Variables（变量）

Create Variables（变量的创建）

Rules for Variable Name：（变量命名规则）

letters, numbers, underscores（由字母、数字、下划线构成）

case sensitive（大小写敏感）

begin with letter（以字母开头）

Create scalar（标量）

```
scalar1 = 1
```

```
scalar1 = 1
```

Create vector（向量）空格&,

```
vector1 = [1 2 3]
```

```
vector1 = 1×3
     1     2     3
```

```
vector2 = [4,5,6]
```

```
vector2 = 1×3
     4     5     6
```

```
vector3 = [4;5;6]
```

```
vector3 = 3×1
     4
     5
     6
```

```
vector_1_2 = [vector1 vector2]
```

```
vector_1_2 = 1×6
     1     2     3     4     5     6
```

Create matrix（矩阵）

```
matrix1= [10 20 30;
          40 50 60;
          70 80 90]
```

```
matrix1 = 3×3
    10    20    30
    40    50    60
    70    80    90
```

```
a = 10:-1:11
```

```
a =

   空的 1×0 double 行向量
```

The use of colon（冒号的使用）

The arithmetic sequence can be simplified with a colon.（等差序列可以使用冒号来简化输入）

In ascending order, the default step is one.（升序时，默认的步长为1）

start **:** step **:** end（格式为：起始值：步长:终止值）

闭区间

Index

使用索引时：

Matlab索引从(1)开始；

```
colon1 = 1:10
```

```
colon1 = 1×10
     1     2     3     4     5     6     7     8     9    10
```

```
colon2 = [1:2:10;2:2:10]
```

```
colon2 = 2×5
     1     3     5     7     9
     2     4     6     8    10
```

In descending order, the step should be indicated.（降序时，必须指出步长值）

```
colon3 = 10:-1:1
```

```
colon3 = 1×10
    10     9     8     7     6     5     4     3     2     1
```

Call the variables and the elements （变量及元素的调用）

Call with the variable name or index.（使用变量名和索引进行调用）

About the index in Matlab, you should know:（Matlab中索引的使用，需注意）

a) The index starts from **1** in Matlab.（Matlab的索引是从**1**开始的）

b) The last index can be represented by **end**.（可以使用**end**来表示最后一个索引。虽然工作区可以看到变量的长度，但代码中不建议使用具体的数值）

c) Use **()** to expand the index.（索引值由小括号括起来）

For scalar（标量引用）

Scalar is stroed as a matrix in Matlab, so the index is also usable.（即便是标量，在Matlab中也是以矩阵的方式存储的，因此也可以使用索引）

```
scalar1
```

```
scalar1 = 1
```

```
scalar1(1)
```

```
ans = 1
```

For vector（向量引用）

```
vector1
```

```
vector1 = 1×3
     1     2     3
```

```
vector3
```

```
vector3 = 3×1
     4
     5
     6
```

```
vector1(1)
```

```
ans = 1
```

```
vector3(end)
```

```
ans = 6
```

For matrix（矩阵引用）

```
matrix1
```

```
matrix1 = 3×3
    10    20    30
    40    50    60
    70    80    90
```

There are several way to call the element of the matrix.（矩阵元素的引用有多种方式）

```
matrix1(2,2)
```

```
ans = 50
```

```
matrix1(2)
```

```
ans = 40
```

```
matrix1([2 3], [1 3])
```

```
ans = 2×2
    40    60
    70    90
```

```
matrix1([1 3], [2 3])
```

```
ans = 2×2
    20    30
    80    90
```

```
matrix1([1,3,5])
```

```
ans = 1×3
    10    70    50
```

```
matrix1(8)
```

```
ans = 60
```

Use of colon（冒号在索引中的应用）

```
colon1
```

```
colon1 = 1×10
     1     2     3     4     5     6     7     8     9    10
```

```
colon1(5:end)
```

```
ans = 1×6
     5     6     7     8     9    10
```

```
colon1(end-1:-2:1)
```

```
ans = 1×5
     9     7     5     3     1
```

```
matrix1
```

```
matrix1 = 3×3
    10    20    30
    40    50    60
    70    80    90
```

```
matrix1(3,:)
```

```
ans = 1×3
    70    80    90
```

```
matrix1(:,3)
```

```
ans = 3×1
    30
    60
    90
```

数组运算

+, - ,.*, **./**, **.**

对元素执行。

`x = A./B`用 A 的每个元素除以 B 的对应元素。

`x = A.\B` 用 B 的每个元素除以 A 的对应元素。

```
A = ones(2,3)
```

```
A = 2×3
     1     1     1
     1     1     1
```

```
B = [1 2 3; 4 5 6]
```

```
B = 2×3
     1     2     3
     4     5     6
```

```
C = A + B
```

```
C = 2×3
     2     3     4
     5     6     7
```

```
C=A.*B
```

```
C = 2×3
     1     2     3
     4     5     6
```

```
C=A./B
```

```
C = 2×3
    1.0000    0.5000    0.3333
    0.2500    0.2000    0.1667
```

```
C=A.\B
```

```
C = 2×3
     1     2     3
     4     5     6
```

矩阵运算

*, /, \, ^, ‘

和线性代数的运算规则相同

```
A = [1 1 1;2 2 2];
B = [1 2 3; 4 5 6; 7 8 9];
C=A*B
```

```
C = 2×3
    12    15    18
    24    30    36
```

一般情况下

方程 Ax = B 的解是x = A\B

```
A = magic(3)
```

```
A = 3×3
     8     1     6
     3     5     7
     4     9     2
```

```
B = [15; 15; 15]
```

```
B = 3×1
    15
    15
    15
```

```
x = A\B
```

```
x = 3×1
    1.0000
    1.0000
    1.0000
```

方程 xA = B 的解是x = B/A , B/A = (A'\B')'。

A'为矩阵A的转置

```
A = [1 1 3; 2 0 4; -1 6 -1];
B = [2 19 8];
x = B/A
```

```
x = 1×3
    1.0000    2.0000    3.0000
```

Plotting（绘图）

Generate signals

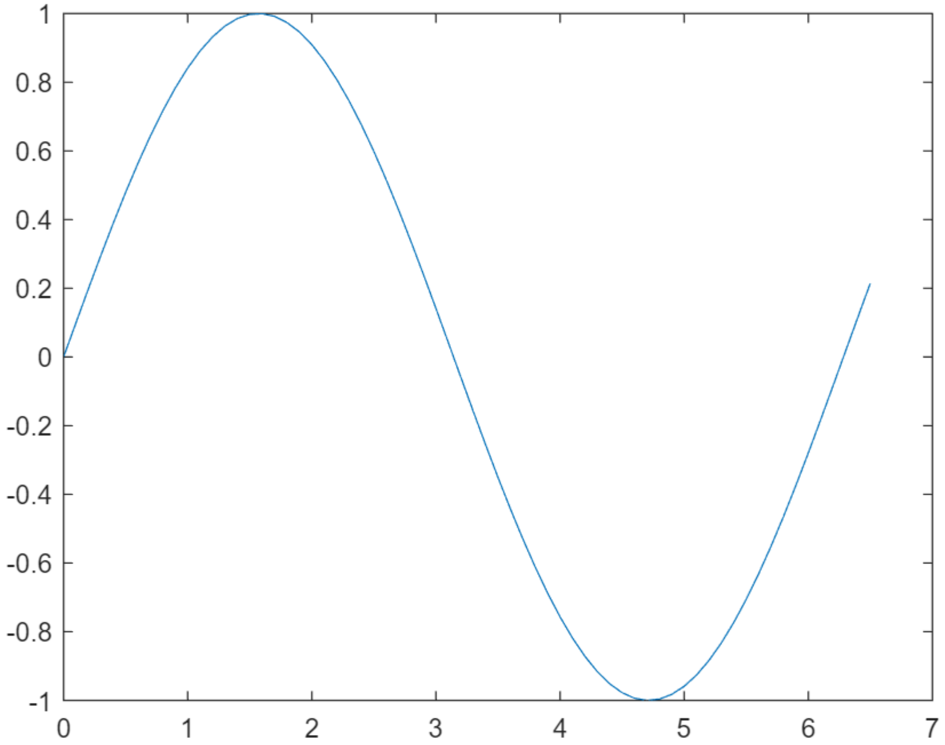
```
clear; clf;
t = 0:0.1:6.5
```

```
t = 1×66
         0    0.1000    0.2000    0.3000    0.4000    0.5000    0.6000    0.7000 ⋯
```

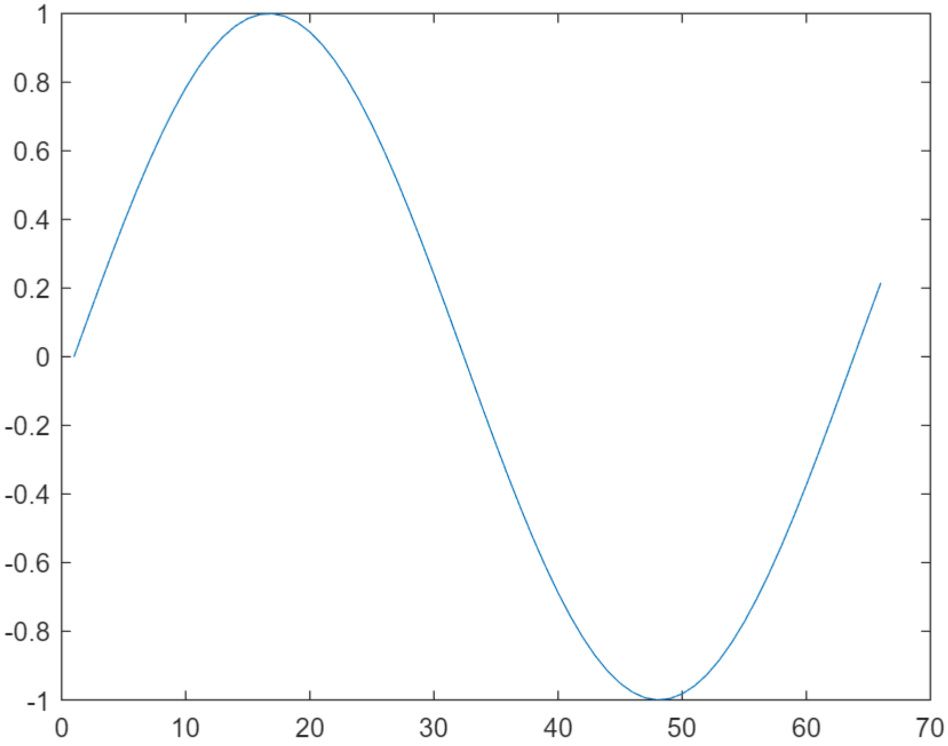
```
sigx = sin(t);
sigy = cos(t);
```

plot & stem (numerical method)

