SI Physics - Full Discipline Demo

Hooke's Law

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term to the best description.

Spring constant

Restoring force

Springs in parallel

Hooke's law

Springs in series

Pulls or pushes toward the equilibrium position — 1

Force equals a negative constant times displacement — 2

Indicator of stiffness — 3

Each experiences the same force — 4

Each experiences the same displacement — 5

Correct answers:

1 Restoring force   2 Hooke's law   3 Spring constant

4 Springs in series   5 Springs in parallel

Identify each statement as true or false.

- An object stretched within its elastic limit follows Hooke's law
- Spring potential energy can be positive or negative, depending on the sign of the displacement
- Spring potential energy varies with the square of the displacement
- The equilibrium position of a spring is the unstretched length
- The restoring force and the displacement are always in the same direction

True	False
1	2

Correct answers:

1 An object stretched within its elastic limit follows Hooke's law

Spring potential energy varies with the square of the displacement

The equilibrium position of a spring is the unstretched length

2

Spring potential energy can be positive or negative, depending on the sign of the displacement

The restoring force and the displacement are always in the same direction

Exploration

The restoring force is proportional to the displacement from the equilibrium.

- True ✔
- False

The restoring force always points away from the equilibrium position.

- True
- False ✔

The spring constant indicates the _____ of the spring.

- length
- mass
- stiffness ✔
- None of the above

Springs combined in parallel will each experience the same _____.

- displacement ✔
- force
- spring constant
- All of the above

A spring stretched beyond its elastic limit will _____.

- return to its original length
- remain deformed ✔
- still follow Hooke's law
- None of the above

The change in spring potential energy of a spring is equal to the amount of _____ on the spring.

- work done ✔
- weight
- mass
- All of the above

Spring potential energy is conserved for a hanging mass on a spring at rest.

- True
- False ✔

Exercise 1

How does the relative stiffness of a spring relate to its spring constant?

The relative stiffness of a spring is directly related to the spring constant, meaning the larger the spring constant, the stiffer the spring.

How does spring potential energy change relative to the displacement of the spring?

The spring potential energy increases like the square of the displacement, meaning the larger the displacement, the greater the spring potential energy.

Use the graph in Graph 1 to define the relationship between the spring force and the displacement of a spring.

The spring force is directly related to the displacement of the spring, as shown by the straight diagonal line shown in Graph 1.

How would the graph in Graph 1 change if the spring were stretched beyond its elastic limit?

The line would no longer be a straight line if the spring were stretched beyond its elastic limit. The directly proportional relationship indicated by Hooke's law would no longer exist.

Was potential energy conserved in your experiment? Use the data from Data Table 2 to support your answer.

No, potential energy was not conserved in this experiment because the smallest difference between spring and gravitational potential energy is 8% and the largest difference is 75%. For potential energy to be conserved, the difference between the two types of potential energy should be much smaller, less than 10%.

Describe possible improvements to the experimental procedure that would increase the accuracy of your results.

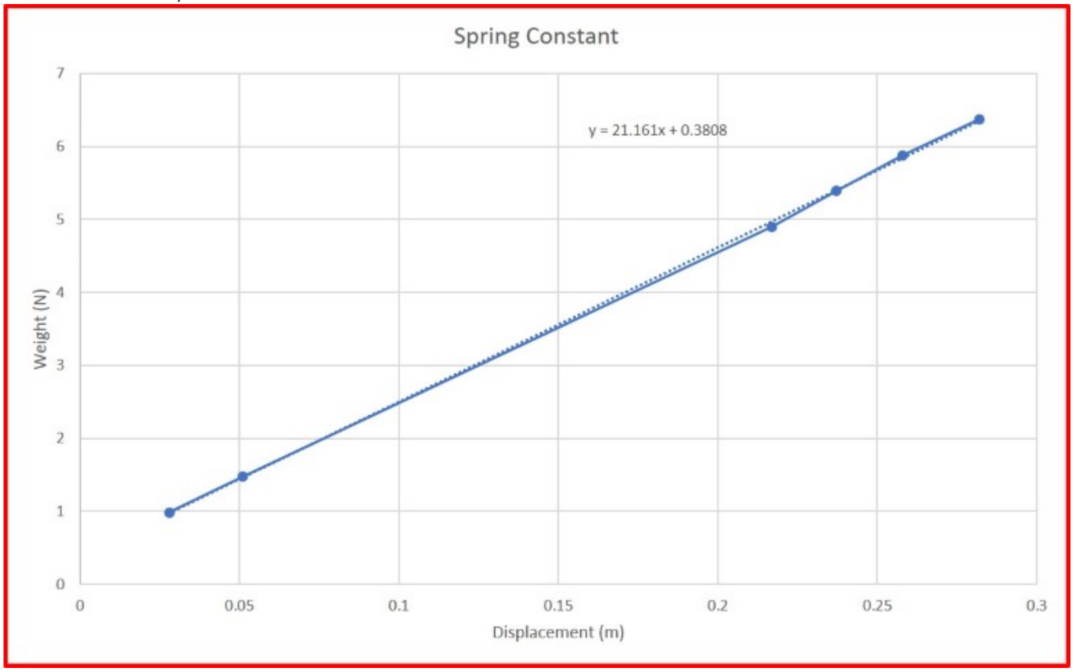
Student answers will vary. Some possible improvements are: eliminate the string from the spring attachment to reduced extra stretching unrelated to the spring, align the ruler more closely with the spring so the measurements are easier to make, take multiple measurements at each mass and each displacement and average.

