

AST 300B – Spring 2017

In-class/take-home Problems Due: Friday Feb. 3

2 pages (see back)

12. Compute the column density and optical depth for the following cases and indicate if the medium is optically thin or optically thick:
- (a) 5.1 MeV gamma ray photons inelastically scattering off electrons (Compton scattering) with $n_e \sim 10^{-4} \text{ cm}^{-3}$ through a distance of 100 Mpc in the intergalactic medium.
 - (b) UV photons ($< 13.6 \text{ eV}$) elastically scattering off electrons (Thompson scattering) with $n_e \sim 10^{-2} \text{ cm}^{-3}$ in an HII region with a depth of 10 pc.
 - (c) 13.6 eV photons impinging on CNM HI clouds of density $n_H \sim 1 \text{ cm}^{-3}$ and thickness 1 pc.
 - (d) Yellow λ photons traveling through the Earth's troposphere ($\sim 15 \text{ km}$) with a N_2 number density of $\sim 2 \times 10^{19} \text{ cm}^{-3}$.

Table 5.1. Sample photon interaction cross-sections^a

Type	Description	Wavelength or energy	Cross-section (cm ²)
$\sigma_{\text{T}}^{\text{b}}$	Thomson scattering	$\ll 0.51 \text{ MeV}$	6.65×10^{-25}
$\sigma_{\text{K-N}}^{\text{c}}$	Compton scattering	0.51 MeV	2.86×10^{-25}
		5.1 MeV	8.16×10^{-26}
$\sigma_{\text{R}}^{\text{d}}$	Rayleigh scattering (N_2)	532 nm	5.10×10^{-27}
	(CO)	532 nm	6.19×10^{-27}
	(CO ₂)	532 nm	12.4×10^{-27}
	(CH ₄)	532 nm	12.47×10^{-27}
$\sigma_{\text{b-b}}^{\text{e}}$	Ly α (natural) ^f	121.567 nm	7.1×10^{-11}
	Ly α (10^4 K) ^g	121.567 nm	5.0×10^{-14}
$\sigma_{\text{HI} \rightarrow \text{HII}}^{\text{h}}$	H ionization	13.6 eV	6.3×10^{-18}
$\sigma_{\text{f-f}}^{\text{i}}$	free-free absorption	21 cm	2.8×10^{-27}

See Irwin for full table footnotes.

13. A spherical optically thick object emits at temperature T_c and is surrounded by an optically thin shell. This shell absorbs/emits thermally with temperature T_s only in a narrow spectral line with absorption coefficient plotted below as a function of ν . Assume there is no background radiation field outside the object and shell.

(a) Sketch the spectrum for this spectral line for rays A and B assuming that $T_s < T_c$. Be careful to indicate the continuum level.

(b) Sketch the spectrum for this spectral line for rays A and B assuming that $T_s > T_c$. Be careful to indicate the continuum level.

