ARLAB

ME/CprE/ComS 557

Computer Graphics and Geometric Modeling

Blending

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OF SCIENCE AND TECHNOLOGY

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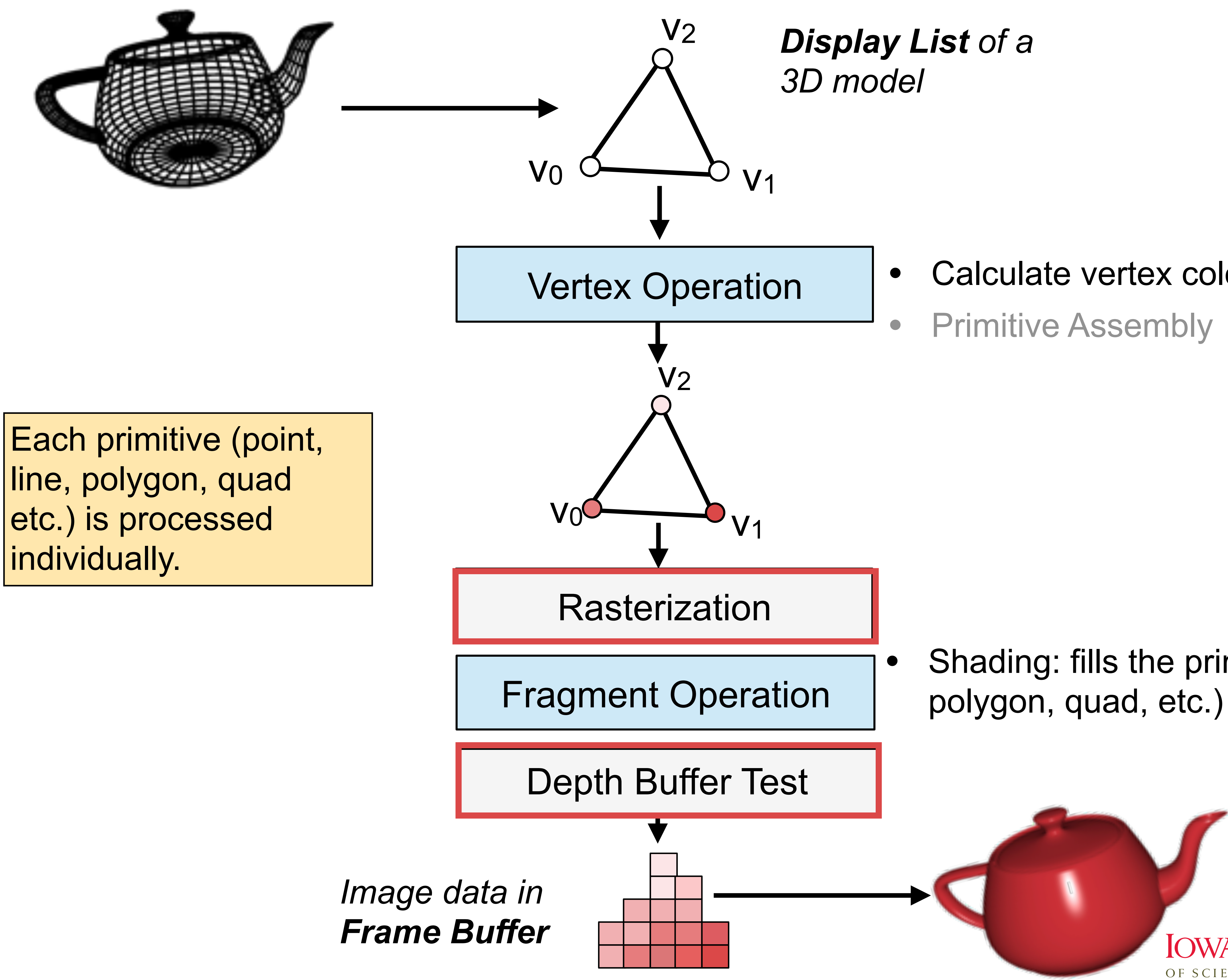
Content

- Blending in OpenGL
- Blending Function
- Blending Equation
- Rendering sequence

Rendering: from model to pixel



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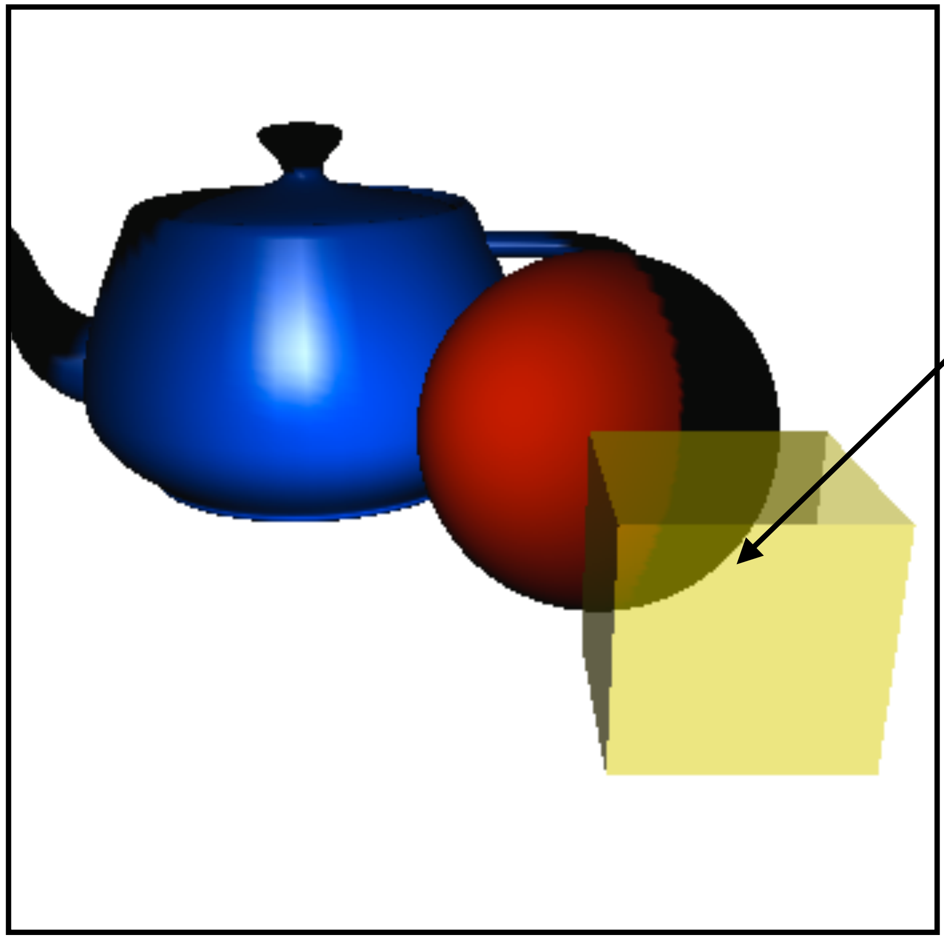
Blending

- Blending in OpenGL is used to blend the color of two or more objects.
- The function is applied before after the depth buffer test.
- Instead of removing the pixels that are already inside the buffer, the colors are mixed.

Why do we want to do something like this?



Output on display

Object transparency: the red sphere is visible through the yellow cube.

- In computer graphics, we simulate transparency by blending the color of objects.
- Blending is a capability of fixed-function rendering pipeline. It must be
  - enabled and a
  - blend value (alpha value) must be set.

Enable / Disable State Machine Functions

```
glEnable(GLenum cap);

glDisable(GLenum cap);
```

Enable or disable a capability of the graphics hardware.

