

SOLAR IRRADIANCE

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Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 3, Problem 3.2.

The luminosity of the Sun is

$$(1) \quad L_S = 3.839 \times 10^{26} \text{ watts}$$

On a sphere of radius r centred at the Sun, the power received is therefore

$$(2) \quad F = \frac{L_S}{4\pi r^2}$$

which is the inverse square law for radiation from a spherically symmetric source. At the distance of the Earth, $r = 1 \text{ AU} = 1.496 \times 10^{11} \text{ m}$ so the solar flux, known as the *solar irradiance*, is

$$(3) \quad F_S = 1365 \text{ W m}^{-2}$$

This is the power received when the Sun is directly overhead, which can occur only between the tropics of Cancer and Capricorn. At my latitude of around 56° N , the highest the Sun can get in the sky occurs at noon on the summer solstice, when the Sun's declination is around $+23^\circ$, putting it at an altitude of $(90 - 56 + 23) = 57^\circ$. The flux here is therefore

$$(4) \quad F_{\text{summer}} = F_S \sin 57^\circ = 1145 \text{ W m}^{-2}$$

At the winter solstice, the Sun's maximum altitude is $90 - 56 - 23 = 11^\circ$, giving a flux of

$$(5) \quad F_{\text{winter}} = F_S \sin 11^\circ = 260 \text{ W m}^{-2}$$

I've actually measured this in my own backyard with my weather station (see the High Solar Rad graph about halfway down the page) and the numbers do check out; in June the highest recorded radiation is between 1100 and 1200 and in December it peaks at around 200.

A somewhat dated comparison is to look at the radiation emitted by an old-fashioned 100 W light bulb. In order for us to receive the solar irradiance from such a bulb, we'd need to be at a distance

$$(6) \quad r = \sqrt{\frac{100}{4\pi \times 1365}} = 7.6 \text{ cm}$$

More modern light bulbs such as LEDs emit just as much light as the old high-power bulbs but consume much less power (a typical LED consumes under 5 watts). This is because most of the energy in an LED goes into emitting light while in an old 100W bulb, a large portion of the energy is radiated as heat (or to be more precise, infrared radiation).

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