COMP220: Graphics & Simulation

6: Materials and Lighting

Learning outcomes

- **Explain** the Phong illumination model
- **Implement** Phong illumination in your own programs
- **Describe** how effects such as normal mapping can be used to render realistic materials

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Vector products

Dot and cross product

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$$a \times b = (|a||b| \sin\theta)n$$

where n is a unit vector **perpendicular** to both a and b with direction given by the **right-hand rule**

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- vector $\cdot$ vector $=$ number; vector $\times$ vector $=$ vector

Surface normals

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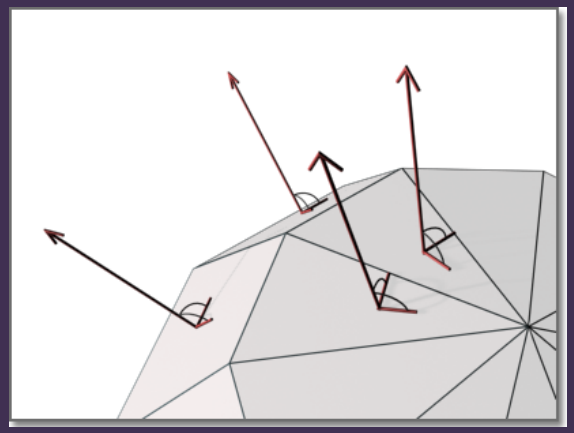

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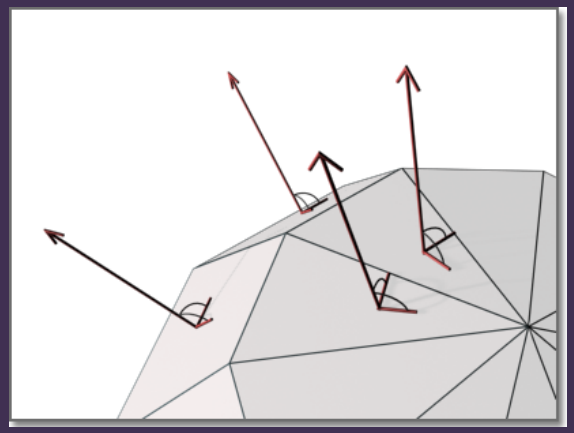

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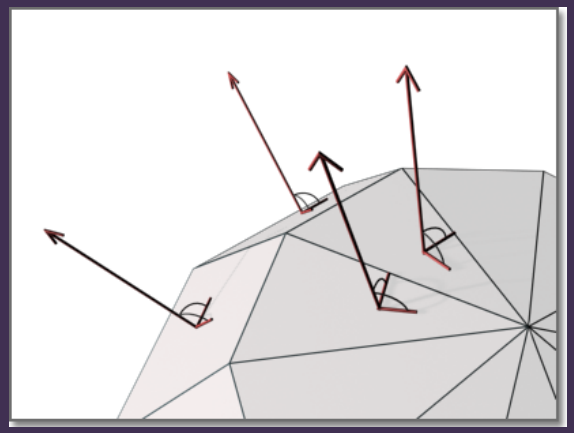

