# Embedded Systems 2010/2011
# Harmonic Oscillator & MATLAB Tutorial

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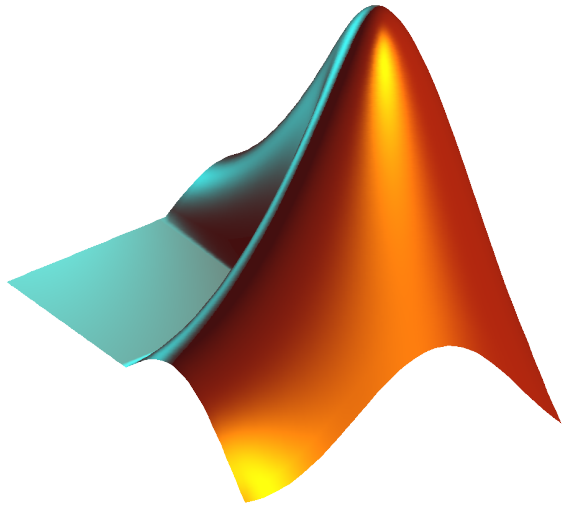
# Assignments and Tutorials

- Assignments
  - Handout / return: Tuesday, before the lecture
  - Teams are allowed (at most 3 students per team)
  - Box is available
- First assignment
  - Handout: Now, also available online
  - Return: Tuesday, 2nd November 2010 (in one week)
- Tutorials
  - Will start on Wednesday, 3rd November
  - Submit and come to any tutorial you like
  - But be prepared to change

# Course Registration

- Do the assignments
- Come to the tutorials
- Subscribe to the mailing list
- HISPOS registration only for the midterm exam needed

# MATLAB - Matrix Laboratory

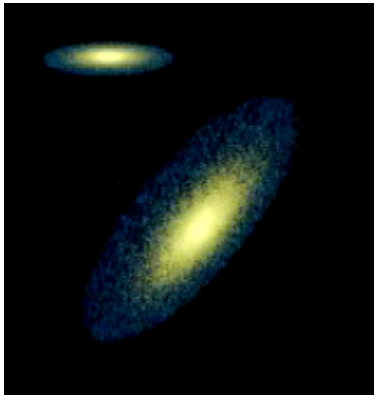
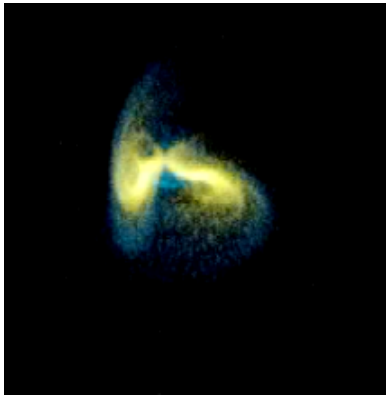
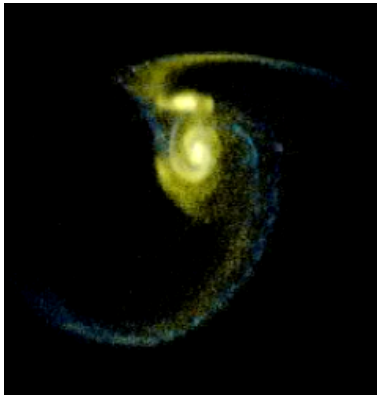


- Produced by Mathworks
- Used for simulation and numerical computation
- No (Maple-like) symbolical solving
- Industrial standard tool for developing embedded systems

# MATLAB Structure

- MATLAB core: IDE for the MATLAB language
- Simulink: Graphical environment for continuous simulation
- Stateflow: Statecharts for Simulink
- Many other add-ons available...

