LETTERS TO THE EDITORS

The Editors do not hold themselves responsible for opinions expressed by their correspondents. No notice is taken of anonymous communications.

Colour Measurement

MR. J. W. PERRY's letter on colour measurement¹ may lead to misconceptions of the nature and status of the C.I.E. colorimetric system by colour workers who have not paid particular attention to the principles of colour measurement. In stating that the numerical colour specification $\chi_{\text{C.I.E.}}$ refers to (a) a normal observer and (b) normal observing conditions, including (c) a field of direct observation of 2°, Perry confuses the colorimetric standard with the procedure recommended for general direct colorimetry.

The 'standard observer' is a set of tables defining what is to be understood physically by colour, and has been adopted internationally for technical and commercial purposes. There is much evidence that this standard has proved satisfactory for a large range of such applications, and we know of none where it has been definitely found unsatisfactory. But whether the present tables are satisfactory or not, they are not restricted in their application to a given field size or field brightness or pupillary aperture or otherwise.

When measurements are made by the indirect spectrophotometric method, it is clear that these factors are irrelevant. Difference in colour merely means difference in $\chi_{\text{C.I.E.}}$, and can be specified to any accuracy attainable by spectrophotometry. Perry appears to think that, owing to the procedure adopted in the experiments on which the standard system was based, there exists a possibility of error in $\chi_{\text{C.I.E.}}$ values. But there is no possibility of error in what is by definition the standard, neither is there any tolerance. The definition is exact and unambiguous. The original measurements of Guild and Wright provided evidence that a standard based on their results would probably prove generally acceptable; once the tables based on these measurements were adopted as a standard, it became irrelevant whether they represented the visual properties of the groups of observers who contributed to the results with a high or a low degree of accuracy, and whether they were obtained with a large or a small field of view. There were in fact important reasons for choosing particular conditions, but it is unnecessary to discuss them here.

The recommendations for using particular conditions in general direct colorimetry were intended to guide a real observer in his efforts to obtain measurements likely to be in satisfactory agreement with the standard observer. When very small colour differences are to be measured, it is known that different conditions of observation should be adopted. It is possible that experience in these or other measurements may show that amendments should be made in the present standards to meet the increasing requirements of technical colorimetry. But any changes will be changes of detail and not of form. No new quantity χ_N , as proposed by Perry, involving a new physical concept, is involved in either differential or absolute colorimetry with large fields. The regional variation of retinal properties is formally irrelevant to appearances in an extended field. A physically uniform field will appear uniform in colour and brightness despite retinal variations, and

colour matches with such fields will result in trichromatic equations of the same form as those obtained with a uniform field of small size. The results may differ numerically but not otherwise. In both cases the numerical differences from the C.I.E. values arise from departures of the colour vision of the real observer from those defined as the standard, that is, they are to be regarded as personal errors. It is well, however, to remember that it is only advantageous to use large fields for visual colorimetry when two specimens closely alike in spectral constitution as well as in colour are to be compared; the perception of a match or of small departures from a match is then very little affected by the observer's peculiarities of vision. In these circumstances all but extremely abnormal observers will obtain results agreeing with the standard to the limits of discrimination. Thus where a large field enables greater precision to be attained usefully, any consequent tendency for colour vision to depart from the standard becomes relatively unimportant.

We believe that Perry's difficulties about the standard observer are not real. Data of this type are formally necessary and sufficient for every colorimetric problem. If modification in the standard should ultimately be found desirable in the light of accumulated experience, it will be found a purely practical matter involving no change of principle. We can see no useful purpose that would be served by the philosophical inquiry desired but, to our minds, only obscurely indicated by Perry.

T. SMITH.

J. GUILD.

R. DONALDSON.

National Physical Laboratory,
Teddington, Middlesex.
Dec. 18.

¹ NATURE, 148, 691 (1941).

MR. J. W. PERRY's remarks¹ directing attention to the difference between the colorimetric concepts which he calls $\chi_{\text{C.I.E.}}$ and χ_N are opportune. As he points out, there is at present no real justification for applying the results of measurements made under the original standard C.I.E. conditions to problems involving other conditions of observation, and if nevertheless we do so, we must clearly realize that this procedure is at best a makeshift pending the publication of more detailed information. There is a need for fundamental research on the whole subject of the colorimetry of wide field systems.

The present position of colorimetry in the paper, printing and printing ink industry (and, I believe, several other industries) is this. If I have a sheet of paper which I have found by measurement to have colour *A*, it should be sufficient for me to order paper of colour *A* from the maker in the moral certainty that the paper, when it arrived, would match my sheet within commercial limits of tolerance; there should be no need for interchange of samples. Unfortunately, this is at present not so. Even if the paper mill and I both have visual colorimeters and they are used by experienced observers, it still does not follow that when the mill and I get identical colorimetric readings, that experimental making and sample will necessarily be a good commercial match. Of course, they may be so, and in any event they will not be widely different; but one cannot guarantee a match.