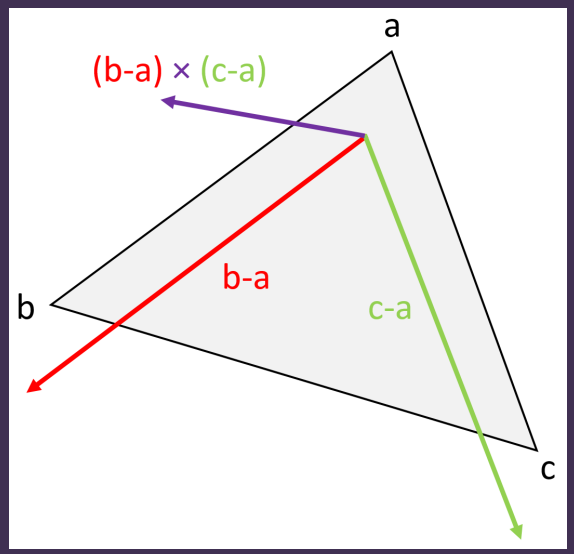

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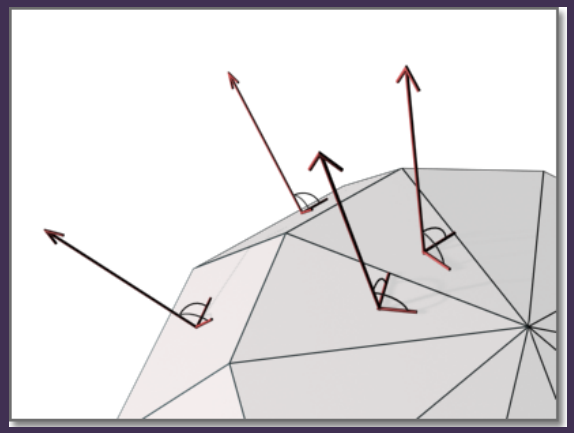

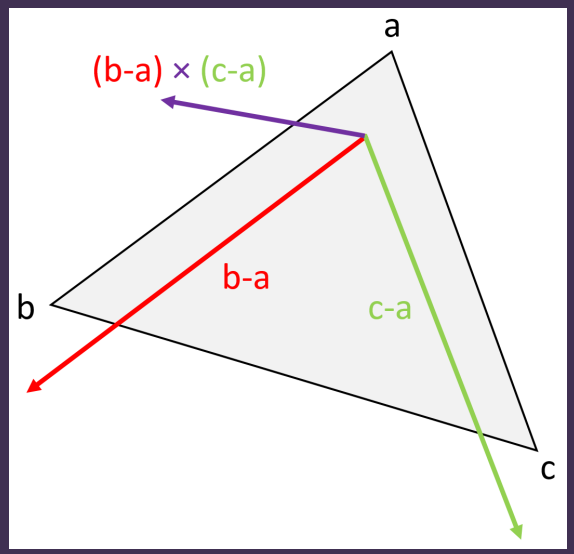

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- For a triangle with vertices a, b, c, two such vectors are $b - a$ and $c - a$
- So the normal is

$$\frac{n}{|n|} \quad \text{where} \quad n = (b - a) \times (c - a)$$

Passing normals to OpenGL

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- We will pass normals as **vertex attributes**

Passing normals to OpenGL

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- For now all vertices of a triangle have the same normal, but this will change later

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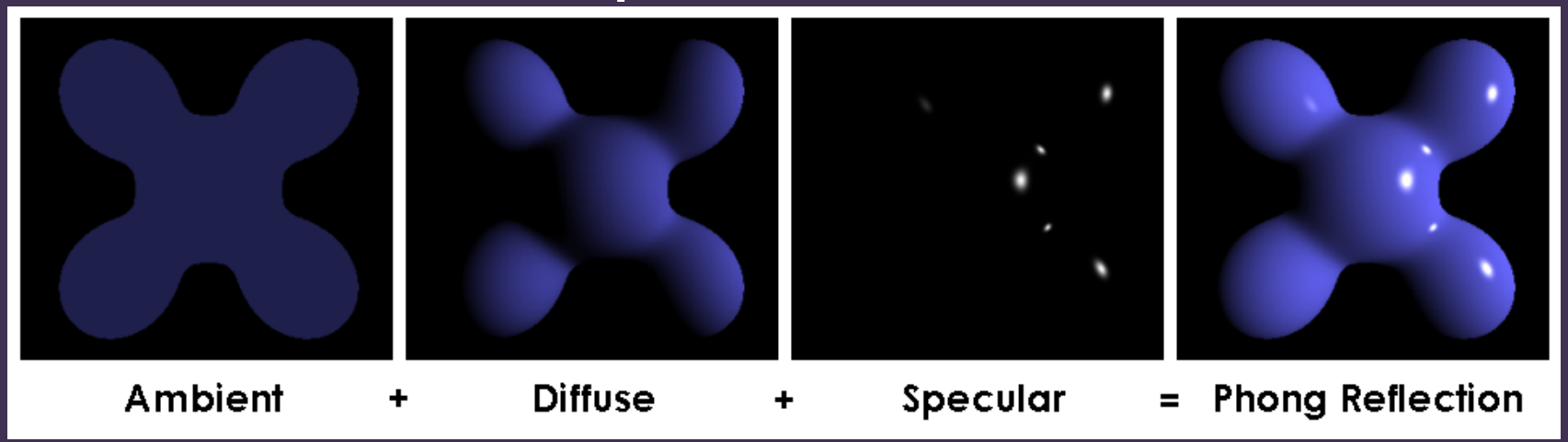

