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Ray-tracing

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Today we will have a look at ray-tracing which can be used to generate extremely realistic images

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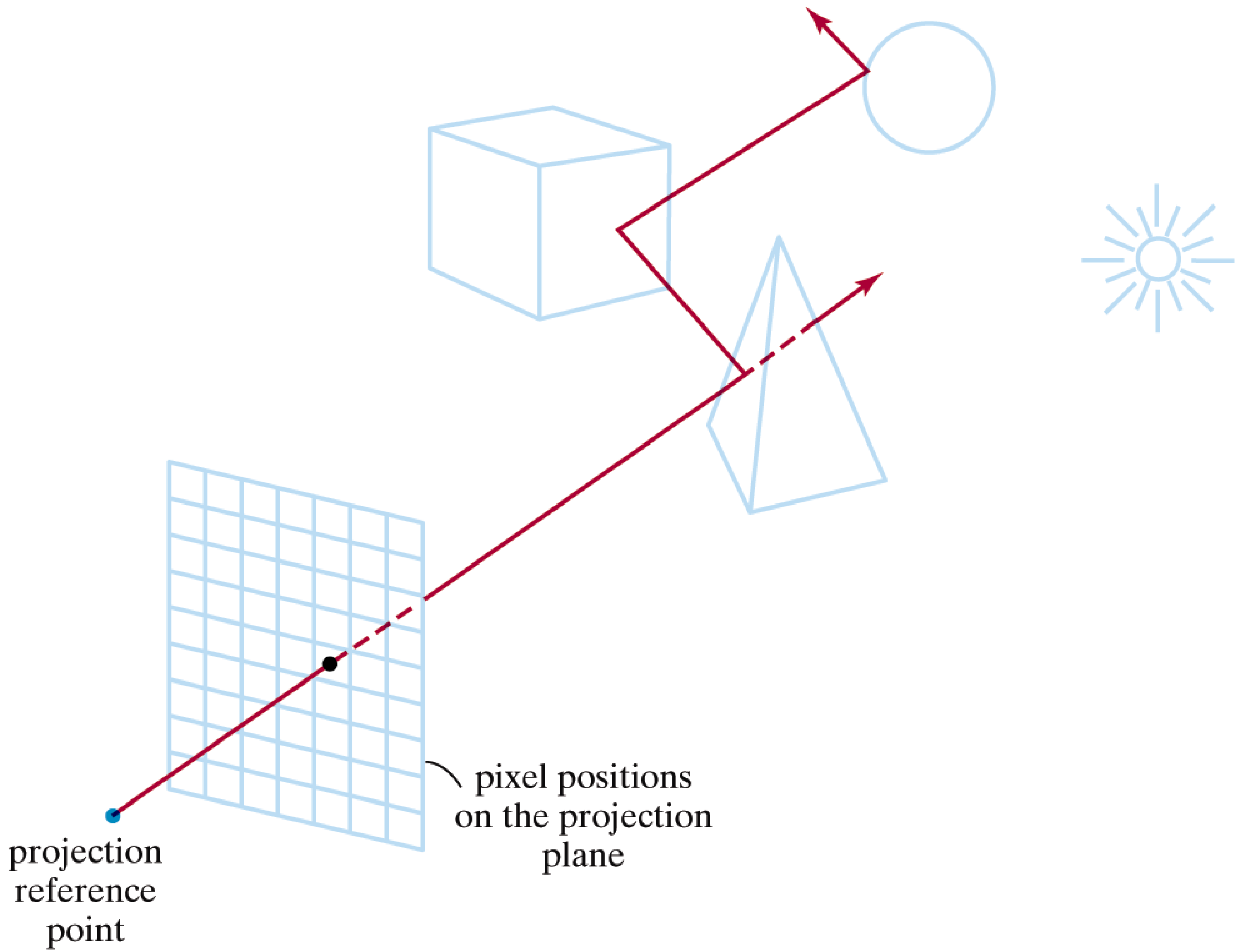
Ray-Tracing Setup



