LEI / LCC
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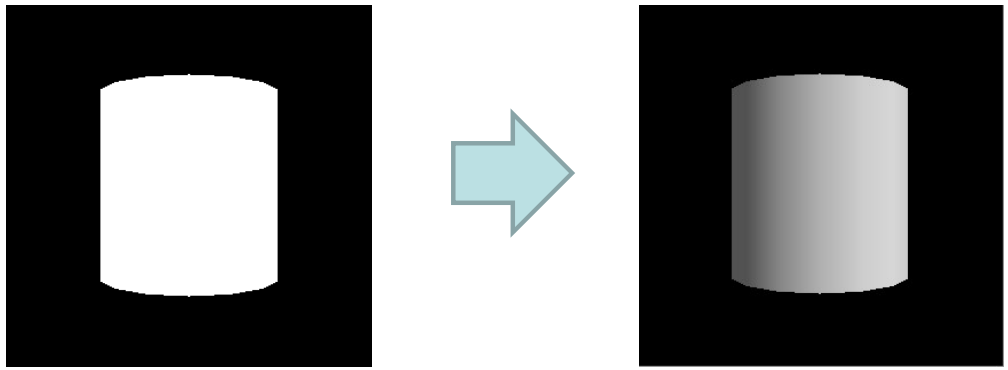
Lighting

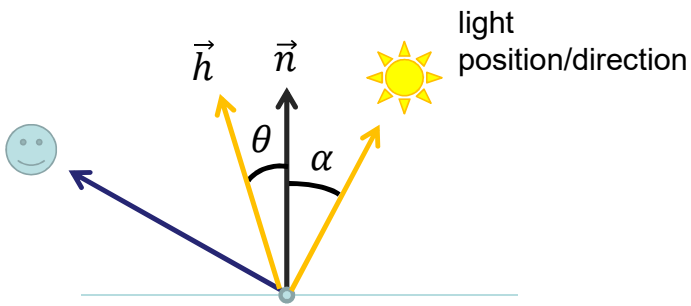
Lights, Materials and Normals

Goal

- To get a lit cylinder



Lighting: a quick refresh



diffuse $I_d = K_d \times L_d \times \cos(\alpha)$

material colors

light colors

material shininess

specular $I_s = K_s \times L_s \times cos\ (\theta)^s$

Needed:
- Setup light
- Define material colors
- Add normals to vertices

Approach

- To lit the cylinder:
  - Setup a light source:
    - Initialization:
      - Turn on lighting
      - Define light color
    - Render:
      - Define position of the light
  - Define a material for the cylinder <- Render
  - Add normals to the cylinder from script 4
    - Initialization:
      - Create an array with the normal vectors for each vertex
      - Create a VBO and copy data to GPU
    - Render:
      - bind, define semantics, draw

Setup a light source

- Turn on lighting

  - Done once in initialization

```
glEnable(GL_LIGHTING);
glEnable(GL_LIGHT0);
```

Turn lighting on. Without this nothing will be lit.

Using a single light source. If more light sources are required it is necessary to lit them all

Setup a light source

- Define light color

  - Done once in initialization

```
GLfloat dark[4] = {0.2, 0.2, 0.2, 1.0};
GLfloat white[4] = {1.0, 1.0, 1.0, 1.0};


// light colors
glLightfv(GL_LIGHT0, GL_AMBIENT, dark);
glLightfv(GL_LIGHT0, GL_DIFFUSE, white);
glLightfv(GL_LIGHT0, GL_SPECULAR, white);
```

for default values check:
https://www.khronos.org/registry/OpenGL-Refpages/gl2.1/xhtml/glLight.xml

Setup a light source

- Define light Position/Direction

  - In render function

```
float pos[4] = {1.0, 1.0, 1.0, 0.0};
glLightfv(GL_LIGHT0,GL_POSITION, pos);
```

Last component defines if this is a point or a vector.

Using a vector produces a directional light, a point will provide a point light or a spotlight

- The light position/direction is affected by geometrical transformations, hence it needs to be set every frame.

