- Previous lecture
  - User-defined functions
    - Function header
    - Input parameters and return variables

- Today's lecture
  - User-defined functions
    - local memory space
    - Subfunction

- Announcement
  - Project 2 due tonight at 11pm
  - Prelim 1 on Oct 4th at 7:30pm. Email Randy Hess (rbh27) now if you have an exam conflict (specify conflicting course and instructor contact info)

Function header is the “contract” for how the function will be used (called)

You have this function:

```
function  [x, y] = polar2xy(r, theta)
% Convert polar coordinates (r, theta) to
% Cartesian coordinates (x,y).  Theta in degrees.
…
```

Code to call the above function:

```
% Convert polar (r1,t1) to Cartesian (x1,y1)
r1= 1;  t1= 30;
[x1, y1]= polar2xy(r1, t1);
plot(x1, y1,‘b*’)
…
```

Returning a value ≠ printing a value

You have this function:

```
function  [x, y] = polar2xy(r, theta)
% Convert polar coordinates (r,theta) to
% Cartesian coordinates (x,y).  Theta in degrees.
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Code to call the above function:

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r1= 1;   t1= 30;
[x1, y1]= polar2xy(r1, t1);
plot(x1, y1,‘b*’)
…
```

Returning a value ≠ printing a value

You have this function:

Function prints instead of returns values

```
function ~~[x, y] =~~ polar2xy(r, theta)
% Convert polar coordinates (r,theta) to
% Cartesian coordinates (x,y).  Theta in degrees.
…  fprintf('(%.1f, %.1f)\n', x, y)
```

Code to call the above function:

```
% Convert polar (r1,t1) to Cartesian (x1,y1)
r1= 1;   t1= 30;
~~[x1, y1]=~~ polar2xy(r1, t1);
plot(x1, y1, 'b*')
…
```

Not possible to do

Now, although you can see the coordinates, this script cannot use them.

Given this function:

```
function m = convertLength(ft,in)
% Convert length from feet (ft) and inches (in)
% to meters (m).

   . . .
```

How many proper calls to convertLength are shown below?

```
% Given f and n
d= convertLength(f,n);
d= convertLength(f*12+n);
d= convertLength(f+n/12);
x= min(convertLength(f,n), 1);
y= convertLength(pi*(f+n/12)^2);
```