# Numerical Computing

- Some problems do not have a closed-form solution
- Approximative numerical solutions often suffice
- Simulation of the physical world

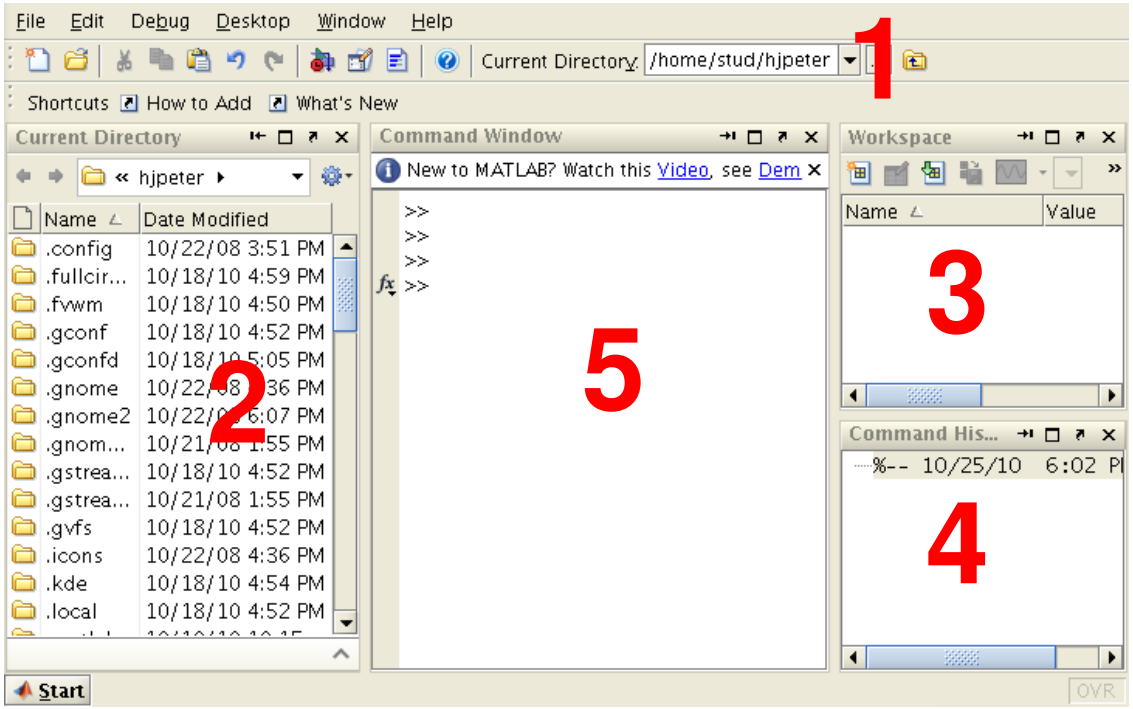
# Starting MATLAB

1. `http://sunray1.studcs.uni-sb.de`
2. Log in
3. Click on `MatLab`

alternatively:

1. Log onto a `cip` workstation
2. Execute `/installer/arch/bin/matlab`

# MATLAB IDE




1. Current directory
2. Directory explorer
3. Workspace
4. Command history
5. Command window

# The MATLAB Language

- Simplified C-like syntax
- Case sensitive
- Interactive shell: command window
- User defined functions: m-files
- Many built-in commands:
  - `lookfor <keyword>`
  - `help <function>`
  - `sprintf (<format str>, v1, v2, ...)`
  - `disp (<object>)`
  - `plot (Y)`
  - `plot (X, Y)`
  - `...`

# Variables

- Each numerical variable is a matrix
- Scalars = $1 \times 1$ matrices
- No explicit declarations / dynamic typing
- Polymorphism
- Removing variables:
  - `clear <variable>`
  - `clear`

# Working with Matrices

- `a = 4`
- `b = [4 8 15 ; 16 23 42 ; 1 2 3]`
- `c = b'`
- `d = ones(4)`
- `e = eye(3)`
- `f = b*b`
- `g = b.*b`
- `h = 0:10`
- `i = 0:0.01:2*pi`

# Script Files

- So called m-files
- Must be located in
  - the current directory or
  - the global search path
- Can be executed from the command window
- Can also define functions

