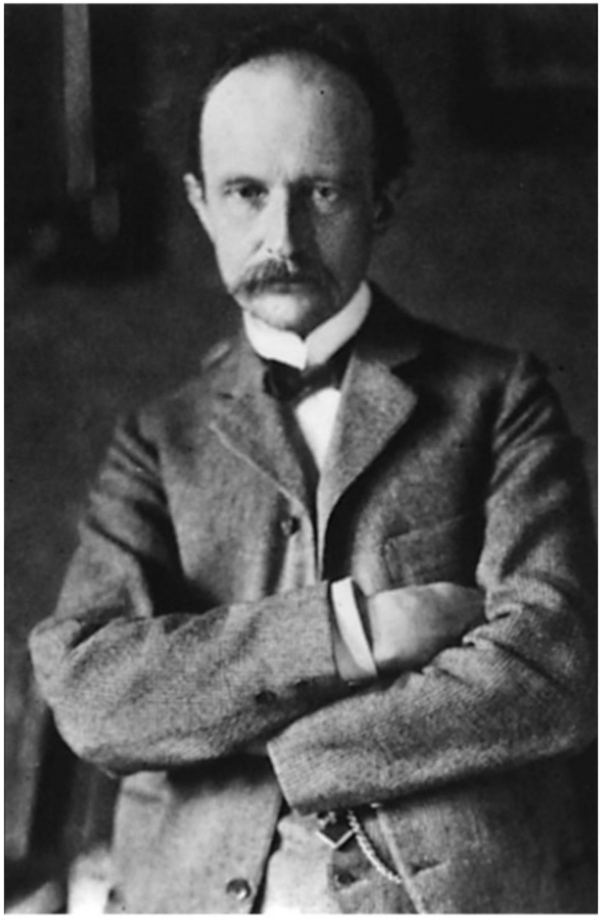
Planck



In 1900

"After some weeks of the most intense work of my life, light began to appear to me and unexpected views revealed themselves in the distance."

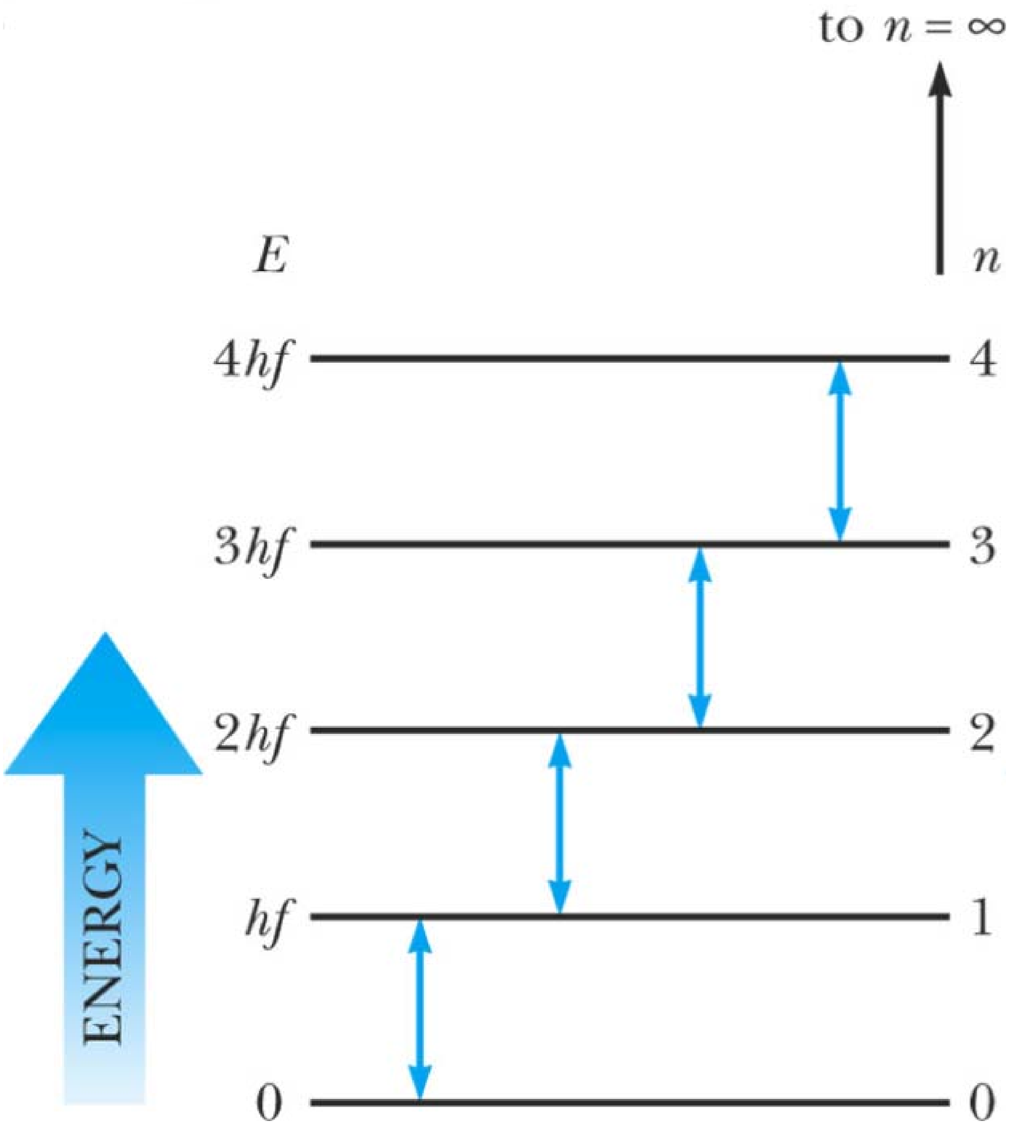
Max Planck (1858-1947)

Planck's Blackbody Radiation Law

$$u(f,T)=\frac{8\pi hf^3}{c^3}\cdot\frac{1}{\exp\left(\frac{hf}{k_BT}\right)-1}$$

