axes; but, in the same way also the results are correct if the resolution is treated as an analytical device and in the final result account is taken of all the overlapping components. Spectroscopes generally consist of three parts: (1) the colli- mator; (2) the analysing appliance, (3) the telescope. The slit of the collimator confines the light to a nearly linear source, the beam diverging from each point of the source being subse- quently made parallel by means of a lens. The parallelism, which is required to avoid aberrations, otherwise introduced by the prism or grating, may often be omitted in instruments of small power. The lens may then be also dispensed with, and the whole collimator becomes unnecessary if the luminous source is narrow and at a great distance, as for instance in the case of the crescent of the sun near the second and third contact of a total solar eclipse. The telescope serves to examine the image of the slit and to measure the angular separation of the different slit images; when photographic methods are employed the telescope is replaced by a camera.

The analysing appliance constitutes the main feature of a spectroscope. It may consist of one of the following:—

α. A prism or a train of prisms. These are employed in instruments of small power, especially when luminosity is a consideration; but their advantage in this respect is to a great extent lost, when, in order to secure increased resolving power, the size of the prisms, or their number, is unduly increased.

*b.* A grating. Through H. A. Rowland’s efforts the con­struction of gratings has been improved to such an extent that their use is becoming universal whenever great power or accuracy is required. By introducing the concave grating which (see Diffraction of Light, § 8) allows us to dispense with all lenses, Rowland produced a revolution in spectroscopic measurement. At present we have still to content ourselves with a much diminished intensity of light when working with gratings, but there is some hope that the efforts to concentrate the light into one spectrum will soon be successful.

*c.* An échelon grating. Imagine a horizontal section of a beam of light, and this section divided into a number of equal parts. Let somehow or other retardations be introduced so that the optical length of the successive parts increases by the same quantity *nλ, n* being some number and λ the wave-length. If on emergence the different portions he brought together at the focus it is obvious that the optical action must be in every respect similar to that of a grating when the nth order of spectrum is considered. A. Michelson produced the successive retarda­tions by inserting step-by-step plates of glass of equal thickness so that the different portions of the beam traversed thicknesses of glass equal to *nλ, 2nλ,* 3nλ, . . . Nλ. The optical effect as regards resolving power is the same as with a grating of N lines in the nth order, but, nearly all the light not absorbed by the glass may be concentrated in one or two orders.@@1

*d.* Some other appliance in which interference with long difference of path is made use of, such as the interferometer of Fabry and Perot, or Lummer’s plate (see Interference of Light).

The echelon and interferometer serve only a limited purpose, but must be called into action when the detailed structure of fines is to be examined. For the study of Zeeman effects (see Magneto-Optics) the échelon seems specially adapted, while the great pliability of Fabry and Perot’s methods, allowing a clear interpretation of results, is likely to secure them perma­nently an established place in measurements of precision.

The power of a spectroscope to perform its main function, which is to separate vibrations of different but closely adjacent frequencies, is called its “ resolving power.” The limitation of power is introduced as in all optical instruments, by the finiteness of the length of a wave of light which causes the image of an indefinitely narrow slit to spread out over a finite width in the focal plane of the observing telescope. The so-called “ diffraction ” image of a homogeneously illuminated slit shows a central band limited on either side by a line along which the

intensity is zero, and this band is accompanied by a number of fainter images corresponding to the diffraction of a star image in a telescope. Lord Rayleigh, to whom we owe the first general discussion of the theory of the spectroscope, found by observation that if two spectroscopic lines of frequencies *n1* and *n2* are observed in an instrument, they are just seen as two separate lines when the centre of the central diffraction band of one coincides with the first minimum intensity of the other. In that case the image of the double line shows a diminu- tion of intensity along the centre, just sufficient to give a clear impression that we are not dealing with a single line, and the intensity at the minimum is 0∙81 of that at the point of maximum illumination. We may say therefore that if the difference between the frequencies *n1* and *η2* of the two waves is such that in the combined image of the slit the intensity at the minimum between the two maxima falls to 0∙81, the lines are just resolved and *n1∣(n1-n2)* may then be called the resolving power. There is something arbitrary in this definition, but as the practical importance of the question lies in the comparison between instruments of different types, the exact standard adopted is of minor importance, the chief consideration being simplicity of application. Lord Rayleigh’s expression for the resolving power of different instruments is based on the assumption that the geometrical image of the slit is narrow compared with the width of the diffraction image. This condition is necessary if the full power of the instrument is to be called into action. Unfortunately considerations of luminosity compel the observer often to widen the slit much beyond the range within which the theoretical value of resolving power holds in practice. The extension of the investigation to wide slits was first made by the present writer in the article “ Spectroscopy ” in the 9th edition of the *Encyclopaedia Britannica.* Reconsideration of the subject led him afterwards to modify his views to some extent, and he has since more fully discussed the question.@@2 Basing the investigation on the same criterion of resolution as in the case of narrow slits, we postulate for both narrow and wide slits that two lines are resolved when the intensity of the combined image falls to a value of o∙810 in the centre between the lines, the intensity at the maxima being unity. We must now however introduce a new criterion the “ purity ” and distinguish it from the resolving power: the purity is defined by *η1/(n1-n2),* where *η1* and n2 are the frequencies of two lines such that they would just be resolved with the width of slit used. With an indefinitely narrow slit the purity is equal to the resolving power. As purity and resolving power are essentially positive quantities, *n1* in the above expression must be the greater of the two frequencies. With wide slits the difference n1-n2 depends on their width. If we write P = p R where P denotes the purity and R the resolving power, we may call *p* the “ purity­factor. ” In the paper quoted the numerical values of *p* are given for different widths of slit, and a table shows to what extent the loss of purity due to a widening of the slit is accom- panied by a gain in luminosity. The general results may be summarized as follows: if the width of the slit is equal *f*λ∕4D (where λ is the wave-length concerned, D the diameter of the collimator lens, and *f* its focal length) practically full resolving power is obtained and a further narrowing of the slit would lead to loss of light without corresponding gain. We call a slit of this width a “ normal slit. ” With a slit width equal to twice the normal one we lose 6% of resolution, but obtain twice the intensity of light. With a slit equal in width to eight times the normal one the purity is reduced to o∙45R, so that we lose rather more than half the resolving power and increase the light 3∙7 times. If we widen the slit still further rapid loss of purity results, with very little gain in light, the maximum luminosity obtainable with an indefinitely wide slit being four times that obtained with the normal one. It follows that for observations in which light is a consideration spectroscopes should be used which give about twice the resolving power of that actually required; we may then use a slit having a width of nearly eight times that of the normal one.

@@@1 Michelson, *Astrophys. Journ.* (1898), 8, p. 36; A. Schuster, *Theory of Optics,* p. 115.

*@@@2 Astrophys. Jοurn.* (1905), 21, p. 197.