DOCUMENT RESUME

ED 025 447 24 SE 006 274

By- Plants, Helen L.; Venable, Wallace S.

Development and Evaluation of Two Approaches to an Elementary Course in Dynamics. Final Report.

West Virginia Univ., Morgantown.
Spons Agency- Office of Education (DHEW), Washington, D.C. Bureau of Research.
Bureau No- BR-8-C-002
Pub Date Dec 68
Grant- OEG-0-8-000002-1805(010)
Note- 68p.
EDRS Price MF-$0.50 HC-$3.50
Descriptors- Achievement, Comparative Analysis, *Engineering, *Instruction, Problem Solving, *Programed Instruction, Teaching Procedures, Undergraduate Study

The purpose of this research was to design and test materials and methods to be used in teaching a first course in undergraduate engineering dynamics. The basic problem in this study was to determine the optimum order of presenting abstract materials and applications in the same course. Tests were administered to determine differences among students' learning of the technical content and their ability to apply this information in open-ended, problem solving situations. The test results indicated that the groups had learned an equivalent amount of the technical content, but had not learned different application skills. One group, introduced to each new topic through practical demonstrations before being exposed to the topical content through programmed materials, was able to generate a larger number of creative solutions to problems and was more effective in solving problems involving inconsistencies. (RP)

BR 8-C-002
PA-24

OE-BR

SE

FINAL REPORT
Project No. 8-C-002
Contract No. OEG-0-8-000002-1805(010)

DEVELOPMENT AND EVALUATION OF TWO APPROACHES TO AN ELEMENTARY COURSE IN DYNAMICS

December 1968

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

FINAL REPORT

Project No. 8-C-002

Contract No. OEG-0-8-000002-1805(010)

DEVELOPMENT AND EVALUATION OF TWO APPROACHES TO AN ELEMENTARY COURSE IN DYNAMICS

Helen L. Plants and Wallace S. Venable

West Virginia University

Morgantown, W. Va.

December 1968

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

Office of Education
Bureau of Research

TABLE OF CONTENTS

LIST OF TABLES

SUMMARY

The basic problem involved in this study is "Which should come first - the theory or the practice?" In courses which contain both abstract material and applications, which should be taught first?

Two sections of the same course were taught the same technical content through extensive use of programmed materials and instructor led demonstrations and discussions. Considerable care was exercised so that only the sequence of the presentations in the two sections differed. Three types of tests were administered to determine differences between students' learning of the technical content, their ability to apply this information in open-ended, problem solving situations, and their attitudes toward the two instructors. To control for the influence of the two instructors, they carefully balanced their appearances in the two classes (conducted simultaneously) and the content of their presentations.

It was hypothesized that the two groups would learn the same technical content but that the group which got practice before theory would develop more ability at recognizing and solving unusual problems and would develop the more positive attitudes toward their teachers.

The test results indicated that the groups had learned an equivalent amount of the technical content as hypothesized but had learned different application skills. The group introduced to each new topic through practical demonstrations before being exposed to the topical content through programmed materials, was able to generate a larger number of creative solutions to problems, and was more effective in solving problems involving inconsistencies but had the less positive reaction to the teachers.

The conclusion drawn is that since the demonstration first group scored significantly better in the skill application tests, the order of presentation affected learning in these areas and that presenting demonstration before theory improves the ability of the student to apply engineering skills.

This should be considered as a pilot study. Further studies should be made refining and expanding this work and supplementing it with data on classroom interaction between students and instructors.

The report also includes detailed descriptions of thirteen classroom demonstrations developed for use with this project.

GENERAL INTRODUCTION

The objectives of this project were to design and test materials and methods to be used in teaching a first course in undergraduate engineering dynamics.

Engineering instruction has not, in general, kept abreast of modern developments in education and psychology. Consequently, engineering colleges are becoming less and less efficient as they attempt to teach an ever-expanding body of knowledge to an ever-increasing student body. Current studies show that 60% of the entering engineering class drops out of engineering before graduation. The tremendous rate of attrition from engineering schools is evidence of the dissatisfaction that students feel toward engineering education.

In order to better the situation it is necessary to do two things. (1) Some basic information must be obtained both about engineering students and about the effectiveness of various sorts of engineering instruction. (2) New educational material and instructional methods must be developed to bring the results of educational and psychological research into engineering teaching.

In an attempt to provide a basis for a solution to these problems the College of Engineering at West Virginia University has embarked upon an extensive program of research into the problems of engineering education. The project described in this report dealt with one small phase of the larger problem.

As a part of an earlier project a completely programmed first course in Dynamics had been developed and class-tested at West Virginia University. One important effect of introducing programmed material was that it freed a considerable amount of classtime that had previously been devoted to lectures.

One objective of this project was to design and test a series of demonstrations that could be incorporated into class sections to utilize the classtime gained by the use of programmed instruction.

The second objective of the project was to investigate the effect of order and mode of presentation upon engineering students, using the programmed materials to insure that the content of the information presented was constant.

Since the two objectives of this project are very dissimilar in nature, they are treated in two separate sections of this report.

Part I

THE EFFECT OF SEQUENCE ON INSTRUCTION

Which should come first- Theory or Practice? This question is basic to the teaching of engineering and all applied science. This study attempted to determine whether the ability of students to recognize anomalies in, and propose multiple solutions to, problems was affected by the order of presentation of material by studying the differences between a class in which demonstration followed pertinent theory and one in which theory followed pertinent demonstrations.

Background for the Study

Interest in instructional processes with content held constant has been high. Many studies have been made in the public school systems studying the effect of many variables. McKeachie and others have studied variables affecting college teaching.

One aspect of sequencing has been examined by Huggins and Entwhistle in their study of the interference effects of sequential topics on each other.

Berlyne has studied the effect of asking students questions rather than presenting them with facts, and has found that asking was more stimulating than telling.

The various studies of teaching effectiveness have primarily produced the agreement that there is very little known about measuring and predicting it. This feeling is probably most effectively summed up by Medley and Mitzel, who upon the basis of their early studies essentially concluded that nothing the teacher does can be shown to make a predictable difference in what his students learn.

Flanders and those following his lead have studied the effect of variations in the social-emotional climate on student achievement and attitudes toward instruction. These studies have demonstrated some relations between teacher behavior and learning.

Recent studies conducted by Soar however lead him to postulate that teacher behavior has greater effect on higher levels of cognitive learning than on lower levels.

Since much engineering instruction aims at analysis, synthesis and evaluation, Soar's findings may be particularly applicable to the problem in hand. The findings of this project may also have considerable relevance to those of Berylne since demonstrations may be staged either to pose a question or to confirm a fact.

Hypotheses

This study has controlled the content of instruction throughout a complete semester of engineering education, and varied the sequence of the theoretical and practical application portions of the course. It was expected that groups exposed to two different sequences would:

1. Learn the same amount of technical content.
2. Demonstrate more flexibility and ideational fluency on novel or open-ended problems after practice-before-theory.

METHODS

Material and Sequence

The subject matter of the course was engineering mechanics-dynamics. To assure the equality of presentation of the subject material the content and homework problems were presented in a set of programmed materials which completely covered the normal content of a semester course in the subject. The same classroom demonstrations and experiments were conducted in each class. A particular lesson was presented to both classes by the same instructor. Both sections were required to take identical quizzes and examinations at the same time and had the same schedule of assignments. The order of presentation of subject matter was the controlled difference between the two groups.

Demonstrations-First Group (DF)

The presentation of a demonstration of a concept to the first group was made before the students in the section had completed the coverage of the topic in the programmed units. As a result of the demonstration the students were expected to evolve a general principle from the observations made. The principle deduced was then derived and utilized more mathematically in the following program unit.

Theory-First Group (TF)

The second group attended demonstration sessions following the completion date for the mathematically based program units. The factual presentation was the same as that given the first group but the discussion was directed toward the acceptance of the demonstration as a verification of the mathematics rather than toward the demonstration being the empirical foundation of the principle.

Teaching Procedures

Both groups were taught by two teachers. The schedule was so arranged that material taught by Teacher A to one class was taught by Teacher A to the other class. Each had twenty-one hours of contact with each class. This was done to minimize the effect of differences in the teachers. Instructor A (the senior author of this paper and of the programs) was an experienced engineer with a long history (over ten years) teaching this subject at this University. Instructor B (the second author) was a young instructor teaching the course for the second time.

In the TF section both teachers taught in an expository mode, lecturing and answering questions. In this section explanation of the theo y involved in a demonstration always precede the demonstration.

In the DF section both teachers taught in an exploratory mode. The class was conducted on a discussion basis and questions were answered by the instructor only as a last resort. Instead an effort was made to help the questioner arrive at his own answer. Demonstrations were invariably used to introduce theory and students were encouraged to draw their own conclusions about the demonstrations.

These differences in teaching modes were the outgrowth of the controlled difference in order of presentation since the differing sequences required different classroom strategies for effectiveness.

The controlled differences may well have introduced other differences which could have contributed to the effects observed -- they could have even been the significant features of this experiment, but due to the practical limitations of this situation, further assessments were not possible at this time.

Students

The students in both sections were for the most part, sophomores. Each section contained a few juniors. All students had completed statics and the mathematics sequence up to differential equations. Students lived in fraternities, dormitories, private housing or with their wives or parents.

Both classes met from 10:30 to 11:20 a.m. Monday, Wednesday, and Friday in adjacent rooms.

Sixty students were registered for the class and divided into two sections by assigning alternate students in alphabetical order to each section. After dividing the classes in this manner adjustments in section assignment were made to balance the following groups in the sections:

1. Pre-registrants
2. Late registrants
3. Foreign Students
4. Students repeating the course

There was no attempt to control interaction between the sections, and, since the College of Engineering is relatively small and closely knit, it may be presumed there was some interaction.

Orientation of Students

At the first meeting the class was informed that they would be participating in an experiment in team teaching, and that they would be divided into two sections meeting simultaneously and both responsible to two instructors. It was pointed out that this would allow the instructor on a particular lesson to make more extensive preparation of class presentations and that the same material would be presented to both sections. The students thus realized during the entire course that they were the subjects of a study and at the end of the term they informed the instructors that they had concluded the investigation was to show the superiority of classrooms equipped with tables and chairs to those equipped with chairs with writing arms since the rooms were differently furnished.

Examinations and Measurement of Outcomes

A. Entering measurements

At the beginning of the term all students were asked to complete a demographic data form and given the Visual-Vocabulary tests. In addition the Mechanical Comprehension Test by Owens and Bennett was administered to all students. The Visual-Vocabulary Test is included in Appendix I. The Mechanical Comprehension Test is available from Psycological Corporation in New York.

B. Tests on Course Content

During the course of the term students took 28 post-tests over the programmed material and four hour examinations. Since these tests merely cover the information usually included in a course in dynamics, they are not included. The combined results of these tests is considered the technical content score.

C. Problem-Recognition Test

This test consists of four problems each of which can be solved incorrectly by an obvious method. The correct solution in each instance was not evident and in one case required the student to make assumptions about certain anomalies in the problem. Its purpose was to measure the ability of the student to recognize the difference between the real problem and the expected problem and to successfully solve the actual problems. A copy of the test is included in Appendix II.

D. Test of Fluency in Generating Alternatives

This test indicated fluency in generating two sorts of alternatives:
1) Creative solutions. Students were asked to generate as many solutions as possible to problems without working out details.
2) Algorithmic Strategies. Students were asked to generate differently detailed algorithms leading to identical solutions.
A copy of the test is included in Appendix III.

Test Criteria

Each attempt was rated independently by each of three instructors familiar with the course. Rating was in accordance with the rating scales shown in Appendix IV.

The rating scale for the Problem Recognition Test reflects whether or not the student is able to comprehend the true problem involved, and if he is able to correctly interpret it, the degree to which he is able to solve it.

The rating scale for the Creative Solutions portion of the test for Fluency in Generating Alternatives reflects both the number of solutions proposed and the grader's opinion of the merit of the solutions proposed.

The rating scale for the algorithmic strategies portion of the test of Fluency in Generating Alternatives is weighted so that each successive independent algorithm receives a higher score than the preceding solution. Again some weight is attached to the merit of the attack.

