Computer Graphics
V - Semester

Unit – 4

Illumination and shading

K.A.Dhamotharan,
Assistant Professor (Senior Grade)

Illumination and Shading

Illumination Vs. Shading

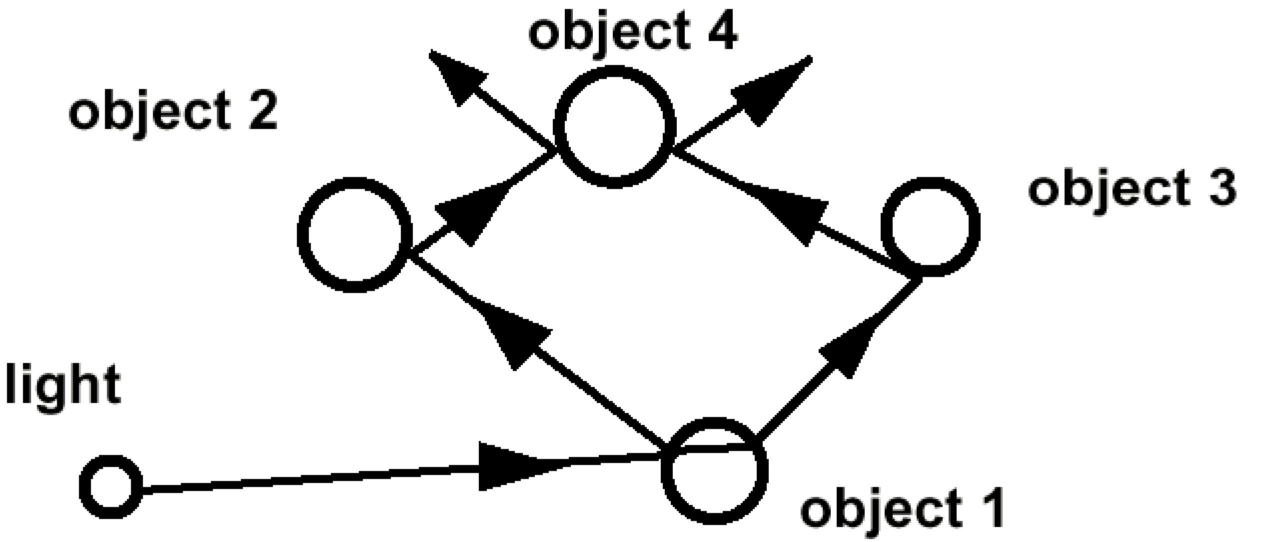
- Illumination (lighting) model: determine the color of a surface point by simulating some light attributes.
- Shading model: applies the illumination models at a set of points and colors the whole image.

Illumination (Lighting) Model

- To model the interaction of light with surfaces to determine the final color & brightness of the surface
  - Global illumination
  - Local illumination

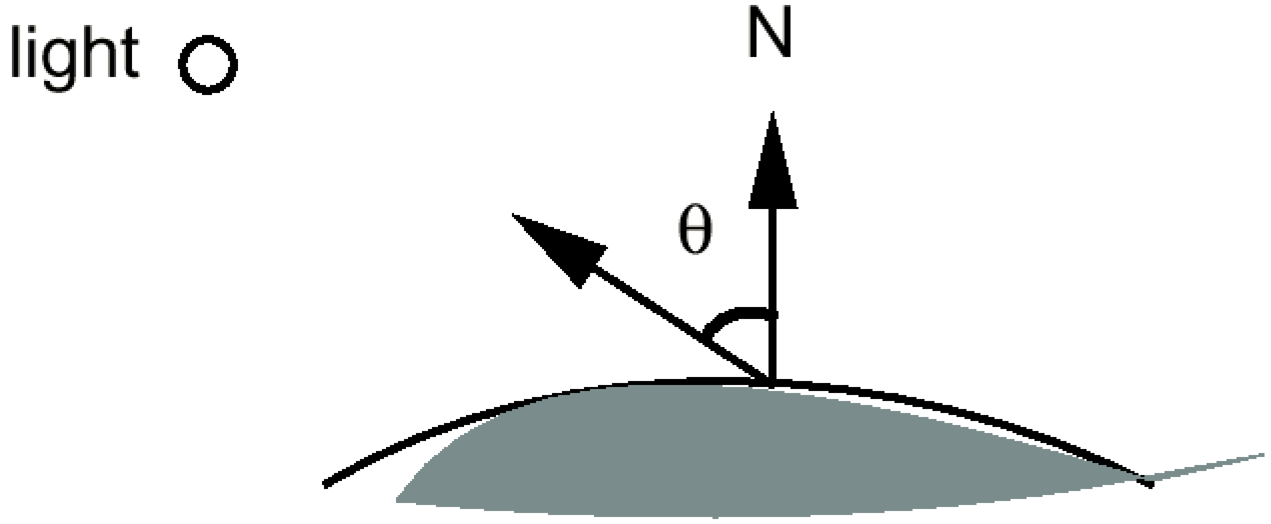
Global Illumination

- Global Illumination models: take into account the interaction of light from all the surfaces in the scene.



Local illumination

- Only consider the light, the observer position, and the object material properties



Basic Illumination Model

- Simple and fast method for calculating surface intensity at a given point
- Lighting calculation are based on:
  - The background lighting conditions
  - The light source specification: color, position

Ambient light (background light)

- The light that is the result from the light reflecting off other surfaces in the environment
- A general level of brightness for a scene that is independent of the light positions or surface directions -> ambient light
- Has no direction
- Each light source has an ambient light contribution, Ia
- For a given surface, we can specify how much ambient light the surface can reflect using an ambient reflection coefficient : Ka (0 < Ka < 1)

Ambient Light

- So the amount of light that the surface reflect is therefore

$$Iamb = Ka * Ia$$

Diffuse Light

- The illumination that a surface receives from a light source and reflects equally in all directions
- This type of reflection is called Lambertian Reflection (thus, Lambertian surfaces)
- The brightness of the surface is indepenent of the observer position (since the light is reflected in all direction equally)

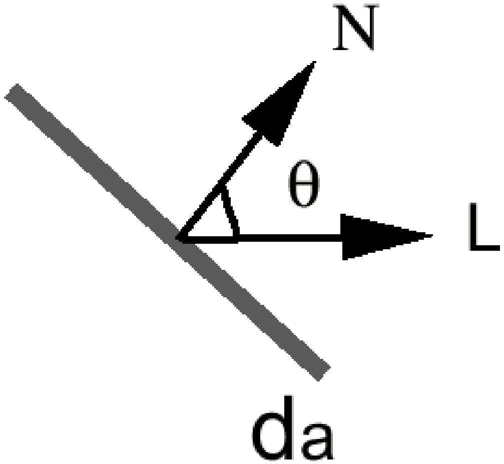
Lambert's Law

- How much light the surface receives from a light source depends on the angle between its angle and the vector from the surface point to the light (light vector)
- Lambert's law: the radiant energy '$\mathbf{I_d}$' from a small surface $\mathbf{d_a}$ for a given light source is:

$$I_d = I_L * \cos(\theta)$$

I_L : the intensity of the light source

θ is the angle between the surface normal (N) and light vector (L)



The Diffuse Component

- Surface's material property: assuming that the surface can reflect K_d ($0<K_d<1$), diffuse reflection coefficient) amount of diffuse light:

  $I_{diff} = K_d * I_L * \cos(\theta)$

  If N and L are normalized, $\cos(\theta) = N*L$

  $I_{diff} = K_d * I_L * (N*L)$

- The total diffuse reflection = ambient + diffuse

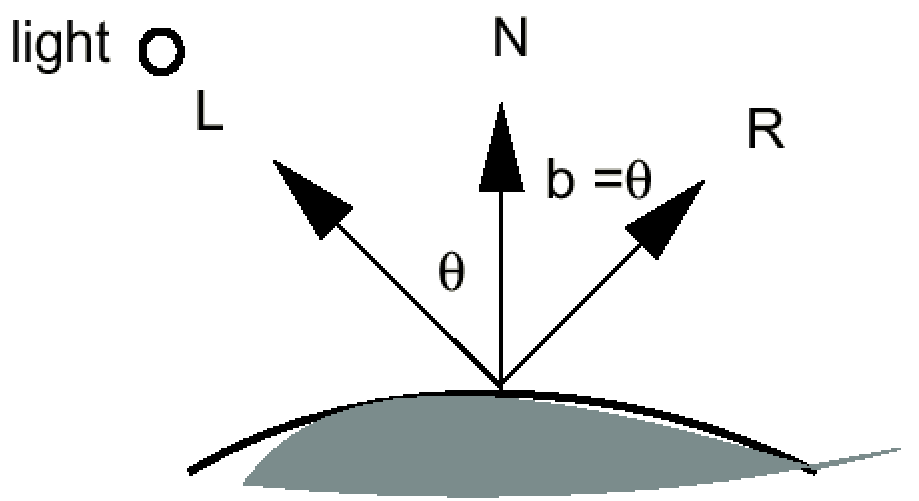
  $I_{diff} = K_a * I_a + K_d * I_L * (N*L)$

Examples

Sphere diffusely lighted from various angles !

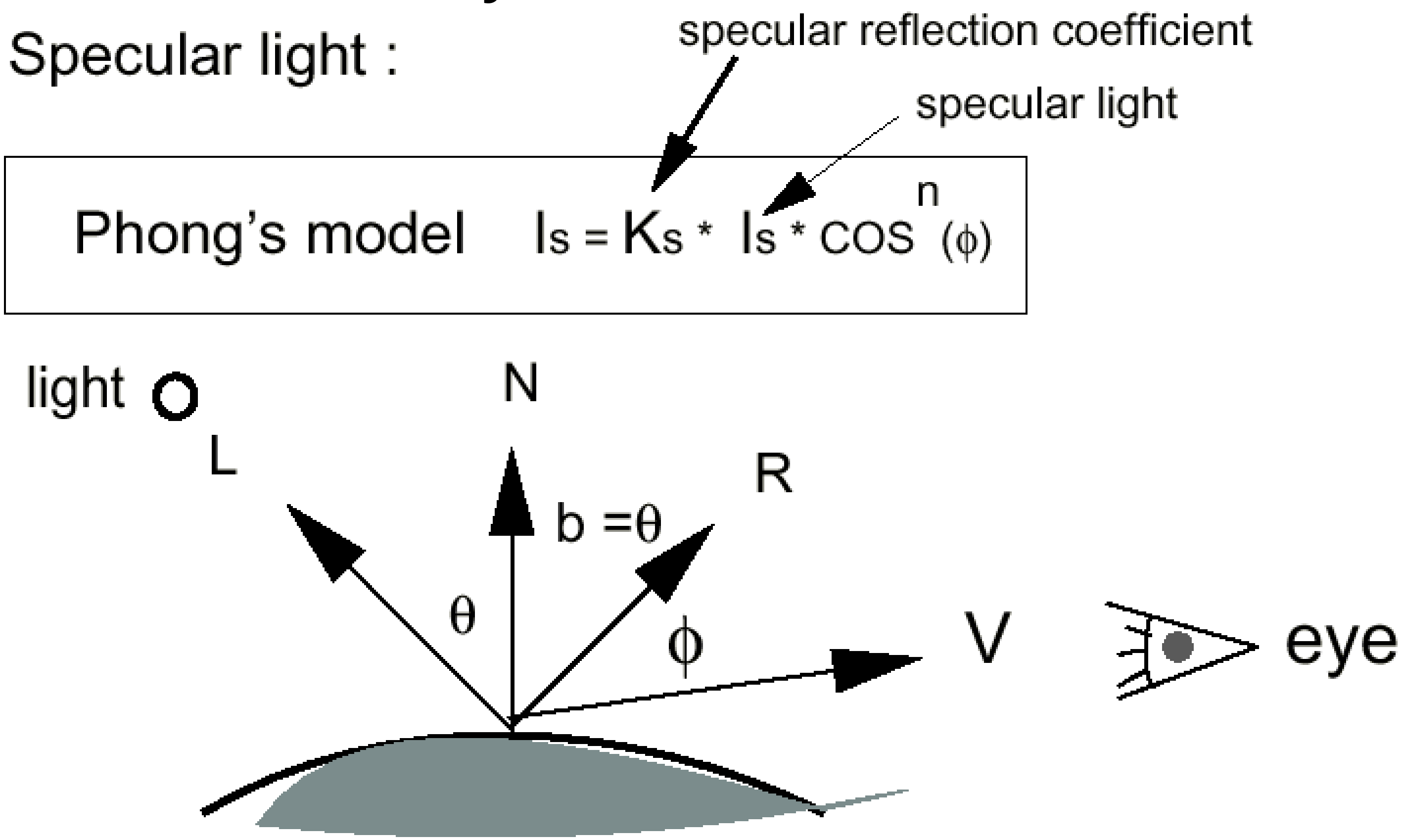
Specular Light

- These are the bright spots on objects (such as polished metal, apple ...)
- Light reflected from the surface unequally to all directions.
- The result of near total reflection of the incident light in a concentrated region around the specular reflection angle