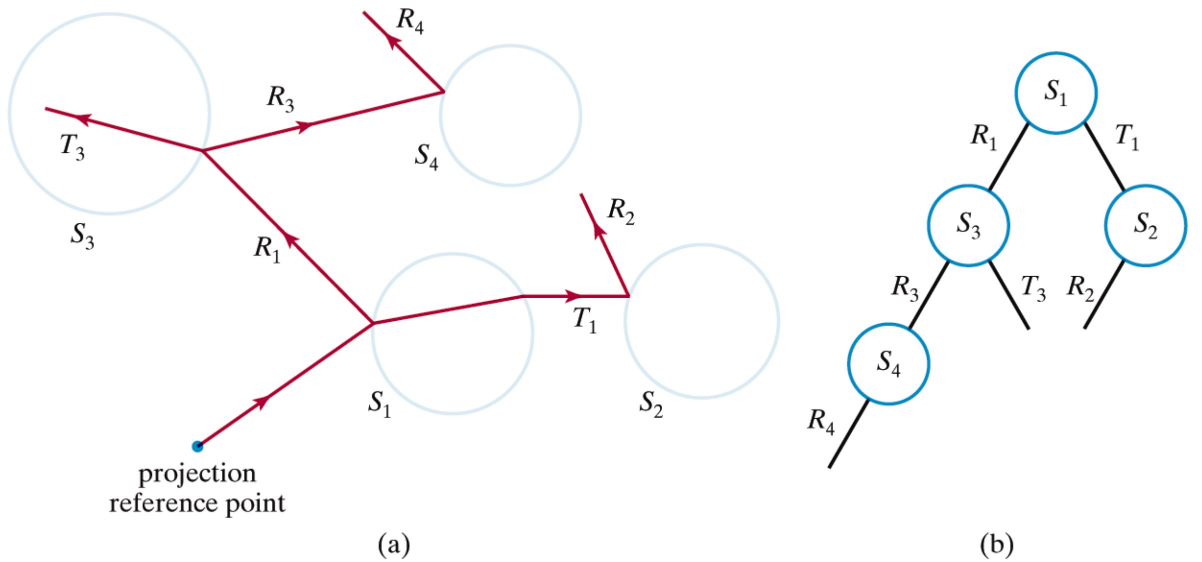


Figure 10-55

The reflection and refraction paths for a pixel ray traveling through a scene are shown in (a), and the corresponding binary ray-tracing tree is given in (b).

Basic Ray-Tracing

Ray tracing proceeds as follows:

- Fire a single ray from each pixel position into the scene along the projection path
- Determine which surfaces the ray intersects and order these by distance from the pixel
- The nearest surface to the pixel is the visible surface for that pixel
- Reflect a ray off the visible surface along the specular reflection angle
- For transparent surfaces also send a ray through the surface in the refraction direction
- Repeat the process for these secondary rays

