MASSACHUSETTS INSTITUTE OF TECHNOLOGY

2.71 Optics **Spring '09**

Problem Set #1 Posted Feb. 9, 2009 — Due Wednesday, Feb. 18, 2009

1. **Spherical waves and energy conservation** We mentioned in class that the amplitude of the electric field describing a plane wave remains constant as the wave propagates, thereby guaranteeing conservation of energy. Using the same argument and the fact that the power (in Watts) is proportional to the square of the electric field amplitude, show that the amplitude of a spherical wave should decay like $1/r$ as function of distance r from the source of the spherical wave.

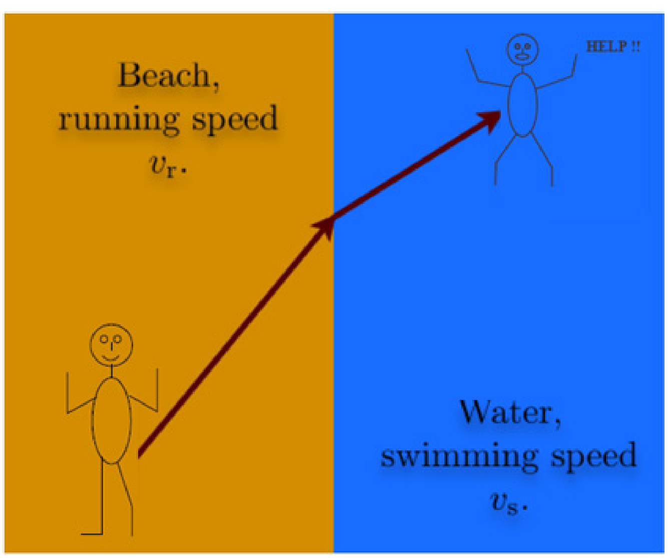
2. **Order of magnitude calculations** The solar irradiance data in $\mathrm{W/m^2}$ for the radiant energy by the sun incident outside the earth's atmosphere are given by the following plot:

   ftp://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SOLAR_IRRADIANCE/irrad031202.jpg

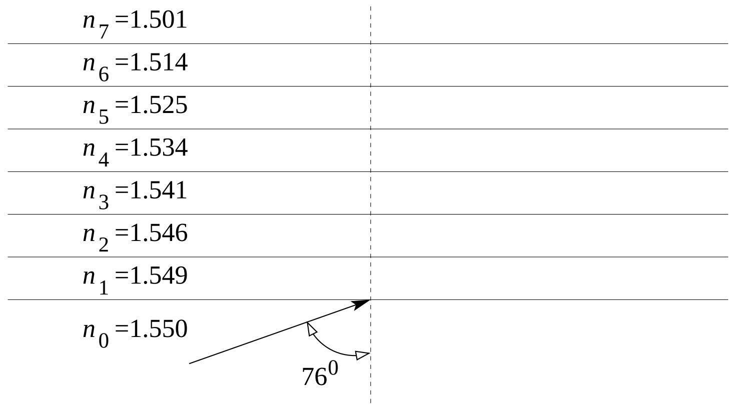
   a) How many commercially available light bulbs placed at 1m away from the atmosphere's edge would generate the same amount of irradiance on an area of $1\mathrm{m}^2$?

   b) What is the equivalent photon flux; *i.e.*, how many photons per second are received from the sun? Assume that the solar energy is uniformly distributed between the ultraviolet and infrared at 300nm and 1μm, respectively.

3. **The lifeguard problem** The lifeguard shown below can run at speed v_r on the sand, and swim at speed v_s in water ($v_\mathrm{r} > v_\mathrm{s}$) in water. The lifeguard notices a drowning person at an angle with respect to the normal from the lifeguard's position to the coastline. Establish your own notation for this geometry, and plan the lifeguard's path that reaches the swimmer in minimum time.



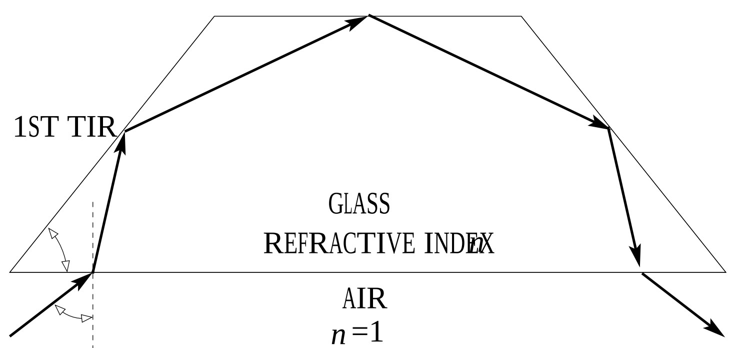
4. **Refraction from a dielectric stack** A light ray is incident on a dielectric stack of refractive indexes as shown below at angle 76° with respect to the normal. What is the exit angle of the ray?



5. **Trapezoidal prism** A light ray enters the trapezoidal glass prism shown below at angle $\theta = 7.5°$ with respect to the normal to the bottom surface. The prism angle is $\psi = 30°$ and the glass material is SF6. Given the dispersion data $n(\lambda)$ from the following website,

http://refractiveindex.info/index.php?group=SCHOTT&material=SF6

show that green light ($\lambda \approx 0.5\mu$m) indeed obeys the TIR condition at the interface marked as "1st TIR," whereas near–infrared light at the telecoms wavelength $\lambda = 1.5\mu$m does not.



6. **Ellipsoidal refractor** A plane wave (parallel ray bundle) is incident on an ellipsoidal refractor of refractive index $n = 1.5$. The ray direction is parallel to the major axis of the ellipsoid.

   a) If the plane wave focuses along the major axis at 25mm from the air-glass interface, what is the length of the major axis?

   b) What is the lateral size of the parallel ray bundle that actually does come to a focus?

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