Two studies concerned with the representational role of demonstrations in teaching concepts and principles of science are reported. The two studies were performed with dimensions of visual TV presentations varied in the context of programmed lessons. Study One compares the effectiveness of realistic (live) with nonrealistic (animated) demonstrations under intuitive and nonintuitive conditions. Time to complete self-placed verbal programs, errors on programs and achievement tests, and interest and credibility measures yielded comparative data. The data suggest that nonintuitive outcomes may have less capacity for confirming student predictions of experimental outcomes than intuitive outcomes. Differences between intuitive and nonintuitive demonstrations were significantly affected by the mode of presentation. Results suggest realistic and unrealistic presentations may have the capacity to reinforce attending behaviors. The capacity appears to depend on the degree of intuitiveness of the phenomena demonstrated. Study Two compared the effects of direct and indirect examples. The study was concerned with three properties of the examples—convergence or divergence of structural and functional characteristics, the degree of internal similarity among examples within a series of examples illustrating a concept, and the availability of mediating verbal responses. Few statistically significant differences were obtained.
THE REPRESENTATIONAL ROLE
OF DEMONSTRATIONS IN TEACHING
CONCEPTS AND PRINCIPLES IN SCIENCE

George L. Gropper • Anita J. Czujko • Zita A. Glasgow • Margaret C. Samways

METROPOLITAN PITTSBURGH EDUCATIONAL TELEVISION STATION
and the AMERICAN INSTITUTES FOR RESEARCH

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U.S. DEPARTMENT OF HEALTH, EDUCATION AND WELFARE
Office of Education

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February 1966

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FOREWORD

The present study was conducted under a grant from the U. S. Office of Education, grant number 7-48-7690-211, title VII-A of the National Defense Education Act of 1958. The proposal title was "An experimental investigation of visual representation in instruction."

Appreciation is due to Dr. Jerry G. Short for his review of the report.

George L. Gropper
Principal Investigator
February 1966
ABSTRACT

When concepts are taught in science, visuals can serve three key functions. They can function as cues, as reinforcement, or as examples. The two studies reported here were concerned with the affect two properties of visuals have on these functions in lessons designed to teach concepts. One property concerns the realism of visuals; the other the literalness with which they represent concepts.

Study 1 - A comparison of live and animated demonstrations.

Two separate lessons, one on Bernoulli's Principle and one on Archimedes' Principle, were programmed for eighth graders. For each lesson, live and animated versions of the visual demonstrations were prepared for television presentation. Each demonstration unit was serially intermixed with a self-paced verbal program covering the same concepts and principles. Dependent measures to contrast the live and animated versions of the visual demonstrations included: time-to-complete the self-paced verbal program, achievement data based on the visual and verbal program, and questionnaire data concerning the interest value and credibility of demonstration outcomes.

No significant differences in achievement were found between the groups receiving realistic and non-realistic visual presentations. On time-to-complete the self-paced verbal program and on questionnaire items requiring students to indicate their level of interest in doing the experiments they had seen or to predict what the outcomes would be if they did them, there were significant differences between realistic and non-realistic treatment groups. But the direction of the difference depended on the intuitiveness or familiarity of the lesson content. The events illustrating balanced forces needed to understand Archimedes' Principle are highly intuitive. The events illustrating Bernoulli's Principle (e.g., candle flames bending toward moving air) are non-intuitive. While there were sizable differences on questionnaire items between intuitive and non-intuitive demonstrations, the differences between realistic and non-realistic versions depended on (i.e., interacted with) the intuitiveness of the material. The most consistent interaction obtained appears to support the summary conclusion shown in the following figure:

<table>
<thead>
<tr>
<th></th>
<th>live</th>
<th>animated</th>
</tr>
</thead>
<tbody>
<tr>
<td>intuitive</td>
<td>Future interest in trying experiments</td>
<td>interest during presentation</td>
</tr>
<tr>
<td></td>
<td>interest during presentation</td>
<td>future interest in trying experiments</td>
</tr>
<tr>
<td>non-intuitive</td>
<td>interest during presentation</td>
<td>future interest in trying experiments</td>
</tr>
</tbody>
</table>

Results were interpreted to mean that when the outcomes of experiments are intuitive, seeing them live results in more interest in wanting to try them than when they are seen in animation. Seeing them in animation, however, results in more immediate interest during the presentation. When outcomes are intuitive, it is animation per se that appears to have the ability to influence students' behavior. The converse is true for non-intuitive demonstrations. A live version appears to be more immediately interesting. The demonstration outcome appears to be better able to reinforce students' interest in doing the experiment. Non-intuitive outcomes in animation results in greater interest in wanting to try the experiment for oneself later on. Because they are believed truly animated, non-intuitive
outcomes may have a lessened capacity to provide confirmation for responses (student predictions). The general conclusion drawn from this study is that visual demonstrations serve equally well as examples (to facilitate concept acquisition) whether they are live or animated. The capacity of live or animated events to confirm responses (predictions or problem solutions) or to reinforce attending behavior depends on the intuitiveness of the events.

Study 2 - A comparison of direct and indirect examples.

Two separate lessons, one on "heat and molecular movement" and one on "surface tension" were programmed for eighth graders. Two versions of each visual lesson were prepared. In one version all the examples used directly illustrated the concept to be taught (e.g., liquid actually shrinking). In the second version all examples used indirectly illustrated the concept; that is, results or consequences were shown rather than the phenomena themselves (e.g., bristles of a brush clinging together when wet as a result of the tendency of liquids to shrink). The visual lessons were shown on TV and each demonstration unit was serially intermixed with a self-paced verbal program covering the same concepts and principles. Dependent measures used to contrast the effectiveness of the direct and indirect versions included: errors on both visual and verbal programs, time-to-complete the verbal program (that always followed a visual demonstration), and achievement results.

Significant differences in error rates were obtained between treatments, but, since the overall error rates were so low (less than ten per cent) it was concluded that the differences were of negligible practical importance. Generally, other differences obtained were not significant.

To account for these findings an analysis was made of the properties of visual examples that appear to influence their capacity to foster response generalization (concept acquisition). The properties identified included: (a) the convergence or divergence of the superficial, structural properties (physical characteristics) of examples and their functional (conceptual) characteristics; for direct examples they coincide; in indirect examples they diverge and for response generalization to occur to the functional properties, a connection must be established between the structural and functional properties; (this difference between direct and indirect suggests an important role for animation, namely, presenting directly (in animation) what is otherwise unobservable in nature and could only be represented indirectly through observable outcomes or effects); (b) the degree of similarity among examples; for response generalization to occur, students must be able to recognize the relevant similarities within a series of examples; and (c) availability of mediating verbal responses to the visual events; it is likely to be the case that by means of mediating verbal responses that relevant similarities among visual events are more easily recognized and the connection between structural and functional properties established; the more readily available such mediating responses are, the less difference, as between direct and indirect examples, one might expect to find in the case of response generalisation.

The series of demonstrations used in this study, both direct and indirect, appear to have possessed a high degree of internal similarity. Mediating verbal responses to the visual examples are likely to have been at high strength. This may account for the negative findings of this study but since no measure of either variable was available, this cannot be stated with confidence. It does suggest, however, that, measures for such variables, although difficult to implement, are likely to be needed for further research on the role of visual examples in teaching concepts and principles.
GENERAL INTRODUCTION

The prospect that pictorial materials might have a unique and effective role to play in education has had a particularly seductive appeal for educators as well as audio-visual specialists. The enthusiastic conviction that a picture is worth a thousand words has, however, clearly outdistanced the research to demonstrate that it is so. And if it is indeed so, research results have failed to identify systematically how the maxim might be appropriately implemented. To paraphrase a perhaps less ancient saying (rather freely), what has been needed for some time is a little more research and a little less unsupported praise for pictures.

Looking at the research that has been done, it is easy to see, as reviewers Spaulding (1955) and Allen (1960) have pointed out, that the bulk of the research on pictorial illustrations has concerned itself with the preferences of children and adults for various types of pictures. Investigations by Bloomer (1960), Bou (1953), French (1952), Miller (1936), and Rudisill (1952) have been concerned with preferences for: pictures in color vs. in black and white; simple vs. complex drawings; photographs vs. line drawings; realistic vs. non-realistic drawings; and various combinations of these dimensions. Rarely in studies of this kind is it made explicit what instructional outcomes are expected as a result of variations in these dimensions. Is color supposed to arouse interest or to facilitate understanding? Will particular responses be cues more easily by a realistic than by a non-realistic presentation? Unless it is made explicit what function pictures, in whichever guise, are expected to accomplish, it is unclear what the consequence of using an unpreferred type of picture rather than a preferred type would be or vice versa.

The implications that seem to underlie preference-research are that some types of pictures will be less successful in arousing interest or in holding attention, or, perhaps, as a result of this effect less successful in generating understanding. Studies linking dimensions of pictures with interest, e.g., MacLean and Baudard (1953), or with measures of understanding, e.g., Fumesson and Bryant (1960), Rosenstein and Hammer, 1961, and Spaulding (1956) are few in number. Moreover, these studies as well as others in audio-visual
areas, because they also fail to identify specific instructional roles for pictures, have produced results of limited generalizability for pictures.

**Barriers to Generalizations about Research Results on Pictorial Presentations**

In common with other research areas, generalization of results from research on pictorial presentations is contingent on such sampling considerations as the selection of: subjects, lesson topics, or learning tasks. There is the danger of results being specific to a particular age or reference groups, to a particular lesson or program, or to a particular kind of learning task. There is also the ever-present problem of how to generalize from a controlled laboratory study to more practical applications or from the instructional process in one global field study to another. As the review of such studies by Travers (1964) makes clear, research on pictorial materials has involved both laboratory type and field type studies. Thus, the familiar difficulties in generalizing are felt here too.

The problems of generalization across laboratory and field studies is not, however, simply a matter of precision of experimental control in the one and not in the other. While it is true that the more global, field studies (by definition) represent an amalgam of variables, controlled experiments can be done within their framework. What is required is the careful preparation of instructional materials so that it is possible to specify the precise instructional role each portion of a total lesson or audio-visual presentation is expected to play. Research can then focus on specific roles and on the capacity of specific dimensions of pictorial materials in fulfilling them.

**Functions of Pictorial Materials**

In response oriented versions of programmed instruction, one requirement in preparing each segment of an instructional sequence is the precise identification of stimuli under whose control responses are to be brought and how such response control is to be produced. Applied to audio-visual presentations the programming approach requires similar identification of the role, or roles, visuals will play in bringing about response control. Based on recent experience in programming science demonstrations, Gropper (1963; 1965a; 1966) has described various functions visuals can fulfill in
bringing about response control. The two primary functions they can fulfill are as criterion or as intermediary stimuli. In the former case, they are the stimuli under whose control responses are to be brought. In the latter case, they already possess response control and are used, in an instrumental way, to cue responses so that control can be transferred to still other stimuli, generally verbal stimuli. Within this primary framework, visual or pictorial materials can be used to cue responses, to reinforce responses, or to serve as examples as a means of facilitating response generalization (that is, acquisition of concepts). For these various roles, it is sometimes possible to choose between words or pictures. In his most recent report, Grupper (1966) has suggested some instructional strategy considerations in opting for pictures. These include the facilitation of learning ease: (a) for students of lesser ability (either due to prior experience or age considerations); (b) for all students when material is particularly complex, and (c) for material presented early in the acquisition stage. In any of these situations, the greater ease of learning from pictures may be capitalized upon to meet the response readiness of the learner.

By specifying the functions visuals are to play at each and every segment of an instructional sequence (whether as contexts, or cues, or response options, or confirmation) it is possible to ascertain how well visuals serve those functions. Unlike global, end-of-lesson evaluations, identification of specific, localized functions can provide analytic and perhaps more generalizable answers to traditional research questions explored in audiovisual instruction. Thus, on the issue of, for example, color vs. black and white, an entire lesson in either form would not be compared on a global basis with a comparable lesson in the other form. While this is a legitimate approach to the problem, the results are likely to be relatively undifferentiated (as to why one form should be better than the other) and hence not as generalizable as one might wish. On the other hand, evidence that color stimuli or black and white stimuli serve well as cues or as confirmation at particular points in a lesson can produce more specific, analytic, and generalizable conclusions. By specifying functions visuals are expected to play, even an applied study can begin to approach the tightness of a laboratory study and as a result to make the process of generalizing easier.
Purpose of Present Study

Two studies were performed in which dimensions of visual presentation were varied in the context of programmed lessons. In this manner it was possible to contrast degrees of realism, in one study, and degrees of literalness of examples, in a second study, as to their capacity to fulfill specific functions in instruction.
STUDY NO.

AN EXPERIMENTAL EVALUATION OF THE
RELATIVE EFFECTIVENESS OF REALISTIC
AND NON-REALISTIC SCIENCE DEMONSTRATIONS
METHOD

The purpose of this study is two-fold: (1) to determine whether concepts and principles are learned as well from non-realistically presented examples (science demonstrations) as from the same examples presented realistically; and (2) to determine whether there are differential effects of a confirmation sequence presented either realistically or non-realistically. Stated as hypotheses: (1) there appears to be little theoretical ground to expect differential effects on concept acquisition contingent on the realism or non-realism of a series of demonstration examples; and (2) since the credibility of a realistically presented example is apt to be greater than for a non-realistically presented example, their confirmation value may be expected to differ.

Design of Experiment

Independent variables. - Two lessons were prepared for presentation on television; one covered Archimedes' Principle, the other Bernoulli's Principle. Each of the two lessons was prepared in two versions: a realistic version consisting of live (on TV tape), table-top demonstrations illustrating the concepts and principles to be learned; and a non-realistic version of the same demonstration presented in animation (transcribed to TV tape). Each lesson was segmented into several fixed-paced TV units, and units were serially intermixed with a verbal self-paced unit covering the same material as was covered in the preceding fixed-paced visual unit. This arrangement is summarized in Figure 1, on page 6.

The primary independent variable, as can be seen from the table, is the realism of the presentation. By using two lessons, a second variable was studied, the intuitiveness of the phenomena demonstrated. The relationship of balanced and unbalanced forces to motion (in preliminary explanation of Archimedes' Principle) is in keeping with the prior learning history of eighth grade students. Phenomena covered by Bernoulli's Principle (to be described below) are not. Thus, demonstrations in keeping with experience (intuitive) could be contrasted with those that are in conflict with or counter to experience (non-intuitive). It is recognized, of course, that while the comparison of realistic vs. non-realistic versions, based as they
<table>
<thead>
<tr>
<th>Lesson #1</th>
<th>Lesson #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ARCHIMEDE'S PRINCIPLE</strong></td>
<td><strong>BERNOULLI'S PRINCIPLE</strong></td>
</tr>
<tr>
<td>Realistic</td>
<td>Non-Realistic</td>
</tr>
<tr>
<td>(Live on TV tape)</td>
<td>(Animated on TV tape)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fixed-paced visual segment</th>
<th>Self-paced verbal segment</th>
<th>Fixed-paced visual segment</th>
<th>Self-paced verbal segment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1
are on the same content, permits generalizations to be drawn, the comparison of intuitive vs. non-intuitive does not. The latter comparison is contingent on the particular lesson chosen and hence results are more limited as to their generalizability.

Independent variables and the design of the experiment may be summarized as follows:

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>realistic</td>
<td>non-realistic</td>
</tr>
<tr>
<td>intuitive</td>
<td>intuitive</td>
</tr>
<tr>
<td>demonstration</td>
<td>demonstration</td>
</tr>
<tr>
<td>non-realistic</td>
<td>realistic</td>
</tr>
<tr>
<td>non-intuitive</td>
<td>non-intuitive</td>
</tr>
<tr>
<td>demonstration</td>
<td>demonstration</td>
</tr>
</tbody>
</table>

Dependent variables. Dependent variables consisted of such learning measures as time-to-complete self-paced verbal programs, errors on programs, and achievement tests. They also consisted of scores on attitude scales relating to the interest level and credibility of the demonstrations seen. (All of these measures will be described in more detail below.)