Phong's Model for Specular

- How much reflection light you can see depends on where you are

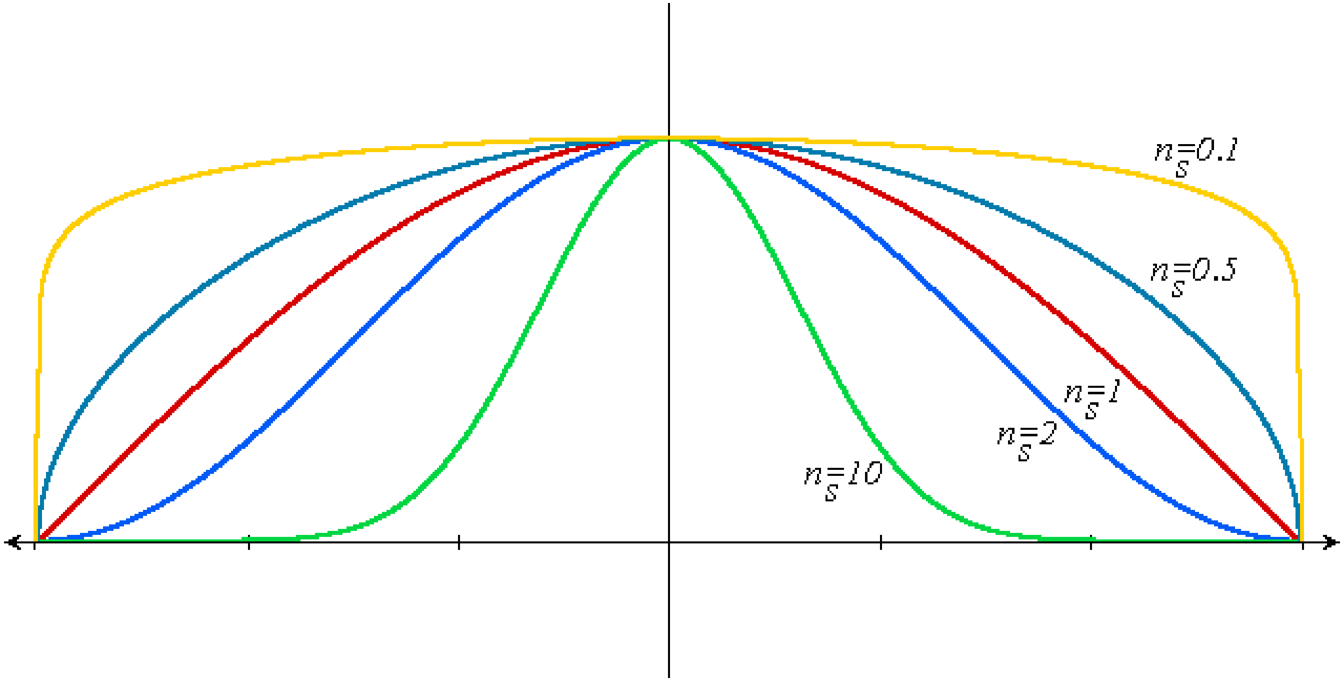


Phong Illumination Curves

Specular exponents are much larger than 1;

Values of 100 are not uncommon.

n : glossiness, rate of falloff



Specular Highlights

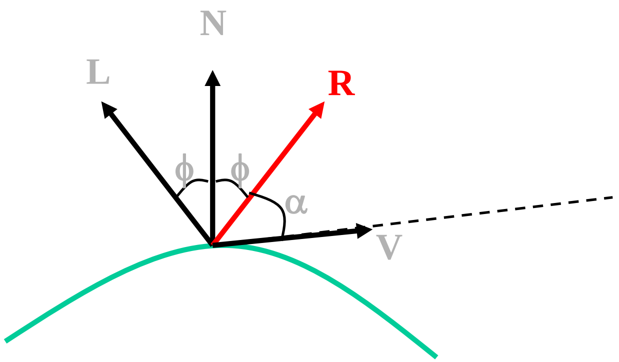
- Shiny surfaces change appearance when viewpoint is changed
- Specularities are caused by microscopically smooth surfaces.
- A mirror is a perfect specular reflector

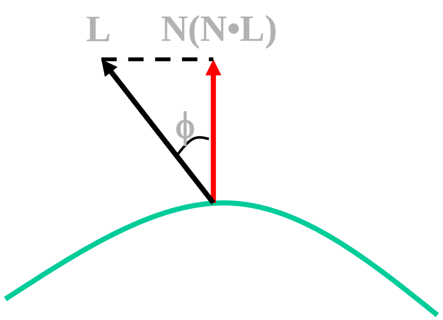
Reflected Ray

How to calculate R?

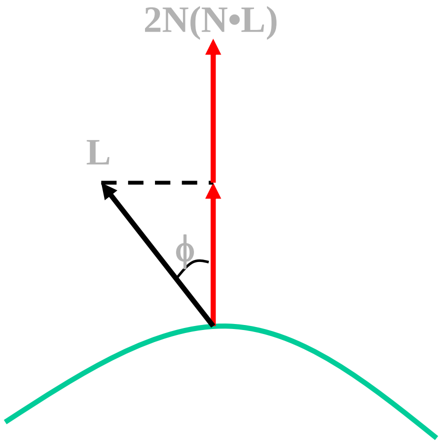
R + L = 2(N*L) N

R = 2(N*L) N - L

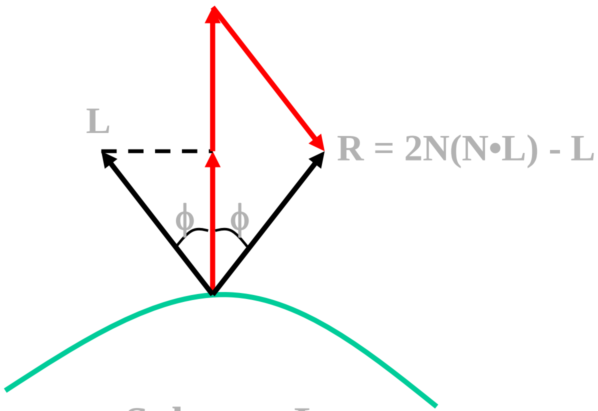




Project L onto N



Double length of vector



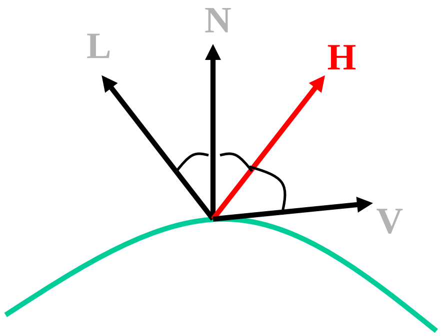
Subtract L

Half Vector

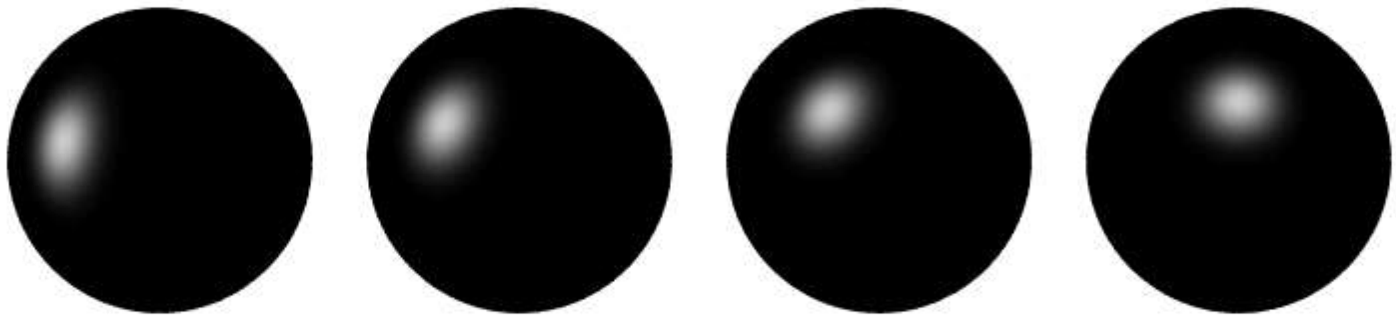
- An alternative way of computing phong lighting is: Is = ks * Is * $(N*H)^n$

