'Simple models of biochemical switches and oscillators'

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1 Abstract

Here, we try to reproduce different graphs related to biological processes.

Motivated by graph theory and nonlinear dynamics, an influential trend in Systems Biology at the moment is to explore small regulatory devices. Examples are circuits of negative feedback loops as oscillators, feedforward loops as noise filtering devices in gene regulation and interlinked feedback loops acting on different time scales for achieving a balance between robustness and rapid reaction to a stimulus. Here we will explore seven 'small devices' described by Tyson et al. (2003). In addition to learning, how certain types of dynamics can be 'implemented' with simple ODE systems, this exploration will also put to use the set of tools for analyzing ODE systems, which we have accumulated so far

2 Introduction

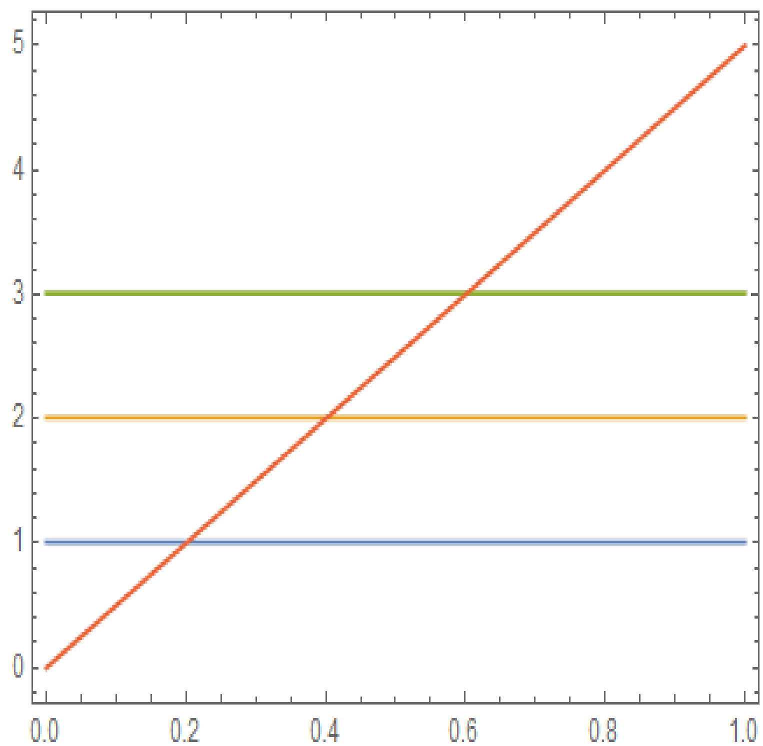
Cellular rhythms are generated by complex interactions among genes, proteins and metabolites. They are used to control every aspect of cell physiology from signaling, motility and development to growth, division and death. By considering specific examples of oscillatory processes, we pick out three general requirements for biochemical oscillations: delayed negative feedback, sufficient 'nonlinearity' of the reaction kinetics, and proper balancing of the time-scales of opposing chemical reactions. Positive feedback is one mechanism to delay the negative feedback signal. Biological oscillators can be classified according to the topology of the positive and negative feedback loops in the underlying regulatory mechanism.

Biochemical oscillations occur in many contexts (metabolism, signaling, development, etc.) where they control important aspects of cell physiology, such as circadian rhythms, DNA synthesis and mitosis, and the development of somites in vertebrate embryos (see Table 1). In the 1950s and 60s, the first clear examples of biochemical oscillations (in metabolic systems) were recognized in glycolysis1, 2, in cyclic AMP production3, and the horseradish peroxidase reaction4, 5. Soon after these discoveries, theoreticians were thinking about the general requirements for chemical oscillations and the specific mechanisms of these examples6, 7. After the molecular biology revolution of the 1980s, many new examples of oscillations in protein interaction networks and in gene regulatory networks came to light, such as the PERIOD proteins in animal circadian control8, the CYCLIN proteins in eukaryotic cell cycle control9, 10, and the Repressilator11 in genetically engineered bacteria.