Procedures

The schedule that follows was adhered to by all participating classes, with minor variations in timing to allow for ongoing or previously scheduled activities in the schools.

Week 1 - in the schools:
1. Administration of pretests.
2. Administration of a program on "Learning From a Program."

Week 2 - in the schools:
1. Administration of a preliminary program on "Force and Motion" (concepts necessary to an understanding of the experimental programs).
Week 4 - in the studios of WQED:

1. Simultaneous administration of two versions of each experimental program on TV tape: (a) balanced forces and Archimedes' Principle; and Bernoulli's Principle.

2. Administration of the identical self-paced verbal programs on the same topics serially intermixed with portions of the TV presentation.

3. Administration of an immediate posttest and a questionnaire.

Week 6 - in the schools:

1. Administration of a retention test (identical with the original test).

Experimental Materials

Instructional materials developed for this study included two pre-experimental programs administered in the schools and two experimental programs administered over closed-circuit TV in the studios of WQED and (simultaneously) in a banquet room of an adjacent hotel.

Pre-experimental materials. - The two programs administered before the conduct of the main experiment were designed to fulfill two different functions. One, entitled "Learning From a Program" was designed, as its title suggests, to familiarize participating subjects with the mechanics of going through a program and of profiting from a program. The program tries to encourage students to produce a response before looking at the confirmation frame or, stated less delicately, not to cheat. This program is reproduced in Appendix A, page 44. The second pre-experimental program deals with concepts of "force" and "motion" both of which are necessary prior concepts for understanding the content of the main experimental programs. Thus, in addition to providing extra familiarization with "programs," the program served to bring participating subjects up to a common level of prior knowledge. The "force and motion" program is reproduced in Appendix A, page 49.

Both preliminary programs, as well as both self-paced verbal programs used in the main experiment, were prepared in the REP style of programming developed by Gropper (1965b). Briefly, this type of program requires the
production or construction of responses only after the student has edited lesson material (leaving key sections of lessons unchanged if they are correct or changing them if they are incorrect). Editing responses in turn are required only after recognition responses are made. The sequence recognition, editing, and production is designed to match the response readiness of the learner at different stages of learning. Other features of this style of programming (some of which are held in common with other styles of programming) are: the acquisition of discriminations through the selection of multiple-choice options; the acquisition of generalizations through multiple and varied examples; the use of make-up-a-sentence type production frames in which students may be expected to produce elements of stimulus contexts, responses, or both; and the requirement of long, complex, verbal responses. A fuller description of the rationale for this style of programming is presented in programmed form in the citation made above (Grupper, 1965b).

Main experimental materials. - Two lessons were prepared for study, one on Bernoulli's Principle, the other on balanced forces and their application to Archimedes' Principle. Each lesson consisted of individual segments made up of fixed-paced demonstrations serially intermixed with self-paced verbal materials. Each demonstration segment and the self-paced, verbal segment that followed it covered the same concepts and principles. The demonstration segments, prepared for showing on TV, were designed to teach concepts and principles through discrimination practice with concrete events. Words used during the demonstration only described the events (in concrete terms) and did not explain them. The concept of balanced forces, for example, was acquired by students as they practiced making discriminations about the alternative consequences of attaching an equal or unequal number of weights to a model truck that moved on a fixed platform. Or, in the lesson on Bernoulli's Principle, students practiced making discriminations about alternative effects of moving air or still air on candle flames, paper held in a horizontal position, etc. Not only were the stimulus materials (examples) that were used for concept acquisition concrete, but response options were also concrete, i.e., pictorial options rather than words. Response booklets containing the pictorial options for both programs appear in Appendix A, starting on pages 22 and 26. This style of programming
was developed by Gropper (1965a). Both verbal programs are reproduced in their entirety in Appendix A, starting on pages 1 and 12.

The demonstration segments of the two lessons were prepared in two forms. The live version was reproduced on TV tape in the studios of WQED. An animated version using the identical sound track was also prepared. With a kinescope of the taped version at hand, the animated version was designed to reproduce in as non-stylized fashion as possible the same demonstrations (containing as nearly as possible the same amount of complexity of stimulus materials).

Before the demonstrations were recorded on TV tape, they were tried out live with subjects taken from the target population (the eighth grade). They were revised until error rates (on visual answer booklets were low, approximately 10 per cent). Verbal programs were also tried out and revised in similar fashion.

Dependent Measures

The achievement tests and the questionnaire forms used in this study are reproduced in Appendix A, starting on pages 29, 31, and 34. The dependent measure, time-to-complete the self-paced materials was obtained for each verbal segment by proctors who monitored students’ work. The ensuing fixed-paced demonstration did not begin until all students completed the self-paced programs.

Subjects

Three eighth grade classes participated in this study, two from a Pittsburgh Parochial School and one from a Pittsburgh City School. Students from each class were assigned at random to each of the two treatment conditions.
RESULTS

Matching Measures

At the completion of the experiment, students who had been assigned at random to experimental treatments were matched for IQ and Work Rate on pre-experimental programs. Only matched cases were selected for the analysis of data, so that the variables IQ and Work Rate could be treated as independent variables, each at two levels. There resulted a 2x2x2 design for data analysis, representing two levels each of IQ and Work Rate and the two experimentally manipulated conditions (live vs. animated presentations). The results of the matching procedure are summarized in Table 1, which is based on seven cases per cell, for a total of 56 cases.

<table>
<thead>
<tr>
<th>GROUP 1</th>
<th>GROUP 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animated: Bernoulli's Principle</td>
<td>Live: Bernoulli's Principle</td>
</tr>
<tr>
<td>Live: Archimedes' Principle</td>
<td>Animated: Archimedes' Principle</td>
</tr>
<tr>
<td><strong>IQ</strong></td>
<td><strong>Pretest</strong></td>
</tr>
<tr>
<td>High IQ</td>
<td>Fast</td>
</tr>
<tr>
<td>Slow</td>
<td>121</td>
</tr>
<tr>
<td>Low IQ</td>
<td>Fast</td>
</tr>
<tr>
<td>Slow</td>
<td>108</td>
</tr>
</tbody>
</table>

*results reported as means; **time-to-complete in minutes

It shows that there was a separation of approximately 11 IQ points between high and low IQ groups. This difference was statistically significant at the .001 level, as shown in Table 1 in Appendix A, page 56. Table 1, both in the text and in the Appendix also, shows that there was not a significant difference in IQ either between experimental treatments or between Work Rate levels. Similar results can be found in text Table 1 for Work Rate and in Appendix Table 2. Fast and slow levels were significantly different on Work Rate at the .001 level. No significant differences were found for Work Rate between the remaining cells of the design. Table 1 also records...
Pretest scores for each of the eight experimental cells. Appendix Table 2 records, as might be expected in advance, a significant difference in Pretest scores between high and low IQ levels. Differences in Pretest scores between other cells were not significant.

Dependent Measures

The results of this study are organized and reported under several headings. Each heading will concern either a measure of achievement or a measure obtained from the questionnaire administered after both lessons were presented.

A. Achievement Measures

(1) recall of demonstration outcomes. - At the conclusion of the two lessons (on Bernoulli’s Principle and Archimedes’ Principle) a questionnaire was distributed to each subject (reproduced in its entirety in Appendix A, starting on page 34). Five questions were asked about each of ten demonstrations. Each of the five questions appeared on a form labeled A, B, C, D, and E. Form B required the subject to indicate what the outcome was for each of ten demonstrations he had seen. The stem was presented in pictorial terms and the options (possible outcomes) were also presented in pictorial form as illustrated in Figure 2 below.

Which way did each of the following experiments turn out? Put an X next to the picture which shows which way it turned out.

It turned out this way. It turned out this way.

blowing air past candle flames

Fig. 2. Sample item from Form B of the questionnaire administered to participating subjects.
Table 2, containing results obtained from Form B, contrasts the realistic and non-realistic versions of the same demonstration. This comparison is made separately for the intuitive and non-intuitive demonstrations. As can be noted in the table, for neither the intuitive nor the non-intuitive demonstrations was there a significant difference between realistic and non-realistic versions in the percentage of correctly recalled outcomes. In general, 95 per cent of all demonstration outcomes were correctly recalled.

Table 2

Percentages of Correctly Recalled Outcomes for Realistic and Non-Realistic Versions of Demonstrations

<table>
<thead>
<tr>
<th></th>
<th>Intuitive Demonstrations</th>
<th>Non-Intuitive Demonstrations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>realistic</td>
<td>non-realistic</td>
</tr>
<tr>
<td>correct</td>
<td>92%</td>
<td>93%</td>
</tr>
<tr>
<td>incorrect</td>
<td>8%</td>
<td>7%</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td># of responses</td>
<td>650</td>
<td>140</td>
</tr>
</tbody>
</table>

Table 3 regroups the data of Table 2 in order to compare the intuitive and non-intuitive demonstrations. This comparison is made separately for the realistic and non-realistic versions. In both versions, the outcomes of the non-intuitive demonstrations were recalled correctly more often than the outcomes of the intuitive. The differences between intuitive and non-intuitive outcomes, although small, were statistically significant in both analyses as summarized in Table 3, page 14.
Table 3
Percentages of Correctly Recalled Outcomes for Intuitive and Non-Intuitive Demonstrations

<table>
<thead>
<tr>
<th></th>
<th>Realistic Demonstrations</th>
<th>Non-Realistic Demonstrations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>intuitive</td>
<td>non-intuitive</td>
</tr>
<tr>
<td>correct</td>
<td>95%</td>
<td>97%</td>
</tr>
<tr>
<td>incorrect</td>
<td>5%</td>
<td>3%</td>
</tr>
<tr>
<td># of responses</td>
<td>650</td>
<td>140</td>
</tr>
</tbody>
</table>

\(X^2 = 4.1, \text{df}=1, P > .05\); \(X^2 = 8.1, \text{df}=1, P < .01\)

(2) Achievement test results. - Achievement test results parallel those just described for recall of demonstration outcomes. Although there are differences between means for realistic and non-realistic treatments, as shown in Table 4, for neither the intuitive nor the non-intuitive demonstrations were these differences significant. Complete analysis of variance results for these comparisons are presented in Tables 4 to 7 in Appendix A.

Table 4
Immediate and Delayed Achievement Test Scores for each of Two Lessons Presented both Realistically and Non-Realistically

<table>
<thead>
<tr>
<th></th>
<th>Intuitive Archimedes' Principle</th>
<th>Non-Intuitive Bernoulli's Principle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate Test</td>
<td>Delayed Test</td>
</tr>
<tr>
<td></td>
<td>Mean S. D.</td>
<td>Mean S. D.</td>
</tr>
<tr>
<td>realistic</td>
<td>15.8 (2.0)</td>
<td>13.9 (2.6)</td>
</tr>
<tr>
<td>non-realistic</td>
<td>14.3 (3.8)</td>
<td>13.4 (3.6)</td>
</tr>
<tr>
<td>analysis of differences</td>
<td>F=3.79 df=1/48</td>
<td>F=.4 df=1/48</td>
</tr>
</tbody>
</table>

*total possible points = 24; **total possible points = 22
(3) **work rate.** Following an intuitive or a non-intuitive demonstration segment presented either in realistic or non-realistic form, all students went through the identical self-paced verbal program (covering the same concepts illustrated by the demonstrations). Time-to-complete each segment was recorded for every student. The sum of such scores for all segments resulted in a work rate score for each participating subject. The work rate scores of subjects who had watched the realistic demonstration were then compared with those of students who had watched the non-realistic demonstrations. This comparison for both the intuitive and non-intuitive demonstrations is summarized in Table 5.

**Table 5**

<table>
<thead>
<tr>
<th>Intuitive</th>
<th>Non-Intuitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archimedes' Principle</td>
<td>Bernoulli's Principle</td>
</tr>
<tr>
<td>realistic</td>
<td>non-realistic</td>
</tr>
<tr>
<td>Mean</td>
<td>S. D.</td>
</tr>
<tr>
<td>34.4</td>
<td>(3.0)</td>
</tr>
<tr>
<td>32.2</td>
<td>(4.0)</td>
</tr>
<tr>
<td>analysis of differences</td>
<td>F=6.03*</td>
</tr>
<tr>
<td>df=1/48</td>
<td>df=1/48</td>
</tr>
</tbody>
</table>

As can be noted in the table, significant differences between treatments resulted. The direction of the differences varied, however, as between the lesson on Archimedes' Principle and the lesson on Bernoulli's Principle. For the "intuitive" lesson on Archimedes' Principle, the animated or non-realistic version of the demonstrations resulted in shorter completion times on the subsequent self-paced verbal program. For the "non-intuitive" lesson on Bernoulli's Principle, the live or realistic version resulted in shorter completion times. The analysis of variance summaries for these comparisons are presented in Tables 8 and 9 in Appendix A.
B. Questionnaire Data

Two item types were employed in the questionnaire administered at the completion of the entire experiment. One type of item was intended to assess the "interest" value of identical demonstrations presented either in realistic or non-realistic versions. The other item type was intended to assess the "credibility" of the demonstration outcomes.

1. interest in trying demonstrations. - Subjects were instructed to indicate their interest in trying demonstrations. The entire questionnaire form (Form A) designed to measure their interest level is reproduced in Appendix A. The beginning portion of the form, including the response options for a sample item, is reproduced in Figure 3.

For each of the experiments which you just saw, put an X in the column which shows whether you would like to try it yourself.

<table>
<thead>
<tr>
<th>Would like to try it very much</th>
<th>Would like to try it</th>
<th>No interest in trying it</th>
</tr>
</thead>
<tbody>
<tr>
<td>blowing air past candle flame</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 3. Sample portion of Form A in the Questionnaire.

A chi-square analysis of the frequencies of endorsements of the three rating categories for all demonstrations resulted in significant chi-square values for both the intuitive and non-intuitive demonstrations (with "very much interested" and "interested" categories combined). Differences between realistic and non-realistic versions varied in direction from intuitive to non-intuitive demonstrations. As noted in Table 6, on page 17, for intuitive demonstrations considerably more interest was expressed in the realistic than in the non-realistic demonstrations. For non-intuitive demonstrations, however, precisely the opposite was found, the magnitude of the
difference being considerably smaller. The non-realistic version drew more positive endorsements than did the realistic version.

Table 6
Ratings of Interest Level for Realistic and Non-Realistic Demonstrations (in percentages)

<table>
<thead>
<tr>
<th></th>
<th>all demonstrations</th>
<th>Intuitive</th>
<th>Non-Intuitive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>realistic</td>
<td>non-realistic</td>
</tr>
<tr>
<td>very much interested</td>
<td>64%</td>
<td>63%</td>
<td>38%</td>
</tr>
<tr>
<td>or interested</td>
<td></td>
<td>36%</td>
<td>62%</td>
</tr>
<tr>
<td>no interest</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td># of responses</td>
<td>734</td>
<td>205</td>
<td>185</td>
</tr>
</tbody>
</table>

\[X^2=30.1, \text{ df}=1, P<.001\]

The data of Table 6 were regrouped to permit a comparison of intuitive and non-intuitive demonstrations. This comparison was made separately for realistic and non-realistic versions. As summarized in Table 7, on page 18, it can be noted that for both the realistic and non-realistic versions, more interest was expressed in the non-intuitive than in the intuitive demonstrations. However, this finding was statistically significant only for the non-realistic version.
Table 7
Ratings of Interest Level for Intuitive and Non-Intuitive Demonstrations (in percentages)

<table>
<thead>
<tr>
<th></th>
<th>all demonstrations</th>
<th>Realistic intuitive</th>
<th>Realistic non-intuitive</th>
<th>Non-Realistic intuitive</th>
<th>Non-Realistic non-intuitive</th>
</tr>
</thead>
<tbody>
<tr>
<td>very much interested</td>
<td>64%</td>
<td>65%</td>
<td>73%</td>
<td>38%</td>
<td>83%</td>
</tr>
<tr>
<td>interested</td>
<td>36%</td>
<td>35%</td>
<td>27%</td>
<td>62%</td>
<td>17%</td>
</tr>
<tr>
<td>no interest</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td># of responses</td>
<td>734</td>
<td>209</td>
<td>185</td>
<td>185</td>
<td>159</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 2.4, df = 1, P > .10 \]

\[ \chi^2 = 69.6, df = 1, P < .001 \]

2 credibility of demonstration outcomes. - Form E of the questionnaire, reproduced in part in Figure 4 below and in its entirety in Appendix A, attempted to get at the reasons for student interest in trying experiments. Options were designed to determine the credibility of demonstration outcomes (and thereby their potential confirmation value).