RESULTS

Entering Student Characteristics

In spite of efforts to equate the two groups of students through randomizing procedures at registration, there were differences as shown in Table 1. In both mechanical comprehension and cumulative grade point averages, the two groups differed appreciable, but neither difference is significant at the 5% level, and the two differences were in opposite directions. Therefore it was concluded that randomization had been successful in providing groups that could be considered equivalent.

Outcomes

The post-measures data of Table 1 indicate that in terms of knowledge of the technical content of the course, the two groups showed the same level of attainment. The mean scores on the tests of problem recognition and fluency in generating alternatives show differences which are not significant, however the distributions of scores on these were apparently non-normal. In view of this, X^2 tests were made of this data. (Tables 2,3 and4)

The differences between the two groups on the problem recognition task is clarified in Table 2, significantly fewer in the demonstration-first group had very low scores than in the theory-first group ($X^2 = 7.84$, $p<.05$)

On the test of ability to generate alternatives, scores on the whole test were not significantly different for the two groups. When the test problems were divided according to the two types of problems represented in the test, significant differences between the groups were observed. (Table 3) Significantly more of the demonstration-first group scored high on the "creative solution problems ($X^2 = 6.15$, $p<.05$). Although this same group also tended to score higher on the "alternative strategies" problems, the difference was not significant.

The inter-judge reliability correlation coefficients were as follows:

Problem recognition - .966

Fluency in Generating Alternatives

Creative Solutions - .797

Algorithmic Strategies - .832

Selection of Classes in X^2 Tests

Since the Problem-Recognition Test (Table 3) and the two parts of the Test of Fluency in Generating Alternatives were all graded on different bases, different maximum scores were possible on each of the three tests. Consequently, no effort was made to standardize the intervals selected as classes in the X^2 Tests. However, it may be noted that the numerical scores on the Creative Solutions Test represent much higher percentage scores than similar numerical scores on either of the other tests.

Table 1

Student Pre-Measures and Post-Measures; Means and Standard Deviations

Group	Pre-Measures			Post-Measures			
					Generation of Alternatives		
	Visual Vocabulary	Mechanical Comprehension	Prior G.P.A.	Problem Recognition	Creative Solutions	Alternative Strategies	Technical Content
Theory First	27.4 (5.68)	50.0 (32.5)	2.36 (.625)	2.62 (2.41)	12.8 (2.96)	14.1 (6.08)	80.03 (9.17)
Demonstration First	27.5 (6.50)	38.7 (30.4)	2.64 (5.31)	3.44 (2.66)	14.5 (3.90)	16.1 (8.67)	78.70 (8.44)
t	0.18	0.60	1.74*	1.18	1.59	0.97	0.53

*Significant at $p < .10$

TABLE 2

Problem-Recognition Test Results
Maximum Possible Score = 60

Group	Test Performance 0-3	4-9	10+
Theory-first	10	6	10
Practice-first	3	15	9

$X^2 = 7.48^*$

*p<.05

TABLE 3

Results of Test of
Fluency in Generating Alternatives

Group	Creative Solutions Max. Poss. Score = 24			Alternative Strategies Max. Poss. Score = 62		
	0-11	12-17	18+	0-11	11-20	21+
Theory-first	9	16	1	7	16	3
Practice-first	7	13	8	8	13	7

Types of Alternatives Produced

$X^2 = 6.15^*$ (Creative Solutions); $X^2 = 1.914$ (n.s.) (Alternative Strategies)

*p<.05

Grade in the Course

The grade in the course was entirely dependent upon the information taught by the programmed texts and is reflected in this report by the term average. The term average was obtained by adding the grades on four hour examinations to the doubled post test average and dividing by six.

The grades on the Problem Recognition Test and the Test for Fluency in Generating Alternatives were not included in any way in determining the term grades.

Student Evaluation

As a part of the overall program of the Department of Theoretical and Applied Mechanics both instructors were evaluated by their classes using the instrument in Appendix V.

Questions 1 to 5 were considered to evaluate topic expertise. Questions 7 to 15 were considered to reflect teaching skills. Questions 16 through 19 were taken as opinions of personal characteristics and Question 20 gave the overall assessment.

Table 5 presents the data on the relationships between the variables assessed. For the group taught by essentially "standard" procedures (theory before demonstration), there is a statistically significant positive relationship between the student's incoming scores and his achievement on the technical contents of the course. This group also had significant correlations between prior GPA and the scores on the Problem Recognition and Alternative Strategies tests.

The group which was tuaght with demonstrations first shows a much smaller number of correlations between measures. For this group the prior grade point average seems to be the only significant prediction of success.

TABLE 4

Student Rating of Instructors

Factors	Differences between the groups (χ^2)	
	Instructor A	Instructor B
1. Topic Expertise	8.45* (DF)	3.33 (DF)
2. Teaching Skills	14.18**(TF)	3.28 (TF)
3. Personal characteristics	6.05 (TF)	2.96 (TF)
4. Overall assessment	5.50 (TF)	1.23 (TF)

*$p<.05$

**$p<.01$

(DF) tendency for the Demonstration-First group to have more positive reaction

(TF) tendency for the Theory-First group to have more positive reaction

TABLE 5

Correlations Between Measures

(Theory-First Group/ Demonstration-First Group)

	Visual Vocabulary	Mechanical Comprehension	Prior G. P. A.	Problem Recognition	Creative Solutions	Alternative Strategies
Mechanical Comprehension	.678*** / .496***					
Prior G. P. A.	.350* / -.045	.420** / .039				
Problem Recognition	.056 / .076	.176 / .086	.481*** / .230			
Creative Solutions	.298 / .339*	.260 / .337*	-.110 / .014	.146 / .234		
Alternative Strategies	.357* / -.232	.213 / -.019	.334* / .669***	.361* / .228	.270 / -.274	
Technical Contents	.445** / -.002	.538*** / .005	.664*** / .654***	.514*** / .155	-.018 / -.006	.460** / .053

Correlation Significant at * .10
** .05
*** .01

DISCUSSION OF RESULTS

Test Results (Tables 3 and 4)

There was a significant difference in the performance of the two sections on two of the three special tests. The group which had received the demonstrations before the theory (DF) scored higher on the Problem Recognition Test, and on the Creative Solutions portion of the test of Fluency in Generating Alternatives. There was no significant difference in performance on the Algorithmic Strategies portion of the latter test.

There was no significant difference in the performance of the two groups on the tests covering the technical content of the course. This was in accordance with the original hypothesis. It is quite possible that the Algorithmic Strategies Test was, in truth, a reflection of the technical content of the course since all of the strategies proposed depended upon the manipulation of material taught in the course.

It appears that the order in which the material was presented and the effect of that order on teacher behaviour did affect the ability of the students to recognize and solve unexpected problems. The DF group was essentially taught to look first at a problem, then at the information necessary to solve it. The TF group was taught to look first at an item of information, then at its possible applications. The training given the DF group apparently gave it the better preparation for applying its knowledge to novel situations.

Correlations (Table 2)

The two tests given at the beginning of the term -- the visual vocabulary test and the mechanical comprehension test showed a significant correlation with the Technical Content Tests in the Theory First group. They showed practically zero correlation with the Technical Content Tests for the Demonstration First group.

The prior GPA of both groups correlated significantly with their performances on the Technical Content Tests indicating that, as usual, the one best indicator of success in a course is past performance on other courses. Prior GPA also correlated significantly with success on the Problem Recognition Test for the TF group but not for the DF group.

The scores on the special tests given at the end of the course failed to show any correlation with one another in either group. There was a significant correlation between performance on the Problem Recognition Test and the Technical Contents Tests in the TF group but not in the DF group.

It should be noted that four correlations which were significant in the TF section were not so in the DF section. These were the correlation of Technical Content Tests with the Visual Vocabulary, Mechanical Comprehension and Problem Recognition. It might be suggested that the TF group represents the more ordinary class and that ordinary predictors of success are correct, while the DF group represents the extraordinary class in which all predictors are wiped out by the extraordinary method of presentation. Apparently this has been accomplished by moving the predictably low men into the middle range.

The results of Creative Solutions Test failed to correlate with any other measure for either section, indicating that this variable is apparently independent of all others. However, the chi-square tests indicate that there was a significant difference between the two sections in their performance on this completely independent test with the DF group performing better.

Scores on the Problem Recognition Test, on the other hand, correlate with both prior GPA and Technical Content Tests for The TF group. These correlations are, as previously noted, wiped out in the DF group. Again Chi-square tests indicate that the DF group scored significantly better on this last test.

These findings seem to indicate that problem recognition and creativity in solution of problems--engineering skills of the highest order--are affected by what the teacher does and can, therefore be taught.

Both of the initial hypotheses appear to have been confirmed.

Teacher Evaluations (Table 5)

The student evaluation of the teachers showed significant differences between the two sections on two items, both relating to the elder teacher. This instructor was rated more expert by the DF group and a better teacher by the TF group.

Although an attempt was made to conduct class sessions in such a way that the students would make as little distinction between the instructors as possible, and no difference in student preferences toward working with one or the other was observed, it is apparent from Table 5 that the students did hold opinions which differed with the instructors. Two possible explanations are proposed here.

Instructor A is a woman who has both experience as a professional engineer and twenty years of teaching practice and is thereby unique at this institution. Instructor B is a junior faculty member with two years of teaching experience.

One suggestion is that the students involved felt that the majority of all administrative and evaluative decisions were being made by the senior member of the team, and therefore the opinions on A should actually be attributed to team as a whole. This theory suggests that the subjects were not able to develop and evaluate an opinion of Instructor B as an independent individual. It should be noted that while the difference in attitude toward Instructor B was far less pronounced, it was in the same direction for both instructors in all cases. Alternatively it is felt that, in view of her more extensive classroom practice Instructor A may have been more adept at suitably modifying her behavior to the desired mode of classroom activity.

The job of conducting the DF group in a "guided discovery mode" gives the instructor the opportunity to display his ability to handle the technical material of the course with above average adroitness, but often results in an apparently disorganized flow of information to and from the class as the instructor locates and clarifies ideas put forward by the students. The combination of higher rating on technical competence combined with lower rating on teaching skills on the student evaluation by the "demonstration-first" section may result from this pattern.

Student Perceptions of Instructors

The items in the Student-Teacher Evaluation Questionnaire were grouped into four sub-categories and student responses examined for the two groups and the two, cooperating instructors. Table 5 indicated considerably greater variation in student evaluations of Instructor A in the two groups than for Instructor B. Significant differences in attitudes toward the instructors were noted only for Instructor A, on the two dimensions of competence in the subject matter ($X^2 = 8.45$, $p<.05$) and in teaching skill ($X^2 = 14.14$, $p<.01$). In these two situations, the two groups saw these competencies quite differently, with the theory-first group believing Instructor A more competent in the subject matter, while the theory-first group saw more competence in teaching skills.

SUBJECTIVE OBSERVATIONS

Reactions of the instructors

Several interesting observations were made by the present instructors as the two groups continued during the semester. Apparently the Theory-First room was a more comfortable place for the instructor. The elder instructor reports, "In the beginning, I thought the demonstration group would be more fun but soon I knew they were going to start pushing me around whenever I met with them. Actually, I enjoyed it more when I knew I was in charge in the theory room. One day, the demonstration class wouldn't let me talk about what I planned; they were either so full of questions or so busy talking with each other that I never did get a chance -- but things only became that extreme in the last few weeks of class."

Reactions to Proctors

Both the Problem Recognition Test and the Fluency Tests were given by two proctors during the absence of the regular instructors.

The first proctor administered the Problem Recognition Test and reported no difficulty with the students. Neither did the students mention any difficulty with the instructor.

The second proctor administered the Fluency Test and reported no difficulty with the Creative Solutions Test. However, during the Algorithmic Strategy Test he reported that the students in the TF group demonstrated a great deal of resentment, throwing papers on his desk, refusing to turn in papers, stalking out, etc. He also reported that he believed there were attempts in the TF group to copy or discuss answeres. He was not aware of any such behavior in the DF section and particularly noticed that in the DF section several students continued to work on algorithmic strategies until time was called, while in the TF class all had quit working before the alloted time expired.