3 Methods

4 Results and Conclusions

4.0.1 Q.no. 1: Rate curves and signal-response curve for the 'linear response case'



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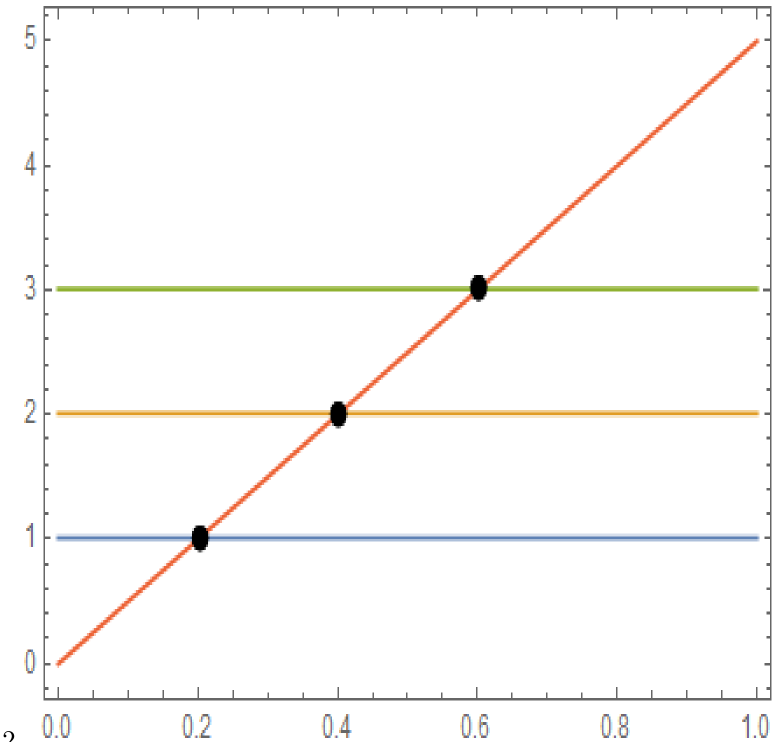

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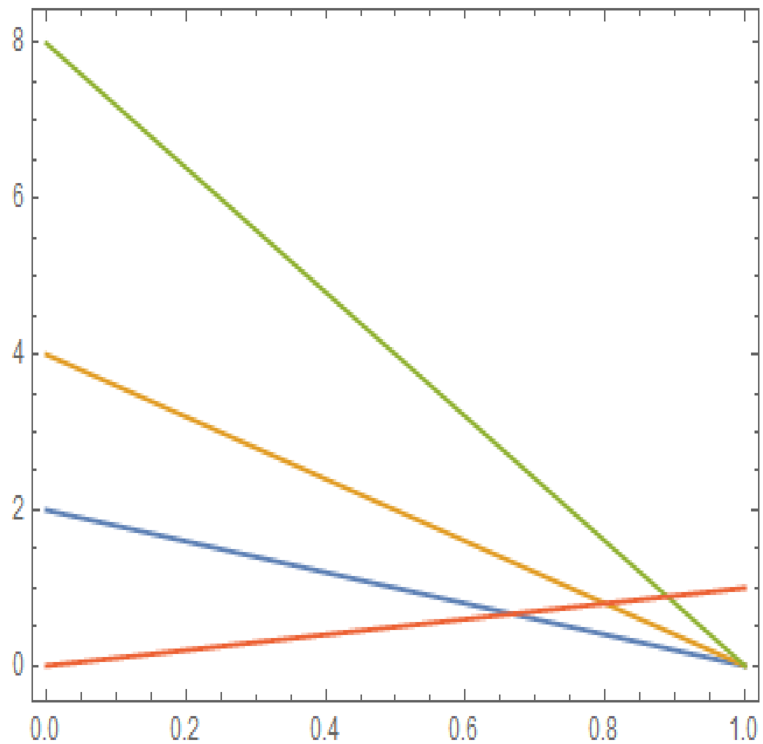
4.0.2 Q.no. 2: Rate curves and Signal-response curve for the 'hyperbolic response case'