Diffuse lighting

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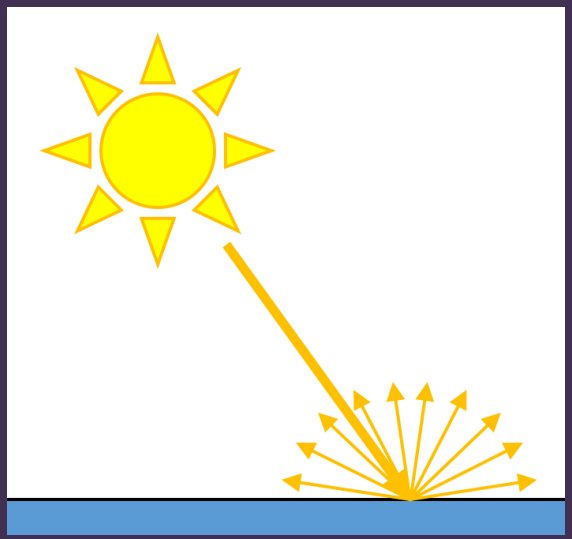

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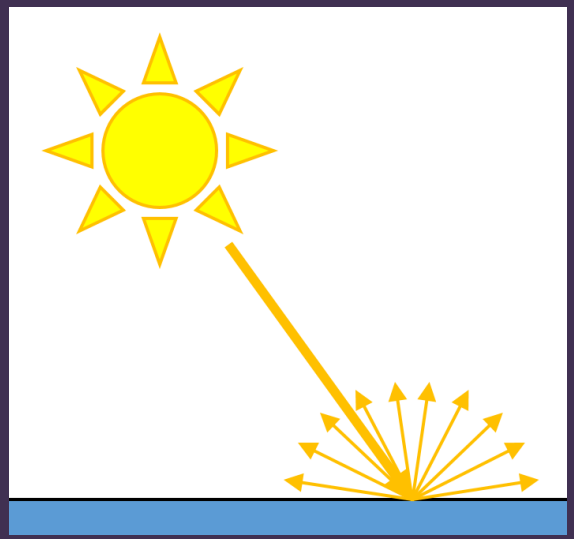
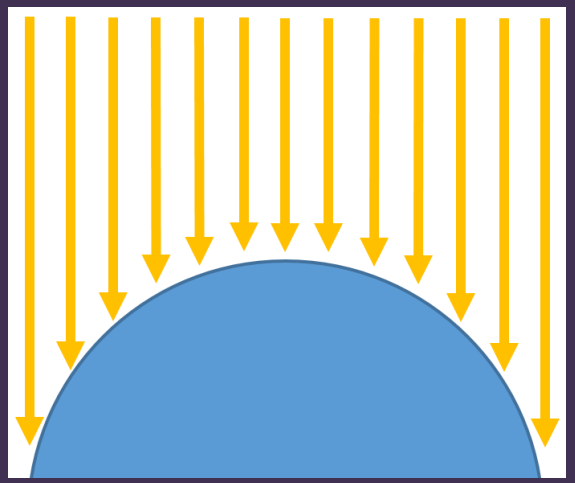
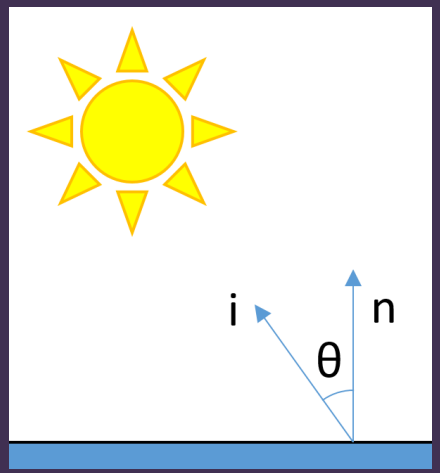


