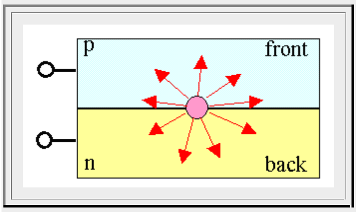
Illustration

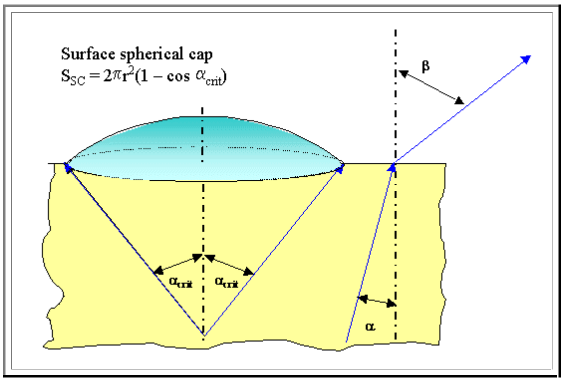
Solution to Exercise 5.2-2: Fresnel Equations and LEDs

Consider a simple light emitting diode schematically working as shown. All light is generated in a small volume as indicates an we assume that the semiconductor is fully transparent (which is not really true). The index of refraction of semiconductors is rather large; you may take it to be ***n*=3**



The simple question is: How much (in **%**) of the light generated is transmitted through the front (upper) surface?

First, it is important to make a drawing of the situation with respect to reflected and transmitted light:



- Light hitting the surface with an angle larger than α_{crit} will suffer total reflection and remains inside the semiconductor where it is eventually absorbed. Light emitted "downwards might get out of the semiconductor but is absorbed in the housing.
- It follows that only light paths' inside the cone with opening angle $2\alpha_{crit}$ will get out to where we need them. Steric analysis gives the surface of the spherical cap belonging to the $2\alpha_{crit}$ cone to $S_{SC} = 2\pi r^2 \cdot (1 - \cos\alpha_{crit})$.
- The percentage of the light intensity I_{out} coming out relative to the light intensity I_{total} emitted into the full sphere with surface $4\pi r^2$ is thus

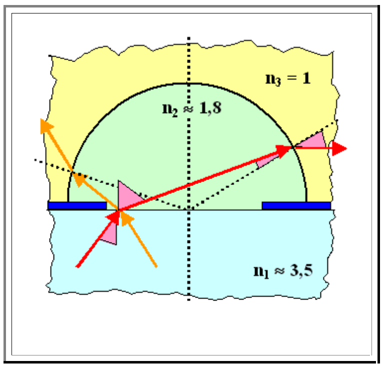
$$\frac{I_{out}}{I_{total}} = \frac{2\pi r^2 \cdot [1 - \cos(\alpha_{crit})]}{4\pi r^2} = \frac{1 - \cos(\alpha_{crit})}{2}$$

Now we need to determine α_{crit}. Looking a the picture (and reversing the arrows) we write Snellius' law for total reflection as $\sin\beta = n \cdot \sin\alpha_{crit} = 1$. It follows that $\alpha_{crit} = n^{-1} \cdot \arcsin\beta$.

- For ***n*=3** this gives us **19,47 °**. Insertion gives $I_{out}/I_{total} = 0{,}0286$
- Only **2.86 %** of the radiation produced is useful**!!!!!** We have a severe problem here!

Suggest measures to improve that percentage.

The *first* thing to do is to add a reflector at the bottom. That doubles the efficiency.
Second thing to do is to put a material with an ***n*** between that of air and the semiconductor on top. This increases α_{crit} and the beneficial effect is clear from the picture .
Third thing to do is to shape you semiconductor in such a way that reflected light will get out after a second internal reflection. An inverted pyramid is a good shape for this (can you see why?).
Fourth.....



You get, maybe, the idea, that **LEDs** with an overall efficiency (electrical energy in / light energy out) of **50 %** are not made "just so" but contain a lot of engineering.