Physics Education Workshop in International Seminar 2008

"Physics Experiments to Stimulate Creativity and Logical Thinking"

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PHYSICS WORKSHOP FOR INTERNATIONAL SEMINAR

FOREWORDS

It is widely accepted among students and teachers alike that physics is a difficult subject to master. It is our aim to overcome this pre-conception by delivering what may seem as difficult physics concepts in an interesting and refreshing manner, to students at an early stage of their education. We feel that it is exceedingly important to stimulate students' interest in physics at an early age, especially considering the role of physics as the fundamental basis of all science and technology

Moreover, a basic understanding of physics and its phenomenon allows students to better appreciate nature and its wondrous workings; routine events that are often overlooked can now be viewed with awe, its beauty and brilliance appreciated. For example, understanding the physics principles of a rainbow or a sun set will let students observe nature more carefully, unravel its mysteries, and ultimately, enrich their lives.

The first and main aim of this workshop is to devise experiments using tools which are made from simple, inexpensive and easily-obtainable materials; this would not only teach scientific principles, but also stimulate the students' creativity and curiosity. It is the latter aim which cannot be fulfilled by commercially available scientific kits on the market today. Furthermore, we feel that this concept is best suited for developing countries, in which many of its schools are not well equipped with adequate experimental tools. It has not escaped us that this activity can also be done within the family in which parents can be actively involved in their children's education process.

Secondly, we want to show that it is possible to train students to think logically using experiments in physics. During an experiment, the variables and conditions can be changed relatively easily, while the results can also be observed directly. If we compare this to mathematics, for example, logical thinking in physics experiments deals with real and tangible objects, and this should benefit students in a more concrete and practical manner.

Thirdly, we also would like to emphasize the importance of observing and understanding the beauty that is nature, in relation to physics. We feel that this is very important in capturing and stimulating the students' interest in physics.

This textbook was organized into the four chapters. First chapter explains the experimental demonstrations of mechanics. The demonstrations of fluid, optics, and electrostatic are described in the second, third and fourth chapter, respectively.

It is our profound hope that this workshop will benefit the education of physics and sciences in Ache in Indonesia.

Fukui, September 2008

Kiichiro Kagawa

2008年９月１８日、日本学生支援機構(JASSO)の「国際大学交流セミナー」の開講式（於：福井大学教育地域科学部理数教育講座）

国際大学セミナーのため福井大学に滞在したインドネシア、シャクハラ大学理学部の学生

CHAPTER 1
MECHANICS

1. Gravity Experiments Using Ping Pong Ball

General purpose: to confirm acceleration is the same regardless of mass

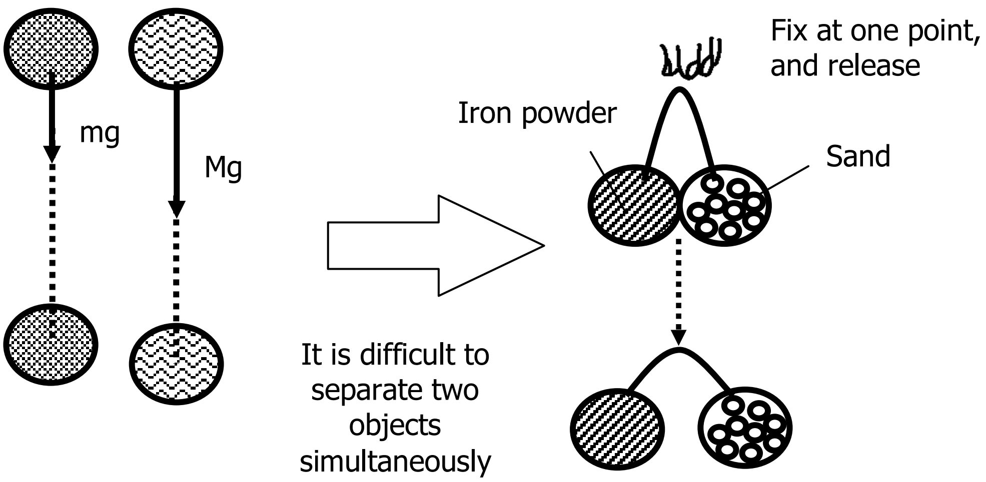
→ Prepare two similarly sized ping pong balls.

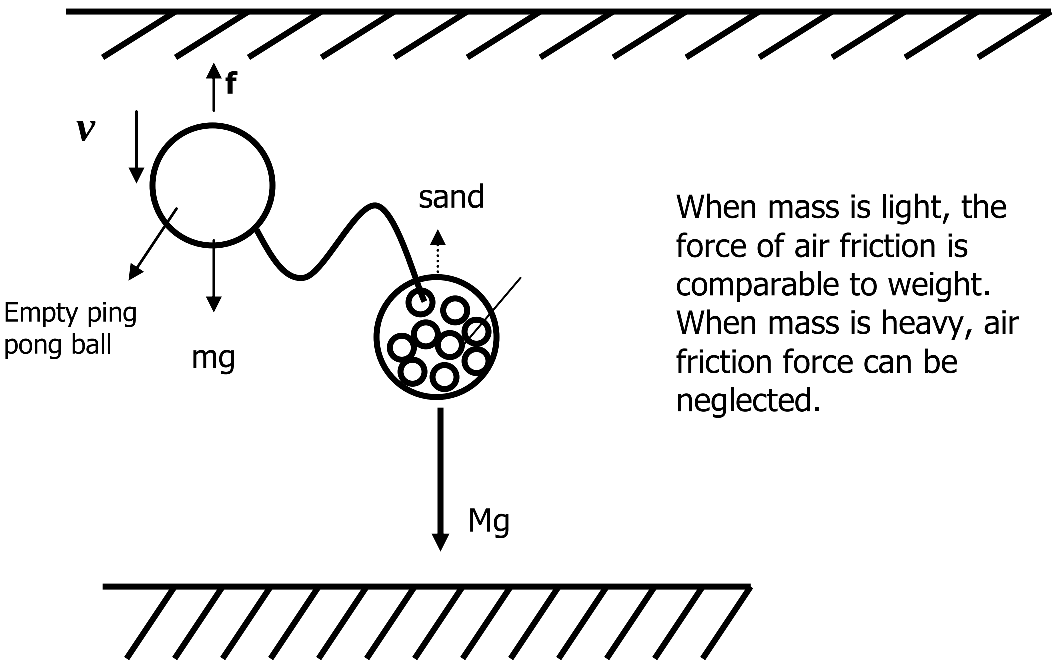
→ Fill the ping pong balls with different weight material.

→ Connect two ping pong balls with a string.

→ Hold the center of the string and release the balls.

→ Confirm that two objects will move with the same speed regardless of the mass difference.





2. Frictionless demonstrations Using Fine Plastic Beads

2.1 Introduction

Mechanics is the most fundamental subject in all branches of physics. It is basically difficult to study other fields of physics without mastering the general laws in mechanics. Thus, it is urgently needed for students to comprehensively grasp the concepts of mechanics. However, in most classes of senior high schools, physics is theoretically taught, and teachers ask the students to practice to solve physics problems related to the studied theory. In this case, the students still don't have clear concepts and finally they become to dislike physics. This is a serious problem for the countries in which the science and the technology are crucial for future development. In order to overcome this problem, the demonstrating experiment, namely visualizing and observing actual phenomena that are being studied theoretically, should be carried out to gain the complete concepts. However, the experiments of fundamental mechanics laws, such as the first law, the second law, and the third law of motions, momentum conservation law, and energy conservation law (between the potential energy and the kinetic energy) are generally difficult to be conducted due to the disturbance of friction between the object and the plate surface.

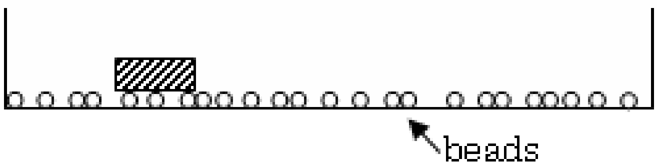


Figure 1 Illustration of how beads on the surface of the flat plate work as ball-bearings

In this textbook, we introduce a new method for demonstrating basic lows of mechanics by using a frictionless two-dimensional plate, which was made by scattering fine plastic beads on a smooth, flat surface such as a glass plate. The fine plastic beads on the glass surface work as ball-bearings to substantially reduce the friction between the object and the surface, as illustrated in Fig. 1. This frictionless plate allows the demonstration of numerous mechanics-related experiments, such as the law of inertia, conservation of momentum, and uniformly accelerated motion. Furthermore, these are not limited to qualitative measurements but can also be adapted to quantitative observation by using stroboscopic techniques or even by using a much simpler and basic stopwatch measurement. In the Nuffield "O" level, similar frictionless demonstration has been reported using actual big metal-ball-bearings. However, it should be stressed that the method presented in this paper is far superior to their method because in their method the frictionless plate can be used for only limited application, such as demonstrating the law of inertia, and the frictionless plate on which actual ball bearings are spread cannot be tilted because the ball bearings fall down due to their weight, while in our case the fine beads never fall till about 5 degree due to the adsorption arising from van der Waals force.

2.2 Experimental Procedure

The plastic beads used in this study are commercially available (Nakamura Rika Kogyou, D-20-1406-01) and these are usually used for experiments in demonstrating artificial rainbow. The beads look like a fine powder on visual inspection. According to the microphotograph observation as shown in Fig. 2, it is seen that the beads consists of small plastic balls, almost perfectly spherical in shape with uniform diameter of approximately 0.3 mm. About 4.5 g of beads were scattered on the plate surface at the base of a box (1000 mm x 1000 mm x 50 mm) which was made of glass plate (8 mm thickness); under this condition the density of the scattered beads on the plate was about 30 pieces/cm^2. It is very important to mention that the coefficient of static friction depends largely on the humidity of the room whereby at high humidity, the resistance faced by the small plastic beads rolling on the glass surface is significantly large. Therefore, before spreading the beads, the glass surface should be cleaned using alcohol, and dried completely using an electric drier. The beads should be stored in a dry-box when not in use. The static friction coefficient was estimated to be 0.001. This was obtained from the experiment in which an object on the beads starts to move when the glass plate was inclined with an angle of θ, where $\theta = \tan^{-1} 0.001$. If the humidity of the room is high, we can use silica gel to reduce the humidity in the glass box under covering with a big transparent vinyl sheet, and after that the good frictionless experiments can be carried out for a certain period of around 20 minutes. The objects used on the frictionless plate are: glass Petri dish (60 mm in diameter) and an aluminum disc (51 mm in diameter and 5 mm thick), both objects have a smooth and flat bottom surface. Marks of "O" or "X" on the top of the aluminum disc were attached to distinguish the objects during the demonstration. In order to make a quantitative experiment, a stroboscopic method was employed using an electronic flash lamp with a repetition of flash of 3 or 4 Hz. The object's images were recorded by a digital camera set directly above the box using a camera tripod so as to observe the entire surface of the box from the top. In the stroboscopic experiment, only the aluminum disks were used as the objects.

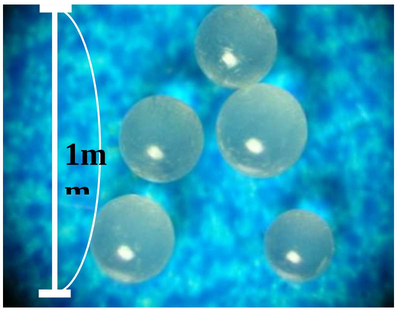
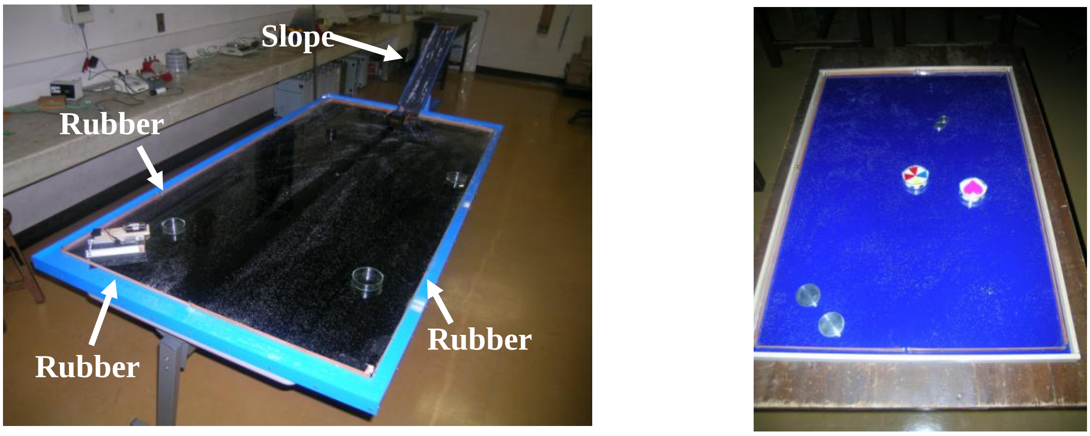


Figure 2 Microphotograph of the beads

We have also constructed two kinds of frictionless plates. One is a big frictionless plate mainly used for demonstrating many kinds of experiments in a big class, and the other was constructed for small group experiments as displayed in Fig. 3a and 3b, respectively. The big frictionless plate was made of a good quality glass plate in flatness (dimensions of 850 mm x 1700 mm and a thickness of 3 mm). The glass plate was placed on the black acrylic plate (a thickness of 3 mm) with the same size of the glass plate and they were put on a good quality wood plate in flatness and hardness (dimensions of 920 mm x 1840 mm and a thickness of 20 mm). This equipment was then fixed on the commercial and movable desk (a length of 1800 mm, a width of 60 mm and a height of 70 mm).



(a) (b)

Figure 3 (a) big frictionless glass plate equipped with a large-angle-frictionless slope (b) Small frictionless glass plate.

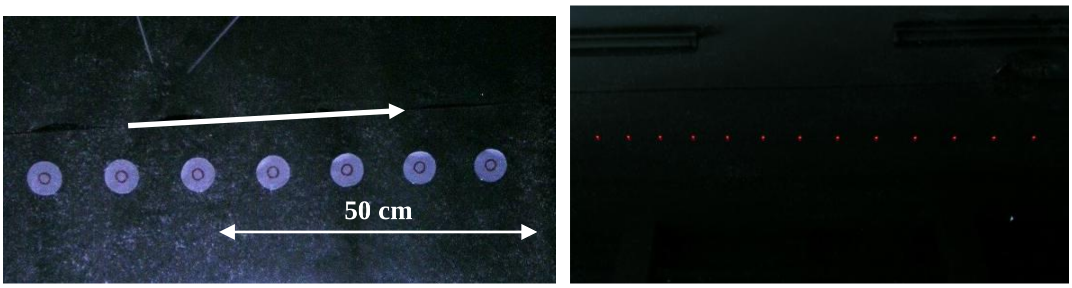
In order to demonstrate the movement of the object on the slope, one side of the frictionless plate was equipped by the slope made of plastic sheet (Kasai Sangyo Co. LTD, K-72116, a thickness of 0.5 mm and a length of 910 mm) attached on the acrylic plate (dimensions of 130 mm x 700 mm, a thickness of 10 mm), and the plastic sheet was smoothly connected on the horizontal glass plate and fixed using a vinyl tape. It should be mentioned that the plastic surface should have enough tension to sustain the object moving on the plastic sheet. The rubber bands (sizes of 320 mm x 17 mm x 1.1 mm) have been employed as sidewalls of glass frictionless plate with expanding them about twice in length and each of two ends of the rubber bands was fixed by the nail. In this method, the Petri dish continued to move back and force with repeated collisions on the horizontal frictionless plate, on which the two parallel rubber bands were placed with a distance of 850 mm. This fact qualitatively proved that the friction between the object and the glass plate is very small and the lost energy due to the collision between the object and the rubber bands is very low.

Another frictionless plate (dimensions of 890 mm x 580 mm) was also constructed with almost the same manner as in the case of a big frictionless plate, while blue acrylic plate was used instead of black acrylic plate. For this case, the frictionless plate does not have the slope. The rubber bands were also set on the four sides of the frictionless plate. The density of the scattered beads is around 10-30 pieces/cm^2; it should be mentioned that the density should not be too high because the friction coefficient becomes a little high.

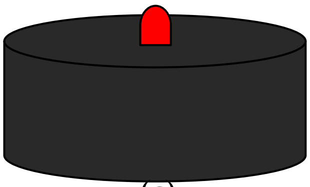
2.3 Results and Discussion

Newton's first law demonstration

Figure 4 shows the stroboscopic photograph for demonstrating movement of constant velocity on the frictionless plate. It is seen that the images of the object show distinct and equal intervals of about 12 cm, from the first image to the last image. Since the flash light interval is 0.33 s and the distance between adjacent images is 12 cm, the moving speed of the object is calculated to be 36 cm/s. The equal intervals also indicate that the object moved with an almost constant velocity during the demonstration, implying that there is negligible friction between the objects and the beads-coated glass surface.



(a) (b)



(c)

Figure 4 (a) Stroboscopic photographs of aluminum disk and (b) pulsed diode emission trace for demonstrating constant speed movement on the frictionless plate. (c) Pulse diode lamp

However the stroboscopic equipment is rather expensive (us$ 2000), therefore in order to overcome the method, we developed a new equipment using a cheap photodiode which connect to the electric circuit so that diode emission takes place with regular frequency. The circuit was set in the Petri dish as shown in Fig. 4 (c).

Figure 5 demonstrates an inelastic collision when the object collided with the glass wall of the frictionless box. From the observed images, it was noted that the speed of the object was reduced by collision with the wall, as indicated by the shorter image distance interval. This slower speed was maintained after the collision, as depicted by the equidistant intervals in the observed images. This result proved that this frictionless equipment can quantitatively demonstrate an inelastic collision, and we can obtain the bound-coefficient from the result.

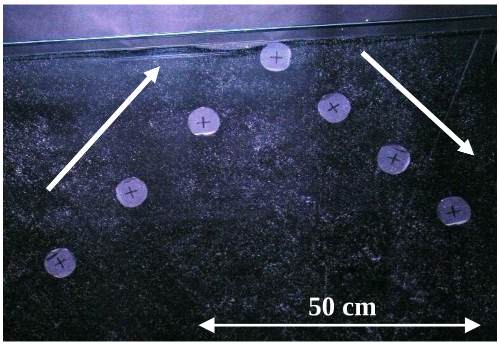


Figure 5 Stroboscopic photograph demonstrating an elastic coefficient

Newton's second law demonstration

Newton's second law of motion is most important law to understand the object's motion and influence of the external forces to the object. However, it is very difficult to demonstrate this principle due to the existence of friction. We have proved that the frictionless equipment also can nicely be used to demonstrate the second law. As shown in Fig. 6, the Petri dish placed on the frictionless is connected to the weight using a string through a pulley. The Petri dish moves with increasing speed (accelerated motion) under the constant force. By this demonstration, we can observe how the velocity increases with time as shown in Fig. 7. In this case, the acceleration is constant because the force is constant. We can easily obtain the acceleration from the slope. It should be noticed that the slope (acceleration) decreases with increasing the mass, it is due to the fact that acceleration (**a**) is inversely proportional to the mass placed in the Petri dish. The graph shown in the Fig. 7 was taken using a stroboscopic method.

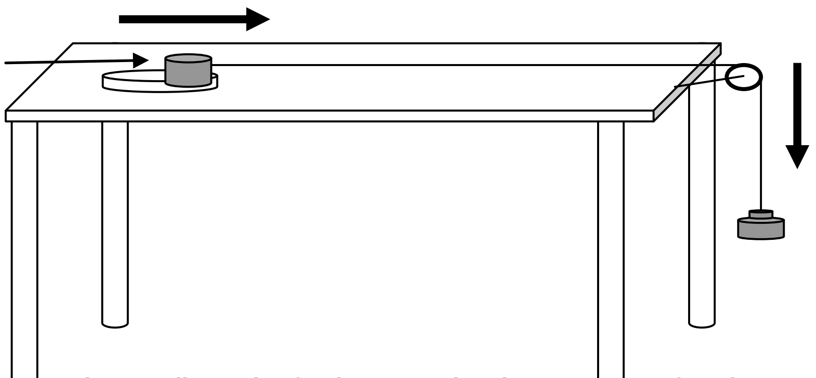


Figure 6 Illustration for demonstrating the second law of motion

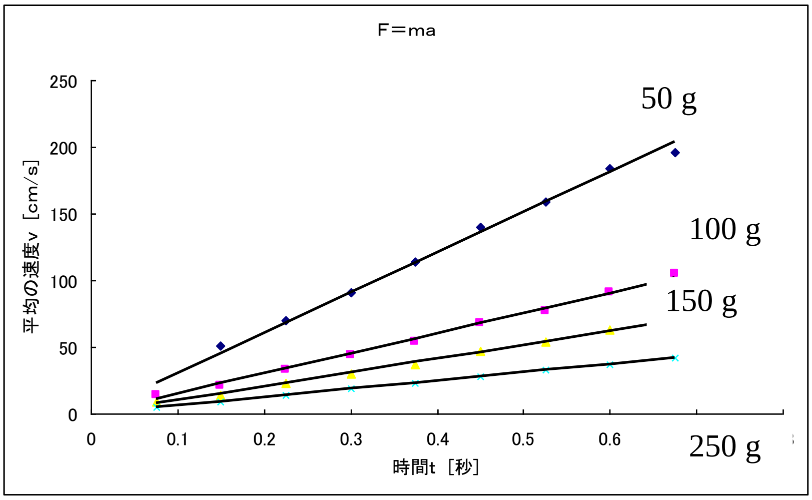


Figure 7 Relationship between velocity and time resulted from demonstrating the second law of motion

Action and reaction law (Newton's third law)

Generally, it is very difficult to understand the action-reaction law (the Newton's third law of motion) because we cannot directly see the existence of the force. In the ordinary high school's textbooks, the action-reaction law is explained using two springs connected each other. When one spring is expanded, another spring also is extended due to the action-reaction force. However, by this demonstration, students cannot be satisfied in understanding the concept of the third law.

In order to overcome this problem, we have developed an interesting and much more understandable method using the frictionless plate. In this method, two peaces of magnetized-Petri dishes, in which a rod magnet was fixed at the center of Petri dish, were employed as objects. Figure 8 shows an illustration for demonstrating the action-reaction law using the two magnetized-Petri dishes on the frictionless plate.

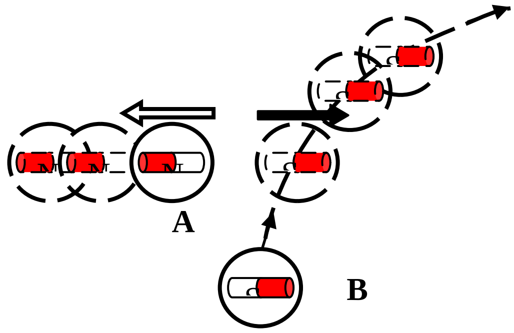
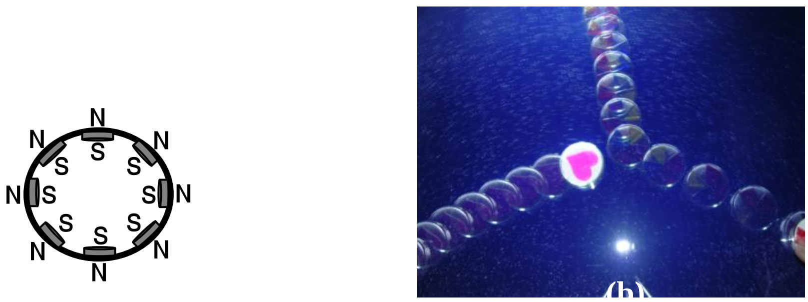


Figure 8 Illustration for demonstrating the action-reaction law

One Petri dish, marked "A", was fixed, while another magnetized-Petri dish, marked "B", moved with a constant speed to close the magnetized-Petri dish "A". The orbit of Petri dish "B" was suddenly bent at the closest region due to the action force from the magnetized-Petri dish "A". Simultaneously, the magnetized-Petri dish "A" started moving due to the reaction force from the magnetized-Petri dish "B". It should be noticed that the speed of the magnetized-Petri dish "B" was decreased after bending because the some parts of the kinetic energy was used as that of the magnetized-Petri dish "A". This demonstration is easily acceptable for the students. However, this demonstration does not always succeed to be conducted because the movement of magnetized-Petri dishes are unstable and they attract each other with being rotated the magnetized-Petri dishes.

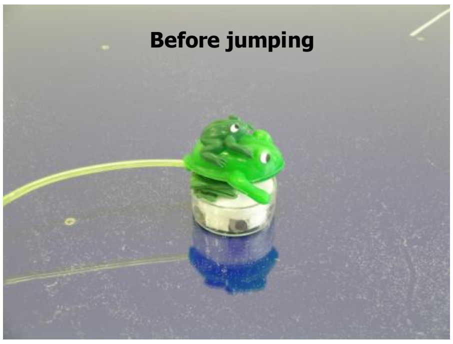
In order to solve this unstable problem, the rod magnet was replaced by the assemble of small magnets as shown in Fig.9a, namely the eight pieces of small neodymium magnets, which have strong magnetic forces, were uniformly arranged at the outer region inside the Petri dish. When we used these special magnetized-Petri dishes, the repulsion force always exists between them without rotation.