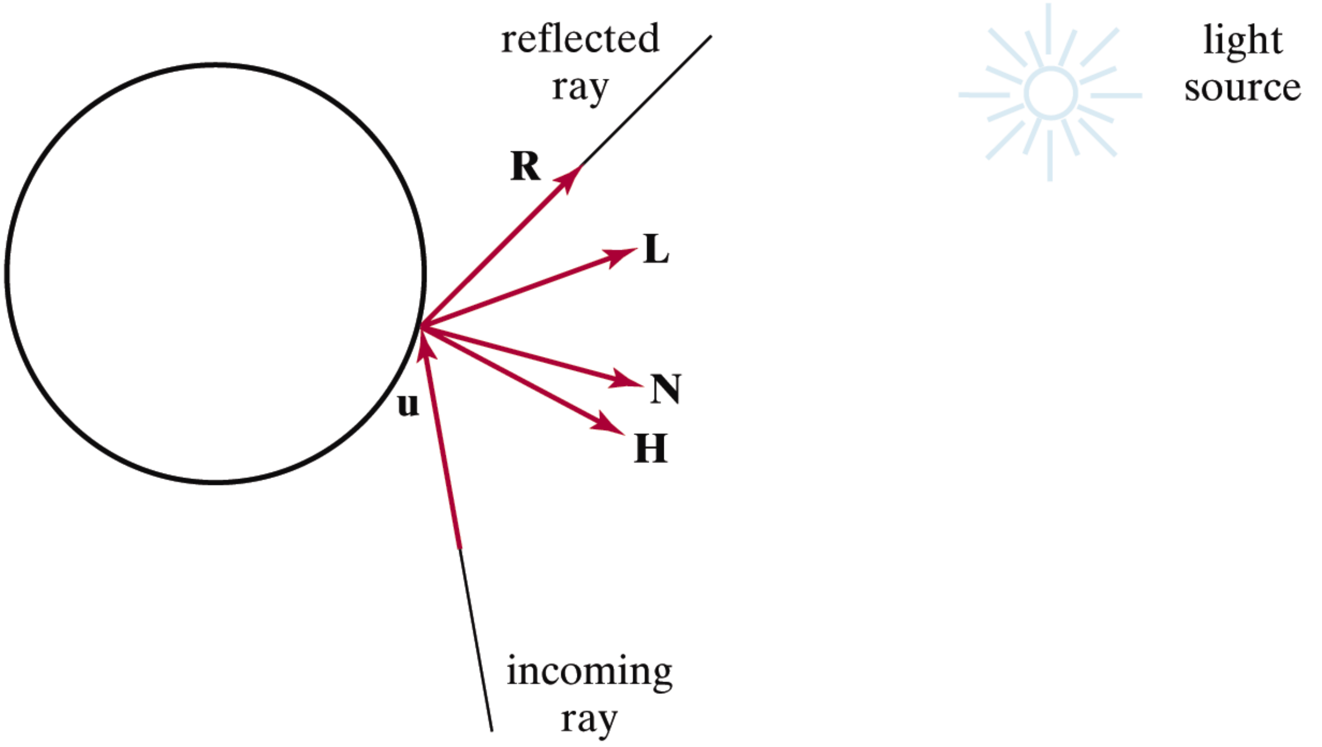
Terminating Ray-Tracing

We terminate a ray-tracing path when any one of the following conditions is satisfied:

- The ray intersects no surfaces
- The ray intersects a light source that is not a reflecting surface
- A maximum allowable number of reflections have taken place

Ray-Tracing & Illumination Models

At each surface intersection he illumination model is invoked to determine the surface intensity contribution



