Problem 2

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Problem 1. *I apply a square wave current of baseline* $0\,\mathrm{pA}$ *and max* $10\,\mathrm{pA}$ *, to a spherical cell with a capacitance of* $0.01\,\mathrm{F/m^2}$ *and diameter* $10\,\mathrm{u}$*, and resting potential is* $-60\,\mathrm{mV}$*,* $R_A = 1\,\Omega\mathrm{m}$*, and* $R_M = 1\,\Omega\mathrm{m}^2$ *. Draw the waveform of the output for 2 full cycles of the stimulus, for a frequency of 10 Hz, 100 Hz, and 1000 Hz respectively. Your graph should be labelled with voltage and time axes. I don't need a word explanation, but you can put in your calculation if you like. Doesn't have to be hugely precise, factor of 2 in the peak height is fine. The graph shape matters too. I suggest you draw in pencil, and scan it in so you can upload as a pdf.*

The equivalent circuit of cell is in fig 1. But we should convert a spherical cell to cylinderical first before we can use this electrical equivalent. Lets assume that both cylinder and sphere has the same volume and surface area. Let assume the radius of cylinder is r' and its length is l and the radius of sphrerical cell is r.

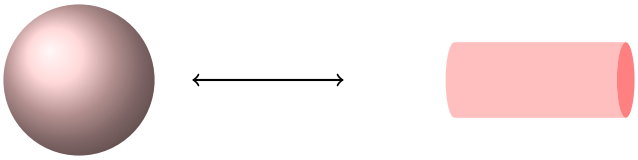


Figure 1: A spherical cell and its equivalent cylinder

$$\frac{4}{3}\pi r^3 = \pi r'^2 l$$
$$4\pi r^2 = 2\pi r' l$$

This gives $r' = \frac{2}{3}r$ and $l = 3r$. We dont have to calculate value of R_a. Values of other parameters are following:

$$R_m = \frac{R_M}{2\pi r' l} = \frac{R_M}{100\pi r^2} = 3.15 \times 10^9 \tag{1}$$
$$C_m = C_M 2\pi r' l = C_M 4\pi r^2 = 3.1416 \times 10^{-12} F \tag{2}$$

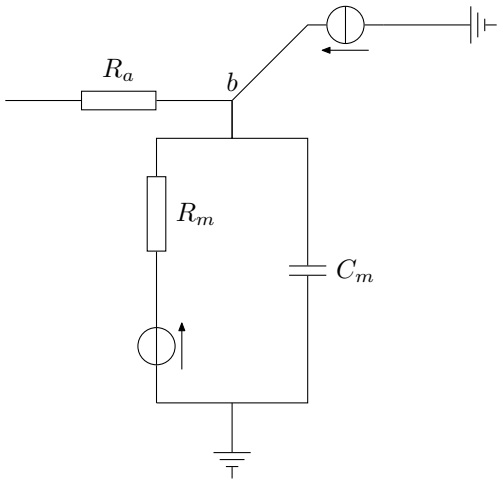


Figure 2: Injecting current into cell. Axial resistance R_a is useless now. We measure voltage at node b when current is being injected into cell.

0.1 Waveform

The peak value will remain -0.060 V of waveform. The resistor will be charged through R_m and the time constant τ of charging is $R_m \times C_m = 0.01$ s. In this time, the waveform get's 63% of peak value i.e. $-60 + 31.5 = -29.5$ mV. Following is spice netlist for this circuit the waveforms. These spice scripts can be found here

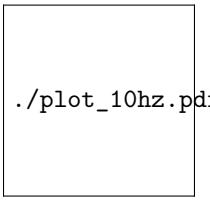
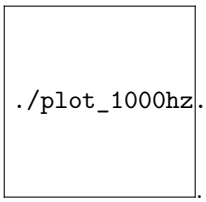


Figure 3: Waveform when 10Hz pulse is applied Since charging and discharging is happening through same path, we see a symmetry.



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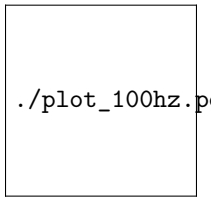

Figure 4: 20 pulse of 100 Hz pulse are applied. Discharging starts before capacitor is fully charged and vice versa.