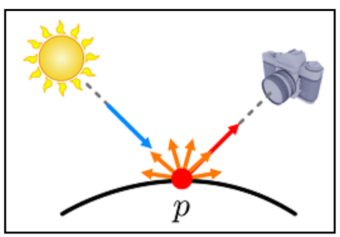
Chapter V
Illumination and Shaders

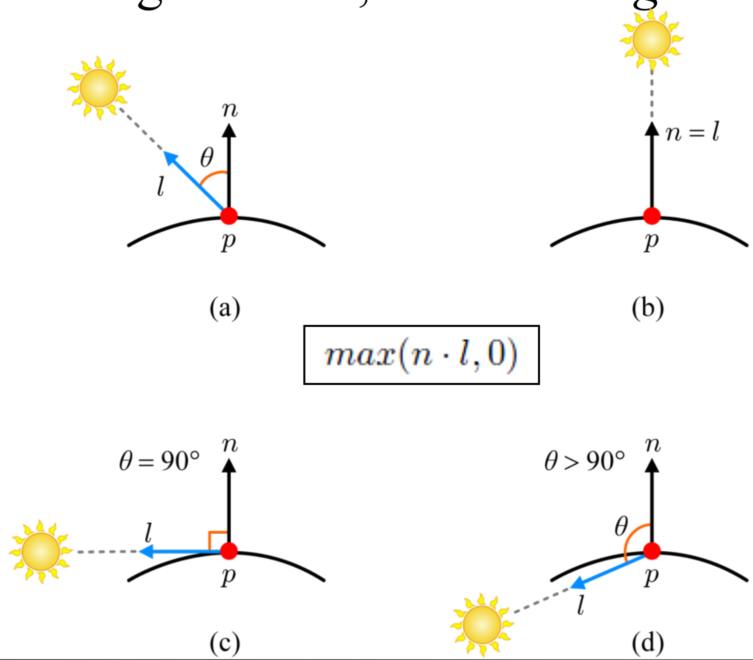
What is Illumination?

- Illumination or lighting refers to the techniques handling the interaction between light sources and objects.
- The lighting models are divided into two categories.
  - Local illumination considers only direct lighting in the sense that the illumination of a surface depends solely on the properties of the light sources and the surface materials. This has been dominant in real-time graphics.
  - In the real world, however, every surface receives light indirectly. (Even though a light source is invisible from a particular point of the scene, light can still be transferred to the point through reflections or refractions from other surfaces of the scene.) For indirect lighting, the global illumination (GI) model considers the scene objects as potential lighting sources.
- Problems of interactive GI
  - The cost is often too high to permit interactivity.
  - The rasterization-based architecture of GPU is more suitable for local illumination.
- Current status of GI
  - Approximate GI instead of pursuing precise GI.
  - Pre-compute GI, store the result in a texture, and use it at run time.

Phong Lighting Model - Diffuse Term

- The most popular local illumination method is based on the *Phong model*. It is composed of diffuse, specular, ambient, and emissive terms.
- The diffuse term is based on Lambert's law. Reflections from ideally diffuse surfaces (Lambertian surfaces) are scattered with equal intensity in all directions.
- So, the amount of perceived reflection is independent of the view direction, and is just proportional to the amount of incoming light.
- Among various light types such as point, area, spot, and directional light sources, let's take the simplest, the directional light source, where the *light vector* (l) is constant for a scene.