# Control Structures

- Conditional

```
if <cond>
  <statements>
[else
  <statements>]
end
```

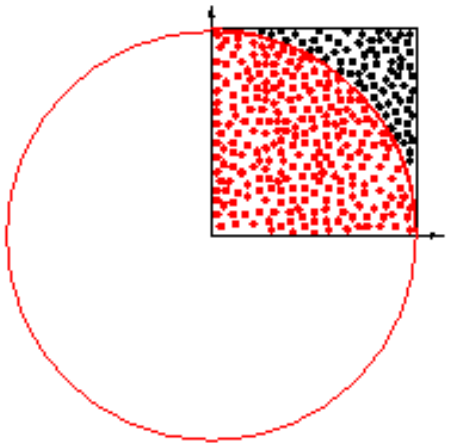
- While loop

```
while <cond>
  <statements>
end
```

- For loop

```
for v = <from>:[<step>:]<to>
  <statements>
end
```

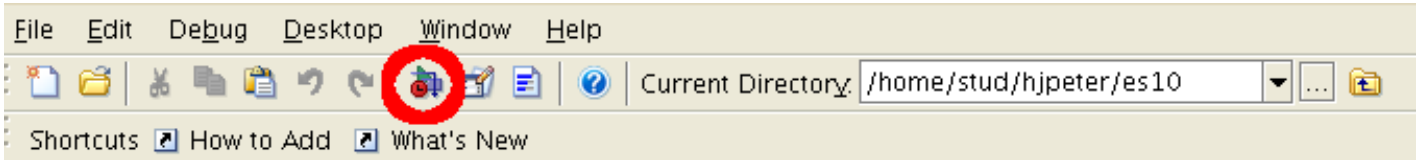
# Example: Computing $\pi$

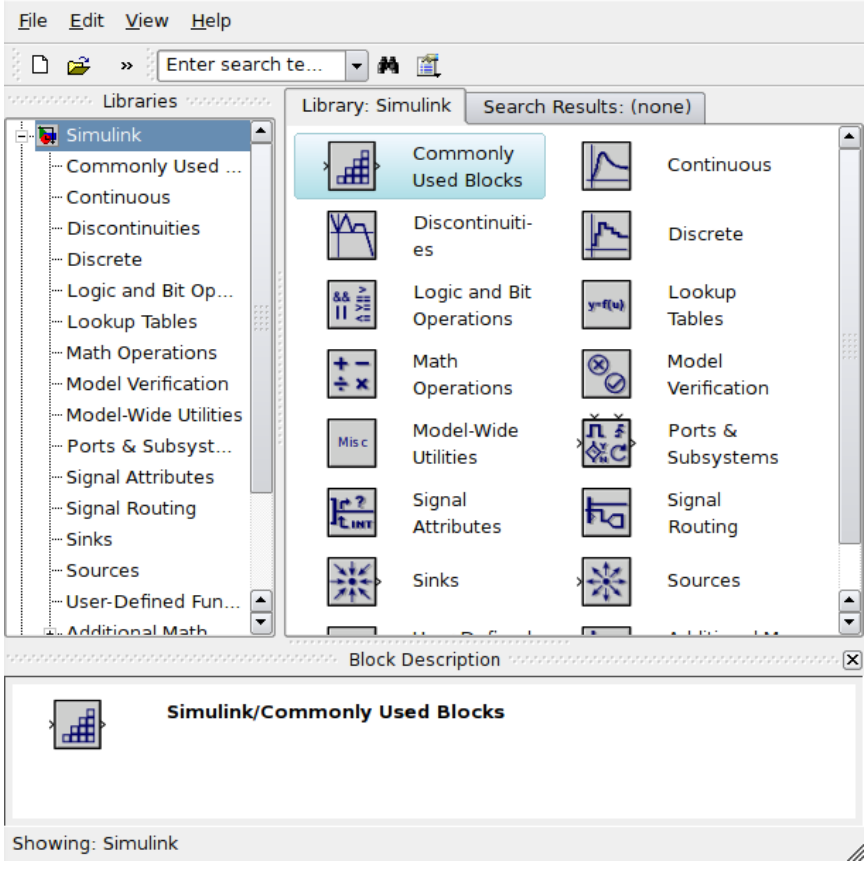


- Monte Carlo method for computing $\pi$

$$\frac{\text{points inside}}{\text{points total}} \approx \frac{\pi}{4}$$

# Simulink


File Edit Debug Desktop Window Help
Current Directory: /home/stud/hjpeter/es10
Shortcuts How to Add What's New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Simulink
Commonly Used ...
Continuous
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Math Operations
Model Verification
Model-Wide Utilities
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Signal Routing