Parameter:

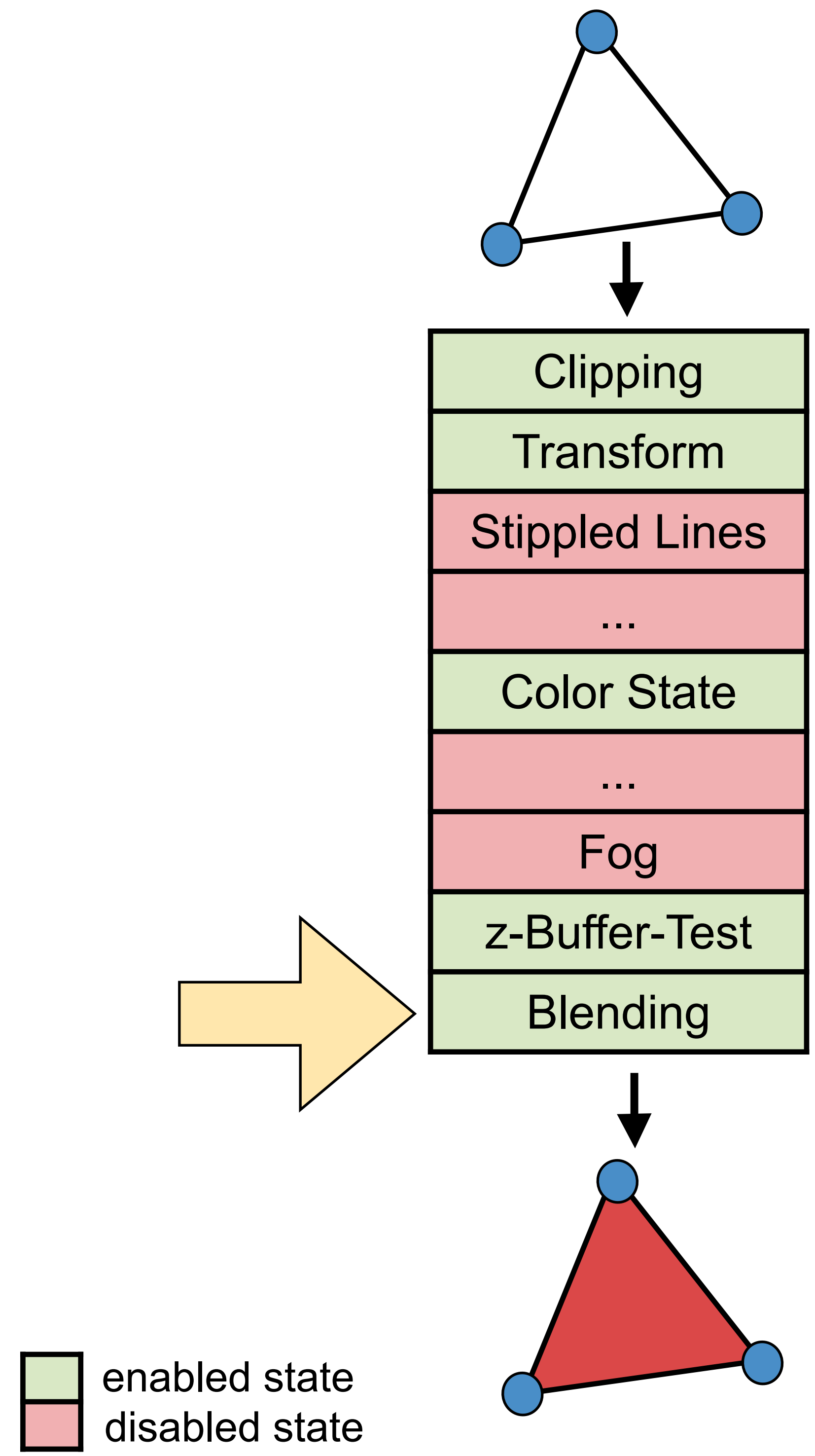
- cap: specifies a symbolic constant that indicates the GL capability

  Examples:

  GL_BLEND: If enabled, blend the computed fragment color values with the values in the color buffers.

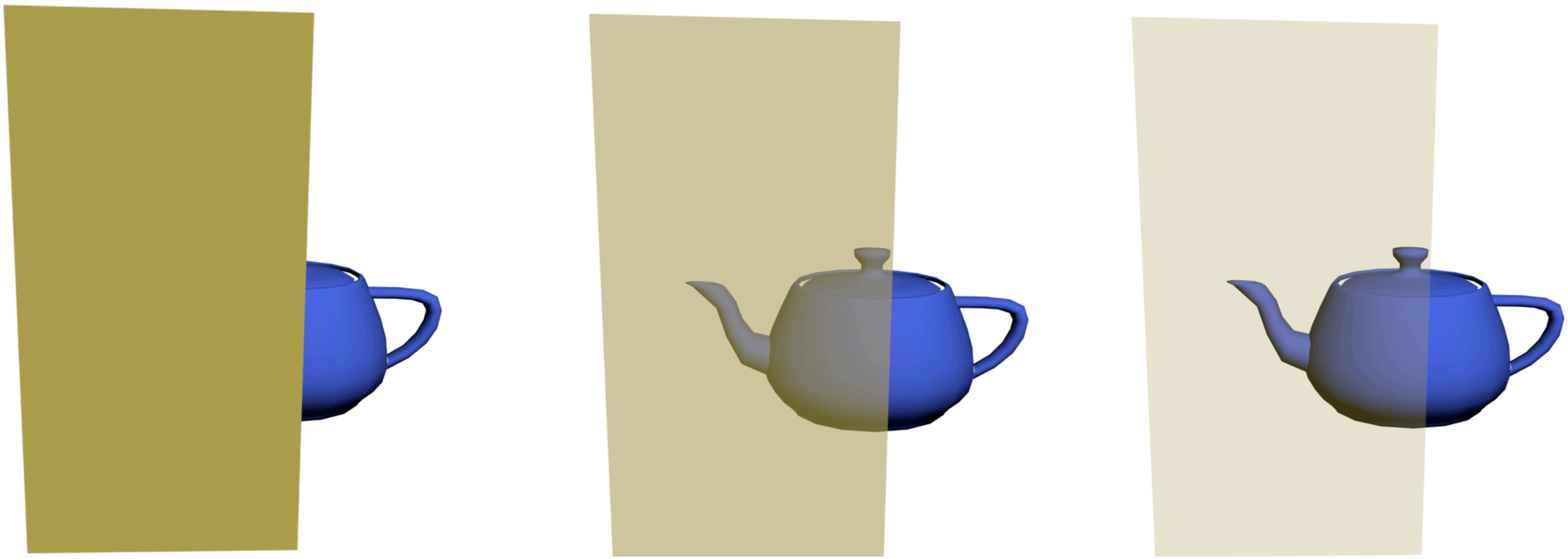
  GL_DEPTH_TEST: If enabled, do depth comparisons and update the depth buffer.

  GL_STENCIL_TEST: If enabled, do stencil testing and update the stencil buffer.



Alpha Value

The alpha value is a key value to determine the “amount of blending” between the object that is already inside the buffer and the object that should be rendered into the frame buffer



Alpha = 1.0 *Alpha = 0.6* *Alpha = 0.3*

```
// create a material for this cube
GLfloat yellow[] = {1.0, 1.0, 0.0, 0.5};
glMaterialfv(GL_FRONT_AND_BACK, GL_DIFFUSE, yellow);
```

Blend Function

```
void glBlendFunc( GLenum sfactor, GLenum dfactor);
```

Pixels can be drawn using a function that blends the incoming (source) RGBA values with the RGBA values that are already in the frame buffer (the destination values). Blending is initially disabled.

