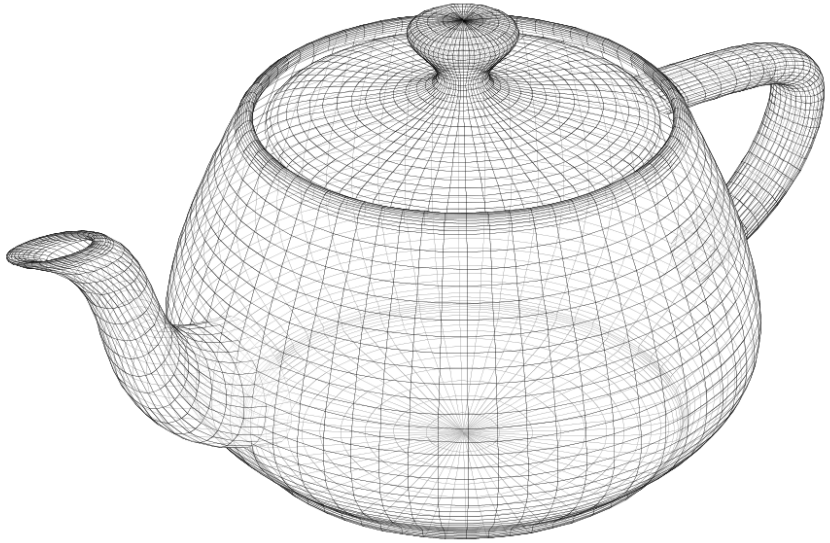


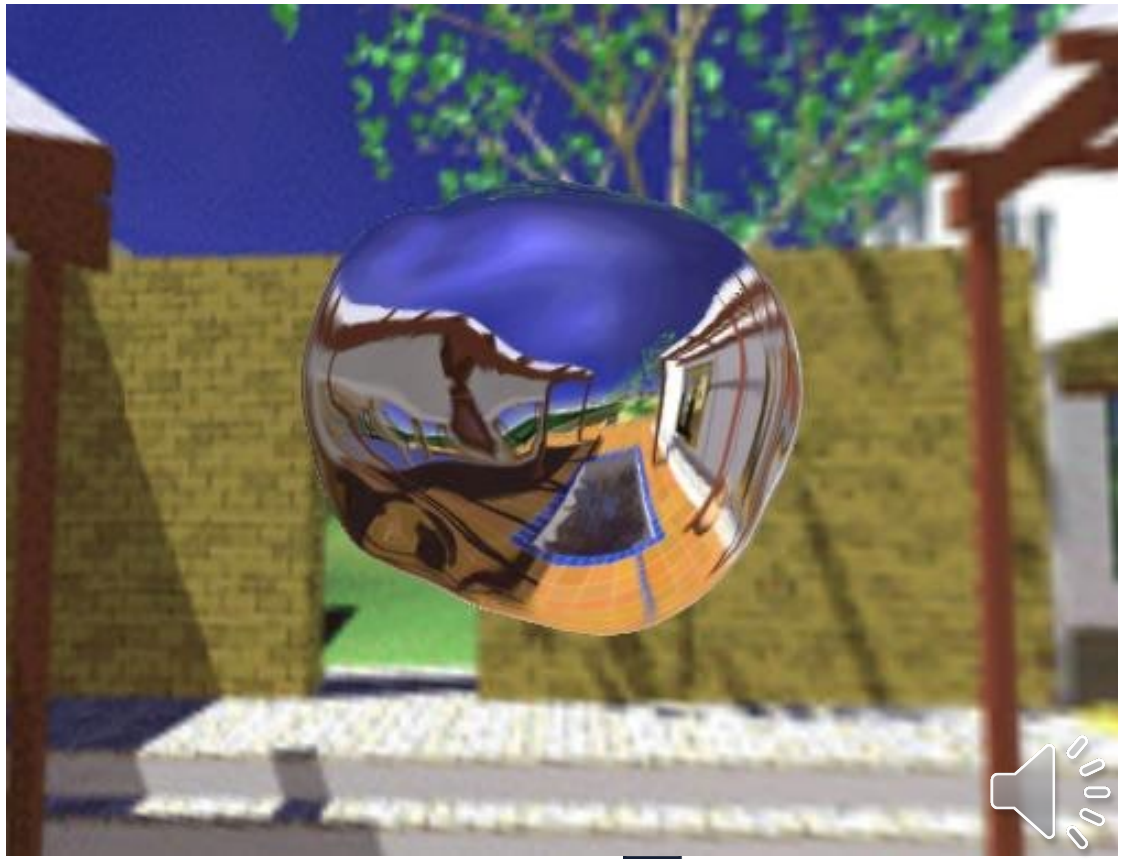
Environment Mapping

Interactive Computer Graphics

Professor Eric Shaffer

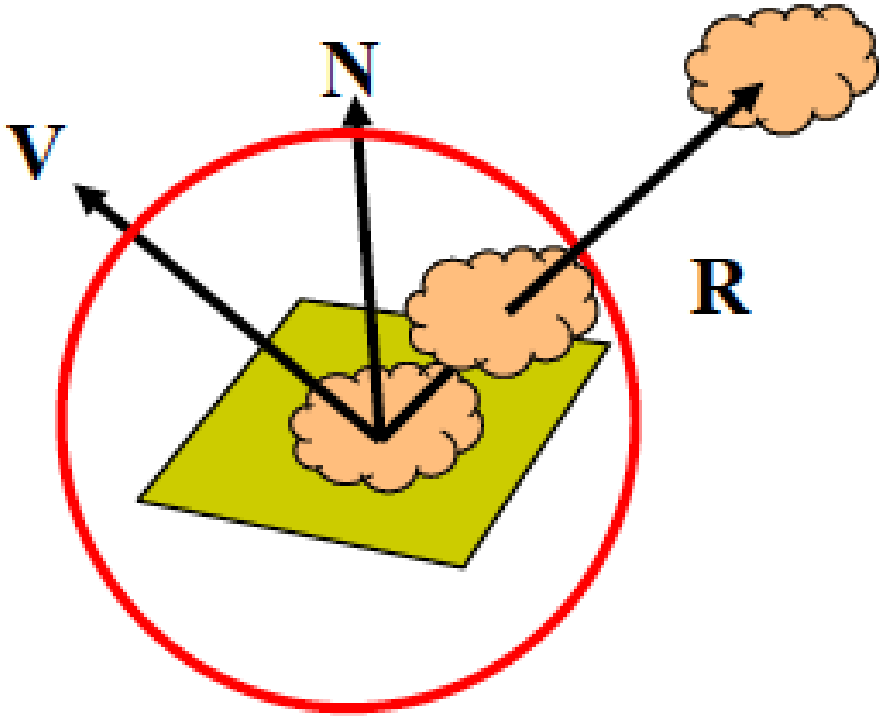
Environment Mapping

- How can we render reflections with a rasterization engine?
  - When shading a fragment, usually don't know other scene geometry
  - Answer: use texture mapping….
- Create a texture of the environment
  - Map it onto mirror object surface
- Any suggestions how generate (u,v)?

