ELE 215
Linear Circuits Laboratory

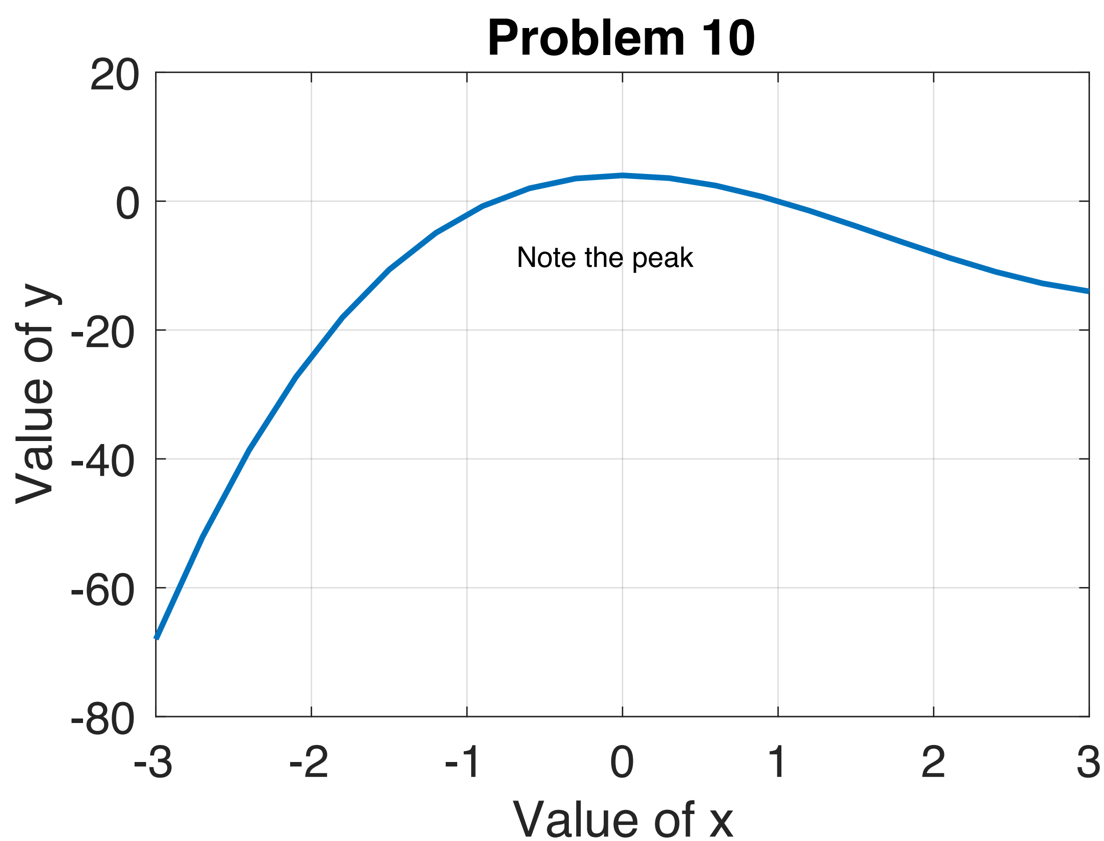
Recitation 5

MatLab plotting and Simulation

Which is easier to understand?

-3.0000	-68.0000
-2.7000	-52.1330
-2.4000	-38.6240
-2.1000	-27.3110
-1.8000	-18.0320
-1.5000	-10.6250
-1.2000	-4.9280
-0.9000	-0.7790
-0.6000	1.9840
-0.3000	3.5230
0	4.0000
0.3000	3.5770
0.6000	2.4160
0.9000	0.6790
1.2000	-1.4720
1.5000	-3.8750
1.8000	-6.3680
2.1000	-8.7890
2.4000	-10.9760
2.7000	-12.7670
3.0000	-14.0000

