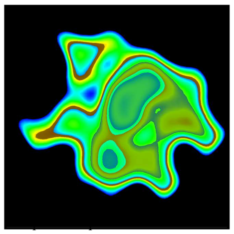
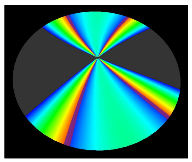
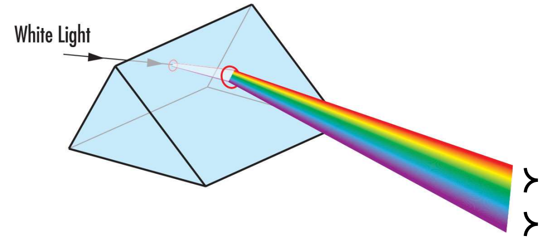
Spectral Effects:
Chromatic Refraction and Wavelength Interference

Oregon State University
Mike Bailey
mjb@cs.oregonstate.edu





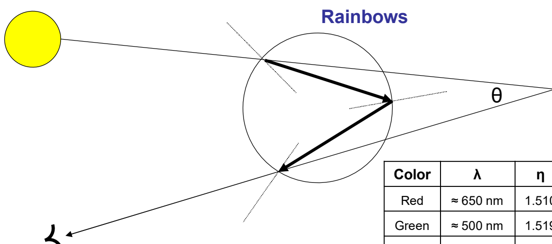
Each Wavelength of Light Has a Slightly Different Index of Refraction so that each Wavelength Bends Differently in a Prism



http://www.edmundoptics.com

Different colors are seen in different places

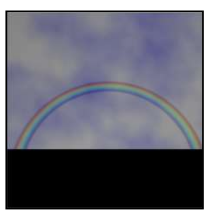
Rainbows



Primary Rainbow

Secondary Rainbow

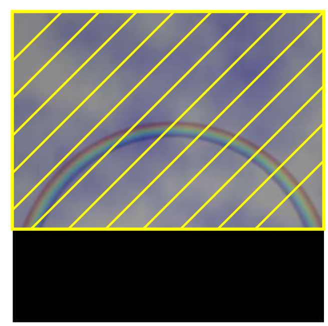
Color	λ	η	Θ	cosΘ	ΘΘ
Red	≈ 650 nm	1.510	42°	0.743	50.0°
Green	≈ 500 nm	1.519	41°	0.755	51.5°
Blue	≈ 400 nm	1.528	40°	0.766	53.0°



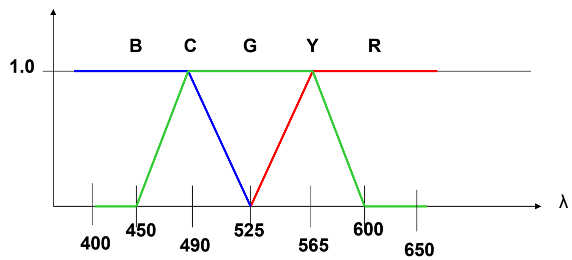
Rainbow Strategy

Or anything else, really. You just need a large “fragment-generator”.

1. Draw one big quadrilateral across the scene
2. Anywhere that .7400 ≤ cos(Θ) ≤ .7700, paint a color
3. Otherwise, discard.



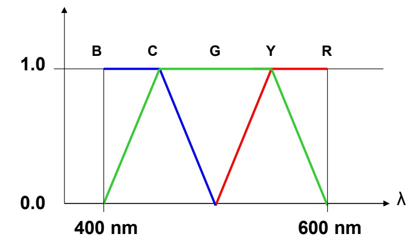
Spectral Colors




```
float
Pulse( float min, float max, float tol, float t )
{
    float a = min - tol;
    float b = min + tol;

    float c = max - tol;
    float d = max + tol;

    return  smoothstep(a,b,t) - smoothstep(c,d,t);
}
```

```
vec3 SunDirection = vec3( 0., SunY, 10. );
vec3 PtToSun = normalize( SunDirection );
vec3 PtToEye = normalize( vec3(0.,0.,0.) - ECposition );
float costheta = dot( PtToEye, PtToSun );

float R = Pulse( .7400, .7490, Tol, costheta );
float G = Pulse( .7490, .7605, Tol, costheta );
float B = Pulse( .7605, .7700, Tol, costheta );
```


Spectral Colors




```
float t = ( λ – 400. ) / ( 600. – 400. );     // 0. to 1.
vec3 rgb = Rainbow( t );
```