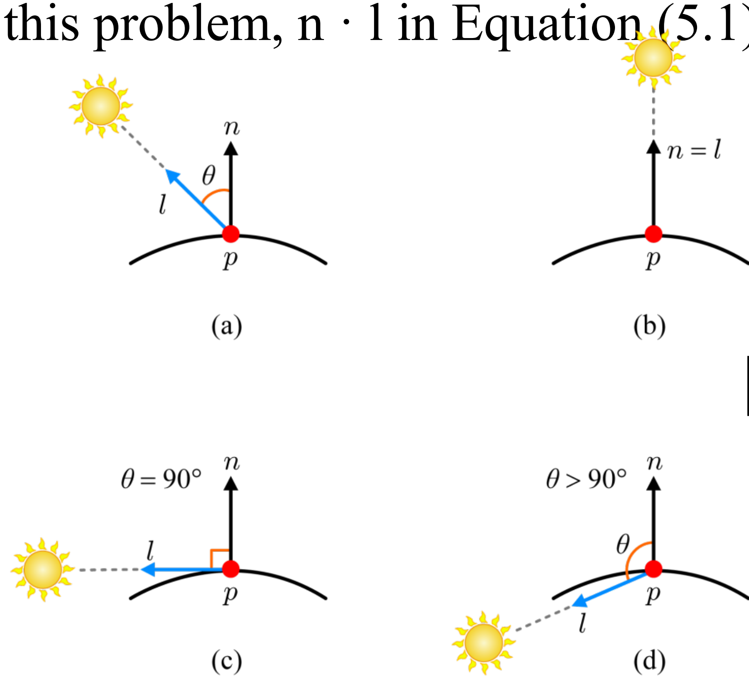




Phong Lighting Model - Diffuse Term

- The incident angle θ of light at p is between l and the surface normal n. If θ bec omes smaller, p receives more light. Assuming l and n are normalized, the dot p roduct of n and l is used to measure the amount of incident light:

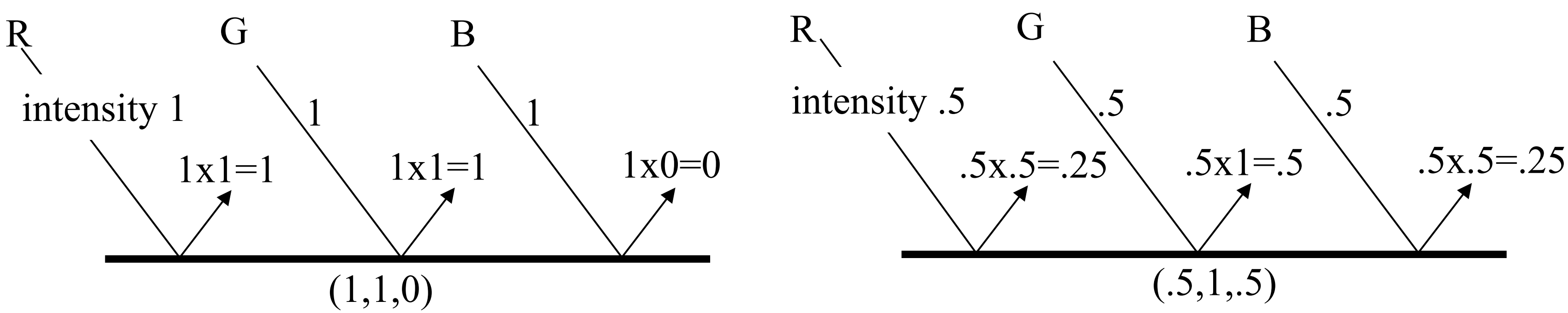
When θ = 0, i.e., n = l, n · l equals 1, and therefore p receives the maximum amoun t of light (Fig. 5.2-(b)). When θ = 90 , n · l equals 0, and p receives no light (Fi g. 5.2-(c)). Note that, when θ > 90 , p does not receive any light (Fig. 5.2-(d)). Therefore, the amount of incident light should be zero, but n·l becomes negativ e. To resolve this problem, n · l in Equation (5.1) is extended to the following: max(n · l, 0)



$\boxed{max(n \cdot l, 0)}$ Determines the amount of incident light

Phong Lighting Model - Diffuse Term (cont'd)

- Suppose a white light (1,1,1). If an object lit by the light appears yellow, it means that the object reflects R and G and absorbs B. We can easily implement this kind of filtering through material parameter, i.e., if it is (1,1,0), then (1,1,1)⊗(1,1,0)=(1,1,0) where ⊗ is component-wise multiplication.

