Understanding Densitometry & Spectrophotometry

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v BB29

X-Rite Training Center

Try and top this #1

"I think there is a world market for about five computers."

-- **Remark attributed to Thomas Watson, chairman of the board of IBM, 1943**

Try and top this #2

"There is no reason for any individual to have a computer in their home."

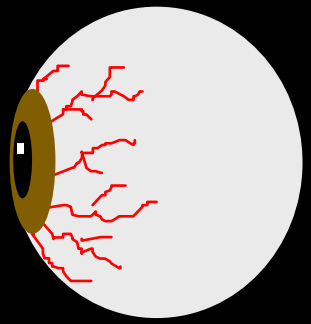
– Ken Olson, president of Digital Equipment Corporation, at the Convention of the World Future Society, 1977

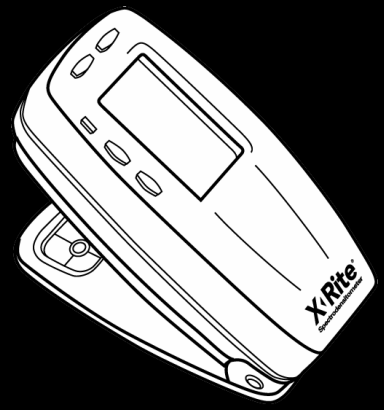
Try and top this #3

"Well-informed people know it is impossible to transmit the voice over wires and that were it possible to do so, the thing would be of no practical value."

-- Editorial in the Boston Post, 1865

What is the ‘best’ color tool?





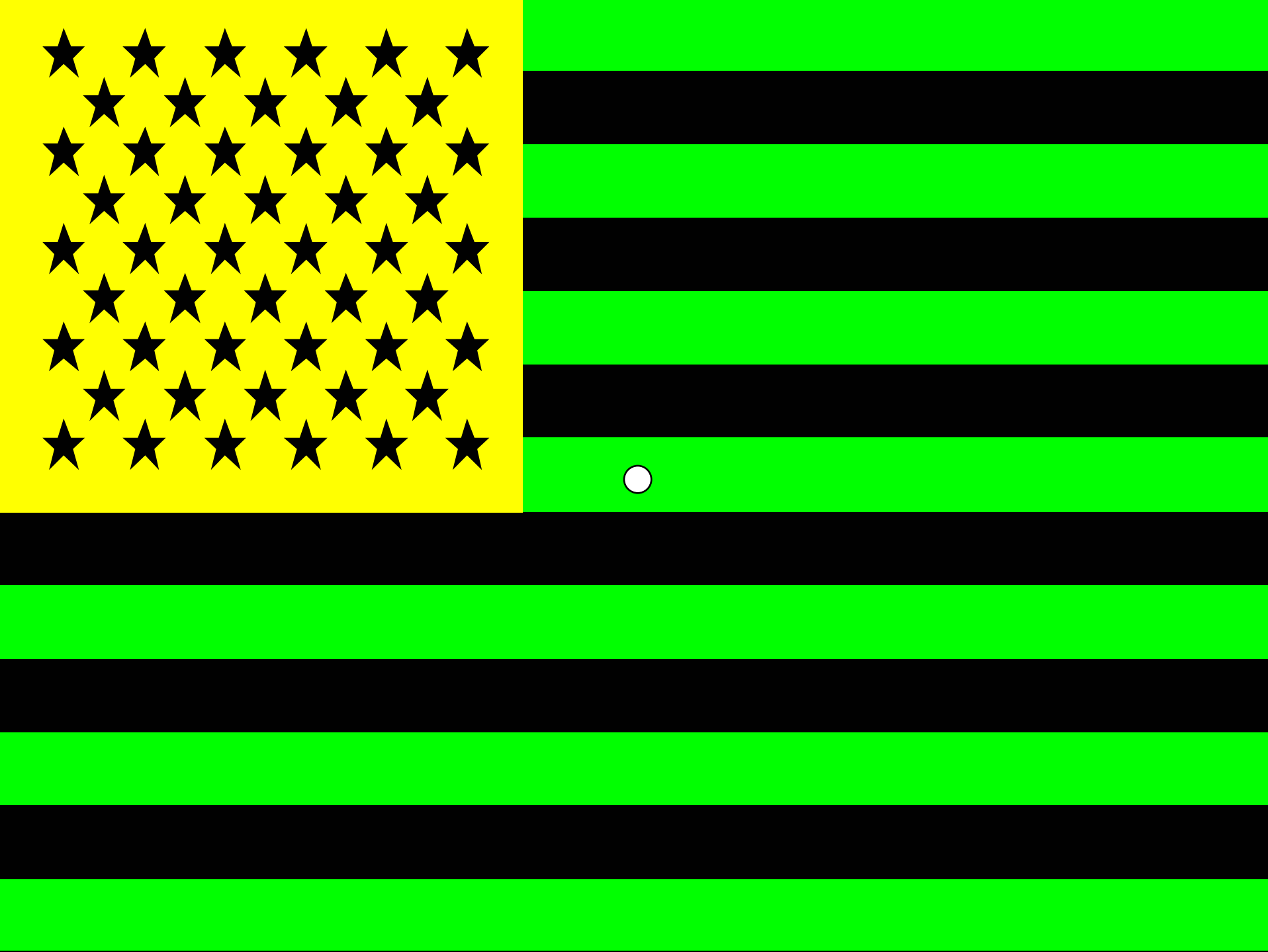
- Why use a color measurement instrument?
  - Are there limitation to the eye?
  - How about limitations with the instrument?

The  Factor

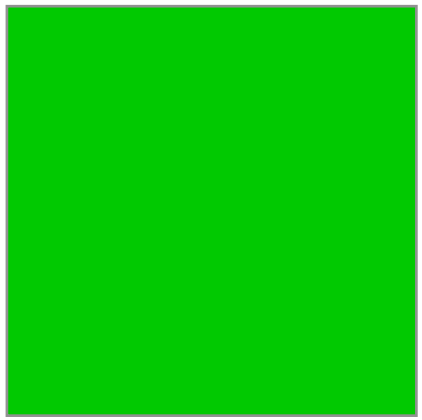
- How many of you think the human eye is a good color judging tool?
- Lets look at some potential problems with the eye…

The  Factor

- Retinal fatigue
  - Brief exposure to strong colors leaves an after image
  - Considerable rest is needed to let the eye recover



Look at the ‘X’



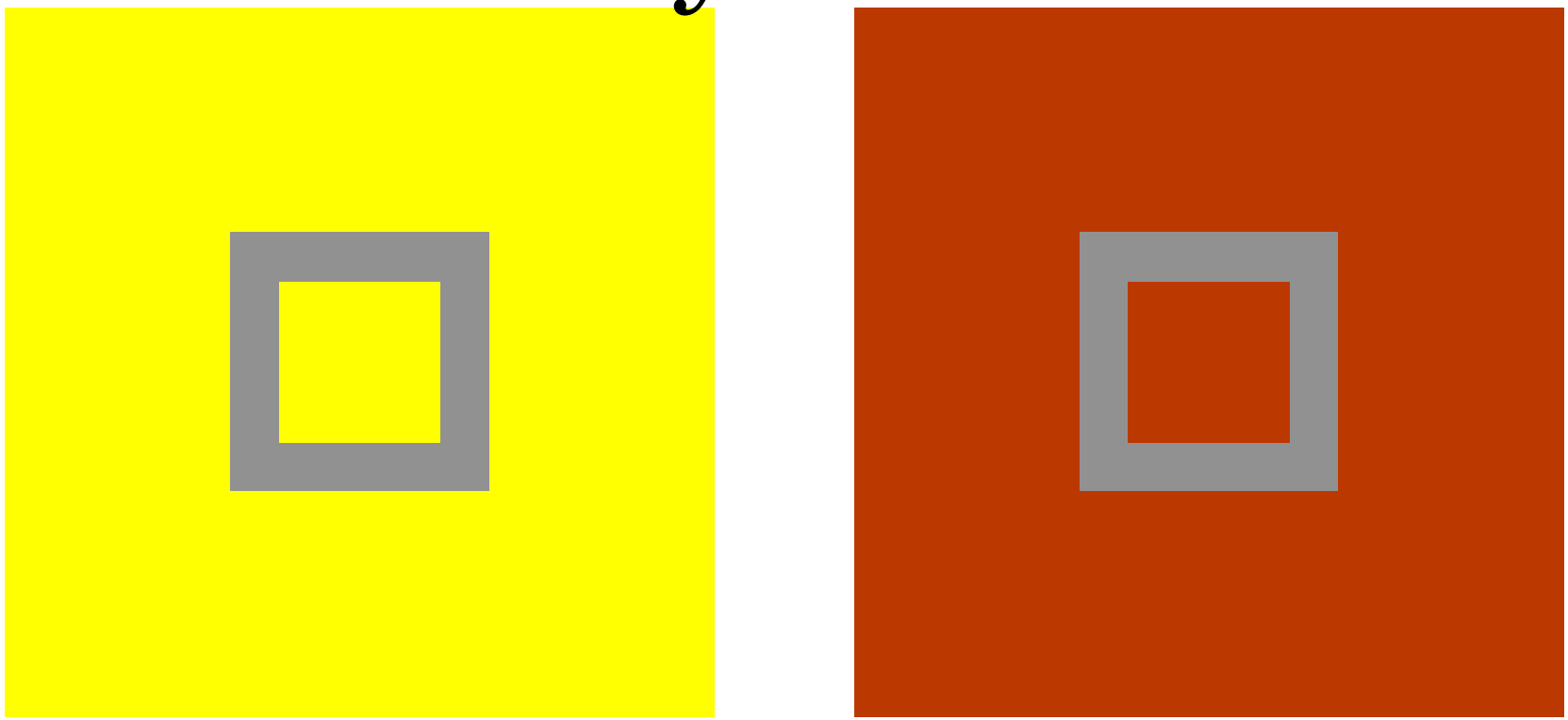
x

X

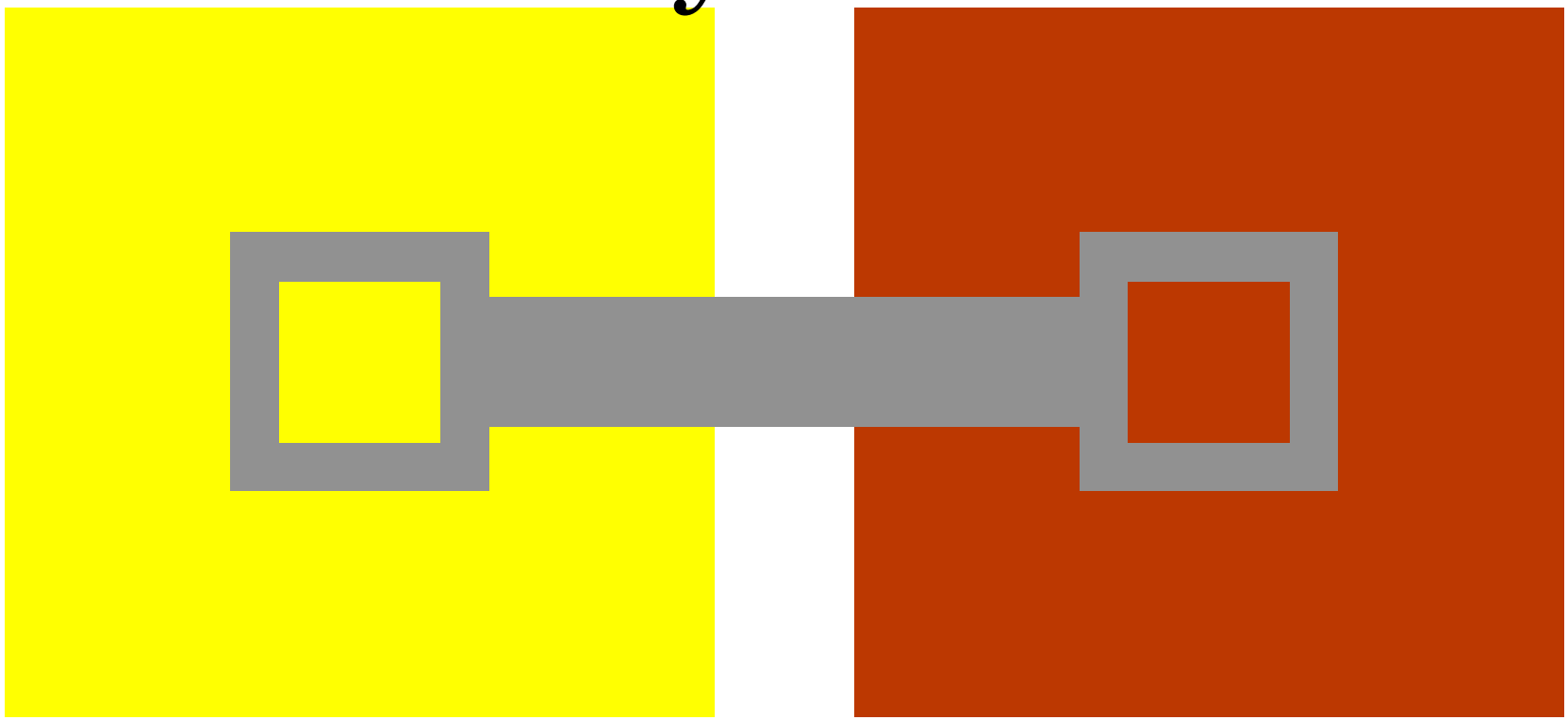
The  Factor

- Retinal fatigue
- Background effects
  - The fovea sees the greatest detail, but is still affected by the rest of the eye
  - Always be aware of your field of view

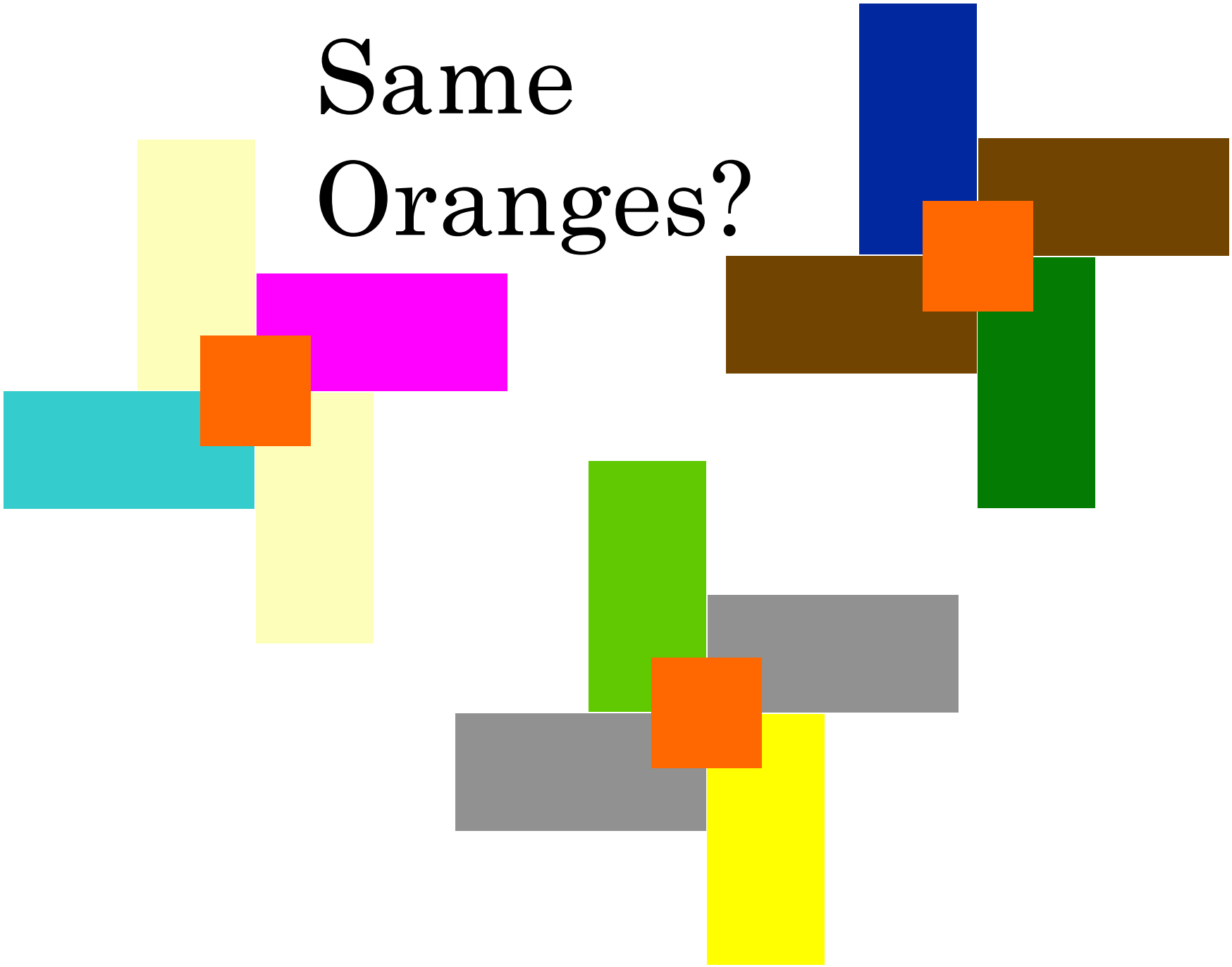
Different Grays?



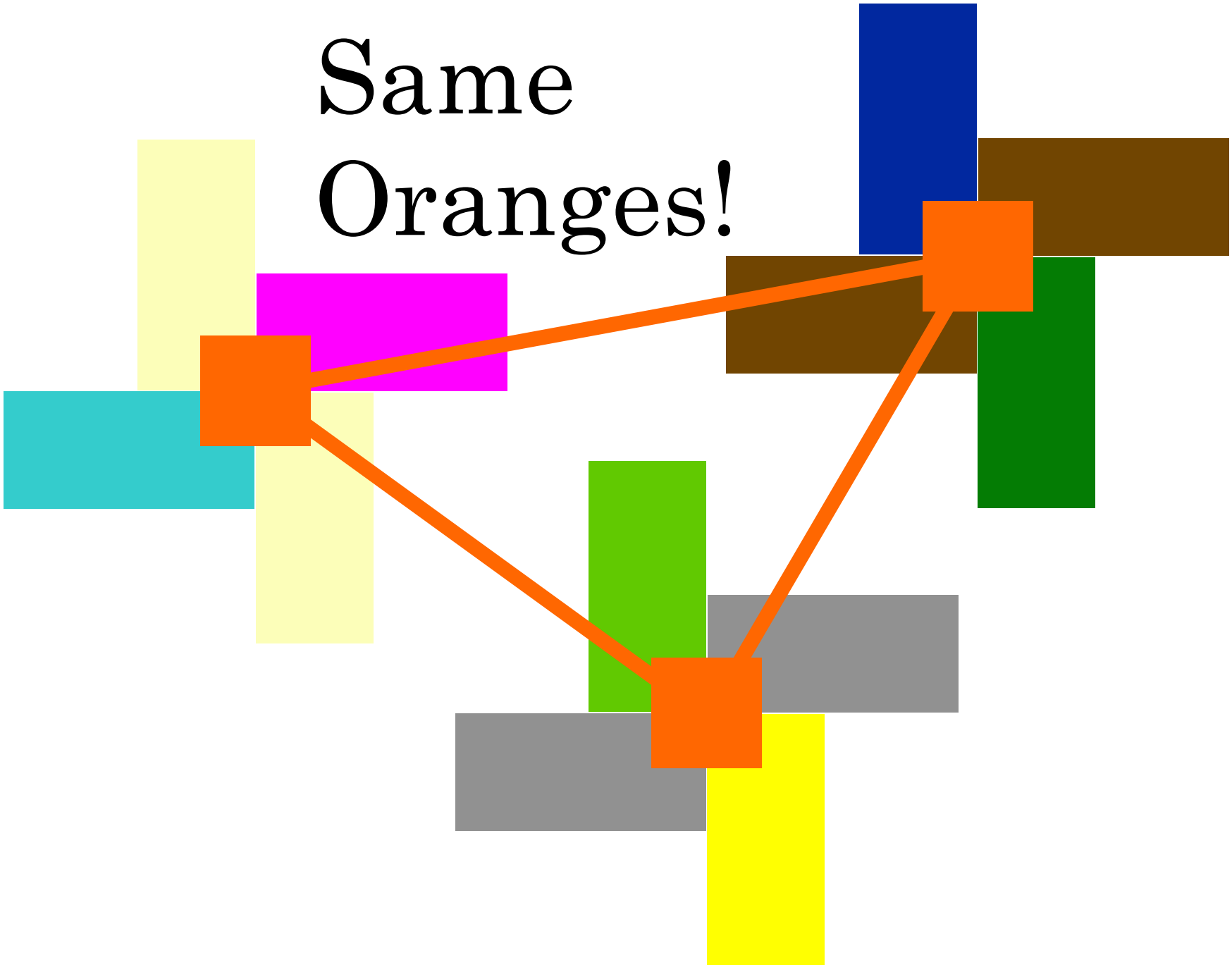
No, Same Gray!



