Relationship between "Mechanical Energy Equipment Apparatus" and the law of conservation of mechanical energy

NaRiKa Corporation

1. Relationship between "Mechanical Energy Equipment Apparatus" and the law of conservation of mechanical energy

Purpose of this product (C15-2352) is that students confirm and understand the theory of mechanical energy conservation based on the results of their experiments while using this product. This product does not guarantees giving you highest accuracy result because it is a science equipment for education in schools, not university level equipment.

The mechanical energy (E) is defined by sum of the potential energy (U) and the kinetic energy (K) (see eq. 1). And you may get Eq. 2 from Eq. 1 under a condition of gravity only such as a free fall. Finally, Eq. 3 is given by Eq. 2 changed. "Work" is defined by product of Force and displacement of an object. Equation of "Work" is given by difference between primary kinetic energy and final kinetic energy (see eq. 4).

$$E = U + K \quad \text{(1)}$$

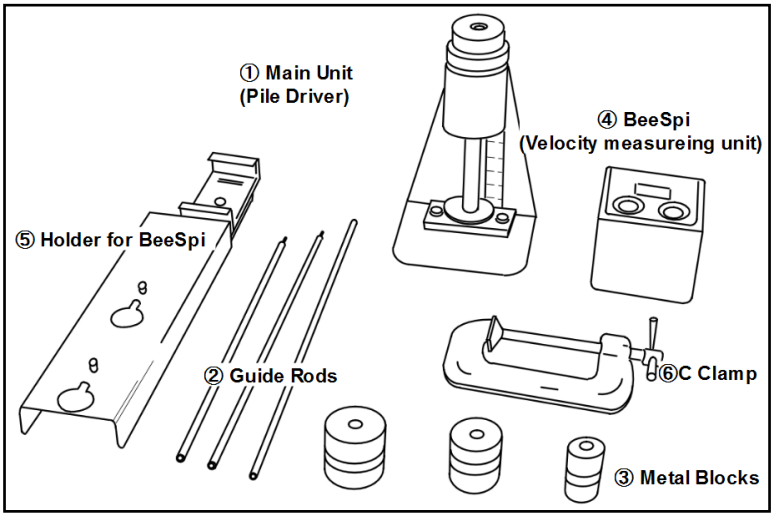
$$E = mgh + \frac{1}{2}mv^2 = \text{Constant} \quad \text{(2)}$$

$$mgh = \frac{1}{2}mv^2 \quad \text{(3)}$$

$$W = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \frac{1}{2}m(v_2 - v_1)^2 \quad \text{(4)}$$

The product may give your student to confirm and understand above relation of equations, which is especially eq. 3 and eq. 4, through experiments using it.

1. **Contents of the product**



① Main Unit (Pile Driver): 1 ② Guide Rods: 3 ③ Metal Block: 3 (50g, 100g,150g)
④ BeeSpi v: 1 ⑤ Holder for BeeSpi: 1 ⑥ C Clamp: 1

2. Function of each part

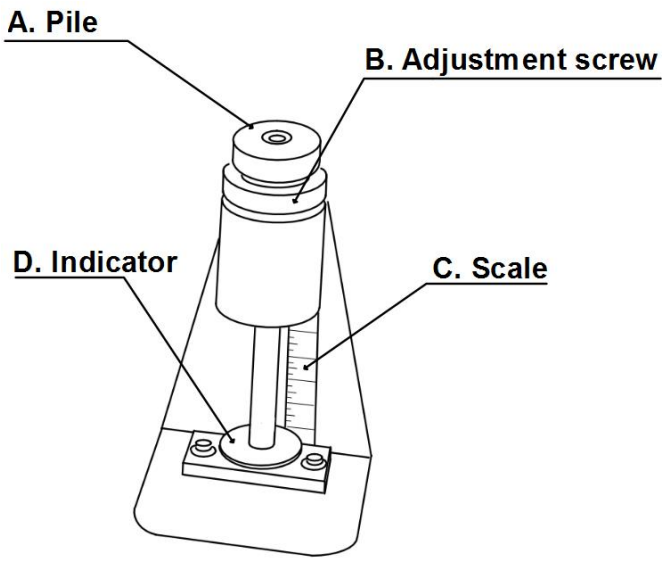
1. Main Unit (Pile Driver)

A. Pile

Pile of the pile driver consists of an impact receiver, a friction block and an indicator and there is a hole for guide rod on the center of its top.

