A Study of Physics Education as a General Education Subject at Hiroshima Jogakuin University
- Targeting Students' Understanding of the Physics Term "Moment"

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―「モーメント」の理解を目指して ―

西　口　理恵子，吉　岡　千　香

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概要
広島女学院大学の理系の教養科目の一つに１年次開講の物理学入門がある。この科目は国際教養学科をはじめとして文系の学生が主に履修をしている。実際、履修学生は数学が苦手で、物理学を高校で履修していない学生が多い。そのため、数学的な知識を必要とする科目ではあるが、履修学生が数学に振り回されずに最後まで授業に参加していけるよう教員側の努力が必要である。本報告では、一般的な物理学の教科書において始めの方に登場する物理概念の「モーメント」を効果的に習得するための一例を紹介しその効果について考察する。

Key words：物理学　Physics,　モーメント　Moment,　教養科目　General Education Subject
文系　Liberal Arts,　物理概念　Physical Concepts,　天秤棒　Rod,　探究心　Spirit of Inquiry

1. Introduction

Three years have passed since the beginning of "Introduction to Physics" as a general education subject at Hiroshima Jogakuin University after the university was reorganized into the Faculty of Liberal Arts and Faculty of Human Life Studies for women in 2012 with corresponding new curricula. This subject is provided as an elective for first-year students. Class sizes are usually about 10 students. For these small class sizes, students frequently ask questions during lessons and readily receive one-to-one feedback from instructors. Most students in the "Introduction to Physics" class did not study physics in their high schools and had weak mathematics skills. When using mathematical expressions, the instructors often attempted to explain the meaning of the expression.

A standard physics textbook, and therefore "Introduction to Physics", describes forces, motion, energy, thermodynamics, waves, electricity and magnetism, and atoms, in this order. Students study moments during the forces unit in context with force equilibrium acting on a rigid body. The term force, learned first, is a common word which students use in their daily lives. When they were required to write a sentence using force before learning its definition, they were able to form their own interpretation, e.g., "force required to lift up a box" and "labor force." The latter answer is clearly not physical. However, after learning the physics definition of forces, they could explain forces as a physics concept, such as the force of gravity acting on a body which they feel when lifting up their bag and the elastic force which they feel when stretching a rubber band during exercise. Judging from examination results and questionnaires about "Introduction to Physics", "moment" (torque) is one term which students find difficult to understand.

According to the guidelines[1] for science, as revised by the Ministry of Education, Culture, Sports, Science and Technology in 2009, senior high school students are required to cultivate a spirit of inquiry. From this, "Introduction to Physics" lessons, where almost all students are beginners in physics, were given a focus on the scientific spirit of inquiry. Furthermore, this report intends to propose a development case for teaching moment to allow students to better understand physics problems, even though they find physics difficult to understand, and to help prevent them from dropping out from lessons early.

2. Development of Teaching "Moment" in "Introduction to Physics"

Section 2 gives a lesson overview. First, demonstration experiments were performed as shown in Figure 1. Toy animals shown in Figure 1 were used because they are so well known in Japan that students would be more attracted to the lesson. Other balanced problems were also presented to them, such as an animal hung to the left and two hung to the right while maintaining balance. A lesson about moment was then carried out by following the textbook. At this time, students could answer at which points should they hang two weights to balance the rod as shown in Figure 2(a). Possible answers are shown in Figures 2(b) and 2(c).