(a)

Figure 9 (a) Assemble of small magnets, (b) stroboscopic photograph for demonstrating third law of motion

Figure 9b shows the stroboscopic photograph for demonstrating the third law of motion using the special magnetized-Petri dishes. The magnetized-Petri dishes have different marks to distinguish each other. We have confirmed using questionnaire that the students were really satisfied and accepted the third Newton's law. It should be mentioned that when we sent the magnetized Petri dish along the straight line, which connects the center of the two magnetized-Petri dishes, to close another magnetized-Petri dish, the speed of magnetized-Petri dish decreased with time and finally stopped, while, the another magnetized-Petri dish started moving along the line keeping the same speed of the former Petri dish. This is a phenomenon due to the action-reaction law. However, it is difficult for students to distinguish from the ordinary demonstration for momentum conservation law.



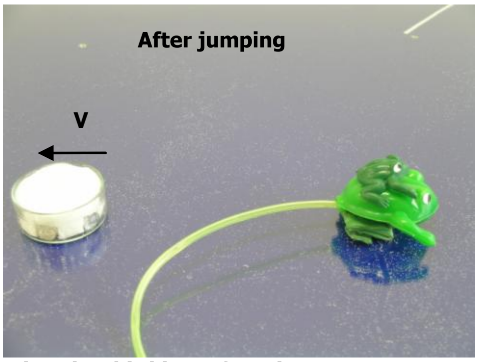


Figure 10 frog-jumping for demonstrating the third law of motion

Figure 10 shows another experiment to demonstrate the third law using frog-toy and Petri dish placed on the frictionless. By varying the mass, the speed of Petri dish changes.

Uniformly accelerated motion

Figure 11 shows the stroboscopic photograph for demonstrating uniformly accelerated motion. In this experiment, the frictionless box was inclined slightly with an angle of θ (θ = 0.8 degree) against the horizontal level. Since the actual acceleration value along the direction of the slope become $g{\cdot}\sin\theta$, as shown in Fig. 12, where g is the acceleration of gravity, we can see that the object accelerates very slowly, like a slow motion movie.

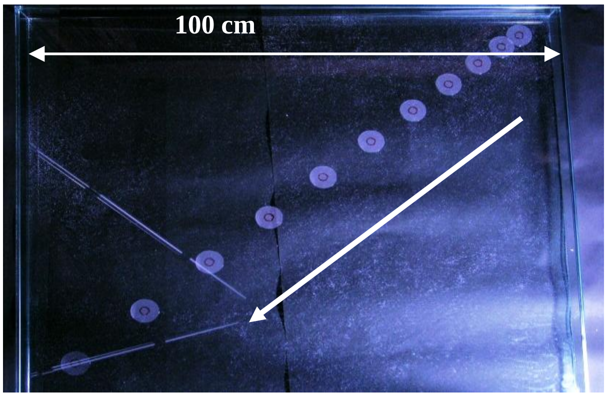


Figure 11 Stroboscopic photograph for demonstrating uniformly accelerated motion

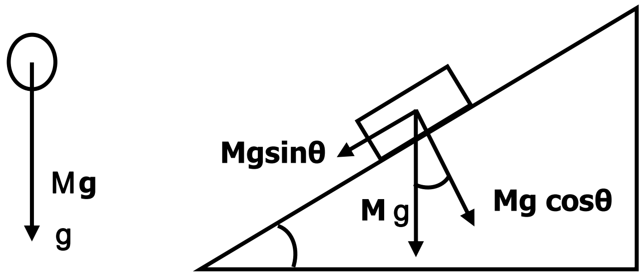


Figure 12 Illustration of the component of gravity force

In the experiment of Fig. 11, the object was released with an initial speed of zero, and the digital camera was exposed for 4 seconds under the strobe-flash with a repetition of 4 Hz. Fig. 13 plots the relationship between the average speed of the object and time, where it was seen that the velocity of the object increases linearly with time; the reason why the curve of Fig.13 does not intercept zero in vertical axis is due to the fact that we cannot control coinciding the starting time in the release of the object and the instant of the flashing of stroboscopic-lamp. The observed acceleration from the curve in Fig. 13 is $0.131 m/s^2$ and this acceleration is in good agreement with the calculated acceleration of $g \cdot \sin\theta$, $0.137\ m/s^2$. It should be stressed that students can confirm by themselves, with rather high precision, the relationship between the time and the moving distance on the slope of the frictionless-plate with the aid of an ordinary stopwatch because the time to measure is rather long, in the order of several seconds.

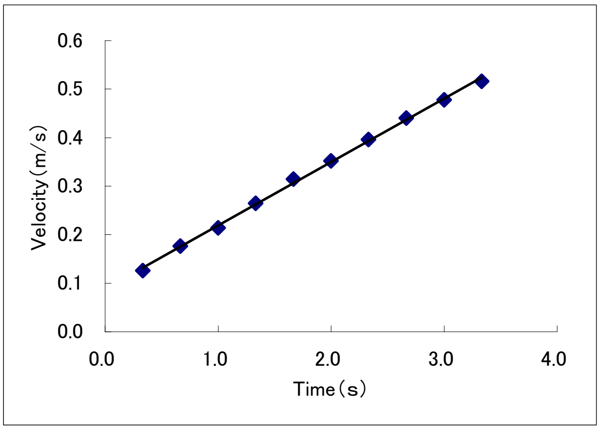


Figure 13 Relationship between the average speed and time uniformly accelerated motion

Momentum conservation

In order to demonstrate the momentum conservation law, two pieces of the same aluminum disks were prepared. One of the aluminum disks was placed stationary in the middle of the frictionless surface; another was moved with a suitable speed so as to collide with the stationary disk from the front direction, in the same axis. The resultant collision caused the stationary disk to move with the same speed as the colliding disk, while the striking disk came to a complete stop after collision. This conservation of momentum experiment is usually demonstrated by employing a one-dimensional air track using an air-cushion system. In contrast, the demonstration of momentum conservation for two-object-angled collision is much more difficult using the air-cushion technique because two dimensional air-cushion systems are much more expensive to construct. Our results have clearly proved that the frictionless plate technique can be nicely used for this purpose.

Figure 14 shows a stroboscopic photograph for demonstrating an angled collision phenomenon. One aluminum disk, which has a mark of "O" , moves with constant speed (34cm/s) from the bottom of the photograph towards the center, while another aluminum disk, marked "X", moves with slightly higher speed (44.5cm/s) from the upper right-hand side towards the center, thus traveling at an angle. They collide at the center of the photograph, and the disk marked "O" travels towards the lower left corner, with a slightly higher speed (49.5cm/s) compared to that prior to collision; the disk marked "X" travels to the top of the photograph, with a speed (26.0cm/s) lower than that prior to collision.

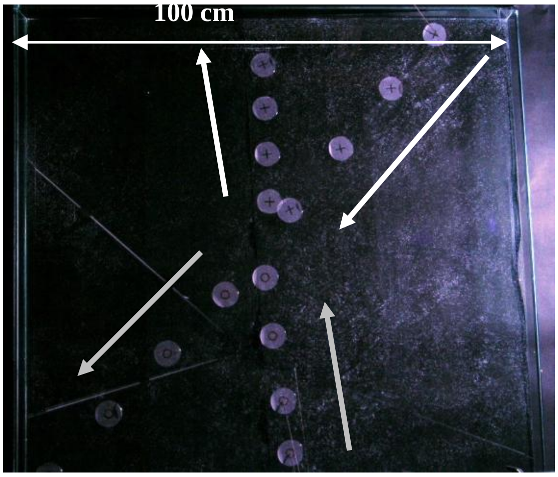


Figure 14 Stroboscopic photograph demonstration an angled collision

Figure 15 is the vector diagram to show how the momentum of each disk changes before and after the collision where it is seen that the two objects changes proportionally, depending on the object moving speed before and after the collision. Also in the figure, it is seen that the resultant vectors before and after the collision are almost the same, implying that the conservation of momentum law is obeyed in this case.

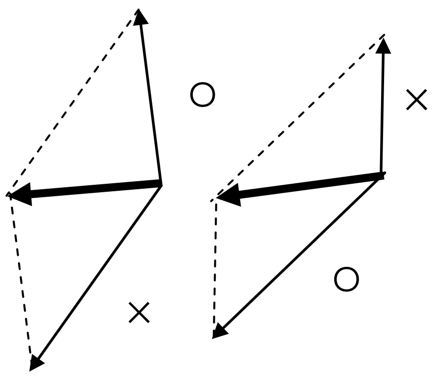


Figure 15 Vector diagram to show the momentum of each disks

Energy conservation

The energy conservation law is also very important concept in mechanics. In the demonstration of energy conservation law, teachers usually use a sphere ball as an object. The object is released to fall down on the large-angled-slope. By using this equipment, the measured speed does not coincide with the theoretical value because some parts of the potential energy are consumed for rotating the object. As reported in the previous work, we have successfully demonstrated the uniformly accelerated motion using tilted frictionless glass plate. However, the frictionless glass plate cannot be inclined more than 5 degrees because the beads fall down from the slope. Therefore, we devised new equipment using a plastic sheet as shown in Fig. 16; namely the beads were attached on the plastic sheet by the electrostatic force and worked as the ball bearings to reduce the friction between the object and the slope.

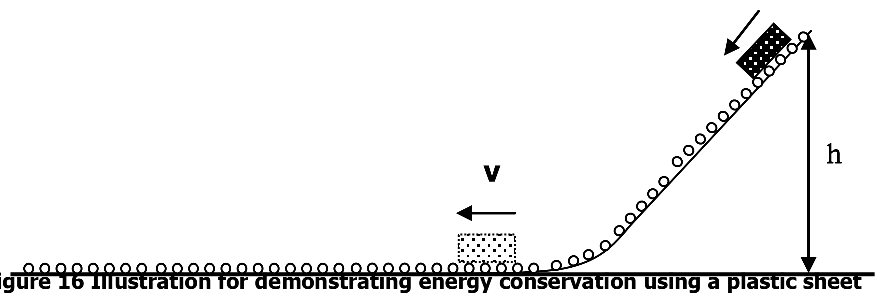


Figure 16 Illustration for demonstrating energy conservation using a plastic sheet

$$mgh_1 + \frac{1}{2}mv_o^2 = mgh_o + \frac{1}{2}mv^2$$

$$mgh_1 + 0 = 0 + \frac{1}{2}mv^2$$

$$\frac{1}{2}mv^2 = mgh_1$$

$$v = \sqrt{2gh_1}$$

In this experiment, a small Petri dish (45 mm in diameter and 18.2 mm in mass, as an object) was released with initial speed of zero from the height, h. The speed of the object increased with declining the slope and finally moved with a constant speed, **v,** on the horizontal frictionless plate. We measured the constant **v** by varying h using a speed meter as shown in Fig. 16. The experimental result is shown in Fig. 17. As well known, the relationship between h and **v** is theoretically derived as follows,

$$\mathbf{v} = \sqrt{2\,g\,h}$$

Where g is gravity constant.

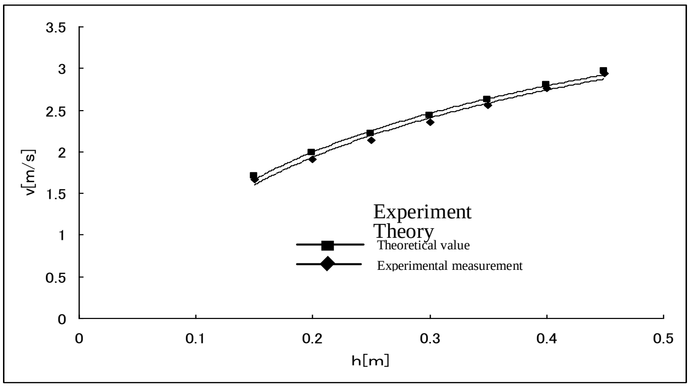


Figure 17 Experimental result for demonstrating energy conservation

The curve in Fig. 17 shows the specific shape of the root function. Also, it is seen that the experimental and theoretical value almost coincide. It should be noticed that the error of the experiment is less 3 %. Therefore this method can really be employed for quantitatively demonstrating the energy conservation law. Using this slope technique, we have also confirmed that the much more complicated experiment like ski-jumping can also be demonstrated as illustrated in Fig. 18. The error of the distance of the object, x, on the horizontal frictionless plate is about 5 %.

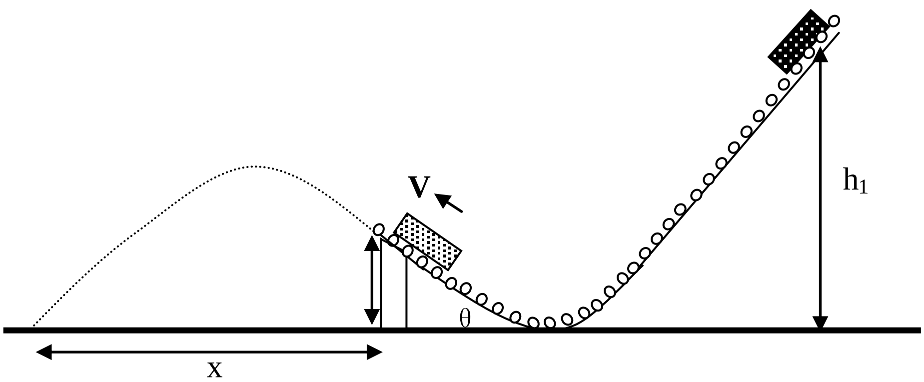


Figure 18 Illustration of ski-jumping experiment using inclined plastic sheet

Group experiment using frictionless plate

A. Speed measurement

a. Tools and Materials

1. beads plate(92 x 60cm)
2. Shooting equipment (fig. 19)
3. Petri dish
4. Rubber bands
5. Digital speed meter

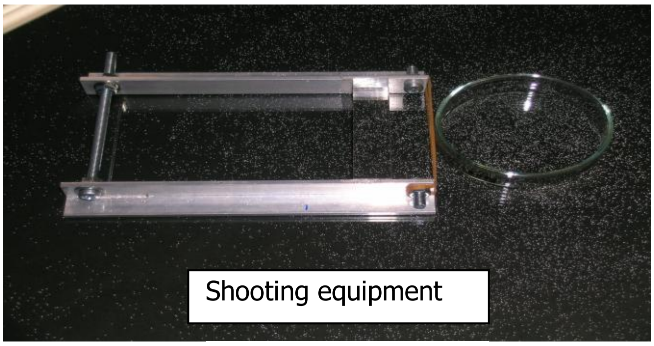


Figure 19

b. Activities and experiments

1. Measure the speed of Petri dish, which is shot out from shooting equipment, using the digital speed meter as described in ig. 20
2. By varying the number of the rubber bands, measure the speed of Petri dish, and examine the relationship between the number of rubber bands and the speed of the Petri dish.
3. Make a graph on the relationship between the number of rubber bands and the speeds.

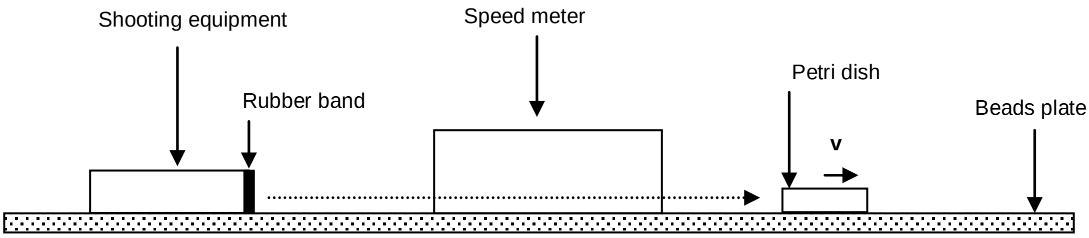


Figure 20

B. Relative motion

It is often found in the daily life that the motion of object seems different with respect to the observer. Namely the motion of object observed by the observer at a rest condition is different with that of the observer moving with velocity **v**.

a. Tools and Materials

1. Two small dolls (A and B) placed in the Petri dishes
2. Frictionless plate

b. Activities

1. Put the Petri dishes on the frictionless plate. Move two Petri dishes with same velocity **V** and **V** (the same speed and the same direction) in parallel and try to think how the doll A sees the motion of the doll B. This phenomenon is similar to that when two trains move with the same velocity **V**. In this demonstration, the velocity of the doll B with respect to the doll A is zero. This result is obtained from the superficial velocity, namely the velocity of the doll B relative to the velocity of the doll A is **V+(-V)=0**.
2. Two Petri dishes move with same speed but opposite direction in parallel and try to think how the doll A sees the velocity of the doll B. In this case, the velocity of the doll A with respect to the doll B is 2**V,** because **V+V=**2**V** .
3. Assume the doll A and B move following the axes of perpendicular directions each other with speed **V** and **V`** on the frictionless plate as shown in Fig. 21. Try to think how the doll A sees the motion of the doll B. In this case, the velocity of the doll B relative to the doll A is like an inclined direction as shown in Fig. 21 (-**V** + **V`**) . This phenomenon is similar to the case when an observer in the moving car observes the rain water; the direction of rain water looks like inclining.

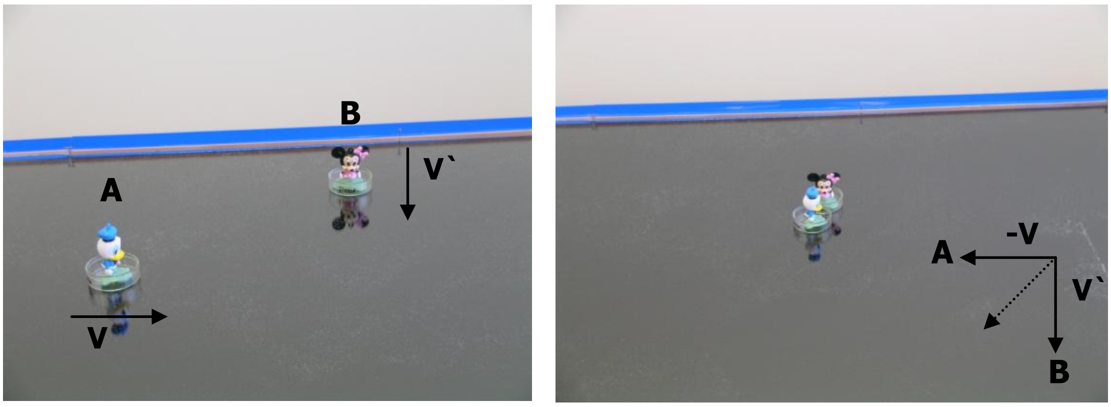


Figure 21 Relative motion between the doll A and B

C. Motion of the object on the inclining slope

C1. Falling Object on the Slope

a. **Tools and Materials**

1. beads plate(92 x 60cm) with inclining using a spacer
2. Spacer with a thickness of about 2 cm
3. Two Petri dish
4. Rubber clay as weight
5. Weight (100 g or so)

b. Activities

At the top of the frictionless plate, put the two Petri dishes with different mass (by putting a weight on one Petri dish) and release in the same time as shown in Fig.22. Observe how the two Petri dishes move with time. Confirm that regardless of the mass, the speed and the acceleration are the same. Acceleration of gravity **g`** = **g**. sin θ

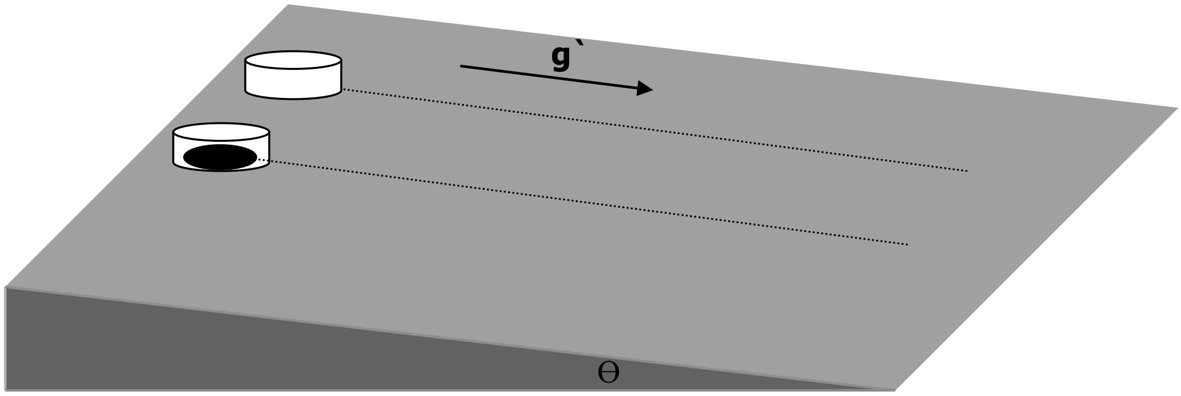


Figure 22 Illustration for demonstrating the falling objects with regardless of masses on the slope

C2. Relationship between the time and the falling distance on the slope

a. Tools and Materials

1. beads plate(92 x 60cm) with inclining using a slope 2.Petri dish
3. Stopwatch 4. Scale meter
5. Calculator 6. Spacer 7. Sphere glass ball

b. Method

1. Arrange the beads plate and the spacer as shown in figure 23.
2. Spread beads homogeneously on the surface to make it frictionless.
3. Measure the time(t) of Petri dish displacements by varying the distances(x). When the Petri dish is released the stopwatch "ON", and the stopwatch is stopped when we hear the sounds of the Petri dish colliding with the object placed at the end of the slope.

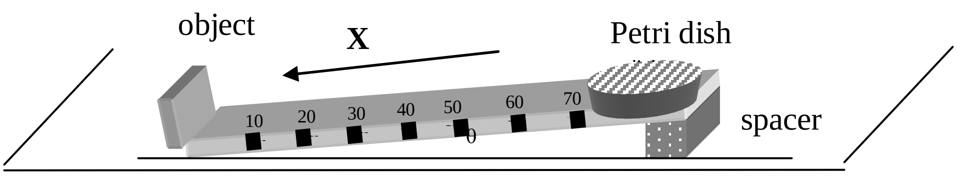
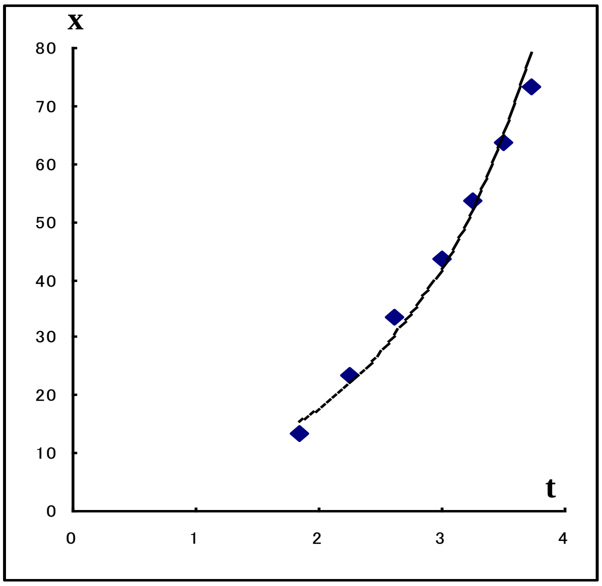


Figure 23

Example of experimental results

x (cm)	t (s)	t: average (s)
13.5	1.73; 1.83; 1.93	1.83
23.5	2.23; 2.22; 2.30	2.25
33.5	2.65; 2.59; 2.58	2.61
43.5	2.97; 3.03; 3.01	3.01
53.5	3.23; 3.28; 3.21	3.24
63.5	3.49; 3.49; 3.49	3.49
73.5	3.82; 3.65; 3.73	3.73



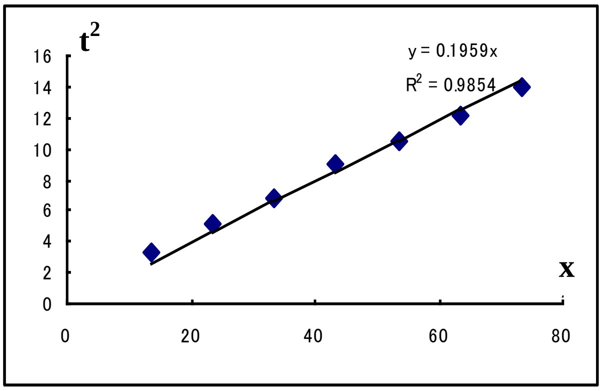


Figure 24(a)

Figure 24(a) shows the relationship between the the time and the displacements length of experimental results. This relation shows parabolic curve. The relationship of displacements length **(x)** and time square (t^2) is shown in figure 24(b)

According to the mechanics theory,

x = 1/2 (**g**`. t^2)......... (1)

where,

g` = **g**. sin θ .... (2)

where θ is the angle of the slope. In this case sin θ is 0.01. This experimental results and theory coincide well. We can calculate the gravity **g** from the slope of the curve in figure 24(b)

Activities

1. Carry out a similar activity as described above, and make a graph on the relationship between the time and distance (t vs. x, and x vs. t^2) using a calculator, graphs paper, and also using Excel program in a computer. It is recommended that each group conducts the experiment with different angle of the slope. Different angle means using different thickness of the spacer.
2. Make similar experiment using sphere glass ball (but without beads on the slope) and compare the result with that of the activity 1.