$$h=6.626\times10^{-34}\,\mathrm{J\cdot s}$$ Planck's constant

$$\hbar=\frac{h}{2\pi}$$



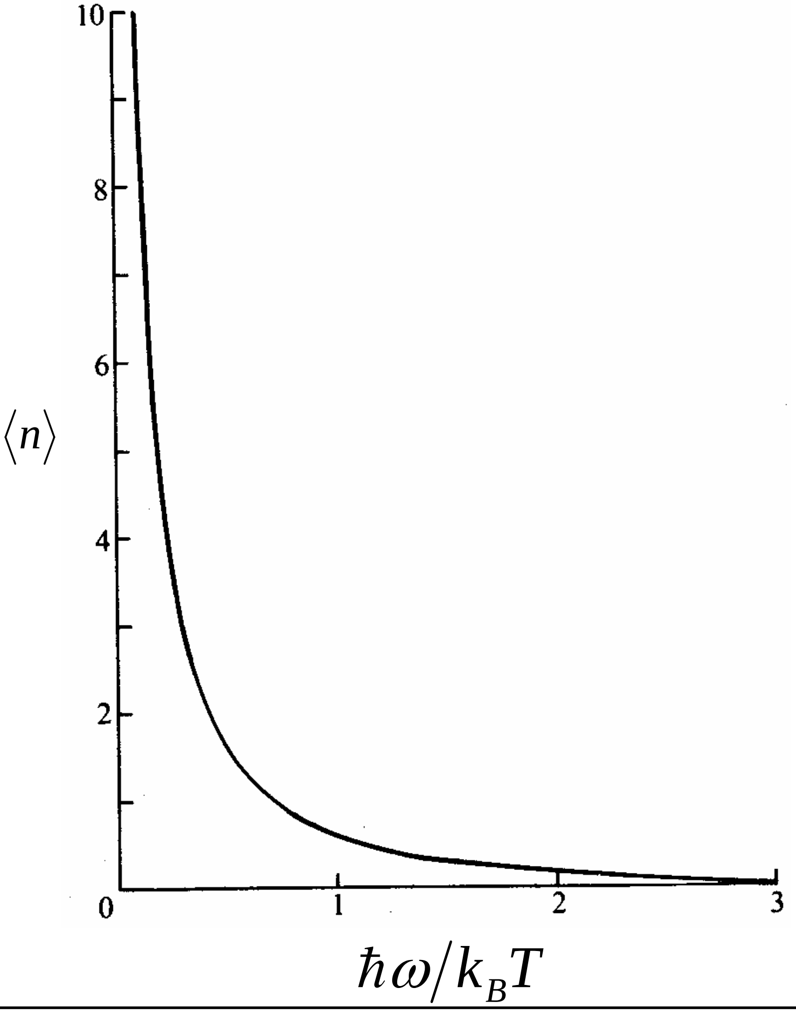
주의

Fig. 3-9, p. 74

Planck's Law I
(for advanced students only)

$$P(n) = \frac{\exp(-E_n/k_B T)}{\sum_n \exp(-E_n/k_B T)}$$

$$A = \exp\left(-\hbar\omega/k_B T\right)$$



$$\langle n \rangle = \sum_n nP(n) = (1-A)\sum_n nA^n$$

$$= (1-A)\,A\frac{\partial}{\partial A}\sum_n A^n = \frac{A}{1-A}$$

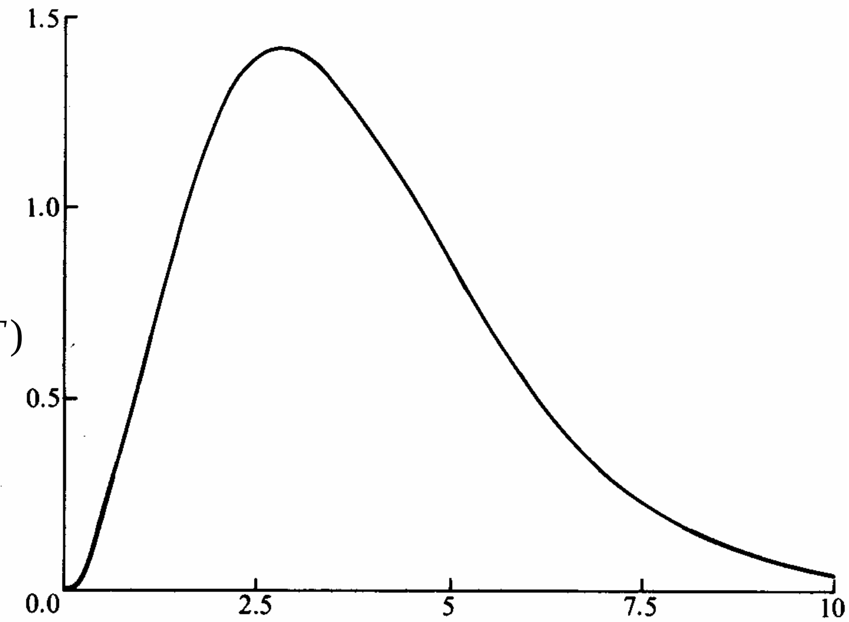
$$\langle n \rangle = \frac{1}{\exp\left(hf/k_B T\right) - 1}$$

Planck's Law II

$$u(f,T) = N(f)\langle n \rangle hf = \frac{8\pi f^2}{c^3} \cdot \frac{hf}{\exp\left(hf/k_B T\right) - 1}$$

$$u(f,T) \approx 8\pi f^2 k_B T / c^3 \quad \left(k_B T >> hf\right)$$

$$\left(h^2 c^3 / 8\pi k_B^3 T^3\right) u(f,T)$$



$$hf/k_B T$$

$$u(f,T) \approx \left(8\pi h f^3 / c^3\right) \exp\left(-hf/k_B T\right) \quad \left(k_B T << hf\right)$$

After All... Due to Einstein

$$u(f,T) = N(f)\langle n \rangle hf = \frac{8\pi f^2}{c^3} \cdot \frac{1}{\exp(hf/k_B T) - 1} \cdot hf$$

Einstein

Nobel Prize in Physics 1921

"for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect"

Photoelectric Effect (광전효과)