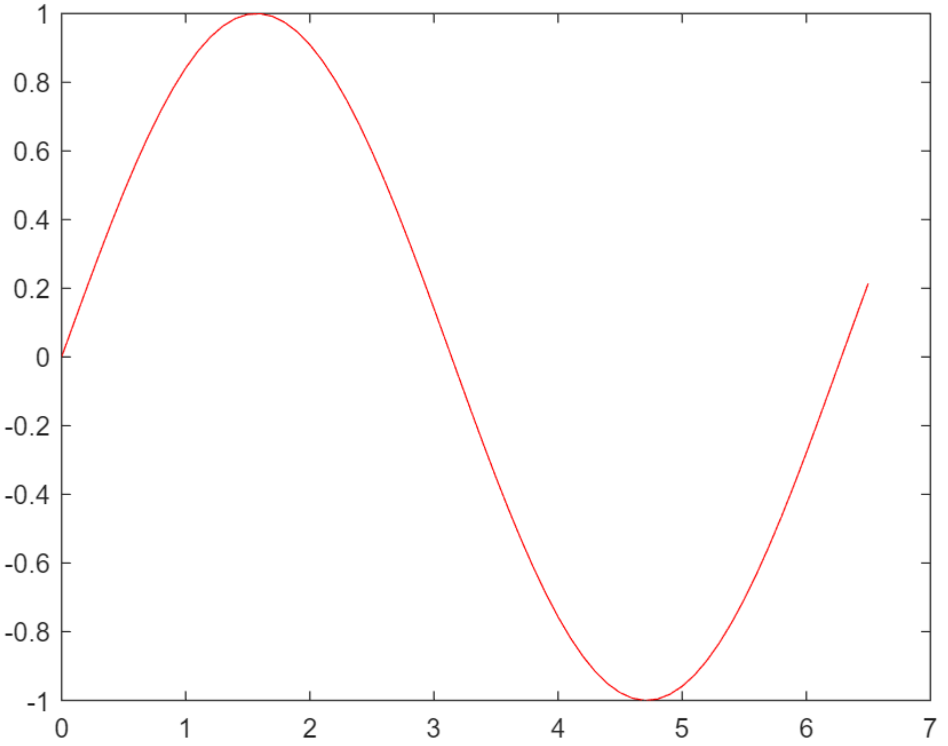
```
plot(t,sigx);
```



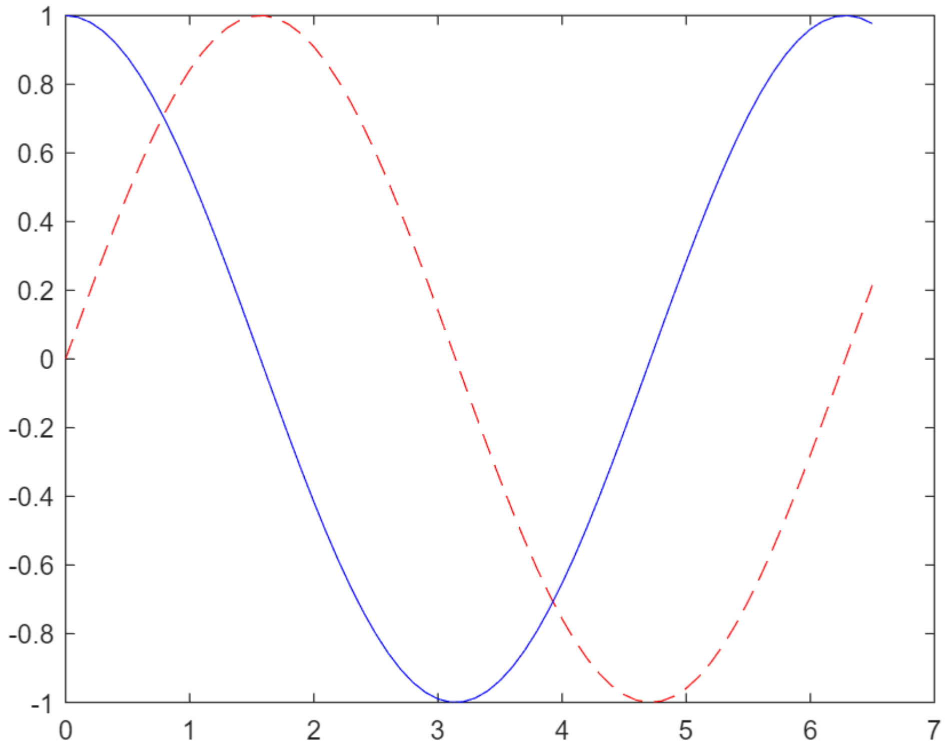
```
plot(sigx);
```


1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
10
20
30
40
50
60
70

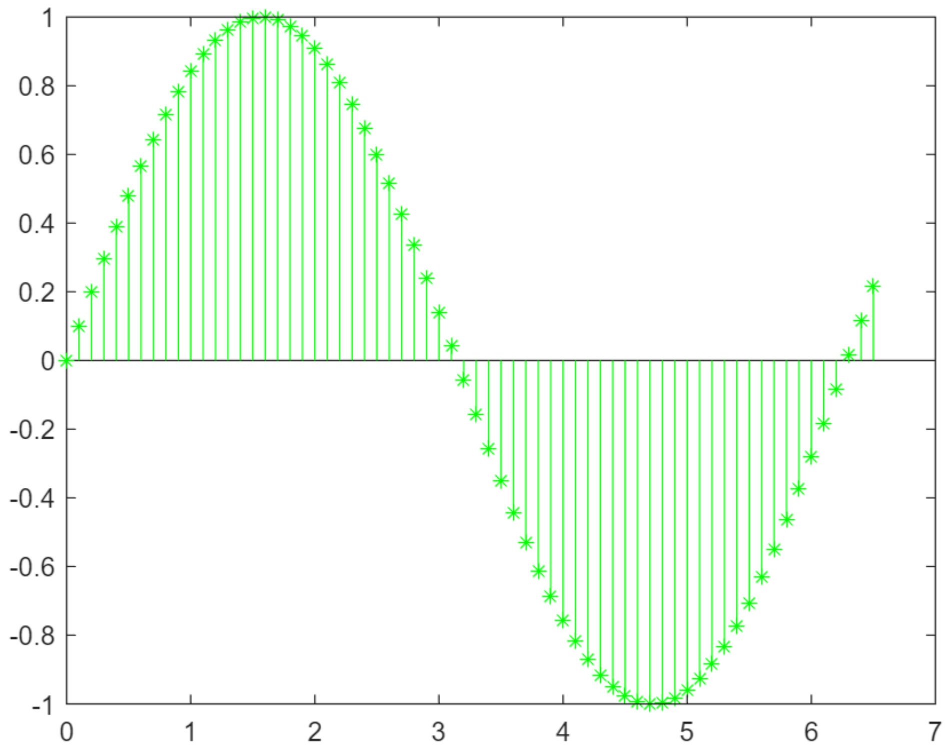
```
plot(t,sigx, '-r');
```


1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
0
1
2
3
4
5
6
7

```
plot(t,sigx,'--r',t,sigy,'b');
```



```
stem(t,sigx,'* g')
```

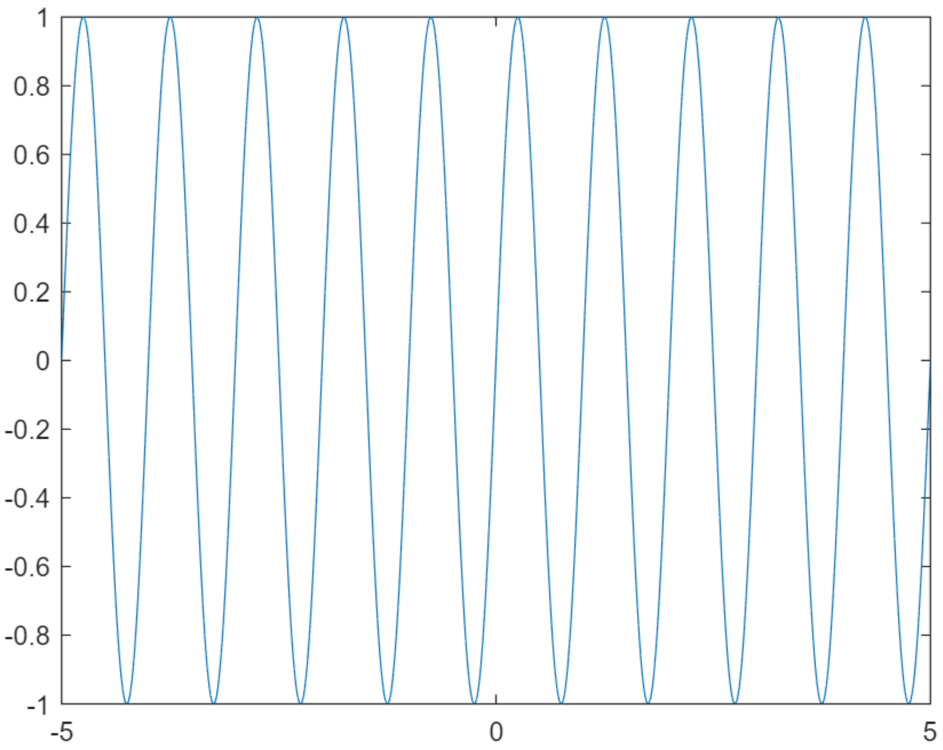


fplot (symbolic method)