What reason(s) would you have for trying each of the following experiments yourself?

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Just curious to see how it would come out.</th>
<th>To check to see if it would come out the same way.</th>
<th>Don't believe it would come out the same way.</th>
</tr>
</thead>
<tbody>
<tr>
<td>blowing air past candle flames</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4. Sample portion of Form E of the Questionnaire.
The data of Table 8 summarize the differences in ratings obtained for realistic and non-realistic versions of the demonstrations. Generally, as shown in the table, non-realistic versions were disbelieved more than their realistic counterparts. The differences were small and, only for the intuitive demonstrations was the difference significant.

Table 8
Reasons Endorsed for Wanting to Try
Realistic and Non-Realistic Demonstrations
(in percentages)

<table>
<thead>
<tr>
<th></th>
<th>all demonstrations</th>
<th>Intuitive</th>
<th>Non-Intuitive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>realistic</td>
<td>non-realistic</td>
<td>realistic</td>
</tr>
<tr>
<td>just curious</td>
<td>37%</td>
<td>32%</td>
<td>33%</td>
</tr>
<tr>
<td>to check</td>
<td>63%</td>
<td>64%</td>
<td>44%</td>
</tr>
<tr>
<td>don't believe outcome</td>
<td>6%</td>
<td>4%</td>
<td>23%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td># of responses</td>
<td>660</td>
<td>145</td>
<td>145</td>
</tr>
</tbody>
</table>

X² = 8.7, df = 2, .02 > P > .01
X² = 1.2, df = 2, .50 > P > .30

Regrouping the data of Table 8, it is possible to contrast the reasons endorsed for wanting to try either intuitive or non-intuitive demonstrations. As shown in Table 9, on page 20, the outcomes of non-intuitive demonstrations were disbelieved more often than were outcomes of intuitive demonstrations. This finding was significant and held true whether or not the comparison was made for realistic or for non-realistic versions.
Table 9
Reasons Endorsed for Wanting to Try Intuitive and Non-Intuitive Demonstrations (in percentages)

<table>
<thead>
<tr>
<th>All Demonstrations</th>
<th>Realistic</th>
<th>Non-Realistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>just curious</td>
<td>33%</td>
<td>37%</td>
</tr>
<tr>
<td>to check</td>
<td>53%</td>
<td>63%</td>
</tr>
<tr>
<td>don't believe outcome</td>
<td>13%</td>
<td>0%</td>
</tr>
<tr>
<td># of responses</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td></td>
<td>660</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td></td>
<td>185</td>
</tr>
</tbody>
</table>

\[ \chi^2 = 39.3, \text{df}=2, P < .001 \] \[ \chi^2 = 33.1, \text{df}=2, P < .001 \]

(3) prediction of outcomes if experiments were to be tried by students. - Forms C and D of the questionnaire further attempted to assess the credibility of the experimental outcomes. Form C required subjects to indicate how the experiment would turn out if they tried it. A sample portion of this form is reproduced in Figure 5.

If you tried each of the following experiments yourself, which way do you think they would turn out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

- It would turn out this way.
- It would turn out this way.

blowing air past candle flames

Fig. 5. A sample portion of Form C of the Questionnaire.
Form D went one step further. It indicated how the demonstration turned out on the screen and then asked how the demonstration would turn out if the subject himself tried it. A sample of this form is reproduced in Figure 6.

When these experiments were done on the screen, they came out a certain way. If you did these experiments yourself, which way would they come out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

This is what happened when air was blown past candle flames.

<table>
<thead>
<tr>
<th>It would turn out this way.</th>
<th>It would turn out this way.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6. Sample portion of Form D of the Questionnaire.

Responses on both Forms C and D were categorized as same outcomes or different outcomes (depending on their agreement with the actual outcomes presented on the screen).

The results of Table 10, on page 22, indicate that for intuitive demonstrations, the realistic version led to more predictions (on both Forms C and D) that were in keeping with outcomes presented on the screen. However, the differences are small and only one of them was significant (Form D). For non-intuitive demonstrations, the reverse was true. More predictions based on the non-realistic version were in keeping with demonstrated outcomes. Here, too, only the difference measure obtained was significant (Form C).
Table 10
Predictions of Outcomes for
Realistic and Non-Realistic Presentations
(in percentages)

<table>
<thead>
<tr>
<th>Predictions of Outcomes</th>
<th>Realistic</th>
<th>Non-Realistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Demonstrations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same Outcome</td>
<td>86%</td>
<td>9%</td>
</tr>
<tr>
<td>Different Outcome</td>
<td>14%</td>
<td>9%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Form C</th>
<th>Realistic</th>
<th>Non-Realistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intuitive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same Outcome</td>
<td>76%</td>
<td>8%</td>
</tr>
<tr>
<td>Different Outcome</td>
<td>24%</td>
<td>15%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Form D</th>
<th>Realistic</th>
<th>Non-Realistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Intuitive</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Same Outcome</td>
<td>81%</td>
<td>82%</td>
</tr>
<tr>
<td>Different Outcome</td>
<td>19%</td>
<td>18%</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

The data of Table 10 are regrouped in Table 11 to compare the intuitive and non-intuitive demonstrations. As shown in this latter table, in all four comparisons intuitive outcomes were predicted correctly more often than non-intuitive outcomes. Three of the four comparisons were statistically significant.
Table 11
Predictions of Outcomes for Intuitive and Non-Intuitive Demonstrations (in percentages)

<table>
<thead>
<tr>
<th>Predictions</th>
<th>All Demonstrations</th>
<th>Realistic</th>
<th>FORM C</th>
<th>Non-Realistic</th>
<th>FORM C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>same outcome</td>
<td></td>
<td>intuitive</td>
<td>non-intuitive</td>
<td></td>
</tr>
<tr>
<td></td>
<td>86%</td>
<td>94%</td>
<td>76%</td>
<td>50%</td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td>different outcomes</td>
<td>14%</td>
<td>6%</td>
<td>24%</td>
<td>9%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td># of responses</td>
<td>666</td>
<td>145</td>
<td>194</td>
<td>182</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td>$X^2=22.1$, df=3, $P&lt;.001$</td>
<td></td>
<td>$X^2=3.1$, df=3, $P&gt;.05$</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>same outcome</td>
<td>88%</td>
<td>90%</td>
<td>81%</td>
<td>92%</td>
</tr>
<tr>
<td></td>
<td>different outcomes</td>
<td>12%</td>
<td>2%</td>
<td>19%</td>
<td>8%</td>
</tr>
<tr>
<td></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td># of responses</td>
<td>629</td>
<td>130</td>
<td>185</td>
<td>185</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>$X^2=20.8$, df=3, $P&lt;.001$</td>
<td></td>
<td>$X^2=0.2$, df=3, $P&gt;.01$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
DISCUSSION

The introduction to this report stressed the need in research on visuals of identifying specific functions assigned to visuals in instruction. It is clear from reading the method section of this report that, in this study, visuals have been assigned several functions. They have served to cue responses and to confirm responses. They have also served as a series of examples to promote response generalization (concept acquisition). The experimental variations involving realism and non-realism have not been specific to any one function. There has not been, for example, a variation in the realism of just confirmation stimuli (with all other functions constant -- that is, all realistic or all non-realistic). The experimental variations in the realism of the presentation have involved all functions. In the non-realistic version, for example, cues, confirmation, and examples were all non-realistic. In the light of this variation in realism for an amalgam of functions, can useful generalizations about realism or non-realism be drawn from the results?

The live (on tape) visual demonstrations used in this study were programmed. This means that visuals were assigned specific functions to fulfill. The program was tried out empirically and revised. The result of this entire procedure was a visual program that produced a low error rate (on response practice items built into the presentation). Within such a tried out program, visual stimuli could be judged to have fulfilled their designated functions adequately, whether as cues, as confirmation, or as examples.

Comparing an animated or non-realistic version of the program with the live or realistic original makes it possible to assess any deterioration in effectiveness (e.g., in error rates) that might result from altering the realistic character of the presentation. While it is true that such a comparison does not attest specifically to the adequacy of non-realistic visuals as cues or of non-realistic visuals as confirmation, etc., it can attest to any change in adequacy of an entire program in which specific functions (in combination) had been previously judged to be adequately fulfilled. Any evidence of deterioration would be a clear indication of the need for a
separate, analytic study of the effect of non-realism on each function. However, error rates for the realistic and non-realistic versions of the visual program were negligible and non-significantly different. Achievement data, while also dependent on the self-paced, verbal programs that were taken by groups receiving either the realistic or the non-realistic versions of the visual demonstrations, also indicate that there were no significant differences between the two groups. Recall of demonstration outcomes also yielded no significant differences between realistic and non-realistic versions.

These achievement data suggest no deterioration in effectiveness from the original live visual demonstration as a result of their presentation in animated or non-realistic form. The capacity of visuals in either mode to serve as cues or as examples should come as no particular surprise. Through experience in the classroom, the theater, or at home in front of the television screen, responses to live events are likely to have generalized not only to filmed or taped representations of them but also to animated representations. The effectiveness of non-realistic presentations in generating understanding might more readily be called into question for those who have not yet had experience with filmed or animated representations of real events. This, of course, means the very young, the disadvantaged, or those in other cultures. But, even in our own culture, and for age groups that have had experience with "representations" of real events, there might be some question whether non-realistically presented demonstration outcomes would have the capacity to confirm responses.

As Cropper (1963) has suggested, visual events come, after a long series of experiences, to confirm the adequacy of our behavior (that we have tied out shoes properly or shaved well, etc.). Visuals are thus presumed to acquire a generalized confirming property. They also confirm the outcomes of others' behaviors and indeed of inanimate events (e.g., science demonstrations). Whether non-realistic, visual events have the same capacity to confirm is what this study has attempted to assess.

The achievement data suggesting no deterioration in effectiveness of the live, original version as a result of its transformation into an animated version could not provide specific evidence of the confirmation adequacy of
of non-realistically presented demonstration outcomes. Achievement data were, as pointed out above, the product of the adequacy of the entire visual presentation in all its functions. Additionally, they were the product not only of the visual presentation but also of the same self-paced, verbal program used in both the realistic and non-realistic treatments. Other data, however, including the questionnaire results, while not providing evidence as to how well the confirmation function was actually fulfilled, are more specifically relevant to the potential value of non-realistic events in providing confirmation.

In questionnaire data and in work rate data for the self-paced, verbal programs, there were differences between the realistic and non-realistic treatment groups. These differences were, however, not simply a function of the realism of the demonstrations. They were in part a function of their intuitiveness. Disbelief was expressed more often for outcomes of the non-intuitive demonstrations. One of the outcomes contrary to prior experience was, for example, candle flames bending toward rather than away from blowing air. Prior experience is more likely to have confirmed that blowing air past a flame is likely to cause it to flicker or that blowing air at an object is likely to cause it to move away from the air. Candle flames moving toward the blowing air is counter to everyday experience. This being the case, non-intuitive visual events may to some extent lose their capacity to confirm student predictions of outcomes. When this does in fact occur, the confirming capacity of the teacher presenting the demonstration may acquire greater importance.

In general, the dimension of intuitiveness appears to have played a more potent role than the dimension of realism. The outcomes of non-intuitive demonstrations were recalled correctly more often than those of intuitive demonstrations. More interest was expressed in wanting to try the non-intuitive experiments. The outcomes of the non-intuitive demonstrations as shown on the screen were disbelieved more often and were more often predicted as likely to be different if students themselves tried them.

Although, in general, students expressed more interest in wanting to try the non-intuitive demonstrations, they were somewhat less likely to want to do so if they had seen it in its realistic version. Interest in
wanting to try the intuitive demonstration, on the other hand, was less likely to be expressed if students had seen the non-realistic version.

Worthy of note is the variation in the magnitude of the differences in expressed interest for the intuitive and non-intuitive demonstrations. The differences between them were sizeable and significant (45%) when the non-realistic versions of the two are compared. The differences between them are considerably smaller (only 8%) and not significant when the realistic versions of the two are compared. Interest in wanting to try experiments was roughly comparable for intuitive and non-intuitive experiments when they were presented realistically. When presented non-realistically, interest in the intuitive experiments dropped sharply.

As to obtained data that might account for this pattern of results, the overall differences observed between realistic and non-realistic versions were small. Those differences that are significant suggest that the credibility of non-realistic versions was questioned more often for intuitive than for non-intuitive demonstrations. This would hardly account for the considerably smaller interest expressed in wanting to try non-realistically presented intuitive demonstrations. Generally, non-realistic presentations led to more disbelief, but this appears to affect intuitive demonstrations more. Disbelief about non-intuitive outcomes appears to be held in abeyance somewhat more when they are non-realistic.

Work rate data (on the self-paced verbal programs administered after each visual segment) also reflect an interaction between intuitiveness and realism. Significantly less time was spent on the program when (a) the demonstration was realistic and non-intuitive; and (b) when it was non-realistic and intuitive. This kind of interaction was identical with that found for questionnaire data reflecting disbelief in outcomes. Although there was no rating of the interest level of the demonstrations per se (only a rating of interest in wanting to try the experiment), the combined work rate data and "disbelief" data might suggest greater interest in the presentation itself as an explanation. Students appear to have worked faster on the verbal material following the visual demonstrations they "disbelieved" more. While time-to-complete is traditionally thought of as a measure of learning, it is also plausible that it may reflect interest.
The relationship is likely to be inverse. Thus, while there is no striking evidence in these data that non-realistic presentations cannot confirm acquisition behavior, there is some evidence to suggest, that realistic or non-realistic presentations may have the capacity to reinforce attending behaviors. This capacity appears to depend, however, on the degree of intuitiveness of the material.
CONCLUSION

Overall, the magnitude of the differences obtained between realistic (live) and non-realistic (animated) demonstrations was small compared to the magnitude of the differences obtained between intuitive and non-intuitive demonstrations. Outcomes of non-intuitive demonstrations were recalled correctly more often than those of intuitive demonstrations. The outcomes of non-intuitive demonstrations were also disbelieved more often. Paralleling these findings, it should be noted, more interest was expressed in wanting to try the non-intuitive experiments. These data suggest that non-intuitive outcomes may have had less capacity to confirm student predictions of experimental outcomes than intuitive outcomes.

Differences between intuitive and non-intuitive demonstrations were, however, not unaffected by the mode of presentation. Significant interactions were observed between the intuitiveness of the demonstration and the realism (or non-realism) of the presentation. When both were presented realistically, small and non-significant differences in interest level were observed between intuitive and non-intuitive demonstrations. On the other hand, when both types were presented non-realistically, the interest level (in wanting to try the experiments) in the non-intuitive demonstrations was significantly and substantially greater.