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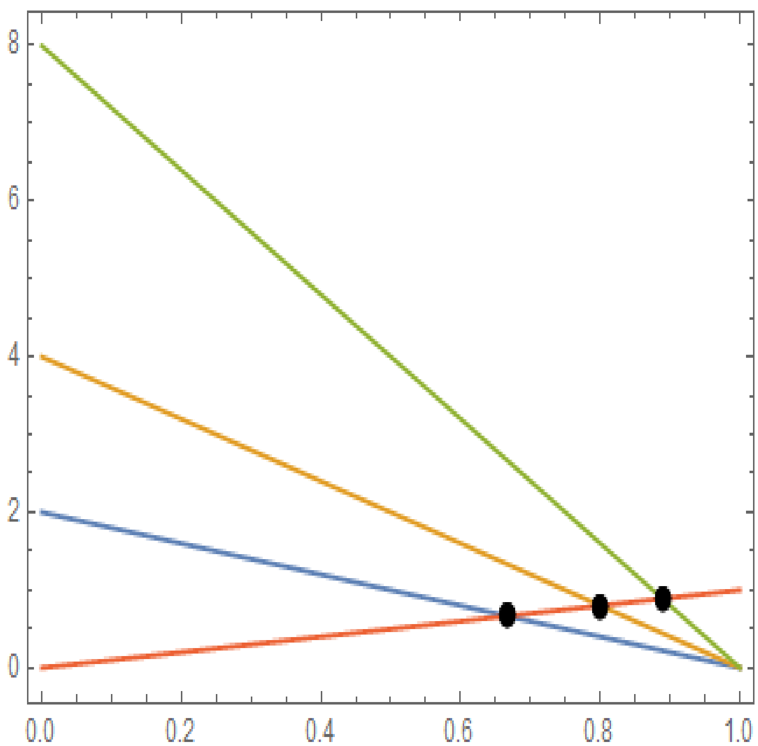

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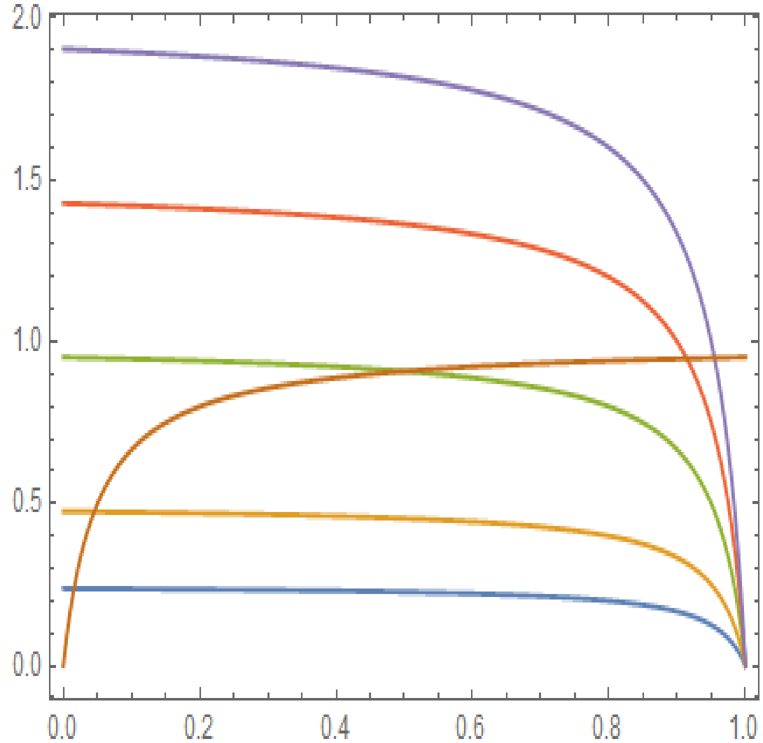
4.0.3 Q.no. 3: Rate curves and signal-response curve for the 'Sigmoidal response case'