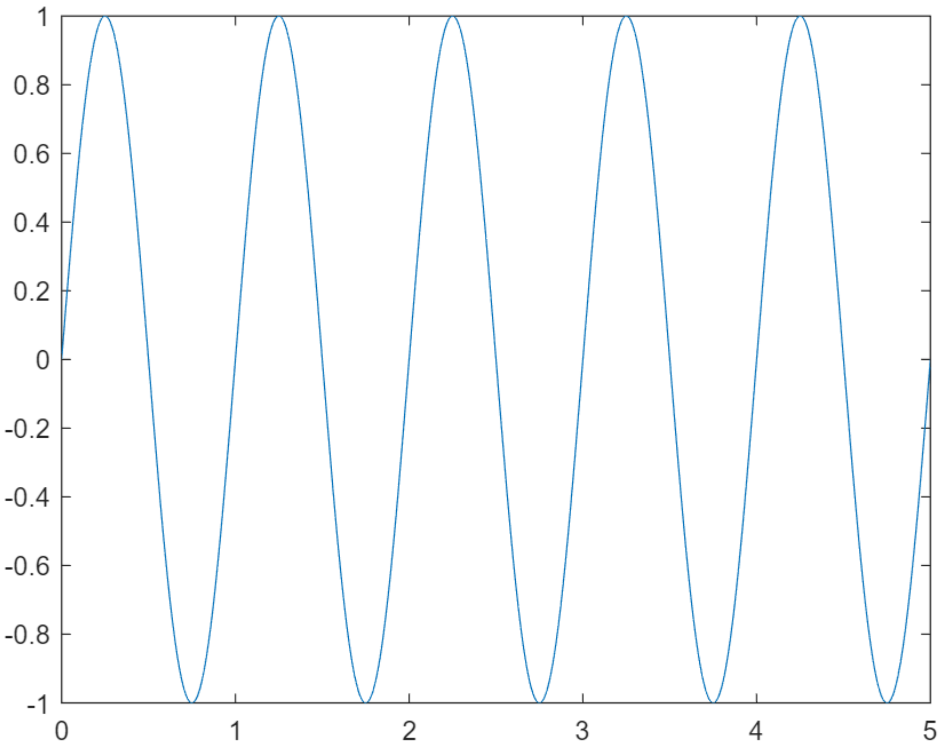
```
syms x
y = sin(2*pi*x)
```

y = $\sin(2\,\pi\,x)$

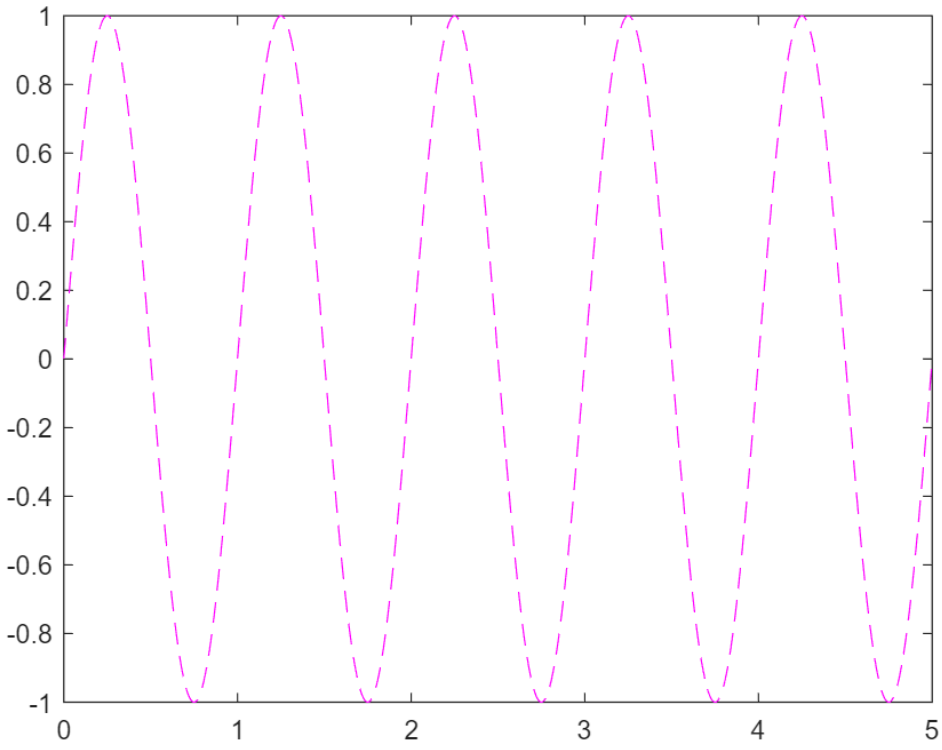
```
fplot(x,y);
```



```
fplot(y,[0 5]);
```

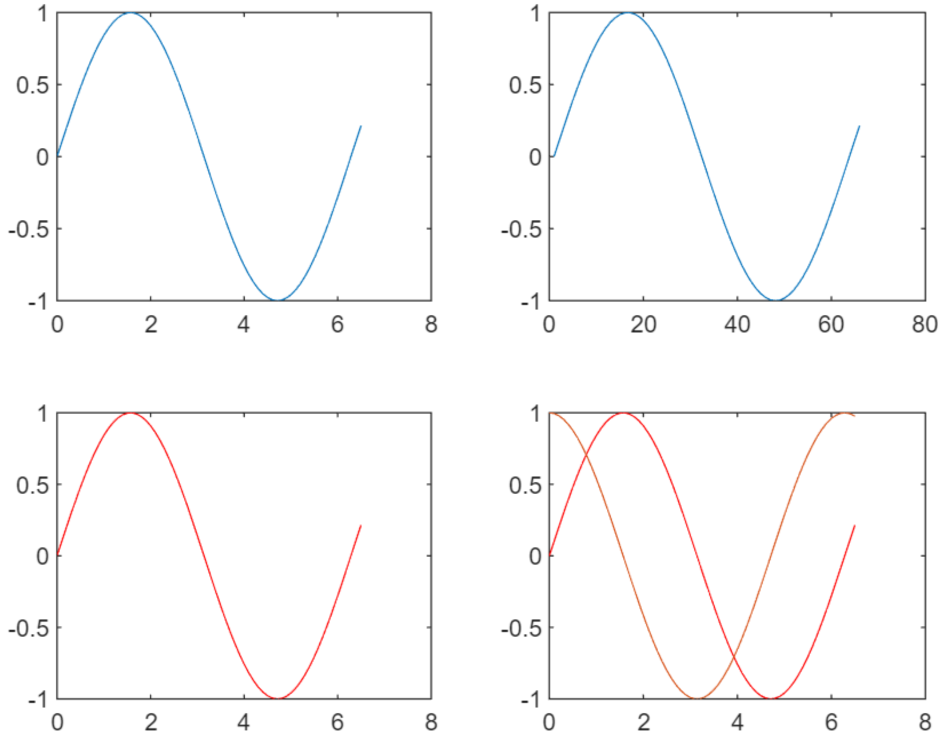


```
fplot(x,y,[0 5],"Color",'m',"LineStyle","--")
```



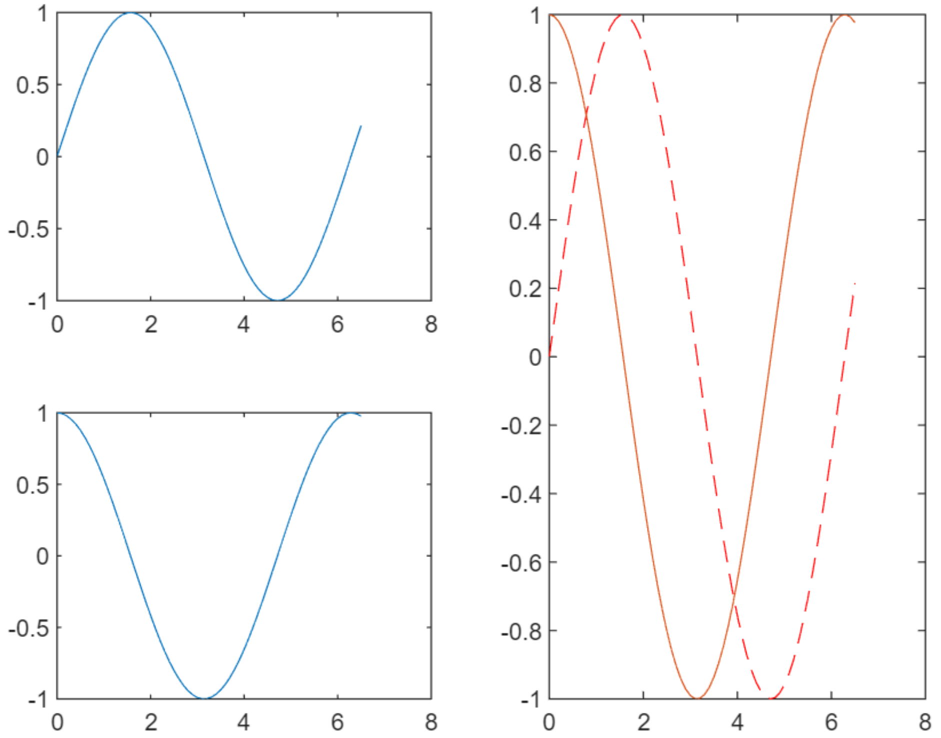
subplot

```
clf;
subplot(2,2,1); plot(t,sigx);
subplot(2,2,2); plot(sigx);
subplot(2,2,3); plot(t,sigx,'-r');
subplot(2,2,4); plot(t,sigx,'-r',t,sigy);
```



