Energy Carried by Electromagnetic Waves

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- (Energy per area) per time
- Power per area
- Units are $\left[\frac{\mathrm{J}}{\mathrm{m^2 s}}\right] = \left[\frac{\mathrm{W}}{\mathrm{m^2}}\right]$.
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There is energy in a region with electric and magnetic fields. (Recall: energy stored in a capacitor may be interpreted as being stored in the electric field.)

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The average of $\vec{S}$ over an integer number of cycles is called wave intensity, I.

$$I = \langle S \rangle = \left\langle \frac{1}{\mu_0} E_{\max} B_{\max} \sin^2(kx - \omega t) \right\rangle$$

$$I = \frac{E_{\max} B_{\max}}{2\mu_0} = \frac{1}{2} c\epsilon_0 E_{\max}^2 = \frac{1}{2}\frac{cB_{\max}^2}{\mu_0}$$

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$$\langle u \rangle \equiv \frac{U}{V} = \frac{U}{Ad} = \frac{U}{A(ct)} = \frac{I}{c}$$

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Exactly half of the energy is in the electric field and exactly half of the energy is in the magnetic field. $\langle u_E \rangle = \frac{\epsilon_0 E_{\max}^2}{4}$ and $\langle u_B \rangle = \frac{B_{\max}^2}{4\mu_0}$.

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Radiation Pressure

IF radiation is completely absorbed,

$$\langle P_{\text{rad}} \rangle = \frac{F}{A} = \frac{U}{V} = \langle u \rangle = \frac{I}{c}$$

IF radiation is completely reflected,

$$\langle P_{\text{rad}} \rangle = \frac{2I}{c}$$

Why is there a difference of a factor of 2?

Example: A radio station broadcasts with a total average power of $50 \mathrm{kW}$. (a) Determine the electric and magnetic field amplitudes measured at a distance of $20 \mathrm{km}$ from the transmitter. (b) How much energy is absorbed in a day by an antenna of area, $0.25\ \mathrm{m}^2$ facing the transmitter $20 \mathrm{km}$ from the transmitter? (c) Determine the force exerted on the antenna by the electromagnetic wave.