# Ch.8: Subtractive Color Mixing.
# Ch.9: Color-Generating Mechanisms

1. Filters. Subtractive Primary Colors.

2. Pigments.

3. Structural Color.

4. Color in Gemstones.

# 1. Filters

Play the Interactive app:
http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Color-Filters/Color-Filters-Interactive
*Do q's 1 and 2 in WS 6*

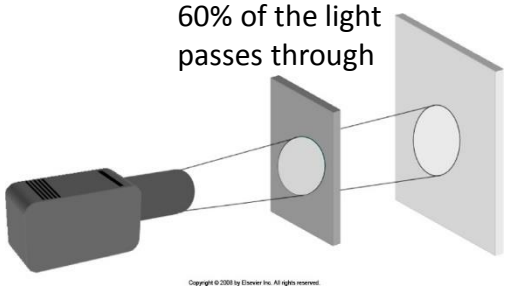



Fig.8.1 A neutral density filter with T=0.6

Filters absorb part of the incident spectrum and transmit another part.

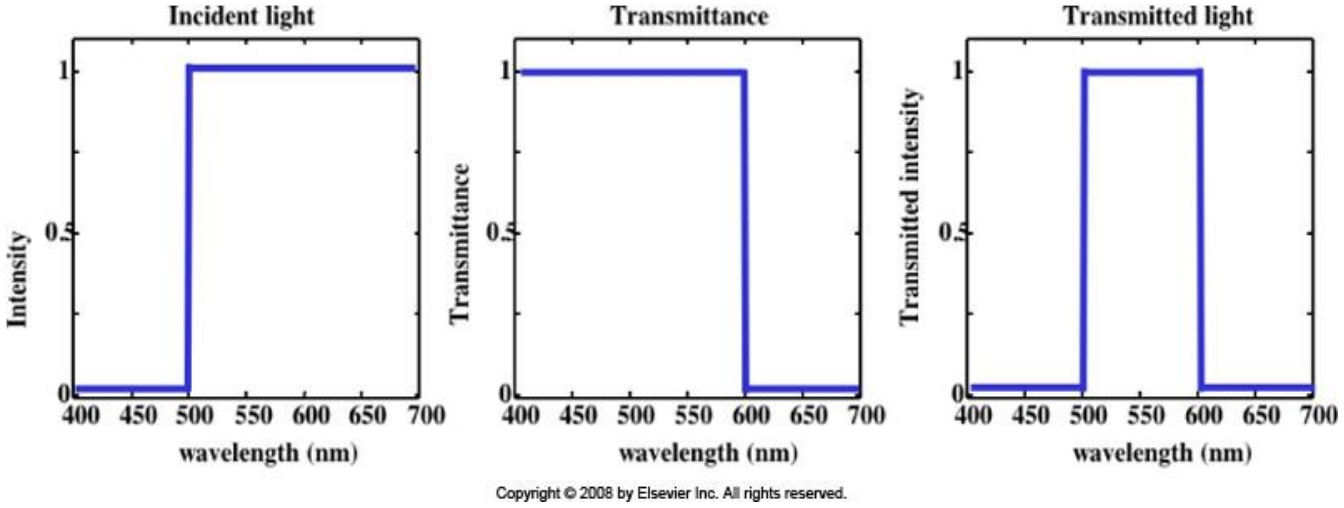
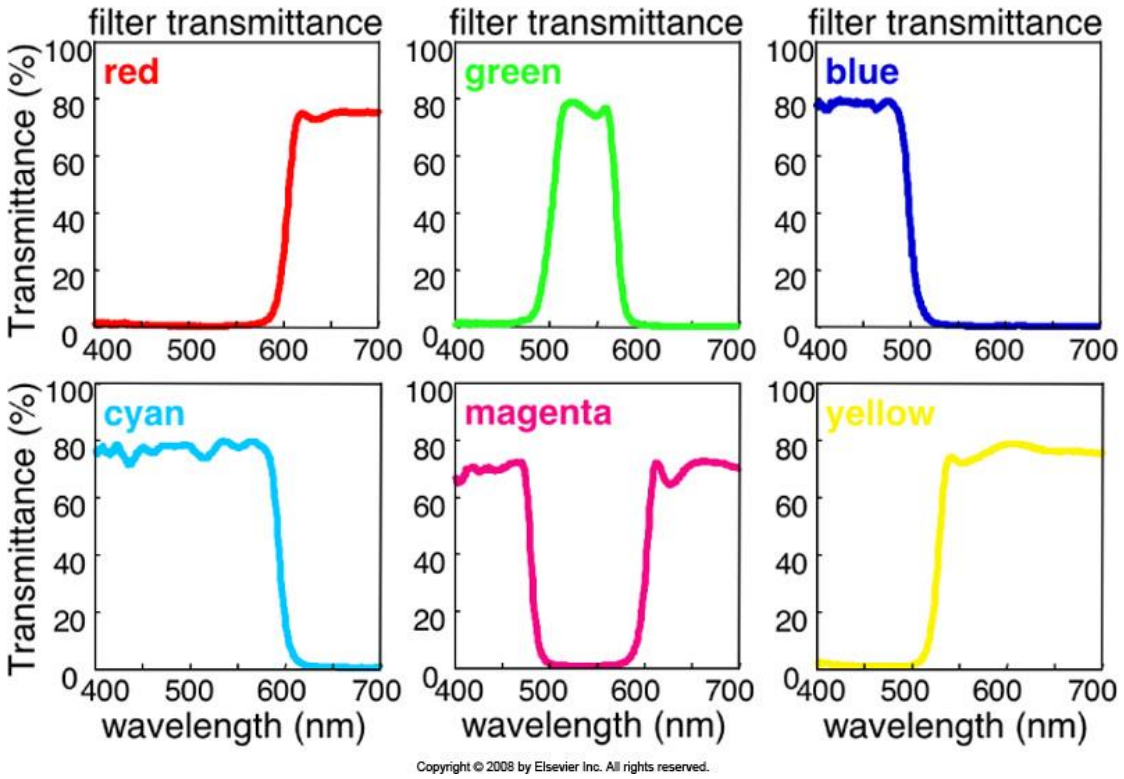


