$$I(\nu) = \frac{2kT\nu^2}{c^2},$$

$$L(\nu) = 4\pi R^2 \times \int_{-\pi}^{\pi}\int_0^{\frac{\pi}{2}} \cos\theta \sin\theta \,\mathrm{d}\theta \,\mathrm{d}\phi \times I(\nu) = 4\pi R^2 \times \pi \times I(\nu),$$

$$F(\nu) = \frac{L(\nu)}{4\pi r^2} \approx 60\mu\mathrm{Jy}.$$

$$R_\odot \approx 6.957 \times 10^8\mathrm{m},$$

$$L_\odot = 4\pi R_\odot^2 \sigma T_\odot^4 \approx 3.9 \times 10^{26}\mathrm{W}.$$

$$L_{入} = L_\odot \frac{\pi R_\mathrm{M}^2}{4\pi r_{\odot\mathrm{M}}^2},$$

$$L_{出} = 4\pi R_\mathrm{M}^2 \sigma T_\mathrm{M}^4,$$

$$T_\mathrm{M} = \sqrt[4]{\frac{L_\odot}{16\pi\sigma r_{\odot\mathrm{M}}^2}} = \sqrt[4]{\frac{R_\odot^2}{4r_{\odot\mathrm{M}}^2}} T_\odot \approx 230\mathrm{K}.$$

$$R_\mathrm{M} = r_\mathrm{EM}\theta_\mathrm{M},$$

$$I_\mathrm{M}(\nu) = \frac{2kT_\mathrm{M}\nu^2}{c^2},$$

$$L_\mathrm{M}(\nu) = 4\pi R_\mathrm{M}^2 \times \int_{-\pi}^{\pi}\int_0^{\frac{\pi}{2}} \cos\theta \sin\theta \,\mathrm{d}\theta \,\mathrm{d}\phi \times I_\mathrm{M}(\nu) = 4\pi R_\mathrm{M}^2 \times \pi \times I_\mathrm{M}(\nu),$$

$$F_\mathrm{M}(\nu) = \frac{L_\mathrm{M}(\nu)}{4\pi r_\mathrm{EM}^2} = 4\theta_\mathrm{M}^2 I_\mathrm{M}(\nu) \approx 4.8 \times 10^{-25}\mathrm{W/(m^2 \cdot Hz)}.$$

$$T_\mathrm{M} = \sqrt[4]{\frac{(1-\alpha)L_\odot}{16\pi\sigma r_{\odot\mathrm{M}}^2}} = \sqrt[4]{\frac{(1-\alpha)R_\odot^2}{4r_{\odot\mathrm{M}}^2}} T_\odot \approx 220\mathrm{K}.$$

$$F_\mathrm{M}(\nu) = \frac{L_\mathrm{M}(\nu)}{4\pi r_\mathrm{EM}^2} = 4\theta_\mathrm{M}^2 I_\mathrm{M}(\nu) \approx 4.7 \times 10^{-25}\mathrm{W/(m^2 \cdot Hz)}.$$

$$P = \frac{2}{3}\frac{q^2\ddot{x}^2}{c^3} = \frac{2}{3}\frac{q^2A^2\omega^4\cos^2(\omega t)}{c^3},$$

$$\bar{P} = \frac{2q^2A^2\omega^4}{3c^3}\frac{\int_{\omega t=-2\pi}^{\omega t=2\pi}\cos^2(\omega t)\,\mathrm{d}t}{\int_{\omega t=-2\pi}^{\omega t=2\pi}\mathrm{d}t} = \frac{2q^2A^2\omega^4}{3c^3}\frac{\int_{-2\pi}^{2\pi}\cos^2\theta\,\mathrm{d}\theta}{\int_{-2\pi}^{2\pi}\mathrm{d}\theta} = \frac{q^2A^2\omega^4}{3c^3}.$$

$$E_\perp = \Re\left[\frac{-i\pi\sin\theta}{c}\frac{I_0 l}{\lambda}\frac{e^{-i\omega t}}{r}\right],$$

$$S = \frac{c}{4\pi}E_\perp^2 \propto \frac{\sin^2\theta}{r^2},$$

$$P(\Omega)\mathrm{d}\Omega = Sr^2\mathrm{d}\Omega \propto \sin^2\theta\mathrm{d}\Omega,$$

$$\iint \sin^2\theta\sin\theta\,\mathrm{d}\theta\,\mathrm{d}\phi = \int\frac{4}{3}\,\mathrm{d}\phi = \frac{8\pi}{3},$$