When the regular instructors returned members of the TF class complained bitterly about the proctor's "attitude" and attempted to defend their behavior. Members of the DF class volunteered no remarks, but when queried, thought the second proctor was "stricter and crosser" than the first.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Two major conclusions may be drawn from this study.

First, what happens in the classroom does make a difference. Learning of the technical content of the course was not affected by the order of presentation and its outgrowing teacher behavior, but the abilities of the students to respond to unusual and unexpected problems was affected. The class in which demonstration preceded theory scored significantly higher on tests designed to measure this competence than did the class in which theory preceded demonstration. Furthermore the effect of the order of presentation was so profound that four significant correlations found in the Theory First group vanished in the Demonstration First, indicating that the experience in that class room had enough effect to cancel much of the effect of other experiences.

Second, since what happens in the classroom is shown to affect problem recognition and creativity, it is apparently possible to design class room experiences to teach these engineering skills.

A third lesser, observation is that what the teacher does affects his feelings about the class and the feelings of the class about the teacher. Both teachers preferred teaching the Theory First class and the Theory First class had more positive feelings about both teachers. The most comfortable class was the less competent class -- perhaps indicating that the mode of instruction preferred by the student may not be best for him.

Recommendations for further study

The measurements used in this study were limited due to several practical as well as theoretical reasons, including the conduct of this course in the ongoing program of a college of engineering and a scarcity of knowledge of the critical factors affecting the learning of certain skills by engineering students. Several additional measurements would have helped in reaching further understanding of the effect of different teaching procedures on students' learning, e. g., measurements of (a) the actual teacher-student-materials interaction in the two classes. (b) personality factors among the students, (c) student behavior during learning (time to read programmed materials, number of errors during reading, etc.) and (d) student attitudes toward the course content, methods and the engineering profession. Considerable refinements in both the methods and measurements could now be built into a second study of similar phenomena.

The measures used for the initial assessment of student characteristics should be expanded to include both cognitive and affective factors (N. Schroder, Driver and Streufer, "Human Information Processing."). During the conduct of the course, the instructors should control and monitor their own classroom behavior through the use of a technique similar to Flanders' Interaction Analysis procedures (Amidon and Flanders). In this manner, some of the "intuitive" reactions of the present instructors could be formulated into testable hypotheses about their own behaviors and the corresponding reactions of the students. The use of trained observers to record and analyze the benaviors of students and instructors would allow a more detailed examination of the effects of the treatment variables. Finally, the measures of outcomes should be refined and expanded; refined to more specifically examine the differences reported in this study, and expanded to permit the assessment of changes in the students that were sensed subjectively by these instructors.

PART II

DEMONSTRATIONS

A. Design of Demonstrations

Fifteen demonstrations were designed and constructed. They were of the following types.

1. Demonstration. Demonstrations were those experiments performed by the teacher. They were used to demonstrate those principles which required fairly sophisticated instrumentation, or complicated set-ups which had to be made prior to the class period. Only one set of equipment was required for each demonstration.

2. Team Project. Team Projects set problems for a group to solve using a kit of simple equipment. The students were expected to collect and interpret data leading to a solution of the problem at hand, according to procedures which they themselves design. One kit was provided for every three to five students.

3. Individual experiment. Individual experiments were performed by the student using a simple kit of equipment to help him discover or verify basic dynamic phenomena. Since the kits were on a loan basis one kit for every three to five students was adequate.

All experiments were designed so that they may be performed in an ordinary classroom furnished with tables and chairs. Various pieces of equipment were used for more than one experiment.

Demonstrations were designed in the following areas:

a. Motion of a rolling body on a moving plane
b. Determination of Moment of Inertia
c. Work and energy
d. Conservation of energy
e. Motion of rolling bodies on stationary planes
f. Motion of nonsymmetrical rolling bodies
g. Acceleration of a system of bodies
h. Determination of velocity and acceleration from observed data on erratic motion
i. Determination of velocity and acceleration along irregular paths
j. Analysis of the kinematics of a mechanism
k. Free body analysis of accelerating body
l. Determination of Moment of Inertia
m. Determination of displacement from acceleration-time curves

Detailed descriptions of these demonstrations will be found in Appendix VI.

As demonstrations were developed they were class-tested. No objective measures of their effectiveness seemed practical but subjective observations were made and are included in the descriptions of the demonstrations.

Dissemination

Upon acceptance of this report by the Office of Education the experiments will be incorporated into a brochure. This brochure will be circulated to all engineering schools accredited by the Engineering Council for Professional Development.

BIBLIOGRAPHY

Amidon, E. J. & Flanders, N. A. The role of the teacher in the classroom. Minneapolis (429 Plymouth Bldg.): Paul S. Amidon and Assoc., 1963.

Berlyne, D. E. Conflict, Arousal and Curiosity. N. Y.: McGraw-Hill, 1960.

Flanders, N. A. Teacher influence, pupil attitudes, and achievement. Coop. Res. Monograph No. 12, OE-25040. Washington: U. S. Department of Health, Education and Welfare, 1965.

Gage, N. L. (Ed) Handbook of research on teaching. Chicago: Rand McNally and Co., 1963.

Huggins, W. H. and Entwisle, D. R. Interference In Meaningful Learning. J. Educ. Psychol., 1964, 75-78.

Hilgard, E. R. Creativity and Problem Solving. In Anderson, H. H. (Ed.), Creativity and its cultivation. New York: Harper & Brothers, 1959, 162-180.

Medley, D. M. & Mitzel, H. E. Some behavioral correlates of teacher effectiveness. J. Educ. Psychol. 1959,239-246.

Mitzel, H. E. Teacher effectiveness. Encyclopedia Educ. Res. (3rd edition), New York: Macmillan Company, 1960,1481-1485.

McKeachie, W. J. Appraising teaching effectiveness. In W. J. McKeachie (Ed.) The appraisal of teaching in large universities. Ann Arbor, Mich.: Univer. of Mich., 1959.

Schroder, Driver, and Streufer. Human Information Processing. New York: Holt, Rinehart and Winston, 1967.

Soar, R. S. An integrative approach to classroom learning. Temple University, Philadelphia, 1966.

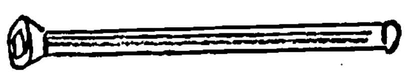
Appendix I - Visual-Vocabulary Test

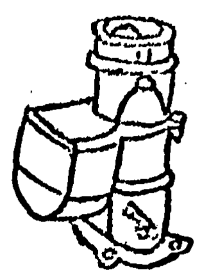
AUTOMOTIVE

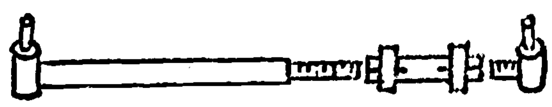
Name ______________

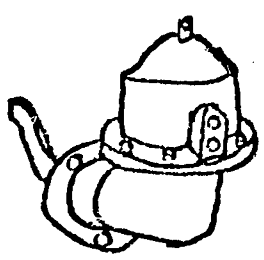
Place the letter corresponding to the name of the object and the number corresponding to the description in the boxes under each illustration.

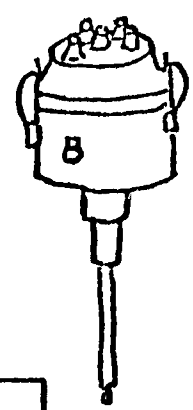
Name	Description
a) Tie Rod	1) Mixes fuel and air
b) Cam shaft	2) Steering connection
c) Distributor	3) Valve Timing
d) Push rod	4) Provides fuel pressure
e) Connecting rod	5) Power transmission
f) Carburator	6) Transmits force to valves
g) Fuel pump	7) Ignition







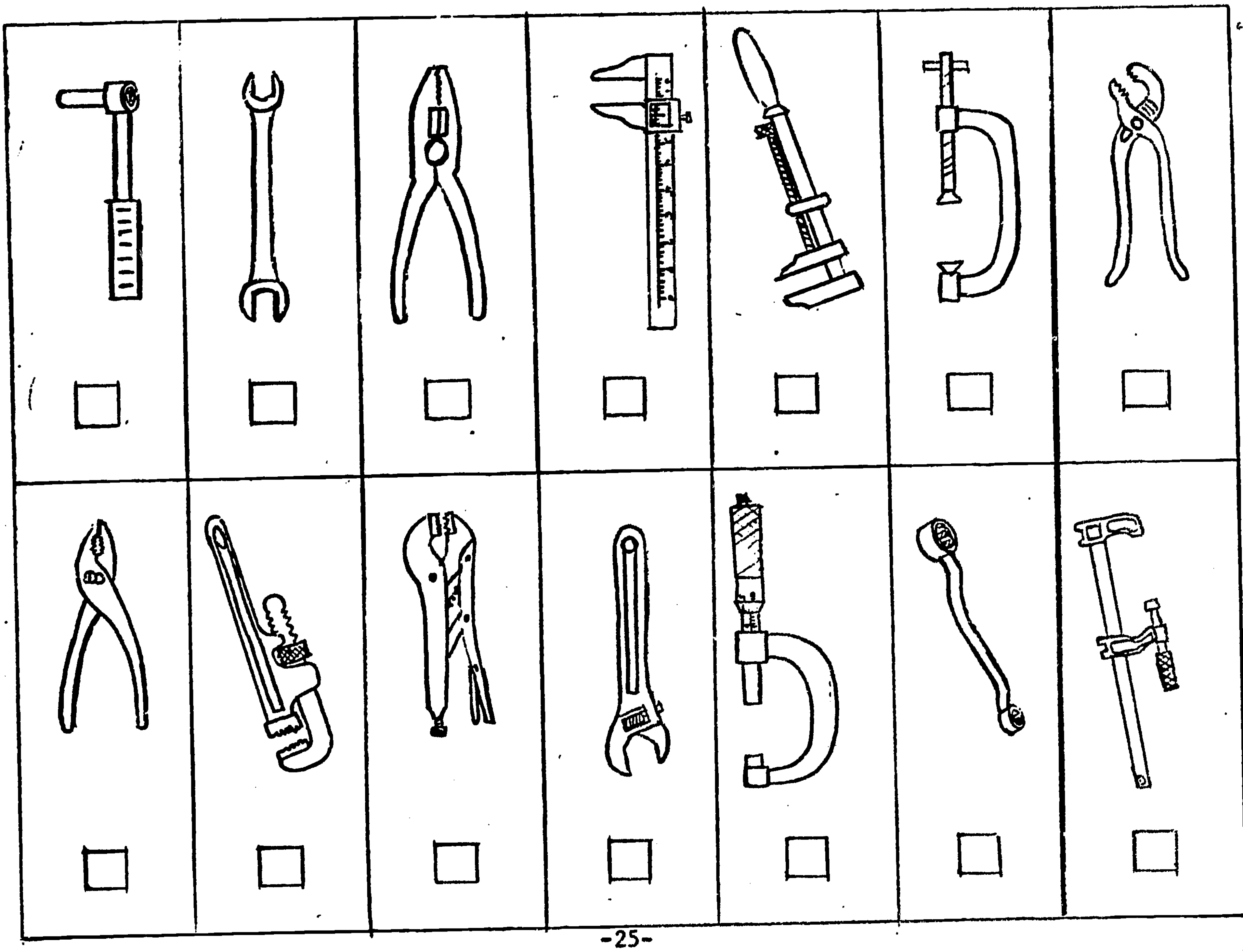




HAND TOOLS Name ____________________

Place the number corresponding to the name of the tool in the box under each illustration.

1. Electrician's pliers
2. C-clamp
3. Box wrench
4. Pipe wrench
5. Socket wrench
6. Bar clamp
7. Vernier calipers
8. Jewelers' pliers
9. Outside calipers
10. Combination pliers
11. Pump pliers
12. Micrometer
13. Open end wrench
14. Vise grips
15. Crescent wrench
16. Monkey or Ford wrench

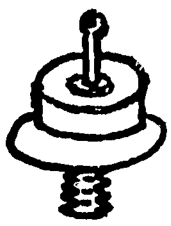


ELECTRONIC

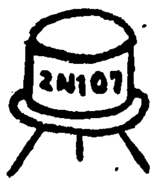
Name ______________________

Place the letter corresponding to the name of the object and the number corresponding to the description in the boxes under each illustration.

