



# مدل سازی شناختی

## Cognitive Modeling

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*Spring 2024,*

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# فہرست مطالب

- دور نما
- ہاجکین و ہاکسلی کی ہستند؟
- دل ہاجکین و ہاکسلی
- شبیہ سازی دل ہاجکین و ہاکسلی یا صفحہ کسترده
- کلام آخر در مورد معادلات دینفراسیل

# فہرست مطالب

- دور نما
- ہاجکین و ہاکسلی کی ہستند؟ ←
- دل ہاجکین و ہاکسلی
- شہ سازمی دل ہاجکین و ہاکسلی یا صفحہ کسترده
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# اساتید صین کار

"**The Squid and its Giant Nerve Fiber**" was filmed in the 1970s at Plymouth Marine Laboratory in England. This is the laboratory where Hodgkin and Huxley conducted experiments on the squid giant axon in the 1940s. Their experiments unraveled the mechanism of the action potential, and led to a Nobel Prize. Long out of print, the film is an historically important record of the voltage-clamp technique as developed by Hodgkin and Huxley, as well as an interesting glimpse at how the experiments were done. [QuickTime](#) video excerpts from the film are presented here.



[Dissection and anatomy \(J.Z. Young\)](#)



[Removing the mantle nerves \(H. Meves\)](#)



[Cleaning and cannulating a giant fiber](#)



[Voltage clamping \(P.F. Baker & A.L. Hodgkin\)](#)



[Injection & perfusion \(R.D. Keynes\)](#)