D. Monkey hunting

D1. Horizontal Projection

a. Tools and Materials

1. Beads plate (92 x 60cm) with inclining using a spacer
2. Shooting equipment (rubber bands)
3. Two Petri dish

b. Activities

One Petri dish is released vertically. At the same time, another Petri dish is shot horizontally using the shooting equipment. Observe that two Petri dish move keeping the same value of Y-axis. It is understood that the motion towards X-axes and towards Y-axes is independent as shown in figure 25

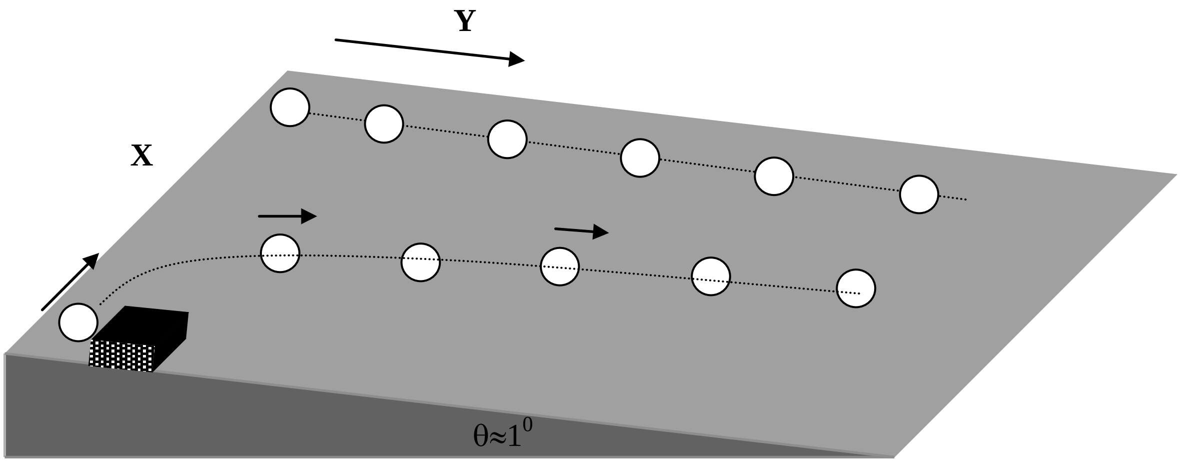


Figure 25

D2. Monkey hunting

a. Tools and Materials

1. Beads plate(92 x 60cm) with inclining using a spacer
2. Shooting equipment (rubber bands)
3. Two Petri dish

b. Activities

One Petri dish is released vertically from the top corner of the beads plate, which should be regarded as a monkey. At the same time, another Petri dish, which should be regarded as the bullet, is shot aiming to the Petri dish located at the top corner using the shooting equipment. Observe that two Petri dish collide always regardless of the speed of the shot Petri dish (figure 26).

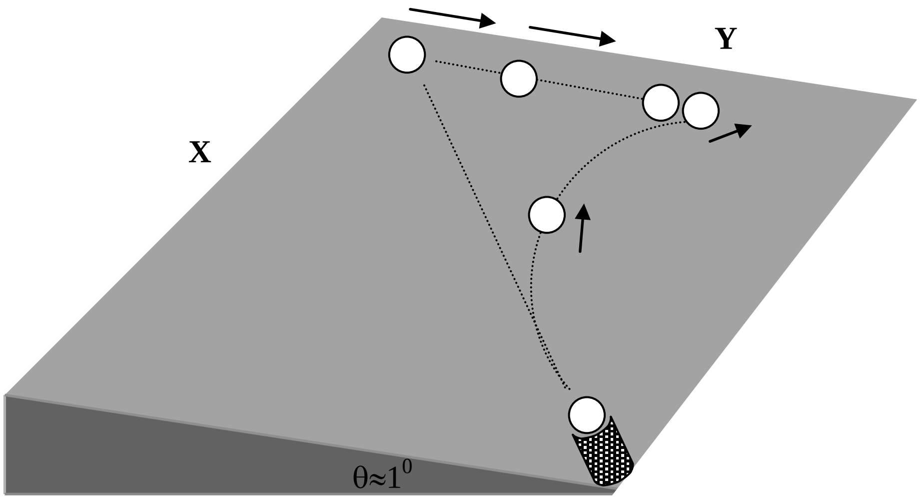


Figure 26

This phenomenon can also be understood when we remind that the motion towards X-axis and towards Y-axis is completely independent, and two objects fall with the same distance within the same time to the direction of Y-axis.

E. Projection angle for most far distance

a. Tools and materials

1. Beads plate(92 x 60cm) with inclining using a spacer
2. Shooting equipment (rubber bands)
3. Petri dish

b. Activities

Device so that Petri dish is shot with the same speed using a rubber band and the stopper placed in the shooting equipment. Examine what angle for shooting gives the farthest distance. According to the theory described below, 45^0 angle give the farthest distance. Confirm this by changing the shooting angle (figure 27). Notice that the speed should not be fast because the Petri dish go over the area of the frictionless beads plate.

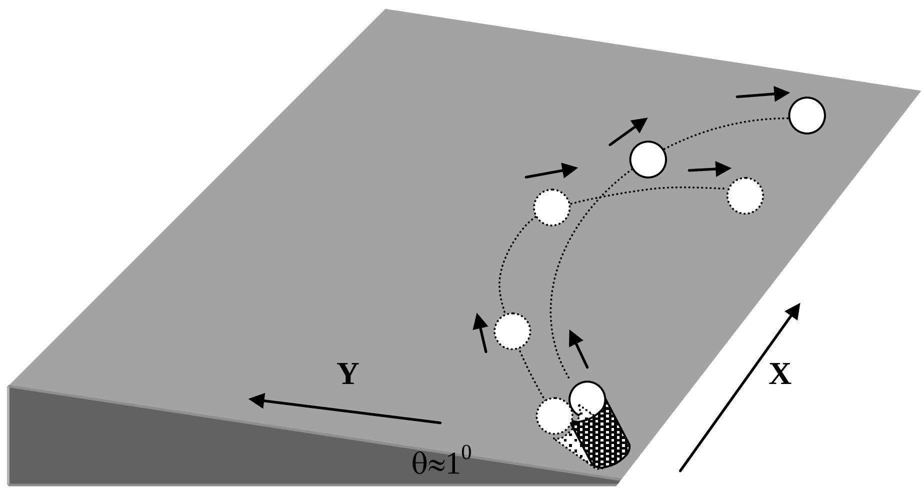


Figure 27

$$x = v_0 \cos\theta \cdot t$$

$$y = -\frac{1}{2} g t^2 + v_0 \sin\theta \cdot t$$

$$y = x\left(\tan\theta - \frac{gx}{2v_0^2 \cos^2\theta}\right)$$

$$x = 0, x = \frac{\tan\theta \cdot 2v_0^2 \cos\theta}{g}$$

$$= \frac{v_0^2 \sin 2\theta}{g}$$

$$x_{\max} \rightarrow \sin 2\theta = 1$$

$$\theta = 45^0$$

F. Inertial force

When the coordinate in which there exists an observer A moves with acceleration **a** with respect to the fixed coordinate in a straight direction, it appears a superficial force of –m**a** on the object O. On the other hand, when observer B observes the object O from the fixed coordinate, there is no movement on the object because no force applies.

Namely when the coordinate moves with acceleration **a**, we must induce a tentative additional force –m**a** to explain the motion using the Newton's motion equation. People call this force as inertial force. Usually it is very difficult to demonstrate this phenomenon due to the existence of friction.

a. Tools and Materials

1. beads plate
2. Two Petri dish (small and big Petri dishes)
3. Dolls as observers
4. Weight

b. Activities

Pull the Petri dish by the weight through the pulley with acceleration a.

Please think how the observers see the motion of the Petri dish which ahs the weight.

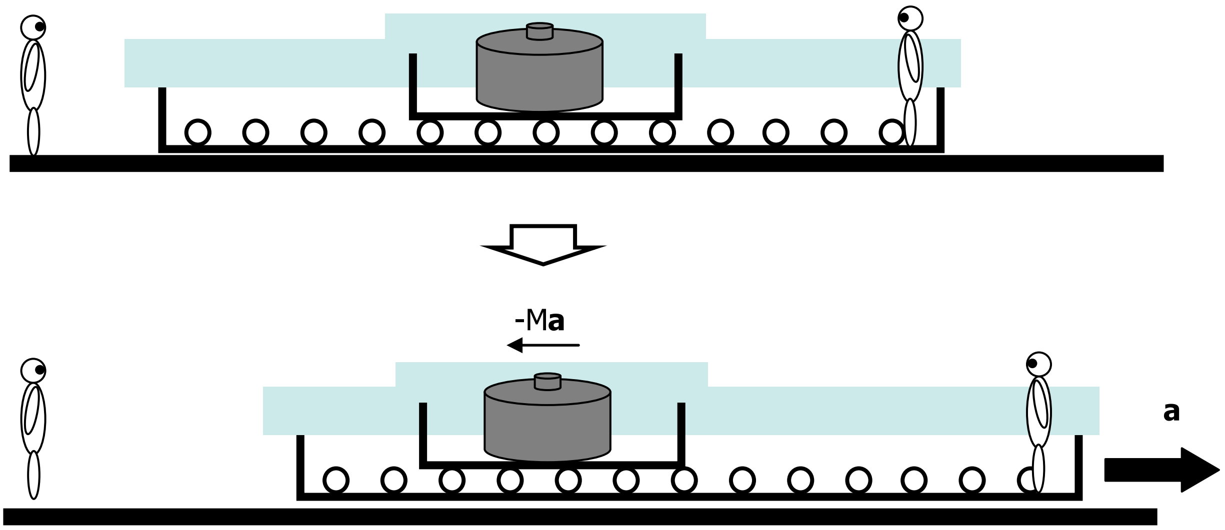


Figure 28

G. Zero Gravity

a. Tools and materials

1. Beads plate(92 x 60cm) with inclining using a spacer
2. Shooting equipment (rubber bands)
3. Two Petri dishes with different size with a diameter of 50 mm and 70 mm, respectively

b. Activities

When the elevator has free-falling motion under the gravity, the human in the elevator feels zero gravity. This phenomenon is explained as follows; the elevator has the same acceleration **g**, therefore, the human (mass m) receives the inertial force of –m**g**, and this force balances with the weight of the human (m**g**). However, if we see this phenomenon from the outside of the elevator, the elevator and the human move with the acceleration **g**, therefore the human receives no reaction force from the floor, which means the human is floating. We can demonstrate this phenomenon using the beads plate and the two Petri dish with different size large, one of which has beads on the surface.

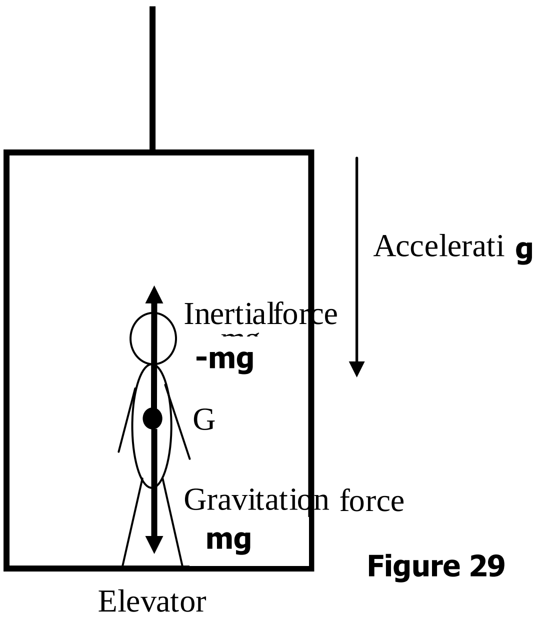


Figure 29

Experiment: on the inclining beads plate, put the two Petri dishes as shown in the Fig.30. First, fix the larger Petri dish by hand on the inclining beads plate and the small one will release from the top corner in the larger Petri dish then we can see the small one will fall downward in the larger Petri dish because there is no friction. Second, the edge of the two Petri dishes is contacted and held by the two fingers to fix on the inclining beads plate, and suddenly release them from the fingers. Observe the two Petri dish fall downward on the beads plate with same speed and acceleration, namely without touching.

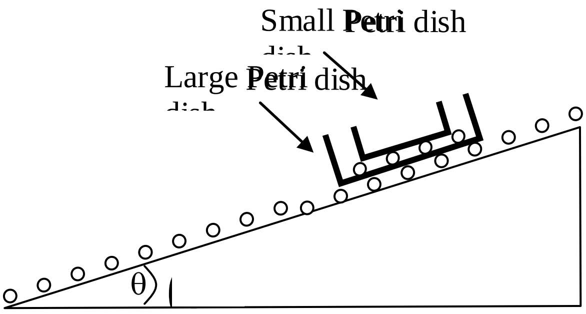


Figure 30

H. Collision

H1. Elastic collision

a. Tools and materials

1. Beads plate(92 x 60cm)
2. Shooting equipment (rubber bands)
3. Aluminum disks (50 mm diameter and 5 mm thickness, 30 mm diameter and 3 mm thickness)

b. Activities

See the collision phenomena for different three cases.

1. Collision between the same mass disks (figure 31a),
2. The small one collides with the bigger one (figure 31b),
3. The big one collides with the smaller one (figure 31c).

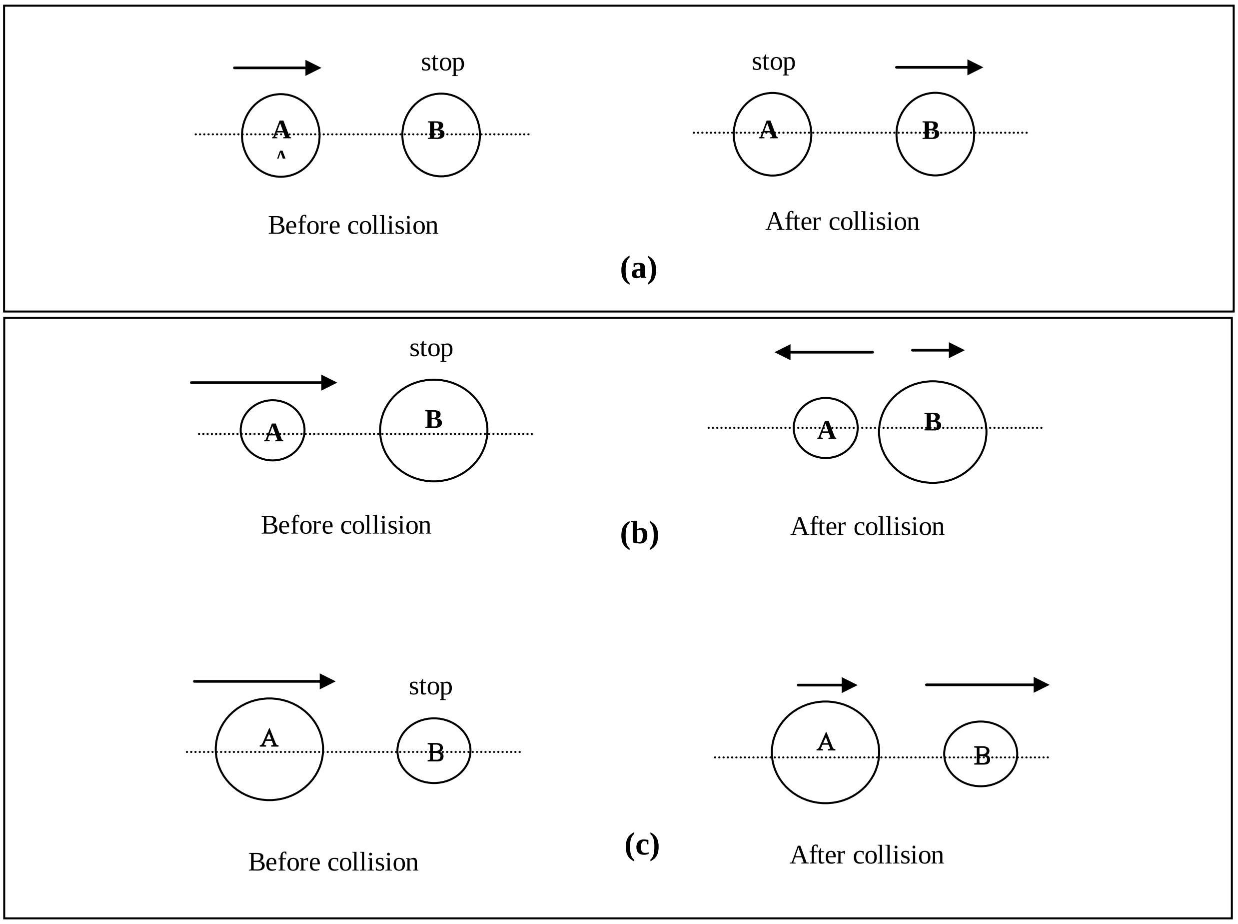


Figure 31

H2 Inelastic collision

a. Tools and materials

1. Two small Petri dishes with same masses
2. Beads plate (92 x 60cm)
3. Small shooting equipment (rubber bands)
4. Rubber clay attached on the one end of Petri dish

b. Activities

Put one small Petri dish A on the frictionless plate. Move the other Petri dish B, on which the rubber clay attached, with a velocity **V** to close and collide with the rest small Petri dish A from the front direction. Observe the two Petri dishes A and B will unify and the speed of them will decrease to be 1/2 **V** as shown in fig. 31

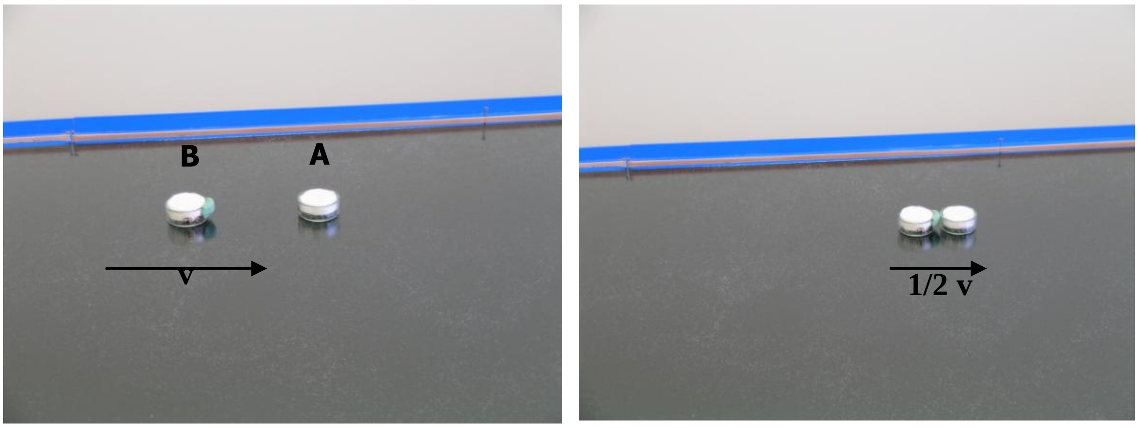


Figure 31 Photograph of inelastic demonstration using two Petri dishes placed on the frictionless plate

I. Simple harmonic Oscillation using horizontal spring

In the textbook, we oten see the harmonic oscillation using horizontal spring, howver, no body see actual motion due to existence of friction between object and the table. Our frictionless plate can nicely demonstrate even this experiment.

A. Tools and materials

1. Petri dish (about 4cm in diameter)
2. Two plastic springs (each has about 30cm in length)
3. Big frictionless plate (90 x 60 cm)

b. Activities

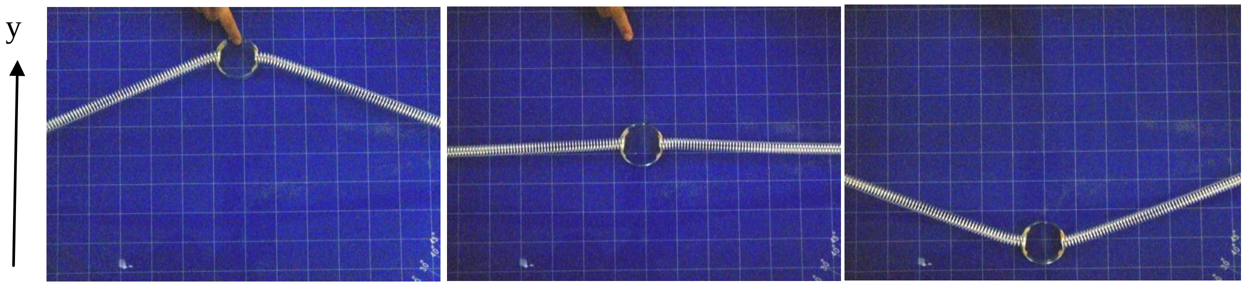


Figure 32. Harmonic oscillation using the frictionless plate.

1. Connect the Petri dish with the plastic springs as shown in Fig.32.
2. Connect the end of these springs to the corner of frictionless plate. For this purpose, two persons should cooperate.
3. Shift the Petri dish from the equilibrium point and release, then the Petri dish starts to make the single harmonic motion with moving left and right side regularly.
4. If two ends of the springs move together with the same speed to the y direction, the trace of the object shows the sine curve, because the relationship between time and displacement can be shown in the frictionless plate.

J. Wave experiment

It is difficult for students to understand the characteristics of wave because the wave propagates very fast. However, it has been proved that the frictionless plate also can be used to demonstrate the wave propagation because we can make the specific wave which propagates with slow speed on the frictionless plate.

a. Tools and materials

1. Small plastic lids 25 peaces (diameter of around 5 cm)
2. Thin Rubber string
3. Big frictionless plate (180 x 90 cm)

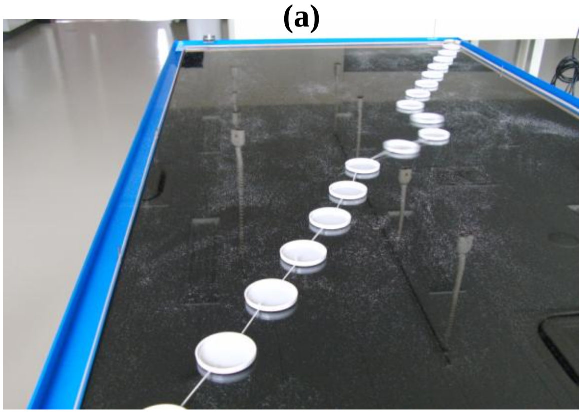
b. Activities

1. Connect the small plastic lids each other using thin rubber string to make long series of small plastic lids.
2. Stretch the long series of small plastic lids in a line on the frictionless plate as shown in fig. 32. Move the end of the long series of lids to the vertical direction so that a pulse wave will be generated. Observe how the wave propagates. Confirm the phase of the wave changes after the reflection.

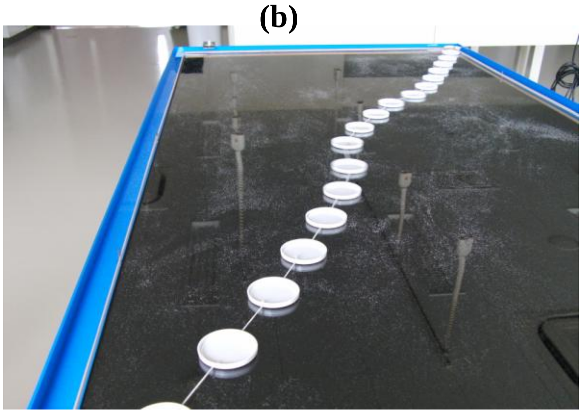
3. Swing the end of the series of small plastic lids periodically to left and right side so that we can continuously send the waves. We can see standing waves at the suitable swing-frequency. If the frequency is high, the distance between a knot and a knot become short; namely the wavelength become short.

(a)

(b)



(c)



(d)

Figure 32 Photograph of wave demonstration using the long series of small plastic lids on the frictionless plate at (a) t=0, (b) t=0.3 s, (c) t=0.5 s, (d) t=1.2 s

CHAPTER 2
DEMONSTRATION EXPERIMENTS FOR FLUID DYNAMICS

2. Experiment to know the existence of atmospheric Pressure

Experiment Using Newspaper

General purpose: even using newspaper, we can demonstrate good physics experiment. One of the interesting demonstrations is to show the atmospheric pressure using a news paper.

