International University
School of Electrical Engineering

Introduction to Computers for Engineers

Dr. Hien Ta

Lecturely Topics

Lecture 1 - Basics – variables, arrays, matrices
Lecture 2 - Basics – matrices, operators, strings, cells
Lecture 3 - Functions & Plotting
Lecture 4 - User-defined Functions
Lecture 5 - Relational & logical operators, if, switch statements
Lecture 6 - For-loops, while-loops
Lecture 7 - Review on Midterm Exam
Lecture 8 - Solving Equations & Equation System (Matrix algebra)
Lecture 9 - Data Fitting & Integral Computation
Lecture 10 - Representing Signal and System
Lecture 11 - Random variables & Wireless System
Lecture 12 - Review on Final Exam

References: H. Moore, *MATLAB for Engineers*, 4/e, Prentice Hall, 2014
G. Recktenwald, *Numerical Methods with MATLAB*, Prentice Hall, 2000
A. Gilat, *MATLAB, An Introduction with Applications*, 4/e, Wiley, 2011

Topics

Relational and logical operators
Precedence rules
Logical indexing

`find` function

Program flow control

`if` – statements
`switch` – statements

Examples:
piece-wise functions, unit-step function, indicator functions, sinc function, echoes

Relational and Logical Operators

Relational and logical functions

```
find, logical, true, false, any, all

ischar, isequal, isfinite, isinf, isinteger
islogical, isnan, isreal
```

```
>> doc is*            % list of all 'is' functions
>> help logical       % convert to logical
>> help true          % logical 1
>> help false         % logical 0
>> help relop         % relational operators
>> help ops           % same as help /
>> help find          % indices of non-zero elements
```

```
>> help precedence
```

Relational Operators

>> help relop

`==`	equal
`~=`	not equal
`<`	less than
`>`	greater than
`<=`	less than or equal
`>=`	greater than or equal

Logical Operators

`&`	logical AND,	e.g., `A&B`, `A,B=expressions`
`|`	logical OR,	e.g., `A|B`
`~`	logical NOT,	e.g., `~A`
`&&`	logical AND for scalars w/ short-circuiting	
`||`	logical OR for scalars w/ short-circuiting	
`xor`	exclusive OR,	e.g., `xor(A,B)`
`any`	true if any elements are non-zero	
`all`	true if all elements are non-zero	

Operator Precedence in MATLAB (from highest to lowest):

1. transpose (.'), power (.^), conjugate transpose ('), matrix power (^)
2. unary plus (+), unary minus (−), logical negation (~)
3. multiplication (.*), right division (./), left division (.\), matrix multiplication (*), matrix right division (/), matrix left division (\)
4. addition (+), subtraction (−)
5. colon operator (:)
6. less than (<), less than or equal to (<=), greater than (>), greater than or equal to (>=), equal to (==), not equal to (~=)
7. element-wise logical AND (&)
8. element-wise logical OR (|)
9. short-circuit logical AND (&&)
10. short-circuit logical OR (||)

```
>> help precedence
```

```
>> a = [1, 0, 2, -3, 7];
>> b = [3, 4, 2, -1, 7];

>> a == b
ans =
     0     0     1     0     1

>> k = a == b      % clearer notation, k = (a==b)
ans =
     0     0     1     0     1

>> class(k)
ans =
     logical

>> a(k)
ans =
     2     7
```

logical indexing

```
>> a = [1, 0, 2, -3, 7];
>> b = [3, 4, 2, -1, 7];

>> a == b
ans =
     0     0     1     0     1

>> k = a == b      % clearer notation, k = (a==b)
ans =
     0     0     1     0     1

>> i = find(a==b)
i =
     3     5

>> a(i)
ans =
     2     7
```

using **find**

regular indexing

`a(a==b), a(find(a==b))`

```
>> a = [1, 0, 2, -3, 7];
>> b = [3, 4, 2, -1, 7];

>> a == b
ans =
     0     0     1     0     1
>> a ~= b
ans =
     1     1     0     1     0


>> i = find(a~=b)
i =
     1     2     4

>> a(i),b(i)
ans =
     1     0    -3
ans =
     3     4    -1
```

```
>> a = [1, 0, 2, -3, 7];

>> ~a
ans =
     0     1     0     0     0

>> a==0
ans =
     0     1     0     0     0

>> i = find(~a)
i =
     2
```