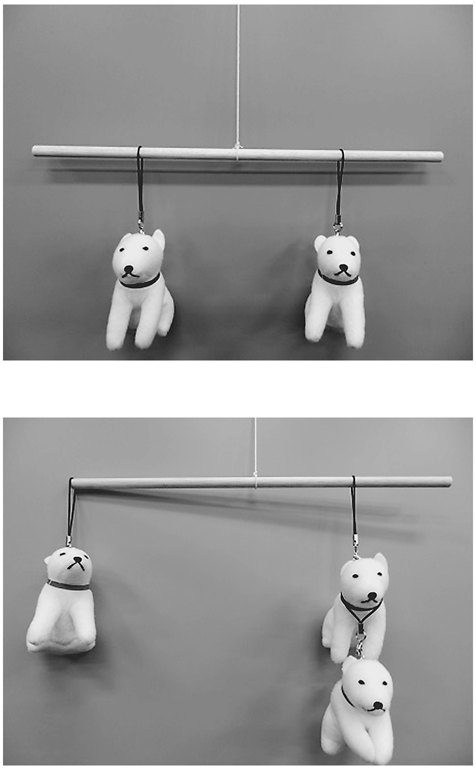


Figure 1 Simple examples of balance problems

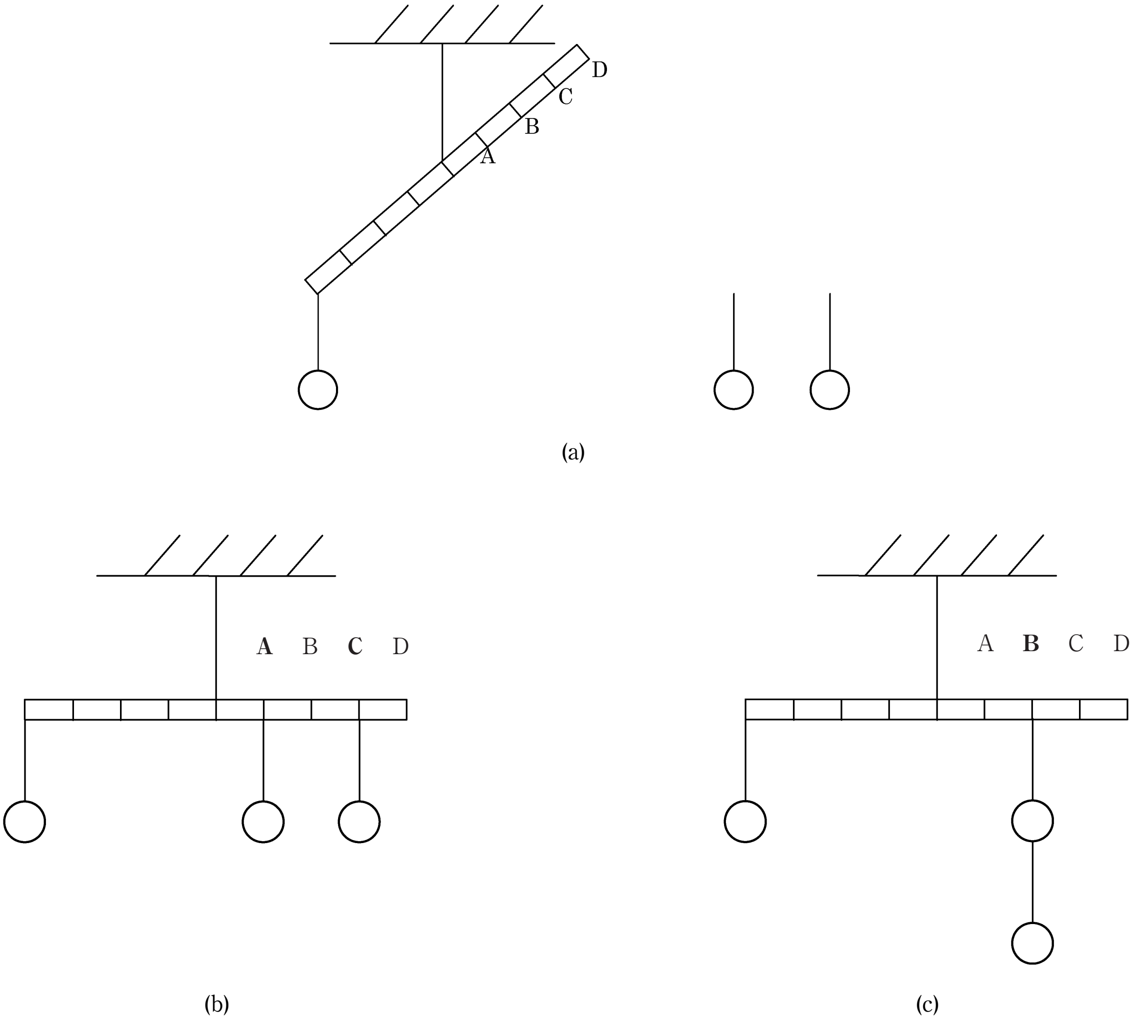
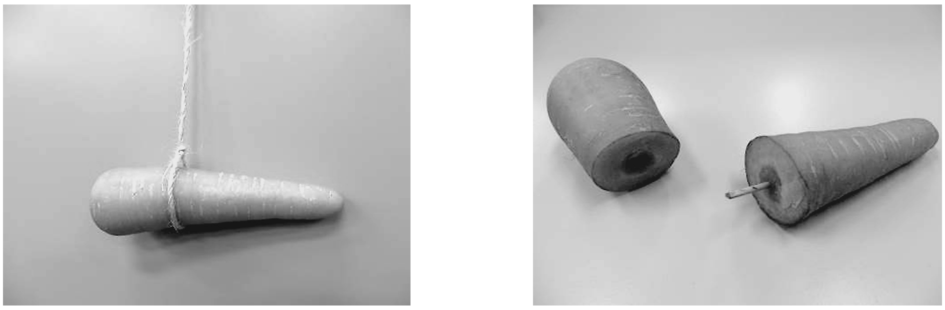


