VU Rendering SS 2015
186.101

Thomas Auzinger

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VU Rendering SS 2015

Unit 01 – Introduction

Overview

- Organization
- Topics
- Definition
- History and Context
- Lecture Scope
- Basic Optics

Course Organization

- **Homepage**
  TISS: https://tiss.tuwien.ac.at/course/courseList.xhtml
  (search for 'Rendering')
  Institute: http://www.cg.tuwien.ac.at/courses/Rendering

- **Registration** in TISS (until 24.3.)
- **Lecture dates** of SS 2015:
  11.3., 18.3., …(all further announced at least a week before)
  13:30 – 15:00, Seminar room 186

Course Organization

- **Notes**

  Lecture slides on the homepage after each lecture

  Additional literature on the homepage

- **Grading**

  - **Assignments**

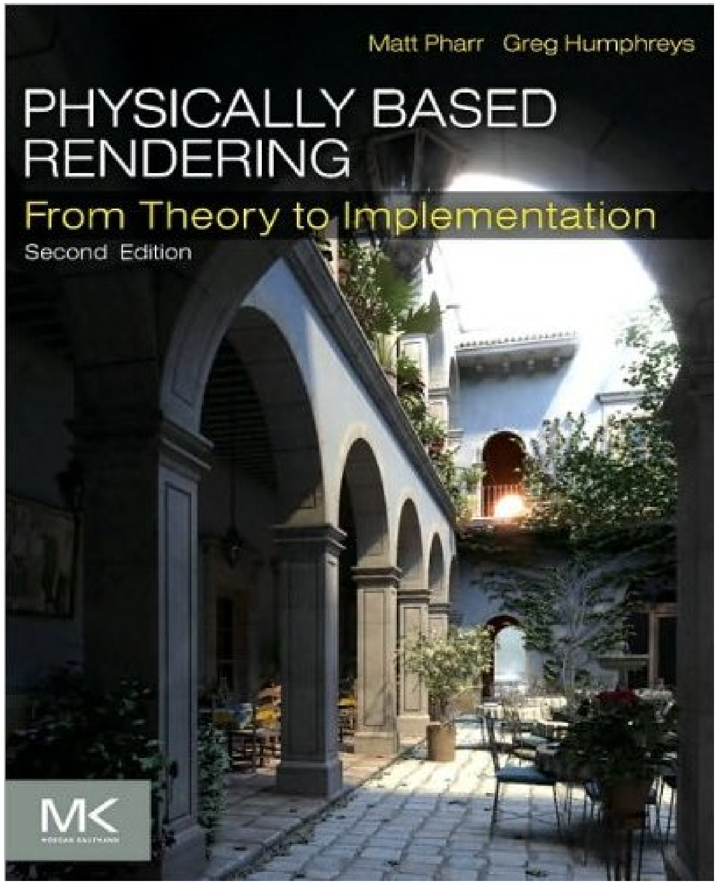
    Hands-on exercises with rendering programs and mathematical problems

  - **Final oral exam**

    About the course material and the assignments

Course Organization

- **Literature**
  Physically Based Rendering, Second Edition
  M.Pharr and G. Humphreys



Course Organization

- **Literature**
  More literature and references to scientific papers on the homepage

Any questions?

Topics

- **Rendering theory**
  Basic optics, rendering equation, filtering
- **Rendering algorithms**
  Ray tracing, radiosity, (bi-directional) path tracing, Metropolis light transport, precomputed radiance transfer, (stochastic progressive) photon mapping, irradiance caching
- **Acceleration techniques**
  Spatial hierarchies, sampling strategies
- **Surface representations**
  BRDF models: Phong, Oren-Nayar, Cook-Torrance

Topics

- **Participating media**
  (Subsurface) Scattering, volumetric photon mapping, photon beams
- **Higher dimensional effects**
  Motion blur, depth of field
- **Camera models**
- **Post processing**
  HDR, tone mapping

Definition

Rendering [ren-der-ing]:

The process of generating an image from a model, by means of a computer program.

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Teglverksgata 2, Google StreetView

d

Teglverksgata 2, P. Guthries

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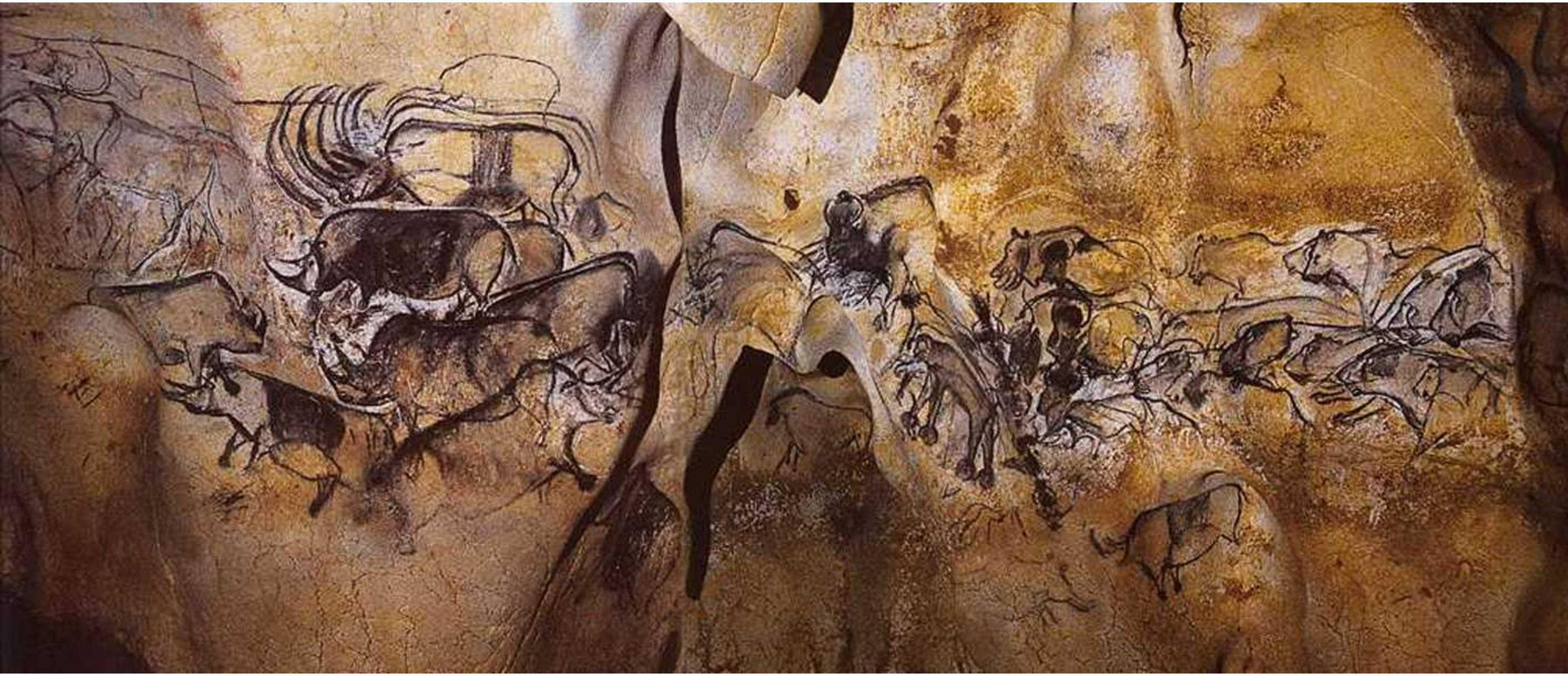
Prehistoric

Cave Paintings (~30 000 BC)



Chauvet-Pont-d'Arc, France (*from http://donsmaps.com/chauvetcave.html*)

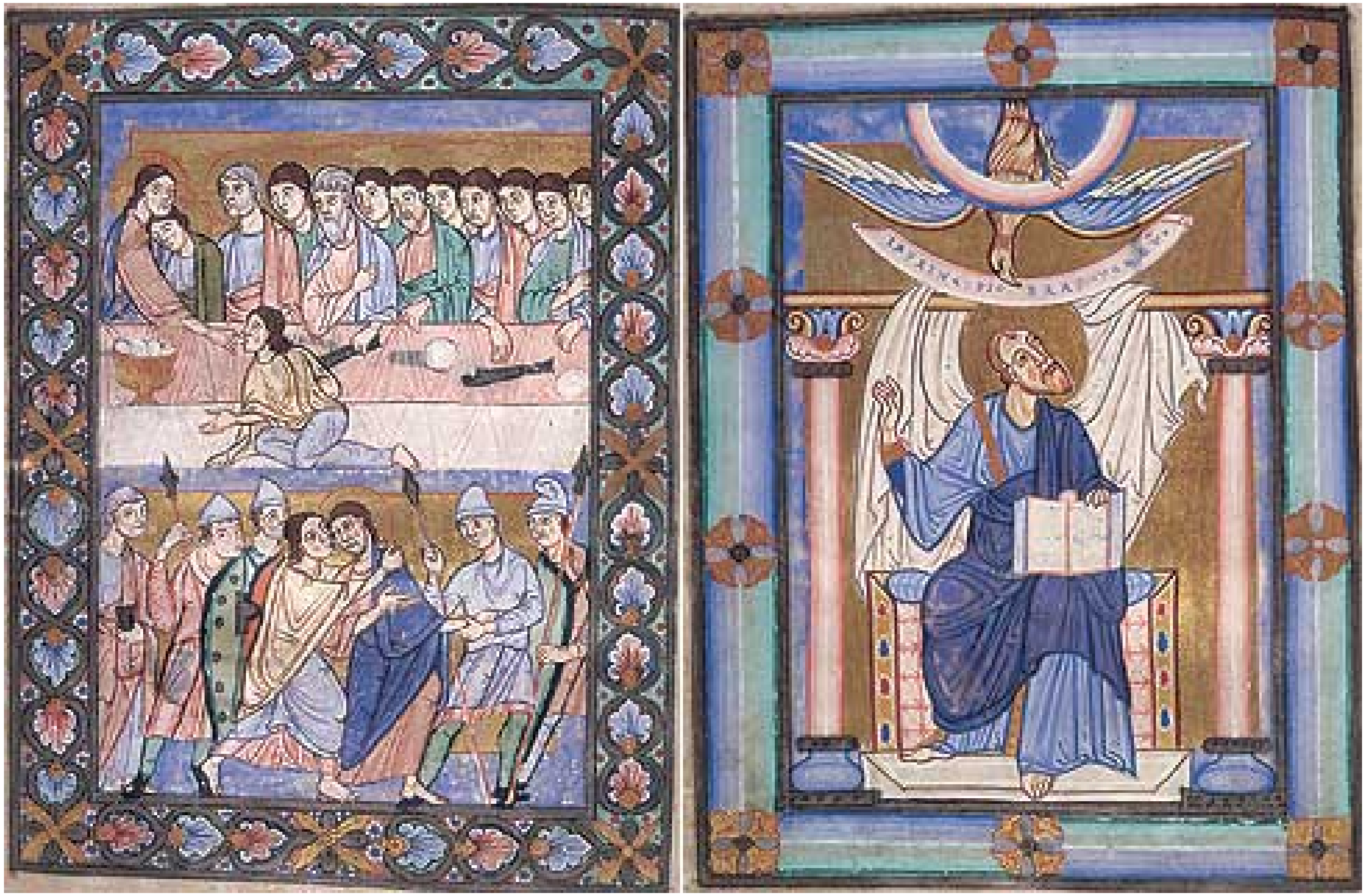
Antiquity

Roman Art (~100 BC)

