

```

1 %% Models
2 m = 1;
3 k = 1;
4
5 initial_conditions = [
6     0.1, 0.1;
7     0.1, 0.5;
8     0.5, 0.1;
9     0.5, 0.5
10 ];
11
12 hd_spring = @(t, x) [x(2); -k/m * (1 + x(1)^2) * x(1)];
13 sf_spring = @(t, x) [x(2); -k/m * (1 - x(1)^2) * x(1)];
14 li_spring = @(t, x) [x(2); -k/m * x(1)];
15
16 %% plot
17 figure;
18 tspan = [0, 20];
19
20 for i = 1:4
21     subplot(2, 2, i);
22     hold on;
23
24     % hd
25     [t, x_hard] = ode45(hd_spring, tspan, initial_conditions(i, :));
26     plot(x_hard(:, 1), x_hard(:, 2), 'r', 'DisplayName', 'Hardening Spring');
27
28     % sf
29     [t, x_soft] = ode45(sf_spring, tspan, initial_conditions(i, :));
30     plot(x_soft(:, 1), x_soft(:, 2), 'g', 'DisplayName', 'Softening Spring');
31
32     % li
33     [t, x_linear] = ode45(li_spring, tspan, initial_conditions(i, :));
34     plot(x_linear(:, 1), x_linear(:, 2), 'b', 'DisplayName', 'Linear Spring');
35
36     xlabel('Position  $y(t)$ ', 'Interpreter', 'latex');
37     ylabel('Velocity  $\dot{y}(t)$ ', 'Interpreter', 'latex');
38     title(sprintf('Initial Condition %d:  $y(0) = %.2f$ ,  $\dot{y}(0) = %.2f$ ', i,
initial_conditions(i, 1), initial_conditions(i, 2)), 'Interpreter', 'latex');
39     legend;
40
41     axis equal;
42     hold off;
43 end
44

```