- H (halfway vector): halfway between V and L: (V+L)/2

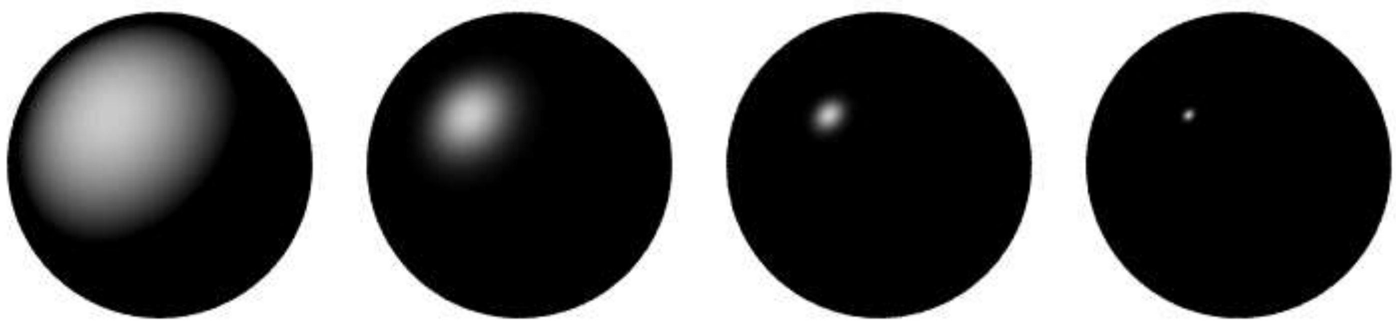
- Fuzzier highlight



Phong Illumination



Moving Light



Change n

Putting It All Together

- Single Light (white light source)

$$I = \text{Ambient} + \text{Diffuse} + \text{Specular} =$$

$$Ka * I_a + Kd * \underbrace{I_L * (N.L)}_{I_d} + Ks * \underbrace{I_L * (R.V)^n}_{I_s}$$

Multiple Light Source

- I_L: light intensity

$$I = Ka * Ia + \sum^{i} (Kd * I_L * (N.L) + Ks * I_L * (R.V)^n)$$

- For multiple light sources
  - Repeat the diffuse and specular calculations for each light source
  - Add the components from all light sources
  - The ambient term contributes only once
- The different reflectance coefficients can differ.
  - Simple “metal”: k_s and k_d share material color,
  - Simple plastic: k_s is white
- Remember, when cosine is negative lighting term is zero!

OpenGL Materials

```
GLfloat white8[] = {.8, .8, .8, 1.}, white2 = {.2,.2,.2,1.},black={0.,0.,0.};
GLfloat mat_shininess[] = {50.};          /* Phong exponent */

glMaterialfv(    GL_FRONT_AND_BACK,
                 GL_AMBIENT, black);

glMaterialfv(    GL_FRONT_AND_BACK,
                 GL_DIFFUSE, white8);

glMaterialfv(    GL_FRONT_AND_BACK,
                 GL_SPECULAR, white2);

glMaterialfv(    GL_FRONT_AND_BACK,
                 GL_SHININESS, mat_shininess);
```

OpenGL Lighting

```
GLfloat white[] = {1., 1., 1., 1.};
GLfloat light0_position[] = {1., 1., 5., 0.}; /* directional light (w=0) */

glLightfv(GL_LIGHT0, GL_POSITION, light0_position);
glLightfv(GL_LIGHT0, GL_DIFFUSE, white);
glLightfv(GL_LIGHT0, GL_SPECULAR, white);
glEnable(GL_LIGHT0);

glEnable(GL_NORMALIZE);     /* normalize normal vectors */
glLightModeli(GL_LIGHT_MODEL_TWO_SIDE, GL_TRUE);/* two-sided lighting*/

glEnable(GL_LIGHTING);
```

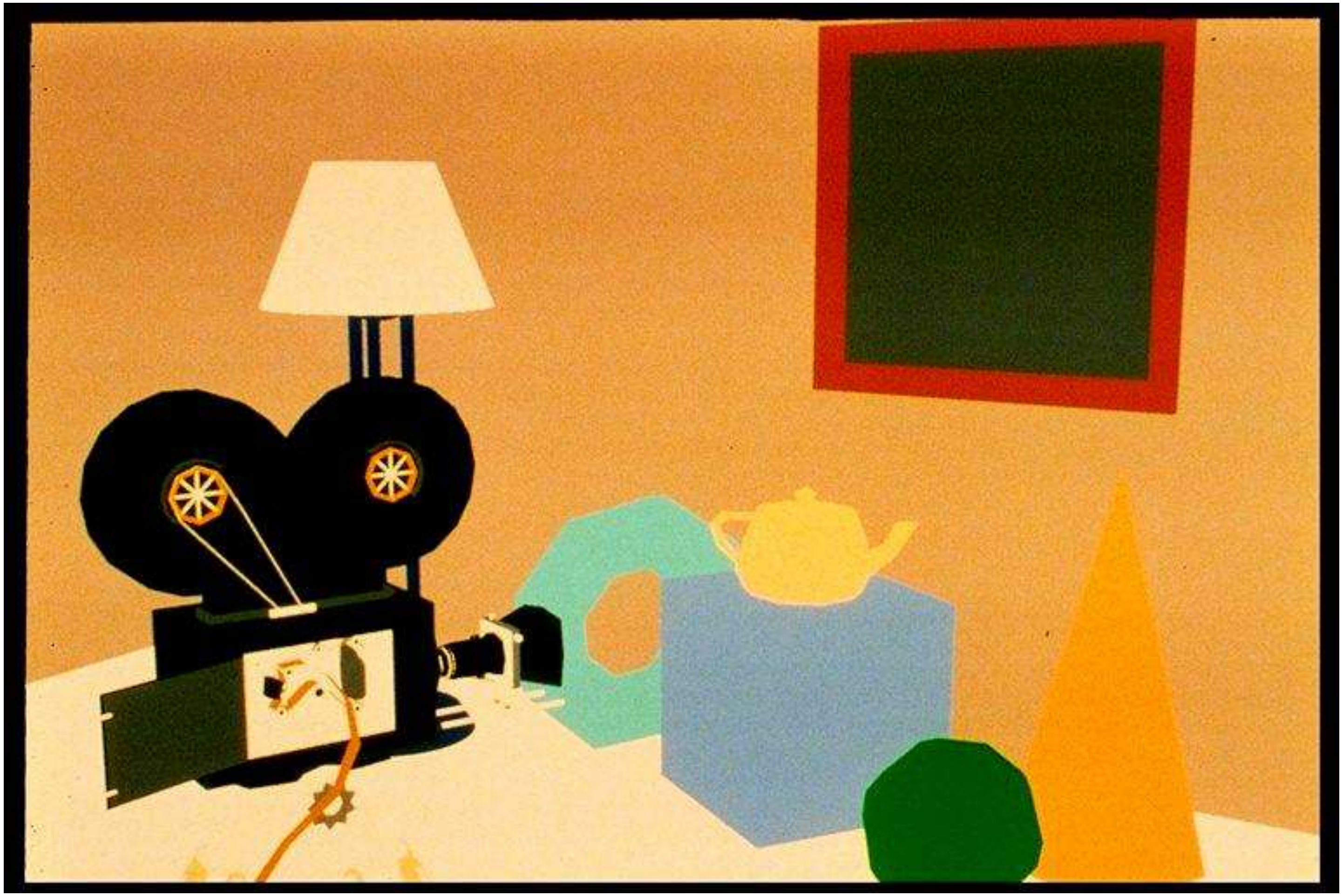
Shading Models for Polygons

- Constant Shading (flat shading)
  - Compute illumination at any one point on the surface. Use face or one normal from a pair of edges. Good for far away light and viewer or if facets approximate surface well.
- Per-Pixel Shading
  - Compute illumination at *every* point on the surface.
- Interpolated Shading
  - Compute illumination at vertices and interpolate color