Parameters:

- sfactor: Specifies how the red, green, blue, and alpha source blending factors are computed. The following symbolic constants are accepted: GL_ZERO, GL_ONE, GL_SRC_COLOR, GL_ONE_MINUS_SRC_COLOR, GL_DST_COLOR, GL_ONE_MINUS_DST_COLOR, GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA, GL_DST_ALPHA, GL_ONE_MINUS_DST_ALPHA. GL_CONSTANT_COLOR, GL_ONE_MINUS_CONSTANT_COLOR, GL_CONSTANT_ALPHA, and GL_ONE_MINUS_CONSTANT_ALPHA. The initial value is **GL_ONE**.
- dfactor: Specifies how the red, green, blue, and alpha destination blending factors are computed. The following symbolic constants are accepted: GL_ZERO, GL_ONE, GL_SRC_COLOR, GL_ONE_MINUS_SRC_COLOR, GL_DST_COLOR, GL_ONE_MINUS_DST_COLOR, GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA, GL_DST_ALPHA, GL_ONE_MINUS_DST_ALPHA. GL_CONSTANT_COLOR, GL_ONE_MINUS_CONSTANT_COLOR, GL_CONSTANT_ALPHA, and GL_ONE_MINUS_CONSTANT_ALPHA. The initial value is **GL_ZERO**.

Blend Function

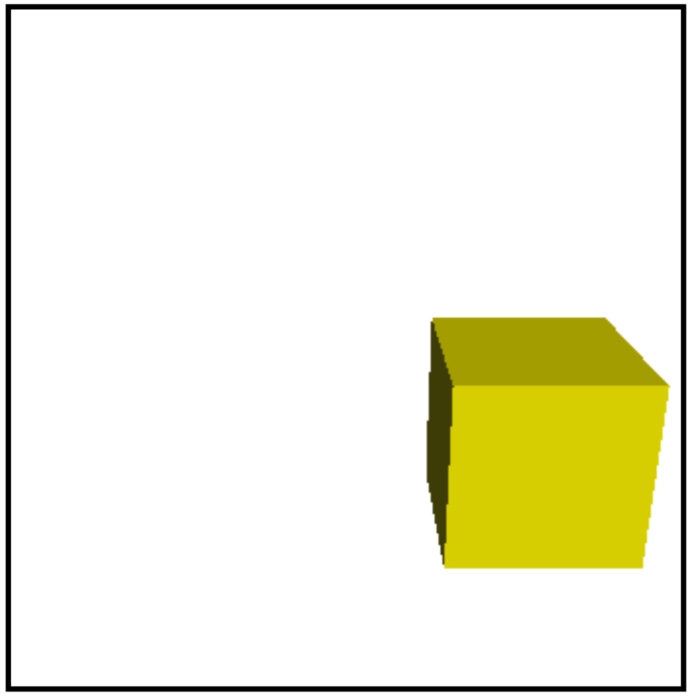
```
void glBlendFunc( GLenum sfactor, GLenum dfactor);
```

$$\begin{bmatrix} (sR \cdot [sfactor]) + (dR \cdot [dfactor]) \\ (sG \cdot [sfactor]) + (dG \cdot [dfactor]) \\ (sB \cdot [sfactor]) + (dB \cdot [dfactor]) \\ (sA \cdot [sfactor]) + (dA \cdot [dfactor]) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$

The blend function is the equation that is used to blend the color

- sR, sG, SB, sA: source; pixel color of the object that need to be rendered to frame buffer
- dR, dG, dB, dA: destination; pixel color that is already inside the frame buffer
- rR, rG, rB, rA: result; the new color which is rendered into the frame buffer

Blend Function Example



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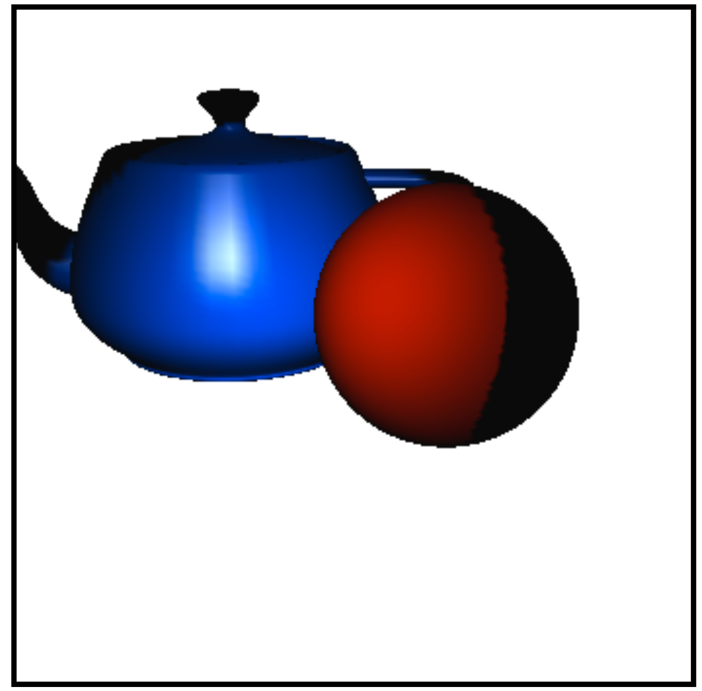

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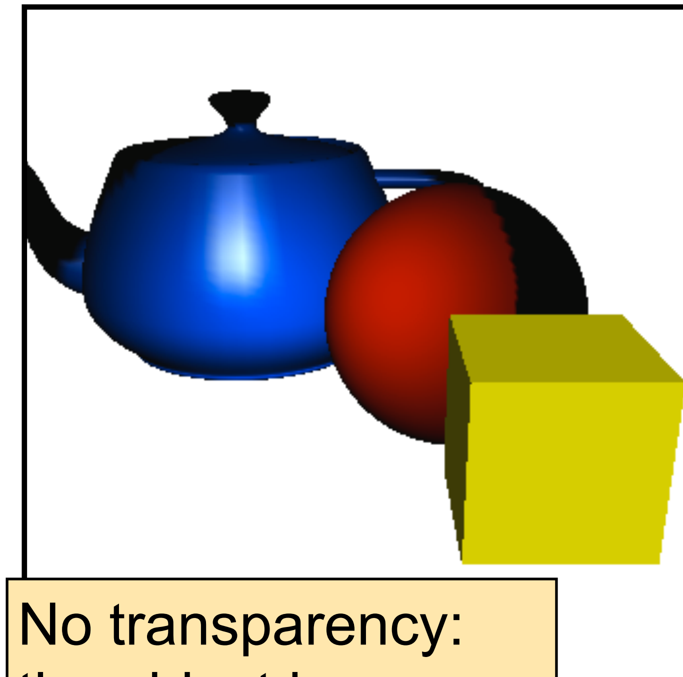