or

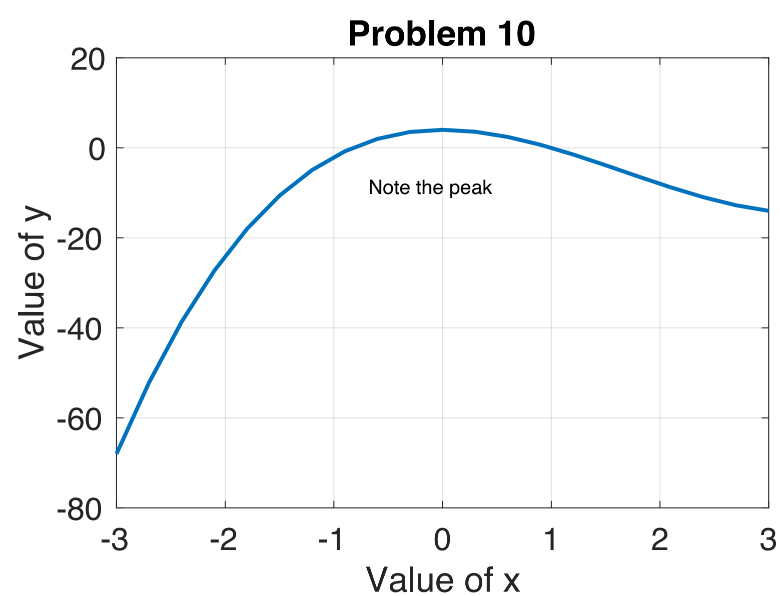


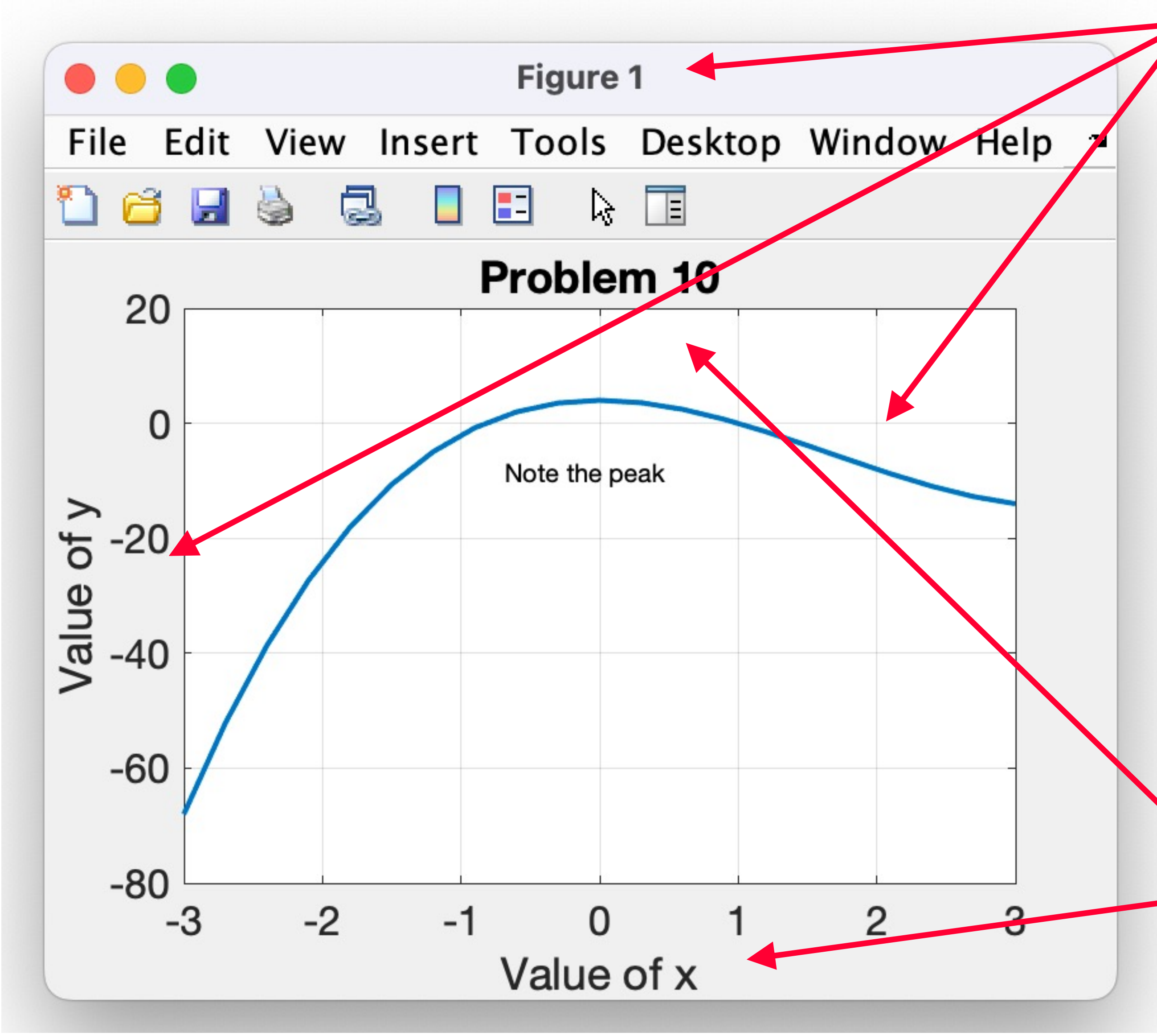
```
xv =  –3:0.1:3;
yv = xv.^3 – 5*xv.^2 + 4;

plot(xv,yv)

xlabel(‘Value of x')
ylabel(‘Value of y')
title('Problem 10’)
gtext(‘note the peak')
```