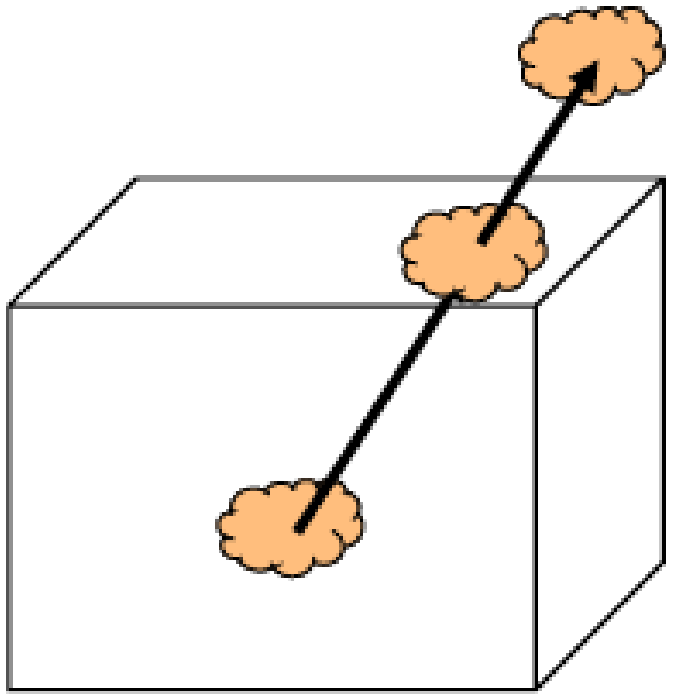


Types of Environment Maps

a) Sphere around object (sphere map)



b) Cube around object (cube map)



Sphere Mapping

- Classic technique…
- Not supported by WebGL

OpenGL supports sphere mapping

Requires a “circular” texture map

Equivalent to an image taken with a fisheye lens

Sphere Map Example

Hand with Reflecting Sphere by MC Escher

Sphere map
(texture)

Sphere map
applied on torus

Acquiring a Sphere Map….