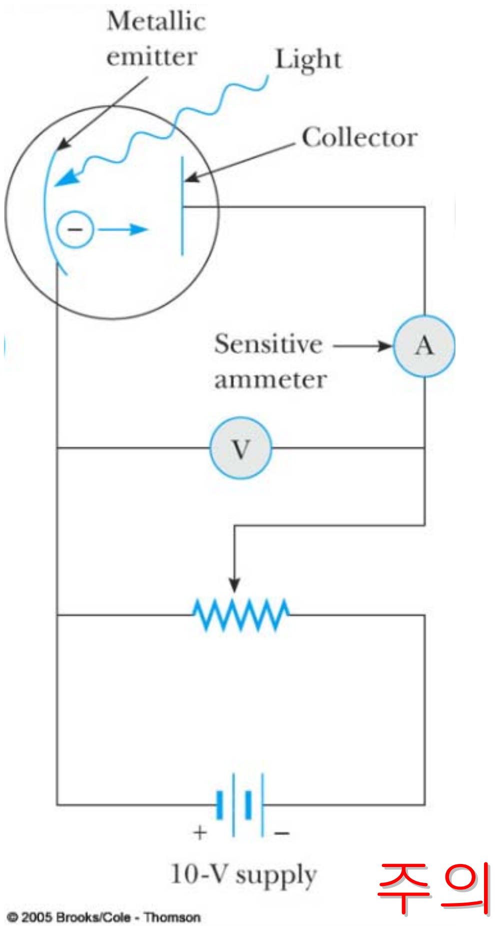


Fig. 3-14, p. 82

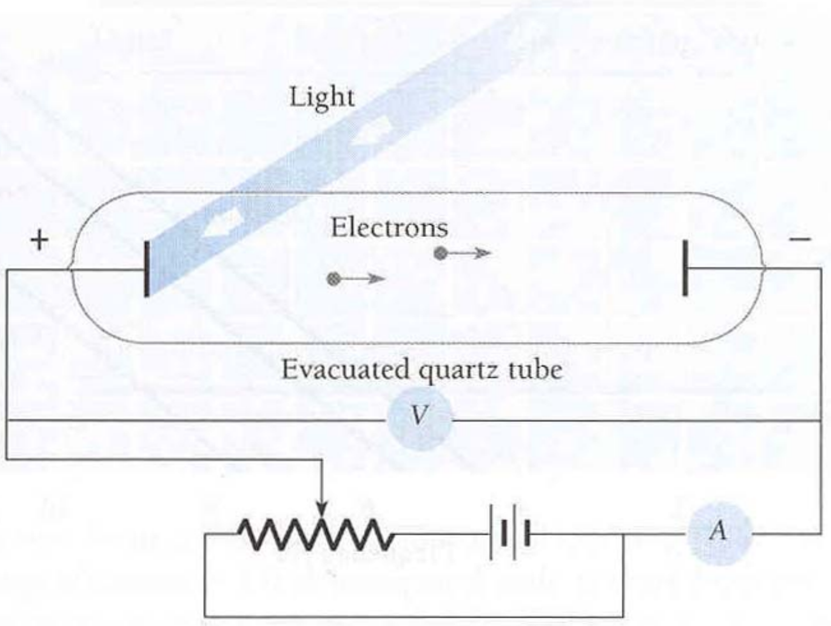


Figure 2.9 Experimental observation of the photoelectric effect.

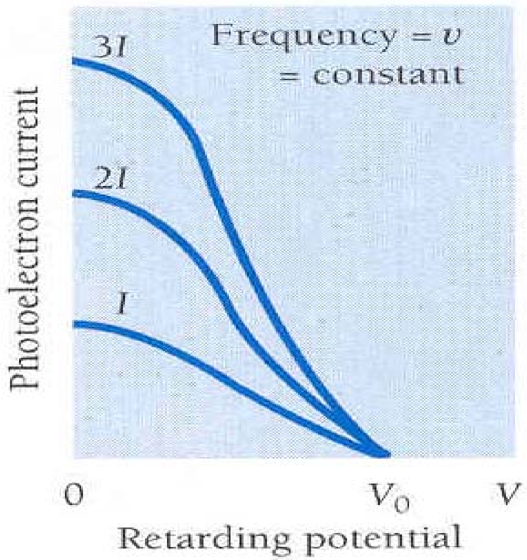


Figure 2.10 Photoelectron current is proportional to light intensity I for all retarding voltages. The stopping potential V_0, which corresponds to the maximum photoelectron energy, is the same for all intensities of light of the same frequency ν.

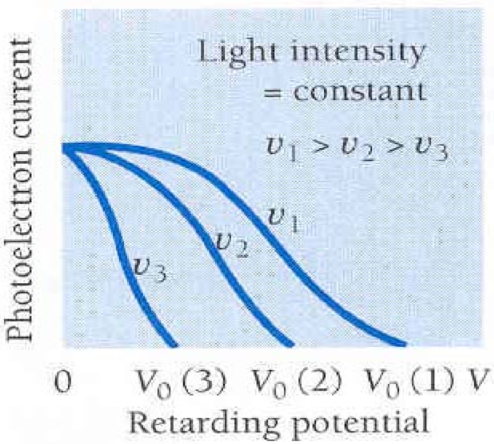


Figure 2.11 The stopping potential V_0, and hence the maximum photoelectron energy, depends on the frequency of the light. When the retarding potential is $V = 0$, the photoelectron current is the same for light of a given intensity regardless of its frequency.

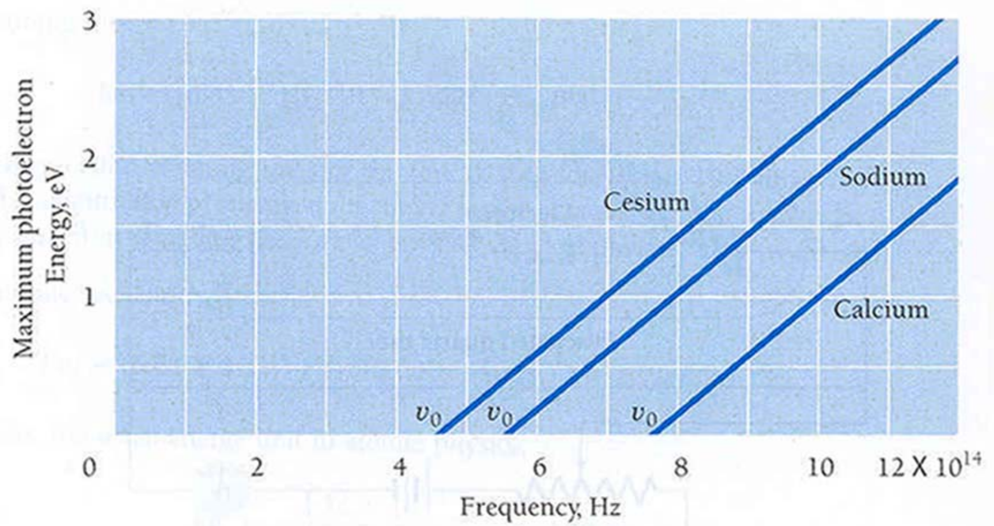


Figure 2.12 Maximum photoelectron kinetic energy KE_{max} versus frequency of incident light for three metal surfaces.

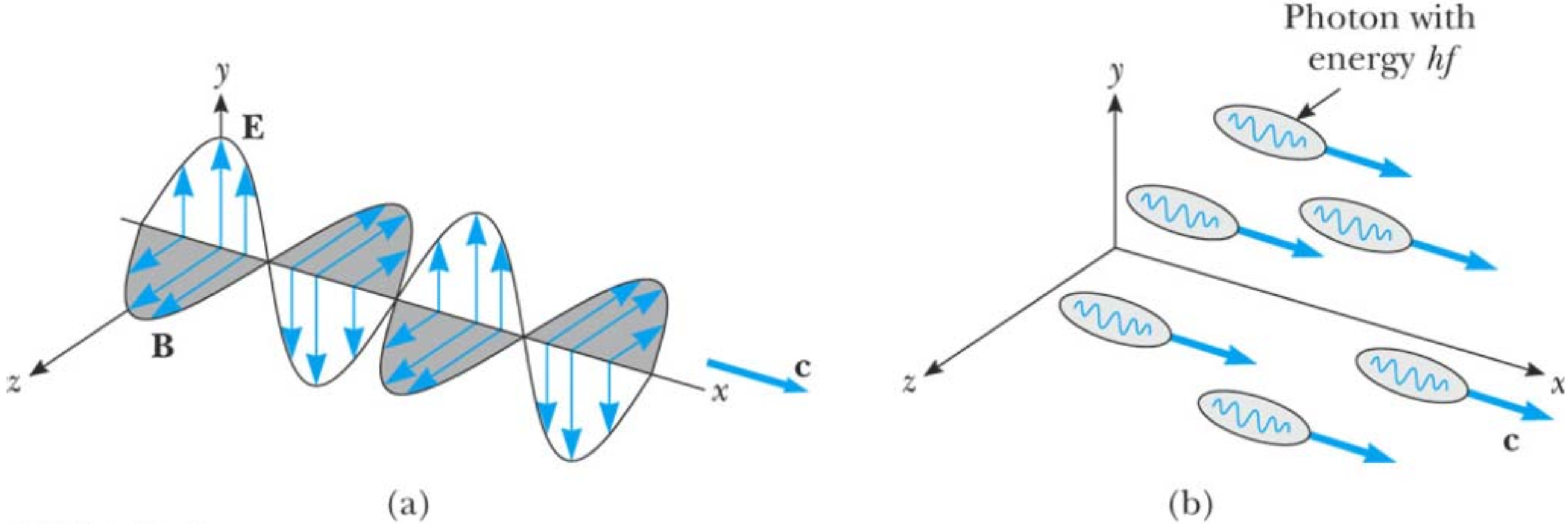


Fig. 3-16, p. 84

光子(Photon)