finds the zero entries of **a**

```
>> a = [1, 0, 2, -3, 7];

>> a~=0
ans =
     1     0     1     1     1
>> ~~a
ans =
     1     0     1     1     1

>> logical(a)
ans =
     1     0     1     1     1

>> i = find(a)
i =
     1     3     4     5

>> a(find(a))
ans =
     1     2    -3     7
```

finds the non-zero entries of **a**

```
>> a = [1, 0, 2, -3, 7];
>> b = [3, 4, 2, -1, 7];
```

case 1: both **a,b** are vectors

```
>> a<b, a>=b
```

a,b are compared element-wise

```
ans =
     1     1     0     1     0
ans =
     0     0     1     0     1

>> i = find(a<b)
i =
     1     2     4

>> a(a<b), a(find(a<b))
ans =
     1     0    -3
ans =
     1     0    -3
```

```
>> a = [1, 0, 2, -3, 7];
>> b = 1;
```

case 2: **a,b** are vector,scalar

```
>> a>=b
```

compare each element of **a** to the scalar **b**

```
ans =
      1     0     1     0     1

>> i = find(a>=b)
i =
      1     3     5

>> a(a>=b), a(find(a>=b)), a(a<b)
ans =
      1     2     7
ans =
      1     2     7
ans =
      0    -3
```

```
>> a = [1, 0, 2, -3, 7];
>> b = [3, 4, 2, -1, 7];

>> a>=1
ans =
     1     0     1     0     1

>> b<=2
ans =
     0     0     1     1     0

>> a>=1 & b<=2          % logical AND
ans =
     0     0     1     0     0

>> a>=1 | b<=2          % logical OR
ans =
     1     0     1     1     1
```

logical operations

logical indexing

```
>> a = [1, 3, 4, -3, 7];

>> k = (a>=2), i = find(a>=2)
k =
     0     1     1     0     1
i =
     2     3     5
```

class(k) is logical

```
>> a(i), a(k)
ans =
     3     4     7
ans =
     3     4     7
```

logical indexing

a(a>=2)

```
>> n = [0 1 1 0 1]
>> a(n)
??? Subscript indices must either be real
positive integers or logicals.

% but note, a(logical(n)) works
```

class(n) is double, but n==k is true

more on logical indexing

```
>> A = [3 4 nan; -5 inf 2]
A =
      3      4    NaN
     -5    Inf      2

>> k = isfinite(A)
k =
      1      1      0
      1      0      1

>> A(k)       % listed column-wise
ans =
      3
     -5
      4
      2

>> A(~k)=0    % set non-finite
A =           % entries to zero
      3      4      0
     -5      0      2
```

```
>> find(k)
ans =
     1
     2
     3
     6
```

```
>> [i,j] = find(k)
[i,j] =
          1   1
          2   1
          1   2
          2   3
```

```
>> A = [3 4 0; -5 5 2]
A =
     3     4     0
    -5     5     2

>> A>2
ans =
     1     1     0
     0     1     0

>> k = find(A>2)
k =
     1
     3
     4
```

```
>> [i,j] = find(A>2);
[i,j] =
        1   1
        1   2
        2   2

>> A(find(A>2))
ans =
     3
     4
     5
```

```
>> K = ['1'    '2'    '3'
        '4'    '5'    '6'
        '7'    '8'    '9'
        '*'    '0'    '#'];
```

find can also be applied to a matrix of characters, e.g., the keypad matrix from week-3

```
>> K=='8'
ans =
     0     0     0
     0     0     0
     0     1     0
     0     0     0
```

compares every element of K with '8'

find the location of the correct element of K

```
>> [i,j] = find(K=='8')
i =
     3
j =
     2
```

i,j matrix indices of the location of '8'

```
>> q = find(K=='8')
q =
     7
```

