

**Fig. 1.1. Photoelectric effect.** (a) The apparatus to measure the effect consists of a vacuum tube containing two electrodes. Monochromatic light of frequency  $\nu$  shines on the cathode and liberates electrons which may reach the anode and create a current  $I$  in the external circuit. The flow of electrons in the vacuum tube is hindered by the external voltage  $U$ . It stops once the voltage exceeds the value  $U_s$ . (b) There is a linear dependence between the frequency  $\nu$  and the voltage  $U_s$ .

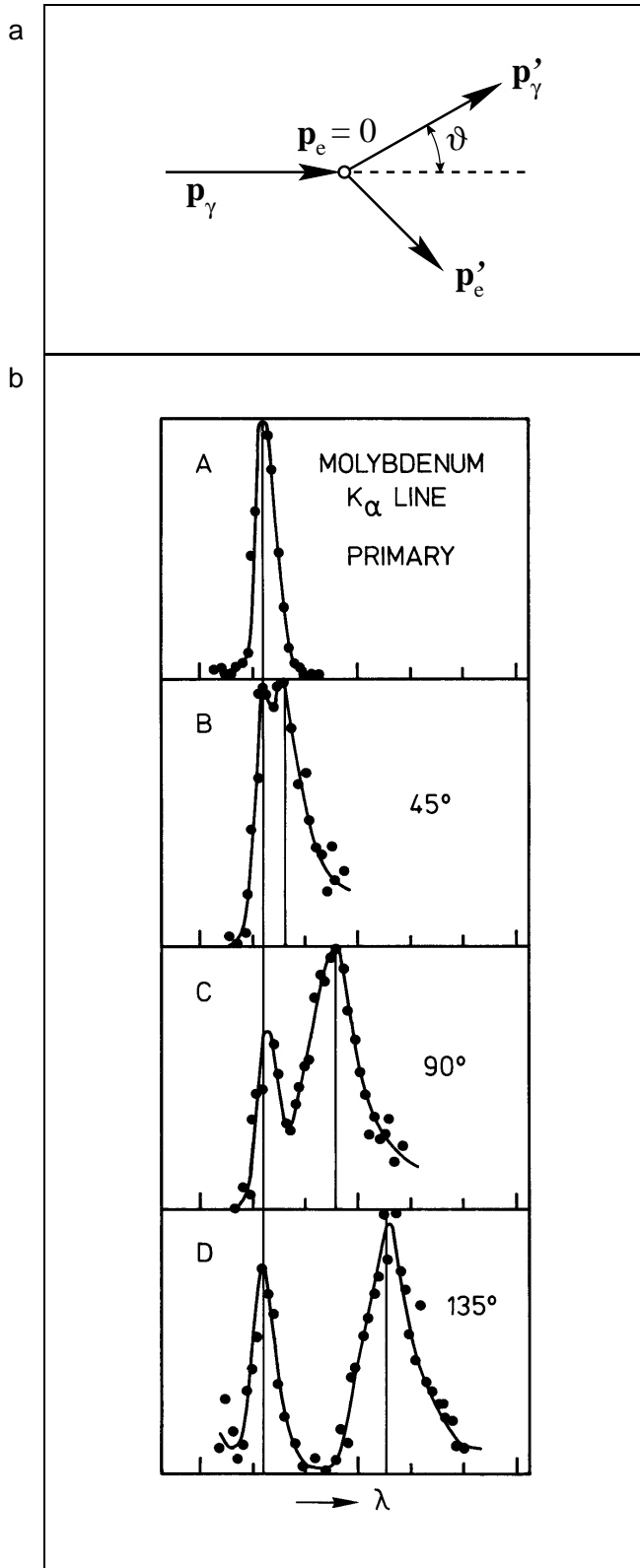
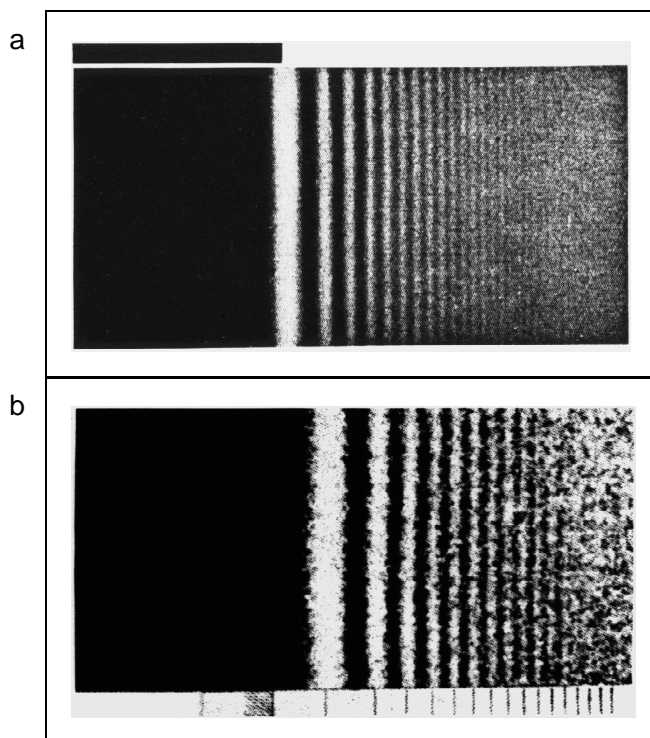
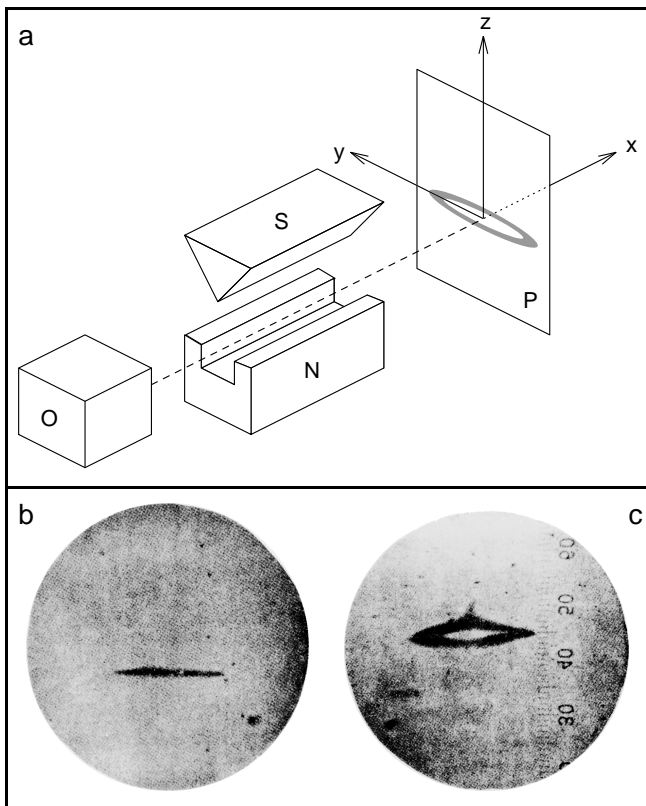