에너지 $$E = hf = \frac{h}{T} = \frac{hc}{\lambda}$$

운동량 $$p = \frac{h}{\lambda}$$

X-Ray

Wilhelm Conrad Röntgen
(1845-1923)

Picture of Mrs. Röntgen's hand, taken on Dec. 22, 1885.

He probably could have made tons of money by patenting his X-ray machine – but he didn't. A friend wrote of him, "His outstanding characteristic was his integrity…. [He] was in every sense the embodiment of the ideals of the nineteenth century: strong, honest and powerful, devoted to his science and never doubting its value." – From J. Hakim, The Story of Science – Newton at the Center, Smithsonian Books, Washington DC, USA, 2005.

X-Ray

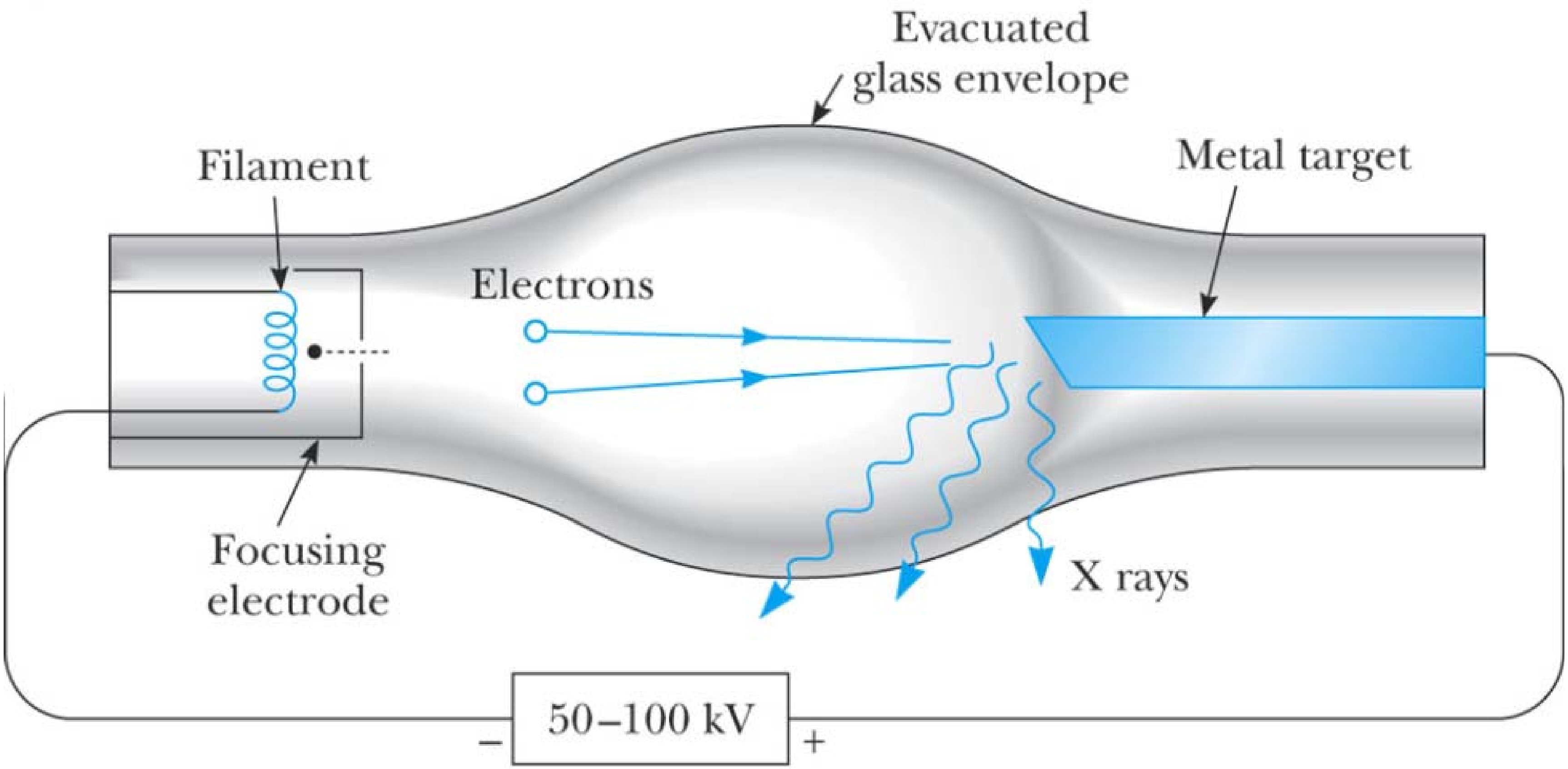
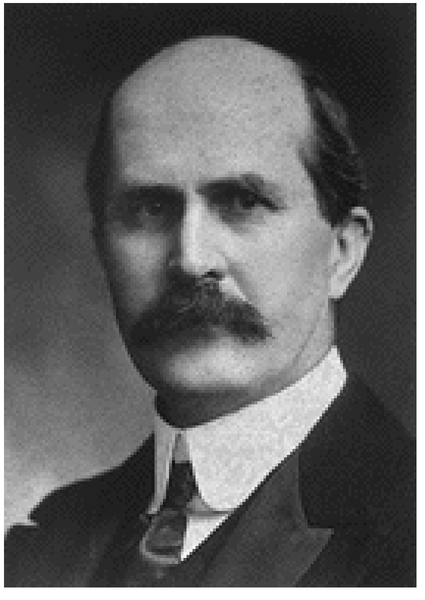


