What is Cube Mapping?

Cube Mapping is the process of creating a representation of an object’s surrounding environment as a collection of 6 images, grouped together as a single “cube map texture”.

Think of it as a folding box. (BTW, I have this box on a 2-sided PowerPoint slide if you want to print and cutout your own.)

BTW, I have this box on a 2-sided PowerPoint if you want to print and cutout your own. Let me know.

Note: as the scene observer, you are inside the box.
BTW, if you would like your very own Nvidia Lobby 3D Cube, print this page and the next page on a single piece of paper.

In the Printer Properties be sure that the Print on both sides setting says:
Yes, flip over
or
Flip pages on Short Edge
Using Cube Mapping to Model a 3D Environment

Take 6 photos in all directions. Warning! It is tricky to do this and get the seams to match correctly.

Go here: 
https://www.humus.name/index.php?page=Textures&start=0

to find lots of cool cube map textures.
You can find lots more cube map textures just by Googling: cube map textures

Cube Map of the Kelley Engineering Center Atrium
Cube Map Texture Lookup:
Given an (s,t,p) direction vector, what (r,g,b) does that correspond to?

- Let L be the texture coordinate of (s, t, and p) with the largest magnitude.
- L determines which of the 6 2D texture “walls” is being hit by the vector (-X in this case).
- The texture coordinates in that texture are the remaining two texture coordinates divided by L:
  \( \frac{s}{L} = \frac{a}{L}, \frac{t}{L} = \frac{b}{L} \)

\[
\begin{align*}
\text{vec3 ReflectVector} &= \text{reflect} (\ \text{vec3 eyeDir, vec3 normal } ); \\
\text{vec3 RefractVector} &= \text{refract} (\ \text{vec3 eyeDir, vec3 normal, float Eta } );
\end{align*}
\]

Remember Angle-of-Reflection-Equals-Angle-of-Incidence from Lighting?

That's what the built-in reflect( ) function does.
Using the Cube Map for Reflection

Vertex shader

```glsl
out vec3 vNormal;
out vec3 vEyeDir;
out vec3 vMC;

void main() {
    vec4 newVertex = gl_Vertex;
    // could possibly apply displacements to newVertex here
    vMC = newVertex.xyz;
    vec3 ECposition = (gl_ModelViewMatrix * newVertex).xyz;
    vEyeDir = ECposition - vec3(0.,0.,0.); // vector from eye to pt
    vNormal = normalize(gl_NormalMatrix * gl_Normal);
    // or newNormal if you have displaced vertices
    gl_Position = gl_ModelViewProjectionMatrix * newVertex;
}
```

Using the Cube Map for Reflection
Using the Cube Map for Reflection

Fragment shader

```glsl
in vec3 vNormal;
In vec3 vEyeDir;
In vec3 vMC;
uniform samplerCube uReflectUnit;

void main( )
{
    vec3 normal = vNormal;
    // if you are bump-mapping, apply noise to normal here using vMC
    vec3 reflectVector = reflect( vEyeDir, normal );
    vec4 reflectColor = texture( uReflectUnit, reflectVector ); // on Macs, use textureCube( )
    gl_FragColor = vec4( reflectColor.rgb, 1. )
}
```

The Index of Refraction, η (eta)

The Index of Refraction (IOR) is a measure of how much light slows down as it passes through a particular material. The larger the IOR, the slower the speed of light in that material.

Snell's Law of Refraction says that:

\[
\frac{\sin \theta_2}{\sin \theta_1} = \frac{\eta_1}{\eta_2}
\]

Or:

\[
\sin \theta_2 = \sin \theta_1 \frac{\eta_1}{\eta_2}
\]

That's what the built-in refract( ) function does.

Notice that there are certain combinations of the η's that require \( \sin \theta_2 \) to be outside the range -1. → +1., which is not possible. This indicates that the refraction has actually become a **Total Internal Reflection**.

https://en.wikipedia.org/wiki/Snell%27s_law

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mjb – December 22, 2023
Common Indices of Refraction

<table>
<thead>
<tr>
<th>Material</th>
<th>η</th>
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<tr>
<td>Air</td>
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<tr>
<td>Ice</td>
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<tr>
<td>Water</td>
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<td>Pyrex</td>
<td>1.47</td>
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<tr>
<td>Window Glass</td>
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<tr>
<td>Quartz</td>
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<tr>
<td>Cubic Zirconia</td>
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</tr>
<tr>
<td>Diamond</td>
<td>2.42</td>
</tr>
<tr>
<td>Moissanite</td>
<td>2.69</td>
</tr>
</tbody>
</table>


Using the Cube Map for Refraction
**Vertex shader**

```glsl
out vec3 vNormal;
out vec3 vEyeDir;
out vec3 vMC;

void main() {
  vec4 newVertex = gl_Vertex;
  // could possibly apply displacements to newVertex here
  vMC = newVertex.xyz;
  vec3 ECposition = (gl_ModelViewMatrix * newVertex).xyz;
  vEyeDir = ECposition - vec3(0.,0.,0.); // vector from eye to pt
  vNormal = normalize(gl_NormalMatrix * gl_Normal);
  // or newNormal if you have displaced vertices
  gl_Position = gl_ModelViewProjectionMatrix * newVertex;
}
```