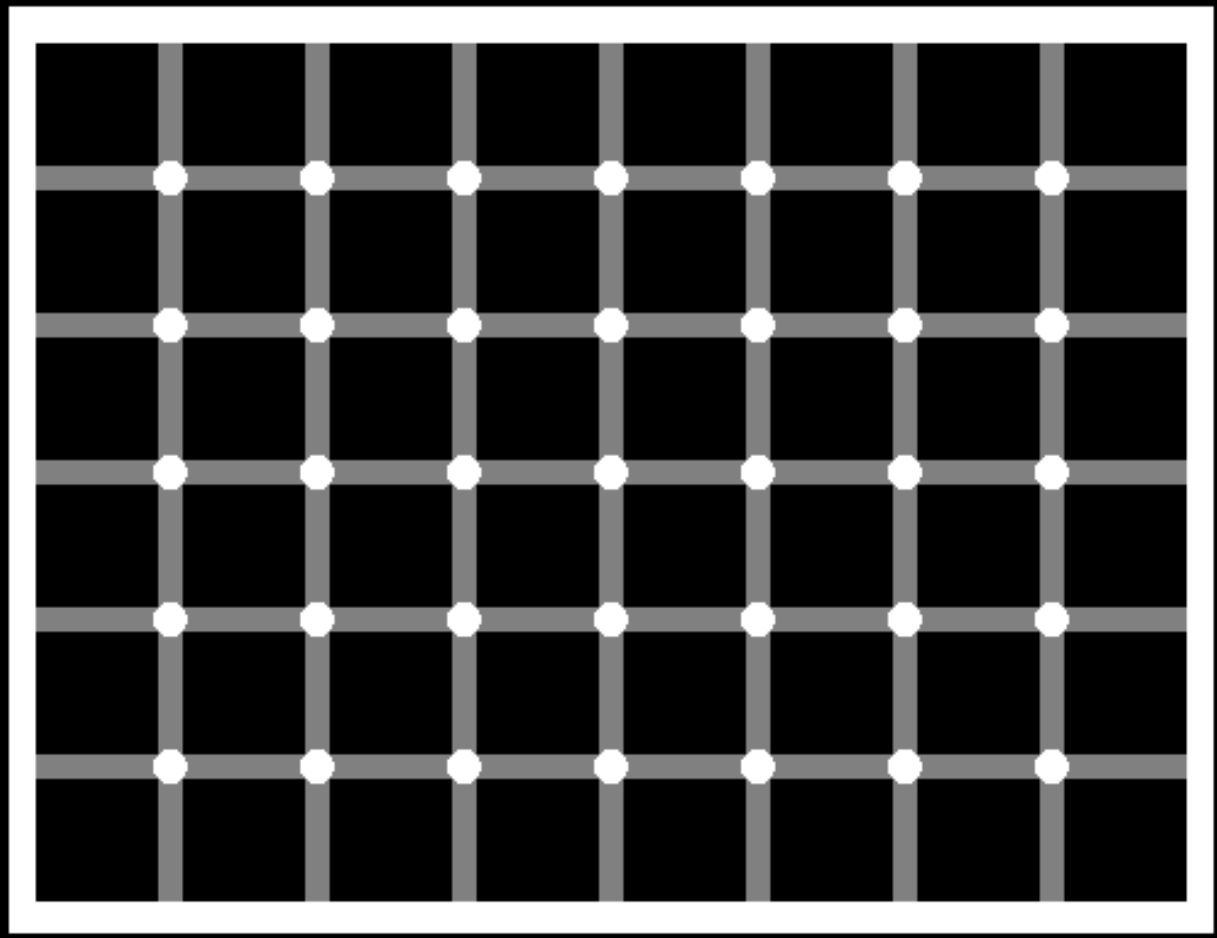
Same Oranges?

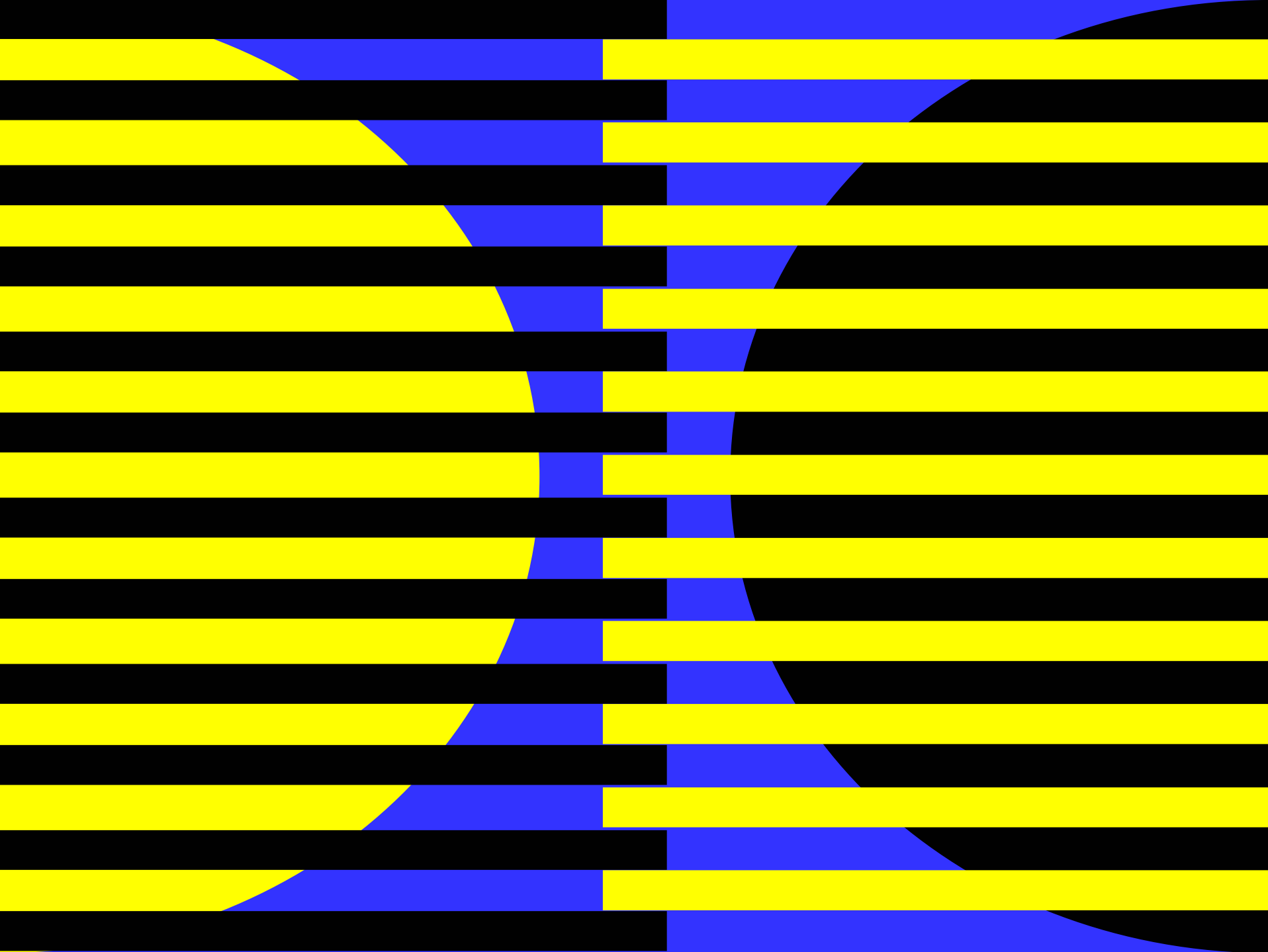


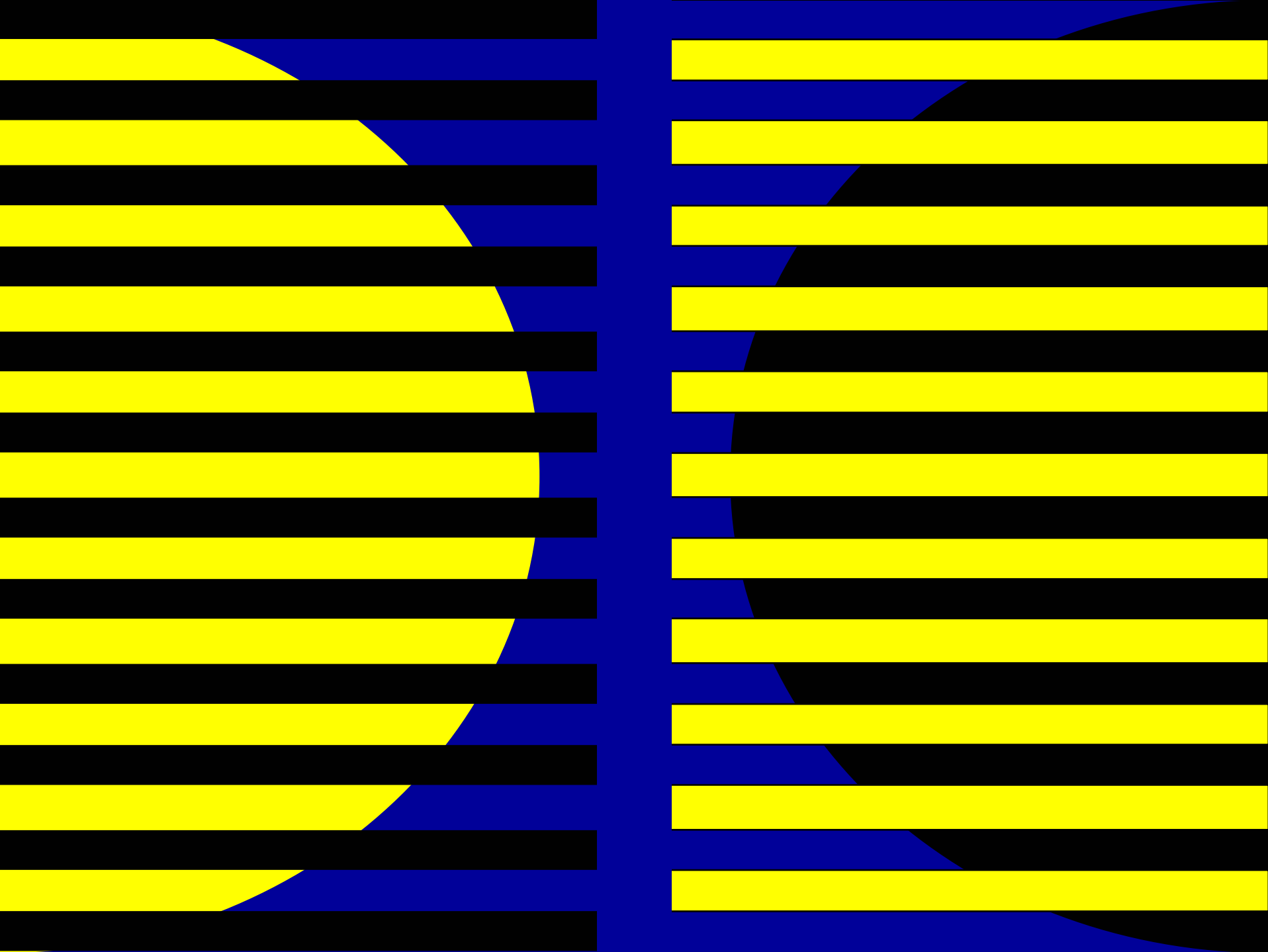
Same Oranges!



The  Factor



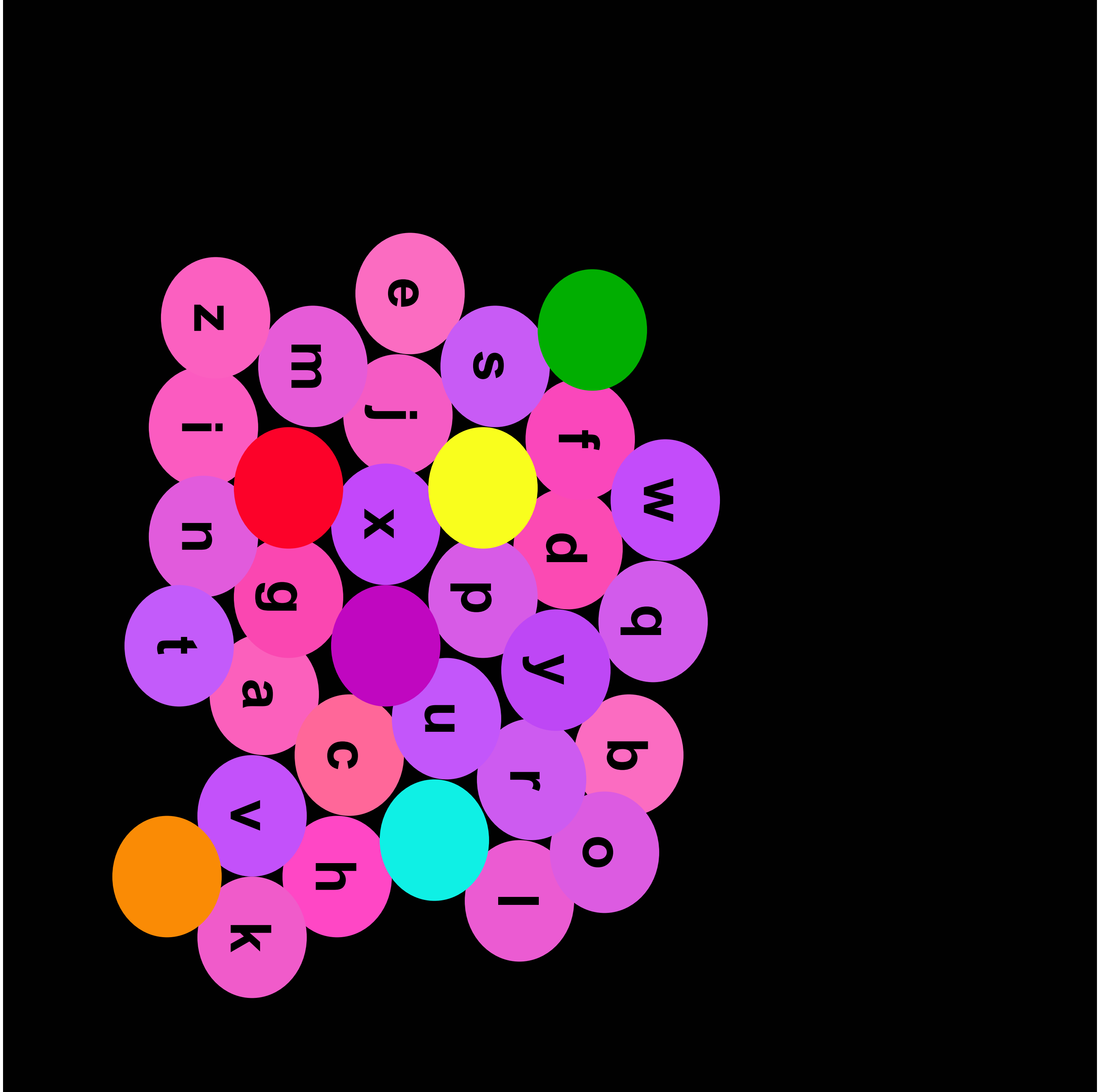




The  Factor

- Retinal Fatigue
- Background effects
- Poor Color Memory
  - Two objects must be viewed simultaneously in order to fully judge their differences

Identify This Color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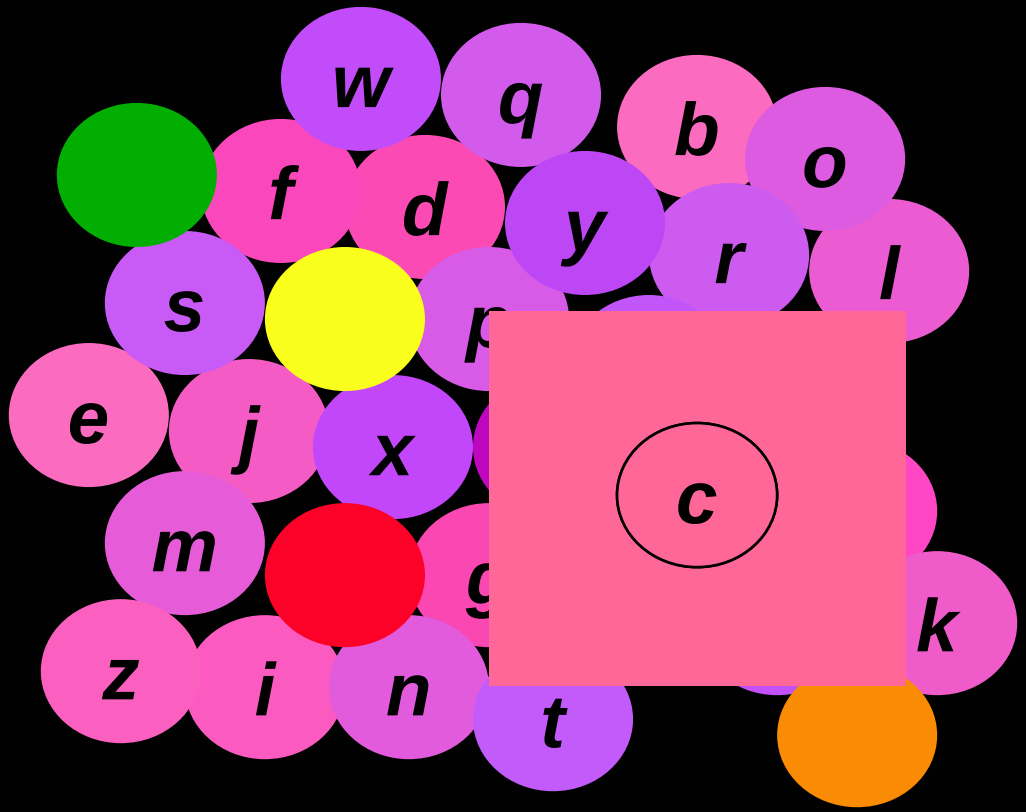
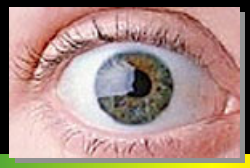
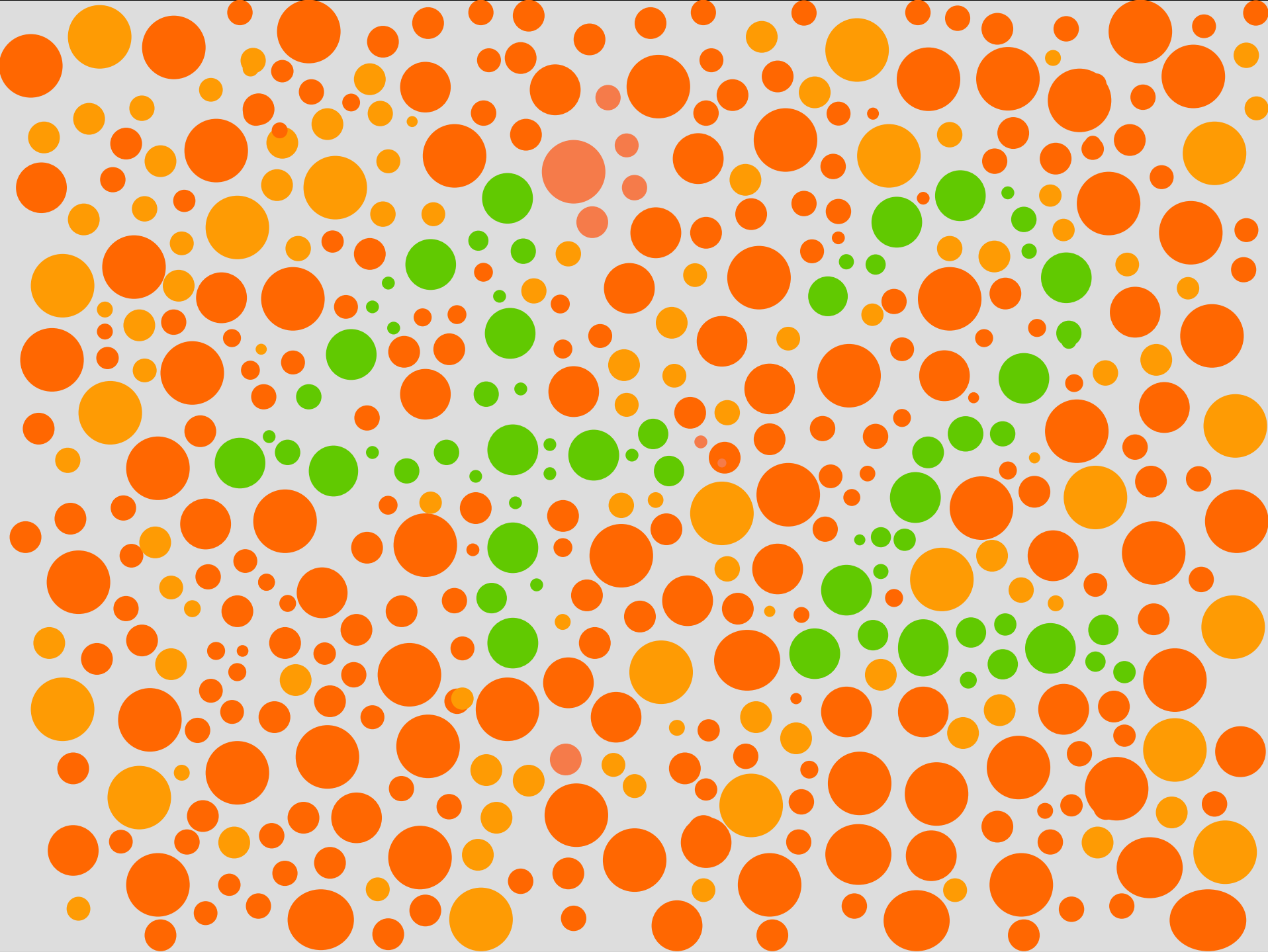
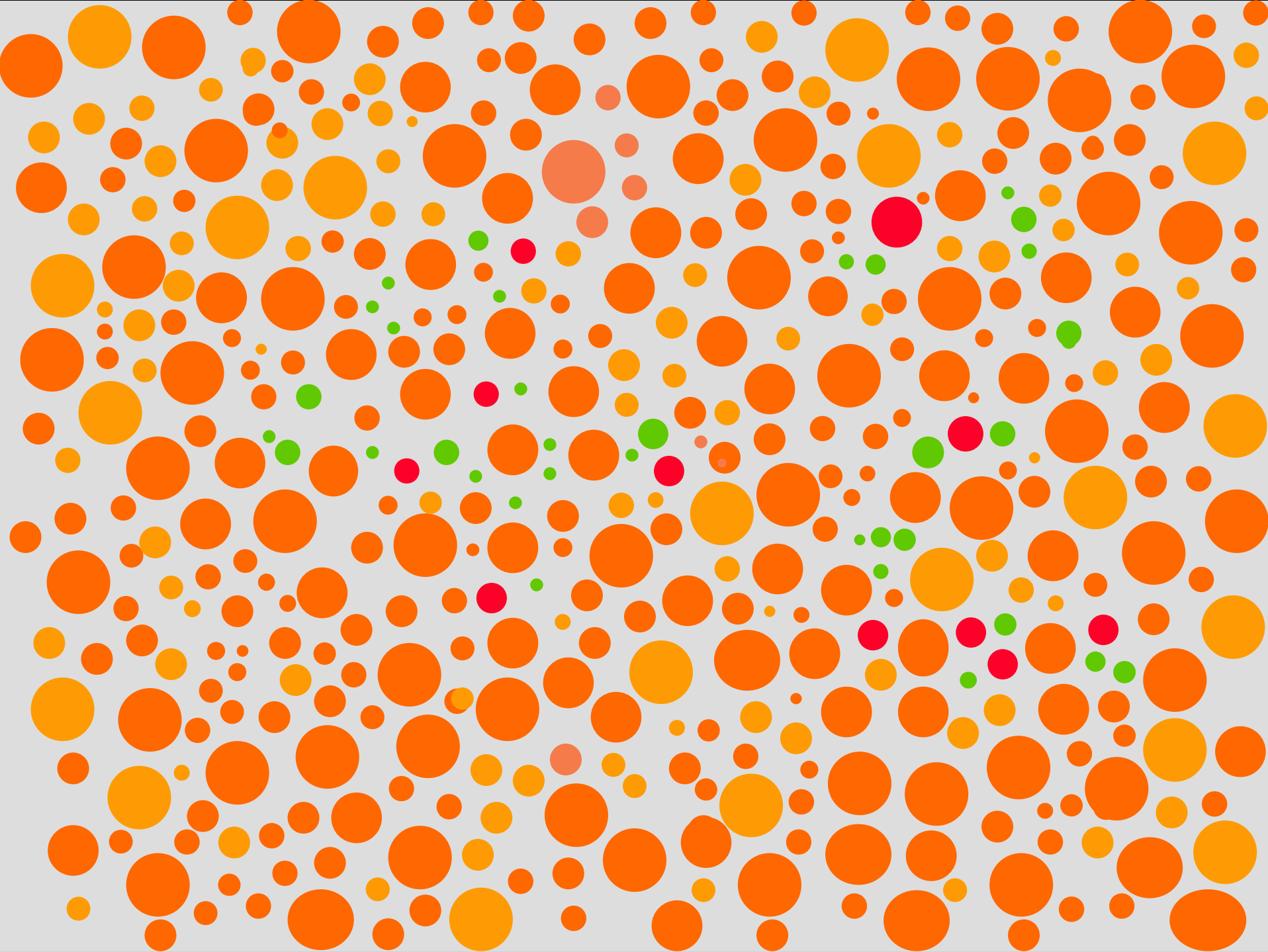
Which Color Is It?