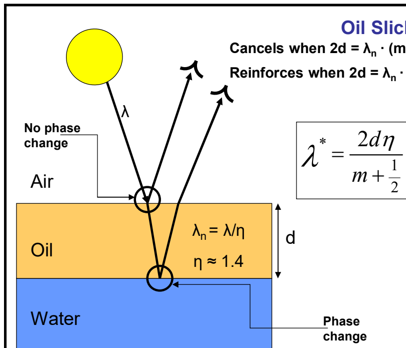

Changing the Range [0.,1.] to Rainbow Colors


```
vec3
Rainbow( float t )
{
        t = clamp( t, 0., 1. );
        vec3 rgb = vec3( 0., 0., 0. );

        // b -> c
        if( t >= 0. )
        {
                // rgb.r = 0.;
                rgb.g = 4. * ( t - (0./4.) );
                rgb.b = 1.;
        }

        // c -> g
        if( t >= (1./4.) )
        {
                // rgb.r = 0.;
                rgb.g = 1.;
                rgb.b = 1. - 4. * ( t - (1./4.) );
        }

        // g -> y
        if( t >= (2./4.) )
        {
                rgb.r = 4. * ( t - (2./4.) );
                rgb.g = 1.;
                // rgb.b = 0.;
        }

        // y -> r
        if( t >= (3./4.) )
        {
                rgb.r = 1.;
                rgb.g = 1. - 4. * ( t - (3./4.) );
                // rgb.b = 0.;
        }

        return rgb;
}
```

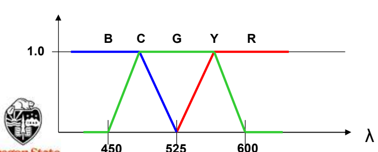

Oil Slicks

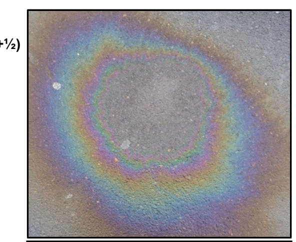
Cancels when $2d = \lambda_n \cdot (m)$

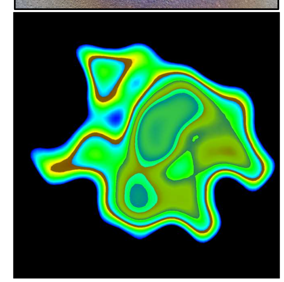
Reinforces when $2d = \lambda_n \cdot (m+½)$



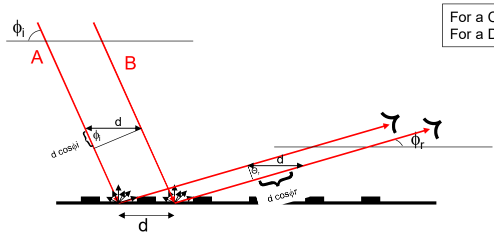
$$\lambda^* = \frac{2d\eta}{m+\frac{1}{2}}$$



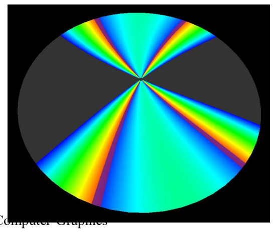




Diffraction Gratings



For a CD, d = 1600 nm
For a DVD, d = 740 nm

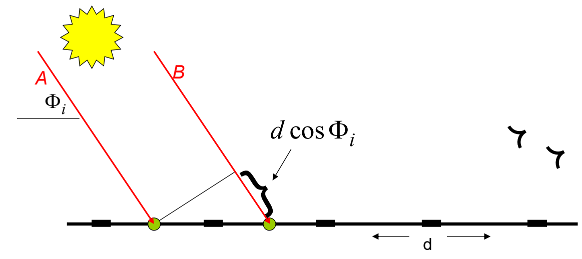


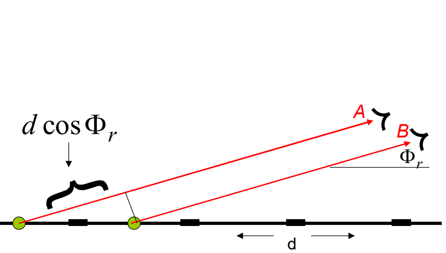
On the way in, Ray A travels *dcos(ϕ_i)* ***less*** than Ray B does.

On the way out, Ray A travels *dcos(ϕ_r)* ***more*** than Ray B does.

So, wavelengths reinforce when abs[dcos(ϕ_i) - dcos(ϕ_r)] is a multiple of the wavelength = mλ

$$\lambda^* = d \cdot |\cos(\phi_i) - \cos(\phi_r)| \;/\; m$$



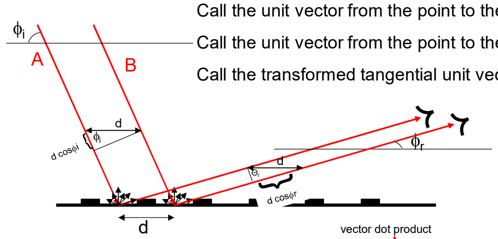


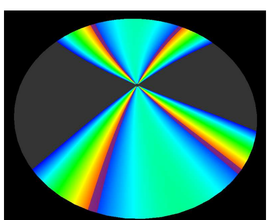
Diffraction Gratings

Call the unit vector from the point to the light **ToLight**.

Call the unit vector from the point to the eye **ToEye.**

Call the transformed tangential unit vector **Tangent.**





vector dot product

Then, cos(ϕ_i) is *ToLight•Tangent*

And, cos(ϕ_r) is *ToEye•(-Tangent)*

So that cos(ϕi) - cos(ϕr) is: *Tangent•(ToLight + ToEye)*

$$\lambda^* = d \cdot |\cos(\phi_i) - \cos(\phi_r)| \;/\; m$$