- Take a picture of a shiny sphere in a real environment
- Or render the environment into a texture (see next slide)

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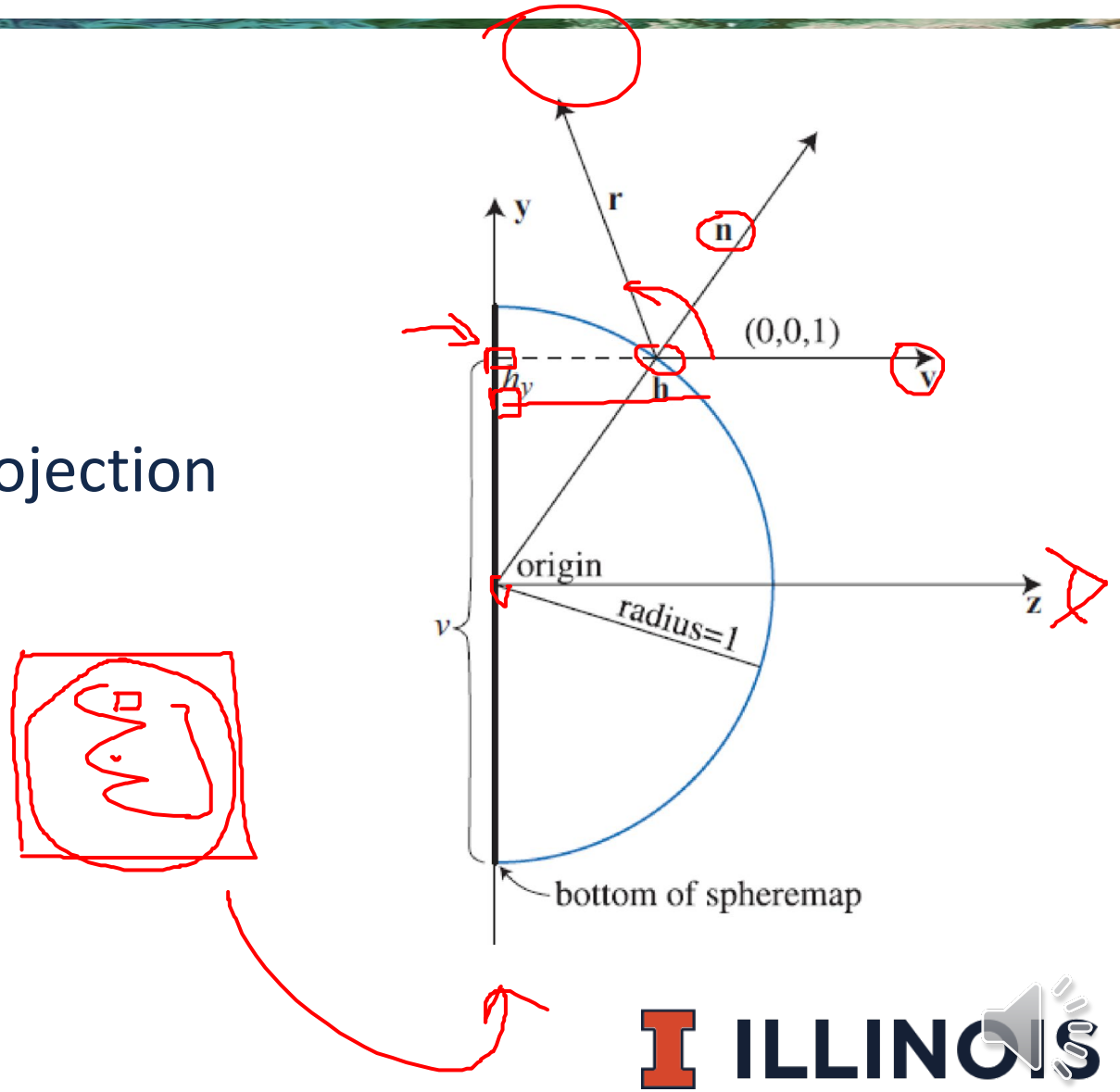
Why View Dependent?