The  Factor

- Retinal Fatigue
- Background effects
- Poor Color Memory
- Colorblindness
  - 1 in every 13 males suffers from red-green colorblindness. 1 in every 300 females



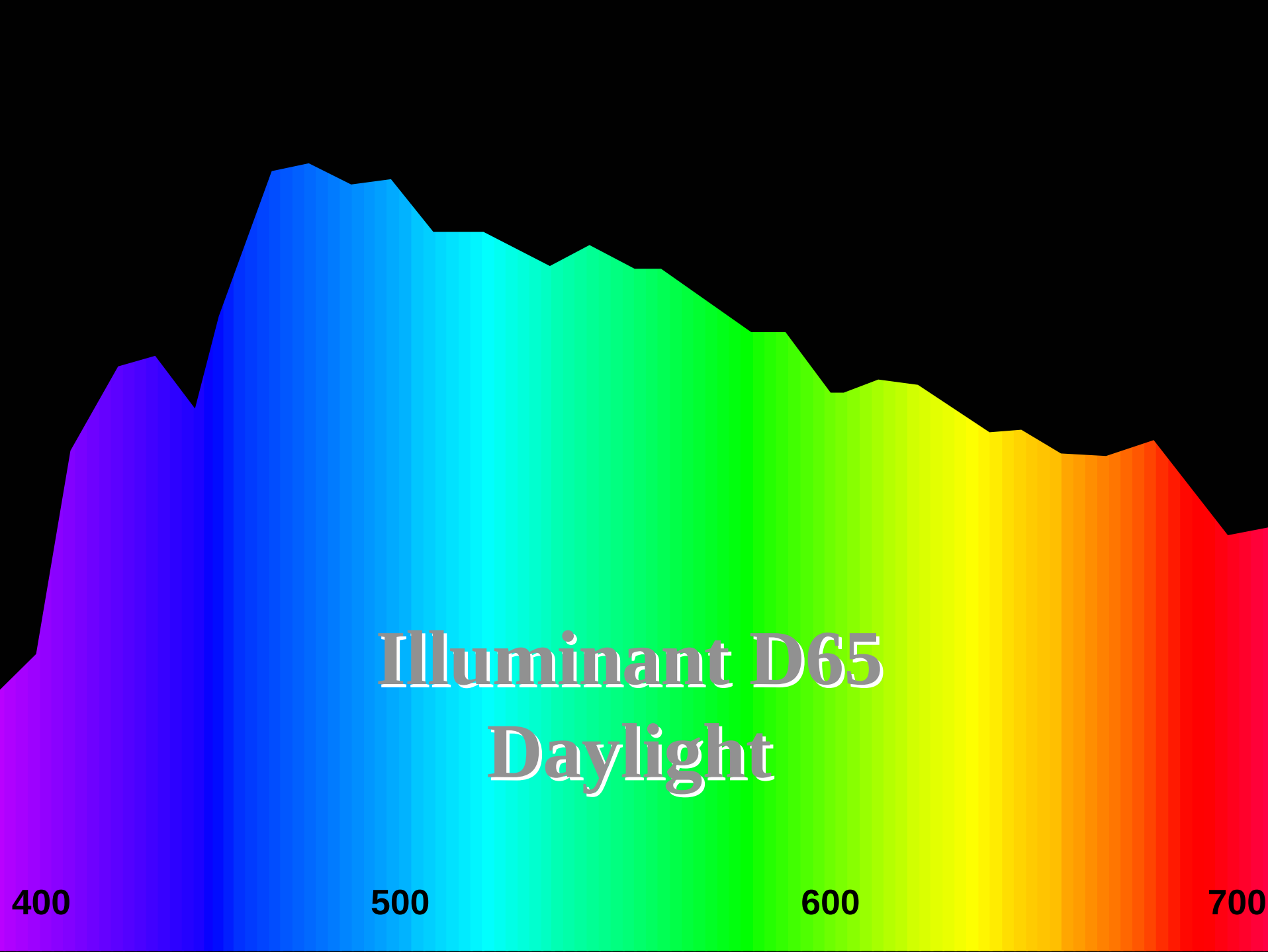


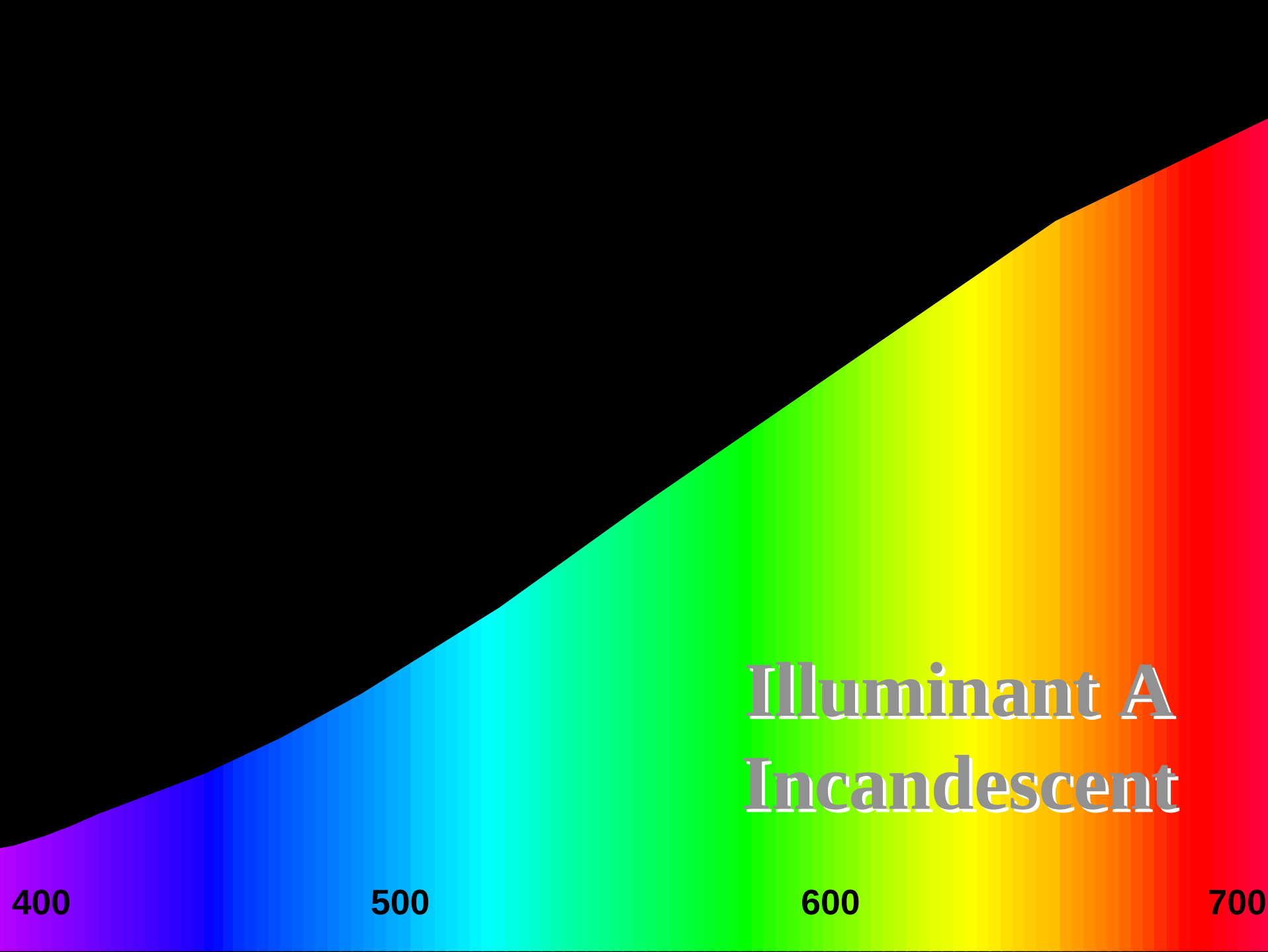
The  Factor

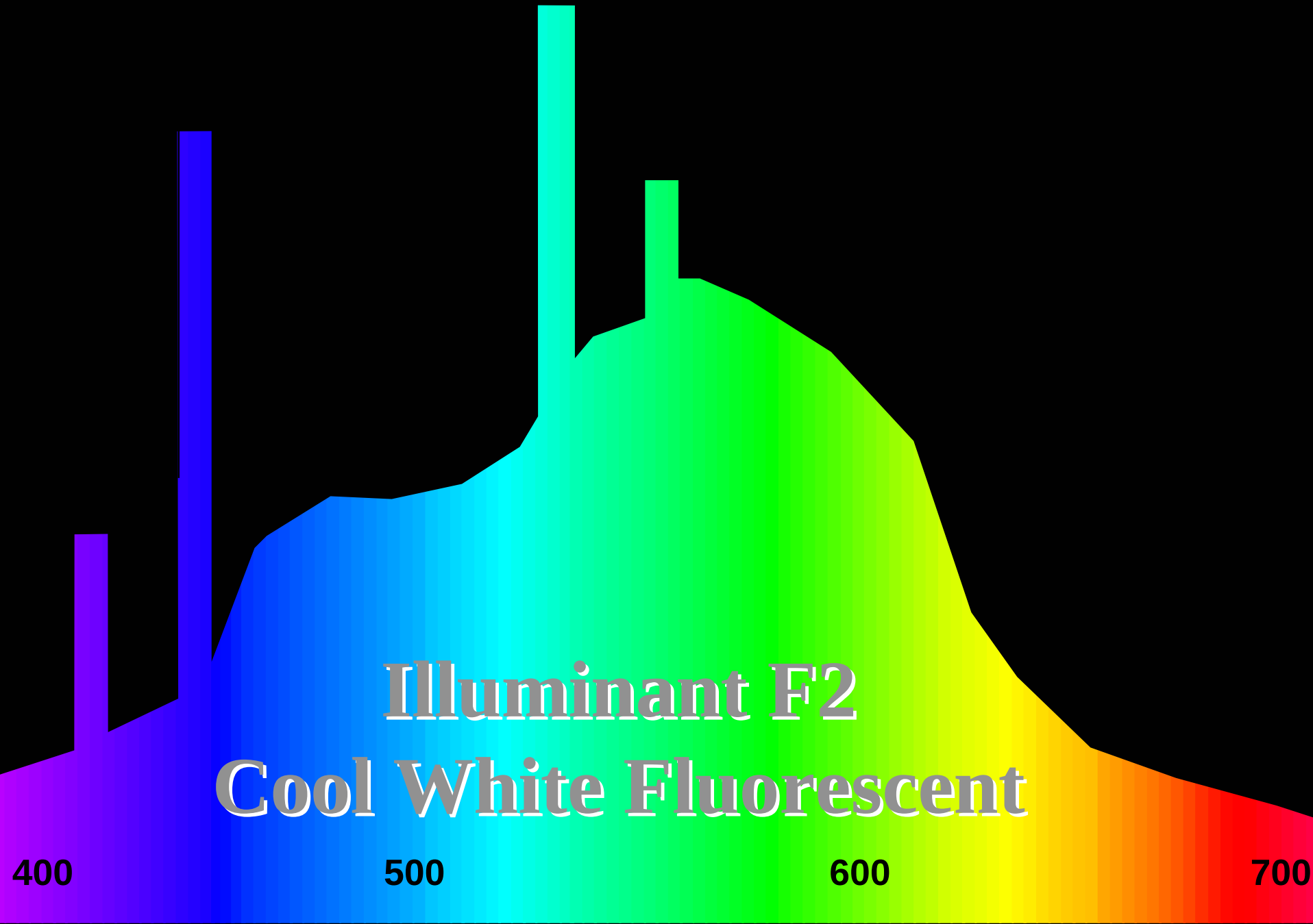
- Retinal Fatigue
- Background effects
- Poor Color Memory
- Colorblindness
- Lighting conditions
  - Failure to adopt standardized viewing conditions often results in poor color decisions

Standard Illuminants

- A Incandescent-Color Temp…2856K
- C Ave Daylight…no UV…6774K
- D50 Ave Daylight…inc UV…5000K
- D65 Ave Daylight…inc UV…6504K
- D75 Ave Daylight…inc UV…7500K
- F2 Cool White Fluorescent
- F7 Daylight White Fluorescent
- F11 TL84…three narrow band white F
- F12 Ultralume 3000


Illuminant D65
Daylight
400
500
600
700


Illuminant A
Incandescent
400
500
600
700

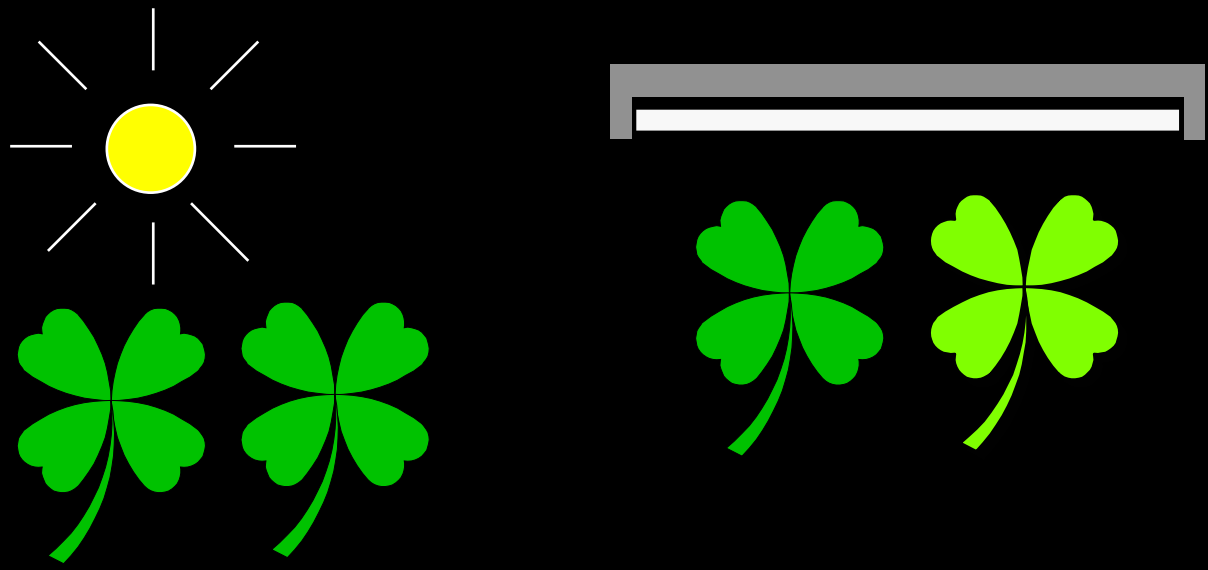

Illuminant F2
Cool White Fluorescent
400
500
600
700

Concept of Metamerism

- It is possible to alter the appearance of a color by varying the viewing conditions
- Metamerism is where two colors may match under one illuminant but not another
- Use of instrumentation in the QC process is the right solution

Light Is Color

- Metamerism examples



The  Factor

- Retinal Fatigue
- Background effects
- Poor Color Memory
- Colorblindness
- Lighting conditions
- Age
  - As we age our color perceptions change. The corneal lens yellows and becomes less flexible

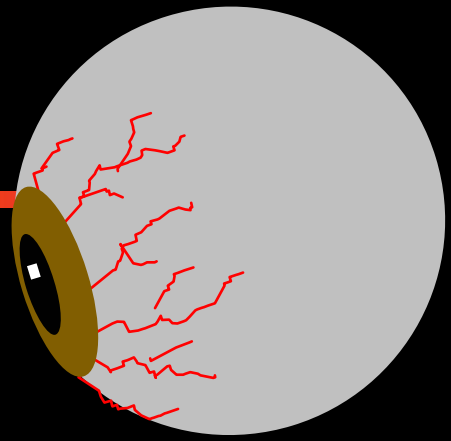
Even More Problems

Michael Marmor Phd - Stanford

How's your vision?

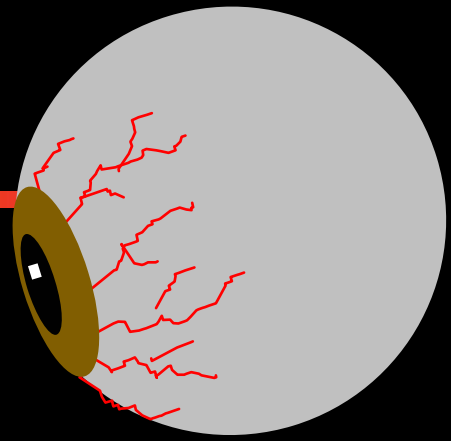
- When was your last eye exam? If your eye sight is not correct, the image will either focus before or behind the most color sensitive part of your eye.
- Do you wear glasses? If so…
  - Do they have an anti-reflective coating?
  - Do they have a UV coating?