A: 1

B: 2

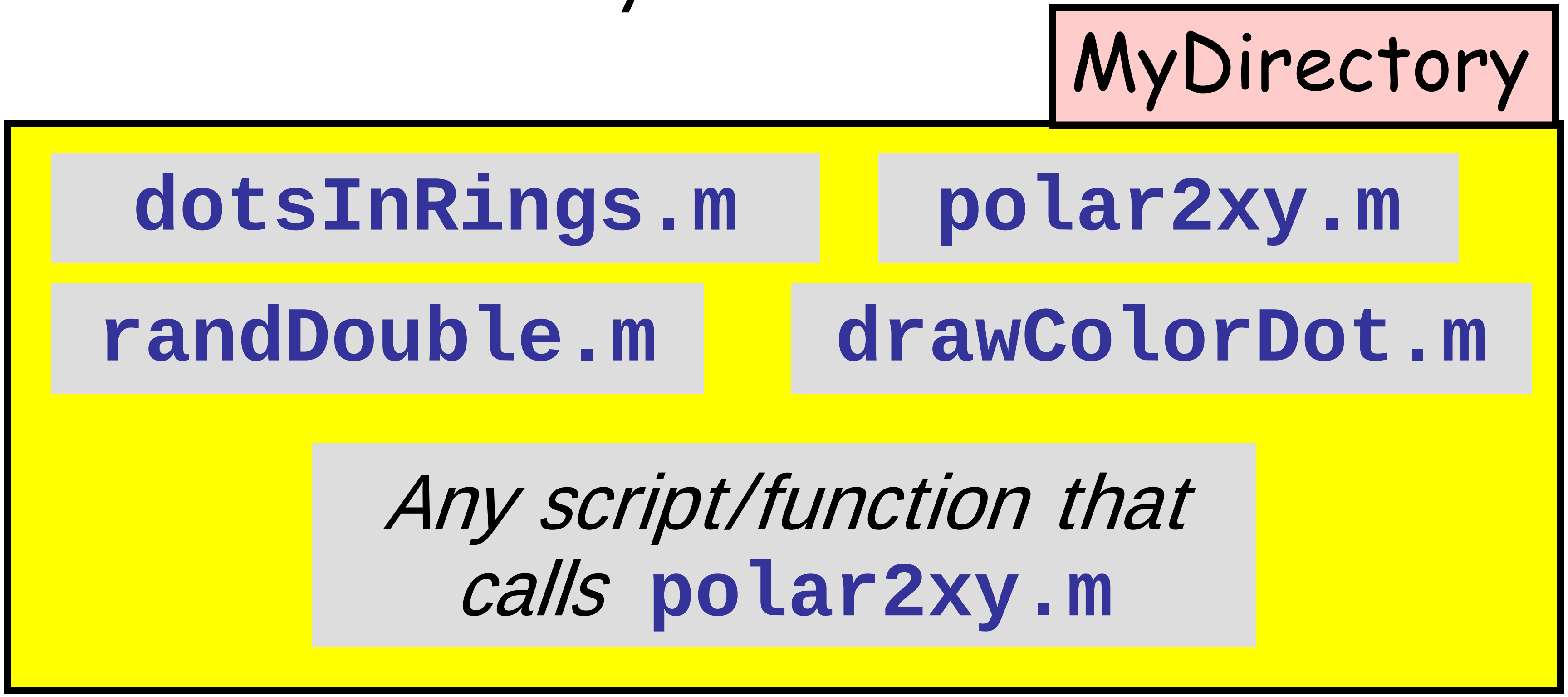
C: 3

D: 4

E: 5 or 0

Accessing your functions

For now*, put your related functions and scripts in the same directory.



MyDirectory

`dotsInRings.m` `polar2xy.m`

`randDouble.m` `drawColorDot.m`

Any script/function that calls `polar2xy.m`

*The **`path`** function gives greater flexibility

Why write user-defined function?

- Easy code re-use—great for “common” tasks
- A function can be tested independently easily
- Keep a driver program clean by keeping detail code in functions—separate, non-interacting files

➡ Facilitate top-down design

```
c= input('How many concentric rings? ');
d= input('How many dots? ');

% Put dots btwn circles with radii rRing and (rRing-1)
for rRing= 1:c
  % Draw d dots
  for count= 1:d

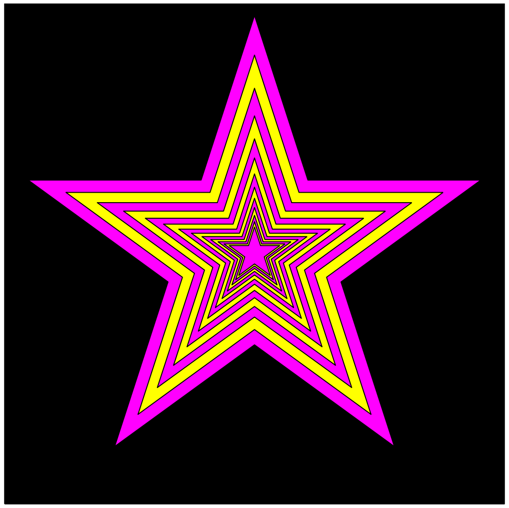
    % Generate random dot location (polar coord.)
    theta=_______
    r=_______

    % Convert from polar to Cartesian
    x=_______
    y=_______

    % Use plot to draw dot
  end
end
```

Each task becomes a function that can be implemented and tested independently

Facilitates top-down design



1. Focus on how to draw the figure given just a specification of what the function **`DrawStar`** does.

2. Figure out how to implement **`DrawStar`**.

To specify a function…

… you describe how to use it, e.g.,

```
function DrawStar(xc,yc,r,c)
% Adds a 5-pointed star to the
% figure window. Star has radius r,
% center(xc,yc) and color c where c
% is one of 'r', 'g', 'y', etc.
```

Given the specification, the user of the function doesn't need to know the detail of the function—they can just use it!