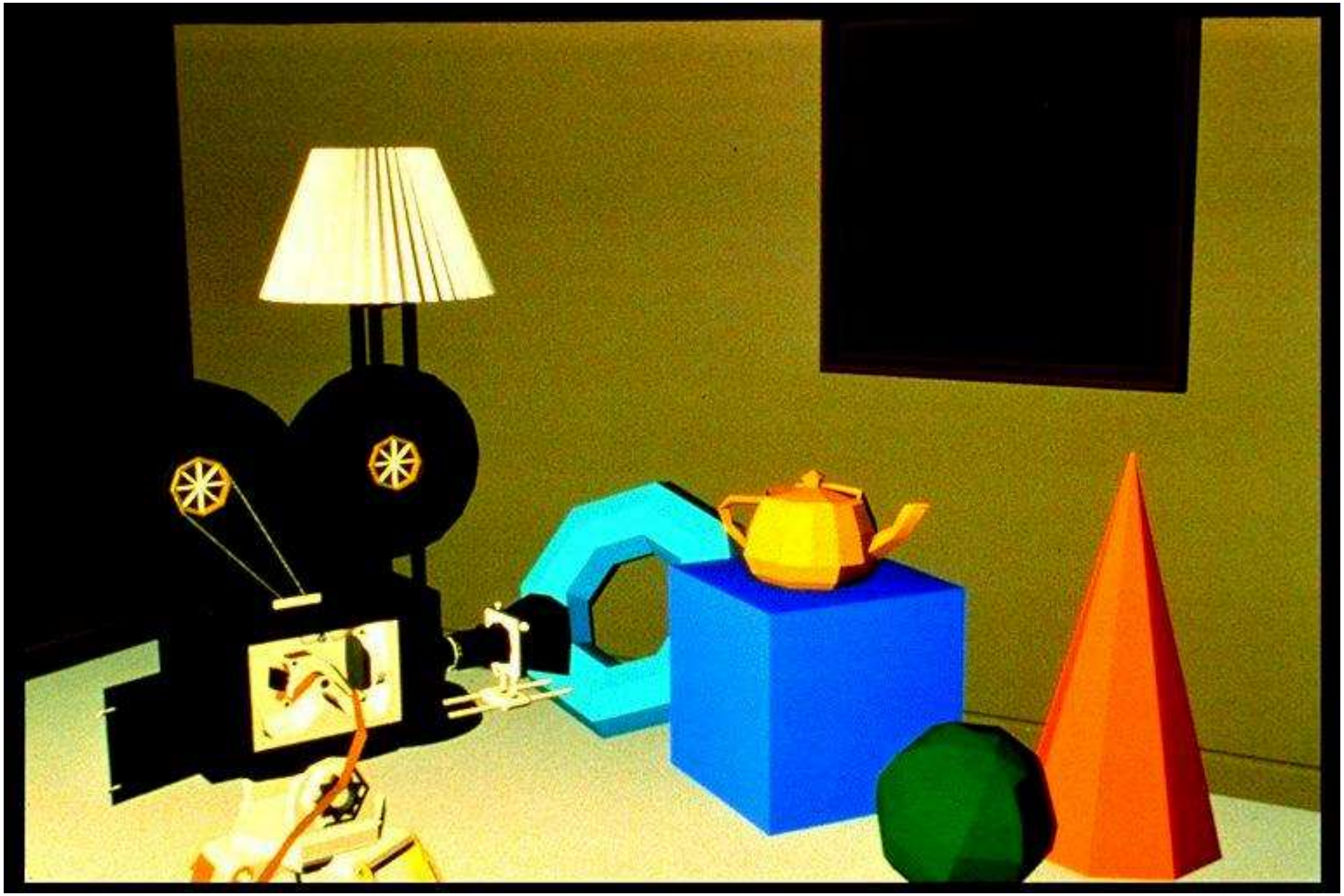
Constant Shading

- Compute illumination only at one point on the surface
- Okay to use if all of the following are true
  - The object is not a curved (smooth) surface (e.g. a polyhedron object)
  - The light source is very far away (so N.L does not change much across a polygon)
  - The eye is very far away (so V.R does not change much across a polygon)
  - The surface is quite small (close to pixel size)