# اساتید صین کار

# اساتید صین کار



<http://www.science.smith.edu/departments/neurosci/courses/bio330/squid.html>

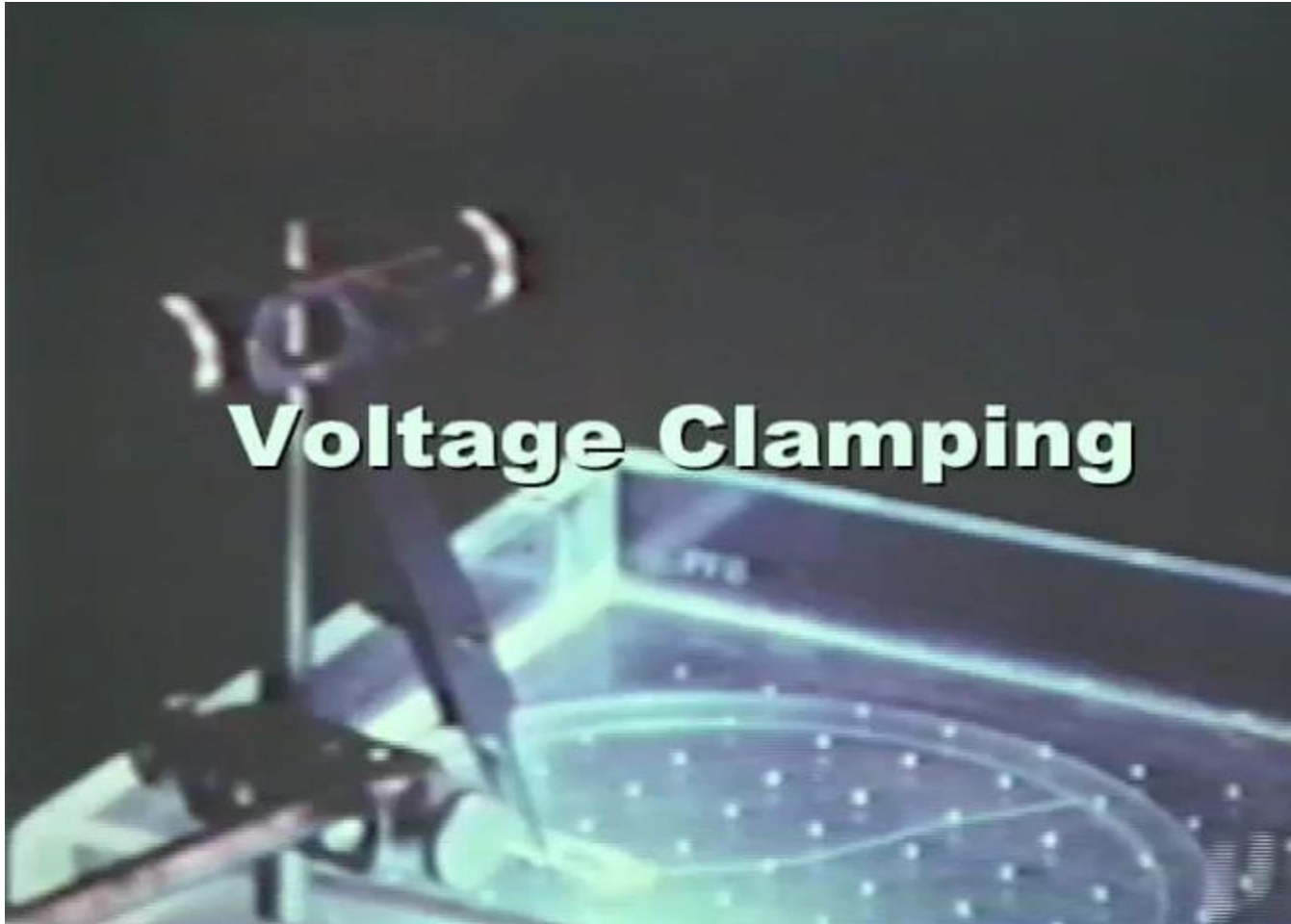


# اساتید صین کار



**Cleaning & Cannulation**

# اساتید صین کار



# اساتید صین کار



<http://www.science.smith.edu/departments/neurosci/courses/bio330/squid.html>

# فہرست مطالب

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# مدل باجکین و ہاگسلی

$$C \frac{dV(t)}{dt} = I_{injected}(t) - [\bar{g}_{Na} m^3 h (V(t) - E_{Na}) + \bar{g}_K n^4 (V(t) - E_K) + \bar{g}_L (V(t) - E_L)]$$

$$\dot{n} = \alpha_n(V)(1 - n) - \beta_n(V)n \quad \alpha_n(V) = \frac{0.1 - 0.01V}{e^{1-0.1V} - 1} \quad \beta_n(V) = 0.125e^{-\frac{V}{80}}$$

$$\dot{m} = \alpha_m(V)(1 - m) - \beta_m(V)m \quad \alpha_m(V) = \frac{2.5 - 0.1V}{e^{2.5-0.1V} - 1} \quad \beta_m(V) = 4e^{-\frac{V}{18}}$$

$$\dot{h} = \alpha_h(V)(1 - h) - \beta_h(V)h \quad \alpha_h(V) = 0.07e^{-\frac{V}{20}} \quad \beta_h(V) = \frac{1}{e^{3-0.1V} + 1}$$

$E_{Na}$	$\bar{g}_{Na}$	$E_K$	$\bar{g}_K$	$E_L$	$\bar{g}_L$
115 mV	120 mS/cm <sup>2</sup>	-12 mV	36 mS/cm <sup>2</sup>	10.6 mV	0.3 mS/cm <sup>2</sup>

# فہرست مطالب

- دور نما
- ہاجکین و ہاکسلی کی ہستند؟
- دل ہاجکین و ہاکسلی
- شہ سازمی دل ہاجکین و ہاکسلی یا صفحہ کسترده ←
- کلام آخر در مورد معادلات دینفراسیل

# ساده سازی «مدل های جکین و هایکسی» در اکسل:

از مبحث سوم درس به خاطر داریم که:

$$\text{مقدار جدید} = \text{مقدار قبلی} + \text{نرخ تغییرات مقدار} \times \text{گام زمانی}$$

## وارد کردن ثابت‌ها و گام شبیه‌سازی:

Row	Column	Value
1	A	Constants:
2	C	E_Na
2	D	g_Na
2	E	E_K
2	F	g_K
2	G	E_L
2	H	g_L
2	C	115
2	D	120
2	E	-12
2	F	36
2	G	10.6
2	H	0.3
4	A	dt
5	A	0.01

$E_{Na}$

$\bar{g}_{Na}$

$E_K$

$\bar{g}_K$

$E_L$

$\bar{g}_L$

115 mV

120 mS/cm<sup>2</sup>

-12 mV

36 mS/cm<sup>2</sup>

10.6 mV

0.3 mS/cm<sup>2</sup>



## وارد کردن برچسب ستون‌ها:

The screenshot shows an Excel spreadsheet with the following data:

1	Constants:	E_Na	g_Na	E_K	g_K	E_L	g_L													
2		115	120	-12	36	10.6	0.3													
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01																			