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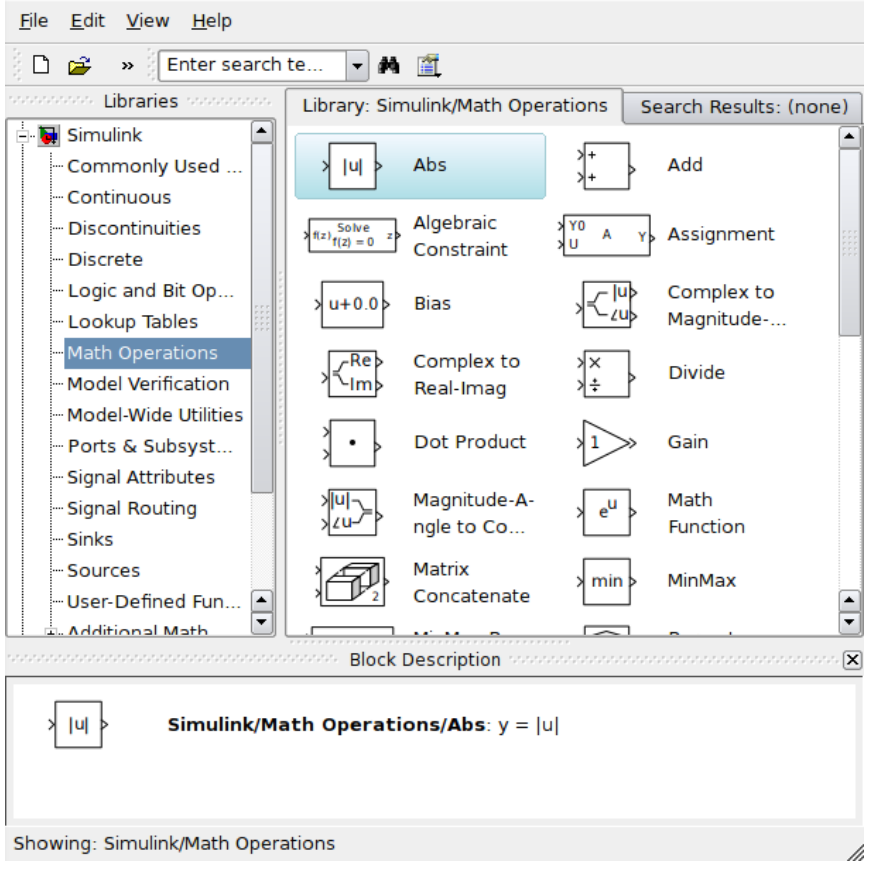
Block Description
Simulink/Commonly Used Blocks
Showing: Simulink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Simulink
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Model Verification
Model-Wide Utilities
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Signal Attributes
Signal Routing
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Sources
User-Defined Fun...
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Algebraic Constraint
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Dot Product
Gain
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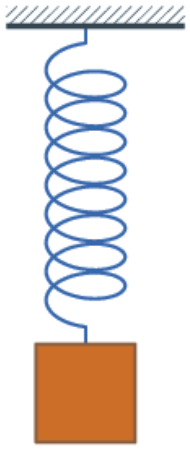
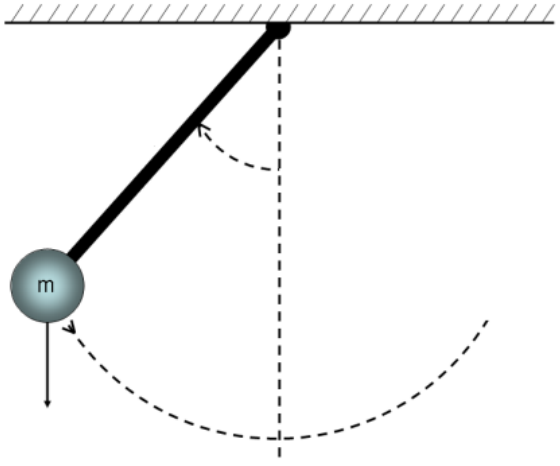
Math Function
Matrix Concatenate
MinMax
Block Description
Simulink/Math Operations/Abs: y = |u|
Showing: Simulink/Math Operations