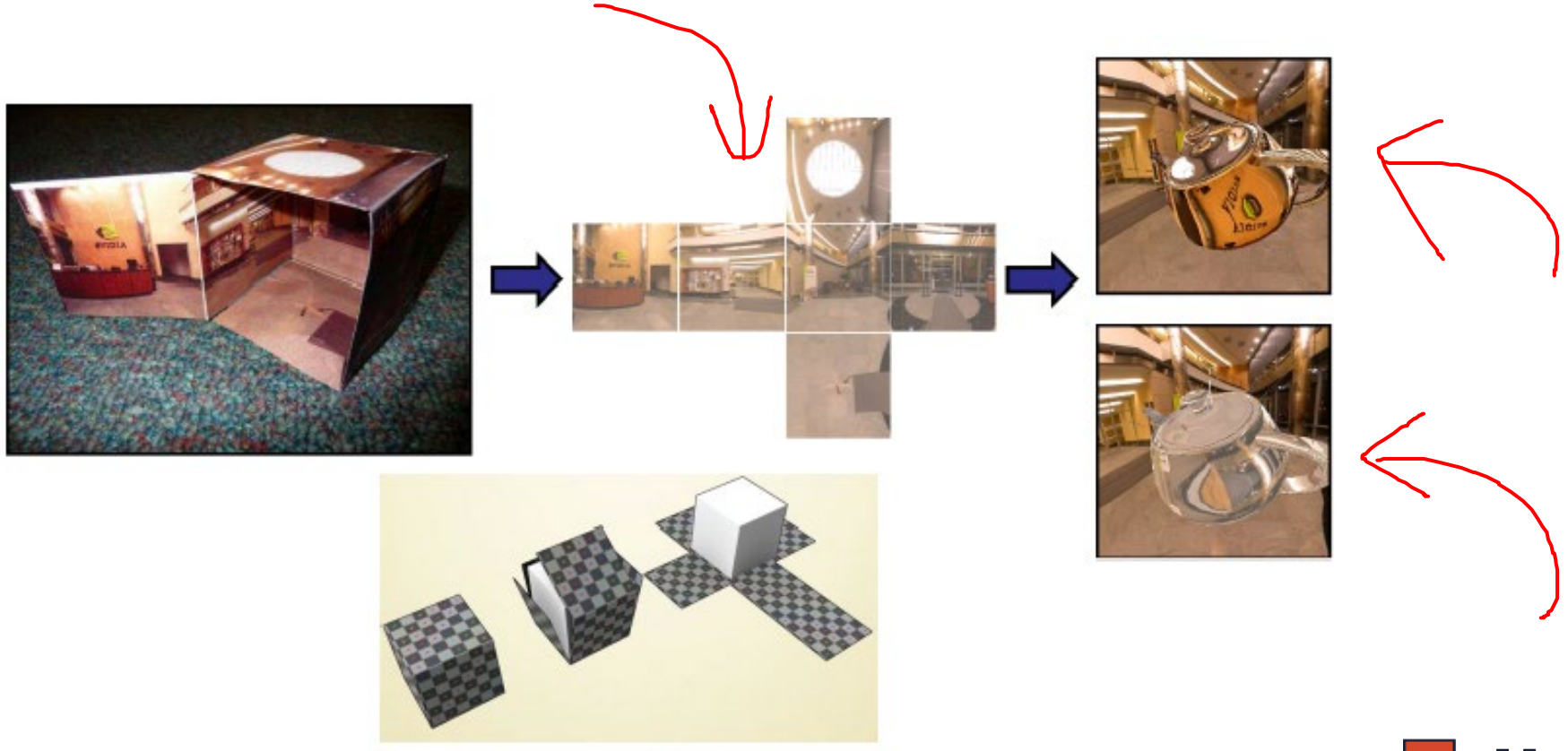
- Conceptually a sphere map is generated like ray-tracing
- Records reflection under orthographic projection
  - From a given view direction
- What is a drawback of this?



Cube Map

Cube mapping takes a different approach….

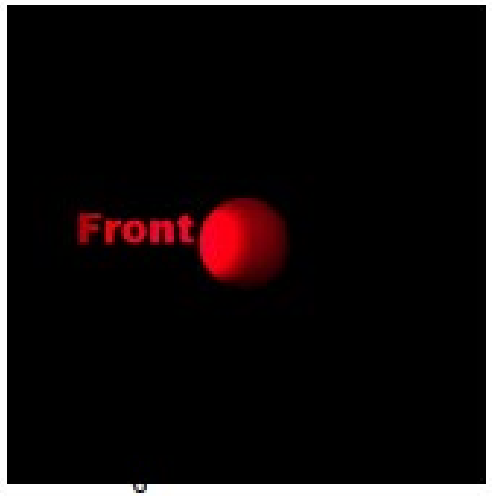
Imagine an object is in a box…and you can see the environment through that box