Define a material for the cylinder

- Materials are like colors, but more configurable

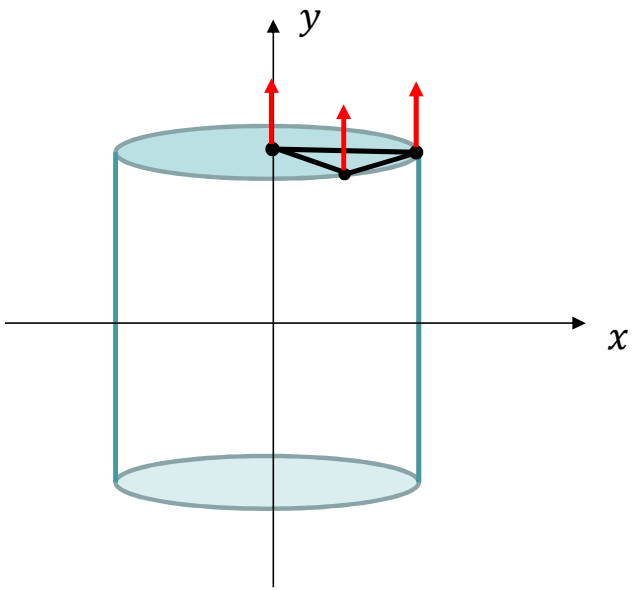
```
float dark[] = { 0.2, 0.2, 0.2, 1.0 };
float white[] = { 0.8, 0.8, 0.8, 1.0 };
float red[] = { 0.8, 0.2, 0.2, 1.0 };

glMaterialfv(GL_FRONT, GL_AMBIENT_AND_DIFFUSE, white);
glMaterialfv(GL_FRONT, GL_SPECULAR, white);
glMaterialf(GL_FRONT, GL_SHININESS, 128);
```

Note: setting the same color for ambient and diffuse because light's ambient color is already dark

- Materials should be set every frame, before drawing the object

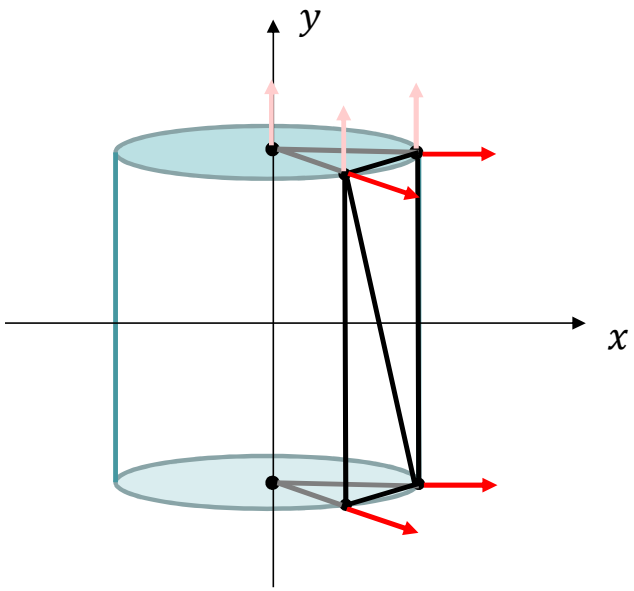
Cylinder Normals

- A normal is a unit length vector perpendicular to the surface
- The top lid vertices have a normal ↑ pointing upwards $(0,1,0)$
- The bottom lid vertices have a symmetrical normal



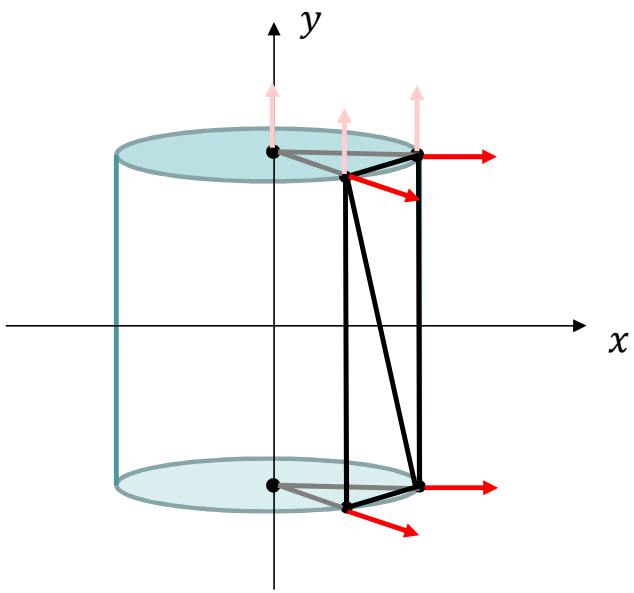
Cylinder Normals

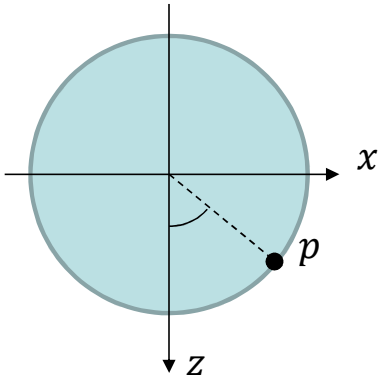
- Consider the triangles of the face of the cylinder
- These vertices have horizontal → normals pointing outwards
- Notice that we are not trying to get the normals of the triangular surface. Instead we want the normals of the underlying surface, the cylinder