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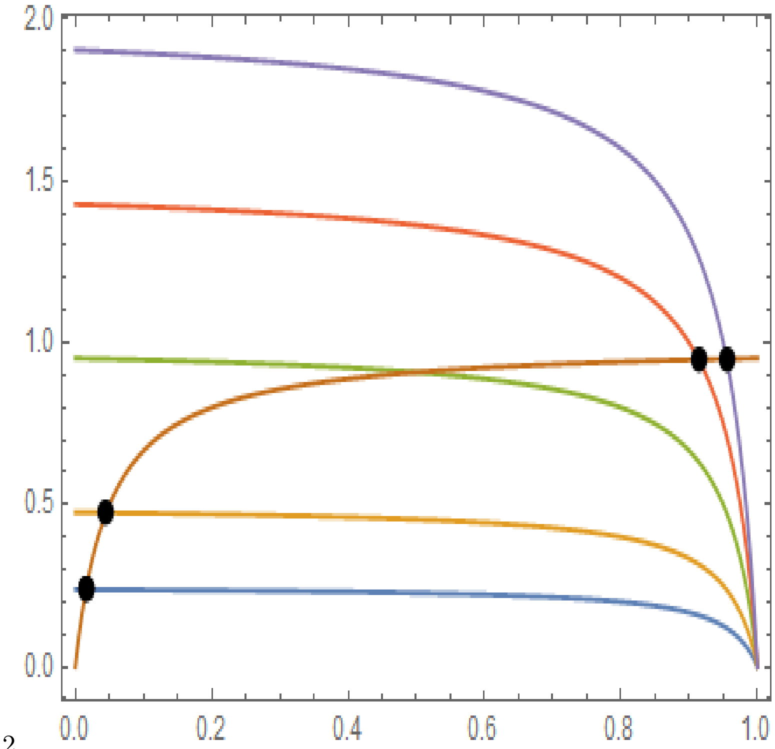

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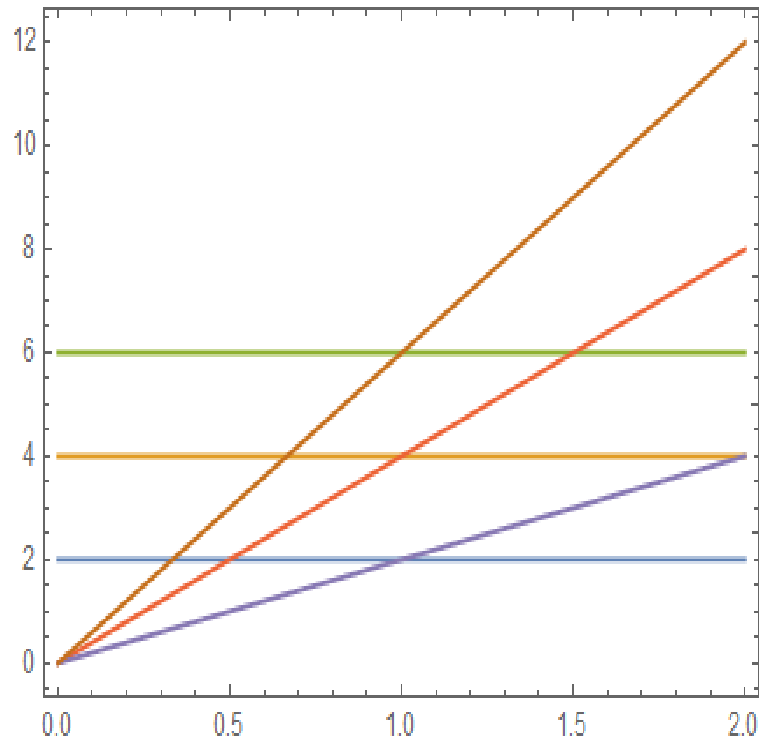
4.0.4 Q.no. 4: Rate curves and time course for the 'adaptation device'