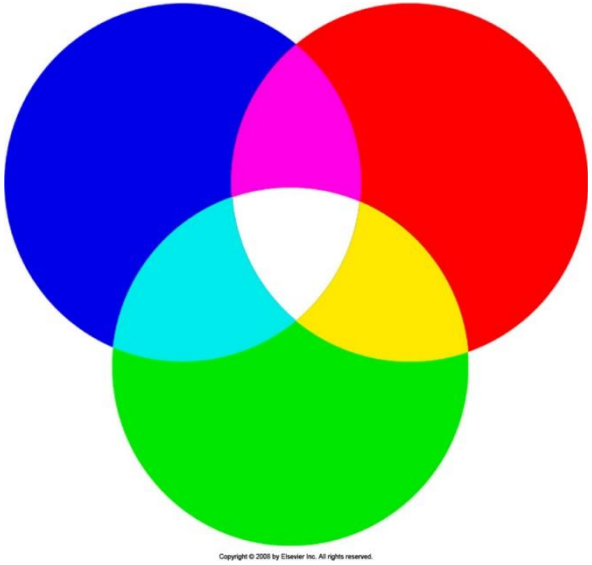

Fig.8.2 What is the color of the incident and transmitted light?

# Transmittance curves of real filters – each of Cyan, Magenta, Yellow subtract the additive primary colors R, G, B:



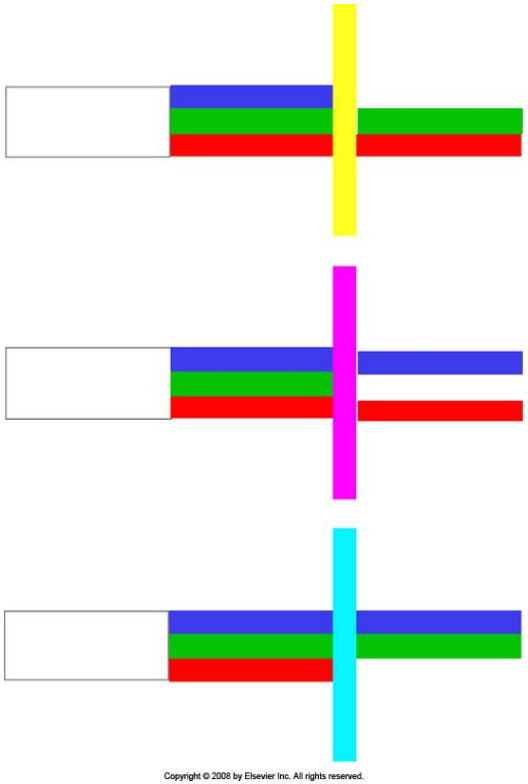


Recall the primary additive colors:

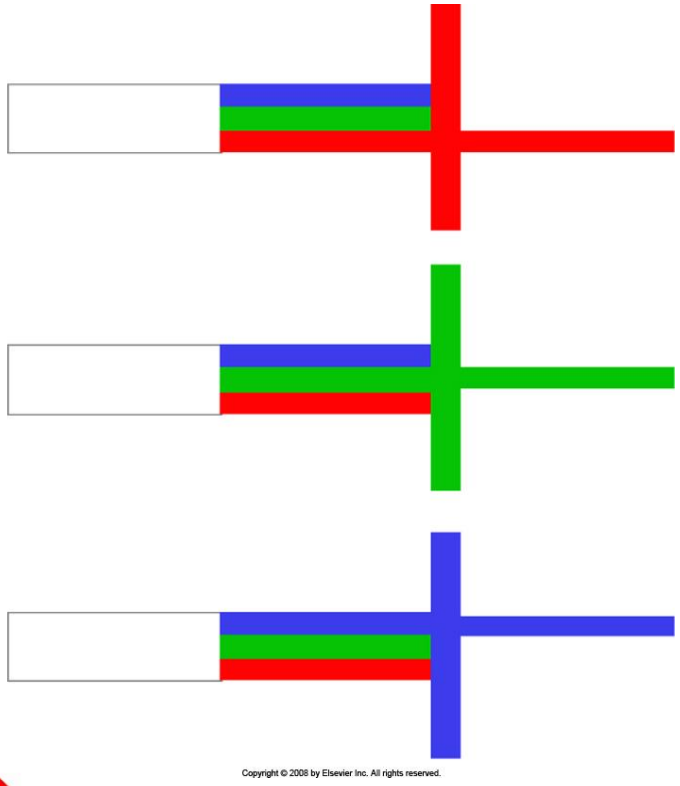



Q: Which ones are complementary colors?

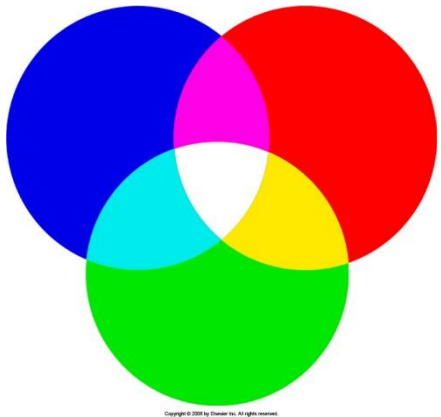
Each filter subtracts (absorbs) its complementary color.
C,M,Y are subtractive primary colors.