To implement a function…

… you write the code so that the function "lives up to" the specification. E.g.,

```
r2 = r/(2*(1+sin(pi/10)));
for k=1:11
    theta = (2*k-1)*pi/10;
    if 2*floor(k/2)~=k
      x(k) = xc + r*cos(theta);
      y(k) = yc + r*sin(theta);
    else
      x(k) = xc + r2*cos(theta);
      y(k) = yc + r2*sin(theta);
    end
end
fill(x,y,c)
```

Don't worry—you'll learn more about graphics functions and vectors soon.

Why write user-defined function?

- Easy code re-use—great for “common” tasks
- A function can be tested independently easily
- Keep a driver program clean by keeping detail code in functions—separate, non-interacting files
- Facilitate top-down design

➡ Software management

Software Management

Today:

I write a function

```
EPerimeter(a,b)
```

that computes the perimeter of the ellipse

$$\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 = 1$$

Software Management

During this year :

You write software that makes extensive use of

```
EPerimeter(a,b)
```

Imagine hundreds of programs each with several lines that reference `EPerimeter`

Software Management

Next year:

I discover a more efficient way to approximate ellipse perimeters. I change the implementation of

```
EPerimeter(a,b)
```

You do not have to change your software at all.

Script vs. Function

- A script is executed line-by-line just as if you are typing it into the Command Window
  - The value of a variable in a script is stored in the Command Window Workspace

- A function has its own private (local) function workspace that does not interact with the workspace of other functions or the Command Window workspace
  - Variables are not shared between workspaces even if they have the same name

What will be printed?

```
% Script file
p= -3;
q= absolute(p);
disp(p)
```

```
function q = absolute(p)
% q is absolute value of p
if (p<0)
   p= -p;
end
q= p;
```

A: -3

B: 3

C: error

What will be printed?

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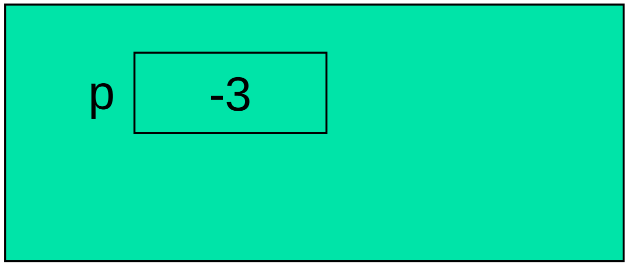
Command Window Workspace



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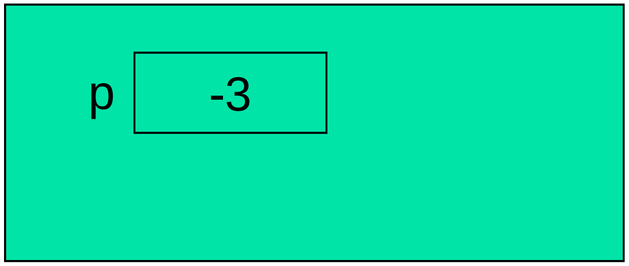

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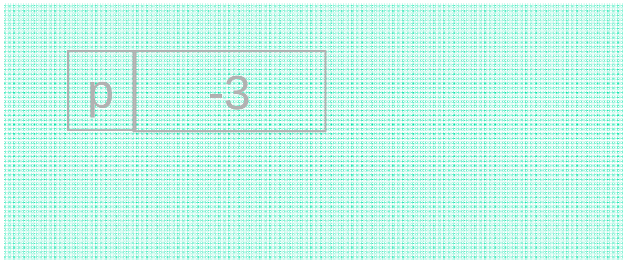
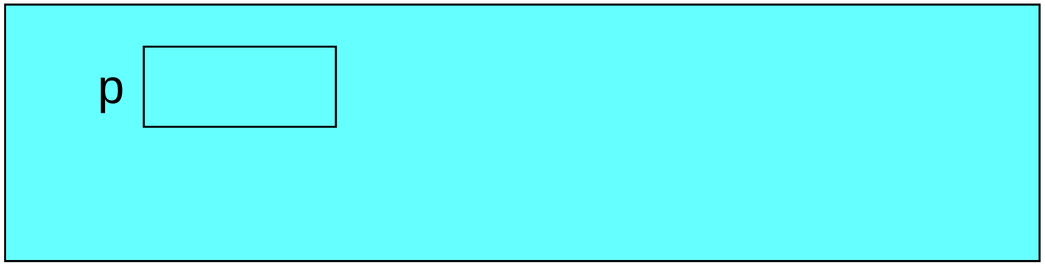