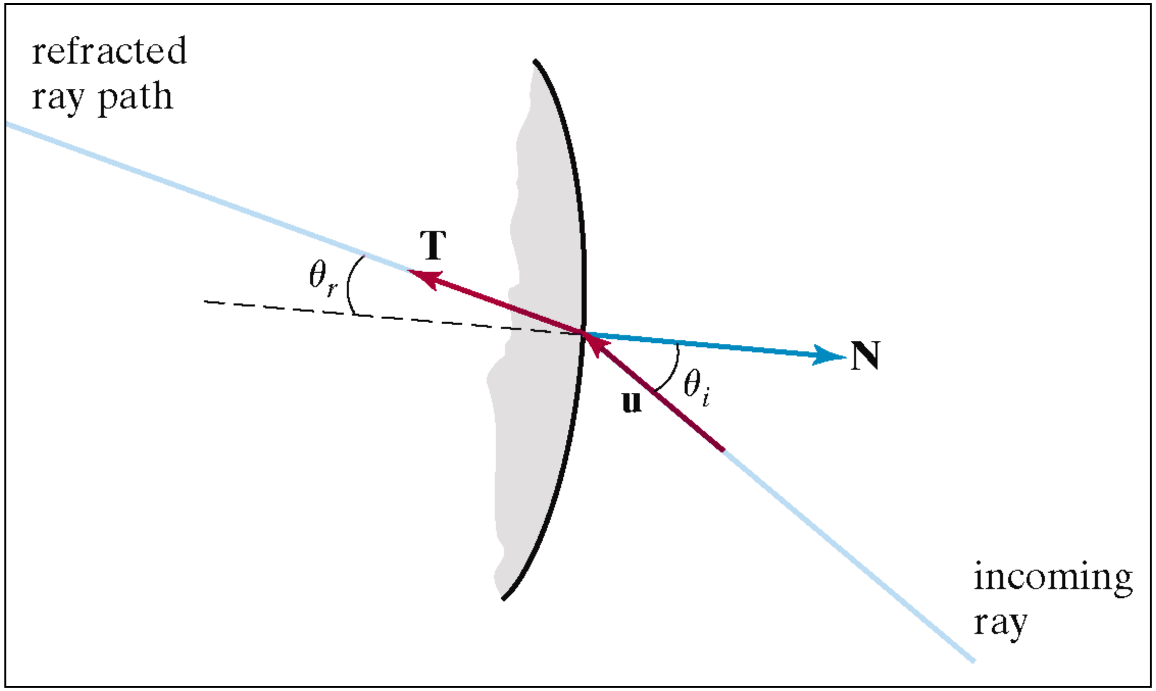
The Shadow Ray

- The path from the intersection to the light source is known as the **shadow ray** (L)
- If any object intersects the shadow ray between the surface and the light source then the surface is in shadow with respect to that source

Ray-Tracing & Transparent Surfaces

For transparent surfaces we need to calculate a ray to represent the light refracted through the material

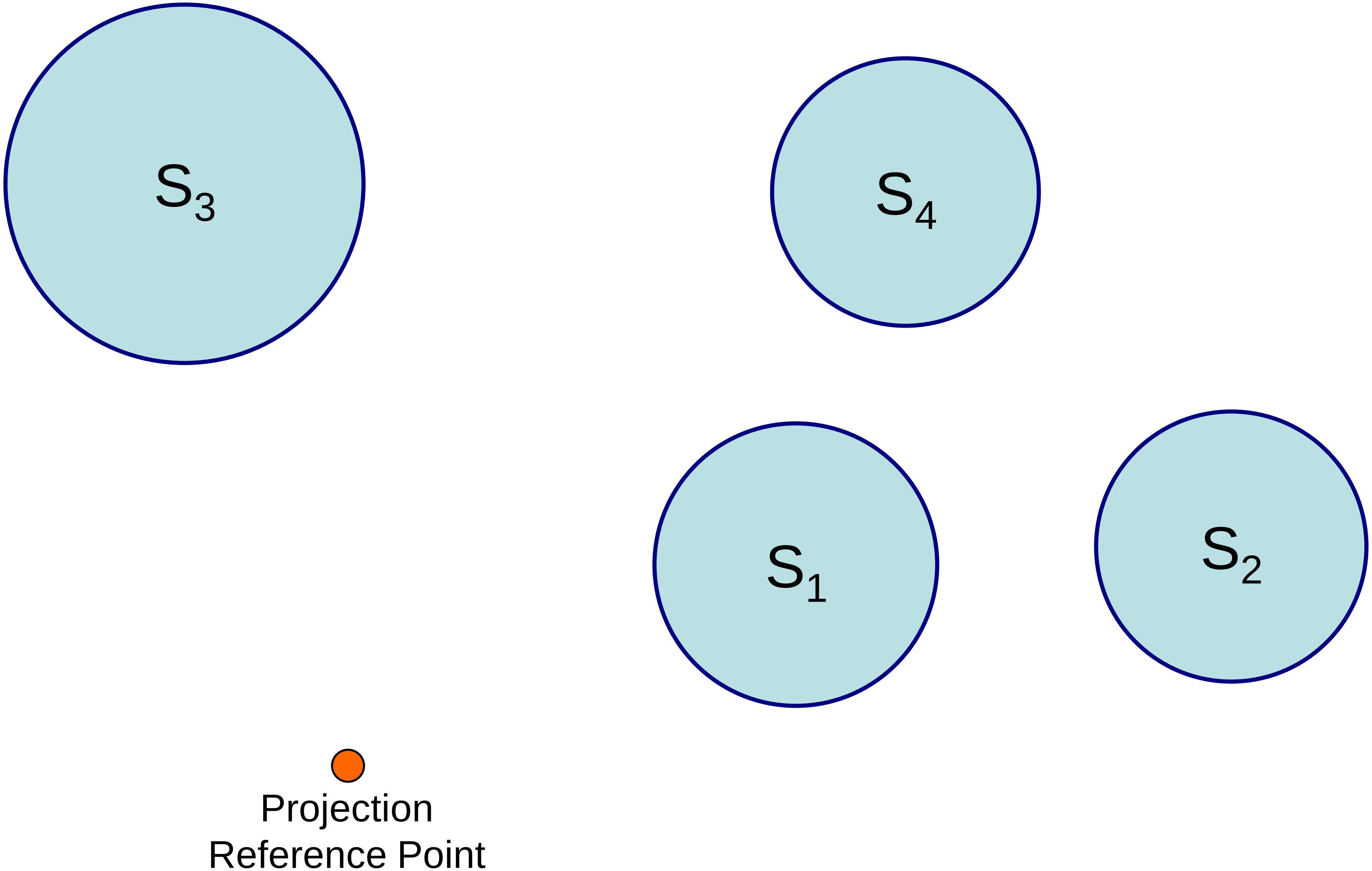
The direction of the refracted ray is determined by the refractive index of the material