Figure 2 Unbalanced and balanced problems
(a) Unbalanced problems (b) Balanced problems: case 1 (c) Balanced problems: case 2

Utagawa et al.[2] reported about difficulties encountered in studying physics. They showed an illustration of a cone-shaped Japanese radish to junior high school students and senior high school students. The radish was hung to be balanced horizontally with a piece of string. The problem is similar to that shown in Figure 3(a). They asked students which of the following answers is correct if the radish was cut in two at the balanced string position: (1) the left part(W_1) is heavier than the right part(W_2), (2) the right part is heavier than the left part, or (3) the two are the same weight. It was described in their report that 72% of students gave the wrong answer, namely (3).

Their report proposed that instead of a Japanese radish, a carrot or a clay model could also be available in demonstration experiments. In this study, a real carrot was used in a demonstration experiment as shown in Figure 3. The shape difference between W_1 and W_2 is considered to be clearly visible and the carrot is smaller than a Japanese radish. Students, who had been taught about moment in an "Introduction to Physics" lesson, were asked the same questions as above. The carrot was actually arranged beforehand as shown in Figure 3(b).



(a) (b)

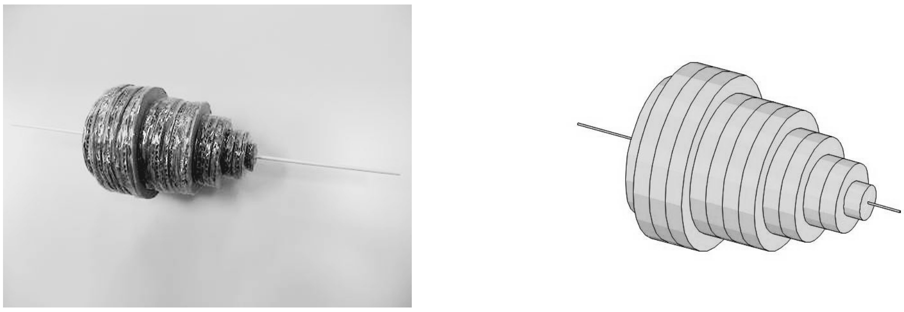
Figure 3 carrot used in the demonstration experiment
(a) carrot tied with a piece of string balanced horizontally.
(b) The carrot in (a) was cut into two parts beforehand. So, that it could be easily reconnected with a stick

The carrot balance quiz results are summarized in Table 1. Students who chose (3) $W_1=W_2$ said that since the rod was balanced horizontally, both W_1 and W_2 should be the same weight. Students who chose (1) $W_1>W_2$ said that judging from the shape difference, the thicker W_1 looked heavier than W_2. From these results, we found that students did not use the concept of moment in choosing their answer even though they had already been taught this concept.

Table 1 The number of respondents about a balance quiz of a carrot

	(1) $W_1>W_2$	(2) $W_1<W_2$	(3) $W_1=W_2$
Number of Respondents	5	0	3

After the carrot was separated into two parts W_1 and W_2, students were asked to pick them up with their hands to recognize the weight difference between W_1 and W_2. Students who chose (3) were surprised at the unexpected result. At the end of the lesson, students were given homework to explain why $W_1 > W_2$. They were also instructed to do the same experiment again by using a carrot at home if possible. In addition, a carrot model made of cardboard as shown in Figure 4(a) was presented to students as a homework hint. The cardboard model is a simplified carrot to represent the concept of moment by expressing a carrot as an aggregate of cylinders. Figure 4(b) is a computer graphics image for Figure 4(a). The model is composed of 13 cylinders which are each 1 cm thick. The radius and volumes of each cylinder are listed in Table 2. Here, k [g/cm^3] is the density of a carrot, r [cm] is the cylinder radius, l [cm] is the thickness, and (pi)r^{2}k [g] represents the cylinder weight where pi is a constant ~3.14. Radius measurements were given only as integers for simplicity. In Table 2, cylinders are numbered from left to right. Because the total volume of the cylinders from No. 1 to No. 4 is equal to that from No. 5 to No. 13, the total weight of the cylinders from No. 1 to No. 4 and that of No. 5 to No. 13 are the same, assuming that each cylinder has the same density. Therefore, the total weight of the cylinders from No. 1 to No. 4 or that from No. 5 to No. 13 is 91(pi)r^{2}k. The point where a carrot is balanced horizontally is 4.13 cm from the left, as shown in Figure 5. In order to help students come up with a balance rod problem as shown in Figure 2, slight spaces are given between cylinders as shown in Figure 5.



