

**5. (Bees collecting pollen and nectar - Optimization)**

Many bees collect both pollen and nectar. Pollen is used for protein, and nectar is used for energy. Suppose the amount of nectar harvested during  $t$  seconds on a flower is

$$F(t) = \frac{t}{1+t}$$

and that the amount of pollen harvested during  $t$  seconds on a flower is

$$G(t) = \frac{t}{2+t}.$$

The bee collects pollen and nectar simultaneously. Travel time between flowers is  $\tau = 1.0$  seconds.

- a) What is the optimal time for the bee to leave one flower for the next in order to collect nectar at the maximum rate?
- b) What is the optimal time for the bee to leave one flower for the next in order to collect pollen at the maximum rate? Why are the two times different?
- c) Suppose that the bee values pollen twice as much as nectar. Find a single function  $V(t)$  that give the value of resources collected by time  $t$ . What is the optimal time for the bee to leave? [You may need to use a computer or calculator to solve this equation.]
- d) Suppose that the bee first collects nectar and then switches to pollen. Assume it spends 1.0 second collecting nectar. How long should it spend on pollen?
- e) Suppose that the flower patch is not as populated and it takes  $\tau = 2.5$  seconds to travel from one flower to the next. How does this impact your answers in (b), (c), and (d)?