- colon and dot notation for arrays
- standard form for plot
- annotation tools



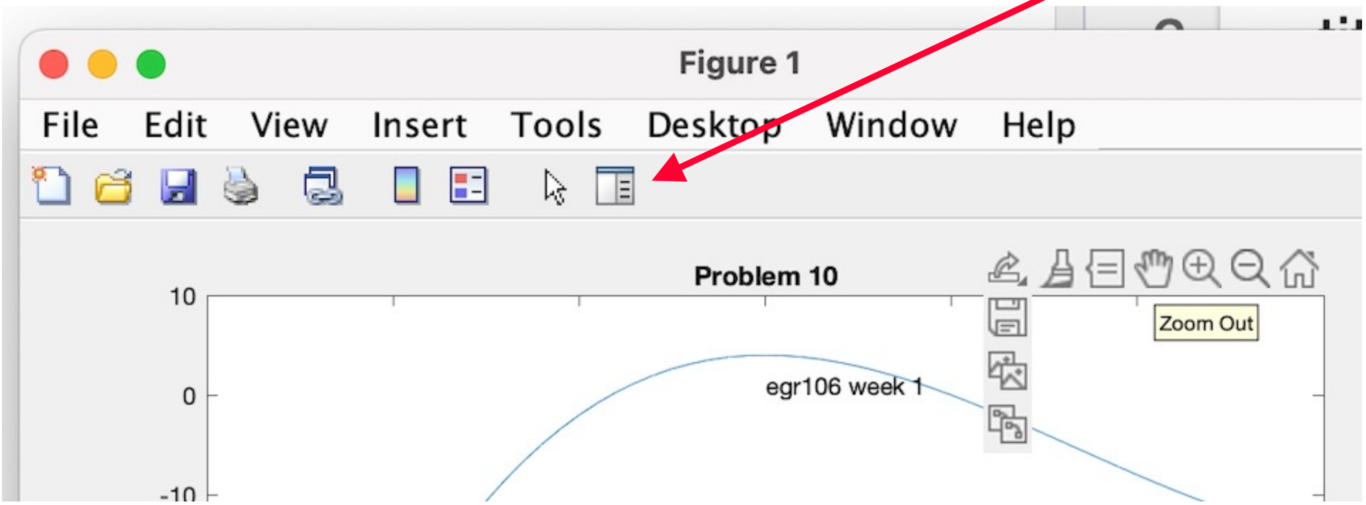


default is Figure 1, thin blue line, auto scaling, and small text

note axis labels, title, and text added

Advanced Plotting

- MatLab figures have a typical menu plus interactive tools for modifications



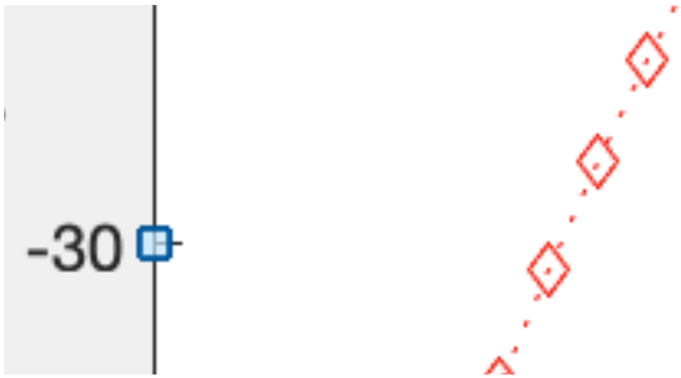
- Command line (i.e. script) manipulation is available through optional additional arguments:

  plot(x,y, 'linespec' , 'Propname' , PropValue)

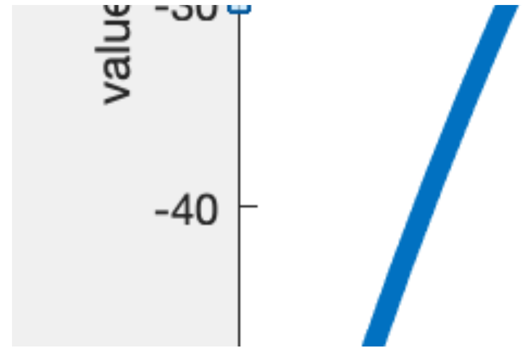
  – line specifiers: color, line type, markers for data
  – property name and value: thickness, size, etc

Examples:

plot(x,y, ' r : d ‘)

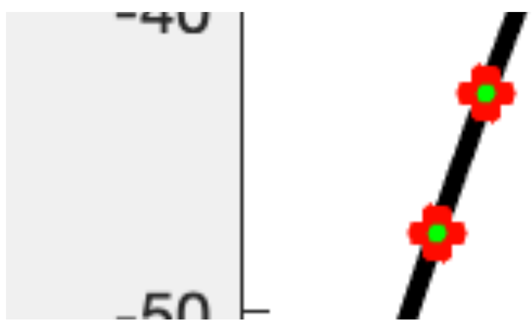


plot(x,y, 'linewidth',5)



plot(x,y, '- k o' , 'LineWidth' , 3 , 'MarkerSize', 6,...