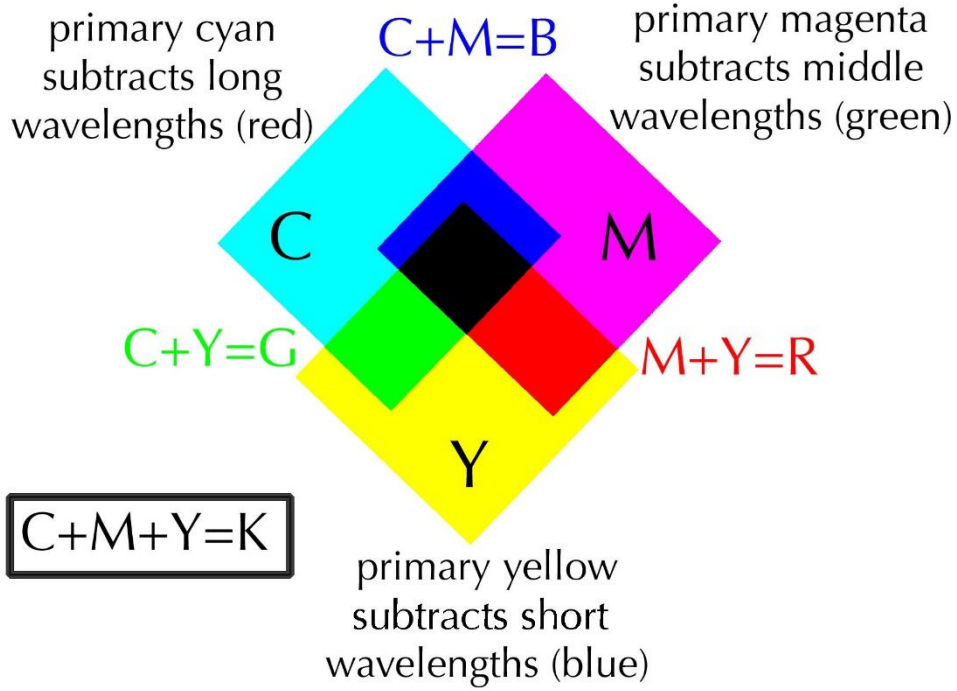




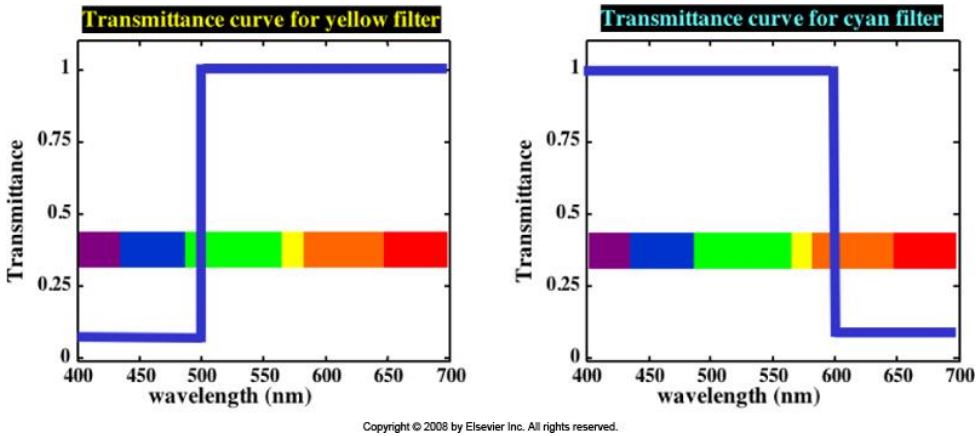




# Subtractively (filters): Red + Green = Black
# Additively (projectors): Red + Green = Yellow

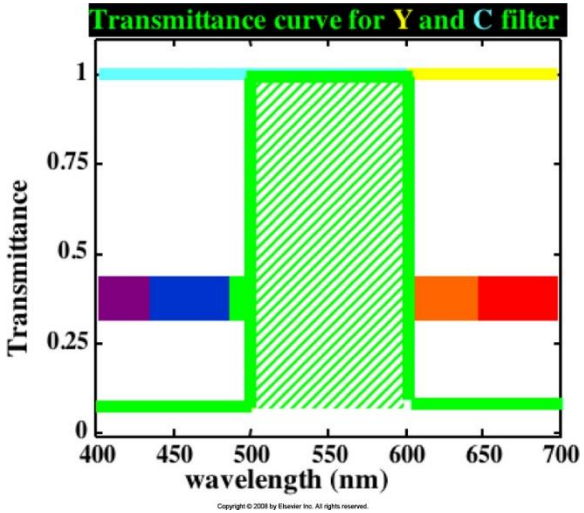


# Combining filters: the incident intensity is