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APPS ON PHYSICS

SPRING PENDULUM

Reference: Simulation is available on Apps on Physics
Interface: Apps on physics>>Oscillations & Waves>>Doppler effect

Abstract:

A **spring pendulum** is a mechanical system that performs oscillatory and periodic motion due to the combined effect of spring's elasticity and gravitational force. It is also known as an **Elastic pendulum.** This project aims to determine the time period of the pendulum and verify the relationship between time period, mass and spring constant (Hooke's law).

Practical visualization of the spring pendulum is provided through the **Spring pendulum App.**

In the app, spring is attached to a mass and it undergoes oscillatory and periodic motion. Motion is driven by **Hook's law**, so the time period of oscillation is given by,

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where:

- T is the period of the oscillation,
- m is the mass,
- k is the spring constant.

- Other parameters:

PHYSICAL QUANTITY	FORMULA
Elongation	$x(t) = A\cos(\omega t + \phi)$
Velocity	$v(t) = -A\omega\sin(\omega t + \phi)$
Acceleration	$a(t) = -A\omega^2\cos(\omega t + \phi) = -\omega^2 x(t)$
Force	$F_{\text{spring}} = -kx$
Energy	$E = K + U = \frac{1}{2}kA^2$

Keywords: spring pendulum, oscillations, periodic motion, elasticity, force.

Aim of the Experiment:

To study the oscillatory motion of a spring pendulum and determine its time period and also verify the relationship between time period, mass and spring constant (Hooke's law).

Introduction:

The spring pendulum experiment examines the oscillatory motion (back and forth motion around the mean position) of a mass attached to a spring.

It demonstrates key concepts of simple harmonic motion (when the oscillations are small oscillatory motion is called as simple harmonic motion), such as Hooke's Law, the spring constant, and the relationship between mass and oscillation period (i.e. shows periodic motion – means it repeats its motion after certain period of time) as well as the energy, force, and acceleration involved in the motion.

This setup helps to understand the behaviour of oscillating systems and the physics of restoring forces.

Formula used:

1) Time Period (T):

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where:

- T is the time period,
- m is the mass attached to the spring,
- k is the spring constant.

2) **Displacement (x):**

$$x(t) = A \cdot \cos(\omega t + \phi)$$

where:

- $x(t)$ is the displacement at time t,
- A is the amplitude of oscillation,
- $\omega = \sqrt{\frac{k}{m}}$ is the angular frequency,
- ϕ is the phase constant (depends on initial conditions).

3) **Acceleration (a):**

$$a = -\frac{k}{m} \cdot x$$

where:

- a is the acceleration,
- k is the spring constant,
- m is the mass attached to the spring,
- x is the displacement from the equilibrium position.

4) **Force (f):**

$$F = -k \cdot x$$

where:

- F is the restoring force,
- k is the spring constant,
- x is the displacement from equilibrium.

5) **Energy (E):**

$$E = K + U = \frac{1}{2}kA^2$$

where:

- E is the total mechanical energy,
- A is the amplitude of oscillation

Procedure:

1. Open apps on physics
2. Tap on Spring pendulum (for reference, see image 1)
3. Set the appropriate parameters like mass, amplitude, spring constant. (for reference, see image 2).
4. Start the simulation (for reference, see image 3)
5. Perform the experiment using different parameters.

Calculation:

For mass = 5 kg, spring constant = 20 N/m.

- Time period is given by,

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Substituting the values:

$$T = 2\pi\sqrt{\frac{5}{20}} \approx 1.57\,\text{seconds}$$

For different sets of adjustable parameters experiment is performed and results are established.

Result:

Time period for different sets of adjustable parameters:

TABLE-1: CONSTANT- MASS & AMPLITUDE,
VARIABLE- SPRING CONSTANT

SET	MASS (m) (Kg)	AMPLITUDE (S) (m)	SPRING CONSTANT (k) (N/m)	ELONGATION Max. (m)	VELOCITY Max. (v) (m/s)	ACCELERATION Max. (a) (m/s^2)	FORCE (f) (N)	TOTAL ENERGY (U) (J)	TIME PERIOD (T) (sec)
1	5	0.05	20	0.05	0.100	0.200	1	0.0250	3.14
			25	0.05	0.112	0.250	1.25	0.0313	2.81
			30	0.05	0.122	0.300	1.50	0.0375	2.57
2	6	0.05	20	0.05	0.0913	0.167	1	0.0250	3.44
			25	0.05	0.102	0.208	1.25	0.0313	3.08
			30	0.05	0.112	0.250	1.50	0.0375	2.81
3	7	0.05	20	0.05	0.0845	0.143	1	0.0250	3.72
			25	0.05	0.0945	0.179	1.25	0.0313	3.32
			30	0.05	0.104	0.214	1.50	0.0375	3.04