'MarkerEdgeColor','red','MarkerFaceColor','green')



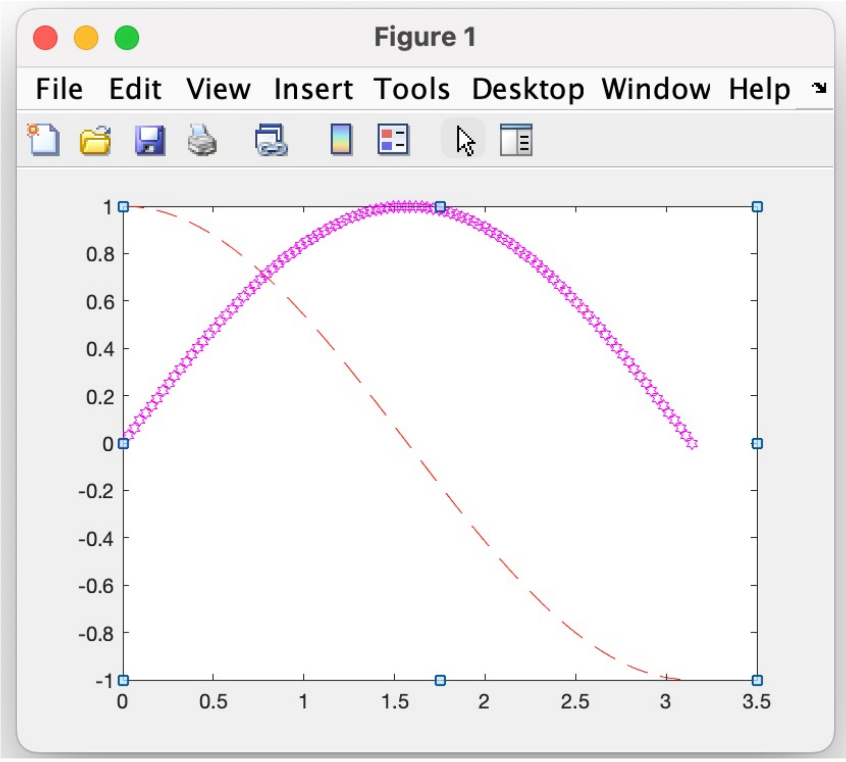
Fine tune your plot:

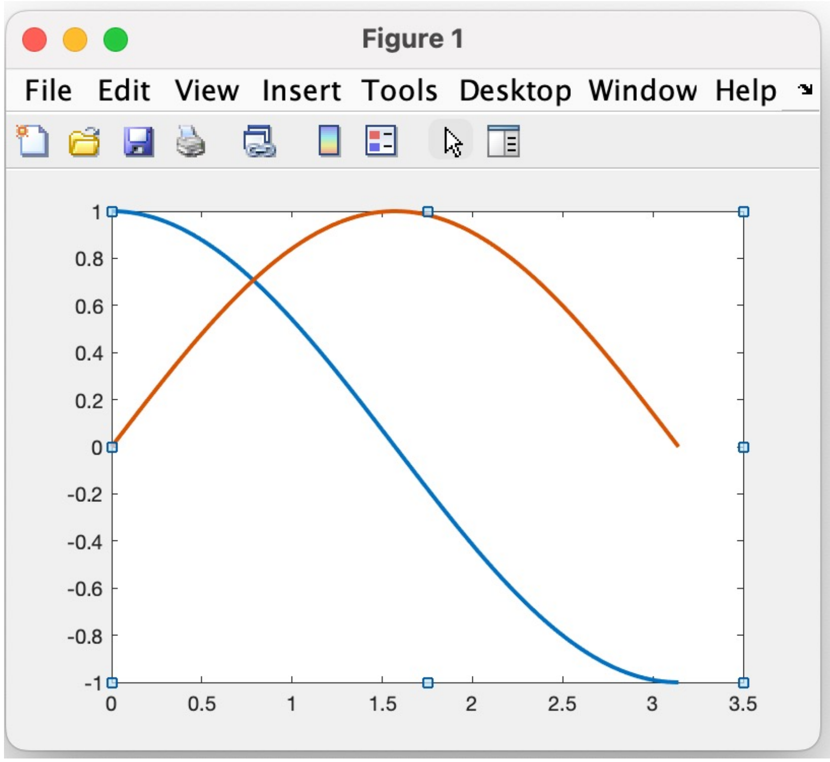
- xlabel('string')
- ylabel('string')
- title('string')
- legend('string1', … 'stringn', loc)
- text(x, y, 'string')
- gtext('string') – cursor controlled
- grid
- axis([xmin xmax ymin ymax])
- xlim ([xmin xmax])
- ylim ([ymin ymax])
- axis equal and axis off

Multiple plots on the same axes – possible with the plot command or with “hold”

```
x = linspace(0,pi,10);
y1 = cos(x);
y2 = sin(x);
plot(x,y1,'ro-',x,y2,'mh--')
```

```
x = linspace(0,pi,10);
y1 = cos(x);
y2 = sin(x);
plot(x,y1,'linewidth',2)
hold on
plot(x,y2,'linewidth',2)
hold off
```