$$G(\theta,\phi) = \frac{3}{8\pi}\sin^2\theta.$$

$$A_\mathrm{e}(\theta,\phi) = \frac{\lambda^2}{4\pi}G(\theta,\phi) = \frac{3\lambda^2}{32\pi^2}\sin^2\theta = \frac{3c^2}{32\pi^2\nu^2}\sin^2\theta,$$

$$P(\nu) = A_\mathrm{e}\frac{S}{2} \approx 5.1\times10^{-26}\mathrm{W/Hz}.$$

$$T_\mathrm{A} = \frac{P(\nu)}{k} \approx 3.7\times10^{-3}\mathrm{K}.$$

$$R_\mathrm{ff} \approx \frac{2D^2}{\lambda} \approx 2\times10^6\mathrm{m}.$$

$$f(l) = g\int_{-\frac{D}{2\lambda}}^{\frac{D}{2\lambda}} e^{-i2\pi lu}\mathrm{d}u = g\left[\frac{e^{-i2\pi lu}}{-i2\pi l}\right]_{-\frac{D}{2\lambda}}^{\frac{D}{2\lambda}} = g\frac{\sin(\pi l\frac{D}{\lambda})}{\pi l}.$$

$$\lambda_\mathrm{D} \approx \sqrt{\frac{kT}{4\pi n_e e^2}},$$

$$b_\mathrm{max} \approx \frac{v}{2\pi\nu},$$

$$\frac{1}{2}m_e v^2 \approx \frac{3}{2}kT,$$

$$b_\mathrm{max} \approx \frac{\sqrt{\frac{3kT}{m_e}}}{2\pi\nu} \approx 1\times10^{-4}\mathrm{m}.$$

$$n_e \approx \frac{kT}{4\pi e^2\lambda_\mathrm{D}^2} \approx 4\times10^{15}\mathrm{m}^{-3}.$$

$$T \approx 10^4\mathrm{K},$$

$$\nu = 100\mathrm{MHz} = 0.1\mathrm{GHz},$$

$$\mathrm{EM} = \int_{R_\odot}^{r_\oplus} \left[N_{e\oplus}\left(\frac{r_\oplus}{r}\right)^2\right]^2 \mathrm{d}r = \left[-\frac{1}{3}N_{e\oplus}^{\ 2} r_\oplus^4 r^{-3}\right]_{R_\odot}^{r_\oplus} \approx \frac{N_{e\oplus}^{\ 2} r_\oplus^4}{R_\odot^3} \approx 5000\mathrm{pc/cm^6},$$

$$\tau_\nu \approx 3.28\times 10^7 \left(\frac{T}{10^4\mathrm{K}}\right)^{-1.35} \left(\frac{\nu}{\mathrm{GHz}}\right)^{-2.1} \left(\frac{\mathrm{EM}}{\mathrm{pc/cm^6}}\right) \approx 2\times 10^{13}.$$

$$\frac{\mathrm{d}}{\mathrm{d}t}(\gamma m_e \vec{v}) = -\frac{e}{c}(\vec{v}\times\vec{B}),$$

$$\frac{\mathrm{d}}{\mathrm{d}t}\gamma = 0,$$

$$\frac{\mathrm{d}}{\mathrm{d}t}\vec{v} = -\frac{e}{\gamma m_e c}(\vec{v}\times\vec{B}),$$

$$\omega^2 r = \frac{e}{\gamma m_e c} vB = \frac{e}{\gamma m_e c}\omega r B,$$

$$\omega = \frac{eB}{\gamma m_e c} = \frac{\omega_\mathrm{G}}{\gamma},$$

$$\sin\alpha \approx 1,$$

$$\nu_\mathrm{c} = \frac{3}{2}\gamma^2 \nu_\mathrm{G}\sin\alpha = \frac{3}{2}\gamma^2\frac{eB}{2\pi m_e c},$$

$$\gamma^2 = \frac{4\pi m_e c \nu_\mathrm{c}}{3eB},$$

$$E = \gamma m_e c^2,$$

$$P = \frac{2e^2}{3c^3}\gamma^2\frac{e^2B^2}{m_e^2c^2}v^2\sin^2\alpha = \frac{2e^2}{3c^3}\gamma^2\frac{e^2B^2}{m_e^2}\left(1-\frac{1}{\gamma^2}\right) \approx \frac{2e^2}{3c^3}\gamma^2\frac{e^2B^2}{m_e^2},$$

$$\tau \approx \frac{E}{p} \approx \frac{3m_e^3c^5}{2\gamma e^4B^2} \approx 9\times 10^7\mathrm{yr}.$$