q is the column-wise index of '8' in K

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

```
>> A<B
ans =
     0   0   1
     1   0   1
     0   0   0
```

```
>> find(A<B)
ans =
     2
     7
     8
```

```
[i,j]=find(A<B)
i =    j =
   2      1
   1      3
   2      3
```

```
>> A==9
ans =
     1   1   0
     0   0   0
     1   0   1
```

```
>> find(A==9)
ans =
     1
     3
     4
     9
```

```
>> A(A==9)=-9
A =
    -9   -9    2
     2    5    4
    -9    8   -9
```

any, all

```
A = [9   9   2
     2   5   4
     9   8   9];
```

```
B = [7   1   7
     3   4   8
     9   4   2];
```

```
any(A==2)
ans =
     1   0   1

any(A==2,2)
ans =
     1
     1
     0
```

```
all(A>B)
ans =
     0   1   0

all(A>B,2)
ans =
     0
     0
     0
```

```
A==B
ans =
     0   0   0
     0   0   0
     1   0   0

any(A==B)
ans =
     1   0   0

any(any(A==B))
ans =
     1
```

```
all(all(A==B));
```

`any,all` operate column-wise, or, row-wise with extra argument

```
>> A = [36 -4 9; 16 9 -25], B = A;

A =
    36    -4     9
    16     9   -25


>> k = (B>=0)

k =
     1     0     1
     1     1     0


>> B(k) = sqrt(B(k));
>> B(~k) = -sqrt(-B(~k))

B =
     6    -2     3
     4     3    -5
```

Example:
take square-roots of the absolute values, but preserve the signs

Comparing Strings

Strings are arrays of characters, so the condition **s1==s2** requires both **s1** and **s2** to have the same length

```
>> s1 = 'short'; s2 = 'shore';
>> s1==s1
ans =
     1     1     1     1     1

>> s1==s2
ans =
     1     1     1     1     0

>> s1 = 'short'; s2 = 'long';
>> s1==s2
??? Error using ==> eq
Matrix dimensions must agree.
```

Comparing Strings

Use **strcmp** to compare strings of unequal length, and get a binary decision

```
>> s1 = 'short'; s2 = 'shore';
>> strcmp(s1,s1)
ans =
      1

>> strcmp(s1,s2)
ans =
      0

>> s1 = 'short'; s2 = 'long';
>> strcmp(s1,s2)
ans =
      0
```

```
>> doc strcmp
>> doc strcmpi
```

case-insensitive

Use **isequal** to compare the contents of matrices or arrays and get a binary decision

Program Flow Control

Program flow is controlled by the following control structures:

1. for . . . end   `% loops`
2. while . . . end
3. break, continue

4. if . . . end   `% conditionals`
5. if . . . else . . . end
6. if . . . elseif . . . else . . . end
7. switch . . . case . . . otherwise . . . end
8. return

for-loops and conditional ifs are by far the most commonly used control stuctures

if - statements

three forms of **if** statements

```
if condition
   statements ...
end
```

```
if condition
   statements ...
else
   statements ...
end
```

```
if condition1
   statements ...
elseif condition2
   statements ...
elseif condition3
   statements ...
else
   statements ...
end
```

several **`elseif`** statements may be present,

`elseif` does not need a matching **`end`**

Example

```
>> x = 1;
>> % x = 0/0
>> % x = 1/0

if isinf(x),
    disp('x is infinite');
elseif isnan(x),
    disp('x is not-a-number');
else
    disp('x is finite number');
end

x is finite number
% x is not-a-number
% x is infinite
```

switch - statements

```
switch expression0

  case expression1
      statements ...

  case expression2
     statements ...

  otherwise
     statements ...

end
```

expression0 is evaluated first, and if its value matches any of the cases expression1, expression2, … , then the corresponding case statements are executed

several case statements may be present

expression comparison rules:

numbers: **isequal(expression0, expression1)**
strings: **strcmp(expression0, expression1)**