B. Adjustment screw

Adjustment screw controls to squeeze friction force against the pile. When you turn the screw clockwise, the friction force against the pile increase. In case of anti-clockwise, the friction force against the pile decrease.



C. Scale

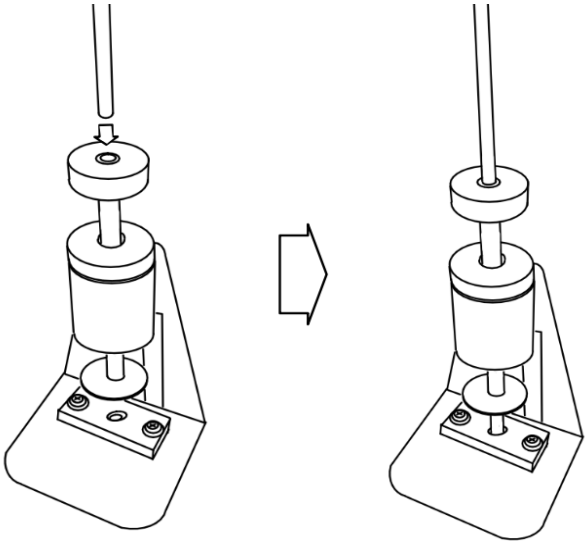
Scale is for reading distance of moving pile by impact of metal block onto the pile. Its scale is in mm.

D. Indicator

A disc plate that functions as an indicator points to the pile moving distance on the scale.

2. Guide Rod

Guide rods are divided in 3 short rods for storage in a package and have 4 range slits on each rod to indicate every 10 cm on it. Please screw those 3 rods together to make one guide rod in the experiment. To set up the equipment, insert an end of screw of the guide rod into a hole of the top pile to the bottom. Then screw the guide rod to the hole of bottom of the pile driver.



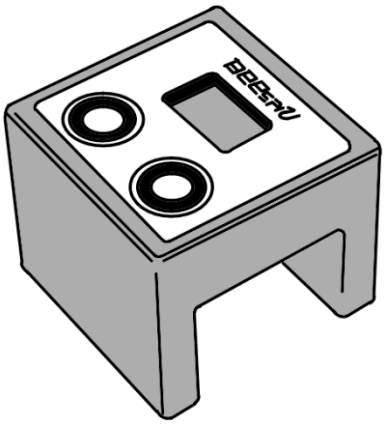
2. Metal Block

There are 3 kinds of metal block which have 50g, 100g and 150g each with a hole in center. Mass ratio is 1:2:3.

3. BeeSpi v (S77-1321-W0)

BeeSpi v is a sensor equipped velocity measuring device.

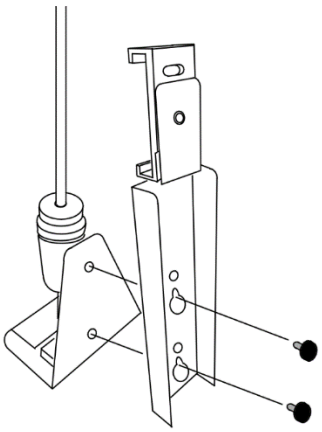
Speed Measurement Range: 0 to 999.9 cm/s, o to 99.99m/s, 0 to 99.99 km/h
Lap Time: 0 to 99.99sec
Accumulated Lap Time: 0 to 99.99sec
Power Source: Two size AAA batteries (sold separately)
Size: 60 x 60 x 50mm, Inside Dimension 40 x 30mm
Weight: 65g (excluding batteries)
Functions: Memory function for saving up to 5 latest measured data, Speed measurement, Lap time measurement

