COMP220: Graphics & Simulation

7: Lighting

Learning outcomes

By the end of this week, you should be able to:

- **Explain** the Blinn-Phong illumination model
- **Describe** how effects such as normal mapping can be used to enhance appearance
- **Implement** basic lighting effects in your scene

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- Lecture (async):
  - **Calculate** the colours in a lit scene using the Blinn-Phong model.

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- Lecture (async):
  - **Calculate** the colours in a lit scene using the Blinn-Phong model.
- Workshop (sync):
  - **Create** a light source and use it to illuminate objects in the scene.
  - **Recap** and **extend** the use of uniforms to pass data to shaders.

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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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  - If $a \cdot b = 1$ and a, b are unit vectors then $\cos\theta = 1$, i.e. $\theta = 0°$: a and b are **parallel**
- Cross product can be used to find a vector **perpendicular** to two others

Surface normals

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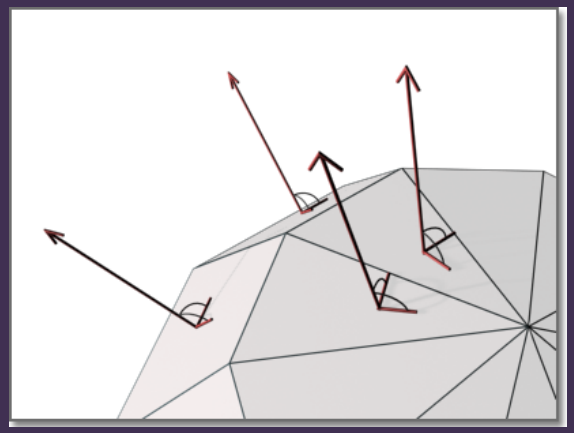

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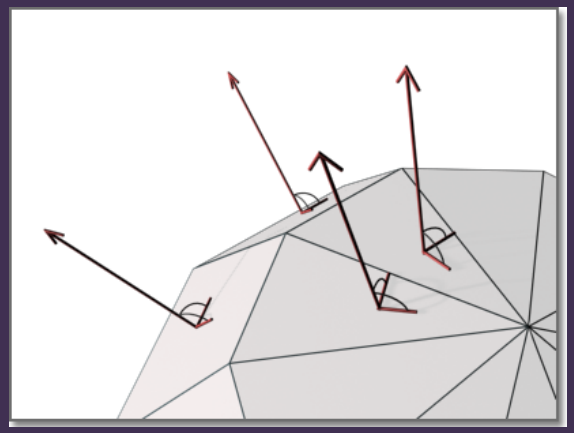

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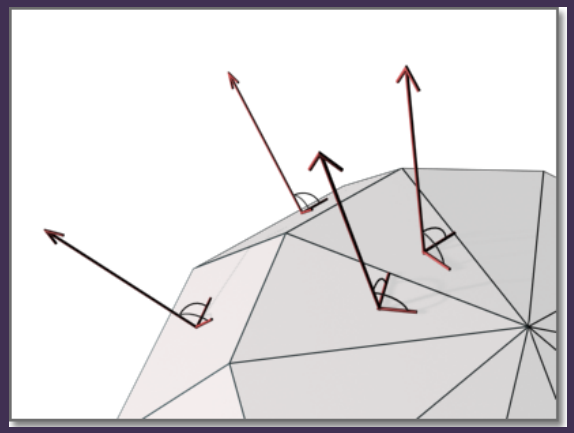