Example: L_1, L_2, and L_∞ norms of a vector

$$\mathbf{x} = [x_1, x_2, \ldots, x_N]$$

$$\|\mathbf{x}\|_1 = \sum_{n=1}^{N} |x_n|$$

$$\|\mathbf{x}\|_2 = \sqrt{\sum_{n=1}^{N} |x_n|^2}$$

$$\|\mathbf{x}\|_\infty = \max\left(|x_1|, |x_2|, \ldots, |x_N|\right)$$

$$d(\mathbf{x}, \mathbf{y}) = \|\mathbf{x} - \mathbf{y}\|$$

used as distance measure between two vectors or matrices

discussed further in week 9

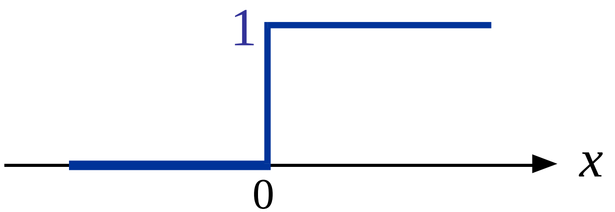
```
>> help norm     % vector and matrix norms
```

```
x = [1, 4, -5, 3];

p = inf;
% p = 1;
% p = 2;

switch p
    case 1
        N = sum(abs(x));                  % N = norm(x,1);
    case 2
        N = sqrt(sum(abs(x).^2));         % N = norm(x,2);
    case inf
        N = max(abs(x));                  % N = norm(x,inf);
    otherwise
        N = sqrt(sum(abs(x).^2));         % N = norm(x,2);
end

>> N
N =
     5
```

equivalent calculation using the built-in function **norm**

Example: unit-step function

$$u(x) = \begin{cases} 1, & x \geq 0 \\ 0, & \text{otherwise} \end{cases}$$

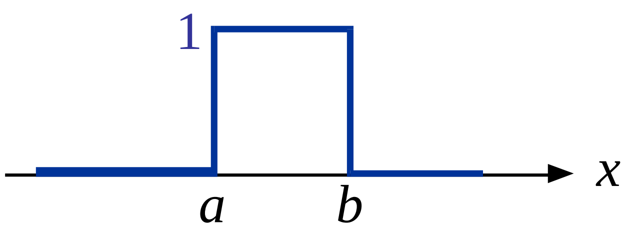



```
u = @(x) (x>=0);        % unit-step function
```

```
e.g., x =-3,-2,-1, 0, 1, 2, 3
    u(x)= 0, 0, 0, 1, 1, 1, 1
```

Example: indicator function

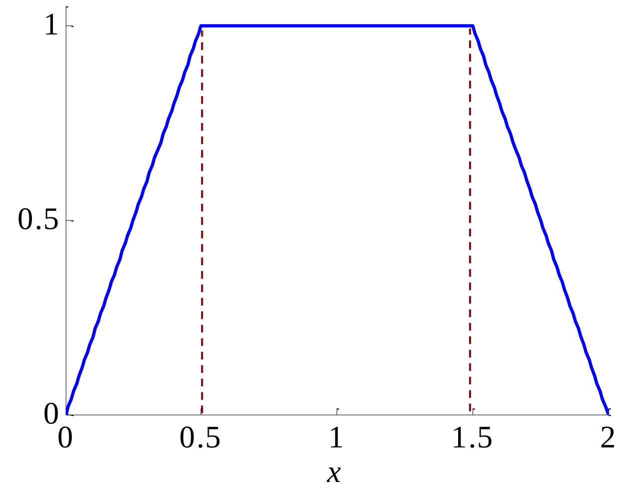
$$v(x,a,b) = u(x-a) - u(x-b)$$




```
v = @(x,a,b) u(x-a)-u(x-b);    % indicator
% v = @(x,a,b) (x>=a & x<b);   % alternative
```

Example: Defining piece-wise functions (method 1)

$$f(x) = \begin{cases} 2x, & 0 \le x \le 0.5 \\ 1, & 0.5 \le x \le 1.5 \\ 4 - 2x, & 1.5 \le x \le 2 \end{cases}$$