Alexander mosaic, Popeii

Middle Ages

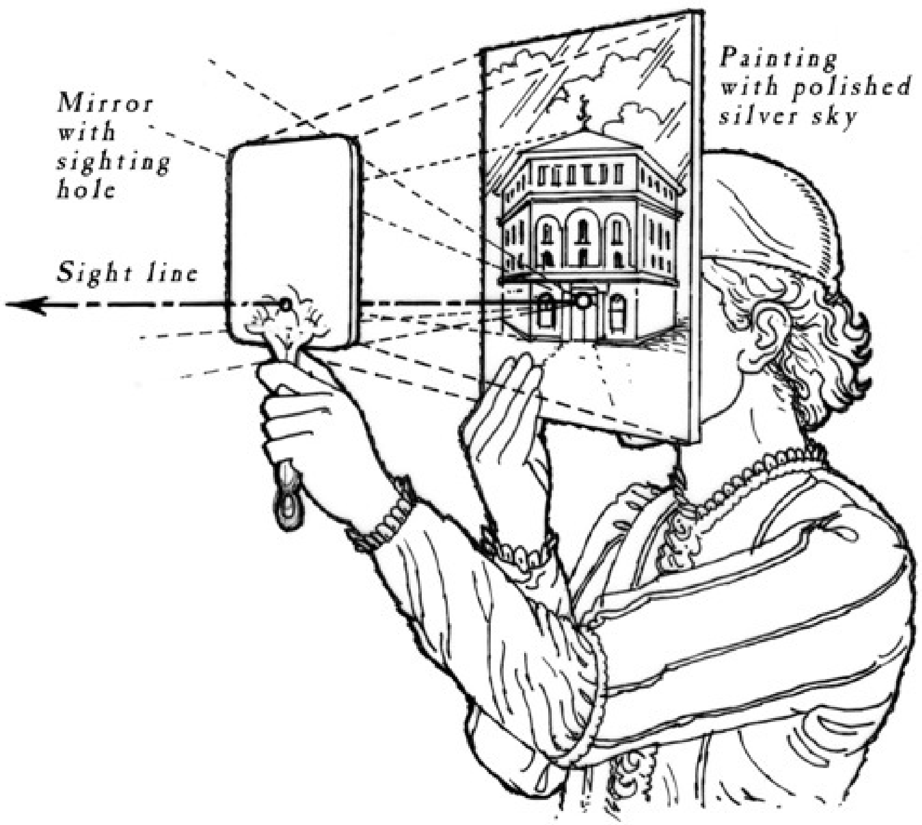
Book Illustration (~1165)



Book print from the gospel book of Kruszwica, Helmarshausen Abbey

Renaissance

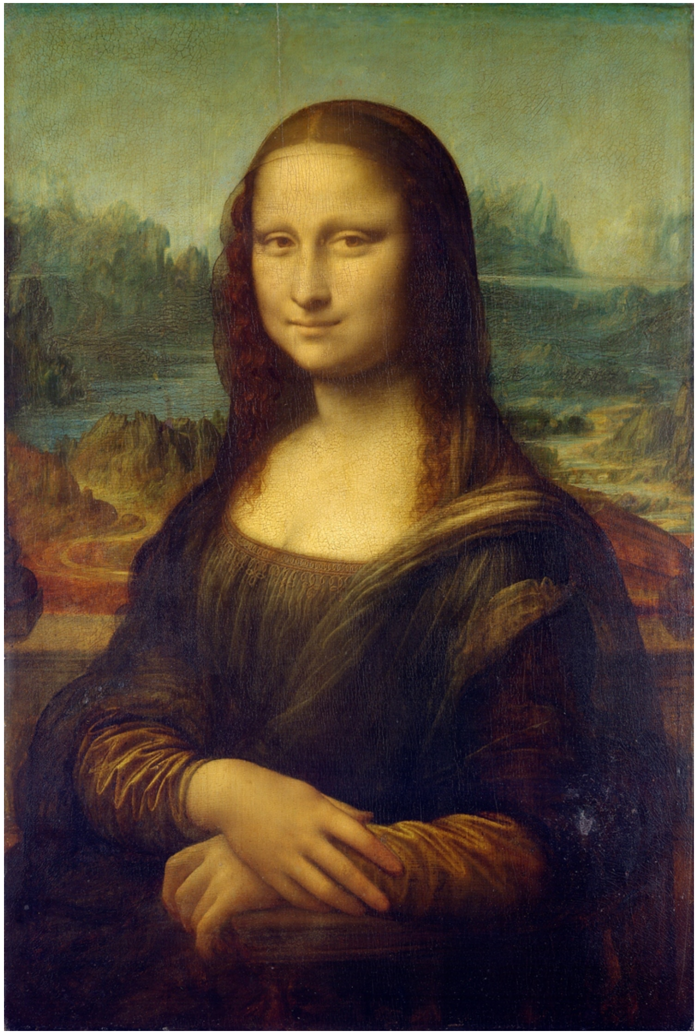
(Re)discovery of Perspective



Filippo Brunelleschi (early 15th century)

Renaissance

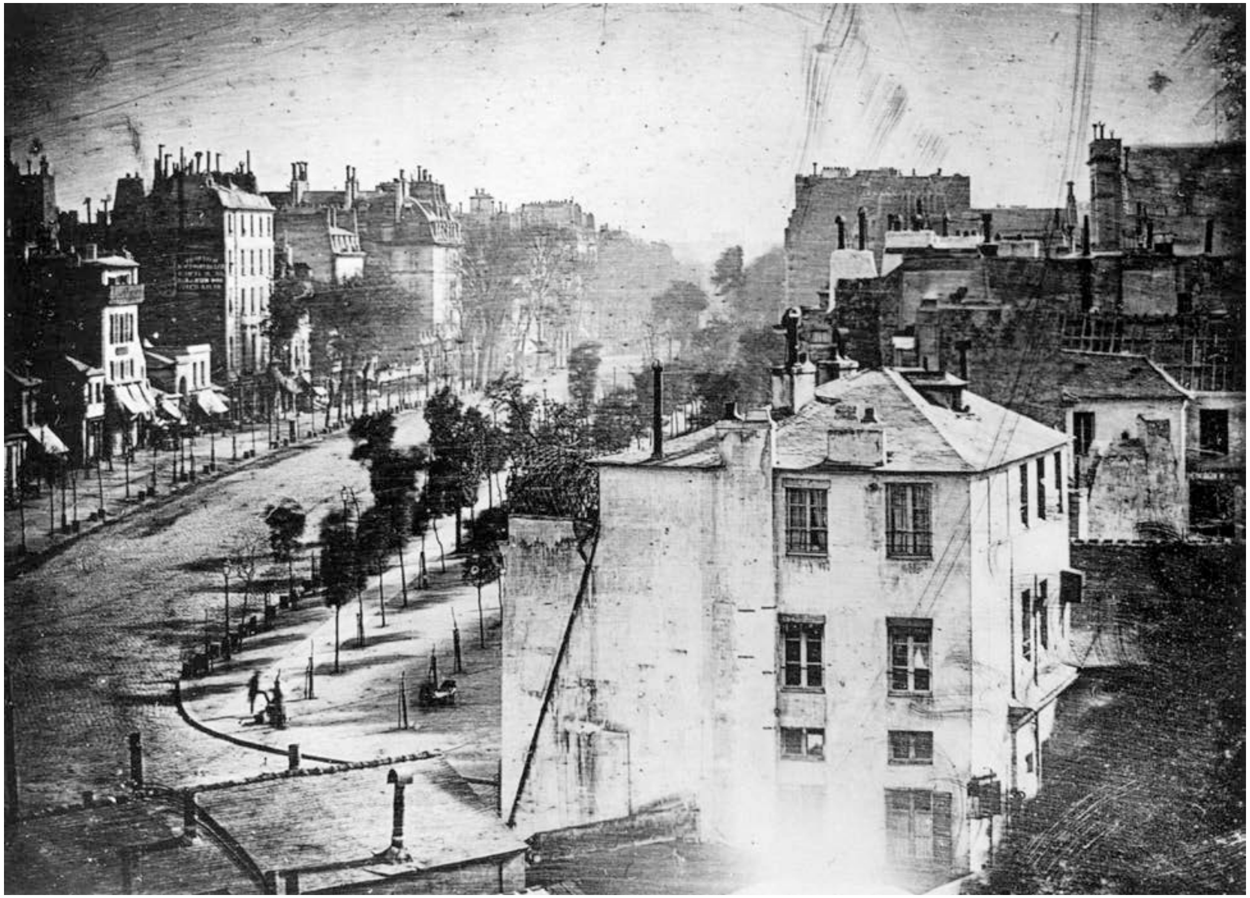
Albrecht Dürer (1471-1528)



Leonardo da Vinci (1452-1519)

Romanticism

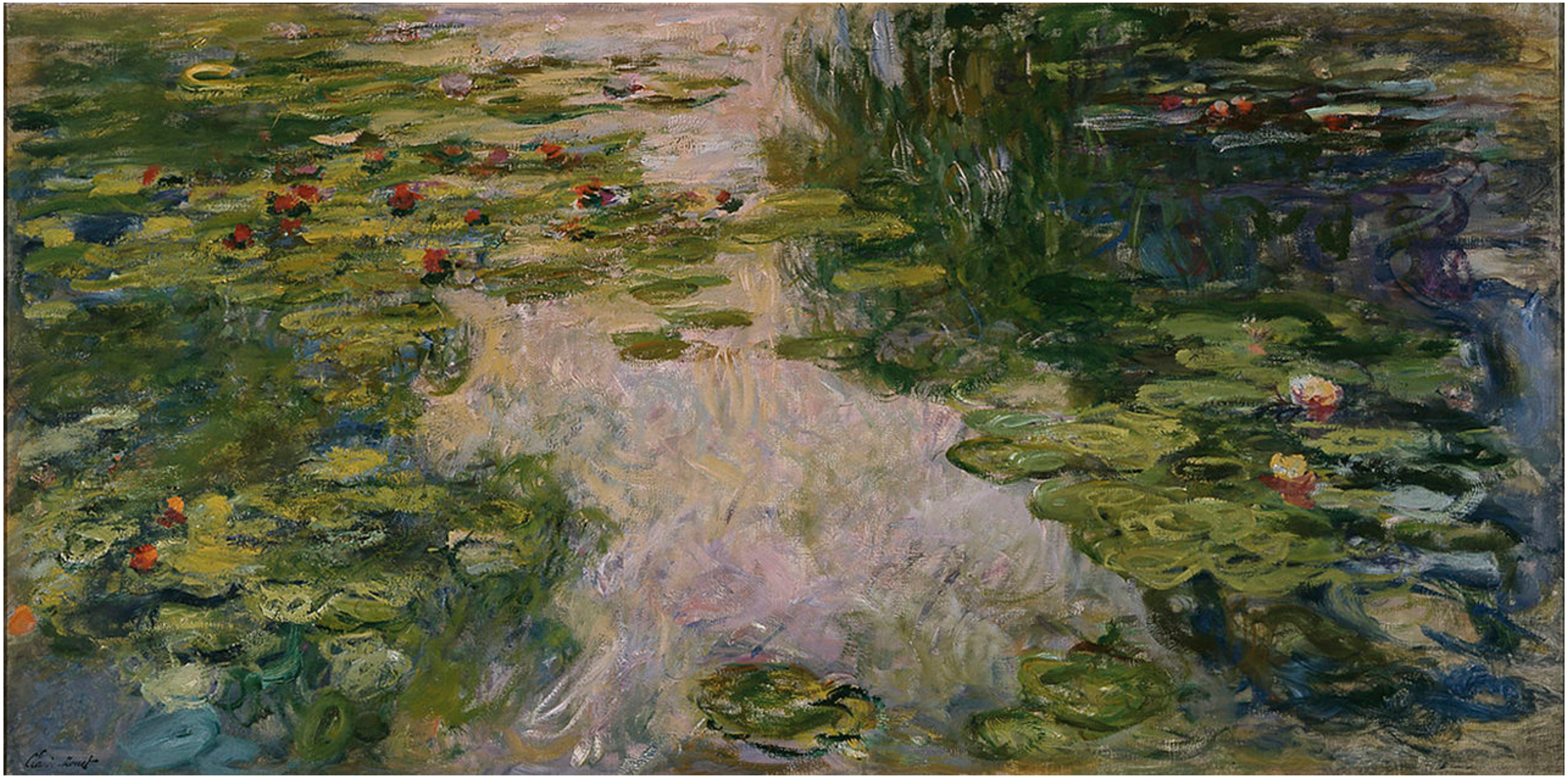
Daguerreotype (1838)



Louis-Jacques-Mandé Daguerre (1787 - 1851)

Modern Painting

Impressionism



Water Lilies - Claude Monet (1840 - 1926)

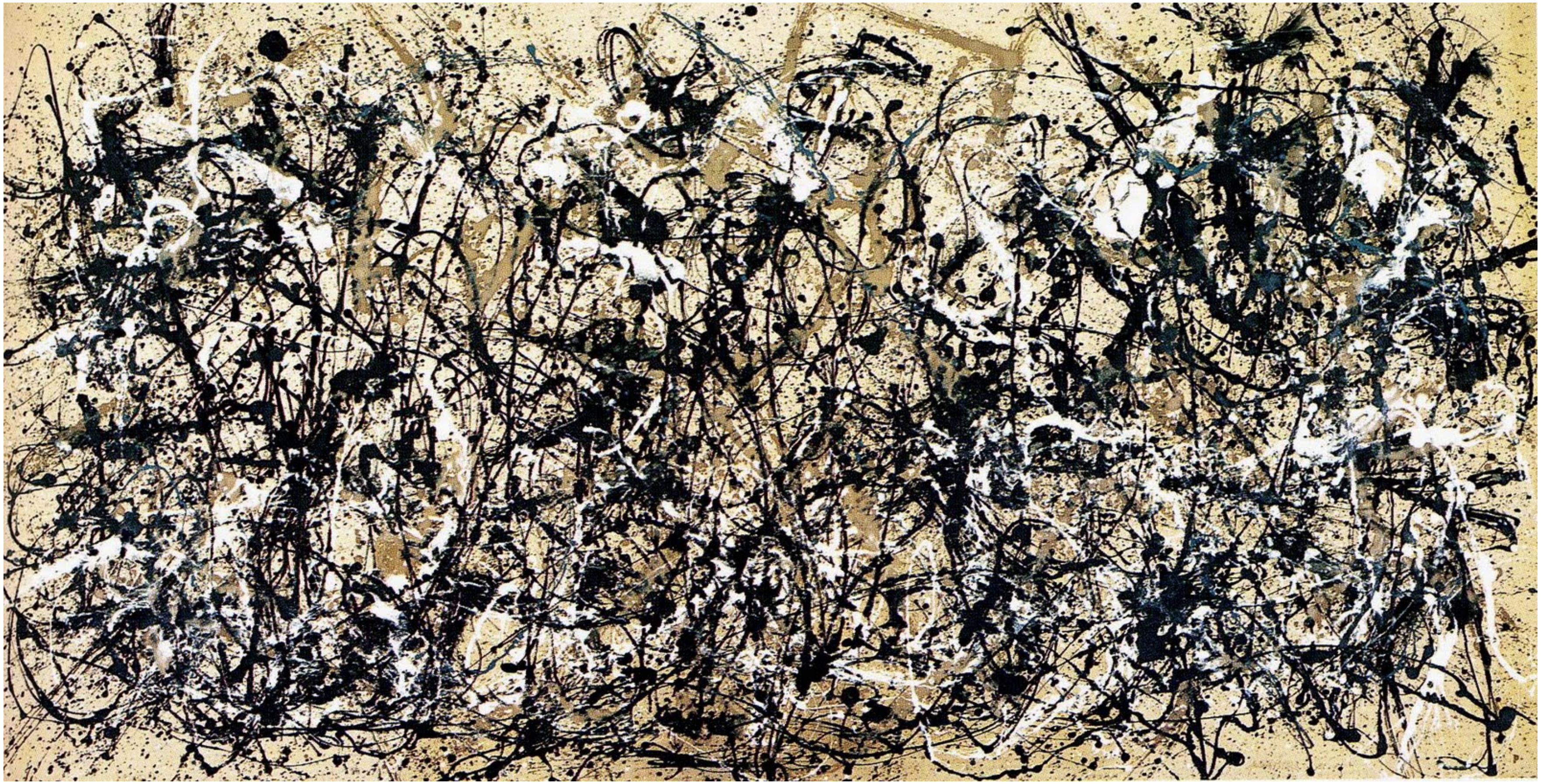
Modern Painting

Cubism

Three Musicians - Pablo Picasso (1881 - 1973)

Modern Painting

Action Painting



Autumn Rhythm - Jackson Pollock (1912 - 1956)

Postmodern Painting

Hyperrealism

Hot Day III - Pedro Campos (1966 -)

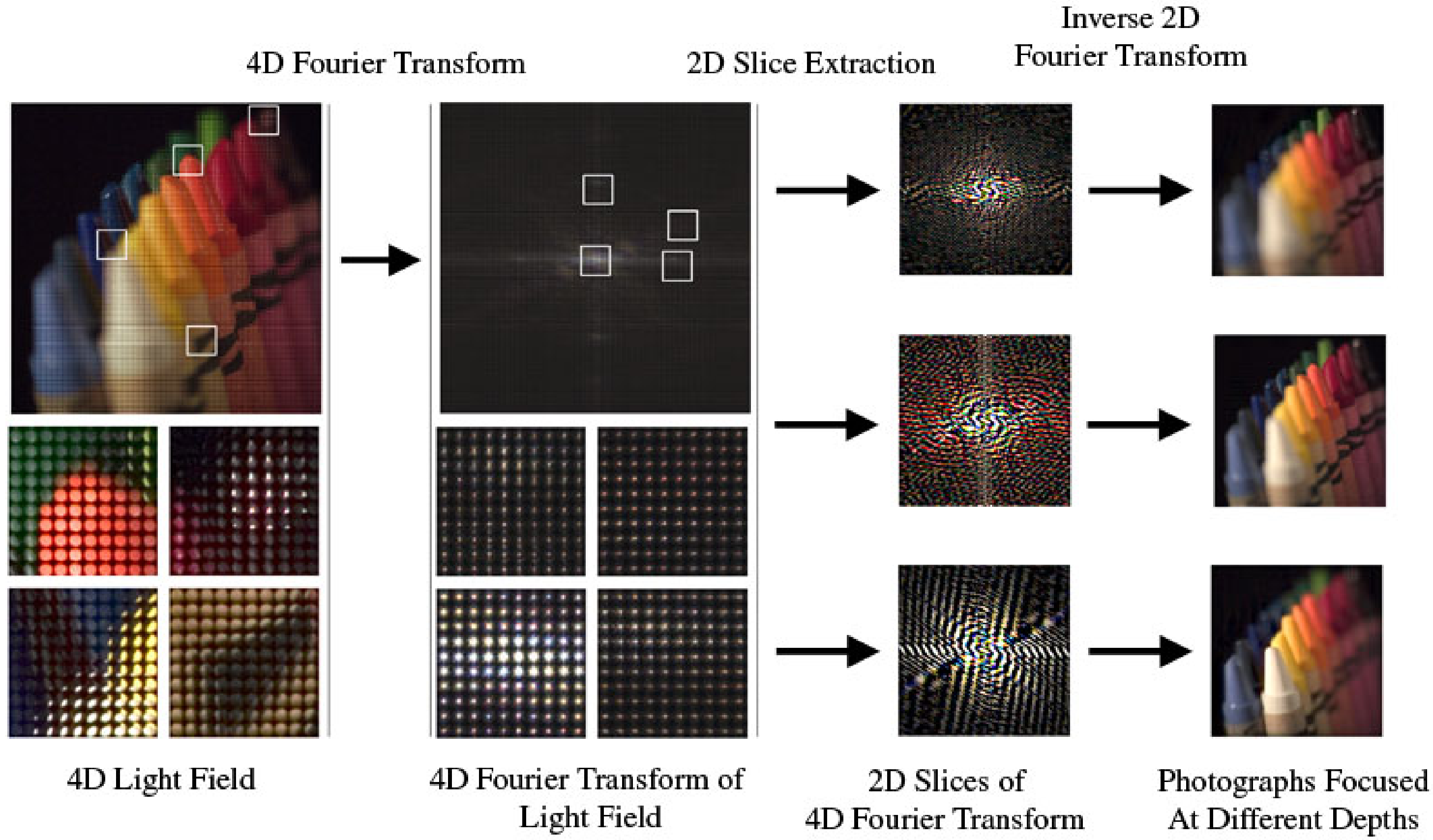
Photography

Digital Photography

Exploded view of a digital single-lens reflex camera

Photography

Computational Photography



Ng R., *Fourier Slice Photography*, in SIGGRAPH 2005

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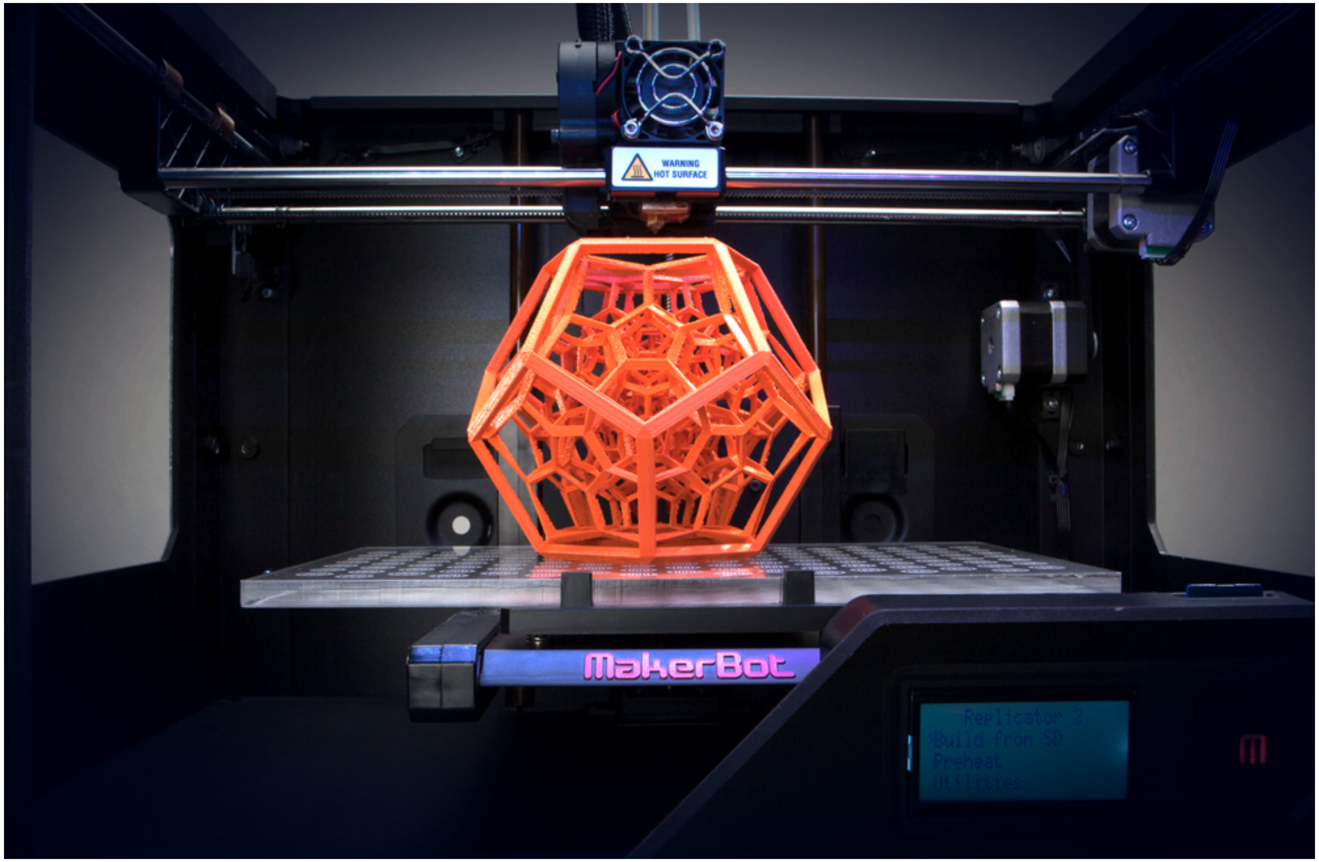
Alternative Output

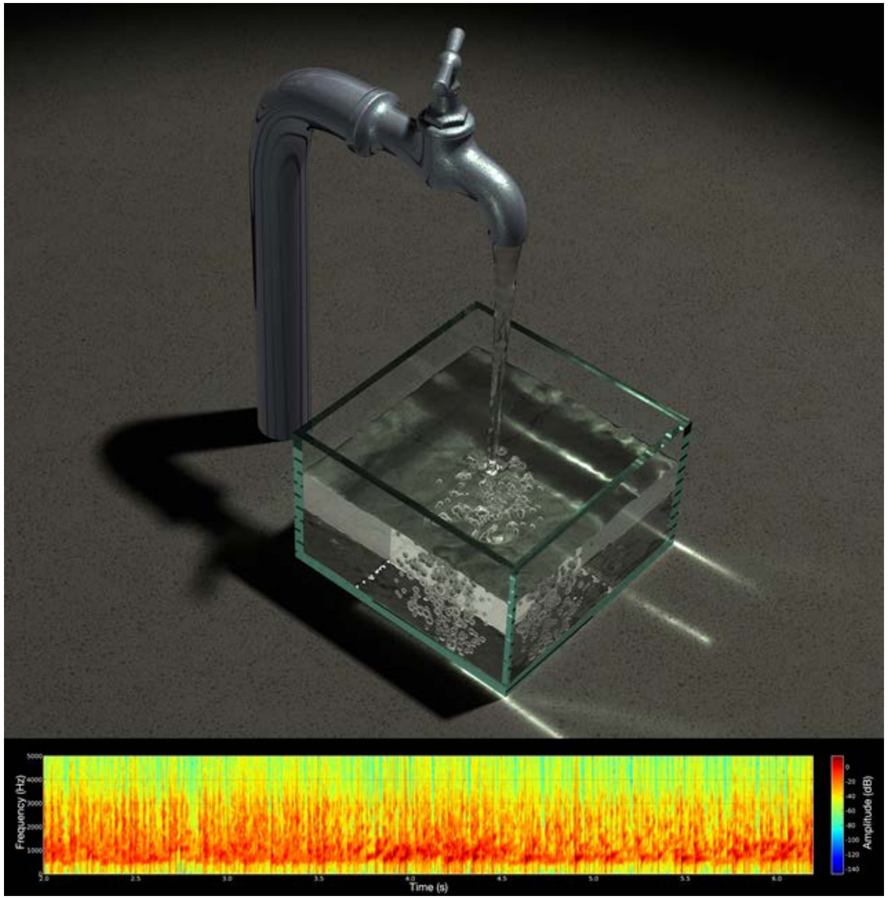
3D Printing



CNN

Alternative Output

Sound



Zheng C., James D.L., *Harmonic Fluids*, in SIGGRAPH 2009

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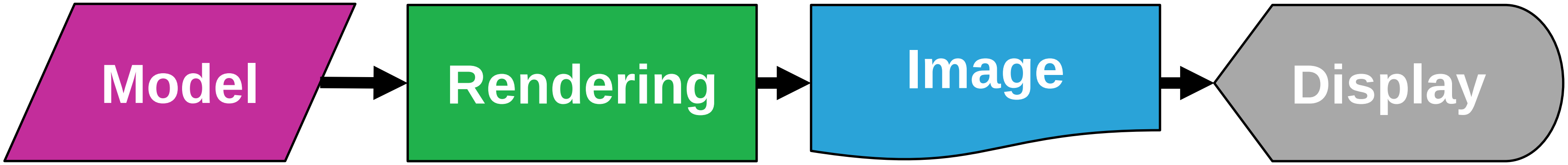

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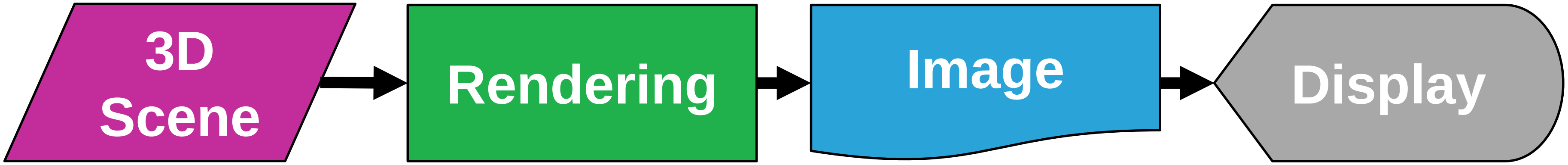

Lecture Scope

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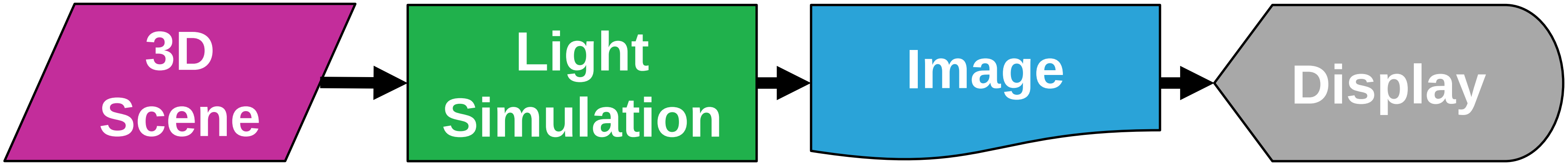

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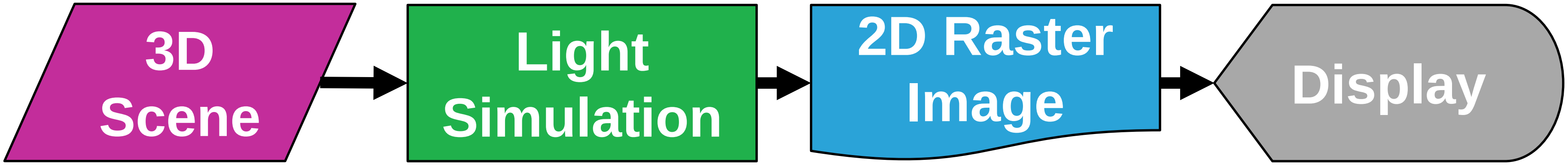

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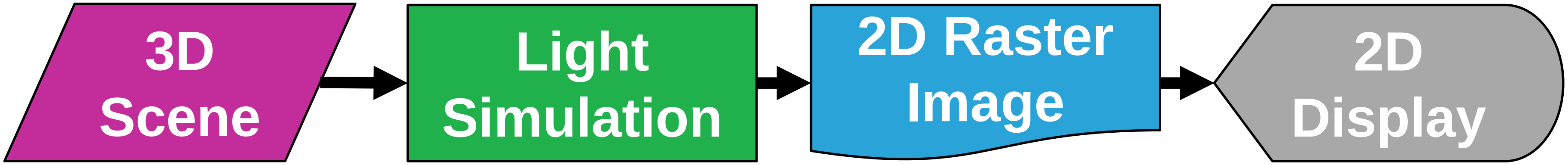

Lecture Scope

Applications

- Games/Simulators
- Interactive Modeling/Design
- Augmented/Virtual Reality/Telepresence
- Movies/VFX
- E-Commerce
- Architecture
- Industrial Design

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Lecture Scope

Immersion

- Interactive/realtime performance paramount
- Realism a secondary goal or not desired
- Dominated by rasterization
- Ray-based rendering is coming but not there yet

Lecture Scope

Skyrim, (*from http://www.flickr.com/javiercc*)

Lecture Scope

Joint Terminal Attack Controller Virtual Trainer Dome, (*from http://gizmodo.com/315435*)

Lecture Scope

Applications

- Games/Simulators
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Lecture Scope

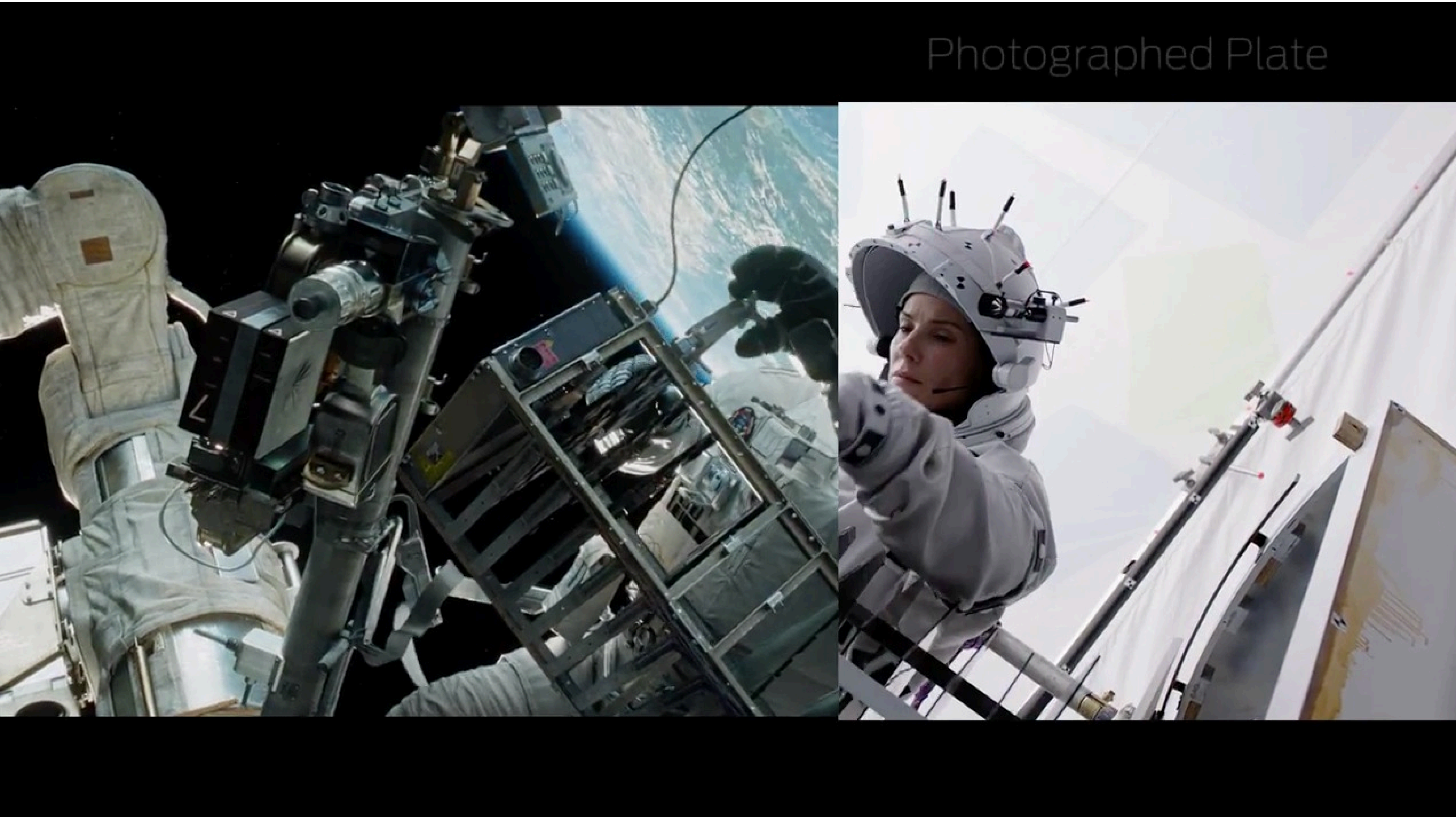
Believable Realism

- Artistic expression paramount
- Realism a secondary goal or not desired
- RenderMan, Maya, 3DMax, …

Lecture Scope

Brave, Pixar

Lecture Scope



Gravity, Warner Bros. Pictures

Applications

- Games/Simulators
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Lecture Scope

Prediction

- Physically correct result paramount
- Realism the primary goal
- Constrained to physically possible scenes
- Radiance, Brazil, Maxwell, …

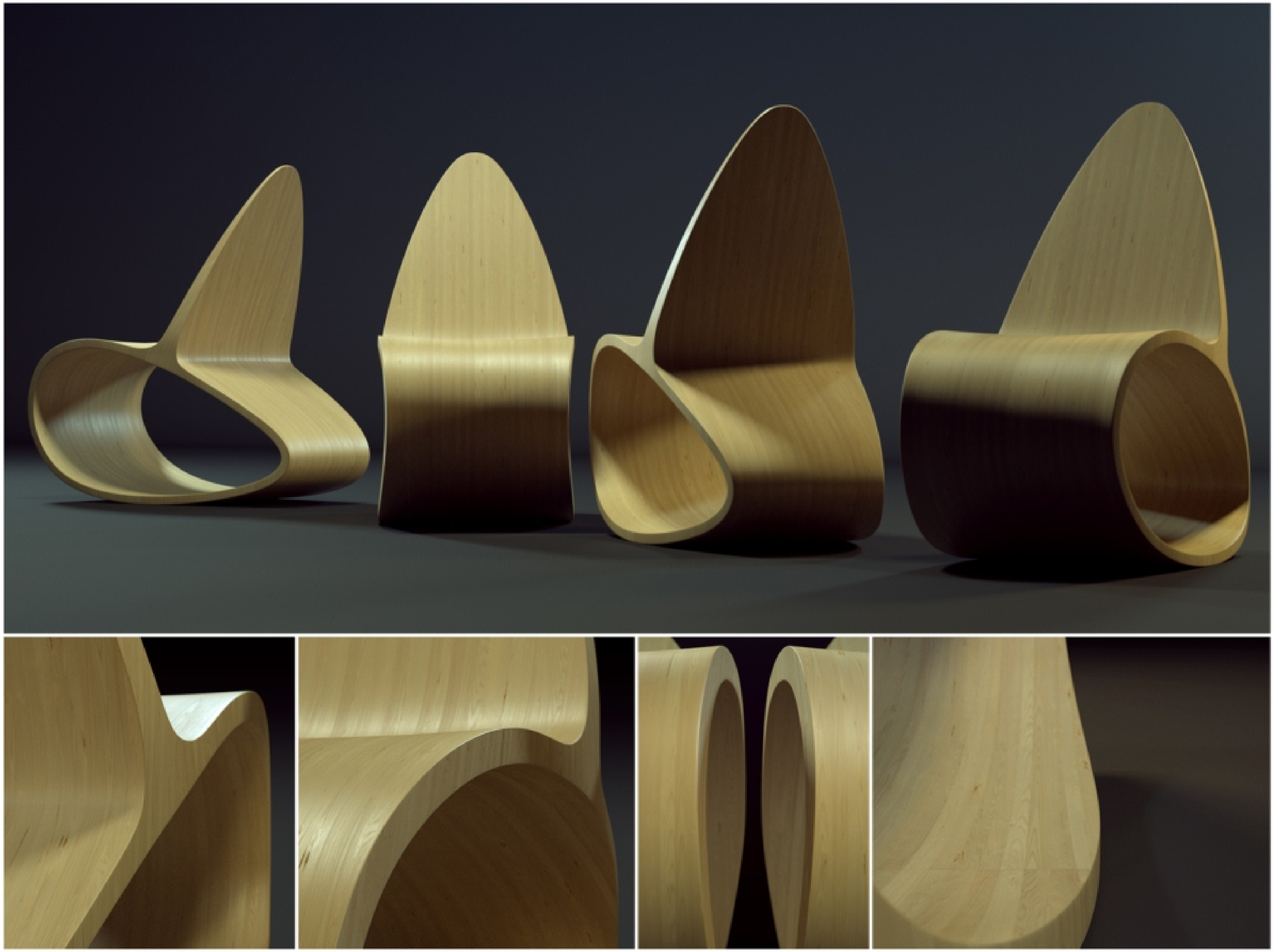
Lecture Scope

Kitchen, Taller Arquitectura Virtual

Lecture Scope

Gemstone, GT Jewelry Design

Lecture Scope



Ocean Rocker, Toni Fresnedo (design Jolyon Yates)

Lecture Scope

Applications

- Games/Simulators
- Interactive Modeling/Design
- Augmented/Virtual Reality/Telepresence
- Movies/VFX
- E-Comme
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VO/UE Computer Graphics

VU Realtime Graphics

Applications

- Games/Simulators
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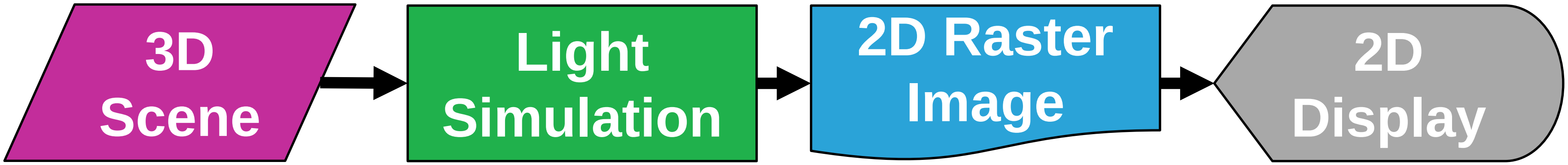
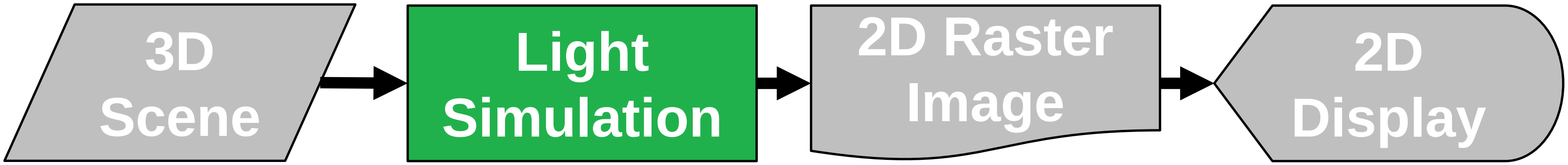
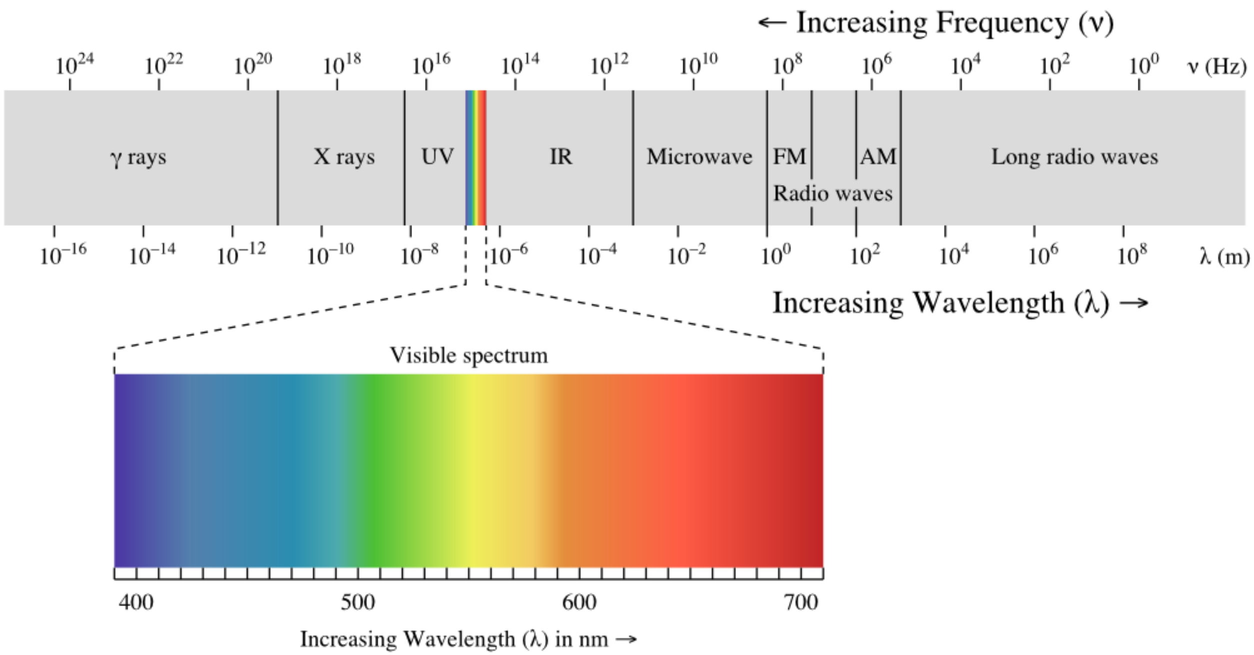
Lecture Scope





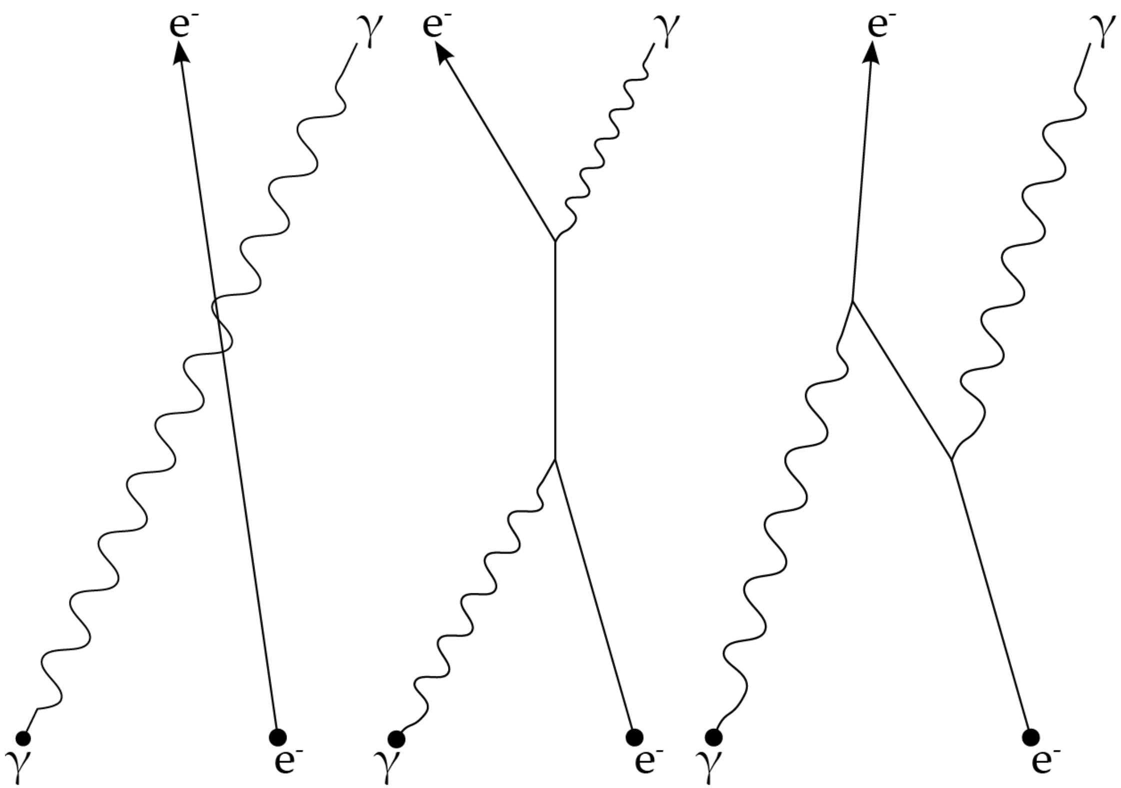
Light



Spectrum of electromagnetic radiation (*from wikipedia*)

Light Simulation

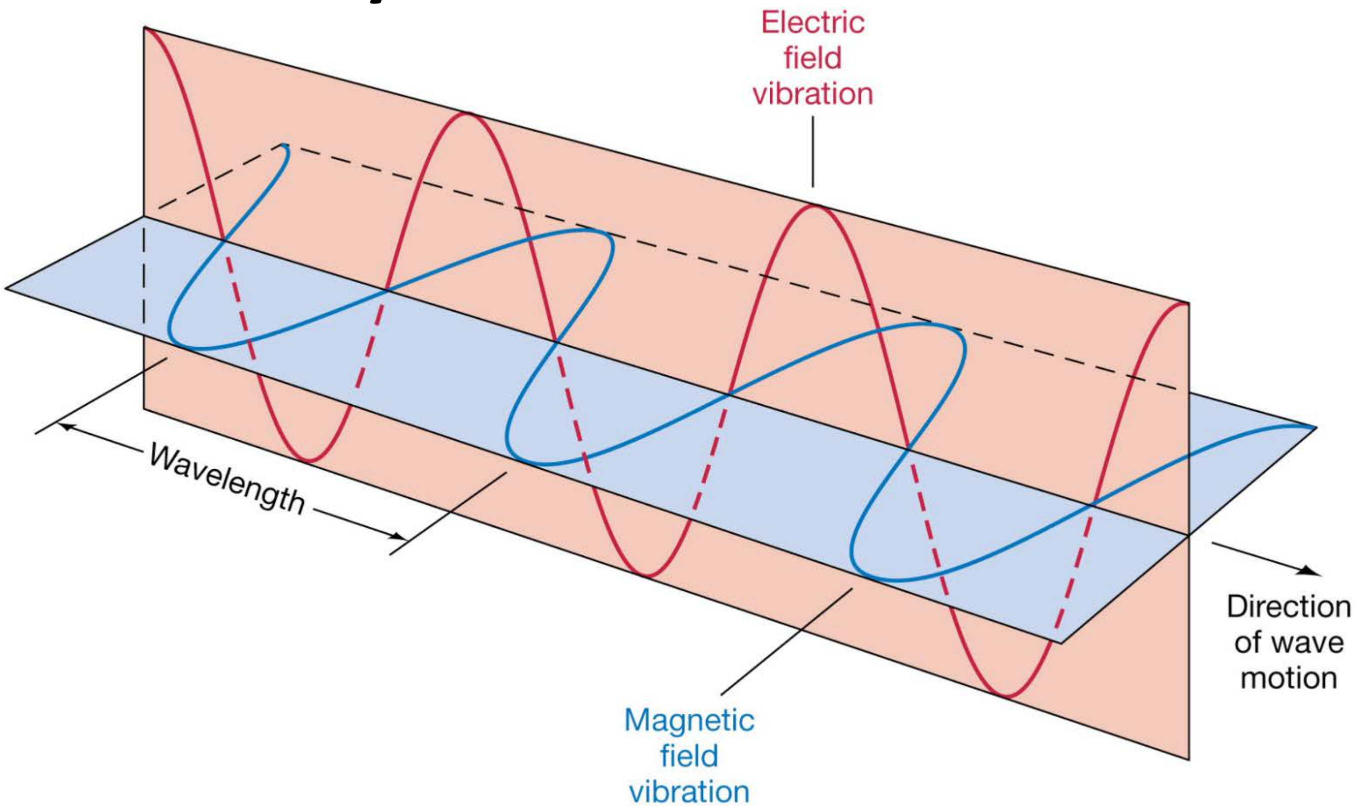
Quantum Electrodynamics



Feynman diagrams of compton scattering

Light Simulation

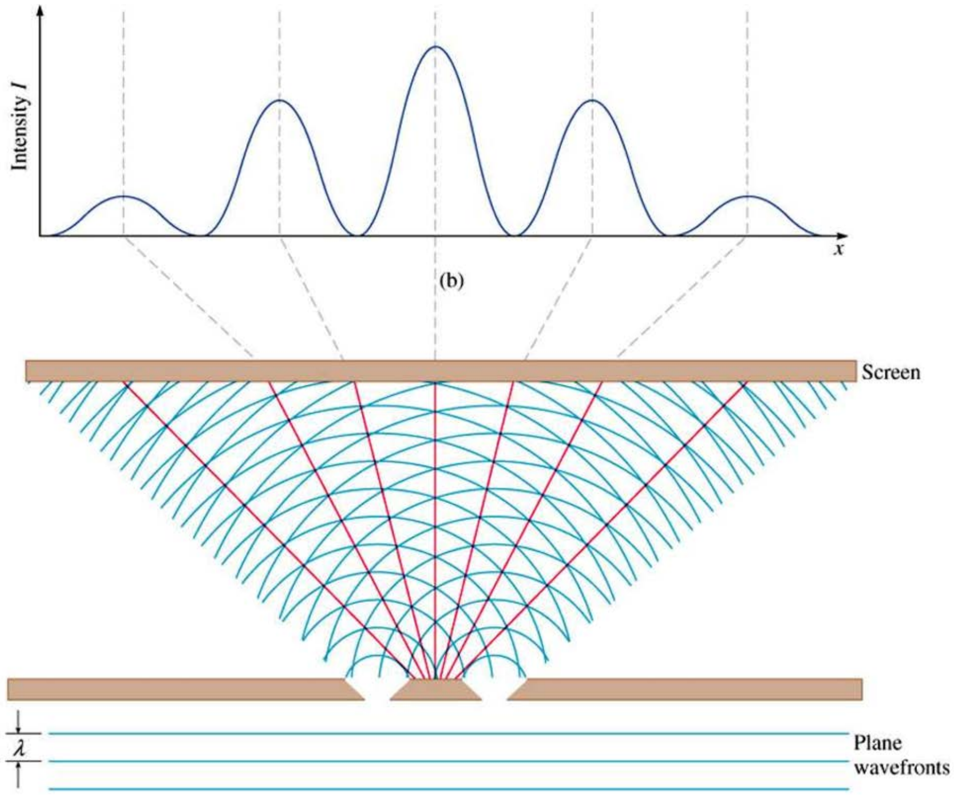
Classical Electrodynamics



Electromagnetic wave

Light Simulation

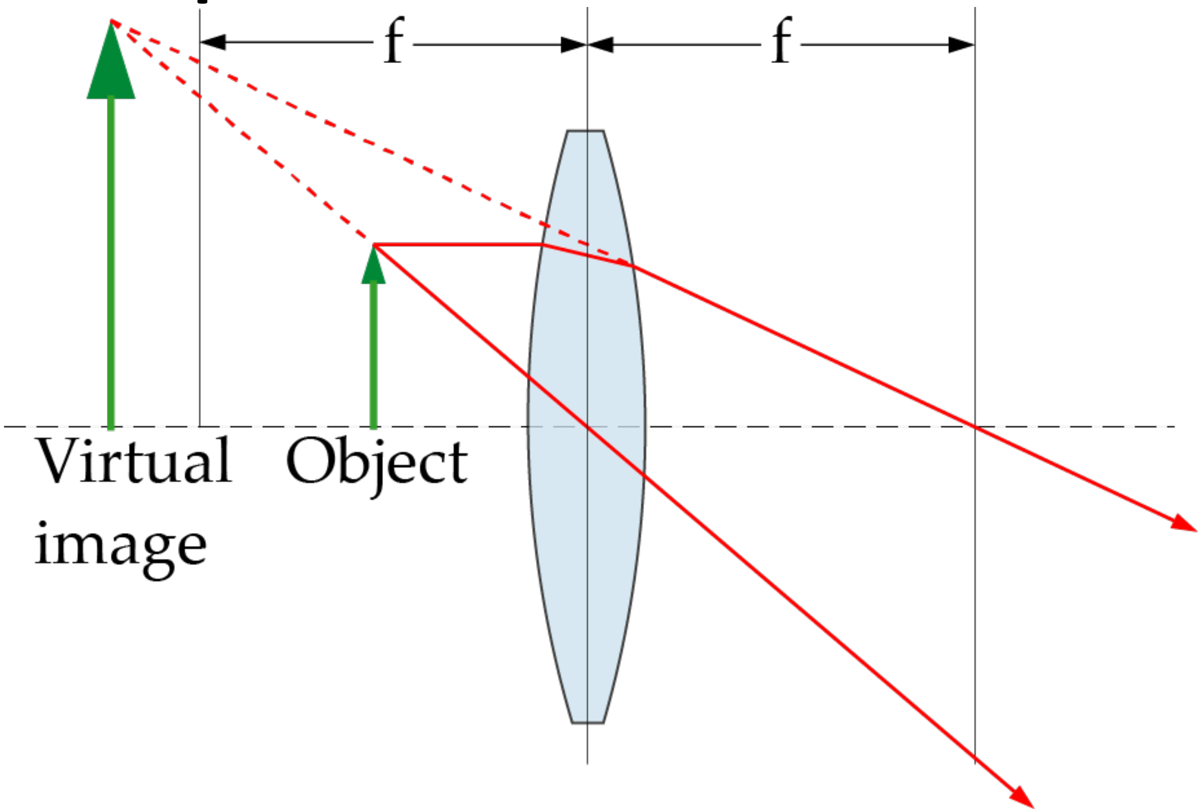
Physical Optics



Diffraction and interference at a double-slit (© *McGraw-Hill Companies Inc.*)

Light Simulation

Geometrical Optics



Ray tracing for a lens (*from wikipedia*)

Radiometry

Measurements of light distribution in space and time

Radiometry

Measurements of light distribution in space and time

Radiant energy Q_e [J] ← Phyical unit

Energy of the light

Radiant flux / radiant power $\Phi_e \left[\mathrm{W} = \mathrm{Js}^{-1}\right]$

Energy per unit of time

Flux too unspecific as it contains no spatial or directional information on the light distribution.

We introduce these quantities in the following slides and start with a directional description of flux (i.e. in which direction is more less flux).

Radiant Intensity $I_e(\omega)\ [\mathrm{W sr}^{-1}]$

Emanated flux per solid angle of a point source

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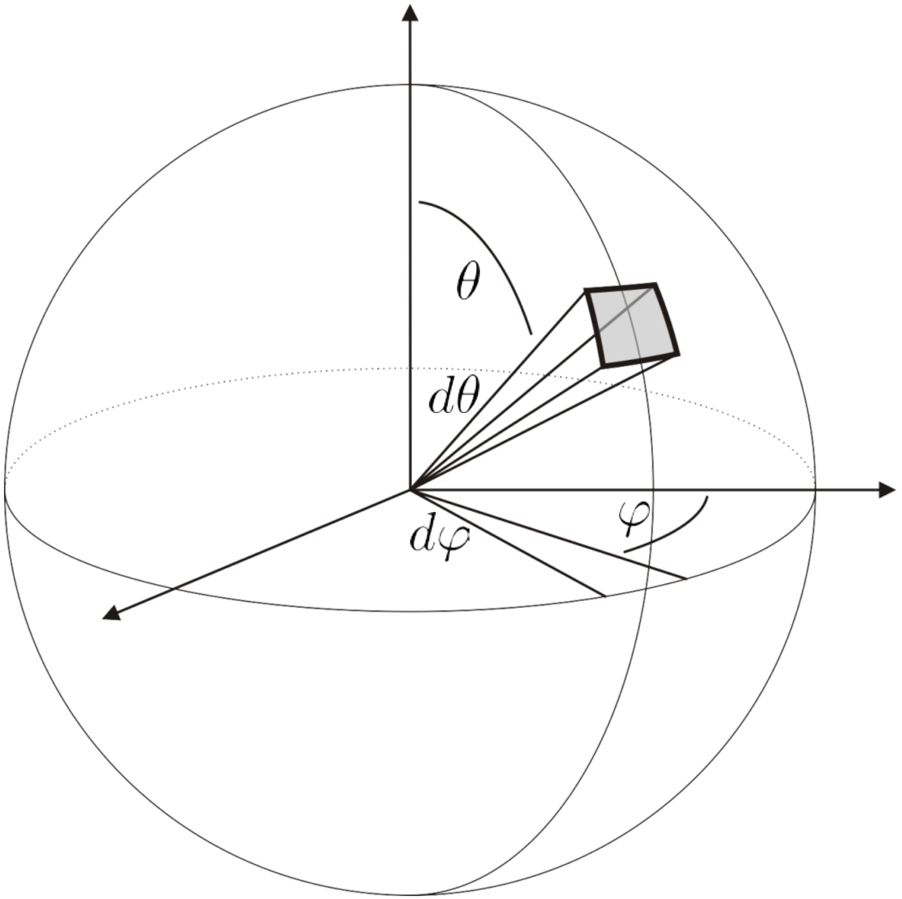
Emanated flux per solid angle of a point source

$$I_e(\omega) = \frac{d\Phi_e}{d\omega}$$



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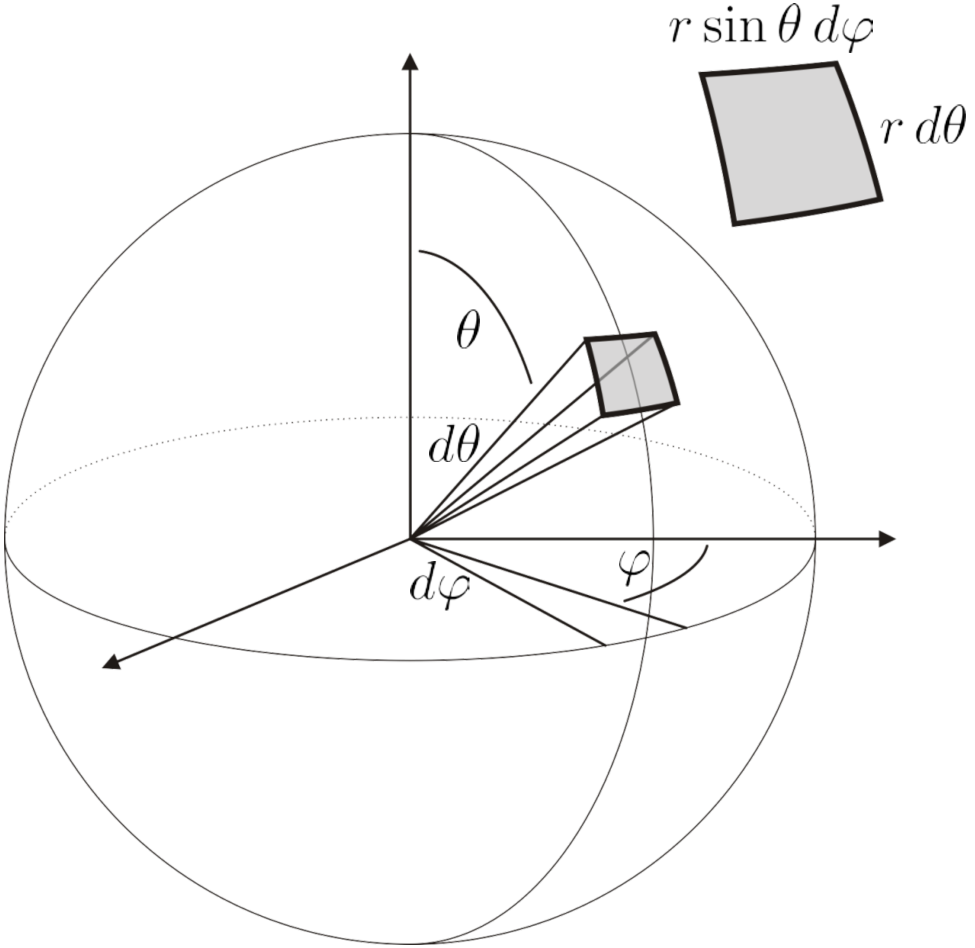
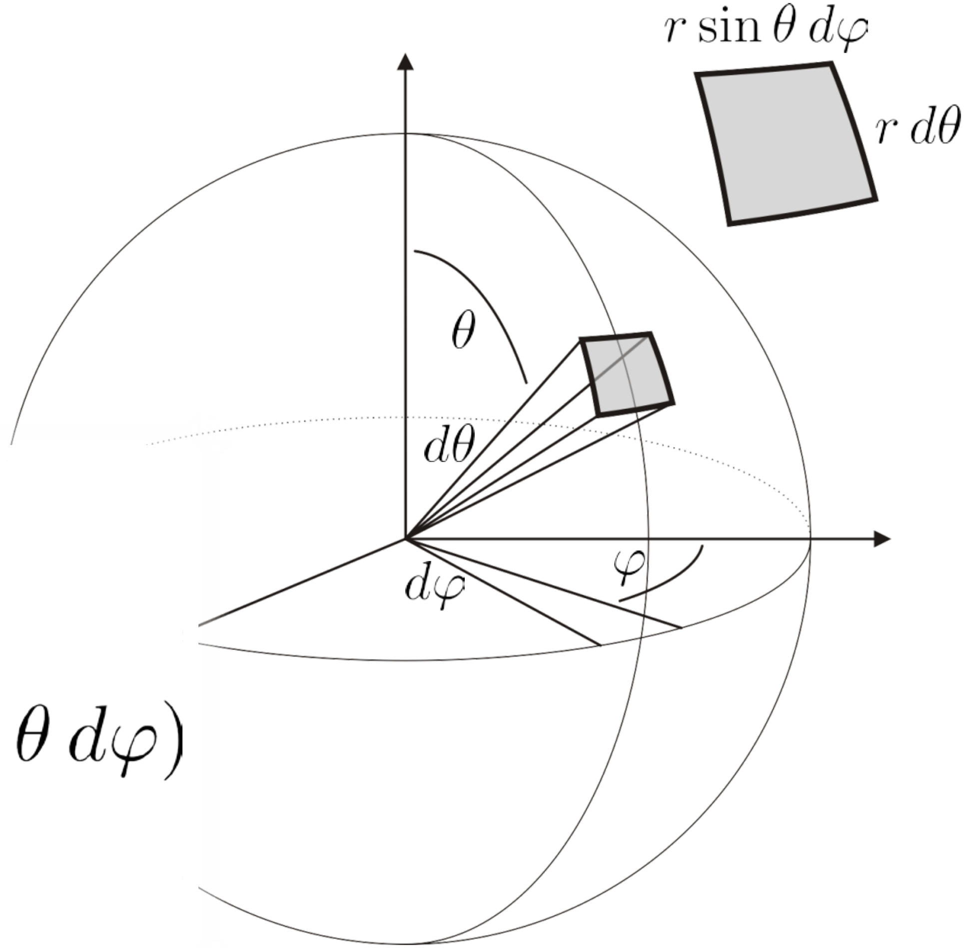


Radiant Intensity $I_e(\omega)$ $[\mathrm{W sr}^{-1}]$

$$I_e(\omega) = \frac{d\Phi_e}{d\omega}$$

$$d\omega = \frac{1}{r^2}\, dA$$
$$= \frac{1}{r^2}(r\, d\theta)(r \sin\theta\, d\varphi)$$
$$= \sin\theta\, d\varphi\, d\theta$$



Radiant Intensity $I_e(\omega)\ \left[\mathrm{Wsr}^{-1}\right]$

Isotropic point source

$$\begin{aligned}\Phi_e &= \int_{\text{Sphere}} I_e(\omega)\, d\omega \\ &= I \int_{\text{Sphere}} d\omega \\ &= I \int_0^{2\pi} \int_0^{\pi} \sin\theta \, d\varphi \, d\theta \\ &= 4\pi I\end{aligned}$$

Radiant Intensity $I_e(\omega)\ [\mathrm{Wsr}^{-1}]$

Isotropic point source

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$$I_e(\omega) = \frac{\Phi_e}{4\pi}$$

We also want to describe the spatial distribution of flux on surfaces (i.e. at which location on the surface is more or less flux arriving or departing).

Irradiance $E_e(x)\ \left[\mathrm{Wm}^{-2}\right]$

Flux per unit area incident on a surface

$$E_e(x) = \frac{d\Phi_{e,\mathrm{i}}}{dA}$$

Irradiance $E_e(x)$ $[\mathrm{Wm}^{-2}]$

Flux per unit area incident on a surface

$$E_e(x) = \frac{d\Phi_{e,\mathrm{i}}}{dA}$$

Radiant exitance $M_e(x)$ $[\mathrm{Wm}^{-2}]$

Flux per unit area emitted from a surface

$$M_e(x) = \frac{d\Phi_{e,\mathrm{e}}}{dA}$$

Irradiance $E_e(x)\ [\mathrm{Wm}^{-2}]$

Flux per unit area incident on a surface

$$E_e(x) = \frac{d\Phi_{e,\mathrm{i}}}{dA}$$

Radiant exitance $M_e(x)\ [\mathrm{Wm}^{-2}]$

Flux per unit area emitted from a surface

$$M_e(x) = \frac{d\Phi_{e,\mathrm{e}}}{dA}$$

Radiosity $J_e(x)\ [\mathrm{Wm}^{-2}]$

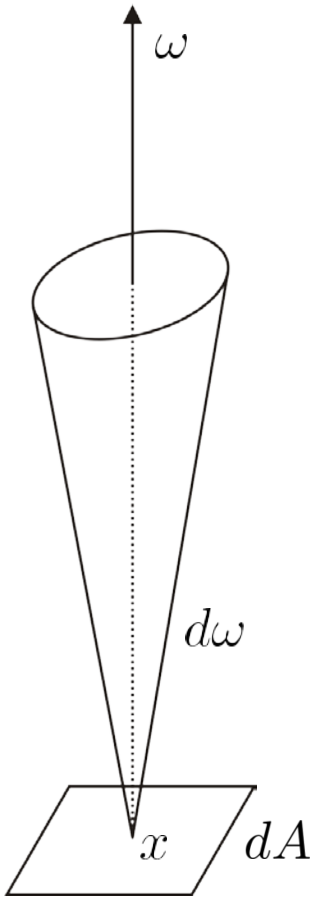
Flux per unit area emitted + reflected from a surface

$$J_e(x) = \frac{d\Phi_{e,\mathrm{er}}}{dA}$$

The fundamental description of light in the context of ractracing is both a spatial and directional quantitiy (i.e. at which location on a surface and to which direction more or less flux is emitted).

Radiance $L_e(x, \omega)\ [\mathrm{W sr^{-1} m^{-2}}]$

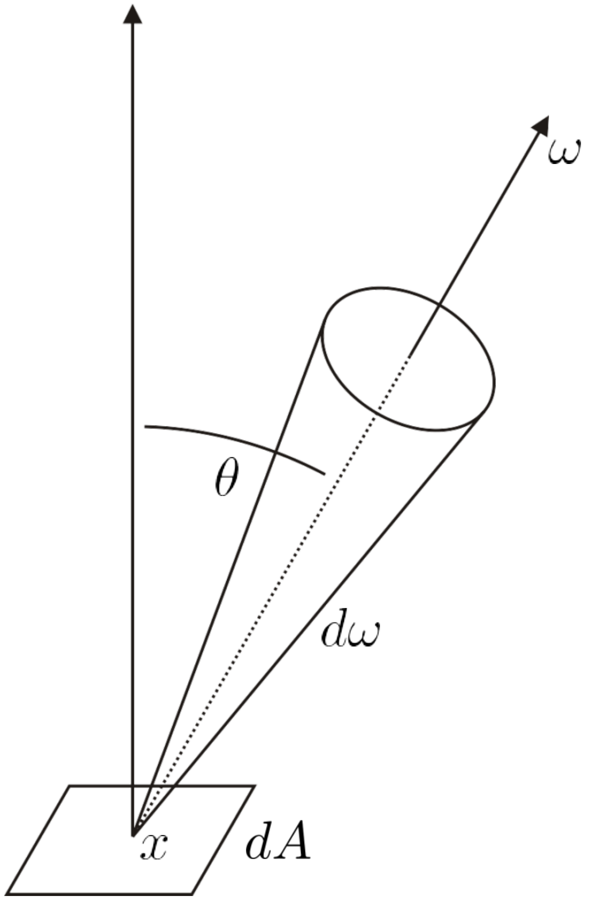
Flux per unit area per solid angle per projected unit area



Radiance $L_e(x, \omega)\ [\mathrm{Wsr^{-1}m^{-2}}]$

Flux per unit area per solid angle per projected unit area

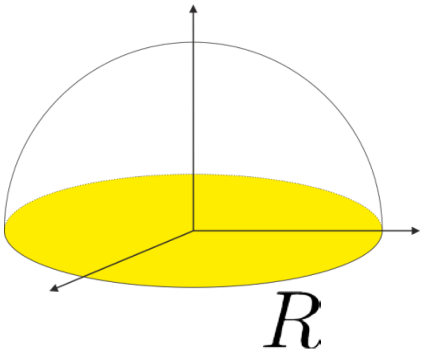
$$L_e(x, \omega) = \frac{d^2\Phi_e}{d\omega\, dA \cos\theta} = \frac{dI_e}{dA \cos\theta}$$



Radiance $L_e(x,\omega)\ [\mathrm{Wsr}^{-1}\mathrm{m}^{-2}]$

Uniform diffuse area source (with radius R)

$$\begin{aligned}\Phi_e &= \int_{Area}\int_{\mathrm{Hemisphere}} L_e(x,\omega)\cos\theta\, d\omega\, dA \\ &= L\int_{Area}\int_{\mathrm{Hemisphere}} \cos\theta\, d\omega\, dA \\ &= L\pi\int_{Area} dA \\ &= L\pi^2 R^2\end{aligned}$$



Spectral quantities

Radiometric quantity per wavelength

e.g. spectral radiance

$$L_{e,\lambda}(x,\omega)\ \left[\mathrm{Wsr}^{-1}\mathrm{m}^{-2}\mathrm{nm}^{-1}\right]$$

$$L_{e,\lambda}(x,\omega) = \frac{d^2\Phi_e}{d\omega\, dA \cos\theta\, d\lambda}$$

Photometry

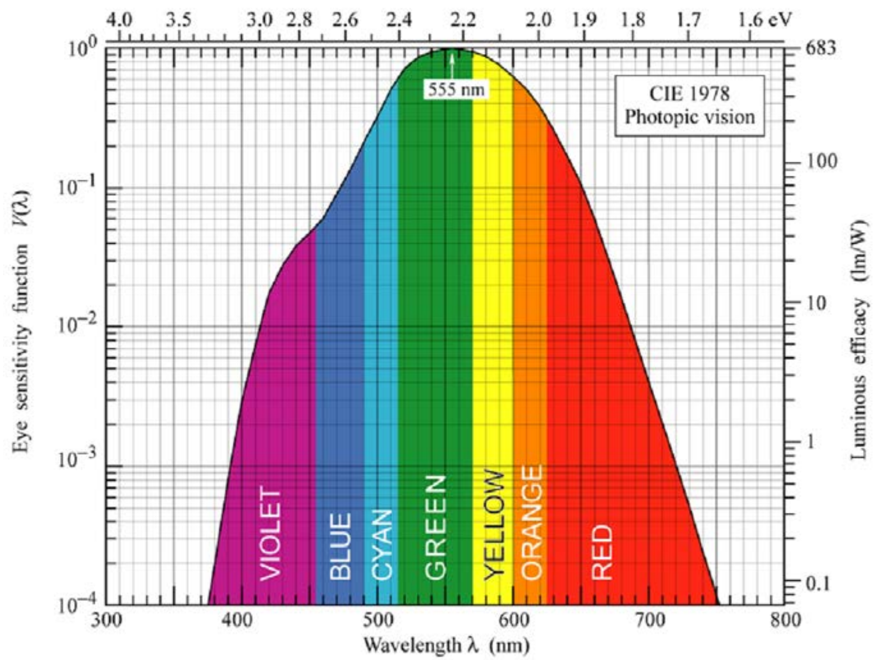
Measurements of perceived brightness of light distribution in space and time

Photometry

Measurements of perceived brightness of light distribution in space and time

Spectral eye sensitivity

$$V(\lambda)\ [\mathrm{lmW}^{-1}]$$



Schubert E., *Light-Emitting Diodes*, ISBN 9780521865388

Conversion

Multiplication with eye sensitivity function for each wavelength

e.g. radiance L_e → luminance L_v

$$L_v = \int L_{v,\lambda} \, d\lambda = \int L_{e,\lambda} V(\lambda) \, d\lambda$$

Radiometry / Photometry

Radiometric quantity	Symbol	Unit	Photometric quantity	Symbol	Unit
Radiant energy	Q_e	[J] *joule*	Luminous energy	Q_v	[lm s] *talbot*
Radiant flux	Φ_e	[W] *watt*	Luminous flux	Φ_v	[lm] *lumen*
Radiant intensity	I_e	[W sr^{-1}]	Luminous intensity	I_v	[cd] *candela*
Radiance	L_e	[W sr^{-1} m^{-1}]	Luminance	L_v	[cd m^{-2}] *nit*
Irradiance	E_e	[W m^{-2}]	Illuminance	E_v	[lx] *lux*
Radiant exitance	M_e	[W m^{-2}]	Luminous emittance	M_v	[lx]
Radiosity	J_e	[W m^{-2}]	Luminosity	J_v	[lx]

Assignment 0

Radiometry

Assuming the sun as a point light source with a total radiant flux of 3.86×10^{26} Watt, what is the Irradiance outside the atmosphere of Mars at the equator?

Assuming a perfect solar collector stationed outside the atmosphere (that transforms all incoming light into electricity), how much area does it need to cover to replace the world's largest nuclear power plant (Kashiwazaki-Kariwa, Japan, 8212MW)?

Hints:

- Consult http://candela.stanford.edu/lectures/09_radiometry/radiometry_slides.pdf
- Consult PBRT 5.5.3
- The final answer is ~$13.5 km^2$

How to submit via email

The result has to be sent to **BOTH** of us in an email. Either as text in the email or as an attachment to it.

The format of both the email **SUBJECT** and the attachment **FILENAME** has to be as follows:

[Rendering_SS2015_($assignment_number)]_($your_matriculation_number),($your_name)

e.g. [Rendering_SS2015_0]_0123456,John Doe

Assignment 0

Deadline

24.03.2015 23:59

Next lecture

18.03.2015 13:30-15:00