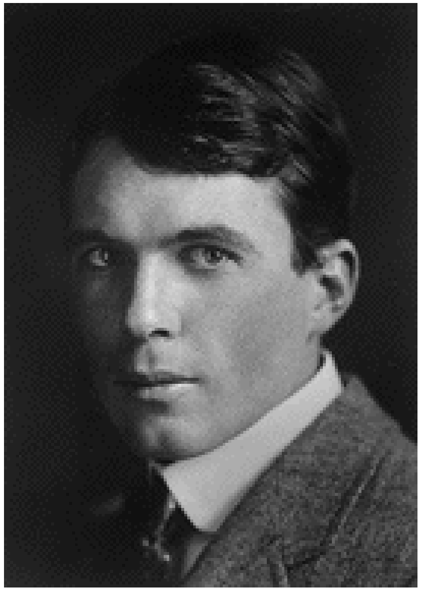
Fig. 3-18, p. 87

The Braggs

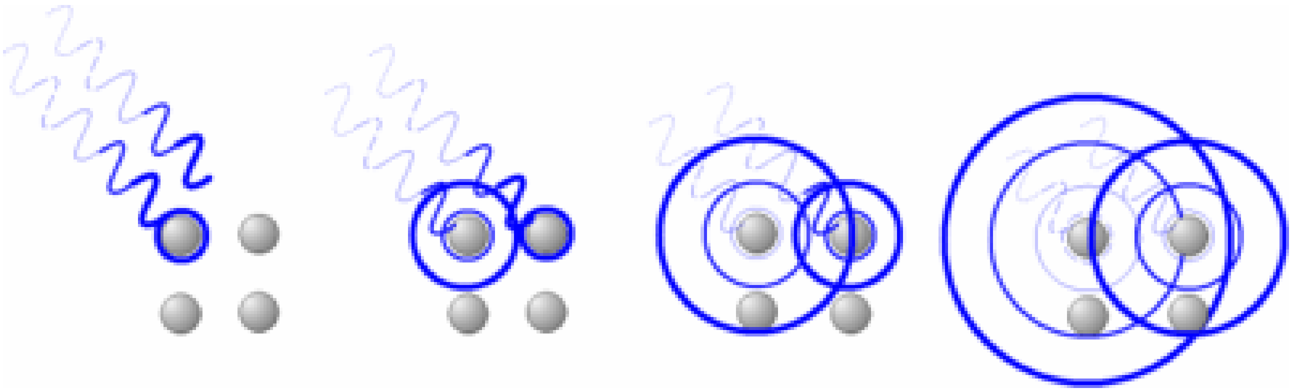
The Nobel Prize in Physics 1915
"for their services in the analysis of crystal structure by means of X-rays"

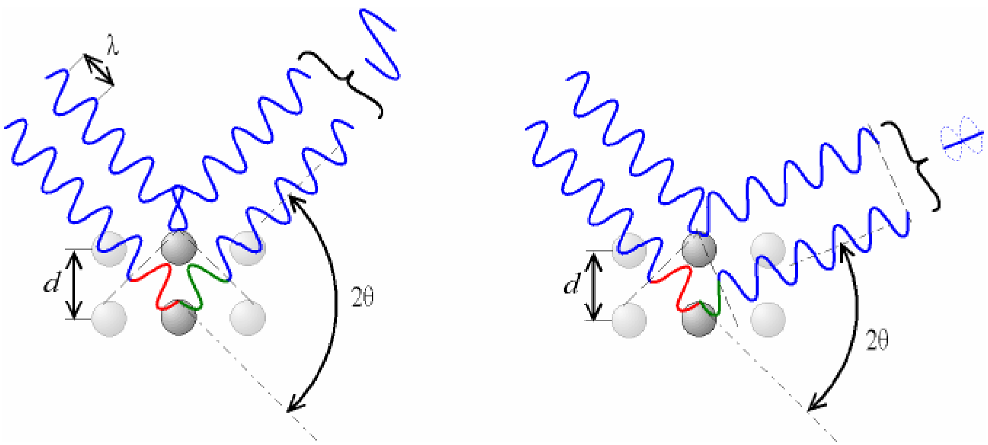


Sir William Henry Bragg
(1862-1942)



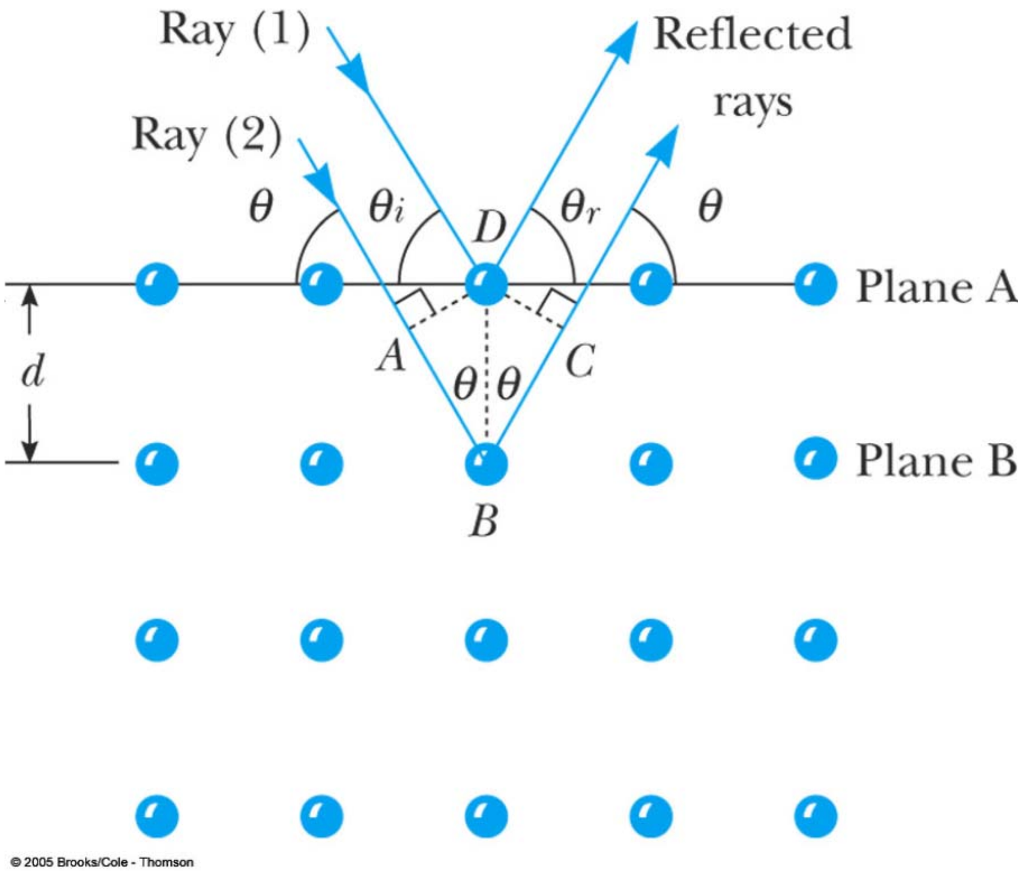
William Lawrence Bragg
(1890-1971)





