For the following system of ODE's,

$$\begin{array}{rcl} c' & = & -\frac{\mu}{y}\frac{cx}{k_1+c} - \frac{\eta}{y}\frac{cax}{k_2+c} + q(c_0 - c) \\ a' & = & -\frac{\eta}{z}\frac{cax}{k_2+c} + q(a_0 - a) \\ x' & = & \mu\frac{cx}{k_1+c} - \eta\frac{cax}{k_2+c} - qx \\ p' & = & \mu\frac{cx}{k_1+c} + \eta\frac{cax}{k_2+c}, \end{array} \tag{1}$$

using the following parameter values,

Parameter	Value
μ	2
y	1
k_1	1.5
k_2	1.5
η	20
q	0.3
c_0	1
a_0	1
z	1,

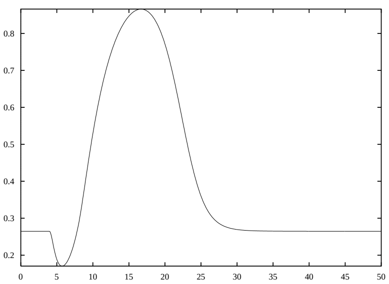
I graphed out how the system behaves when the antibiotics, a, are introduced. To simulate this effect, the equation for a' was changed to

$$\begin{array}{lrcl} & \alpha' & = & -\frac{\eta}{z}\frac{cax}{k_2+c} + q(-a + a_0[h(t_{start}, t) - h(t_{end}, t)]), \\ \text{where} & h(x,y) & = & \frac{x^n}{y^n+x^n}, \\ & t_{start} & = & 4, \\ & t_{end} & = & 8, \\ \text{and} & n & = & 150. \end{array} \tag{2}$$

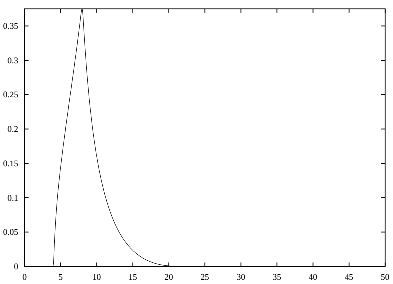
With this change we have that $\alpha'(x) = a'(x), \forall x, 4 \leq x \leq 8$. The graphs can be seen in Figure 1 and in Figure 2.

The effect of replacing $\frac{cax}{k_2+c}$ with $\frac{k_2cax}{(k_1+c)(k_2+c)}$ in (1) was again examined. As before, it was determined that there is no noticable effect from this change.

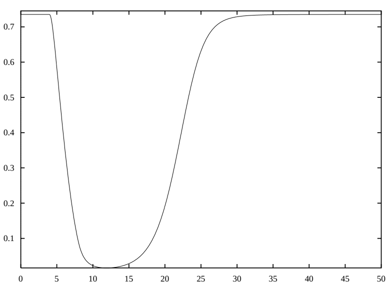
A plot of how p' changed with time can be seen in Figure 3.



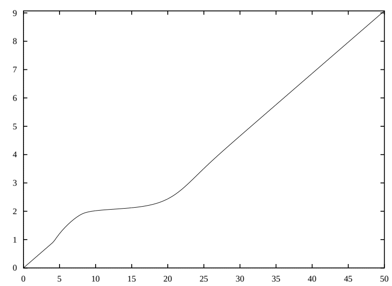
(a)



(b)



(c)



(d)

Figure 1: (a) c vs. time, (b) a vs. time, (c) x vs. time, and (d) p vs. time

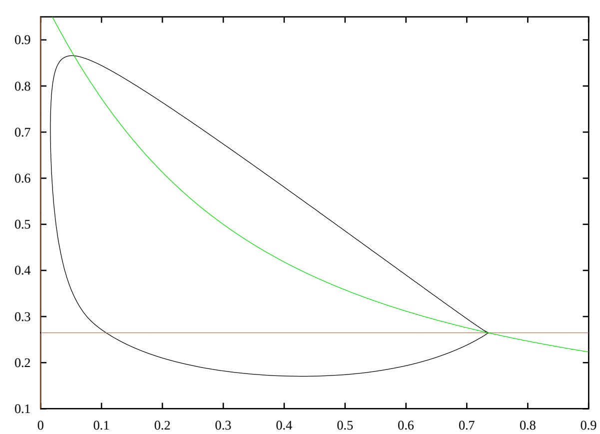


Figure 2: Phase portrait of x and c

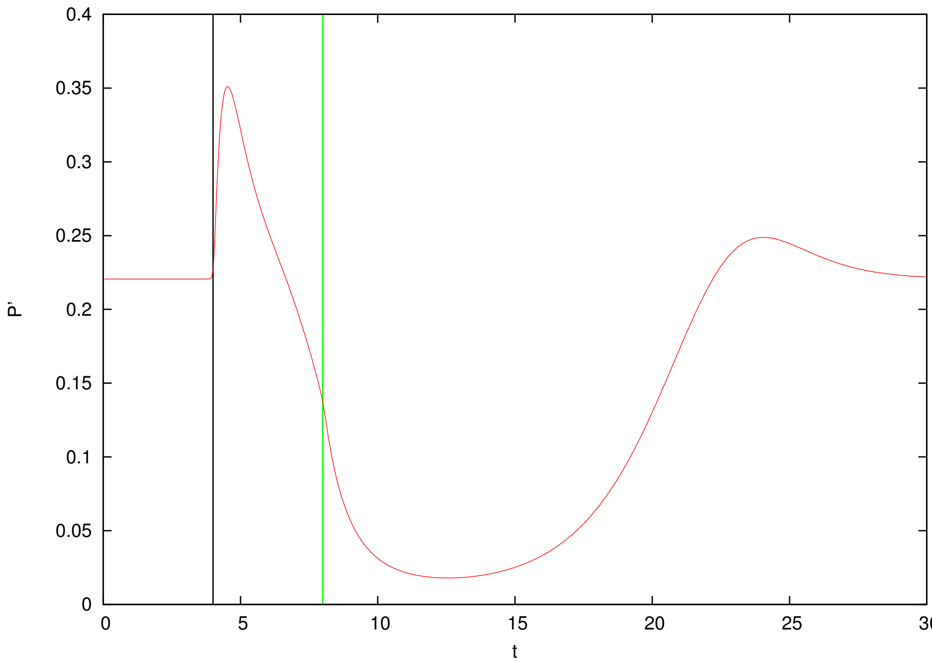


Figure 3: Plot of p' vs. time. The black line indicated when the antibiotics are introduced into the system, the green line shows the time they stopped.