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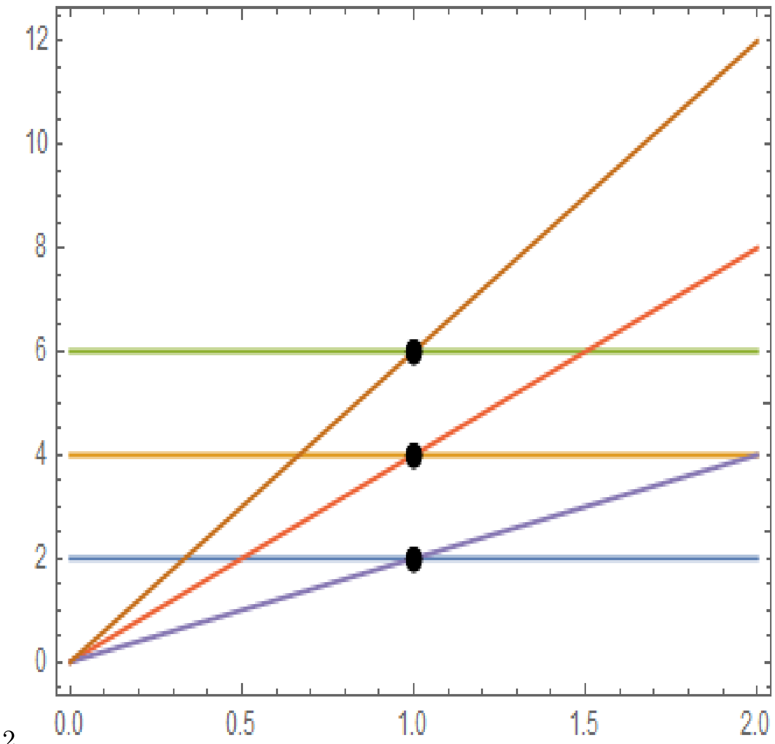

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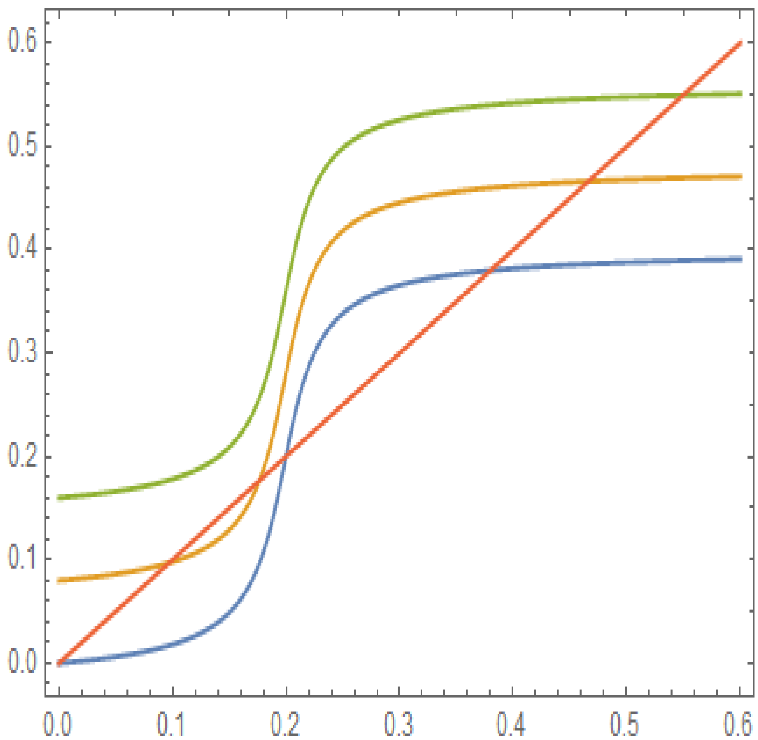
4.0.5 Q.no. 5: Rate curves and signal response curve for the 'irreversible switch'