No transparency: the object is rendered with its original color

Need to be added

Already inside the frame buffer

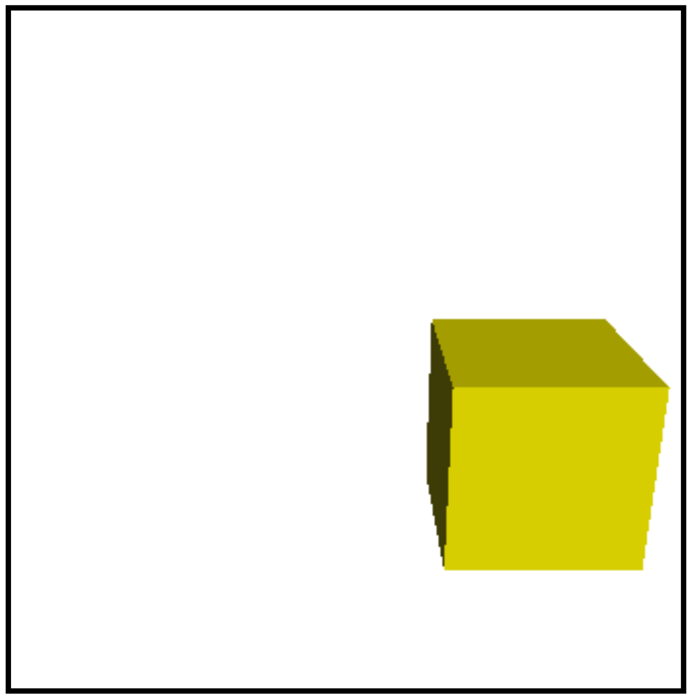
```
glBlendFunc( GL_ONE, GL_ZERO);
```

$$\begin{bmatrix} (sR \cdot 1) + (dR \cdot 0) \\ (sG \cdot 1) + (dG \cdot 0) \\ (sB \cdot 1) + (dB \cdot 0) \\ (sA \cdot 1) + (dA \cdot 0) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$

s: source *d: destination* *r: result*

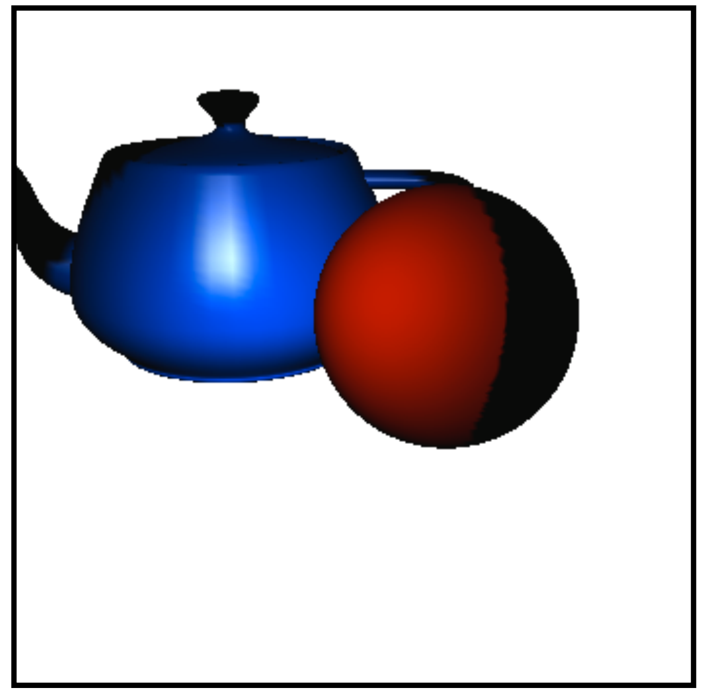
```
GL_ZERO: 0
GL_ONE: 1
```

Blend Function Example



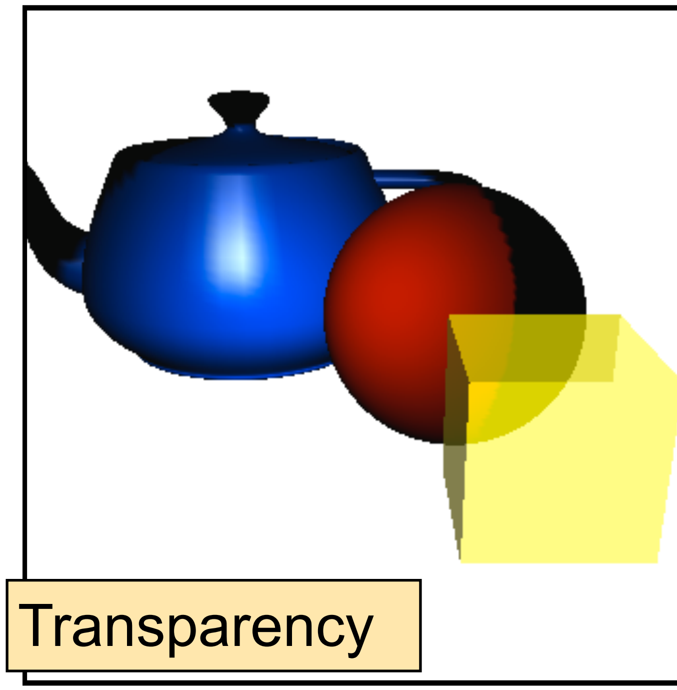
Need to be added

+



Already inside the frame buffer

=



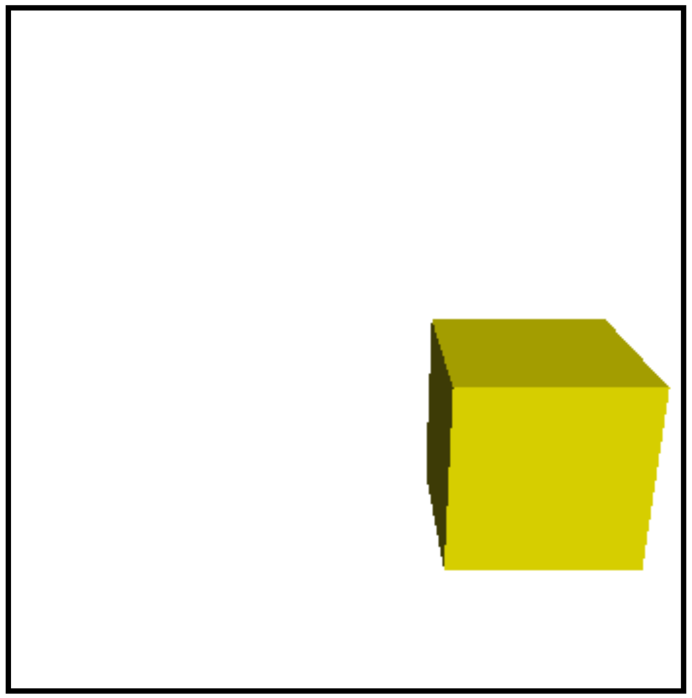

```
glBlendFunc( GL_ONE, GL_ONE_MINUS_SRC_ALPHA);
```

$$\begin{bmatrix} (sR \cdot 1) + (dR \cdot (1 - sA)) \\ (sG \cdot 1) + (dG \cdot (1 - sA)) \\ (sB \cdot 1) + (dB \cdot (1 - sA)) \\ (sA \cdot 1) + (dA \cdot (1 - sA)) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$

s: source   d: destination   r: result

```
GL_ONE: 1
GL_ONE_MINUS_SRC_ALPHA: 1 – sA
```