multiplied by the filter transmittance

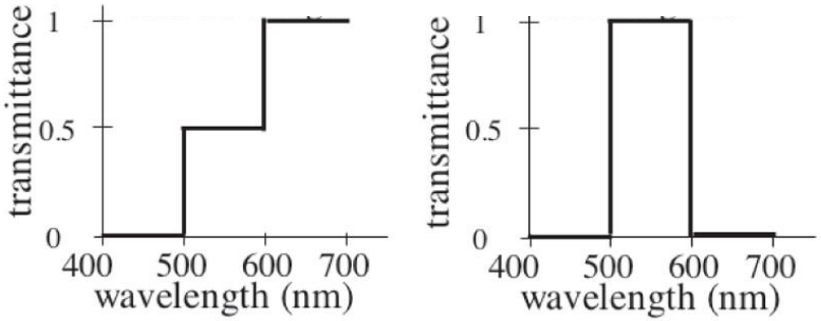




| | $T_{yellow}$ | $T_{cyan}$ | $T_y \times T_c$ |
|---|---|---|---|
| B | 0 | 1 | 0 |
| G | 1 | 1 | 1 |
| R | 1 | 0 | 0 |



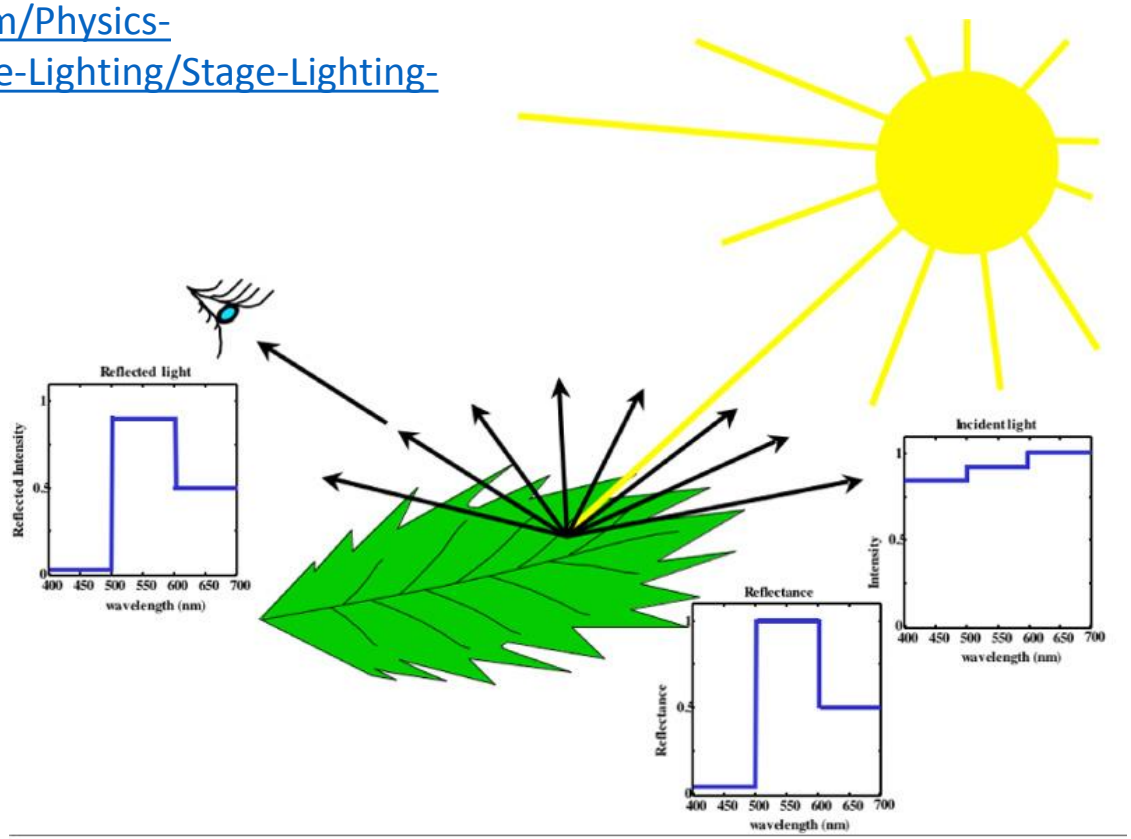

What colors are these filters?



