Computational Photography

Instructor: Sanjeev J. Koppal

MWF

1145am-1235pm

BEN 328

Acknowledgements

Some slides from

Narasimhan (Carnegie Mellon),

Zickler (Harvard),

Efros (Berkeley)

and others…

About me

- Undergrad at the University of Southern California
- Ph.D. at Carnegie Mellon (Robotics)
- Post-doc at Harvard
- Couple of years at Texas Instruments Imaging R&D

Course Format

Show Syllabus

Course Format

- One Midterm assignment - 30 %
- One Final Exam - 35 %
- Participation - 20 %
- Presentation (Paper, Project, Photographs) - 15 %

Requirements

- Attendance and Participation

- *Nice to have (but not necessary):*

- access to a good camera

- access to a good machine with Matlab?

- access to textbooks
  (Robot Vision and Multiview Geometry)

A note on the Exams

- Take home

- High level

- Mostly checking if you understood the *basic* concepts

Other than the Exams

- Presentation
  - A group effort (find your group quickly or I will randomly assign)
  - Can range from presenting a random paper (least effort and learning) to a full project (most effort and learning)
  - ICCP: International Conference on Computational Photography 2016 deadline in Dec – If you do well we can submit a paper.

Presentations

- Teams of 2 or 3 are preferred
- Email me this or next week for initial discussion
- Finalize by mid-semester when we have mid-semester practice presentations
- Give final presentation in December

New this Year!

- 3D Printing project

- Combine Computer Vision Concepts with 3D printing

- Completely Gradeless and Optional!

- You will learn Solidworks

Participation

Participation

A question in this font and color

Example

What is your name?

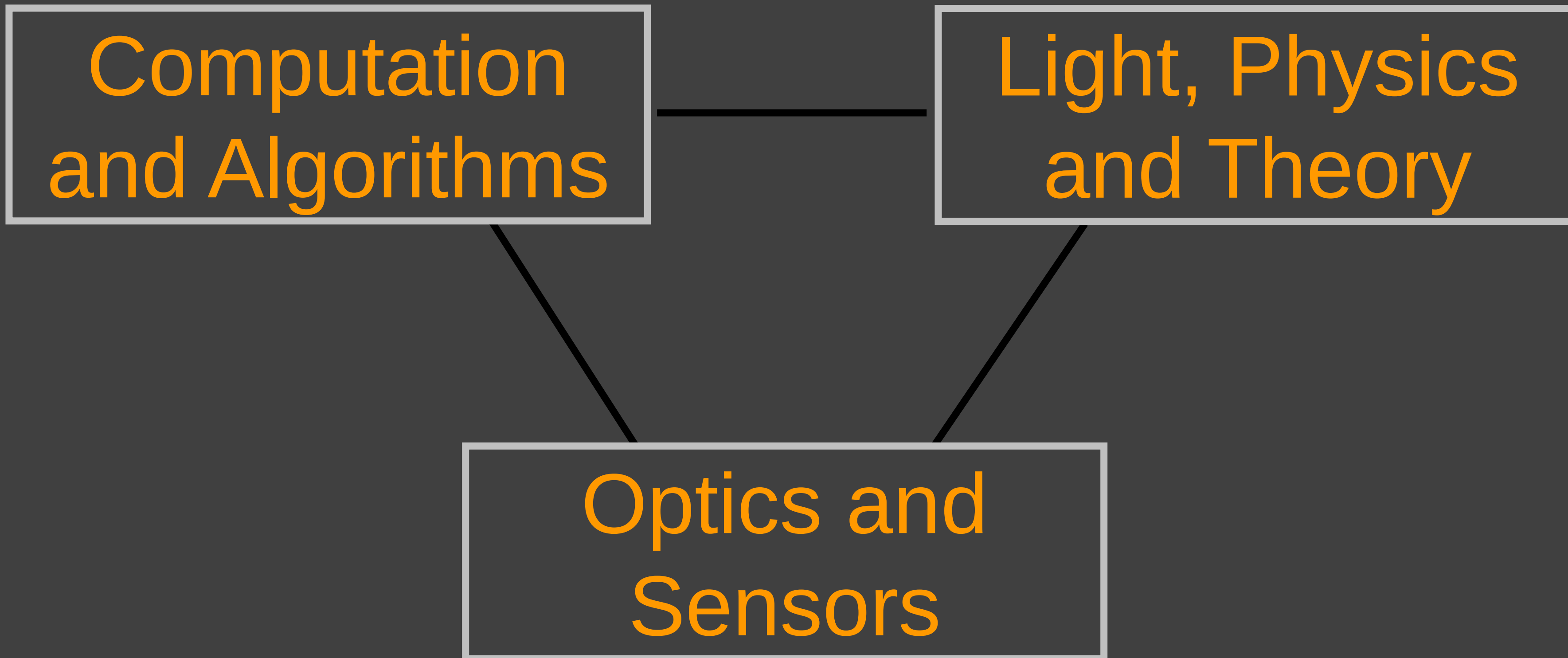
Lesson X

Lessons like this will show up throughout the class.

The last slide will be as summary of the lessons.

Yes, I may mess up the Lesson numbers.

What is Computational Photography?



Lesson 1

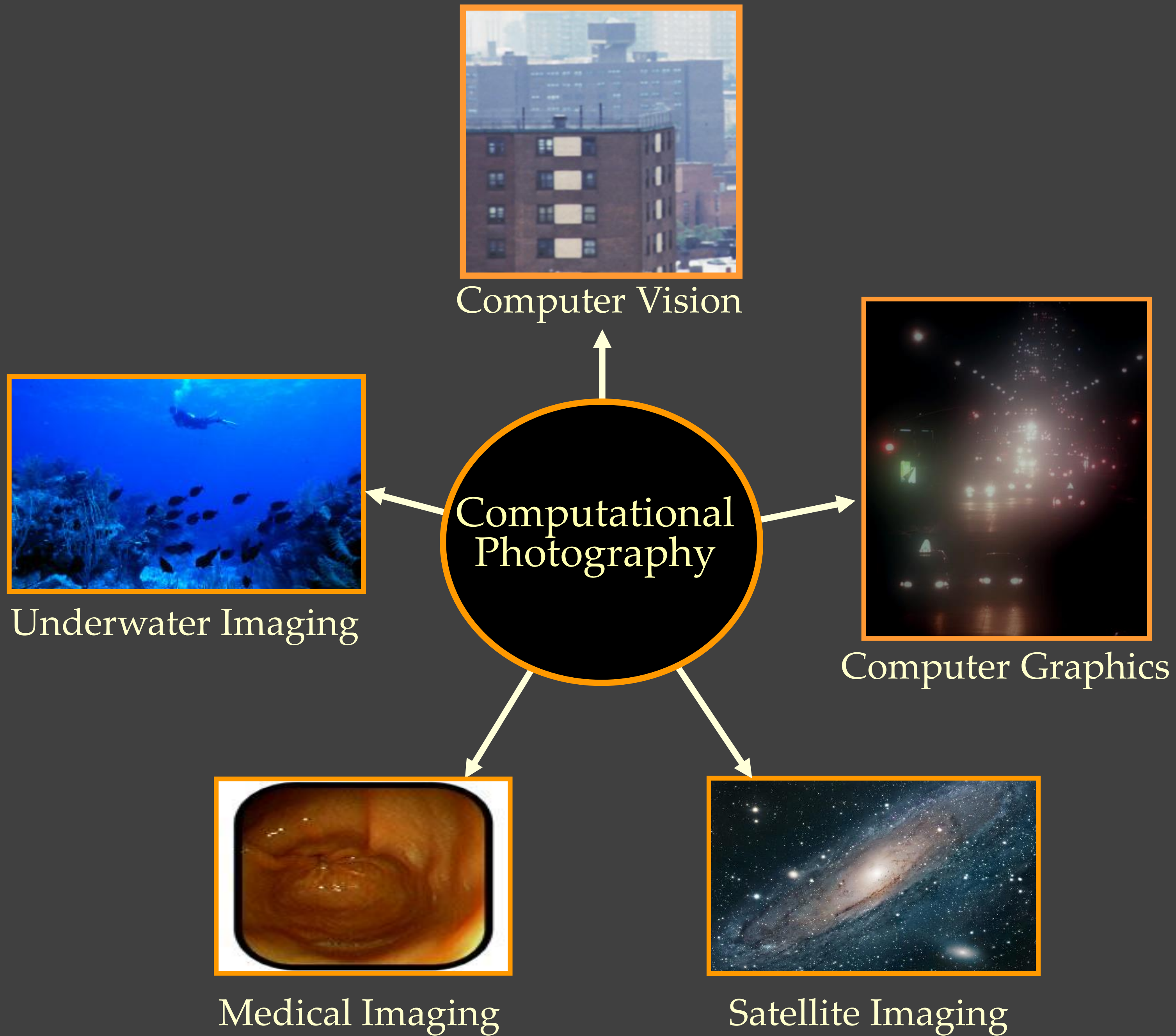
Computational Photography involves

- computers and algorithms

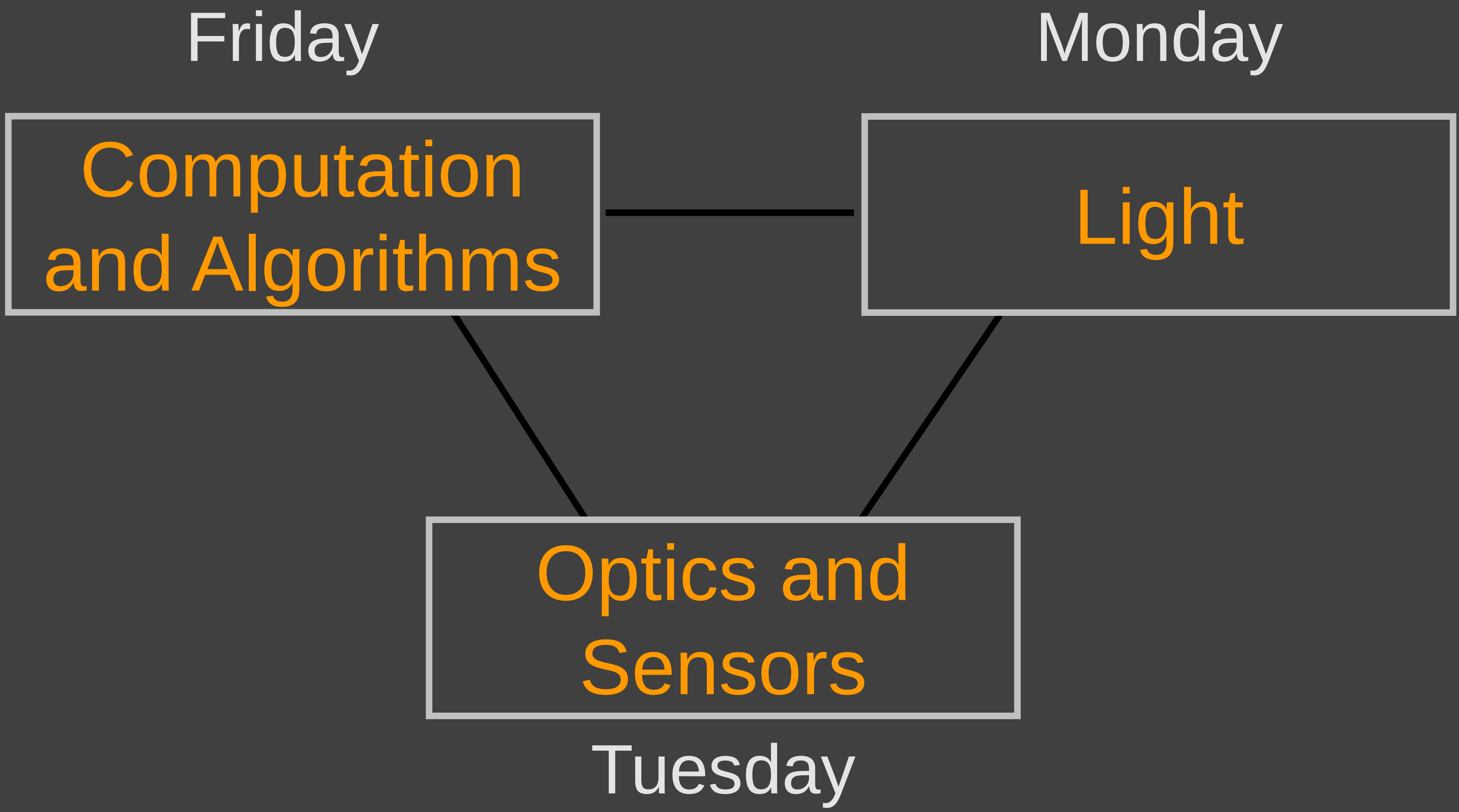
- light/optics/sensors

- math

Why study Computational Photography?