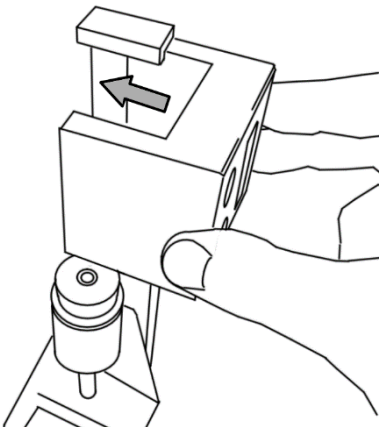


4. Holder for BeeSpi v

The holder is for BeeSpi v to measure a dropping speed of object and is specially designed for it.

[Setting the holder for BeeSpi v to the main unit]
When you want to measure velocity of dropping metal block, you must set BeeSpi v into its holder. Assemble the holder for BeeSpi v with the main unit by fastening knurled screws (see fig. below), and then insert BeeSpi v into the holder (see fig. below). Before measurement of velocity using BeeSpi v, check whether or not the guide rod blocks the photogates of BeeSpi v. If they are blocked, move the BeeSpi v to clear the space, so that the photogates can do the measurement.





5. C Clamp
The C type clamp is to be used with the main unit. In case of doing experiments with cart collision, you need the clamp to fix the main unit to a table etc.

3. Setup of BeeSpi v

1) Insert two AAA batteries in BeeSpi v after sliding off the battery cover.

2) Check if four numeric characters, "0" (zero), appears on the LCD display. In case of using BeeSpi v with batteries already inserted, you may find nothing appears on the LCD display, which means it is off. If so, turn the power on by pressing "START" or "SELECT" button.

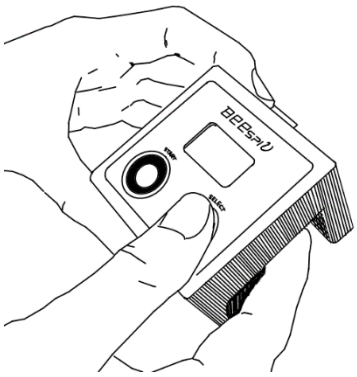
3) Measurement unit appears at the right edge of the LCD display. Unit of "m/s" is selected for every experiment covered in this teachers' guide. To select the measurement unit, press "SELECT" button for more than two seconds to change the unit in order of "m/s" → "m/h" → "cm/s".

4) Press "START" button to set BeeSpi v into measurement mode after confirming "m/s" unit is appearing on the LCD display.

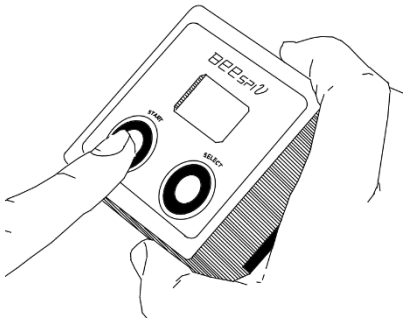
5) In the measurement mode, BeeSpi v is activated if the selected unit "m/s" is flashing. In this

state, speed measurement starts when the first photogate is shielded and ends when the second photogate is shielded by the moving object running through the BeeSpi v.

6) BeeSpi v retains up to five latest measurement results that can be brought up with data number (1~5) at the upper-left of the LCD display by repeatedly pressing "SELECT" button.