TABLE-2: CONSTANT- SPRING CONSTANT & AMPLITUDE,
VARIABLE- MASS

SET	MASS (m) (Kg)	AMPLITUDE	SPRING CONSTANT (k) (N/m)	ELONGATION Max. (m)	VELOCITY Max. (v) (m/s)	ACCELERATION Max. (a) (m/s²)	FORCE (f) (N)	TOTAL ENERGY (U) (J)	TIME PERIOD (T) (sec)
1	5	0.05	20	0.05	0.100	0.200	1	0.0250	3.14
	6	0.05		0.05	0.0913	0.167	1	0.0250	3.44
	7	0.05		0.05	0.0845	0.143	1	0.0250	3.72
2	5	0.05	25	0.05	0.112	0.250	1.25	0.0313	2.81
	6	0.05		0.05	0.102	0.208	1.25	0.0313	3.08
	7	0.05		0.05	0.0945	0.179	1.25	0.0313	3.32
3	5	0.05	30	0.05	0.122	0.300	1.50	0.0375	2.57
	6	0.05		0.05	0.112	0.250	1.50	0.0375	2.81
	7	0.05		0.05	0.104	0.214	1.50	0.0375	3.04

TABLE-3: CONSTANT- SPRING CONSTANT & MASS,
VARIABLE- AMPLITUDE

SET	MASS (m) (Kg)	SPRING CONSTANT (k) (N/m)	AMPLITUDE	ELONGATION Max. (m)	VELOCITY Max. (v) (m/s)	ACCELERATION Max. (a) (m/s²)	FORCE (f) (N)	TOTAL ENERGY (U) (J)	TIME PERIOD (T) (sec)
1	5	20	0.05	0.05	0.100	0.200	1	0.0250	3.14
			0.06	0.06	0.120	0.240	1.20	0.0360	3.14
			0.07	0.07	0.140	0.280	1.40	0.0490	3.14
2	6	20	0.05	0.05	0.0913	0.167	1	0.0250	3.44
			0.06	0.06	0.110	0.200	1.20	0.0360	3.44
			0.07	0.07	0.128	0.233	1.40	0.0490	3.44
3	7	20	0.05	0.05	0.0845	0.143	1	0.0250	3.72
			0.06	0.06	0.101	0.171	1.20	0.0360	3.72
			0.07	0.07	0.118	0.200	1.40	0.0490	3.72

Conclusion:

- For a spring pendulum with **constant mass and amplitude**, as the **spring constant increases**, the **velocity, acceleration, force, and energy all increase,** while the **time period decreases**. This indicates that a stiffer spring results in a faster, more energetic oscillation. **(table -1)**

- For a spring pendulum with a **constant spring constant and amplitude**, as **the mass increases**, the **velocity and acceleration decrease,** while **the time period increases**. The force and total energy remain unaffected by changes in mass, highlighting that mass primarily influences the motion dynamics, leading to slower oscillations and longer periods**. (table-2)**

- For a spring pendulum with a **constant spring constant and mass, as the amplitude increases, the velocity, acceleration, force, and total energy all increase**. However, the **time period remains unchanged**, indicating that while the system's dynamics (velocity, force, energy) are influenced by the amplitude, the time required for one complete oscillation remains constant**. (table-3)**

The results reflect expected physical behaviour:
- Force, total energy, and time period increase with mass and spring constant.
- Velocity and acceleration fluctuate slightly due to the combined effects of mass and spring constant.
- The time period decreases with a higher spring constant and increases with mass, consistent with the formula $T = 2\pi\sqrt{\frac{m}{k}}$.