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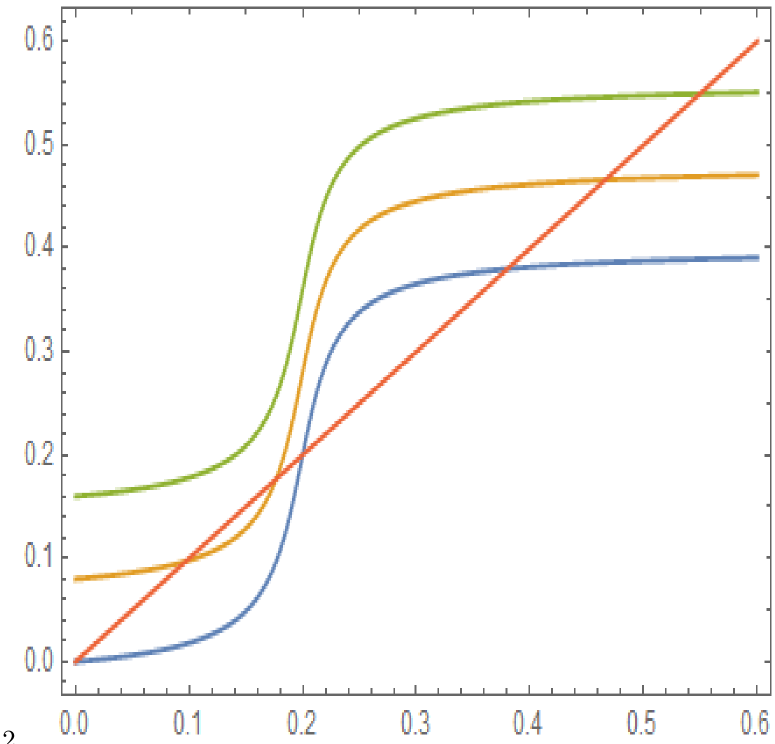

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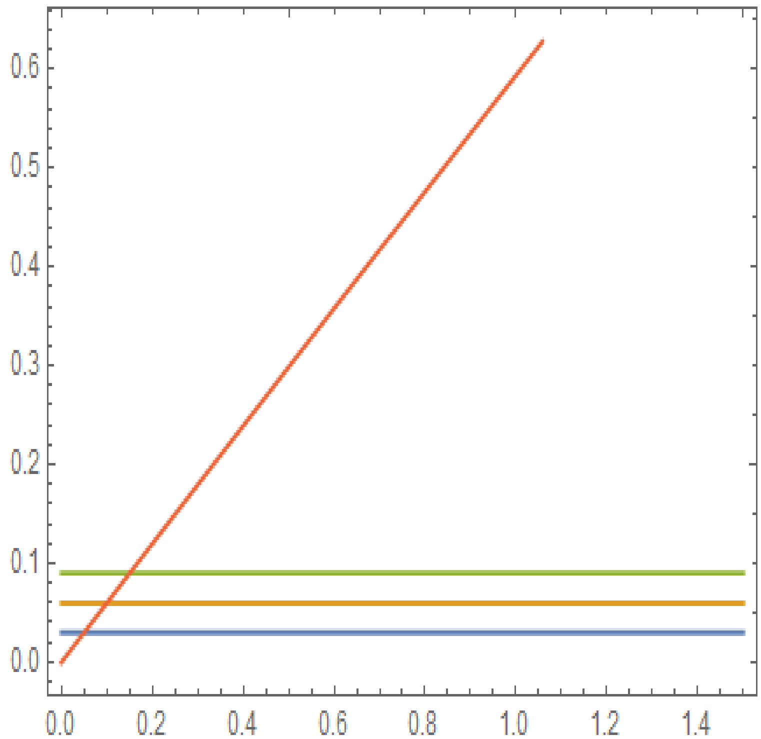

