# Introduction to Ray Tracing

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SIGGRAPH 2021

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# Ray Tracing

Rajesh Sharma

# Course Outline

-✔- Intro, Model, Sampling
-✔- Rays, Intersections
-✔- Scene,  Recursion
-✔- Materials, BRDF
-✔- BRDF-2
-- Systems View: Integrators, Accelerators, BRDF-3
-- Wrap up, Learn more

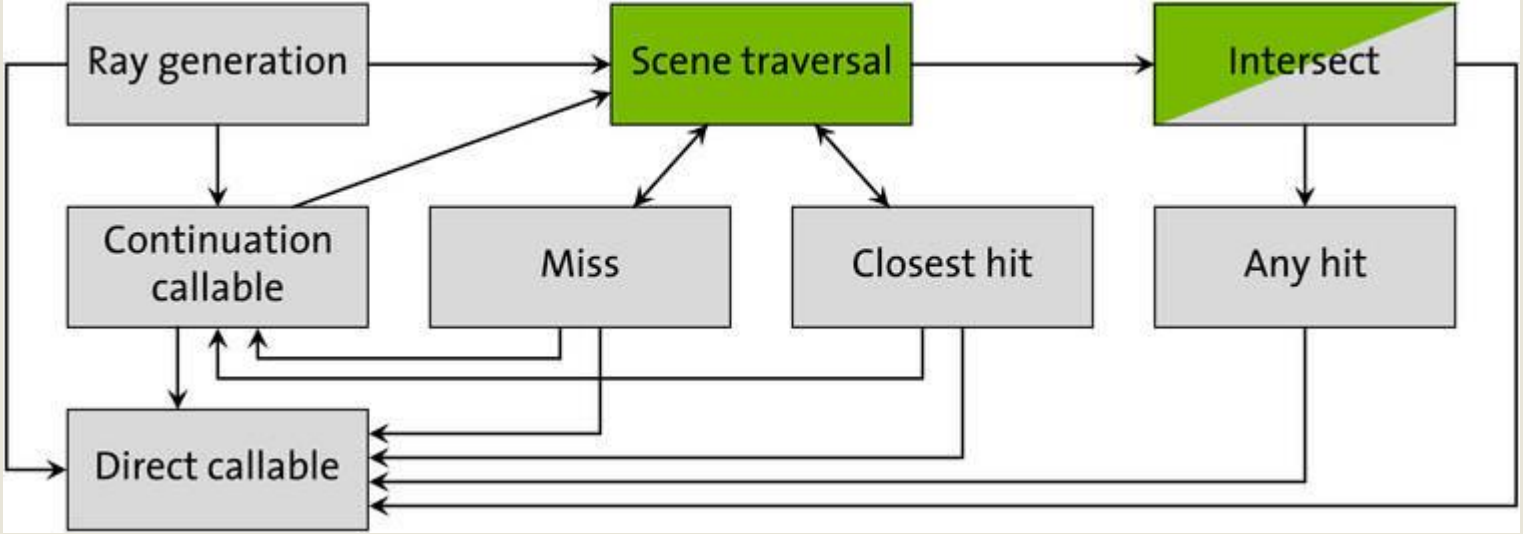
# Today

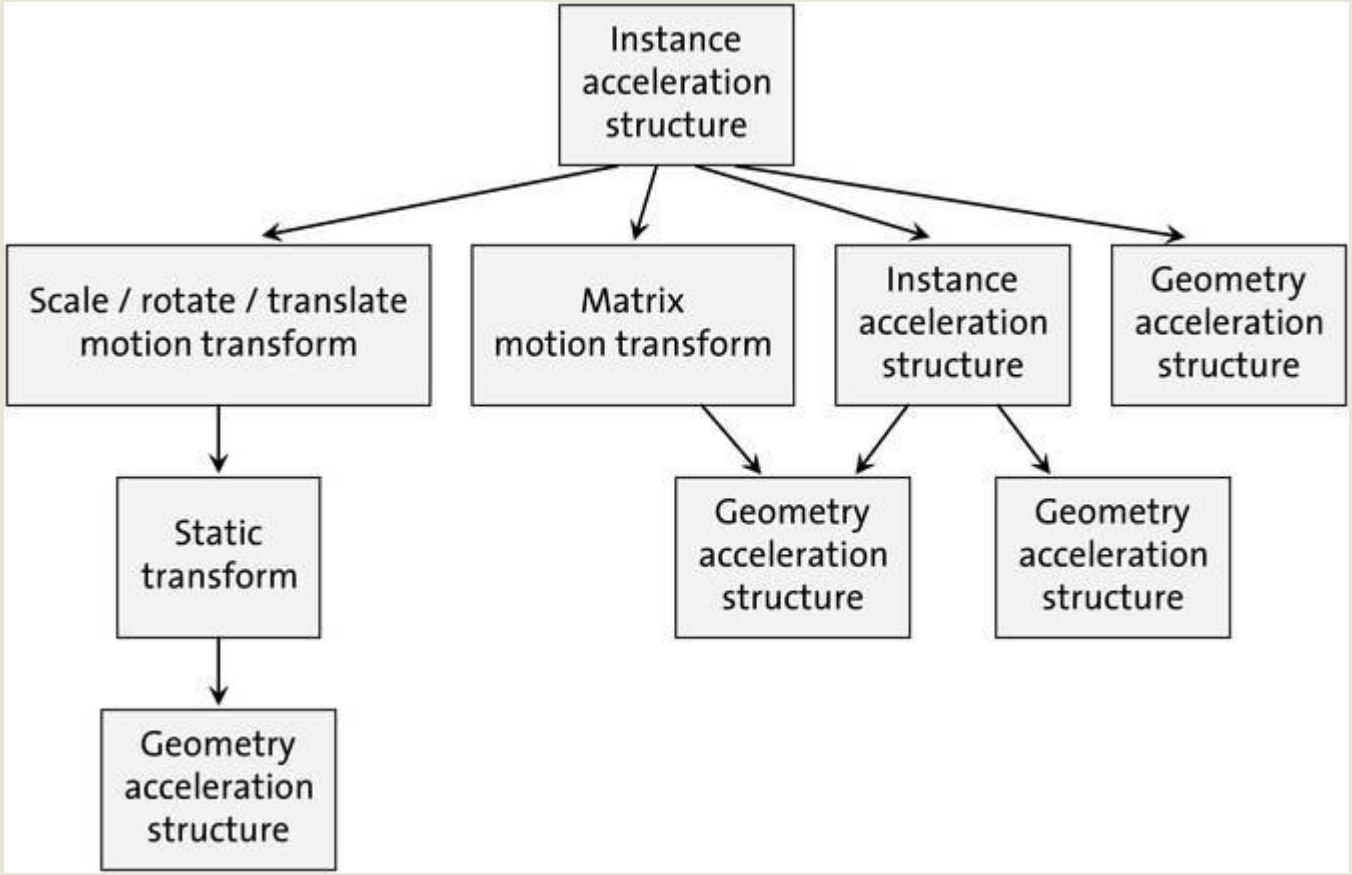
- Guest: Keith Morley
- Recap
- More BRDF
- Shadows

# Keith Morley

**Keith Morley** is currently a development technology engineer, responsible for helping key partners design and implement ray-tracing based solutions on NVIDIA GPUs. Keith joined NVIDIA after graduating from Princeton. In his ten years at the company, Keith focused on various ray-tracing efforts both as a research engineer and one of the original developers of the Optix API.

NVIDIA OptiX



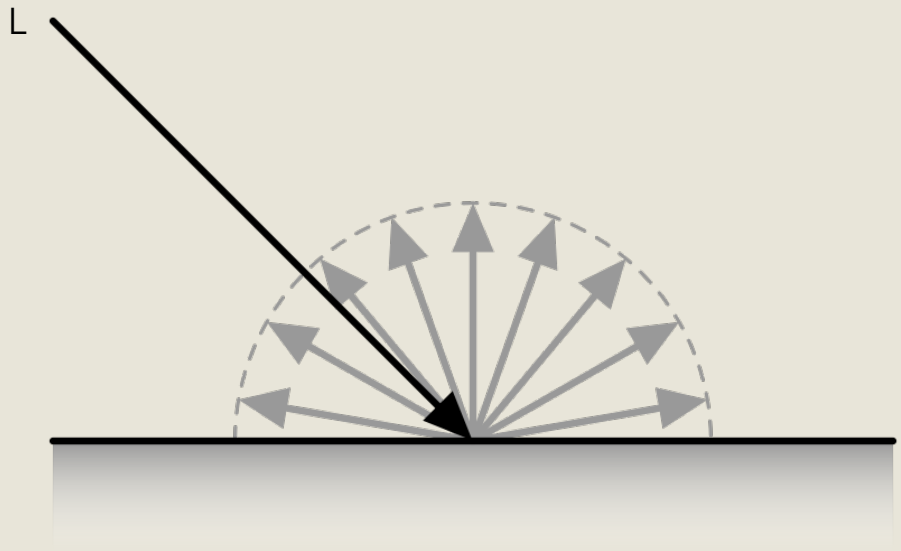

Instance acceleration structure
Scale / rotate / translate motion transform
Matrix motion transform
Instance acceleration structure
Geometry acceleration structure
Static transform
Geometry acceleration structure
Geometry acceleration structure
Geometry acceleration structure

# Housekeeping

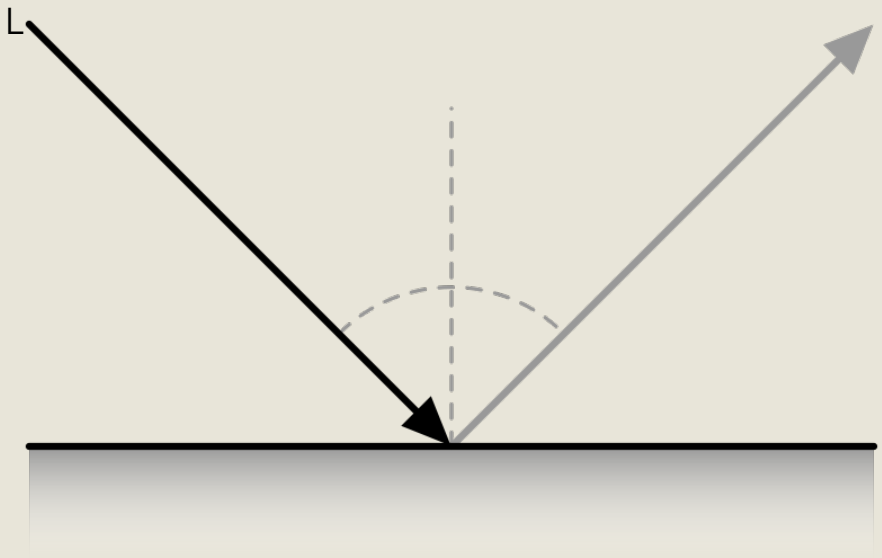
- Link to today's slides and shaderToys:
  - Log in to your google drive
  - Google drive folder: https://bit.ly/3viTHez
  - Code: https://www.shadertoy.com/user/xarmalarma
- Use the chat to ask questions, help others
- After the lecture: @xarmalarma, #siggraph2021

# Materials

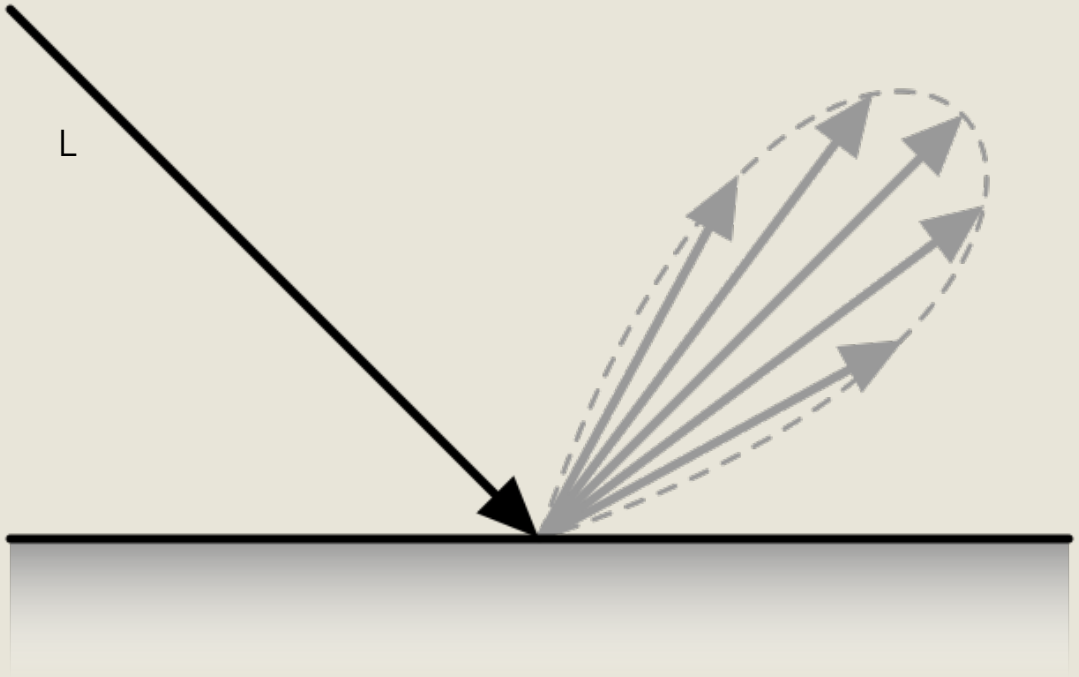
- So far our material is just a color and possibly a texture
- We have diffuse (Lambertian) surfaces



# Materials - Mirror

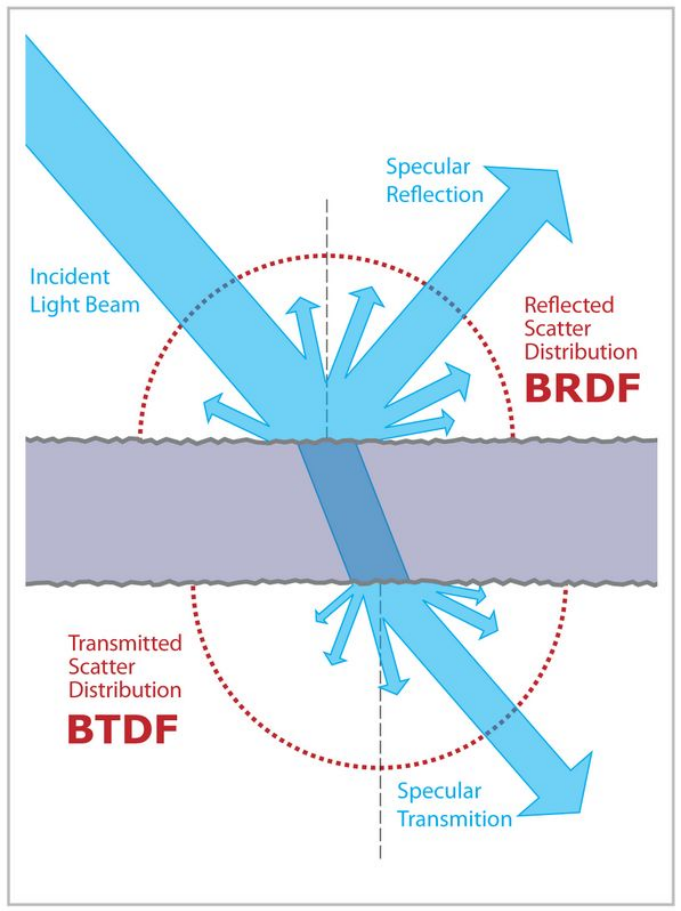


# Materials - Glossy



# Materials - Things can get complicated

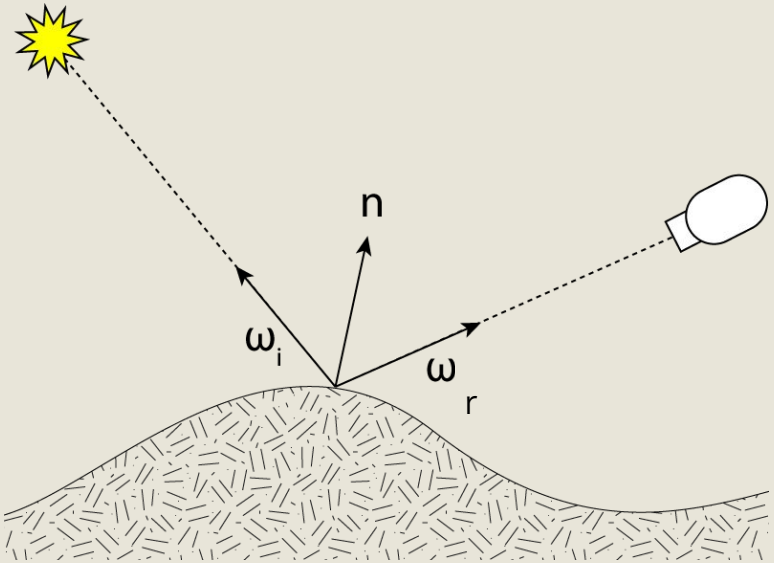
L




Mirror - Specular
Metal - Glossy
Skin - Subsurface
Glass - Transparent
Plaster, Paper - Diffuse

# Materials - Simplify

$$f_r(\omega_i, \omega_r) = \frac{\mathrm{d}\, L_r(\omega_r)}{\mathrm{d}\, E_i(\omega_i)} = \frac{\mathrm{d}\, L_r(\omega_r)}{L_i(\omega_i) \cos\theta_i \; \mathrm{d}\, \omega_i}$$

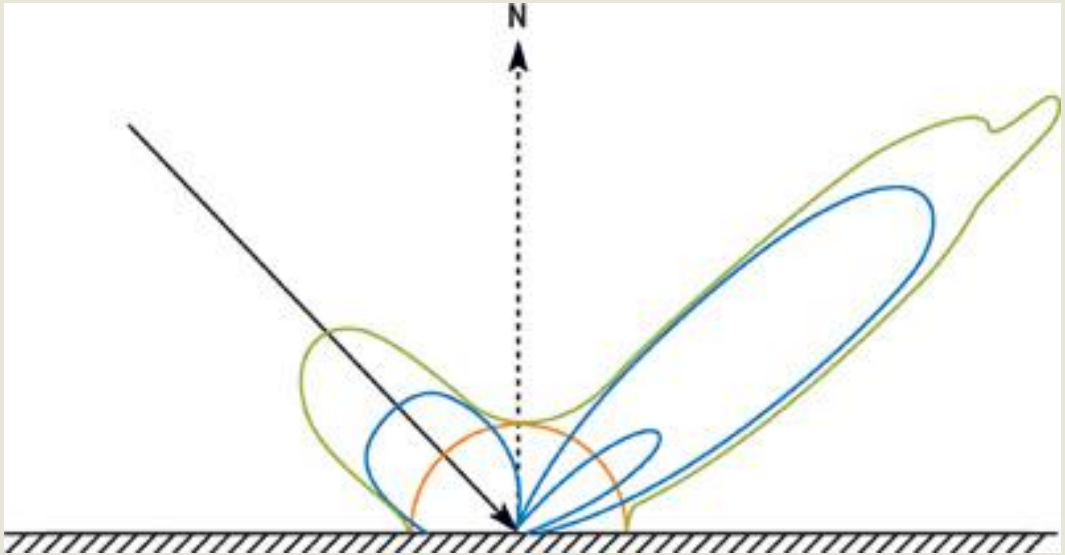



For Diffuse of Lambertian: $\omega_r$ doesn't matter

So, the BRDF in that case is simply the reciprocal of the dot product of normal and incident direction.

# Materials - BRDFs for different materials

$$f_r(\omega_i, \omega_r) = \frac{\mathrm{d}\, L_r(\omega_r)}{\mathrm{d}\, E_i(\omega_i)} = \frac{\mathrm{d}\, L_r(\omega_r)}{L_i(\omega_i) \cos\theta_i \;\mathrm{d}\,\omega_i}$$

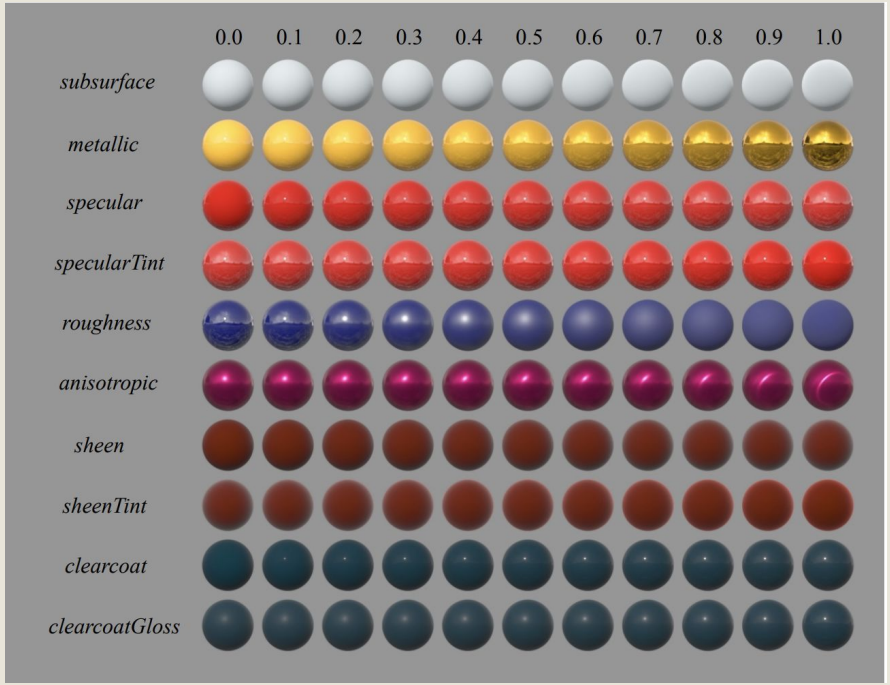



Multiple lobes

https://developer.nvidia.com/sites/all/modules/custom/gpugems/books/GPUGems/elementLinks/fig18-02.jpg

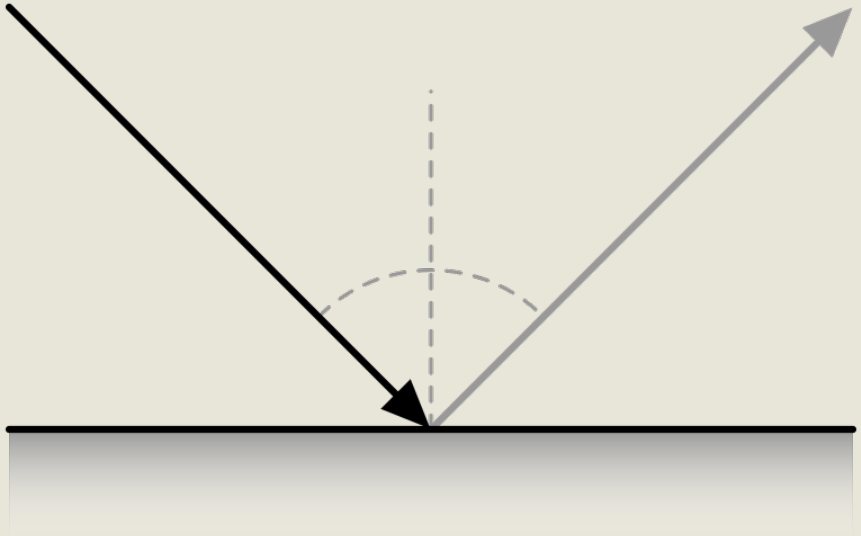
# Materials - BRDFs for different materials

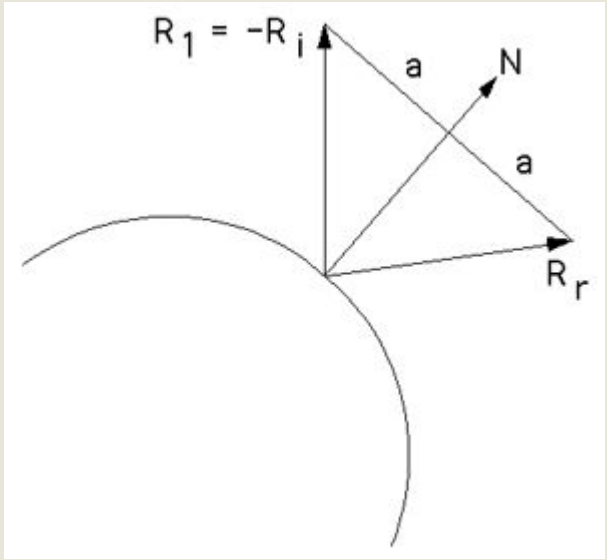
$$f_r(\omega_i, \omega_r) = \frac{\mathrm{d}\, L_r(\omega_r)}{\mathrm{d}\, E_i(\omega_i)} = \frac{\mathrm{d}\, L_r(\omega_r)}{L_i(\omega_i) \cos\theta_i \, \mathrm{d}\, \omega_i}$$




https://www.disneyanimation.com/publications/physically-based-shading-at-disney/

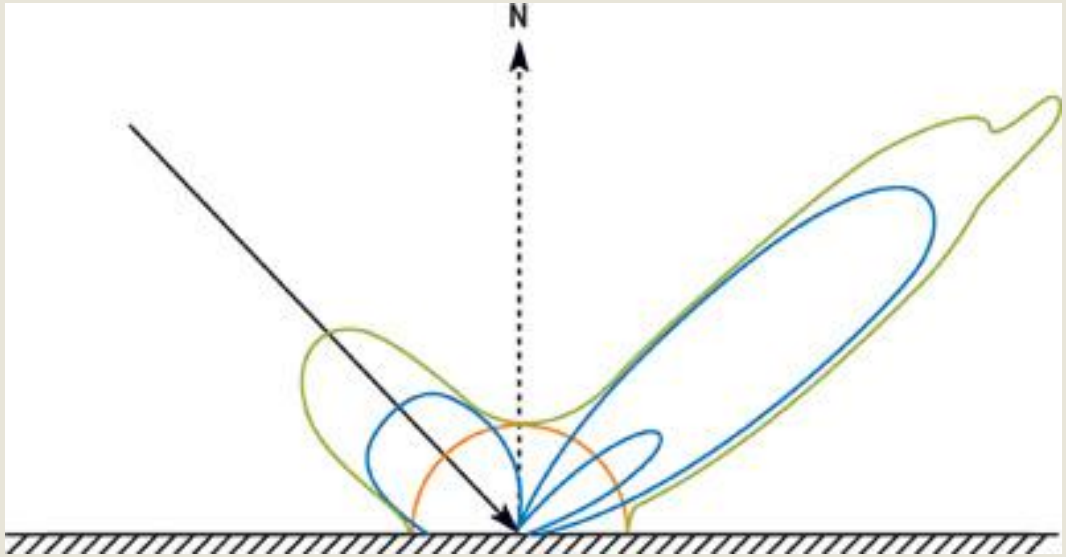
# Materials - Mirror



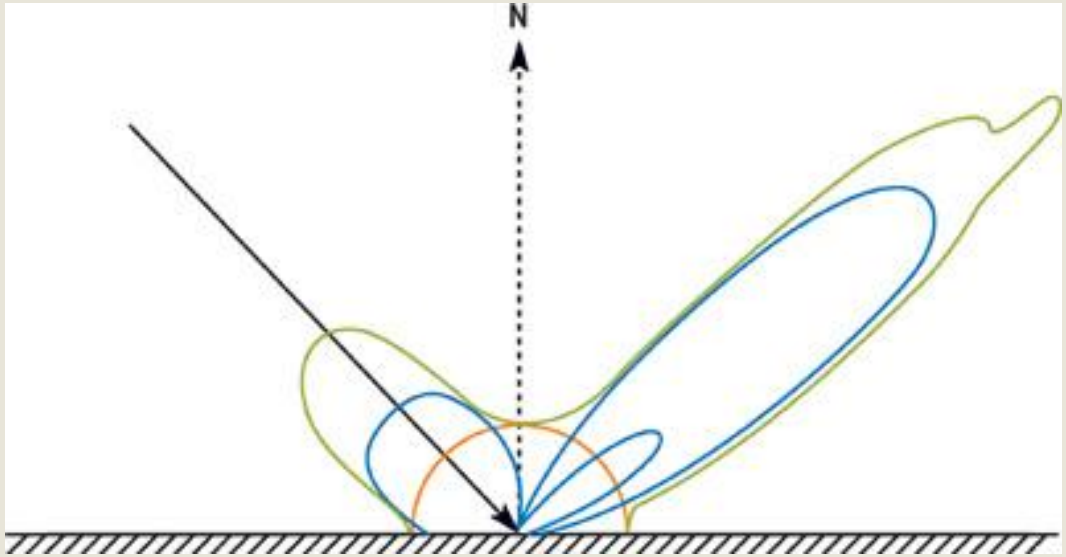



$$R_r = R_i - 2\,N\,(R_i \cdot N)$$

# Materials - Generalizing

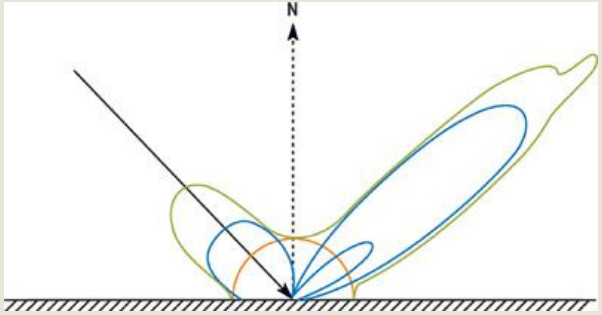


# Not enough to just compute the BRDF



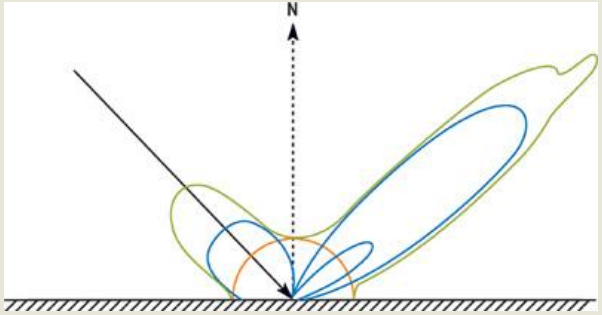
# Need to sample it!

- In the diffuse case we chose not to choose
- In the mirror case, we chose to ‘reflect’
- In other cases we have to choose the direction of outgoing ray



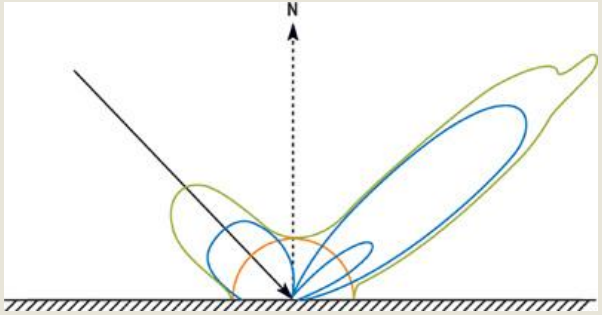
# Probability Density Function (PDF)

- Sample the distribution: get new direction
- Evaluate the BRDF
- Attenuate the result with the PDF



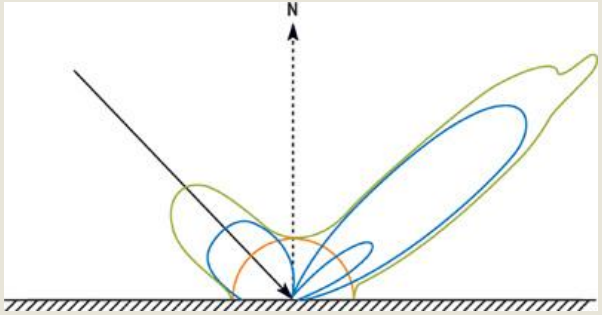
# Each sub-part of the BRDF has its own PDF

- Specular
- Diffuse
- etc.



# If we have multiple components we can..

- Choose one at equal probability on each hit
- Or use MIS by weighting the samples.



# Next Class

- Sampling the BRDF and lights
- Unifying everything, optimize
- Homework:
  - Try different materials on each sphere
  - @xarmalarma, #siggraph2021

# QUESTIONS?

- Chat
- #xarmalarma