Computer Vision
Computational Photography
Underwater Imaging
Computer Graphics
Medical Imaging
Satellite Imaging

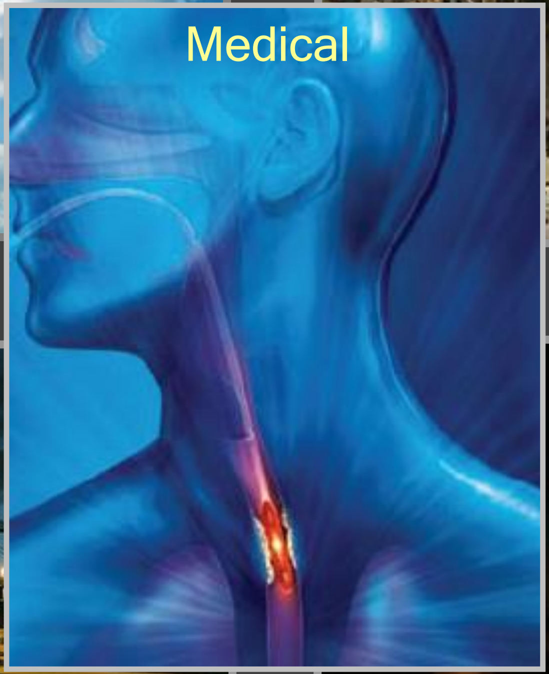
Computational Photography over the week



Light

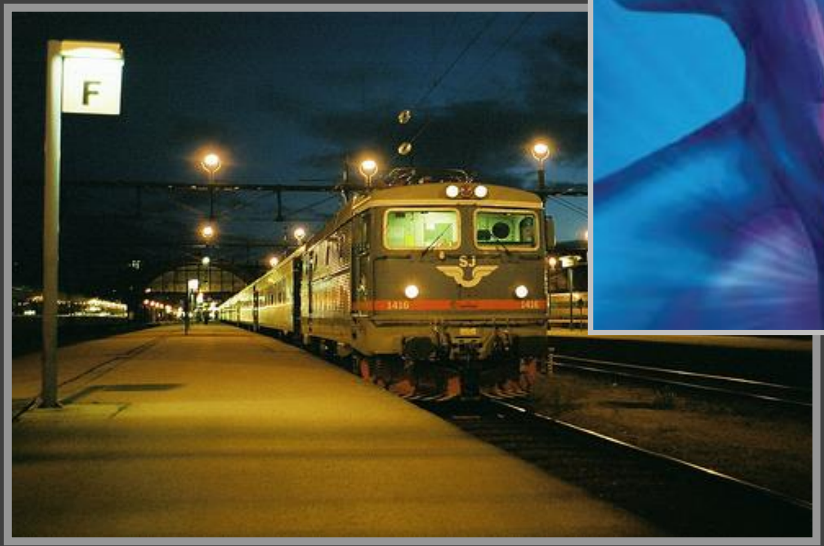
Light-sources are ubiquitous

Outdoors



Medical

Indoors



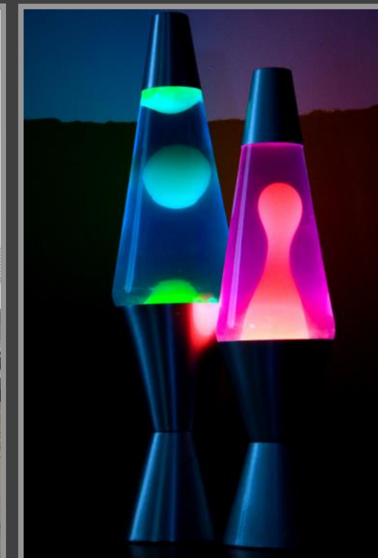
Transport

Display

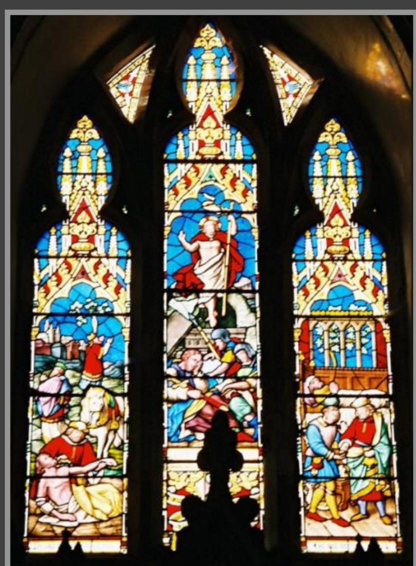
Light-sources have diversity

Light fixtures

Street lights



Lava lamps



Stained Glass

Neon signs

Searchlights

What is Light?

$$\nabla \cdot \mathbf{E} = \frac{\rho_v}{\varepsilon} \qquad \text{(Gauss' Law)}$$

$$\nabla \cdot \mathbf{H} = 0 \qquad \text{(Gauss' Law for Magnetism)}$$

$$\nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \qquad \text{(Faraday's Law)}$$

$$\nabla \times \mathbf{H} = \mathbf{J} + \varepsilon \frac{\partial \mathbf{E}}{\partial t} \qquad \text{(Ampere's Law)}$$

What are these?

Maxwell’s Equations

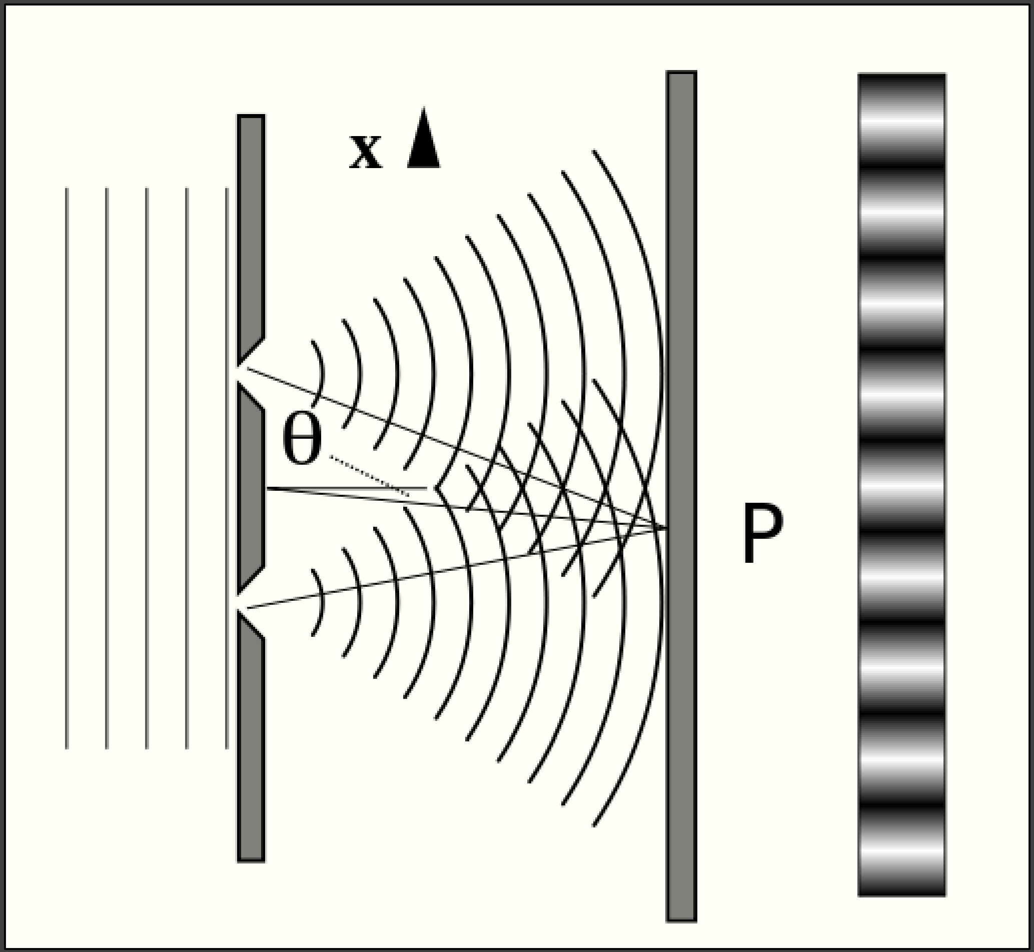
$$\nabla \cdot \mathbf{E} = \frac{\rho_v}{\varepsilon} \qquad \text{(Gauss' Law)}$$

$$\nabla \cdot \mathbf{H} = 0 \qquad \text{(Gauss' Law for Magnetism)}$$

$$\nabla \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \qquad \text{(Faraday's Law)}$$

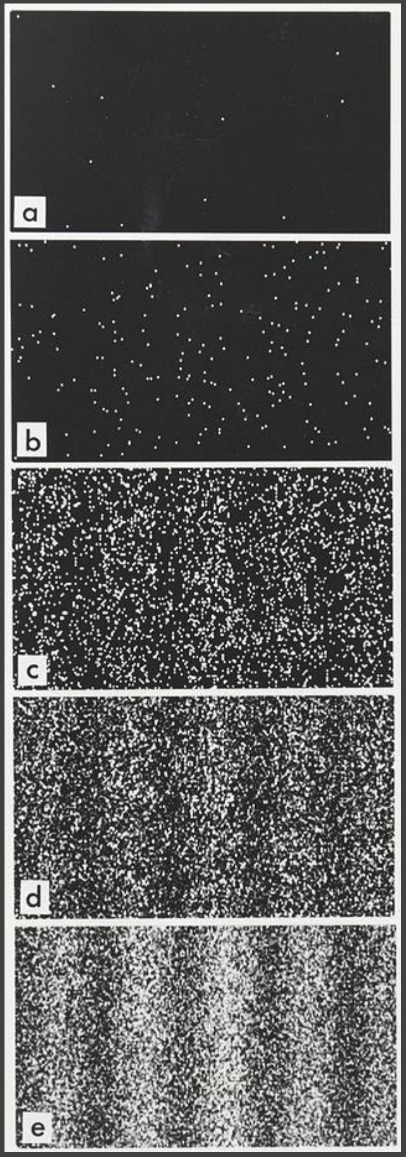
$$\nabla \times \mathbf{H} = \mathbf{J} + \varepsilon \frac{\partial \mathbf{E}}{\partial t} \qquad \text{(Ampere's Law)}$$

