Let's Read !

■ Work and Energy

Work

Sometimes in science we use words in a different sense to the way they are normally used in everyday life. In its everyday sense, the term work means to do something that takes physical or mental effort. But in physics, **work** has a **distinctly** different meaning. When a **force acts** upon an **object** to cause a **displacement** of the object, it is said that work was done upon the object.

Work is defined as the force times the distance moved in the direction of the force.

This means that if there is no movement in the direction of the force, then no work is done.

Work is a **scalar quantity** and is measured in **joules**. It is independent of the mass of the object being moved and the path taken. It only depends on the **magnitude** of the force and the distance moved in the direction of the force.

The equation for work is:	$W=Fs$

Energy

Types of Energy

Energy is the ability to do work. The **unit** of energy is the joule [J]. Energy is a scalar quantity. We usually **classify** energy as the following forms:

1 Kinetic energy
2 Gravitational potential energy
3 Elastic potential energy
4 Thermal or heat energy
5 Light energy
6 Sound energy
7 Chemical energy
8 Electrical energy
9 Magnetic energy
10 Nuclear energy

Kinetic energy

Kinetic energy (*K*) is the energy an object has because it is in **motion**. The word kinetic refers to motion.

The kinetic energy of an object with **mass** m moving at a **velocity** v is one half the product of the mass of the object and the square of its velocity, i.e., $K = 1/2\, mv^2$.

Kinetic energy **depends on** both an object's speed and its mass. If a bowling ball and a volleyball are **traveling** at the same speed, which do you think has more kinetic energy? You may think that because they are moving with **identical** speeds they have exactly the same kinetic energy. However, the bowling ball has more kinetic energy than the volleyball traveling at the same speed because the bowling ball has more mass than the volleyball.

Gravitational potential energy

Gravitational potential energy (*U*) is the energy **stored** in an object because of its position, in particular, its **vertical height** relative to a given point.

For example, a stone **resting** on the edge of a cliff has potential energy due to its position in the earth's **gravitational field**. If it falls, the force of gravity (which is equal to the stone's weight) will act on it until it strikes the ground; the stone's gravitational potential energy is equal to its mass **times free-fall acceleration** times the distance it can fall, i.e., $U=mgh$.

Note that the height, h, is measured from an **arbitrary zero level**. In the example of the stone, if the ground is the zero level, then h is the height of the cliff, and mgh is the gravitational potential energy relative to the ground. Alternatively, if the edge of the cliff is the zero level, then h is zero. Thus, the potential energy associated with the stone relative to the edge of the cliff is zero.

Conservation of mechanical energy

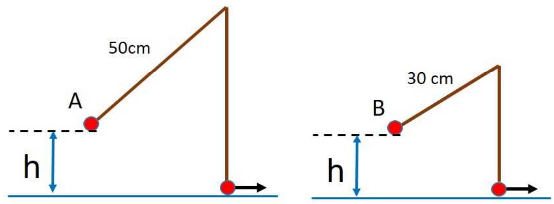
In the **absence** of **friction**, the total **mechanical energy** remains the same. This **principle** is called **conservation of mechanical energy**. Although the amount of mechanical energy is constant, mechanical energy itself can change form. This law is one of the most important laws that we use in physics. For instance, consider the forms of energy for the falling egg. As the egg falls, the potential energy is continuously **converted** into kinetic energy. If the egg were thrown up in the air, kinetic energy would be converted into gravitational potential energy. In either case, mechanical energy is converted.

$$1/2\ mv^2_{initial} + mgh_{initial} = 1/2\ mv^2_{final} + mgh_{final}$$

$$1/2\ mv^2_{initial} + 1/2\ kx^2_{initial} = 1/2\ mv^2_{final} + 1/2\ kx^2_{final}$$