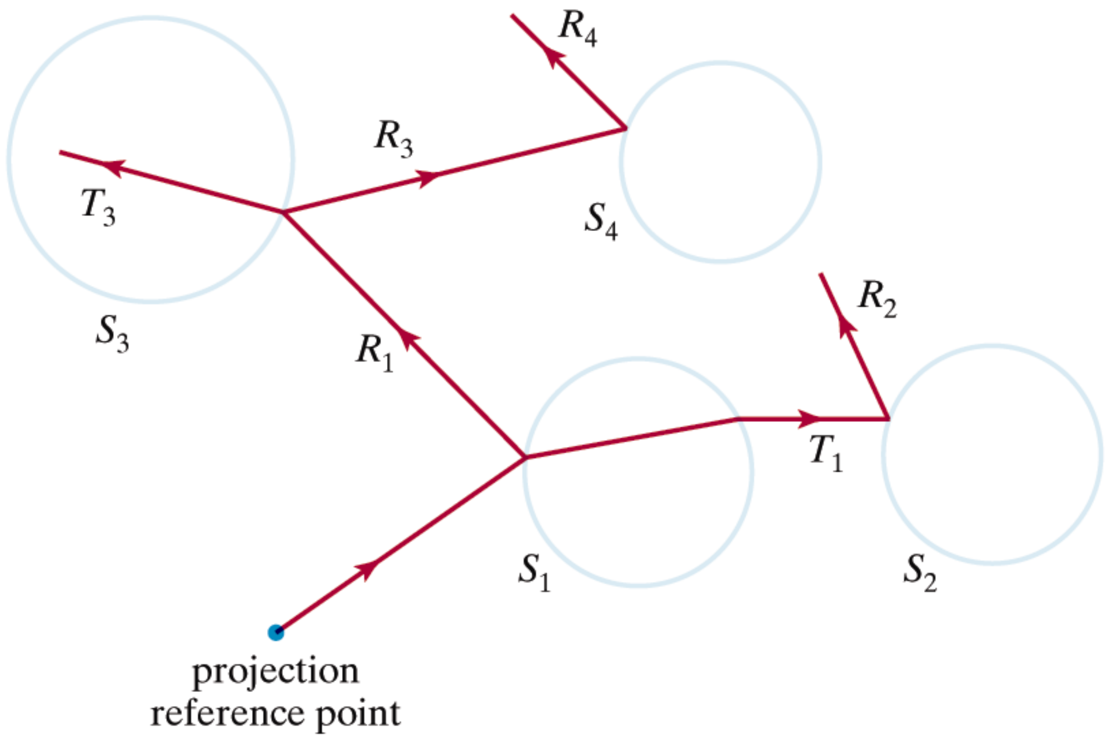
Ray-Tracing Tree

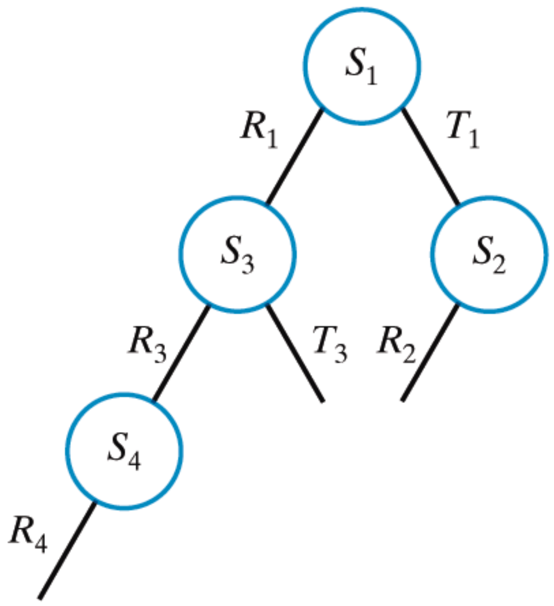
- As the rays ricochet around the scene each intersected surface is added to a binary **ray-tracing tree**
  - The left branches in the tree are used to represent reflection paths
  - The right branches in the tree are used to represent transmission paths
- The tree's nodes store the intensity at that surface
- The tree is used to keep track of all contributions to a given pixel

Ray-Tracing Tree Example



Ray-Tracing Tree Example (cont…)





Ray-Tracing Tree (cont…)