Data Table 1: Measuring the Spring Constant of a Spring

(SAMPLE ANSWER BELOW)

Mass (kg)	Displacement (m)	Weight (N)	k = slope (N/m)
0.100	0.028	0.98	21.16
0.150	0.051	1.47	
0.500	0.217	4.90	
0.550	0.237	5.39	
0.600	0.258	5.88	
0.650	0.282	6.37	

Graph 1: Force versus Displacement
(SAMPLE ANSWER BELOW)



Data Table 2: Potential Energy for m = 0.500 kg
(SAMPLE ANSWER BELOW)

Push Up

Y_1-Y_0 (m)	Y_1 (m)	Y_2 (m)	U_{g1} (J)	U_{g2} (J)	U_{s1} (J)	U_{s2} (J)	ΔU_g (J)	ΔU_s (J)	% Diff.
0.010	0.200	0.219	0.981	1.074	0.452	0.542	0.093	0.090	4
0.020	0.190	0.227	0.932	1.113	0.408	0.582	0.181	0.174	4
0.030	0.180	0.236	0.883	1.158	0.366	0.629	0.275	0.263	4
0.040	0.170	0.245	0.834	1.202	0.327	0.678	0.352	0.352	5
Pull Down									
0.010	0.220	0.203	1.079	0.996	0.547	0.466	0.083	0.081	3
0.020	0.230	0.192	1.128	0.942	0.598	0.186	0.186	0.181	3
0.030	0.240	0.182	1.177	0.893	0.651	0.374	0.284	0.277	3
0.040	0.250	0.171	1.226	0.839	0.706	0.330	0.387	0.376	3

Exercise 2

Compare the Weight and Displacement data collected in Exercise 1 in Data Table 1 to the Applied Force and Displacement data collected in Exercise 2 in Data Table 3. How are these data similar and how are they different? Discuss the reasons for these similarities and differences.

The Weight in Data Table 1 is equivalent to the Applied Force in Data Table 3. The Applied Force is a pulling force or pushing force, depending on the sign, so that the horizontal spring can be stretched or compressed, whereas the Weight is only a pulling force, stretching the spring. The Weight is the Applied Force caused by the force of gravity on the hanging mass. The magnitudes of the values in Table 1 are much smaller (displacements between 0.4 and 13 cm and weights between 1 and 7 N compared to displacements between 4 and 100 cm and forces between 20 and 100 N) which makes sense because the spring constants in Data Table 3 are much larger (100-500 N/m compared to 42 N/m) than the spring constant in Data Table 1. For both data sets, as one variable (Force or Weight) increases, the other (Displacement) increases linearly. This makes sense if the springs in both cases are within their elastic limit and obey Hooke’s Law.

Is the effective spring constant for springs in parallel larger or smaller than the spring constant of each individual spring? Is the effective spring constant for springs in series larger or smaller than the spring constant of each individual spring? Explain your answers.

The effective spring constant for springs in parallel is equal to the sum of the spring constants for each individual spring, so it is larger than each individual spring constant. The effective spring constant for springs in series is the inverse of the sum of the inverse of the spring constants for each individual spring, so it is smaller than any individual spring constant.

What is the relationship between the applied force of a hanging mass on a spring and the spring force of the spring? Use the data in Data Table 3 to support your answer.