Blend Function Example



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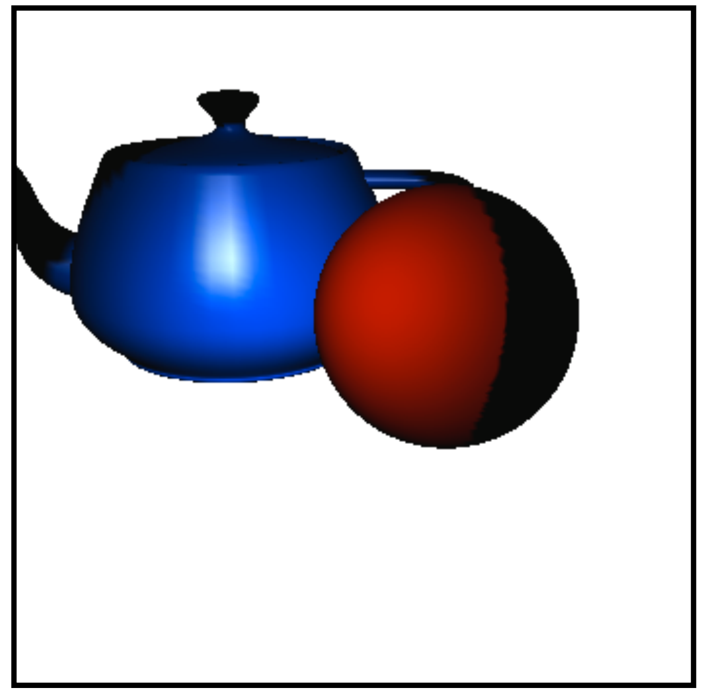
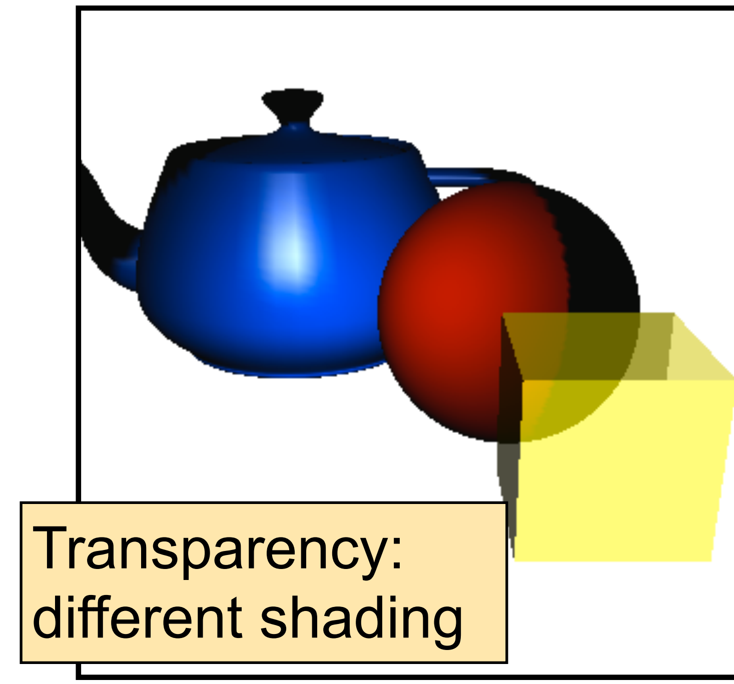


=



Need to be added

Already inside the frame buffer

```
glBlendFunc( GL_SRC_COLOR, GL_ONE_MINUS_SRC_ALPHA );
```

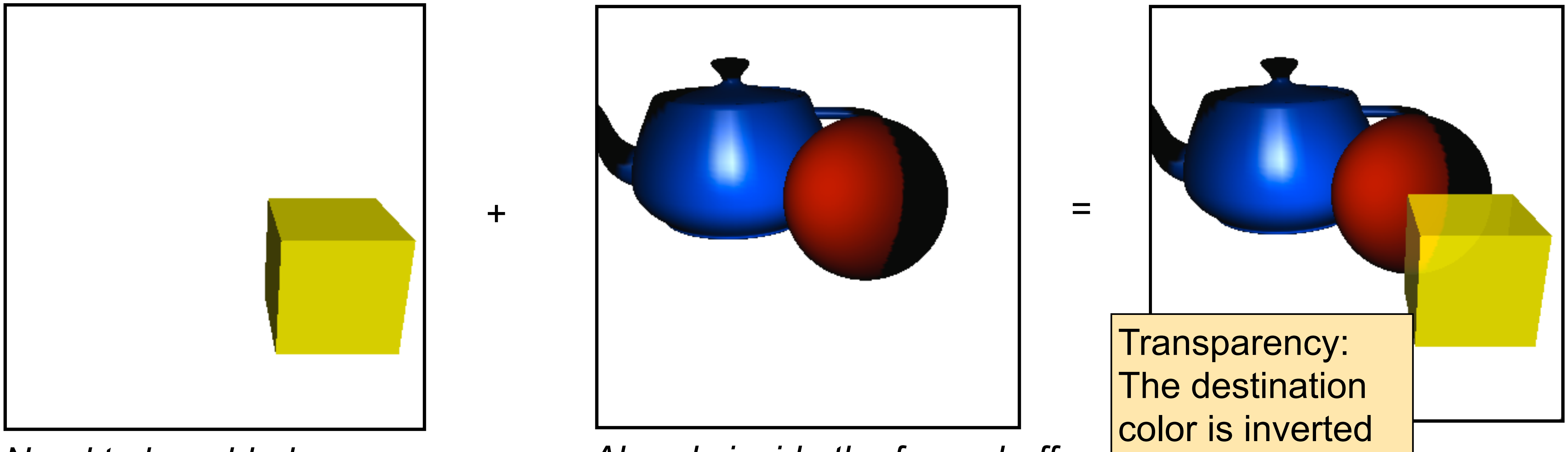
$$\begin{bmatrix} (sR \cdot sR) + (dR \cdot (1 - sA)) \\ (sG \cdot sG) + (dG \cdot (1 - sA)) \\ (sB \cdot sB) + (dB \cdot (1 - sA)) \\ (sA \cdot sA) + (dA \cdot (1 - sA)) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$

s: source *d: destination* *r: result*

`GL_SRC_COLOR: sR, sG, sB, sA`

`GL_ONE_MINUS_SRC_ALPHA: 1 – sA`

Blend Function Example



Need to be added

Already inside the frame buffer

```
glBlendFunc( GL_ONE, GL_ONE_MINUS_DST_COLOR);
```

$$\begin{bmatrix} (sR \cdot \boxed{1}) + (dR \cdot \boxed{(1 - dR)}) \\ (sG \cdot 1) + (dG \cdot (1 - dG)) \\ (sB \cdot 1) + (dB \cdot (1 - dB)) \\ (sA \cdot 1) + (dA \cdot (1 - dA)) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$

`GL_ONE: 1`

`GL_ONE_MINUS_DST_COLOR: 1 – d[RGB]`

s: source *d: destination* *r: result*

glBlendEquation

```
void glBlendEquation(GLenum mode)
```

The blend equations determine how a new pixel (the "source" color) is combined with a pixel already in the framebuffer (the "destination" color).

Parameters:

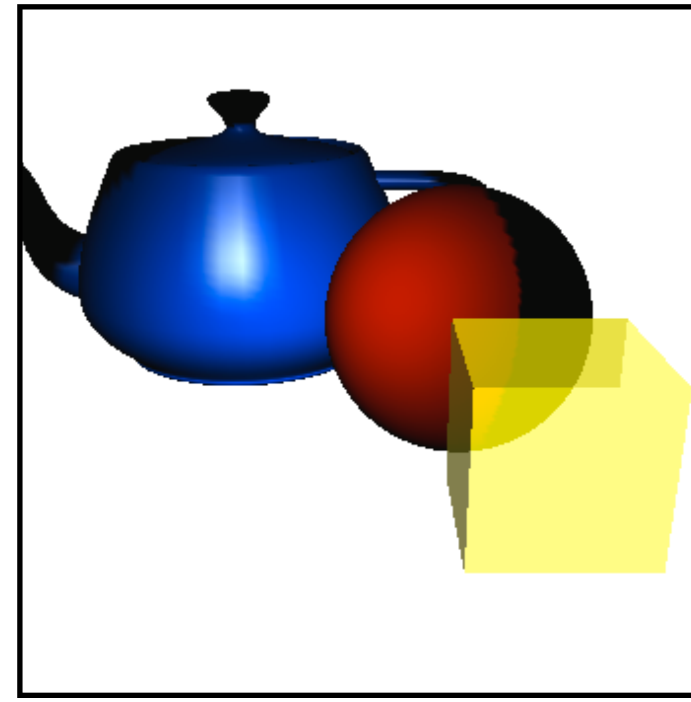
- mode: specifies how source and destination colors are combined.
  It must be GL_FUNC_ADD, GL_FUNC_SUBTRACT, GL_FUNC_REVERSE_SUBTRACT, GL_MIN, GL_MAX.