When light hits a “”rough surface, it is **scattered equally in all directions**

The amount of light hitting the surface depends on the **angle** between the surface and the light source



Diffuse lighting formula



Diffuse lighting formula

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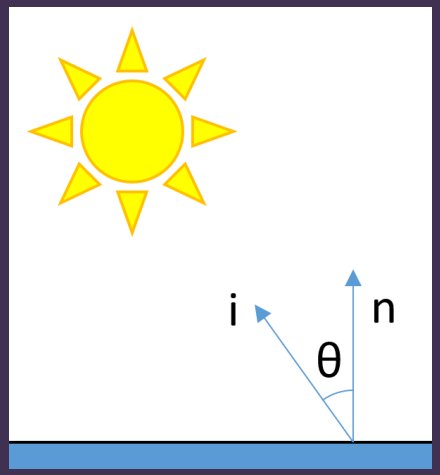

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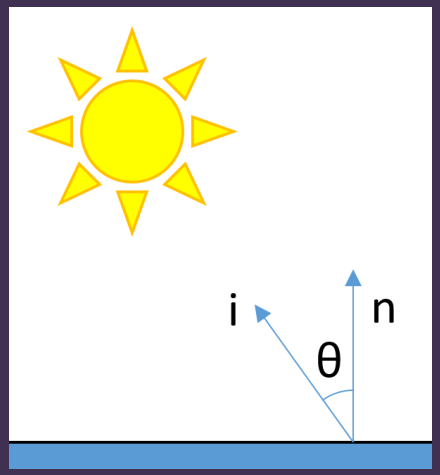

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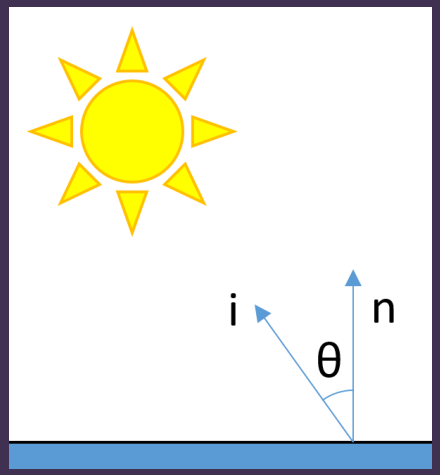

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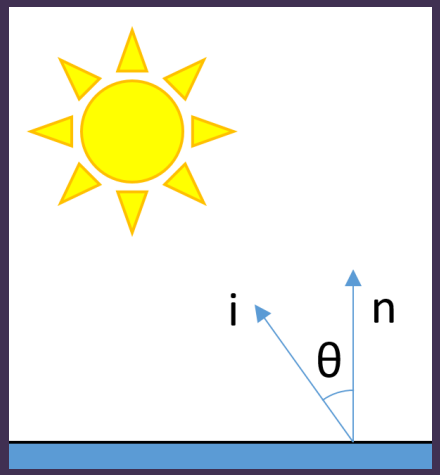

