Plasma II - Exercises

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Solutions to problem set 12 - May 23, 2025

Multiple-choice question

In the course (p14) you have seen that the Bremsstrahlung emission of a thermal plasma decreases with increasing frequency. What limits the increase of Bremsstrahlung at low frequencies?

( ) At sufficiently low frequency Bremsstrahlung is replaced by line radiation.

( ) There is no limit and Bremsstrahlung emission approaches a constant value as the frequency decreases towards zero. As the energy carried by each emitted photon, $h\nu$, depends on the frequency the photon flux diverges (*infrared divergence*).

(x) At low frequency inverse Bremsstrahlung, i.e. photon absorption on free charges, becomes increasingly important and limits the net emission.

Measuring emission of an optically thin plasma

The geometry is shown in the schematic below.

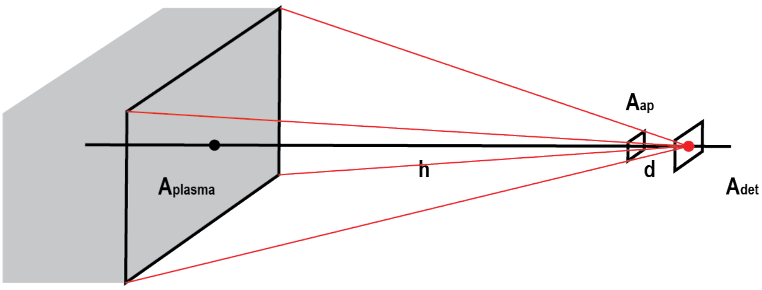

Figure 1: Schematic of the viewing geometry.

a) The seen plasma volume emits the power $P = \int \epsilon dV_{\text{plasma}}$ isotropically, of which only a fraction $dA_{\text{det}}/4\pi h^2$ is detected with the detector element,

$$dP_{\text{det}} = \int \epsilon dV_{\text{plasma}} \frac{dA_{\text{det}}}{4\pi h^2}$$

b) The plasma volume seen by the detector element is determined by the size and position of the aperture. The cross-sectional area of the plasma seen by the detector relates to the area of the aperture as the ratio of the squares of their respective distances to the detector,

$$\frac{A_{\text{plasma}}}{A_{\text{ap}}} = \frac{h^2}{d^2} \quad .$$

The length of the plasma volume is determined by the length of the LoS. The plasma volume, therefore, is,

$$dV_{\text{plasma}} = A_{\text{plasma}} dl = \frac{A_{\text{ap}} h^2}{d^2} dl$$

c) The detected power is,

$$\begin{aligned} P_{\text{det}} &= \int_{\text{det}} \int_{\text{plasma}} \epsilon dV_{\text{plasma}} \frac{1}{4\pi h^2} dA_{\text{det}} \\ &= \int_{\text{det}} \int_{\text{plasma}} \epsilon \frac{A_{\text{ap}} h^2}{d^2} dl \, \frac{1}{4\pi h^2} dA_{\text{det}} \\ &= \frac{A_{\text{ap}} A_{\text{det}}}{4\pi d^2} \int_{\text{plasma}} \epsilon dl \quad . \end{aligned}$$

The quantity $\mathrm{A}_{\text{ap}} A_{\text{det}}/d^2$ is also referred to as the *etendue* or *A* Ω *product* of the optical system. It describes how the optical system translates the radiant flux emitted by the plasma surface per unit solid angle (*radiance*) $\frac{1}{4\pi} \int_{\text{plasma}} \epsilon dl$ into a signal.