

### Color threshold formula LABJNDS 1985 for NW achromatic colours

$$\Delta E_{JND,NW}^* = Y_0 [(\Delta Y_W)^2 + (\Delta c_{ab,W} \cdot Y_W)^2]^{1/2} / (s + q \cdot Y_W^t)$$

$$= Y_0 [(\Delta Y_N)^2 + (\Delta c_{ab,N} \cdot Y_N)^2]^{1/2} / (s + q \cdot Y_N^t)$$

$$a = x/y \quad a_n = x_n/y_n \quad b = -0,4 z/y \quad b_n = -0,4 z_n/y_n$$

$$c_{ab} = [a_0^2(a - a_n)^2 + b_0^2(b - b_n)^2]^{1/2} \quad n = D65 \text{ or } A \text{ (surround)}$$

$$Y = (Y_1 + Y_2) / 2 \quad \Delta Y = Y_1 - Y_2 \quad \Delta a = a_1 - a_2 \quad \Delta b = b_1 - b_2$$

$$p_{c,NW} = c_{ab} / c_{ab,NW} \quad s = 0,0170 \quad q = 0,0058 \quad t = 1,0$$

$$a_0 = 1,0 \quad b_0 = 1,8 \quad Y_0 = 1,5 \quad \text{surround D65}$$

$$a_0 = 1,0 \quad b_0 = 1,7 \quad Y_0 = 1,0 \quad \text{surround A}$$

**Just noticeable difference of complementary (c) NW colours with:**

$$(a_W - a_n)Y_W = (a_N - a_n)Y_N; \quad (b_W - b_n)Y_W = (b_N - b_n)Y_N; \quad c_{ab,W}Y_W = c_{ab,N}Y_N$$

$$\Delta Y_W = \text{const} (s + q \cdot Y_W^t) / Y_0 \quad \text{in luminance direction } WN$$

$$\Delta c_{ab,W} \cdot Y_W = \text{const} (s + q \cdot Y_W^t) / Y_0 \quad \text{in any chromaticity direction } c_{ab}$$

$$\Delta c_{ab,N} \cdot Y_N = \text{const} (s + q \cdot Y_N^t) / Y_0 \quad \text{and for the NW purity } p_{c,NW}=0$$

1-000030-L0

UE110-3N

### Color threshold formula LABJNDS 1985 for Ostwald (o) colours

$$\Delta E_{JND,o}^* = Y_0 [(\Delta Y_o)^2 + (a_0 \Delta a_o \cdot Y_o)^2 + (b_0 \Delta b_o \cdot Y_o)^2]^{1/2} / (s + q \cdot Y_o^t)$$

$$= Y_0 [(\Delta Y_o)^2 + (\Delta c_{ab,o} \cdot Y_o)^2]^{1/2} / (s + q \cdot Y_o^t)$$

$$a = x/y \quad a_n = x_n/y_n \quad b = -0,4 z/y \quad b_n = -0,4 z_n/y_n$$

$$c_{ab} = [a_0^2(a - a_n)^2 + b_0^2(b - b_n)^2]^{1/2} \quad n = D65 \text{ or } A \text{ (surround)}$$

$$Y = (Y_1 + Y_2) / 2 \quad \Delta Y = Y_1 - Y_2 \quad \Delta a = a_1 - a_2 \quad \Delta b = b_1 - b_2$$

$$p_{c,o} = c_{ab} / c_{ab,o} \quad s = 0,0170 \quad q = 0,0058 \quad t = 1,0$$

$$a_0 = 1,0 \quad b_0 = 1,8 \quad Y_0 = 1,5 \quad \text{surround D65}$$

$$a_0 = 1,0 \quad b_0 = 1,7 \quad Y_0 = 1,0 \quad \text{surround A}$$

**Just noticeable difference of complementary (c) Ostwald (o) colours with:**

$$(a_o - a_n)Y_o = (a_{oc} - a_n)Y_{oc}; \quad (b_o - b_n)Y_o = (b_{oc} - b_n)Y_{oc}; \quad c_{ab,o}Y_o = c_{ab,oc}Y_{oc}$$

$$\Delta Y_o = \text{const} (s + q \cdot Y_o^t) / Y_0 \quad \text{in luminance direction } WN$$

$$\Delta c_{ab,o} \cdot Y_o = \text{const} (s + q \cdot Y_o^t) / Y_0 \quad \text{in any chromaticity direction } c_{ab}$$

$$\Delta c_{ab,oc} \cdot Y_{oc} = \text{const} (s + q \cdot Y_{oc}^t) / Y_0 \quad \text{and for the Ostwald purity } p_{c,o}=1$$

1-000030-L0

UE110-7N

TUB-test chart UE11; Colour threshold spaces  
LABJND & ABYJND, and modifications