The applied force is equal in magnitude and points in the opposite direction as the spring force for the spring in all cases, regardless of the spring constant as is demonstrated by the values for the applied force and spring force respectively of 20 and -20 N, for example.

Compare the effective spring constants calculated in Data Table 4 and Data Table 5 and the spring constants derived from the graphs in Graph 2 and Graph 3. Which method gives more reliable results and why?

The effective spring constants calculated from the equations in the data tables are essentially identical to the effective spring constants determined from the graphs. Those calculated from the equations are theoretical, while those from the graphs are experimental. Experimental results are a more reliable indicator of the actual conditions of the experiment, so the effective spring constants found from the graph are more reliable. However, since this was a simulation, the theoretical and experimental data match exactly.

What is the relationship between the spring potential energy of a spring and the spring constant of the spring? Use the data in Data Table 6 to support your answer.

For a given displacement, and/or applied force, the potential energy increases as the spring constant increases. When the spring constant doubles from 100 N/m to 200 N/m for a displacement of 0.20 m, the spring potential energy also doubles from 2 J to 4 J. This is a linearly proportional relationship.

Compare the graph in Graph 4 to the Energy Plot in the Energy page of the simulation. What do these two graphs tell you about the relationships between potential energy, displacement, and spring force?

The graphs both show a parabolic shape which indicates a squared polynomial relationship between the potential energy and the displacement as well as the spring force.

Data Table 3: Intro

(SAMPLE ANSWER BELOW)

Applied Force (N)	Spring Force (N)	Displacement (m)
k = 200 N/m		
20	-20	0.100
50	-50	0.250
100	-100	0.500
-50	50	-0.250
k = 100 N/m		
20	-20	0.200
50	-50	0.500
100	-100	1.000
-50	50	-0.500
k = 500 N/m		
20	-20	0.040
50	-50	0.100
100	-100	0.200
-50	50	-0.100

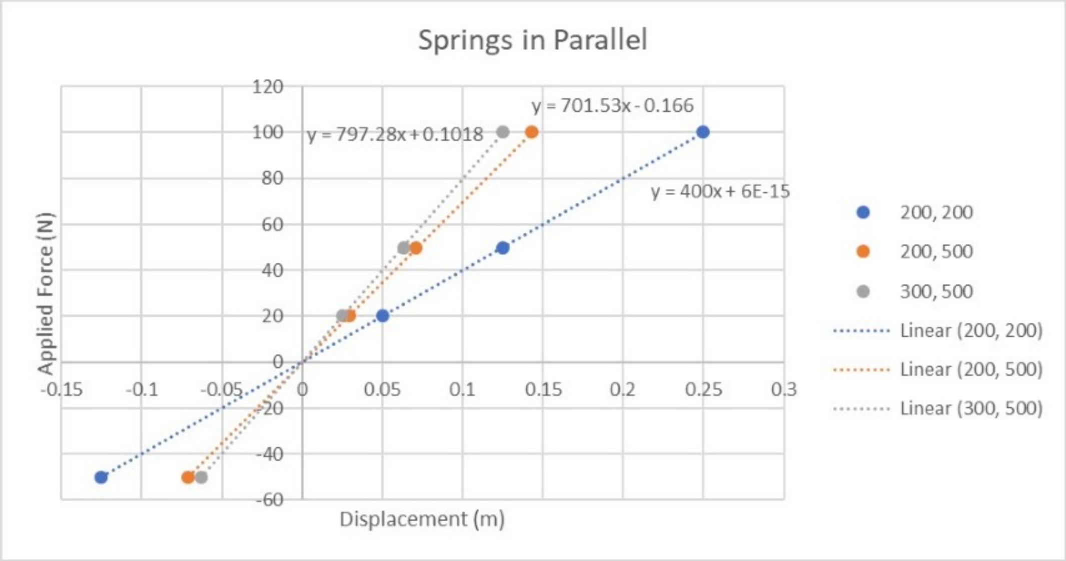
Data Table 4: Springs in Parallel

(SAMPLE ANSWER BELOW)

Applied Force (N)	Top Spring Force (N)	Bottom Spring Force (N)	Displacement (m)	Spring Constant (N/m)
Top Spring Constant = 200 N/m, Bottom Spring Constant = 200 N/m				
20	-10.0	-10.0	0.050	400
50	-25.0	-25.0	0.125	
100	-50.0	-50.0	0.250	
-50	25.0	25.0	-0.125	
Top Spring Constant = 200 N/m, Bottom Spring Constant = 500 N/m				