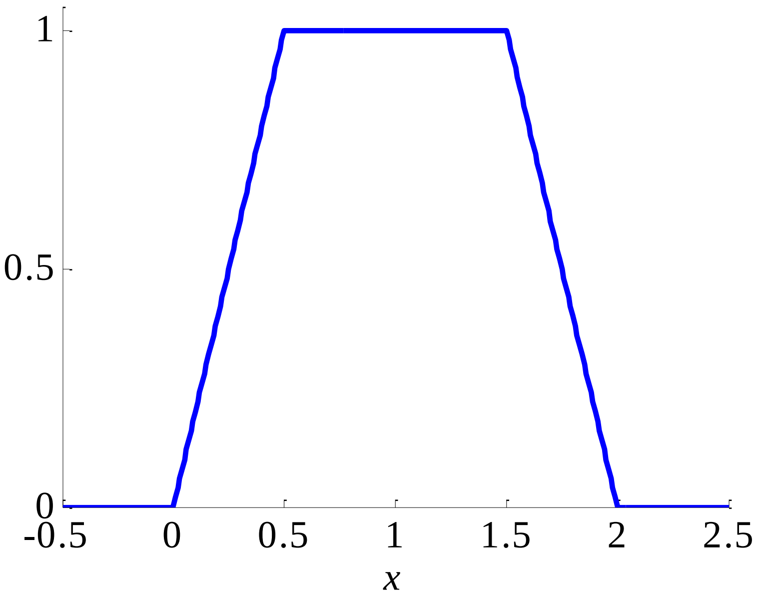


$$v(x, a, b) = \begin{cases} 1, & a \le x < b \\ 0, & \text{otherwise} \end{cases} = \text{(indicator function)}$$

$$f(x) = 2x\, v(x,\ 0,\ 0.5) + v(x,\ 0.5,\ 1.5) + (4 - 2x)\, v(x,\ 1.5,\ 2)$$

```
f = @(x) 2*x .* (x>=0 & x<0.5) + ...
                (x>=0.5 & x<1.5) + ...
       (4-2*x).* (x>=1.5 & x<2);

x = linspace(-0.5,2.5,301);

figure; plot(x,f(x), 'b-');
```

method 1 – vectorized
method 2 – vectorized
method 3 – not vectorized



Understanding the conditions `(x>=0 & x<0.5)`, etc.

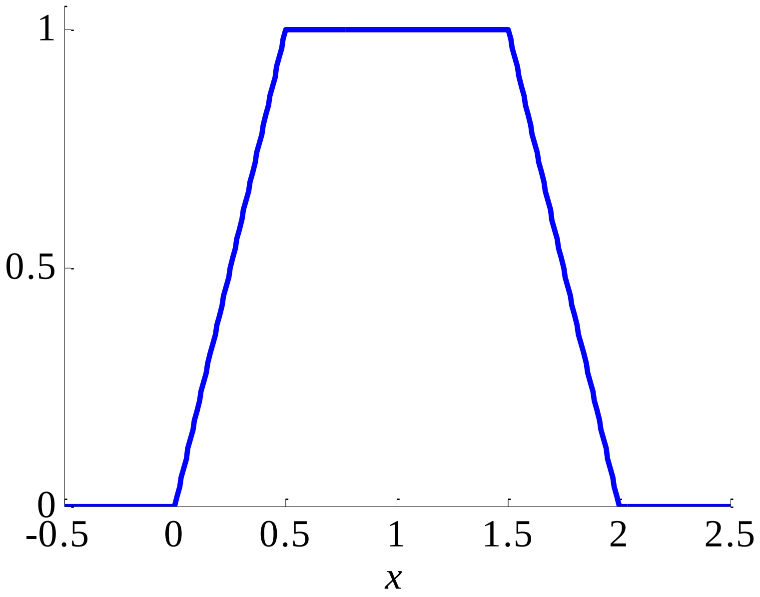
```
x = [-0.5 -0.4 -0.3 -0.2 -0.1  0.0  0.1  0.2 ...
       0.3  0.4  0.5  0.6  0.7  0.8  0.9  1.0 ...
       1.1  1.2  1.3  1.4  1.5  1.6  1.7  1.8 ...
       1.9  2.0  2.1  2.2  2.3  2.4  2.5];

(x>=0 & x<0.5)
ans =
  0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

(x>=0.5 & x<1.5)
ans =
  0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0

(x>=1.5 & x<2)
ans =
  0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0
```

```
[2*x.*(x>=0 & x<0.5); (x>=0.5 & x<1.5); (4-2*x).*(x>=1.5 & x<2)]'
```

```
ans =                                sum =
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
       0.2         0         0               0.2
       0.4         0         0               0.4
       0.6         0         0               0.6
       0.8         0         0               0.8
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         1         0                 1
         0         0         1                 1
         0         0       0.8               0.8
         0         0       0.6               0.6
         0         0       0.4               0.4
         0         0       0.2               0.2
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
         0         0         0                 0
```