Understanding Main Concepts

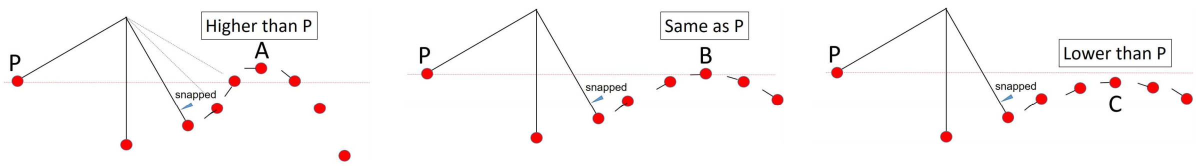
1. Two small balls, A and B, of equal mass m attached to strings of length 50 cm and 30 cm respectively. If the balls are released from rest at a height h above the ground, which velocity of the balls is higher at the bottom of the swing?



   a. A is higher **b.** B is higher **c.** Both are the same

2. If the ball is released from rest at point P, then the string breaks at point Q. Assume negligible air resistance throughout the motion, the motion of the ball after the string breaks is

   a. A **b.** B **c.** C



【Vocabulary】

本文			
work	noun	仕事	a force acting upon an object to cause a movement
distinctly	adv	はっきりと、明瞭に	
force	noun	力	
act	verb	働く、作用する	
object	noun	物体	
displacement	noun	変位	
direction	noun	方向	a course along which someone or something move
scalar quantity	noun	スカラー	
joule	noun	ジュール《エネルギーの単位》	
magnitude	noun	大きさ	
unit	noun	単位	a fixed quantity that is used as a standard measurement
classify	verb	分類する	
kinetic energy	noun	運動エネルギー	the energy an object has because it is in motion
motion	noun	動き、運動	in motion: 動いている
mass	noun	質量	the quantity of matter which a body contains
velocity	noun	速度	the speed of something in a particular direction
depends on		(によって)決まる	
travel	verb	進む、動く	
identical	adj	同一の	
gravitational potential energy	noun	重力による位置エネルギー	the energy stored in an object because of its position
gravity	noun	重力	the force that attracts a body towards the center of the earth
store	verb	蓄える	
vertical height	noun	鉛直高さ	
rest	verb	静止している	
gravitational field	noun	重力場	
times	verb	かける	
free-fall acceleration	noun	重力加速度	the acceleration due to gravity
arbitrary	adj	任意の	
zero level	noun	ゼロレベル	
absence	noun	ないこと	
friction	noun	摩擦力	the resistance of one surface to another surface
mechanical energy	noun	力学的エネルギー	
principle	noun	原理、法則	a general or scientific law that explains how something works or why something happens
conservation of mechanical energy	noun	力学的エネルギーの保存	the total mechanical energy in a system remains constant as long as the only forces acting are conservative forces
convert	verb	変換する	
授業			
uniform motion	noun	等速直線運動	
A **is proportional to** B		A は B に比例する	

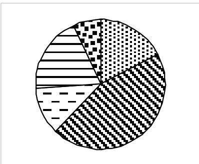
■ Conservation of Mechanical Energy

Scientific Communication

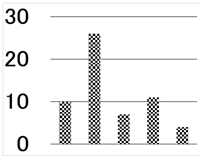
「グラフ」を説明してみよう！

■グラフの用語

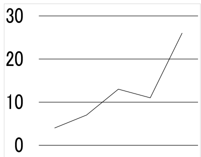
pie chart



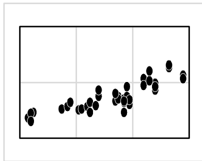
bar graph



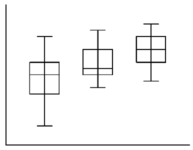
line graph



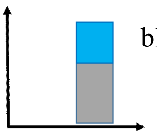
correlation diagram



box plot



vertical axis



blue portion

horizontal axis

solid line
dotted line
double line
broken line

thin line
thick line

Figure: image, diagram, or photograph
Table : information presented in columns and rows

■グラフの説明表現

B は A に比例する	B is proportional to A.
A が大きければ大きいほど、B も大きくなる	the ＋比較級 A, the ＋比較級 B
B は A に反比例する	B is inversely proportional to A.
A が増加すると B も増加する	B increases as A increases
A が増加すると B は減少する	B decreases as A increases
変化が見られない	remain constant

