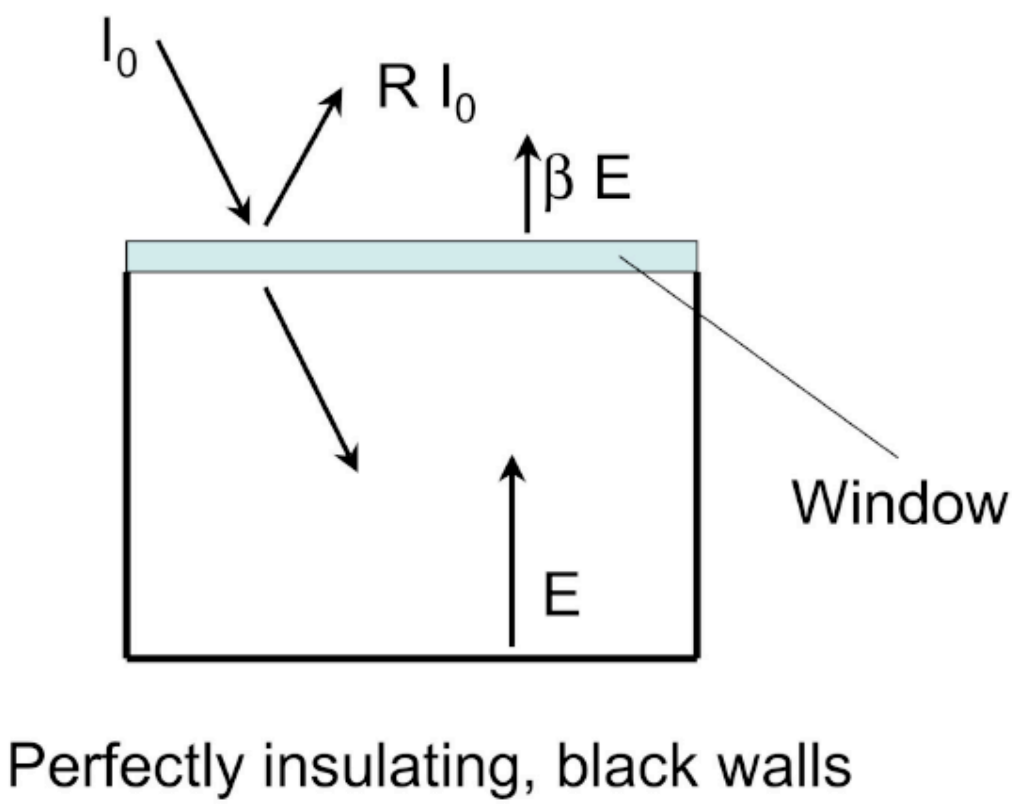
MAE 119 Winter 2017 Homework 2
Professor G.R. Tynan, MAE Department UCSD
Assigned 20 January 2017
Due 27 January 2017

Quiz 2 will be Wednesday 1 February 2017
Subject: EROEI, Simple models of Earth's heat balance

1. Visible light with a power flux of I_0 shines through a window into a box with perfectly insulating black walls as shown in the schematic below. A fraction of the visible light, R, is reflected, and the remainder is absorbed by the walls of the box, which then re-radiate all of this absorbed power upwards through the window. The window traps some of this re-radiated energy so that only a fraction, b, of this re-radiated energy escapes. If the walls radiate like a perfect blackbody, find an expression for the temperature inside the box.



2. Let us develop a model of the transport of infra-red radiation through a simple uniform atmosphere of thickness d. If there are *two species* of greenhouse gas molecules in the atmosphere, with densities N_{gg1} and N_{gg2} molecules/m^3, respectively and probabiliy*volume/unit length for an infra-red photon to be absorbed given as σ_1 and σ_2 for these two species (with units of m^2), then find a relation between the infra-red transmission coefficient, β, the gas density N_{gg1} and N_{gg2}, the probabilities s_1 and s_2, and the atmosphere thickness d.

3. Using the 0-D heat balance analysis developed in lecture, make a plot of the Infra-red (IR) emission of the Earth and the Atmosphere, E1, and E2 vs. the IR transmission coefficient ranging from the present value, 0.05, down to the minimum possible value, 0.0. Now, assuming that both the atmosphere and the earth emit as ideal blackbodies, plot the earth and atmosphere temperatures for the same range of values for the IR transmission coefficient.

4. Referring to the slab model for radiation transport in an absorbing atmosphere which we developed in class, find the IR transmission coefficient if the CO2 concentration is doubled from pre-industrial levels.

5. Using the relative change in infra-red transmission coefficient that you found in problem 4 above, by how much would the Earth's surface temperature change if CO2 concentrations doubled, but the other parameters in the 0-D coupled atmosphere-Earth heat balance model that was introduced in lecture were fixed ?

6. Consider the crudest heat budget for the earth (without atmosphere and hydrological cycle) and assume the following dependency of the albedo on temperature: At low temperatures, much ice and clouds cover the earth, yielding a high albedo, whereas at high temperatures, the absence of ice and clouds reduce the albedo to zero. Taking the functional dependence of the visible light albedo as

$$\alpha = 0.5 \quad \text{for } T \leq 250 \text{ K},$$

$$\alpha = \frac{270 - T}{40} \quad \text{for } 250 \ K \leq T \leq 270 \text{ K},$$

$$\alpha = 0 \quad \text{for } 270 \text{ K} \leq T,$$

solve for the earth's average temperature *T*. Discuss the compare the solutions.

7. Using the Internet, research the EROEI for major energy sources, including "conventional" petroleum recovered from shallow (few km) land-based wells, for petroleum recovered using "hydraulic fracturing" techniques (i.e. "fracking"), conventional natural gas, and gas recovered using fracking techniques. Then determine the energy payback time for solar PV renewable energy systems, and assuming a useful lifetime of 30 years for a solar PV system, estimate the EROEI for solar PV. Compare all of these EROEI values and discuss.