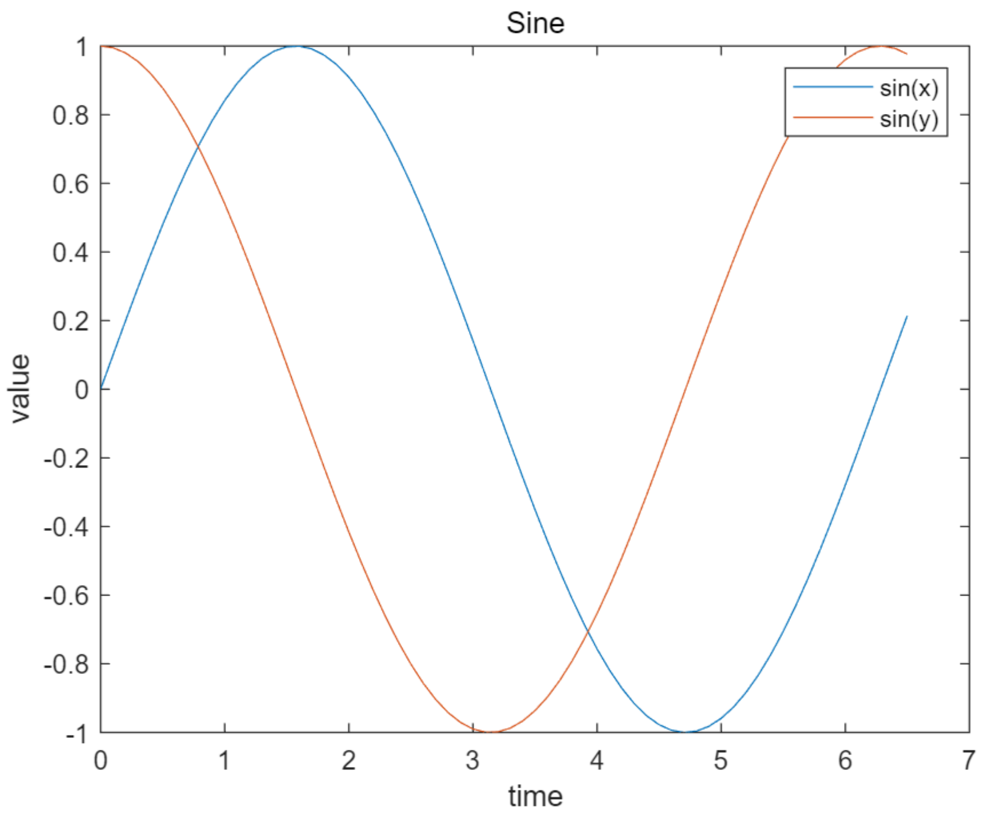
subplot merge area（合并区域绘图）

```
clf;
subplot(2,2,1); plot(t,sigx);
subplot(2,2,3); plot(t,sigy);
subplot(2,2,[2 4]); plot(t,sigx,'--r',t,sigy);
```



Label & Title & Legend（绘图标注）

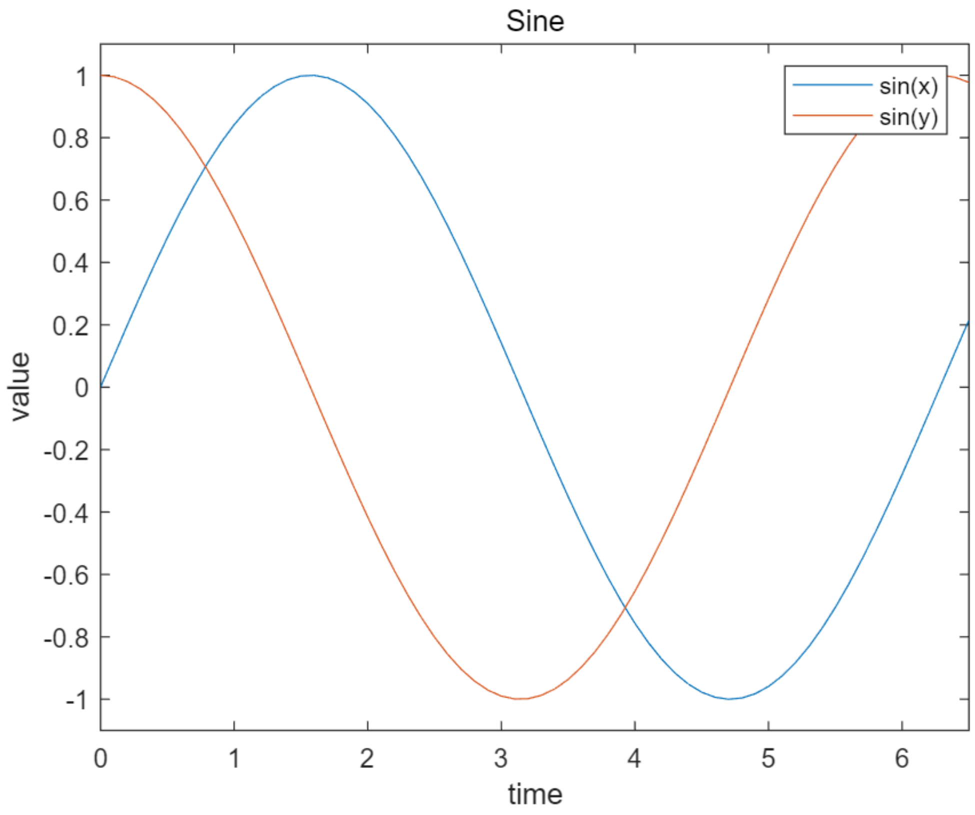
```
clf;
plot(t,sigx,t,sigy);
title('Sine');
xlabel('time');
ylabel('value');
legend('sin(x)','sin(y)');
```



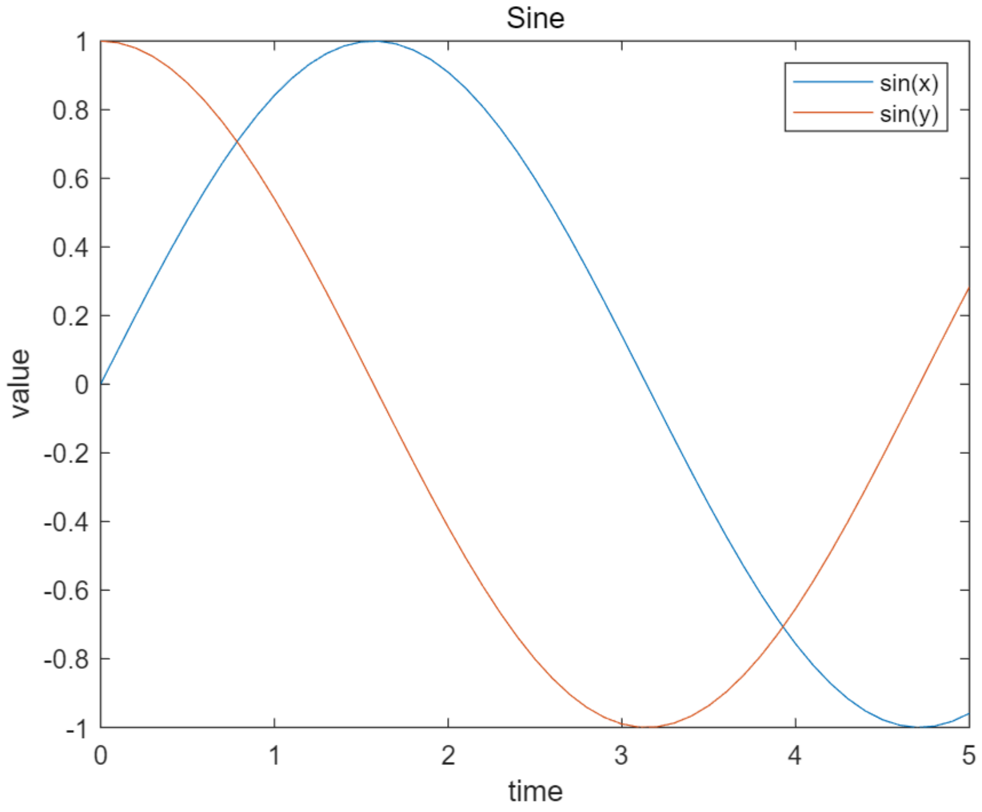
Range（设定图片显示范围）

When several pictures have a comparative relationship, the display range should be set to be consistent.

```
axis([0 6.5 -1.1 1.1]);
```

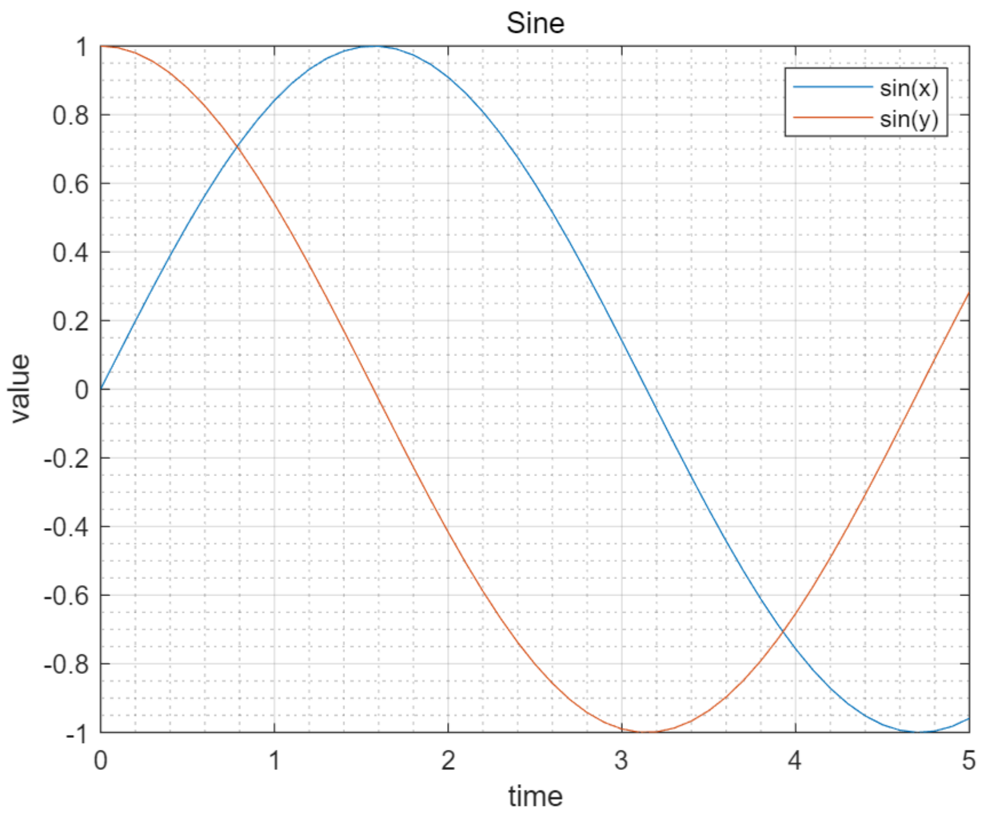


```
xlim([0 5]);
ylim([-1 1]);
```



Grid（网格）

```
grid on;
grid minor;
```



Functions to Generate Elementary Signal（数值法及符号法创建信号）

Both methods is ok：sin、cos、sinc、exp、heaviside、diract（两种方法均可的函数）

sin(t)、cos(t)