Looking at the intuitive demonstrations alone, students expressed more interest in wanting to try them if they had seen them presented realistically. The converse was true for non-intuitive demonstrations. Students were more apt to want to try them if they had seen the non-realistic version. Other data, however, suggest that interest levels during the presentation may have been the reverse of those just noted (e.g., suggested by time-to-complete data). During the presentation, students, it is interpreted, were more interested in the animated intuitive demonstrations and in the live, non-intuitive demonstrations. These latter types may therefore have been more successful in reinforcing immediate attention. What exactly provided the reinforcement may have been different. In the one instance it was likely to have been the non-intuitive nature of the outcome. In the other case, it may have been the mode of presentation (animation).
The most clear-cut pattern of interaction found in this study is summarized in the figure below.

<table>
<thead>
<tr>
<th></th>
<th>live</th>
<th>animated</th>
</tr>
</thead>
<tbody>
<tr>
<td>intuitive</td>
<td>Future interest in trying experiments</td>
<td>interest during presentation</td>
</tr>
<tr>
<td></td>
<td>interest during presentation</td>
<td>future interest in trying experiments</td>
</tr>
<tr>
<td>non-intuitive</td>
<td>interest during presentation</td>
<td>future interest in trying experiments</td>
</tr>
</tbody>
</table>

The differences between realistic and non-realistic presentations appear to depend on the intuitiveness of the phenomena presented. Thus, it appears that content (degree of intuitiveness of outcomes) as much as, or perhaps more than, the mode of presentation may be relevant for the capacity to confirm student predictions or to reinforce attending behaviors. Since, in this study, there was only one instance each of intuitive and non-intuitive demonstrations, replication is clearly in order. There does appear to be an interaction between realism and intuitiveness, but only with replication can the reliability of the apparent interactions be more clearly ascertained.
AN EXPERIMENTAL EVALUATION OF THE INSTRUCTIONAL EFFECTIVENESS OF LITERAL AND NON-LITERAL DEMONSTRATIONS
Science demonstrations may be used as a series of examples in order to facilitate response generalization. In teaching concepts and principles, they are often used in precisely this way and, indeed, concept acquisition is contingent on the use of a series of examples, either in a visual or verbal mode. When they are visual, they may be presented either realistically or non-realistically (see Study No. 1 in this report). Another dimension along which visual examples may vary, is the literalness with which they represent the concept to be taught (Gropper, 1963). Examples may literally represent a principle (as when an object is shown to expand when heated). The principle concerning the relationship between heat and expansion may also be non-literally represented. The effect of expansion may be shown rather than expansion itself (as when a heated ball no longer passes through a ring).

The purpose of the present experiment is to assess the effect the literalness of examples may have on the ease with which concepts are acquired.

METHOD

Design of Experiment

Independent variables. - Two lessons were prepared for presentation on television; one covered phenomena having to do with "surface tension," the other "heat and molecular action." Each of the two lessons was prepared in two versions: one version contained examples that directly or literally illustrated the concept being taught; a second version contained non-literal examples that indirectly illustrated the same concepts. Each lesson, in whichever version, was segmented into several fixed-paced TV units, and these units were serially intermixed with a verbal self-paced unit covering the same material as was covered in the preceding fixed-paced visual unit. This arrangement is summarized in Figure 1, on page 32.
Lesson #1
HEAT AND MOLECULAR ACTION

Lesson #2
SURFACE TENSION

Figure 1
As can be seen from an inspection of the table, the independent variable studied is the directness or indirectness of the visual examples. The use of two lessons merely serves to provide replication.

The design of the experiment may be summarized as follows:

<table>
<thead>
<tr>
<th>Group I</th>
<th>Group II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lesson 1: direct</td>
<td>Lesson 1: indirect</td>
</tr>
<tr>
<td>Lesson 2: indirect</td>
<td>Lesson 2: direct</td>
</tr>
</tbody>
</table>

Dependent variables. - Dependent variables consisted of such learning measures as time-to-complete the self-paced verbal program, errors on the program, and achievement test scores.

Procedures

The schedule below indicates the time intervals between the administration of the several instructional and evaluation materials used in this study. All participating classes adhered to the schedule with minor variations occurring for those schools previously committed to other school activities.

Week 1 - in the schools:

1. Administration of pretests.
2. Administration of a program on "Learning From a Program."

Week 2 - in the schools:

1. Administration of a self-paced preliminary program on "Atoms and Molecules" (concepts necessary to an understanding of the experimental programs).

Week 4 - in the studios of WQED:

1. Simultaneous administration of the direct and indirect versions of each of the two experimental programs (on "heat" and on "surface tension").
(2) Administration of an identical self-paced verbal program to both experimental groups; verbal programs covered the same concepts illustrated by the televised demonstrations and were serially intermixed with the demonstrations.

(3) Administration of an immediate posttest.

Week 7— in the schools:

(1) Administration of a retention test (identical with the original test).

Experimental Materials

As can be noted in the above schedule, the instructional materials for this study included two pre-experimental self-paced programs administered in the schools and two experimental programs administered over closed-circuit TV in the studios of WQED and (simultaneously) in a banquet room of an adjacent hotel.

Pre-experimental materials. - The two programs administered before the conduct of the main experiment were designed to fulfill two different functions. One, entitled "Learning From a Program" was designed, as its title suggests, to familiarize subjects with the mechanics of going through a program and of profiting from the program. The program is reproduced in its entirety in Appendix A, page 44. The second pre-experimental program dealing with "atoms and molecules" is reproduced in Appendix B, page 31. Its primary purpose was, in addition to providing additional familiarization with "programs," to bring participating subjects up to a common level of prior knowledge, knowledge judged to be necessary for successful work in the main experimental programs. Both preliminary or pre-experimental programs, as well as both self-paced verbal programs used in the main experiment, were prepared in the REP style of programming developed by Gropper (1965b). A brief rationale for this style appears in Study No. 1, beginning on page 8.

Main experimental materials. - The visual portions of the lessons on "heat" and on "surface tension" were programmed in the style developed by Gropper (1965b). This is described in Study No. 1, page 9. Briefly, the programming approach used calls for discrimination practice with concrete
events (and minimal use of language) as a means of teaching concepts and
principles. When language is used, it is concrete and describes rather
than explains what is occurring. The explanation (the principle) is
acquired inductively through discrimination practice based on a series
of visual (concrete) examples.

The visual, demonstration segments of each of the two lessons were
prepared in two versions. In one version, examples were direct. In the
other, they were indirect. The differences between the two can be
illustrated by describing demonstrations used in the lesson on surface
tension. The fact that "liquids tend to shrink" was demonstrated in the
direct version by: a wet spot on a smooth surface becoming smaller and
occupying less area; soap film in a funnel getting smaller, etc. The same
tendency of liquids to shrink was illustrated in the indirect version by
its effects. When dipped in water and then removed, the bristles of a paint
brush or the fibres of a fur piece cling more tightly to each other (as a
result of the tendency of liquids to shrink). While in the literal version
the fact or principle was directly illustrated, in the non-literal version
it was illustrated by consequences it had for other phenomena. One impon-
tant feature of the visual program was the animation of phenomenon, invisible
in nature, as direct examples. Moving molecules was one such an instance.

Before the demonstrations were recorded on TV tape, they were tried
out live with subjects drawn from the target population (the eighth grade).
They were revised until relatively low error rates (on problems posed in
visual work books) were low, approximately 10-15 per cent. (See Appendix
B for copies of the answer books.)

Verbal, self-paced programs were similarly tried out and revised.
These programs, reproduced in Appendix B, pages 1 and 12, were serially
intermixed with and were identical for both the direct and indirect visual
demonstrations.

Dependent Measures

The achievement tests used to assess student knowledge before, immedi-
ately after, and three weeks after the administration of the experimental
lessons are reproduced in Appendix B, pages 28-30. Time-to-complete the
self-paced materials that followed each visual demonstration was also
recorded.
Subjects

Three eighth grade classes drawn from City and Parochial schools participated in the study. Students from each class were assigned at random to each of the two treatment conditions.
RESULTS

Matching Measures

At the completion of the experiment, students who had been assigned at random to experimental treatments were matched for IQ and Work Rate on pre-experimental programs. Only matched cases were selected for the analysis of data, so that the variables IQ and Work Rate could be treated as independent variables, each at two levels. There resulted a 2x2x2 design for data analysis, representing two levels each of IQ and Work Rate and the two experimentally manipulated conditions (direct vs. indirect examples). The results of the matching procedure are summarized in Table 1, which is based on eight cases per cell, for a total of 64 cases.

Table 1

<table>
<thead>
<tr>
<th>GROUP 1</th>
<th>GROUP 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct: Heat</td>
<td>Indirect: Surface Tension</td>
</tr>
<tr>
<td>IQ</td>
<td>Protest</td>
</tr>
<tr>
<td>Fast</td>
<td>128</td>
</tr>
<tr>
<td>Slow</td>
<td>126</td>
</tr>
<tr>
<td>Direct: Surface Tension</td>
<td>Indirect: Heat</td>
</tr>
<tr>
<td>IQ</td>
<td>Protest</td>
</tr>
<tr>
<td>Fast</td>
<td>115</td>
</tr>
<tr>
<td>Slow</td>
<td>113</td>
</tr>
</tbody>
</table>

*results reported as means; **time-to-complete in minutes

The table shows that there was a separation of approximately 12 IQ points between high and low IQ groups. This difference was statistically significant at the .001 level, as shown in Table 1 in Appendix B. Table 1, both in the text and in the Appendix also, shows that there was not a significant difference in IQ either between experimental treatments or between Work Rate levels. Similar results for Work Rate can be found in text Table 1 and in Appendix B, Table 2. Fast and slow levels were significantly different on Work Rate at the .001 level. No significant differences were found.
for Work Rate between the remaining cells of the design. Table 1 also records Pretest scores for each of the eight experimental cells. Appendix B, Table 2, records no significant differences between cells on Pretest scores.

Dependent Measures

The results of all comparisons between groups receiving direct and indirect examples are summarized in Table 2.

Table 2
Summary Comparison of Means on Dependent Measures for Groups Receiving Direct and Indirect Versions of Visual Lessons

<table>
<thead>
<tr>
<th></th>
<th>Direct Mean (S.D.)</th>
<th>Indirect Mean (S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of correct responses on visual program*</td>
<td>11.6 (0.6)</td>
<td>11.5 (0.7)</td>
</tr>
<tr>
<td># of errors on verbal program**</td>
<td>4.1 (3.9)</td>
<td>2.1 (2.6)</td>
</tr>
<tr>
<td>time-to-complete verbal program (in minutes)</td>
<td>31.7 (4.8)</td>
<td>33.7 (8.2)</td>
</tr>
<tr>
<td>immediate posttest+++</td>
<td>15.5 (2.7)</td>
<td>15.6 (3.1)</td>
</tr>
<tr>
<td>retention test+++</td>
<td>13.5 (4.0)</td>
<td>13.6 (3.9)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Direct Mean (S.D.)</th>
<th>Indirect Mean (S.D.)</th>
</tr>
</thead>
<tbody>
<tr>
<td># of correct responses on visual program*</td>
<td>10.8 (1.3)</td>
<td>11.4 (1.1)</td>
</tr>
<tr>
<td># of errors on verbal program**</td>
<td>2.1 (2.9)</td>
<td>3.8 (3.8)</td>
</tr>
<tr>
<td>time-to-complete verbal program (in minutes)</td>
<td>19.7 (4.0)</td>
<td>18.8 (3.1)</td>
</tr>
<tr>
<td>immediate posttest+++</td>
<td>9.3 (2.8)</td>
<td>9.0 (3.3)</td>
</tr>
<tr>
<td>retention test+++</td>
<td>5.9 (2.8)</td>
<td>6.3 (2.9)</td>
</tr>
</tbody>
</table>

*total number of responses possible on visual "heat" program = 12; on visual "surface tension" program = 13
**total number of responses possible on "heat" program = 76; on "surface tension" program = 61
***total number of points possible on "heat" test = 22; on "surface tension" test = 16
*significance at the .05 level; **significance at the .01 level

The significant differences are underlined and starred; the variance analyses for all comparisons appear in Appendix B.
Although there were statistically significant differences in errors on the verbal program, the direction was reversed on the two different programs. More important, however, was the fact that on neither program did the error rate approach 10 per cent. Thus, as can be noted in the table, few statistically significant differences were obtained. Of those obtained, all were of negligible magnitude and appear to be of little practical importance.
DISCUSSION

In Study No. 1, it was suggested that for the acquisition of concepts, the mode of lesson presentation (realistic or non-realistic) was not nearly so important as other characteristics of its content. The intuitiveness or familiarity of lesson content appeared to be more crucial. Here, too, other content considerations may be as important in influencing the ease of concept acquisition as the directness or indirectness of examples.

By concept acquisition we mean that the learner acquires a generalized response to a class of objects or events. Concepts, such as "liquids shrink" or "molecules move faster when heat is applied to objects" are the kinds of response generalizations required of students watching a series of science demonstrations. For such generalization to occur, the learner must be able to recognize and respond to the similarities among the objects or events. Acquiring the concepts on the basis of visual examples is likely to require some form of verbal mediation, particularly if this kind of visual lesson is to facilitate transfer to verbal lessons that follow it (Gropper, 1965a). It is to the essential similarities of the visual example that mediating verbal responses have to be made if response generalization is to occur.

As Gropper (1963) has pointed out, most visual examples can bear either a structural and/or functional similarity to one another. To illustrate: all examples illustrating the expansion that follows the application of heat, are functionally or conceptually similar. They all illustrate the relationship between heat and expansion. Structurally, that is, in terms of the physical events presented, they may be highly dissimilar, e.g., water rising in a tube, a balloon filled with air inflating, cracks in railroad tracks widening, a ball no longer passing through a ring, a thermostat bending, etc. These structural characteristics of events are highly visible and are dissimilar. Despite their relevance to the concept to be learned, their dissimilarity may interfere with response generalization to the less superficial and critical functional or conceptual features (the expansion of the matter involved). The greater the dissimilarity among the superficial, structural events or attributes of objects, the more likely
is interference with response generalization to the functional characteristics to occur.

The highest degree of similarity is, of course, identity. This, too, creates problems, for we wish responses to generalize to all members of a class. Solids, liquids, gases -- in all shapes, sizes, colors, etc., expand when heated. With insufficient variation in these attributes, generalization is likely to be limited. The problem thus arises in using visual examples of arriving at a proper balance: how to achieve sufficient variation and at the same time sufficient similarity. It is in the reconciliation of this problem that words, as mediators, can play one of their most effective roles in audio-visual instruction.

In direct examples, structural and functional (conceptual) properties coincide. Expanding objects directly illustrate the principle that heat leads to expansion; submerged objects result in reduced scale readings directly illustrating the principle that there is an "apparent" loss of weight when objects are weighed in water; rubber balls or sponges spring back to shape when stresses are removed, directly illustrating what happens to perfectly elastic bodies when stresses are removed; etc. Since structural and functional properties do not diverge, there is no barrier to response generalization to the functional or conceptual properties. This is not to say, however, that within a series direct examples will not be dissimilar. The depressed rubber ball or a squashed sponge or a stretched metal coil all will return to their original shape. But there are physical differences among them which may obscure the fact that all are variations of a single concept, i.e., that they return to their original shape. So that all are recognized as instances of a class, the essential relevant similarities may have to be pointed out (in words). Only then is response generalization likely to occur.

In indirect examples structural and functional properties diverge from one another. Water may rise in a tube after it is heated, a ball no longer passes through a ring, and a balloon inflates when air expands. Or, as in this study, the hairs of a brush may cling together as a result of being dipped in water. The student thus sees the result of water shrinking, rather than seeing the actual shrinking. For indirect examples to lead to
efficient response generalization, two things are required: (a) the connection between structural and functional properties must be recognized; and (b) as is also the case for direct examples, similarity among examples must obtain. Even though they are indirect, examples can be highly similar. When this is so, the only barrier to response generalization is establishing the connection between structural and functional properties. Words can serve a mediating role in this regard.