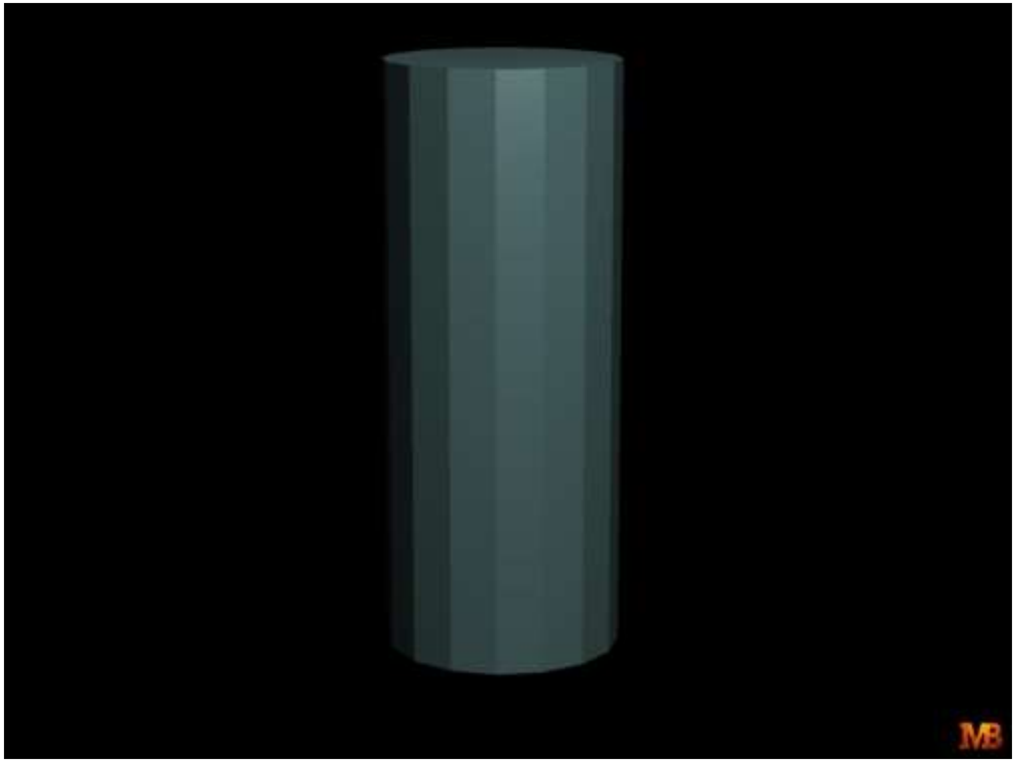
Un-lit



Flat Shading

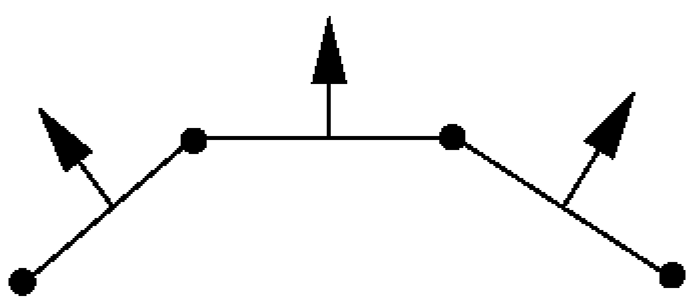


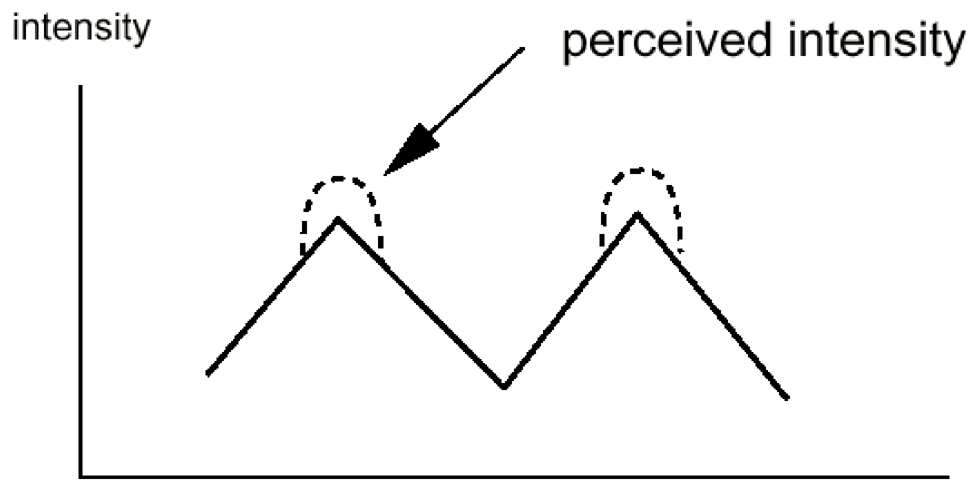
Mach Band ?



Polygon Mesh Shading

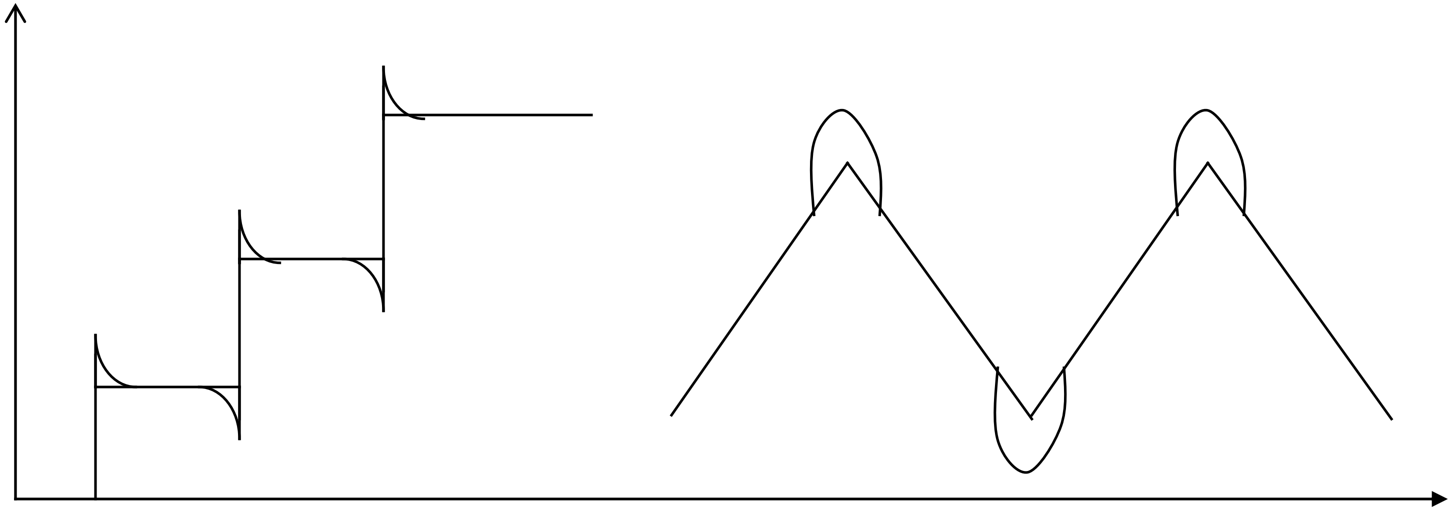
- Shading each polygonal facet individually will not generate an illusion of smooth curved surface
- Reason: polygons will have different colors along the boundary, unfortunately, human perception helps to even accentuate the discontinuity: mach band effect





Mach Banding

- Intensity change is exagerated
- Dark facet looks darker and lighter looks even more lighter

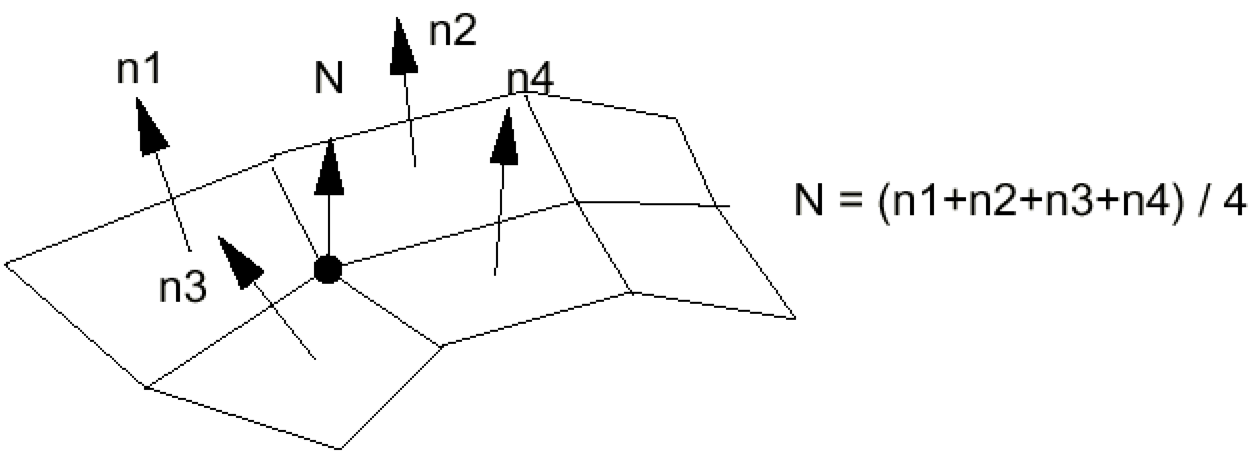


Smooth Shading

- Need to have per-vertex normals
- Gouraud Shading
  - Interpolate color across triangles
  - Fast, supported by most of the graphics accelerator cards
- Phong Shading
  - Interpolate normals across triangles
  - More accurate, but slow. Not widely supported by hardware

Gouraud Shading

- Normals are computed at the polygon vertices
- If we only have per-face normals, the normal at each vertex is the average of the normals of its adjacent faces
- Intensity interpolation: linearly interpolate the pixel intensity (color) across a polygon surface