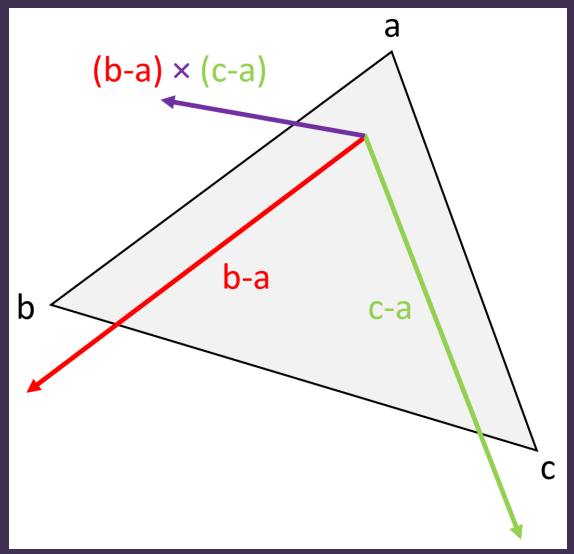

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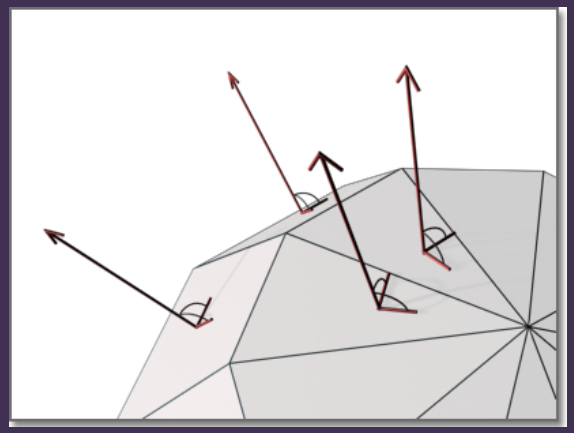

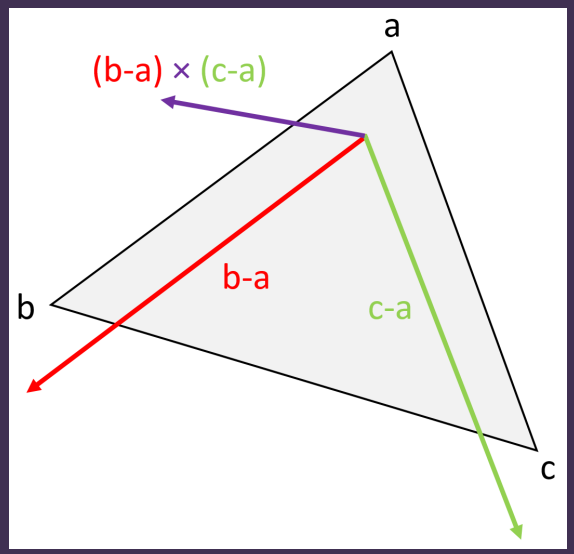

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- For a triangle with vertices a, b, c, two such vectors are $b - a$ and $c - a$
- So the normal is

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

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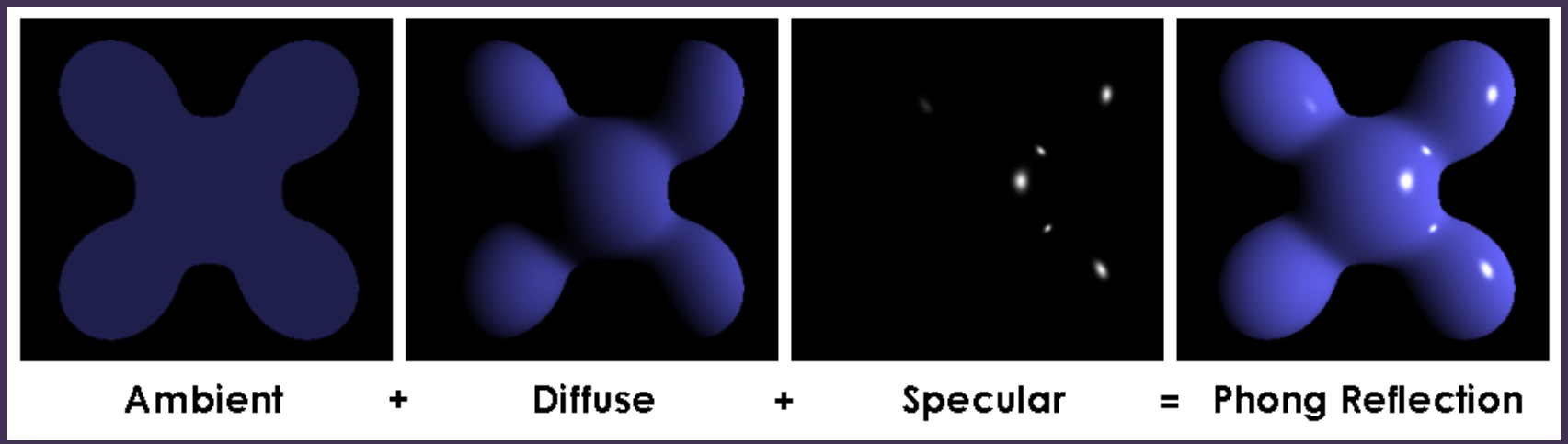