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- If the surface is **pointing away** from the light source, we get $\theta > \frac{\pi}{2}$ so $\cos\theta < 0$ — in this case we **clamp** the answer to 0

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- For a **point** light source (e.g. a lightbulb):
  - Direction is calculated by subtracting the light position from the fragment position
  - Intensity obeys an **inverse square law**: if the distance between the fragment and the light source is d, then the light intensity is $\frac{1}{d^2}$

Specular lighting

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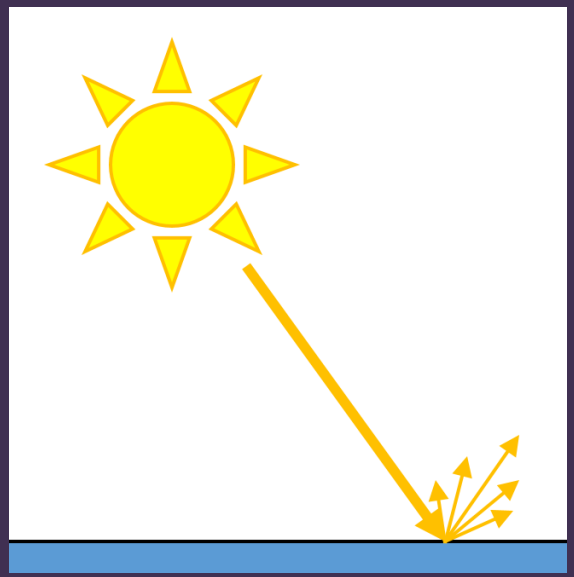
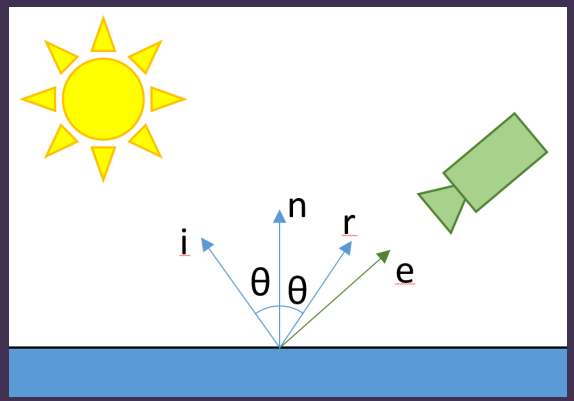


When light hits a "smooth" surface, it is **reflected** across a narrow range of angles

Specular lighting formula



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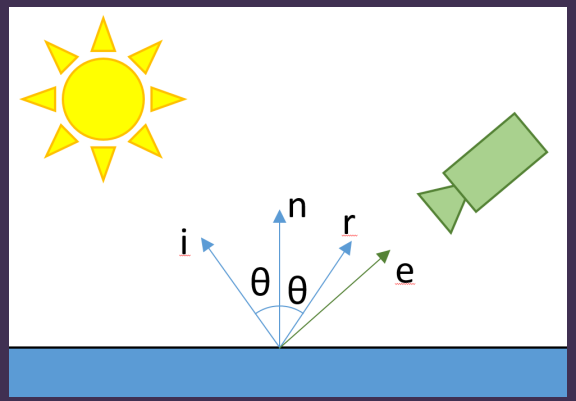

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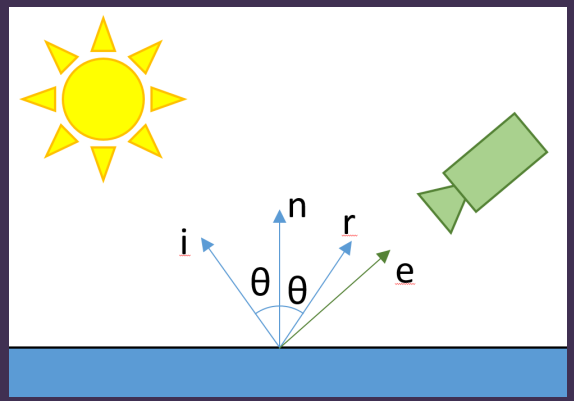