http://en.wikipedia.org/wiki/Bragg%27s_law

Bragg's Law



$$2d \sin\theta = n\lambda$$

$$(n = 1, 2, 3, \cdots)$$

Fig. 3-20, p. 87

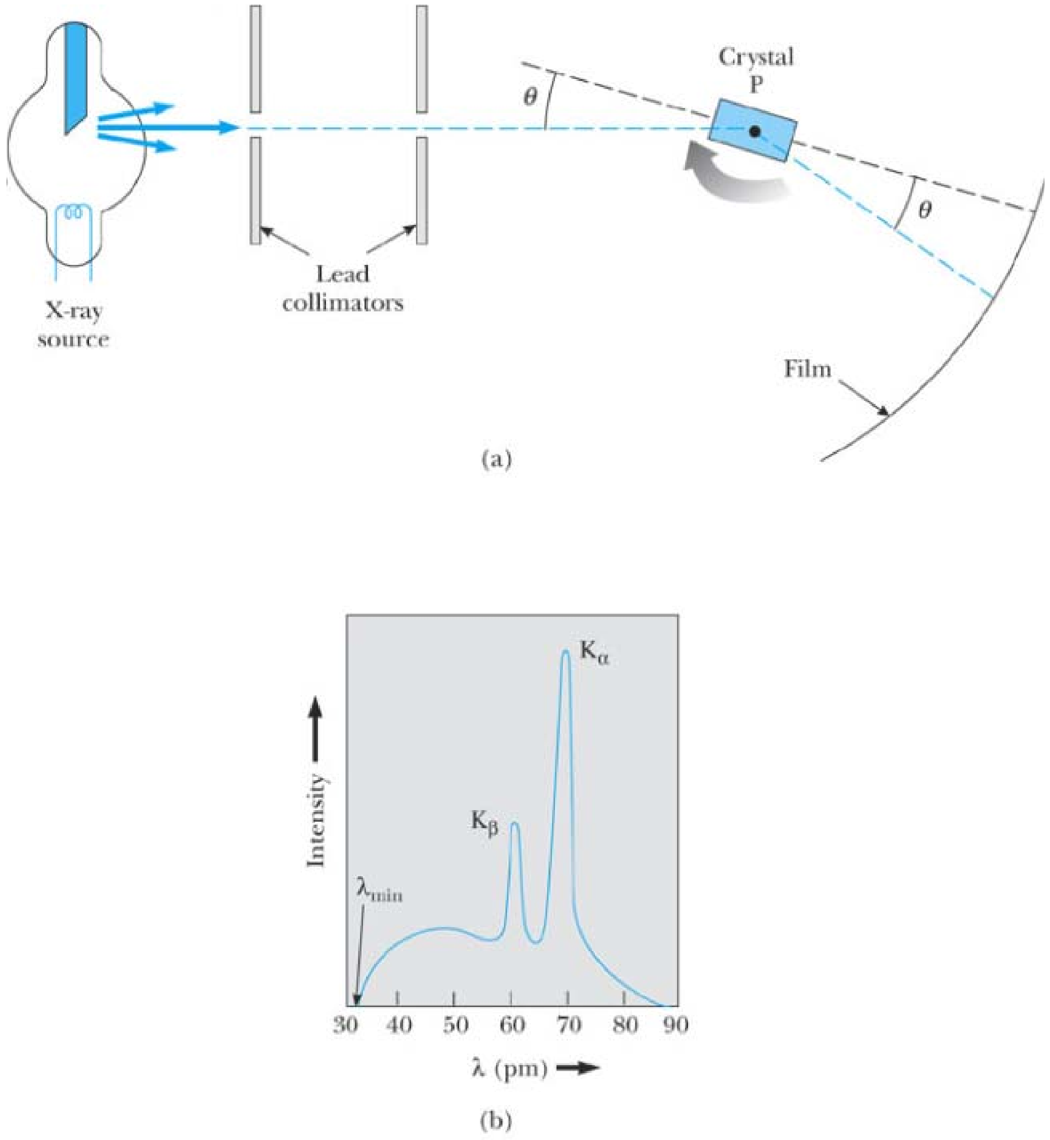

X-ray source
Lead collimators
Crystal P
θ
θ
Film
(a)
Intensity
Kα
Kβ
λmin
30 40 50 60 70 80 90
λ (pm)
(b)