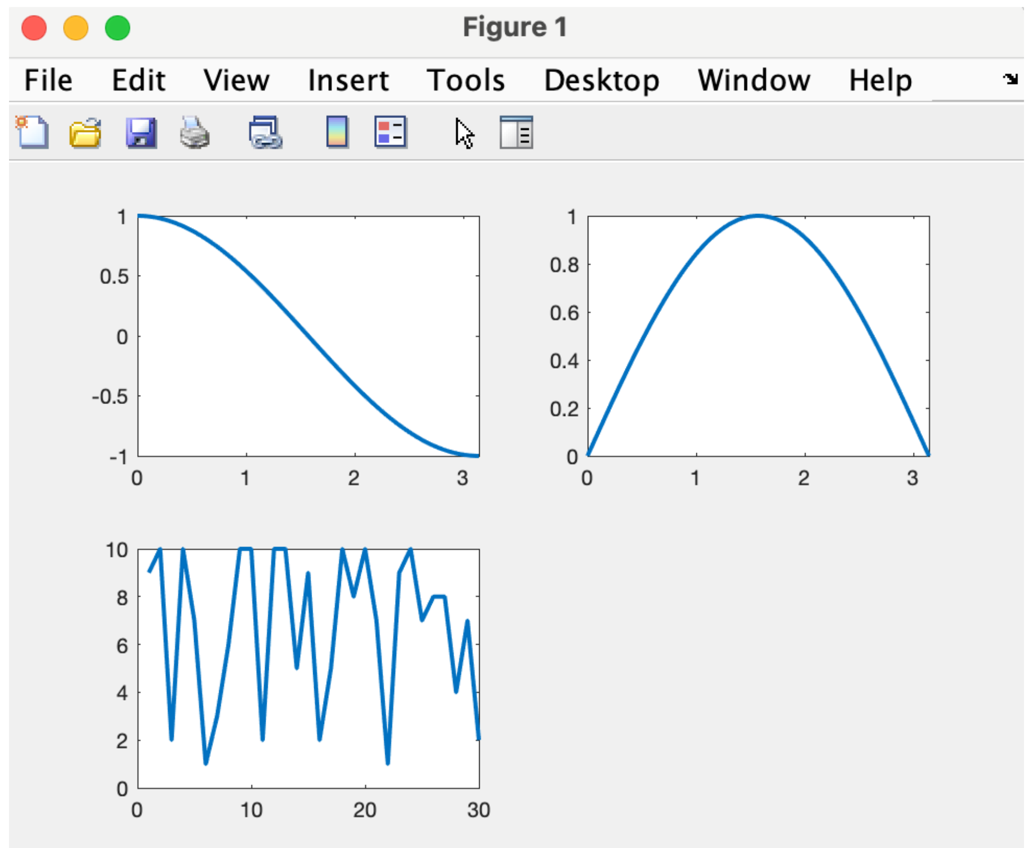




Other stuff:

- semilogx(x,y) semilogy(x,y) loglog(x,y)
- Saving to various formats, including copying
- Multiple plots in same window using subplot

```
subplot(2,2,1)
plot(x1,y1)
subplot(2,2,2)
plot(x2,y2)
etc.
```



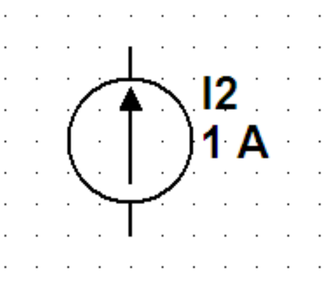
Simulation – What is it?

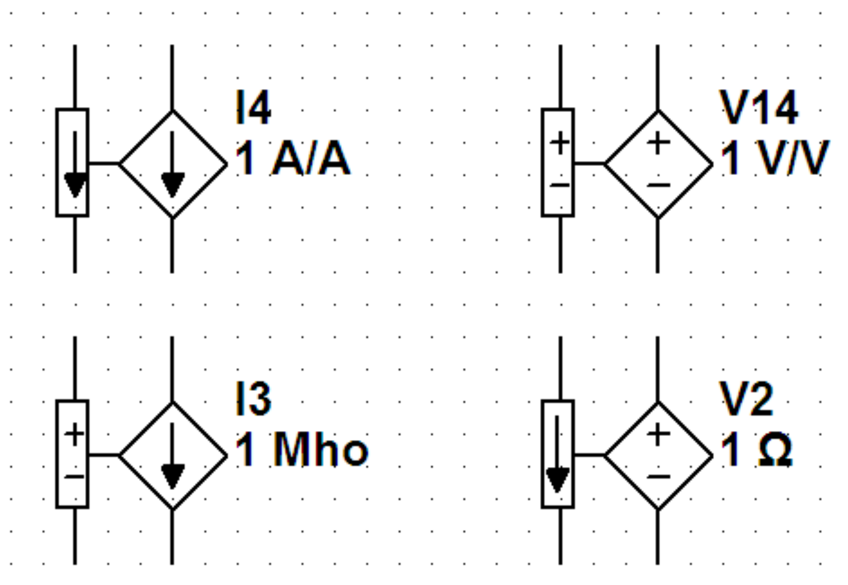
- Evaluating the specific performance of a complex system by numerical methods
  - MultiSim
  - SPICE

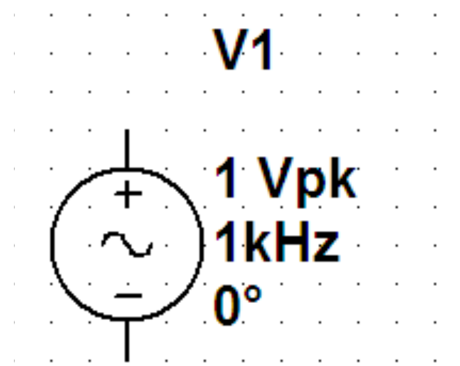
- Evaluating the average performance of a system with random variation (statistical methods)
  - Monte Carlo simulation

