$$\nu_{Na} = 115\text{mV}, \quad \nu_K = -12\text{mV}, \quad \nu_{Na} = 10.6\text{mV}, \quad C = 1\mu\text{Farad}/\text{cm}^2,$$

where "Ω" is one Ohm, the unit of resistance.

Non-dimensionalise with $v = \nu/\nu_{Na}$ and $\tau = t/[5\text{ms}]$, as $\tau_n(\nu) \sim O(5\text{ms})$, and we have

$$\epsilon \frac{dv}{d\tau} = I_{ext}^* - g(v,n) \overset{def}{=} I_{ext}^* - \left[m_\infty^3(v)(0.85-n)(v-1) + \gamma_K n^4(v+v_K) + \gamma_L(v-v_L) \right]$$

$$\frac{dn}{d\tau} = k(v,n) \overset{def}{=} \frac{1}{\tau_n^*(v)} \left[n_\infty(v) - n \right], \tag{21}$$

with

$$\epsilon = \frac{C}{G_{Na}[5\text{ms}]} = 2 \times 10^{-3}, \quad \gamma_K = \frac{G_K}{G_{Na}} \sim 0.3, \quad \gamma_L = \frac{G_L}{G_{Na}} \sim 3 \times 10^{-3},$$

$$I_{ext}^* = \frac{I_{ext}}{G_{Na}\nu_{Na}}, \quad v_K = -\frac{\nu_K}{\nu_{Na}} \sim 0.1, \quad v_L = -\frac{\nu_L}{\nu_{Na}} \sim 0.1, \quad \tau_n^*(v) = \tau_n(\nu)/[5\text{ms}] \sim O(1).$$

We can now sketch the nullclines, and noting the different timescales of the membrane potential response to the gating variable response (as $\epsilon \ll 1$) we can consider the phase plane trajectories in terms of fast and slow dynamics.
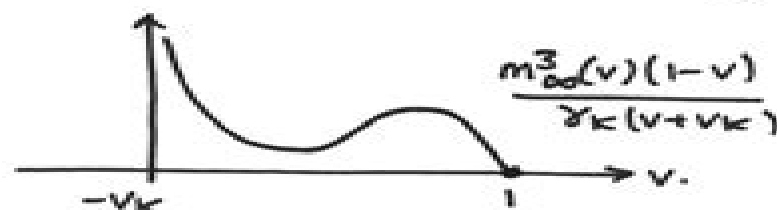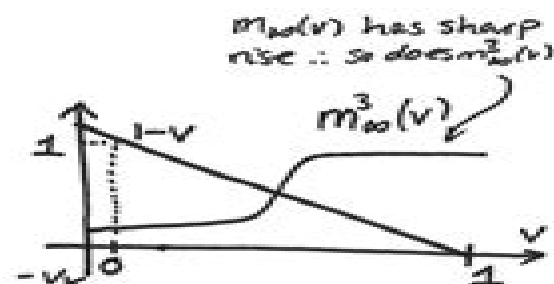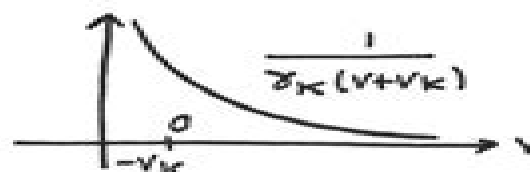
Plotting nullclines. $I_{ext}^* = 0$.

$$-\epsilon \, dv/d\tau = g = m_\infty^3(v)(0.85-n)(v-1) + \gamma_K n^4(v+v_K) + \gamma_L(v-v_L)$$

$$dn/d\tau = k = \frac{1}{\tau_n^\#(v)} \left[n_\infty(v) - n \right]$$

γ_L small $\therefore$ neglect this below.