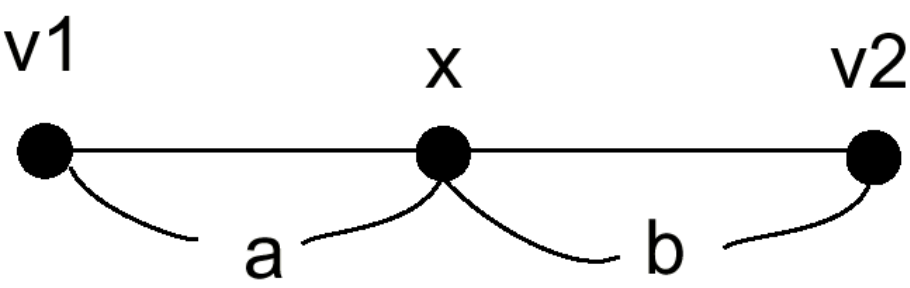
Linear Interpolation

- Calculate the value of a point based on

the distances to the point's two neighbor points

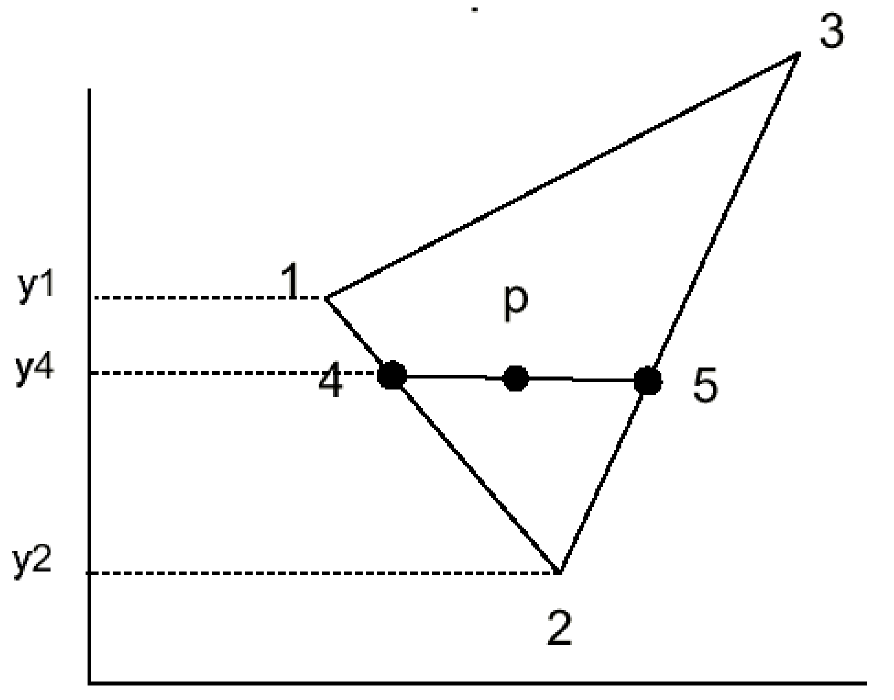
- If v1 and v2 are known, then

$$x = b/(a+b) * v1 + a/(a+b) * v2$$

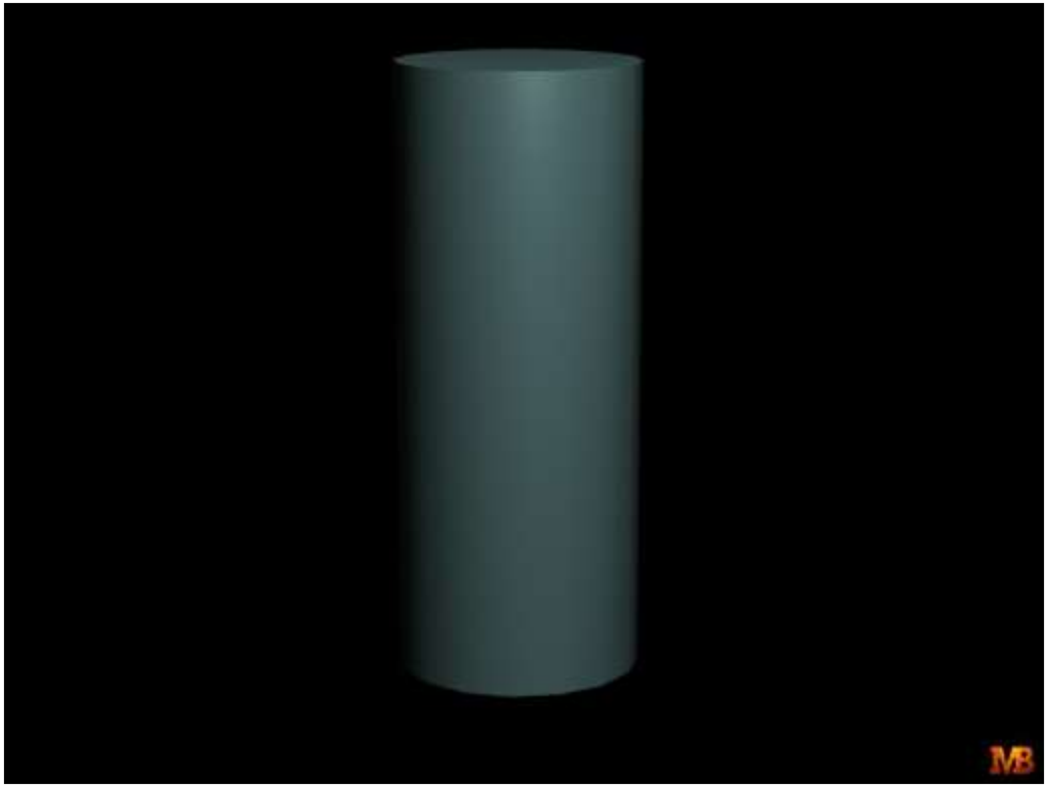


Linear Interpolation in a Triangle

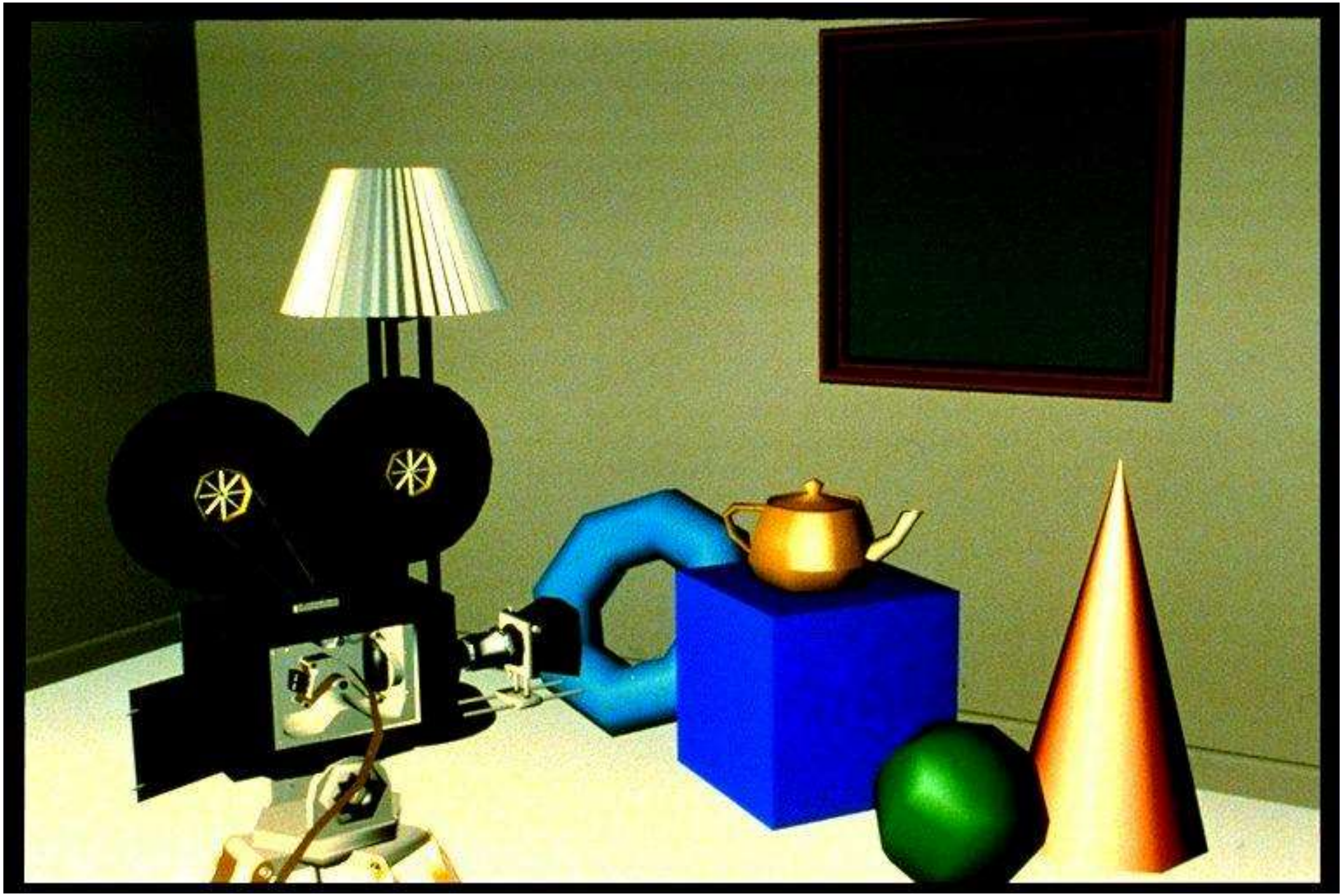
- To determine the intensity (color) of point P in the triangle,
- we will do:
- determine the intensity of 4 by linearly interpolating between 1 and 2
- determine the intensity of 5 by linearly interpolating between 2 and 3
- determine the intensity of P by linear interpolating between 4 and 5