MultiSim

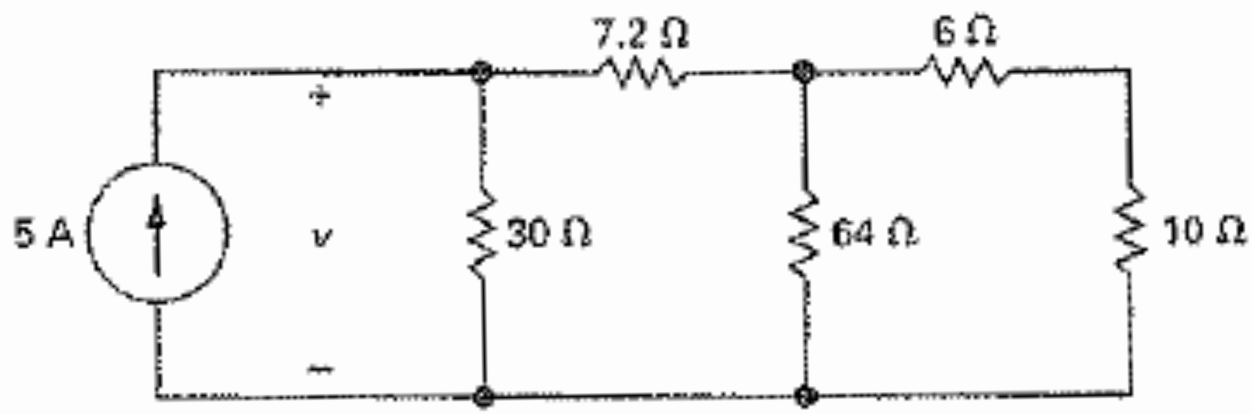
- Prior experience in ELE 202 (I think)
  - CMOS gates, power supplies, some devices (resistors, capacitors, LEDs), oscilloscopes
- For electronics, we add inductors, current sources, dependent sources, op amps, signal generator, meters, …