### Complementary optimal colours: Relation XYZ and chromatic values A, B

| nonlinear color terms                        | name and relationship with tristimulus values XYZ, and the chromatic values (A, B)                                                                                                                                         | notes                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Threshold space ABY-JND1 equation (1)</b> | $\Delta E_{ABY}^* = Y_0 \{ [a_0 \Delta A_{01}]^2 + [b_0 \Delta B_{01}]^2 + [\Delta Y_{01}]^2 \}^{1/2}$<br>$= Y_0 \{ [c_0 \Delta C_{ab,01}]^2 + [\Delta Y_{01}]^2 \}^{1/2}$                                                 | $A = (a - a_n) \cdot Y$<br>$= (x/y - x_n/y_n) \cdot Y$<br>Normalization similar to CIELAB:<br>$X_{01} = X/X_n; Y_{01} = Y/Y_n; Z_{01} = Z/Z_n$<br>Relation for complementary (c) colours:<br>$X_{01c} = 1 - X_{01}; Y_{01c} = 1 - Y_{01}; Z_{01c} = 1 - Z_{01}$<br>Chromatic values:<br>$A_{01} = (a_{01} - a_{01n}) \cdot Y_{01}$<br>$= (x_{01} / y_{01} - 1) \cdot Y_{01}$<br>$= (X_{01} / Y_{01} - 1) \cdot Y_{01}$<br>$= X_{01} - Y_{01} = -A_{01c}$ |
| <b>Threshold space ABY-JND2 equation (2)</b> | $\Delta E_{ABY}^* = Y_0 \{ [a_0 \Delta A_{01}]^2 + [b_0 \Delta B_{01}]^2 + [\Delta Y_{01} / Y_{01}]^2 \}^{1/2}$<br>$= Y_0 \{ [c_0 \Delta C_{ab,01}]^2 + [\Delta Y_{01} / Y_{01}]^2 \}^{1/2}$                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Threshold space ABY-JND3 equation (3)</b> | $\Delta E_{ABY}^* = Y_0 \{ [a_0 \Delta A_{01} / A_{01}]^2 + [b_0 \Delta B_{01} / B_{01}]^2 + [\Delta Y_{01} / Y_{01}]^2 \}^{1/2}$<br>$= Y_0 \{ [c_0 \Delta C_{ab,01} / C_{ab,01}]^2 + [\Delta Y_{01} / Y_{01}]^2 \}^{1/2}$ |                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Properties complementary colours</b>      | $a_{01c} = -a_{01}; b_{01c} = -b_{01}; C_{ab,01c} = C_{ab,01};$<br>$\Delta a_{01c} = \Delta a_{01}; \Delta b_{01c} = \Delta b_{01}; \Delta C_{ab,01c} = \Delta C_{ab,01}; \Delta Y/Y = \text{const}$                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

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UE111-3N

### Complementary optimal colours: Relation XYZ and chromatic values A, B

| nonlinear color terms                        | name and relationship with tristimulus values XYZ, and the chromatic values (A, B)                                                                                                                                                                              | notes                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Threshold space ABY-JND1 equation (1)</b> | $\Delta E_{ABY}^* = Y_0 \{ [a_0 \Delta A_{01}]^2 + [b_0 \Delta B_{01}]^2 + [\Delta Y_{01}]^2 \}^{1/2}$<br>$= Y_0 \{ [c_0 \Delta C_{ab,01}]^2 + [\Delta Y_{01}]^2 \}^{1/2}$                                                                                      | $A = (a - a_n) \cdot Y$<br>$= (x/y - x_n/y_n) \cdot Y$<br>Normalization similar to CIELAB:<br>$X_{01} = X/X_n; Y_{01} = Y/Y_n; Z_{01} = Z/Z_n$<br>Relation for complementary (c) colours:<br>$X_{01c} = 1 - X_{01}; Y_{01c} = 1 - Y_{01}; Z_{01c} = 1 - Z_{01}$<br>Chromatic values:<br>$A_{01} = (a_{01} - a_{01n}) \cdot Y_{01}$<br>$= (x_{01} / y_{01} - 1) \cdot Y_{01}$<br>$= (X_{01} / Y_{01} - 1) \cdot Y_{01}$<br>$= X_{01} - Y_{01} = -A_{01c}$ |
| <b>Threshold space ABY-JND4 equation (4)</b> | $\Delta E_{ABY}^* = Y_0 \{ [a_0 \Delta A_{01} / Y_{01}]^2 + [b_0 \Delta B_{01} / Y_{01}]^2 + [\Delta Y_{01} / Y_{01}]^2 \}^{1/2}$<br>$= Y_0 \{ [c_0 \Delta C_{ab,01} / Y_{01}]^2 + [\Delta Y_{01} / Y_{01}]^2 \}^{1/2}$                                         |                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Threshold space ABY-JND5 equation (5)</b> | $\Delta E_{ABY}^* = Y_0 \{ [a_0 \Delta a_{01} \cdot Y_{01}]^2 + [b_0 \Delta b_{01} \cdot Y_{01}]^2 + [\Delta Y_{01}]^2 \}^{1/2} / (c + d \cdot Y_{01})$<br>$= Y_0 \{ [c_0 \Delta c_{ab,01} \cdot Y_{01}]^2 + [\Delta Y_{01}]^2 \}^{1/2} / (c + d \cdot Y_{01})$ |                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Properties complementary colours</b>      | $a_{01c} = -a_{01}; b_{01c} = -b_{01}; C_{ab,01c} = C_{ab,01};$<br>$\Delta a_{01c} = \Delta a_{01}; \Delta b_{01c} = \Delta b_{01}; \Delta C_{ab,01c} = \Delta C_{ab,01};$                                                                                      | $c = 0,017; d = 0,580$                                                                                                                                                                                                                                                                                                                                                                                                                                   |

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input: w/rgb/cmyk -> w/rgb/cmyk-  
output: no change