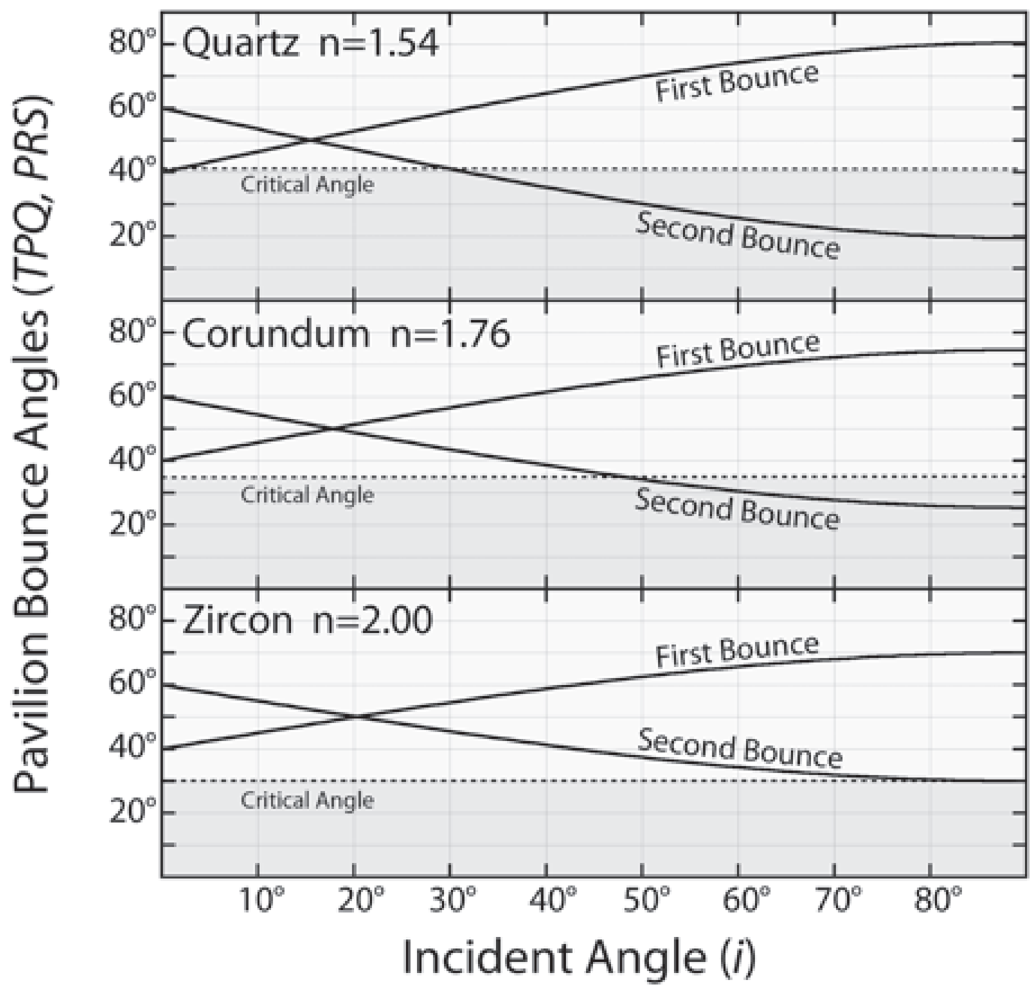

Figure 10-11 The angles of the first and second pavilion bounces for a light ray entering the table for quartz (top), corundum (middle), and zircon (bottom). The horizontal dashed line indicates the critical angle for each material. Note that quartz runs into trouble – the second incident angle is below critical – for light entering the table at angles greater than approximately 30°, while zircon is fine for essentially all input angles.

the culet facets will not produce total internal reflection, and the light will leak out. This means that a quartz SRB gemstone has a "capture cone" of about 30°. In other words, light rays entering the table within 30° of vertical will experience two bounces and have a good chance of contributing to the brightness and sparkle of the gem.[1]

Now look at the other two plots. For corundum, (middle plot), leakage occurs for table incident angles above 50°, while for zircon (bottom), essentially all input angles produce double TIR goodness.

Figure 10-12 shows schematically the SRB capture cone for various gemstone materials. As expected, the higher refractive index gems do a better job of collecting light from a broad range of input angles. This is one reason why high-index stones appear brighter and flashier.

[1] Note that an incident angle of only 25° causes leakage on the second bounce in Section 10.3, but there, the culet angle is 43°, not 40°. Perhaps 40° is a good angle after all!