Limitations

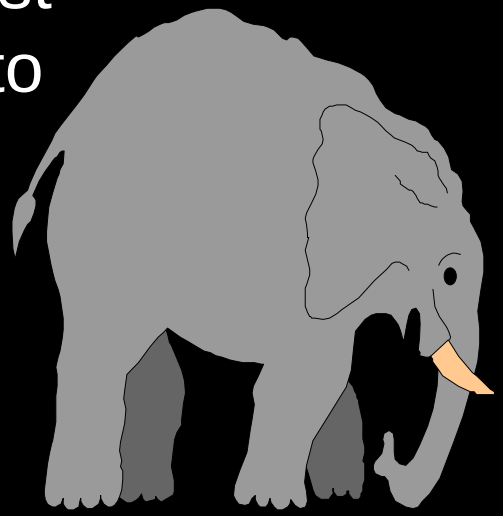


- Retinal Fatigue
  - Brief exposure to strong colors leaves an afterimage
  - Considerable rest is required to refresh the eye's rhodopsins

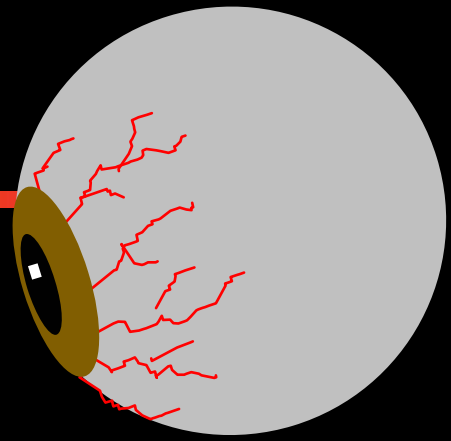
Limitations



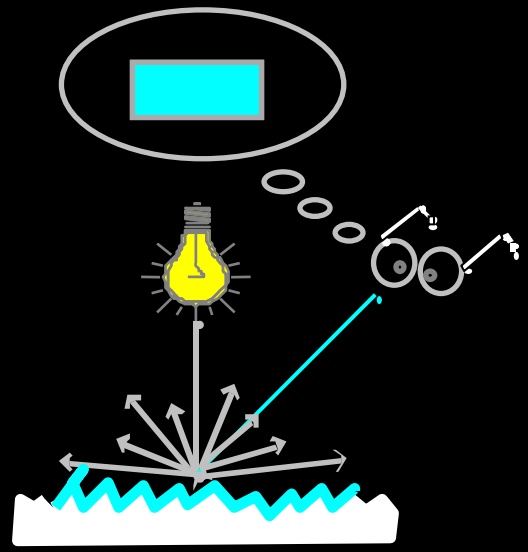
- Retinal Fatigue
- Poor Color Memory
  - A printer knows that two objects must be viewed simultaneously in order to fully judge their differences



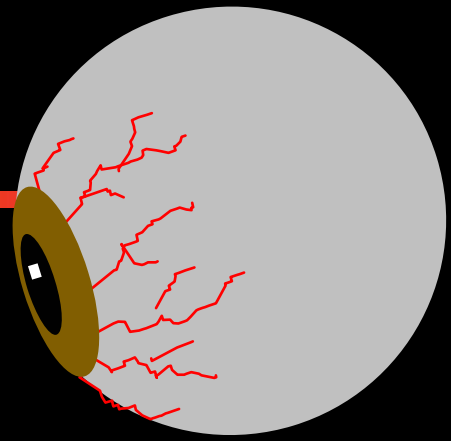
Limitations



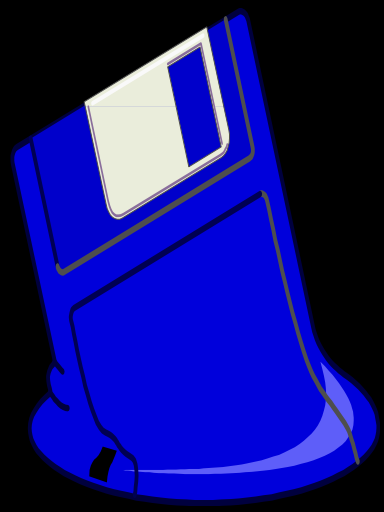
- Retinal Fatigue
- Poor Color Memory
- Background Effects
- Colorblindness
- Lighting conditions
  - '**Light is color**'; failure to adopt good viewing habits often results in bad color decisions.



Limitations



- Retinal Fatigue
- Poor Color Memory
- Background Effects
- Colorblindness
- Lighting conditions
- Recordability
  - Stress, time of day, fatigue, ambient conditions... all will affect the way in which we see color.



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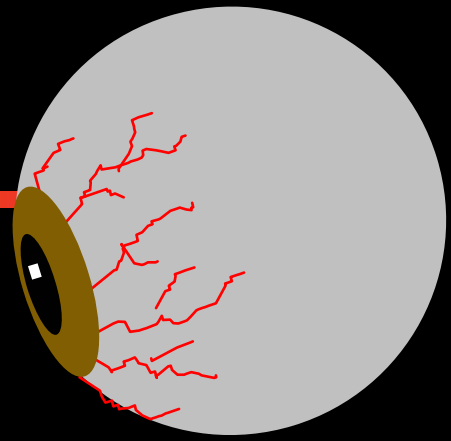


- Retinal Fatigue
- Poor Color Memory
- Background Effects
- Colorblindness
- Lighting conditions
- Recordability
- Age -
  - Yes friends... as we age our visual response changes.

Even More Problems…

- How's your vision?
- When was your last eye exam? If your eye sight is not correct, the image will either focus before or behind the most color sensitive part of your eye.
- Do you wear glasses? If so…
  - Do they have an anti-reflective coating?
  - Do they have a UV coating?

Even more problems…

- Tell me what color you see, not the word…

BLUE

GREEN

YELLOW

The “I” Factor

- How does the individual effect the perception of Color?
  - Inherited
  - Learned
  - Geographic
  - Regional/Ethnic
  - Climate
  - Light
  - Income Level

Understanding Densitometry

- Important Factors of Densitometry
  - Status
  - Calibration
- Densitometric Functions
  - Density
  - Print Contrast
  - Dot Area(Tone Value)
  - Dot Gain(Tone Value Increase)
  - Hue Error / Grayness
  - Trap

Before we start……

- 1) Determine what measuring status you are using

E ?

I ?

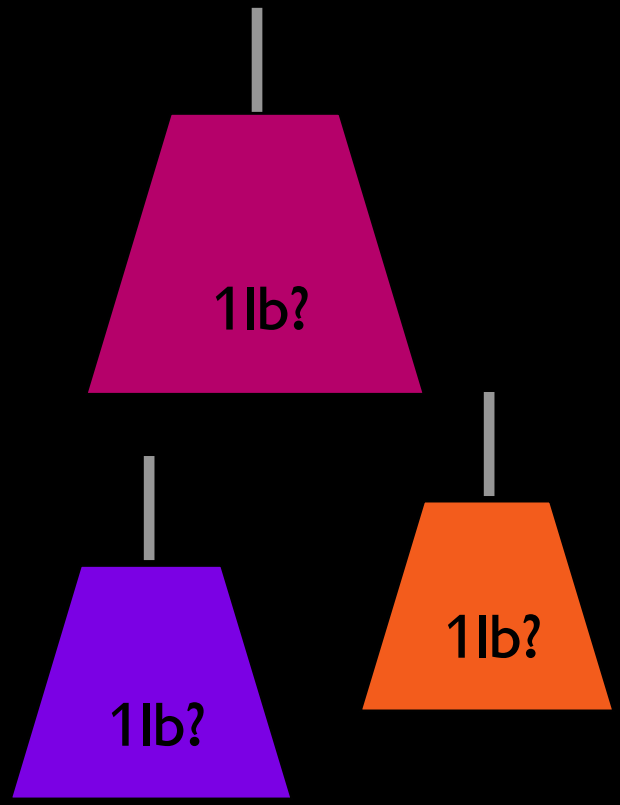
T ?

A ?

G ?

Before we start…

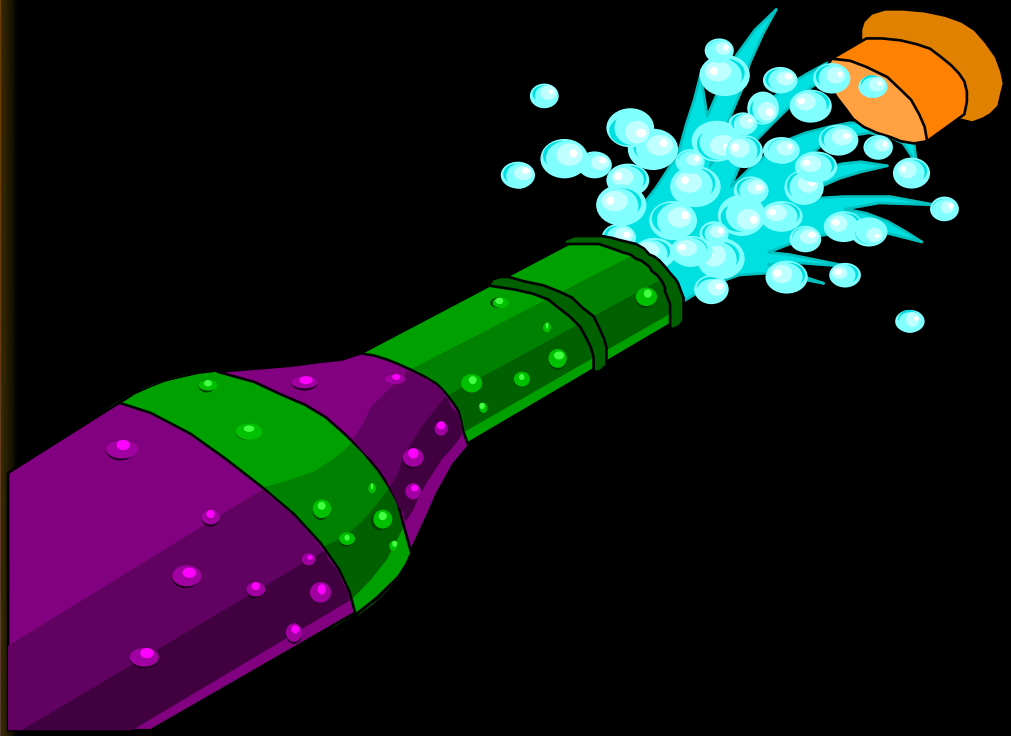
- 2) Why should I calibrate?
  - How long is a foot?
- 3) When should I calibrate?
  - How accurate are you?



Hands on Exercise

- Let’s learn how to calibrate the 500’s

- Congratulations, you have now successfully calibrated the densitometer



Understanding Densitometry

- Densitometric Functions
  - Density
  - Print Contrast
  - Dot Area(Tone Value)
  - Dot Gain(Tone Value Increase)
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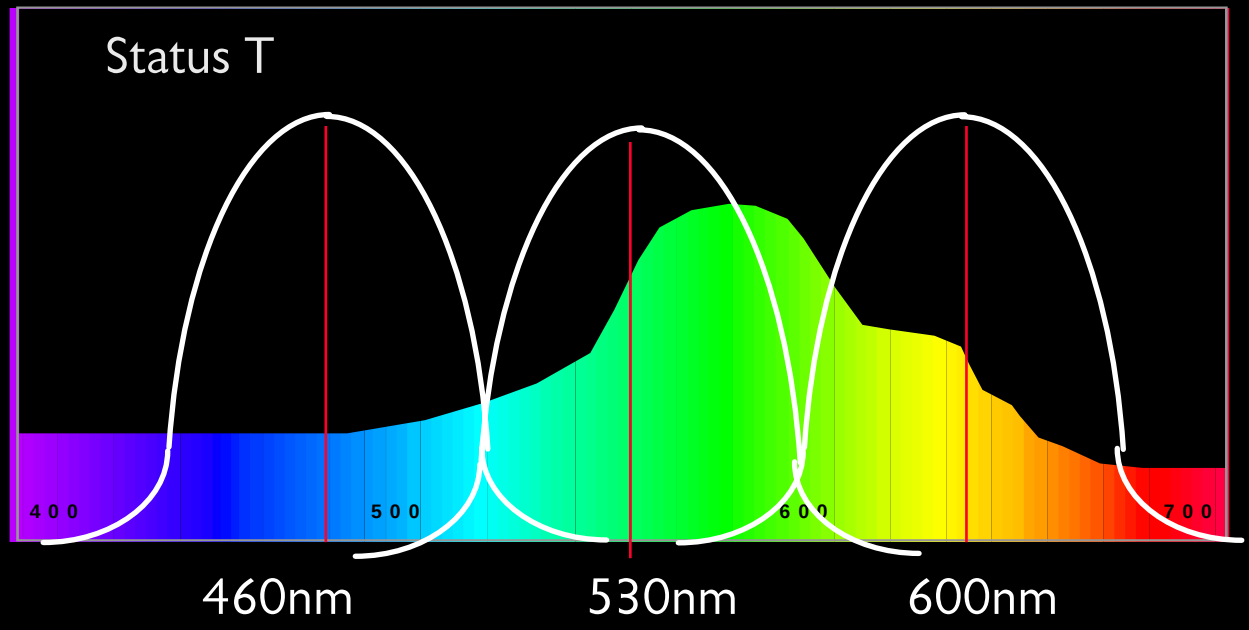
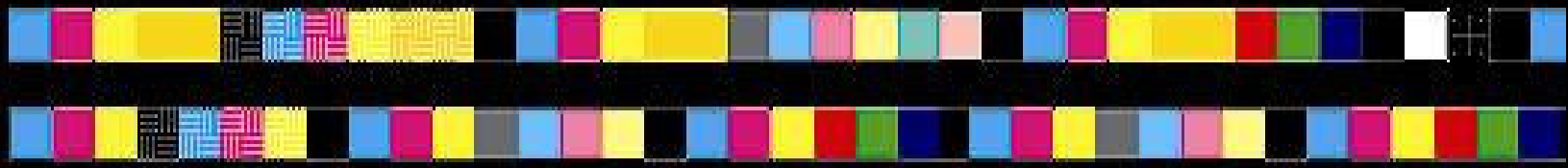
Densitometer

- Measures in three different area's across the spectrum from 400nm to 700nm.



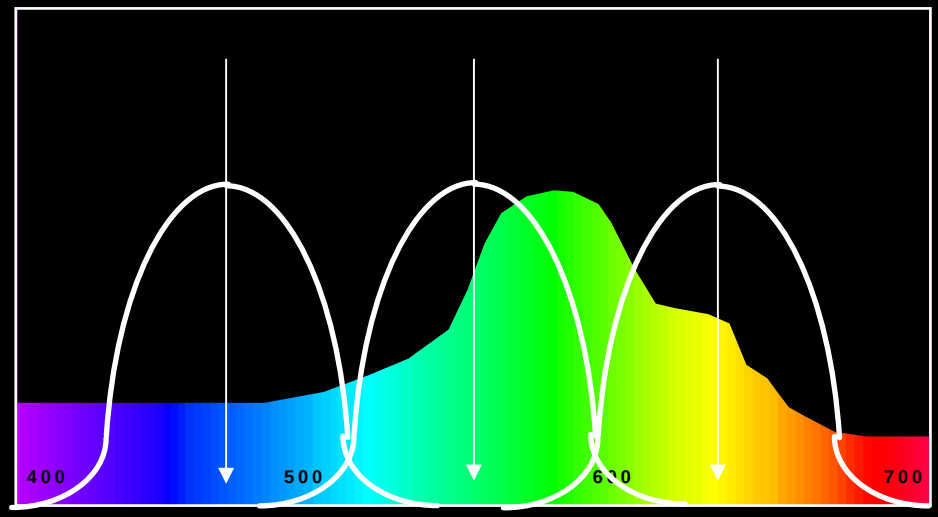
Densitometric Functions

- Density



Densitometer

- How it views the spectrum



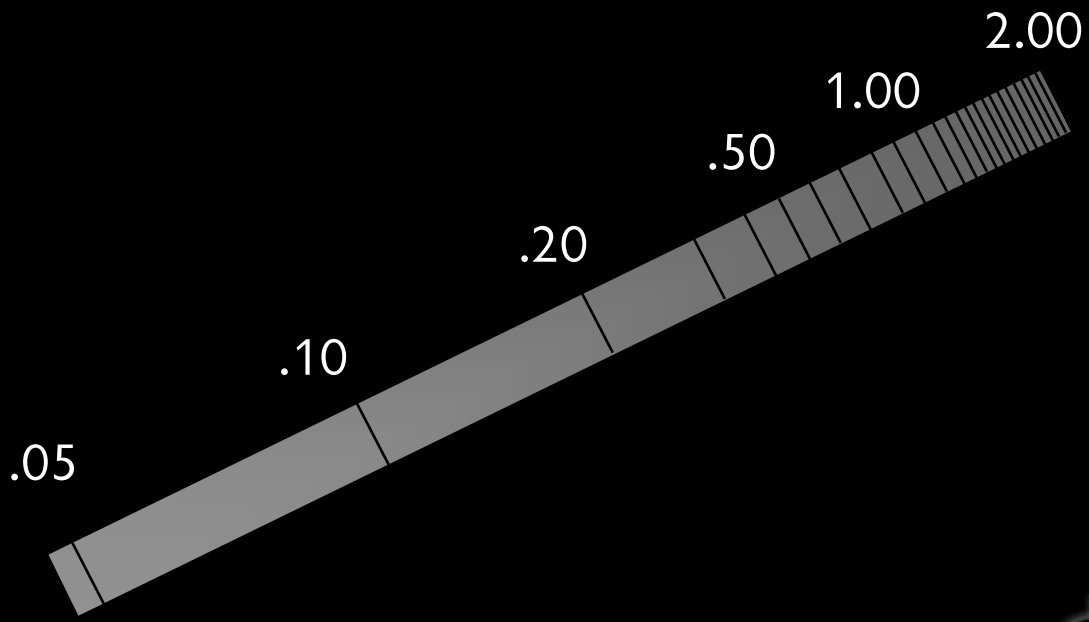
Densitometer

- Are Density values…..
- Linear?
- Logarithmic?
- Reverse Mega-Kelvin Reciprocal of the temperature of the measured color?

What is Density?

- Density is not linear…Density = log 1/R
  - Density units are larger at low numbers
  - Density units are smaller at high numbers

- 100% R= 0.0D
- 10%R=1.0D
- 1%R=2.0D
- 0.1%R=3.0D
- 0.01%R=4.0D

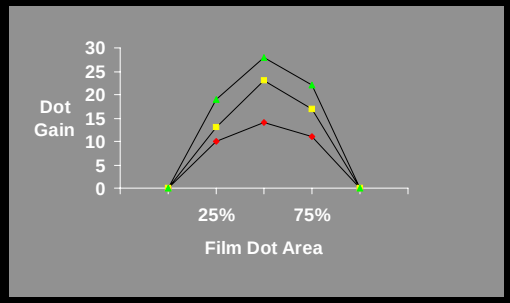


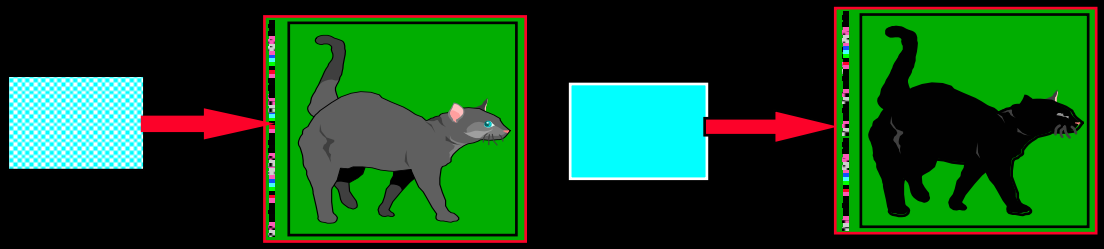
Why Do We Measure Density?

- Measuring ink on the press sheet
  - Solid ink density (SID)
    - During make-ready to bring the press up to color
    - During press run to match an OK sheet
    - Monitor the consistency of a run

Why Do We Measure Density?

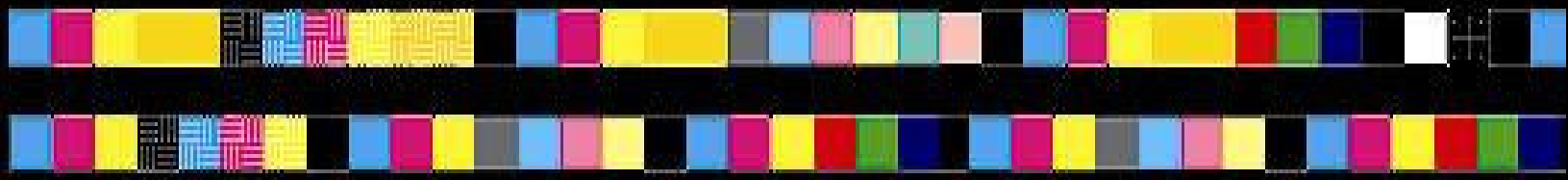
- Also used to Calculate
  - Print Contrast
  - Dot Area (TV) / Dot Gain (TVI)
  - Hue Error / Grayness
  - Trap





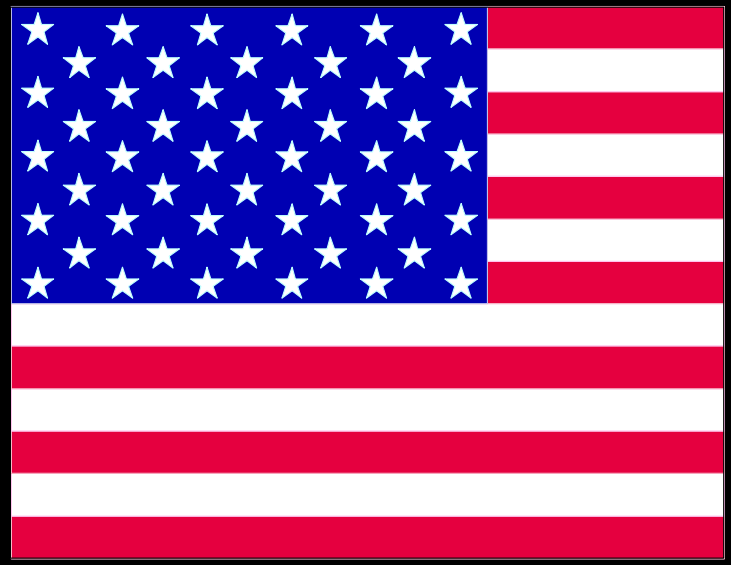
Where Do We Measure Density?