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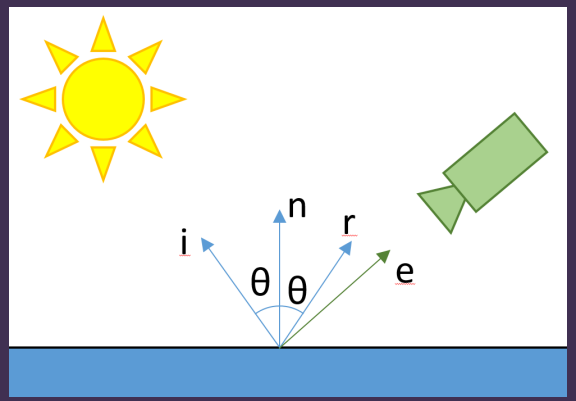

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- Specular light intensity is proportional to

$$\text{clamp}(e \cdot r)^s$$

where s is a "shininess" parameter, and clamp(x) clamps its argument between 0 and 1

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- Another option would be to add more light sources...

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- Using different normals for the vertices can give a "curved" look

Normal mapping

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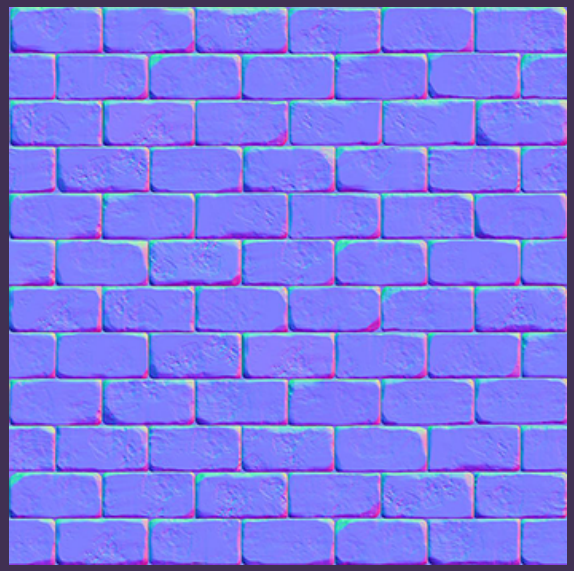

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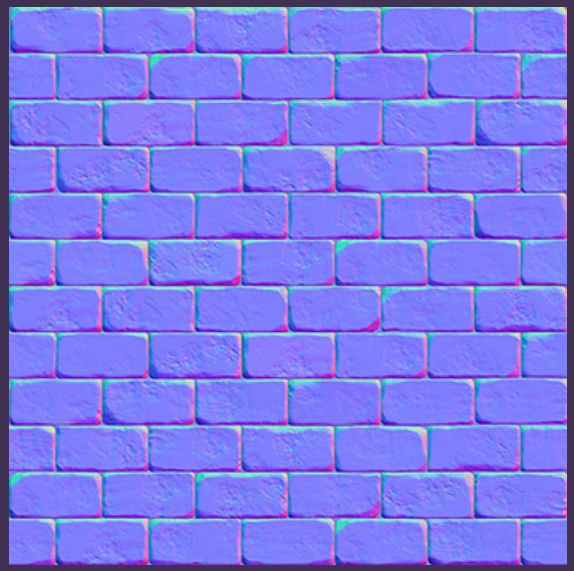