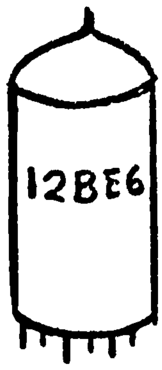
Name	Description
a) Resistor	1) Solid state rectifier
b) Capacitor	2) Inductive element
c) Coil	3) Stores charge
d) Transistor	4) Thermionic valve
e) Diode	5) Solid state triode
f) Vacuumetube	6) Limits current
g) Multivibrator	7) Solid State Transducer



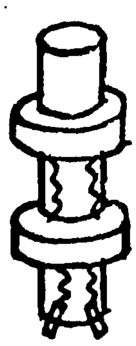
☐ ☐



☐ ☐

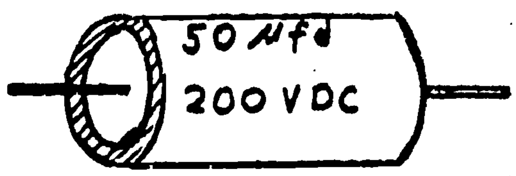


☐ ☐



☐ ☐

☐ ☐



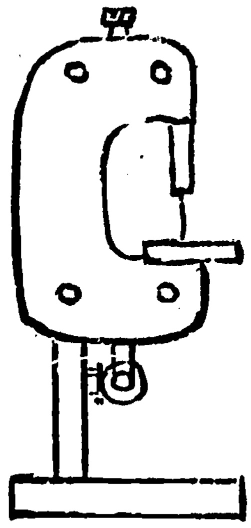
☐ ☐

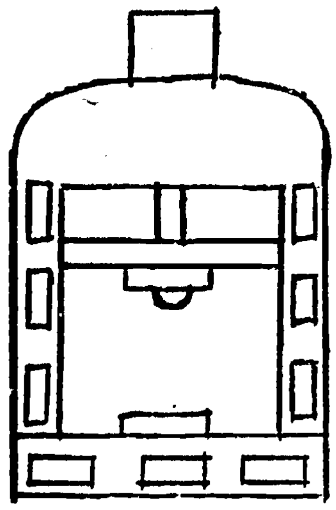
MACHINE TOOLS

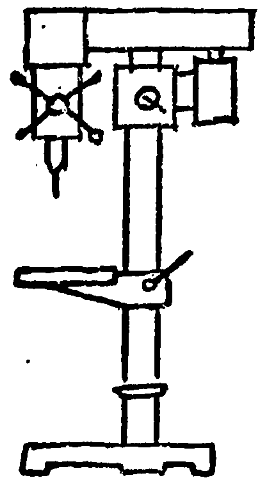
Name ________________

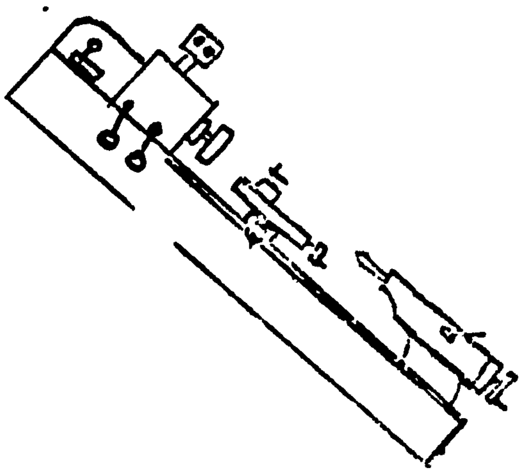
Place the letter corresponding to the name of the object and the number corresponding to the description in the boxes under each illustration.

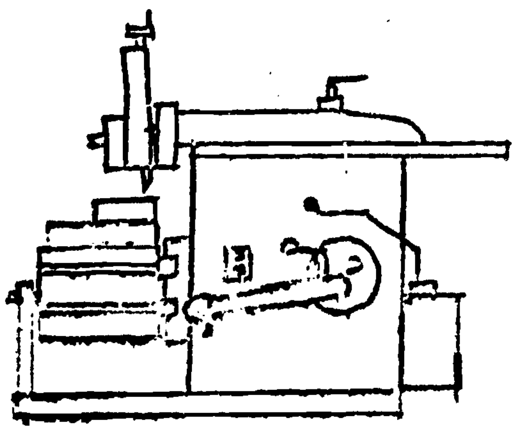
Name	Description
a) Lathe	1) Forms metal by impact
b) Roll Forming Machine	2) Surface finish, push-pull motion
c) Milling Machine (Horizontal)	3) Surface finish, rotary tool
d) Shaper	4) Makes holes
e) Drill Press	5) Turning
f) Band Saw	6) Continuous blade
g) Drop Forge	7) Upsets rivets

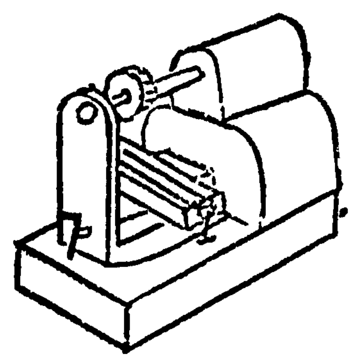












Appendix II - Problem Recognition Test

Do not turn pages until instructed to do so.

Instructions to the Student

This test consists of several problems, each on a separate sheet. You will have a stipulated amount of time to work each problem. Do not begin work until instructed to do so, and stop immediately when instructed. When you are instructed to stop, tear off the sheet you have been working on and turn it in. As soon as you have torn off one problem, begin work on the next.

Do not forget to put your name on each sheet as you turn it in.

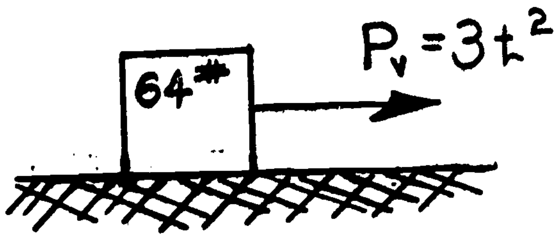
In the course of these problems you may have to make assumptions. State all assumptions on your paper as part of your solution. These problems will be graded primarily on method of attack.

Do all of your work on the problem sheet.

At your instructor's signal, tear off this sheet and begin.

10 minutes

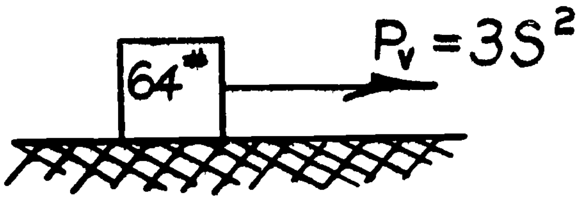
1. The coefficient of friction between the block and the plane is 0.2. When t=0 the block is at rest. Determine its velocity when t=3 sec.



(Problem Recognition Test)

10 minutes

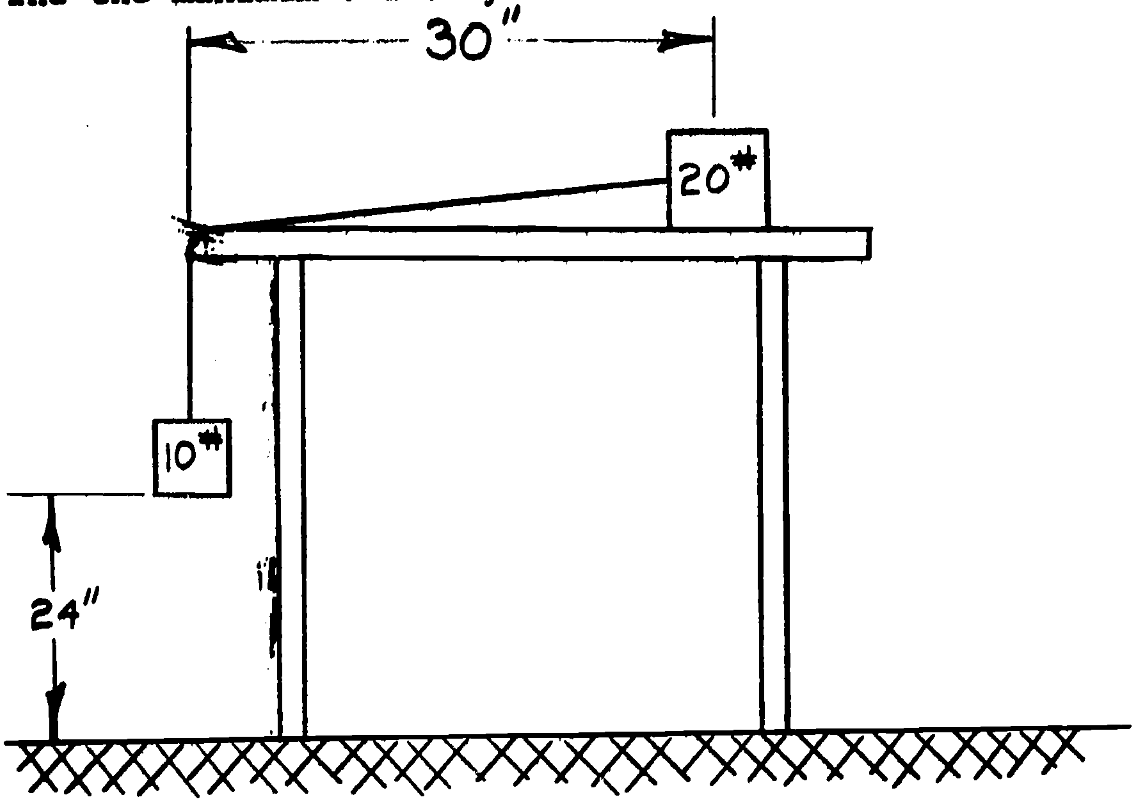
2. The coefficient of friction between the block and the plane is 0.2. When s=0 the block is at rest. Determine its velocity when s=3 ft.



(Problem Recognition Test)

15 minutes

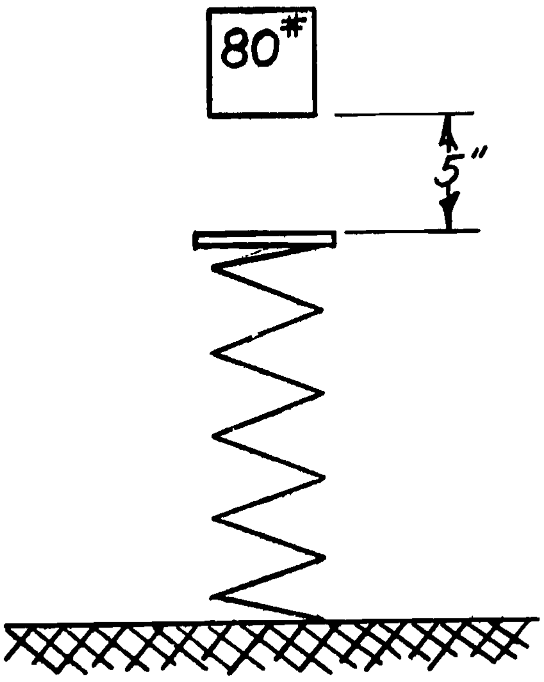
3. The coefficient of friction between the 20 lb block and the table is .2. Find the maximum velocity of the 20 lb block.



(Problem Recognition Test)

10 minutes

4. The spring modulus is 20 lb/in. Determine the maximum deflection of the spring and the maximum velocity of the 80 lb weight.



(Problem Recognition Test)

Appendix IV

Test of Fluency in Generating Alternative Solutions

Do not turn pages until instructed to do so.

Instructions to the Student

This test consists of several problems, each on a separate sheet. You will have a stipulated amount of time to work each problem. Do not begin work until instructed to do so, and stop immediately when instructed. When you are instructed to stop, tear off the sheet you have been working on and turn it in. As soon as you have torn off one problem, begin work on the next.

Do not forget to put your name on each sheet as you turn it in.