Although there is no immediate evidence available in this study bearing on the problem, it is perhaps important that if examples are direct, all examples be direct; if indirect, that all be indirect. Such was the case in the present study. Within a series of examples, all direct or all indirect, it is also probably important that the relevant features that are similar be highly visible (i.e., easily responded to) so that generalization can occur.

A review of the examples used in the present study indicates that the direct version of the lesson contained examples that were similar to one another. The indirect version also contained examples that were similar to one another. Thus, although there was no measure of similarity and it is likely to be a difficult measurement problem to achieve one, both versions may be said to have had a fairly high degree of internal similarity. The two versions were different then only with respect to the need for a connection to be made between structural and functional properties in the indirect version.

Based on the foregoing analysis, one might expect concept acquisition to have been more difficult for the indirect version. In this version the connection between structural and functional properties had to be established. In the direct version, the connection was already established. However, differences were not observed between the two versions.

Under what kinds of circumstances might one expect direct and indirect examples to be equally effective? This would seem likely to occur: (1) when there is an approximately equal degree of internal similarity within the series of direct and within the series of indirect examples; and (2) when, in the indirect version, students have available the verbal response needed to mediate the connection between the effects they see and the
concept the effects indirectly represents. In the present study, there was no measure of internal similarity and, indeed, measuring it represents, it would seem, a particularly difficult scaling problem. Future research on visual examples will, it seems clear, have to come to grips with this problem. As to the second point, concerning availability of mediating verbal responses, this too was not assessed quantitatively. If a judgment were to be made, it would be that by virtue of the particular events chosen to illustrate both heat and surface tension concepts, mediating verbal responses of relatively high strength were probably available. This fact may have accounted for the results obtained.
CONCLUSION

The discussion of direct and indirect examples used to teach concepts in this study has centered on three properties of examples: (a) the convergence or divergence of structural and functional characteristics of examples; (b) the degree of internal similarity among examples within a series of examples illustrating a concept; and (c) the availability of mediating verbal responses.

In direct examples, there is a high degree of convergence between the structural or physical properties of examples and their functional or conceptual properties. This means that the physical events directly illustrate the concept (e.g., expanding objects directly illustrate the relationship between heat and expansion). In indirect examples, there is a divergence between the two sets of characteristics. The heated ball no longer passing through a ring indirectly represents the concept of expansion (expansion itself is not shown). Because of this divergence of structural and functional characteristics in indirect examples, we might expect response generalization (to the functional characteristics) to occur less readily than in a situation employing direct examples where the two sets of characteristics coincide. The latter instance highlights the practical value that animation may have in being able to present directly what would otherwise have to be represented indirectly (e.g., increased molecular movement in animation rather than the external consequences of it). In the case of indirect examples, however, the availability of verbal responses to mediate the connection between structural and functional characteristics of examples may render indirect examples as "easy" as direct ones.

Achievement data, based on lesson materials used in this study, revealed no differences between lesson versions using direct and indirect examples. It was suggested in explanation that perhaps other properties of examples may play an equally important role than directness/indirectness. The series of direct examples used in the study possessed a high degree of internal similarity. The same was true for the indirect examples. Because response generalization depends on the ability to respond to the relevant, critical features of a class of events, similarity among such features facilitates its occurrence. The degree of example similarity was not measured in this
study, and accordingly no quantitative comparison is possible. Thus whether
the series of direct and the series of indirect examples bore equal degrees
of internal similarity remains quantitatively unknown. They were, however,
both judged to possess a higher degree of internal similarity. A more
crucial test of the relative effectiveness of using direct or indirect
examples would appear to depend on the availability of quantitative measures
of internal similarity. Similar considerations merit attention in the case
of the availability of mediating, verbal responses.

Audio-visual research on and practical efforts to foster concept acqui-
sition, it seems clear, must concern itself with properties of visual examples,
that influence response generalization. It is suggested that these include:
(a) the degree of similarity among examples; (b) the directness or indirect-
ness of examples and (c) the degree of availability of mediating verbal
responses. Some of these may be capable of quantitative treatment (e.g.,
perceived similarity). Others may be more profitably studied through logical
analysis (e.g., the relationship between concept and example used to illus-
trate it). In either case, needed information will be gathered about vari-
ables affecting an important role visuals play in instruction: examples
serving to facilitate concept acquisition.
REFERENCES


## APPENDIX A

### Archimedes' Principle and Bernoulli's Principle
(Study No. 1)

<table>
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<td>2. Bernoulli's Principle</td>
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<td>2. Force Program</td>
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<td></td>
<td>A-56</td>
</tr>
</tbody>
</table>
ARCHIMEDES' PRINCIPLE*

1. A wagon moves toward the left when you push it toward the
   left     right
   ________  ________  ________
   X

   You would make the wagon move in the opposite direction if you applied a force toward the
   left     right
   ________  ________  ________
   ________  ________  ________
   ________  ________  ________

2. If you push a box toward the NORTH, while someone else pushes a box toward the SOUTH, the two forces applied to the box are
   in the same     in opposite
   ________  ________  ________
   ________  ________  ________
   ________  ________  ________

3. One boy applies a force to the East while another boy applies a force to the West.

   NEXT THIS SENTENCE
   The forces are applied in the same direction.

   If correct, copy the underlined words.
   If incorrect, change the underlined words.

   THE FORCES ARE APPLIED IN OPPOSITE DIRECTIONS.

4. If you push a wagon with a 15-lb. force and someone else pushes the wagon with a 15-lb. force, the two forces applied to the wagon are
   not equally strong     equally strong
   ________  ________  ________
   ________  ________  ________
   ________  ________  ________

5. For each of the following examples, write E if the forces are equally strong. Write N if the forces are not equally strong.

   A 14-lb. force     A 22-lb. force
   & a 36-lb. force   & a 22-lb. force
   ________  ________
   ________  ________
   ________  ________

   N
   N

   A 92-lb. force
   & a 67-lb. force
   ________
   ________
   ________

   N

6. Make up a sentence using the words below. You may use any other words in addition to the words below, but make sure your sentence includes all of the words below.

   a 35-lb. force     A 35-lb. FORCE AND A
   a 21-lb. force     21-lb. FORCE ARE NOT
equally strong     EQUALLY STRONG.

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.
7. 
EDIT THIS SENTENCE
A 300-lb. UPWARD force and a 200-lb. DOWNWARD force are in the same direction and are equally strong.

If correct, copy the underlined words.

If incorrect, change the underlined words.
IN OPPOSITE DIRECTIONS AND ARE NOT EQUALLY STRONG.

8. 
Make up a sentence using the words below. You may use any other words in addition to the words below, but make sure your sentence includes all of the words below.
5-lb. downward force
9-lb. downward force
direction
strong

A 5-LB. DOWNWARD FORCE AND A 9-LB. DOWNWARD FORCE ARE IN THE SAME DIRECTION, BUT ARE NOT EQUALLY STRONG.

9. 
When two forces are in opposite directions and are also equally strong, we say that the forces are balanced.

Which of the following is an example of balanced forces?
One boy applies a 34-lb. force to the left and another boy applies a 41-lb. force to the right.
One boy applies a 26-lb. force to the left and another boy applies a 26-lb. force to the right.

X

10. 
Which of the following is an example of balanced forces?
a 49-lb. upward force and a 16-lb. downward force

a 21-lb. upward force and a 21-lb. downward force

X

11. 
A force toward the North and a force toward the South are applied to a wagon. The two forces are balanced if they are equally strong not equally strong

X

12. 
In order to be called balanced, two forces have to be both equally strong and also in opposite directions.
Two 59-lb. forces applied to a box are balanced if one force is toward the left and the other is toward the right.

X

13. 
Which of the following is an example of balanced forces?
two 300-lb. upward forces and a 700-lb. downward force

two 300-lb. upward forces and a 700-lb. downward force

X
14. Two 400-lb. forces are applied to a boat. These two forces are balanced only if they are in the same direction opposite directions

X

15. A 38-lb. force to the left and a 38-lb. force to the right are applied to a wagon. The forces are only equally strong only in opposite directions

equally strong and also in opposite directions

X

Therefore, we say that the forces are balanced not balanced

X

16. When two forces are equally strong and also in opposite directions, we say that the forces are balanced unbalanced

X

17. Two people are applying balanced forces to a wagon. If we know that one person applies a 19-lb. force toward the left, we know that the other person applies a 25-lb. force to the right

19-lb. force 25-lb. force to the left to the right

X

18. Two balanced forces are applied to a ball. If we know that one of the forces is 2 lbs. toward the right, we know that the other force is 2 lbs. toward the left.

19. A 3-lb. force to the South is applied to a table. Tell how you would apply a force so that balanced forces would be applied to the table.

APPLY A 3-LB. FORCE TO THE NORTH.

20. In order for us to say that two forces are balanced, the forces only have to be in opposite directions only have to be equally strong

have to be both in opposite directions and also be equally strong

X
21. EDIT THIS SENTENCE

A 37-lb. upward force and a 37-lb. downward force applied to a table are not balanced forces.

If correct, copy the underlined words.

If incorrect, change only the underlined words.

BALANCED FORCES

22. Make up a sentence using the words below.

Two forces are balanced if one is 5 lbs. to the West and the other is 5 lbs. to the East.

23. Make up a sentence using the words below.

Balanced forces are equally strong and in opposite directions.

24. When two forces are not balanced, we say that the forces are unbalanced.

For each example below, write B if the forces are balanced. Write U if the forces are unbalanced.

Two opposite forces are applied. One is 16 lbs. and the other is 13 lbs. A 23-lb. force is applied toward the left and a 23-lb. force is applied toward the right.

25. A 17-lb. force is applied toward the East and a 28-lb. force is applied toward the West.

The forces are equally strong not equally strong

Therefore, we say the forces are balanced unbalanced

26. Two 39-lb. forces are both applied toward the South.

The forces are in opposite directions in the same direction

Therefore, we say that the two forces are balanced unbalanced

27. For each example below, write B if the forces are balanced. Write U if the forces are unbalanced.

Two 36-lb. A 49-lb. force to the South and a 49-lb. force to the North are applied.

A-4
28. A 14-lb. force to the East and a 25-lb. force to the East are applied to a box.

The forces are not equally strong and ALSO in the same direction.

Therefore, we say that the forces are balanced.

X

29. A 37-lb. upward force and a 45-lb. downward force applied to a table are unbalanced forces.

If correct, copy the underlined words.

UNBALANCED FORCES

If incorrect, change only the underlined words.

X

30. For each example below, write B if the forces are balanced. Write U if the forces are unbalanced.

A 30-lb. force is applied toward the left and a 30-lb. force is applied toward the right.

U B

A 67-lb. force and a 45-lb. force are applied toward the right.

U U

31. For each example below, write B if the forces are balanced. Write U if the forces are unbalanced.

Two equally strong forces are applied in the same direction.

U B

Two forces are in the same direction and are not equally strong.

U U

32. Make up a sentence using the words below.

two 700-lb. forces
Two 700-lb. forces are applied in the same direction and are unbalanced.

U U
33. Make up a sentence using the words below.
   two forces  TWO FORCES IN
   opposite directions  OPPOSITE DIRECTIONS
   unbalanced if  ARE UNBALANCED IF
   stronger  ONE FORCE IS STRONGER.

34. A 60-lb. force to the NORTH and a
   60-lb. force to the SOUTH are applied
   to a boat. We say that the two forces
   are BALANCED because they are EQUALLY
   STRONG AND IN OPPOSITE DIRECTIONS.

35. Two boys are applying BALANCED forces to
   a bicycle.
   Make up an example of two forces which the
   boys might be applying to the bicycle, using a specific number of lbs. and a
   specific direction for each of the two

   ONE BOY APPLIES A 35-LB. FORCE TO THE
   LEFT AND THE OTHER APPLIES A 35-LB.
   FORCE TO THE RIGHT.

36. A wagon will remain at rest, even when
   two boys are pushing it, if the boys are
   applying balanced forces.
   However, if the boys apply forces which
   are unbalanced, the wagon will
   start to move  remain at rest
   X  ___  ___

37. Two boys both push a table toward the
   left. One boy applies a 16-lb. force
   and the other boy applies a 23-lb. force.
   The table will
   remain at rest  start to move
   ___  ___
   The reason for this is that the forces are
   balanced  unbalanced
   ___  ___
   ___  ___

38. When two boys on the same side of a wagon
   pull equally hard in the same direction, the
   wagon
   starts to move  remains at rest
   ___  ___
   X  ___
   The reason for this is that the forces are
   balanced  unbalanced
   ___  ___
   ___  ___

39. Two people are pushing on opposite sides
   of a swinging door. If one person pushes
   harder than the other, the door will
   remain at rest  open
   ___  ___
   ___  ___
   X  ___
   The reason is that the forces are
   balanced  unbalanced
   ___  ___
   ___  ___
40. A car parked on a hill will start to move whenever the forces applied to it are

<table>
<thead>
<tr>
<th>balanced</th>
<th>unbalanced</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

41. A 40-lb. force to the left and a 40-lb. force to the right are applied to a wagon. The wagon starts to move or remains at rest.

The reason for this is that the forces are

<table>
<thead>
<tr>
<th>balanced</th>
<th>unbalanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

42. When two boys push a box equally hard in opposite directions, the box remains at rest or starts to move.

The reason is that the forces are

<table>
<thead>
<tr>
<th>balanced</th>
<th>unbalanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

43. When two forces are applied to a wagon but the wagon remains at rest, we know that the two forces are

<table>
<thead>
<tr>
<th>balanced</th>
<th>unbalanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

44. Two boys playing tug-of-war are applying unbalanced forces to a box. The box will remain at rest or start to move.

<table>
<thead>
<tr>
<th>remain at rest</th>
<th>start to move</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

45. When two balanced forces are applied to an object, the object starts to move or remains at rest.

<table>
<thead>
<tr>
<th>starts to move</th>
<th>remains at rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

46. When two equally strong forces are applied to an object in opposite directions, the object remains at rest or starts to move.

The reason is that the forces are

<table>
<thead>
<tr>
<th>balanced</th>
<th>unbalanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

47. Make up a sentence using the words below.

start to move | A CHAIR WILL NOT START TO MOVE IF BALANCED
chair | FORCES ARE APPLIED
48.
No matter what is happening to a 4-lb. object, the downward force of gravity applied to it is always 4 lbs.
The downward force of gravity applied to a 9-lb. ball is 9 lbs.
when the ball is falling and also
when it is on the
ground

X

49.
When you hold a 17-lb. stone in your hand, the stone feels heavy because the force of gravity pulling it down
is not 17 lbs. even though anymore the stone isn't falling

X

50.
Under each of the examples below, write
the number of lbs. to which the force of gravity is pulling the object down.
a 2-lb. ball.
a 500-lb. boat.
which is thrown up in the air
which is floating in water

2 LBS.
500 LBS.

51.
Make up a sentence using the words below.
gravity applies
downward force of
3 LBS. TO A 3-LB.
to a 3-lb. ball
in water

52.
When a ping-pong ball floats in water, the water applies an upward force to the ball. The ball doesn't sink, even though the downward force of gravity is applied to it, because
the water applies
an upward force to
the ball

53.
When you let go of a sponge under water, the sponge rises to the top of the water. This upward movement is evidence that the water applies
an upward force to
the sponge

A-8
54.
When you fall, you move downward because the force of gravity applied to you is in
an upward direction X
and a downward direction

However, you can swim in water without sinking because
the downward force of gravity is no longer applied to you
the water applies an upward force to you

55.
When you drop a stone in air, it falls quickly.
When you drop a stone in water, it falls more slowly because
gravity applies a smaller downward force to stones in water
the upward force of the water slows down the stone

56.
When an object is in water,
the downward force of gravity is applied but the water applies no upward force
the water applies an upward force but the downward force of gravity is NOT applied

57.
Make up a sentence using the words below.
gravity applies GRAVITY APPLIES A
water applies DOWNWARD FORCE AND
upward force UPWARD FORCE TO A

58.
Name the forces applied to a fish in water and name the DIRECTION of each force.
UPWARD FORCE OF THE WATER
DOWNWARD FORCE OF GRAVITY

59.
When a ball is in water, gravity applies a force to the ball and the water also applies a force to the ball.
These two forces are in the same direction but in opposite directions

60.
When a piece of wood is in water, the two forces applied to it are
in the same direction

X
61. Gravity applies a 500-lb. force to a boat that weighs 500 lbs. The water applies an upward force to the boat of 500 lbs. These two forces are in opposite directions and are also equally strong not equally strong X 
Therefore, the two forces are balanced unbalanced X

62. When a 600-lb. box is in water, gravity applies a force to the box and the water also applies a force to the box. These two forces are balanced if the force of the water is 300 lbs. 600 lbs. 900 lbs. X

63. When a 2-lb. toy boat is in water, the force of gravity applies a downward force and the water applies an upward force to the boat.