20	-5.7	-14.3	0.029	700
50	-14.3	-35.7	0.071	
100	-28.6	-71.4	0.143	
-50	14.3	35.7	-0.071	
Top Spring Constant = 300 N/m, Bottom Spring Constant = 500 N/m				
20	-7.5	-12.5	0.025	800
50	-18.8	-31.3	0.063	
100	-37.5	-62.5	0.125	
-50	18.7	31.2	-0.063	

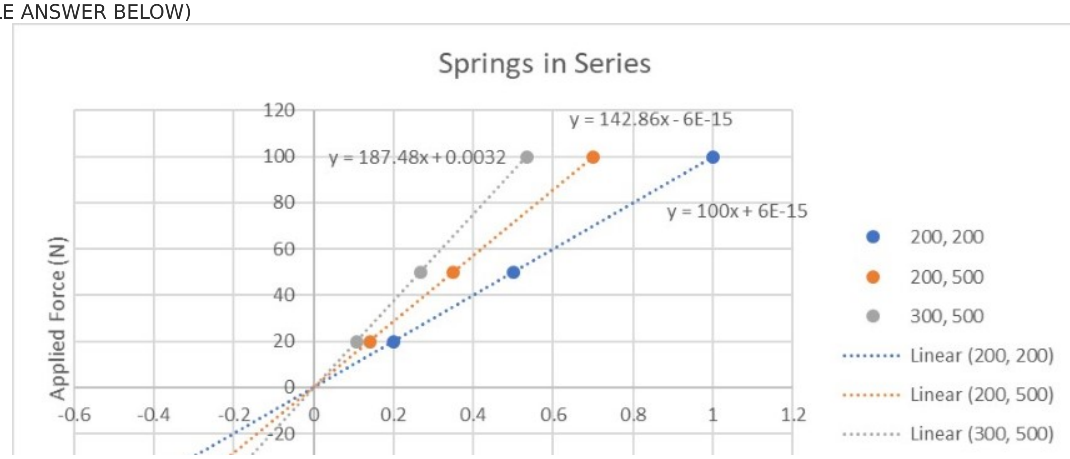
Graph 2: Spring Constant for Springs in Parallel
(SAMPLE ANSWER BELOW)

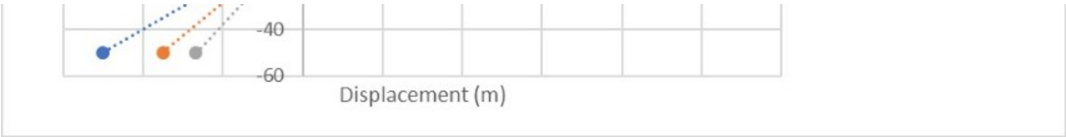


Data Table 5: Springs in Series
(SAMPLE ANSWER BELOW)

Applied Force (N)	Left Spring Force (N)	Right Spring Force on Applied Force (N)	Right Spring Force on Left Spring(N)	Displacement (m)	Spring Constant (N/m)
Left Spring Constant = 200 N/m, Right Spring Constant = 200 N/m					
20	-20	-20	20	0.200	100
50	-50	-50	50	0.500	
100	-100	-100	100	1.000	
-50	50	50	-50	-0.500	
Top Spring Constant = 200 N/m, Right Spring Constant = 500 N/m					
20	-20	-250	20	0.140	143
50	-50	-50	50	0.350	
100	-100	-100	100	0.700	
-50	50	50	-50	-0.350	
Top Spring Constant = 300 N/m, Right Spring Constant = 500 N/m					
20	-20	-20	20	0.107	188
50	-50	-50	50	0.267	
100	-100	-100	100	0.533	
-50	50	50	-50	-0.267	

Graph 3: Spring Constant for Springs in Series
(SAMPLE ANSWER BELOW)