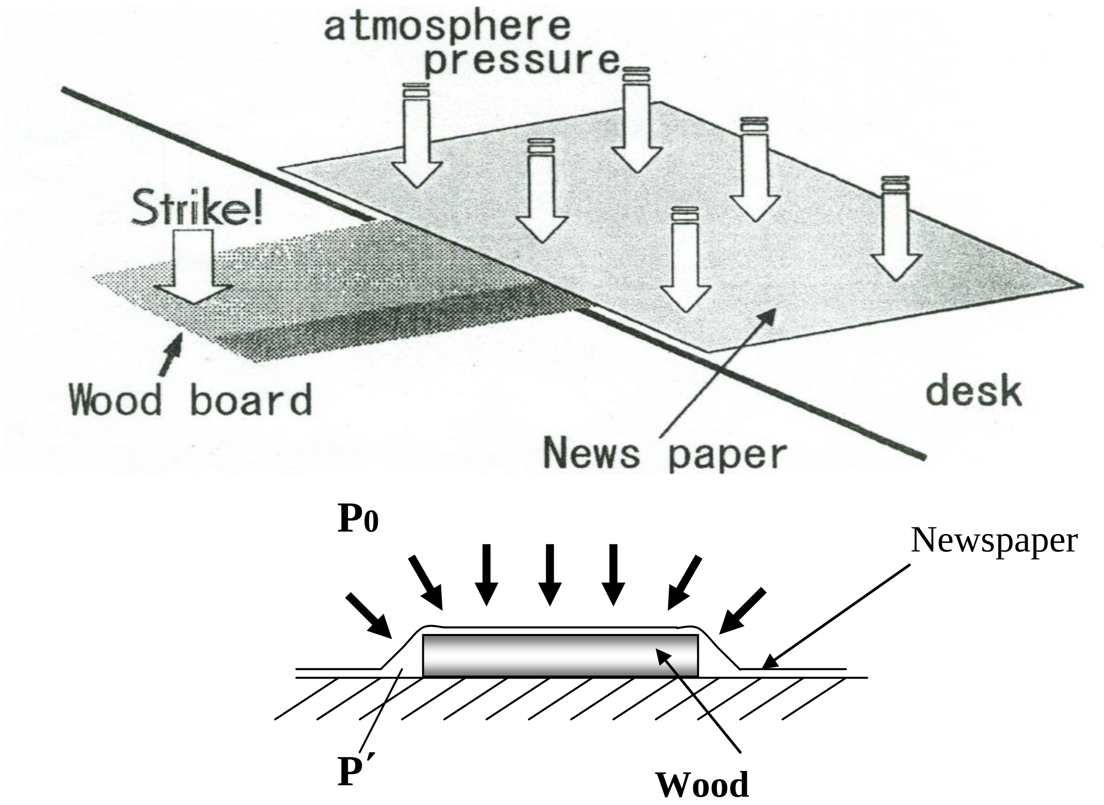


Figure 1

Methods:

1. Prepare wood plate with dimensions of 70 cm x 15 cm x 1 cm.
2. Put the wood plate on the corner of the table such that 20 cm of the plate extends away from the table.
3. Cover the wood plate part on the table with newspaper as shown in the above figure.

4. First, gently push down the outside wood plate which is not covered by the newspaper using your hand. See how the newspaper will rise easily.
5. Second, strike, with force, the outside wood plate which is not covered by the newspaper using your hand. Observe how the atmospheric pressure strongly opposes the motion of the newspaper. In this case, the newspaper will not rise.
6. Compare with the case when we use cloth in place of the news paper (in this case air coming into the space through the mesh)

Experiment using glass cup

Prepare a cup containing water of some amount and a card paper of which size is about 10 cm square. Attach the card paper on the cup by pushing your hand, and make up-side down the cup with the card paper.

Confirm the water never fall down by the support of the card paper. This is due to the fact that the pressure of the air, which is surrounded by the wall of the cup and the water, is lower than that of the atmospheric pressure ($P' < P_o$).

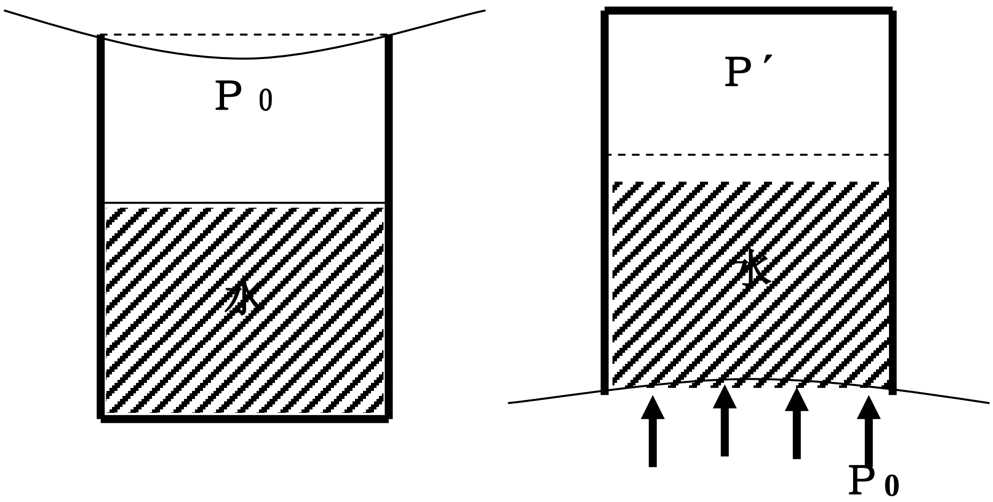


Figure 2

Fluid Experiment Using Pet Bottle

General purpose: Fluid mechanics is also important to understand phenomena observed in our ordinary life. We can do many important experiments using waste pet bottles.

1. Observation of atmospheric pressure:

Prepare a waste pet bottle (the volume of about 2 l). Pour some amount of hot boiling water in the pet bottle and close with the lid of the pet bottle; the water vapor coming from the hot water occupies the space of the pet bottle in place of the air.

Soon, pour a lot cold water on the outside wall of the pet bottle. The pet bottle will be crushed with a strong sound. This is due to the fact that the pressure inside of the pet bottle is decreased suddenly because the water vapor changes to the droplets which have much more small volume (1/1800) compared to the vapor.

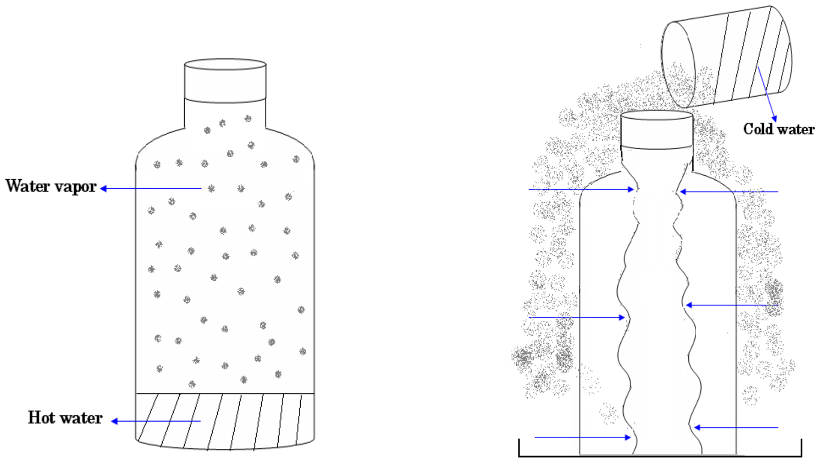


Figure 3

2. Pressure in the liquid

The pressure in the liquid increases with increasing the depth; the pressure at the depth h from the surface of the liquid is

$$P = \rho g h$$

, where ρ is the density of the liquid and g is the gravity.

This is easily derived as the followings:

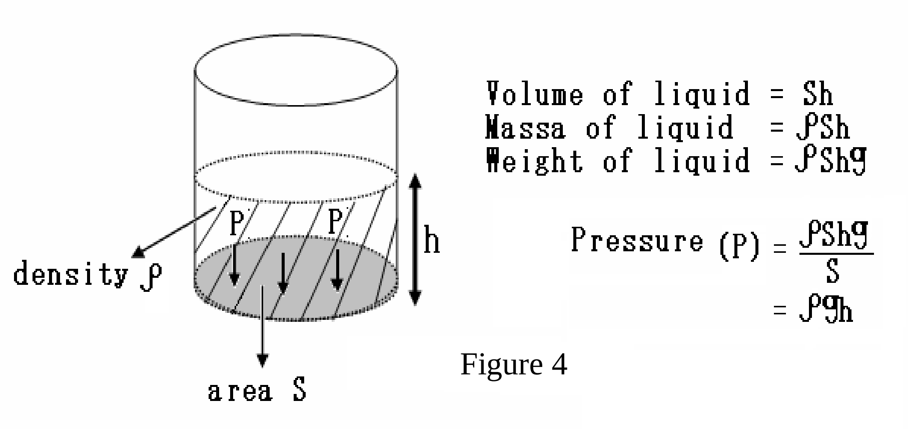


Figure 4

Confirm the existence of the water-pressure by observing the fountain phenomenon using a plastic cup and a big beaker (1 l).

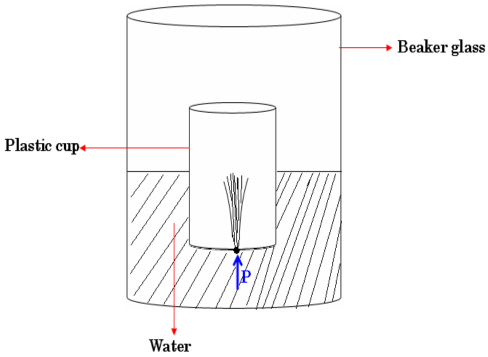


Figure 5

Some of the important characteristics of the liquid can be demonstrated using pet bottles.

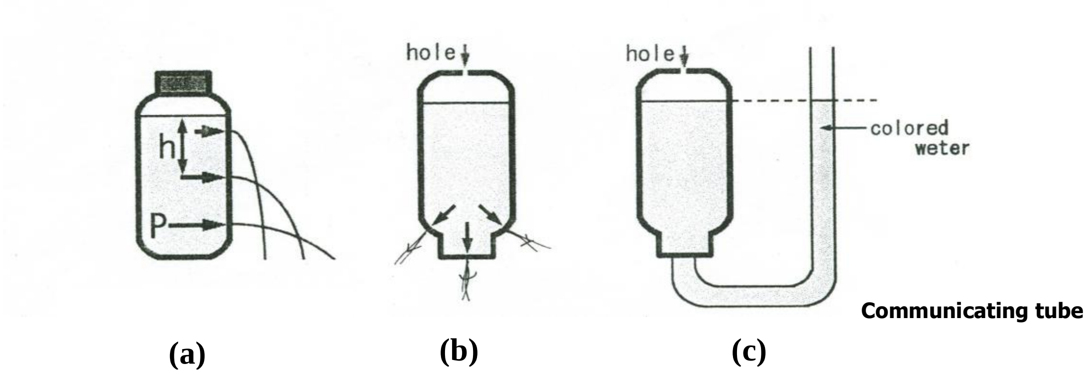
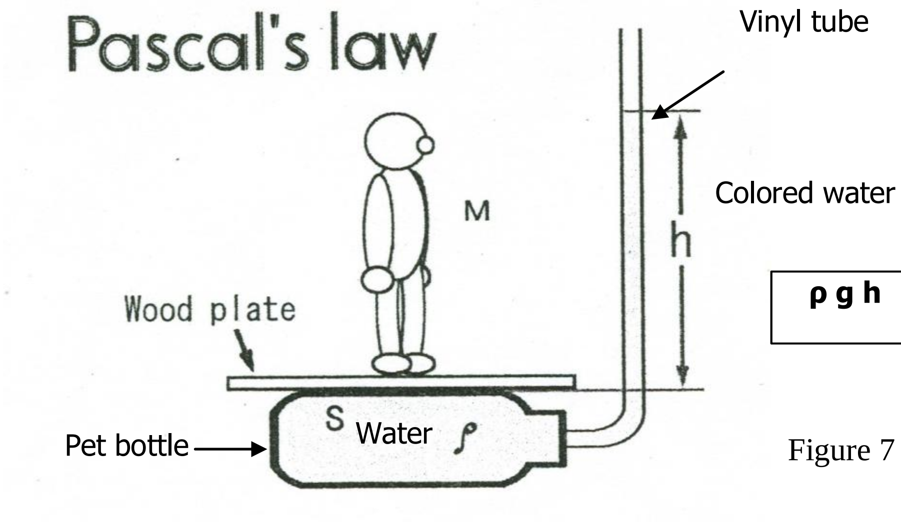


Figure 6

3. Application of Pascal's law to measure human weight

By obtaining h we can calculate the weight of an object.



$$\rho g h = M g / s$$

Figure 7

4. Mechanism of intravenous drip

Mechanism of intravenous drip used in hospitals can also be shown using pet bottle.

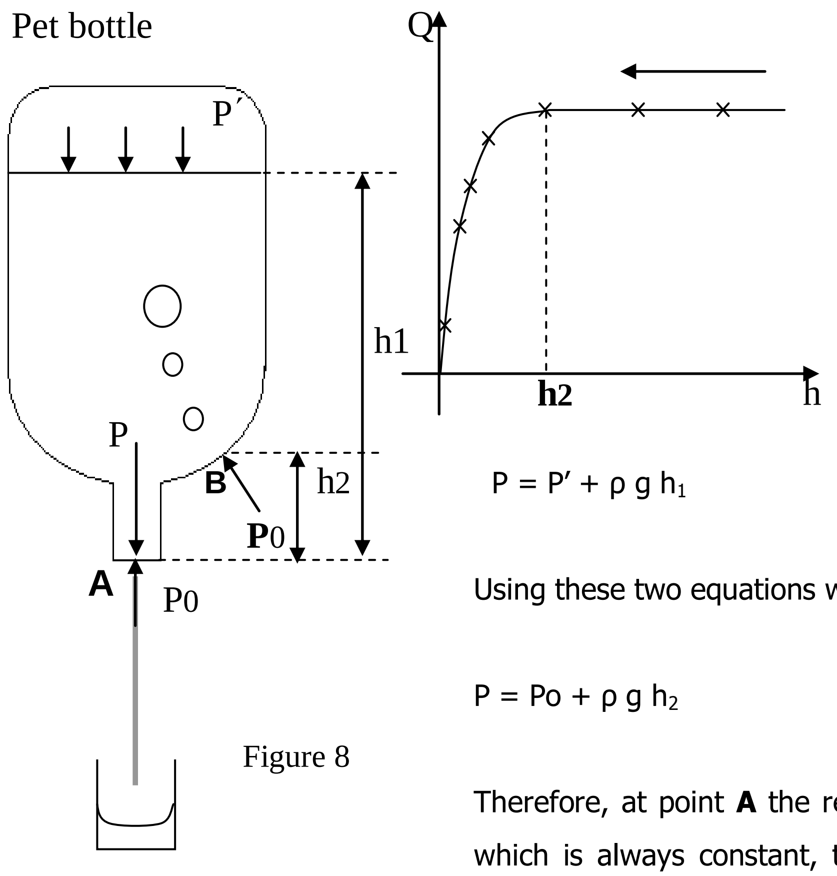


Figure 8

At point **B** there is pressure balance,

$P' + \rho\, g(h_1 - h_2) = Po$

At point **A** the pressure from the top side, namely P, is

$P = P' + \rho\, g\, h_1$

Using these two equations we can eliminate P′ as

$P = Po + \rho\, g\, h_2$

Therefore, at point **A** the resulting pressure is $\rho g h_2$, which is always constant, therefore until the water level reaches point **B**, the flow rate (cc/second) is always constant.

Methods:

1. Prepare a pet bottle and make hole to its lid less than 1 mm and put the water inside the pet bottle
2. Stand the pet bottle upside down
3. Using stopwatch, measure the amount of water flowing out in a given time period, eg: 30 seconds.
4. By changing the water level, we can measure the change in the rate of flow

5. Siphon

Siphon is often used in the daily life. Interesting phenomenon takes place when we take out water or oil contained in the tank using a tube. People feel strength why the water moves to upward in the tube. It looks like difficult problem, but once we simplify the experiment step by step, we can very easily understand the concept as shown in the following figure.

In physics the important thing is what the important factors to control the phenomena are and how we modify and transfer the problem to more simplified problems.

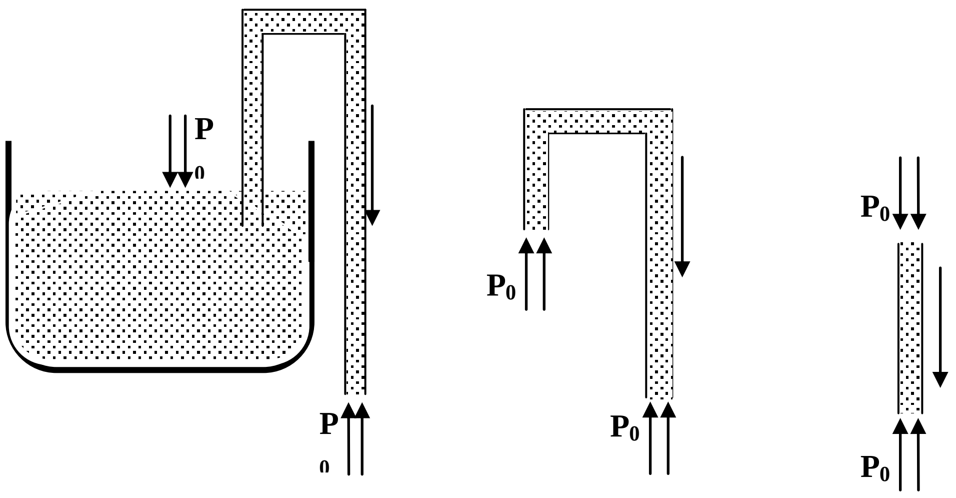


Figure 9

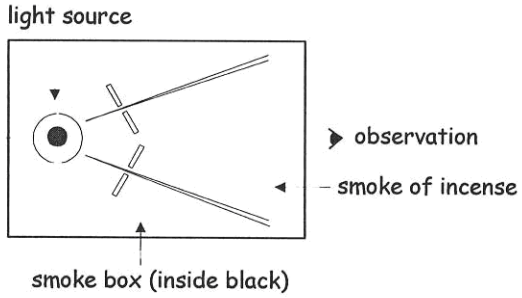
CHAPTER 3
DEMONSTRATION EXPERIMENTS FOR FUNDAMENTAL OPTICS

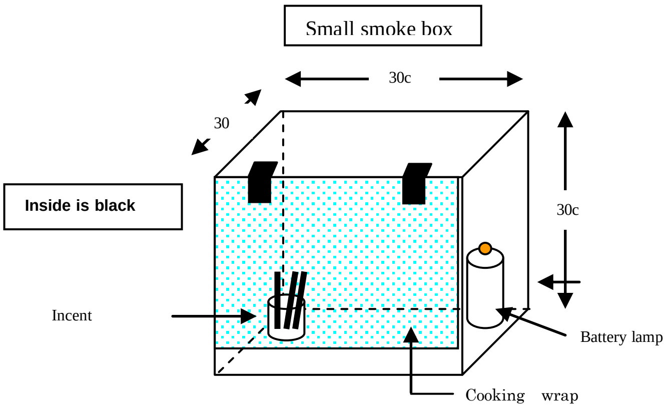
3. Directivity of Light Ray

3.1. Observation of light ray in a smoke box

Confirm light rays emitted from a point source propagate straightly in all direction (battery lamp, slit, smoke box made of cardboard)

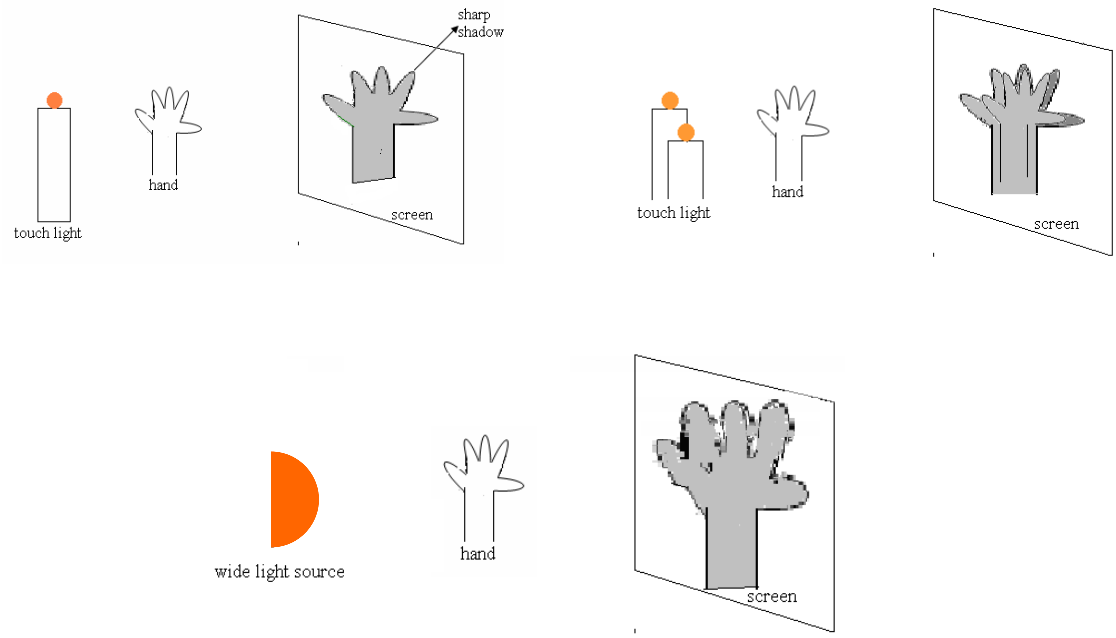
→ *Group experiment*





1.2. Shadow image

See the image of the shadow using the battery lamp as a point light source.
Put the two battery lamp and see how the shadow will change.
Change the battery lamp to a lamp with wide area of illumination, shadow image becomes unclear.

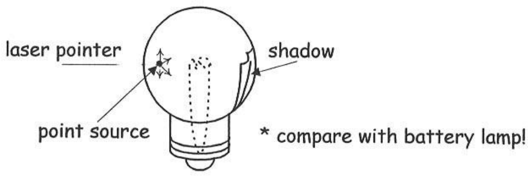


Make an enlarged image of the film sheet on the screen using the battery lamp.

→ *Group experiment*

1.3. See the inside of a light bulb using the shadow image

Scattered light rays propagate straight line and produce shadow (laser pointer, battery lamp, bulb) *Group experiment*

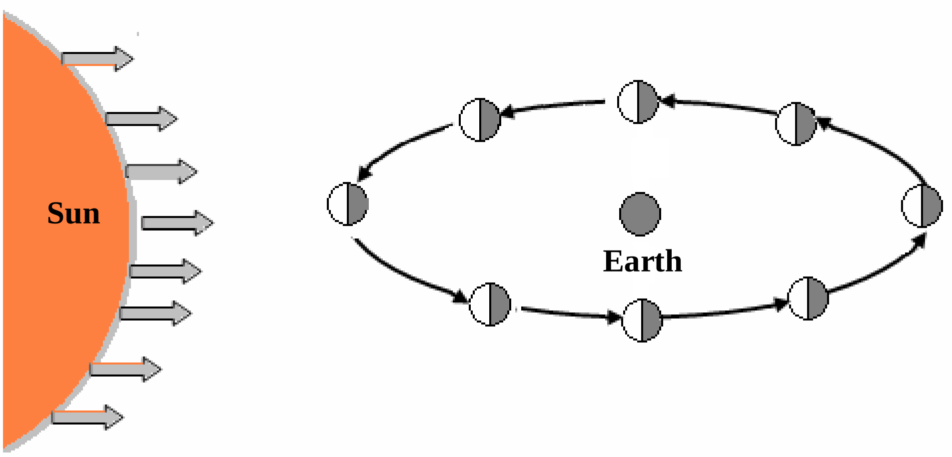


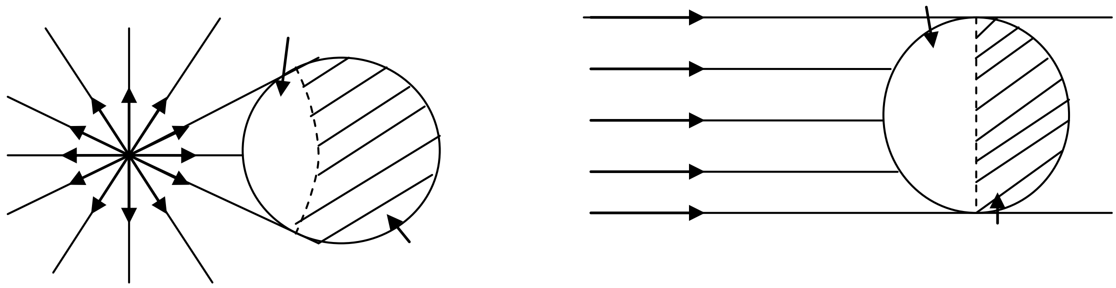
1.4. Explanation of the moon shape

This phenomenon is also related to the directivity of light ray.

Notice the following 5 facts to explain the moon shape.

1. Sun locates at so far distance, therefore the light is almost parallel light ray.
2. Universe is completely dark, and object is illuminated by the sun light to show the shape in the dark background, thus we can see the object
3. Moon is sphere in shape and rotate around the earth having a near circular orbit,
4. When the sphere object is illuminated in the dark space, namely in universe, by the parallel ray (sun light), only half sphere region is bright.
5. Depending on the direction of the observer, half sphere shape (moon) changes from circle (full moon) to completely dark object.