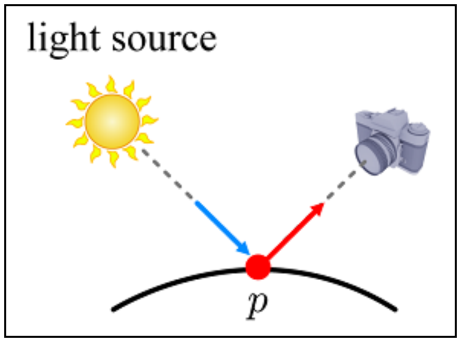


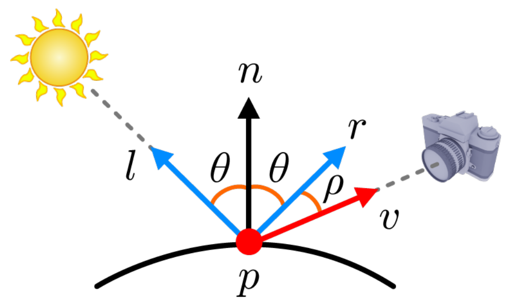
$$\boxed{s_d \otimes m_d}$$

- The diffuse term: $max(n \cdot l, 0)s_d \otimes m_d$

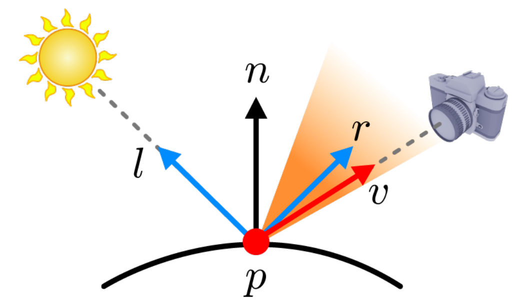
Phong Lighting Model - Specular Term

- The specular term is used to make a surface look shiny via *highlights*, and it requires *view vector* (v) and *reflection vector* (r) in addition to *light vector* (l).



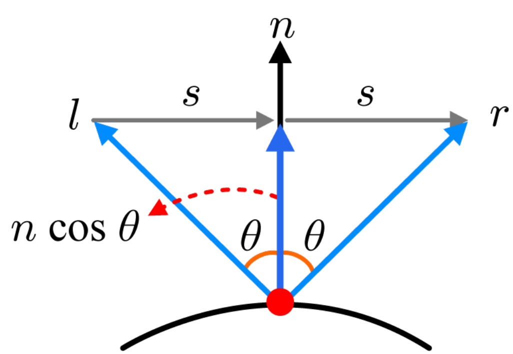


(a)



(b)

- Computing the reflection vector

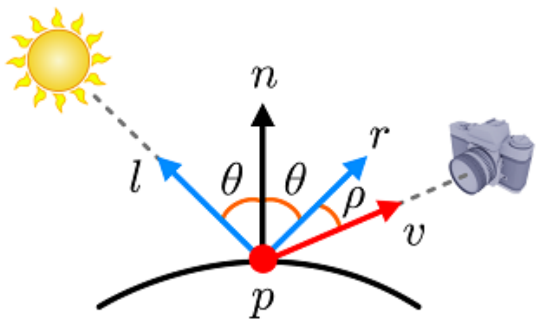


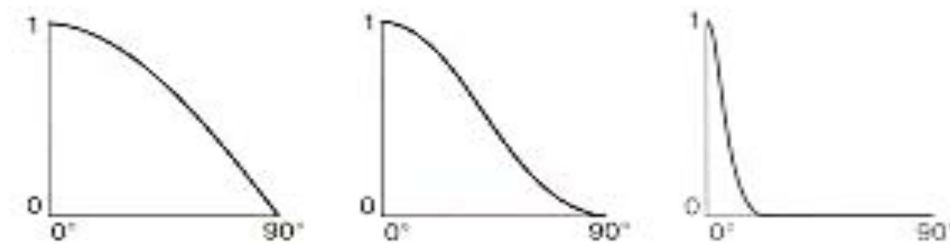
$$s = n\cos\theta - l$$
$$s = r - n\cos\theta$$

$$\begin{aligned} r &= 2n\cos\theta - l \\ &= 2n\,(n\cdot l) - l \end{aligned}$$

Phong Lighting Model - Specular Term (cont'd)