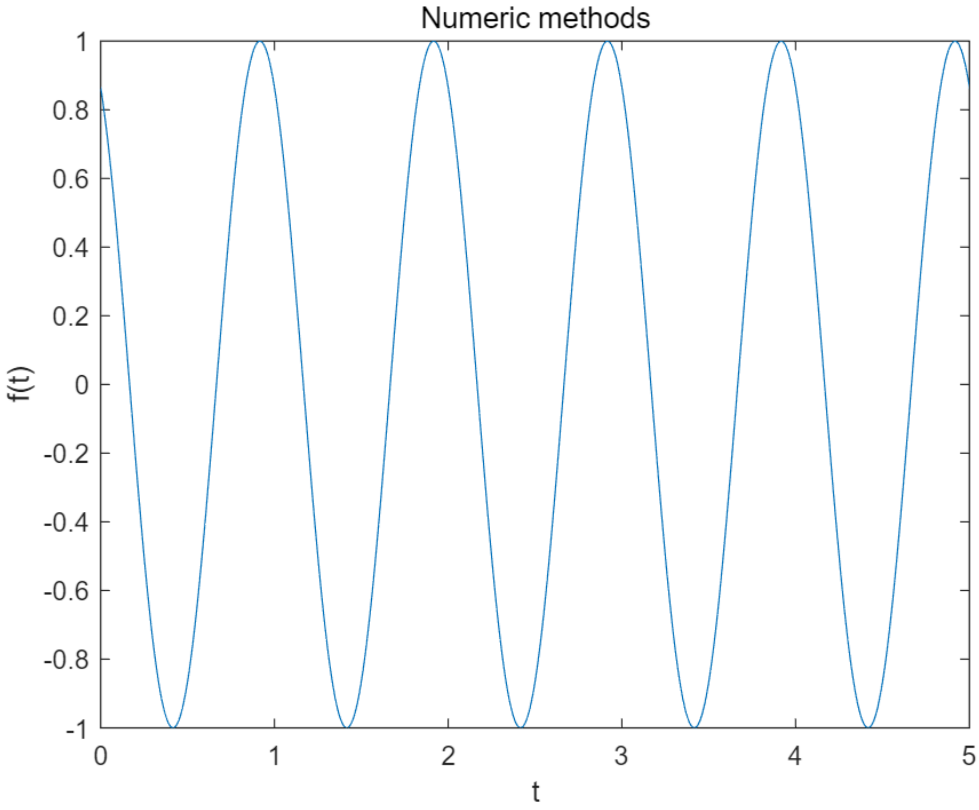
(三角函数，多用途)

t：time axis（时间轴）

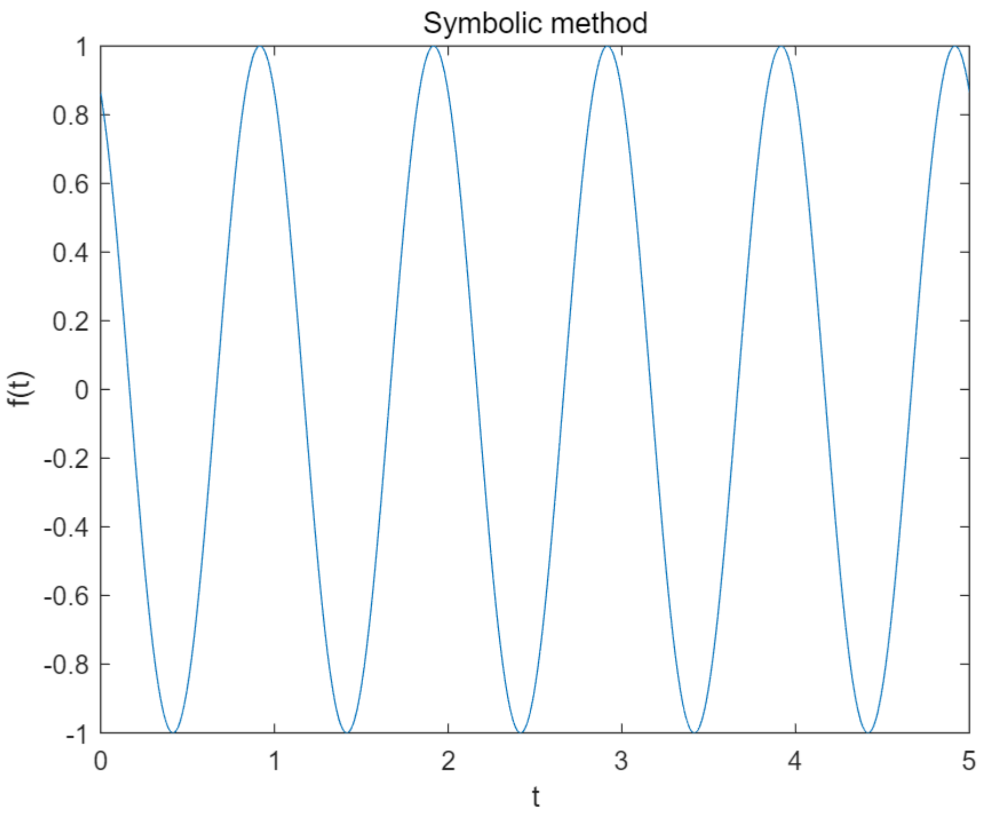
Radian frequency and radian is used for **cos** and **sin**.

（Matlab中三角函数使用的是角频率和弧度值，不是频率和角度值）

```
clear; clf;
A = 1;
w = 2*pi;
phi = pi/6;
% Numeric methods
t = 0:0.01:10;
fn = A*cos(w*t+phi);
plot(t,fn); axis([0 5 -1 1]);
xlabel("t");ylabel("f(t)");title('Numeric methods');
```



```
% Symbolic methods （不做要求）
syms ts
fs = A*cos(w*ts+phi);
fplot(fs); axis([0 5 -1 1]);
xlabel("t");ylabel("f(t)");title('Symbolic method');
```



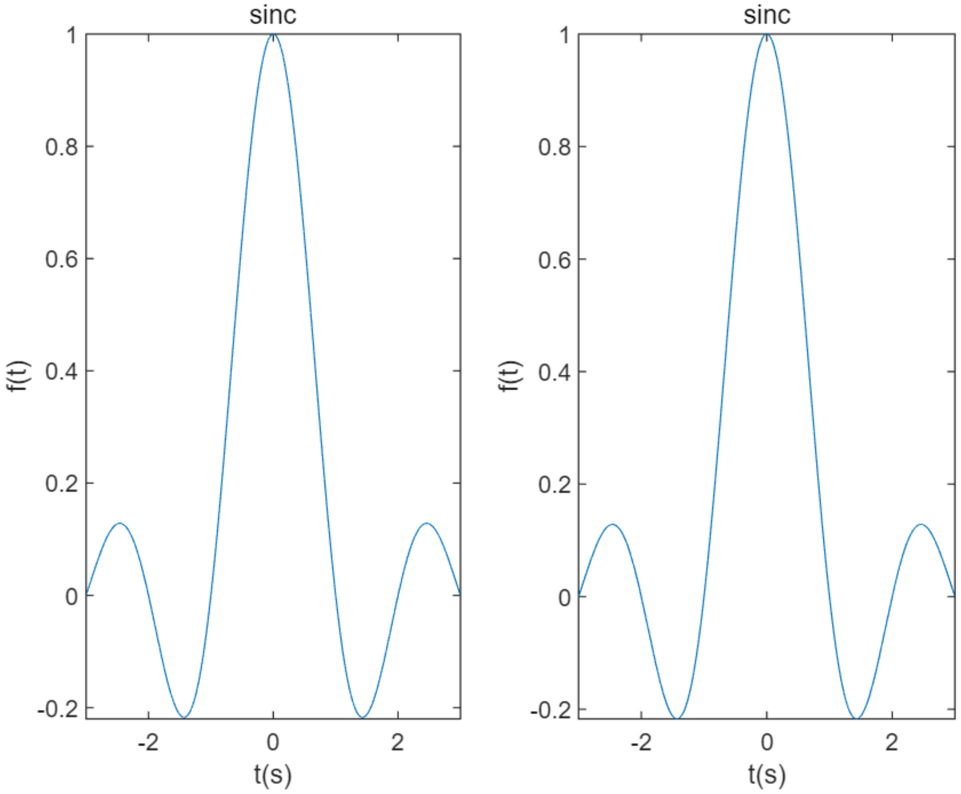
Sampling: **sinc(t)**

（采样信号）

t: time axis（时间轴）

```
clear; clf;
% Numeric methods
t = -3:0.01:3;
ft = sinc(t);
subplot(1,2,1);plot(t,ft); axis([-3 3 -0.22 1])
title('sinc'); xlabel('t(s)');ylabel('f(t)');

% Symbolic methods （不做要求）
syms x
y =sinc(x);
subplot(1,2,2);fplot(y,[-3 3])
title('sinc'); xlabel('t(s)');ylabel('f(t)');
```

