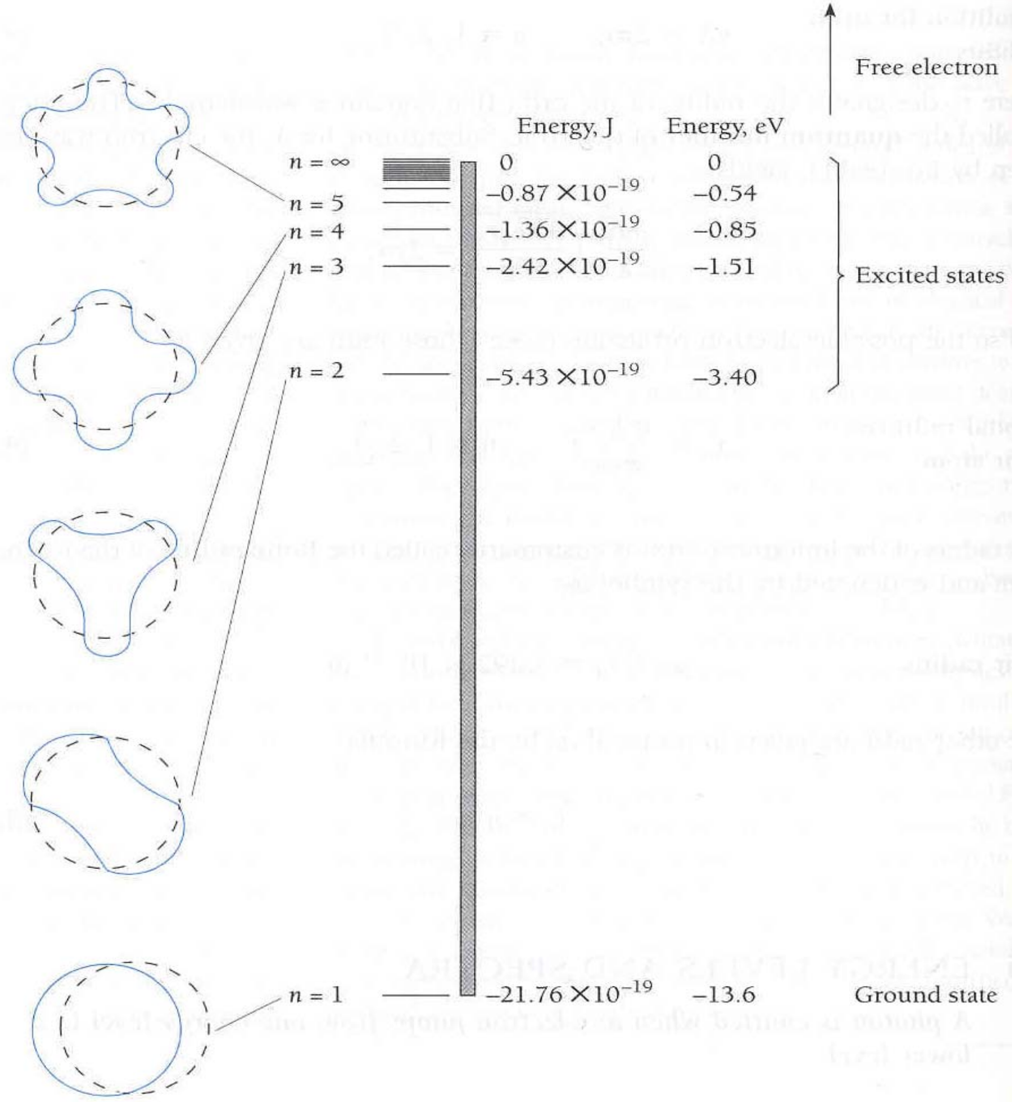


Circumference = 4 wavelengths



Circumference = 8 wavelengths




Free electron
Energy, J
Energy, eV
n = ∞
0
0
n = 5
−0.87 ×10^−19
−0.54
n = 4
−1.36 ×10^−19
−0.85
n = 3
−2.42 ×10^−19
−1.51
Excited states
n = 2
−5.43 ×10^−19
−3.40
n = 1
−21.76 ×10^−19
−13.6
Ground state