A yellow callout box contains the text: "به ترتیب وارد کردن عنوان ستون‌ها توجه کنید! چرا با این ترتیب؟"

$$C \frac{dV(t)}{dt} = I_{injected}(t) - [\bar{g}_{Na} m^3 h (V(t) - E_{Na}) + \bar{g}_K n^4 (V(t) - E_K) + \bar{g}_L (V(t) - E_L)]$$

# وارد کردن جریان ورودی:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0																		
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
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15		0																		

## وارد کردن مقادیر اولیه:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0							0	0	0							0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		
16		0																		
17		0																		

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

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SUM :  $\times$   $\checkmark$   $fx$   $= (2.5 - 0.1 * T5) / (EXP(2.5 - 0.1 * T5) - 1)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	$= (2.5 - 0.1 * T5) / (EXP(2.5 - 0.1 * T5) - 1)$						0	0	0							0	0
6		0																		
7		0																		
8		0																		
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12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%

$$\alpha_m(V) = \frac{2.5 - 0.1V}{e^{2.5 - 0.1V} - 1}$$



## وارد کردن فرمول‌ها:

Excel spreadsheet showing a formula being entered into cell E5. The formula bar displays  $=4*EXP(-T5/18)$ .

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	=4*EXP(-T5/18)					0	0	0							0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

$$\beta_m(V) = 4e^{-\frac{V}{18}}$$

## وارد کردن فرمول‌ها:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	= (0.1-0.01*T5)/(EXP(1-0.1*T5)-1)				0	0	0							0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

$$\alpha_n(V) = \frac{0.1 - 0.01V}{e^{1-0.1V} - 1}$$

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$  =0.125\*EXP(-T5/80)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	=0.125*			0	0	0							0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%

$$\beta_n(V) = 0.125e^{-\frac{V}{80}}$$

## وارد کردن فرمول‌ها:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	=-0.07*E		0	0	0							0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

The formula bar shows the formula being entered in cell H5:  $=-0.07*EXP(-T5/20)$

$$\alpha_h(V) = 0.07e^{-\frac{V}{20}}$$

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

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SUM :  $\times$   $\checkmark$   $f_x$  =1/(EXP(3-0.1\*T5)+1)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	=1/(EXP	0	0	0							0	0
6		0																		
7		0																		
8		0																		
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10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT

$$\beta_h(V) = \frac{1}{e^{3-0.1V} + 1}$$

## وارد کردن فرمول‌ها:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	=D5/D5						0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

$$\dot{m} = \alpha_m(V)(1 - m) - \beta_m(V)m$$



## وارد کردن فرمول‌ها:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	=F5/(F5-					0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
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14		0																		
15		0																		

The formula bar shows the formula:  $=F5/(F5+G5)$

$$\dot{n} = \alpha_n(V)(1 - n) - \beta_n(V)n$$

## وارد کردن فرمول‌ها:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	=H5/(H5				0	0
6		0																		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
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14		0																		
15		0																		

The formula bar shows the formula being entered in cell O5:  $=H5/(H5+I5)$ .

$$\dot{h} = \alpha_h(V)(1 - h) - \beta_h(V)h$$

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $=\$D\$2*M5^3*O5*(T5-\$C\$2)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	=D5*E5			0	0
6		0																		
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15		0																		

Sheet1

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$$C \frac{dV(t)}{dt} = I_{injected}(t) - \left[ \bar{g}_{Na} m^3 h (V(t) - E_{Na}) + \bar{g}_K n^4 (V(t) - E_K) + \bar{g}_L (V(t) - E_L) \right]$$

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

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SUM :  $=\$F\$2*N5^4*(T5-\$E\$2)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	-\$E\$2		0	0
6		0																		
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10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT

$$C \frac{dV(t)}{dt} = I_{injected}(t) - \left[ \bar{g}_{Na} m^3 h (V(t) - E_{Na}) + \bar{g}_K n^4 (V(t) - E_K) + \bar{g}_L (V(t) - E_L) \right]$$

## وارد کردن فرمول‌ها:

The screenshot shows an Excel spreadsheet with the following data and formula:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	=SH\$2*(	0	0
6		0																		
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8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

The formula bar shows:  $=SH\$2*(T5- \$G\$2)$

$$C \frac{dV(t)}{dt} = I_{injected}(t) - \left[ \bar{g}_{Na} m^3 h (V(t) - E_{Na}) + \bar{g}_K n^4 (V(t) - E_K) + \bar{g}_L (V(t) - E_L) \right]$$

# وارد کردن فرمولها:

The screenshot shows the Microsoft Excel interface with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6			=C5+\$A\$5																	
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				
15																				