Fig. 1.2. The Compton effect. (a) Kinematics of the process. A photon of momentum  $\mathbf{p}_\gamma$  is scattered by a free electron at rest, one with momentum  $\mathbf{p}_e = \vec{0}$ . After the scattering process the two particles have the momenta  $\mathbf{p}'_\gamma$  and  $\mathbf{p}'_e$ , respectively. The direction of the scattered photon forms an angle  $\vartheta$  with its original direction. From energy and momentum conservation in the collision, the absolute value  $p'_\gamma$  of the momentum of the scattered photon and the corresponding wavelength  $\lambda' = h/p'_\gamma$  can be computed. (b) Compton's results. Compton used monochromatic X-rays from the  $K_\alpha$  line of molybdenum to bombard a graphite target. The wavelength spectrum of the incident photons shows the rather sharp  $K_\alpha$  line at the top. Observations of the photons scattered at three different angles  $\vartheta$  ( $45^\circ$ ,  $90^\circ$ ,  $135^\circ$ ) yielded spectra showing that most of them had drifted to the longer wavelength  $\lambda'$ . There are also many photons at the original wavelength  $\lambda$ , photons which were not scattered by single electrons in the graphite. From A. H. Compton, *The Physical Review* **22** (1923) 409, copyright © 1923 by the American Physical Society, reprinted by permission.



**Fig. 1.3.** (a) Interference pattern caused by the scattering of red light on a sharp edge. The edge is the border line of an absorbing half-plane, the position of which is indicated at the top of the figure. (b) Interference pattern caused by the scattering of electrons on a sharp edge. *Sources:* (a) From R. W. Pohl, *Optik und Atomphysik*, ninth edition, copyright © 1954 by Springer-Verlag, Berlin, Göttingen, Heidelberg, reprinted by permission. (b) From H. Boersch, *Physikalische Zeitschrift*, **44** (1943) 202, copyright © 1943 by S.-Hirzel-Verlag, Leipzig, reprinted by permission.



**Fig. 1.4. Stern–Gerlach experiment.** Experimental setup with oven O, magnet pole shoes N and S, and glass screen P (a). Silver deposit on screen without field (b) and with field (c) as shown in Stern’s and Gerlach’s original publication. The splitting is largest in the middle and gets smaller to the left and the right of the picture because the field inhomogeneity is largest in the  $x, z$  plane. *Source:* (b) and (c) from W. Gerlach and O. Stern, *Zeitschrift für Physik* **9** (1922) 349 © 1922 by Springer-Verlag, Berlin, reprinted by permission.