Fig. 3-21, p. 88

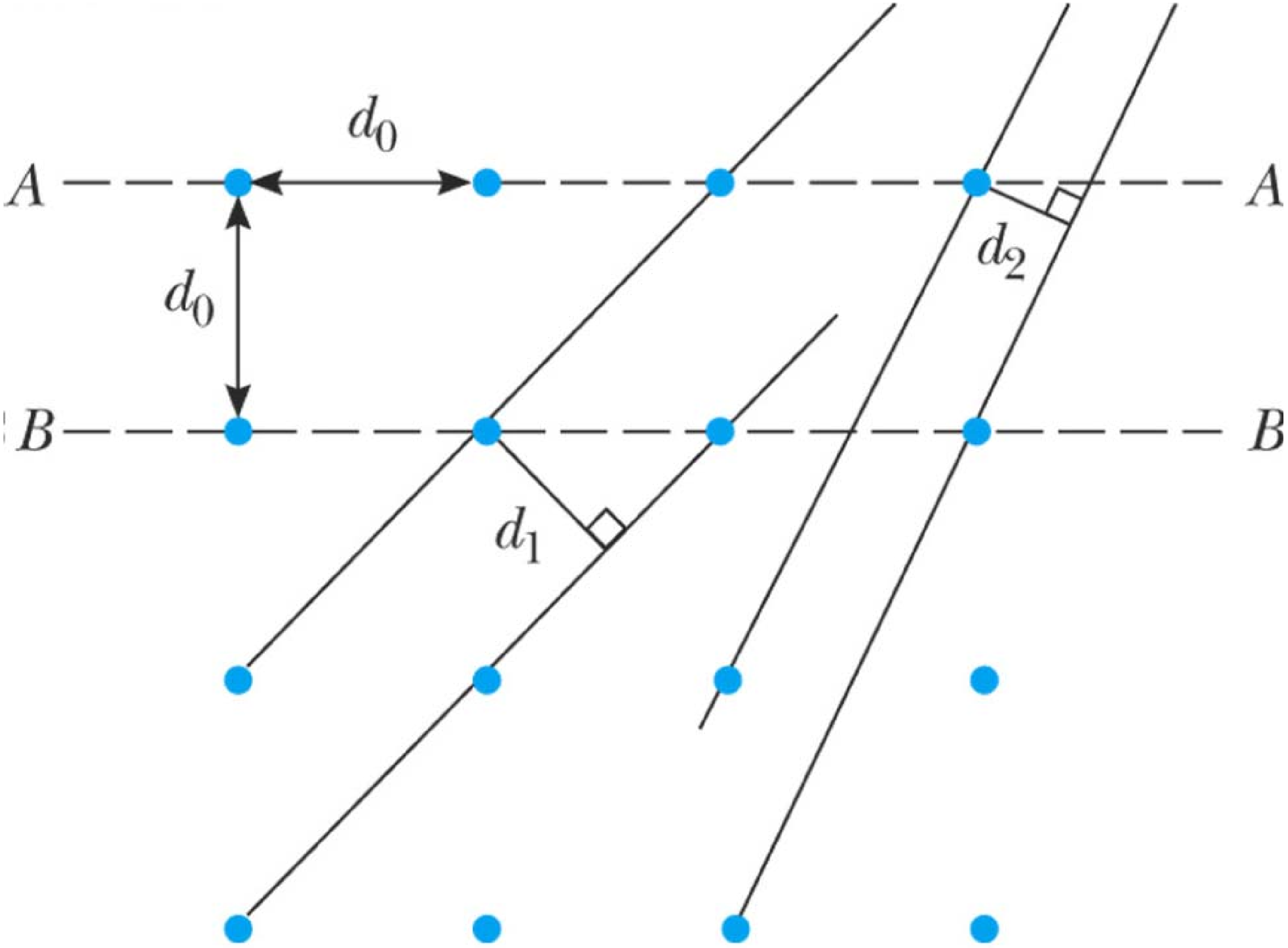


Fig. P3-38, p. 104

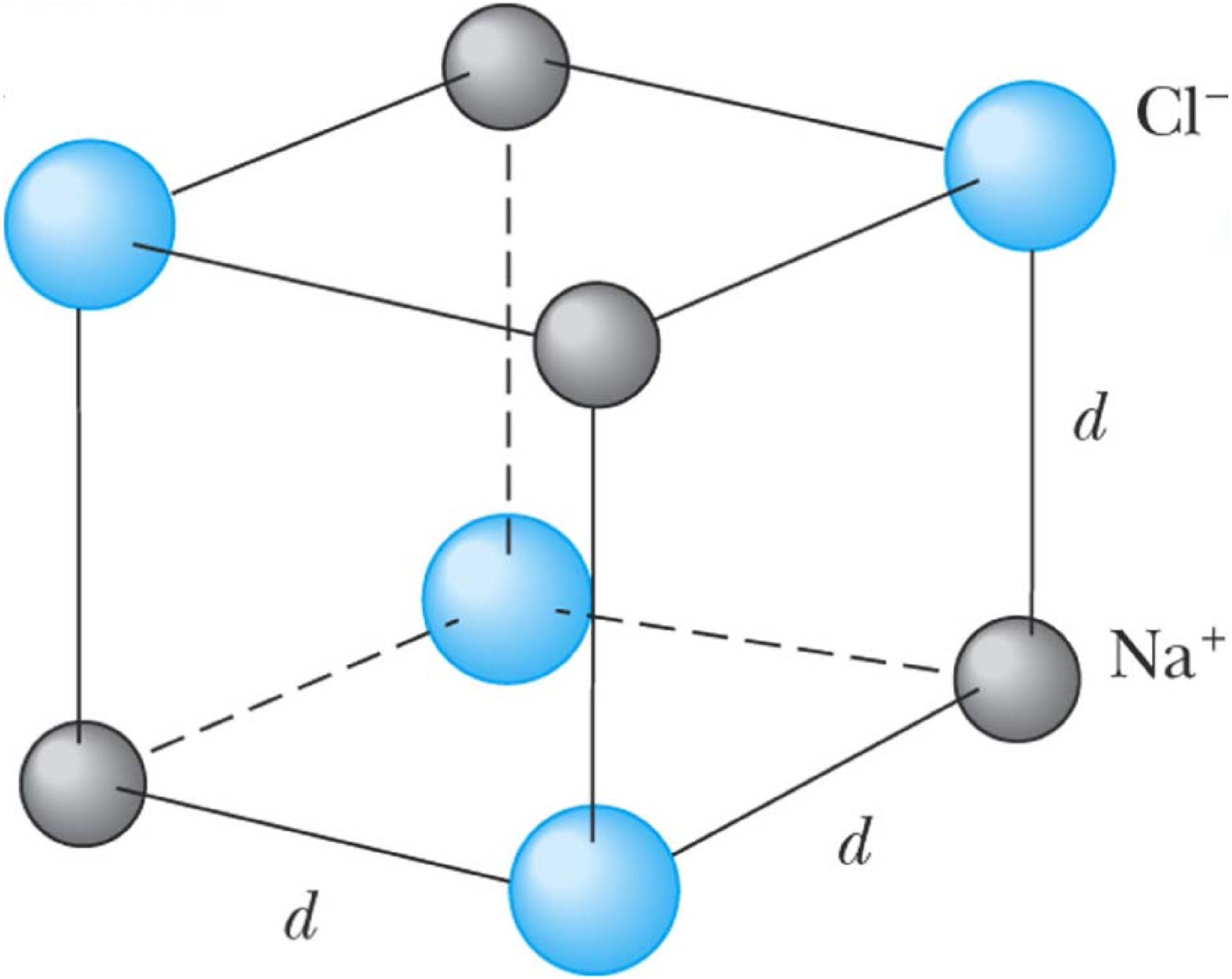


Fig. P3-39, p. 104

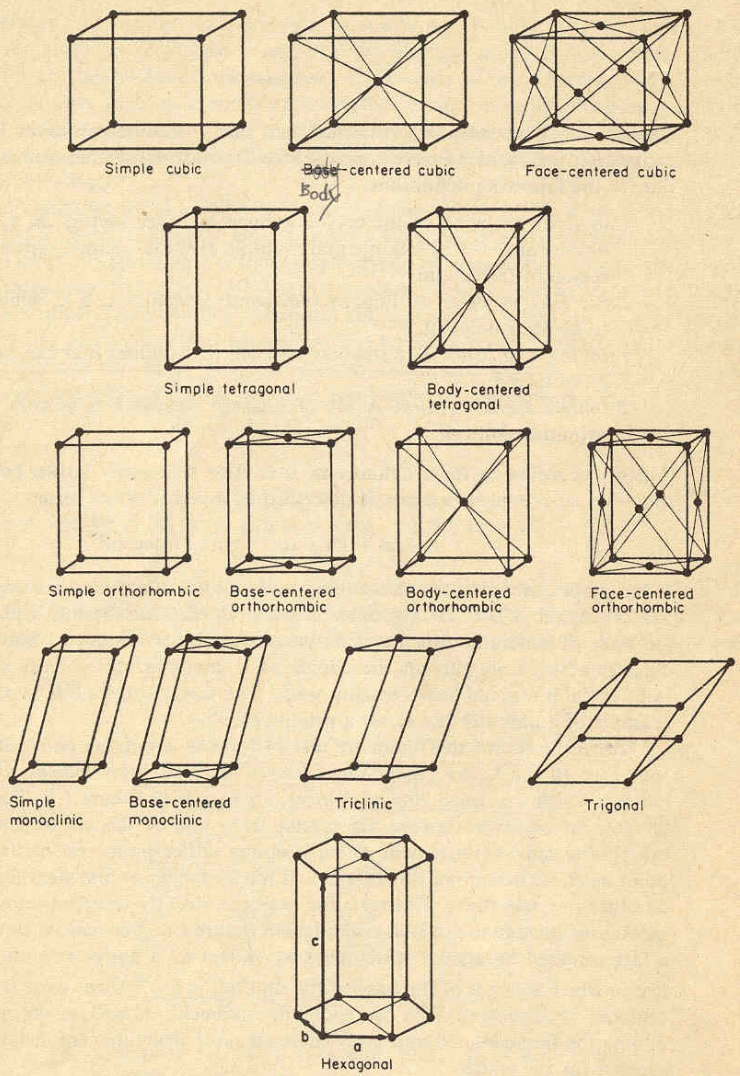
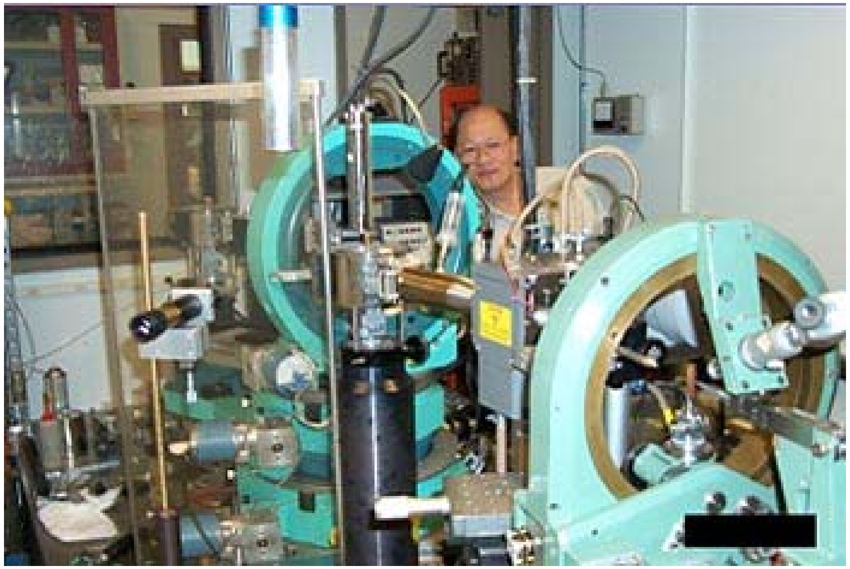
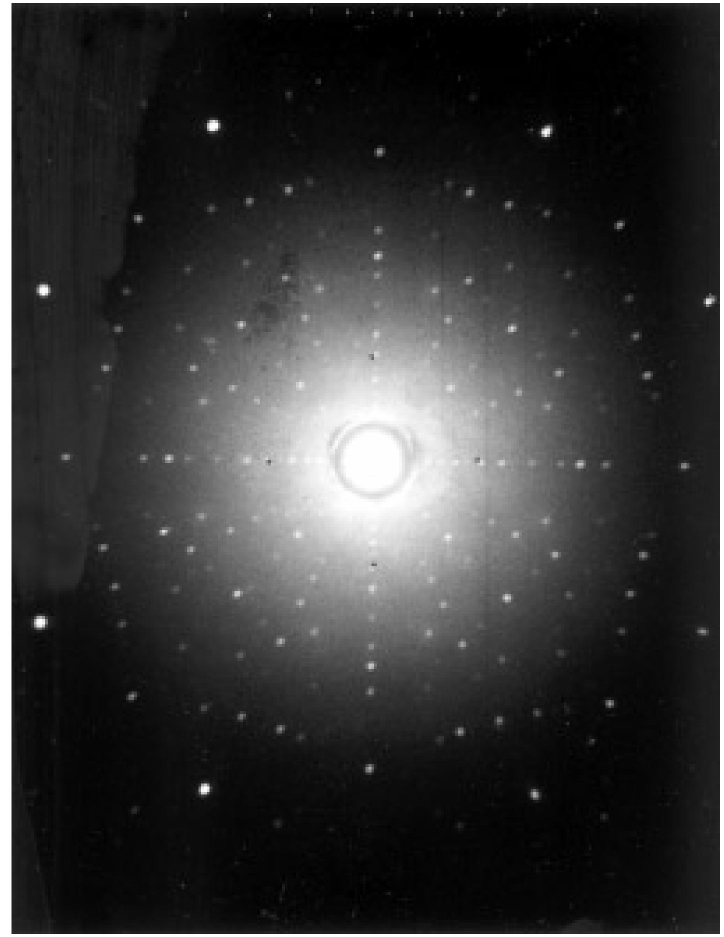