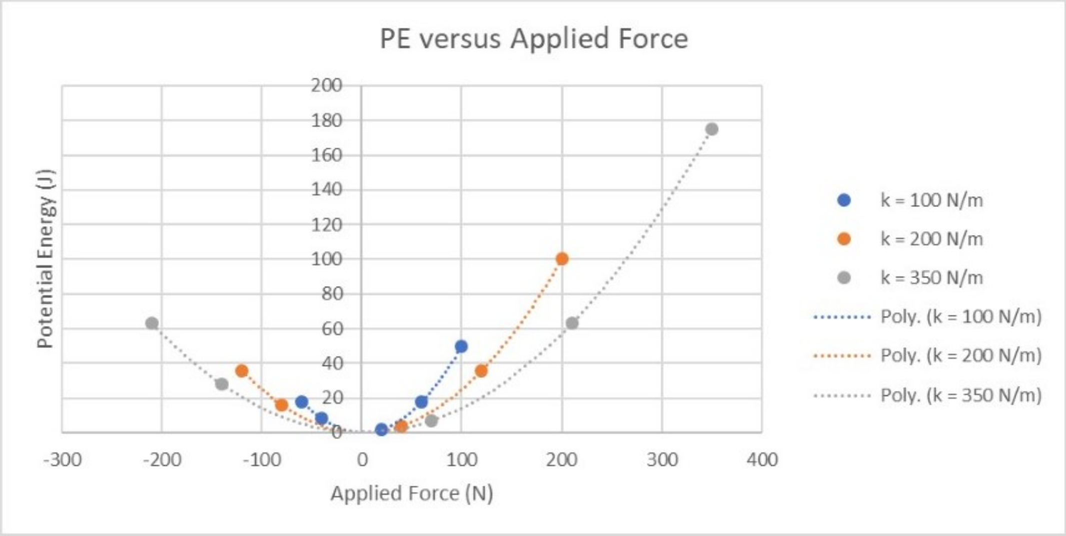
Data Table 6: Energy
(SAMPLE ANSWER BELOW)

Displacement (m)	Applied Force (N)	Spring Potential Energy (J)
Spring Constant = 100 N/m		
0.200	20	2.0
0.600	60	18.0
1.000	100	50.0
-0.400	-40	8.0
-0.600	-60	18.0
Spring Constant = 200 N/m		
0.200	40	4.0
0.600	120	36.0
1.000	200	100.0

-0.400	-80	16.0
-0.600	-120	36.0
Spring Constant = 350 N/m		
0.200	70	7.0
0.600	210	63.0
1.000	350	175.0
-0.400	-140	28.0
-0.600	-210	63.0

Graph 4: Energy versus Force

(SAMPLE ANSWER BELOW)



Competency Review

A mass on a spring is subject to Hooke's law.

- True ✔
- False

_____ is the position where a spring is neither stretched nor compressed.

- Displacement
- Elastic limit
- Equilibrium ✔
- None of the above

The _____ indicates the stiffness of a spring.

- applied force
- spring constant ✔
- spring force
- All of the above

Two or more springs aligned in series or in parallel have a single equivalent spring constant.

- True ✔
- False

Any material that is subject to a restoring force is considered to be _____.

- springy
- flexible
- elastic ✔
- All of the above

The applied force points in the same direction as the restoring force of Hooke's law.

- True
- False ✔

The spring potential energy is calculated using the equation _____.

- $U_{sp} = \frac{1}{2}k\Delta x$
- $U_{sp} = mgy$
- $U_{sp} = \frac{1}{2}k\Delta x^2$ ✔
- None of the above

The spring constant of a spring is equal to the _____ of the line formed by graphing the spring force against the displacement.

- inverse of the slope
- slope ✔
- constant times the slope
- None of the above

Spring potential energy for a given spring is constant for all displacements.

- True
- False ✔

The effective spring constant for springs in parallel is equal to the _____ of the individual spring constants.

- sum ✔
- difference
- product
- None of the above

A spring of spring constant 25 N/m is hung vertically and a 0.300 kg mass is attached to one end, causing a displacement of the end of the spring of _____ m.

- 0.01
- 0.12 ✔
- 0.77
- All of the above

Spring A has a spring constant of 100 N/m and spring B has a spring constant of 200 N/m, and both have the same displacement of 0.20 m. The spring potential energy of spring A is _____ that of spring B.

- twice
- half ✔
- the same as
- None of the above

Extension Questions

A spring on Earth has a 0.500 kg mass suspended from one end and the mass is displaced by 0.3 m. What will the displacement of the same mass on the same spring be on the Moon, where the acceleration due to gravity is one sixth that of Earth? Show your work. (SAMPLE ANSWER BELOW)

The spring constant is found from Hooke's law: F = mg = -kx, or k = mg/x = 0.5*9.8/0.3 = 16.33 N/m. The spring constant and mass won't change on the Moon, so the new displacement can be found using these constants and the new g = 9.8/6 = 1.63 m/s^2: x = mg/k = 0.5*1.63/16.33 = 0.05 m. The spring will stretch 0.05 m or 5 cm on the Moon.