Diffuse lighting

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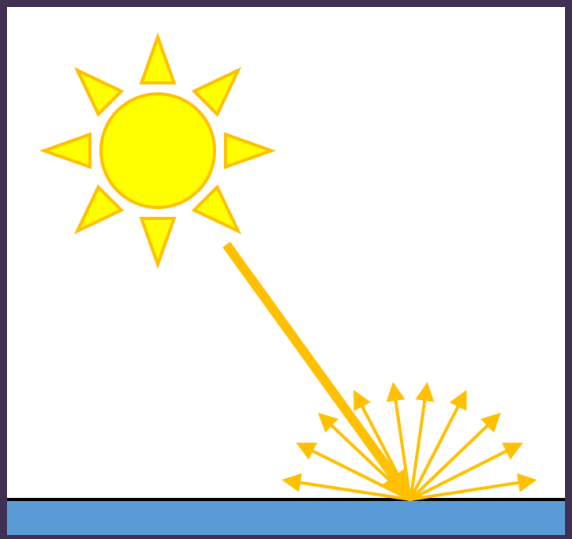

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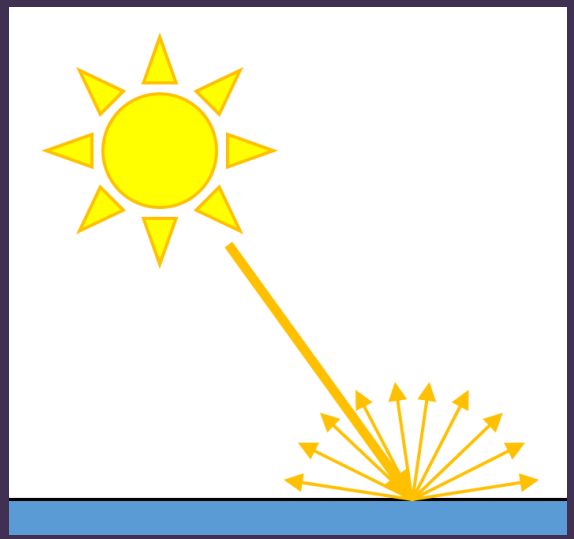
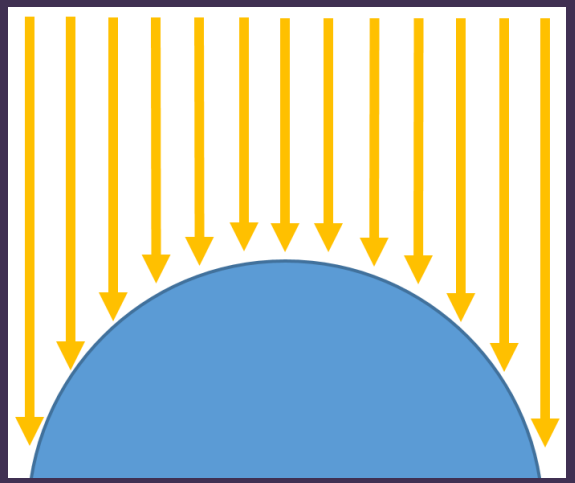
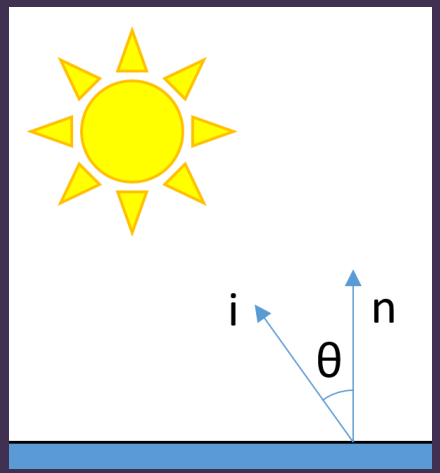