It's Your Turn -Activities with TA-

【Role play】

A:	B:
What does <u>Fig 1</u>. show?	Acceleration <u>is proportional to</u> force.
What does <u>Fig 2</u>. show?	<u>The bigger</u> the force, <u>the greater</u> the acceleration.
What does <u>Fig 3</u>. show?	Gravitation is inversely proportional to distance.
What does <u>Fig 4</u>. show?	Lifting power <u>increases as</u> velocity of the wind increases.
What does <u>Fig 5</u>. show?	Current decreases as distance increases.

be proportional to

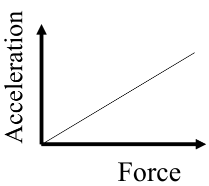


Fig. 1

The bigger, the greater

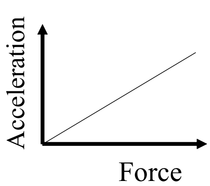


Fig. 2

be inversely proportional to

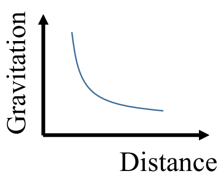


Fig. 3

... increases as _ increases

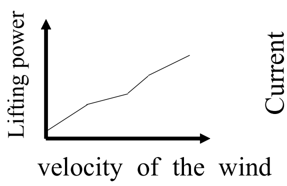


Fig. 4

... decreases as _ increases

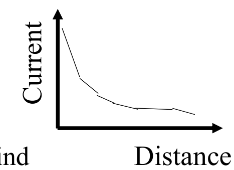
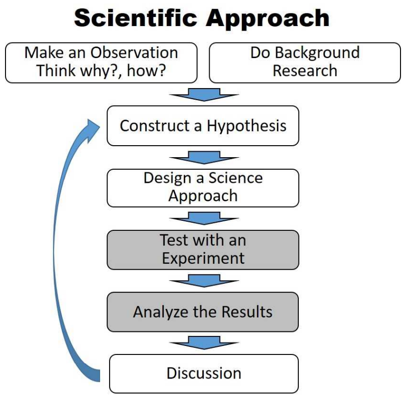


Fig. 5

English Science

Words learned through English Science

Test with an Experiment



●課題を解決するための科学的手法の１つに、「実験、観察、調査等の方法や結果を記録し、整理すること」があります。

信頼性の観点から、実験は再現可能でなければなりません。すなわち、他の研究者が同じ条件で同じ実験を行ったら、同じ結果にならなければなりません。そのため、方法では、実験の詳細（使用した材料 materials、器具 instruments、過程 procedures used、条件 conditions）を述べる必要があります。さらには、どうして特定の方法を用いたのか、どうして仮説の検証に適当なのかを伝える必要があります。

ここでは、実験結果に影響を与える他の要因（影響要因 Influence factor）を意識して実験を行い、実験結果をグラフに表現する方法を学びましょう。

補足：仮説を検証するには、実験等を行いますが、生物や地学の一部では、「再現可能」な実験を行うことができない場合があります。そのような場合でもその結果が再現可能であることを保証する統計的解析という手法があります。

Hypothesis & Science Approach

● Aim of your research

To confirm experimentally whether mechanical energy is conserved using a swing.

Equation of free fall: $H = \frac{1}{2} g t^2$

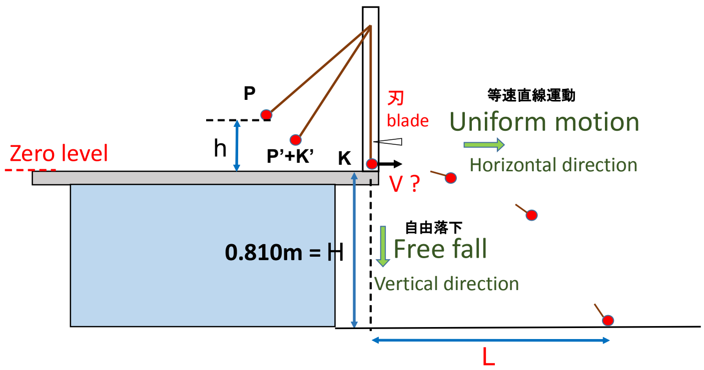


Figure 1: The motion of a ball after a string has broken

Understanding Energy 1

The diagram above shows the the motion of a ball after a string has broken at the bottom of the swing. Use the diagram, answer the questions that follows.