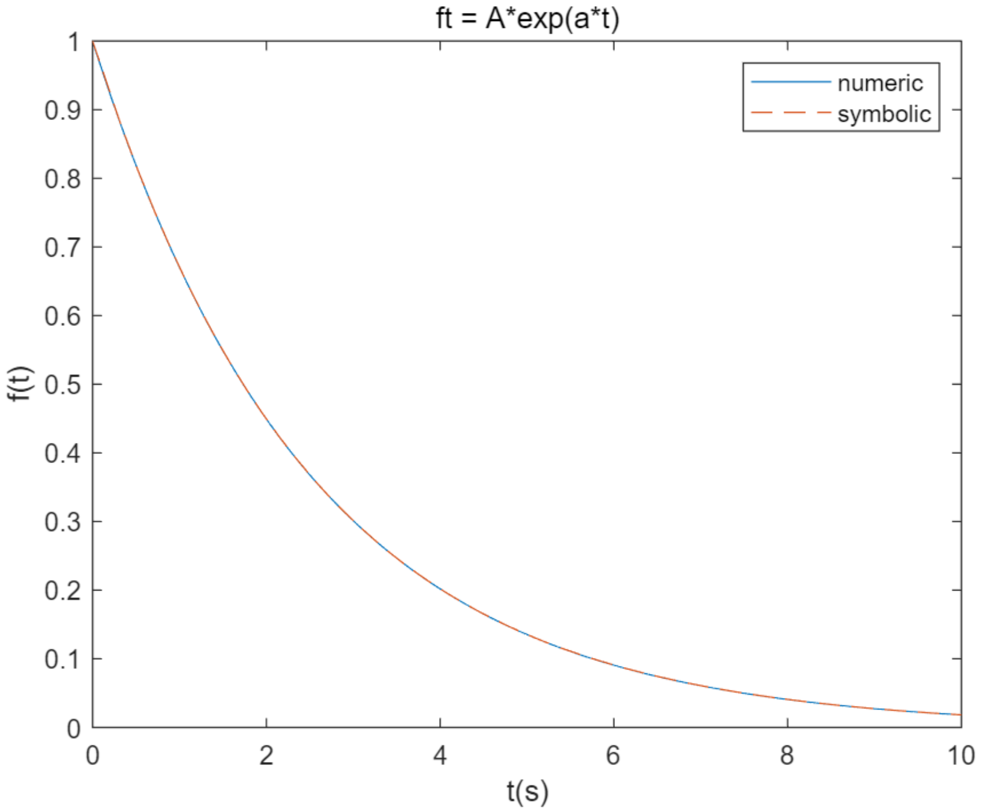


Exponential: **A*exp(a*t)**

（指数信号）

t: time axis（时间轴）

```
clear; clf;
A = 1;  a = -0.4;
% Numeric methods
t = 0:0.01:10;
ft = A*exp(a*t);
plot(t,ft); hold on;
% Symbolic methods
syms x
y = A*exp(a*x);
fplot(x,y,[0 10],'--'); hold off;
title('ft = A*exp(a*t)'); xlabel('t(s)');ylabel('f(t)');legend("numeric","symbolic");
```



Aperiodic Triangle： tripuls(t,w,s)

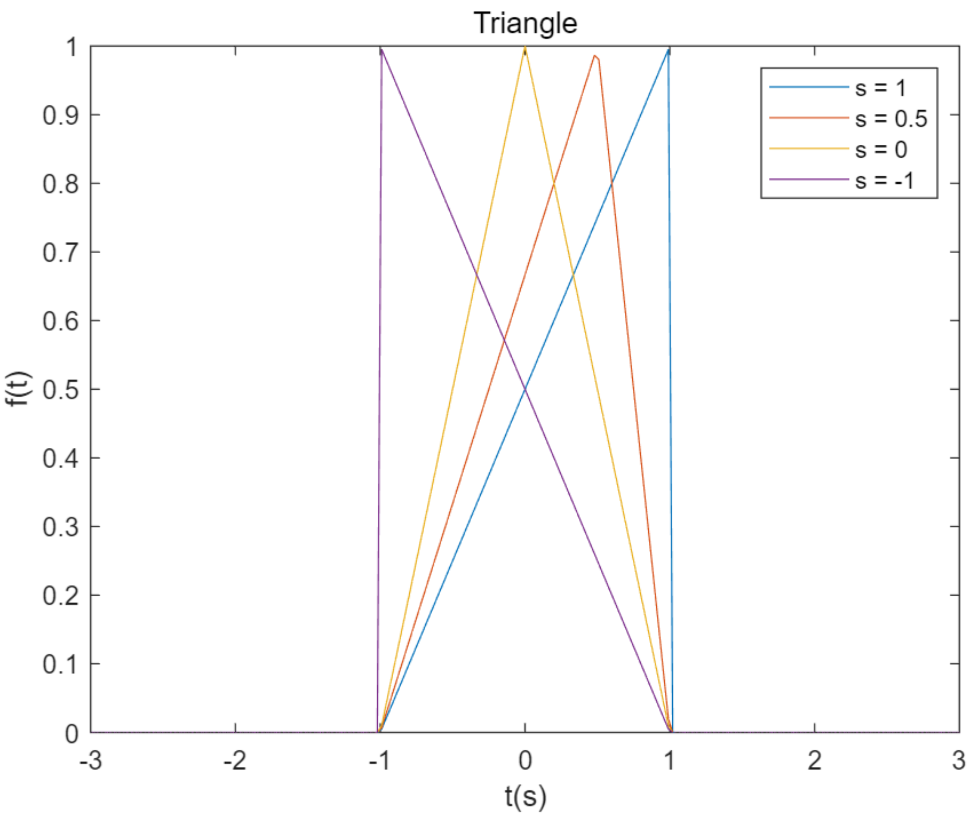
（ 三角（形）信号）

t：time axis（时间轴）

w：The width of the base of the triangle, centered at 0.（三角形的底边宽度，以0为中心）

s：Vertex position, range: [-1 1].（顶点位置， 范围： [-1 1]）

```
clear; clf;
t = -3:0.03:3;
ft1 = tripuls(t,2,1);
ft2 = tripuls(t,2,0.5);
ft3 = tripuls(t,2,0);
ft4 = tripuls(t,2,-1);
plot(t,ft1,t,ft2,t,ft3,t,ft4);
title('Triangle'); xlabel('t(s)');ylabel('f(t)');
legend('s = 1','s = 0.5','s = 0 ','s = -1')
```



Sawtooth or triangle wave：sawtooth(t,xmax)

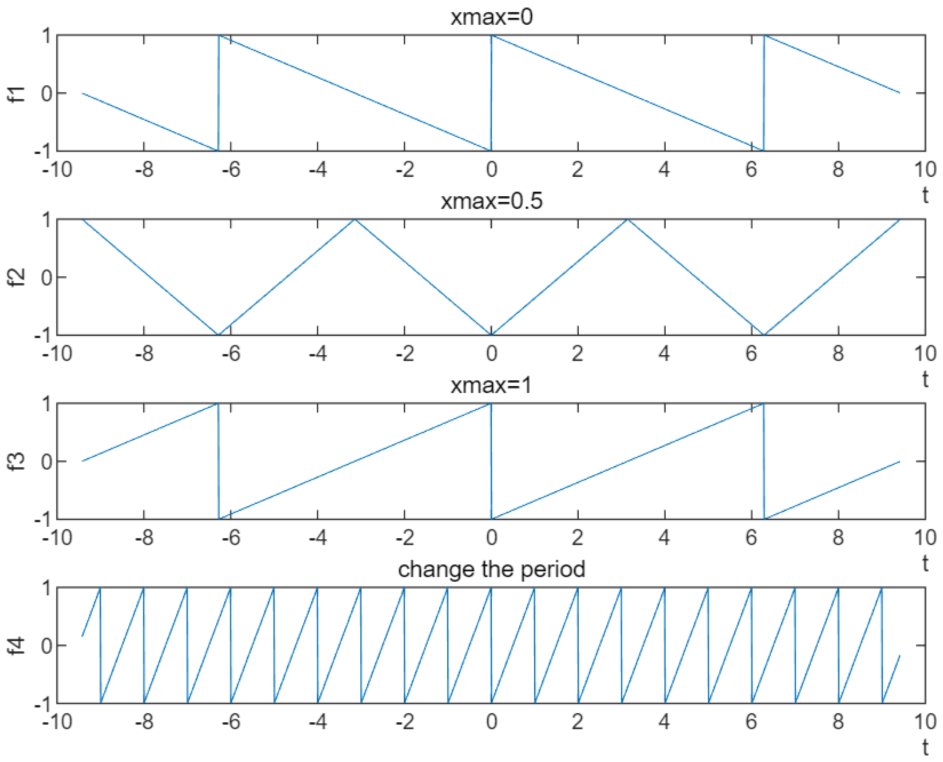
（锯齿波）

t：time axis（时间轴）

xmax：Vertex position, range: [0 1], periodic: 2pi（ 顶点位置， 范围：[0 1]，周期：2pi）

```
clear; clf;
t = -3*pi:0.01:3*pi;
ft1 = sawtooth(t,0);
ft2 = sawtooth(t,0.5);
ft3 = sawtooth(t,1);
subplot(4,1,1); plot(t,ft1); title('xmax=0'); xlabel('t','position',[10 -1.5 0]);ylabel('f1');
subplot(4,1,2); plot(t,ft2); title('xmax=0.5'); xlabel('t','position',[10 -1.5 0]);ylabel('f2')
subplot(4,1,3); plot(t,ft3); title('xmax=1'); xlabel('t','position',[10 -1.5 0]);ylabel('f3');

ft4 = sawtooth(2*pi*t,1);
subplot(4,1,4); plot(t,ft4); title('change the period'); xlabel('t','position',[10 -1.5 0]);yla
```