- Whereas the diffuse term is view-independent, the specular term is highly view-dependent.
  - For a perfectly shiny surface, the highlight at p is visible only when ρ equals 0.
  - For a surface that is not perfectly shiny, the maximum highlight occurs when ρ equals 0, but falls off sharply as ρ increases.
  - The rapid fall-off of highlights is often approximated by $(r \cdot v)^{sh}$, where sh denotes shininess.



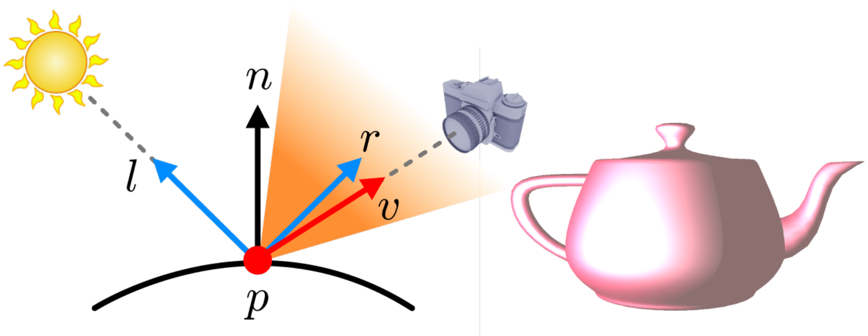


$cos\rho$ $\quad$ $cos^2\rho$ $\quad$ $cos^{64}\rho$

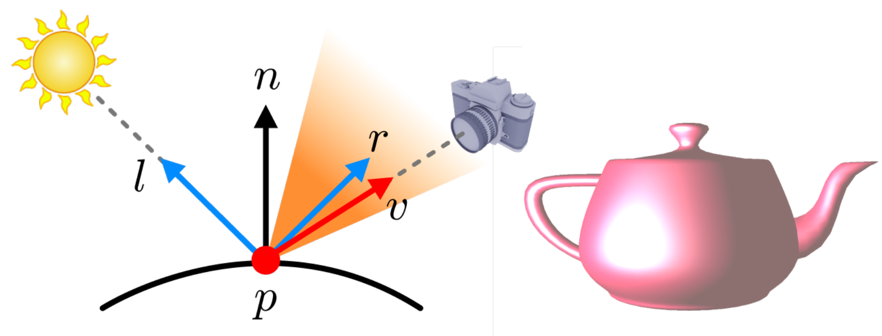
$$\boxed{(r \cdot v)^{sh}}$$

- The specular term: $(max(r \cdot v, 0))^{sh} s_s \otimes m_s$
- Unlike m_d, m_s is usually a gray-scale value rather than an RGB color. It enables the highlight on the surface to end up being the color of the light source.

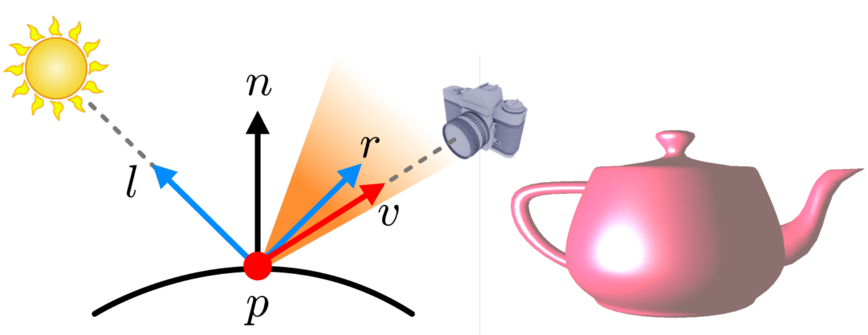
Phong Lighting Model - Specular Term (cont'd)