EDIT THIS SENTENCE If the upward force of the water is LESS THAN 2 lbs., balanced forces are applied to the boat. If correct, copy the underlined words. If incorrect, change only the underlined words.

UNBALANCED FORCES

64. When a 6-lb. beach ball floats in water, two balanced forces are applied to the ball. Tell the STRENGTH and DIRECTION of the two balanced forces applied to the ball.
6 LB. UPWARD FORCE, 6 LB. DOWNWARD FORCE

65. An ice cube falls when you let go of it because an upward force the downward force of is applied to it gravity is applied to it X

In order to keep the ice cube from falling, you must apply an upward force to it apply a downward force to it X

66. An ice cube floats in a glass of water instead of sinking to the bottom of the glass because the downward force of gravity and the upward force of the water are balanced unbalanced X

67. A raft floats on the lake instead of sinking because the forces applied to the raft are balanced unbalanced X
68. An object sinks when you put it in water only if the forces applied to the object are balanced unbalanced X

69. While an old shoe is sinking in water, we know that the forces applied to the shoe are balanced unbalanced X

When you let go of a beach ball under water, it rises to the top of the water. The ball moves upward because the forces applied to it are unbalanced balanced X

70. When a boat is in water and the forces applied to the boat are balanced, the boat sinks floats X

71. Because unbalanced forces are applied to a stone in water, the stone floats sinks X

72. EDIT THIS SENTENCE
A beach ball floats in water because the force of gravity and the force of the water are balanced. If correct, copy the underlined word.

If incorrect, change only the underlined word. BALANCED

73. EDIT THIS SENTENCE
An object SINKS in water because the force of gravity and the force of the water are balanced. If correct, copy the underlined word.

If incorrect, change only the underlined word. UNBALANCED

74. Make up a sentence using the words below. You may use any other words in addition to the words below, but make sure your sentence includes all of the words below.

sponge A SPONGE FLOATS IN WATER because the forces applied to it are balanced. floats in water because TO IT ARE BALANCED.

75. A 900-lb. whale floats in water because the forces applied to it are balanced. Tell the strength of the two balanced forces applied to the whale. 900 LBS.

Name the directions of the two balanced forces applied to the whale. UPWARD AND DOWNWARD
BERNOULLI'S PRINCIPLE

1. During a hurricane, air is moving still __________ X __________
   But, on a calm day, the air is moving still ______ X ______

2. An empty bottle contains air.
   The air inside a bottle is an example of moving air still air ______ X ______

3. When we turn on an electric fan we feel a breeze.
   This is an example of moving air still air ______ X ______

4. Put an S below the example of still air.
   Put an M below the example of moving air.
   Curtains fluttering in an open window. The air inside an automobile tire. ______ M ______ S

5. You can feel moving air applying a force when you extend your arm. sit inside a parked car from a moving car with the windows closed ______ X ______

6. You can see moving air applying a force when a man's hat blows the branches of a tree off his head bend in the breeze ______ ______
   both ______ neither ______ ______ X ______

7. When you put your hand on the nozzle of a vacuum cleaner you feel a pull. The reason is moving air applies a force to your hand.
   If correct, copy the underlined words. MOVING AIR APPLIES A FORCE
   If incorrect, change the underlined part and make it correct.

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.

A-12
8. The air inside a balloon is not moving. Nevertheless, the balloon holds its shape because the still air is applying a force on the outside and a force on the inside.

9. We know that moving air applies a force. It is sometimes surprising to learn that still air also applies a force. 

10. You can sip pop through a straw and put your finger on the top of the straw. The pop will not spill out because your finger is applying a force to the pop and the still air is applying an upward force to the pop.

11. Make up a sentence about the picture using these words: THE WATER DOES NOT SPILL because still air is applying an upward force to the water.

12. A force can be applied by air. Complete this sentence: The air can be either MOVING AIR OR STILL AIR.

13. A boy is pushing one side of a wagon with a force of 30 lbs. A boy is also pushing the other side with a force of 30 lbs. The wagon will not move because the forces are equal. 

14. In Fig. A, the box will not move because the forces are equal. In Fig. B, the box will move because the 10-lb. force is stronger.
15. Below, the ball will be pushed up by the 12 lb. force down by the 17 lb. force.

12 lb. 17 lb.

16. Circle the stronger force in the above picture. The stronger force will move the box to the right or left.

17 lbs. 12 lbs.

17. 15 lb. 10 lb.

EDIT THIS SENTENCE
The box will be pushed to the LEFT because the 15-lb. force is weaker.
If correct, copy the underlined words.
If incorrect, change the underlined words.
RIGHT stronger or, RIGHT because THE 10-LB. FORCE IS WEAKER.

18. Complete this sentence. The box will be pushed DOWN because THE 18-LB. FORCE IS STRONGER (THAN THE 13-LB. FORCE).

18 lb. 13 lb.

19. A group of boys are playing tug-of-war. There are three boys on each side. If one boy lets go of the rope, the amount of force on his side of the rope will become stronger weaker.

stronger weaker

20. Part I 12 lbs. changes to Part II 7 lbs.

12 lbs. 12 lbs.

In Part I, the ball will not move because the forces are equal. In Part II, the force on the left has become weaker. The force on the right will move the ball do nothing.

21. If two boys are pushing opposite sides of a box with equal forces, the box will not move. Complete the following sentence.
If one boy should weaken the force on his side, the other boy will be able to MOVE THE BOX.
22. Forces A and B are equal. If force A becomes weaker, force B will be
stronger than A. weaker than A

Part I changes to Part II 14 lbs. 11 lbs.

Using the words "BECOMES WEAKER" and "STRONGER," explain what happens to the forces when Part I changes to Part II.
FORCE Y BECOMES WEAKER; THEREFORE, FORCE X IS STRONGER.

What will happen to the box in Part II?
THE BOX WILL MOVE TOWARD THE RIGHT.

24. still air still air
In the picture, the air is still.
The ball hanging from the ceiling by a rope will not move because the forces are
equal unequal

25. The air on one side is still but on the other side the air is moving past the ball.
The forces are
moving air still air equal not equal

26. left right
If we blow air past the left side of the ball, the ball will move toward the left.
If we blow air past the right side of the ball, the ball will move toward the right.

27. When air moves past one side of an object, the moving air applies a weaker force. Thus, the still air on the other side applies a stronger force weaker force

28. When air is moving past one side of an object, it applies less force. Thus, the still air on the other side applies less force more force

A-15
29. still air ➔ moving air

In the picture, air is moving past one side. On the other side, a stronger force is applied by the moving air ➔ still air ➔

The stronger force will move the ball toward the left ➔ right ➔

30. still air ➔ moving air

A stronger force is applied by the still air ➔ moving air ➔

The stronger force will move the ball up ➔ down ➔

31. moving air ➔ still air ➔

Make up one sentence about the picture using these words:

the ball will move toward the right ➔ TOWARD THE LEFT ➔
still air applies ➔ BECAUSE STILL AIR ➔
force ➔ APPLIES A STRONGER ➔

32. A stronger force is applied by still air, but a weaker force is applied by the moving air ➔ still air ➔

33. A force is applied by both still air and moving air. Still air applies a stronger force ➔ weaker force ➔

While moving air applies a stronger force ➔ weaker force ➔

34. moving air ➔ still air ➔

Here, the air moving past the ball applies a weaker force ➔ stronger force than still air ➔

The ball will move to the left ➔ right ➔
35. moving air ↑ still air
The ball will move toward the left because air moving past the still air will push the ball toward the moving air.

36. EDIT THIS SENTENCE
Still air applies a weaker force than air moving past an object.
If correct, copy the underlined words.
If incorrect, change the underlined words.

37. moving air ↓ still air
The ball will move up because still air applies a stronger force than the air moving past the top.

38. EDIT THIS SENTENCE
If we blow air past one side of an object, the still air on the other side will push the object toward the moving air.
If correct, copy the underlined words.
If incorrect, change the underlined words.

39. still air → moving air
The weaker force is on the left because the ball will move toward the right.

40. If you want the paper to move up, past which side would you blow air?
X past the top

41. The faster air moves, the less force it applies. Thus, as air moves faster the amount of force it applies becomes stronger weaker X
42. Air moving at 17 miles per hour applies less force than air moving at 12 miles per hour. In the picture, put an X under the amount which is applying the smaller force.

15 miles per hour

____

30 miles per hour

____ X

43. In each example, put an X in the box where the air is applying a smaller force.

☐ 3 miles per hour

☐ 5 miles per hour

☐ 17 miles per hour

☐ 8 miles per hour

☐ 4 miles per hour

44. 10 m.p.h. \( \rightarrow \) 5 m.p.h. The slower air moves the more force it applies. Thus, a stronger force is being applied by the air moving at 10 m.p.h. \( \rightarrow \) 5 m.p.h. \( \rightarrow \) X

45. Put an X in front of the stronger force.

\[ \begin{array}{c}
6 \text{ miles per hour} \\
5 \text{ miles per hour} \\
13 \text{ miles per hour}
\end{array} \]

The stronger force will move the ball down

X

46. In the picture below, which force will move the ball?

\[ \begin{array}{c}
3 \text{ m.p.h.} \\
5 \text{ m.p.h.} \\
7 \text{ m.p.h.}
\end{array} \]

47. 20 m.p.h. \( \rightarrow \) 30 m.p.h.

EDIT THIS SENTENCE

Above, the air moving at 30 miles per hour is moving faster but it applies less force. If correct, copy the underlined words.

IS MOVING FASTER BUT IT APPLIES LESS FORCE

If incorrect, change the underlined words.

48. Make up one sentence using these words.

slower THE SLOWER AIR MOVES THE simpler FORCE IT applies.
49. Make up one sentence using these words.

air THE FASTER AIR MOVES THE
faster WEAKER THE FORCE IT
force APPLIES.

50. 10 miles per hour

What will happen to the umbrella? Explain why. THE UMBRELLA WILL BE
PUSHED UP BECAUSE THE SLOWER
MOVING AIR IS APPLYING A STRONGER
UPWARD FORCE.

51. When an airplane is in flight, air
is moving past it.
The airplane stays up because air
is applying a
stronger force on the bottom
stronger force on the top
X

52. If a stronger force is on the bottom
of an airplane, then a weaker force is
applied by the air moving past the
top of an
bottom of an
airplane airplane
X

53. An airplane wing is shaped like this.
Compare the distance along
the top to the distance along the
bottom.
The air moving over the top must travel a
closer distance farther distance
X

54. Starting at A, the air moving past the
curved top of an airplane wing and the
air moving past the bottom will arrive
at B at the same time.
To arrive at B at the same time as the
air on the bottom, the air on the top
must move both farther and
faster slower
X

55. Because the top of an airplane wing
is curved, the air moving past the
top must move farther and
faster slower
X
56. The faster air moves, the less force it applies. Thus, the faster air moving past the top of an airplane wing applies a stronger force to the top of the wing, weaker force to the bottom of the wing.

The slower air moving past the bottom of the wing applies a weaker force to the bottom of the wing, stronger force to the top of the wing.

57. Air moving past the top of an airplane wing moves faster and is weaker.

58. EDIT THIS SENTENCE
A stronger force is applied by the faster air moving past the top of an airplane.
If correct, copy the underlined words.
If incorrect, change the underlined words. A WEAKER FORCE

59. Make up a sentence using these words. top of an airplane wing
air moves over

60. On the bottom of an airplane wing, the air travels a shorter distance and moves faster and is weaker.

The air on the bottom applies a stronger force and is weaker.

The airplane stays up because the force applied to the wing is stronger at the bottom.

61. EDIT THIS SENTENCE
The air going past the airplane wing moves slower and applies a weaker force to the bottom of the wing.
If correct, copy the underlined words.
If incorrect, change the underlined words. STRONGER FORCE

62. Make up one sentence using these words. air moves on the bottom of an airplane wing.

A WEAKER FORCE

THE AIR MOVING OVER THE TOP OF AN AIRPLANE WING MOVES FASTER AND APPLIES LESS FORCE.
63. Write weaker on the side where air applies less force to the wing. Write stronger on the side where air applies more force to the wing.

64. EDIT THIS SENTENCE

An airplane rises because the slower moving air beneath the wing pushes it up.

If correct, copy the underlined words.

THE SLOWER MOVING AIR BENEATH THE WING PUSHES IT UP.

If incorrect, change the underlined words.

65. Complete this sentence.

On an airplane wing the stronger force is on the bottom because the air on the bottom is moving slower than the air on the top.

66. Complete this sentence.

An airplane stays up in the air because the slower moving air on the bottom applies a stronger force.
Visual Answer Booklet

ARCHIMEDES' PRINCIPLE
Visual Answer Booklet - Archimedes' Principle

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Page 12

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Page 13

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A-25
Visual Answer Booklet - Bernoulli's Principle

Make up any sentence using these words:

PARTER  AIR  FORCE
Achievement Tests

ARCHIMEDES' PRINCIPLE

Part I - Fill-ins

1. A 500-lb. rowboat floats in water because the forces applied to it are _________.
   The upward force of the water applied to the rowboat is
   ____ stronger than 500 lbs.
   ____ equal to 500 lbs.
   ____ less than 500 lbs.

2. An anchor sinks in water because the forces applied to it are _________.

3. In order for two forces to be balanced, what must be true about the strength and the direction of the two forces?

4. We say that two forces are unbalanced if the two forces are

5. Tell what happens when balanced forces are applied to a baseball at rest on the ground.

6. Two boys are pulling a rope. One boy applies a 16-lb. force to the left. If the two boys apply balanced forces, what force does the other boy apply?

A-29
Achievement Tests - Archimedes' Principle

7. When a 58-lb. piece of wood floats in water, two forces are applied to it. Tell the strength and direction of these two forces.

8. In a tug of war, if unbalanced forces are applied to the rope, what will happen?

---

Part II

There are five examples below of different combinations of forces applied to objects. For each combination, check whether the forces are balanced or unbalanced and also whether the object to which the forces are applied will move.

<table>
<thead>
<tr>
<th>The forces are:</th>
<th>The object will:</th>
</tr>
</thead>
<tbody>
<tr>
<td>balanced</td>
<td>unbalanced</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. two 47-lb. forces applied in the same direction

2. two 10-lb. forces, one applied upward the other applied down

3. two unequal forces applied, both applied in a right-hand direction

4. two unequal forces applied in opposite directions

5. a 5-lb. force applied toward the East and a 5-lb. force applied to the West
Achievement Tests

BERNOULLI'S PRINCIPLE

Part I - Fill-ins

1. A ping pong ball is hanging by a string, as in the example below.

   ![Diagram of Still Air and Moving Air]

   STILL AIR \[\uparrow\] MOVING AIR

   a. If we blow air past the right-hand side of the ping pong ball, in which direction will the ping pong ball move?

   b. Why does it move in that direction?