Using the indicator function

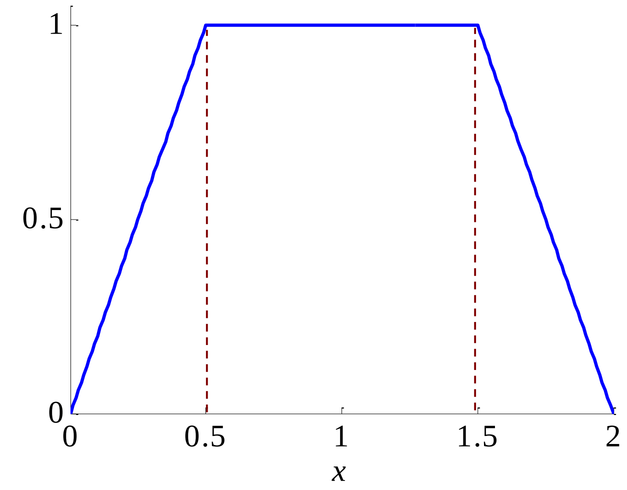
```
v = @(x,a,b) ((x>=a) & (x<b));

f = @(x) 2*x .* v(x, 0, 0.5) + ...
                v(x, 0.5, 1.5) + ...
     (4-2*x).* v(x, 1.5, 2);
```



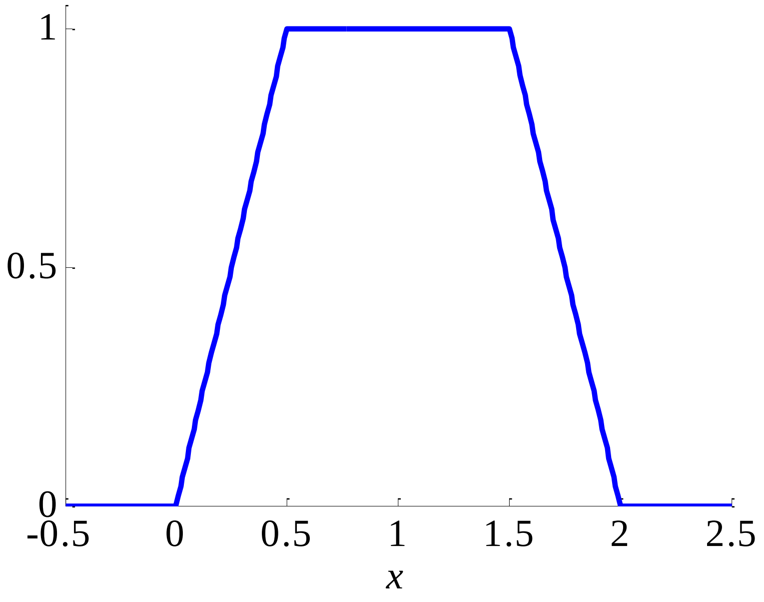
Example: Defining piece-wise functions (method 2)

`x` is a vector

```
function y = f(x)

y = zeros(size(x));

i1 = find(x>=0 & x<0.5);
y(i1) = 2*x(i1);

i2 = find(x>=0.5 & x<1.5);
y(i2) = 1;

i3 = find(x>=1.5 & x<2);
y(i3) = 4-2*x(i3);
```