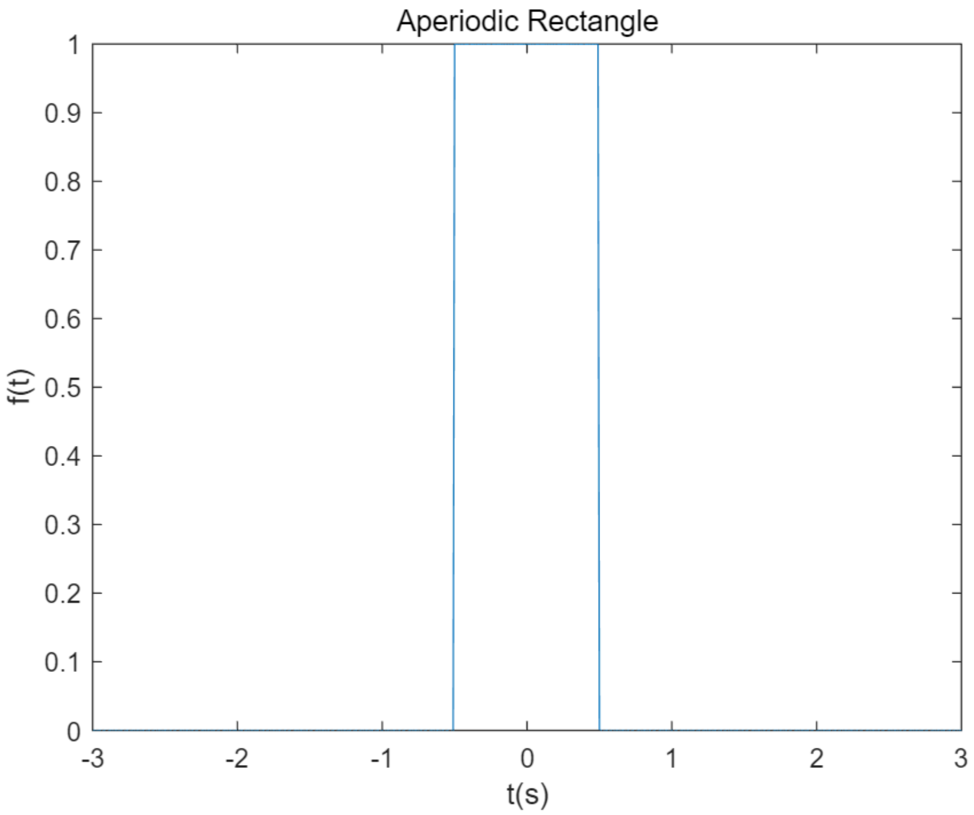
Aperiodic Rectangle：rectpuls(t,w)

（矩形（窗）信号）

t：time axis（时间轴）

w：rectangle width（矩形宽度）

```
clear; clf;
t = -3:0.01:3;
ft = rectpuls(t,1);
plot(t,ft);
title('Aperiodic Rectangle'); xlabel('t(s)');ylabel('f(t)');
```



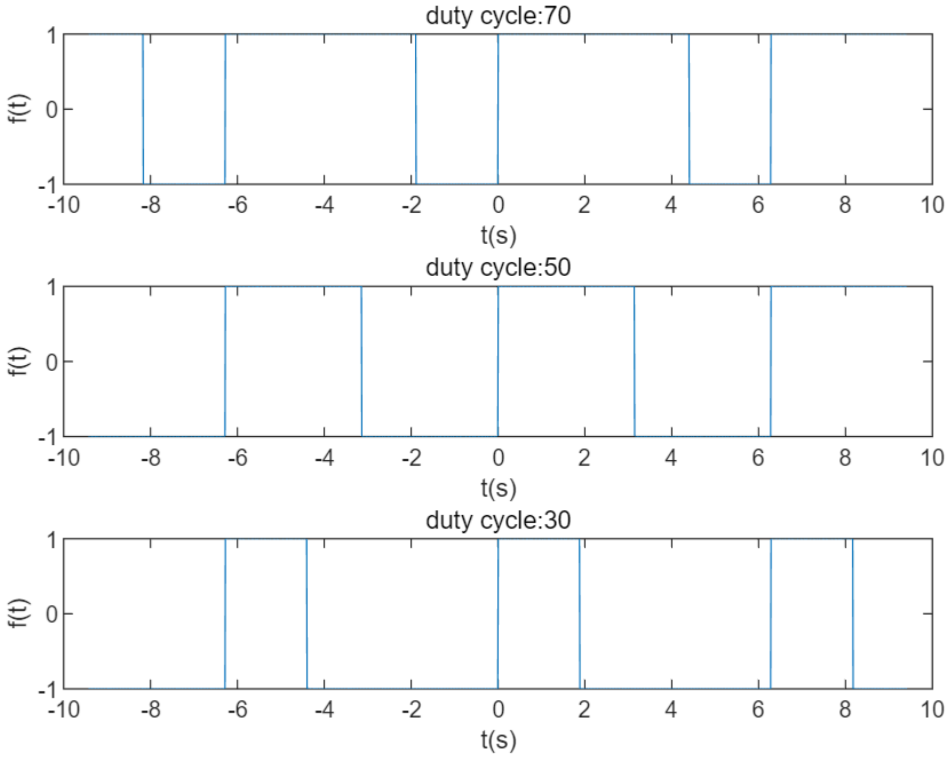
Square Wave：square(t,d)

（方波信号）

t：time axis（时间轴）

d：Duty cycle, the proportion of the positive part of the signal, range: [0 100]（占空比，信号为正的部分所占比例，范围：[0 100]）

```
t = -3*pi:0.01:3*pi;
ft = square(t,70);
subplot(3,1,1); plot(t,ft); title('duty cycle:70'); xlabel('t(s)');ylabel('f(t)');
ft = square(t,50);
subplot(3,1,2); plot(t,ft); title('duty cycle:50'); xlabel('t(s)');ylabel('f(t)');
ft = square(t,30);
subplot(3,1,3); plot(t,ft); title('duty cycle:30'); xlabel('t(s)');ylabel('f(t)');
```


duty cycle:70

duty cycle:50

duty cycle:30

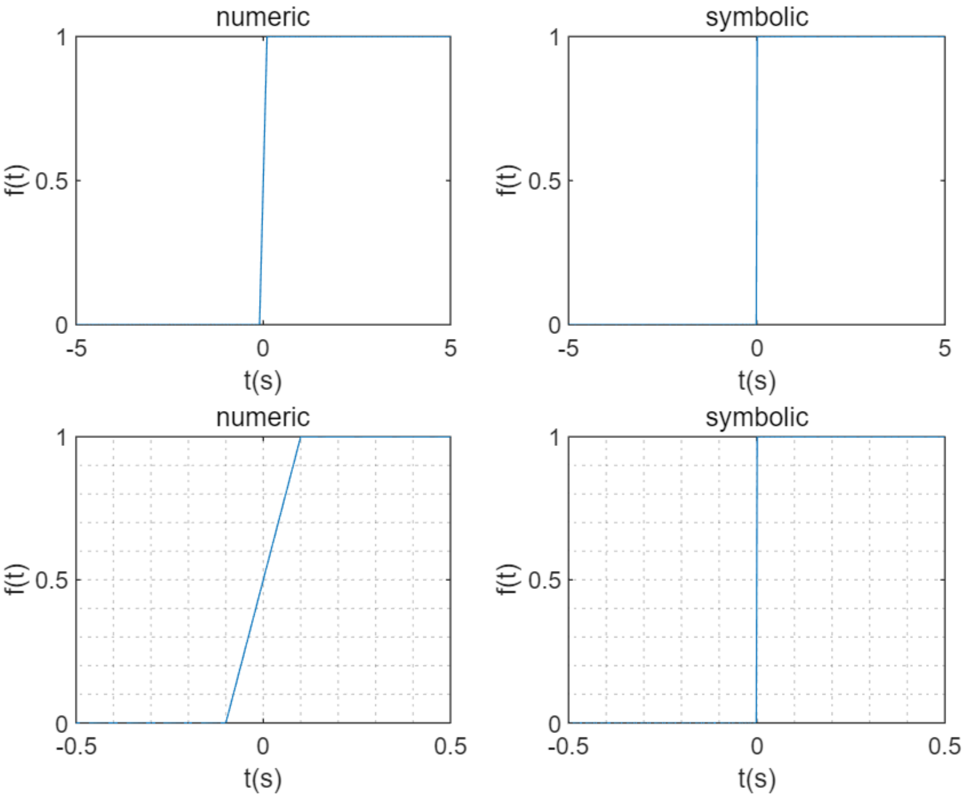
Step Function：heaviside(t)

（阶跃信号）

```
clear;clf;
t = -5:0.1:5;
ft = heaviside(t);

syms x
y = heaviside(x);

subplot(2,2,1); plot(t,ft); title('numeric');xlabel('t(s)');ylabel('f(t)');
subplot(2,2,2); fplot(x,y); title('symbolic');xlabel('t(s)');ylabel('f(t)');
subplot(2,2,3); plot(t,ft); axis([-0.5 0.5 -inf inf]); title('numeric');xlabel('t(s)');ylabel('
subplot(2,2,4); fplot(x,y,[-0.5 0.5]); title('symbolic');xlabel('t(s)');ylabel('f(t)');grid mir
```



Signal Operation（信号运算）

Dot Operation & Matrix Operation

The difference between the operation with and without dot.

```
clear; clf;
b = ones(3,3)       % 1*5 matrix
```

```
b = 3×3
     1     1     1
     1     1     1
     1     1     1
```

```
c = 2*ones(3,3)       % 1*5 matrix
```

```
c = 3×3
     2     2     2
     2     2     2
     2     2     2
```

```
b*c
```

```
ans = 3×3
     6     6     6
     6     6     6
     6     6     6
```

```
b.*c
```

```
ans = 3×3
     2     2     2
     2     2     2
     2     2     2
```

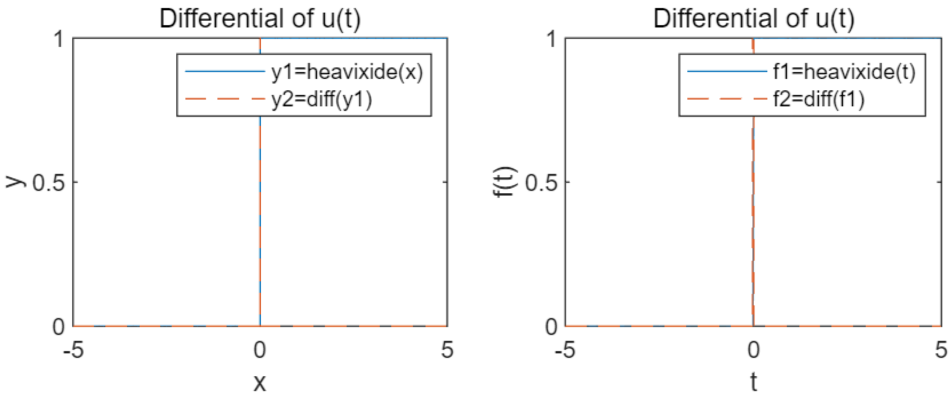
Differential and Integral（微分和积分）

Differential（微分/差分）

diff(S, 'V', N)

```
clear; clf;
% symbolic method
syms x
y1 = heaviside(x);          % 阶跃信号
y2 = diff(y1,x);            % 微分，y1对x进行微分（求导，定义详见数学分析&高等数学）
subplot(2,2,1);
fplot(y1);hold on;
fplot(sign(y2),'--'); hold off;
legend("y1=heavixide(x)","y2=diff(y1)")
xlabel("x"); ylabel('y');title('Differential of u(t)')

% numeric method
dt = 0.01;
t = -5:dt:5;
f1 = heaviside(t);
f2 = diff(f1)/dt;
subplot(2,2,2);
plot(t,f1);hold on;
plot(t(1:end-1),f2,"--");hold off;
axis([-5 5 0 1]);
legend("f1=heavixide(t)","f2=diff(f1)")
xlabel("t"); ylabel('f(t)');title('Differential of u(t)')
```