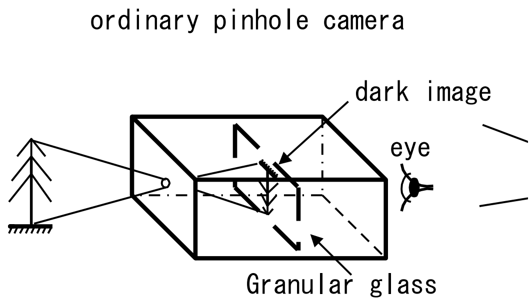


Point light source

Parallel light source

1.5. Principle of pinhole camera

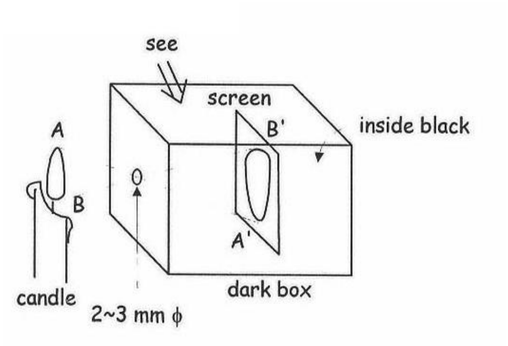
Ordinary type of pinhole camera is not ideal because the image is too dark and moreover we see scattered pinhole image directly.

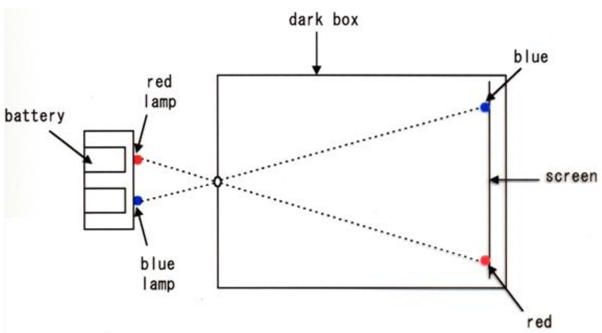


Make a principally similar experiment of pinhole camera using a candle light and the dark box (pin-hole diameter is around 2 – 3 mm)

Confirm the image is inverted, and see how the image change when the distance between the hole and the candle is varied, or etc.

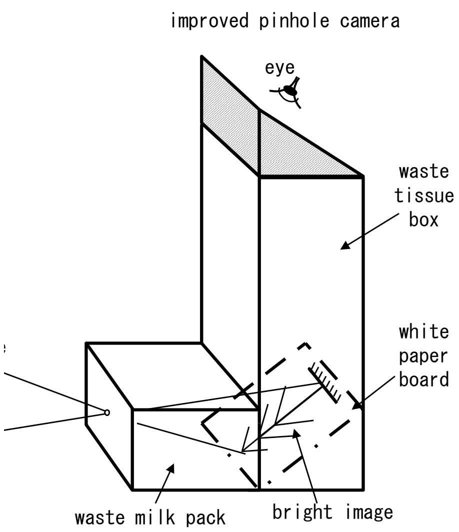
⟶ *Group experiment*





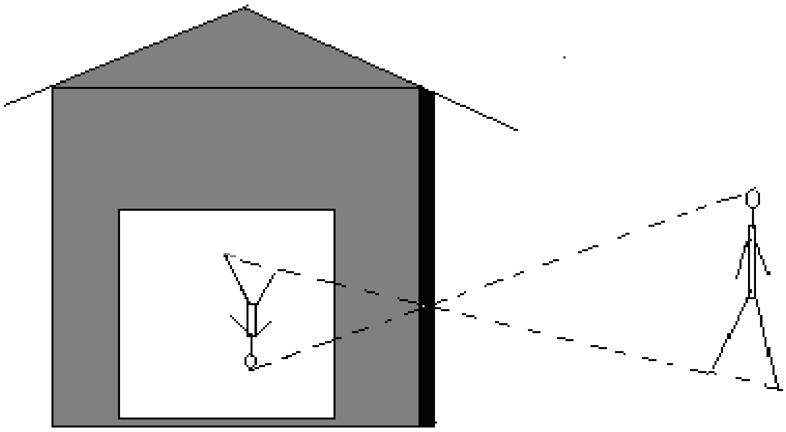
1.6. **Improved pinhole camera**, which will be constructed by yourself using recycled materials (waste tissue box, waste milk box, white paper as screen)

⟶ *Group experiment*



1.7. Big pinhole camera using a dark room

Make the room be dark, make a hole with a diameter of 3-4 cm on the room wall. By this scheme, you will enjoy to see a big image of any object located at outside.



1.8. Pinhole camera using an old camera

Buy a cheap used camera. Take out the lens, then attach a paper cup painted black on the mount of the lens. Make a small hole on the bottom of the cup using sewing needle. While keep the rolling function as it is. Set color film, and exposure time is around a few seconds

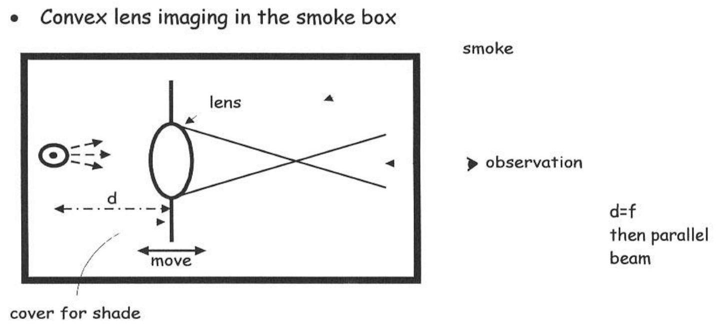
Students will be surprised to see the color image because they think this simple camera makes white and black photo.

2. Convex Lens

2.1. Observe the light rays passing through a lens with shielding plate in the small smoke box, for different 3 cases; a<f, a=f, a>f, where f is focal lengths of the lens and a is the distance between the lens and the object. When a<f, the beam from the battery lamp expands.

Confirm the way how to make a parallel light (a=f)

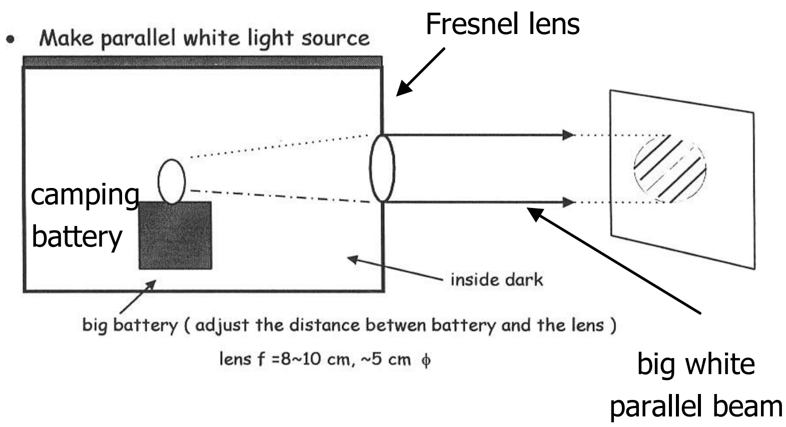
→ *Group experiment*



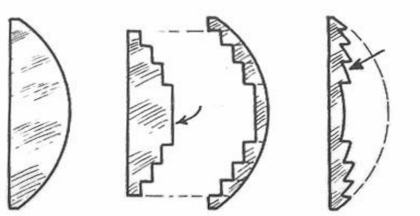
2.2. Observe the laser light from a laser pointer propagating in the small smoke box (also demonstrate in a big dark room)
Brightness of the scattered light is different depending on the direction of the observation, Θ=0 or 180 degree is maximum.
⟶ *Group experiment*

2.3. Learn how to make white parallel beam using lamp and convex lens

How to make the parallel beam with the wide area using camping battery and Fresnel lens



Fresnel Lens



2.4. Mechanism of camera and projector. Explain it standing in front of the white screen with a lens and candle

$$1/a + 1/b = 1/f$$

where f is the focal length, a is the distance between the object and the lens, and b is the distance between the lens and the image plane.

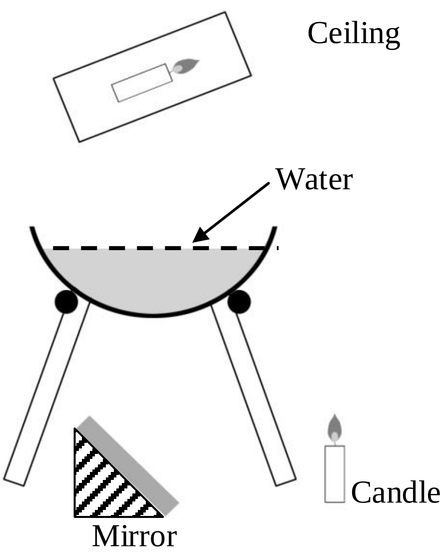
Change the distance between the lens and the object (candle light), The ration between the size of the object and that of the image, m, is m=b/a;
a>>b is for camera, and a ~ f (but a>f) is for projector.
(⟶ *Group experiment)*

How to estimate the focal length of the lens. Make an image of the lamp on the ceiling (a>>f then b≈f, ability to make rough estimation is important)

2.5. Camera to enjoy the projected image on screen (waste tissue box, milk box, white paper, lens with f = 130 mm) ⟶ *Group experiment*

Big camera to enjoy the projected image on the screen (box of 43 X 30 X 30 cm, hole of about 10 mm Φ, lens with f ~ 40)

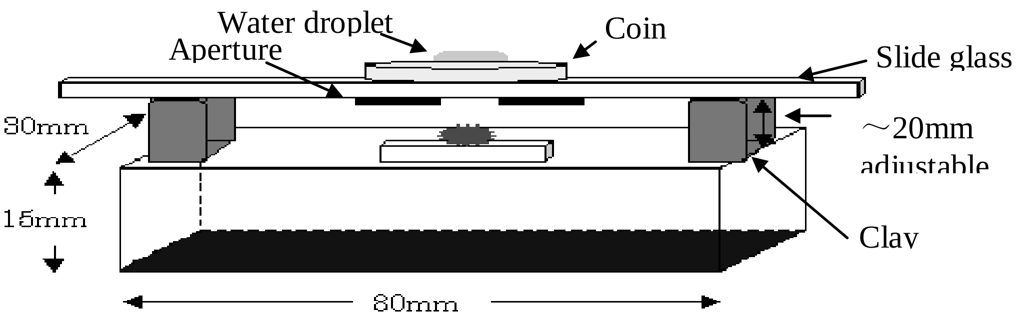
2.6. Make the water lens using sphere plastic container and project candle light image on the ceiling (put the suitable aperture below the water lens)



Also confirm the water lens works as magnifier by looking small letters in a newspaper

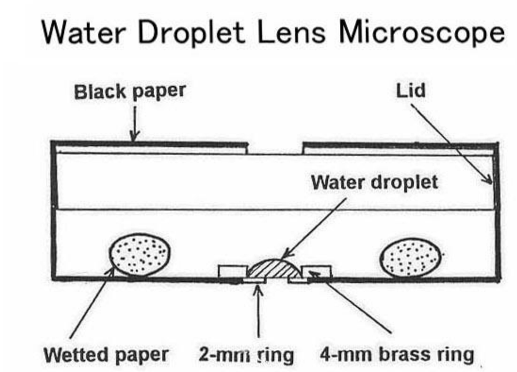
2.7. Water lens microscope → very useful in developing country

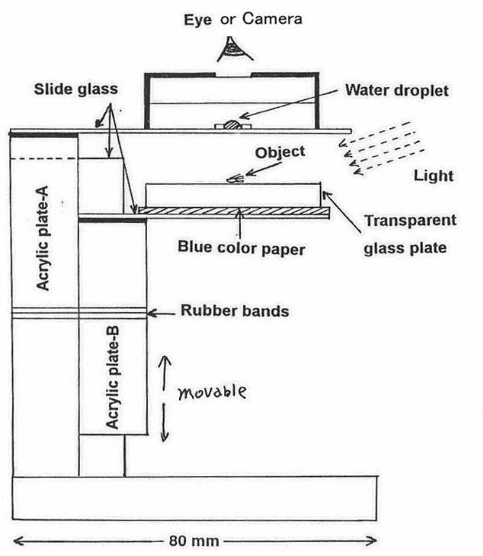
m = D/f (D = 25 cm, distance of distinct vision) magnification is about x6 to x30 (→ *Group experiment)*



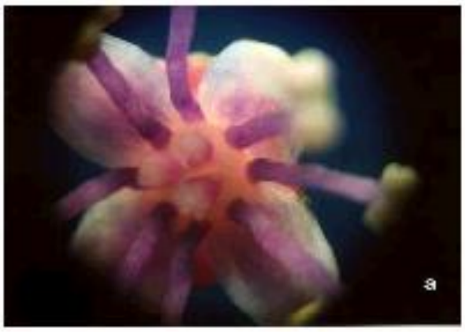
2.8. Improved water lens microscope

Improved points: good shape ring, to suppress vaporizations, aperture, simple focusing adjustment





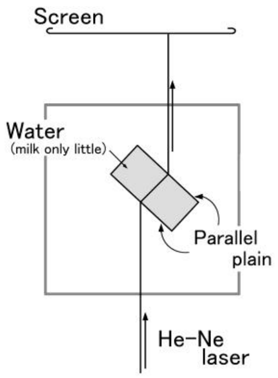
Even simple experiment there are several important points. Students can learn logical thinking even from this kind of small experiment

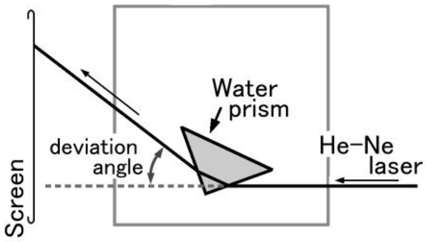


Microphotographs taken by a compact camera using the water droplet lens. The distance between the object and the lens is 21.5 mm (Physics Education, Vol.36 pp.97-101)

3. Dispersion of Light

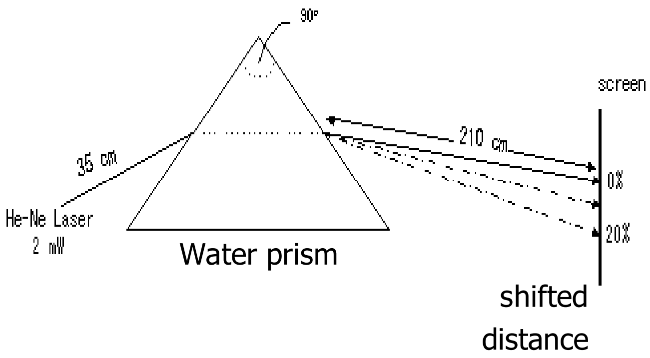
3.1. Beam deviation using parallel plane or triangle with apex angle using water

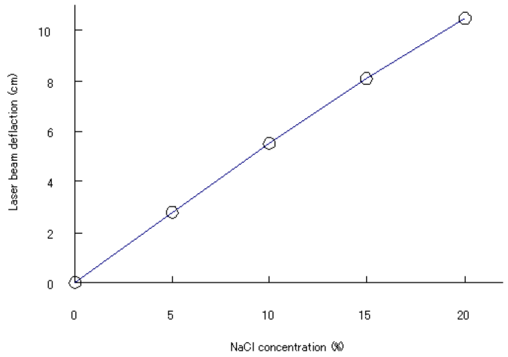




Confirm no bending happened in the laser beam for parallel planes. Bending happened for triangle with apex angle

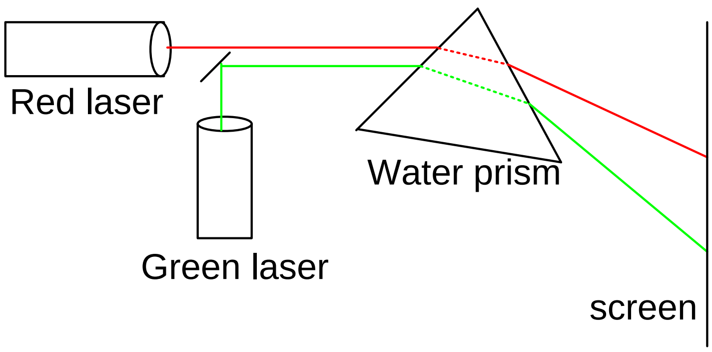
3.2. By increasing the refractive index, deviation angle increased.
By adding the impurity into the water, the refractive index increases.
Confirm by adding salty water into the water prism, deviation angle is increased.





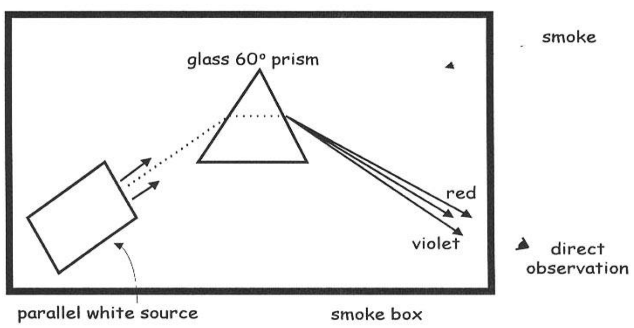
Students can confirm the linear relationship between concentration of salt and shifted distance of the laser spot.

3.3 Refractive index increases with decreasing the wavelength of light, resulting in the separation of light ray depending on the color; wavelength of green light is shorter than that of red light.
No dispersion takes place when the two planes are in parallel, while when the two planes are inclining, color dispersion occurs.



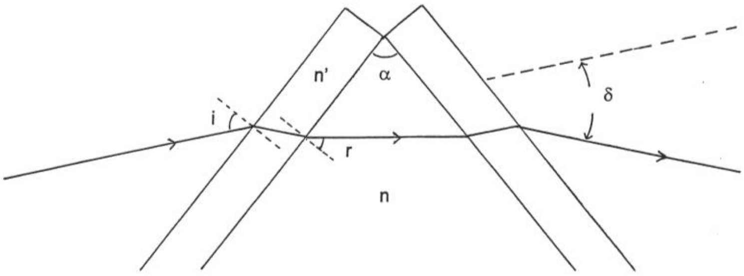
3.4. Observe the color dispersion by sending parallel white light beam into a water prism (slit should be set on the light source, and take distance between the prism and the screen so that the color separates sufficiently)

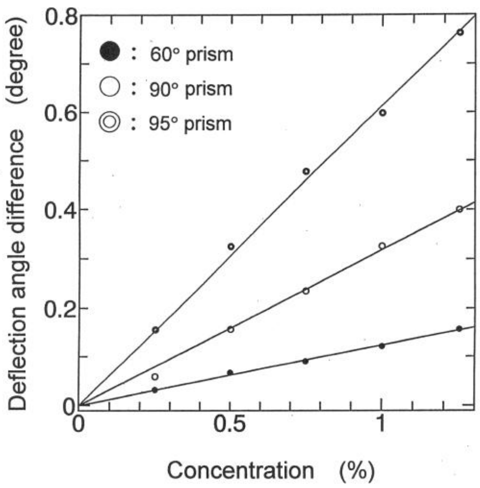
- Observation of optical dispersion

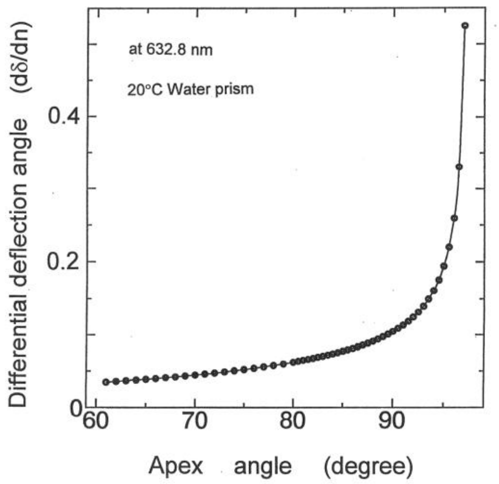


Confirm if the beam is not parallel like ordinary battery lamp, no good color dispersion happened
(⟶ *Group experiment)*

3.5. Dependence of apex angle of water prism on the dispersion
A water prism of which apex angle is about 90° is nice (for 95°, due to total reflection the light cannot come out)
Aquarium also becomes a good water prism since its corner has 90° angle
Even one mirror, which is soaked in water, works as a nice prism to make color dispersion

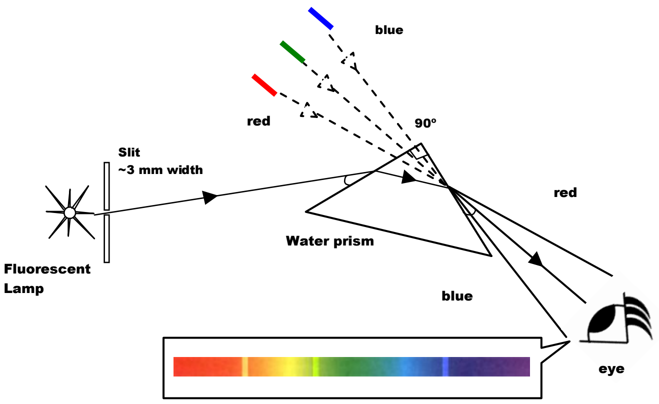






Construction of water prism and see the spectrum of fluorescence lamp using slit → *Group experiment*

3.6. Principle of spectroscope
See the slit image through the water prism.
Each color light make each image of the slit at different see angle, thus there appear the series of slit image, which construct the spectrum of the light source.



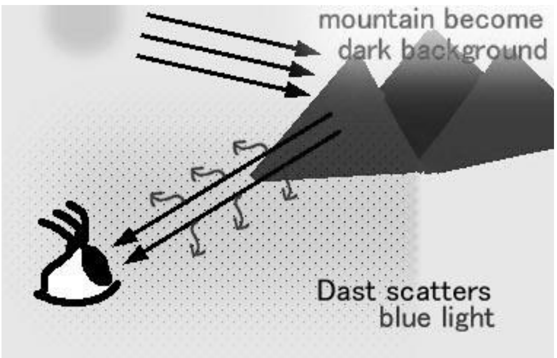
Construct a water prism spectroscope and see the spectrum of fluorescence lamp → *Group experiment*

4. Scattering of Light

4.1. Why the sky is blue?

The background of the sky is completely dark. On the dark background, we can see scattered blue light. Light of shorter wavelength (blue) is scattered by small particles much more than those of longer wavelength (red)

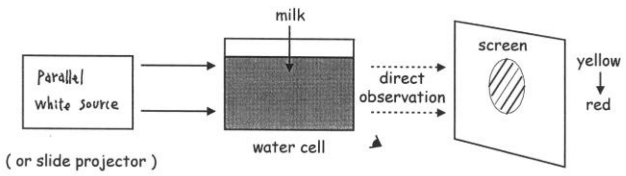
Why the color of mountains far distance is blue?