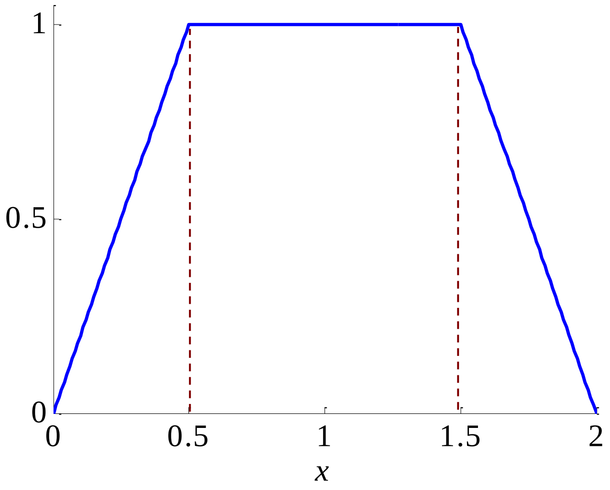
```
x = linspace(-0.5,2.5,301);
y = f(x);

figure; plot(x,y, 'b-');


yaxis(0,1.2, 0:0.5:1)
xaxis(-0.5,2.5, -0.5:0.5:2.5);
xlabel('\itx');
```



Example: Defining piece-wise functions (method 3)

x must be a scalar

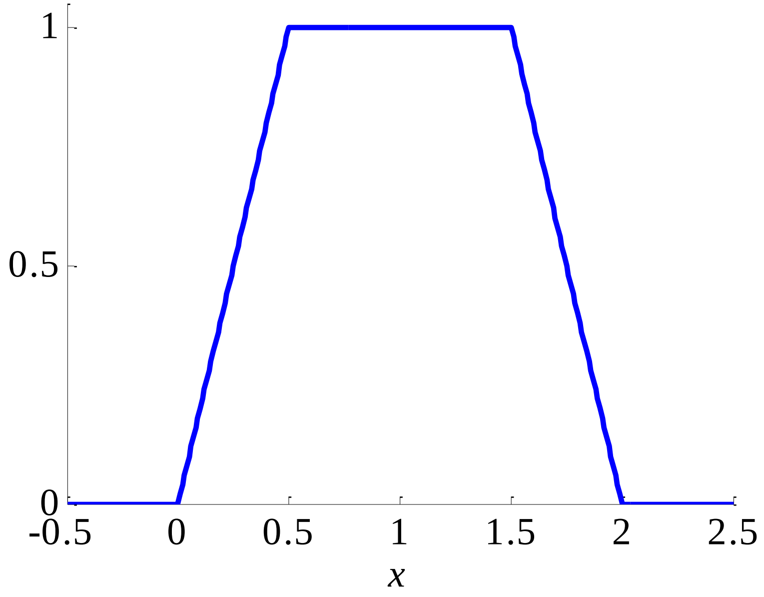
```
function y = f(x)

if x>=0 & x<0.5
   y = 2*x;
elseif x>=0.5 & x<1.5
   y = 1;
elseif x>=1.5 & x<2
   y = 4-2*x;
else
   y = 0;
end
```



pitfall: function produces wrong results if applied to a vector **x**, why?

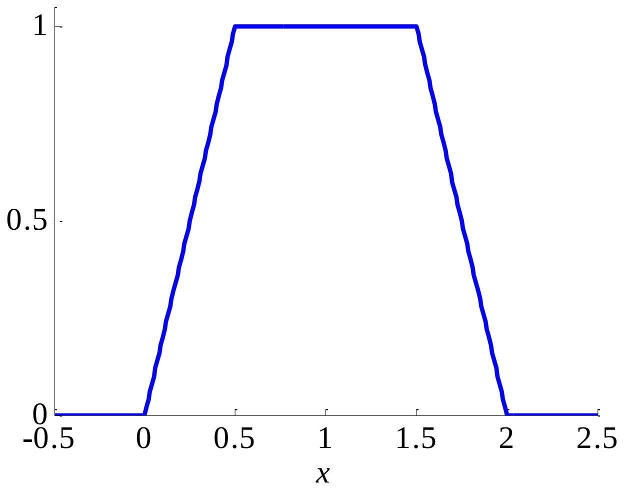
```
x = linspace(-0.5,2.5,301);

for n=1:length(x)
   y(n) = f(x(n));
end

figure; plot(x,y, 'b-');
yaxis(0,1.2, 0:0.5:1)
xaxis(-0.5,2.5, -0.5:0.5:2.5);
xlabel('\itx');
```

apply function separately to each element of **`x`**, instead of the whole **`x`**