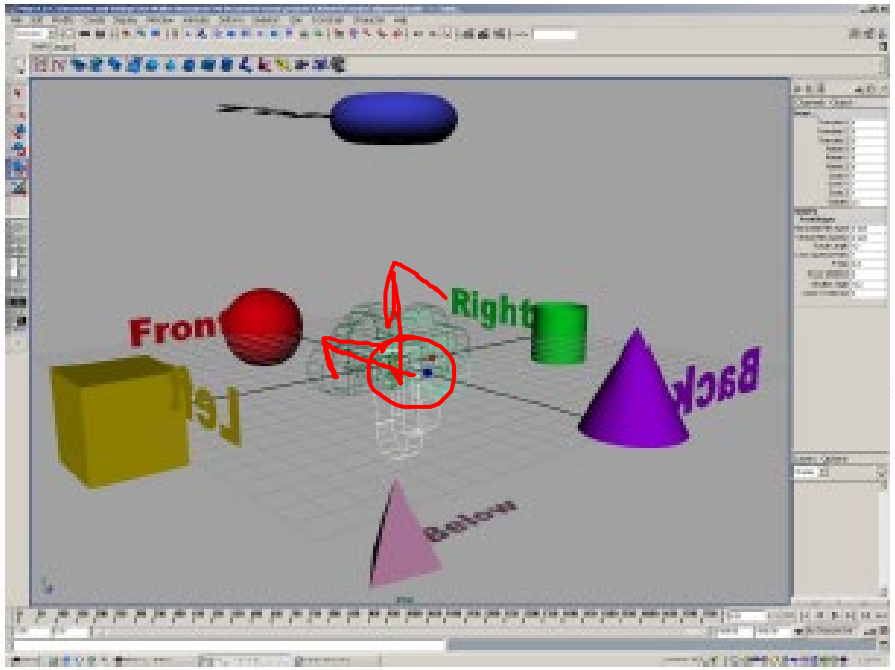


Forming a Cube Map

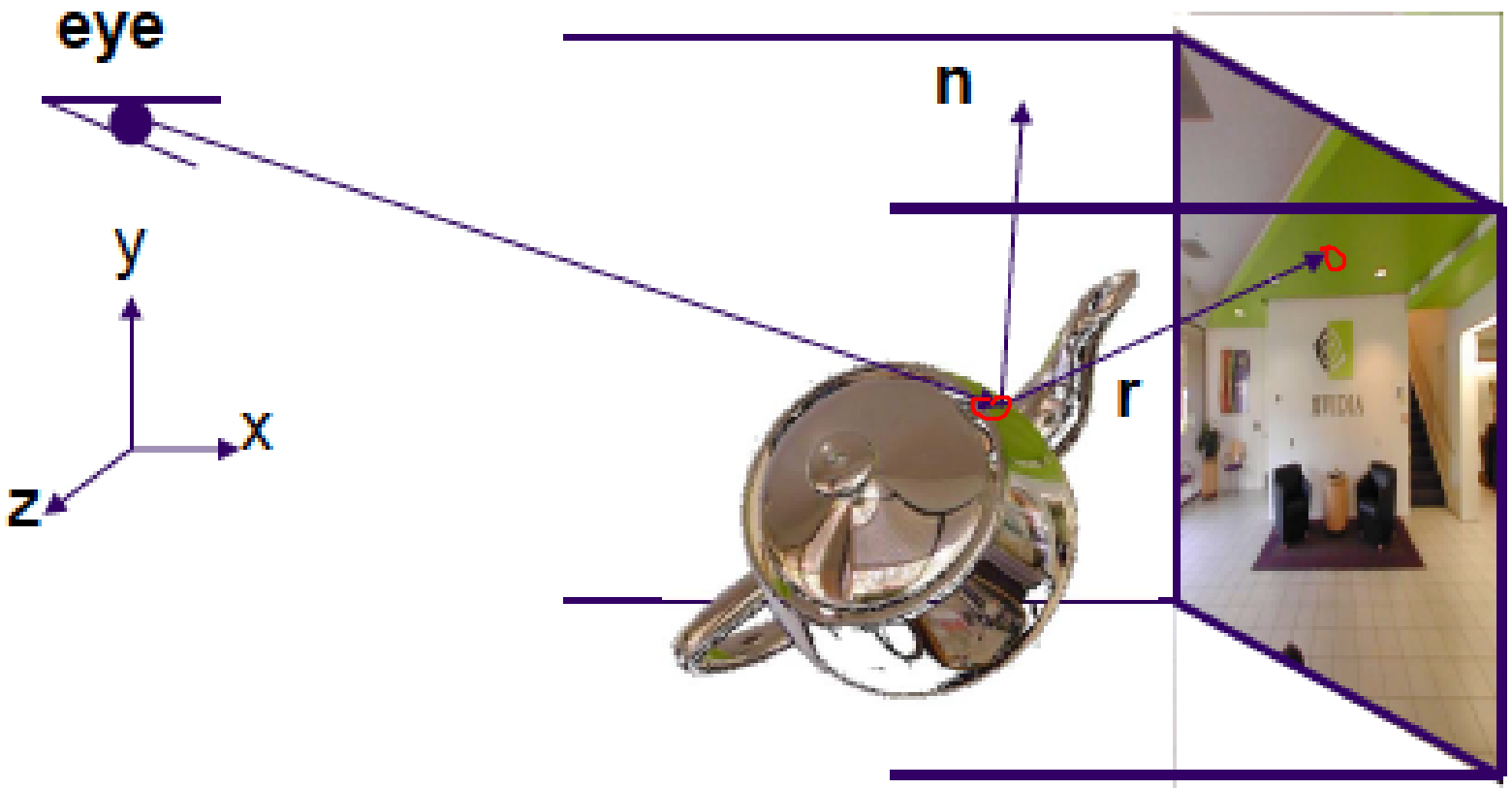
A cube map requires 6 images

Each covers a 90 degree angle from the center of the cube





Index using the Reflection Vector



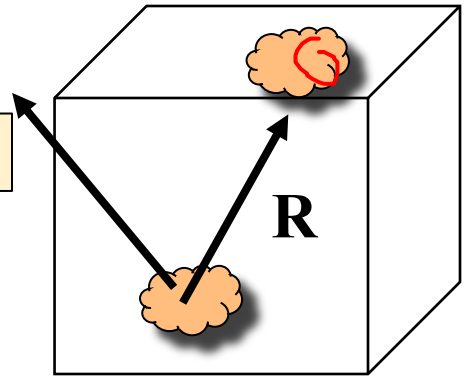
How Does WebGL Index into Cube Map?

- To access the cube map you compute

  R = 2(**N**·**V**)**N**-**V**

- Then, in your shader

```
vec4 texColor = textureCube(texMap, R);
```



- How does WebGL compute the index?

- Assume object at origin
- Largest magnitude component of R determines face of cube
- Other two components give texture coordinates

Example

- R= (-4,3,-1)
- Normalize so max value has magnitude of 1
  R=(-1, ¾ , - ¼)
  - Remap texture coordinates…x,y,z are in [-1,1]
  - Need them on [0,1]
    - v = ½ + ½ x ¾ = 0.875
    - u = ½ + ½ x -¼ = 0.375
- Use face x = -1
- Texture coordinates of (u,v) = (0.375, 0.875)

Vertex Shader

```
varying vec3 R;
attribute vec4 vPosition;
attribute vec4 vNormal;
uniform mat4 modelViewMatrix;
uniform mat4 projectionMatrix;
void main(){
  //…other code
  gl_Position = projectionMatrix*ModelViewMatrix*vPosition;
  vec4 eyePos  = ModelViewMatrix*vPosition;
  vec4 N = ModelViewMatrix*vNormal;
   R = reflect(eyePos.xyz, N.xyz);   }
```

Fragment Shader

```
precision mediump float;

varying vec3 R;
uniform samplerCube texMap;

void main()
{
    vec4 texColor = textureCube(texMap, R);
    gl_FragColor = texColor;
}
```

Limitations

What do you not see here that you should?