Function absolute's Workspace



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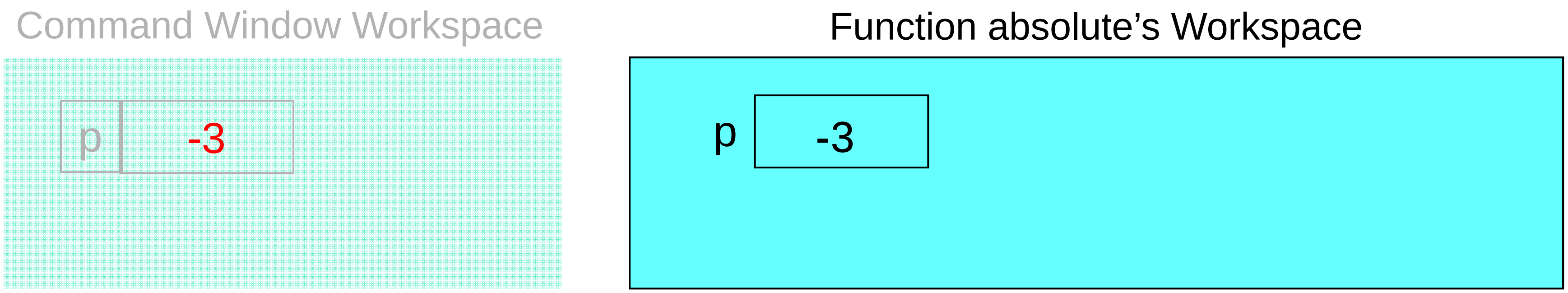

Command Window Workspace

p -3

Function absolute's Workspace

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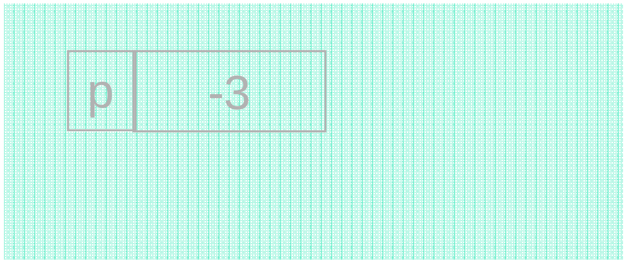
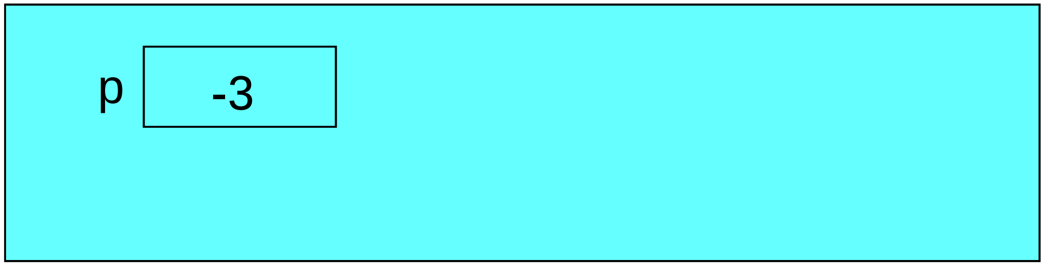