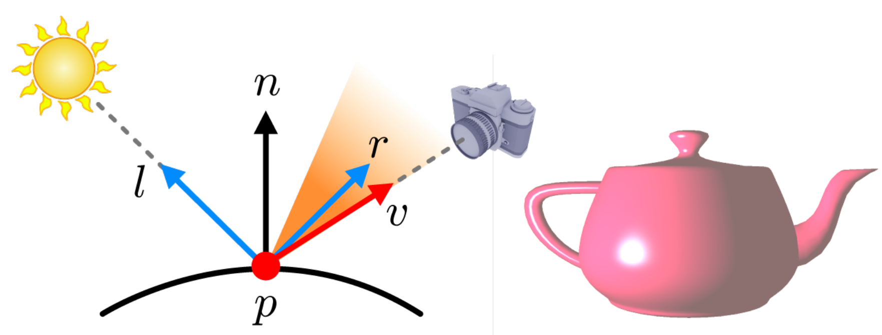
(a) $sh = 5$



(b) $sh = 10$



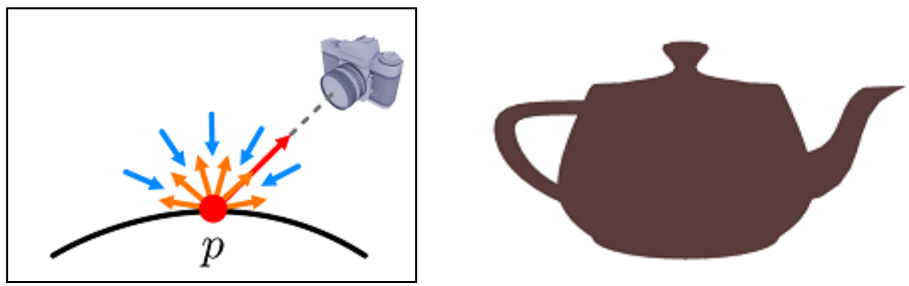
(c) $sh = 20$



(d) $sh = 80$

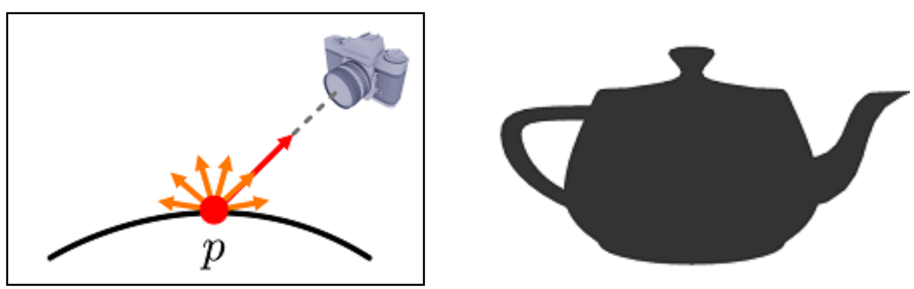
Phong Lighting Model – Ambient and Emissive Terms

- The ambient light describes the light reflected from the various objects in the scene, i.e., it accounts for *indirect lighting*.
- As the ambient light has bounced around so much in the scene, it arrives at a surface point from all directions, and reflections from the surface point are also scattered with equal intensity in all directions.