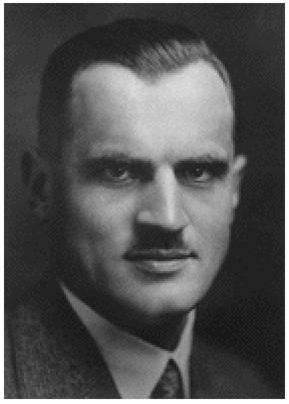
FIGURE 1.3. The fourteen Bravais lattices.





Lawrence Livermore National Laboratory, USA

Compton Effect



Arthur Holly Compton
(1892-1962)

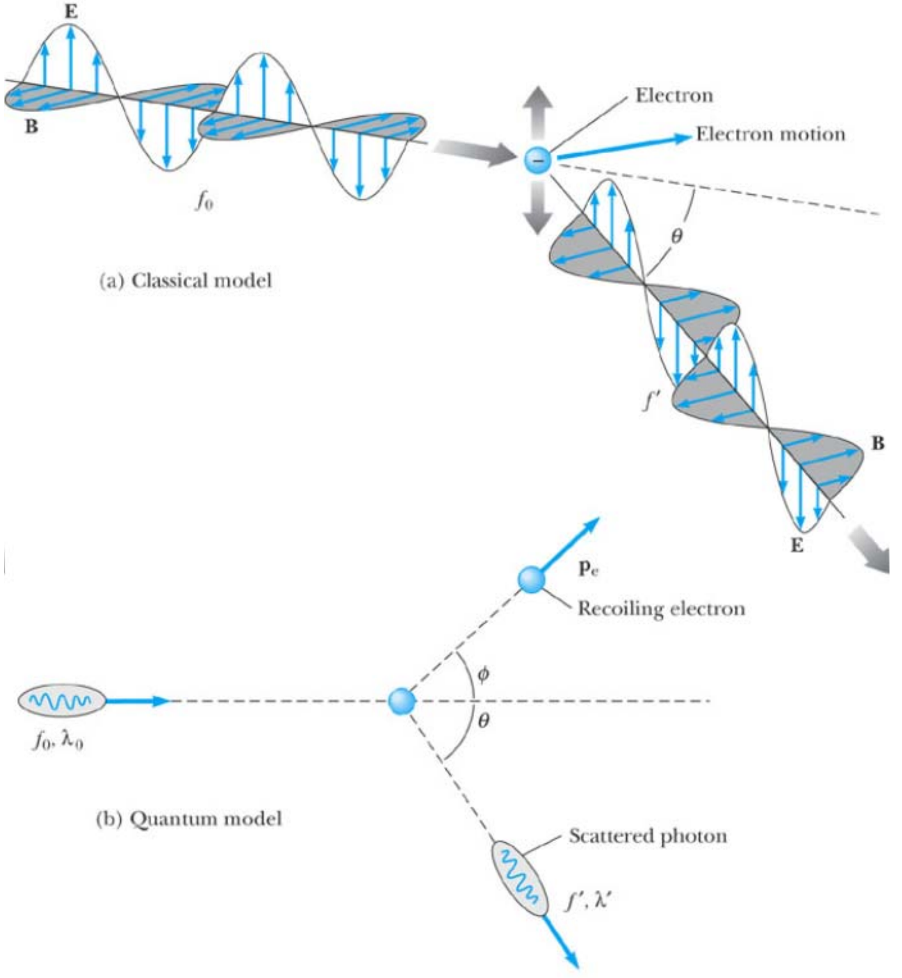


Fig. 3-22, p. 90