- Color Bars
  - Always the best choice
  - Use a bar that best helps you control your press



Where Do We Measure Density?

- Image Area
  - Avoid if possible
- Read solid areas only



Hands on Exercise

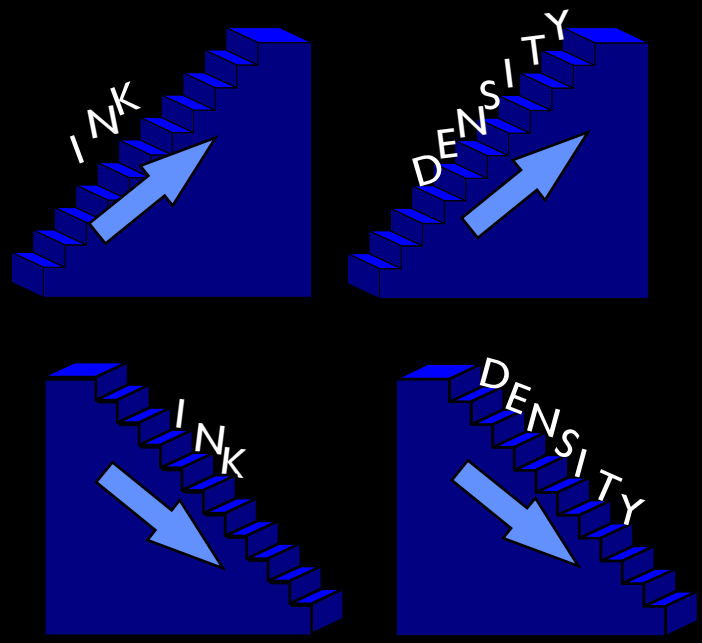
- Let’s learn how to measure density

How Do We Measure Density?

- Watch what you're measuring over
  - Be conscious of the other side of your sheet
  - Place sheet on a black surface of 1.50D or more

What Do the Numbers Mean?

- Numbers reflect the amount of ink on paper
  - The ink film thickness goes up, the density numbers rise
  - Ink film thickness goes down, the density numbers fall



What numbers should I aim for?

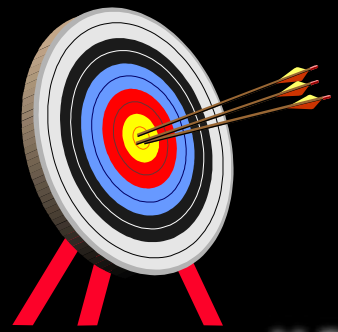
- What specifications are you using?
  - SNAP
    - **S**pecifications for **N**ewsprint **A**dvertising **P**rinters
  - GRACoI
    - **G**eneral **R**equirements for **A**pplication in **C**ommercial **O**ffset **L**ithography
  - SWOP
    - **S**pecifications **W**eb **O**ffset **P**ublications
  - FIRST
    - **F**lexographic **I**mage **R**eproduction **S**pecifications & **T**olerances

What numbers should I aim for?

- Typical Density Values-Offset

	Black	Cyan	Magenta	Yellow
Sheetfed offset	1.70D	1.40D	1.50D	1.05D
Web offset	1.60D	1.30D	1.40D	1.00D
Non-Heat set web, News	1.05D	0.90D	0.90D	0.85D

Status T, Density Absolute



What numbers should I aim for?

- Typical Density Values-Flexo

	Black	Cyan	Magenta	Yellow
WIDE WEB Paper	1.50D	1.25D	1.25D	1.00D
WIDE WEB Film	1.40D	1.25D	1.20D	1.00D
NARROW WEB Paper	1.50D	1.35D	1.25D	1.00D
NARROW WEB Film	1.40D	1.25D	1.20D	1.00D

Status T, Density Absolute

What numbers should I aim for?

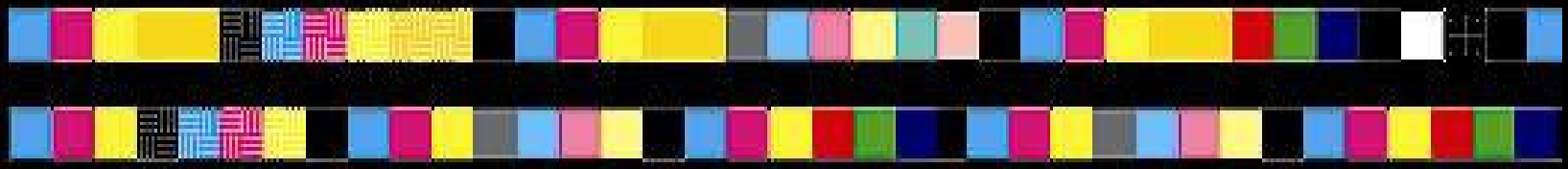
- Typical Density Values-SNAP Offset

Black	Cyan	Magenta	Yellow
1.05D	0.90D	0.90D	0.85D

Status T, Density Absolute

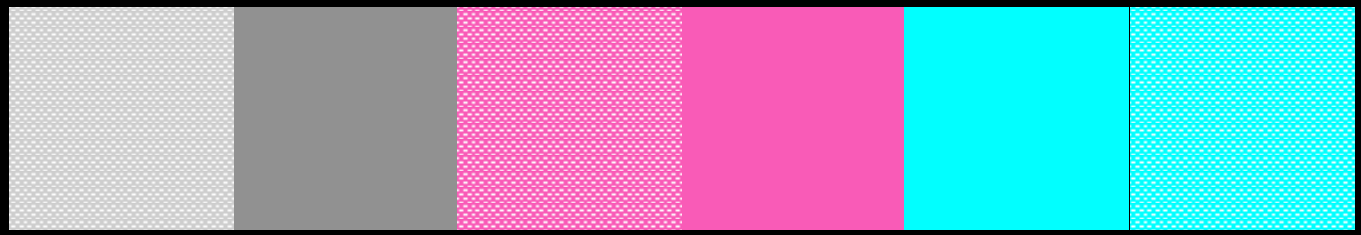
Densitometric Functions

- Density
- Print contrast



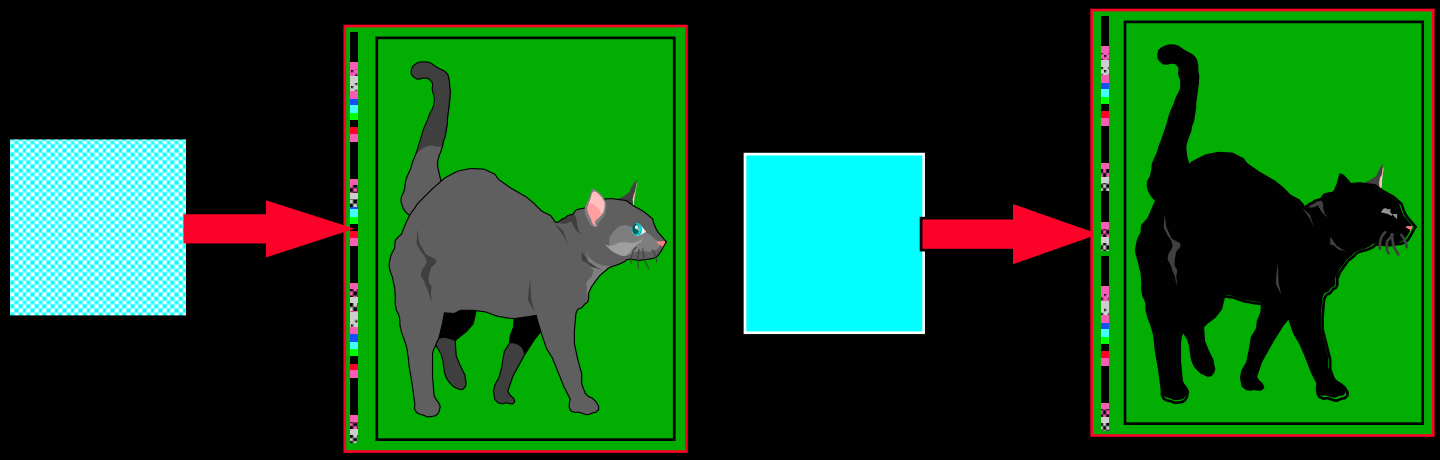
What is Print Contrast

- Difference between a solid and shadow tint
- Measure of shadow detail
- Print Contrast $= \frac{Ds - Dt}{Ds} \times 100$



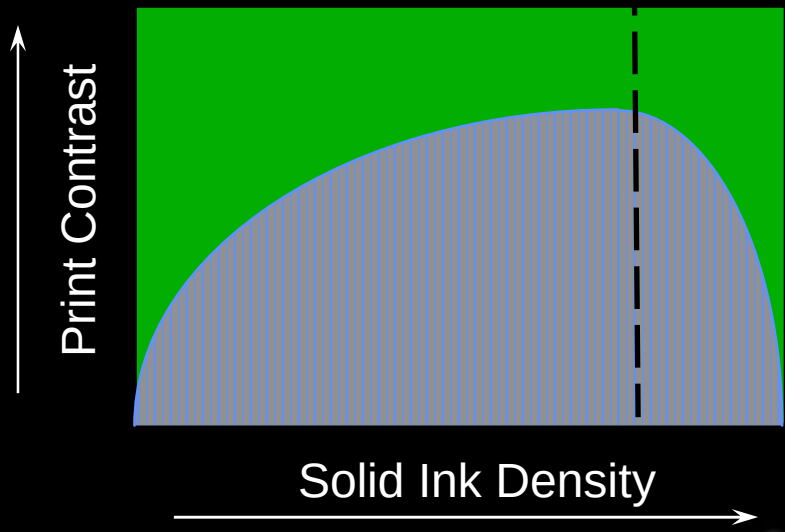
Why Measure Print Contrast?

- Monitor ink and water balance
- Determine plugging in shadow region
- Determine optimal target SID value



Related Topics

- Using PC to determine optimal SID values
  - Start press run, adjust solid ink densities up/down
  - Pull samples, measure SID and PC
  - Increment density
  - Graph results
  - Peak is optimum



Hands on Exercise

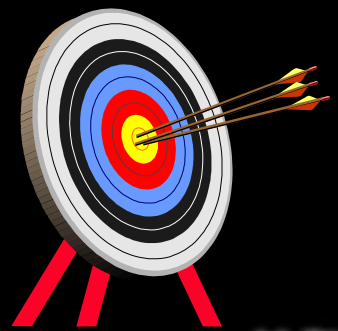
- Let’s learn how to measure Print Contrast

What numbers should I Aim for?

- Typical Print Contrast Values-Offset

	Black	Cyan	Magenta	Yellow
Sheetfed offset	40	36	36	30
Web offset	36	31	31	28
Non-Heat set web, News	24	22	22	18

Status T, measuring at a 75% film tint

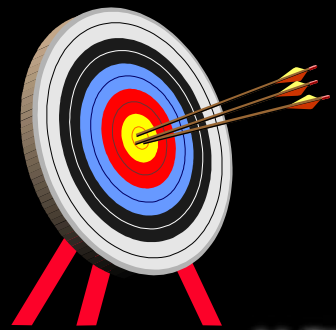


What numbers should I Aim for?

- Typical Print Contrast Values-Flexo

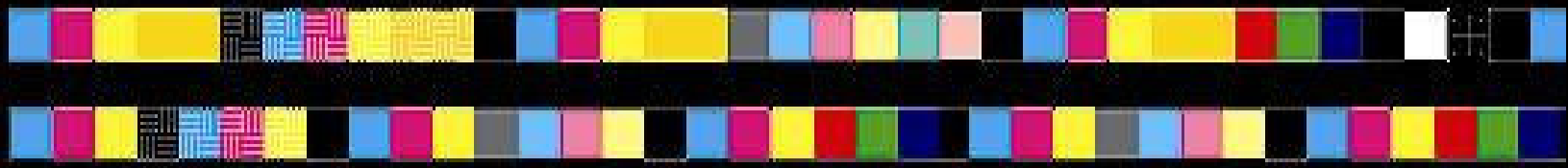
Black	Cyan	Magenta	Yellow
≥20%	≥20%	≥20%	≥15%

Status T, measuring at a 75% film tint



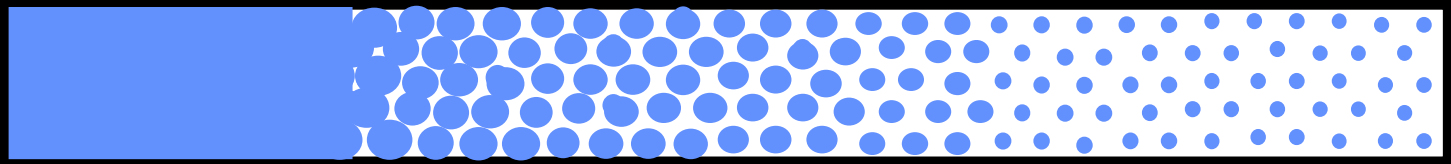
Densitometric Functions

- Density
- Print Contrast
- Dot Area / Dot Gain
  - Tone Value / Tone Value Increase



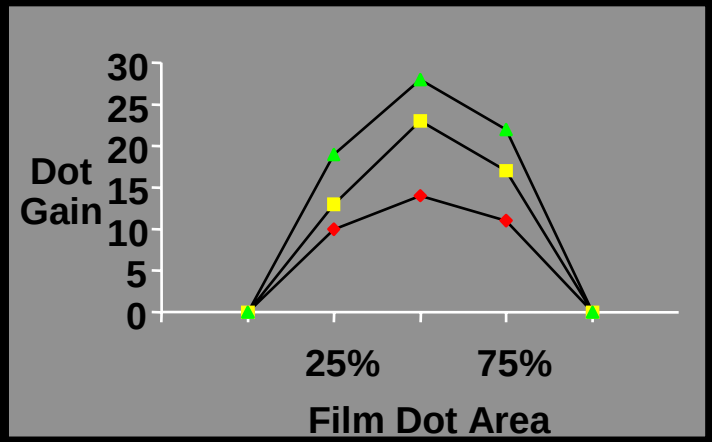
Why Do We Use Dots?

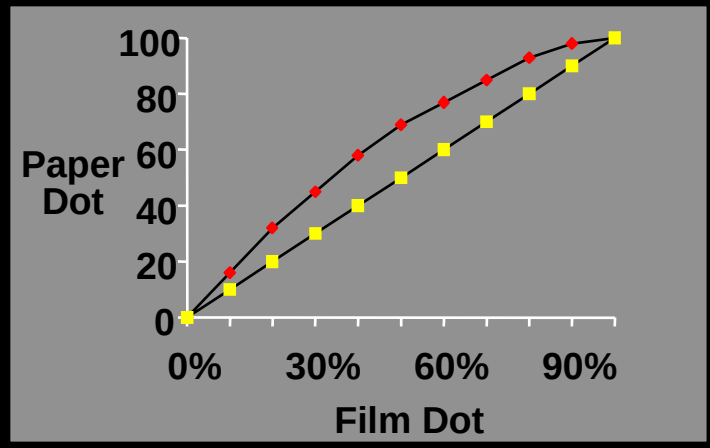
- Presses don’t print continuous tones
  - Ink on; Ink off
  - No shades
  - Different size dots simulate continuous tone



Why Do We Measure Dot Area?

- To see if the press is printing dots correctly
- Controlling dot gain on press





Where Do We Measure Dot Area?

- Must read substrate & solid ink density
  - Color bars are easiest to use
  - Difficult to find in image area
- Accuracy in measuring
  - Read on a consistent surface
  - Be aware of backing on sheet
  - Use a solid near the tint

Hands on Exercise

- Let’s learn how to measure Dot Area

What Do the Numbers Mean?

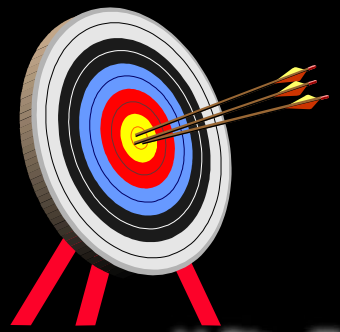
- How do I change dot gain?
  - Dramatic changes point to problems
    - ✓ Plate wear
    - ✓ Oxidation
    - ✓ Ink/Water balance
    - ✓ Solid ink density
    - ✓ Ink emulsification / change in ink tack
    - ✓ Doubling / Slurring
    - ✓ Picking

What numbers should I aim for?

- Typical Midtone Dot Gain Values

	Black	Cyan	Magenta	Yellow
Sheetfed offset	22%	20%	20%	18%
Web offset	22%	20%	20%	18%
Non-Heat set web, News	32%	33%	34%	30%

Status T, Calculated using Murray/Davies equation measured at a 50% film tint



Related Topics

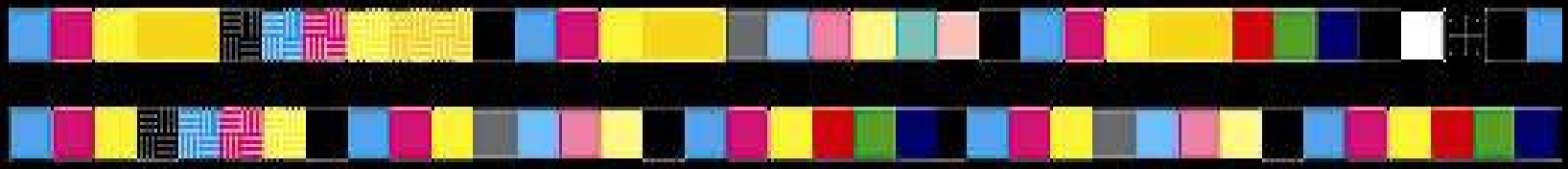
- Mechanical Dot Gain Vs Optical Dot Gain . . .
- Using an N-Factor . . .
- Reading Plates . . .

Mechanical Vs Optical Dot Gain

- Mechanical
  - Any physical growth of the dot
    - Doubling or slurring
    - Fill in
    - Growth created by pressure of the press
- Optical
  - Dot gain due to light scattered / absorbed by substrate
  - Shadowing effect

Densitometric Functions

- Density
- Print Contrast
- Dot Area / Dot Gain
- Hue Error / Grayness



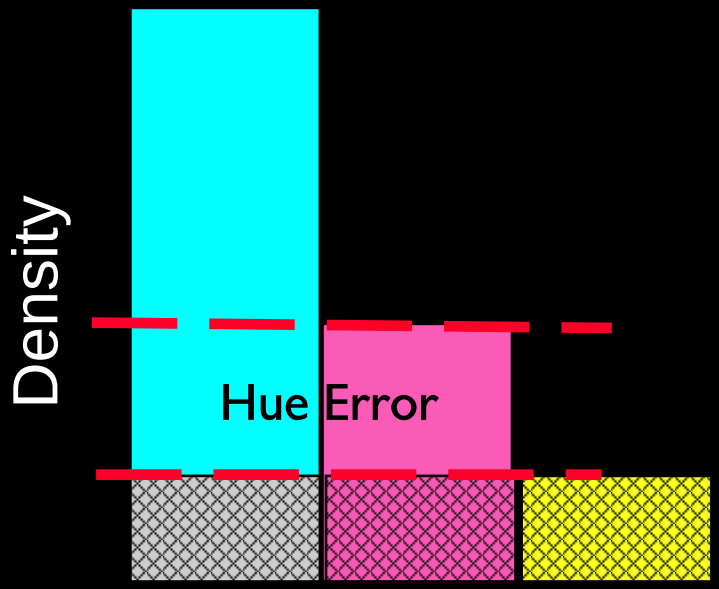
What is Hue Error & Grayness?

- Inks are not pure; they appear to be contaminated
- Each ink has TWO “unwanted” components
  - Larger component changes HUE of the Ink
  - Smaller component makes the ink GRAY

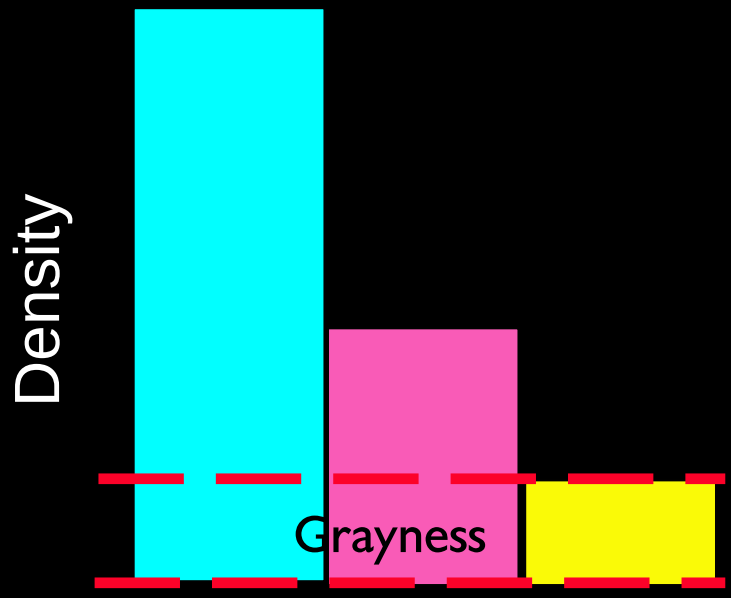
m **HUE ERROR**

y **GRAYNESS**

What are Hue Error & Grayness?