SELECT Button:
To activate measurement mode



START Button:
To select unit and retrieve measurement results

2. Experiment 1: Relationship of Kinetic energy and Potential energy

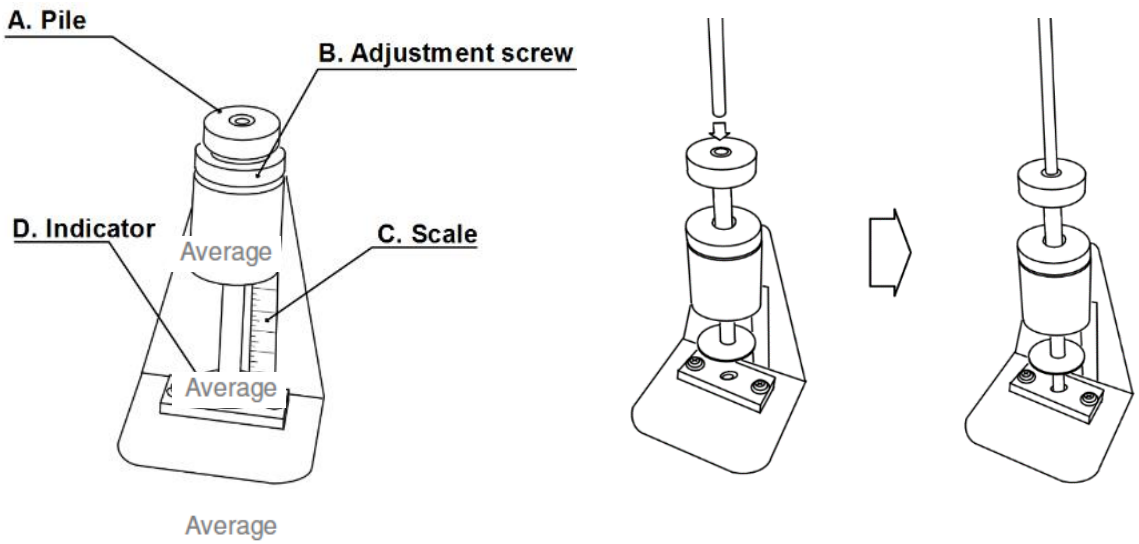
1. Calibration of friction force

As preparation, calibration of friction force is necessary for measuring the kinetic energy. You should adjust force of friction against the pile to set up suitable condition for experiment, in which the indicator of pile moves 50 mm when Metal block (150g) is dropped from 400 mm height which is position of first slit from top of the guide rod.

1) Inserts an end of screw of the guide rod into a hole of the top pile to the bottom (see fig. below). Pull the pile up to top position.

2) Drop the metal block (150g) from 400mm height use first slit from the top of the guide rod as indicator.

3) Check a numerical value of the scale of pile driver (main unit). Adjust the friction force of pile to be about 50 mm of the scale of pile driver using the adjustment screw. During the experiment, do not change the friction force of pile driver.



2. Measurement of Pile depth

1. Purpose of experiment

The purpose is to confirm the relationship between the kinetic energy and the potential energy from a graph of data in the result. Measure the pile depth by dropping each metal block (50g, 100g, 150g) from each 100mm height (100mm, 200mm, 300mm, 400mm) after calibration. Then fill out the results in table similar to the one below. After that make a graph of those average data.

2. Experiment tips

When you decide the height of dropping metal block, it is useful to align the bottom of block and the slit of the guide rod. On the other hand, to get same height when an upper side or a center of block is aligned with the slit of rod, the dropping height of block may become unstable.

Table 1. Result of Pile depth by dropping each weight from each height.

Weight (g)	Height (mm)	100			200			300			400		
150	Depth of Pile (mm)	16.0	17.0	16.0	32.0	31.0	30.0	45.0	45.0	42.0	53.0	52.0	55.0
	Advantage (mm)	16.3			31.0			44.0			53.3		
100	Depth of Pile (mm)	9.0	10.0	9.0	17.0	19.0	18.0	26.0	28.0	29.0	34.0	34.0	34.0
	Advantage (mm)	9.3			18.0			27.7			34.0		
50	Depth of Pile (mm)	4.0	4.0	4.0	8.0	7.0	7.5	10.0	11.0	10.0	14.0	14.0	15.0
	Advantage (mm)	4.0			7.5			10.3			14.3		