Function absolute’s Workspace



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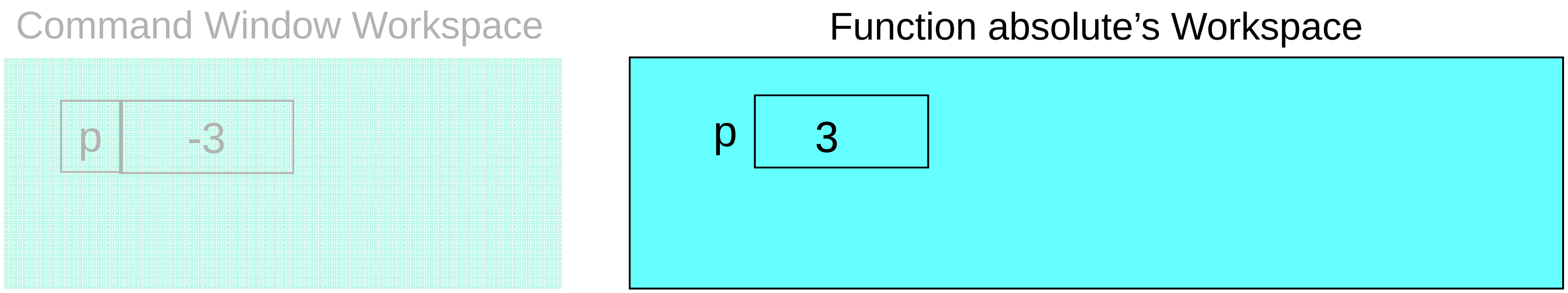

Command Window Workspace

p -3

Function absolute’s Workspace

p 3

What will be printed?

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% Script file
p= -3;
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```

```
function q = absolute(p)
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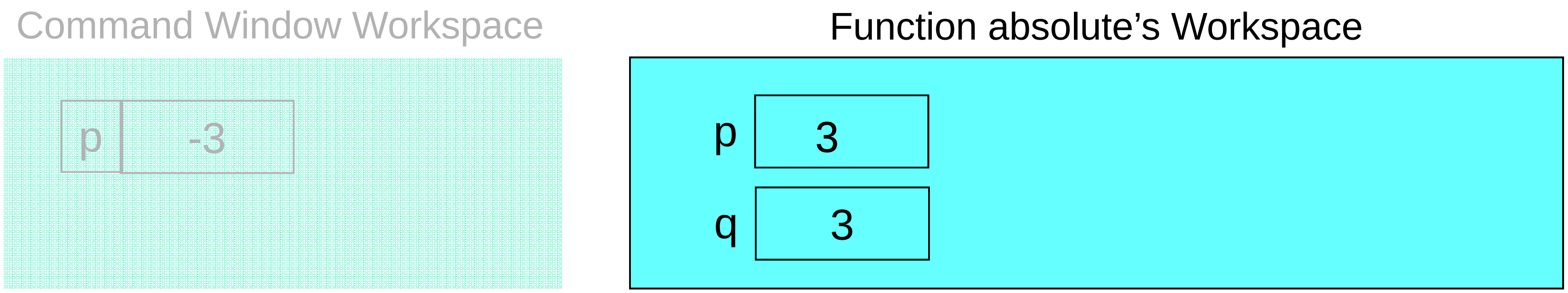
```



Command Window Workspace

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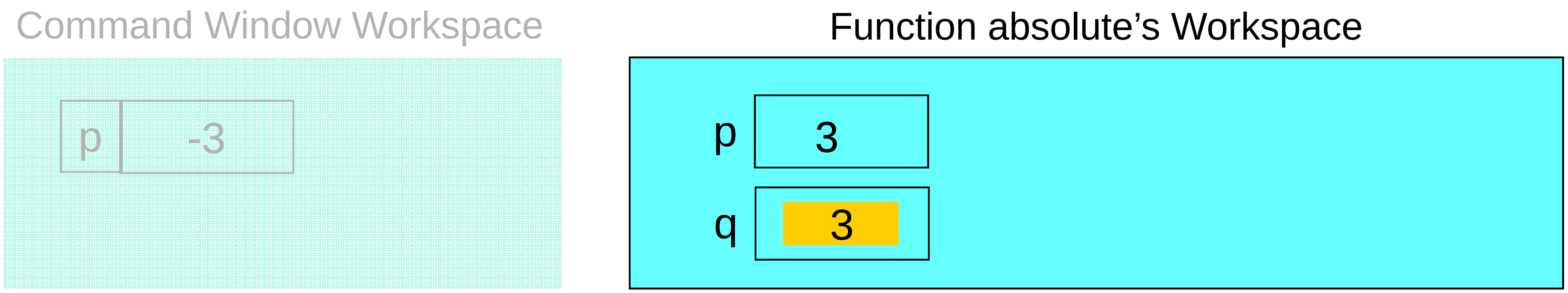