$s_a \otimes m_a$

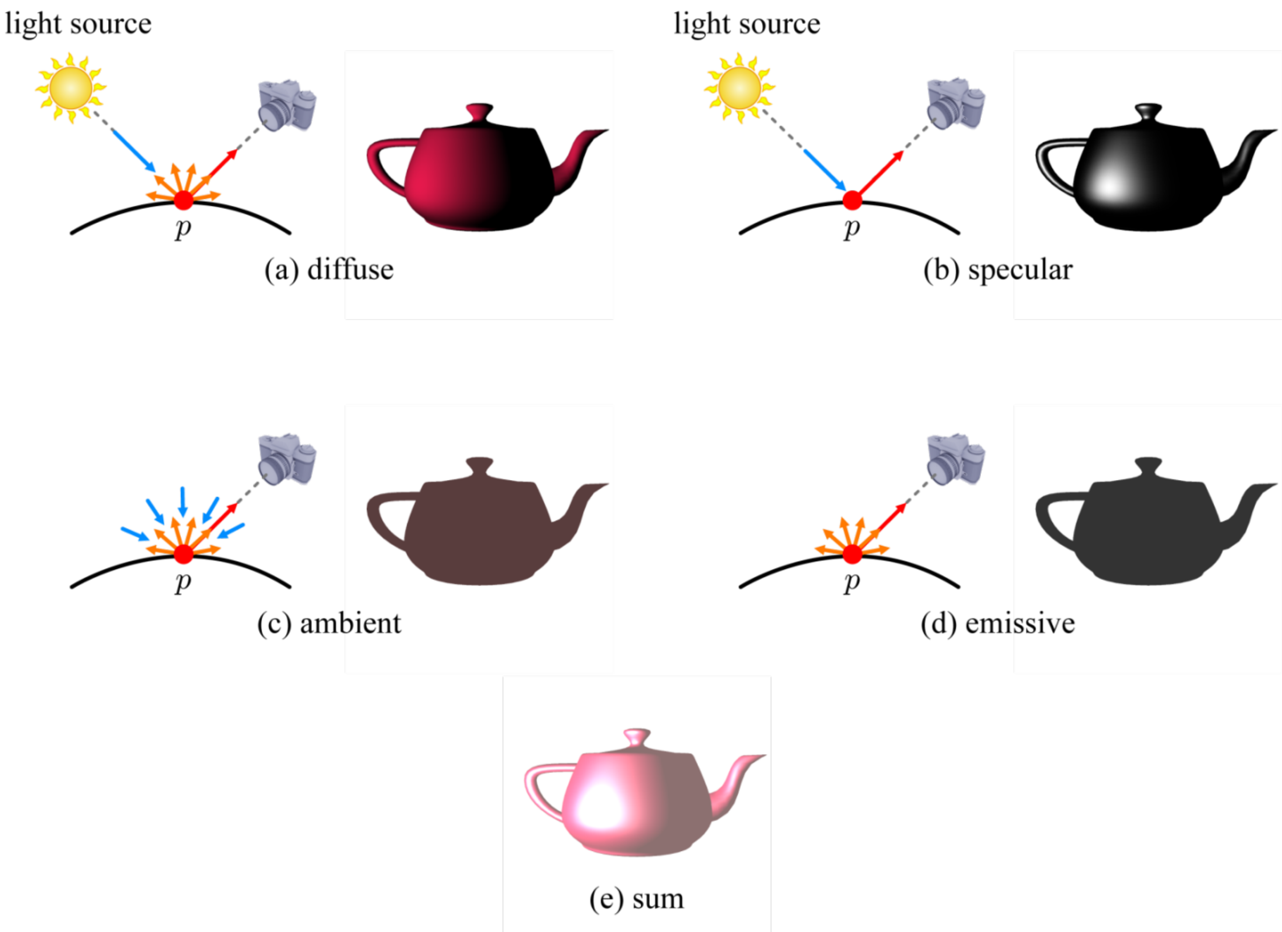
- The last term of the Phong model is the emissive term m_e that describes the amount of light emitted by a surface itself.



Phong Lighting Model

- The Phong model sums the four terms!!

$$\boxed{max(n \cdot l, 0)s_d \otimes m_d + (max(r \cdot v, 0))^{sh} s_s \otimes m_s + s_a \otimes m_a + m_e}$$



(a) diffuse
(b) specular
(c) ambient
(d) emissive
(e) sum