v nullcline

$$\frac{n^4}{0.85-n} = \frac{m_\infty^3(v)(1-v)}{\gamma_K(v+v_K)}$$

$m_\infty(v)$ has sharp rise $\therefore$ so does $m_\infty^3(v)$

$$\frac{n^4}{0.85-n}$$

$$\frac{1}{\gamma_K(v+v_K)}$$

$$m_\infty^3(v)$$

$$\frac{m_\infty^3(v)(1-v)}{\gamma_K(v+v_K)}$$

Mathematical Physiology

P.Bilgin, P.D. Williams, M. Sekiguchi, J. K. Galbraith, S. T. Inayatullah, J. Wiener, R. A. Schrire, I.L. Murphy

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Mathematical Cardiac Electrophysiology Piero Colli Franzone,Luca Franco Pavarino,Simone Scacchi,2014-10-30 This book covers the main mathematical and numerical models in computational electrocardiology ranging from microscopic membrane models of cardiac ionic channels to macroscopic bidomain monodomain eikonal models and cardiac source representations These advanced multiscale and nonlinear models describe the cardiac bioelectrical activity from the cell level to the body surface and are employed in both the direct and inverse problems of electrocardiology The book also covers advanced numerical techniques needed to efficiently carry out large scale cardiac simulations including time and space discretizations decoupling and operator splitting techniques parallel finite element solvers These techniques are employed in 3D cardiac simulations illustrating the excitation mechanisms the anisotropic effects on excitation and repolarization wavefronts the morphology of electrograms in normal and pathological tissue and some reentry phenomena The overall aim of the book is to present rigorously the mathematical and numerical foundations of computational electrocardiology illustrating the current research developments in this fast growing field lying at the intersection of mathematical physiology bioengineering and computational biomedicine This book is addressed to graduate student and researchers in the field of applied mathematics scientific computing bioengineering electrophysiology and cardiology   Introduction to Mathematical

<u>Physiology and Biology</u> ,1999 **Applied Mathematical Models in Human Physiology** Johnny T. Ottesen,Mette S. Olufsen,Jesper K. Larsen,2004-02-01 This book introduces mathematicians to real applications from physiology Using mathematics to analyze physiological systems the authors discuss models reflecting current research in cardiovascular and pulmonary physiology In particular they present models describing blood flow in the heart and the cardiovascular system as well as the transport of oxygen and carbon dioxide through the respiratory system and a model for baroreceptor regulation This is the only book available that analyzes up to date models of the physiological system at several levels of detail both simple real time models that can be directly used in larger systems and more detailed reference models that show the underlying physiological mechanisms and provide parameters for and validation of simpler models The book also covers two dimensional modeling of the fluid dynamics in the heart and its ability to pump and includes a discussion of modeling wave propagation throughout the systemic arteries *An Introduction to Undergraduate Research in Computational and Mathematical Biology* Hannah Callender Highlander,Alex Capaldi,Carrie Diaz Eaton,2020-02-17 Speaking directly to the growing importance of research experience in undergraduate mathematics programs this volume offers suggestions for undergraduate appropriate research projects in mathematical and computational biology for students and their faculty mentors The aim of each chapter is twofold for faculty to alleviate the challenges of identifying accessible topics and advising students through the research process for students to provide sufficient background additional references and context to excite students in these areas and to enable them to successfully undertake these problems in their research Some of the topics discussed include Oscillatory behaviors present in real world applications from seasonal outbreaks of childhood diseases to action potentials in neurons Simulating bacterial growth competition and resistance with agent based models and laboratory experiments Network structure and the dynamics of biological systems Using neural networks to identify bird species from birdsong samples Modeling fluid flow induced by the motion of pulmonary cilia Aimed at undergraduate mathematics faculty and advanced undergraduate students this unique guide will be a valuable resource for generating fruitful research collaborations between students and faculty **An Introduction to Mathematical Modeling in Physiology, Cell Biology, and Immunology** James Sneyd,2002 In many respects biology is the new frontier for applied mathematicians This book demonstrates the important role mathematics plays in the study of some biological problems It introduces mathematicians to the biological sciences and provides enough mathematics for bioscientists to appreciate the utility of the modelling approach The book presents a number of diverse topics such as neurophysiology cell biology immunology and human genetics It examines how research is done what mathematics is used what the outstanding questions are and how to enter the field Also given is a brief historical survey of each topic putting current research into perspective The book is suitable for mathematicians and biologists interested in mathematical methods in biology **Differential Equations for Studies in Computational Electrophysiology** Karoline Horgmo Jæger,Aslak Tveito,2023-05-27 This open

