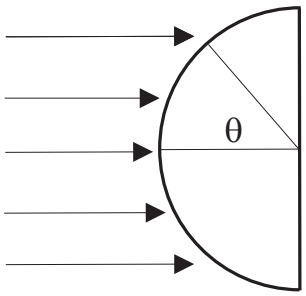
PHYS 40 Lab 11

Equilibrium surface temperatures for airless planets

Consider a planet orbiting a star. Its surface temperature can be calculated starting with the assumption that the energy received by the star is equal to the energy emitted by the planet (per unit time). For simplicity, we also assume that the planet rotates very slowly and does not have an atmosphere.

The amount of energy absorbed per unit surface area depends on the latitude θ, which can be visualized using the diagram below.



The resulting noon-time equilibrium surface temperature can be shown to be:

$$T_s = 279\,^\circ\mathrm{K}\left[\frac{L(1-A)\cos\theta}{\epsilon r^2}\right]^{1/4}, \tag{1}$$

where L is the intrinsic luminosity of the star in Solar units, A is the albedo (the fraction of light reflected), ϵ is the emissivity of the surface (as a fraction), and r is the distance from the star to the planet in "astronomical units" (AU), where the distance from the Sun to the Earth is 1 AU. This temperature in Kelvins can be converted to Fahrenheit degrees using the formula:

$$T[^\circ\mathrm{F}] = \frac{9}{5}\left(T[^\circ\mathrm{K}] - 273.15\,^\circ\mathrm{K}\right) + 32\,^\circ\mathrm{F}. \tag{2}$$

1. Input/output

Write a Python program that allows you to enter the luminosity of the star, the albedo of the planet, the emissivity, the distance from the star to the planet, and the latitude — and then calculates the temperature in degrees Fahrenheit.

Output your results to the screen using printf-type **formatting**.

Assume a planet–star system like the Earth–Sun ($L = 1$, $r = 1$), with $A = 0.30$, $\epsilon = 0.95$. What is the temperature at the equator at noon? How does this compare to actual temperatures on the Earth, and why do you think it differs?

Consider also the Moon with $A = 0.11$, $\epsilon = 0.90$: what is the temperature?

Now consider a brighter star, with $L = 2$. What is the noon temperature at the equator for the "Moon"? At what latitude is the temperature equal to 32 °F?

Experiment with different values for albedo and emissivity, and discuss their relative effects on temperature.

2. Plotting

Make a **plot** to examine the dependence of T_s on other parameters. Show the curve of T_s versus $param_i$ for at least two parameters, on the same plot. Use appropriate plot decorations such as a legend and axis labels with units.

Submit your code and your plot, as well as responses to the questions above.