Command Window Workspace

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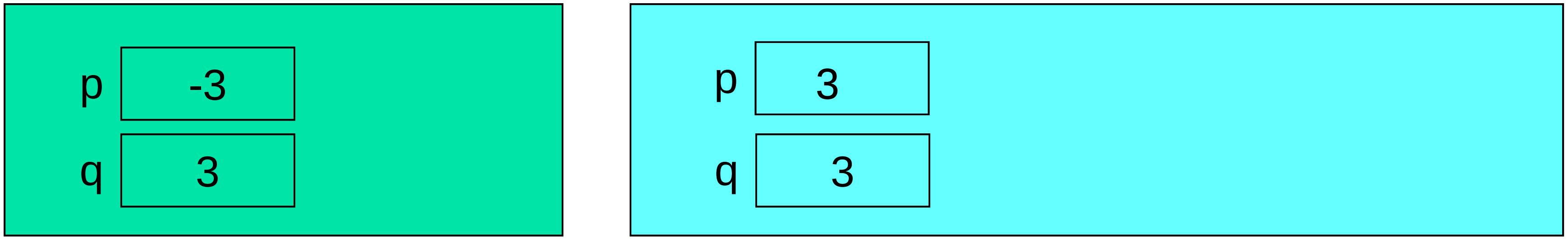

Command Window Workspace

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q 3

Function absolute’s Workspace

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q 3

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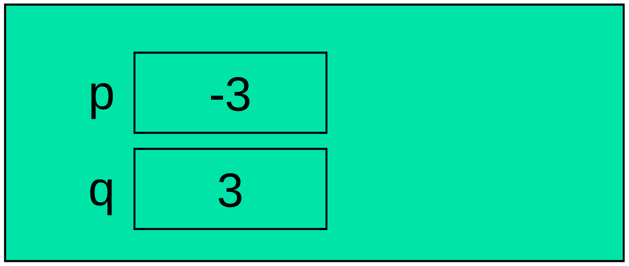

p -3

q 3

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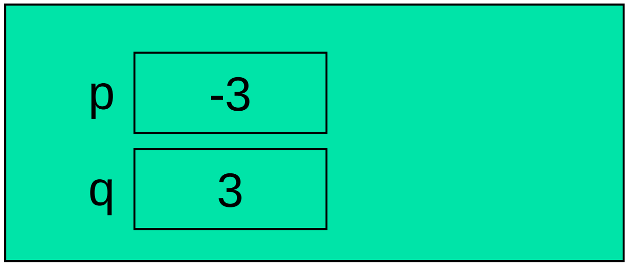

p -3

q 3

REVIEW!!!

```
% Script file
p= -3;
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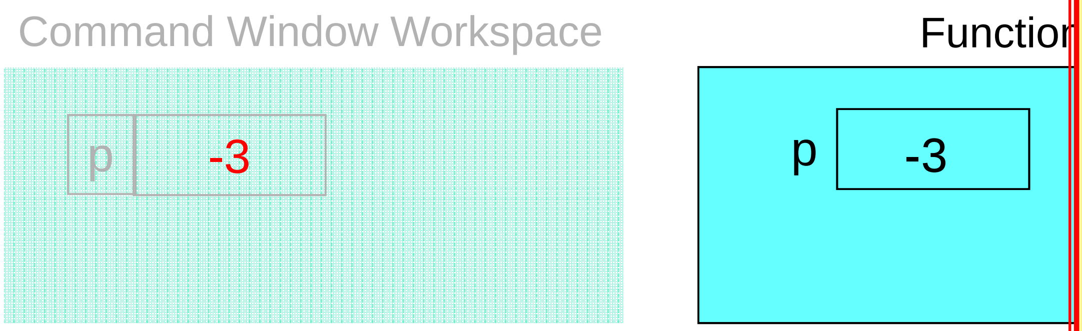
disp(p)
```

```
function q = absolute(p)
% q is the absolute value of p
if (p<0)
   p= -p;
end
q= p;
```

A value is passed to the function parameter when the function is called.