Dual Nature of Light

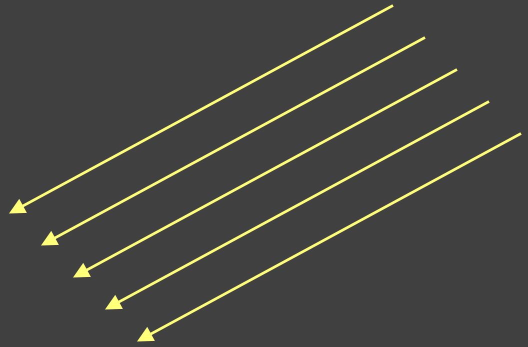


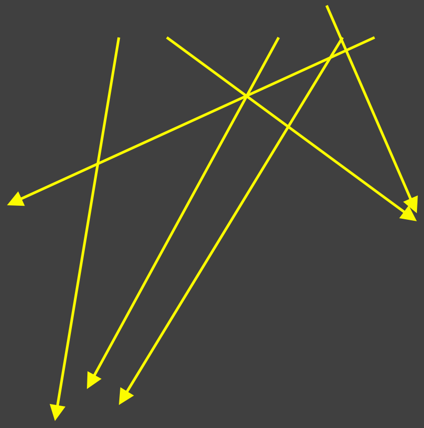
Young's double slit experiment

Photon noise



What makes light sources different



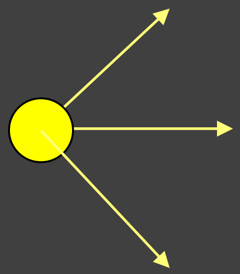


Fall-off

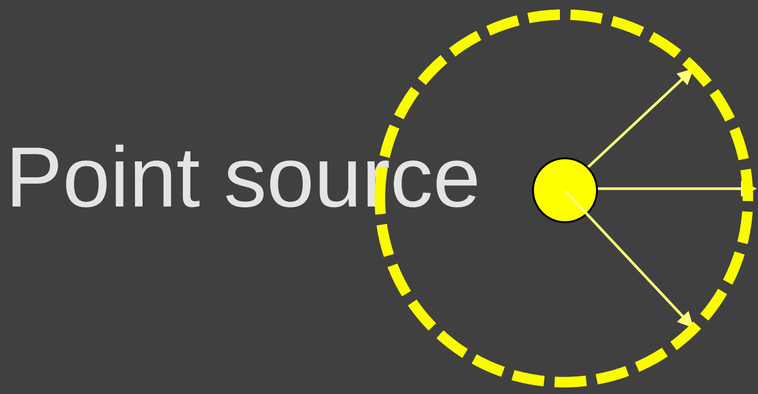
Point source 

Fall-off

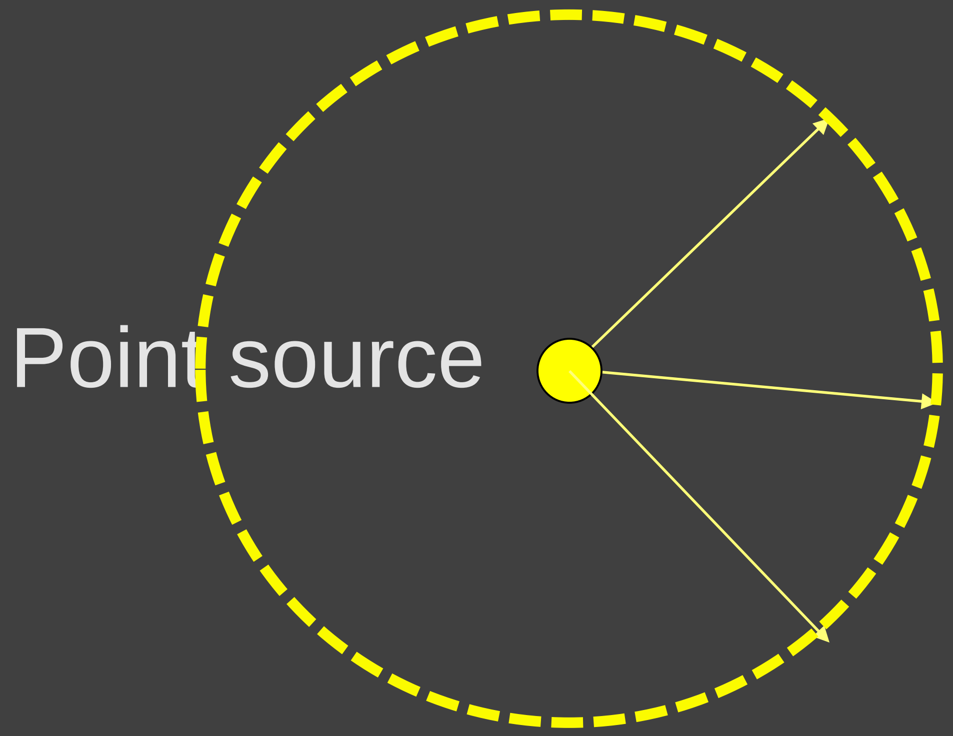
Point source



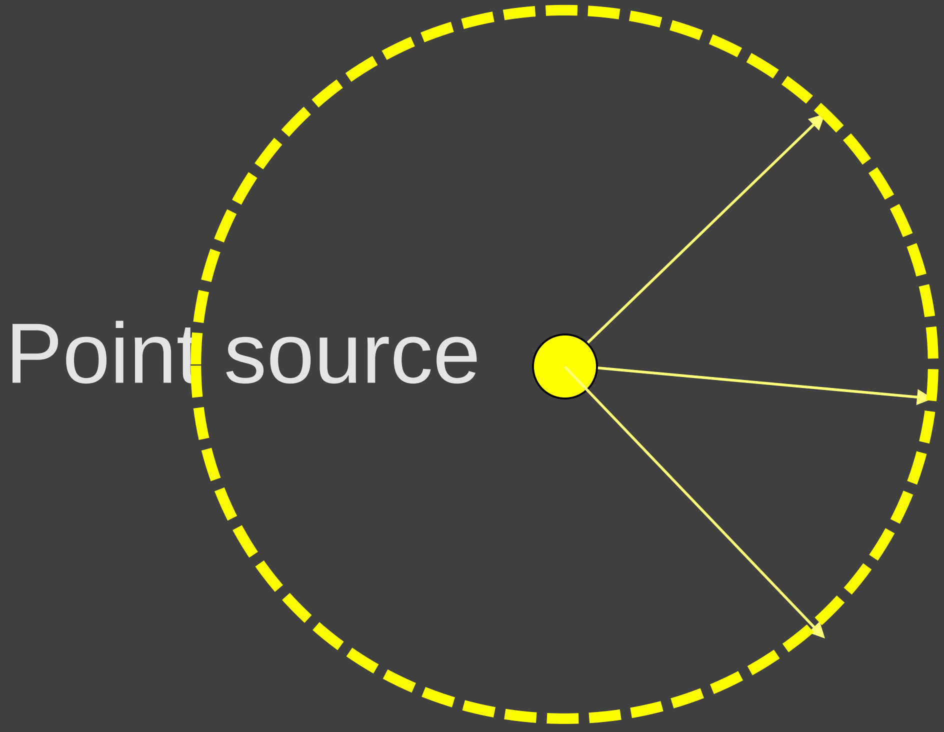
Fall-off



Fall-off

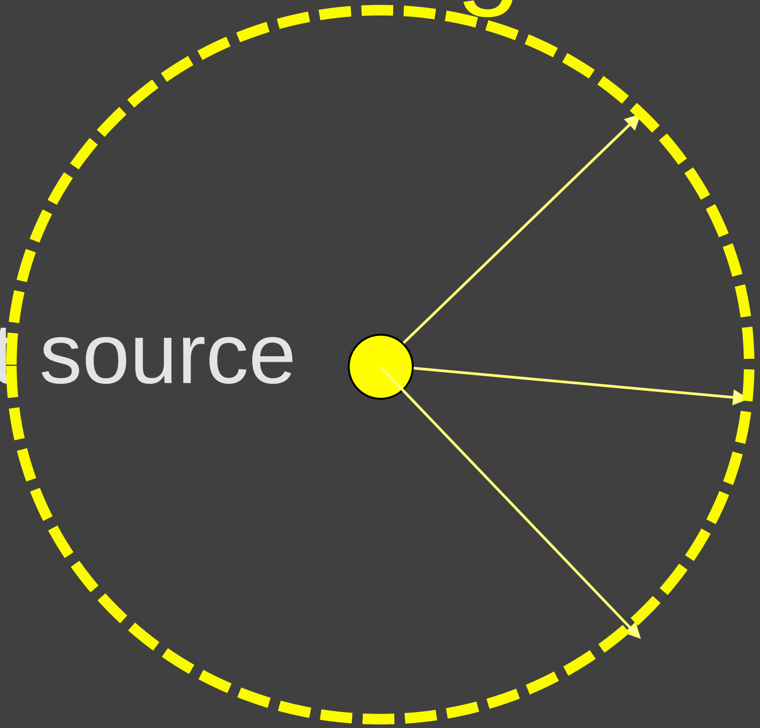


Fall-off



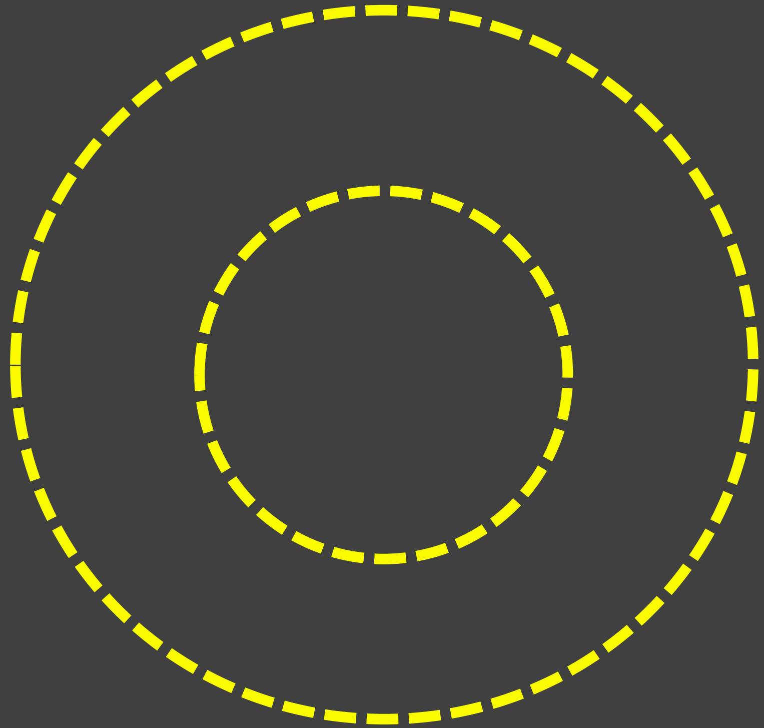
1/R^2

The fall-off depends on geometry

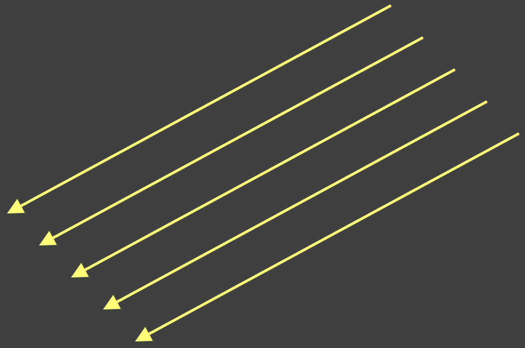


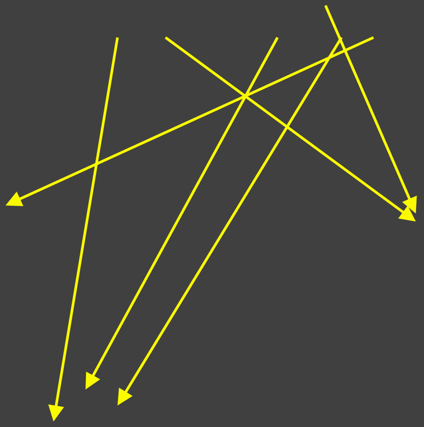
1/R^2

The inverse is true



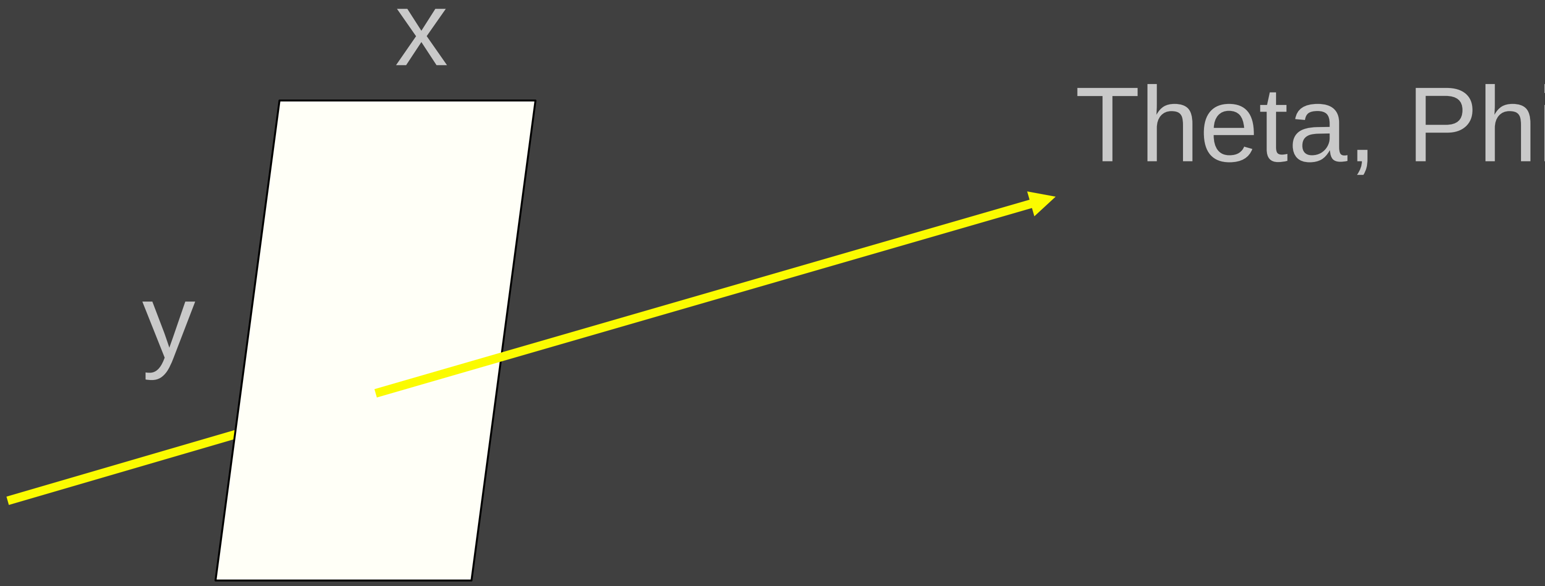
$1/R^2$





What are the fall-offs for these?

What is a light-source?



Any light source is a set of rays

X1, Y1, Theta1, Phi1

X2, Y2, Theta2, Phi2,

.

.

.

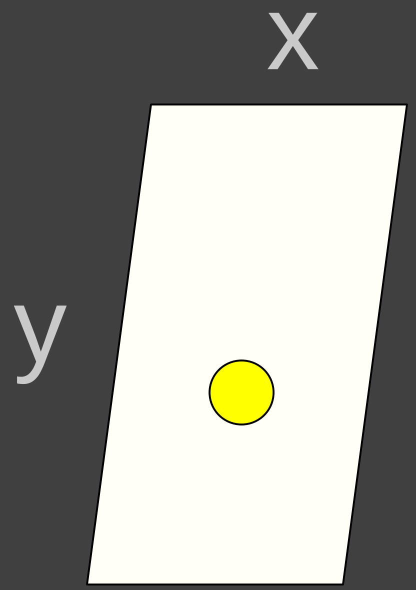
Four dimensional definition

(X,Y, Theta, Phi)

overcast sky	uniform source	∞	∞	∞	∞	4
Cyberware^{TM} scanner		∞	∞	∞	0	3
		∞	∞	0	∞	
fluorescent tube	linear source	∞	0	∞	∞	3
		0	∞	∞	∞	
sunlight	point source at infinity	∞	∞	0	0	2
	uniform distribution of rays in a plane	∞	0	∞	0	2
		0	∞	0	∞	
louvered linear source (see text)	fan of rays perpendicular to a linear source	∞	0	0	∞	2
		0	∞	∞	0	
small panel light	point source	0	0	∞	∞	2
sunlight through crack in doorway	parallel rays in a plane	∞	0	0	0	1
		0	∞	0	0	
rotating spotlight	fan of rays	0	0	0	∞	1
		0	0	∞	0	
spotlight or laser	single ray	0	0	0	0	0