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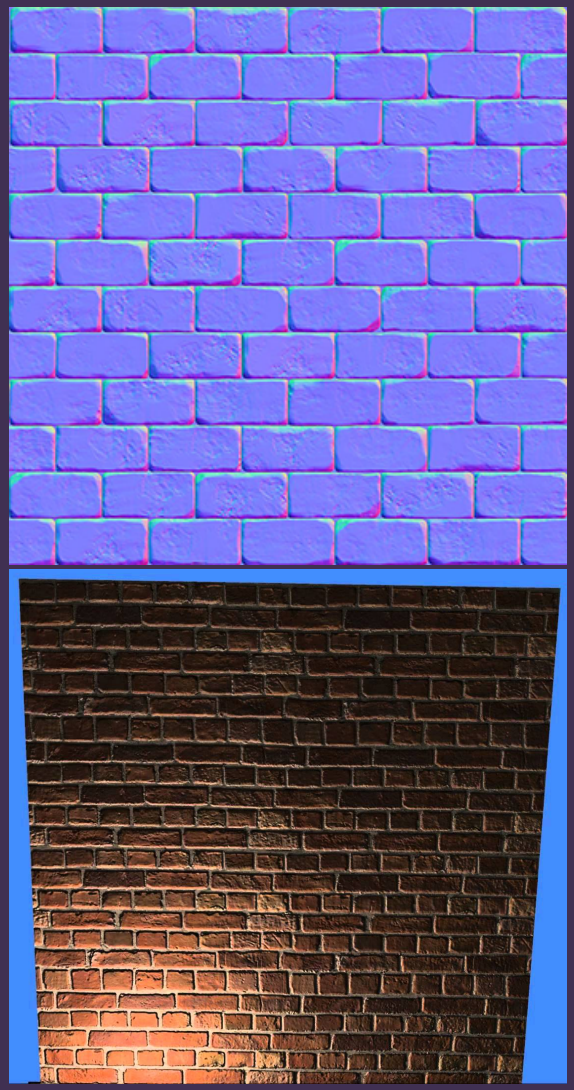

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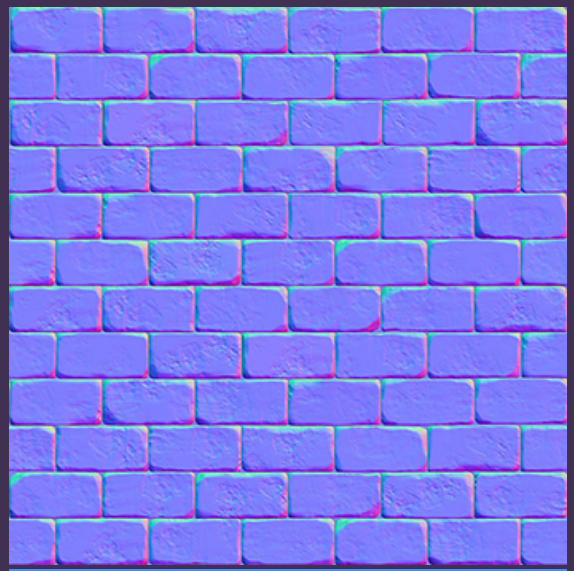

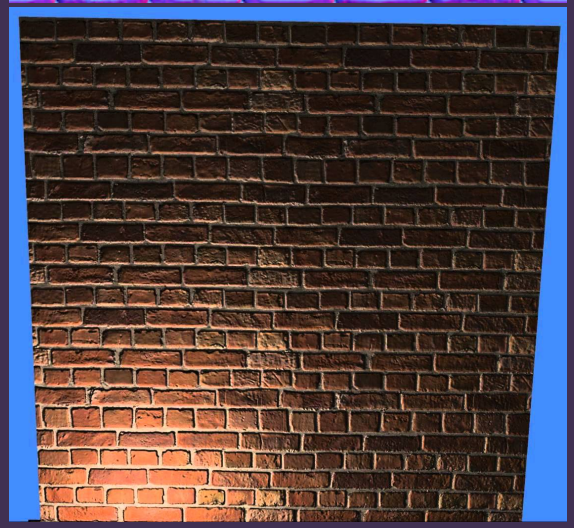

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- Can use textures to change other lighting parameters across a surface, e.g. **specular mapping**

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