MONT 101N – Analyzing Environmental Data
Problem Set 1 – **due**: Friday, February 2

A. On page 33 of *Thinking in Systems*, Meadows gives the *rule of thumb* that "the time it takes for an exponentially growing stock to double in size, the "doubling time," equals approximately 70 divided by the growth rate (expressed as a percentage)" (this means to use the growth rate per unit time).

(1) Do Exercise 7 in Chapter 5 of our text *Elementary Mathematical Modeling and Data Analysis with Environmental Applications.*
(2) Then check the accuracy of the *rule of thumb* above if $Q(t)$ is growing at 5% per unit time and 10% per unit time.
(3) Why does the *rule of thumb* work as well as it does?

B. Download and examine the spreadsheet `Figure32.xlsx` from the course homepage. This gives a difference equation model duplicating the behavior described in the text leading to the oscillations shown Figure 32 in *Thinking in Systems.*

- Column C gives the inventory on hand
- Column D gives the actual sales, with the 10% increase from 20 cars to 22 cars starting in Day 6.
- Column G gives the "perceived sales" – the sales, *averaged over the 5 most recent days.*
- Column I gives the Desired Inventory (always 10·Perceived Sales)
- Column J (the "Discrepancy") is the difference between the Desired Inventory and the Inventory on the lot from Column C.
- Column E gives the orders to the factory, computed by adding the perceived sales and 1/3 of the Discrepancy. (The numerator of 3 represents the response delay described in the text – each day the manager orders an additional number of cars from the factory representing 1/3 of the Discrepancy).

Using this information, and modifying the spreadsheet as needed, Answer these questions:

(1) Why is the Discrepancy value negative on some days? What does that mean in real-world terms?
(2) Describe how the inventory on hand changes (relative to the original plot) if the perception delay is increased to 10 days instead of 5. (You'll need to start the averaging in day 11 rather than day 6).
(3) Describe how the inventory on hand changes (relative to the original plot) if the delivery delay is reduced to 3 days instead of 5 days. (Note: You'll see where the delivery delay is included if you look at the entries in Column F, starting at Row 10.)
(4) Describe how the inventory on hand changes (relative to the original plot) if the response delay is increased from 3 days to 5 days. (Note: the response delay is the denominator of 3 in formulas in Column E, starting in row 10). Roughly speaking this means that the manager is going to be slower in making up discrepancies between the desired inventory and the actual inventory.

(5) Describe a strategy for reducing the severity of the oscillations in the inventory on the lot (making the amplitude smaller, and/or the period longer). Note: The oscillations cannot be removed entirely if these delays are taken into account(!)