# Harmonic Oscillator

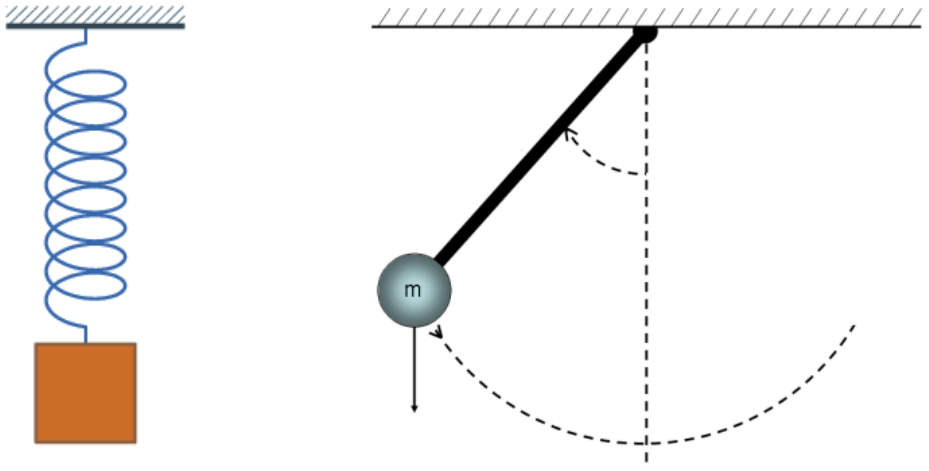





Hooke's Law: $F = -ky$

- $F$: restoring force
- $k$: positive constant that characterizes the oscillator
- $y$: amplitude or displacement

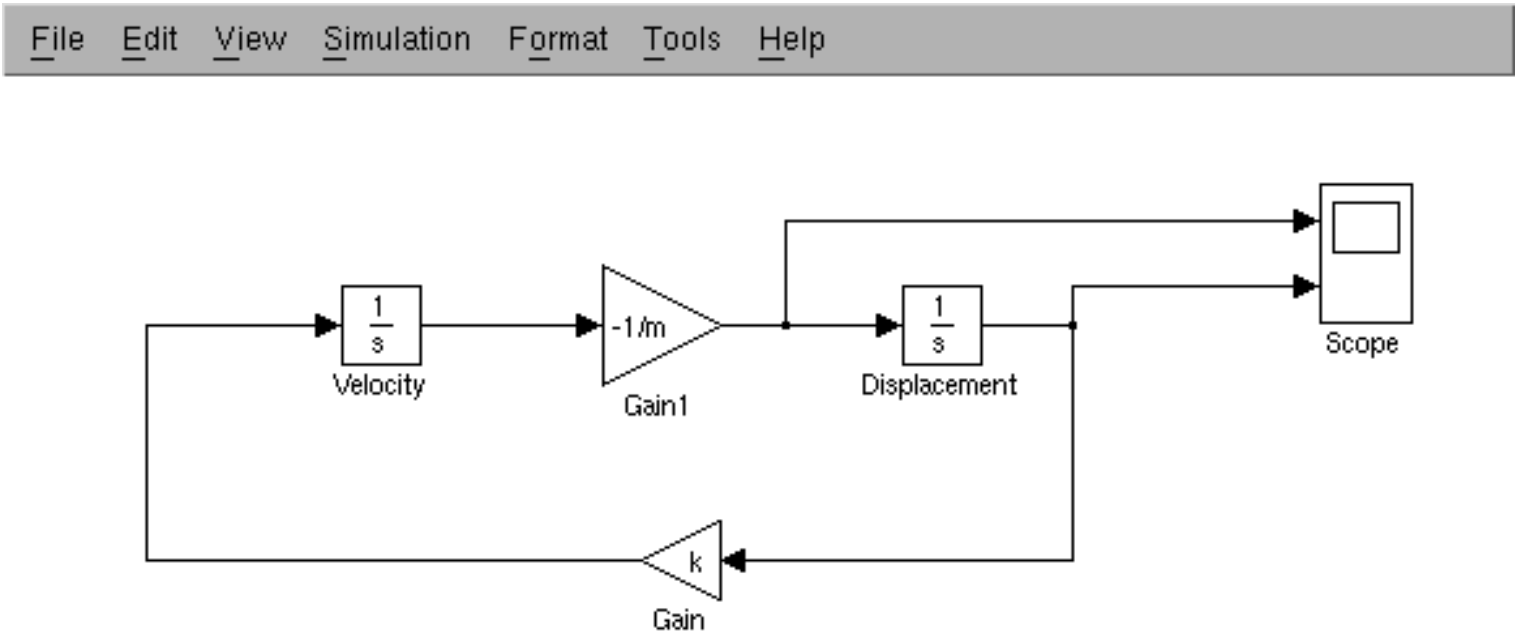
# Harmonic Oscillator (2)