# وارد کردن فرمولها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$   $= (2.5 - 0.1 * T5) / (EXP(2.5 - 0.1 * T5) - 1)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6			0.01	$= (2.5 - 0.1 * T5) / (EXP(2.5 - 0.1 * T5) - 1)$																
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%

# وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$  =4\*EXP(-T5/18)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	=4*EXP(-															
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

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## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$   $= (0.1 - 0.01 * T5) / (EXP(1 - 0.1 * T5) - 1)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	T5)-1)														
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
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15		0																		

Sheet1

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# وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$   $=-0.125*EXP(-T5/80)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	$=-0.125*$													
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

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# وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$  =0.07\*EXP(-T5/20)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	=5/20												
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

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# وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$  =1/(EXP(3-0.1\*T5)+1)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	T5)+1)											
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%



## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$  =D6\*(1-M5)-E6\*M5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	=D6*(1-I										
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%

$$\dot{m} = \alpha_m(V)(1 - m) - \beta_m(V)m$$

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $fx$  =F6\*(1-N5)-G6\*N5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	=F6*(1-N									
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT

$$\dot{n} = \alpha_n(V)(1 - n) - \beta_n(V)n$$

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$  =H6\*(1-O5)-I6\*O5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	=H6*(1-O5)								
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%

$$\dot{h} = \alpha_h(V)(1 - h) - \beta_h(V)h$$

# وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit

SUM :  $\times$   $\checkmark$   $fx$  =M5+J6\*\$A\$5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	=M5+J6*							
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT

100%

# وارد کردن فرمولها:

The screenshot shows an Excel spreadsheet with the following data:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	=N5+K6						
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

# وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit

SUM :  $\times$   $\checkmark$   $fx$  =O5+L6\*\$A\$5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	=O5+L6*					
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%



کپی کردن روابط از سطر قبل برای ...

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

P5 :  $=\$D\$2*M5^3*O5*(T5-\$C\$2)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18		
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

READY AVERAGE: -0.000107903 COUNT: 6 SUM: -0.000647418 100%

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

SUM :  $=B6-(P6+Q6+R6)$

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	=B6-(P6+Q6+R6)	
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

$$C \frac{dV(t)}{dt} = I_{injected}(t) - \left[ \bar{g}_{Na} m^3 h (V(t) - E_{Na}) + \bar{g}_K n^4 (V(t) - E_K) + \bar{g}_L (V(t) - E_L) \right]$$

## وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

SUM :  $\times$   $\checkmark$   $f_x$  =T5+S6\*\$A\$5

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	*\$A\$5
7		0																		
8		0																		
9		0																		
10		0																		
11		0																		
12		0																		
13		0																		
14		0																		
15		0																		

Sheet1

EDIT 100%

$$C \frac{dV(t)}{dt} = I_{injected}(t) - \left[ \bar{g}_{Na} m^3 h (V(t) - E_{Na}) + \bar{g}_K n^4 (V(t) - E_K) + \bar{g}_L (V(t) - E_L) \right]$$