【TAs Question】

Q1.

Q2.

Q3.

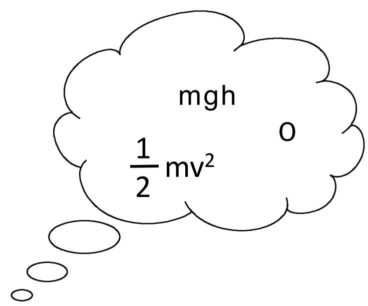
Q4.

Q5.

Q6.

【Your Answer】

Q1.～ Q6.



Exercise 1

1. After the string has broken, in the vertical direction, the motion of the ball is in free fall. If the height of the desk is 0.810m, calculate the time taken to reach the floor. Use g = 9.8 [m/s^2].

Solution
hint : $H = \frac{1}{2}gt^2$ **Ans.** ________________ [s]

2. In the horizontal direction, what is the motion of the ball?

Ans. ________________

3. If the ball moves L[m] to the horizontal direction when the ball hits the floor, represent V using L.

Because,
Ans. V = ________ [m/s]

● Hypothesis & Design a Science Approach

In order to test this hypothesis, you design the following experiment (Figure 1).

Hypothesis	:	The gravitational potential energy at the top of the swing is equal to the kinetic energy at the bottom of the swing.
Independent variable	:	The height of a ball at the top of the swing
Dependent variable	:	The velocity of a ball at the bottom of the swing
Methods	:	Measure the gravitational potential energy at the top of the swing and the kinetic energy at the bottom of the swing. Then compare the amount of both energies.

1 Test with an Experiment

If you construct a hypothesis, the next step is to test the hypothesis through an experiment.

Activity 1

Before you start the experiment, look at the apparatus of other groups. In this experiment, the independent variable is the height of a ball and the dependent variable is the velocity of a ball.

1. Write down other values/factors/things/variables which are different from your group.

2. Talk about whether each of the values can have an effect on the results of this experiment, and whether you should keep the same throughout the experiment, then divide the values into two groups.

Controlled variable (Values you should keep the same)	Values you do not need to keep the same

2 Analyze the Results -Present your data in a useful format-

Organizing Data

Activity 2

Create a table in which to record your data, then start the experiment.

Group	m[kg]	h[m]	U[J] mgh	L[m]	V[m/s] $V = \frac{L}{0.405}$	v^2	K[J] $\frac{1}{2}mv^2$
Group___							

In order to express the results of an experiment more exactly, error bars which represent the uncertainty or variation of the corresponding coordinates of each point are put on the graph.

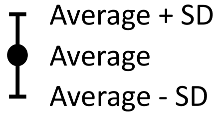
Organizing Data

Exercise 2 Use the data below, put the error bar on a dot. h=0.15 and h=0.20 are done for you.

Table 1 : Relationship between height and v^2 (n=10)

h [m]	V^2 [m^2/s^2]										average	SD
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	[m^2/s^2]	
0.10	2.04	1.88	1.99	1.96	1.96	2.10	1.93	1.54	1.90	2.02	**1.93**	**0.15**
0.15	2.79	2.76	2.82	2.34	2.89	2.86	2.89	2.86	2.89	2.92	**2.80**	**0.17**
0.20	4.20	3.69	4.04	3.50	4.12	3.72	3.88	3.96	4.08	4.12	**3.93**	**0.23**

error bar



標準偏差
Standard deviation (SD) $= \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$

