

Twenty-Two Colors of Maximum Contrast

by Kenneth L. Kelly

Requests for sets of colors which would be maximally different for use in color coding, providing maximum contrast for those with deficient color vision, have resulted in the selection of 22 shades from the ISCC-NBS Centroid Colors.

A number of requests have been made to the Inter-Society Color Council for sets of colors, 2 up to 22 colors per set, which would be maximally different for use in color coding. The author was requested to determine such sets from the ISCC-NBS centroid colors since these colors will be widely distributed and always available in chart form as well as in 9-by 12-inch sheets, both at very reasonable prices. The list of centroid colors in Table 1 is given as the solution to this request.

The development and designation of the ISCC-NBS centroid colors have been covered in great detail in the literature over the past 30 years. The three documents that give information basic to this problem are the set of ISCC-NBS Centroid Color Charts (1), the color names dictionary (5) and a Universal Color Language (4).

The selection of the ISCC-NBS centroid colors from which to choose colors for coding was made for the following reasons: the centroid colors were developed by the Inter-Society Color Council and the National Bureau of Standards (ISCC-NBS), they will be widely available, the price is

extremely reasonable, they may be obtained in one-by-one-inch size in the centroid chart form and in 9-by-12-inch sheets from Munsell Color Company, Inc., Baltimore, Maryland, and repaints will color match the originally selected colors within very stringent tolerances.

It was immediately obvious that to list these colors in sets of 2, 3, 4, 5, 6, 7 and so on up to 22, would involve duplication of the colors of one set in those of the next higher numbered set. Therefore, it was decided to present these centroid colors in a list in such an order that the desired number would be obtained by taking that number from the top of the list. That is, if one desires 3, 7, or 19 colors for a job, one would simply use the first 3, 7 or 19 colors from this list. If the colors for a job are selected from this list but not in numerical order as described above, the desired effectiveness with respect to color blindness and visual contrast will be reduced.

It was also obvious that the second question by the user would concern the effect of color blindness on the selection and thus the use of these colors. Earlier work by Judd (2) (3)

led to the selection of nine colors which would be maximally different not only to the color-normal observer but to most red-green deficient observers, and would, at the same time, be readily distinguished by color name. It was therefore decided to use the nine centroid colors which would effectively duplicate the nine colors in Judd's selection as the first nine colors in this list. These colors have been arranged in such an order that the second color contrasts maximally with the first, the third color contrasts satisfactorily with the first pair, the fourth color contrasts maximally with the third, and pairs of maximum contrast are added up through the eighth color. The ninth color is medium gray. This is as far as any claim can be made with respect to red-green confusers, and this division is indicated by a line drawn across the list between colors 9 and 10.

The succeeding 13 colors (10 through 22) in this list are claimed to contrast maximally only for the color-normal observer. Each successive color has been selected so that it will contrast maximally with the color just preceding it and satisfactorily with the

earlier colors in the list. That is, the color following Green is Purplish Pink which differs considerably from Green in lightness and is almost complementary to it in hue. The next color, Blue, differs also from Purplish Pink considerably in lightness and is almost complementary to it in hue. This method was followed as far as possible in the selection of the centroid colors in the rest of the list.

Application

Some color codes such as diagrams, maps and illustrations, apply to detailed patterns shown by black lines on white paper and require that the first two colors, black and white, of this list be omitted from the code. Thus, for this purpose, the required number of colors is taken from the top of the list starting with color number 3. For other color codes where white and black are acceptable, such as to indicate contents of containers (for drugs, chemicals or any industrial material) or to indicate numerical values of some property of a manufactured article or component, the desired number of colors is taken from the top of the list starting with color number 1.

List of Colors

Table I lists the 22 colors in order, giving for each its serial and therefore its selection number, the general color name, the ISCC-NBS centroid or color-name block number, the ISCC-NBS color name and the Munsell renotation taken from the table in the front of the set of ISCC-NBS Centroid Color Charts.