2. Why is an airplane supported in the air?

   [Blank space for answer]

3. In the example below, what will happen to the paper? Explain why.

   ![Diagram of Airflow]

   20 MILES PER HOUR  
   MOVING AIR

   10 MILES PER HOUR  
   MOVING AIR

A-31
Achievement Tests - Bernoulli's Principle

4. Draw an airplane wing.

a. When the airplane is moving air applies a stronger force to one part. To which part of the airplane wing does air apply the stronger force? ________________________________

b. Why is the force stronger there? ________________________________

5. If you put a ping pong ball in a funnel and turn it upside down, it would fall out. If you wanted to keep the ball from falling out while the funnel was upside down, past which side would you blow air? Put an X in front of the correct answer in the picture below.

   __ past the top
   __ past the left    __ past the right
   __ past the bottom

Explain why you chose that answer. ________________________________

6. When there is an increase in the speed of air, what happens to the force it applies? ________________________________
Achievement Tests - Bernoulli's Principle

Part II - Multiple Choice

1. The smallest force is applied by
   ___ air moving past an object at 10 miles per hour.
   ___ air moving past an object at 15 miles per hour.
   ___ air which is not moving.

2. During a hurricane the air is moving past the top of the house but the air inside is still. What will happen?
   ___ The still air will pull the roof down.
   ___ The still air will push the roof up.
   ___ The moving air will push the roof down.
   ___ The moving air will lift the roof up.

3. When a convertible automobile is moving along a highway, the roof may be pushed up because
   ___ the moving air is applying a stronger force.
   ___ the still air is applying a weaker force.
   ___ the still air is applying a stronger force.
   ___ none of the above.

4. If air starts to move past the right-hand side of an object, what will happen?
   ___ The force becomes weaker on the right-hand side.
   ___ The force becomes stronger on the right-hand side.
   ___ The force becomes weaker on the left-hand side.
   ___ The force stays the same.
   ___ None of the above.

5. One of the reasons an airplane flies is
   ___ the force applied to the bottom is weaker.
   ___ the force applied to the top is weaker.
   ___ the force applied to the top is stronger.
   ___ the forces are equal.
   ___ none of the above.   A-33
A. For each of the experiments which you just saw, put an X in the column which shows whether you would like to try it yourself.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Would like to try it very much</th>
<th>Would like to try it</th>
<th>No interest in trying it</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. blowing air past candle flames</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. release ping pong ball in middle of tank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. blowing air under paper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. putting different numbers of blocks on each side so that the car will move</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. turning glass of water upside down</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A-34
<table>
<thead>
<tr>
<th>Activity</th>
<th>Would like to try it very much</th>
<th>Would like to try it</th>
<th>No interest in trying it</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. finding out how to distribute the blocks to make the car move to the right</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. blowing air past top of paper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. putting the right number of blocks on each side so car doesn't move</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. blowing air past an airplane wing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. release heavy ball at top of water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
B. Which way did each of the following experiments turn out? Put an X next to the picture which shows which way it turned out.

<table>
<thead>
<tr>
<th>Experiment Description</th>
<th>Picture 1</th>
<th>Picture 2</th>
<th>Picture 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. blowing air past candle flames</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>2. release ping pong ball in middle of tank</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>3. blowing air under paper</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>4. putting different numbers of blocks on each side so that the car will move</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
<tr>
<td>5. turning glass of water upside down</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
<td>[Diagram]</td>
</tr>
</tbody>
</table>
An Attitude Scale

6. finding out how to distribute the blocks to make the car move to the right

7. blowing air past top of paper

8. putting the right number of blocks on each side so car doesn't move

9. blowing air past an airplane wing

10. release heavy ball at top of water

It turned out this way.

It turned out this way.

It turned out this way.

A-37
An Attitude Scale

C. If you tried each of the following experiments yourself, which way do you think they would turn out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

1. blowing air past candle flames

2. release ping pong ball in middle of tank

3. blowing air under paper

4. putting different numbers of blocks on each side so that the car will move

5. turning glass of water upside down

A-38
An Attitude Scale

6. finding out how to distribute the blocks to make the car move to the right.

7. blowing air past top of paper.

8. putting the right number of blocks on each side so car doesn't move.

9. blowing air past an airplane wing.

10. release heavy ball at top of water.
An Attitude Scale

D. When these experiments were done on the screen, they came out a certain way. If you did these experiments yourself, which way would they come out? Put an X next to the picture which shows which way you think it would turn out if you tried it.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Picture 1</th>
<th>Picture 2</th>
<th>Picture 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Air blown past candle flames</td>
<td><img src="image1" alt="Picture 1" /></td>
<td><img src="image2" alt="Picture 2" /></td>
<td><img src="image3" alt="Picture 3" /></td>
</tr>
<tr>
<td>2. Ping pong ball released in middle of tank</td>
<td><img src="image4" alt="Picture 1" /></td>
<td><img src="image5" alt="Picture 2" /></td>
<td><img src="image6" alt="Picture 3" /></td>
</tr>
<tr>
<td>3. Air blown under paper</td>
<td><img src="image7" alt="Picture 1" /></td>
<td><img src="image8" alt="Picture 2" /></td>
<td><img src="image9" alt="Picture 3" /></td>
</tr>
<tr>
<td>4. Different numbers of blocks put on each side</td>
<td><img src="image10" alt="Picture 1" /></td>
<td><img src="image11" alt="Picture 2" /></td>
<td><img src="image12" alt="Picture 3" /></td>
</tr>
<tr>
<td>5. Glass of water turned upside down</td>
<td><img src="image13" alt="Picture 1" /></td>
<td><img src="image14" alt="Picture 2" /></td>
<td><img src="image15" alt="Picture 3" /></td>
</tr>
</tbody>
</table>
An Attitude Scale

6. This is what happened when we found out how to distribute the blocks to make the car move to the right.

7. This is what happened when air was blown past the top of paper.

8. This is what happened when the right number of blocks were put on each side so the car didn't move.

9. This is what happened when air was blown past an airplane wing.

10. This is what happened when the heavy ball was released at top of water.
An Attitude Scale

E. What reason(s) would you have for trying each of the following experiments yourself?

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Just curious to see how it would come out.</th>
<th>To check to see if it would come out the same way.</th>
<th>Don't believe it would come out the same way.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. blowing air past candle flames</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. release ping pong ball in middle of tank</td>
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</tr>
<tr>
<td>5. turning glass of water upside down</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A-42
<table>
<thead>
<tr>
<th>An Attitude Scale</th>
<th>Just curious to see how it would come out.</th>
<th>To check to see if it would come out the same way.</th>
<th>Don't believe it would come out the same way.</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. finding out how to distribute the blocks to make the car move to the right</td>
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<td>10. release heavy ball at top of water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

F. In a sentence or two, tell which experiments you preferred seeing and why, the live experiments or the experiments done in animation.

A-43
LEARNING FROM A PROGRAM

1. This is a new kind of lesson, called a "program." A program does NOT try to find out what you already know. Place an X in one of the two boxes below.

A program
A program is not a test.

2. A nice thing about a program is that everyone in the class doesn't have to finish at the same time. This means that in a program you work

at the same speed at your own
as everyone else best speed

3. John likes to work a little slower than Mary. They both learn well from a program because in a program they work

at their at the same speed as the own speed rest of the class

4. EDIT THIS SENTENCE

When he worked on a program, Bob worked at the same speed as everybody else in the class.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

5. Make up a sentence.

Use all the words listed below. Add any extra words you need to make a complete sentence. Write your sentence below.

Make up a sentence.

program speed class

6. It doesn't make any difference how fast or slow you work as long as you work accurately. You must remember to

answer without reading the page carefully and page carefully answer accurately

7. Programs help you by telling you things before asking you questions about them. You learn by

answering the questions without reading carefully then answering carefully the questions

8. EDIT THIS SENTENCE

Peter nearly always got his answers right in the program because he read the page carefully first.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses. The first nine frames did not have confirmation frames.

A-44
9. It's easy to get correct answers in a program as long as you answer accurately. Katie was careless and inaccurate in writing her answers, so therefore she didn't ________.

10. Make up a sentence which includes all the words listed below. Write your complete sentence below.
   correct answers __________
   read carelessly __________

10a. CHECKING PAGE
This is a checking page. Programs usually have checking pages like this one.

The sentence you just wrote doesn't have to be exactly like the one below, but it should mean the same.

YOU CAN'T GET THE CORRECT ANSWERS IF YOU READ THE PAGE CARELESSLY.

11. You're supposed to learn algebra.
   If you simply copy somebody's answer on one problem, later on
   you will be able ________
   to solve other problems by yourself ________
   you won't be able ________
   to solve other problems by yourself ________

12. It is easy to get the right answers if you are told the answer first. But you always learn better if you figure things out for yourself. You learn well from a program because
   you can look up the answers ________
   read the answers for yourself ________

13. Teachers have discovered that students remember what is in a lesson if they find out whether their answer is correct right after they have figured it out. They forget if they look at the answer without trying to figure it out figured it out ________

14. If you figure things out for yourself instead of copying the answer you
   forget quicker ________
   remember better ________

15. A program is not a test, but after you have finished the program you usually take a test. The way to remember things in a program and to pass the test afterwards is to
   just copy the answers ________
   figure the answers out for yourself ________
16. The checking page is for checking your answer after you have figured it out. It tells you if your answer was correct. You should look at the checking page before you figure out the answer.

17. You remember lessons better if you figure answers out for yourself, not by copying them. Therefore, in a program it is important to look at the checking page first and then write your answer at the checking page first and then look at the checking page.

18. The way to learn how to solve problems by yourself is to get practice in solving them, not just look up the answers. Therefore, in a program it is important to look at the checking page first and then write your answer at the checking page first and then look at the checking page.

19. Being able to look answers up on the checking page is important, but it only helps you to remember if you merely copy the answers from the checking page. Therefore, in a program it is important to look at the checking page first and then write your answer at the checking page first and then look at the checking page.

20. You can get the right answers on a program just by copying them. If you do copy, later on you will be able to do new problems by yourself, but you won’t be able to do new problems by yourself.

21. EDIT THIS SENTENCE
A reason people remember so well what they learn from programs is that they can copy the answer from the checking page without first trying to figure it out for themselves. If the underlined part of the sentence is correct, COPY it. If the underlined part is incorrect, CHANGE it.

22. Complete this sentence.
You are more likely to forget what’s in a program if you simply copy the answers from the checking page.

23. It is important to figure out answers for yourself in a program because it helps you REMEMBER (or, UNDERSTAND, LEARN) better.
24. The physics teacher told the class they were going to take a program. The program would tell them things and then ask questions. There would be no grade given for the work, because a program is not a test.

25. You can learn new subjects by answering questions in a program like this one. A program is supposed to teach you to see something new, what you already know.

26. **EDIT THIS SENTENCE**

Although you answer questions in a program, a program is just like a test.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

**NOT LIKE A TEST**

27. Make up a sentence which includes all the words listed below. Write your complete sentence below.

program, A PROGRAM IS NOT A TEST.

test

28. Complete this sentence.

Even though you answer questions in a program, you don't get grades because a program is supposed to teach you something and not to test you.

29. Jim and Dave both worked on a program. They both got the right answers in the program, but Dave had merely copied his answers each time. Later on, when they were given a test, Jim remembered better and got a better test score. Why?

JIM REMEMBERED BETTER BECAUSE WHILE WORKING ON THE PROGRAM HE FIGURED OUT THE ANSWERS OUT FOR HIMSELF AND THEN CHECKED THEM AFTERWARDS.

30. When a teacher has you figure answers out on a test, it's because the teacher wants to find out what you have already learned and something new.

When a teacher has you figure answers out in a program, it's because the teacher wants to find out what you have already learned and something new.

31. What is the difference between a program and a test? A PROGRAM IS MEANT TO TEACH YOU SOMETHING, AND NOT TO FIND OUT WHAT YOU ALREADY KNOW.
32. You will be surprised how much this program has taught you already. Mark the statements below as "T" (true) or "F" (false).

- A program is a test. **F**
- You can get your answers correct in a program if you read carefully. **T**
- You all have to work at the same speed in a program. **F**
- It is not important to work accurately. **F**
- After you have given your answer, the program has a checking page, which tells you if your answer was correct. **T**

33. After you finish a program, you sometimes are given a test to find out what you have learned. What is the best way to work on the program in order to get the best mark on the test given afterwards?

**IT’S BEST TO TRY TO FIGURE OUT PROBLEMS FIRST AND THEN CHECK TO SEE IF THE ANSWERS ARE RIGHT.**

34. Write a few sentences describing what you have learned about programs.

- **A PROGRAM IS MEANT TO TEACH YOU SOMETHING, NOT TO TEST YOU.**
- You must read carefully before you answer.
- As long as you work accurately, you can work at your own speed.
- You can remember things better if you look at the checking page after you have written your answer.
1. We say that an object is "at rest" when it isn't moving. An automobile is at rest when it is parked, speeding, X.

2. A ball is at rest when it is lying on a table or rolling off the table. X.

3. Unless you push a book which is lying still on a table, the book will remain at rest, start to move. X.

4. We use the words "apply a force" whenever someone pushes or pulls an object. If a man applies a force to a ball, the ball will remain at rest, start to move. X.

5. If a man doesn't apply a force to a box, the box will remain at rest, start to move. X.

6. A man can make a wagon start to move if he applies a force to it. He can apply a force to the wagon by getting in back, getting in front, and pushing it, and pulling it either way.

7. EDIT THIS SENTENCE
When a man pushes a box, he is applying a force to the box. If the underlined part of the sentence is correct, copy the underlined words.

APPLYING A FORCE TO THE BOX
If the underlined part of the sentence is incorrect, change the underlined words.

8. Make up one correct sentence out of all of these words. You can be in any order you want. You can change the tenses of the verbs if you want. You can add any words you want to make a complete sentence.

YOU APPLY A FORCE TO AN OBJECT BY PUSHING OR PULLING IT.
9. **EDIT THIS SENTENCE**

When a man applies a force to a cart, the cart will remain at rest.

If the underlined part of the sentence is correct, copy the underlined words.

If incorrect, change the underlined words.

**NOT REMAIN AT REST or START TO MOVE**

10. Make up one sentence using all these words and any other words you need.

```
baby carriage  WHEN YOU APPLY A FORCE
apply a force to  TO A BABY CARRIAGE, IT
start to move  WILL START TO MOVE or

THE BABY CARRIAGE
STARTED TO MOVE WHEN
THE MAN APPLIED A
FORCE TO IT.
```

11. Make up one sentence out of these words.

```
apply a force  IF YOU APPLY A FORCE
remain at rest  TO AN OBJECT, IT WILL

NOT REMAIN AT REST or,

UNLESS YOU APPLY A FORCE
TO AN OBJECT, IT WILL

REMAIN AT REST.
```

12. When a sailboat stays perfectly still in the middle of a lake, it's because

**NO FORCE IS BEING APPLIED TO IT.**

13. If you push something in a forward direction, the direction of the push is said to be

```
forward  backward

X
```

Since a push is one kind of force, we can also say that the direction of the force is

```
forward  backward

X
```

14. If you pull a bucket up to the roof with a rope, the force pulling on the bucket is

```
in a right-hand direction  in a left-hand direction

X
```

in a upward direction

```
in a downward direction
```

15. When you throw a ball up in the air, you are applying a force to the ball in

```
an upward direction  a downward direction

X
```

A-50
16. When you push a box toward the door, you are applying a force to the box in a direction toward the door.

```
X
```

17. You apply a force to a box; if you apply a force in a right-hand direction, the box will move in a right-hand direction.

```
X
```

18. An example of a force and movement being in the same direction is when you push clothes down in a hamper and the clothes move up.

```
move up
X
```

19. If you push a box toward the left, the box will move to the left. The force you apply and the movement of the box are in the same direction.

```
X
```

20. EDIT THIS SENTENCE

If you push an object forward and the object moves forward, we would say that the force and the movement are in the opposite direction.

