

AST 300B – Spring 2018

In-class/take-home Problems Due: Friday Feb. 2

2 pages (see back)

13. 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 diameter 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 ($\sim 10 \text{ km}$) 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)
σ_{T^b}	Thomson scattering	$\ll 0.51 \text{ MeV}$	6.65×10^{-25}
σ_{K-N^c}	Compton scattering	0.51 MeV	2.86×10^{-25}
		5.1 MeV	8.16×10^{-26}
σ_{R^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}
σ_{b-b^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}
$\sigma_{HI \rightarrow HII^h}$	H ionization	13.6 eV	6.3×10^{-18}
σ_{f-f^i}	free-free absorption	21 cm	2.8×10^{-27}

See Irwin for full table footnotes.

14. 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.