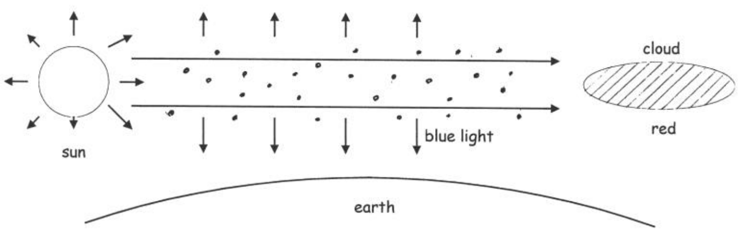


4.2. Model experiment for sunset

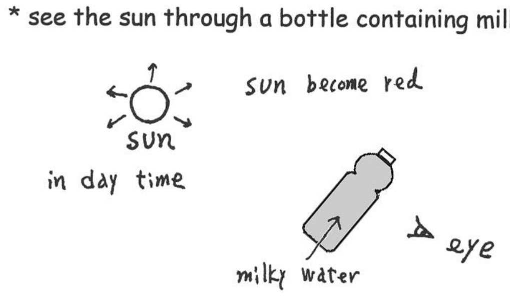
Shorter wavelength is scattered and lost (white parallel beam, water containing a little milk, screen)

- Principle of sunset

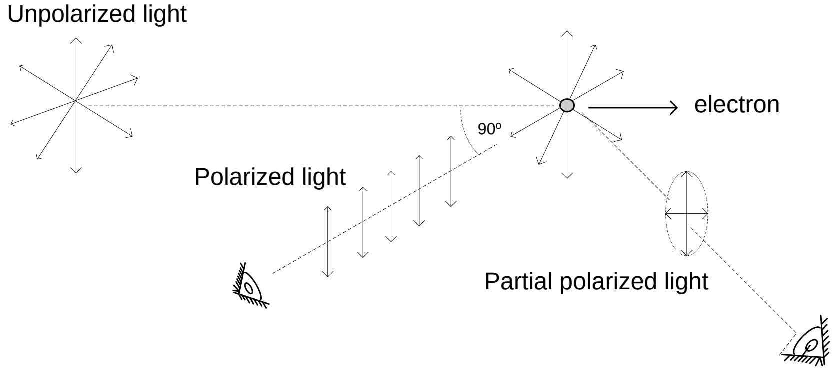




4.3. See the red sun through a pet bottle containing a little milk



4.4. Confirm the scattered light is polarized using a polarizer (degree of polarization depends on the observation angle)

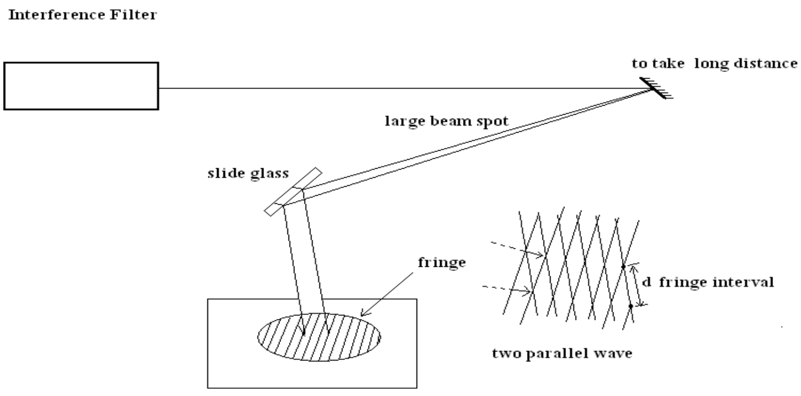


5. Interference and Diffraction

5.1. Explain the wave interference using two OHP sheets on which two spherical waves are drawn (summation of maximum and minimum, maximum and maximum)

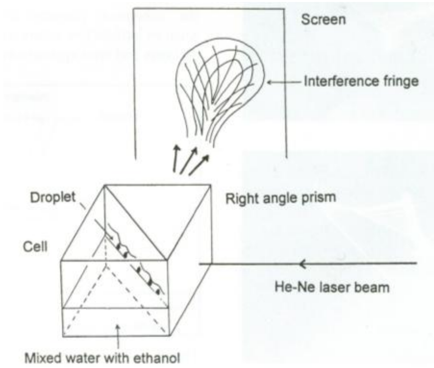
5.2. Observation of interference fringe made by superposing two plane waves, which are reflected on the surface of a glass slide plate
Observe oscillation wave using spring and how the summation of two waves (same face and anti face) happened

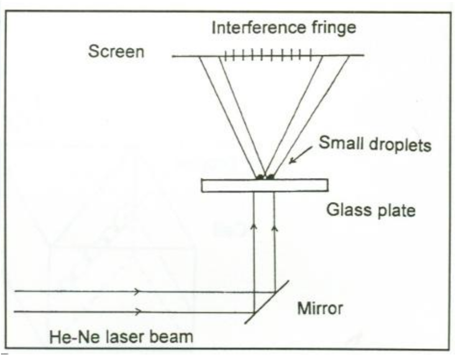
Newton's Ring Observation. (Group Experiment)



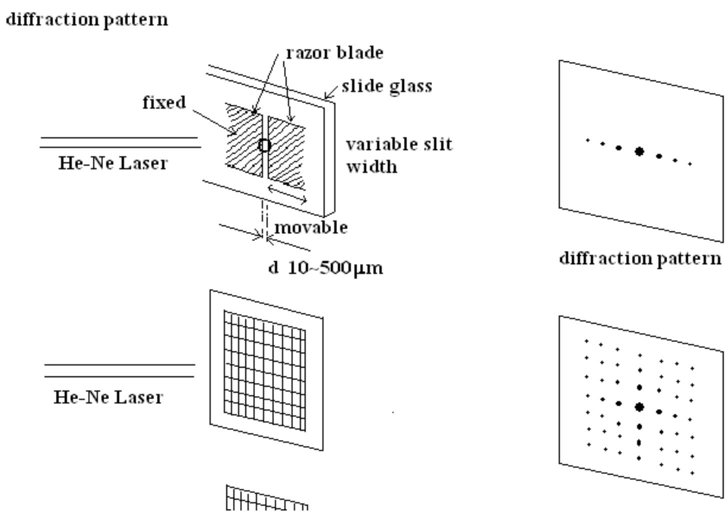
5.3. Dancing fringe (attraction)

Laser light is expanded by a dynamically changeable droplet which made of water and alcohol

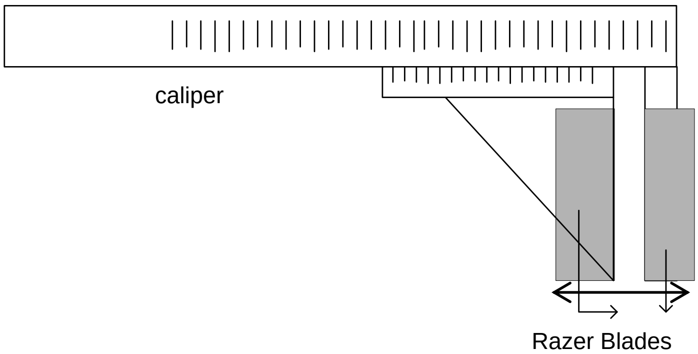




5.4. Light diffraction due to a single slit and mesh



Variable slit is made using caliper attached two razor blades

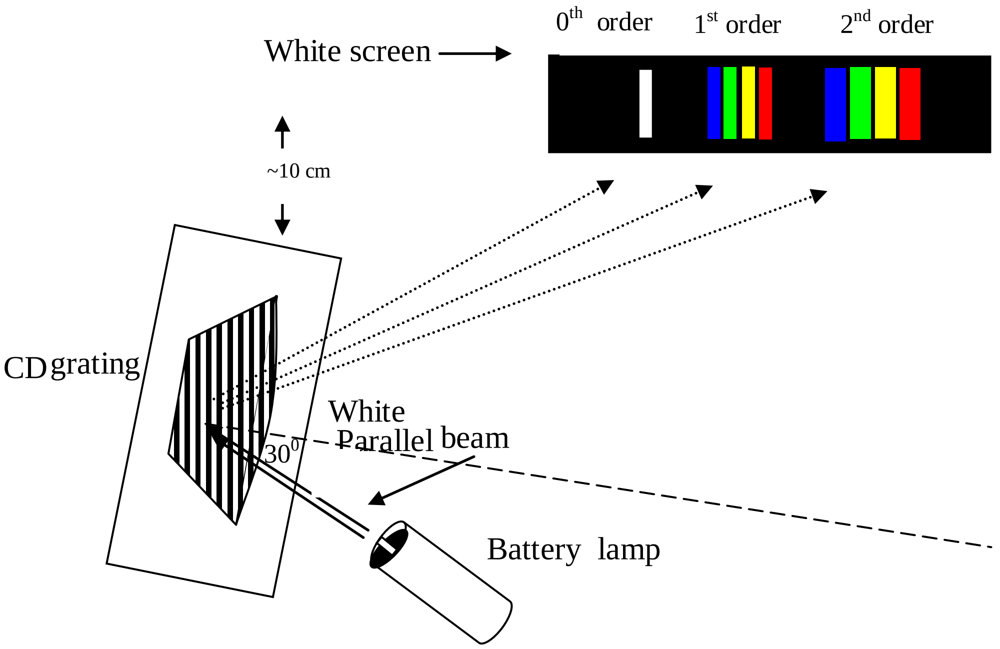


5.5. See a battery lamp source through a mesh placed in front of your eye, then you can see the diffraction pattern (compare using two batteries lamps and two color films)

Same phenomenon happened when we see light source far away through curtain or cotton banner

5.6 Dispersion of light due to CD grating

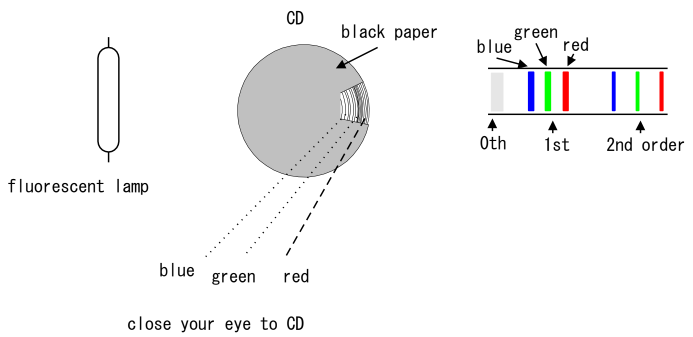
Send the white parallel beam to a CD grating; depending on the wavelength the dispersion angle is different, thus we can see the color on the screen.



5.7 Construction of spectroscope using CD grating

Principle of the spectroscope: Principle is the same as 3.5

See the fluorescent lamp through the CD grating.

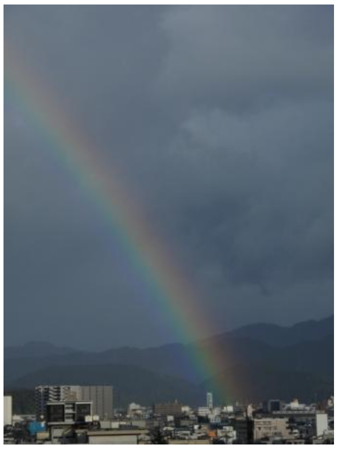


Construction of CD grating spectroscope.

→ *Group experiment*

6. Principle of Rainbow

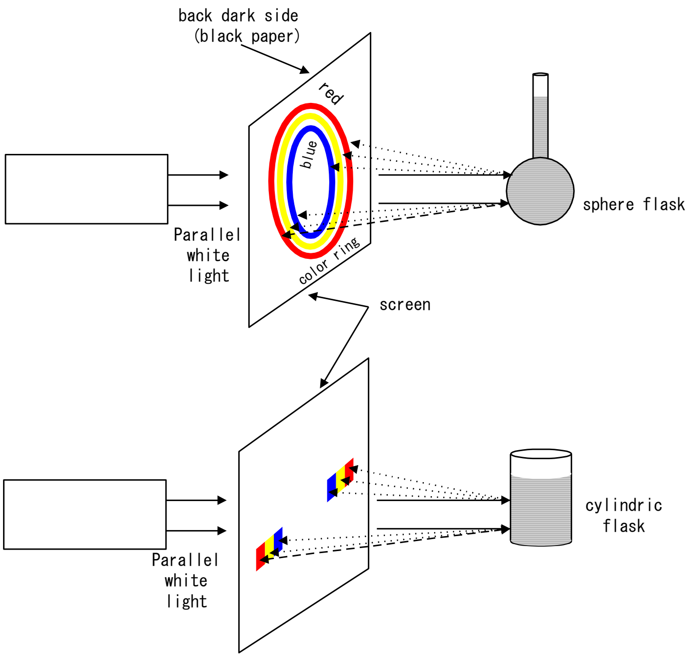
6.1. Picture of rainbow



6.2. Necessary condition to make rainbow (direct sunshine, droplet, dark background, angle relation)

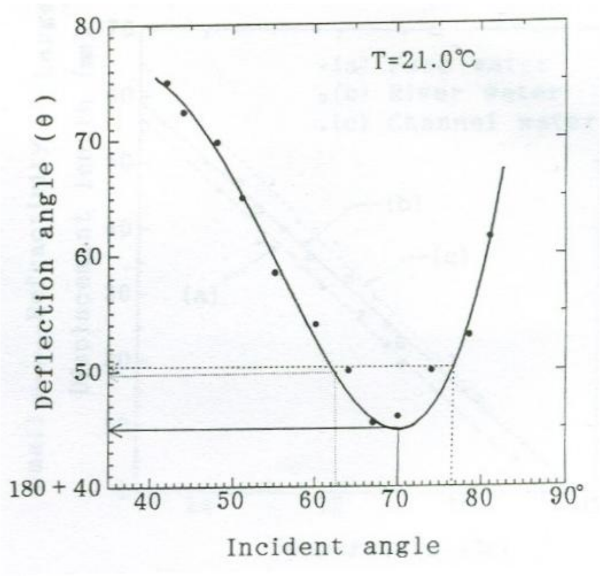
6.3. Model experiment using a small sphere flask and cylindrical flask (we can see color at the edge of the sphere)

Model experiment using sphere flask containing water, color ring can be seen on a screen when illuminated by white parallel beam (observe how the ring diameter change when water is replaced by alcohol)

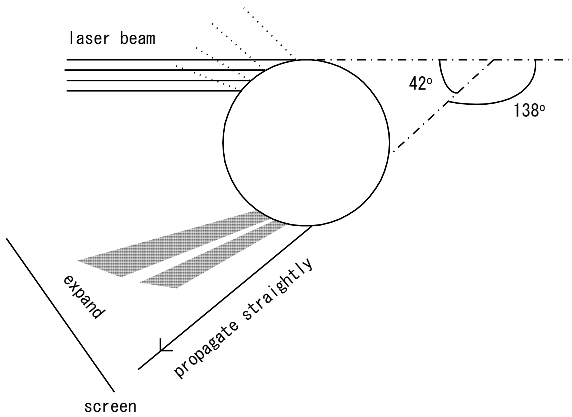


Model experiment using a test tube (face your back to the sun and put the test glass tube containing water in front of your face, look for optimum angle)

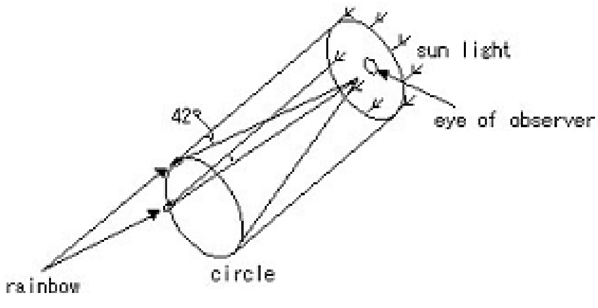
6.4. The relationship between the incident angle and deviation angle



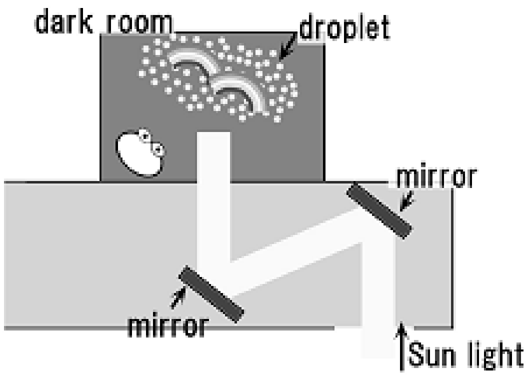
6.5. Confirm the existence of minimum deviation (cylindrical cell, He-Ne Laser, white screen paper)
The minimum deviation angle differs depending on the color (wavelength)

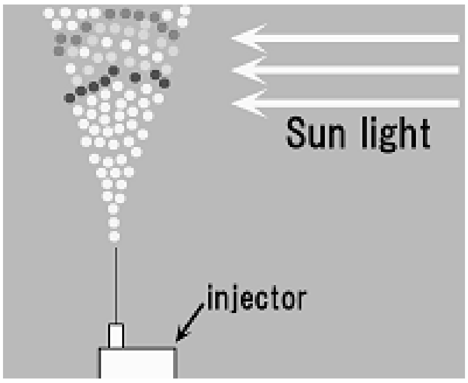


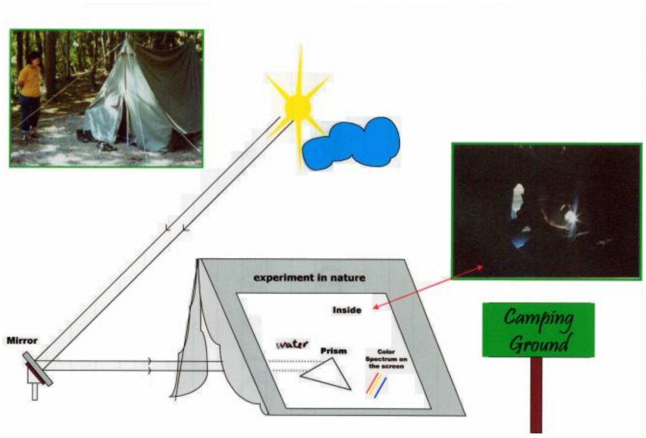
6.6. The reason why the rainbow is circle shape (explain using several compasses on the blackboard)



6.7. Observation of rainbow in a dark room using sunlight guided to the room with the aid of a few big size mirrors (we can see four rainbow and their supernumerary rainbow)







GROUP EXPERIMENTAL MANUAL

I. Small Smoke Box

a. Tools and Materials

1. Cardboard (30cm x 30cm x 30cm).
2. Black vinyl tape.
3. Plastic cooking wrap.
4. Used plastic cup half-filled with sand/rice grains.
5. Incense or mosquito coils.
6. Black spray paint.
7. Battery lamp (torchlight)

b. Method

1. Paint the inner surfaces of the cardboard using the black spray paint.

2. Cover one of the open sides of the cardboard using the plastic cooking wrap provided (refer to Fig. III. 1). Place the incense/mosquito coil firmly into the cup filled with sand and leave inside the box until its full of smoke.

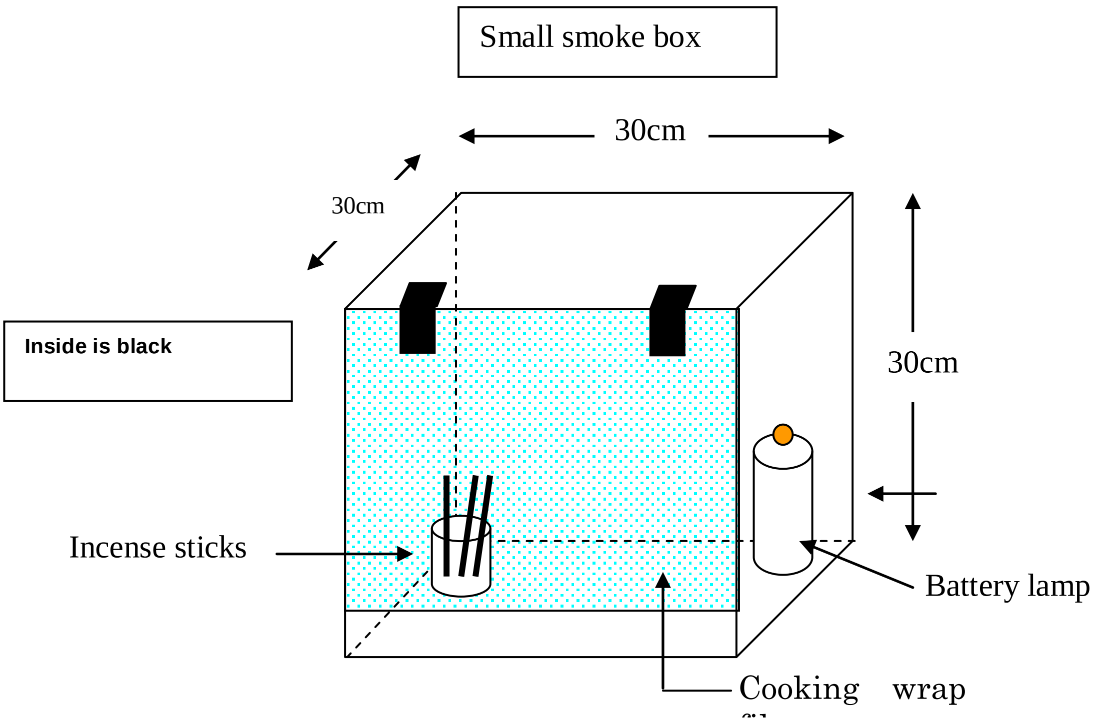


Figure III.1

c. Activities and Experiments using this box.

1. Place a torchlight in one corner of the box and observe how light travels in all directions by placing the hard black paper which has a hole like a slit shape or circle shape as shown in the figure III.2.
2. Make a small hole on one side of the box and carry out the demonstration to explain

the principle of the pinhole camera. See the image of the pinhole camera using a candle light source. Notice that the image is inverse, upside-down. See how the image changes by varying the distance between the candle and the small hole.

In a small smokes box

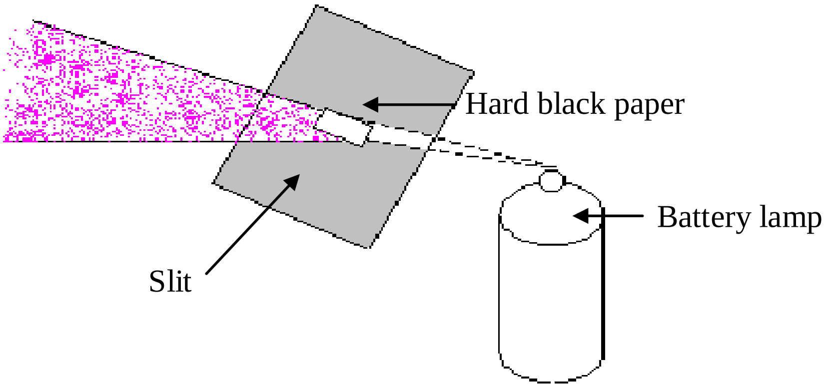


Figure III.2

3. The principles of a convex lens can be analyzed by varying the distance between the lens and the light source (see Fig. III.3). Fix the lens (f≈50mm) in place using the black tape.

In a small smokes box

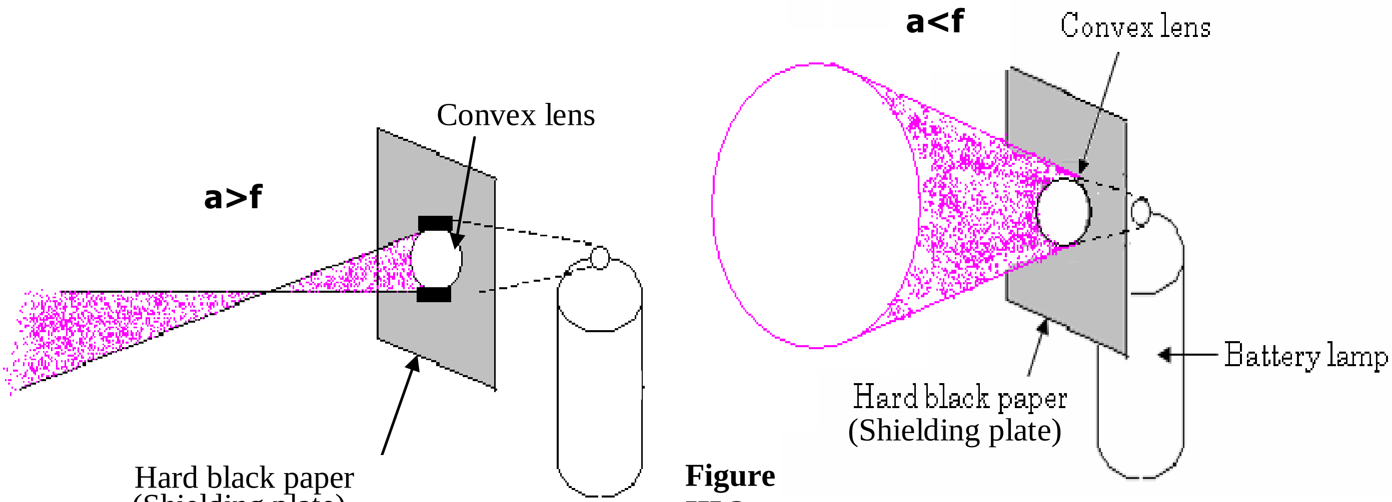


Figure III.3

II. White Parallel Beam Source

a. Tools and Materials

1. Torchlight
2. Tube made from hard paper (length: 90mm)
3. Convex lens (f=50-60mm)
4. Black vinyl tape.

b. Method

1. Fix the lens on one end of the tube using the black vinyl tape until securely fastened (refer Fig. III.4).
2. The other end of the tube is placed onto the torchlight.

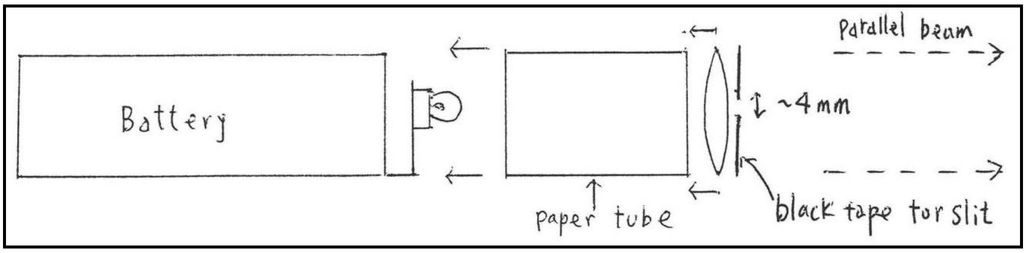


Figure III.4

c. Activities

Test the parallel beam source in a dark room (or the dark smoke box) to observe the rays coming from the torchlight, whether the rays are parallel and have low divergence. To test the divergence, place a screen at different distances from the light source.
NOTE: This parallel beam source is a very compact and useful tool in experiments involving optics, such as: rainbow observation experiments, prism dispersion etc. Depending on the experiment, make a slit approximately 4~5 mm on the lens using the black vinyl tape (see Fig. III.4)

III. Water Prism

a. Tools and Materials

1. Microscope glass slide 3 pieces (l: 76 mm, 1 piece and l:55 mm, 2 pieces).
2. Triangular acrylic plate 2 pieces (as provided).
3. Instant glue.
4. Hypodermic needle.
5. Black vinyl tape.

b. Method

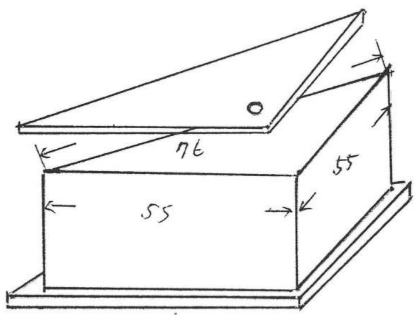


Figure III.5

1. Form a triangle using the microscope glass slide, as shown in the diagram. Use rubber bands to temporarily hold the slides together and then apply a small amount of power glue to the edges to hold the triangle firmly in its place.
2. Place the glass triangle above one of the triangular acrylic plates provided – apply some power glue to prevent slippage. Seal all contact points between the glass triangle with the acrylic plate using araldite adhesive, ensuring that the seals are water-proof. Wait for the adhesive to dry, approx. 10-15mins. Please note that during this entire

process, the surfaces of the glass triangle should be kept clean, remove any smudges using alcohol.