(a) (b)

Figure 4 (a) Cardboard carrot model (b) Computer graphics image of (a)

Table 2 Cylinder radii and volumes from Figure 4

Cylinder No.	1	2	3	4	5	6	7	8	9	10	11	12	13
Radius (cm)	4	5	5	5	4	4	4	4	3	3	2	2	1
Volume*1 (cm³)	16pi*2	25pi	25pi	25pi	16pi	16pi	16pi	16pi	9pi	10pi	4pi	4pi	1pi
Subsection total (cm³)	91pi				91pi								

*1Each cylinder is 1 cm thick.
*2pi is a constant(3.14).

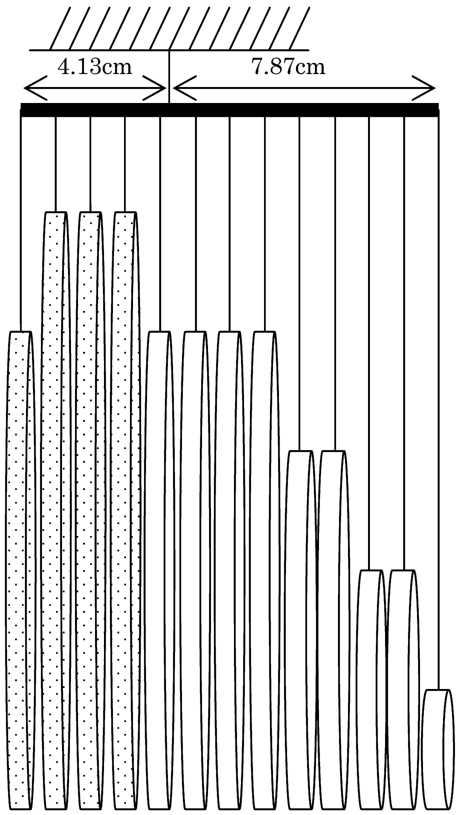


Figure 5 13 cylindrical weights to simulate a real carrot
13 cylindrical weights were hung on a rod to simulate a real carrot. The total weight of the dotted cylinders is equal to that of the non-dotted ones.

3. Discussion

Computer-based training (CBT) in physics lessons is a good virtual laboratory method so that physics experiments can be shown to students easily and safely. CBT in physics lessons used to be given to students in our university, but the expected effects were not produced. Students tended to click the buttons on the computer screen before taking time to think about problems taught in lessons.

In the present study, a demonstration experiment introduced the moment concept, a lesson on moments was taught by using a textbook, and simple balance rod problems were given to them. A real carrot quiz was then given as an advanced problem based on an idea of Utagawa et al.[2] . It was necessary to help students recognize the physics concept of moments because they initially answered the quiz by appearance and did not consider the concept. It is not just an interesting or surprising experiment to cut a carrot to confirm weights. If just an image of a real carrot is used, math-challenged students may exhaust themselves by attempting to calculate the center of gravity before they have the answer, while the procedure with a physical carrot may encourage them to further their spirit of inquiry. Therefore, in order to allow students to easily calculate values such as the center of gravity and moment, a physical model of a cardboard carrot designed as an aggregate of cylinders with easy-to-calculate numerical values was designed along with an accompanying illustration. This had a helpful effect in allowing students to become familiar with the workings of a balanced rod. By judging the results of their homework, students were able to do their homework scientifically with the use of this model.

4. Summary

In the present study for an "Introduction to Physics" lesson, we aimed to achieve an educational effect by allowing students to first interact with a physical concept to cultivate their scientific spirit of inquiry. The report is summarized by the following three key points:

(1) Demonstration of a cylindrical carrot with integer-multiple radii ----- > simplicity, familiarity
(2) Real and model carrots (cardboard and illustration) ----- > visual effect on learning a physics concept
(3) Experiment easy for students to review at homes ----- > trial with their own hands

In the future, the authors intend to design a teaching plan for the physics concept of work, which is one factor that highly contributes to general comprehension measurements in the previous report[3] .

References

1) http://www.mext.go.jp/component/a_menu/education/micro_detail/__icsFiles/afieldfile/2010/01/29/1282000_6.pdf
2) Shigeo Utagawa et al. Journal of the Physics Education Society of Japan 49(2),196-209, 2001
3) Rieko Nishiguchi and Chika Yoshioka, Journal of Faculty for Human Life Science, Hiroshima Jogakuin University 20,105-112, 2013