After the ray-tracing tree has been completed for a pixel the intensity contributions are accumulated

We start at the terminal nodes (bottom) of the tree

The surface intensity at each node is attenuated by the distance from the parent surface and added to the intensity of the parent surface

The sum of the attenuated intensities at the root node is assigned to the pixel

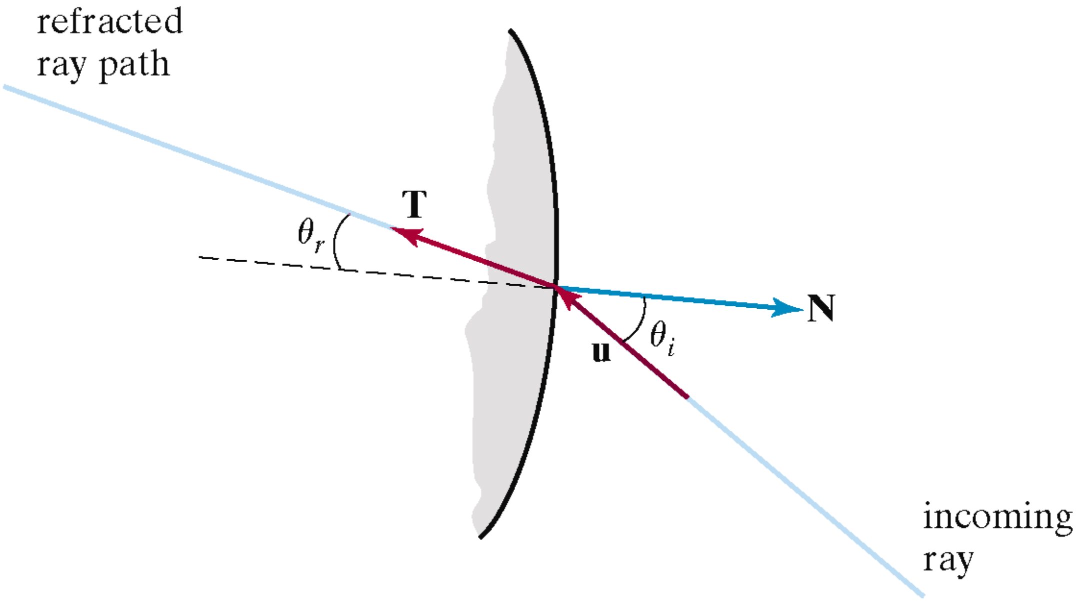


Figure 10-57

Refracted ray-transmission path **T** through a transparent material.

The unit transmission vector T

$$T = \frac{\eta_i}{\eta_r} u - \left(\cos\theta_r - \frac{\eta_i}{\eta_r} \cos\theta_i \right) N$$