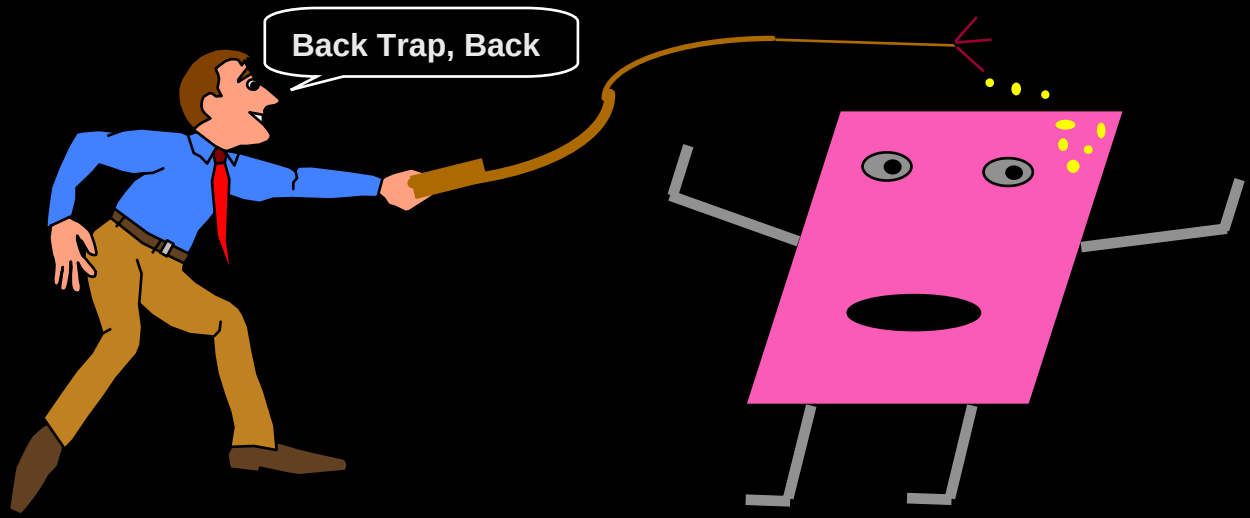
Apparent Hue Error
of Cyan Ink



Grayness
of Cyan Ink

Why Do We Measure H/G?

- Quality Control of incoming inks
- Check for back-trapping

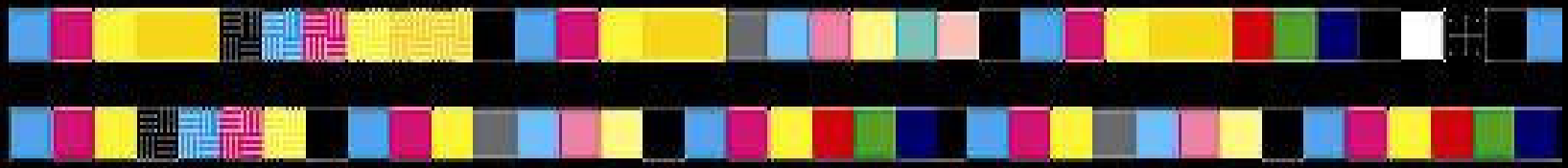


Where Do We Measure H/G?

- On the Press Sheet
  - Measure Solid ink density patch
    - Color bar (preferred) or image area
- Draw downs from ink Manufacturer
  - Find an area with densities similar to densities you run on press
  - Subtract Paper!!
  - Measure H/G in this area

Densitometric Functions

- Density
- Print Contrast
- Dot Area / Dot Gain
- Hue Error / Grayness
- Trap



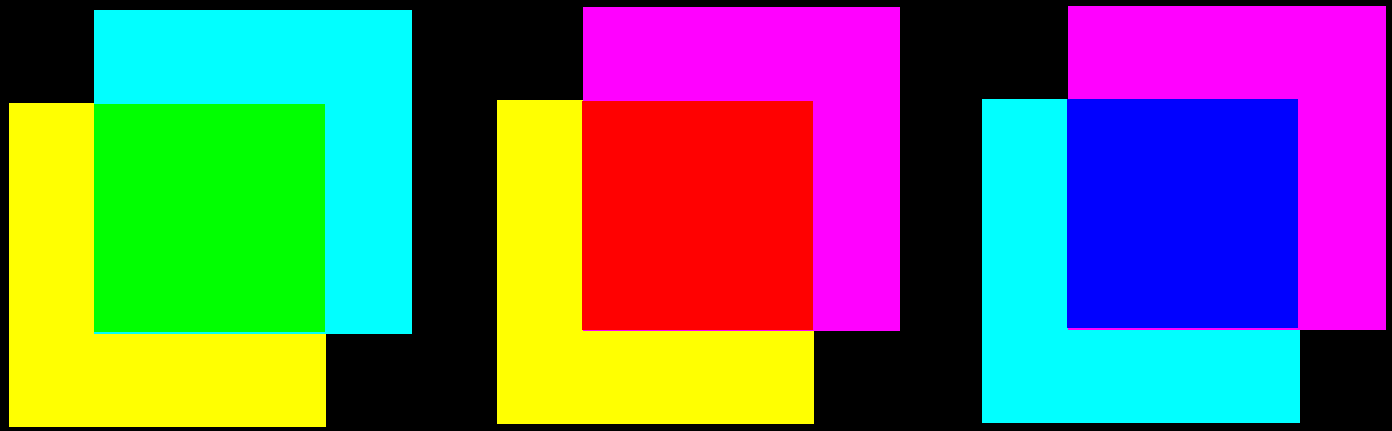
What is Apparent Trap?

- The ability of an ink film to adhere to another ink film, compared to it's ability to adhere to paper.
  - The calculation is a percent from 0% to 100%
  - Due to additivity failure, 100% Apparent Trap may not be attainable; it's a relative measurement only.

- Apparent trap calculations are only meaningful if the process color printing sequence is known!

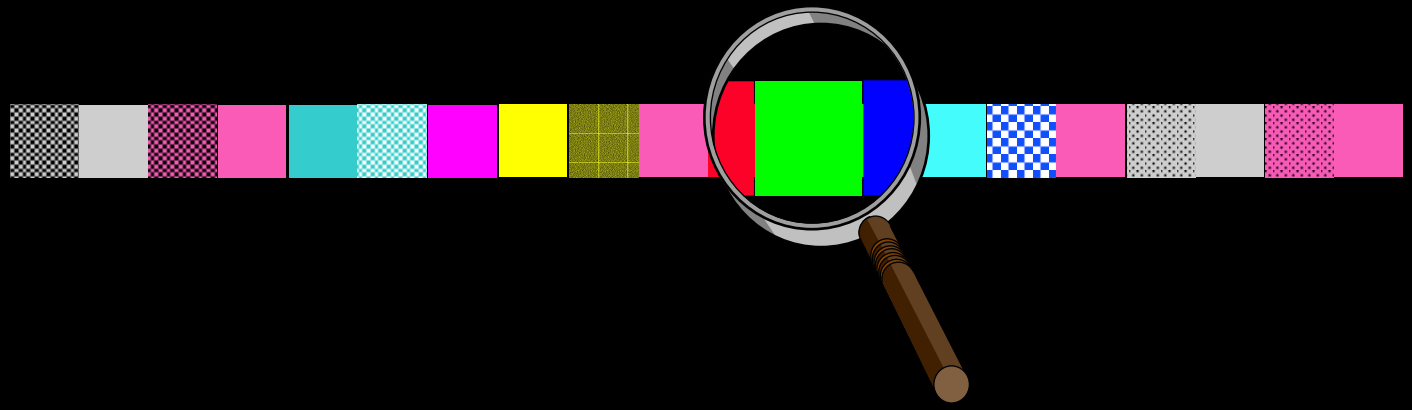
Why Do We Use Trap?

- Check for proper overprinting
- Monitor ink tack
- Check the opacity of the yellow ink



Where Do We Measure Trap?

- Must be measured from a color bar
  - Paper
  - Overprint
  - Second ink down
  - First ink down

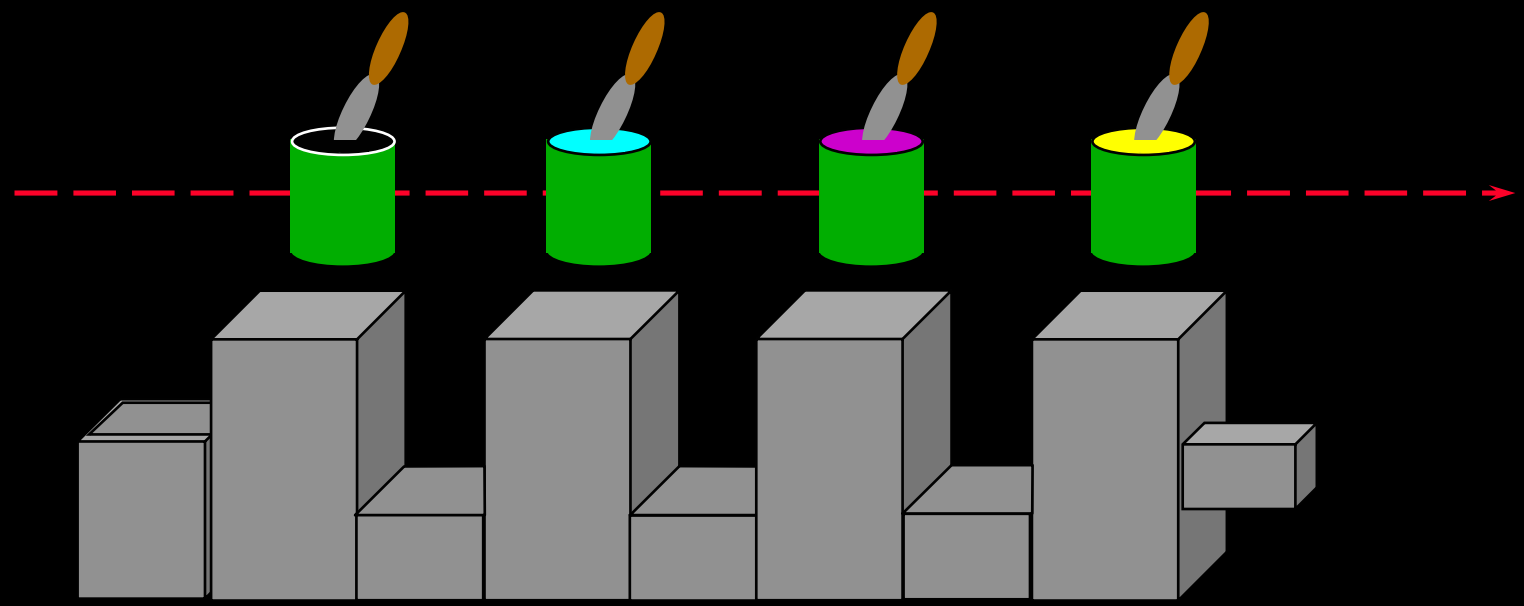


Hands on Exercise

- Let’s learn how to measure Trap

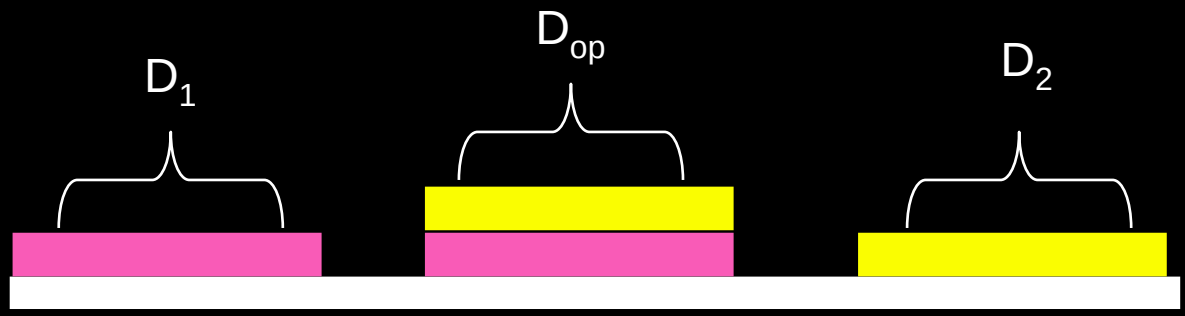
How Do We Measure Trap?

- Must know the ink sequence on press



How is Apparent Trap Calculated?

Apparent Trap (Preucil)



$$TRAP = \frac{D_{op} - D_1}{D_2} \times 100$$

D_{OP}= The Density of the two-color overprint, minus paper

D_1= The Density of the first-down ink, minus paper

D_2= The Density of the second=down ink, minus paper

What Do the Numbers Mean?

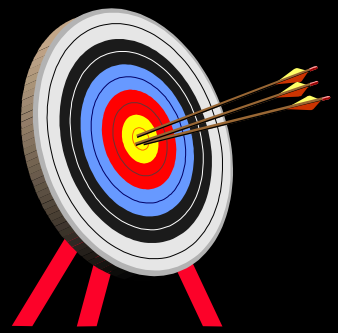
- Do I always need 100% trap???
  - Not necessarily!
- How do I change or control trap?
  - ✓ Change ink properties or sequence
  - ✓ Change solid ink density
  - ✓ Adjust ink and water balance
  - ✓ Change paper

What numbers should I Aim for?

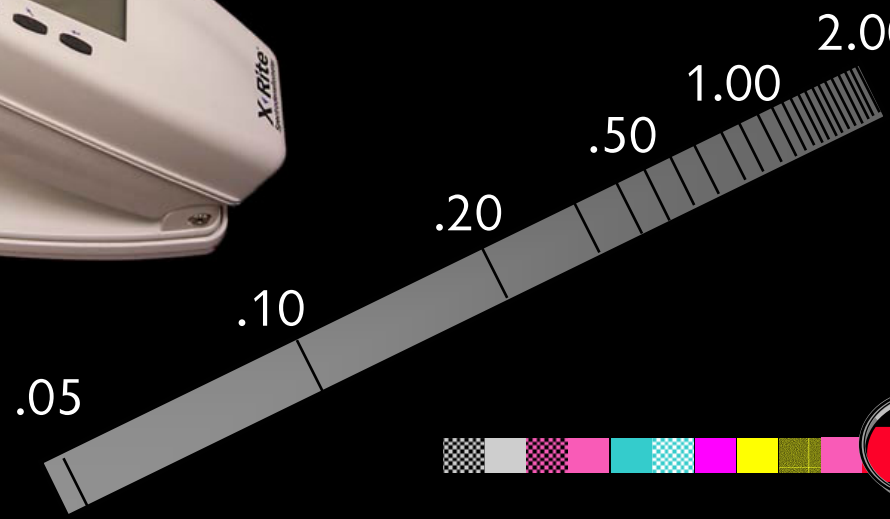
- Typical Apparent Trap Values

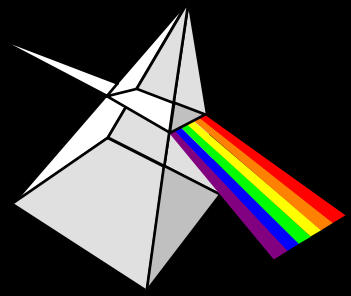
	Red	Green	Blue
Sheetfed offset	70%	80%	75%
Web offset	65%	75%	70%
Non-Heat set web, News	55%	65%	60%

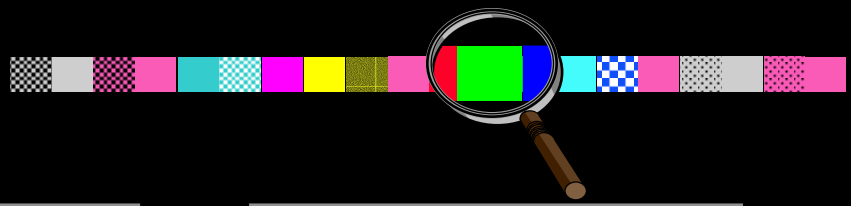
Status T, Calculated using the Preucil formula

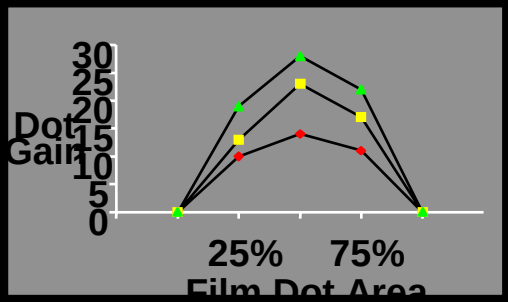


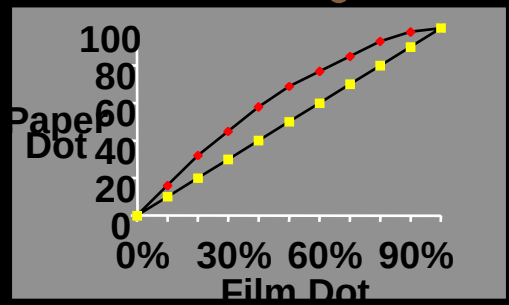
Density Questions and Answers











IF YOU REMEMBER NOTHING ELSE, REMEMBER THIS

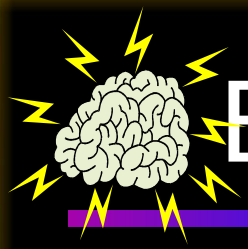
- We measure DENSITY to check press variables…a densitometer is colorblind!!!
- We measure DOT SIZE/DOT GAIN because that is what we print.
- We measure PRINT CONTRAST to be certain the shawdows are printing properly and that our printing has PIZAZZ!
- We measure TRAP to be sure that we are proplerly making the thousands and thousands of colors produced by dot overlay properly.

Pressroom Color Control

Part 2…The Measurement of Color…A NEW language

v BB29

X-Rite Training Center



Exercise – New Language

- Lemon?
- Lime?
- Which license plate is which fruit and why?

L=62
C=55
H=92

L=54
C=46
H=141

The Trouble with Color

- Color Reproduction
  - Language problems

- Color Subjectivity
  - Your brain on color

Color Communication
  - Break down ahead

Is this effective communication?

- Add contrast
- Add density
- Add snap
- Air out
- Balance the neutrals
- Beef up color
- Blown-out
- Blue Out
- Burn down
- Burner
- Chalky
- Choked up
- Choppy midtones
- Clean up
- Color too skinny
- Color OK but more density
- Colors all jammed up
- Color OK but flat
- Color OK but thin
- Color OK but too heavy
- Colors too strong
- Commercially acceptable color
- Contrasty
- Cooler
- Crisp color
- Delete a little red
- Dirty and flat
- Do a little better here
- Does not have shine of transparency
- Dull down
- Exaggerate the condition
- Fleshier flesh tones
- Flesh needs weight & color
- Flick less
- Add contrast
- Give it a kiss wash
- Give me a pretty picture
- Give me more shape
- Give me pleasing color
- Give it a strong wash
- Give the reds a bump
- Grainy
- Greek out
- Harsh
- Hold highlight

Is this effective communication?

- Increase contrast in middletones
- Increase detail
- Increase saturation
- Increase sharpness
- Be livelier
- It’s got to jump
- I want the reds to jump off the page
- Lacks snap
- Livelier
- Make it brighter
- Make colors cleaner
- Make colors warmer
- Make colors colder
- Make it glossier
- Make it sing
- Make it sky blue
- Make it pop
- Maintain gray balance
- Match attached
- Match copy
- Match the crossover
- Moiré!!!
- More guts or gutsier
- More metallic
- More neutral
- More sock
- More texture
- Muddy
- Mushy
- Needs dimension
- Needs more depth
- Needs luminosity
- Needs warmth
- N.G.
- Neutral brown
- O.K.!!!
- O.K.???
- O.K. with correction
- Over-etched-see 1st proof
- Open shadows
- Open up shadows
- Out of color balance
- Plugged
- Pushy
- Raw
- Redder reds
- Reduce blue 2%
- Reduce one more step
- Reduce overall
- Reduce 2%
- Ruddy

Effective Communication ?

- + Shape
- Soften back
- Strengthen
- Subdue
- Tad less
- Tone down
- Too dull
- Too flat
- Too hot or cold
- Too Jumpy
- Too much internal contrast
- Too muddy
- Too piny
- Too weak
- UGH!
- Whiter whites but hold detail
- Wrong shade of red
- Yellow O.K. but see the proofs
- You Went Too Far

*Generated at the Research & Engineering Council Roundtable Discussion, Chicago, October, 1976

Effective Communication

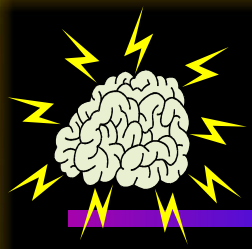
- Remember a few months ago we were searching for the snipers in the D.C. area… we looked for months then something happened that lead to their IMMEDIATE capture???

*

Effective Communication

- First, it was this about their car…….
- Then, they said….
- And finally, the missing piece of the puzzle….
- The all important license plate number!!!