Constructing Graphs

x-axis ⇒ independent variable
y-axis ⇒ dependent variable

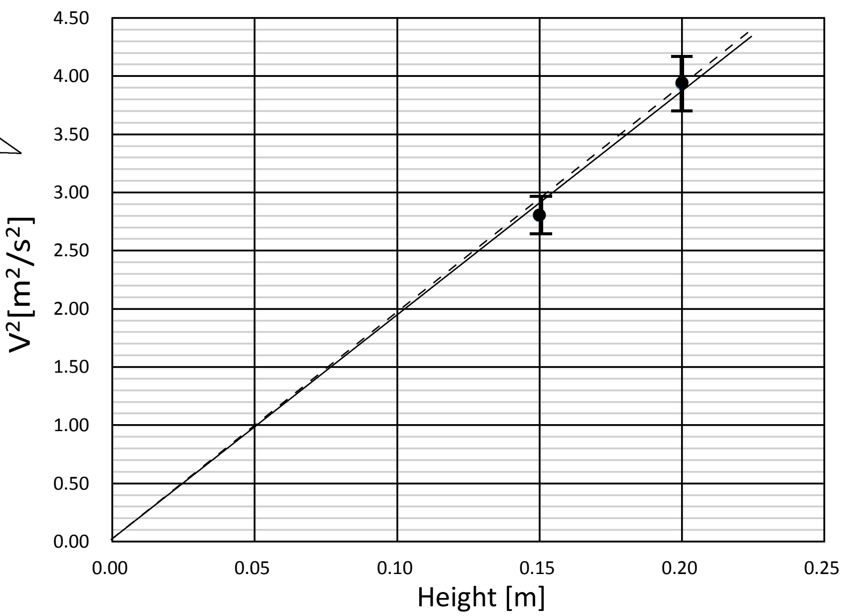


Figure 2 : Relationship between height and v^2 (n=10)

Describing Graphs

Exercise 3

Describe the experimental results and fill in the spaces to complete the sentences.

- Table 1 shows velocity squared ____________ as the height increases.
- If data is plotted in the graph of velocity squared versus height, the graph shows velocity squared ___ ______________ _____ the height (Figure 2).
- If the relation between velocity squared versus height is approximately represented in a regression line through the origin using the least squares method, then, _________ (r^2=0.993) is obtained. This is shown in the solid line in the figure 2.

Discussion

Making Predictions & Evaluating Results

Exercise 4

Evaluate results and fill in the spaces to complete the sentences.

If the gravitational potential energy at the top of the swing changes into kinetic energy at the bottom of the swing, $mgh = \frac{1}{2}mv^2$, then we get the equation ________________ . This is shown in the broken line in the figure 2.

Although there is slight difference between the slopes when comparing calculated and experimental lines, the calculated line falls within one standard deviation from the mean.

Drawing Conclusions

In conclusion, we have confirmed that the gravitational potential energy at the top of the swing is equal to the kinetic energy at the bottom of the swing.

Evaluating Methods

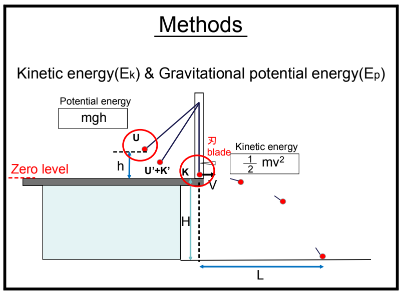
Exercise 4

What source of experimental error might have affected your results?

Exercise 5

You are going to give a short presentation by using four slides with the title "The Relationship between Kinetic Energy and Gravitational Potential Energy." The second slide followed by the title slide, and the third slide and its scripts are as shown below. The last slide's title is "Conclusion."

2nd slide



3rd slide

________________ $V = \frac{L}{0.405}$

	m[kg]	h[m]	U[J] mgh	L[m]	V[m/s]	v^2	K[J] $mv^2/2$
Group 1	0.36	0.20	0.70	0.75	1.8	3.4	0.61
Group 2	0.36	0.20	0.70	0.77	1.9	3.6	0.64
Group 3	0.36	0.20	0.70	0.80	2.0	3.9	0.69
Group 4	0.067	0.20	0.13	0.80	2.0	3.9	0.13
Group 5	0.067	0.20	0.13	0.79	2.0	3.8	0.13
Group 6	0.36	0.15	0.53	0.65	1.6	2.5	0.46
Group 7	0.36	0.15	0.53	0.65	1.6	2.5	0.46
Group 8	0.067	0.15	0.10	0.64	1.6	2.5	0.084
Group 9	0.067	0.15	0.10	0.69	1.7	2.9	0.10
Group 10	0.067	0.15	0.10	0.69	1.7	2.9	0.10