Mach Band ?

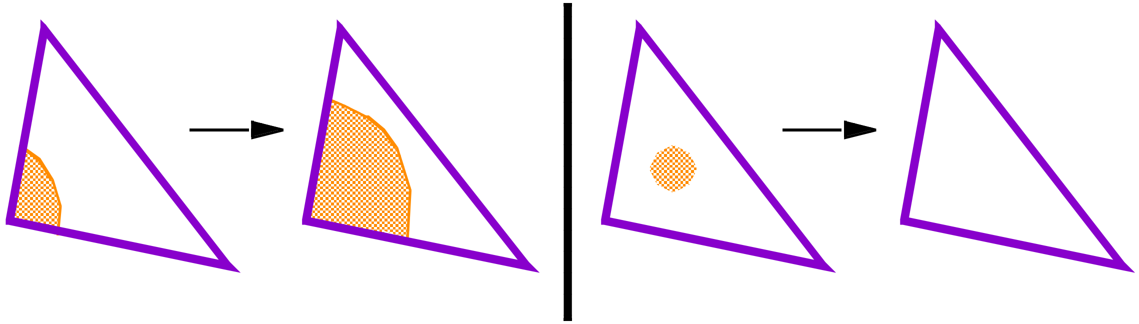


Image

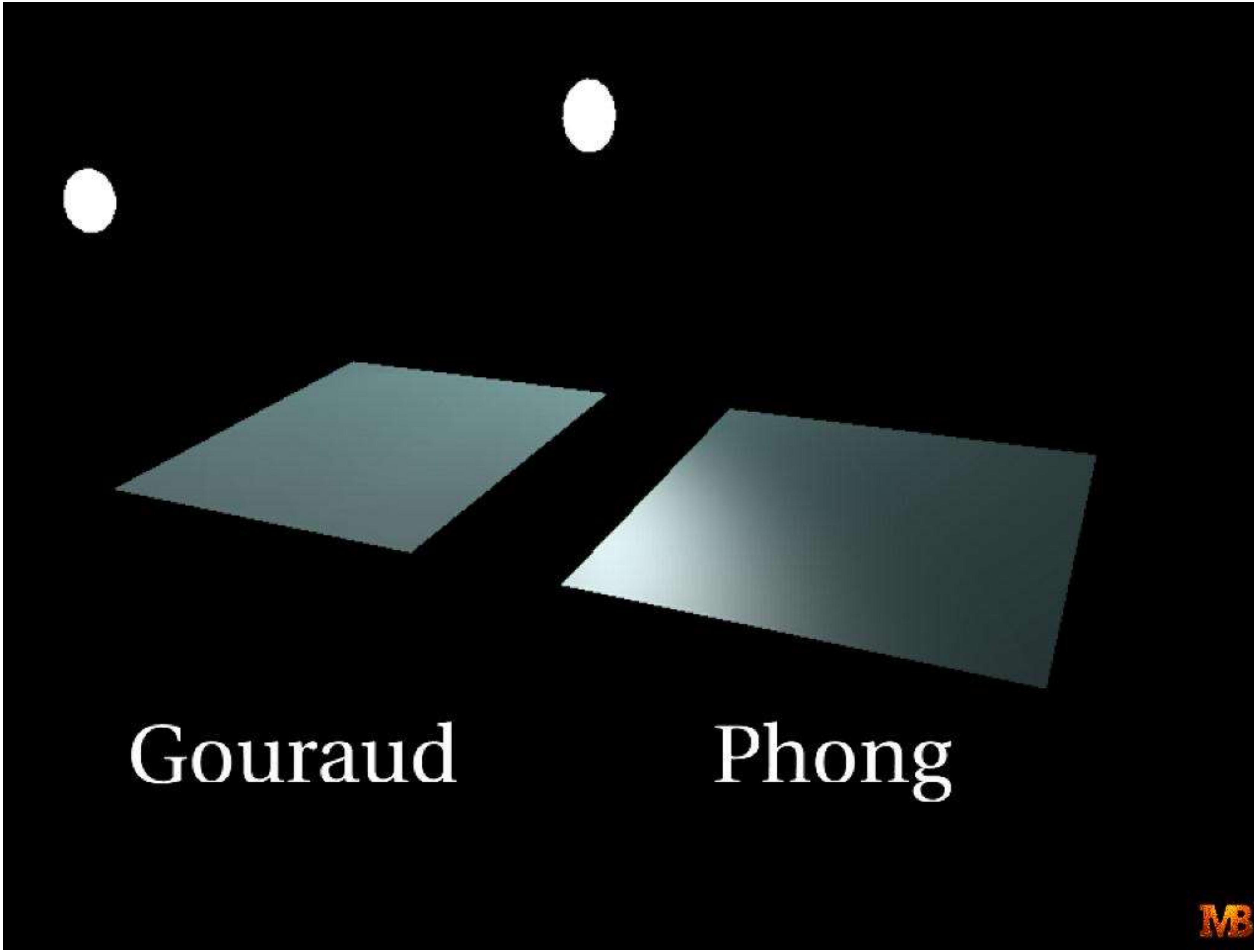


Phong Shading Model

- Gouraud shading does not properly handle specular highlights, specially when the *n* parameter is large (small highlight).



- **Reason:** colors are interpolated.
- **Solution:** (Phong Shading Model)
  - 1. Compute averaged normal at vertices.
  - 2. Interpolate *normals* along edges and scan-lines. (component by component)
  - 3. Compute *per-pixel* illumination.


Gouraud
Phong