period of time, for example, hourly irradiation or daily irradiation, and is measured in $\mathrm{Wh/m^2}$. Furthermore, only the symbols B_0, B, D, R and G will be used, respectively, for extraterrestrial, direct, diffuse, albedo and global irradiance, whereas a first subscript, h or d, will be used to indicate hourly or daily irradiation. A second subscript, m or y, will refer to monthly or yearly averaged values. Furthermore, the slope and orientation of the concerned surface are indicated among brackets. For example, $G_{\mathrm{dm}}(20{,}40)$ refers to the monthly mean value of the daily global irradiation incident on a surface tilted $\beta = 20^\circ$ and oriented $\gamma = 40^\circ$ towards the west. For surfaces tilted towards the equator ($\gamma = 0$), only the slope will be indicated. For example, $B(60)$ refers to the value of the direct irradiance incident on a surface tilted $\beta = 60^\circ$ and oriented towards the south (in the Northern Hemisphere).

An important concept characterising the effect of atmosphere on clear days is the *air mass*, defined as the relative length of the direct-beam path through the atmosphere compared with a vertical path directly to sea level, which is designed as *AM*. For an ideal homogeneous atmosphere, simple geometrical considerations lead to

$$AM = \frac{1}{\cos\theta_{\mathrm{ZS}}} \tag{20.12}$$

which is generally sufficient for most engineering applications. If desired, more accurate expressions, considering second-order effects (curvature of the Earth, atmospheric pressure etc.), are available [4].

At the standard atmosphere $AM\,1$, after absorption has been accounted for, the normal irradiance is generally reduced from B_0 to 1000 $\mathrm{W/m^2}$, which is just the value used for the standard test of PV devices (see Chapter 16). Obviously, that can be expressed as $1000 = 1367 \times 0.7^{AM}$. For general AM values, a reasonable fit to observed clear days data is given by [5].

$$G = B_0 \cdot \varepsilon_0 \times 0.7^{AM^{0.678}} \tag{20.13}$$

A particular example can help to clarify the use of these equations, by calculation of the sun co-ordinates and the global irradiance on a surface perpendicular to the sun, and also on a horizontal surface, over two geographic positions defined by $\phi = 30^\circ$ and $\phi = -30^\circ$, at 10:00 (solar time) on 14 April, being a clear day. The solution is as follows:

$$14 \text{ April} \Rightarrow d_{\mathrm{n}} = 104; \varepsilon_0 = 0.993; \delta = 9.04^\circ$$

$$10{:}00 \text{ h} \Rightarrow \omega = -30^\circ$$

$$\phi = 30^\circ \Rightarrow \cos\theta_{\mathrm{ZS}} = 0.819 \Rightarrow \theta_{\mathrm{ZS}} = 35^\circ \Rightarrow \cos\psi_{\mathrm{S}} = 0.508 \Rightarrow \psi_{\mathrm{S}} = -59.44^\circ$$
$$\Rightarrow AM = 1.222 \Rightarrow G = 902.4\ \mathrm{W/m^2}$$
$$\Rightarrow G(0) = G \cdot \cos\theta_{\mathrm{ZS}} = 739\ \mathrm{W/m^2}$$

$$\phi = -30^\circ \Rightarrow \cos\theta_{\mathrm{ZS}} = 0.662 \Rightarrow \theta_{\mathrm{ZS}} = 48.54^\circ \Rightarrow \cos\psi_{\mathrm{S}} = 0.403 \Rightarrow \psi_{\mathrm{S}} = -66.28^\circ$$
$$\Rightarrow AM = 1.510 \Rightarrow G = 846.9\ \mathrm{W/m^2}$$
$$\Rightarrow G(0) = G \cdot \cos\theta_{\mathrm{ZS}} = 561\ \mathrm{W/m^2}$$