access text aims at giving you the simplest possible introduction to differential equations that are used in models of electrophysiology It covers models at several spatial and temporal scales with associated numerical methods The text demonstrates that a very limited number of fundamental techniques can be used to define numerical methods for equations ranging from ridiculously simple to extremely complex systems of partial differential equations Every method is implemented in Matlab and the codes are freely available online By using these codes the reader becomes familiar with classical models of electrophysiology like the cable equation the monodomain model and the bidomain model But modern models that have just started to gain attention in the field of computational electrophysiology are also presented If you just want to read one book it should probably not be this one but if you want a simple introduction to a complex field it is worth considering the present text   **A Math Primer for Engineers** C.W. Cryer,2014-03-04 Mathematics and engineering are inevitably interrelated and this interaction will steadily increase as the use of mathematical modelling grows Although mathematicians and engineers often misunderstand one another their basic approach is quite similar as is the historical development of their respective disciplines The purpose of this Math Primer is to provide a brief introduction to those parts of mathematics which are or could be useful in engineering especially bioengineering The aim is to summarize the ideas covered in each subject area without going into exhaustive detail Formulas and equations have not been avoided but every effort has been made to keep them simple in the hope of persuading readers that they are not only useful but also accessible The wide range of topics covered includes introductory material such as numbers and sequences geometry in two and three dimensions linear algebra and the calculus Building on these foundations linear spaces tensor analysis and Fourier analysis are introduced All these concepts are used to solve problems for ordinary and partial differential equations Illustrative applications are taken from a variety of engineering disciplines and the choice of a suitable model is considered from the point of view of both the mathematician and the engineer This book will be of interest to engineers and bioengineers looking for the mathematical means to help further their work and it will offer readers a glimpse of many ideas which may spark their interest
     Computational Electrophysiology Shinji Doi,Junko Inoue,Zhenxing Pan,Kunichika Tsumoto,2010-03-10 Biological systems inherently possess much ambiguity or uncertainty Computational electrophysiology is the one area from among the vast and rapidly growing discipline of computational and systems biology in which computational or mathematical models have succeeded This textbook provides a practical and quick guide to both computational electrophysiology and numerical bifurcation analysis Bifurcation analysis is a very powerful tool for the analysis of such highly nonlinear biological systems Bifurcation theory provides a way to analyze the effect of a parameter change on a system and to detect a critical parameter value when the qualitative nature of the system changes Included in this work are many examples of numerical computations of bifurcation analysis of various models as well as mathematical models with different abstraction levels from neuroscience and electrophysiology This volume will benefit graduate and undergraduate students as well as researchers in diverse fields

of science   **Mathematical Physiology; Blood Flow and Electrically Active Cells** H. Melvin Lieberstein,1973
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Julian Blanco Gálvez, Sixto Malato Rodríguez, E. Delyannis, Vassilis G. Belessiotis, S. C. Bhattacharya and S.
Kumar,2010-11-20 Solar Energy Conversion and Photoenergy Systems Thermal Systems and Desalination Plants theme in
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Governance relates the critical international issues of the post war era to the major decisions of the UN and its IGO network
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     Range and Animal Sciences and Resources Management - Volume II Victor R. Squires,2010-07-07 Range and
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twenty one Encyclopedias Rangelands comprise over forty percent of the earth s land surface and as one of the most
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