When light hits a "rough" surface, it is **scattered equally in all directions**

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



Diffuse lighting formula



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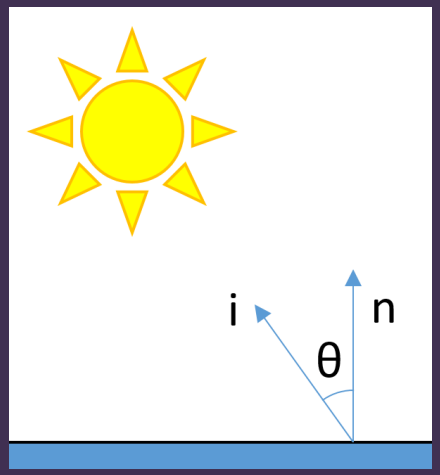

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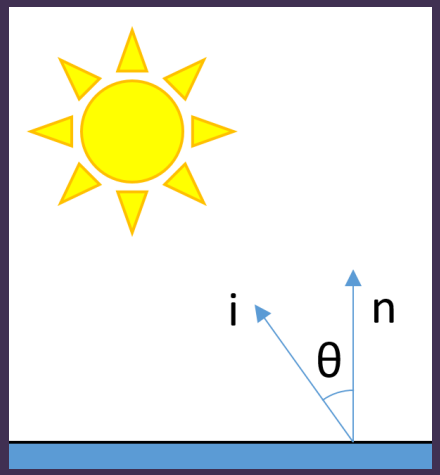

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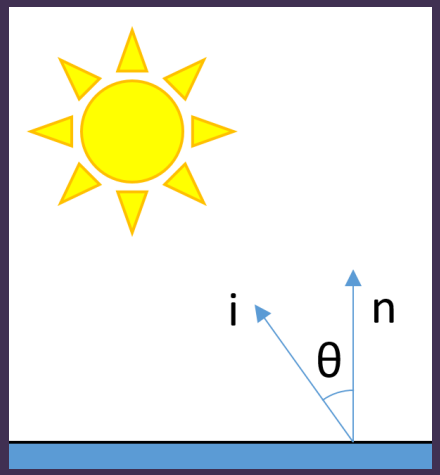

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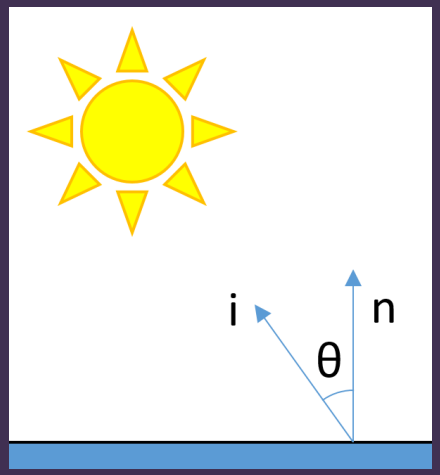

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- If the surface is **pointing away** from the light source, we get $\theta > \frac{\pi}{2}$ so $\cos\theta < 0$ — in this case we **clamp** the answer to 0

Light direction and intensity

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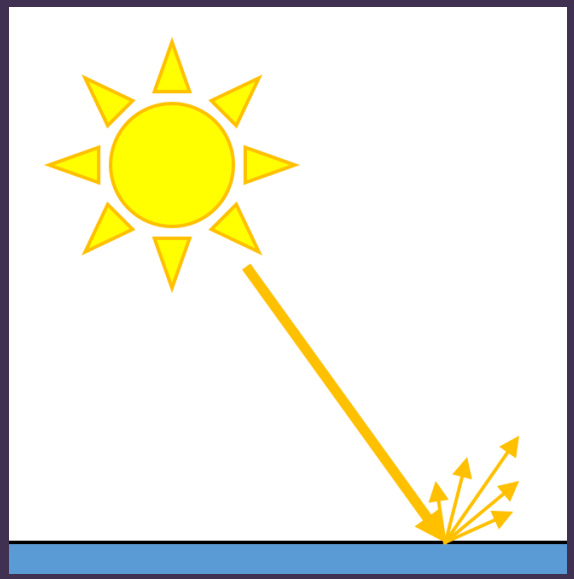
- For a **point** light source (e.g. a lightbulb):
  - Direction is calculated by subtracting the fragment position from the light position
  - Intensity is usually **attenuated**, e.g. using an **inverse square law**: if the distance between the fragment and the light source is d, then the light intensity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