Cylinder Normals

- Since the normals are horizontal the y coordinate is zero





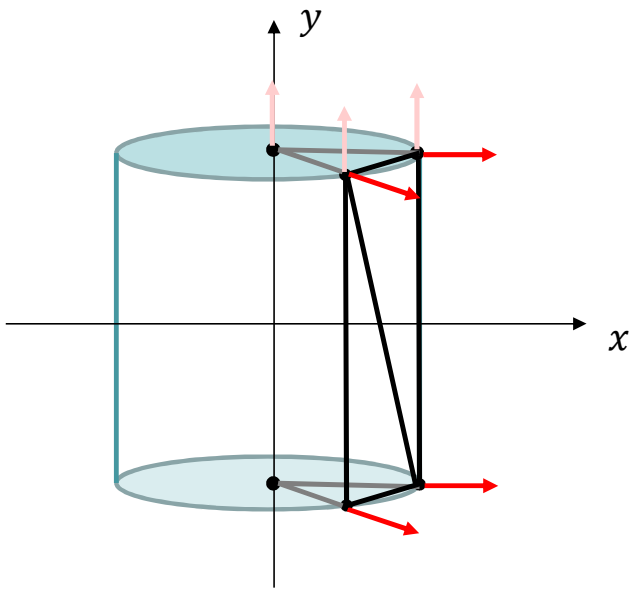
Consider a vertex on the lid.
How to compute its coordinates?

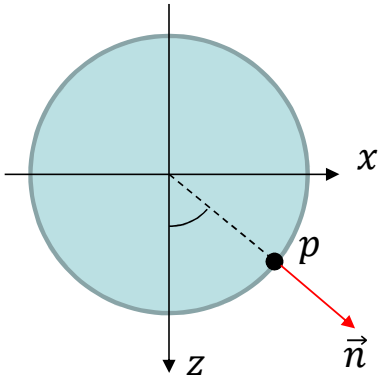
Polar coordinates

$$x = r\ sin(\alpha)$$
$$z = r\ \cos(\alpha)$$

Cylinder Normals

- Since the normals are horizontal the y coordinate is zero





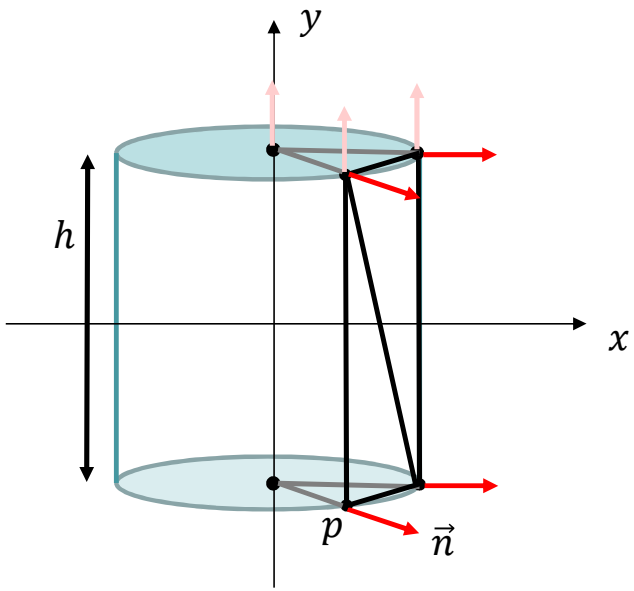
Polar coordinates

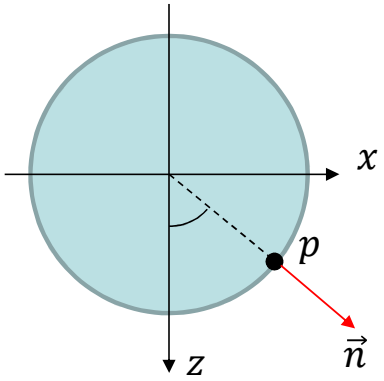
$$x = r\ sin(\alpha)$$
$$z = r\ \cos(\alpha)$$

Notice that the normal has the same direction than the vector from the center of the lid to the vertex.