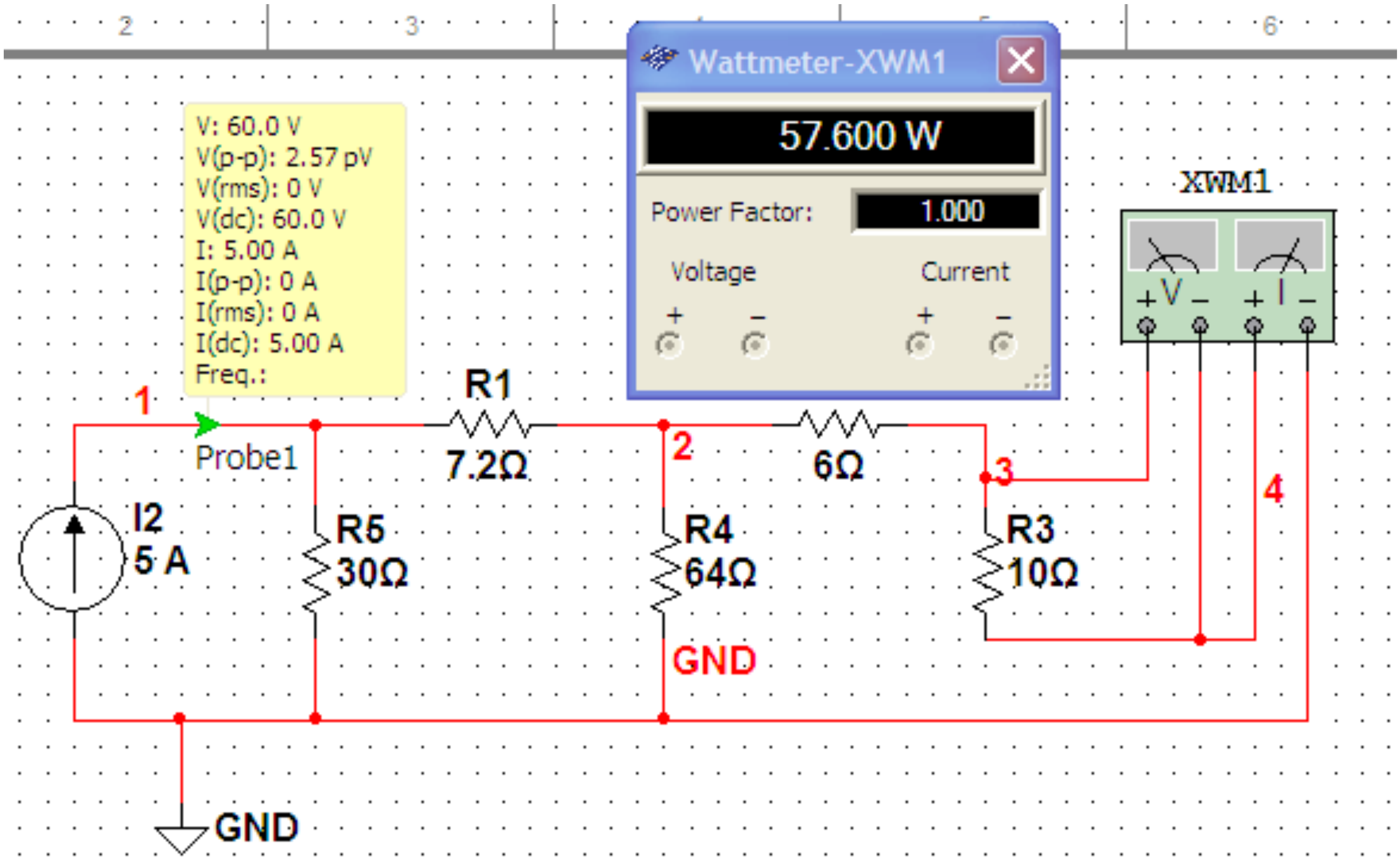






- DC example #1 – for the circuit shown, find
  - (a) the voltage marked v,
  - (b) the power dissipated by the $10\ \Omega$ resistor.




2
3
6
Wattmeter-XWM1
57.600 W
Power Factor:
1.000
Voltage
Current
+
–
+
–
XWM1
V
I
V: 60.0 V
V(p-p): 2.57 pV
V(rms): 0 V
V(dc): 60.0 V
I: 5.00 A
I(p-p): 0 A
I(rms): 0 A
I(dc): 5.00 A
Freq.:
1
Probe1
R1
7.2Ω
2
6Ω
3
4
I2
5 A
R5
30Ω
R4
64Ω
R3
10Ω
GND
GND

Monte Carlo Simulation

- In real circuits there is variation in component parameters
  - ± 5% variation in resistances
  - ± 20% variation in capacitors

- We can use Monte Carlo methods to evaluate how this variation impacts performance:
  - Randomly select component values
  - Analyze circuit – e.g. solve simultaneous equations
  - Repeat – e.g. use loops
  - Compute mean and standard deviation, perhaps plot a histogram

Random Numbers in MatLab

- Generate random numbers
  - Integers uniformly selected from {1,2,…n}

```
randi(n,r,c)
```

  - Values uniformly distributed on [0,1]

```
rand(r,c)
```

  - Example of a random 500 Ω, $\pm$5% resistor

```
500 * ( 1 + 0.05*( 2*rand(1) - 1 ) );
```

Statistical Tools

- Mean – a measure of the center of the data; in MatLab

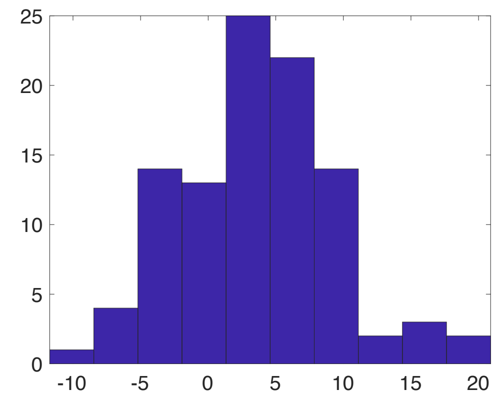
```
mean(X)
```

- Standard deviation – a measure of how the data spreads about the mean

```
std(X)
```

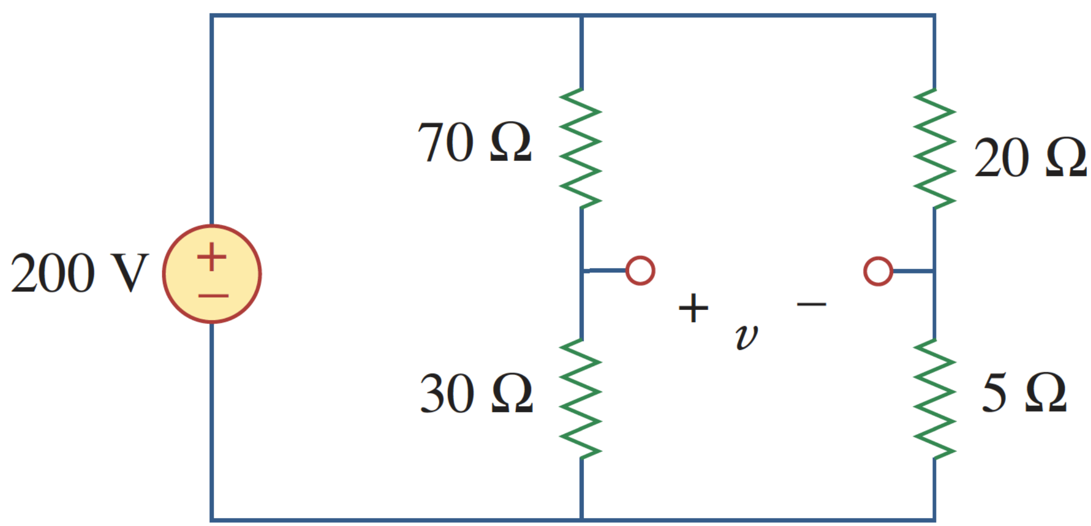
- Histogram – a picture of the data, counted in ranges

```
hist(X)
```