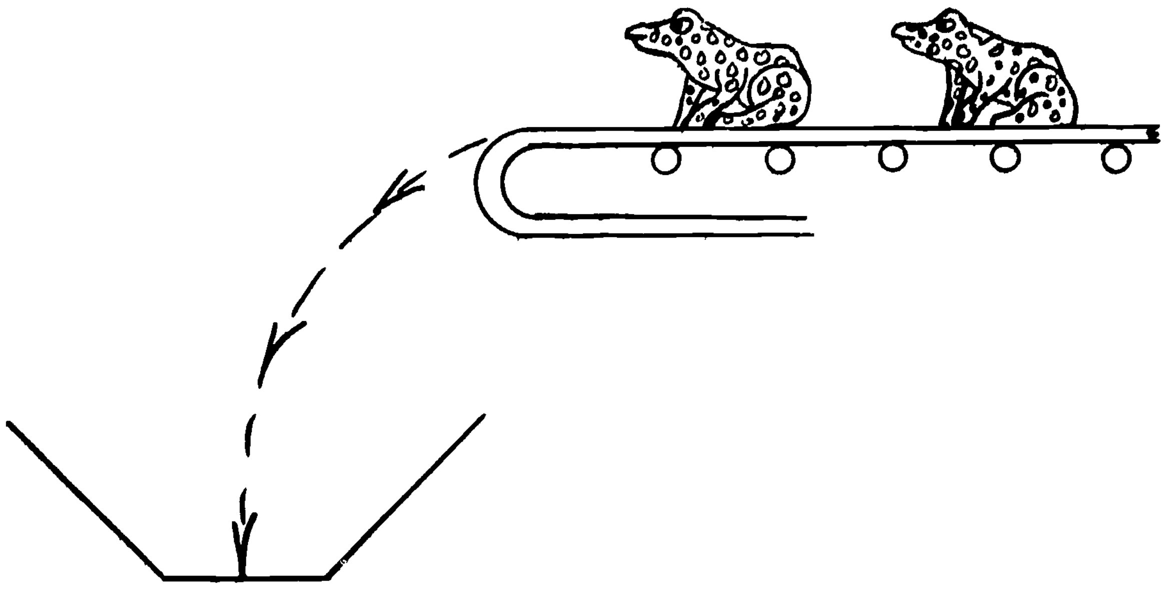
In the course of these problems you may have to make assumptions. State all assumptions on your paper as part of your solution. These problems will be graded primarily on method of attack.

Do all of your work on the problem sheet.

At your instructor's signal, tear off this sheet and begin.

5 minutes

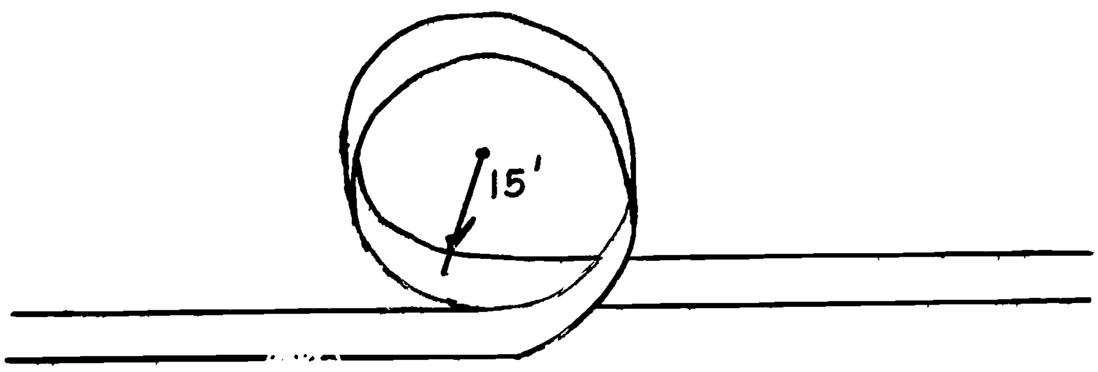
1. Toy frogs are delivered by conveyor belt to a hopper as shown. One out of three is "jumping" out of the hopper, resulting in breakage, lost time and general mess. Offer as many suggestions as you can for ways to correct the situation.



(Test of Fluency in Generating Alternatives)

5 minutes

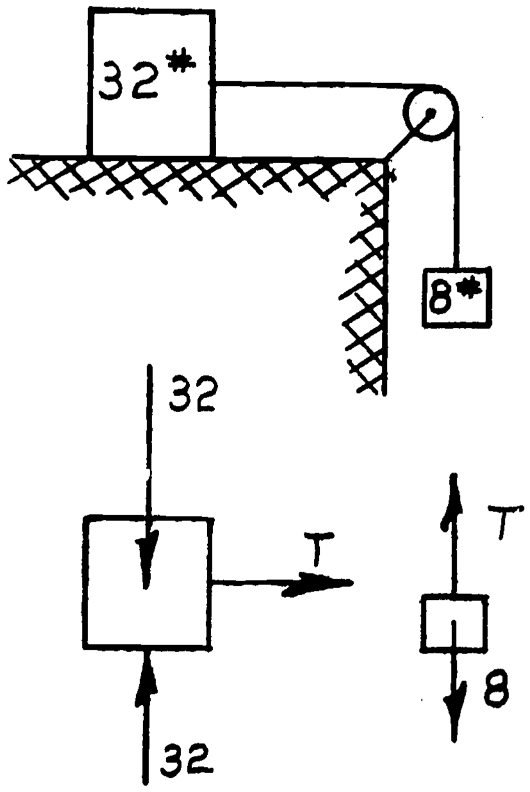
2. The sketch shows the track for a daredevil motorcycle ride. A motorcycle with a top speed of 120 mph will not make the loop safely. What should you redesign and how should you change it?



(Test of Fluency in Generating Alternatives)

10 minutes

3. A problem is solved at the left by means of Newton's Second Law. Find the acceleration of the system by a completely different method.



$T = 1a$

$T - 8 = -1/4a$

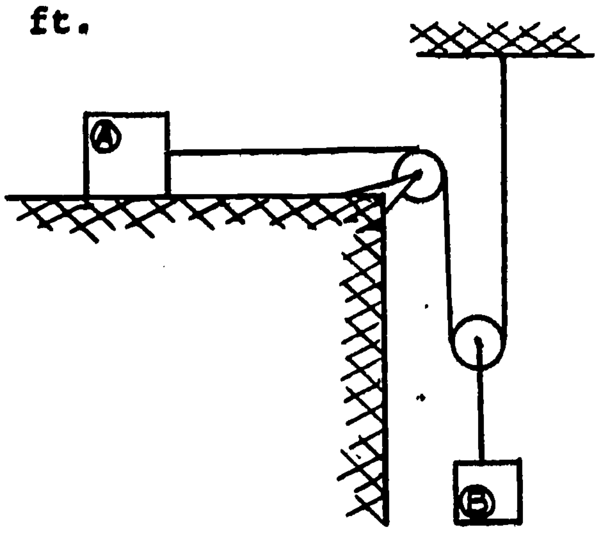
$a - 8 = -1/4a$

$a = 4/5\ 8 = 6.4\ \text{fps}^2$

(Test of Fluency in Generating Alternatives)

5 minutes

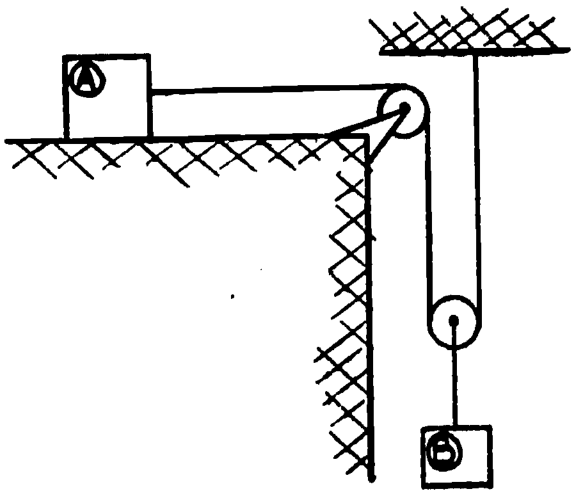
4. Block A weighs 32 lb and rests on a smooth plane. Block B weighs 2 lb. The system is released from rest. Find the velocity of B when it has traveled 2 ft.



(Test of Fluency in Generating Alternatives)

10 minutes

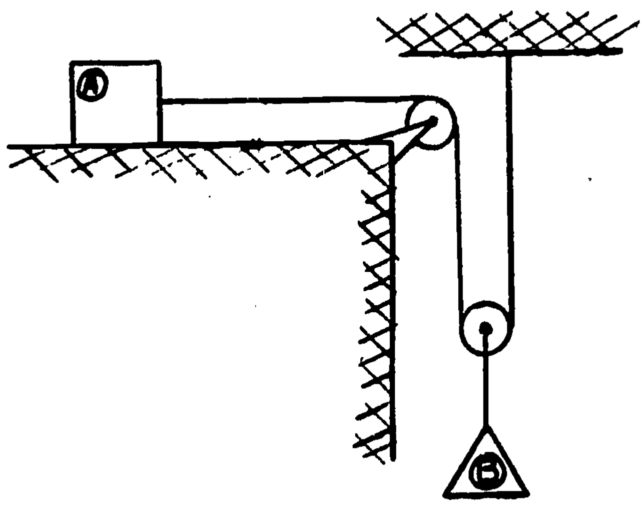
5. Block Ⓐ weighs 32 lb and rests on a smooth plane. Block Ⓑ weighs 2 lb. The system is released from rest. Find the velocity of B when it has traveled 2 ft, by a different method than that used in the preceding problem.



(Test of Fluency in Generating Alternatives)

10 minutes

6. Block A weighs 32 lb and rests on a smooth plane. Block B weighs 2 lb. The system is released from rest. Find the velocity of B when it has traveled 2 ft, by a different method than that used in the preceding problems.



(Test of Fluency in Generating Alternatives)

Appendix IV - Rating Scales

Rating Scale for Problem Recognition Test

Rate	If
0	No evidence of recognition of problem, before or after working it
1	Evidence of recognition of trouble Changes Problem or "fudges" work Makes assumptions of trivial nature only
2	Rationalizes answer or attempts explanation Arrives at correct conclusion by wrong method States some valid and relevant assumptions
3	"Sees"* problem from beginning. Attempts solution by any means. "Sees" problem correctly after getting illogical answer
4	"Sees" problem. Attempts solution by some possible means but does not complete or handle details correctly
5	Correct solution or correct except for errors in algebra, arithmetic or units

* Paper shows evidence that critical elements of problem were noted by student.

Rating Scale

Test of Fluency in Generating Alternate Solutions

Prob. 1-2-3

0 - No Attempt
1 - Poor Attempt, too sketchy, or mostly wrong
2 - Fair Attempt at least mostly right
3 - Good Attempt - mostly right - some originality
4 - Excellent Attempt

Prob. 4-5-6

On Prob. 4	a) Give grade of 2 on theoretically correct method; proceeds to some solution
	b) Give grade of 1 on a fair attempt even if it wouldn't work out or if student knows what to do but can't do it.
On Prob. 5	Case a) 3
	Case b) 2 take working full time into consideration indicated by 10 min. *
On Prob. 6	Case a) 4
	Case b) 3 take working full time into consideration *

* Give any fraction of the alloted points that seems merited by the solution.

Appendix V

STUDENT-TEACHER EVALUATION QUESTIONNAIRE

Your instructor is interested in improving his teaching. You can help by giving honest responses to the items on this form.

PART 1

In part 1, you are asked to compare your teacher in this course with other teachers you have had, on each of 19 traits, and then in Item No. 20 to make an over-all evaluation.

Do not write on this sheet. Use the I.B.M. card provided, marking each item according to the following scale:

With respect to the matter asked, this instructor is:

A. one of the best
B. better than the average
C. about average
D. not as good as the average
E. one of the poorest

Please answer each item, unless you are positive that you are not in a position to have judgment, in which case you may leave the item blank.