To summarize: the ISCC-NBS centroid colors listed in Table I have been carefully selected to provide maximum contrast in color coding. The first nine colors have been selected so as to yield satisfactory contrast for red-green-deficient as well as color-normal observers, while the following 13 colors have been selected, of necessity, to be useful only for color-normal observers. This list of colors is intended primarily to be of use in establishing new color codes and secondarily as a guide in the revision of existing color codes. Such revision might consist of shifting the color for a designated meaning so that it will be more effectively seen by a greater percentage of the population

(normal plus red-green-deficient observers). This list of colors can also serve as a guide when new colors have to be added to an existing color code.

LITERATURE REFERENCES

- (1) ISCC-NBS Centroid Color Charts, Standard Sample No. 2106, obtainable from the Office of Standard Reference Materials, National Bureau of Standards, Washington, D. C. 20234 for \$3.00 per set of 18 charts.
- (2) Judd, Deane B., Color Perceptions of Deuteranopic and Protanopic Observers, *J. Research NBS* 41, 247 (1948).
- (3) Judd, Deane B., Report of the Working Group on a Color Code for Compressed Gas Cylinders and Pipe Lines, Minutes and Proceedings of the 29th Meeting Armed Forces - NRC Vision Committee, page 37, Nov. 16-17, 1951, U. S. Submarine Base, New London, Conn. (Stamped Confidential)
- (4) Kelly, Kenneth L., A Universal Color Language, *Color Engineering* 3, 16 (1965).
- (5) Kelly, Kenneth L. and Judd, Deane B., The ISCC-NBS Method of Designating Colors and a Dictionary of Color Names, NBS Circular 553, Nov. 1, 1955 (reprinted May 1, 1965), U. S. Government Printing Office, Washington, D. C. 20402, for \$2.00 per copy.

The Author

KENNETH L. KELLY, a physicist in the Photometry and Colorimetry Section of the National Bureau of Standards, Washington, D. C., has been involved in the color names project for nearly 30 years. In 1936 he commenced work at the National Bureau of Standards to assign boundaries to color ranges for designations derived on the basis laid down by I. H. Godlove, then chairman of the Inter-Society Color Council Committee on Measurement and Specification.

Three years later, Mr. Kelly and Dr. Deane B. Judd prepared research paper RP1239, Method of Designating Colors, which was approved by the ISCC for use in pharmaceutical literature. In 1955, again with Dr. Judd, he prepared the ISCC-NBS Method of Designating Colors and a Dictionary of Color Names. Three years later he authored the research paper, Central Notations for the Revised ISCC-NBS Color-Name Blocks.

Mr. Kelly, long active in many phases of color, is chairman of the ISCC Subcommittee on Color Names and a member of the subcommittee on Expression of Historical Color Usage.

TABLE I—COLORS OF MAXIMUM CONTRAST

Color Serial or selection number	General color name	ISCC-NBS centroid number	ISCC-NBS color-name (abbreviation)	Munsell renotation of ISCC-NBS Centroid Color
1	white	263	white	2.5PB 9.5/0.2
2	black	267	black	N 0.8/
3	yellow	82	v.Y	3.3Y 8.0/14.3
4	purple	218	s.P	6.5P 4.3/9.2
5	orange	48	v.O	4.1YR 6.5/15.0
6	light blue	180	v.I.B	2.7PB 7.9/6.0
7	red	11	v.R	5.0R 3.9/15.4
8	buff	90	gy.Y	4.4Y 7.2/3.8
9	gray	265	med.Gy	3.3GY 5.4/0.1
10	green	139	v.G	3.2G 4.9/11.1
11	purplish pink	247	s.pPk	5.6RP 6.8/9.0
12	blue	178	s.B	2.9PB 4.1/10.4
13	yellowish pink	26	s.yPk	8.4R 7.0/9.5
14	violet	207	s.V	0.2P 3.7/10.1
15	orange yellow	66	v.OY	8.6YR 7.3/15.2
16	purplish red	255	s.pR	7.3RP 4.4/11.4
17	greenish yellow	97	v.gY	9.1Y 8.2/12.0
18	reddish brown	40	s.rBr	0.3YR 3.1/9.9
19	yellow green	115	v.YG	5.4GY 6.8/11.2
20	yellowish brown	75	deep yBr	8.8YR 3.1/5.0
21	reddish orange	34	v.rO	9.8R 5.4/14.5
22	olive green	126	d.OIG	8.0GY 2.2/3.6