3. On a separate piece of acrylic plate, make a small hole with a diameter of approx. 2-3mm; refer to Fig. III.5 above.
4. Combine the pieces from step 2 and 3, first, using power glue to shape the structure, then using the araldite adhesive to ensure that the contacts are all water-proof. Wait to dry.
5. Fill the prism cavity with clean water (aqua) using the hypodermic needle until almost full. Ensure that there are no air bubbles on the inner walls of the prism; should there be any, shake the prism gently to remove the air bubbles (figure III.6).
6. Seal the small hole using black tape.
7. Cover the underside of the prism with black tape as well.

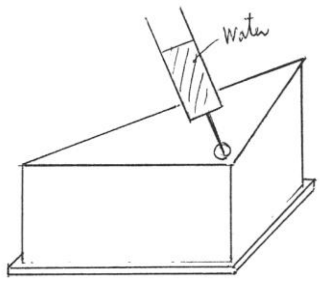


Figure III.6

IV. Light Dispersion using a water prism

a. Tools and Materials

1. Parallel light source, with a 4mm slit on the lens.
2. Water prism.
3. White screen.

b. Activities using water prism

1. Direct the parallel light source to the ceiling and adjust the tube to achieve a bright, parallel light ray.
2. Place your eye on the water prism and look at any object (preferably an object with white edges). You should be able to observe a rainbow-colored object which underwent refraction.
3. Place a fluorescence bulb vertically, at a distance of approx. 1m from the prism. Observe the spectrum of colors caused by the refraction of light; adjust the position of the prism until you achieve a clear, well-defined spectrum of colors.
4. Simple spectroscope. Make a small slit of approx. 4mm on the fluorescent light. Observe this using the water prism, and adjust to obtain a good spectrum; compare this with the one obtained in Step. 3 above.
5. White parallel light source and water prism (dark room experiment)

   a. Place the white parallel light source and the water prism on the table as shown on Fig.III.7. Ensure that the slit on the light source is perpendicular to the table surface. Place the white screen approx. 1m away from the prism and observe the resulting rainbow spectrum on the screen.

   b. Remove the screen and place our eye in its place. By shifting the position of the eye gently, you should be able to observe the basic colors of red, yellow, green and blue.

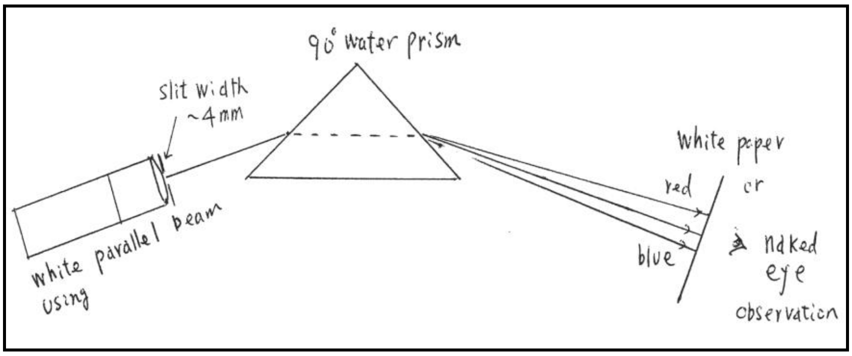


Figure III.7

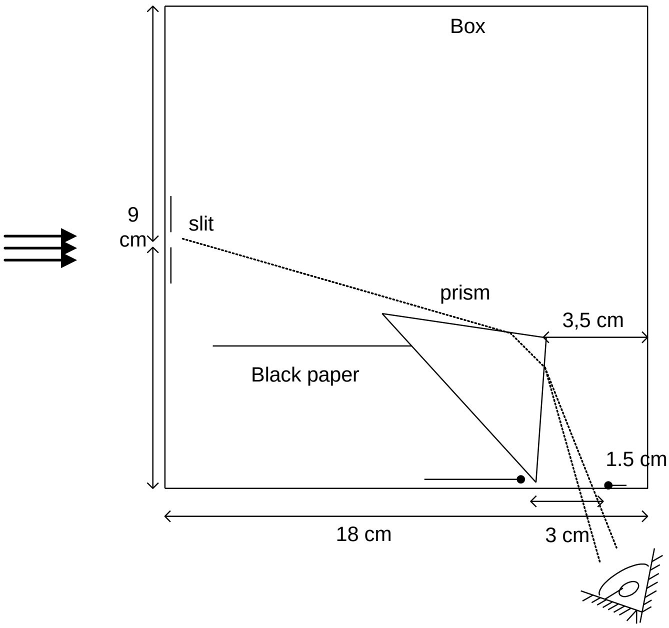


Figure III.8

Simple spectroscope experiment using water prism

1. Blacken the inner surfaces of the box and its lid.
2. Make a gap on one side of the box and attach a slit in its place. Slit width is 1 mm.
3. Make another gap on another side for observation. The configuration of the slits should be as shown in Fig.III.8. The size of the second hole(gap) should be 3cm x 2.5cm.
4. Place the prism as shown in Fig. III.8. Use a fluorescent lamp to adjust the position of the prism such that a sharp and bright image of a spectrum can be seen from the observation gap (Fig.III.9). Fig. III.9 is a photograph of a spectrum from a fluorescent light source.
5. Fasten the water prism by double tape and black vinyl tape.

Figure III.9

V. Water Lens Microscope

b. Tools and Materials

6. Microscope slide glass 1 piece
7. Screw ring A (outside diameter of 9.0 mm, inside diameter of 4.5 mm), as a container of the water droplet
8. Screw ring B (outside diameter of 7.5 mm, inside diameter of 3.5 mm) as an aperture
9. Acrylic plate (15 x 30 x 100 mm) with a hole to insert a diode lamp, as a base
10. Rubber clays, as spacers between slide glass and base
11. White diode lamp equipped with batteries, battery box, and switch
12. Medical injector to put water in the screw ring to make a water lens
13. Black paper to cover back side of slide glass
14. Black paper formed a cylindrical pipe to cover the water lens
15. black spray

b. Method

1. Attach the screw ring A in the centre of the top side of slide glass by glue (figure III.10a)
2. Attach the screw ring B in the centre of the back side of slide glass by glue, the centre of two screw rings should be coincide (figure III.10b)
3. Attach the black paper on the back side of slide glass except for the area of the screw ring B (figure III.10d)
4. Connect White diode lamp, switch, and battery box equipped batteries, which will be used as illumination light of the microscope (figure III.10c)
5. Put the rubber clays on the both side of the acrylic plate, and place slide glass which have been equipped of the screw ring on the rubber clays (figure III.10e)
6. Put water in the screw ring A using the medical injector, notice : the water should not come out from the ring, good circle shape of water droplet is the key point
7. to make a suitable shape of water droplet, a tip of the tissue paper is little attached to absorb the water droplet

8. Confirm the shape of the water lens using a magnifier whether it is really complete circle. The shape of the water droplet is the key point for the quality of the image.
9. Insert the white diode lamp in the hole of the acrylic plate
10. Put a sample on the acrylic plate at around above the white diode lamp
11. Put the Black paper, formed a cylindrical pipe, in order to protect surrounding light
12. Adjust the height of the rubber clay so as to have a good image of the sample.
13. When we need high magnification, the curvature of the droplet water should be large, resulting in short distance between the sample and the water lens

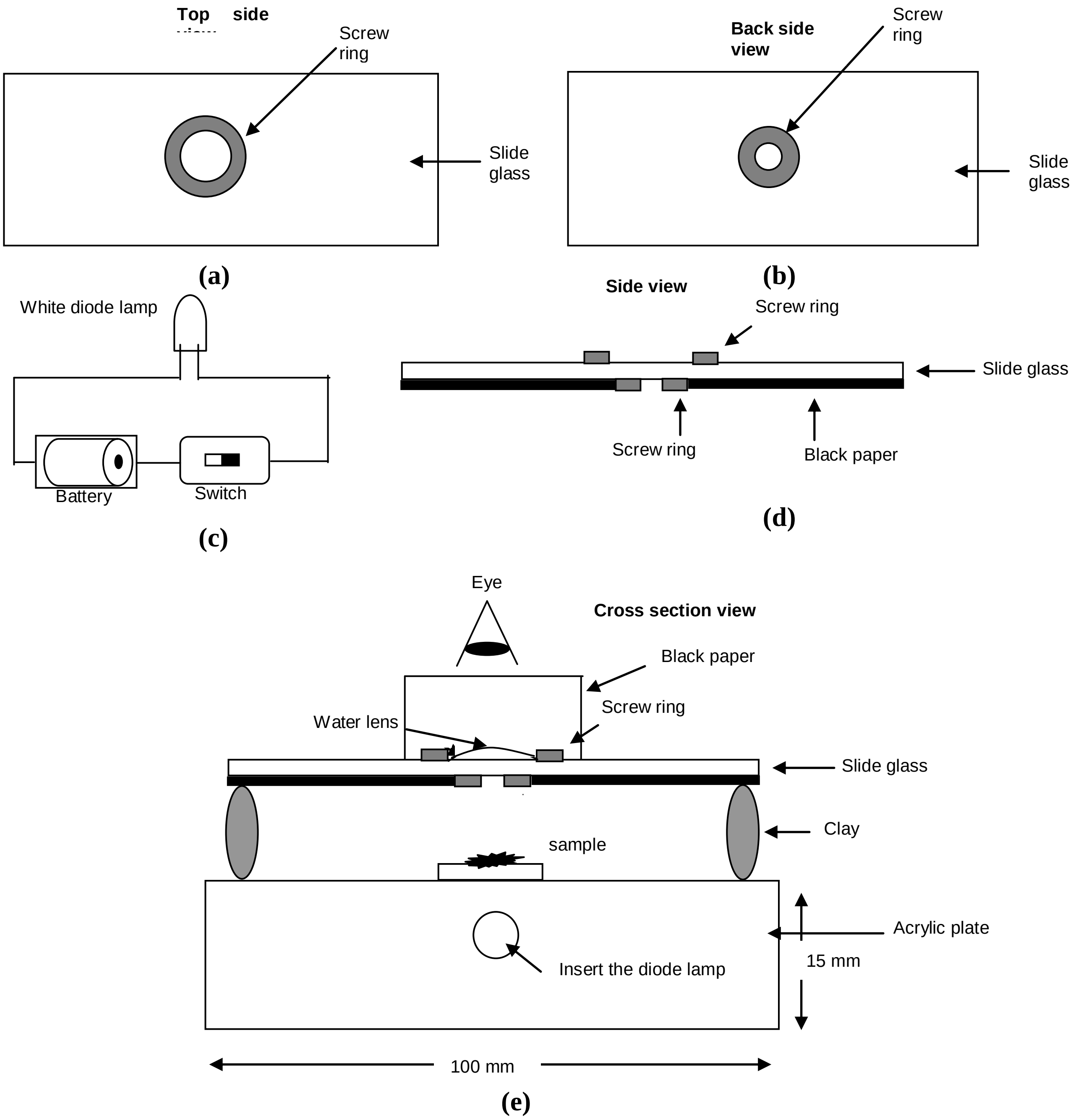


Figure III.10

c. Activities and experiments

A. The sample used in the experiments are :

1. Seed of dandelion and its hair
2. small insect
3. small Living thing in the water
4. Salt powder(NaCl crystal)
5. Thin skin of union

B. Try to take a photo by a digital camera. Place the camera above the water lens.

VI. Camera

A. Pinhole Camera

a. Tools and Materials

1. Empty tissue box (250 x 115 x 85mm)
2. Milk carton made of paper.
3. Hard carton paper.
4. White hard paper (80 x 110 mm)
5. Black carton and black plastic sheet.
6. 'Double tape' and black vinyl tape.
7. Black spray paint.

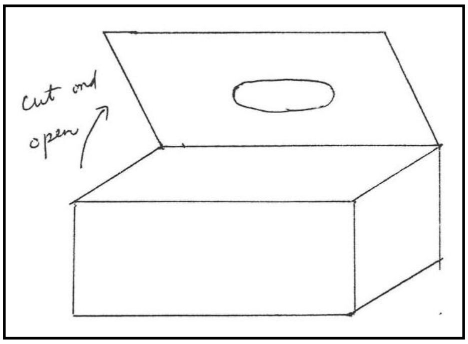


Figure III.11

b. Method

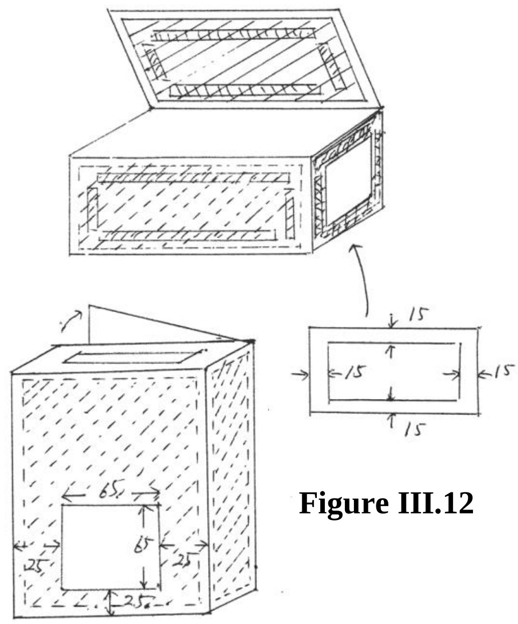


Figure III.12

1. Cut out one of the sides of the tissue box, such that it can be opened and closed, as shown in Fig.III.11.
2. Cut out two rectangular gaps as detailed in Fig.III.12, all units are in millimeters.
3. On all sides of the tissue box, attach hard carton paper and paint it black.
4. Attach the white carton paper inside the tissue box using black vinyl tape, as shown in Fig.III.13. Close the box and seal the edges with black vinyl tape to prevent light from entering.

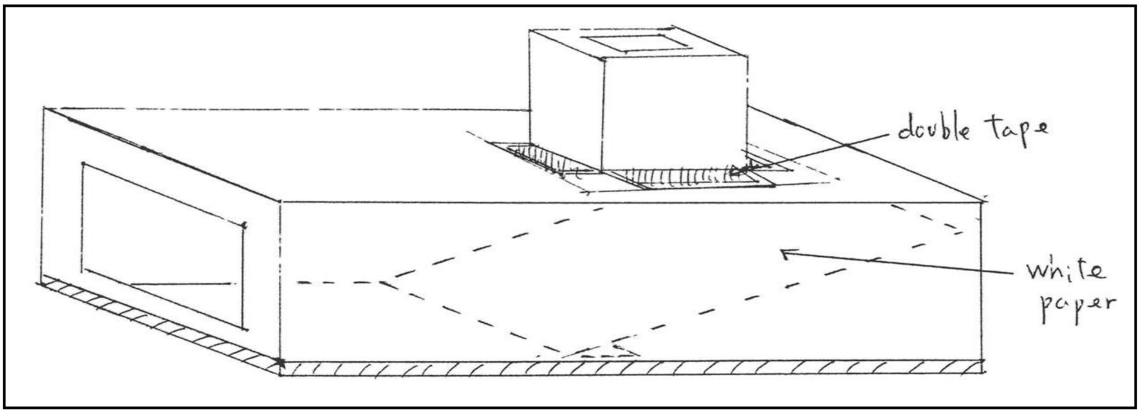


Figure III.13

5. Cut out the milk carton according to Fig.III.14. Paint it black.

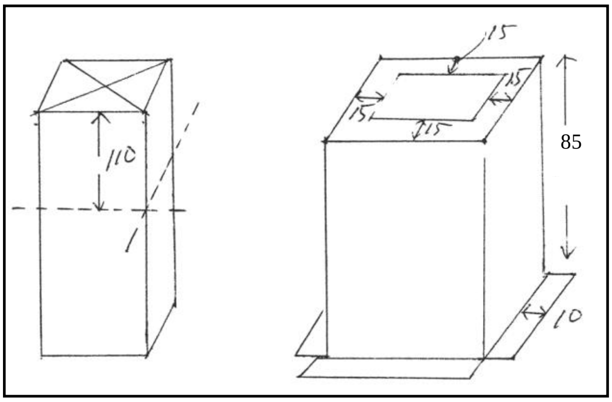


Figure III.14

6. Attach the milk carton to the tissue box using the 'double tape' and seal all the edges of the box with black vinyl tape. (Fig.III.15)

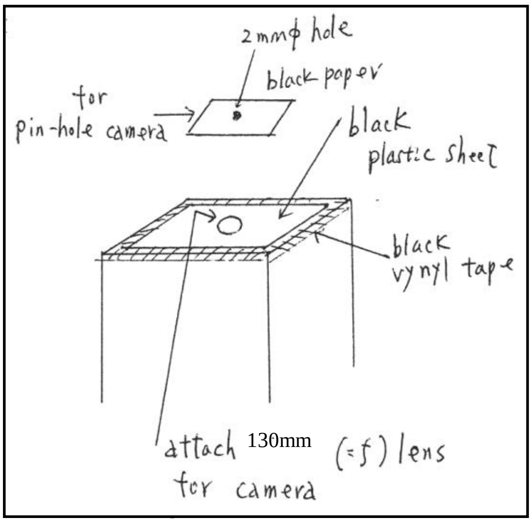


Figure III.15

7. Attach a sheet of black plastic on top of the milk carton and cover the edges with black vinyl tape.
8. On a black carton paper, make a hole of diameter 2mm and attach onto the plastic sheet.
(Figure .III.15).
9. Attach black carton paper onto the observation side; functions as a shield, preventing interference from ambient light. (Fig. III.16)

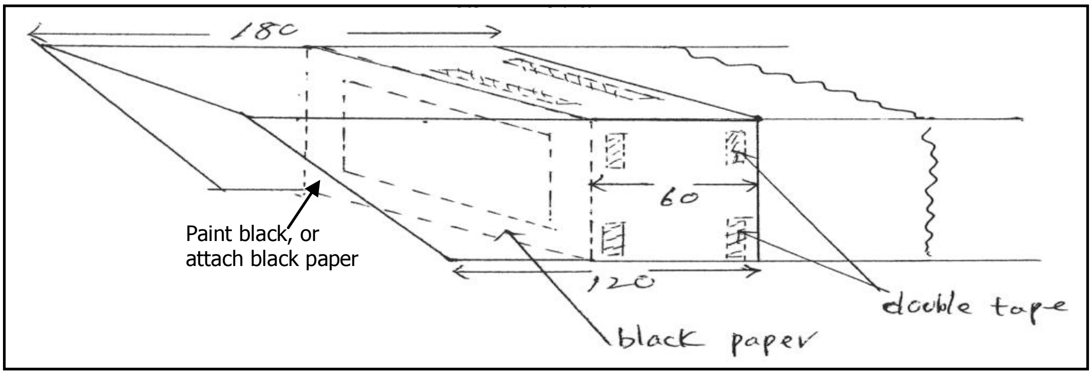


Figure III.16

c. Activities

Observe the outside scenery from the inside of the room using the pinhole camera that you have made.

B. Watching Camera

a. Tools and Materials

1. Pinhole camera constructed above
2. Convex lens; f=130 mm, diameter=40 mm
3. Black plastic for the holder of the convex lens

b. Procedure.

Detach the black plastic sheet (which has a pinhole) from the pinhole camera and replace this with another black plastic sheet. Attach a convex lens on the black plastic sheet. Cover the edges of the lens with black vinyl tape to fix on the black plastic sheet (Fig.III.17).

Compare the view obtained with the normal pinhole camera. Image of this camera is much brighter than that of a pin hole camera. Enjoy the view with your own hand-made camera.

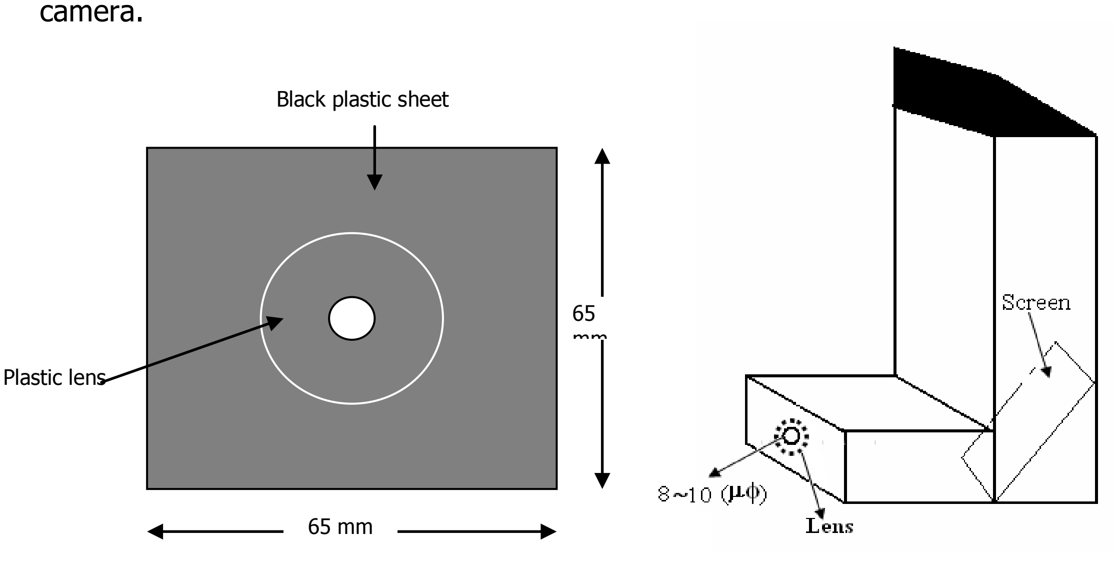


Figure III.17

Additional activity:
By combining two card box (big one and small one), we can make a big watching camera. As a lens, we can use lens of eyes glass for old man.

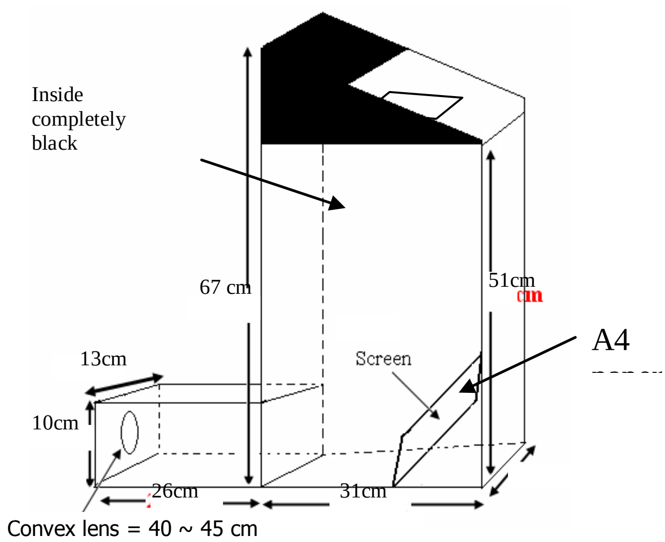


Figure III.18

E. CD Grating Spectroscope

a. Tools and materials

1. Cake box (50 x 97 x 125 mm), inner inside painted black
2. Hard paper (90 x 123 mm), painted black
3. Acrylic plate (15 x 30 x 48 mm) painted black
4. Slide glass (25 x 50 mm)
5. Black plastic sheet (1 mm thick)
6. Small piece of CD grating (this is made by cutting from the ordinary CD)
7. Black spray
8. Fluorescence lamp and candle

b. Method

1. On the front side of the cake box, make a square hole for a slit and for observation hole as shown in the figure III.19. Paint each hole black using the black marker.

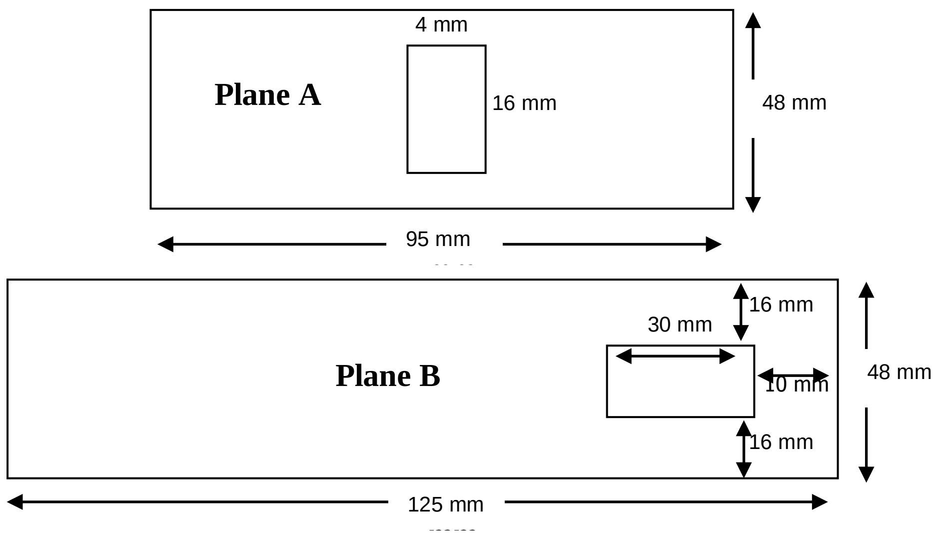


Figure III.19

2. Attach two black plastic sheets onto the glass slide to make a slit with a width of 0.3 mm as shown in the figure III.20a. Make sure that the slit is perfectly parallel to each other.

