(3) On the beach at noon, with a clear sky, you made a good snapshot at $f/8$ and $1/500$ s. At midnight the same scene is lit by the full moon. You want to make an equally well-exposed picture. You have a tripod to hold the camera for a time exposure, and the aperture can be opened up to $f/2.8$. What would be a good exposure time to try?

The question boils down to this: How much brighter is sunlight than moonlight? If the moon were a perfectly reflecting sphere like the shiny satellite in the first problem for May, it would scatter sunlight isotropically and the ratio at Earth of moonlight to sunlight would be $R^2/4D^2$, where R is the moon's radius and D the moon's distance from earth. As R/D is about $1/200$, this ratio would be $1/160\ 000$. But the moon is rough and gray—not much whiter than asphalt pavement. That will reduce the total scattered light by a considerable factor. For a rough estimate we might take $1/10^6$ as the ratio of full-moon light to sunlight. Opening the camera aperture by three stops buys us a factor of 8, so the exposure time called for is $(1/8)(1/500) \times 10^6$ s, or about 4 min. At least, that would be a reason-termed *reciprocity*. Whether this is a safe assumption depends on the type of film used. Failure of reciprocity would necessitate an even longer exposure in moonlight.

The actual ratio of full-moon light to sunlight is approximately $1/400\ 000$. [See Allen, *Astrophysical Quantities*, 3rd ed., Athlone Press, p. 144 (1973).] It would be considerably smaller were it not for an extraordinary property of the moon's surface which like glass beads (but for quite a different reason) concentrates the scattered light in the backward direction. In fact, we receive from the full moon about ten times as much light as from the half-moon, whereas for a matte Lambert Law sphere the ratio would be just π. Of course the midnight picture will differ from the midday snapshot in another respect: if the season is summer, the full moon will be low in the sky; the shadows will resemble those of a winter sun.