- In a practical spring pendulum, the motion is periodic, with oscillations driven by the spring's restoring force and gravity. Over time, damping effects like air resistance cause the amplitude to decrease.
- The total energy oscillates between kinetic and potential energy, but real-world factors like friction lead to gradual energy loss and changes in the motion.

(Results are observed with respect to varying parameter increases)

Constant Parameter(s)	Varying Parameter(s)	Time Period (T)	Velocity	Force	Acceleration	Energy (E)
Mass, Amplitude	Spring Constant (k)	Decreases	Increases	Increases	Increases	Increases
Spring Constant, Amplitude	Mass (m)	Increases	Decreases	No Change	Decreases	No Change
Spring Constant, Mass	Amplitude (A)	No Change	Increases	Increases	Increases	Increases

(Table: Results for all possible cases)

References: https://www.walter-fendt.de/html5/phen/

Image 1: Spring pendulum Practical Demonstration.

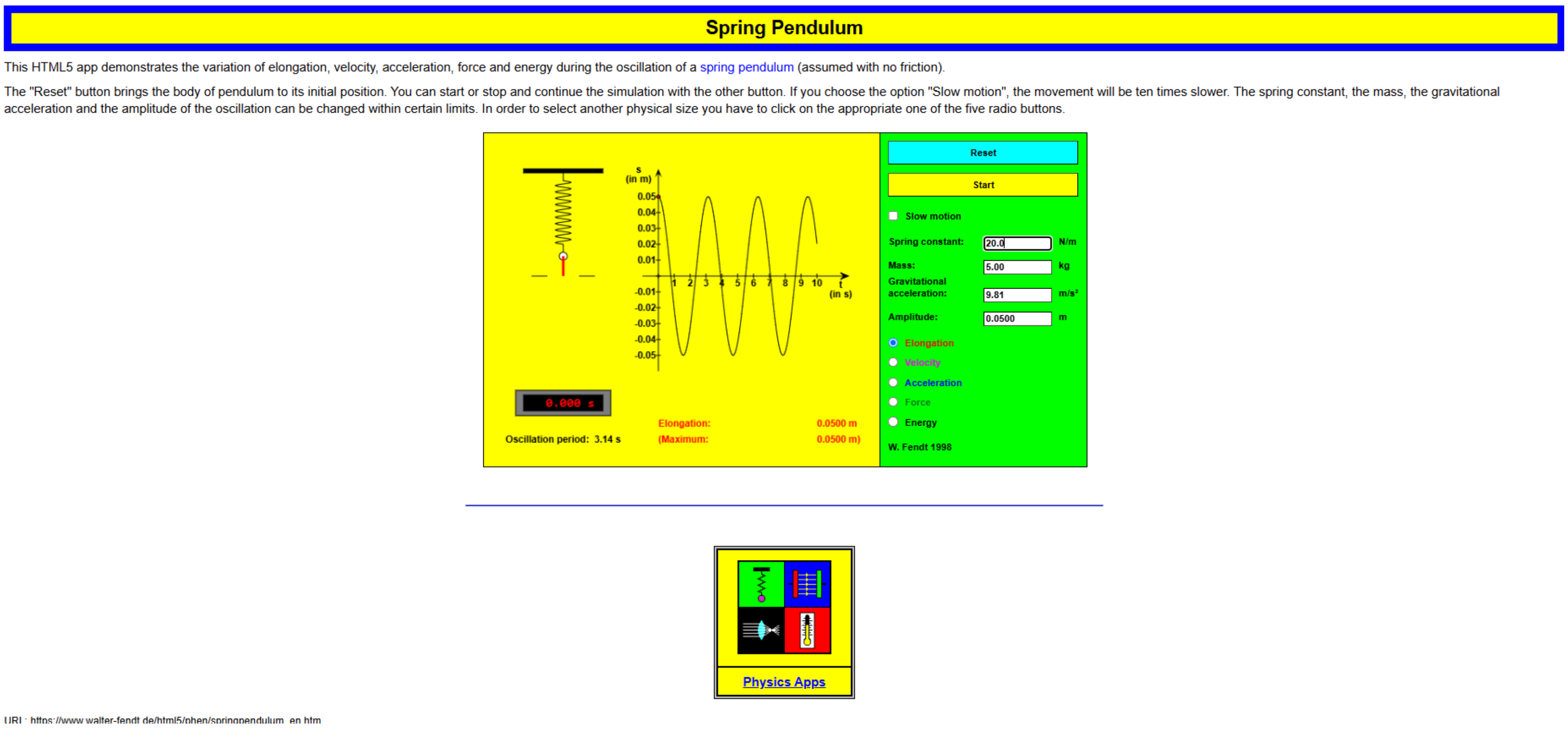


Image 2: Modify Required Parameters from the Panel & spring pendulum set up.