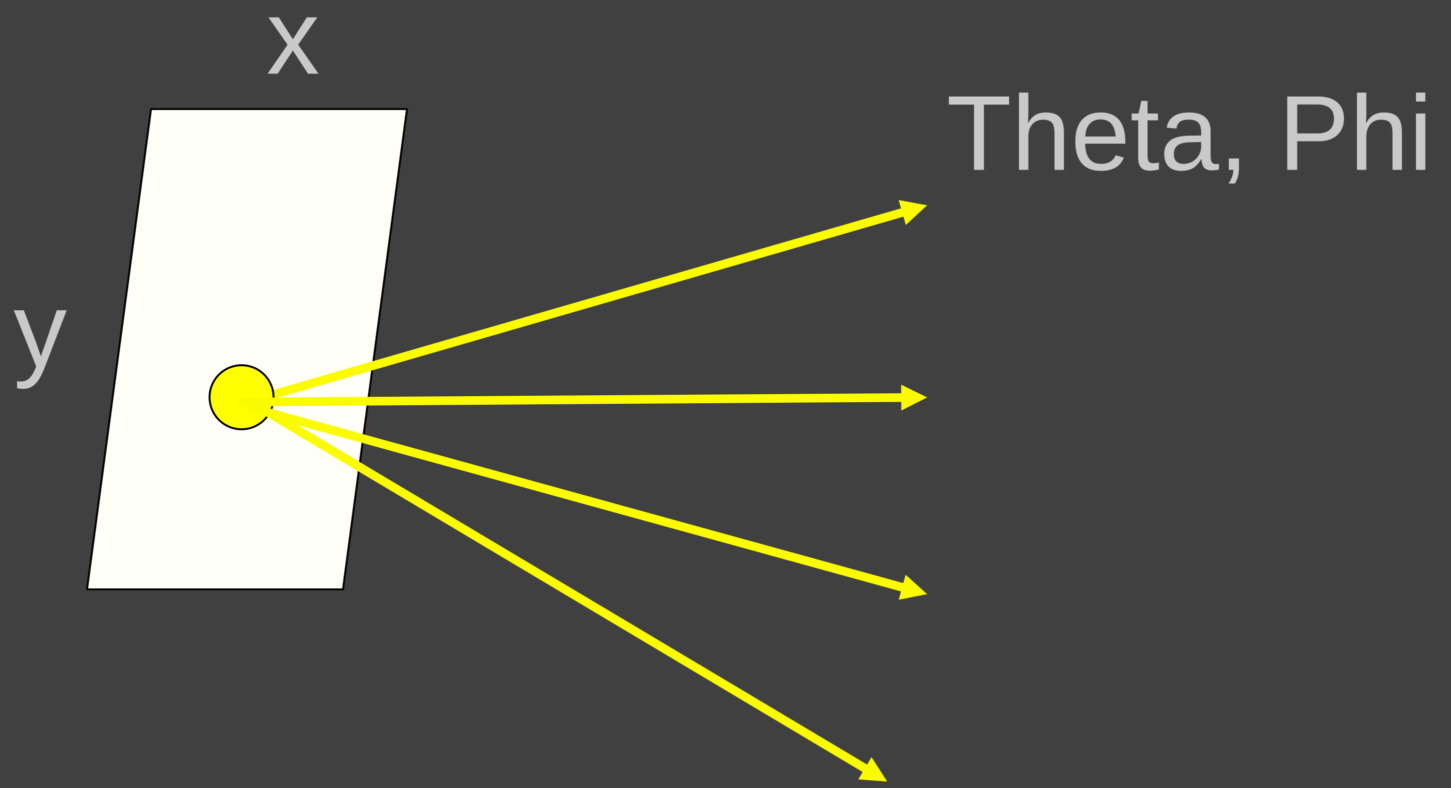
Langer and Zucker

Point source



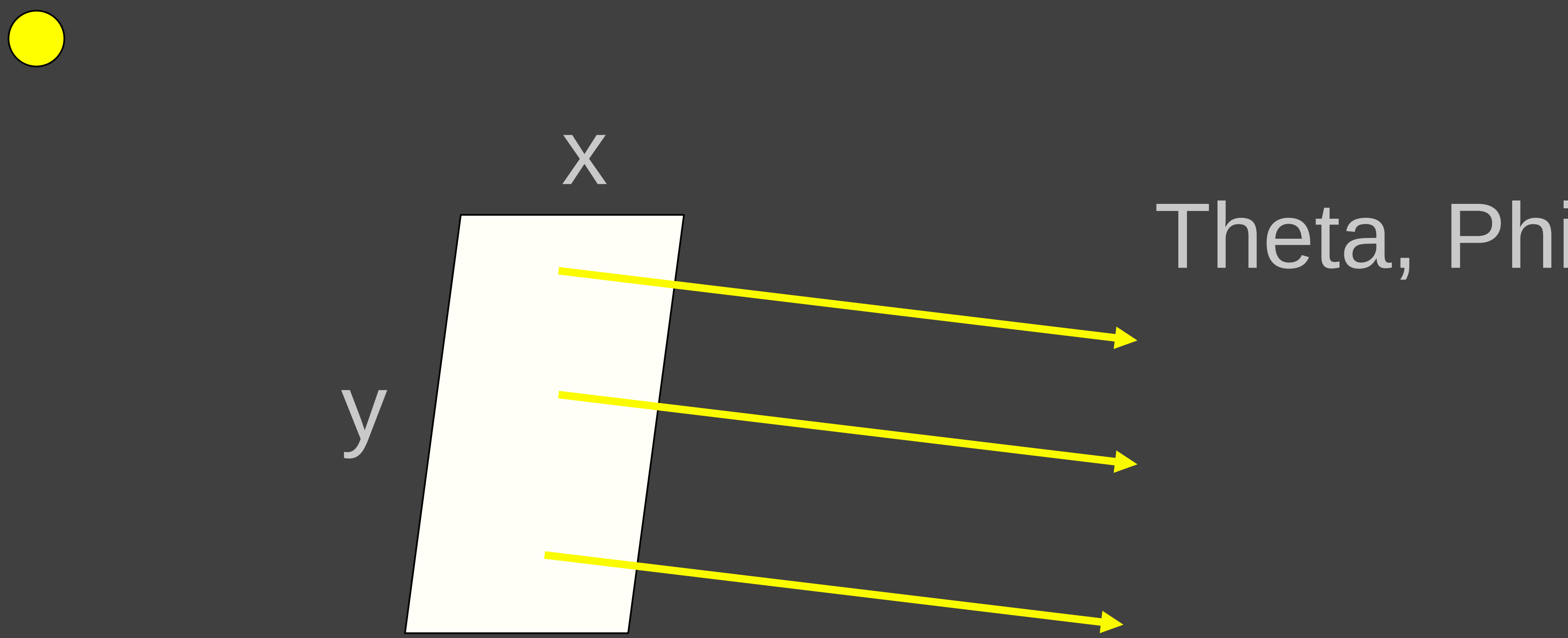
Theta, Phi

Point Source



Constant, Constant, 360, 180

Sun



[0 infinity], [0 infinity], constant, constant

Four dimensional definition

(X,Y, Theta, Phi)

overcast sky	uniform source	∞	∞	∞	∞	4
Cyberware^{TM} scanner		∞	∞	∞	0	3
		∞	∞	0	∞	
fluorescent tube	linear source	∞	0	∞	∞	3
		0	∞	∞	∞	
sunlight	point source at infinity	∞	∞	0	0	2
	uniform distribution of rays in a plane	∞	0	∞	0	2
		0	∞	0	∞	
louvered linear source (see text)	fan of rays perpendicular to a linear source	∞	0	0	∞	2
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sunlight through crack in doorway	parallel rays in a plane	∞	0	0	0	1
		0	∞	0	0	
rotating spotlight	fan of rays	0	0	0	∞	1
		0	0	∞	0	
spotlight or laser	single ray	0	0	0	0	0

Why are there sixteen rows?

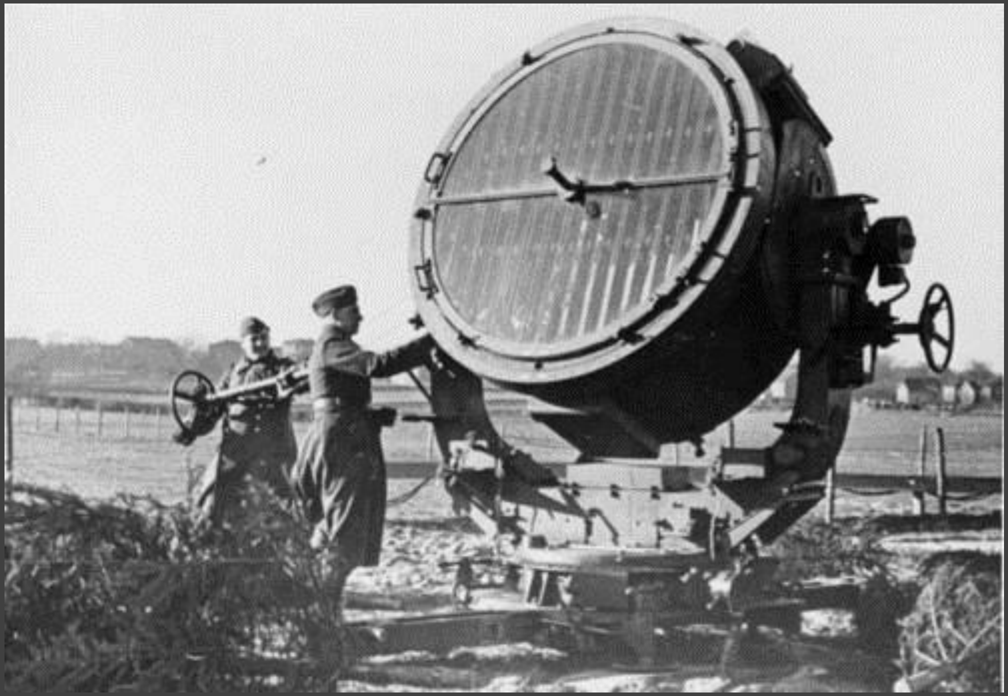
Lesson 2

Computational Photography uses models of light, most of which are geometric in nature.