Blend Equation Example

glBlendFunc(GL_ONE, GL_ONE_MINUS_SRC_ALPHA);

glBlendEquation(GL_FUNC_ADD);

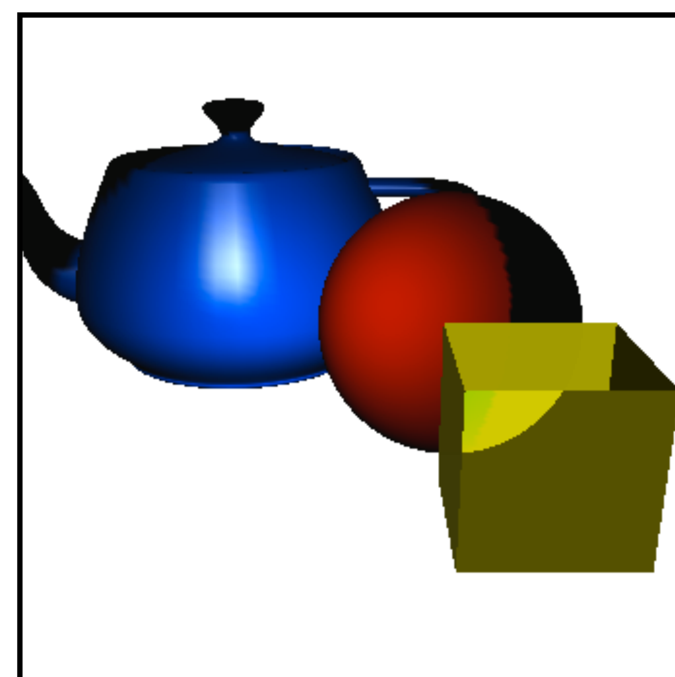
$$\begin{bmatrix} (sR \cdot 1) + (dR \cdot (1 - sA)) \\ (sG \cdot 1) + (dG \cdot (1 - sA)) \\ (sB \cdot 1) + (dB \cdot (1 - sA)) \\ (sA \cdot 1) + (dA \cdot (1 - sA)) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$



glBlendFunc(GL_ONE, GL_ONE_MINUS_SRC_ALPHA);

glBlendEquation(GL_FUNC_SUBTRACT);

$$\begin{bmatrix} (sR \cdot 1) - (dR \cdot (1 - sA)) \\ (sG \cdot 1) - (dG \cdot (1 - sA)) \\ (sB \cdot 1) - (dB \cdot (1 - sA)) \\ (sA \cdot 1) - (dA \cdot (1 - sA)) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$

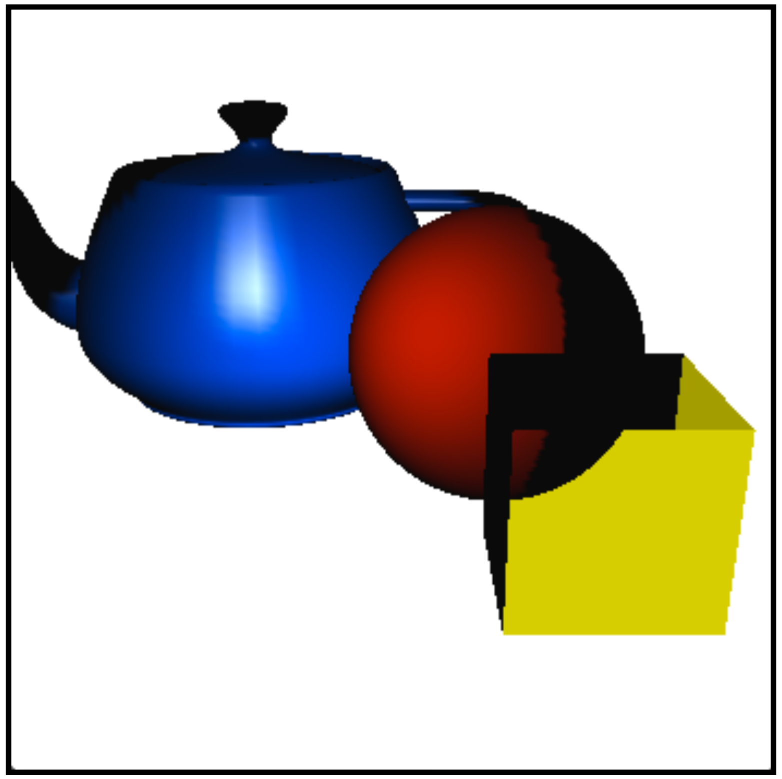


Blend Equation Example

glBlendFunc(GL_ONE, GL_ONE_MINUS_SRC_ALPHA);

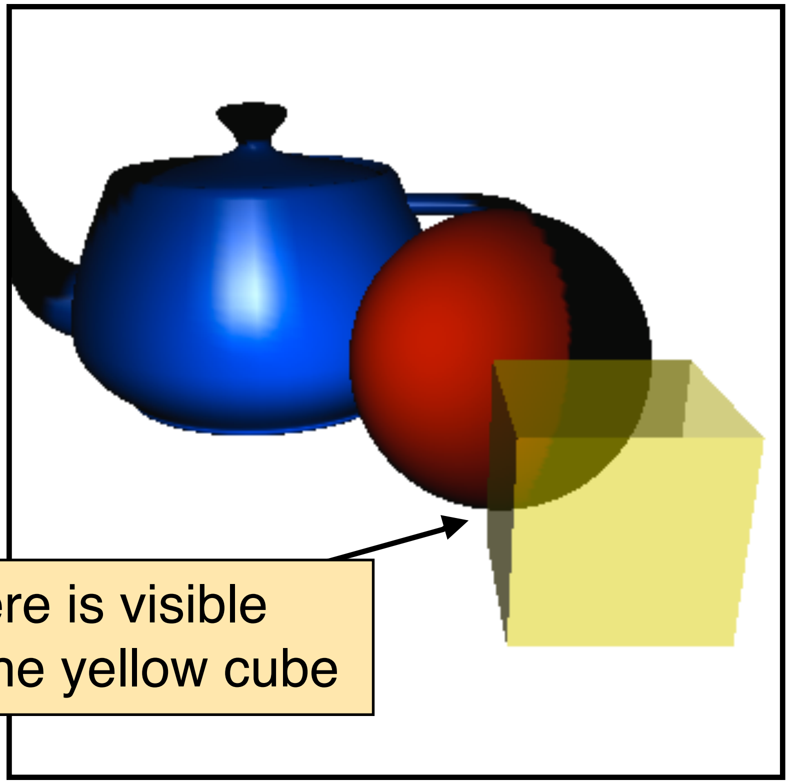
glBlendEquation(GL_MIN);

$$\begin{bmatrix} \boxed{min}(sR, dR) \\ min(sG, dG) \\ min(sB, dB) \\ min(sA, dA) \end{bmatrix} = \begin{bmatrix} rR \\ rG \\ rB \\ rA \end{bmatrix}$$



- Not all combinations are useful. You need to decide on your own which results you want to achieve.
- The “common” transparency of e.g. a window is *glBlendFunc(GL_ONE, GL_ONE_MINUS_SRC_ALPHA)* *glBlendEquation(GL_ADD);*

