a) Determination of the position of a free particle.—As a first example of the destruction of the knowledge of a particle's momentum by an apparatus determining its position, we consider the use of a microscope.[1] Let the particle be moving at such a distance from the microscope that the cone of rays scattered from it through the objective has an angular opening ϵ. If λ is the wave-length of the light illuminating it, then the uncertainty in the measurement of the x-co-ordinate (see Fig. 5) according to the laws of optics governing the resolving power of any instrument is:

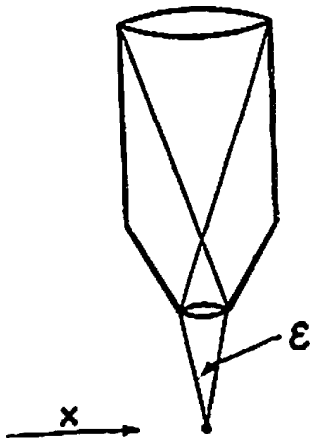

FIG. 5

$$\Delta x = \frac{\lambda}{\sin \epsilon} . \tag{16}$$

But, for any measurement to be possible at least one photon must be scattered from the electron and pass through the microscope to the eye of the observer. From this photon the electron receives a Compton recoil of order of magnitude h/λ. The recoil cannot be exactly known, since the direction of the scattered photon is undetermined within the bundle of rays entering the microscope. Thus there is an uncertainty of the recoil in the x-direction of amount

$$\Delta p_x \sim \frac{h}{\lambda} \sin \epsilon , \tag{17}$$

and it follows that for the motion after the experiment

$$\Delta p_x \Delta x \sim h . \tag{18}$$

[1] N. Bohr, *loc. cit.*