

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

where " $\Omega$ " is one Ohm, the unit of resistance.

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

$$\begin{aligned} \epsilon \frac{dv}{d\tau} &= I_{ext} - g(v, n) \stackrel{\text{def}}{=} I_{ext} - [m_{\infty}^3(v)(0.85 - n)(v - 1) + \gamma_K n^4(v + v_K) + \gamma_L(v - v_L)] \\ \frac{dn}{d\tau} &= k(v, n) \stackrel{\text{def}}{=} \frac{1}{\tau_n^*(v)} [n_{\infty}(v) - n], \end{aligned} \quad (21)$$

with

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

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

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.

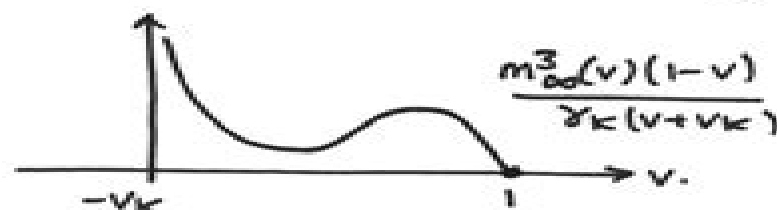
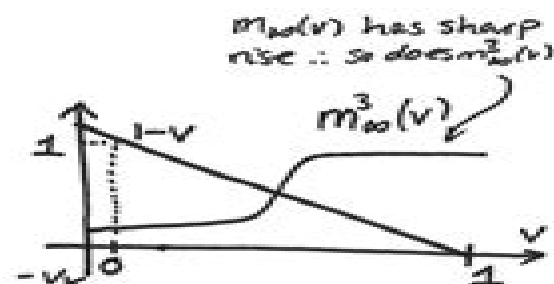
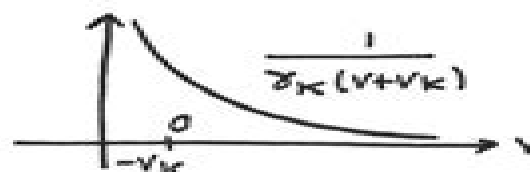
Plotting nullclines.  $I_{ext} = 0$ .

$$\begin{aligned} -\epsilon dv/d\tau = g &= m_{\infty}^3(v)(0.85 - n)(v - 1) + \gamma_K n^4(v + v_K) + \gamma_L(v - v_L) \\ dn/d\tau = k &= \frac{1}{\tau_n^*(v)} [n_{\infty}(v) - n] \end{aligned}$$

$\gamma_L$  small: neglect this below.

v nullcline

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



# Mathematical Physiology

**H. Melvin Lieberstein**



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