Script

・Look at this table.
・This is the result of our experiment.
・From our experiment, we could say that ____________

1. Choose the most suitable title for the third slide from the following ①～④.
   ① Introduction ② Background Research ③ Hypothesis ④ Results
2. Choose the most suitable sentence to fill the blank for the third slide from the following ①～④.
   ① the higher the height of the ball, the greater the amount of potential energy at the top of the swing if the mass of the ball remains constant.
   ② the smaller the mass of the ball, the smaller the kinetic energy at the bottom of the swing.
   ③ the length L which the ball moves to the horizontal direction is proportional to velocity at the bottom of the swing.
   ④ the amount of potential energy at the top of the swing is almost equal to the amount of kinetic energy at the bottom of the swing.

【Presentation Exercise】 Let's try to have a presentation using the following slides and script.

Introduction

The Relationship between
Kinetic Energy and
Gravitational Potential Energy

Aim of research

To confirm experimentally whether mechanical energy is conserved.

・Hello everyone! My name is ・・・

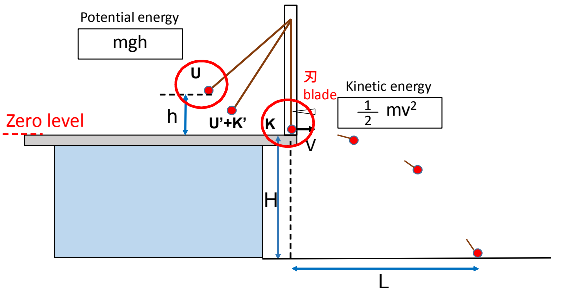
・Today I'm going to talk about <u>the relationship between Kinetic Energy and Gravitational Potential Energy</u>.

・In order to <u>confirm</u> <u>whether mechanical energy is conserved</u>, we designed the following experiment.

Body 1

Methods

Kinetic energy(E_K) & Gravitational potential energy(E_P)



・By making these kinds of apparatus, we measured the <u>potential energy</u> at the top of the swing and the <u>kinetic energy</u> at the bottom of the swing.

Body 2

Results

$V = \frac{L}{0.405}$

	m[kg]	h[m]	U[J] mgh	L[m]	V[m/s]	v^2	K[J] $mv^2/2$
Group 1	0.36	0.20	0.70	0.75	1.8	3.4	0.61
Group 2	0.36	0.20	0.70	0.77	1.9	3.6	0.64
Group 3	0.36	0.20	0.70	0.80	2.0	3.9	0.69
Group 4	0.067	0.20	0.13	0.80	2.0	3.9	0.13
Group 5	0.067	0.20	0.13	0.79	2.0	3.8	0.13
Group 6	0.36	0.15	0.53	0.65	1.6	2.5	0.46
Group 7	0.36	0.15	0.53	0.65	1.6	2.5	0.46
Group 8	0.067	0.15	0.10	0.64	1.6	2.5	0.084
Group 9	0.067	0.15	0.10	0.69	1.7	2.9	0.10
Group 10	0.067	0.15	0.10	0.69	1.7	2.9	0.10

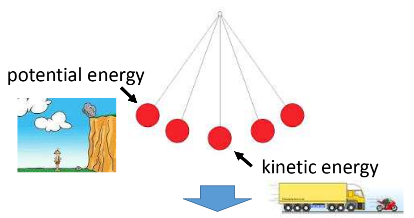
・Look at this table.

・This is the result of our experiment.

・From our experiment, we could say that the amount of potential energy at the top of the swing is almost equal to the amount of kinetic energy at the bottom of the swing.

Conclusion

Conclusion



Conservation of mechanical energy

・This relationship is called <u>conservation of mechanical energy</u>.

・Thank you for listening.