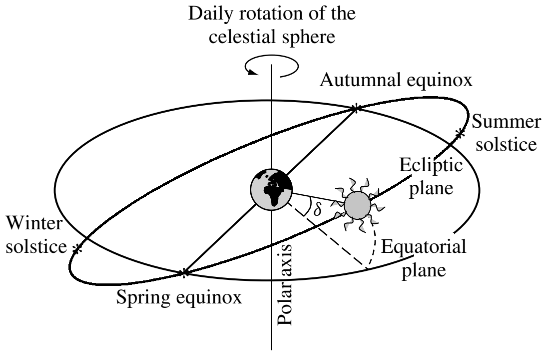

Figure 20.4 The celestial sphere and the ecliptic plane

points represents a direction towards the sky as seen from the Earth. The intersection of the celestial sphere with the equatorial plane defines the *celestial equator*. The points of intersection with the polar axis are called the *celestial poles*. Using this form of representation, the movement of the Earth around the stationary sun may instead be seen as a movement of the Sun with the Earth taken as fixed. The sun then travels through a great circle of the celestial sphere, the *ecliptic*, which forms an angle of 23.45° with the celestial equator. The sun completes this circuit once a year while the celestial sphere rotates once a day around the Earth (regarded as fixed). In this way, the sun marks out a circle around the Earth. The diameter of the circle changes daily, reaching a maximum on the equinoxes and a minimum on the solstices. The rotation of the sun around the ecliptic is in the opposite direction to that of the celestial sphere around the Earth.

Now, landing on a particular location on the Earth's surface, where a PV system is going to be used, it is convenient to specify the position of the sun by means of two angles that refer to the horizontal plane and to the vertical. The vertical intersects the celestial sphere at points known as the zenith and the nadir. Figure 20.5 attempts to visualise these concepts. The *solar zenith angle*, θ_{ZS}, is between the vertical and the incident solar beam; and the *solar azimuth*, ψ_S, is between the meridians of the location and the sun. The complement of the zenith angle is called the *solar altitude*, γ_S, and represents the angle between the horizon and the solar beam in a plane determined by the zenith and the sun. In the Northern (Southern) Hemisphere, the solar azimuth is referenced to south (north) and is defined as positive towards the west, that is, in the evening, and negative towards the east, that is, in the morning.

At any given moment, the angular coordinates of the sun with respect to a point of geographic latitude ϕ (north positive, south negative) are calculated from the equations:

$$\cos\theta_{ZS} = \sin\delta\sin\phi + \cos\delta\cos\phi\cos\omega = \sin\gamma_S \tag{20.4}$$

and

$$\cos\psi_S = \frac{(\sin\gamma_S\sin\phi - \sin\delta)}{\cos\gamma_S\cos\phi}[\mathrm{sign}(\phi)] \tag{20.5}$$

where ω is called the true solar time, or local apparent time, or solar hour, and is the difference between noon and the selected moment of the day in terms of a 360° rotation