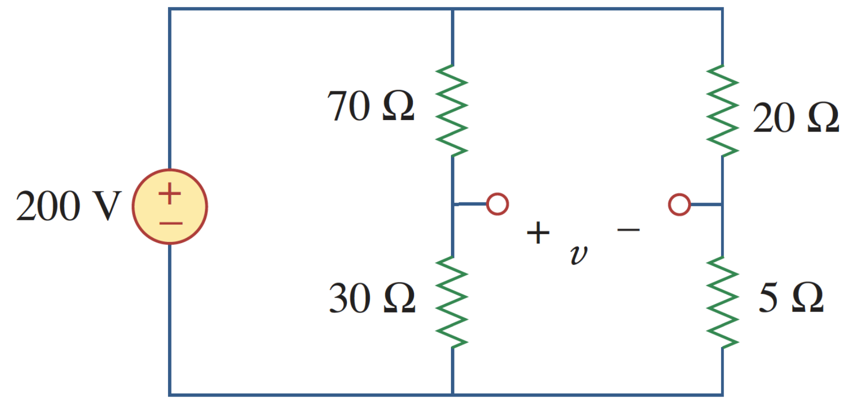
Example:

- Allowing all the resistors in this circuit to have a ± 5% tolerance, how does the voltage v vary?
  - Analysis method: use voltage division to find v

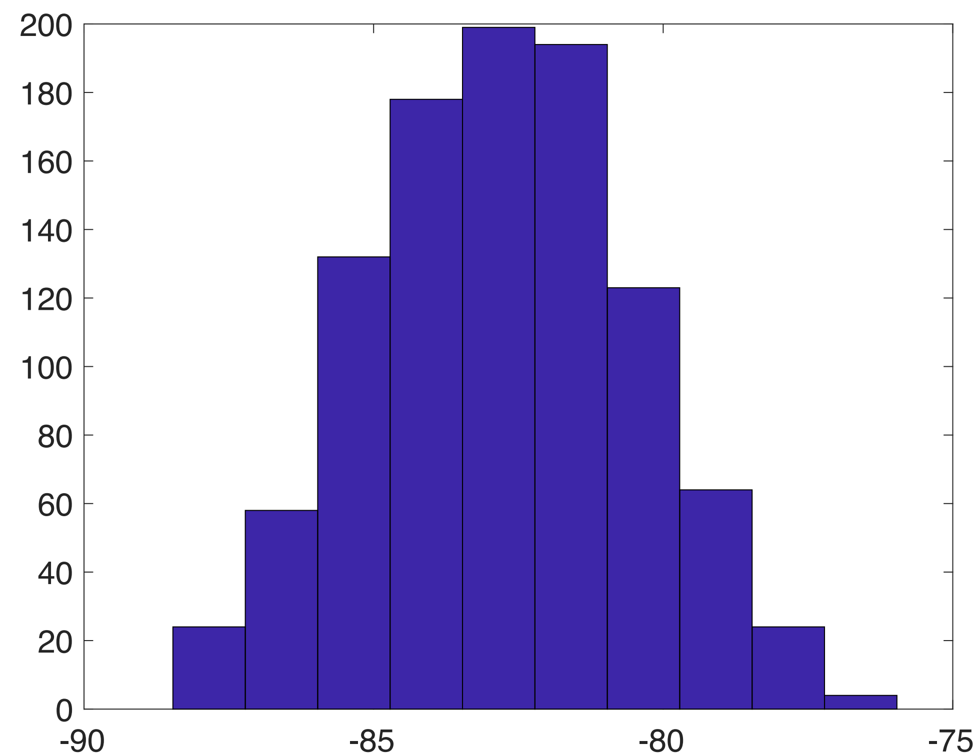


- Solution – 1000 trials:

```
for k = 1:1000
   R1 = 70*( 1 + 0.05*( 2*rand(1)-1 ));
   R2 = 30*( 1 + 0.05*( 2*rand(1)-1 ));
   R3 = 20*( 1 + 0.05*( 2*rand(1)-1 ));
   R4 = 50*( 1 + 0.05*( 2*rand(1)-1 ));
   vp = 200* R2/(R1+R2);
   vn = 200* R4/(R3+R4);
   v(k) = vp-vn;
end
mean(v)
std(v)
hist(v)
```




```
ans =
  -8.2810e+01
ans =
   2.2881e+00
```



Specifics for next week

- Continue work on Exercise 1 (programming)

- Exercise 2 (solving linear equations) due on Monday

- Lab 3 – 50 points (individual)
  - Instructions posted on ELE 215 website
  - Summary sheets available in lab rooms and on website
  - Due by 5 PM Wednesday Mar 4

- Exercise 3 – 75 points (individual) – circuit simulation in MatLab – instructions and initial value submission online, Brighspace submission of simulation results – due by 9 AM Monday Mar 23