the significance) of the results of any PV design exercise, irrespective of the complexity of the radiation and PV array models supporting the particular design tool. This means that for stand-alone PV systems, reliability can only be properly estimated for Loss of Load Probabilities greater than 10^{-2}. For grid-connected systems, it implies that yield predictions should be understood to have an uncertainty that can reach up to $\pm 30\%$, for monthly values, and $\pm 10\%$ for annual ones.

Regarding the behaviour of PV modules in arbitrary operating conditions, an $I-V$ model based on the incident irradiance and ambient temperature is presented. Particular attention is paid to the consideration of incidence angle effects, which can be significant in several real situations. Further refinements to incorporate the effects of wind speed, solar spectrum and low irradiance effects are also described. These second-order effects help to explain temporary differences between predicted and observed values, but are of minor importance when long-term energy production calculations are considered.

Finally, some problems related to relevant applications are particularly addressed: the reliability of stand-alone PV systems, the case of Solar Home Systems (SHS) (characterised by a large variety of individual real energy consumption values in contrast to only a few standard ones for design purposes), and the energy yield of grid-connected PV systems.

20.2 MOVEMENT BETWEEN SUN AND EARTH

Although the movement of the sun relative to a fixed point on the Earth seems very familiar, because the sun is fortunately there everyday, the mathematics that governs it is surprisingly complex. In fact, the understanding of such movement was among the longest scientific adventures of mankind. It seems that the very first sundials were built in the Babylonian time (1800 BC), and that the attempts to explain the evolution of the "gnomon" shadow led to the first proposed models of the Sun–Earth movement, which in turn led to the beginning of geometry, in Greece [1]. Figure 20.1 pays a fully

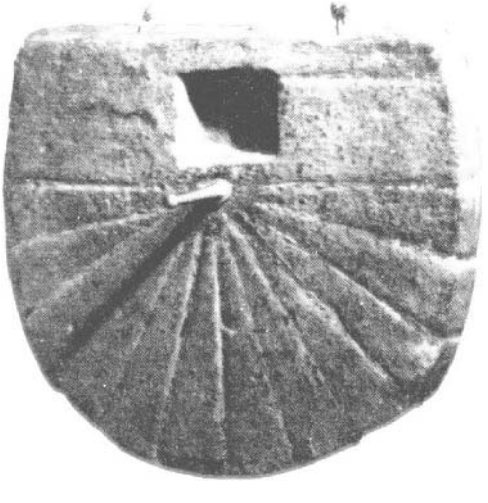

Figure 20.1 Sundial about 2000 years old