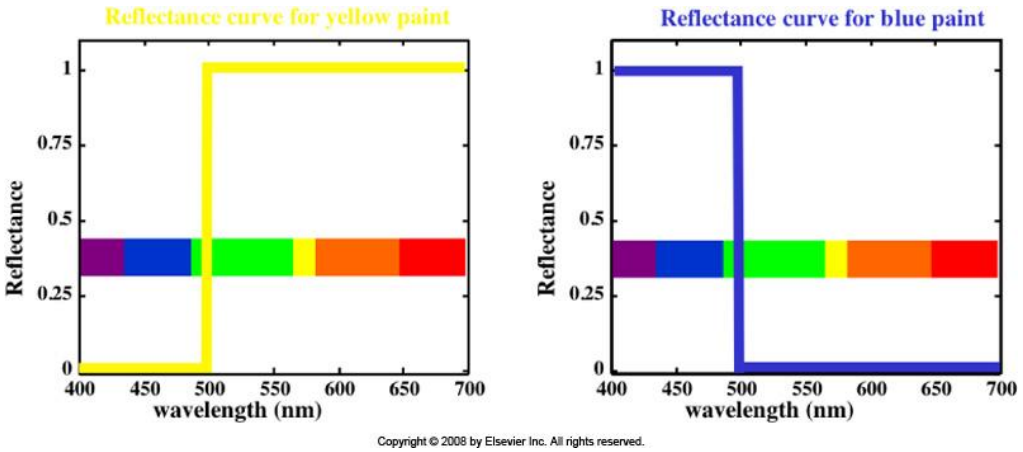
# 2. Pigments – the color depends on their reflectance and on the incident spectrum

Dependence on incident light:

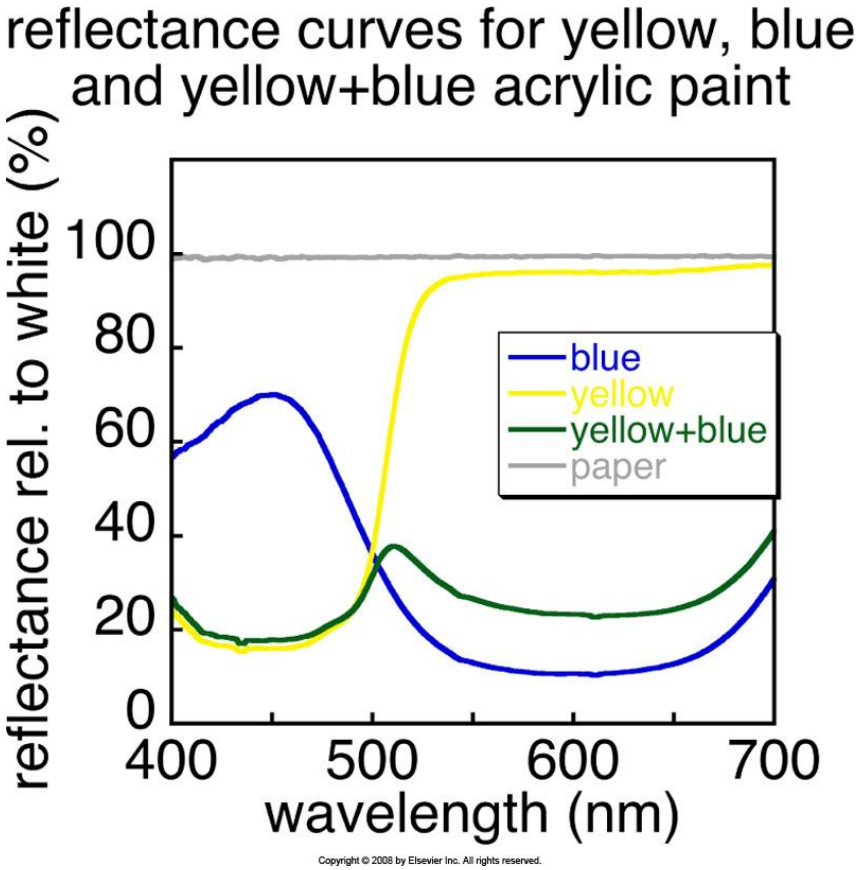
http://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Stage-Lighting/Stage-Lighting-Interactive



# Mixing paints:
# Blue + Yellow = ?









The idealized steep curves will tell B + Y = Black

The real reflectance curves are less steep, so the result is dark green.

# Why do tree leafs change color in the fall?



Fig.9-1a



Fig.9-1b

This is one of the topics to explore in Lab Journal 3.