Properties of Light

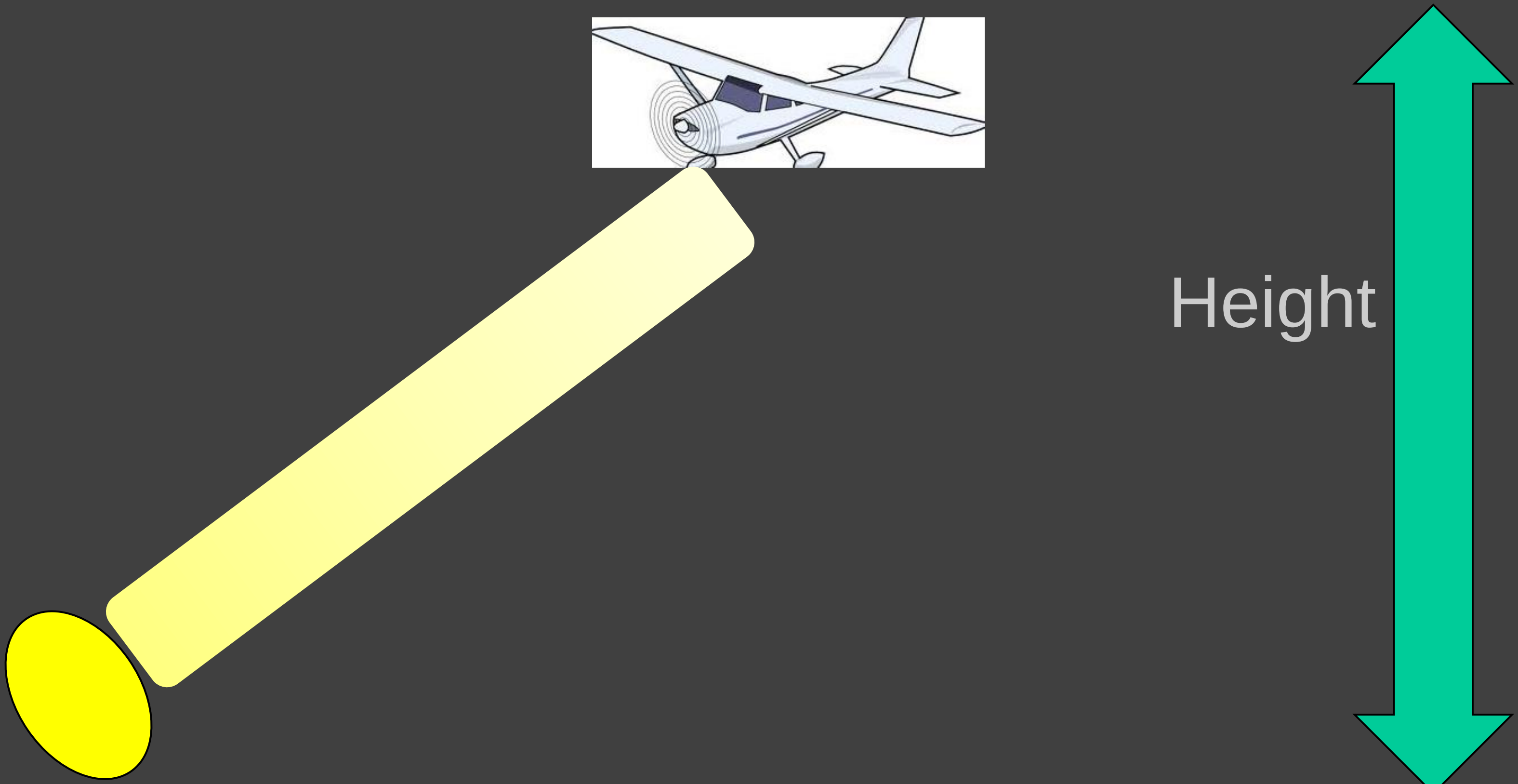
Properties of Light: Intensity

WW 2 Searchlights



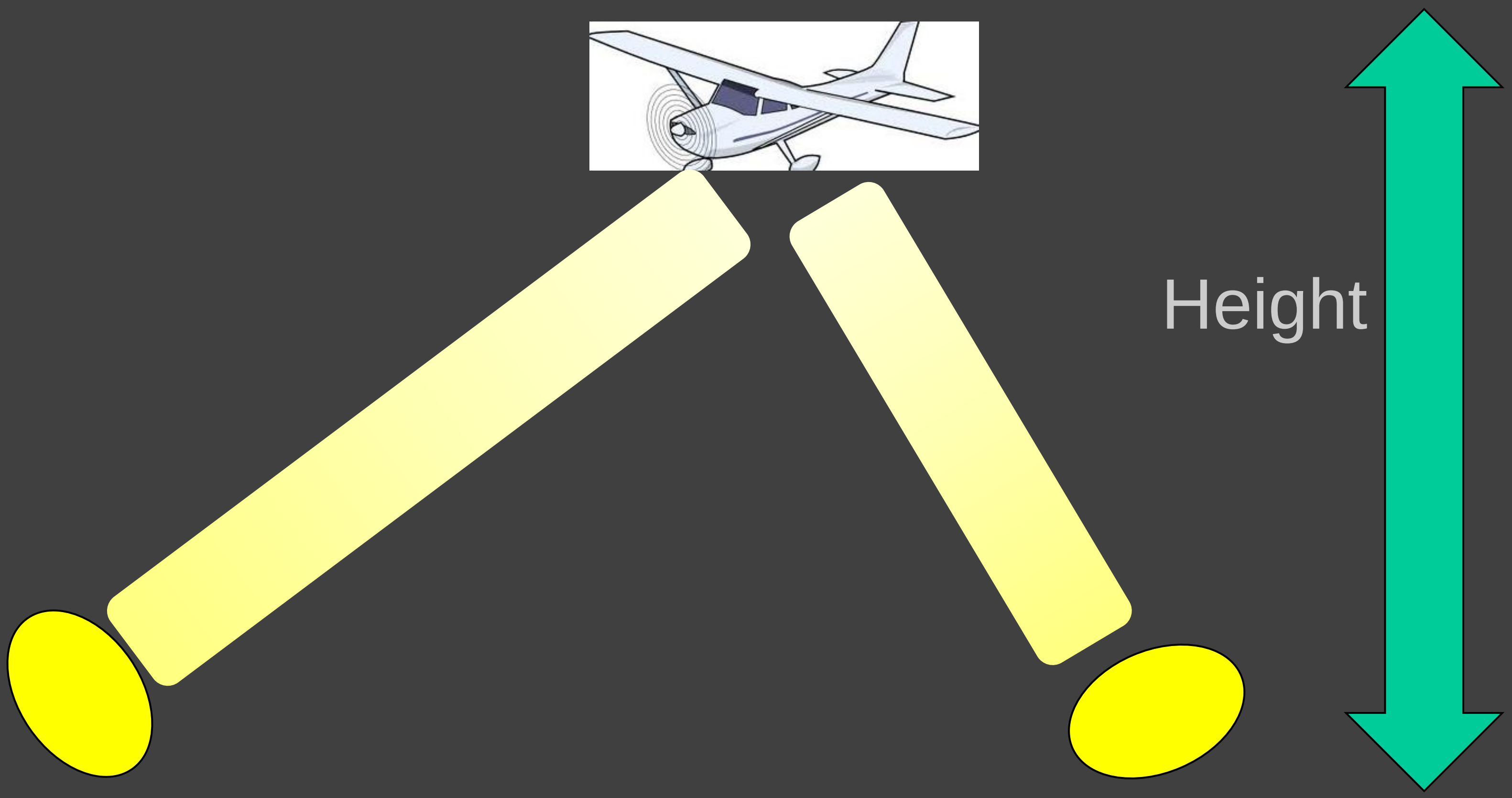
WW 2 Searchlights

Geometric question

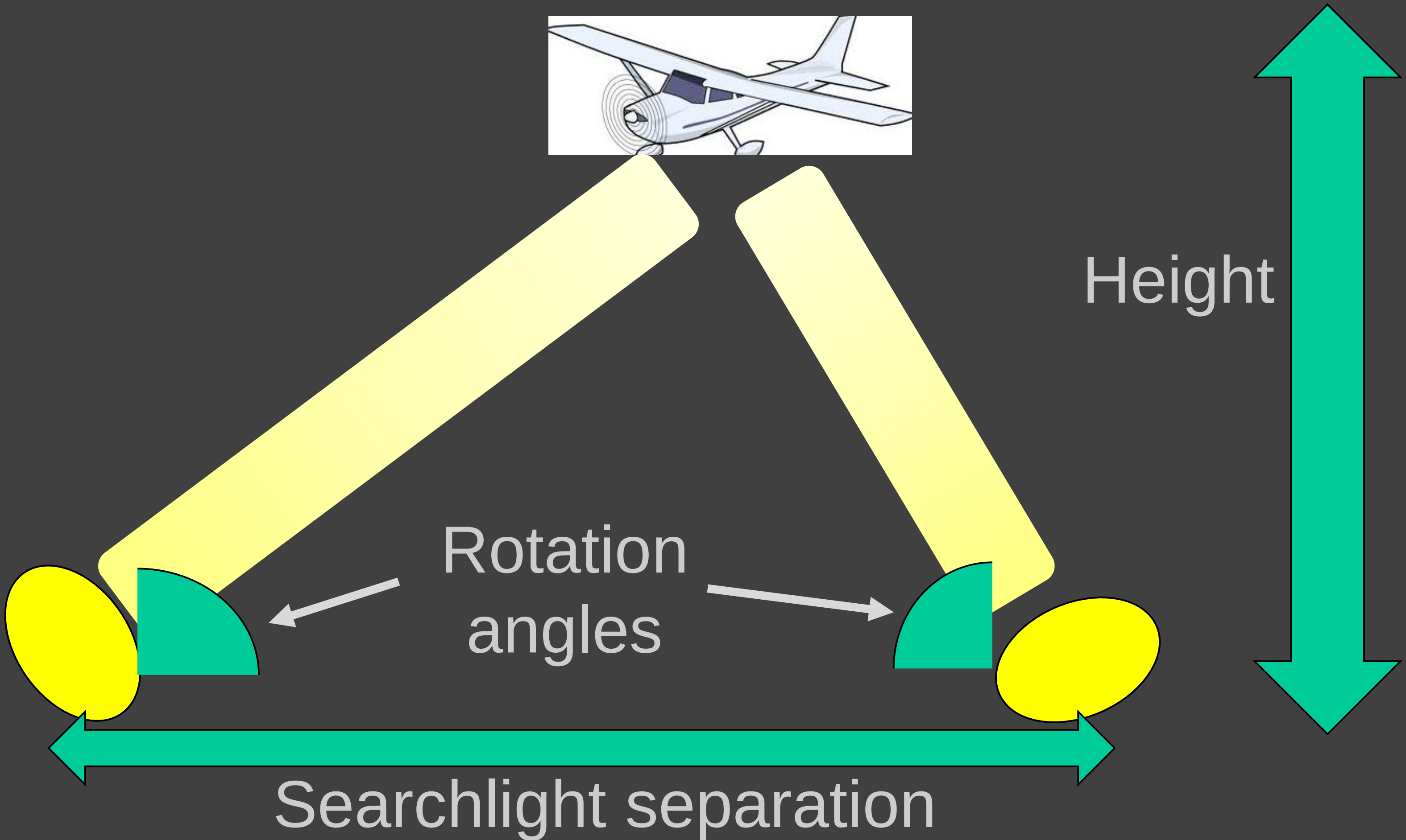


WW 2 Searchlights

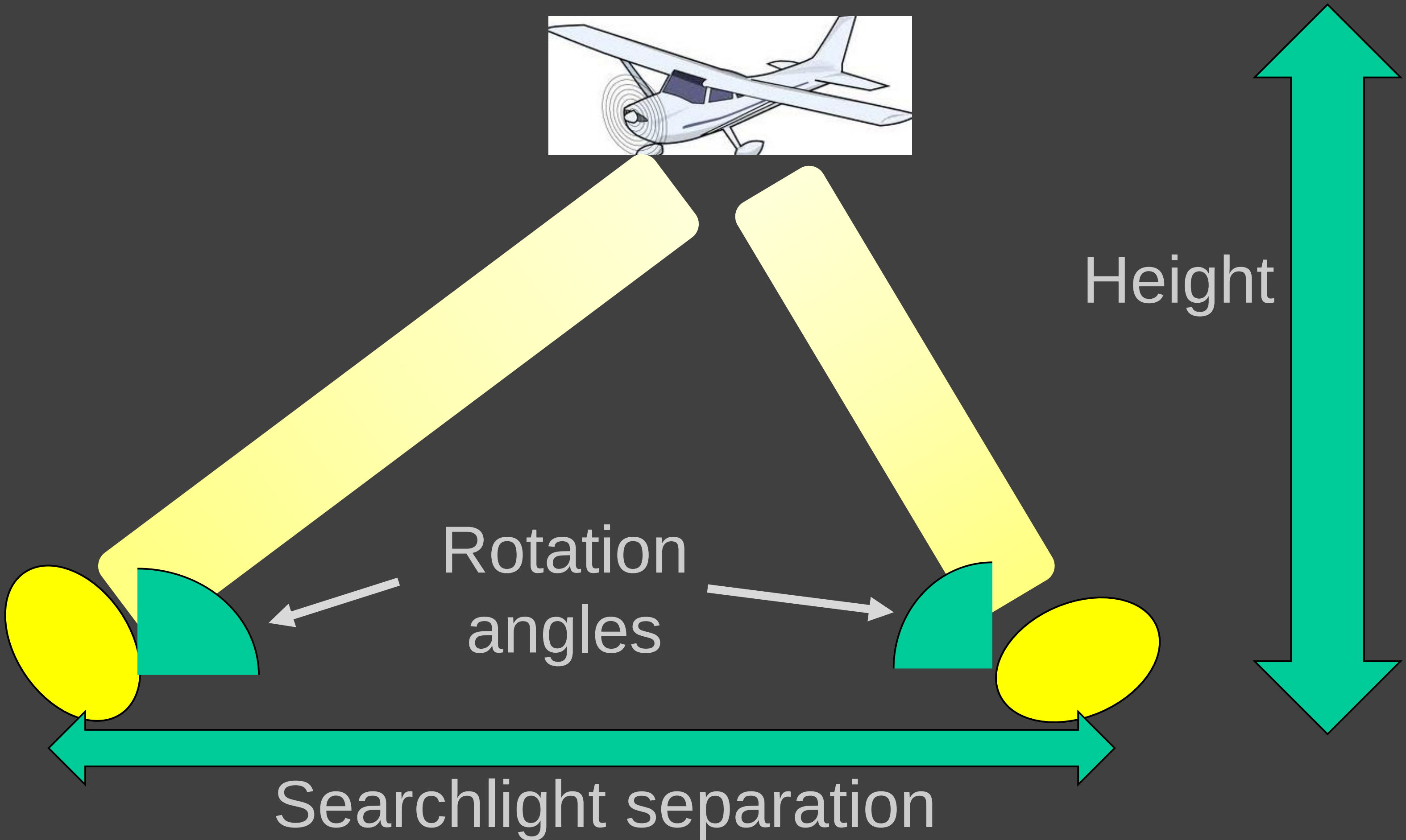
Geometric question



Geometric question



Geometric question



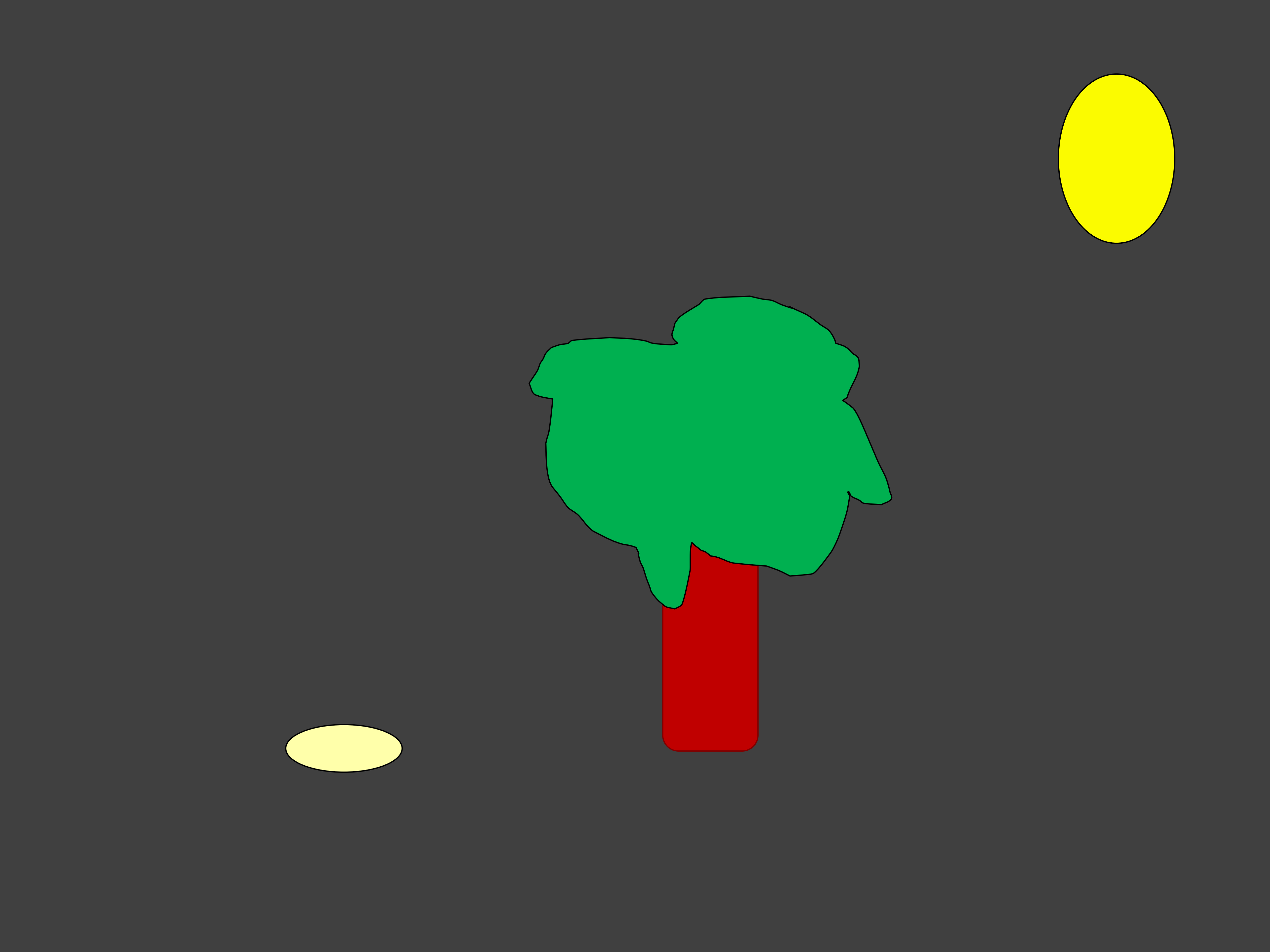
How do we know when this intersection happens?