Cylinder Normals

- Since the normals are horizontal the y coordinate is zero





Polar coordinates

$$x = r\ sin(\alpha)$$
$$z = r\ \cos(\alpha)$$

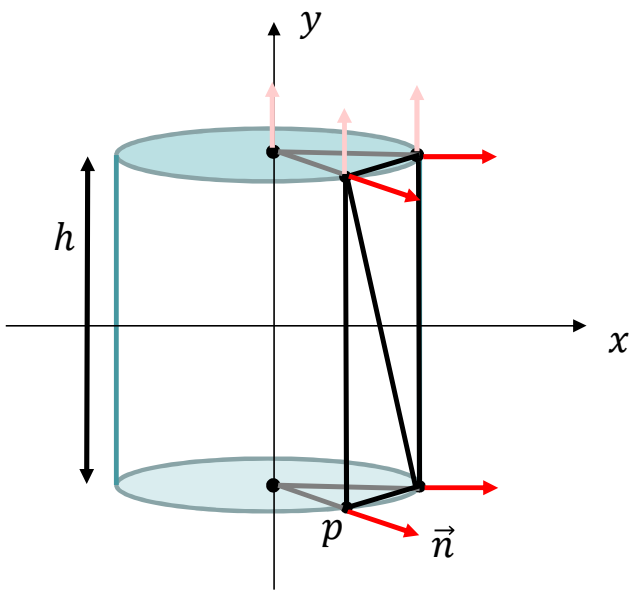
Therefore, if

$$p = \left(r\ sin(\alpha), \frac{h}{2}, r\ \cos(\alpha)\right)$$

then

$$\vec{n} = (r\ sin(\alpha), 0, r\ \cos(\alpha))$$

Cylinder Normals



- Note: position p gives rise to two distinct vertices. One from the bottom lid, and one from the face of the cylinder.
- Vertices are distinct if one of their components is different, and in this case the normals are different.
- This implies that in the position and normal arrays p must appear twice. Once belonging to the lid, and once belonging to the face of the cylinder

VBOs: Normals and Vertices

The position and normal arrays must have the same vertex order

posições

p_0x	p_0y	p_0z	p_1x	p_1y	p_1z	p_2x	p_2y	p_2z	. . .	p_nx	p_ny	p_nz

vértices

n_0x	n_0y	n_0z	n_1x	n_1y	n_1z	n_2x	n_2y	n_2z	. . .	n_nx	n_ny	n_nz

OpenGL – Normals and VBOs

- The process to use VBOs with normals is similar to the one we used before with vertex positions.

- VBO Init

  - Step 1 a) Enable Buffers

```
glEnableClientState(GL_VERTEX_ARRAY);
glEnableClientState(GL_NORMAL_ARRAY);
```

OpenGL – Normals and VBOs

- VBO Init

  - Step 1 b – Allocate and fill the vertex and normal arrays

```
// vertex array
float *vertexB;
// fill the array
…
// normal array
float *normalB;
// fill the array
...
```

  - Step 1 c (optional) – Allocate and fill the index array

```
unsigned int *indices;
...
```

OpenGL – Normals and VBOs

- VBO Init

- Step 1 d : Create the VBOs

```
GLuint buffers[2];
// two buffers: vertex coordinates and normals
float *vertexB, *normalB;
...
// create two buffers
glGenBuffers(2, buffers);

// bind and copy data
glBindBuffer(GL_ARRAY_BUFFER,buffers[0]);
glBufferData(GL_ARRAY_BUFFER,arraySize, vertexB, GL_STATIC_DRAW);

glBindBuffer(GL_ARRAY_BUFFER,buffers[1]);
glBufferData(GL_ARRAY_BUFFER, arraySize, normalB,GL_STATIC_DRAW);
```

OpenGL – Normals and VBOs

- Draw with VBOs
  - Step 2 a – Semantics
    - For each buffer: what will it be used for

```
glBindBuffer(GL_ARRAY_BUFFER,buffers[0]);
glVertexPointer(3,GL_FLOAT,0,0);

glBindBuffer(GL_ARRAY_BUFFER,buffers[1]);
// normals always have 3 components
glNormalPointer(GL_FLOAT,0,0);
```

OpenGL – Normals and VBOs

- Draw with VBOs
  - Step 2 b: Drawing
    - With an index list

```
glDrawElements(GL_TRIANGLES, count, GL_UNSIGNED_INT, indices);
```

    - Without an index list

```
glDrawArrays(GL_TRIANGLES, first, count);
```

Note: count is the number of vertices/indices to draw

Assignment

- Define the normal vectors for the cylinder
- Add all the required instructions to draw a cylinder lit by a directional light
- Try using the specular component

Questions?

- What happens if we perform some geometrical transformation before placing the light? For instance:

```
glRotatef(45, 0,1,0);
glLightfv(GL_LIGHT0,GL_POSITION, dir);
```

- What happens if the light is placed before the gluLookAt?

```
gluLookAt(camX,camY,camZ,
          0.0,0.0,0.0,
          0.0f,1.0f,0.0f);
glLightfv(GL_LIGHT0,GL_POSITION, dir);
```

VS

```
glLightfv(GL_LIGHT0,GL_POSITION, dir);
gluLookAt(camX,camY,camZ,
          0.0,0.0,0.0,
          0.0f,1.0f,0.0f);
```

Questions?

- What happens when we don't provide normal with length != 1 ?

- What happens if we use (1,0,0) as the light color, and (0,1,0) as the objects color?
  - Why?
  - How to fix this assuming that we really want a red light lighting a green object?