*



Exercise – Old Language

- Write down a description of these colors and pass it forward…

Exercise – New Language

- Lemon?
- Lime?
- Which license plate is which fruit and why?

L=62	L=54
C=55	C=46
H=92	H=141

ALBERT MUNSELL… The designer of the color "license plate"

- He was an artist and teacher
  - A graduate of the Julian Academy
  - A powerful and practical observer

- Munsell brought order to color
  - Developed the first numerical scheme
  - Laid the foundations for color science

Munsell's Hue

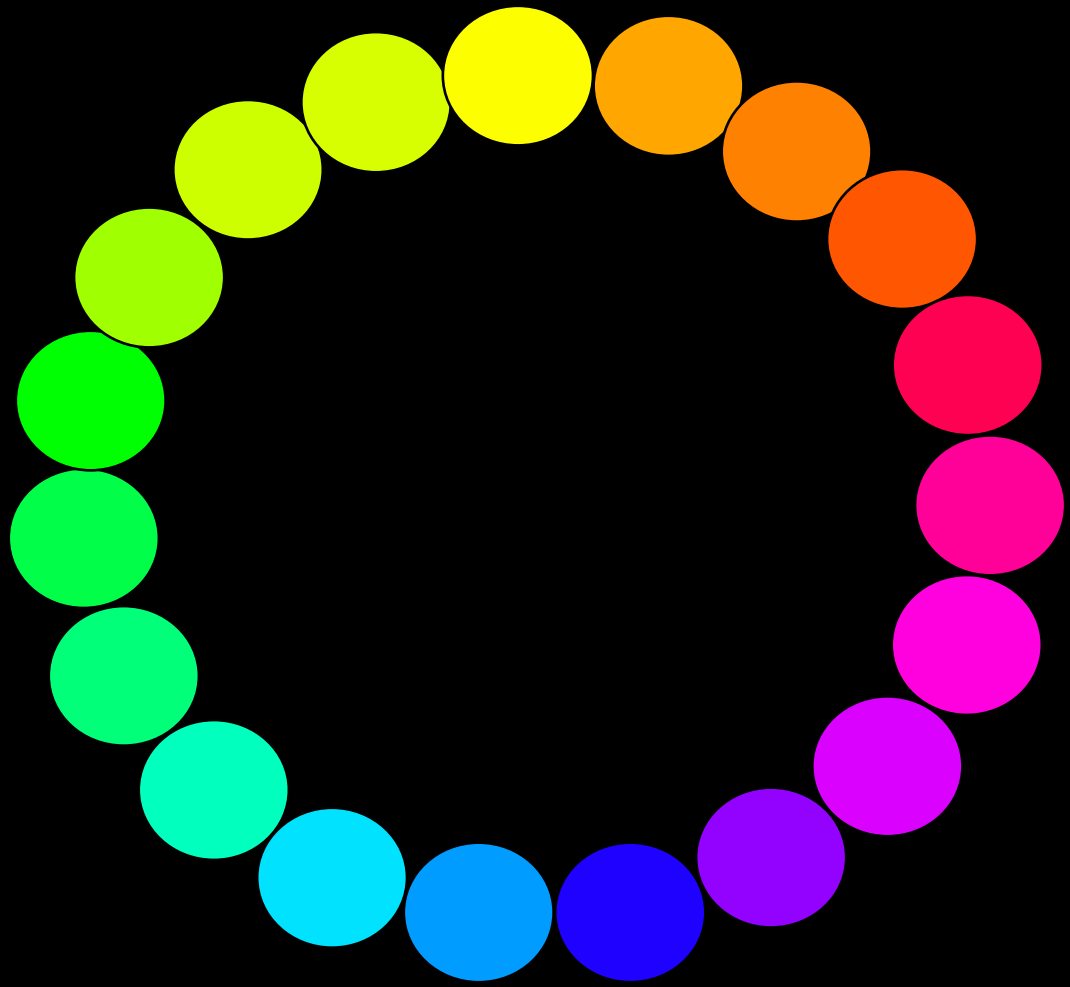
h°

- The name of a color (or color family)

Red, Green, Yellow, Orange

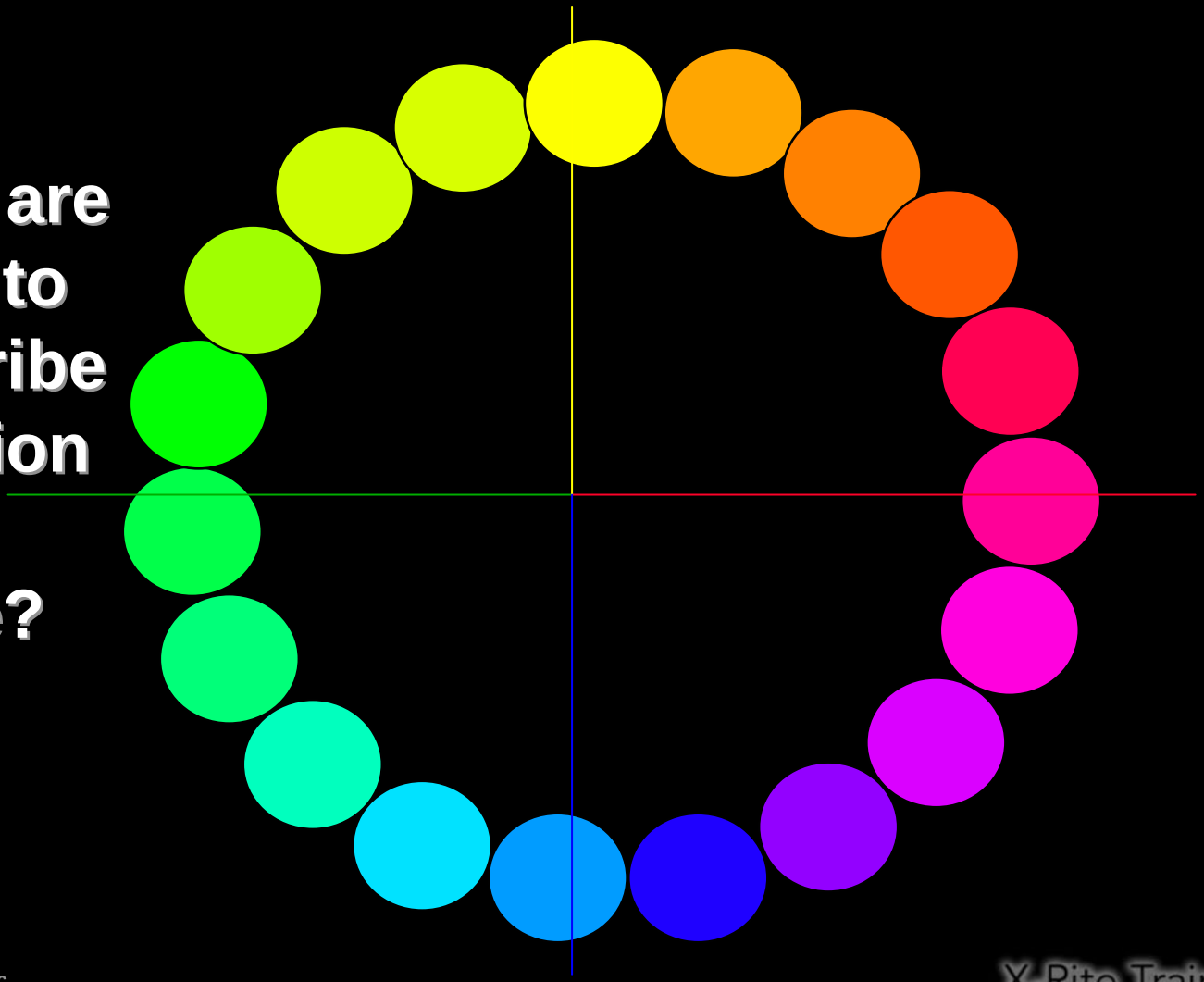
- The quality by which we distinguish one group of similar colors from another

Munsell Organized Hues in a Circle



Munsell Organized Hues in a Circle

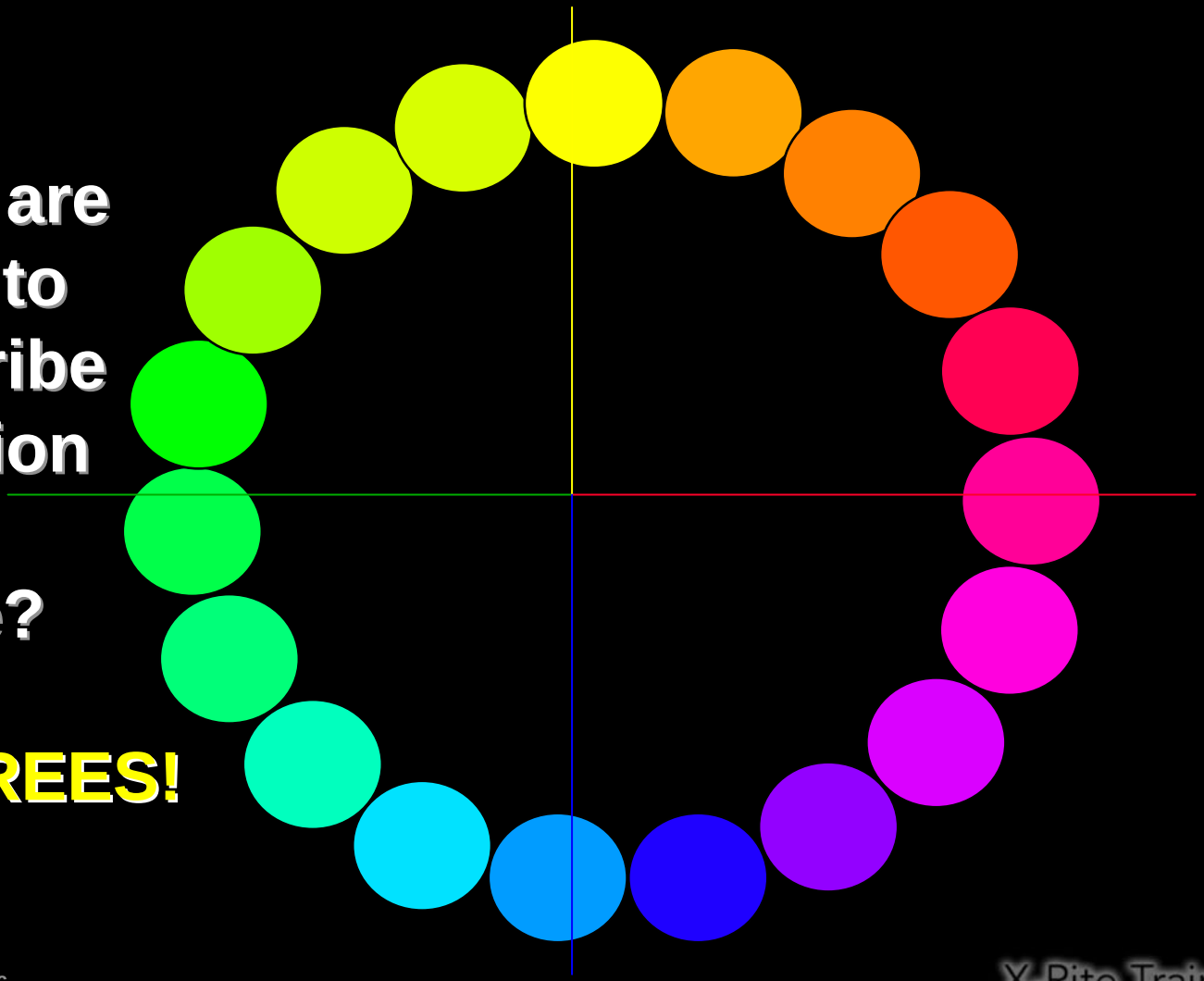
What units are used to describe position on a circle?



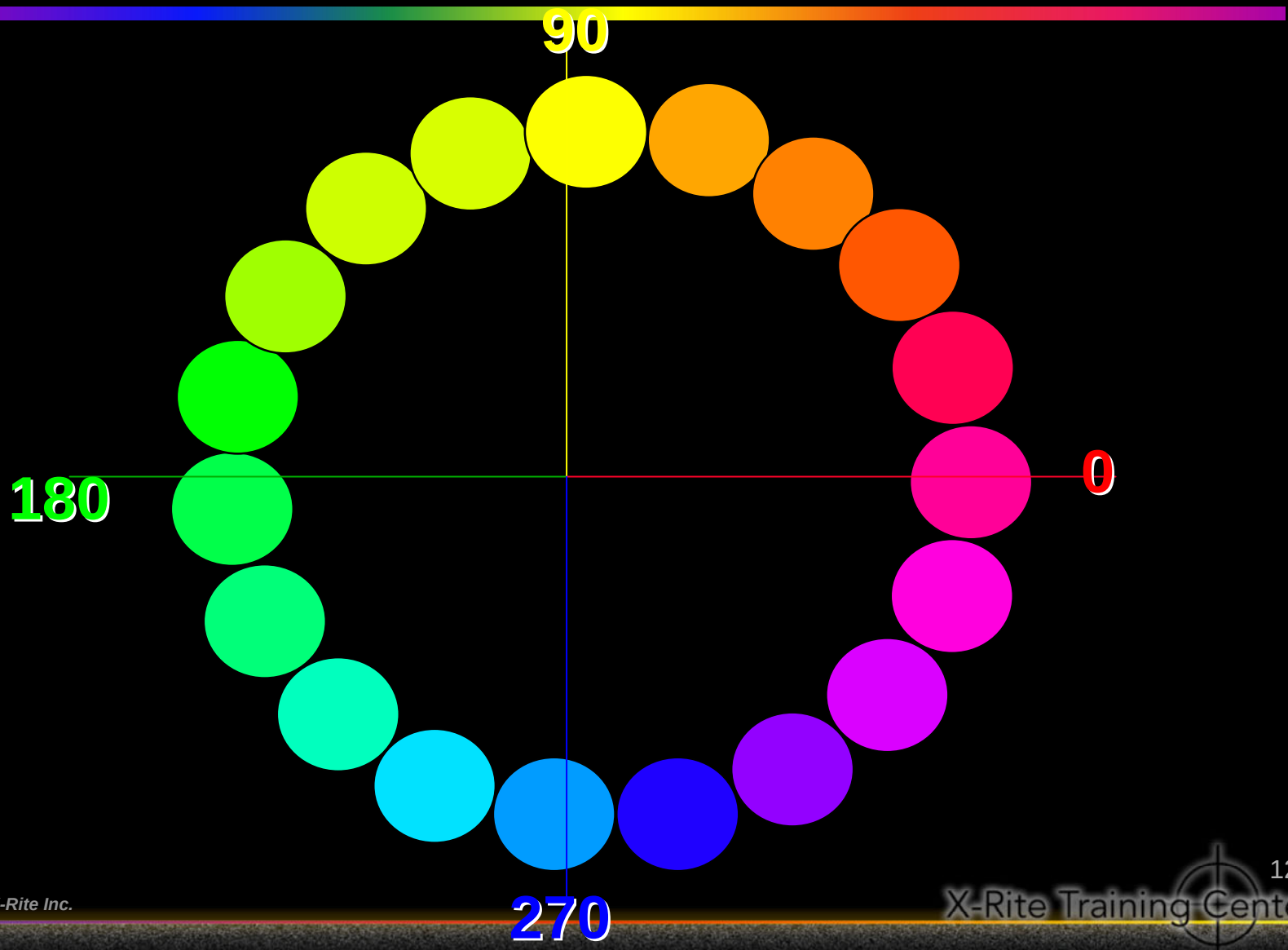
Munsell Organized Hues in a Circle

What units are used to describe position on a circle?

DEGREES!



Munsell Organized Hues in a Circle



Munsell's Value (Lightness)

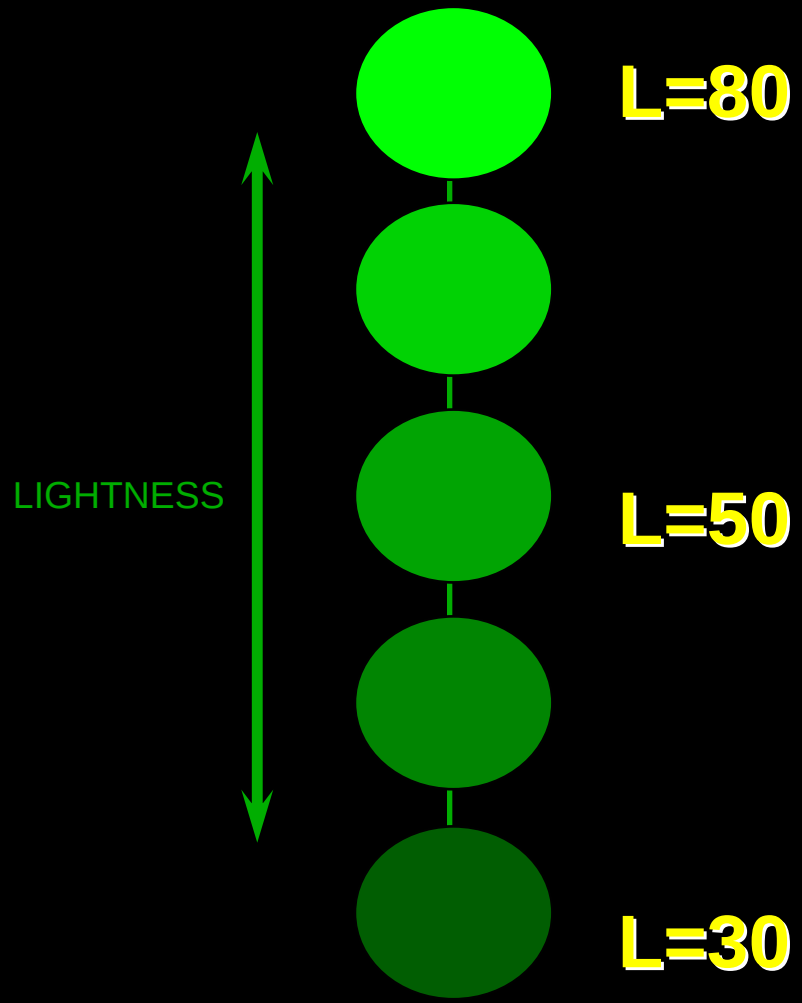
L*

- The lightness of a color

Light Green, **Dark Brown**, **White**

- The quality by which we distinguish lighter shades from darker ones

Lightness (“value”)



Munsell's Chroma

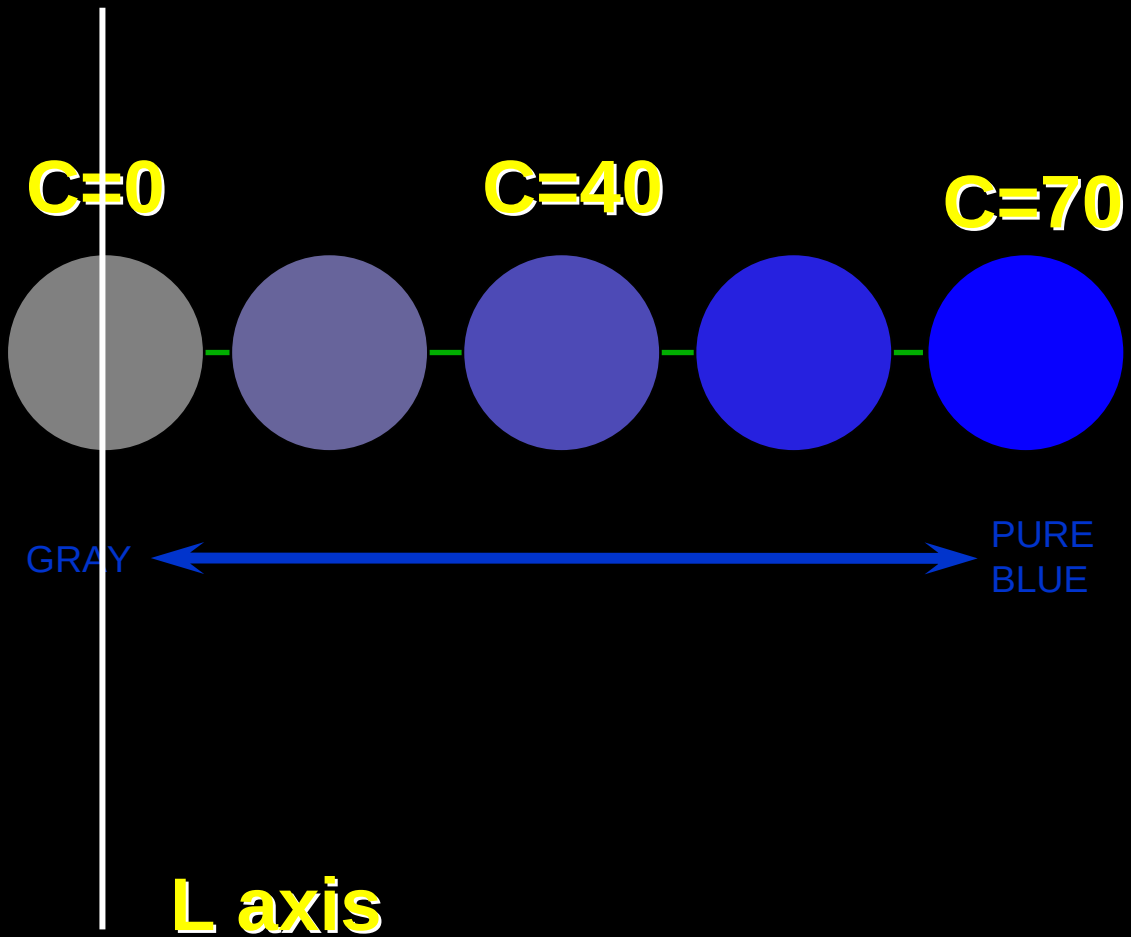
C*

- The strength of a color (distance from gray)