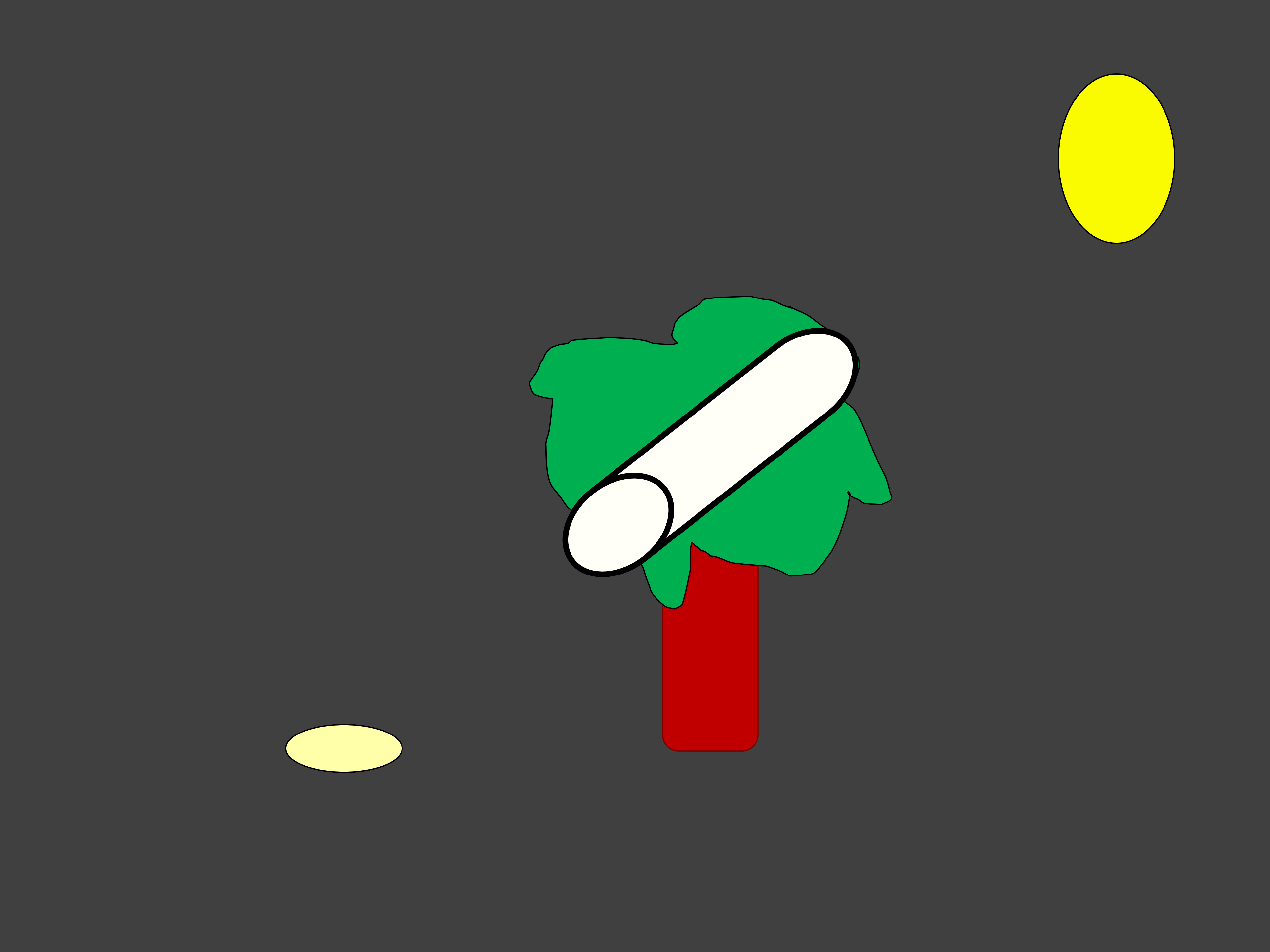
Lesson 3

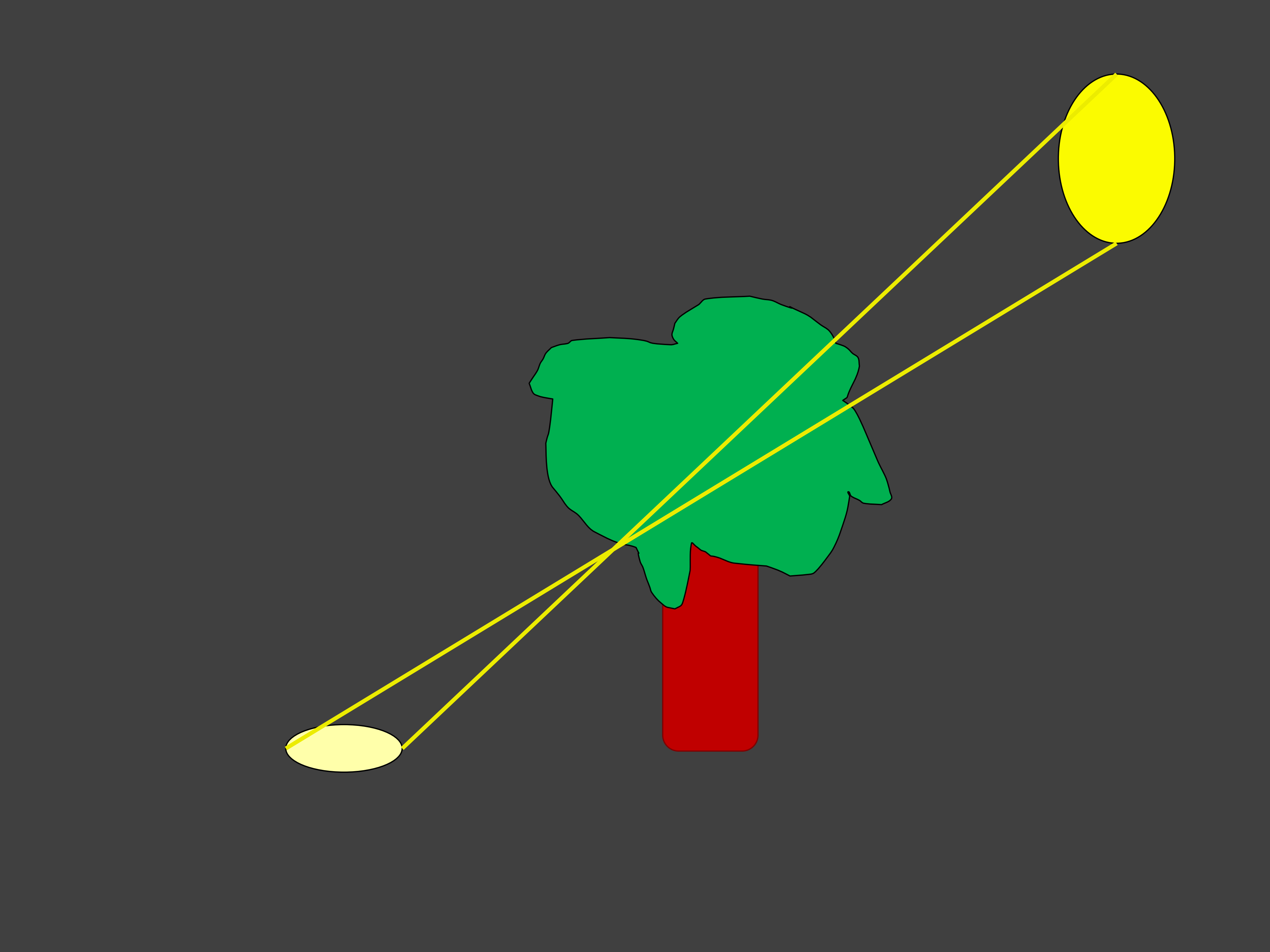
Light can be a tool to find information

Intensity of Light in Photographs

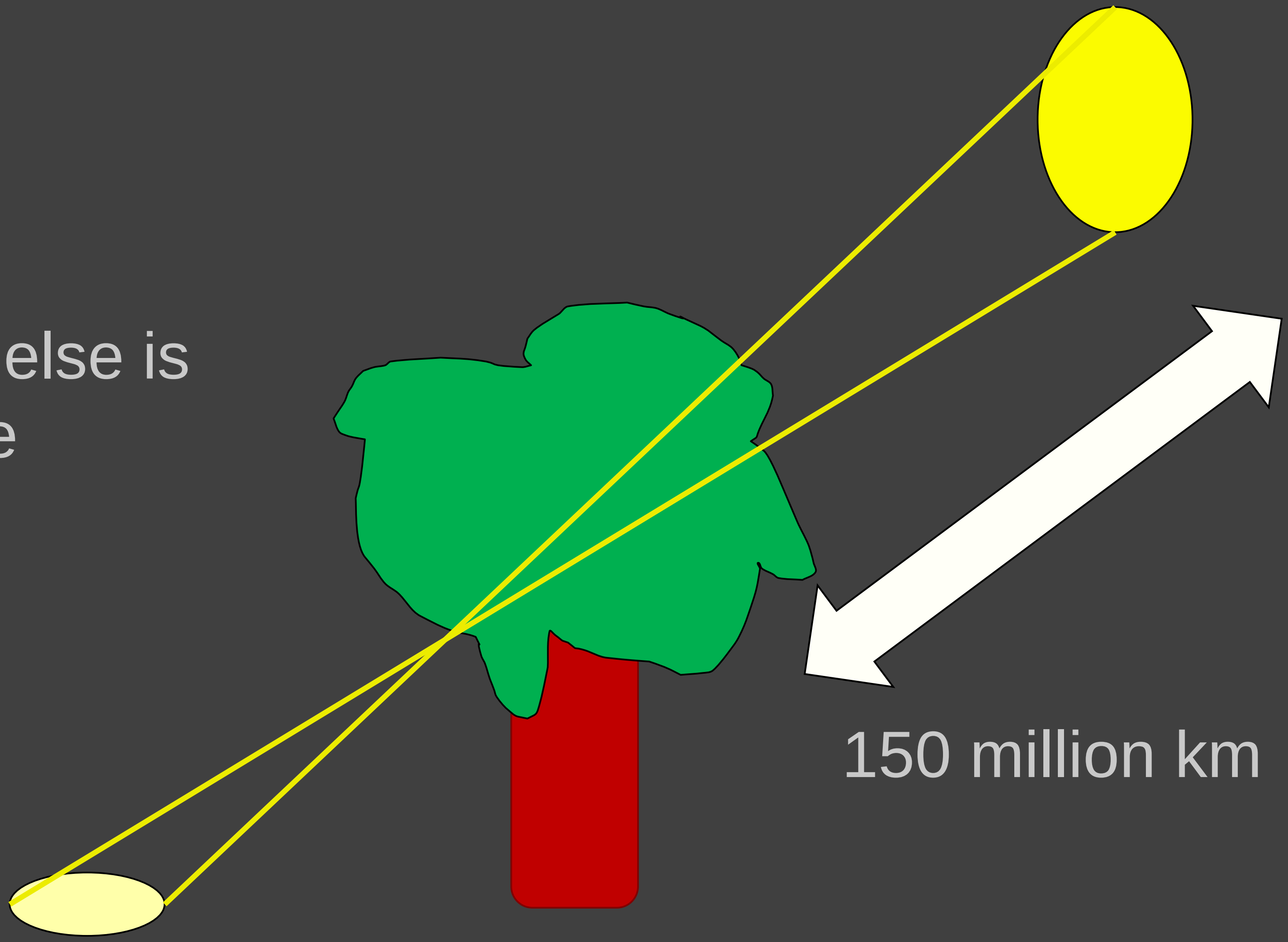
Why is there dappled light?








Everything else is measurable



The intensity of light in photographs is important

Reflections


Why does the moon reflection become a thick line?