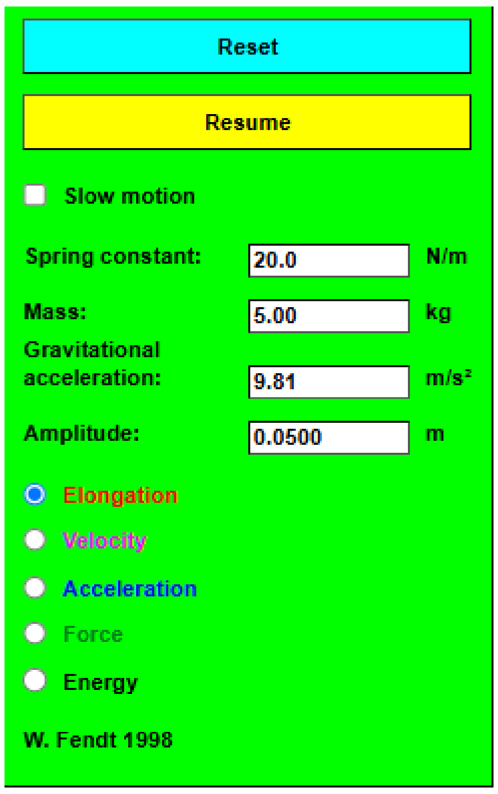
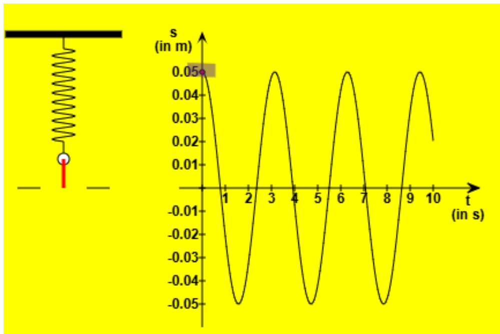


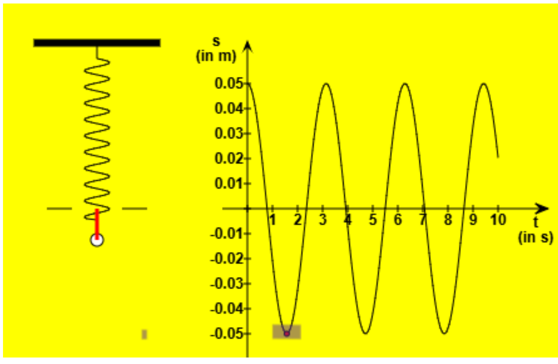
Image 3: Experiment performed for the given set,

- Mass-5 kg
- Spring constant-20N/m
- Amplitude-0.0500m
- g=9.8

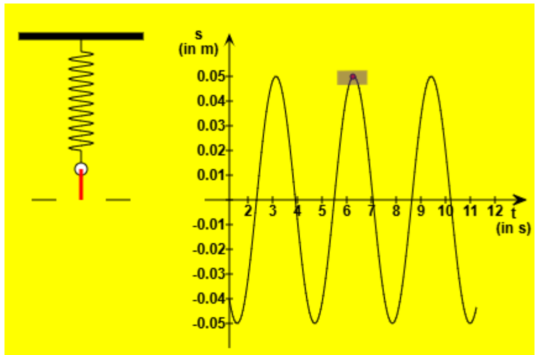
1)Displacement:



1.Mean position

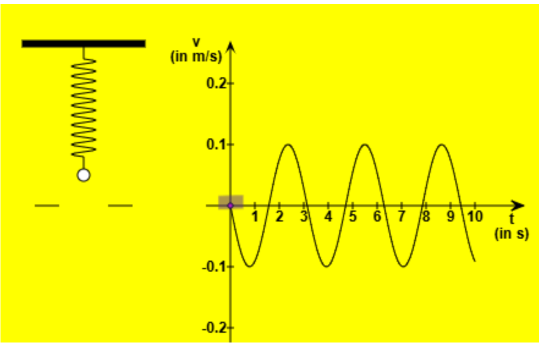


2.stretched spring

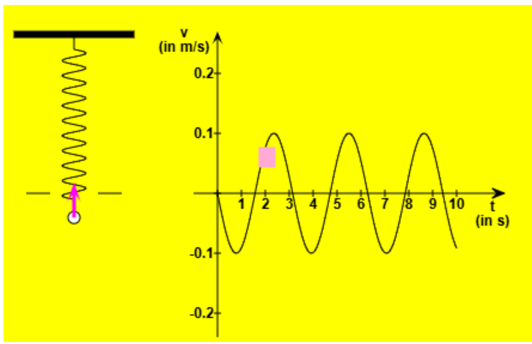


3.compressed spring

2)Velocity:



1.Mean position



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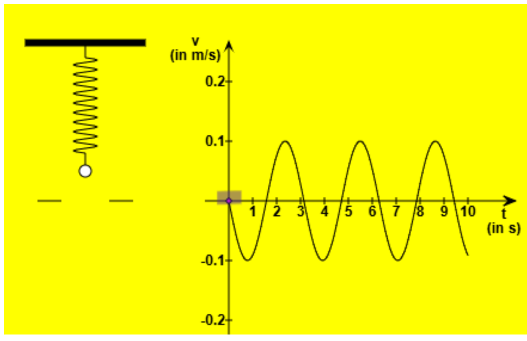
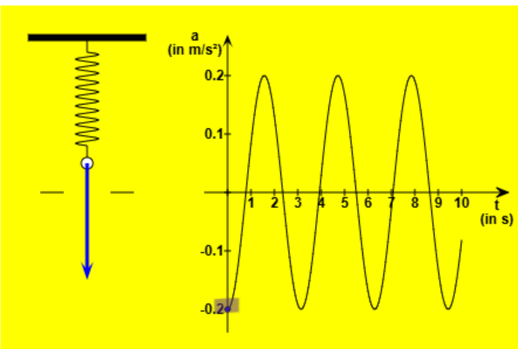
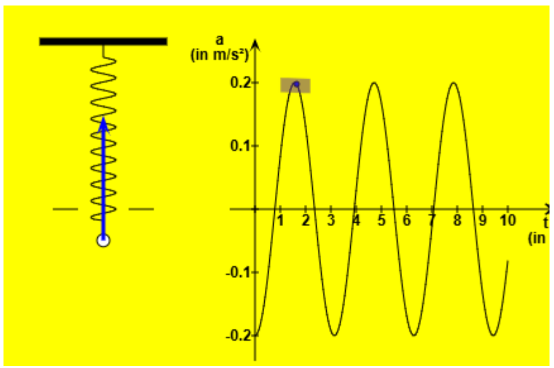


3.compressed spring

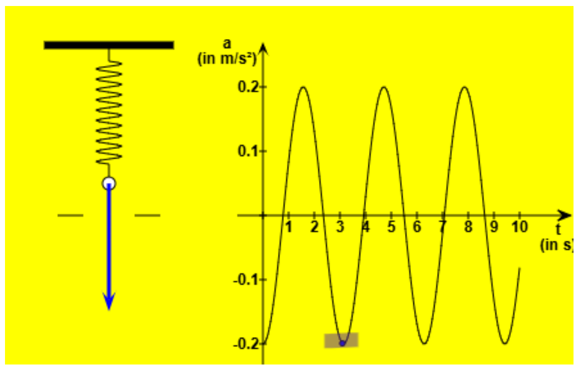
3)Acceleration:



1.Mean position

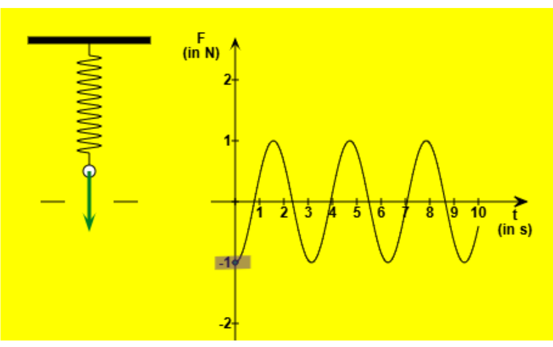


2.stretched spring

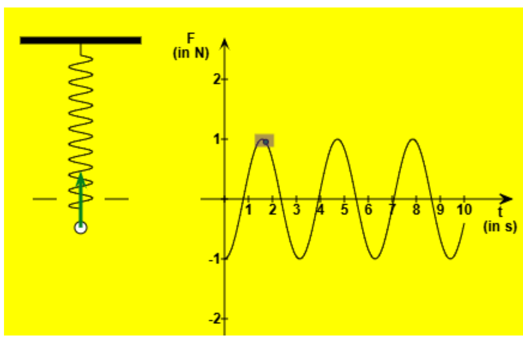


3.compressed spring

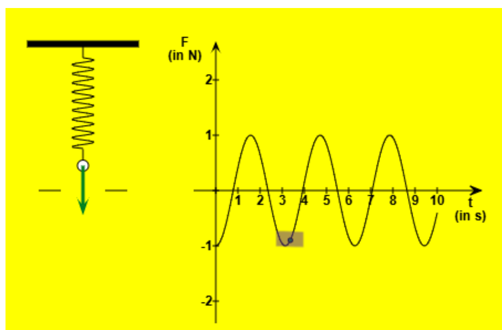
4)Force:



1.Mean position

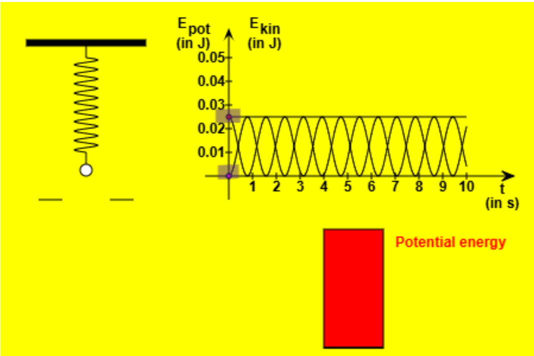


2.stretched spring

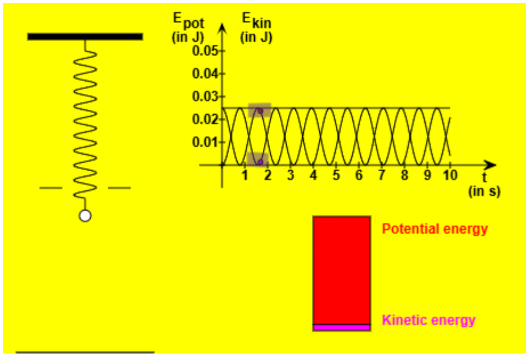


3.compressed spring

5)Energy:



1.Mean position



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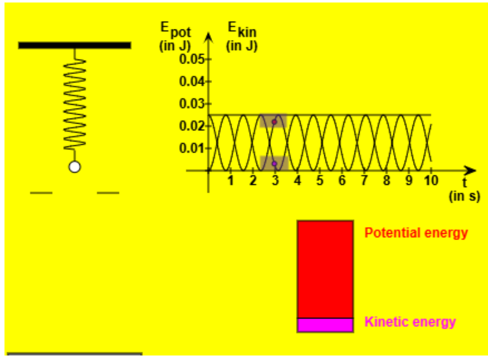
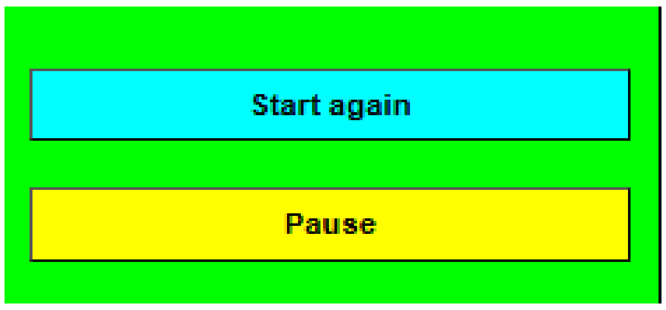


3.compressed_spring

To start again or Pause



start & pause button