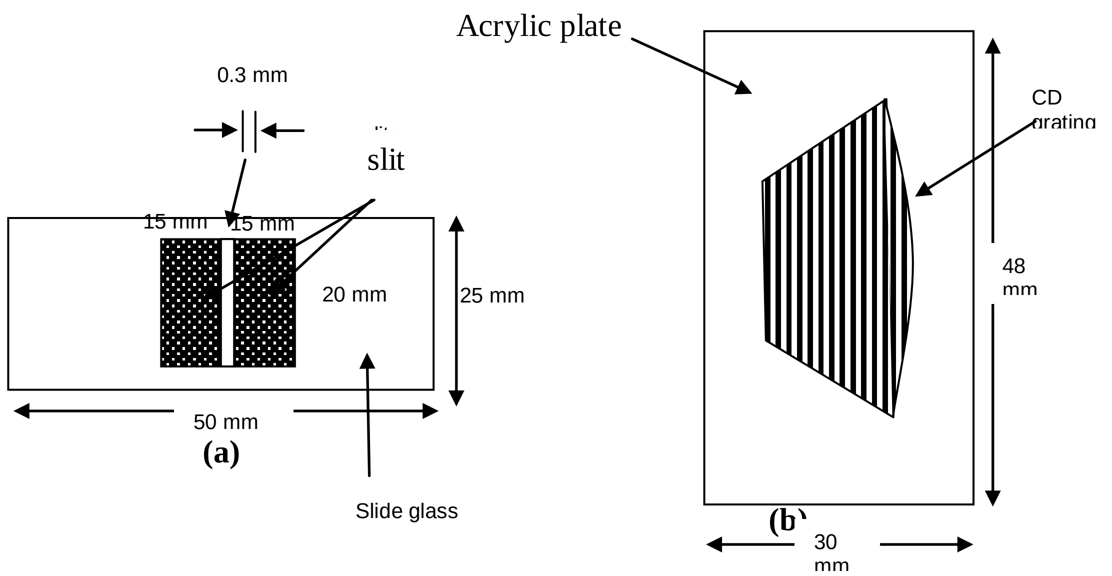
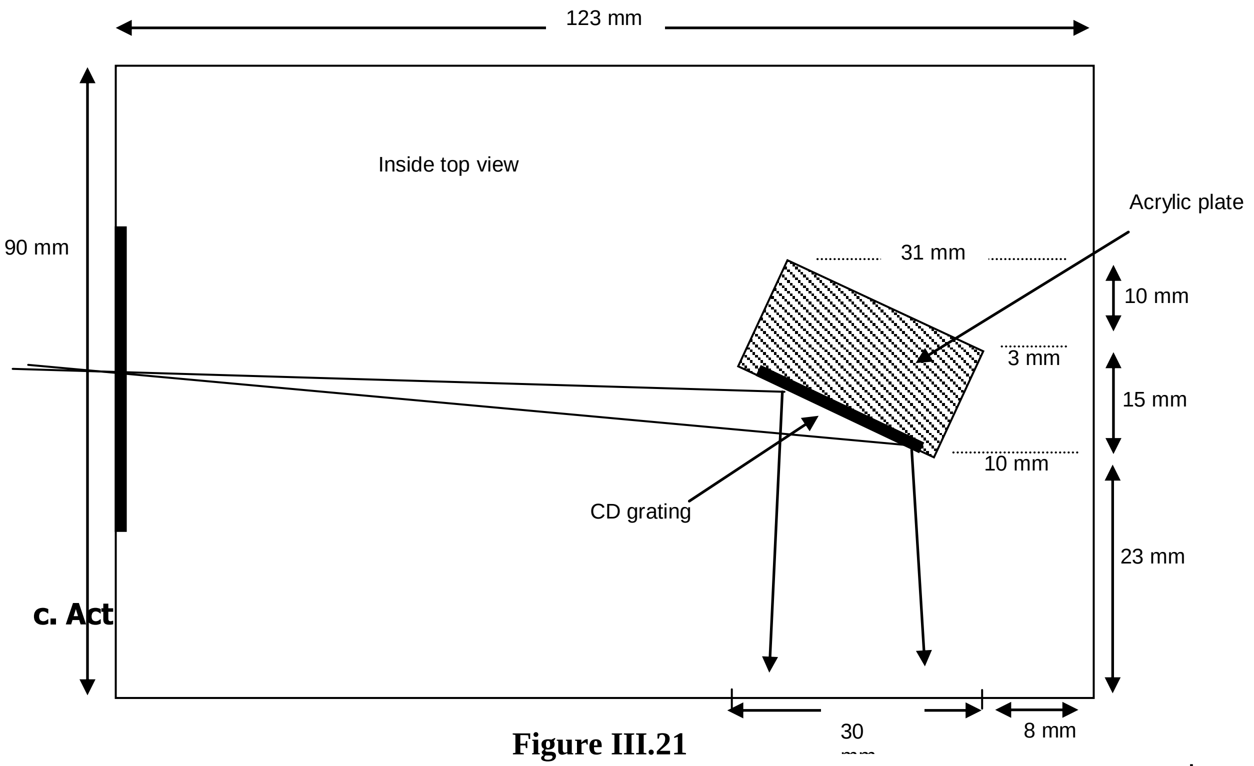


Figure III.20

3. Attach a small CD using double tape on the black acrylic plate as shown in figure III.20b. Cover the edge of the CD grating by the vinyl black tape.
4. Attach the slit made of slide glass inside the cake box, back side on the plane A. So that the slit locates of the centre of the hole in the plane A.
5. Put the acrylic plate which has a CD grating in the cake box as shown in the figure III.21.



c. Act

Figure III.21

1. Make spectrum observation from multiple light sources
   Light source: fluorescent lamp, sun light, torch light,
2. Confirm the color dispersion is much higher than the case of water prism method.
3. Notice that we can see two spectrum series; first order spectrum and second order spectrum. First order will be used for eye observation, and the second order for taking picture.
4. Spectrum observation of atomic emission spectrum, molecular emission line (broad), continuous emission spectrum (rainbow colors) :
5. Put a little mount of salt on the top of the candle and fire the candle. Then in the fire of the candle Na atom will be excited. By the spectrum observation, we can see the sharp Na-D line (orange color) in the spectrum. We can also see broad emission band in the region of green and blue, which come from molecules consisting of C and H, which mostly populated in the blue region in the candle flame. Continuous spectrum showing the rainbow color is due to the black body radiation from the carbon particles in the flame. This is very interesting, because we can see three different kind of spectrum, namely, line spectrum, band spectrum and continuous spectrum using ordinary tool like candle. Please understand, this spectroscope is very simple, but the spectrum resolution is very high, therefore, we can see the nice spectrum.
6. Using the digital camera, take pictures of the spectrum from the observation gap of the spectroscope as shown in figure III.22.

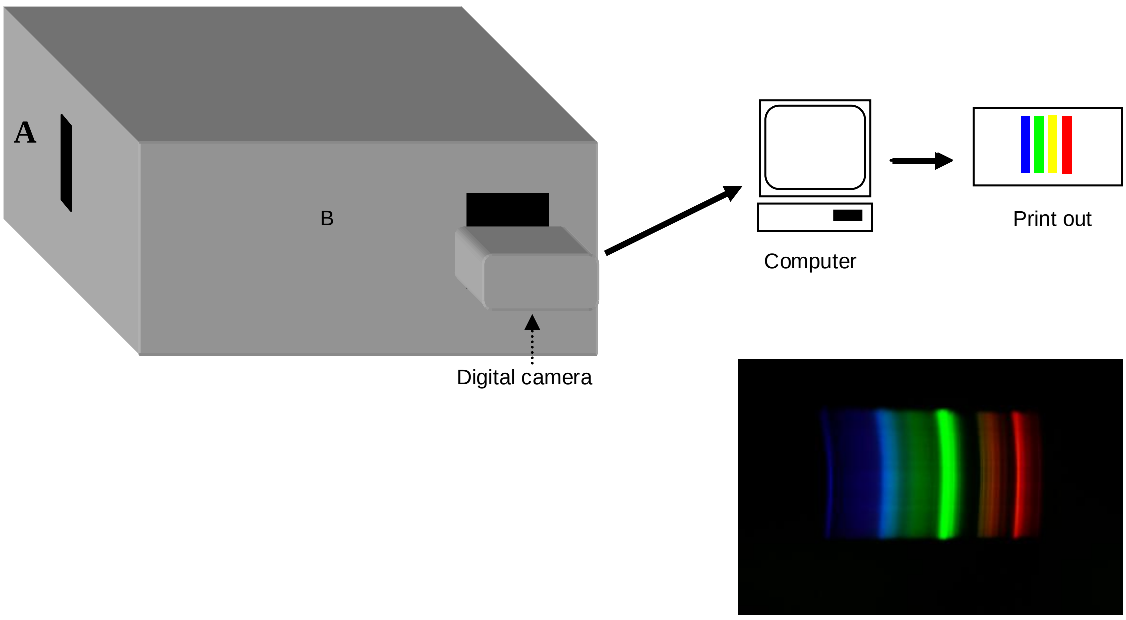


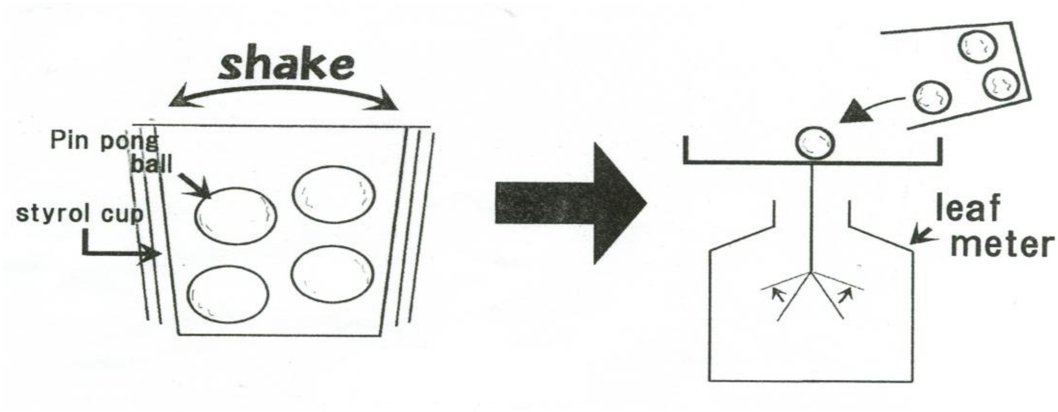
Figure III.22

CHAPTER 4
DEMONSTRATION EXPERIMENTS FOR ELECTROSTATICS AND ELECTROMAGNETICS

Electrostatics

1. How to Charge Ping Pong Balls Through Friction

General purpose: to prove charge amount

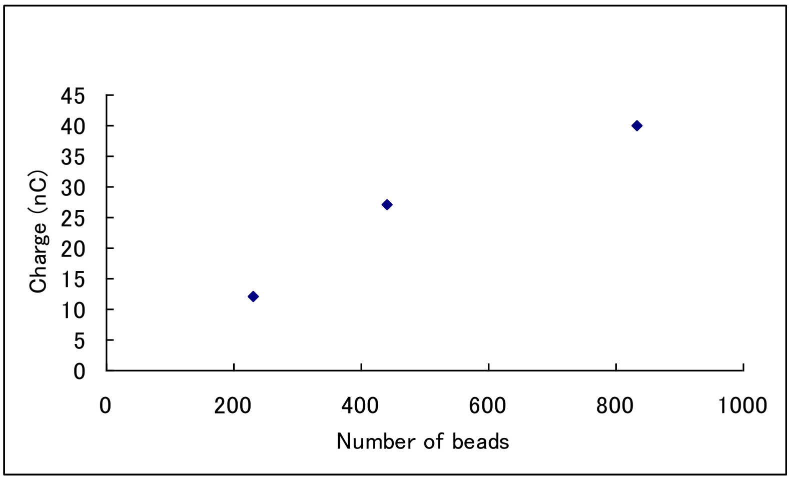


Methods:

1. Put 2 or 3 ping pong balls in a dry noodle cup
2. Cover the cup with a plastic sheet
3. Shake the noodle cup several times to charge ping pong balls through friction
4. On the upper side of the leaf meter, place a metal dish.
5. Put ping pong ball one by one and observe how the leaf meter will react by the increasing number of ping pong ball
6. Direct proof of the charge amount can be clearly observed
7. In place of ping pong balls, you can use few tens of metal clip and shake in the dry noodle cup as described before. Similar phenomena can be clearly observed

Relationship between the number of plastic balls and the charge amount

1. Prepare a lot of small sphere plastic ball (diameter of around 3mm)
2. Put the small plastic balls in the noodle cup, and shake enough
3. Measure the charge amount using a digital charge meter by changing the number of the balls
4. Confirm a linear relationship between the number and the total charge amount by drawing a graphic as shown in fig.
5. From this fact, we can understand electrostatics has the characteristics as quantity, while if we use only an ebonite stick and cat's fur as usually described in ordinary textbook, we can not understand the quantitative nature.



2. Charge Up by Hard Striking

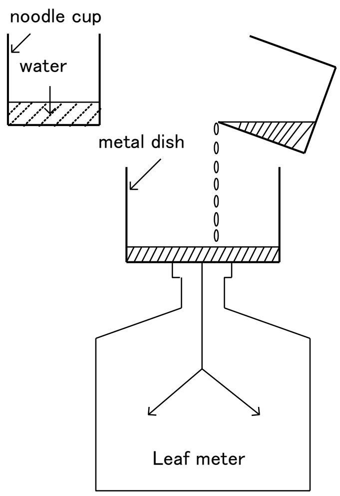
Methods:

1. Cut cling wrap or cooking wrap (containing chlorine) into 20 cm x 20 cm
2. Fold the cling wrap to the size of 5 cm x 5 cm.
3. Put the folded cling wrap on your left hand palm and then strike with your right hand palm strongly
4. Put the cling wrap onto the leaf meter and see how the leaf meter reactions
5. Confirm whether the charge is positive or negative by using an ordinary digital tester (voltmeter).

3. Charge Transfer Into Water

Methods:

1. Prepare dry noodle cup and dry tissue
2. Use tissue to rub inside of the dry noodle cup (several times)
3. Pour water into the noodle cup
4. Put metal dish onto the top of the leaf meter
5. Slowly pour the water onto the metal dish
6. Observe how the leaf meter will react with the increasing of water amount
7. From the above experiment, water contain charge



4. Charge Up the Body and Release the Charge

Methods:

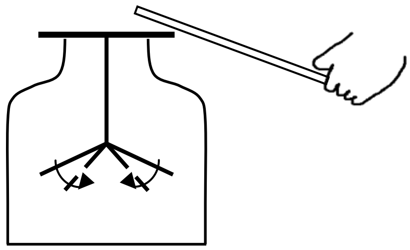
1. Sitting on the chair with vinyl cover and rub your trouser with the vinyl chair. Your body will charge up by this friction
2. Release your body charge by touching the leaf meter. The leaf meter will be reacted.
3. Again charge up your body with the same technique as above

4. Put your finger into water in a cup. Your body charge will be transferred to water
5. Touch your finger to leaf meter and quite no reaction in the leaf meter

5. See the Conductivity of Material

Methods:

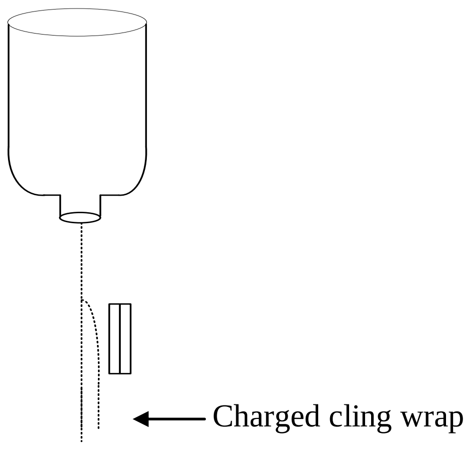
1. Charge up the leaf meter until leaf meter spread maximum
2. Touch the material to be tested by your hand to the leaf meter, the charge flow to your body through the material.
3. Closing speed of the leaf meter will be different depend on the conductivity
4. Please check for glass rod, plastic scalar, wood chopstick, graphite, pencil etc



6. Attracting Force Observation Using Small Flow Water

Methods:

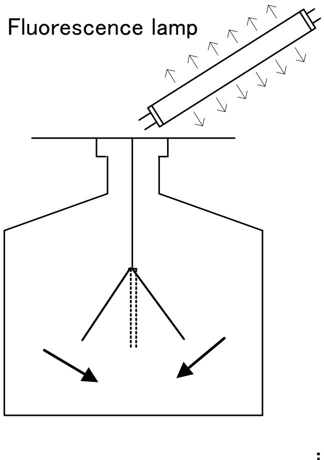
1. Prepare PET bottle of around 2 liter volume and fill it with water of around 1 liter. Make a small hole of diameter of around 1 mm in the centre of the lid. Close the upper lid of the pet bottle
2. Reverse the PET bottle to make thin flow water from the hole.
3. Put charged cooking wrap close to the water flow and observe how the water flow will move closer to the charged cling wrap; the water droplet is polarized and attracted by the charge of the cooking wrap.



7. Flash Fluorescence Lamp Using Static Electricity

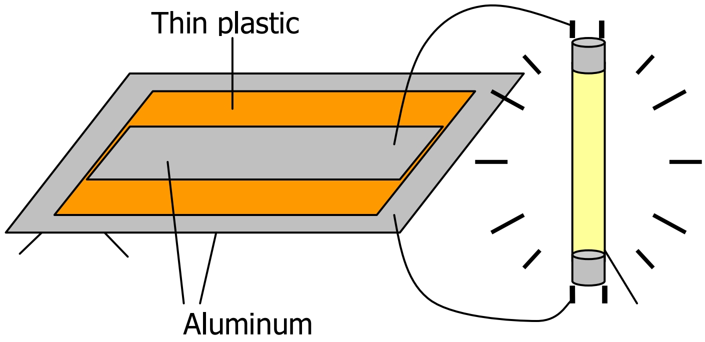
Methods:

1. In the dark room, rub the fluorescence lamp tube with clothes, faint emission could be observed
2. Charge up leaf meter until maximum. Touch the fluorescence lamp electrode to the leaf meter, faint emission could also be observed if the room is enough dark.



8. Make a strong flash using a large quantity of electrostatic charge

1. Prepare a big size thin plastic sheet (0.5 x 300 x 500 mm)
2. Rub one side surface of the plastic sheet using a dry tissue paper and sand- witch the plastic sheet by two sheets of aluminum foil.

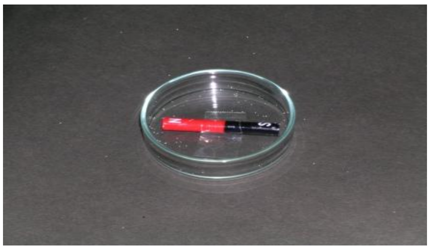


3. Contact the fluorescence lamp electrodes to each of the aluminum foil, then rather strong flash emission could be observed at a moment because the total charge amount is large.

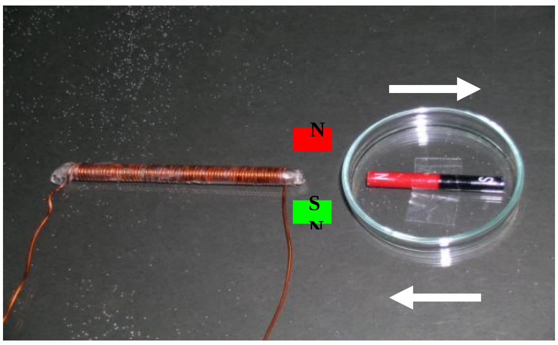
Electromagnetics

1. Compas demonstration

Compas is a sensitive detector for electromagnetic field because it is very light and supported in one point with small friction. We have found that our frictionless plate can be used to demonstrate the detection of electromagnetic field. As shown in fig., a bar of magnet (50 cm in length and 7 mm in diameter) was fixed on the small petri dish by the tape and placed on the frictionless plate. As a result, the petri dish rotates so that the north pole of the magnet directs to the north pole of earth.



2. Detection of electromagnetic field using frictionless plate



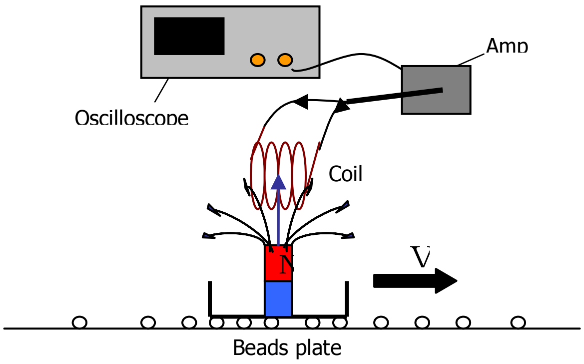
Frictionless plate also can be applied to the experiment of magnetic field induced by current wich is usually demonstrated using a compas in the textbook. As shown in fig., a coil and magnet are placed on the frictionless plate. When the currect is flowed to the coil so that the end of the coil becomes **N** magnetic pole, the magnet placed in the petri dish is pushed away with a high speed from the coil. Reversely, if the end of the coil becomes **S** magnetic pole, the magnet attracts strongly to the coil. This method is much easier to undersatnd the fact current make magnet comared to the ordinary way using the comaps.

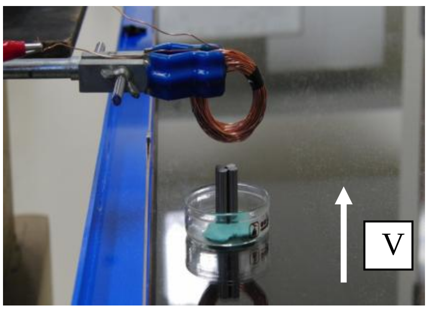
3. Electromagnetic induction

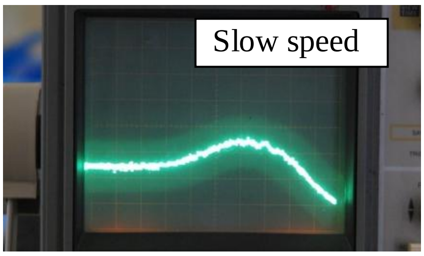
A coil (75 in turns and 5 cm in diameter) made of coating wire with a diameter of 0.5 mm was fixed above the frictionless plate as shown in fig. A bundle of strong magnets placed perpendicularly on the petri dish move with the constant velocity **V** on the frictionless plate. When the magnets just pass below the coil, we can detect the electromotive force from the coil; it can be detected using conventional osciloscope. The intensity of the electromotive force depends on the speed of the magnets placed on the petri dish. According to the well known principle of the electromagnetic induction,

$$V= - d\phi/dt,$$

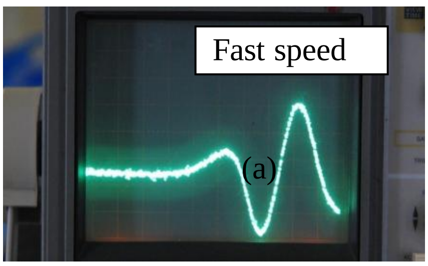
by varying the speed, we can observe the intensity of the electromotive force. It should be mentioned that the distance between top of the magnets and bottom of the coil should be closed. Figure a shows the electromagnetic force induced by the magnets moving with slow speed and fig. b shows the electromagnetic force when the magnets move with high speed. This demostration is much easier to undertand compared to the demonstration showed in the ordinary textbook where the magnet fall down pass through the centre of the coil.







(a)



(b)

<Group Experimental manual>

Constructing a simple electro leaf meter

a. Tools and Materials

1. Glass bottle with a plastic lid (90mm in diameter and 180 m in height)
2. Big nail (diameter of 5mm and length of 150mm)
3. Aluminum foils (2 sheets, thickness of 1 μm, dimensions of 5 x 30mm)
4. Metal dish (pie dish with a diameter of 100 mm)
5. Instant conductive epoxy- adhesive
6. Blade of cutter (or thin metal plate)

b. Method

1. Make a hole of 5 mm in diameter at the center of the metal dish and the lid of the glass bottle.
2. Cut the nail to shorten by 30 mm
3. Incise the edge of the nail so that the blade can be fixed to the nail
4. Penetrate the nail through the metal dish and the lid
5. Fix the head of the nail to the metal dish using instant conductive adhesive
6. Fix the blade at the ditch made at the end of the nail using instant conductive adhesive
7. Attach the end of the foils on the blade using instant conductive adhesive
8. Make clean using alcohol on the plastic lid surface so that good divorce can be kept