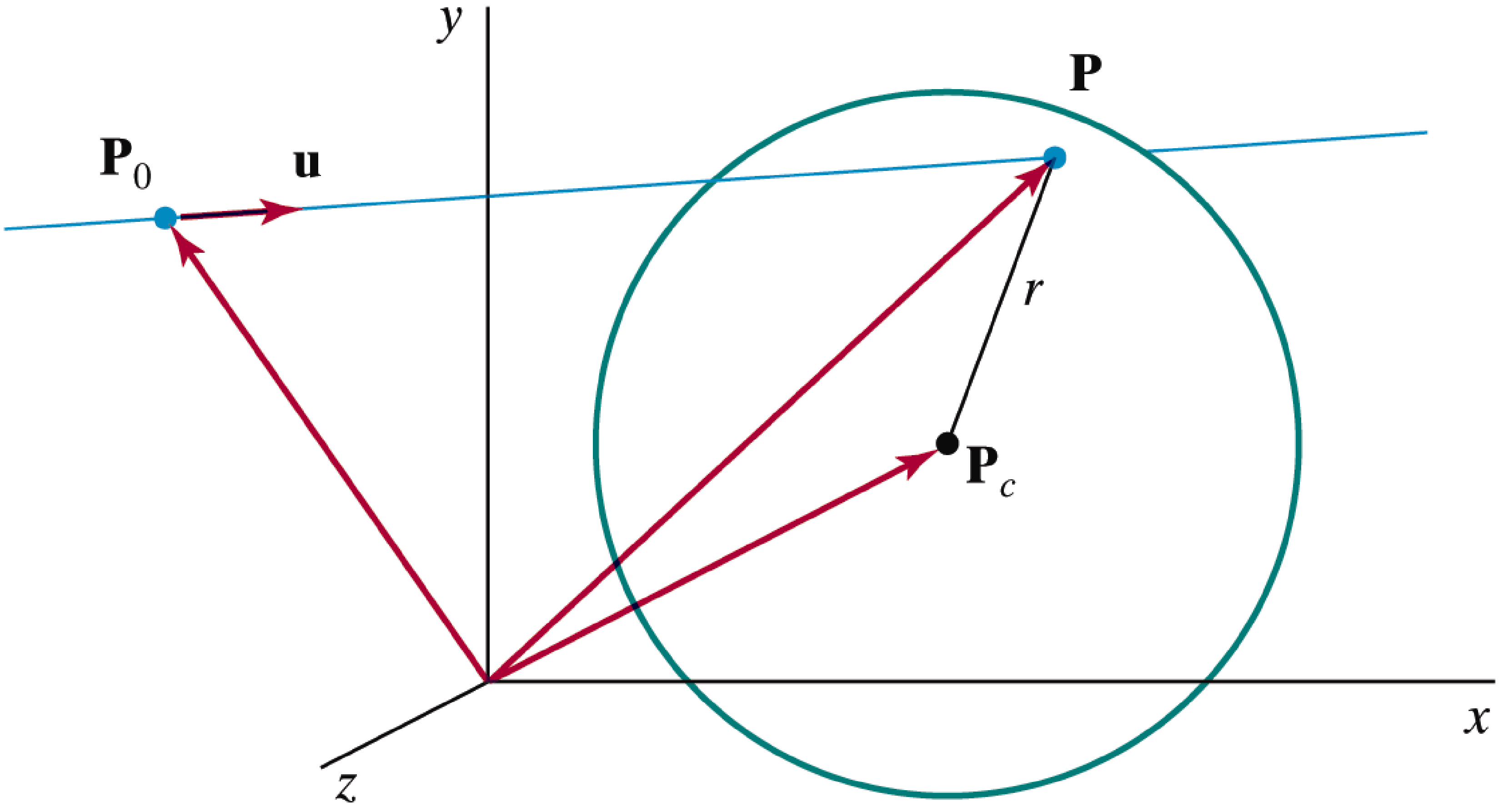
$$\cos\theta_r = \sqrt{1 - \left(\frac{\eta_i}{\eta_r} \right)^2 \left(1 - \cos^2\theta_i \right)}$$

Ray-Surface Intersection

$$P = P_0 + su$$

$$u = \frac{P_{pix} - P_{prp}}{\left|P_{pix} - P_{prp}\right|}$$

Ray-Sphere Intersection



Ray-Sphere Intersection

A sphere of radius r and center position $\mathbf{P}_c$

$$|\mathbf{P} - \mathbf{P}_c|^2 = r^2$$

$$|\mathbf{P}_0 + s\mathbf{u} - \mathbf{P}_c|^2 - r^2 = 0$$