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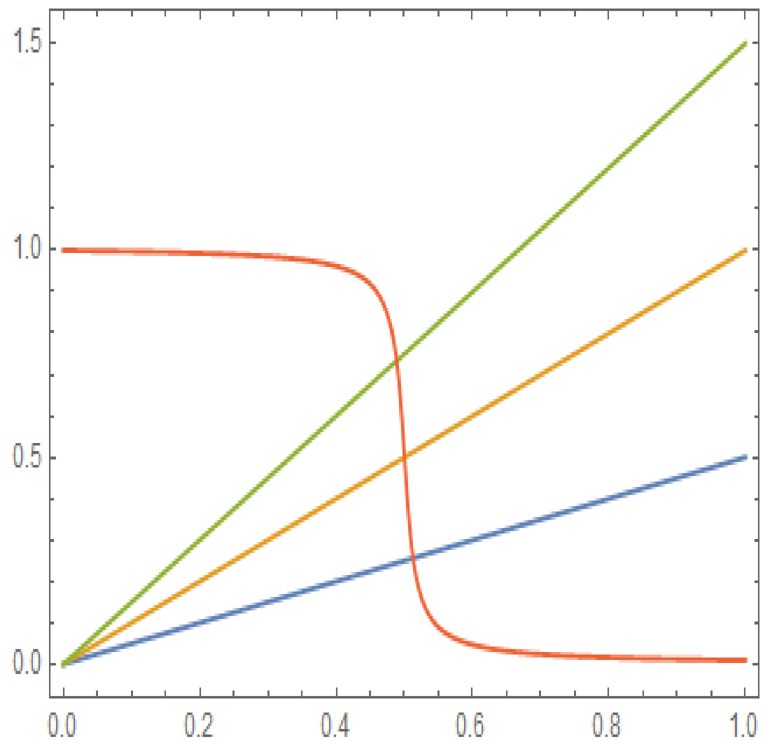
4.0.6 Q.no. 6: Rate curves and the signal response curve for the 'homeostatic response'



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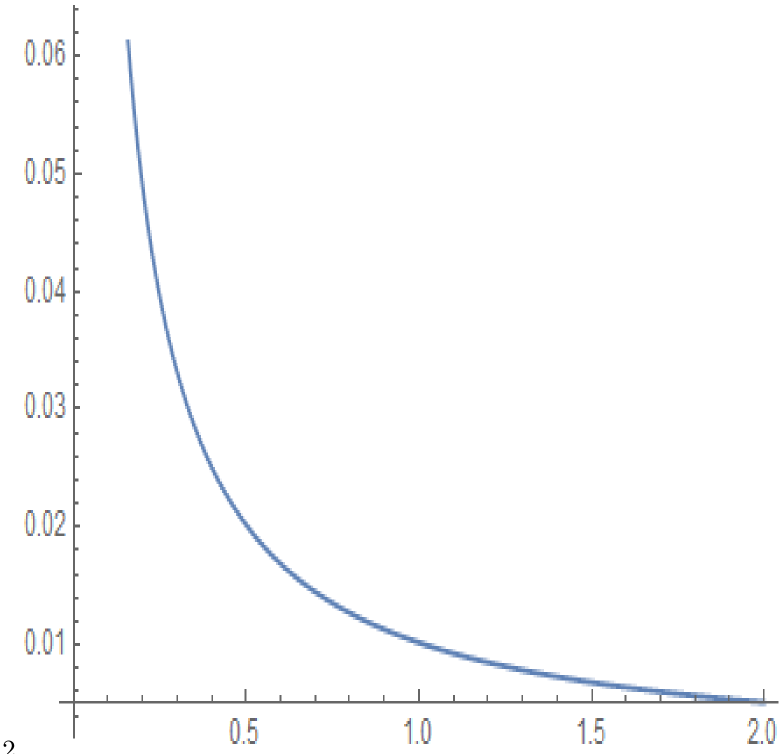

