

**ESYS 10: Introduction to Environmental Systems**  
**Winter 2008**  
**Problem Set #1**

1.) Earth's average temperature is determined in part by the amount of CO<sub>2</sub> in the atmosphere, by way of the greenhouse effect. The atmospheric CO<sub>2</sub> content may in turn be affected by photosynthetic activity of plants, which convert CO<sub>2</sub> into plant tissue (organic carbon); however, the rate of photosynthesis depends on the amount of CO<sub>2</sub> in the atmosphere and on global air temperature. The components of this system, atmospheric CO<sub>2</sub> content, global temperature, and photosynthesis rate, are intimately interconnected. By increasing global photosynthesis rates, plants would tend to lower the atmospheric CO<sub>2</sub> level. In doing so, however, the plants would tend to cool Earth. This cooling, together with the CO<sub>2</sub> level, might tend to reduce the photosynthetic activity of plants.

- a. On the basis of this discussion, draw a system diagram of the photosynthetic rate-CO<sub>2</sub> –temperature system.
- b. How many feedback loops are there?
- c. Are the feedback loops positive or negative?
- d. Describe the response of the system to the following perturbations:
  - (i) An increase in atmospheric CO<sub>2</sub>
  - (ii) A decrease in temperature
- e. How might the system respond to a continued forcing--an increase in solar luminosity through time?

2.) Daisyworld has a companion planet that is similar in all ways except that the daisies are black.

- a. What is the effect of an increase in black-daisy coverage on planetary temperature? Express your answer graphically.
- b. Assuming that the effect of temperature on daisy coverage is the same on black-daisy Daisyworld as on white-daisy Daisyworld, draw a stability diagram--a diagram analogous to Figure 2-10 – for black daisy Daisyworld. Include two equilibrium states.
- c. Which of the two equilibrium states in part (b) is stable?
- d. Is the stable equilibrium state of part (c) cooler or warmer than that of white-daisy Daisyworld?
- e. How would this system respond to a decrease in solar luminosity? Express your answer graphically and in terms of the feedback factor.
- f. Is  $f$  of part (e) greater than or less than 1?
- g. Prof. Charles mentioned in class that fictitious "Daisyworld" makes a veiled analogy to the behavior of water in the Earth's (real) climate system. Briefly explain the parallels between daisies and water in their respective systems.