If the underlined words are correct, copy them.

If incorrect, correct them.

```
IN THE SAME DIRECTION
```

21. If a wagon moves because you have applied a force to it, the movement of the wagon moves and the direction of the force you applied to it are the same.

```
X
```

22. EDIT THIS SENTENCE

If an object moves because a force is applied to it, the object will move in the same direction as the force which is applied to it.

If the underlined part of the sentence is correct, copy the underlined words.

```
THE OBJECT WILL MOVE IN THE SAME DIRECTION AS THE FORCE APPLIED TO IT
```

If incorrect, change the underlined words.

23. Make up one sentence out of these words.

A cart will move in the same direction as the force applied to it.
24. A wagon will start to move toward
the east only if the force applied
is toward the east.

25. Make up your own example of when the
direction of a force and the direction
of the movement are the same.
A man pushes an object toward the
right-hand side of a room and the
object moves toward the right-
hand side of the room.

26. One man can’t push a stalled car by
himself. Five men can push it,
because the force they apply to the
car is
strong enough too weak

27. A large boulder is NOT likely to be
moved when the force applied to it is
weak strong very strong

28. When the force applied to an object is
too weak, the object will
start to move remain at rest

29. When the force applied to an object
is strong enough, the object will
start to move.

If the sentence is correct, copy the
underlined words.

If the sentence is incorrect, change the
underlined words.

30. Make up one sentence out of these words.
force IF THE FORCE IS APPLIED TO AN
too weak OBJECT IS TOO WEAK, THE OBJECT
move WILL NOT MOVE.

31. The strength of forces is measured in lbs.
The strongest force is the
10-lb. force 3-lb. force 5-lb. force

32. Compare a 200-lb. force and a 100-lb. force.
The 200-lb. force is
stronger weaker

33. A 100-lb. force is LESS likely to make a
stalled car move than a 200-lb. force
because the 100-lb. force is
weaker stronger
34. We talk about how STRONG a force is. We DON'T talk about how much a force weighs. Therefore, if a man applies a 30-lb. force, the 30 lbs. tells us how strong the force is:

<table>
<thead>
<tr>
<th>how strong the force is</th>
<th>how much the force weighs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

35. A man's weight is measured in lbs. The STRENGTH of forces is ALSO measured in lbs. If a 10-lb. force is applied to a box, 10 lbs. tells us the strength of the force:

<table>
<thead>
<tr>
<th>strength of the force</th>
<th>weight of the force</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td></td>
</tr>
</tbody>
</table>

36. When we talk about a force of 15 lbs. or 25 lbs., the number of lbs. tells us how much the force weighs:

<table>
<thead>
<tr>
<th>how much the force weighs</th>
<th>how strong the force is</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

37. Compare a 30-lb. force and a 10-lb. force. The 30-lb. force weighs more and is stronger:

<table>
<thead>
<tr>
<th>weighs more</th>
<th>is stronger</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

38. A boy was just barely able to make a wagon move when he applied a force of 45 lbs. to it.

EDIT THIS SENTENCE

If the boy had applied less force, the wagon wouldn't move because the force would not be strong enough.

If correct, copy the underlined words.

THE WAGON WOULDN'T MOVE BECAUSE THE FORCE WOULD NOT BE STRONG ENOUGH.

If incorrect, make it correct.


EDIT THIS SENTENCE

The number of lbs. tells us how much the force weighs.

If the underlined part of the sentence is correct, copy the underlined words.

If incorrect, change the underlined words.

HOW STRONG THE FORCE IS

40. Make up one sentence out of these words.

we measure | WE MEASURE THE STRENGTH
of a force | OF A FORCE IN LBS.
in lbs.

41. Construct a sentence out of these words.

remain at rest | AN OBJECT WILL REMAIN AT
force | REST IF THE FORCE APPLIED
strong | TO IT IS NOT STRONG ENOUGH.
42. Make up your own example of a situation where something doesn't move because the force applied to it isn't strong enough.

If a boy tries to lift a car, the car doesn't move because the boy isn't strong enough.

43. A 3-lb. book on a desk applies a 3-lb. downward force to the desk. A 10-lb. box on the desk applies a downward force of:

<table>
<thead>
<tr>
<th>3 lbs.</th>
<th>10 lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

44. A 180-lb. man standing on the floor applies:

- a downward force of 180 lbs. to the floor
- an upward force of 180 lbs. to the floor

X

45. The more an object weighs, the stronger the downward force it applies, and the weaker the downward force it applies.

X

46. Compare a 2000-lb. and a 3000-lb. automobile. The downward force applied to the road by the 3000-lb. car is stronger than the downward force applied to the road by the 2000-lb. car.

X

47. The strength of a downward force which an object applies to a table depends on the weight of the object and the weight of the table.

X

48. We want to put one box on a table, but the table is in danger of breaking. It would be better to select the 200-lb. box because it will apply a weaker downward force to the table than the 250-lb. box.

X

49. A pile of books is lying on a table. If we know how much the books weigh, we also know the strength of the downward force which is applied to the table.

X

50. A 15-lb. box is resting on the floor. The strength of the downward force on the box weighs 15 lbs. to the floor is 15 lbs.

X
51. A 95-lb. boy lying on a bed applies a downward force to the bed of

less than exactly more than
95 lbs. 95 lbs. 95 lbs.

X

52. EDIT THIS SENTENCE

A 30-lb. bag of sand applies a downward force of less than 30 lbs. to the ground.

If the underlined part of the sentence is correct, copy the underlined words.

If incorrect, change the underlined words.

A DOWNWARD FORCE OF EXACTLY 30 LBS. TO THE GROUND

53. | Box |

Make up one sentence about this picture using these words.

downward force applied by the weight depends on
THE STRENGTH OF THE DOWNWARD FORCE APPLIED BY THE BOX TO THE TABLE DEPENDS ON HOW MUCH THE BOX WEIGHS.

54. An object lying on a table applies a downward force to the table. The strength of the force is equal to THE WEIGHT OF THE OBJECT.

55. Complete this sentence.

An object at rest will start to move only if you apply a force to it.

56. How can you apply a force to objects?

BY PULLING THEM OR PUSHING THEM.

57. The direction in which an object moves depends on the direction of the force applied to it.

58. An object will remain at rest unless the force you apply to it is strong enough.

59. How much downward force does an object apply to the surface on which it's lying?

A FORCE EQUAL TO ITS WEIGHT.

60. When a 30-lb. object is on the ground, what does the object do to the ground?

APPLIES A DOWNWARD FORCE OF 30 LBS. TO THE GROUND.

61. When you lift an object off the ground what are you doing to the object?

APPLYING A FORCE TO IT.
### ADDITIONAL RESULTS

#### Table 1
Summary of Analysis of Variance for the Matching of Ss for: Otis IQ

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>DEGREES OF FREEDOM</th>
<th>SUMS OF SQUARES</th>
<th>MEAN SQUARES</th>
<th>F</th>
</tr>
</thead>
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Significance levels: * = .05; ** = .01; *** = .001.

#### Table 2
Summary of Analysis of Variance for the Matching of Ss for: Work Rate

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Significance levels: * = .05; ** = .01; *** = .001.
### Table 3
Summary of Analysis of Variance for the Hatching of Ss for: Pretest Scores

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### Table 4
Summary of Analysis of Variance: Posttest - Archimedes' Principle

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### Table 5
Summary of Analysis of Variance: Retention Test - Archimedes' Principle

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### Table 6
Summary of Analysis of Variance: Posttest - Bernoulli's Principle

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### Table 8
Summary of Analysis of Variance:
Work Rate - Archimedes' Principle

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A. Experimental Programs
  1. Heat ........................................... B-1
  2. Surface Tension .............................. B-12

B. Visual Answer Booklets
  1. Heat - Direct ............................... B-20
  2. Heat - Indirect ............................ B-21
  3. Surface Tension - Direct ............... B-22
  4. Surface Tension - Indirect ............. B-25

C. Achievement Tests
  1. Heat ......................................... B-28
  2. Surface Tension ......................... B-30

D. Pre-Program
  1. Atoms and Molecules ....................... B-31

E. Additional Results ........................ B-42
HEAT

1.
As an object gets hotter, its molecules start to move faster.
When you heat a pan of water on the stove, the speed of the water molecules starts to
increase decrease
X

2.
When you toast a marshmallow in a fire, the molecules of the marshmallow will start moving slower faster
X

However, when you blow on the marshmallow and make it cooler, the molecules start to move
slower faster
X

3.
Since, when an object is heated, the molecules move faster slower
X

you know that when something feels very hot, the molecules are very far apart moving very fast

4.
The temperature of an object is related to the speed of its molecules.
How hot a cup of coffee feels depends on how fast the molecules of coffee are moving
how big the molecules of coffee are
X

5.
How warm the air outside feels depends on how close together the molecules of air are how fast molecules of air are moving
X

6.
Make up a sentence using all of the words below. Add any other words that you need.
molecules MOLECULES DO NOT MOVE FASTER move fast WHEN THEY ARE COOLED. cooled

7.
Every object is made of molecules which are always moving.

EDIT THIS SENTENCE
As its molecules start to move faster, an object starts to feel cooler.
If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

WARMER

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.
8. The way to get the molecules of an object to move more slowly is to COOL IT.

9. The speed of the molecules in an object depends on HOW MUCH THE OBJECT IS HEATED.

10. An object starts to feel hotter when its molecules start to MOVE FASTER.

11. Make up a sentence using all of the words below.
   temperature of an object molecules
   THE TEMPERATURE OF AN OBJECT GOES UP AS THE MOLECULES MOVE FASTER.

12. A slow-moving molecule which comes near another slow-moving molecule will not increase the speed of the slow-moving molecule. However, a fast-moving molecule that comes near to a slow-moving molecule makes the slow-moving molecule move faster than before.

13. After a fast-moving air molecule has approached a slow-moving air molecule, the slow-moving molecule will move at the same speed as before and a faster speed than before.

14. If a slow-moving molecule is approached by a fast-moving molecule, the slow-moving molecule will move faster than before, no faster than before. But, when it is approached by another slow-moving molecule, the slow-moving molecule will move faster than before, no faster than before.

15. When a slow-moving gold molecule comes near another slow-moving gold molecule, the speed of the second molecule will stay the same as before and increase.

16. A slow-moving molecule can be speeded up only when it is approached by another slow-moving molecule and a fast-moving molecule.
17. A slow-moving molecule starts to move faster than before if it is approached by a fast-moving another slow-moving molecule.

A slow-moving molecule continues to move slowly when it is approached by a fast-moving another slow-moving molecule.

18. Draw lines connecting each sentence on the left side with the sentence on the right side which tells what happens.

1. A slow-moving molecule is approached by another slow-moving molecule.
   a. The slow-moving molecule continues to move at the same speed.
   b. The slow-moving molecule starts to move faster.

19. EDIT THIS SENTENCE

   A slow-moving molecule starts to move faster if it is approached by another slow-moving molecule.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

   A FAST-MOVING MOLECULE

20. Make up a sentence using all of the words below.
   a slow-moving molecule approached by a slow-moving molecule continues to move slowly.

21. What happens to a slow-moving sugar molecule when a fast-moving sugar molecule comes close to it?
   IT STARTS TO MOVE FASTER.

22. A slow-moving molecule will start moving faster than before when a fast-moving molecule
    stays far away comes near it.

23. In order to make a slow-moving molecule move faster than before, a fast-moving molecule has to
    approach the slow-moving molecule move away from the slow-moving molecule.
A fast-moving molecule makes a slow-moving molecule move faster.

**EDIT THIS SENTENCE**

A slow-moving molecule will move faster whether or not the fast-moving molecule comes near it.

If the underlined part of the sentence is correct, **COPY** it.

If the underlined part is incorrect, **CHANGE** it.

**ONLY WHEN A FAST-MOVING MOLECULE COMES NEAR IT.**

---

A slow-moving molecule starts to move faster only if a FAST-MOVING MOLECULE COMES NEAR IT.

---

At Jim's party, 20 people were crowded into a small room.

At Bob's party, 20 people were spread out in a large room.

People bumped into each other more often at

**Jim's party**  **Bob's party**

**X**

---

Five hundred cars are crowded together on a section of the highway.

In one hour's time, many cars come near only a few cars each other come near each other

**X**

However, if the 500 cars are spread far apart on the highway, the cars come near each other many times only a few times

**X**

---

Many boys are playing tag on a small playground. Because the boys are spaced close together, the boys move near one another very often not very often

**X**

Molecules that are packed closely together also move near each other very often not very often

**X**

---

A bottle of water contains more molecules than a bottle filled with air. Therefore, we know that the water molecules are spaced closer together farther apart than air molecules than air molecules

**X**

and therefore we also know that, compared to the air molecules, the water molecules come near each other more frequently less frequently

**X**

---

Because copper molecules are closely packed, they come near each other very often not very often

**X**

Water molecules, however, are more widely spaced. Therefore, water molecules approach each other very often not very often

**X**
31. The molecules that make up a metal knife are packed tightly together. In one second, the molecules come near each other only a few times: many times

32. Molecules of water are spaced farther apart than molecules of metal. Therefore, in a glass of water, the molecules approach each other more often: not as often

33. Write 1 under the substance whose molecules approach each other most often.
Write 3 under the substance whose molecules approach each other least often.
Write 2 under the remaining substance. gold molecules, alcohol molecules, spaced very close spaced together moderately far apart

34. The molecules in a silver fork are spaced close together. The silver molecules do not approach each other very frequently.

35. The molecules that make up an object do not come near each other frequently if the molecules are closely spaced.

36. Make up a sentence using all of the words below. frequently molecules come near each other other frequently when they are spaced closely spaced.

37. A flask of oxygen gas contains molecules that are very far apart. As the molecules move around in the flask, what happens to the molecules? They approach each other very infrequently.
38. How frequently the molecules that make up an object come near each other depends on how closely packed the molecules are.

39. When heat travels through an object, we say that heat is conducted.
When a pot is on the stove, we say heat is conducted if:
- Heat goes through the pot and the handle gets hot (only near the flame)
- Heat stays only in the bottom of the pot near the flame (X)

40. A short time after you heat one end of a silver wire,
- The rest of the wire also gets hot (only near the flame)
- The heat spreads through the wire (X)

Therefore, heat travels quickly through silver (X)

41. We say that a bar of gold conducts heat because, when you apply a flame to one end of the bar,
- Heat spreads through the bar near the flame (X)

42. A metal spoon is a good conductor of heat. If you apply a flame to one part of a spoon,
- Only that part gets hot
- All of the spoon gets hot (X)

However, if heat is applied to one part of a tube of water, which is a poor conductor of heat,
- Only the heated part gets hot
- All of the water gets hot (X)

43. When heat spreads quickly through an object, we say the object is a good conductor of heat.
Because heat travels slowly through water, water is a poor conductor of heat (X)

44. Heat travels very slowly through alcohol. Therefore, we say alcohol is a poor conductor of heat.

However, heat goes through a metal bar from one part to another very quickly because metal is a good conductor of heat (X)
45. **EDIT THIS SENTENCE**
When one part of a tube of air is heated, the rest of the air stays cool. