Lecture 6:

Rendering

COSC 124 Lec

Computer Graphics

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IS THIS REAL?

This image was created by Gilles Tran with POV-Ray 3.6 using Radiosity. The glasses, ashtray and pitcher were modeled with Rhino and the dice with Cinema 4D.
(http://en.wikipedia.org/wiki/File:Glasses_800_edit.png)

WHAT IS RENDERING?

- **Rendering** is the process of generating an image from a ***model***, by means of computer programs.
- The model is a description of three-dimensional objects in a strictly defined language or data structure. It would contain geometry, viewpoint, texture, lighting, and shading information. The image is a digital image or raster graphics image.

WHAT IS RENDERING? (CONT.)

- The term may be by analogy with an "artist's rendering" of a scene. Rendering is also used to describe the process of calculating effects in a video editing file to produce final video output.
- It is one of the major sub-topics of 3D computer graphics, and in practice always connected to the others.

WHAT IS RENDERING? (CONT.)

- In the graphics pipeline, it is the last major step, giving the final appearance to the models and animation.
- Rendering has uses in architecture, video games, simulators, movie or TV special effects, and design visualization, each employing a different balance of features and techniques.

WHAT IS RENDERING? (CONT.)

- As a product, a wide variety of renderers are available. Some are integrated into larger modeling and animation packages, some are stand-alone, some are free open-source projects.
- On the inside, a renderer is a carefully engineered program, based on a selective mixture of disciplines related to: light physics, visual perception, mathematics, and software development.

WHAT IS RENDERING? (CONT.)

- In the case of 3D graphics, rendering may be done slowly, as in pre-rendering, or in real time.
- ***Pre-rendering*** is a computationally intensive process that is typically used for movie creation, while ***real-time rendering*** is often done for 3D video games which rely on the use of graphics cards with 3D hardware accelerators.

ALGORITHMS & TECHNIQUES OF RENDERING

- When the pre-image (a wireframe sketch usually) is complete, rendering is used, which adds in bitmap textures or procedural textures, lights, bump mapping, and relative position to other objects. The result is a completed image the consumer or intended viewer sees.
- For movie animations, several images (frames) must be rendered, and stitched together in a program capable of making an animation of this sort. Most 3D image editing programs can do this.

ALGORITHMS & TECHNIQUES OF RENDERING (CONT.)

1. **shading** — how the color and brightness of a surface varies with lighting
2. **texture-mapping** — a method of applying detail to surfaces
3. **bump-mapping** — a method of simulating small-scale bumpiness on surfaces
4. **fogging/participating medium** — how light dims when passing through non-clear atmosphere or air
5. **shadows** — the effect of obstructing light

ALGORITHMS & TECHNIQUES OF RENDERING (CONT.)

6. **soft shadows** — varying darkness caused by partially obscured light sources
7. **reflection** — mirror-like or highly glossy reflection
8. **transparency or opacity** — sharp transmission of light through solid objects
9. **translucency** — highly scattered transmission of light through solid objects
10. **refraction** — bending of light associated with transparency

ALGORITHMS & TECHNIQUES OF RENDERING (CONT.)

11. **diffraction** — bending, spreading and interference of light passing by an object or aperture that disrupts the ray
12. **indirect illumination** — surfaces illuminated by light reflected off other surfaces, rather than directly from a light source (also known as global illumination)
13. **caustics (a form of indirect illumination)** — reflection of light off a shiny object, or focusing of light through a transparent object, to produce bright highlights on another object

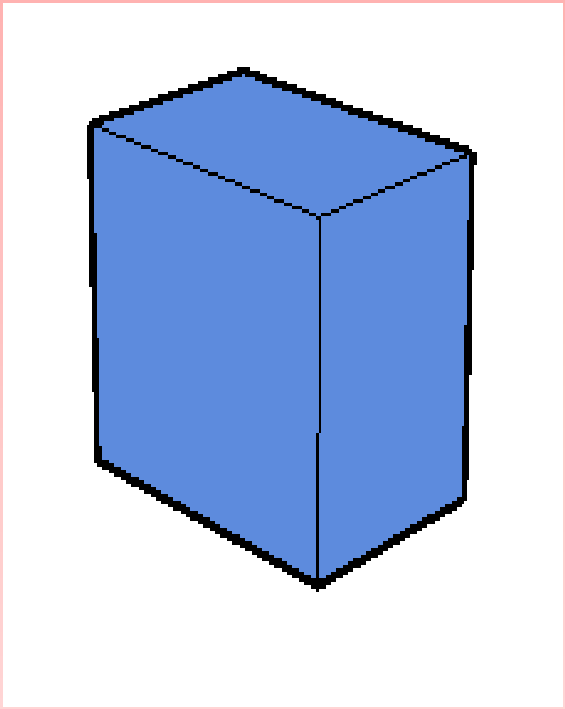
ALGORITHMS & TECHNIQUES OF RENDERING (CONT.)

14. **depth of field** — objects appear blurry or out of focus when too far in front of or behind the object in focus motion
15. **blur** — objects appear blurry due to high-speed motion, or the motion of the camera
16. **non-photorealistic rendering** — rendering of scenes in an artistic style, intended to look like a painting or drawing

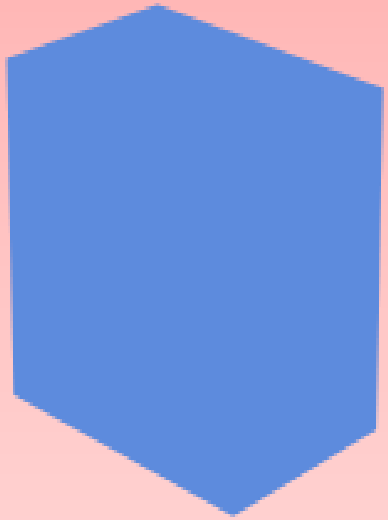
SHADING

- **Shading** refers to depicting depth perception in 3D models or illustrations by varying levels of darkness.
- In computer graphics, **Shading** refers to the process of altering a color based on its angle to lights and its distance from lights to create a photorealistic effect. Shading is performed during the rendering process.
- For a list of common shading algorithms, visit ***http://en.wikipedia.org/wiki/Shading_model***

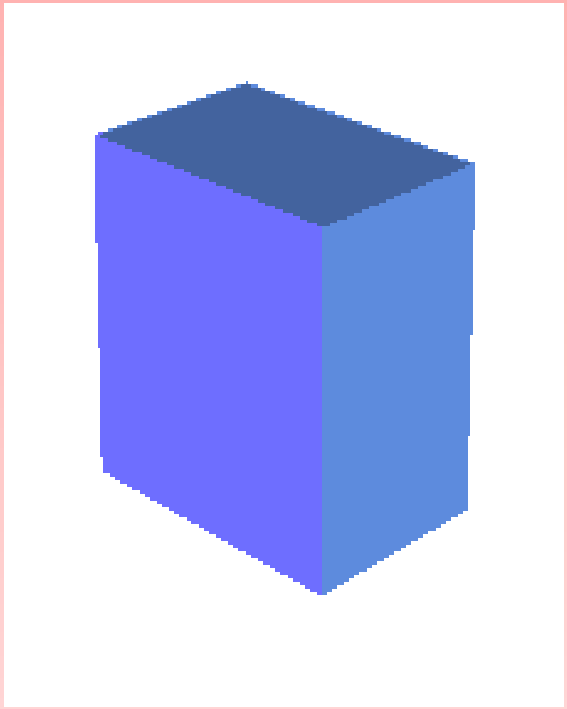
SHADING (CONT.)



Rendered image of a box. This image has no shading on its faces, but uses edge lines to separate the faces.

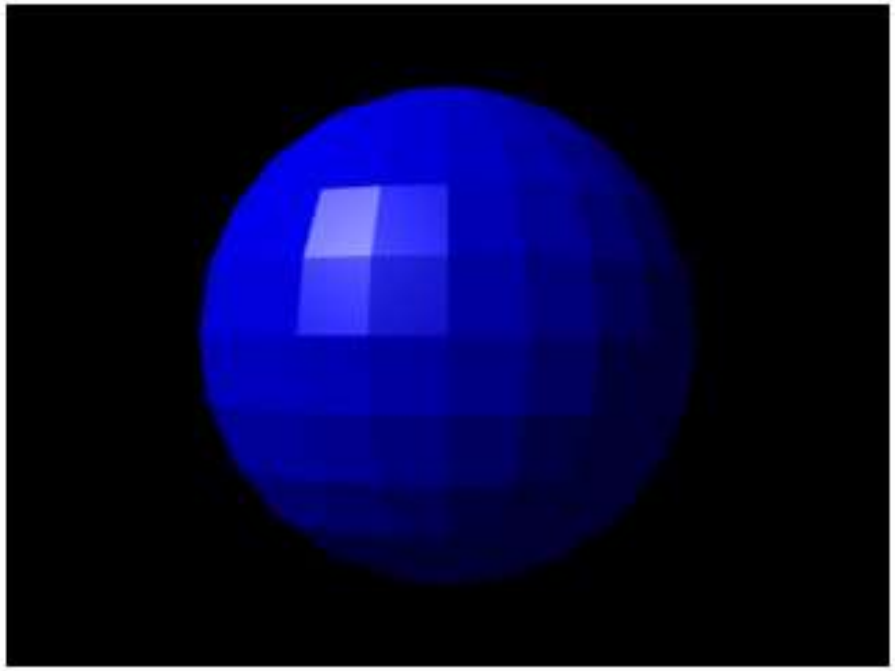


This is the same image with the edge lines removed.

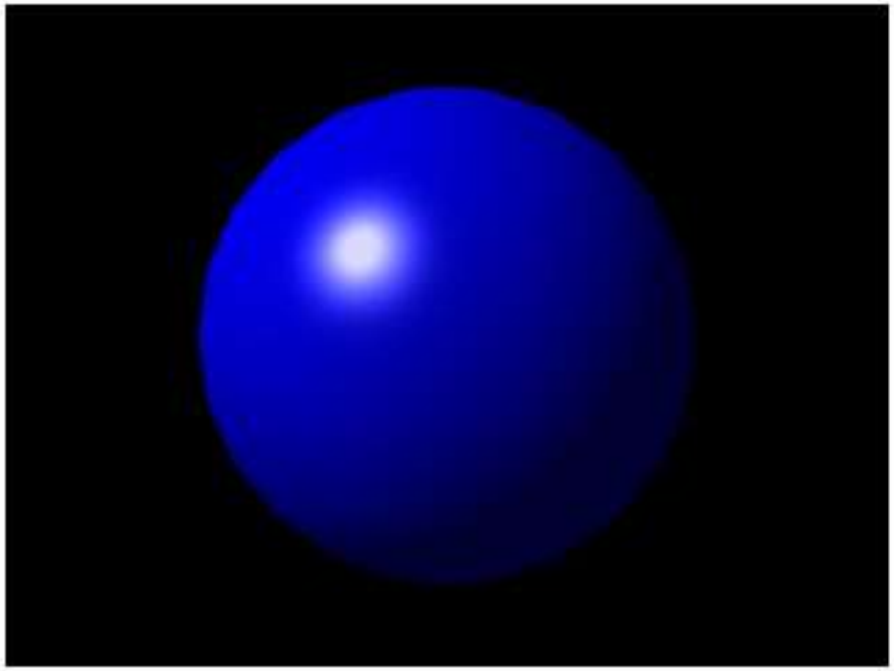


This is the same image rendered with shading of the faces to alter the colors of the 3 faces based on their angle to the light sources.

SHADING (CONT.)



FLAT SHADING



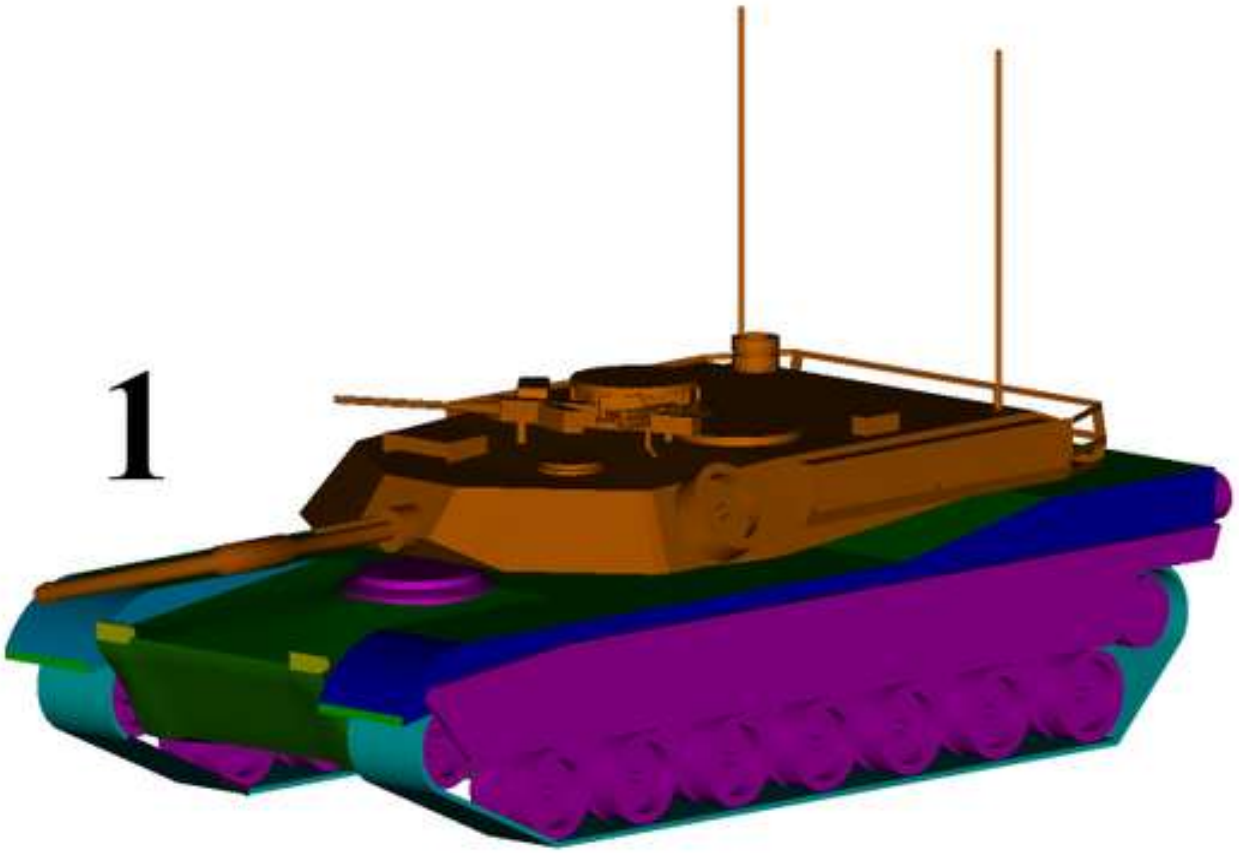
PHONG SHADING

TEXTURE MAPPING

- **Texture mapping** is a method for adding detail, surface texture (a bitmap or raster image), or color to a computer-generated graphic or 3D model. Its application to 3D graphics was pioneered by Dr Edwin Catmull in his Ph.D. thesis of 1974.
- A **texture map** is applied (mapped) to the surface of a shape or polygon. This process is akin to applying patterned paper to a plain white box.

Textured vs Non-textured 3D Model of a M1A2 Abrams

1

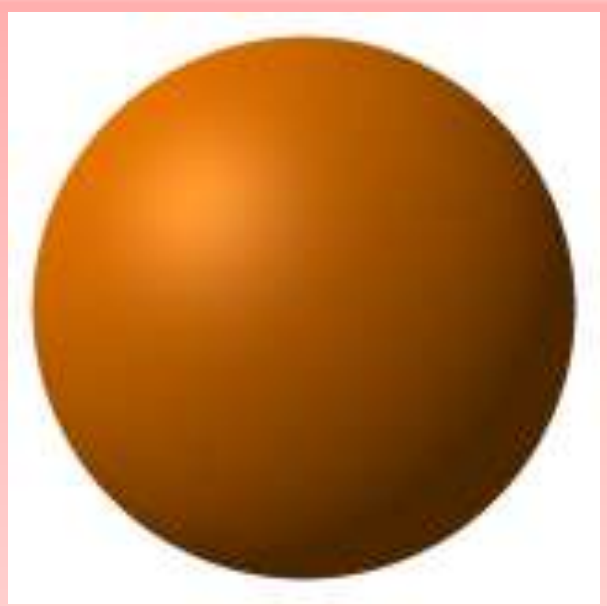


2

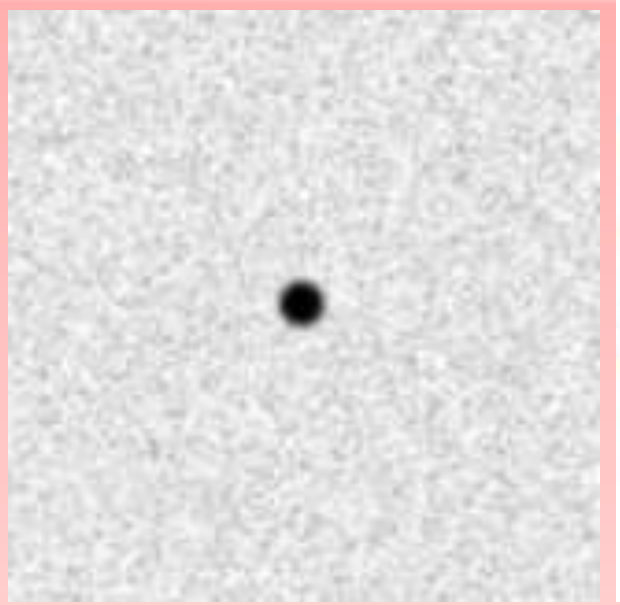
BUMP MAPPING

- Bump mapping is a computer graphics technique to make a rendered surface look more realistic by modeling the interaction of a bumpy surface texture with lights in the environment. Bump mapping does this by changing the brightness of the pixels on the surface in response to a heightmap that is specified for each surface.
- A **heightmap** or **heightfield** is a raster image used to store values, such as surface elevation data, for display in 3D computer graphics.

BUMP MAPPING (CONT.)



A sphere without bump mapping.



The bump map that will be applied to the sphere.

This sphere is geometrically the same as the first, but has a bump map applied.

DISTANCE FOG

- **Distance fog** is a technique used in 3D computer graphics to enhance the perception of distance by simulating fog.

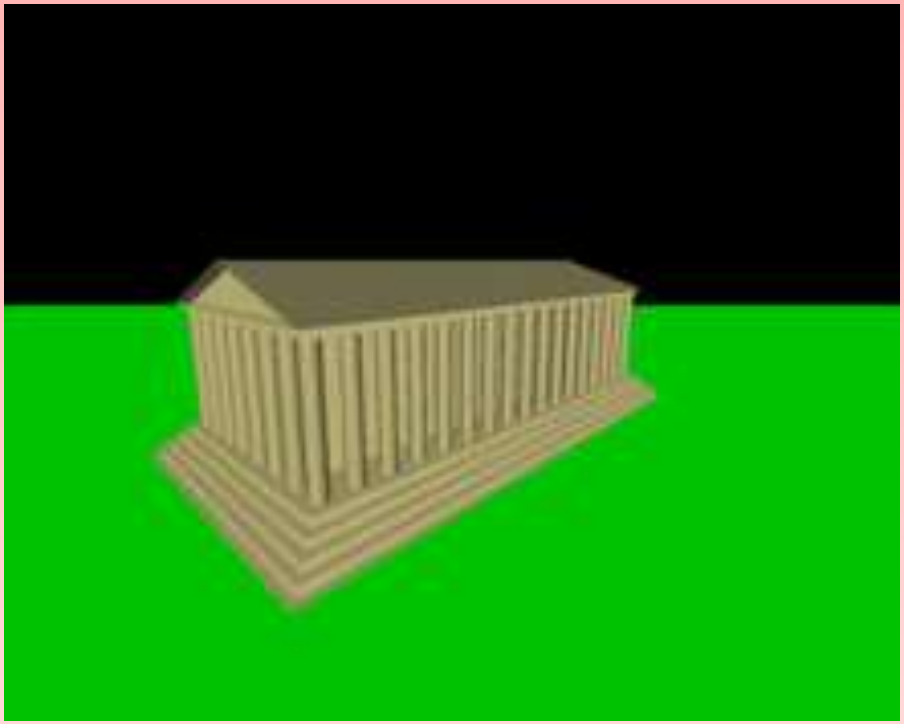
SHADOW MAPPING

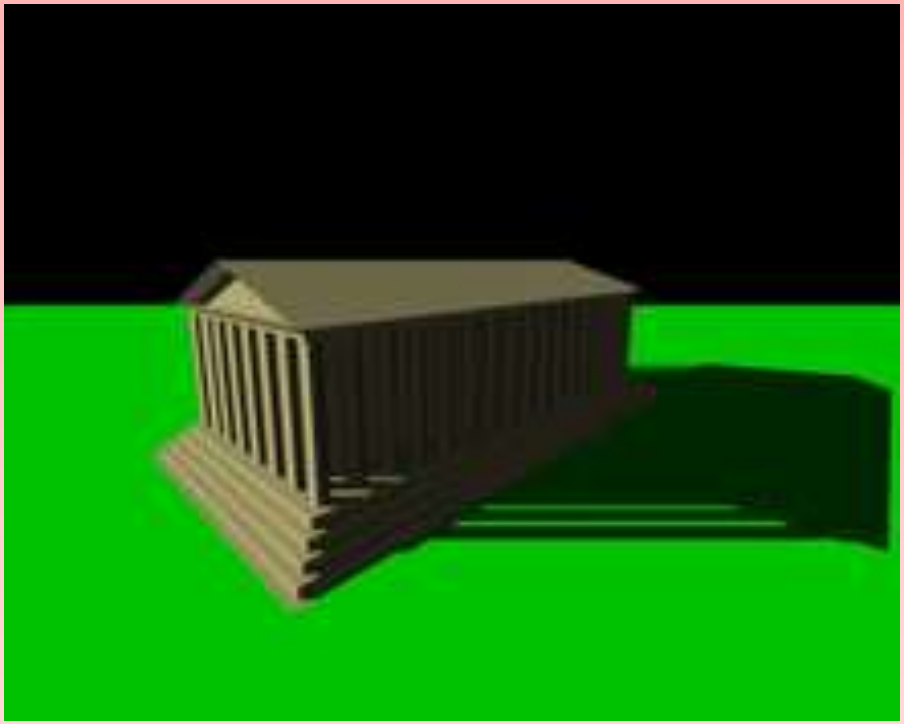
- **Shadow mapping** or **projective shadowing** is a process by which shadows are added to 3D computer graphics.
- This concept was introduced by Lance Williams in 1978, in a paper entitled "Casting curved shadows on curved surfaces". Since then, it has been used both in pre-rendered scenes, in real-time, even in many console and high-end PC games.

SHADOW MAPPING (CONT.)

- Shadows are created by testing whether a pixel is visible from the light source, by comparing it to a z-buffer or *depth* image of the light source's view, stored in the form of a texture.
- Shadow mapping is used by Pixar's RenderMan, and likewise, shadow mapping has been used in such films as *Toy Story*.

SHADOW MAPPING (CONT.)





REFLECTION

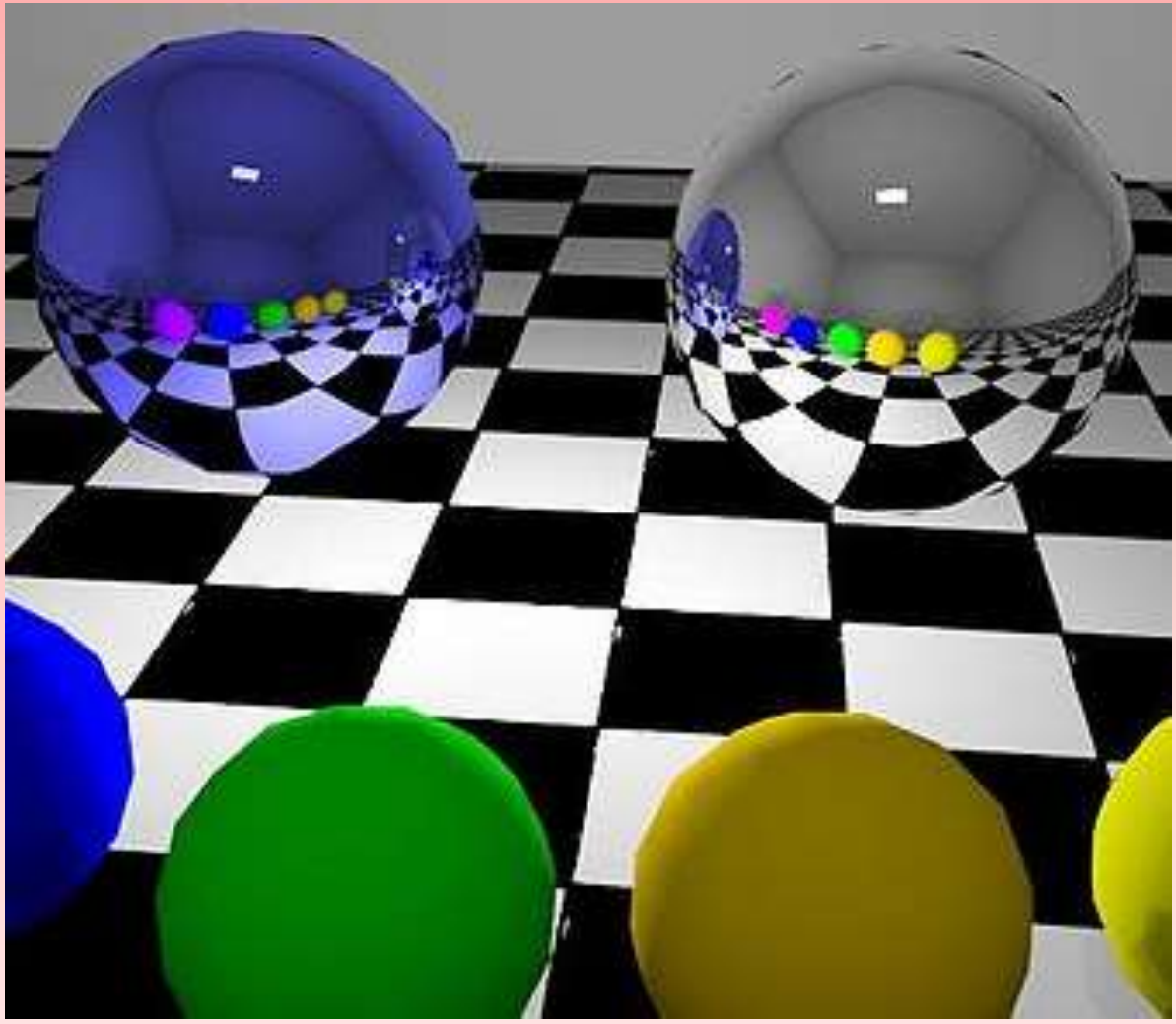
- **Reflection** in computer graphics is used to emulate reflective objects like mirrors and shiny surfaces.
- Reflection is accomplished in a ray trace renderer by following a ray from the eye to the mirror and then calculating where it bounces from, and continuing the process until no surface is found, or a non-reflective surface is found. Reflection on a shiny surface like wood or tile can add to the photorealistic effects of a 3D rendering.

REFLECTION (CONT.)

- **Polished** - A Polished Reflection is an undisturbed reflection, like a mirror or chrome. Mirrors are usually almost 100% reflective.

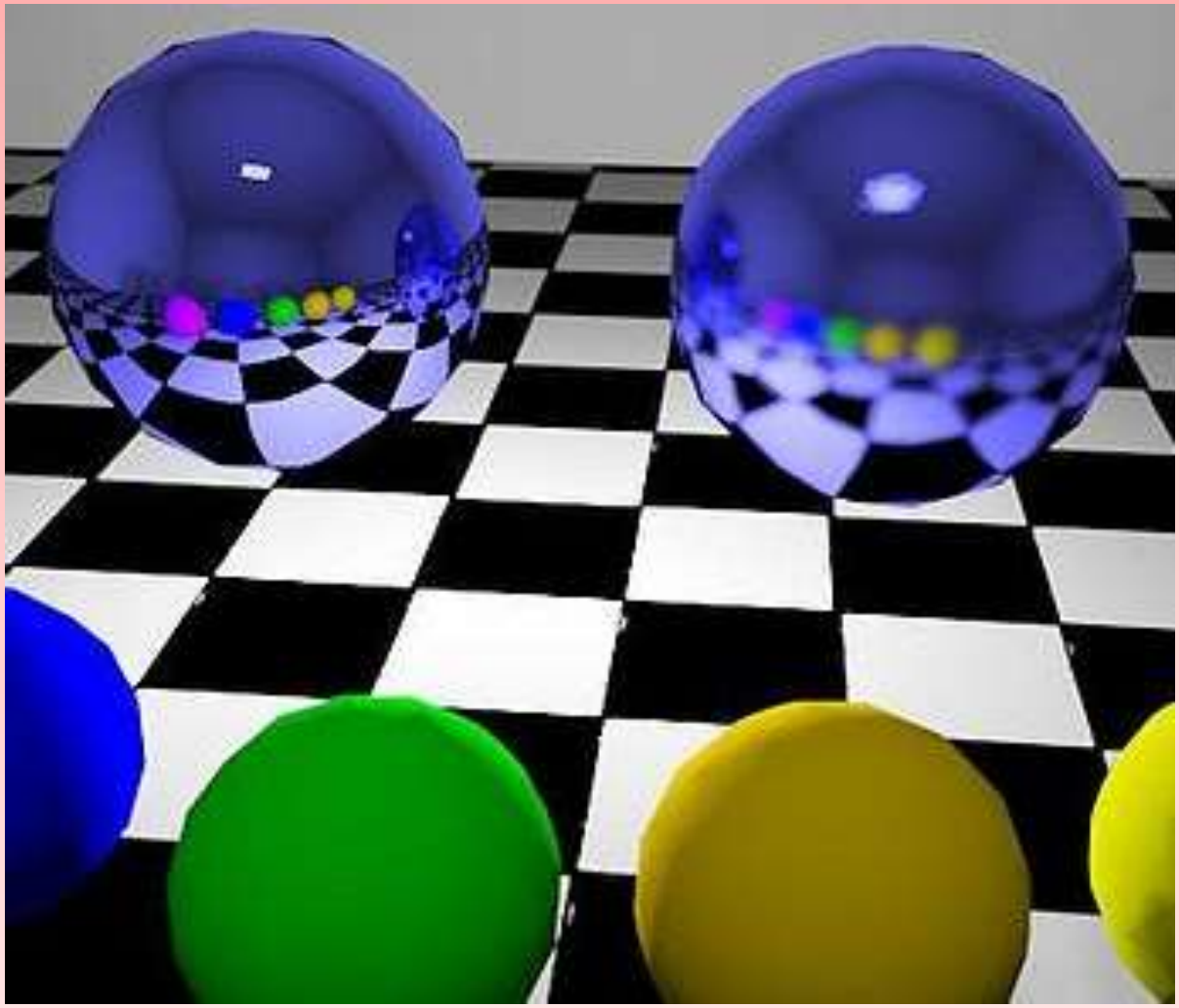
REFLECTION (CONT.)

- **Metallic** - A reflection is Metallic if the highlights and reflections retain the color of the reflective object.



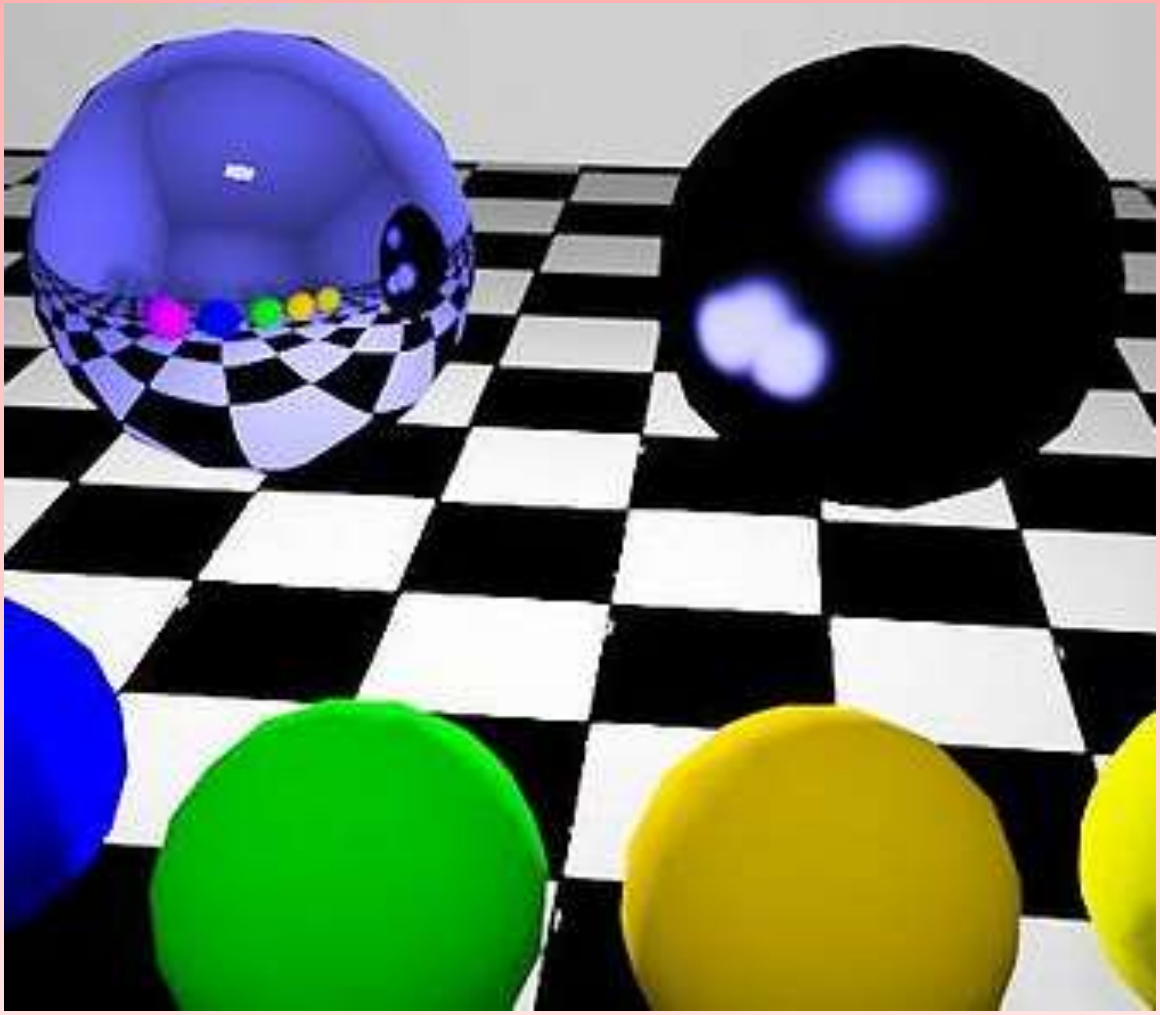
REFLECTION (CONT.)

- **Blurry** - A Blurry Reflection means that tiny random bumps on the surface of the material cause the reflection to be blurry.



REFLECTION (CONT.)

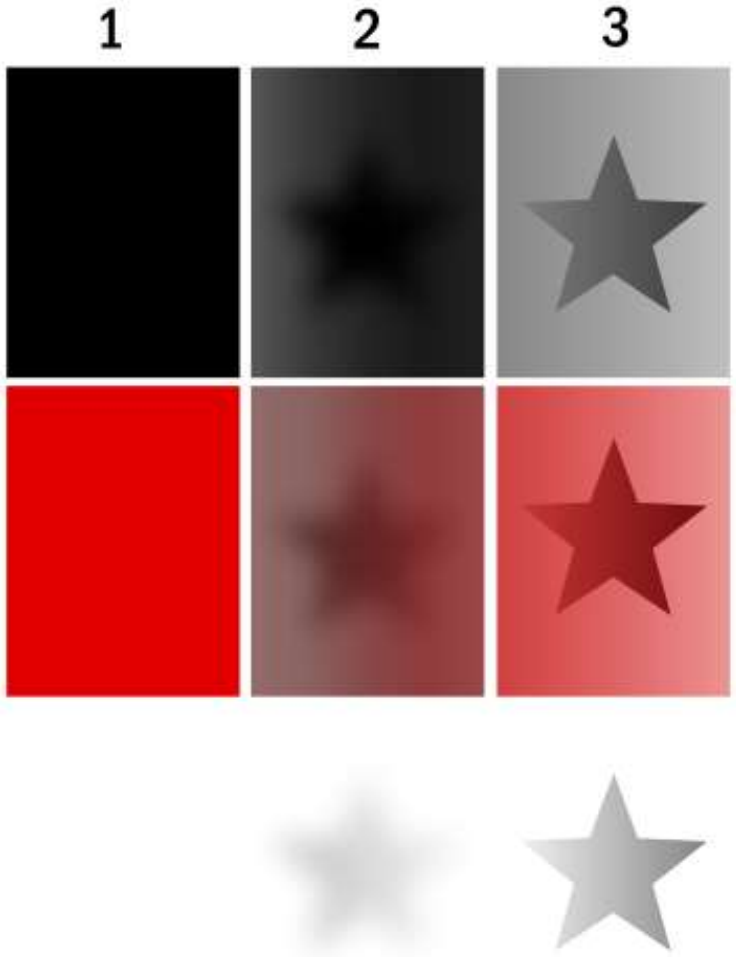
- **Glossy** - Fully glossy reflection, shows highlights from light sources, but does not show a cleat reflection from objects.



TRANSPARENCY & TRANSLUCENCY

- **Transparency**) is the physical property of allowing light to pass through a material.
- **Translucency** only allows light to pass through diffusely.
- The opposite property is **opacity**.
- Transparent materials are clear, while translucent ones cannot be seen through clearly.

TRANSPARENCY & TRANSLUCENCY (CONT.)

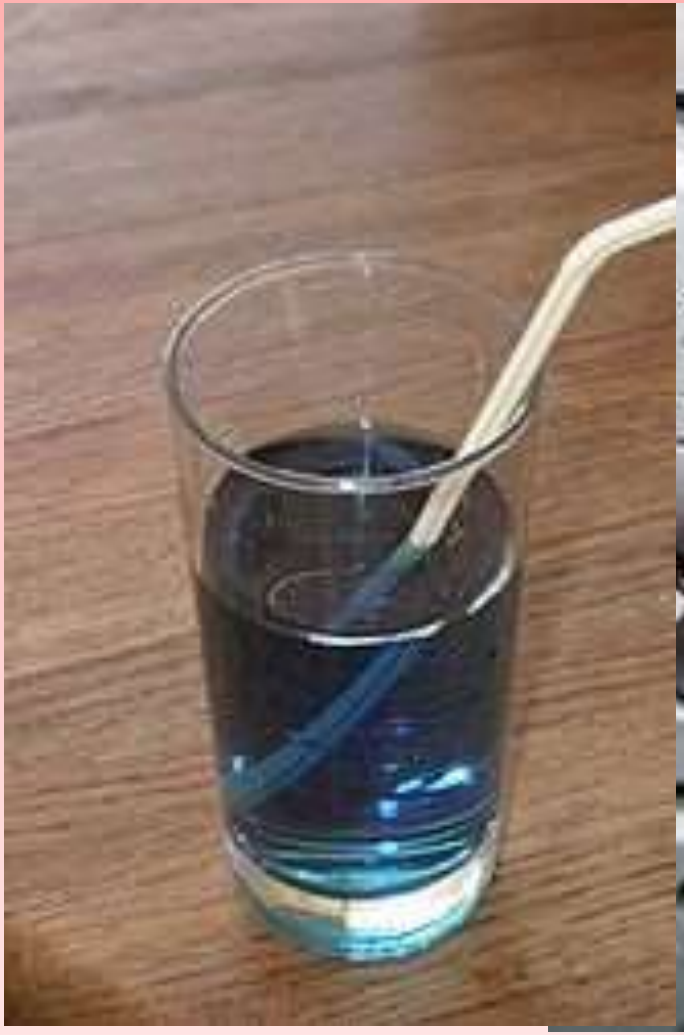


Comparisons of

1. opacity,
2. translucency, and
3. transparency;

behind each panel is a star

REFRACTION



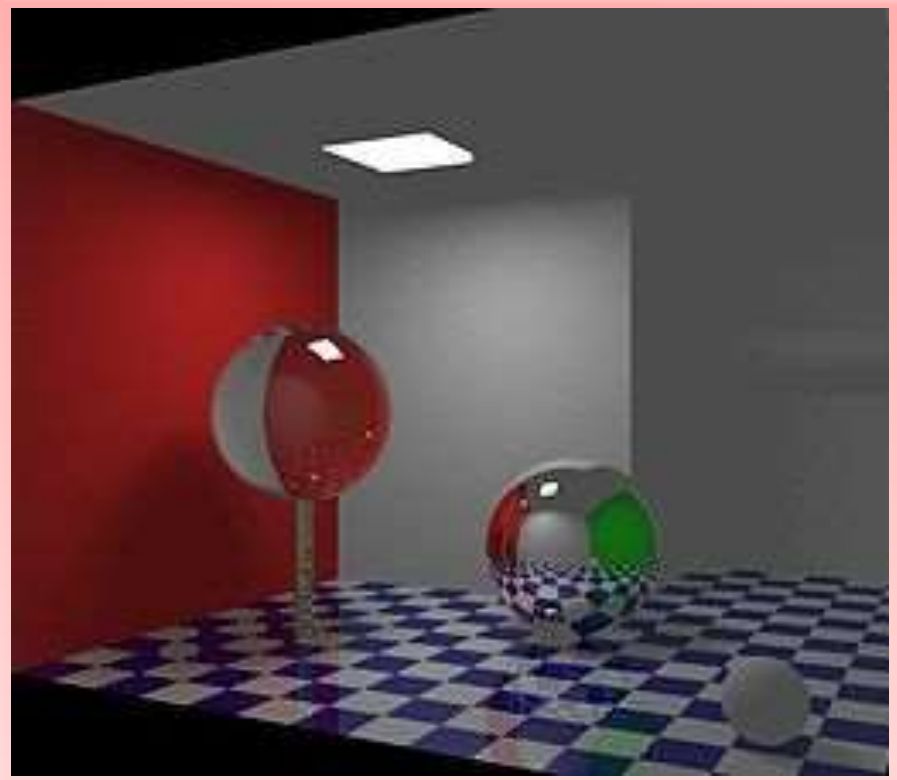
GLOBAL ILLUMINATION

- **Global illumination** is a general name for a group of algorithms used in 3D computer graphics that are meant to add more realistic lighting to 3D scenes. Such algorithms take into account not only the light which comes directly from a light source (*direct illumination*), but also subsequent cases in which light rays from the same source are reflected by other surfaces in the scene, whether reflective or non (*indirect illumination*).

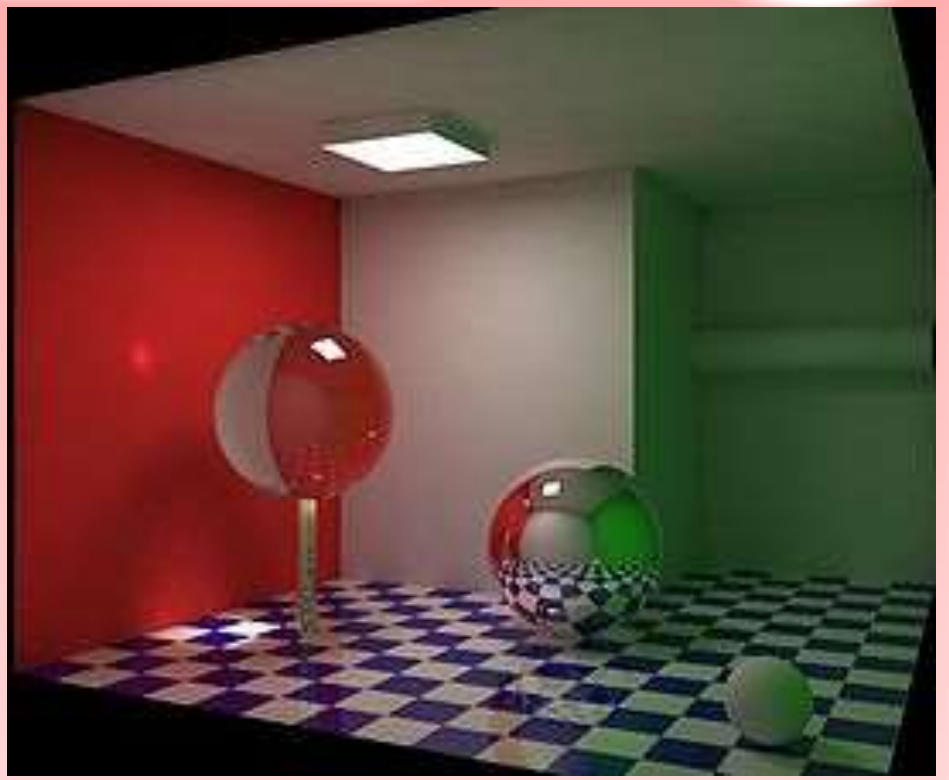
GLOBAL ILLUMINATION (CONT.)

- Radiosity, ray tracing, beam tracing, cone tracing, path tracing, Metropolis light transport, ambient occlusion, photon mapping, and image based lighting are examples of algorithms used in global illumination, some of which may be used together to yield results that are fast, but accurate.

GLOBAL ILLUMINATION (CONT.)



Rendering without global illumination.



Rendering with global illumination.

CAUSTICS

- A **caustic** is the envelope of light rays reflected or refracted by a curved surface or object, or the projection of that envelope of rays on another surface. *Caustic* can also refer to the curve to which light rays are tangent, defining a boundary of an envelope of rays as a curve of concentrated light.

CAUSTICS (CONT.)

- A common situation where caustics are visible is when light shines on a drinking glass. The glass casts a shadow, but also produces a curved region of bright light.

CAUSTICS (CONT.)

- Another familiar caustic is the rainbow. Scattering of light by raindrops causes different wavelengths of light to be seen in arcs of differing radius.
- In computer graphics, most modern rendering systems support caustics. Some of them even support volumetric caustics. This is accomplished by raytracing the possible paths of the light beam through the glass, accounting for the refraction and reflection. Photon mapping is one implementation of this.

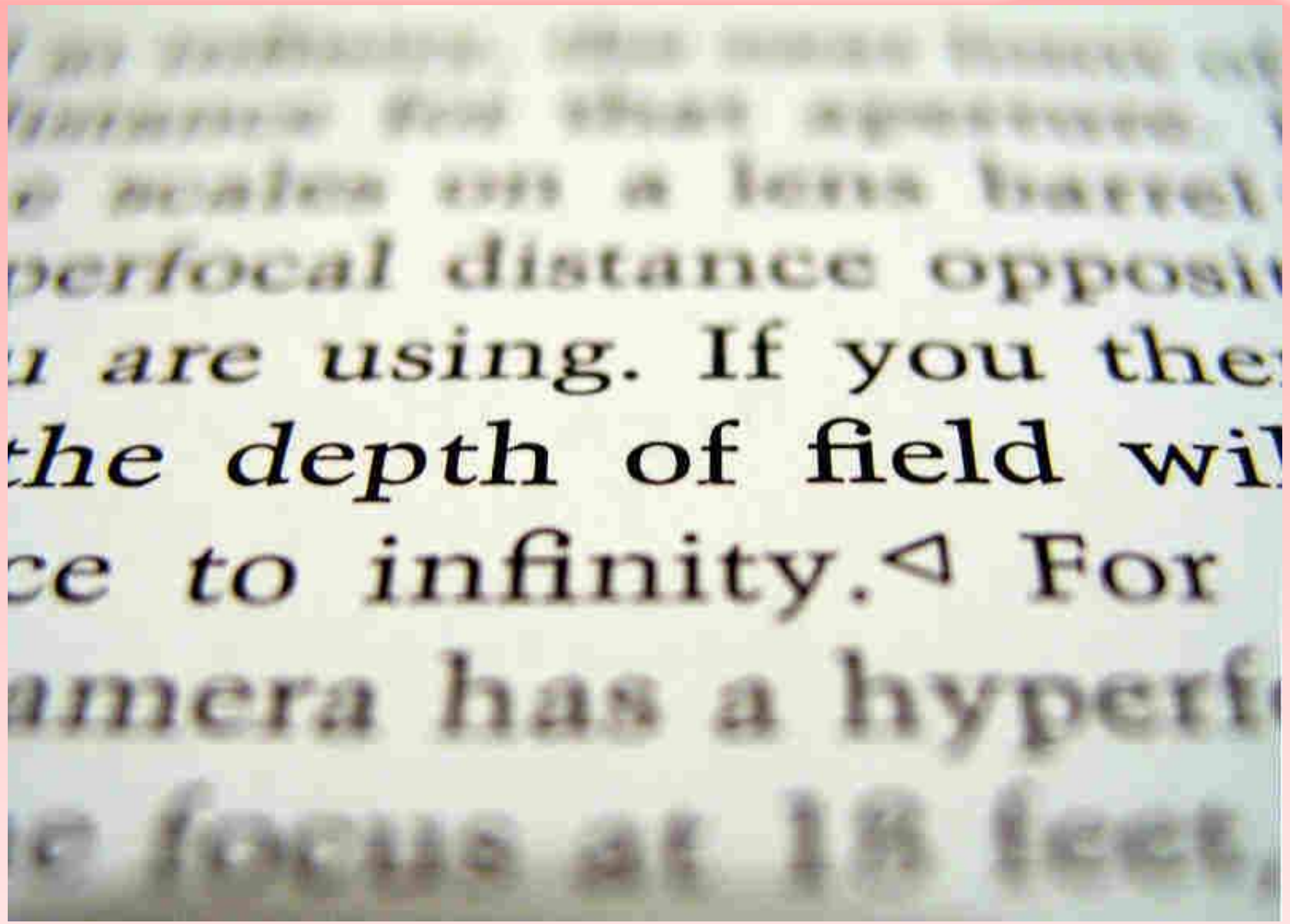
CAUSTICS (CONT.)

Computer-generated image showing caustic lighting

DEPTH OF FIELD

- In optics, particularly as relates to film and photography, the **depth of field** (DOF) is the portion of a scene that appears acceptably sharp in the image. Although a lens can precisely focus at only one distance, the decrease in sharpness is gradual on each side of the focused distance, so that within the DOF, the unsharpness is imperceptible under normal viewing conditions.

DEPTH OF FIELD (CONT.)



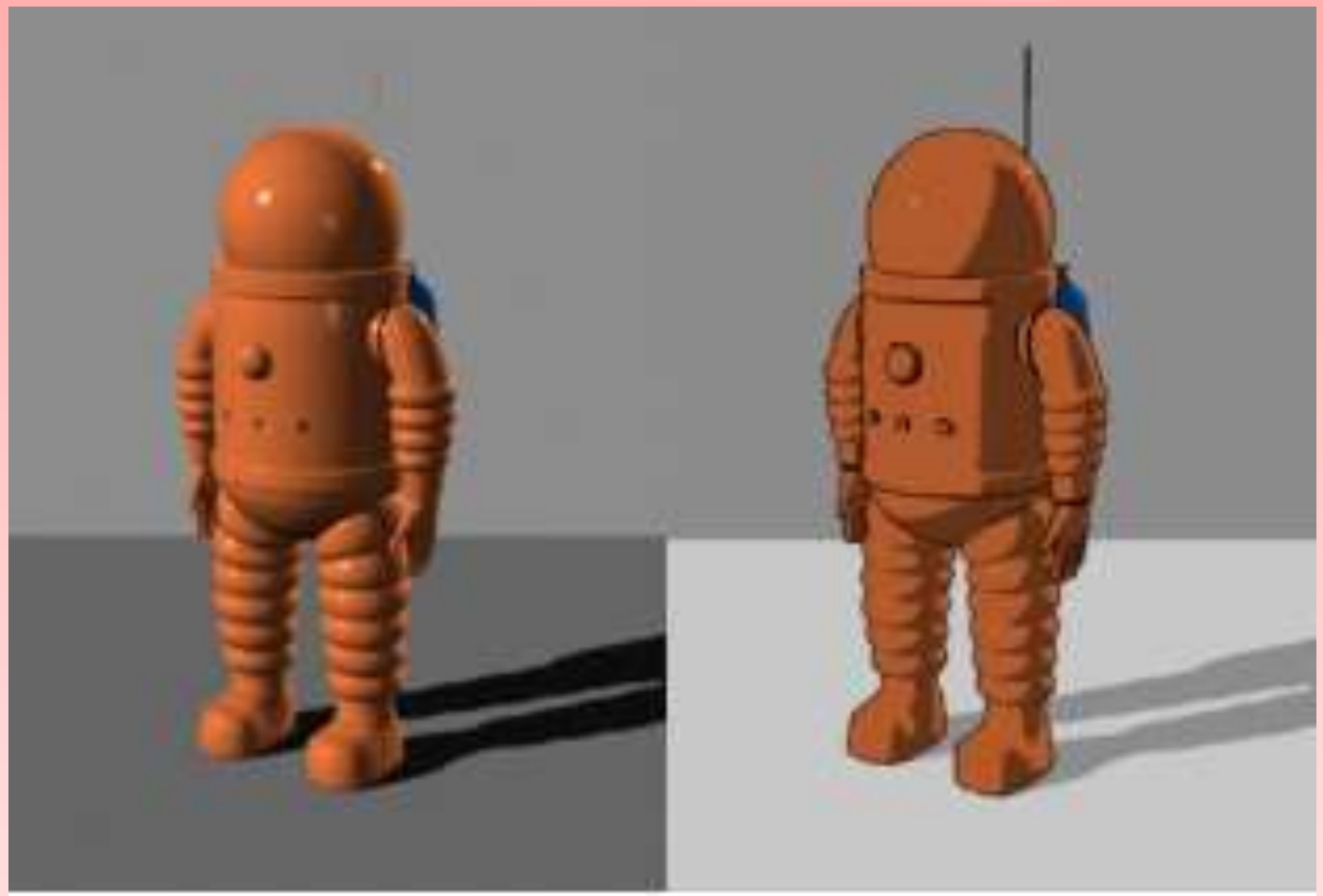
MOTION BLUR

- **Motion blur** is the apparent streaking of rapidly moving objects in a still image or a sequence of images such as a movie or animation.

NON-PHOTOREALISTIC RENDERING

- **Non-photorealistic rendering** (NPR) is an area of computer graphics that focuses on enabling a wide variety of expressive styles for digital art.
- In contrast to traditional computer graphics, which has focused on photorealism, NPR is inspired by artistic styles such as painting, drawing, technical illustration, and animated cartoons.

NON-PHOTOREALISTIC RENDERING (CONT.)

- NPR has appeared in movies and video games in the form of "toon shaders," as well as in architectural illustration and experimental animation. An example of a modern use of this method is that of Cel-shaded animation.
- **Cel-shaded animation** (also called **cel-shading** or **toon shading**) is a type of non-photorealistic rendering designed to make computer graphics appear to be hand-drawn. Cel-shading is often used to mimic the style of a comic book or cartoon.

NON-PHOTOREALISTIC RENDERING (CONT.)