Specular lighting

Specular lighting



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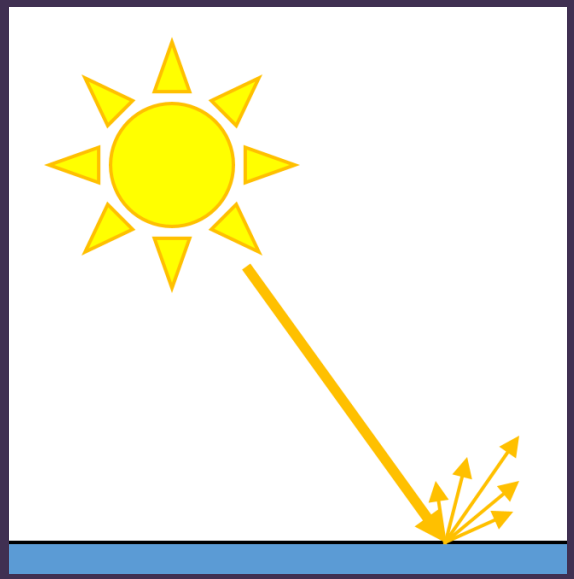

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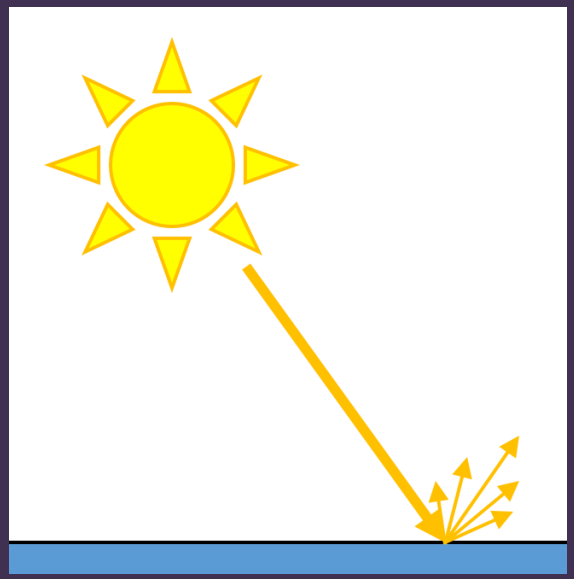
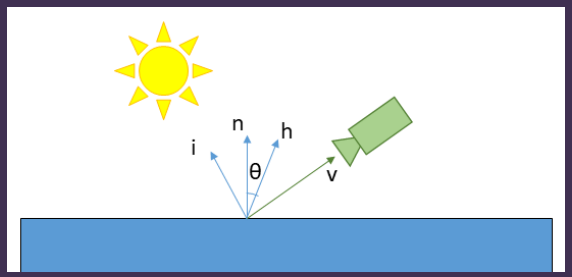


- When light hits a "smooth" surface, it is **reflected** across a narrow range of angles
- This creates a **specular highlight**, with intensity dependent on the **view direction** as well as the direction to the light source.