**Fragment shader**

```glsl
in vec3 vNormal;
in vec3 vEyeDir;
in vec3 vMC;
uniform float uEta;
uniform samplerCube uReflectUnit;
uniform samplerCube uRefractUnit;
uniform float uMix, uWhiteMix;
const vec3 WHITE = vec3(1.,1.,1.);

void main() {
  vec3 normal = vNormal;
  // if you are bump-mapping, apply noise to normal here using vMC
  vec3 reflectVector = reflect(vEyeDir, normal);
  vec3 reflectColor = texture(uReflectUnit, reflectVector).rgb; // on Macs, use textureCube()
  vec3 refractVector;
  if( all(equal(refractVector, vec3(0.,0.,0.))) ) // like saying "if all elements of the refractVector are == 0.0 ...
    refractColor = reflectColor;
  else
    refractVector = refract(vEyeDir, normal, uEta);
    refractColor = texture(uRefractUnit, refractVector).rgb; // on Macs, use textureCube()
    refractColor = mix(refractColor, WHITE, uWhiteMix);
  vec3 color = mix(refractColor, reflectColor, uMix);
  color = mix(color, WHITE, uWhiteMix);
  gl_FragColor = vec4(color, 1.);
}
```
Cube Mapping in glman

These must be listed in the order:

+X, -X, +Y, -Y, +Z, -Z

These have nothing to do with the cube mapping. They are here to create the six walls, without which the cube mapping looks ridiculous.
Cube Mapping in a C/C++ Program

```c
void InitGraphics( )
{
    // open the window . . .
    // setup the callbacks . . .
    // initialize glew . . .
    // create and compile the shader . . .

    glGenTextures( 1, &CubeName );
    glBindTexture( GL_TEXTURE_CUBE_MAP, CubeName );
    glTexParameteri( GL_TEXTURE_CUBE_MAP, GL_TEXTURE_WRAP_S, GL_REPEAT );
    glTexParameteri( GL_TEXTURE_CUBE_MAP, GL_TEXTURE_WRAP_T, GL_REPEAT );
    glTexParameteri( GL_TEXTURE_CUBE_MAP, GL_TEXTURE_WRAP_R, GL_REPEAT );
    glTexParameteri( GL_TEXTURE_CUBE_MAP, GL_TEXTURE_MAG_FILTER, GL_LINEAR );
    glTexParameteri( GL_TEXTURE_CUBE_MAP, GL_TEXTURE_MIN_FILTER, GL_LINEAR );

    for( int file = 0; file < 6; file++ )
    {
        int nums, numt;
        unsigned char * texture2d = BmpToTexture( FaceFiles[file], &nums, &numt );
        if( texture2d == NULL )
            fprintf( stderr, "Could not open BMP 2D texture '%s'", FaceFiles[file] );
        else
            fprintf( stderr, "BMP 2D texture '%s' read -- nums = %d, numt = %d\n", FaceFiles[file], nums, numt );
        glTexImage2D( GL_TEXTURE_CUBE_MAP_POSITIVE_X + file, 0, 3, nums, numt, 0,
                      GL_RGB, GL_UNSIGNED_BYTE, texture2d );
        delete [ ] texture2d;
    }
}
```
Cube Mapping in a C/C++ Program

```c
void Display( )
{
    . . .
    int uReflectUnit = 5;
    int uRefractUnit = 6;
    float uAd = 0.1f;
    float uBd = 0.1f;
    float uEta = 1.4f;
    float uTol = 0.f;
    float uMix = 0.4f;

    Pattern.Use( );
    glActiveTexture( GL_TEXTURE0 + uReflectUnit );
    glBindTexture( GL_TEXTURE_CUBE_MAP, CubeName );
    glActiveTexture( GL_TEXTURE0 + uRefractUnit );
    glBindTexture( GL_TEXTURE_CUBE_MAP, CubeName );

    Pattern.SetUniformVariable( "uReflectUnit", uReflectUnit );
    Pattern.SetUniformVariable( "uRefractUnit", uRefractUnit );
    Pattern.SetUniformVariable( "uMix", uMix );
    Pattern.SetUniformVariable( "uEta", uEta );

    glCallList( SphereList );
    Pattern.UnUse;
}
```

Sidebar: You Can Also Use Cube Mapping to "Surround" an Object with a Texture:
A Cube Map of the World
Use the normal \((n_x, n_y, n_z)\) as the \((s,t,p)\) for the 3D lookup

Sidebar: You Can Also Use Cube Mapping to "Surround" an Object with a Texture: A Cube Map of the World

Vertex shader

```glsl
out vec3 vNormal;
void main()
{
    vNormal = normalize( gl_Normal );
    gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```

Fragment shader

```glsl
uniform samplerCube uTexUnit;
in vec3 vNormal;
void main()
{
    vec4 newcolor = texture( uTexUnit, vNormal );
    gl_FragColor = vec4( newcolor.rgb, 1. );
}
```