Slides for Statistics, Precision, and Solid Angle

22.01 – Intro to Radiation
October 14, 2015
Solid Angles, Dose vs. Distance

• Dose decreases with the inverse square of distance from the source:

\[ Dose \propto \frac{1}{r^2} \]

• This is due to the decrease in solid angle subtended by the detector, shielding, person, etc. absorbing the radiation.
Solid Angles, Dose vs. Distance

• The solid angle is defined in *steradians*, and given the symbol $\Omega$.
• For a rectangle with width $w$ and length $l$, at a distance $r$ from a point source:

$$\Omega = 4\arctan \left[ \frac{wl}{2r\sqrt{4r^2 + w^2 + l^2}} \right]$$

• A full sphere has $4\pi$ steradians (Sr)
Solid Angles, Dose vs. Distance

- Total *luminance (activity)* of a source is constant, but the *flux* through a surface decreases with distance.

http://www.powerfromthesun.net/Book/chapter02/chapter02.html

Courtesy of William B. Stine. Used with permission.
Exponential Gamma Attenuation

• Gamma sources are *attenuated* exponentially according to this formula:

\[ I = I_0 e^{-\left(\frac{\mu}{\rho}\right)px} \]

Initial intensity \quad Mass attenuation coefficient \quad Distance through material

Transmitted intensity \quad Material density

• *Attenuation* means removal from a narrowly collimated beam *by any means*
Exponential Gamma Attenuation

Look up values in NIST x-ray attenuation tables:
http://www.nist.gov/pml/data/xraycoef/

\[ I = I_0 e^{-\left(\frac{\mu}{\rho}\right) \rho x} \]

- Initial intensity
- Transmitted intensity
- Mass attenuation coefficient
- Distance through material
- Material density
Exponential Gamma Attenuation

Initial intensity

Mass attenuation coefficient

Transmitted intensity

Material density

Distance through material

For compound materials, just add their total attenuation coefficients:

\[ \mu_{total} = \left( \frac{\mu}{\rho} \right)_1 \rho_1 + \left( \frac{\mu}{\rho} \right)_2 \rho_2 + \cdots \]

Look up values in NIST x-ray attenuation tables:

http://www.nist.gov/pml/data/xraycoef/
Mass Attenuation Coefficients


Public domain, from U.S. NIST.
Confidence increases with *counting time* and *counting rate*:

\[
\sigma = \sqrt{\frac{\text{count rate}}{\text{counting time}}}
\]

Count rates are expressed in counts per time plus or minus standard deviations:

*counts per minute* = *CPM* ± *σ*
Remember to measure a background count rate with its own uncertainty:

\[ \sigma_b = \sqrt{\frac{CPM_b}{t_b}} \]

Express total uncertainties in quadrature:

\[ CPM_{net} = CPM_{total} - CPM_b \quad \sigma_{net} = \sqrt{\frac{CPM_{total}}{t_{total}} + \frac{CPM_b}{t_b}} \]