There is one last chapter to this mathematical tale. Figure 10-12 significantly underemphasizes the value of a wide "capture cone." It turns out that a 60° cone captures *much* more light than a 30° cone. This is because the amount of light depends on the "area of sky" from which the gem can gather photons (Figure 10-13). How big is the area of sky for a given angle? The derivation is well beyond the scope of this chapter, but here's the answer for a cone whose opening angle is θ from the vertical :

$$\text{Area} = \pi \cdot \big(1 - \cos(\theta)\big)$$

where π is 3.14159…, the ratio of the circumference of a circle to its diameter. Incidentally, our old friend Archimedes (see page 3 and Chapter 20.2.1) worked this area relation out more than two thousand years ago. Now that you are no longer frightened (if you ever were) by trigonometric calculations, you can figure out on your pocket calculator that, for example, a YAG gem (n=1.84) with a 60° capture cone gathers 3.7 times as much light as a quartz gem (n=1.54) with a 30° cone.

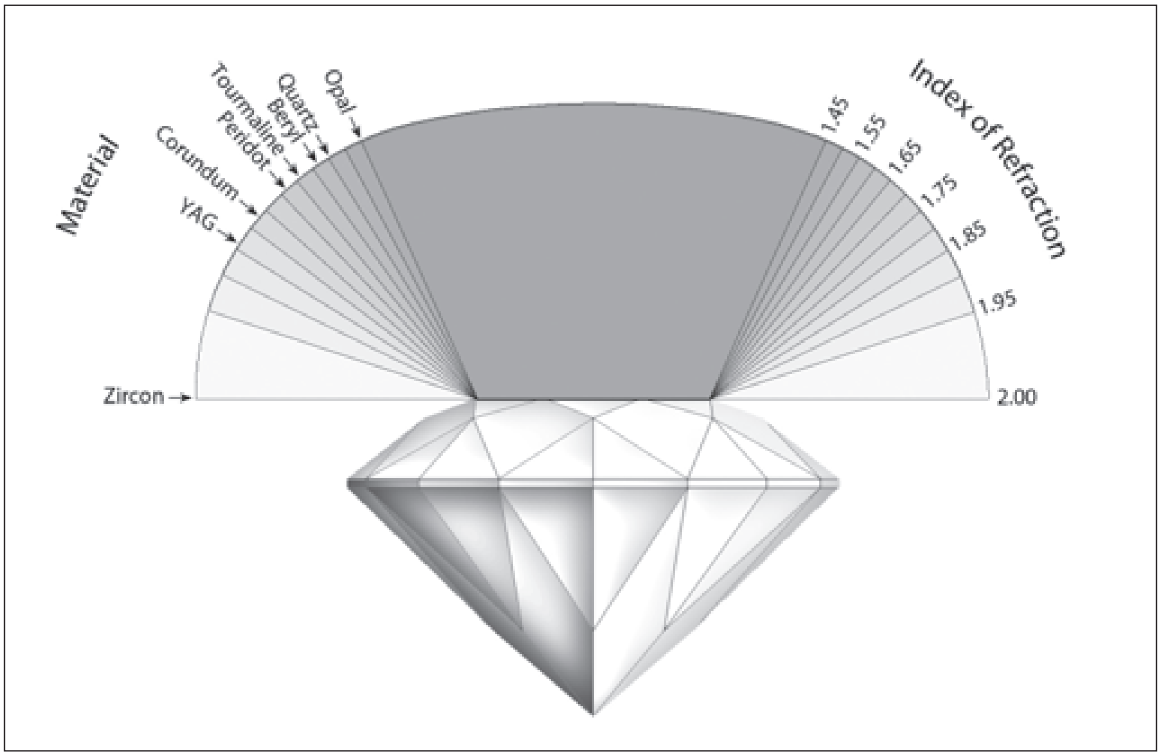

Figure 10-12 The range of incident angles for light entering the table of a gemstone which produces two total internal reflections in the pavilion. A little trigonometry shows that for lower refractive indices (darker areas), only light striking the table relatively close to perpendicular will bounce twice and re-emerge out of the crown. For higher index materials, a much broader range of incidence angles will contribute to the brightness of the gem, and materials with an index of 2 or above will capture essentially all rays.

The pocket-protector crowd will point out at this stage that all of these calculations are a simplification, since not every point on the table can gather light from the entire capture cone – we have, after all, been considering the somewhat optimistic case of light striking the culet facet on the same side of the gem as the incident ray. Fair enough. In fact, this example makes several assumptions that reasonable people could question, despite their overprotectiveness of their shirt pockets. Nevertheless, the overall message remains the same: higher index gems will capture more light from more angles and channel it more magically up to your eyes.