Rendering Sequence

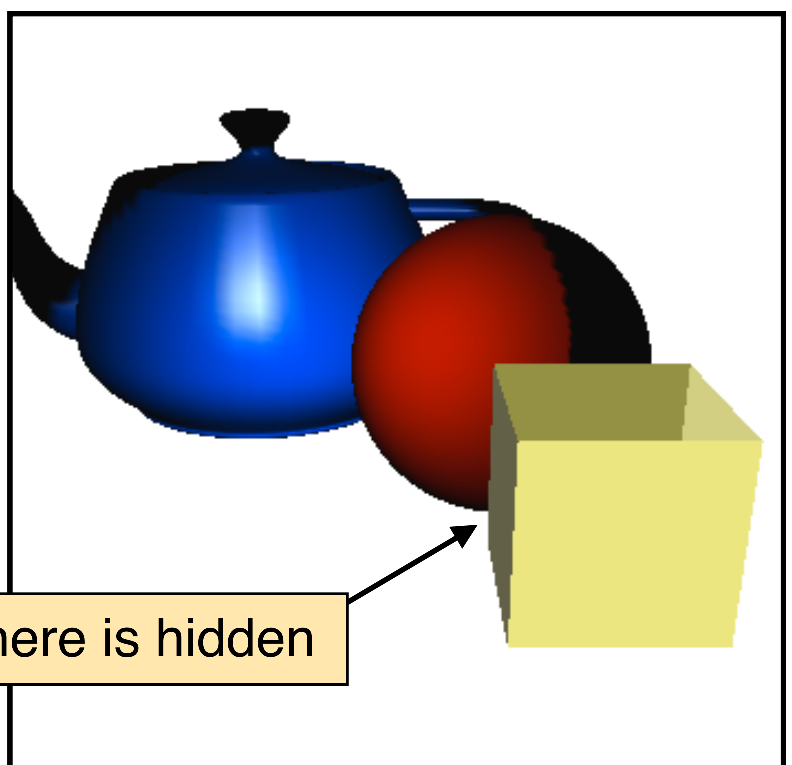



```
void draw_scene(void)
{
    glEnable(GL_DEPTH_TEST);

    // draw a solid sphere
    draw_solid_sphere();

    // draw a teapot
    draw_solid_teapot();

    // draw solid cube
    draw_solid_cube();
}
```




```
void draw_scene(void)
{
    glEnable(GL_DEPTH_TEST);

    // draw solid cube
    draw_solid_cube();

    // draw a solid sphere
    draw_solid_sphere();

    // draw a teapot
    draw_solid_teapot();
}
```

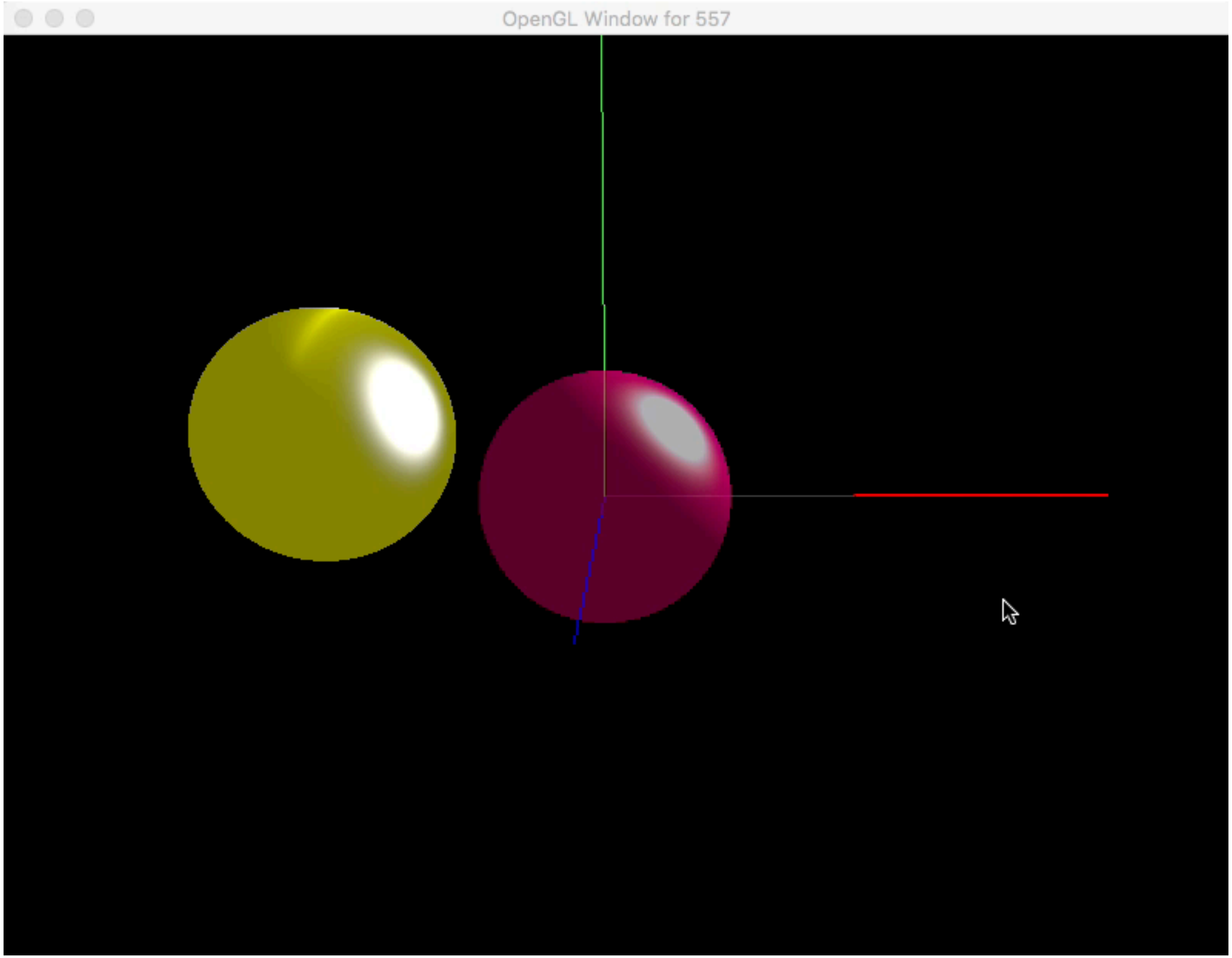
The depth test considers the rendering order of objects. The object that should appear through a transparent object must already be in the frame buffer before the transparent object is drawn. Otherwise, the object behind the transparent object will disappear.

Reason: the red sphere will not pass the z-buffer test. All pixels, which are behind the yellow cube are removed in this test; the pixels of the yellow cube have smaller z-values than the pixels of the red sphere.

Render sequence:

1. Render all opaque objects
2. Render all transparent objects

Video



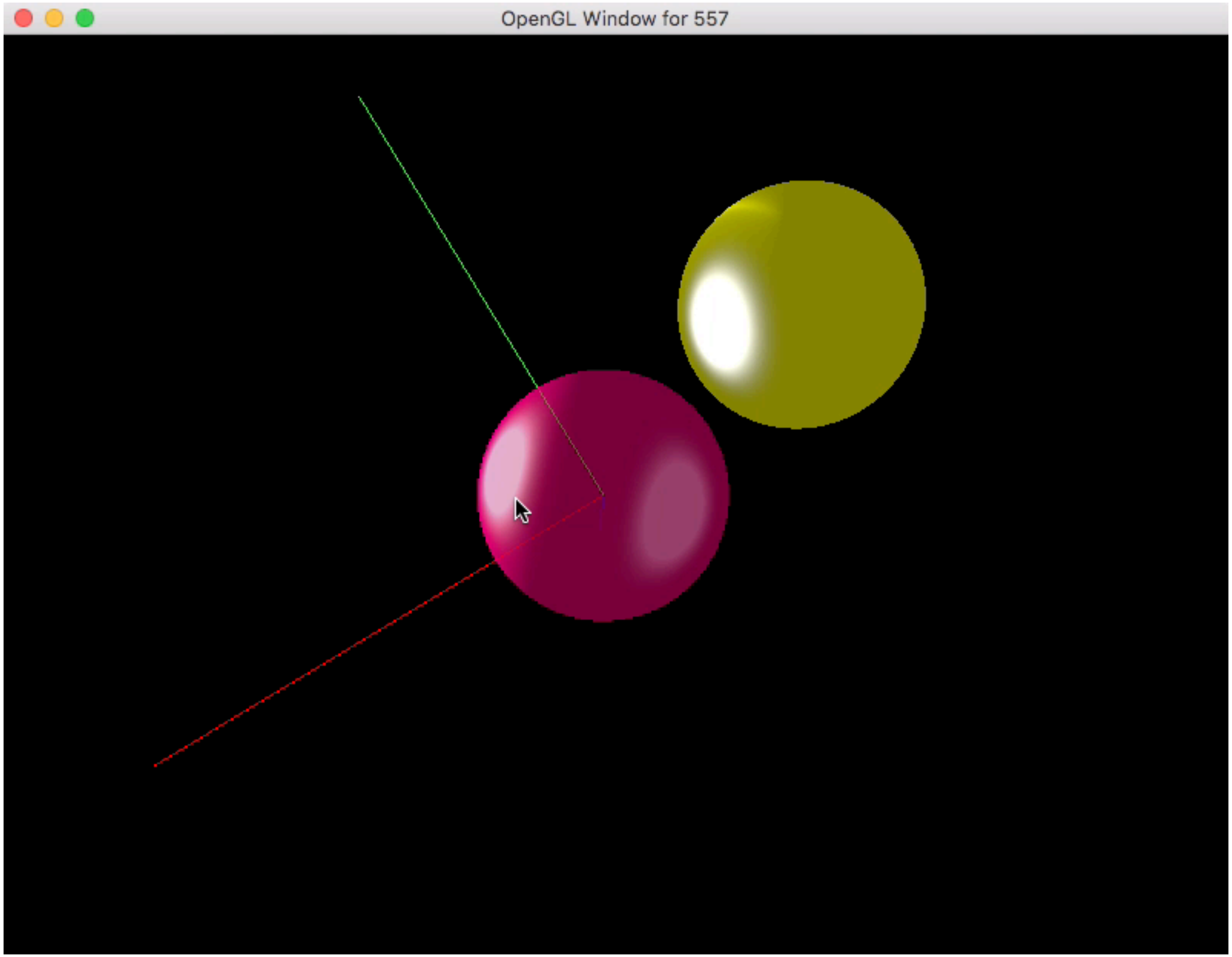
Two objects in the correct rendering order

```
while ...
{

   // draw a yellow sphere
   draw_yellow_sphere();

   // draw the red sphere
   draw_red_sphere();
}
```

Video



Two objects in the wrong rendering order

```
while ...
{

  // draw the red sphere
  draw_red_sphere();

  // draw a yellow sphere
  draw_yellow_sphere();

}
```

Reference Table

Parameter	(f_R, f_G, f_B, f_A)
GL_ZERO	$(0,0,0,0)$
GL_ONE	$(1,1,1,1)$
GL_SRC_COLOR	$\left(\frac{R_{s0}}{k_R}, \frac{G_{s0}}{k_G}, \frac{B_{s0}}{k_B}, \frac{A_{s0}}{k_A}\right)$
GL_ONE_MINUS_SRC_COLOR	$(1,1,1,1) - \left(\frac{R_{s0}}{k_R}, \frac{G_{s0}}{k_G}, \frac{B_{s0}}{k_B}, \frac{A_{s0}}{k_A}\right)$
GL_DST_COLOR	$\left(\frac{R_d}{k_R}, \frac{G_d}{k_G}, \frac{B_d}{k_B}, \frac{A_d}{k_A}\right)$
GL_ONE_MINUS_DST_COLOR	$(1,1,1,1) - \left(\frac{R_d}{k_R}, \frac{G_d}{k_G}, \frac{B_d}{k_B}, \frac{A_d}{k_A}\right)$
GL_SRC_ALPHA	$\left(\frac{A_{s0}}{k_A}, \frac{A_{s0}}{k_A}, \frac{A_{s0}}{k_A}, \frac{A_{s0}}{k_A}\right)$
GL_ONE_MINUS_SRC_ALPHA	$(1,1,1,1) - \left(\frac{A_{s0}}{k_A}, \frac{A_{s0}}{k_A}, \frac{A_{s0}}{k_A}, \frac{A_{s0}}{k_A}\right)$
GL_DST_ALPHA	$\left(\frac{A_d}{k_A}, \frac{A_d}{k_A}, \frac{A_d}{k_A}, \frac{A_d}{k_A}\right)$
GL_ONE_MINUS_DST_ALPHA	$(1,1,1,1) - \left(\frac{A_d}{k_A}, \frac{A_d}{k_A}, \frac{A_d}{k_A}, \frac{A_d}{k_A}\right)$
GL_CONSTANT_COLOR	(R_c, G_c, B_c, A_c)
GL_ONE_MINUS_CONSTANT_COLOR	$(1,1,1,1) - (R_c, G_c, B_c, A_c)$
GL_CONSTANT_ALPHA	(A_c, A_c, A_c, A_c)
GL_ONE_MINUS_CONSTANT_ALPHA	$(1,1,1,1) - (A_c, A_c, A_c, A_c)$
GL_SRC_ALPHA_SATURATE	$(i,i,i,1)$

GL_SRC1_COLOR	$\left(\frac{R_{s1}}{k_R}, \frac{G_{s1}}{k_G}, \frac{B_{s1}}{k_B}, \frac{A_{s1}}{k_A}\right)$
GL_ONE_MINUS_SRC1_COLOR	$(1,1,1,1) - \left(\frac{R_{s1}}{k_R}, \frac{G_{s1}}{k_G}, \frac{B_{s1}}{k_B}, \frac{A_{s1}}{k_A}\right)$
GL_SRC1_ALPHA	$\left(\frac{A_{s1}}{k_A}, \frac{A_{s1}}{k_A}, \frac{A_{s1}}{k_A}, \frac{A_{s1}}{k_A}\right)$
GL_ONE_MINUS_SRC1_ALPHA	$(1,1,1,1) - \left(\frac{A_{s1}}{k_A}, \frac{A_{s1}}{k_A}, \frac{A_{s1}}{k_A}, \frac{A_{s1}}{k_A}\right)$

Mode	RGB Components	Alpha Component
GL_FUNC_ADD	$Rr = R_s s_R + R_d d_R$ $Gr = G_s s_G + G_d d_G$ $Br = B_s s_B + B_d d_B$	$Ar = A_s s_A + A_d d_A$
GL_FUNC_SUBTRACT	$Rr = R_s s_R - R_d d_R$ $Gr = G_s s_G - G_d d_G$ $Br = B_s s_B - B_d d_B$	$Ar = A_s s_A - A_d d_A$
GL_FUNC_REVERSE_SUBTRACT	$Rr = R_d d_R - R_s s_R$ $Gr = G_d d_G - G_s s_G$ $Br = B_d d_B - B_s s_B$	$Ar = A_d d_A - A_s s_A$
GL_MIN	$Rr = min(R_s, R_d)$ $Gr = min(G_s, G_d)$ $Br = min(B_s, B_d)$	$Ar = min(A_s, A_d)$
GL_MAX	$Rr = max(R_s, R_d)$ $Gr = max(G_s, G_d)$ $Br = max(B_s, B_d)$	$Ar = max(A_s, A_d)$

Note, all values k are a so called blend value. Consider it as 1.0; we discuss it later in class

Thank you!

Questions

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