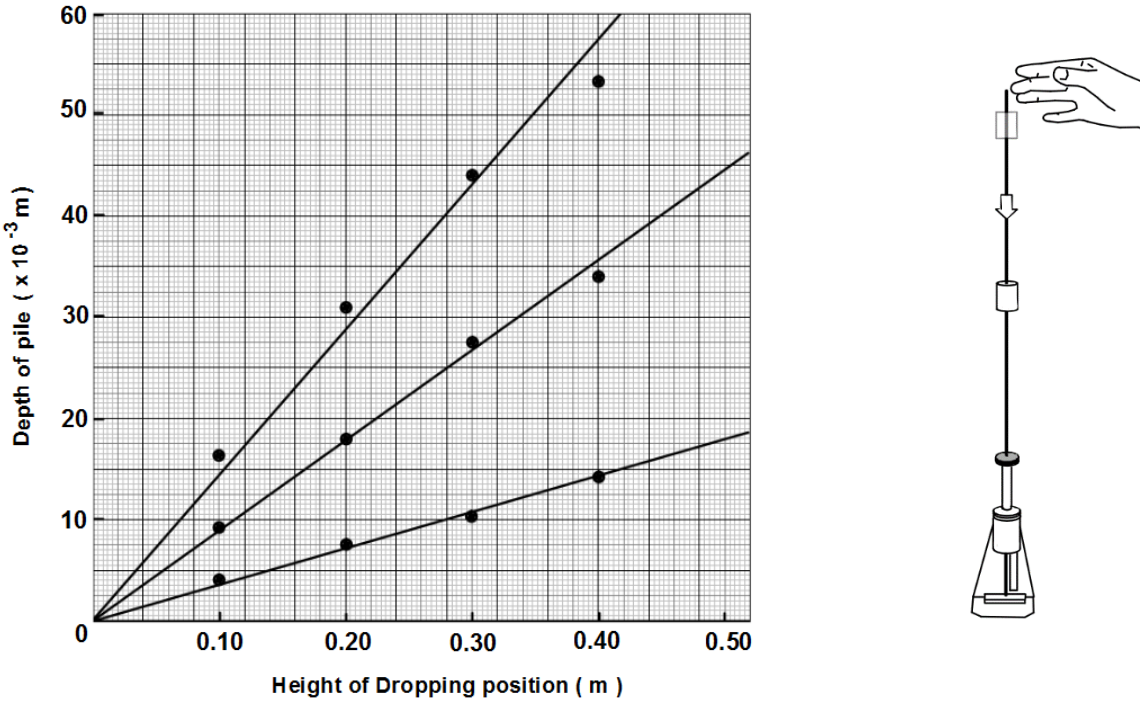


Fig. 1 Result of Pile depth by dropping each weight from each height

The result of this experiment is shown in Table 1 and Fig. 1. The graph in Fig. 1 means that the relationship of the depth of pile and height of dropping (drop distance) are in a direct proportion with each other and are linear function. On the other hand, theoretical formula (5) is given from equation (1), (2) and (3). The kinetic energy K means a direct function with an inclination mg and height h.

$$K = mgh \qquad (5)$$

Students can confirm the relationship between the kinetic energy and the potential energy as in eq. 5 through their graph and result of experiment using this equipment.

3. Experiment 2: Measurement of Velocity of metal block dropping

1. Purpose of Experiment

The purpose is to confirm relationship between the kinetic energy and the potential energy from a graph of data in the result. Measure the velocity of metal block dropping, and the pile depth by dropping each metal block (50g, 100g, 150g) from each 100mm height (100mm, 200mm, 300mm, 400mm) after finished the calibration.

2. Experiment tips

When you decide the height of dropping metal block, it is useful to align the bottom of block and

the slit of the guide rod. On the other hand, to get same height when an upper side or a center of block is aligned with the slit of rod, the dropping height of block may become unstable.

