Radiometry

- Radiometry: study of the propagation of electromagnetic radiation in an environment
- Four key quantities: flux, intensity, irradiance and radiance
- These radiometric quantities are described by their spectral power distribution (SPD)

Spectral representation

fluorescent light

 SPD

lemmon skin
Color

- Need a compact, efficient and accurate way to represent functions like these.
- Find proper basis functions to map the infinite-dimensional space of all possible SPD functions to a low-dimensional space of coefficients.
- For example, \( B(\lambda) = 1 \), bad approximation.

Spectrum

- In core/color.*
- Not a plug-in, to use inline for performance.
- **Spectrum** stores a fixed number of samples at a fixed set of wavelengths. Better for smooth functions.

```cpp
#define COLOR_SAMPLE 3
class COREDLL Spectrum {
public:
    <arithmetic operations>
private:
    float c[COLOR_SAMPLES];
    ...
};
```

Human visual system

- Tristimulus theory: all visible SPDs can be accurately represented for human observers with three values, \( x_\lambda \), \( y_\lambda \), and \( z_\lambda \).
- The basis are the *spectral matching curves*, \( X(\lambda) \), \( Y(\lambda) \) and \( Z(\lambda) \).
- Not a good model for computation:

\[
\begin{align*}
x_\lambda &= \int_\lambda S(\lambda)X(\lambda) d\lambda \\
y_\lambda &= \int_\lambda S(\lambda)Y(\lambda) d\lambda \\
z_\lambda &= \int_\lambda S(\lambda)Z(\lambda) d\lambda
\end{align*}
\]
XYZ color

void XYZ(float xyz[3]) const {
    for (int i = 0; i < COLOR_SAMPLES; ++i) {
        xyz[0] += XWeight[i] * c[i];
        xyz[1] += YWeight[i] * c[i];
        xyz[2] += ZWeight[i] * c[i];
    }
}

pbrt uses RGB

float Spectrum::XWeight[COLOR_SAMPLES] = {
    0.412453f, 0.357580f, 0.180423f
};
float Spectrum::YWeight[COLOR_SAMPLES] = {
    0.212671f, 0.715160f, 0.072169f
};
float Spectrum::ZWeight[COLOR_SAMPLES] = {
    0.019334f, 0.119193f, 0.950227f
};
Spectrum FromXYZ(float x, float y, float z) {
    float c[3];
    c[0] =  3.240479f * x + -1.537150f * y + -0.498535f * z;
    c[1] = -0.969256f * x +  1.875991f * y +  0.041556f * z;
    c[2] =  0.055648f * x + -0.204043f * y +  1.057311f * z;
    return Spectrum(c);
}

Basic radiometry

- Pbrt is based on Radiative transfer: study of the transfer of radiant energy based on radiometric principles and operates at the geometric optics level (light interacts with objects much larger than the light’s wavelength)
- Based on the particle model, diffraction and interference can’t be easily accounted for.

Flux (Φ)

- Radiant flux, power
- Total amount of energy passing through a surface per unit of time (J/s,W)
**Irradiance (E)**

- Area density of flux (W/m²)  \[ E = \frac{\Phi}{dA} \]

\[ E = \frac{\Phi}{4\pi r^2} \]

\[ E = \frac{\Phi}{A} \]

\[ E = \frac{\Phi \cos \theta}{A} \]

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**Solid angle**

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**Intensity (I)**

- Flux density per solid angle  \[ I = \frac{d\Phi}{d\omega} \]
- Intensity describes the directional distribution of light

**Radiance (L)**

- Flux density per unit area per solid angle  \[ L = \frac{d\Phi}{d\omega dA} \]

- Most frequently used, constant along ray.
- All other quantities can be derived from radiance