PHYS 1169 tutorial 8

1) (See questions on tut sheet)
   a) True
   b) True – myelin sheath adds extra distance between charges inside/outside and is also better insulator than the axon membrane alone.
   c) False. Chlorine concentration is high **outside**.
   d) False. “For a particular axon, the shape and peak size of the action potential curve are independent of the strength of the initial above threshold stimulus.” P439 Chapter 18 K&S.
   e) True
   f) True
   g) False Na+ is pumped out, K+ is pumped in.
   h) True
   i) True

2)

3)
   a) Explain the space parameter of an axon and how a myelin sheath changes its value?

   The space parameter $\lambda$ is the length along the axon at which the current loss due to the resistance of the axoplasm will be the same as the current leaking out through the membrane. Alternatively, the length, $\lambda$ where axoplasm R = $\rho_a\lambda/\pi r^2$ = resistance across membrane = 1/Conductance (G) = $(R_m)$. $(1/2\pi r\lambda)$.

   A myelin sheath makes the value for $R_m$ larger thus increasing $\lambda$.

   b) Calculate $\lambda$ using $r = 1\times10^{-6}$m and values in Table18.1 of K&S for (i) myelinated and (ii) unmyelinated axons.

   From the above, $\lambda^2 = r\,R_m/2\rho_a$, and given that $r = 1\times10^{-6}$m, myelinated $R_m$ = 40 ohm.m$^2$, unmyelinated $R_m$ = 0.2 ohm. m$^2$ and in both cases $\rho_a$ = 2 ohm.m, then $\lambda$ = (i) 3mm (ii) 0.2mm

4)

5)
   a) Find the equilibrium potential at 37 C for Ca++ if the concentration of calcium ions outside is 16 moles/m$^3$ and inside 1 moles/m$^3$.

   Using the Nernst equation: $\log_e(C_o/C_i) = q(V_i - V_o) / k_BT$ ….and remembering that T is in Kelvin (37C = 310K), $k_B=1.38\times10^{-23}$J/K AND by convention $V_o$ = 0V, then $V_i = \log_e(16/1) \div (+2\times1.6\times10^{-19}\text{C}) \times(1.38\times10^{-23}\ \text{J/K}\times 310\ \text{K})$ = 37mV

6)

7) A myelinated axon with $\lambda$ = 0.5cm has it's potential raised from –90 mV to –80 mV. Find the potential at distances (a) 0.5 (b) 1.0 cm..

a) The DIFFERENCE in the potential from equilibrium potential decays exponentially with distance (see information on tute sheet). To begin with at x = 0 cm, this difference is +10mv. Then at 0.5cm: $V_d$ =10mV $\times$ $e^{-(x/\lambda)}$. The total potential at this distance is –90mV + $V_d$ = -86.3mV

b) Using the same formula with x = 1cm, -90mV – $V_d$ = -88.6mV.

8) (a) Which properties of an axon determine the velocity of propagation of a signal along it? (b) Estimate the time taken for a nerve impulse to travel 2m given information in Table 18.1 of K&S

a) Radius of the axon, r; capacitance per unit area of membrane $C_m$; resistivity of the axoplasm $\rho_a$; and length between nodes of Ranvier, X.

b) velocity = $r/(\rho_a C_m X)$. Values given in textbook + estimating X =0.001m, time = distance/velocity = 40ms (note that outside your brain most of your nerves are myelinated).

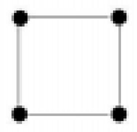
9) $1m^2$ of axon membrane has resistance = 0.2 ohms, and is 7.5 $\times 10^{-9}$ m thick

a) What is the resistivity? $R = \rho_a d/A$ therefore $RA/d = \rho_a = 2.67\times10^{-7}$ ohm m

b) The same membrane's resistance is due to cylindrical pores 7.5 $\times10^{-9}$ m deep, 3.5 $\times10^{-10}$ m in radius and with fluid inside the pore of resistivity = 0.15 ohm m. How many pores should there be in $1m^2$ of membrane to match the resistance given above = 0.2 ohm (in $1m^2$)?

The resistance of a single pore $R = \rho_a d/\pi r^2$ BUT all these are connected in PARALLEL across the membrane so, for "n" pores the total resistance = $(n \times 1/R)^{-1} = (n \times \pi r^2/\rho_a d)^{-1}$. For a particular number, "n" this should be equal to the resistance of $1m^2$ of membrane = 0.2 ohm. Then, by inverting: $(n \times \pi r^2/\rho_a d) = 1/(0.2) = 5$…from which we can find n.

c) If the distance from mid-pore to mid-pore is "a" then in any square pattern as shown, of area $a^2$, the density of pores will be $1/a^2$. NOTE: only one quarter of each pore is actually within the square! Then the density of pores/$m^2$ = $n/1m^2 = 1/a^2$.



10)

a) The change in charges will be proportional to the change in voltage through the relation Q = CV, presuming capacitance remains constant. Then, for positive increase of 0.13V, there must be a change in the excess charge (largely on the inside) of $Q = 0.13\ V \times 3 \times 10^{-9}\ F = 3.9 \times 10^{-10}\ C$.

b) Charge on one Na+ ion = $+1.6 \times 10^{-9}$ C. Therefore number of sodium ions going in to generate this change in charge = $3.9 \times 10^{-10}\ C / 1.6 \times 10^{-9}\ C$