# وارد کردن فرمول‌ها:

CM\_07.xlsx - Excel

FILE HOME INSERT PAGE LAYOUT FORMULAS DATA REVIEW VIEW Foxit Sign in

A2

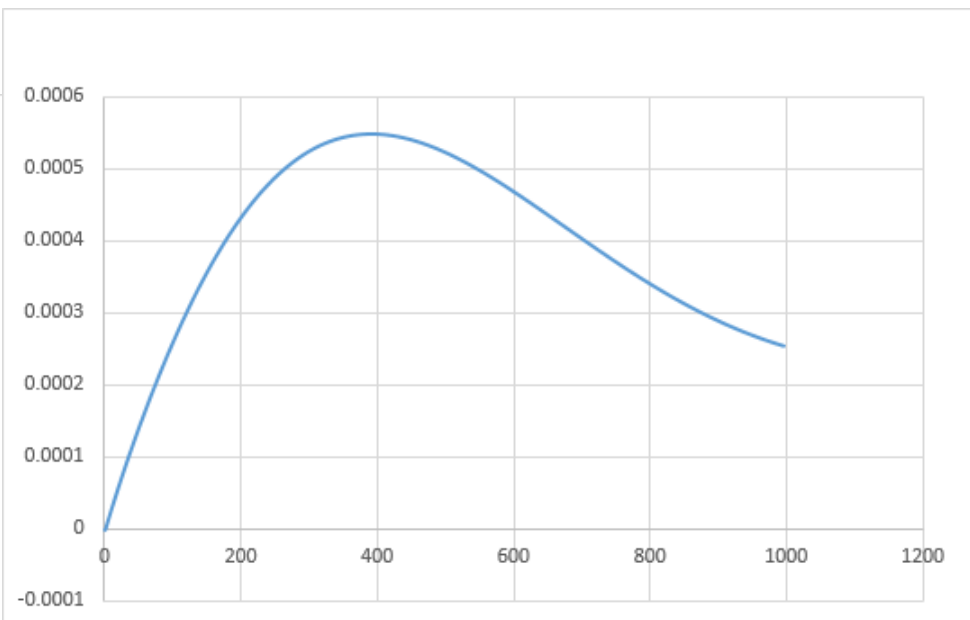
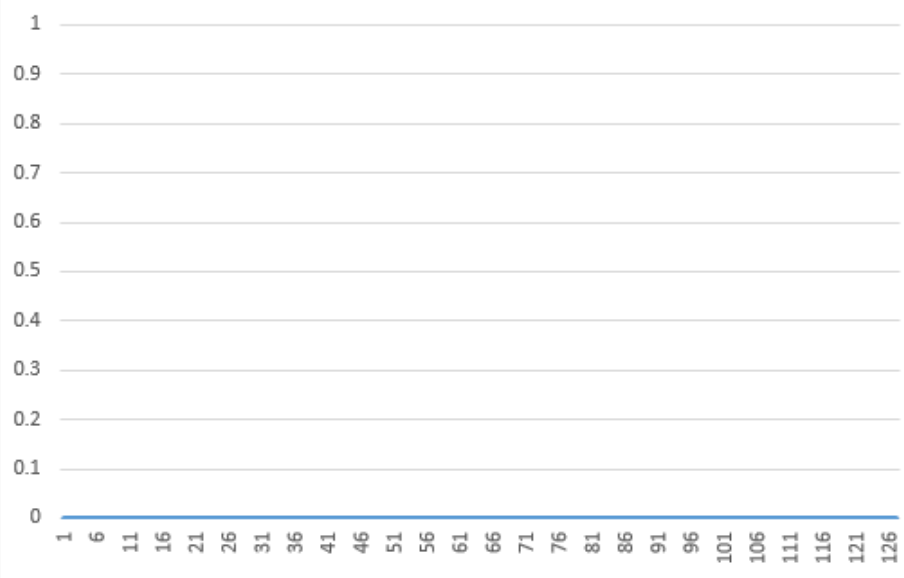
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1	Constants:		E_Na	g_Na	E_K	g_K	E_L	g_L												
2			115	120	-12	36	10.6	0.3												
3																				
4	dt	I_inject	t	alpha_m	beta_m	alpha_n	beta_n	alpha_h	beta_h	m_dot	n_dot	h_dot	m	n	h	I_Na	I_K	I_L	V_dot	V
5	0.01	0	0	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0	0
6		0	0.01	0.2236	4	0.0582	0.125	0.07	0.0474	0	0	0	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	3E-06
7		0	0.02	0.2236	4	0.0582	0.125	0.07	0.0474	9E-08	9E-09	-1E-08	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	6E-06
8		0	0.03	0.2236	4	0.0582	0.125	0.07	0.0474	2E-07	2E-08	-3E-08	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	1E-05
9		0	0.04	0.2236	4	0.0582	0.125	0.07	0.0474	2E-07	3E-08	-4E-08	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	1E-05
10		0	0.05	0.2236	4	0.0582	0.125	0.07	0.0474	3E-07	4E-08	-5E-08	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	2E-05
11		0	0.06	0.2236	4	0.0582	0.125	0.07	0.0474	4E-07	4E-08	-7E-08	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	2E-05
12		0	0.07	0.2236	4	0.0582	0.125	0.07	0.0474	5E-07	5E-08	-8E-08	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	2E-05
13		0	0.08	0.2236	4	0.0582	0.125	0.07	0.0474	5E-07	6E-08	-9E-08	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	3E-05
14		0	0.09	0.2236	4	0.0582	0.125	0.07	0.0474	6E-07	7E-08	-1E-07	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	3E-05
15		0	0.1	0.2236	4	0.0582	0.125	0.07	0.0474	6E-07	8E-08	-1E-07	0.0529	0.3177	0.5961	-1.22	4.3997	-3.18	0.0003	3E-05