Refractions

Fish eye lens

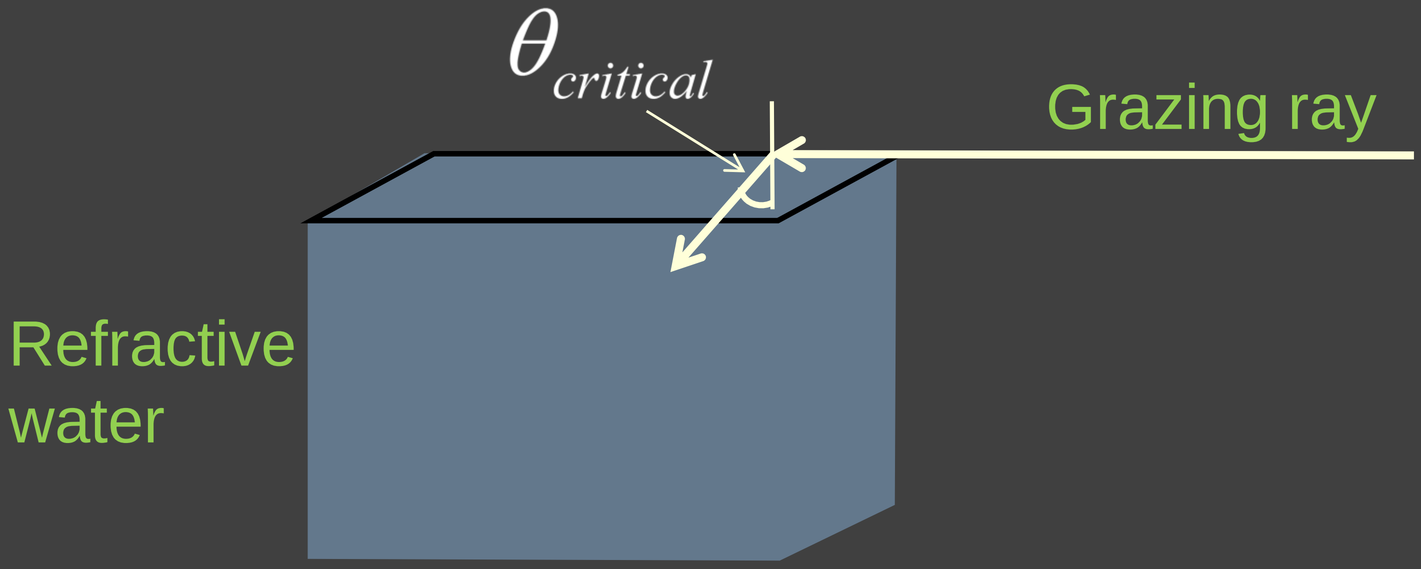
Fish eye

Fish eye lens

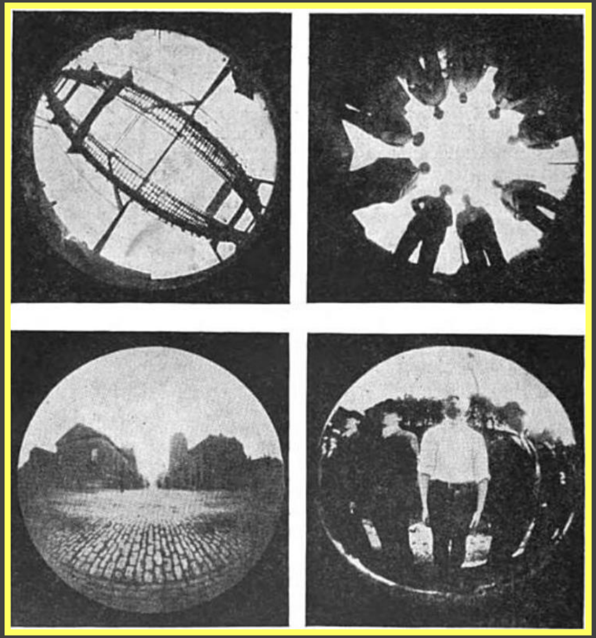
Fish eye

Why is a fish eye lens called that?

Snell's window



Snell's window in imaging

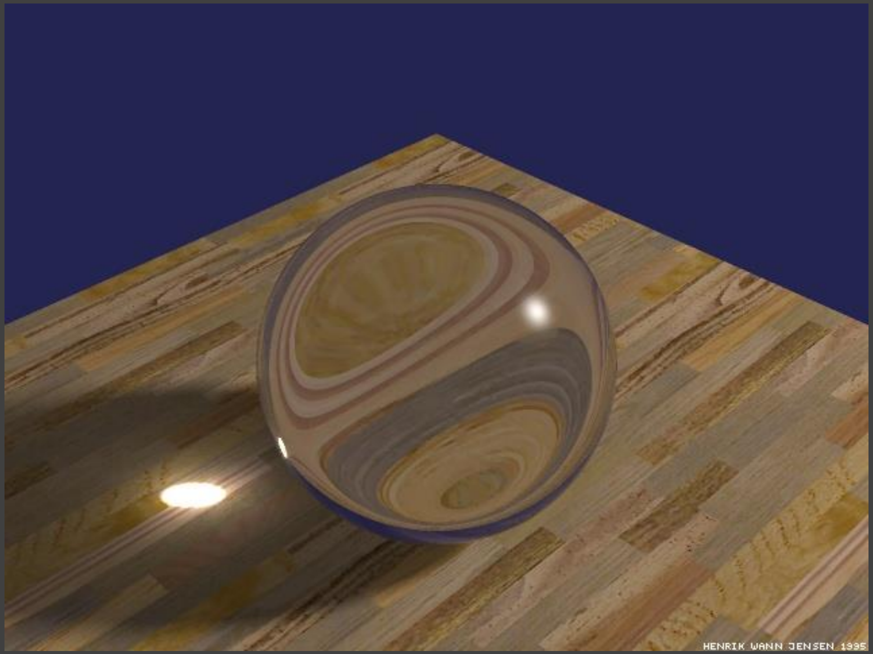


"Water" camera

Underwater photography

Wood 1911, Flickr

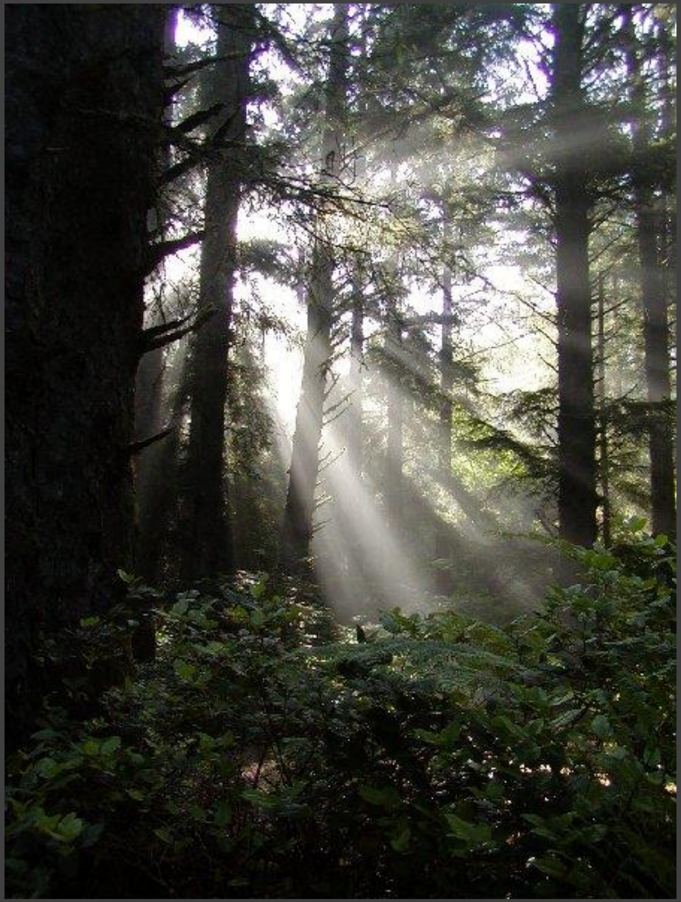

HENRIK WANN JENSEN 1995


HENRIK WANN JENSEN 1995

Interreflections


Mies Courtyard House with Curved Elements

Scattering



Haze

De-hazed


More Complex Appearances


RENDERED BY HENRIK WANN JENSEN - 2001


RENDERED BY HENRIK WANN JENSEN - 2001

Hair

Marschner et al.











Other Properties of Light:

Color

Polarization

Coherence/Incoherence

Other Properties of Light: Color

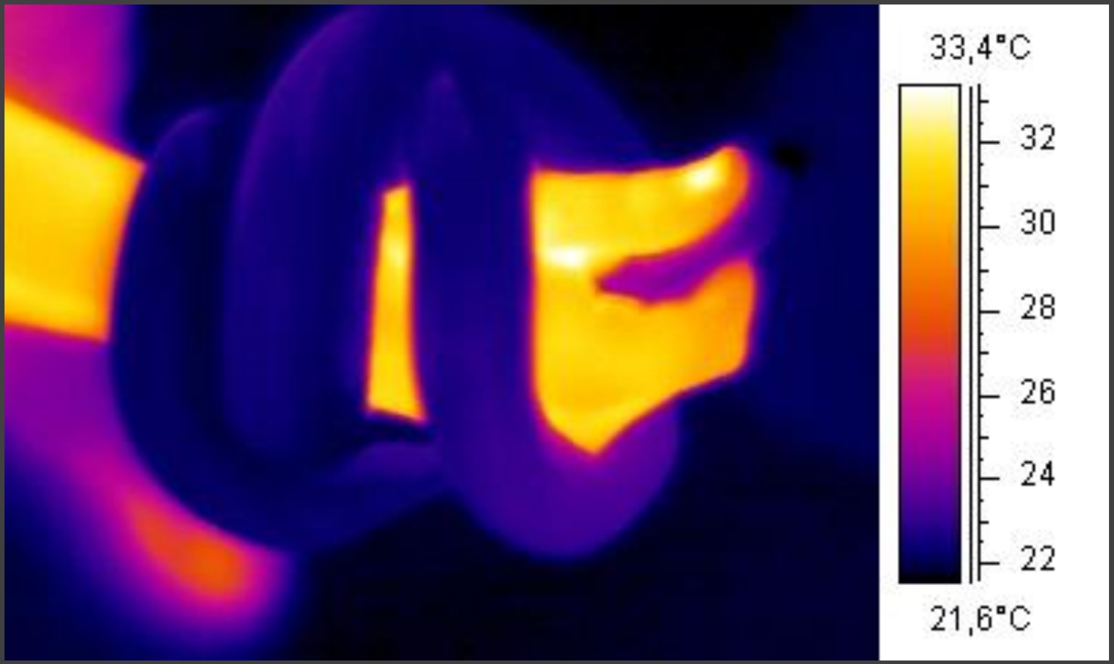
Color

Color

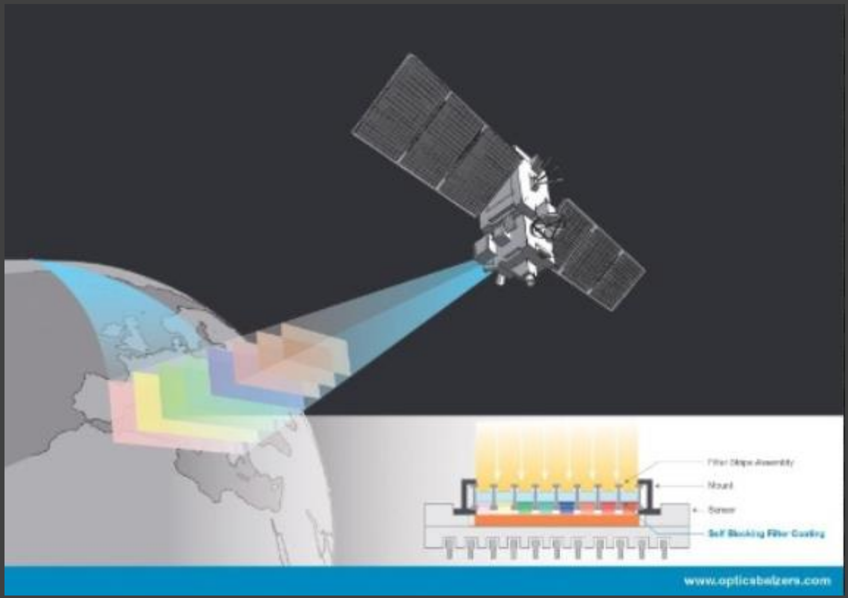
What has changed?

