Project 1.

Mixing Problem*

Sewage entering a local municipal treatment center contains a noxious chemical A which a local company is permitted to discharge into the municipal sewer system. (It's only a coincidence that the company's CEO is the mayor's brother-in-law.) After a preliminary treatment which does little to eliminate A, the wastewater stream enters a $300 m^3$ treatment pond at a rate of 0.3 cubic meters per minute containing A at a concentration of 0.05 kg/m^3. A biochemical agent is also added to the pond which causes A to decompose in a third-order reaction,

$$A \rightarrow B, rate\ (kg/m^3.\min) = 500 C_A^3.$$

When the process is started up, the pond contains wastewater with the concentration of A equal to that in the feed stream ($C_A(0) = 0.05$).

Consider the pond to be perfectly mixed (a highly questionable assumption) and that liquid leaves the pond at the rate of 0.3 cubic meters per minute and is discharged into a nearby stream.

(a) Show that the balance equation is,

$$\frac{dC_A}{dt} = \frac{1}{20000} - \frac{C_A}{1000} - 500 C_A^3..$$

(b) Use the Maple V command *DEplot1* (remember you must call up *with(DEtools)* first) and generate a graph of the solution to the balance equation on the *t* interval 0..20 with stepsize of 0.1. Use the mouse to estimate the concentration at *t=20.*

(c) Use Maple V to determine the ultimate concentration (that is as $t \rightarrow \infty$.).

(d) EPA officials now visit the treatment plant and decree that the concentration of A in the liquid leaving the pond and being discharged into the nearby stream must be reduced to 0.005 kg/m^3. As an engineering consultant you consider 3 different ways of doing this.
(i) Increase the size of the pond.
(ii) Decrease the rate of flow into (and out of) the pond.
(iii) Figure out what the concentration in the feed stream must be to achieve this.

Come up with answers for each of these.

*I am grateful to Professor Felder (Chemical Engineering) for suggesting this type of problem to me.