Sheet1

READY

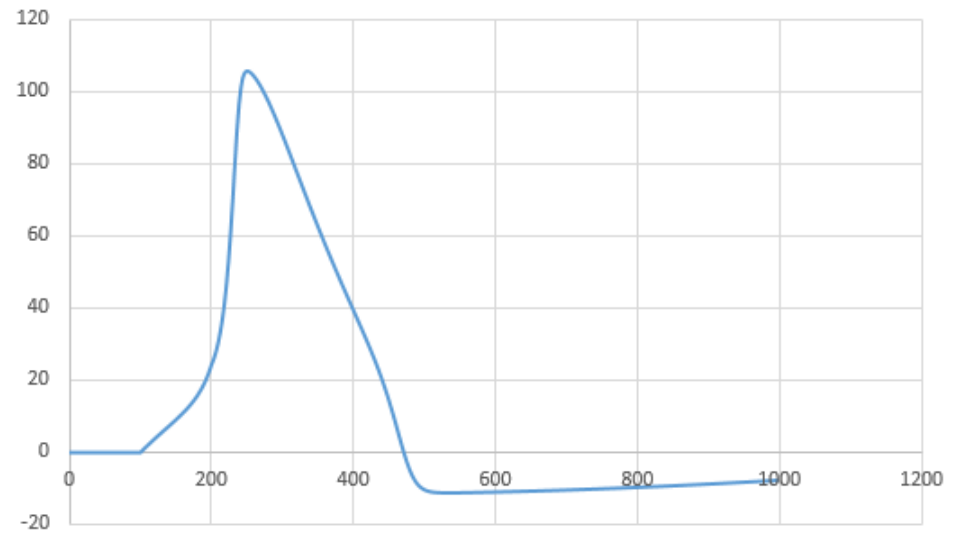
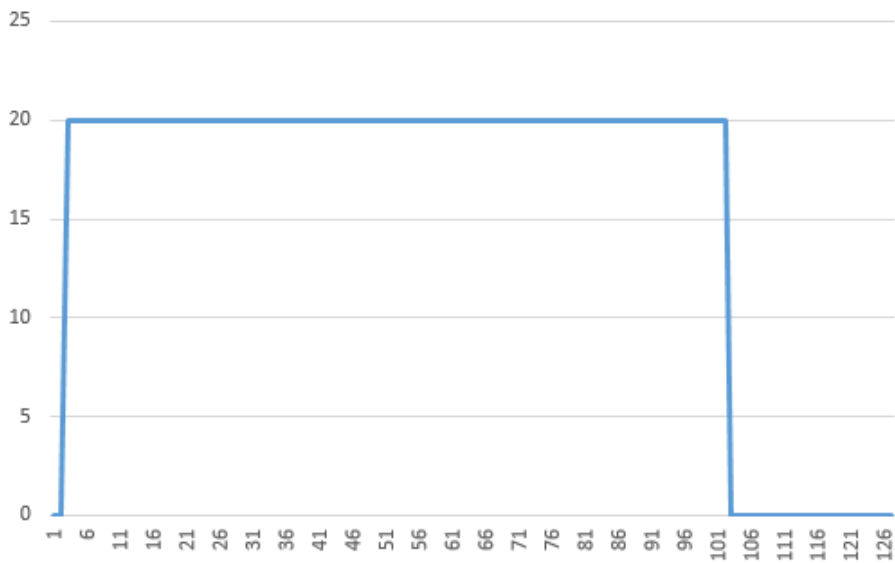
ترسیم و نمایش نتایج:

Injected Current



## ترسیم و نمایش نتایج:

Injected Current



# فہرست مطالب

- دورنا
- ہاجکین و ہاکسلی کی ہستند؟
- مدل ہاجکین و ہاکسلی
- شیہ سازی مدل ہاجکین و ہاکسلی یا صفحہ کسترده
- کلام آخر در مورد معادلات دینفراسیل  ←



# فہرست مطالب

- دورنا ✓
- ہاجکین و ہاکسلی کی ہستند؟ ✓
- دل ہاجکین و ہاکسلی ✓
- شیہ سازی دل ہاجکین و ہاکسلی یا صفحہ کسترده ✓
- کلام آخر در مورد معادلات دینفراسیل ✓

به کسانی که به شما حسودی می کنند احترام بگذارید،  
زیرا آنها کسانی هستند که از صمیم قلب معتقدند:  
شما بهتر از آنها هستید...



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