1. In your opinion, does he have a sufficient knowledge of the subject matter of this course?

2. Does this instructor show an interest in his subject?

3. Do his interests extend beyond the subject matter of his course?

4. Are his explanations of subject matter clear?

5. Are his presentations to the class well organized and easy to follow?

6. How do you rate the textbook used in this course?

7. Are his assignments reasonable?

8. Are his assignments fair?

9. Are his tests fair?

10. Do his tests cover the most important points covered in the course?

11. Are his methods of grading fair?

12. Is he open-minded, i.e. willing to consider different points of view, tolerant of disagreement?

13. Does he appear to have a real interest in teaching?

14. Does he appear to be interested in his students?

15. Is the instructor available for additional help?

16. Does he have a good sense of humor?

17. Does he appear to be at ease and self-confident?

18. Is he satisfactorily groomed and neatly dressed?

19. Does he stimulate student interest in this course?

20. Compared with all University instructors you have had, how would you rate this instructor as a teacher?

There are three additional parts to this questionnaire as administered, but since they generated no useful data they are not included.

Appenidx IV
Descriptions of Demonstrations

DYNAMIC ATTENTION GETTERS

Helen L. Plants and Wallace S. Venable

West Virginia University
Morgantown, W. Va.

1968

LIST OF DEMONSTRATIONS

1. Determination of Velocity and Acceleration of an Erratically Moving Body
2. Determination of Velocity and Displacement of a Moving Body From Acceleration-Time Curve
3. Determination of Radial and Tangential Components of Velocity
4. Acceleration of a Point on a System of Links
5. Kinematics of Rolling Bodies
6. Free-Body Analysis of an Accelerating Body
7. Moment of Inertia
8. Kinetics of General Plane Motion
9. Kinetics of Rolling Bodies
10. Coplanar Motion of Systems
11. Unbalanced Wheel
12. Work of Weight and Spring
13. Work and Energy

INTRODUCTION

The purpose of the following pages is to describe a series of classroom demonstrations and devices developed at West Virginia University for use in a first course in dynamics.

The developers of these demonstrations aimed for simple, inexpensive devices which could be used as discussion starters in the classroom. The objective of the demonstrations was primarily to create interest rather than to provide accurate measurements. An effort was made to focus attention on the principle being discussed rather than on sophisticated measuring devices. In the interests of avoiding complexity, as well as of providing as much showmanship as possible, toys were found to provide a good source of demonstration material.

All the demonstrations described have been class-tested and found to be of some value, although not all are of equal merit. A description of the way the authors used each device in their classes is included with a subjective evaluation of its effectiveness as used.

The use of the devices in general seemed to somewhat enhance the learning and to considerably stimulate the interest of the students, so they were judged effective in meeting the authors' objectives for them.

It is hoped that others may find some use for the devices described or may be moved by them to design other discussion starters that are tailored to their individual needs.

These devices were developed as a part of a project sponsored by the United States Department of Health, Education and Welfare and by the Engineering Experiment Station of West Virginia University.

Morgantown, W. Va. 1968

DEMONSTRATION 1

DETERMINATION OF VELOCITY AND ACCELERATION OF AN ERRATICALLY MOVING BODY

Objective: To have the students obtain an estimate of the velocity and acceleration of a body moving on an erratic path from simple measurements of time and distance.

Context: This demonstration was used with the class unit dealing with displacement, velocity and acceleration.

Equipment: Toy truck with bump-and-go action powered by flashlight batteries.
Vinyl Cloth 5' x 6' marked off in 9" squares, each numbered.
Flasher set to light at three second intervals.
2 x 2's to serve as bumpers around the edges of the cloth.

Procedure: The truck was placed on the cloth and started. One member of the class was assigned to count aloud the flashes of the timer. Every other member was assigned one or more squares to watch. As the counter called out the number of the flash, the student in whose square the truck was at that instant wrote down the number called. After about 20 flashes the truck was stopped.

Working at the blackboard the instructor reconstructed the path of the truck by plotting on a grid its position at each flash. A coordinate system was then established on the grid and plots made showing changes in position in each coördinate direction versus time. By taking the slope of the x-t curve during a given time interval the average velocity in the x direction during that time interval was obtained. The velocity in the y direction was obtained in a similar manner. From plots of velocity versus time, average accelerations were obtained and plotted. By vectorially combining accelerations in the coordinate directions the maximum total acceleration was estimated.

At the close of the demonstration, students were asked to write a list of the assumptions that were made and of ways that the accuracy of the results could have been improved.

Reaction: As an interest getter, this was excellent. Despite the simplicity of the demonstration the class seemed to find it very interesting. They seemed to find satisfaction in having arrived at any conclusions from such an exceedingly erratic motion. Carry-over into other problems involving average velocity and average acceleration was only fair.

Cost: Truck - $2.95
Flasher - relaxation oscillator built at a cost of about $8.00 for materials
Vinyl Cloth - $4.00
Bumper Boards - scrap lumber

DEMONSTRATION 2

DETERMINATION OF VELOCITY AND DISPLACEMENT ON A MOVING BODY FROM ACCELERATION TIME CURVE

Objective: To have the students obtain from an acceleration-time curve of a moving body the displacement and velocity curves for that body.

Context: This demonstration was used in conjunction with the class unit dealing with velocity-time curves.

Equipment: For preparation: Elevator
Accelerometer
Strip-chart recorder
For class presentation: Reproductions of acceleration trace

Procedure: The strip-chart recorder and the accelerometer were connected and the accelerometer system was placed on a freight elevator in the engineering building. Then the race of the acceleration versus time was made as the elevator was run from the ground floor to the top floor of the building. Several traces were made. The best of the traces was then selected and reproduced copies of the trace were handed out to the individual members of the class at the beginning of the class hour. The instructor began the period with some discussion of v-t curves and then led the class into a discussion, resulting in the conclusion that similar results to the v-t relationships could be derived for a-t or acceleration time curves. The class then was asked individually to compute the change in velocity during each consecutive one second time period on the curve. A member of the class was asked to plot the resulting velocity on a master chart at the blackboard. The class then as a group proceded to take the data from the velocity-time curve and compute a displacement-time curve for the elevator. Having computed the approximate displacement of the elevator from the bottom to the top of the building, the students were then asked to compare this with other observations of this distance they might have made in the course of reading post-cards or taking surveying courses or otherwise making measurements or estimates of the height of the building. As an instructors summary, the instructor then proceded to tell how a similar technique could be used in aero-space vehicles or other types of vehicles in which acceleration-time curve was easily obtainable and that this method is of use in inertial navigations or inertial reference type problems.

Reaction: The class seems impressed with both the general method and with the accurate data which can be generated with this method. They seem to find it a more relevant experiment than many of the demonstrations which have been conducted in class.

Cost: The cost of reproduction of the acceleration-time-curves was the only out-of-pocket cost incurred as the instrumentation was borrowed from research and advanced laboratory equipment available to us and was only in use for a very short period of time.

DEMONSTRATION 3

DETERMINATION OF RADIAL AND TANGENTIAL COMPONENTS OF VELOCITY

Objective: The object of this demonstration was to have the student determine the radial and tangential components of the velocity of a point moving an a curve whose mathematical equation was not known.

Context: Used with a class unit dealing with velocity in polar coordinates.

Equipment: Fixed cam with moving rolling follower
Troll Doll
Cam profiles drawn on sheets of drawing paper
String, rulers, protractors, pencils

Procedure: The class discussion and work was opened by the instructor who presented to the class a model amusement park ride which consisted of a cam and a rolling follower and a doll which rode a cart mounted on the rolling follower. The instructor pointed out that it is often impossible to know the exact mathematical shape of a curve which may be used in a real engineering situation and that in such cases graphical methods may be used in order to determine such unknown stresses or forces which determine the design of such a piece of equipment. The students were then divided into working groups and each group was given a paper cam and told to assume that the follower was guided by a radial arm which rotated with a constant velocity about a designated center. Students were then to compute the velocity components. The determination of the velocity by the student groups was generally made by laying off the finite displacement vector, computing the finite time lapse which during the motion occurred and then finding the average velocity vector by dividing the displacement by time. Many of the student groups chose to use radial and tangential systems since the radial direction can be easily specified and the angular velocity of the radius was given as a constant. Other student groups preferred to work in the Cartesian coordinate systems to which they are more accustomed. At the close of the period the instructor brought the entire class together for a brief discussion of the implications of choosing longer or shorter displacements and a general summary and contrasting of the Cartesian and Polar Coordinates solutions.

Reaction: The general class reaction to this demonstration is that this project requires too much work. The students seemed to dislike having to do any plotting or computational work of their own in a class in addition to their homework. On this experiment the make-up of the group determines what they will get from the experiment. Many groups are able to proceed very quickly to the point, many other groups, however, get lost and take either extremely large intervals or neglect to consider the velocity as a vector and concern themselves with the computation of speed only.

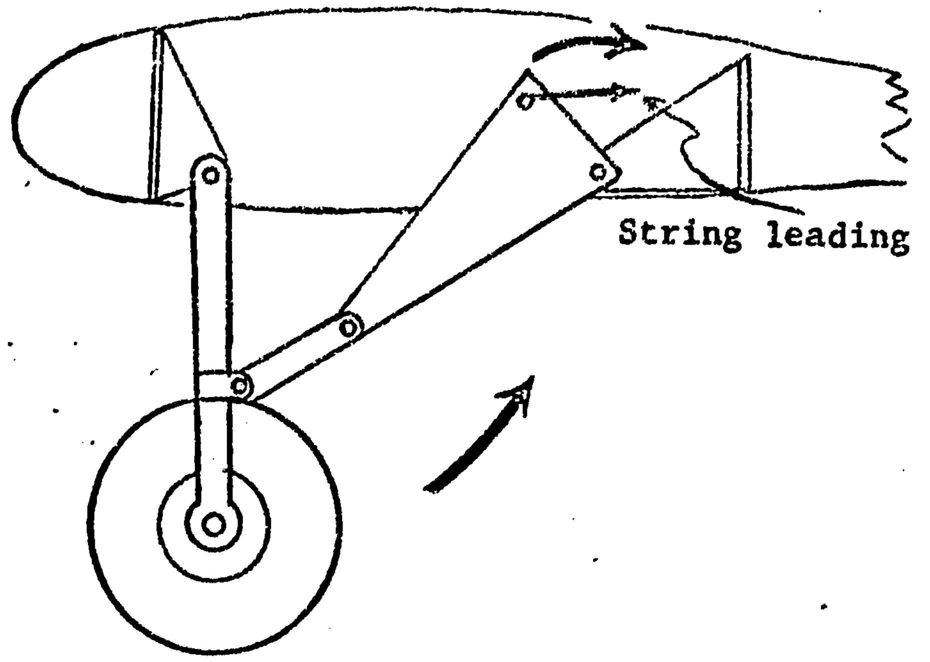
Cost: 1 plastic troll - $1.00
Miscellaneous scraps of plywood, wood and miscellaneous hardware approximately - $2.00
Shop time approximately 2-3 hours to construct
Miscellaneous drawing paper, pencils, paper, rulers, protractor.

ACCELERATION OF A POINT ON A SYSTEM OF LINKS

Objective: To have the students apply the formuli for the kinematics of a point in a moving reference system.

Context: This demonstration was used with the class unit on acceleration in moving reference systems.

Equipment: Model of aircraft landing gear
Rulers
"Interoffice memoranda" (See following page)



Procedure: A series of "interoffice memos" of a fictional aircraft manufacturer informed the class that the selection of the hydraulic cylinder used to retract the landing gear on a new airplane depended on a prediction of the acceleration of the wheels and suggested that the new men with their fresh knowledge of textbook kinematics should be able to make the calculations quickly.

The class was then shown a model of the landing gear and divided into groups to solve the problem. Each group presented and defended its solution. After all groups had reported, the teacher summarized and combined their work.

The "memos" contain some suggestions which are incorrect, and part of the fun of this demonstration lies in discussing the merits of accepting or rejecting the boss's suggestions.

Reaction: A large minority of the class took an active part in this discussion and it proved to be a stimulating period for both class and instructor. It is difficult to estimate whether it added to the students' knowledge of fundamental concepts but it seems well suited toward making the student work at analysis and synthesis.