Specular lighting formula



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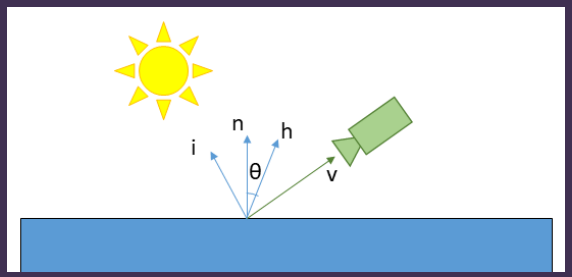

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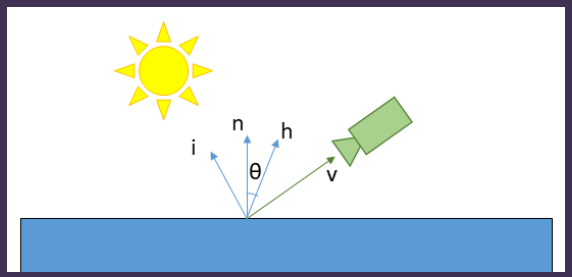

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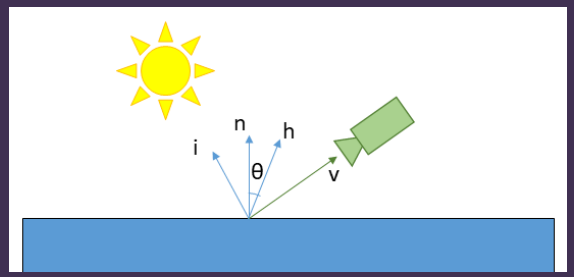

- Let h be the "halfway vector", calculated by $i + v$
- The closer h is to n, the higher the specular contribution.
- Specular light intensity is proportional to

$$\text{clamp}(n \cdot h)^s$$

where s is a "shininess" parameter, and $\text{clamp}(x)$ clamps its argument between 0 and 1

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

Normal mapping

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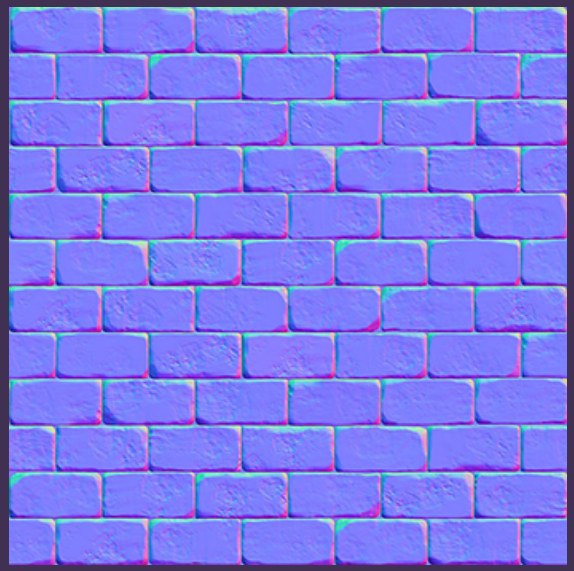

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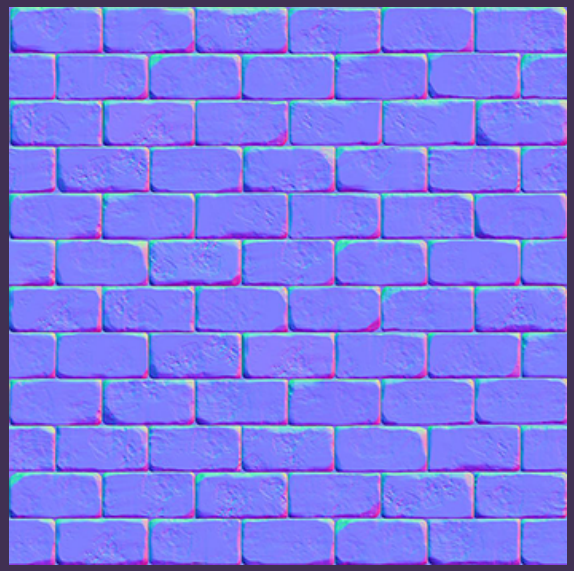

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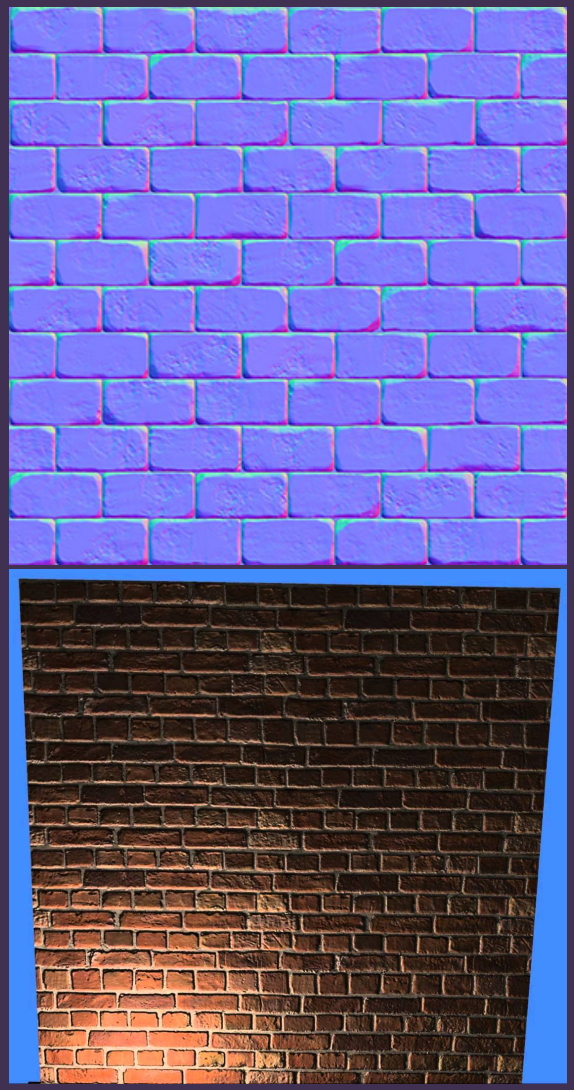

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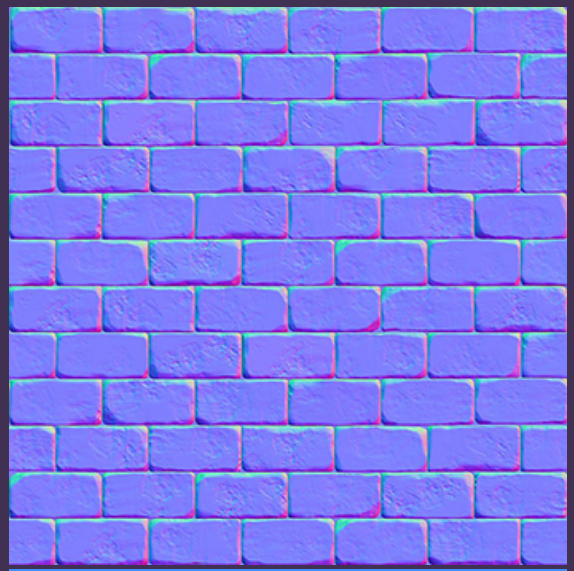

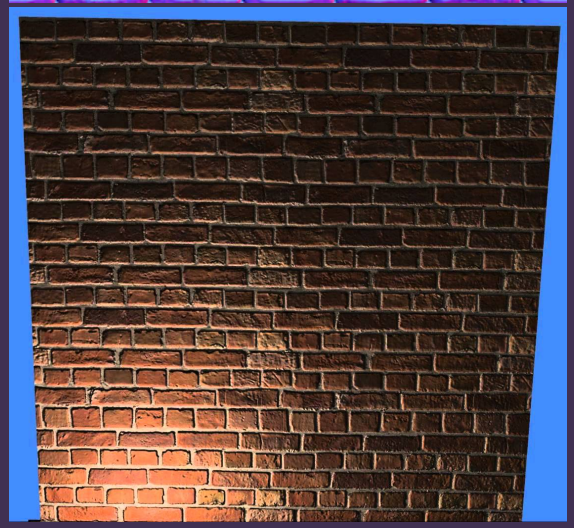

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  - Each pixel in the normal map represents a 3D vector, with *xyz* mapped to RGB
- Can be used to add detail to flat, low-poly surfaces
- Can use textures to change other lighting parameters across a surface, e.g. **specular mapping**

Next steps

- **Review** the additional asynchronous material for more background on different lighting models and effects.
- **Attend** the workshop to practice creating light sources and using them to illuminate the scene.