The two variables, both called p, live in different memory space and do not interfere.

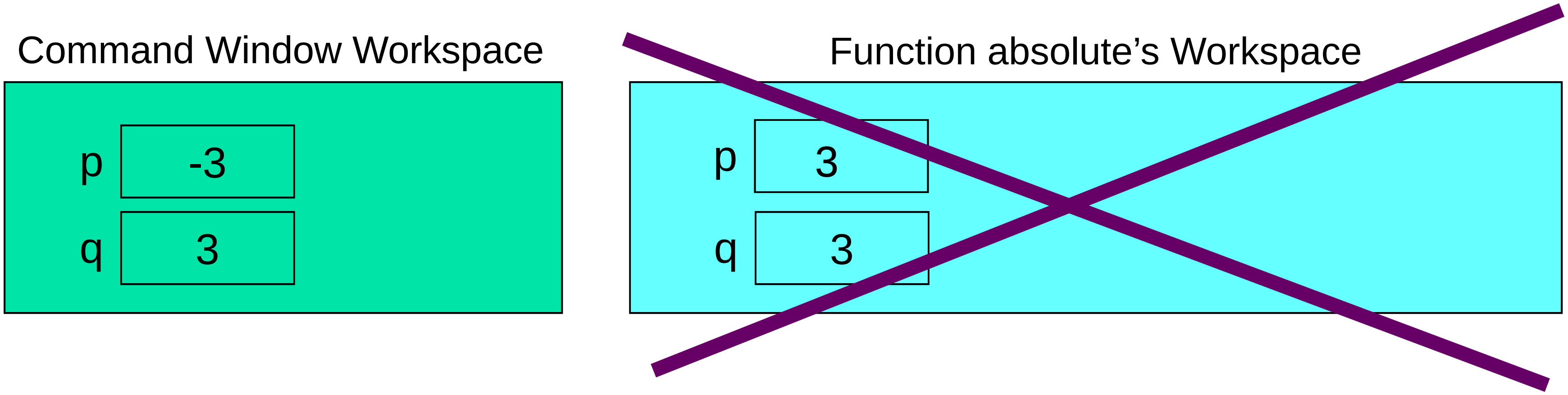


REVIEW!!!!

```
% Script file
p= -3;
q= absolute(p);
disp(p)
```

```
function q = absol
% q is the absolute
if (p<0)
   p= -p;
end
q= p;
```

When a function reaches the end of execution (and returns the output argument), the function space—local space—is deleted.



Command Window Workspace

p	-3
q	3

Function absolute’s Workspace

p	3
q	3

What is the output?

```
x = 1;
x = f(x+1);
y = x+1;
disp(y)
```

```
function y = f(x)
x = x+1;
y = x+1;
```

A: 1 B: 2 C: 3 D: 4 E: 5

Execute the statement `y= foo(x)`

- Matlab looks for a function called foo (m-file called foo.m)
- Argument (value of x) is copied into function foo's local parameter
  - called "pass-by-value," one of several argument passing schemes used by programming languages
- Function code executes within its own workspace
- At the end, the function's output argument (value) is sent from the function to the place that calls the function. E.g., the value is assigned to y.
- Function's workspace is deleted
  - If foo is called again, it starts with a new, empty workspace

Subfunction

- There can be more than one function in an M-file
- top function is the main function and has the name of the file
- remaining functions are subfunctions, accessible only by the functions in the same m-file
- Each (sub)function in the file begins with a function header
- Keyword **end** is not necessary at the end of a (sub)function