UV Photographs

Thermal imagery

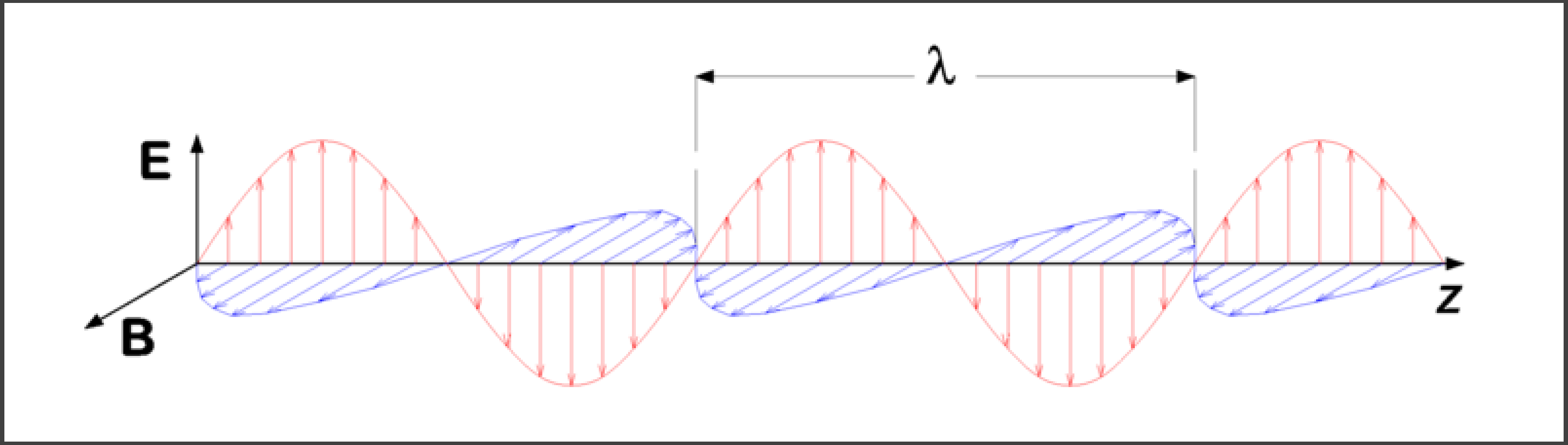


Multispectral imaging in remote sensing

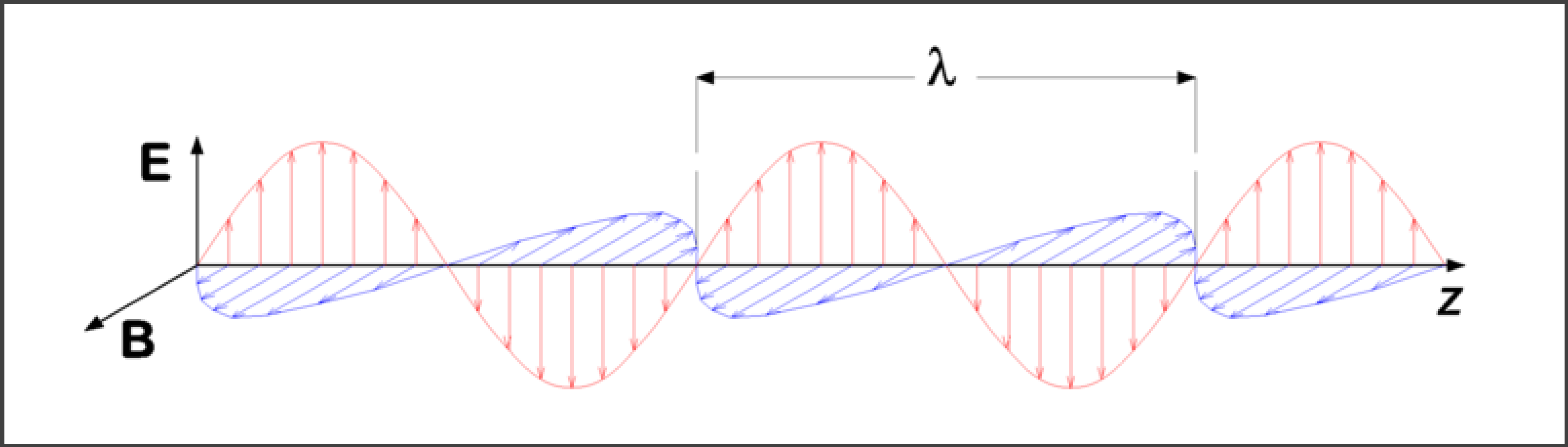


Other Properties of Light: Polarization

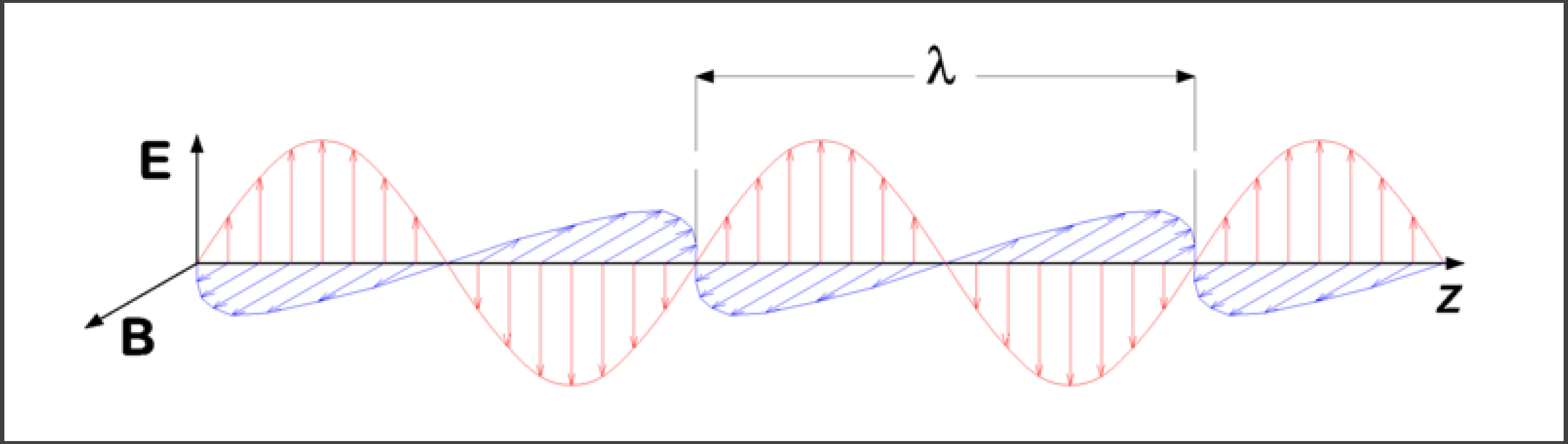
Polarization

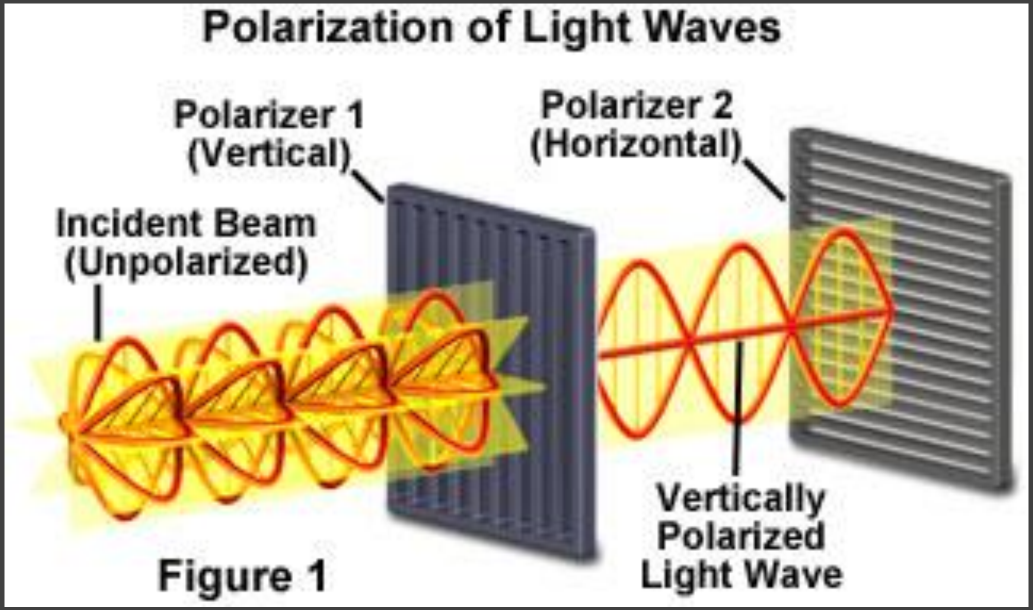


Polarization

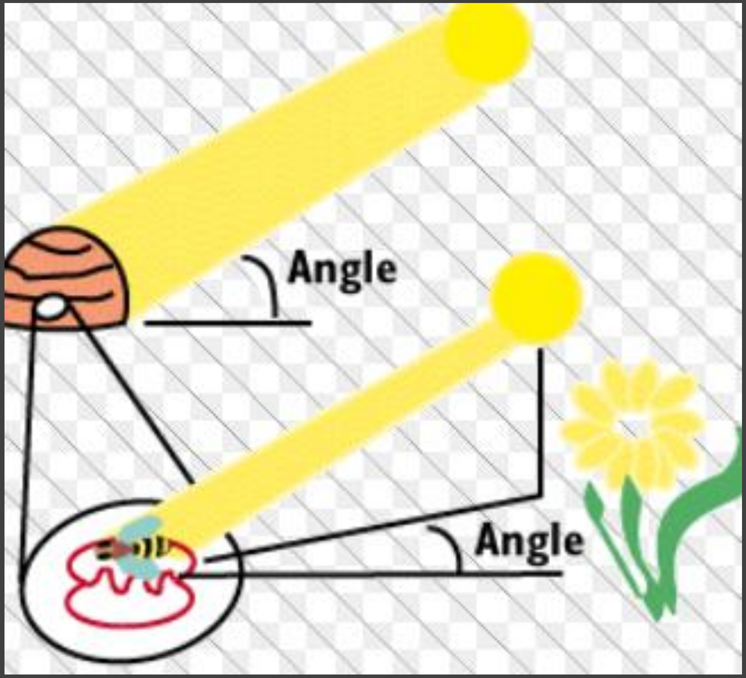


Polarization

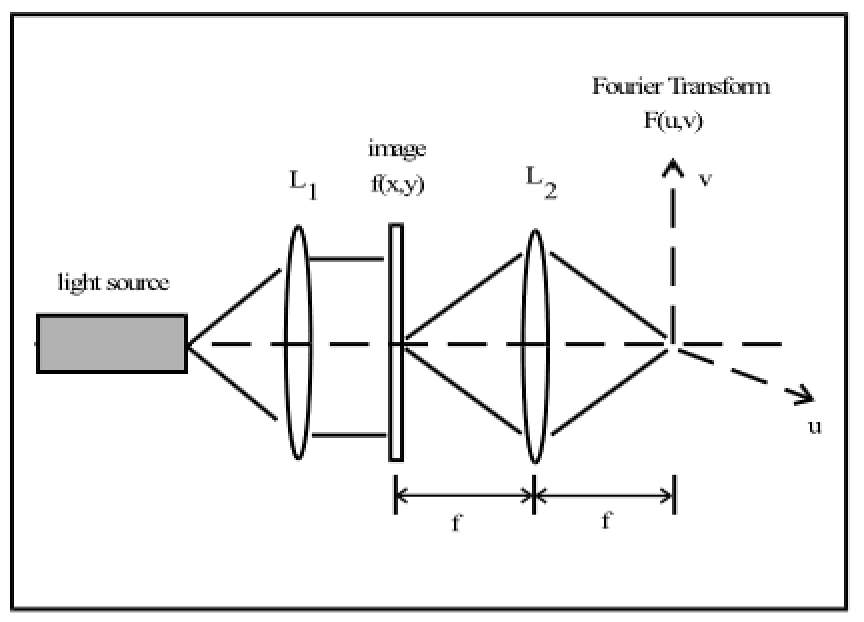




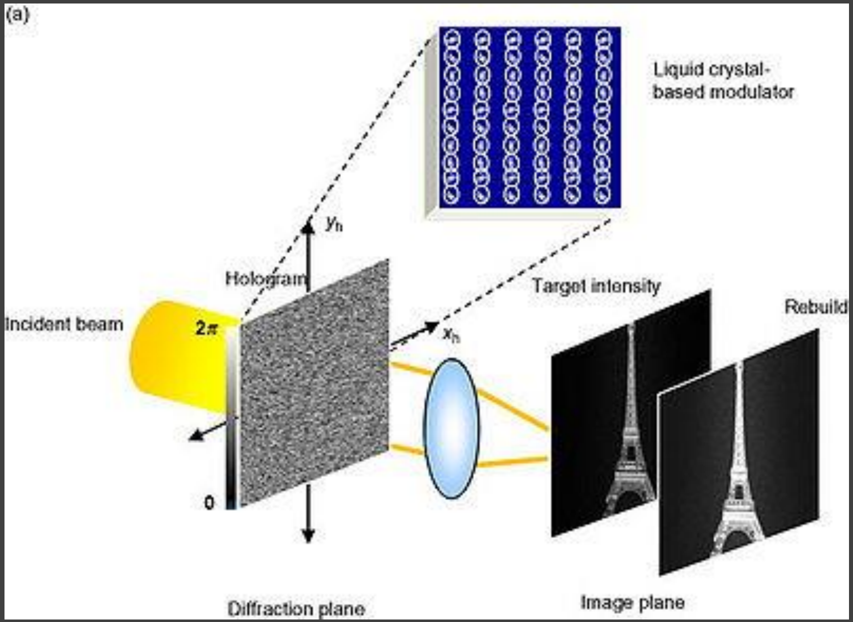
Polarization is everywhere



Other Properties of Light: Coherence



Fourier Transform
F(u,v)
image
f(x,y)
L1
L2
v
light source
u
f
f



(a)
Liquid crystal-based modulator
Hologram
Target intensity
Rebuild
Incident beam
2π
0
Diffraction plane
Image plane

Other Properties of Light: Scale

Scale is Everything

Geometry vs. Reflectance vs. Statistics vs. Sensor

Lesson 4

Various optical phenomenon

Reflection

Refraction

Polarization

Diffraction

Caustics

Interreflections

Scattering

Interference

Thank you

Lesson summary:

1. Comp. Photography involves algorithms, optics, models of light and theory.

2. There are many geometric models of different light sources.

3. Light can be used as a tool to find out scene information

4. Photographs show a tremendous number of light effects such as reflection, refraction, polarization, scattering, interference and others