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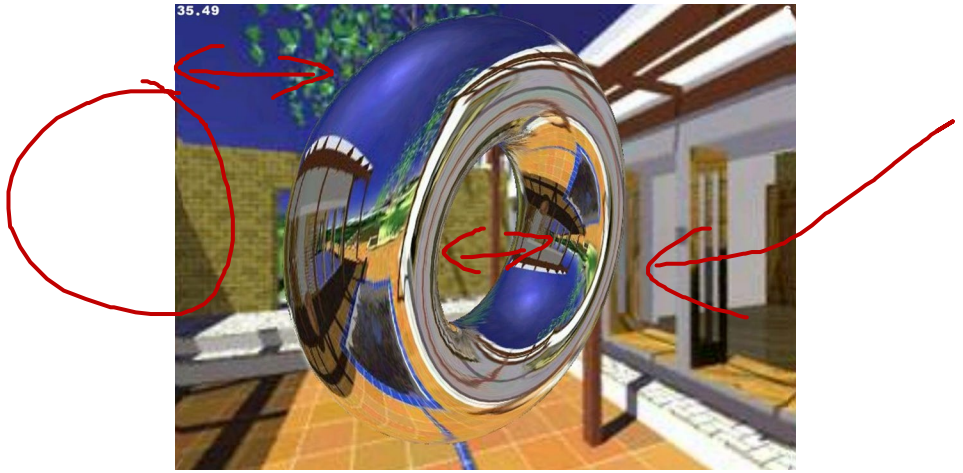
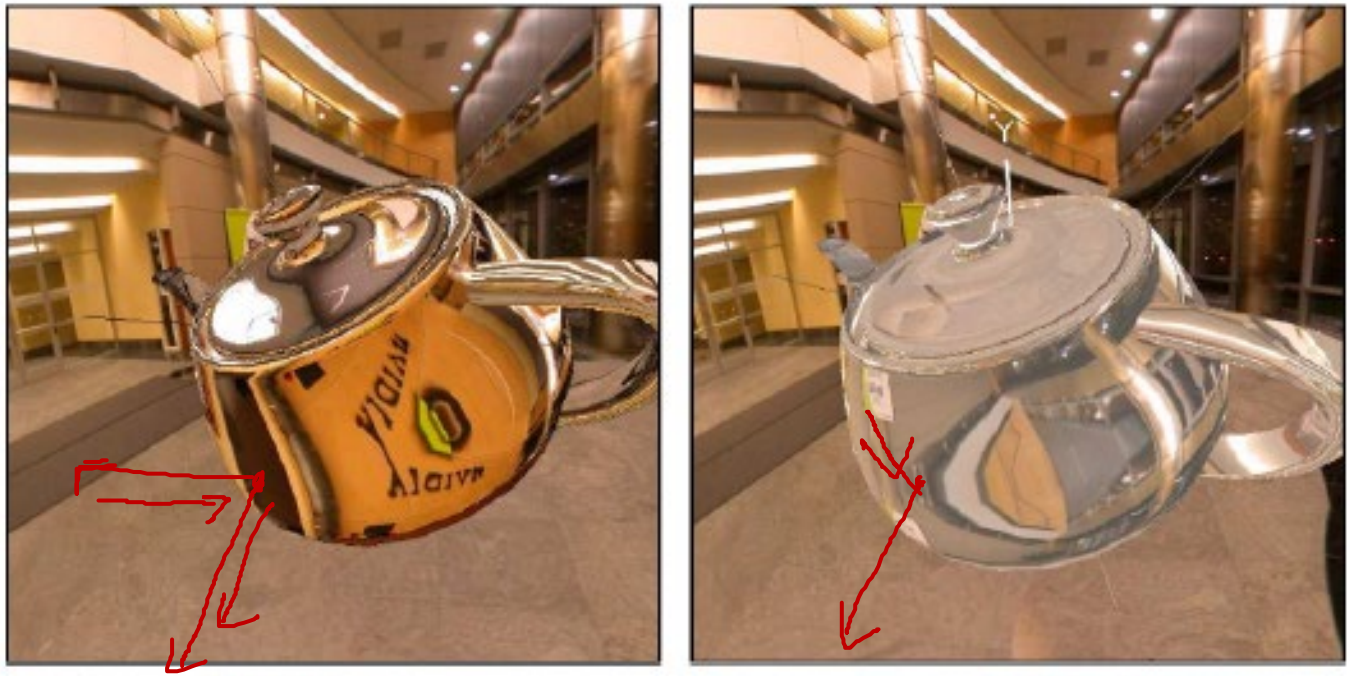
Issues

- Change in object position or objects in scene require recomputation
- Object cannot be concave (no self reflections possible)
- No reflections between objects



Refraction

- Can also use cube map for refraction (transparent)

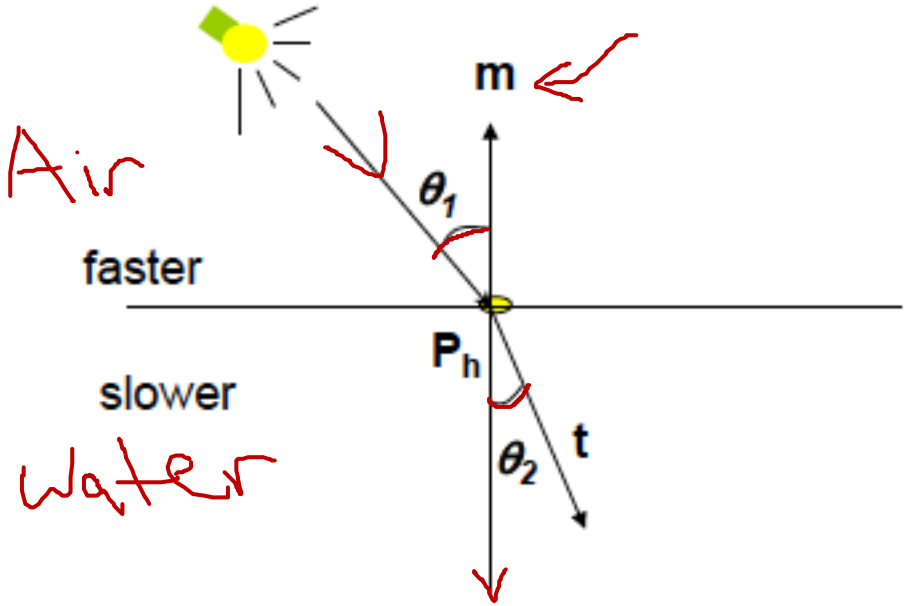


Reflection

Refraction

Snell's Law

- Transmitted direction obeys **Snell's law**
- Snell's law: relationship holds in diagram below