Cost: Model - $5.00 (for wheels, plywood, and scrap metal)
Shop time - 1 to 2 days

Colossal Aircraft

Interoffice Memo

CONFIDENTIAL

To: Hydraulics Group

From: Design Coordinator

Re: XK-104

The landing gear mock-up is complete except for the hydraulic system. How stong a cylinder will we need to retract gear in 2 seconds?

* * *

To: Analysis

From: Hydraulics

We're stuck! We can't find the angular acceleration of the main strut. If you can give us that we'll do the rest.

* * *

To: Kinematics

From: Analysis

Dash this off. I think we can safely assume that the point where the cable is attached has a constant velocity.

DEMONSTRATION 5

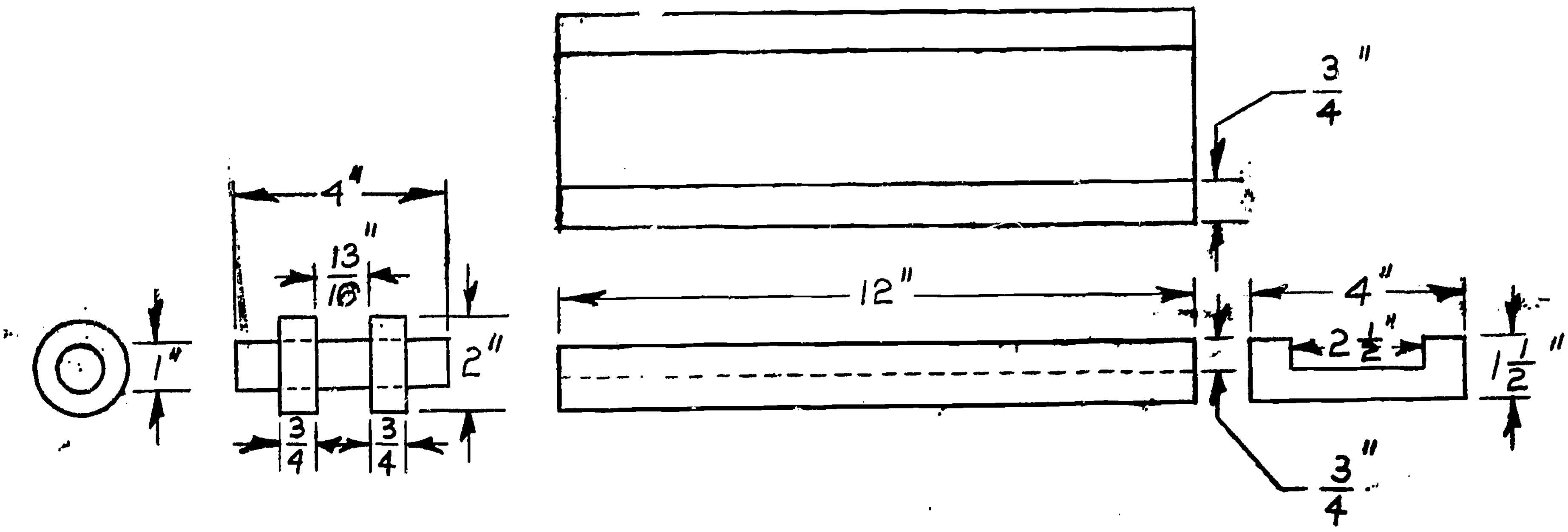
KINEMATICS OF ROLLING BODIES

Objective: To have the student observe the relationship between the angular displacement of a rolling body and the linear displacement of several points on the body.

Context: Used with a lesson on rolling without slipping.

Equipment: A "Rolling Motion Kit" consisting of a wooden wheel and track as shown

Part of a tape measure
Some transparent tape
Set of Questions



Wheel

Track

Procedure: Each student was asked to "check out" a kit at his convenience, to do what was described in the question set, and to keep the completed paper for his notes.

Reaction: While this was expected to be done individually no effort was made to keep students from working together and it was observed that many students worked in groups of three or four. Such groups seemed to generate remarkably lively discussions and to find the demonstration more interesting than had been expected. Individuals working alone showed less apparent interest.

The underlying objective for this experiment was to increase the students' ability to recall the facts for rolling motion when he needed them later in the course by helping him form some meaningful associations for the concept. (Past experience had shown that while students learned rolling motion easily, they forgot it more easily.) The "busy work" involved in this demonstration apparently did increase retention of this material since very few questions were raised when it appeared in later problems and the problems were solved correctly. Later classes have come to call this the "idiot kit," but many individuals ask for it even when its use has not been assigned in class. This has been found to be most effective when it precedes instruction on the topic.

Cost: Odds and ends of scrap plywood and lumber for ten sets - $3.00
Shop time: Three to four hours

DEMONSTRATION 6

FREEBODY ANALYSIS OF AN ACCELERATING BODY

Objective: To have the student utilize Newton's Second Law to determine acceleration and to defend his results by means of a free body analysis.

Context: Used with the first lesson on the kinetics of a particle.

Equipment: Postal scales
Small weight
Elevator

Procedure: Since there are four elevators in the class building, the class was divided into four parties and told to measure the acceleration of an elevator using the equipment listed above. After taking measurements each party had a buzz session, then reported its results to the instructor who required that a freebody analysis be made.

Reaction: Many students seemed horrified at their inability to put their data together in a meaningful manner and to reach the proper conclusions. From past experience with physics, they knew what they should be doing but couldn't do it. Most students seemed to gain respect for the free body diagram as a tool for the solution of problems. This demonstration loses a great deal of its effectiveness if it does not preced instruction on the topic.

Cost: Postal scales can usually be borrowed. If not, a very satisfactory one can be purchased for about $5.00.

WORKSHEET ON ROLLING WITHOUT SLIPPING

Part 1

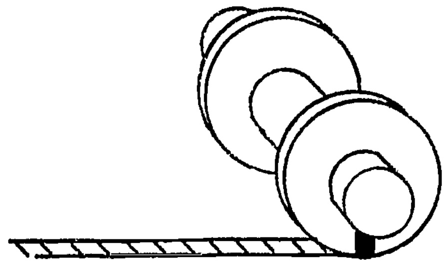
Procedure

1. Measure the inner diameter and the outer diameter of the spool.

   Inner radius = ______________________

   Outer radius = ______________________

2. Scotch Tape tape measure to outer rim of the spool and wind several turns.



3. Tape (or hold) free end of tape to table.

4. Note location of mark on spool. Position it against table. Read tape measure at mark.

5. Roll spool one full turn. Read tape measure at mark.

6. How far did the center of the spool travel in one rotation?

   ____

7. Through what angle did the spool turn? Express your answer in radians.

   ____

8. What is the ratio of the distance traveled by the center of the spool to the angle through which it turned?

   ____

9. Tape end of tape to axle of wheel and wind several turns on axle.

10. Tape or hold free end to base of track.

11. Repeat steps 4 & 5, rolling spool on track.

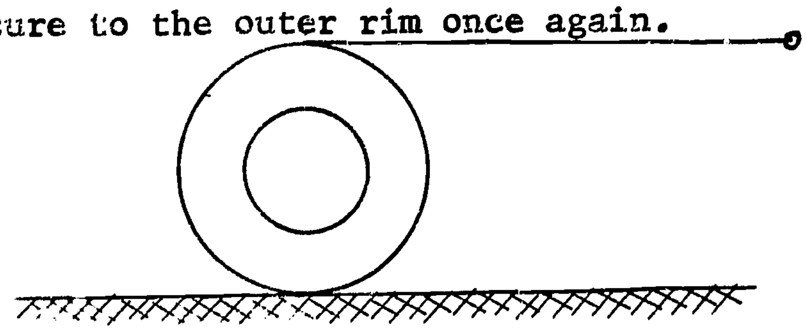
12. Determine ratio of distance traveled to angle turned.

13. Formulate a general statement relating the distance traveled by the spool to the angle turned.

Part II

1. Tape the tape measure to the outer rim once again.

A



2. Position the spool as shown in picture A and roll the spool through one revolution clockwise.

3. How far did the center of the spool move?

____

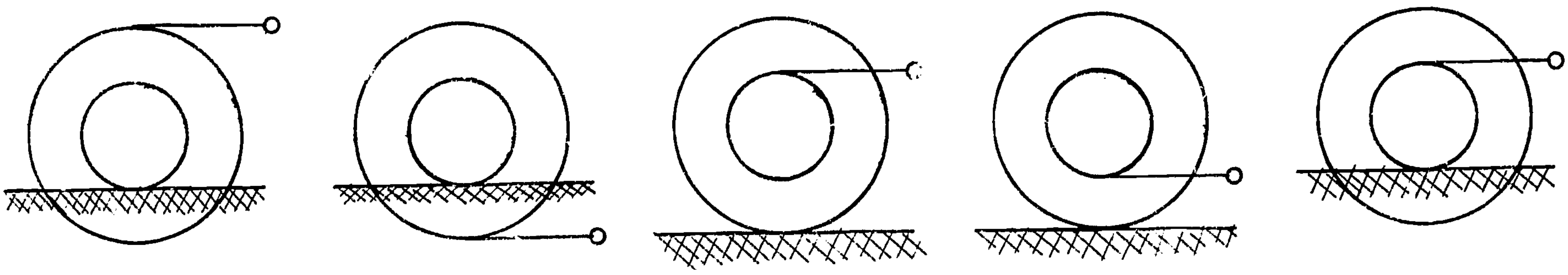
4. How far did the end of the tape move with respect to the center of the spool? (That is, how much tape was unrolled?)

5. The displacement you found in (3) plus the displacement you found in (4) will give you the displacement of the end of the tape. What was it?

____

6. What was the distance from the point of contact with the track to the point of attachment of the tape?

____



B C D E F

7. Repeat the steps you just performed for each of the configurations shown and complete the following table.

	Displacement of Center	Amount of Tape Unwound	Displacement of end of tape	Distance from point of contact to point attachment	Ratio of Distance traveled by end of tape to angle turned
A					
B					
C					
D					
E					
F					

8. From your observations form a statement of the relationship between displacement and angle turned for various points on a rolling body.

9. Using your answer to 8, differnetiate to find similar relationships involving velocity and tangential acceleration.

DEMONSTRATION 7

MOMENT OF INERTIA

Objective: To have the student associate moment of inertia with mass distribution and resistance to rotation.

Context: This demonstration was used in conjunction with the class unit on the kinetics of rotation.

Equipment: Styrofoam spheres
Lead weights
String

Procedure: A 6" sphere with two weights made from about 4 oz. of solder set into it on a diameter was hung from two strings at hooks on other diametral axes and the sphere was made to oscillate in rotation about a vertical axis. The time which the sphere took to make 10 cycles was measured by the class, first with the weights moving in a horizontal plane, then with the weights located on the vertical axis.

The class was able to observe that the lower rate of angular acceleration (and longer period of oscillation) corresponded with the situation giving the higher moment of inertia.

The class was then encouraged to develop their "feel" for moment of inertia by giving an angular acceleration to a similar sphere with their hands. In this case the difference in resistance to rotation can be sensed with fingers.

Reaction: Reaction from class was generally lackadaisical but several students appeared to be more firmly convinced of the relationship between torque and angular acceleration after toying with the second sphere.

Cost: Styrofoam spheres - $1.00 each
Weights made from solder - $1.00

DEMONSTRATION 8

KINETICS OF GENERAL PLANE MOTION

Objective: To have the student verify the qualitative relationships between force and linear and angular acceleration in plane motion.

Context: This demonstration was used in conjunction with the analytical treatment of the plane motion of symmetrical bodies.

Equipment: Truck - extra long bed, battery powered with remote switch
Drum - 3" Section of 3" steel pipe with styrofoam ends
The truck which we purchased required modification of the body in order to obtain a long bed and wheelbase and additional batteries in order to obtain suitable acceleration.

Procedure: The truck was placed at rest on the table and the drum was placed at the front of the bed. The class was then asked to state the direction of the acceleration of the drum when the truck was started. Generally that "it will roll backward off the truck so the acceleration is backward" is the first reaction.