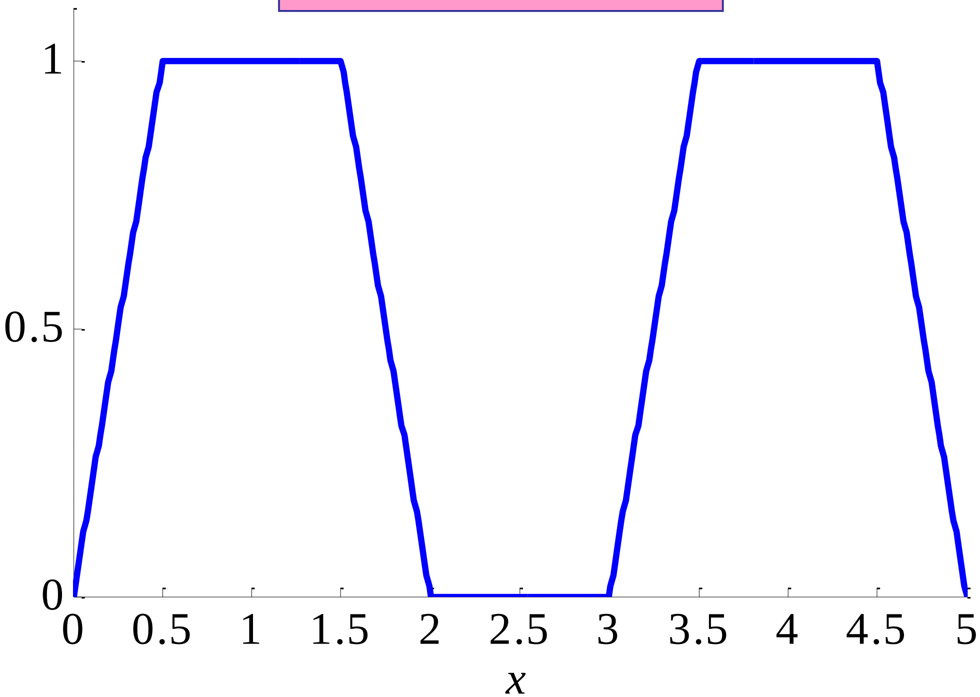
```
x = linspace(-0.5,2.5,301);

for n=1:length(x)
   if x(n)>=0 & x(n)<0.5
      y(n) = 2*x(n);
   elseif x(n)>=0.5 & x(n)<1.5
      y(n) = 1;
   elseif x(n)>=1.5 & x(n)<2
      y(n) = 4-2*x(n);
   else
      y(n) = 0;
   end
end

figure; plot(x,y, 'b-');
yaxis(0,1.2, 0:0.5:1)
xaxis(-0.5,2.5, -0.5:0.5:2.5);
xlabel('\itx');
```

direct implementation using if-elseif statements within a for-loop



```
f = @(x) 2*x .* (x>=0 & x<0.5) + ...
                 (x>=0.5 & x<1.5) + ...
      (4-2*x).* (x>=1.5 & x<2);

x = linspace(0,5,501);

figure; plot(x,f(x)+f(x-3), 'b-');
```

replicating f(x)



Example: Evaluating the sinc function

```
function y = my_sinc(x)

y = sin(pi*x)./(pi*x);

y(isinf(x)) = 0;

y(x==0) = 1;
```

generates **NaN**s for **x=inf** and **x=0**

fix **NaN** when **x=inf**

fix **NaN** when **x=0**

Note: built-in **sinc** function returns **NaN** when **x=inf**

```
x = [0, 0, inf, 0, nan];
y = sin(pi*x)./(pi*x)
y =
   NaN   NaN   NaN   NaN   NaN

isinf(x)
ans =
     0     0     1     0     0
y(isinf(x)) = 0
y =
   NaN   NaN     0   NaN   NaN

x==0
ans =
     1     1     0     1     0
y(x==0) = 1
y =
     1     1     0     1   NaN
```