When setting up BeeSpi with its holder, you should be careful about the position of its photogates. Please check whether the guide rod blocks the photogates of BeeSpi v or not. If the guide rod blocks the photogates, change the position of the BeeSpi in the holder to make some space for the photogates not to be blocked by the guide rod, then conduct the experiment.

Table 2. Result of Pile depth and Velocity by dropping each weight from each height.

Heigth(mm)	100		200		300		400	
Weight of Block	Depth of Pile	Velocity (m/s)	Depth of Pile	Velocity (m/s)	Depth of Pile	Velocity (m/s)	Depth of Pile	Velocity (m/s)
150 g	13	1.18	28	1.82	34	2.27	50	2.66
	14	1.17	29	1.83	40	2.31	43	2.62
	15	1.18	28	1.83	34	2.28	39	2.61
Ave.	14.0	1.177	28.3	1.827	36.0	2.287	44.0	2.630
100g	9	1.20	18	1.83	23	2.29	33	2.67
	10	1.21	18	1.84	25	2.30	31	2.65
	10	1.19	16	1.85	25	2.30	30	2.67
Ave.	9.7	1.200	17.3	1.840	24.3	2.297	31.3	2.663
50g	3	1.2	8	1.84	12	2.32	13	2.68
	3	1.19	8	1.84	11	2.27	14	2.72
	4	1.21	8	1.84	11	2.31	13	2.62
Ave.	3.3	1.200	8.0	1.840	11.3	2.300	13.3	2.673

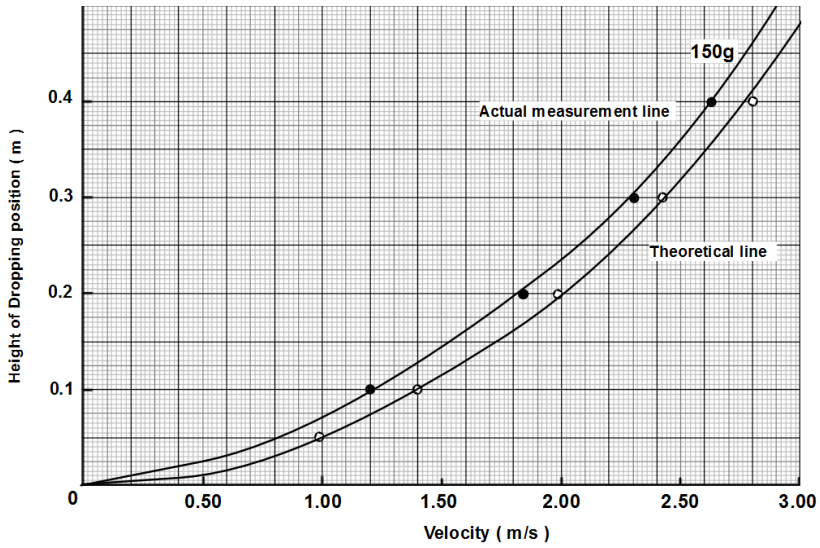


Fig 2. Relationship with height of dropping position and velocity

Measure the depth of pile and velocity at the impact with the pile of height dropped (100, 200, 300, 400 mm) of Metal block with weight (50, 100 and 150g). The result in Table 2 shows that the velocity relates only with height of dropping position not weight of the metal block. The graph of results with 150g metal block are typical result and based on the results theoretical calculated value is shown in Fig. 2. Its graph has the vertical axis (y-axis) of the height of drop position and the horizontal axis (x-axis) of the velocity.

On the other hand, you may transform equation 3 to be equation 6 & 7. The equation 7 means a quadratic function of height and velocity.

$$v^2 = 2gh \qquad (6)$$

$$h = \frac{v^2}{2g} \qquad (7)$$

The graph shows both curves are similar to the quadratic function which is based on equation 7. You may see that curve of measured values (150g) and of theoretical calculated values are similar in Fig. 2. And those curves are shown in quadratic function curve.