The truck was then started and the motion of the drum observed.

The students were then asked to make a "free body diagram" for the drum, which shows that the friction between the truck and drum will actually accelerate the drum in the forward direction. The class as a group worked out a qualitative solution which shows that the absolute acceleration of the drum is forward but smaller in magnitude than that of the truck so its relative motion is to the rear.

Reaction: This demonstration is excellent for showing the student that careful analysis is generally important in kinetics problems since his first insights often reveal relative rather than absolute motion.

Cost: Truck - $4.00 Modifications may take 2 to 3 hours of shop work and odds and ends of metal and plywood
Drum - scrap

DEMONSTRATION 9

KINETICS OF ROLLING MOTION

Objective: To have the students develop a relationship between the forces applied to a wheel and the direction of its acceleration.

Context: This demonstration was used in connection with a lesson on the application of Newton's laws to bodies having coplanar motion.

Equipment: Several yo-yos
Rolling without slipping kit as described in Demonstration 5.

Procedure: Placing the yo-yo on edge of the table, the instructor told the class the angle at which the yo-yo string would be pulled and invited the class to give opinions on the direction the yo-yo would roll. This was repeated for various angles and various positions for the string both with the yo-yo and with the spool from the kit. (Using the rolling without slipping kit allowed the pull to be applied below the plane on which the body rolled). Free bodies were drawn as needed and the students were encouraged to postulate a method of determining the direction of the acceleration. After class the equipment was available for further experimentation.

Reaction: This was undoubtedly one of the most effective demonstrations used. Students become both argumentative and mystified and always mob the equipment after class to try for themselves. In fact, it has become necessary to have at least one yo-yo that could be taken apart so that students could see there was no trickery involved. Carry-over into working problems involving wheels also seems to be very good.

Cost: Yo-yos range in cost from fifteen cents to a dollar. It has been found convenient to have several of various sizes and weights, but only one is really necessary.
Cost of the rolling without slipping kit is given in Demonstration 5.

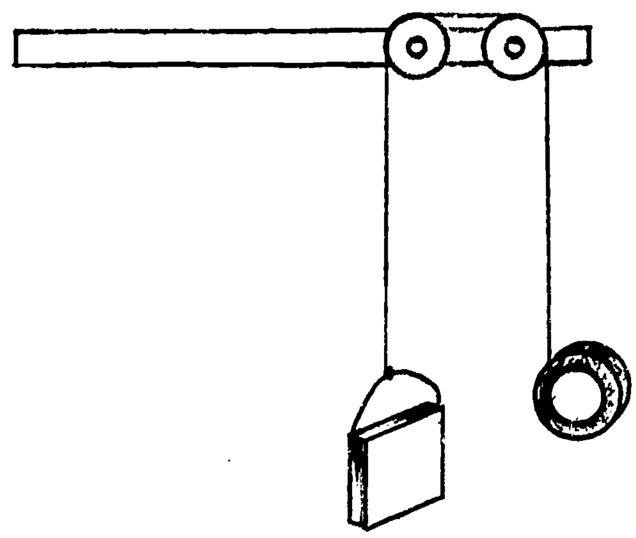
DEMONSTRATION 10

COPLANAR MOTION OF SYSTEMS

Objective: To have the students observe and explain the motion of an interconnected system of bodies.

Context: Used with a lesson on coplanar motion.

Equipment: A yo-yo and a block of exactly equal weight
String
Ball-Bearing Pulleys mounted on a wooden stand



Procedure: The yo-yo string was wound up until the two bodies were separated by about 12". The class was informed that the system was about to be hung over the pulleys and invited to predict how each rigid body would move. After the predictions were made the experiment was performed. The students who had made the most accurate predictions were asked to explain how they knew and their explanations were augmented as necessary with free body diagrams and explanations by the teacher. This demonstration was frequently run the same day as the cart and drum demonstration - Demonstration 8.

Results: Interest in attempting to predict the motion was quite high and the demonstration did provide a good spring board for free-body analysis. While probably not a very effective "teaching" device, this does start good discussions.

Cost: Materials: Heavy yo-yo - $1.00
Block - scrap
Pulleys
Lumber for stand - scrap

Shop Time: 2 hours

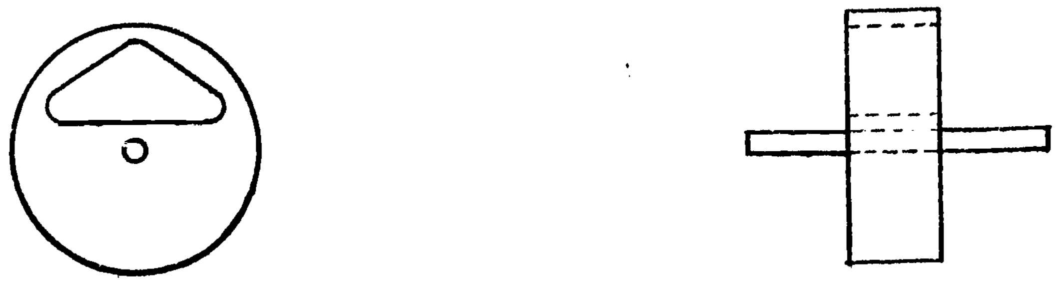
DEMONSTRATION 11

UNBALANCED WHEEL

Objective: The object of this experiment was to allow the student to observe the motion of an unbalanced wheel both rotating about a fixed axis and rolling on a fixed plane.

Context: This was used in connection with the lesson on rotation and the lesson on coplanar motion.

Equipment: Unbalanced aluminum wheel 3 inches in diameter and 1 inch thick
6 inch piece of 1/8 inch rod at its geometric center



Procedure: The wheel was taken to class and demonstrated by the instructor who spun it in his fingers calling attention to the "feelable" change in the reactions and rolled it along a horizontal plane and an inclined plane; calling attention to the visual evidence of its erratic motions.

Free bodies were drawn and equations of motion written for several positions. After class students were encouraged to try it out.

Reaction: About half the class stopped by on the way out to try out the demonstration, showing mild interest. Whether or not their understanding of the problem was increased is unknown.

Cost: Materials - 1 inch piece of 3 inch aluminum rod - $.50
6 inch piece of 1/8 inch aluminum rod - $.05

Shop Time - One hour

DEMONSTRATION 12

WORK OF WEIGHT AND SPRING

Objective: To have the student apply the principles of work and energy to an experimental situation.

Context: This demonstration was used in conjunction with class assignments on work and energy.

Equipment: Support to hold upper end of spring
Felt pen
6 inch coil spring
20 ounce weight
Strip of paper backed with fiberglass tape and fittings to attach one end to spring and other to weight

Procedure: The series combination of spring, paper strip and weight was hung on the support and the felt pen adjusted so that it marked on the paper strip, recording the displacement of the weight. The weight was lifted until the spring was unstretched and held there with a thread. With the system at rest in this configuration, the thread was cut and the weight allowed to fall, extending the spring. The maximum travel of the weight was measured on the paper strip and from this and the known weight the students were asked to determine the spring constant.

Reaction: The class reaction to this is that it is primarily just another problem but it does help to emphasize how measurements on some dynamic systems may be made by using static measurements.

Cost: Very small. Parts constructed from odds and ends of plywood and metal.

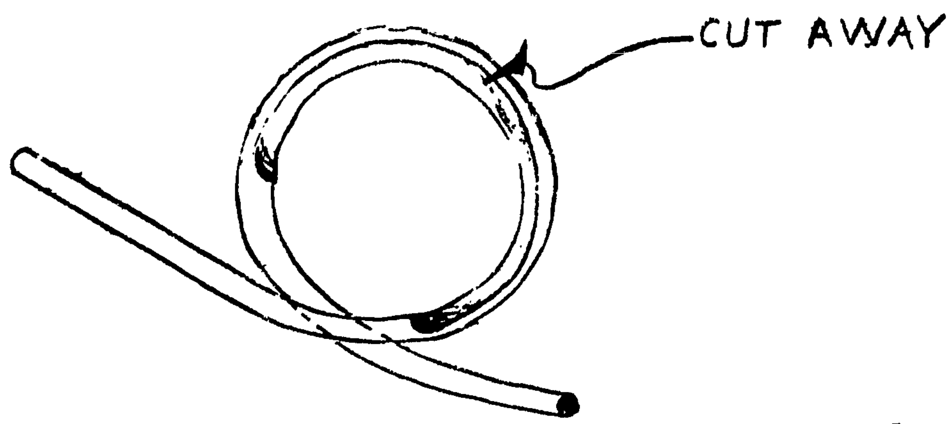
DEMONSTRATION 13

WORK AND ENERGY

Objective: To have the student compute and verify experimentally the height from which a ball must roll to successfully travel a curved path.

Context: Used with a lesson on work and energy. Could also be used with a lesson on conservation of energy.

Equipment: A 3/8 inch steel diameter ball (ball bearing)
A piece of one inch diameter steel pipe bent into a circle 24 inches in diameter and cut as shown in the sketch.



Procedure: The class was asked to compute the height from which the ball had to be started in order to loop-the-loop. The ball was started from the agreed upon height--and failed to make it. The class then tried again. Classes usually take three trials to solve. The first trial is usually based on the idea of zero velocity at the top of the path. The second trial is based on sufficient velocity to give the requisite normal acceleration but treats the ball as a particle. The next and almost successful trial is based on getting the same linear velocity as in the second trial but recognizes that the ball does roll and must therefore be given enough enbrgy to provide the necessary angular velocity as well. The last trial takes the third result and raises it a little to take care of energy losses that are due to a bit of apparently unavoidable slipping and bouncing.

Reaction: The class has a ball with this one and argues vigorously about what went wrong on each try. (In fact, you can usually hear them still arguing in the hall after class.) It seems to bring home the difference between an ideal particle and a real body very vividly.

Cost: Material: Scrap
Shop Time: 2 hours
If finding equipment to bend the pipe presents difficulties, a piece of plastic garden hose makes a fair substitute. It may not be practical to cut away the hose section, however.

OE 6000 (REV. 9-66)

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF EDUCATION

ERIC ACCESSION

(TOP)

ERIC REPORT RESUME

CLEARINGHOUSE ACCESSION NUMBER	RESUME DATE	P.A.	T.A.
	12 -23 -68		

IS DOCUMENT COPYRIGHTED? YES ☐ NO ☒
ERIC REPRODUCTION RELEASE? YES ☒ NO ☐

TITLE
Development and Evaluation of Two Approaches to an Elementary Course in Dynamics. (Dynamic Attention Getters)

PERSONAL AUTHOR(S)
Plants, Helen L. Venable, Wallace S.

INSTITUTION (SOURCE)
West Virginia University, Morgantown, W. Va.

SOURCE CODE

REPORT/SERIES NO.

OTHER SOURCE

SOURCE CODE

OTHER REPORT NO.

OTHER SOURCE

SOURCE CODE

OTHER REPORT NO.

PUB'L. DATE — —

CONTRACT/GRANT NUMBER OEG-0-8-000002-1805(010)

PAGINATION, ETC.
67p

RETRIEVAL TERMS
Sequence of Instruction
Elementary Dynamics
Programmed Instruction
Classroom Demonstrations

IDENTIFIERS

ABSTRACT

Two sections of the same course were taught the same technical content through extensive use of programmed materials and instructor led demonstrations and discussions. Considerable care was exercised so that only the sequence of the presentations in the two sections differed. Three types of tests were administered to determine differences between student learning of the technical content, ability to apply this information in open-ended, problem solving situations, and their attitudes toward the two instructors. The test results indicated that the groups had learned an equivalent amount of the technical content as hypothesized but had learned different application skills. The group introduced to each new topic through practical demonstrations before being exposed to the topical content through programmed materials, was able to generate a larger number of creative solutions to problems, and was more effective in solving problems involving inconsistencies but had the less positive reaction to the teachers. The conclusion drawn is that since the demonstration first group scored significantly better on the skill application tests, the order of presentation affected learning in these areas and that presenting demonstration before theory improves the ability of the student to apply engineering skills.

In addition the report contains detailed descriptions of thirteen classroom demonstrations in elementary dynamics.