Candy Apple Red, **Chrome Yellow**

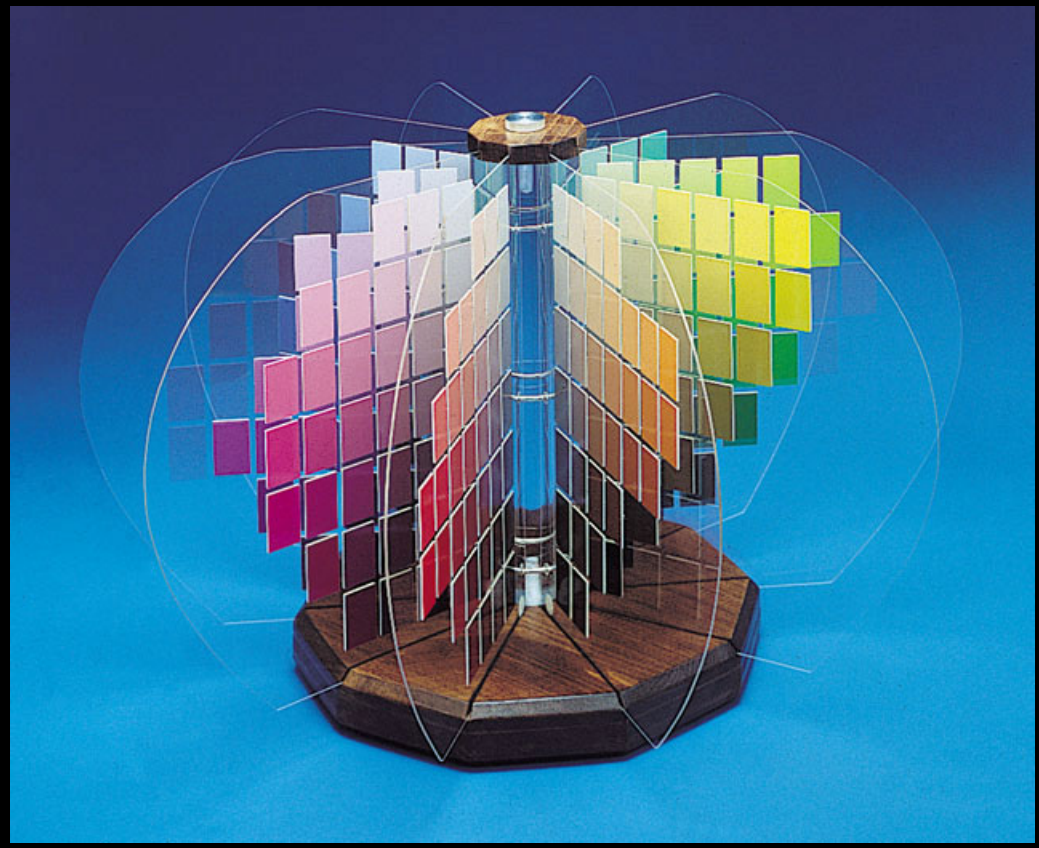
- The quality by which we distinguish strong saturated colors from weak, achromatic ones

Chroma

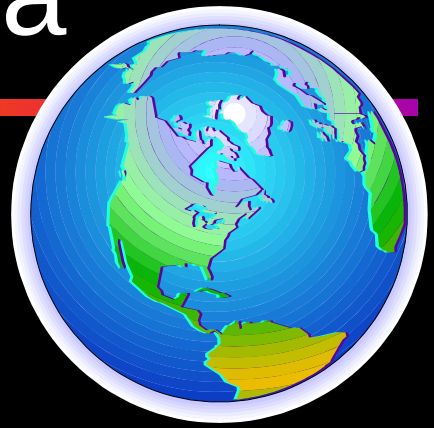


The Munsell System

- Hue
- Value
- Chroma



Hue, Value & Chroma



- Three independent variables

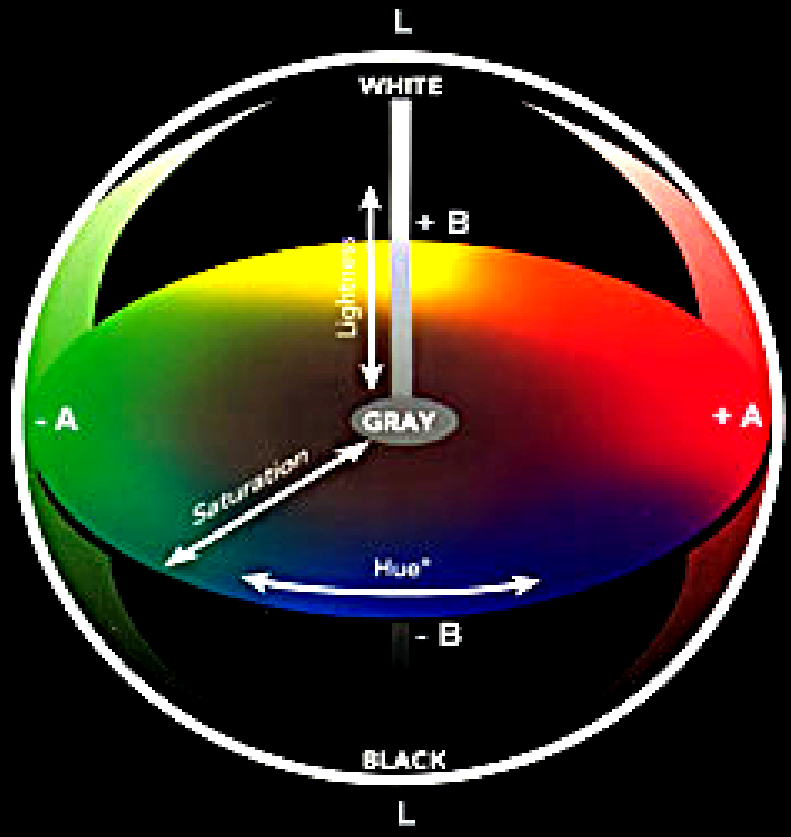
A three-dimensional model like:

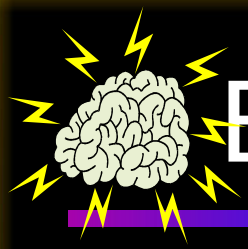
longitude, latitude, altitude

length, width, depth.

Albert Munsell was the first person to present a practical color order system by which an individual could specify color-by-the-numbers!!!

CIE L*a*b*/ L*C*h°





Exercise – New Language

- Lemon?
- Lime?
- Which license plate is which fruit?

L=62
C=55
H=92

L=37
C=26
H=118

Don’t forget …….

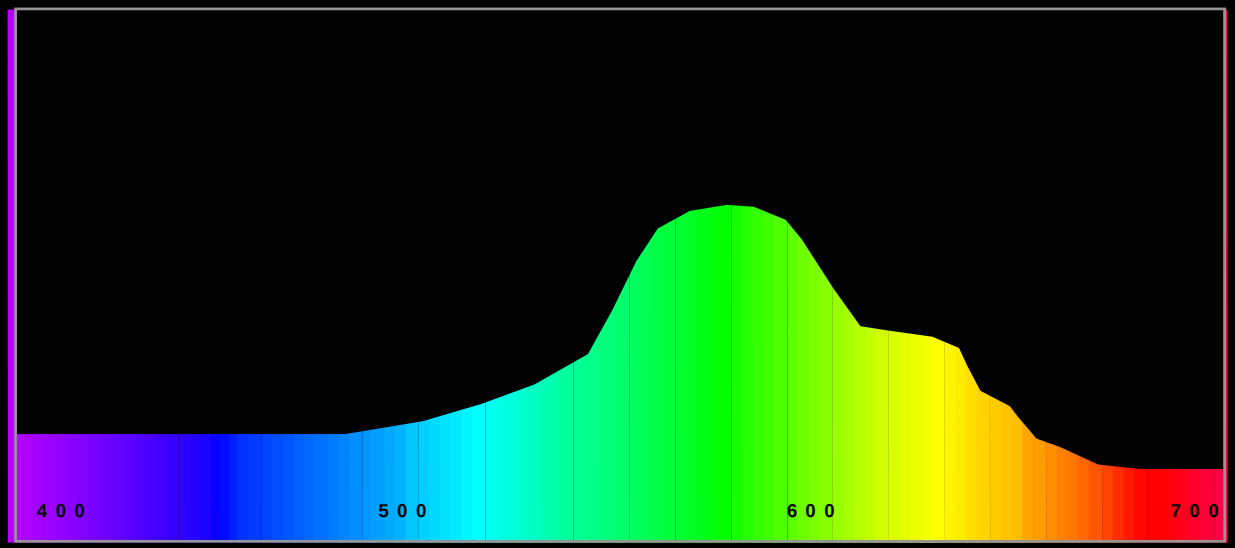
- Lightness is... The quality by which we distinguish lighter shades from darker ones.
- Chroma is... The quality by which we distinguish strong saturated colors from weak, achromatic ones.
- Hue is... The name we give to a color (or a color’s family).

Instrument Types

- Densitometers
  - Color levels
  - Density
  - Print attributes
- SpectroDdensitometers
  - Color levels
  - Density
  - Print Attributes
  - Spectral data
  - Color Space
  - Color difference
  - CIE Lab/LCh
  - ΔE

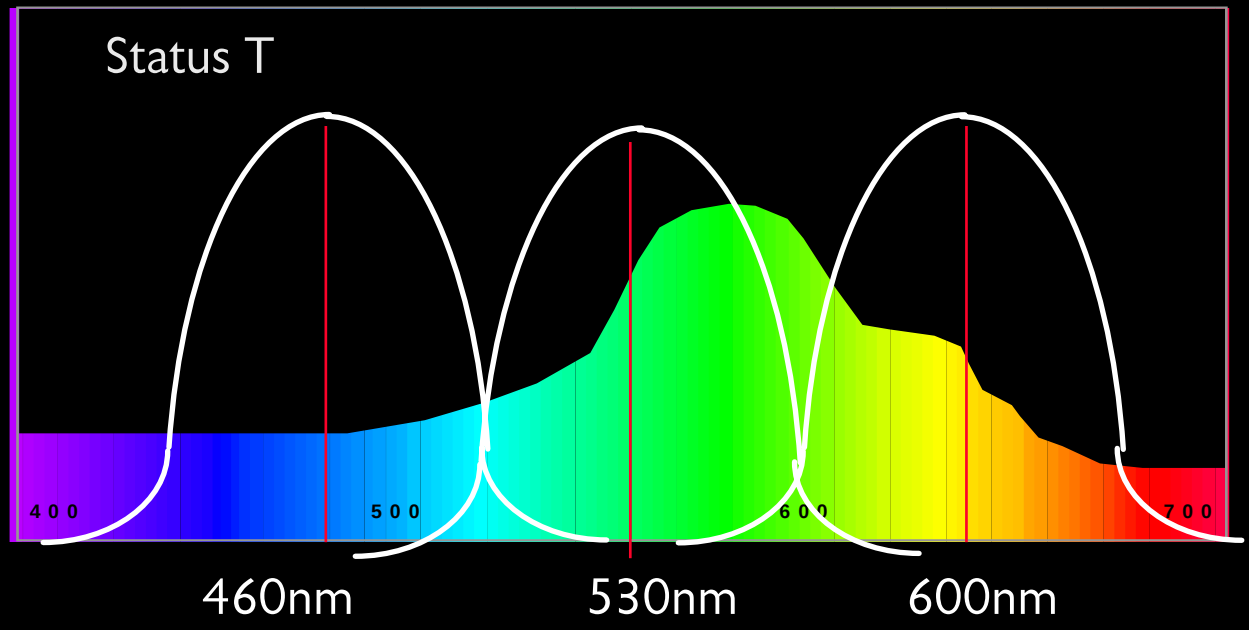
Why Different Instruments?

- Densitometers
- Spectrophotometers



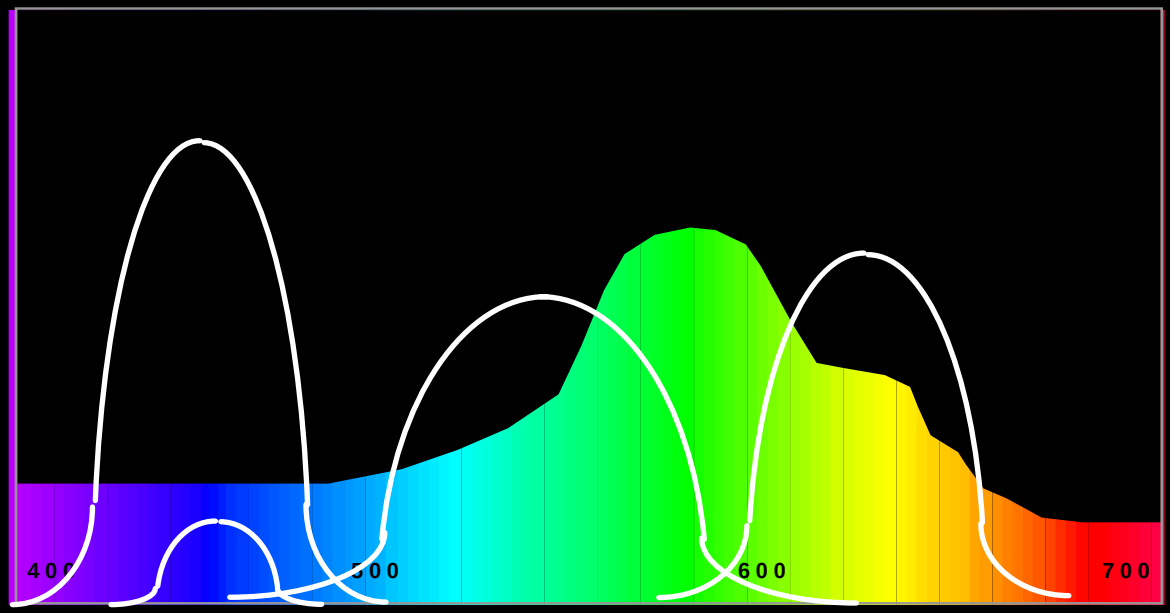
Densitometer

- Measures in three different area's across the spectrum from 400nm to 700nm.



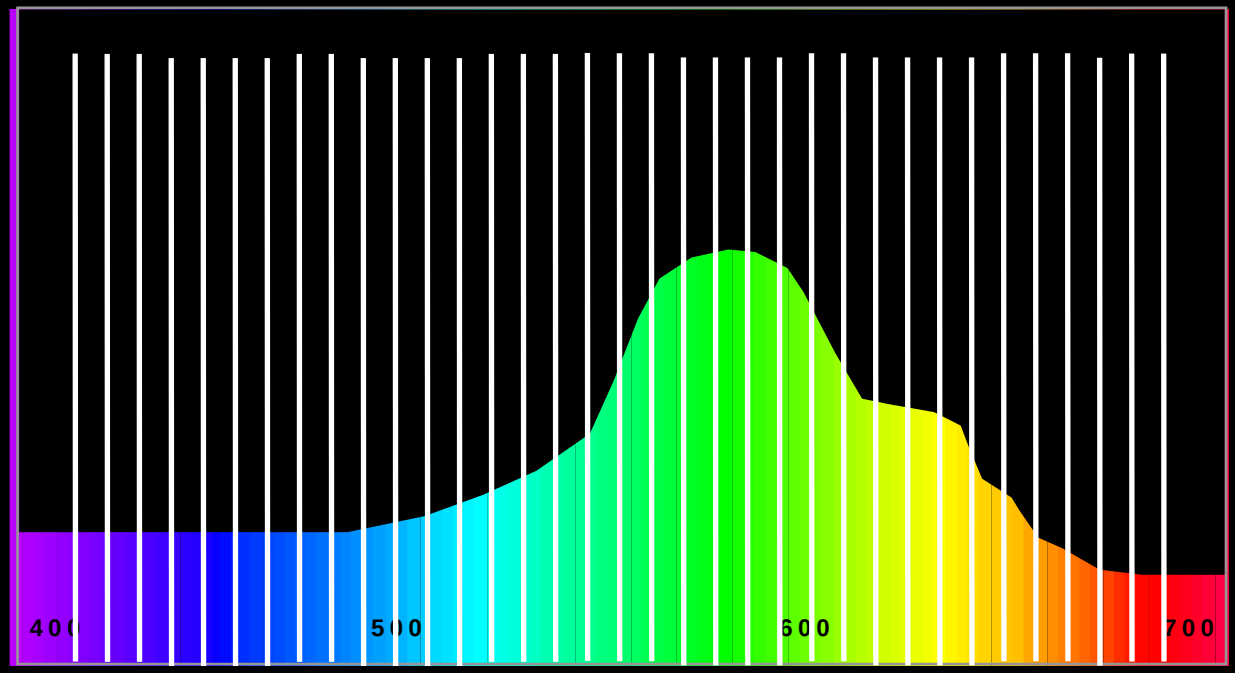
Colorimeter

- Measures in three different area’s across the spectrum from 400nm to 700nm

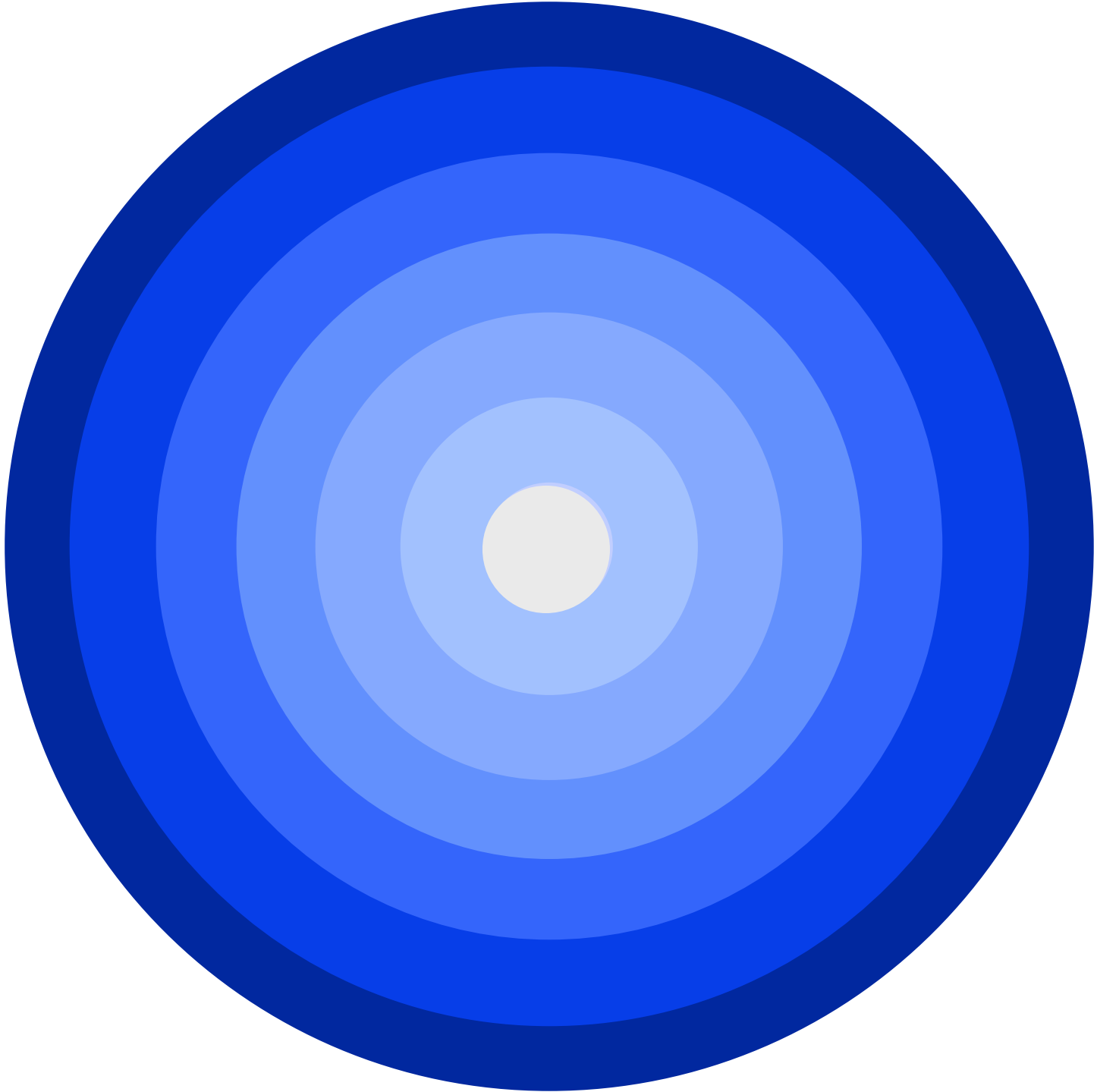


SpectroDensitometer

- Measures all the way across the spectrum from 400nm to 700nm



One last eye test….




That's All Folks!

Questions and Answers