# Pigments (cont.)


Watch the video and answer the questions:

- What happens to sunlight illuminating the surface of an orange? A green leaf?
- Do pigments (paints) emit different colors of light?

  How do you explain their colors?

Dependence on reflectance: https://www.youtube.com/watch?v=yLshU-FokYI

Animal pigments:

- Melanin *(black, gray, beige, or brown)*
- Carotenoids *(yellow, orange, pink, or red)*

Plant pigments:

- Chlorophylls *(green)*
- Carotenoids *(yellow, orange, pink, or red)*
- Tannin *(black or brown)*
- Anthocyanins *(red or bluish-purple)*

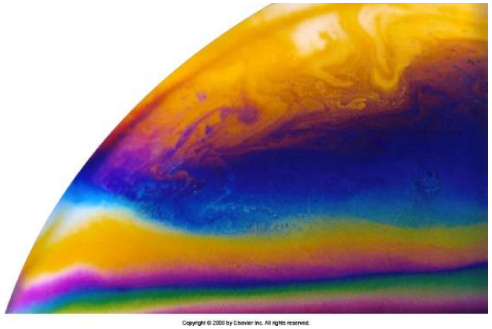
# 3. Structural Color

Why is blue such a rare color in nature?
https://www.youtube.com/watch?v=3g246c6Bv58

Fig.9.2. There is no blue color in this butterfly – it is generated by iridescence. The color of beetle shells is similarly generated.

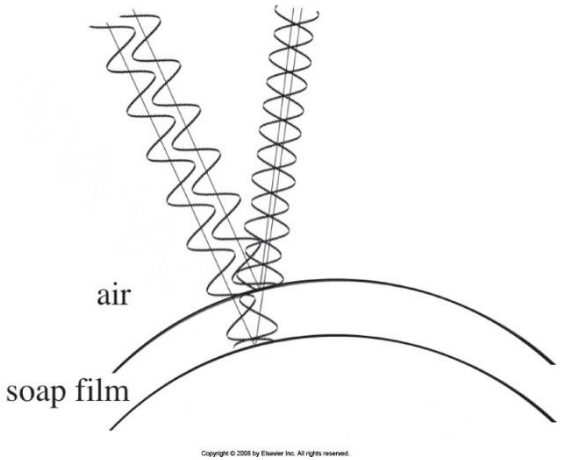
Pits in CDs also produce structural color

# Examples of interference of light in thin films



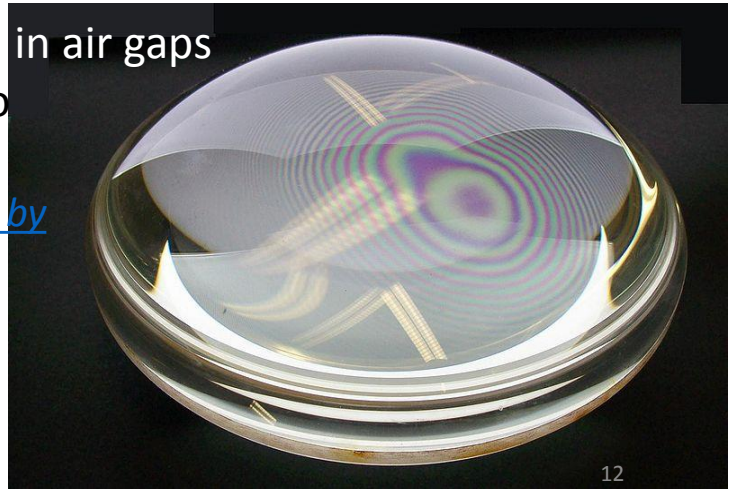
Interference in soap bubbles.






Figs. 9.3 – 9.5

Interference in air gaps between two lenses. *In the public domain by user Ulfbastel*



Example of soap bubbles changing thickness:
https://www.youtube.com/watch?v=4I34jA1fDp4

# 4. Colors of Gemstones


Fig.9.10 Different crystals with Cr impurities


Fig.9.11 Same crystal (beryl) with different impurities

Ruby: $Al_2O_3$ with Cr
Saphire: $Al_2O_3$ with Fe, Mg, Ti,
or other inclusions, causing various colors