$$\frac{\sin(\theta_2)}{c_2} = \frac{\sin(\theta_1)}{c_1}$$

c_1, c_2 are speeds of light in medium 1 and 2

Medium is Important

- If ray goes from faster to slower medium, ray is bent **towards** normal
- If ray goes from slower to faster medium, ray is bent **away** from normal

Material	Refractive index
Air	1.00
Water	1.33
Ice	1.309
Glass	1.52
Diamond	2.42

The refractive index of a material is the ratio of the speed of light in a vacuum to the speed of light in the medium.

For example, the speed of light through water is about ¾ the speed of light in vacuum so we have:

$$\eta = \frac{c}{\frac{3c}{4}} \approx 1.33$$

In GLSL, the **`refract`** function expects the index of refraction to be specified as c1/c2 where:

C1 is the index of the outside medium
C2 is the index of the inside medium

So, to go from air to water you would call:

```
T=refract(V,N, 1.00/1.33)
```

Refraction Vertex Shader

```
void main() {
   gl_Position = Projection*ModelView*vPosition;
   vec4 eyePos  = vPosition;              // calculate view vector V
   vec4 NN = ModelView*Normal;           // transform normal
   vec3 N =normalize(NN.xyz);            // normalize normal
   T = refract(eyePos.xyz, N, iorefr);      // calculate refracted vector T
}
```

Was previously `R = reflect(eyePos.xyz, N);`

T is a varying….

Also eyePos.xyz needs to be the normalized view direction

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Refraction Fragment Shader

```
void main()
{
    vec4 refractColor = textureCube(RefMap, T);   // look up texture map using T
    refractcolor = mix(refractcolor, WHITE, 0.3);  // mix pure color with 0.3 white

   gl_FragColor = texColor;
}
```

T is a varying….
RefMap is a uniform

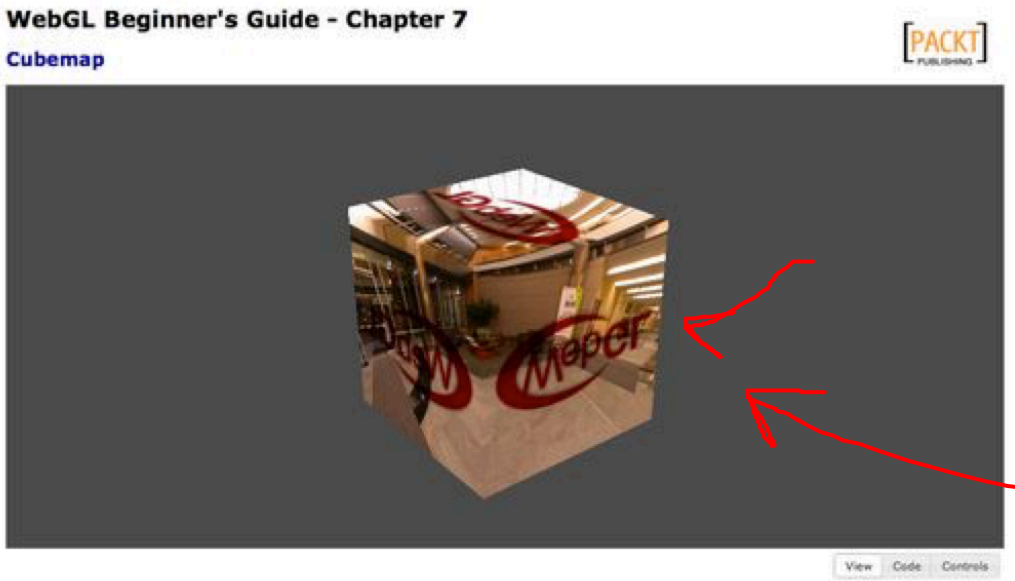
What's Wrong with this Code?

- From an actual published book…which has some good stuff in it:

7. And then in the fragment shader's main function, add the code to actually sample the cubemap and blend it with the base texture:

```
gl_FragColor = texture2D(uSampler, vTextureCoord) * textureCube(uCubeSampler, vVertexNormal);
```

8. We should now be able to reload the file in a browser and see the scene shown in the next screenshot:



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