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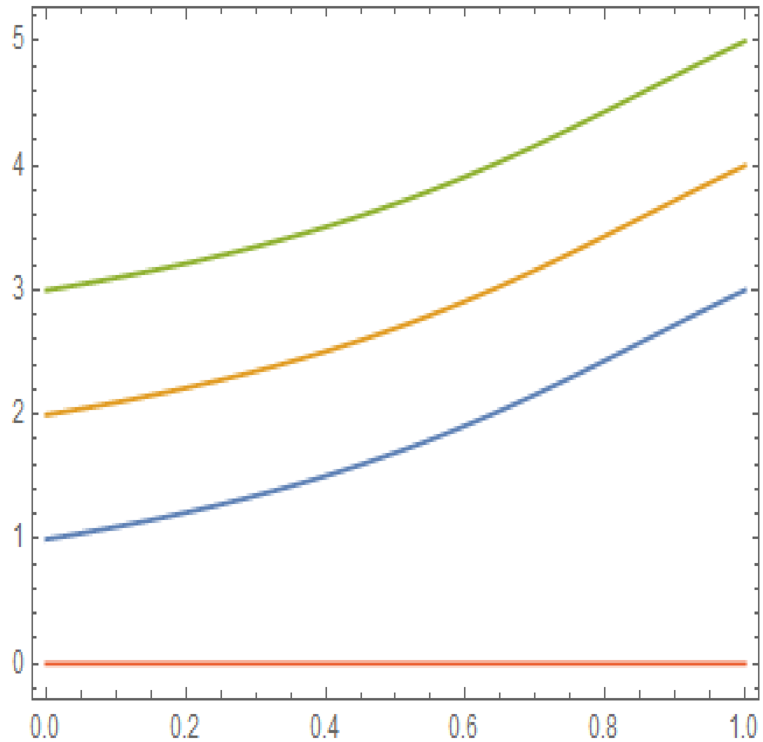
4.0.7 Q.no. 7: Phase portrait and bifurcation diagram for the 'activator-inhibitor device'



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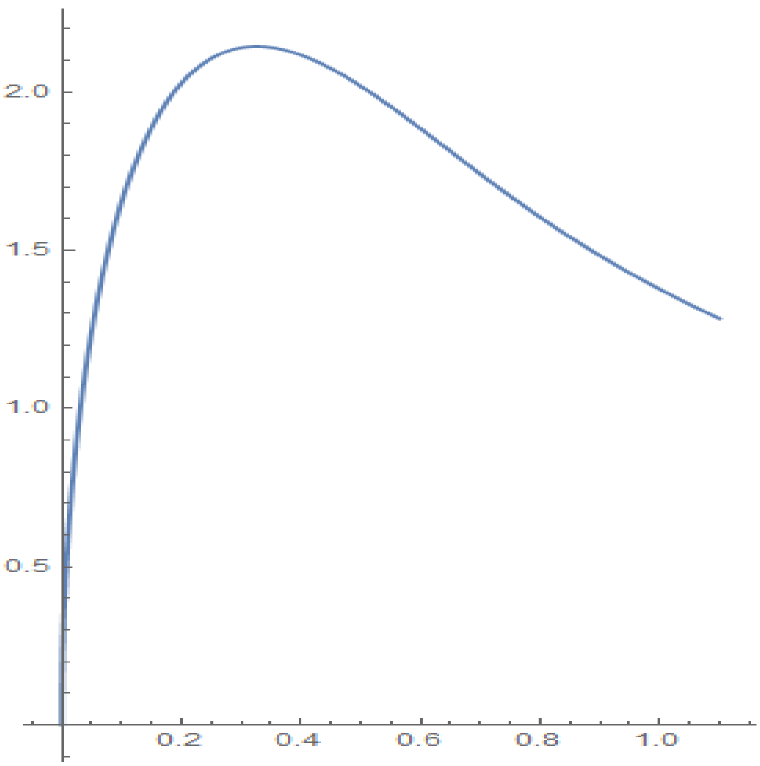

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5 References

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