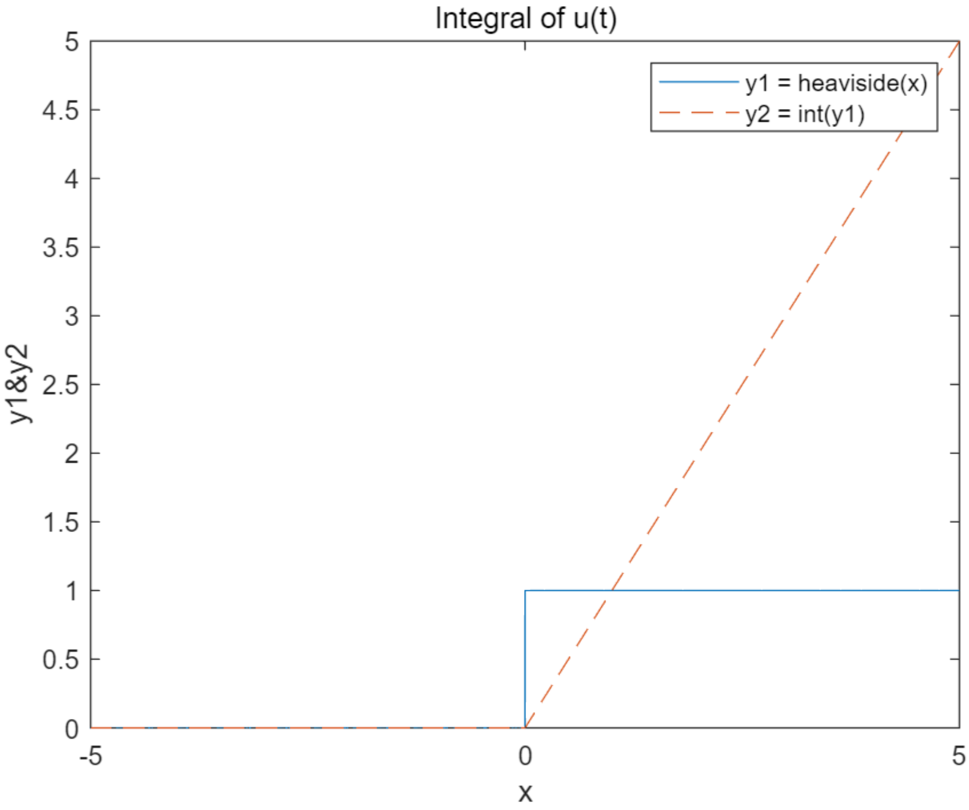
Integral（积分）

Indefinite integral（不定积分）：

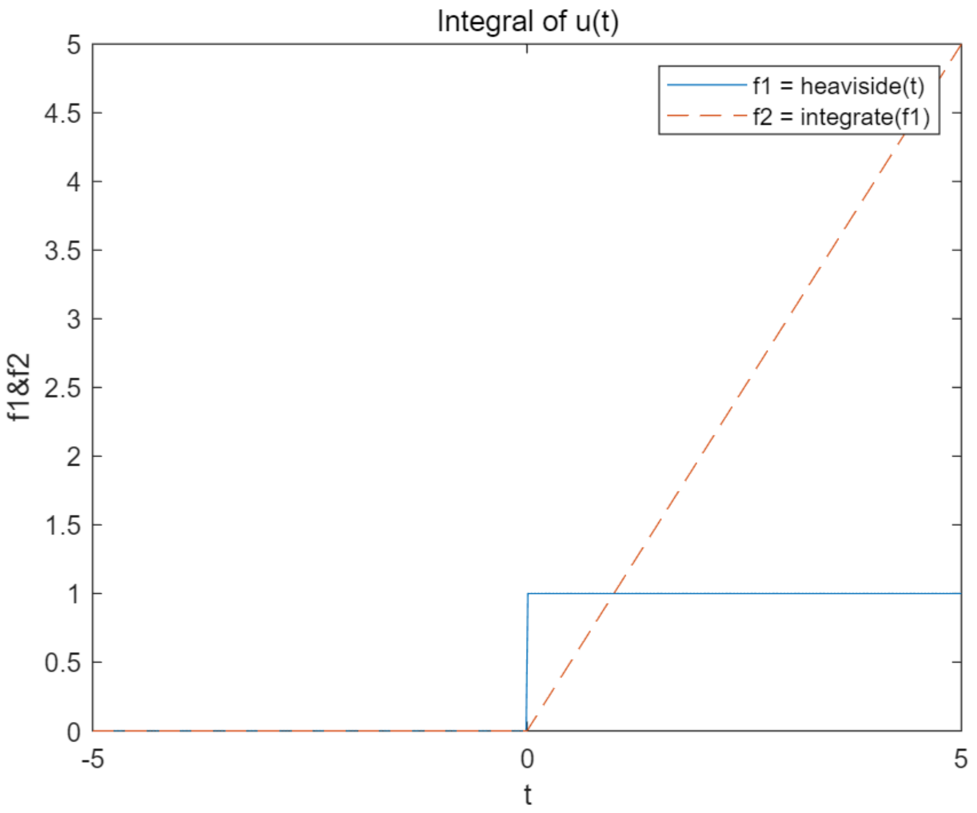
symbolic method：int(S, v)

numeric method：cumtrapz(t, y)

```
clear; clf;
% symbolic method
syms x
c = 0;
y1 = heaviside(x);
y2 = int(y1,x)+c;           % 积分，y1对x进行积分（定义详见数学分析&高等数学）
fplot(y1);hold on;
fplot(y2,'--');hold off;
legend('y1 = heaviside(x)','y2 = int(y1)');
xlabel('x');ylabel('y1&y2');title('Integral of u(t)')
```



```
% numeric method
dt = 0.01;
t = -5:dt:5;
f1 = heaviside(t);
f2 = cumtrapz(t, f1)+c;                 % 如何使用help
plot(t,f1,t,f2,'--');
legend('f1 = heaviside(t)','f2 = integrate(f1)');
xlabel('t');ylabel('f1&f2');title('Integral of u(t)')
```



definite integral（定积分）：

symbolic method： int(S, v, a, b)

numeric method： trapz(t, y)

```
clear; clf;
% symbolic method
syms t1
int(heaviside(t1),-1,2)          % 查阅help
```

```
ans = 2
```

```

% numeric method
t2 = -1:0.01:2;
trapz(t2,heaviside(t2))          % 查阅help
```

```
ans = 2
```

Programing Structure（结构）

Loop（循环）

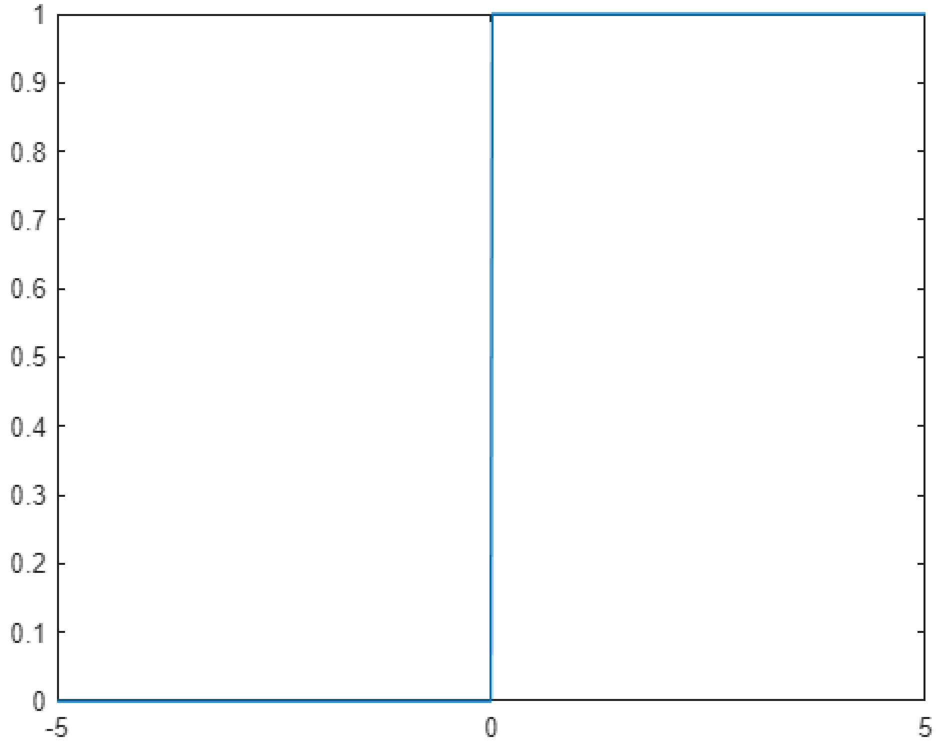
```
% for loop
a = zeros(1,10);
```

```
for i = 1:10
    a(i) = i;
end                 % 结束需要end
a
```

```
a = 1×10
     1     2     3     4     5     6     7     8     9    10
```

Branch（分支）

```
% if-else-end
t = -5:0.01:5;
f = zeros(1,length(t));
for i=1:length(t)
    if t(i) < 0
        f(i) = 0;
    elseif t(i) == 0        % 与python中elif相同
        f(i) = 0.5;
    else
        f(i) = 1;
    end
end
clf
plot(t, f);
```


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-5
0
5