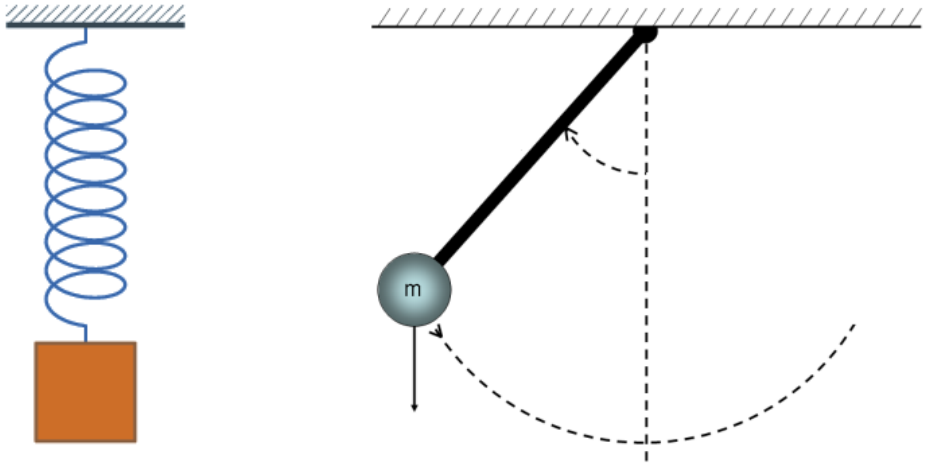

- $m$: mass constant
- $k$: spring constant
- $y_0$: initial displacement
- $y$: current displacement
- $v = \dot{y}$: current velocity
- $a = \dot{v} = \ddot{y}$: current acceleration

$$
\begin{aligned}
& F = ma = -ky \\
\Leftrightarrow \quad & ma + ky = 0 \\
\Leftrightarrow \quad & m\ddot{y} + ky = 0 \\
\Leftrightarrow \quad & m\dot{v} + ky = 0
\end{aligned}
$$

# Harmonic Oscillator in Simulink



# Damped Harmonic Oscillator




- $m$ = mass constant
- $R$ = damper constant
- $k$: spring constant
- $y_0$: initial displacement
- $y$: current displacement
- $v = \dot{y}$: current velocity
- $a = \dot{v} = \ddot{y}$: current acceleration

$$m\ddot{y} + R\dot{y} + ky = 0$$
$$\Leftrightarrow \quad m\dot{v} + Rv + ky = 0$$

# Damped Harmonic Oscillator in Simulink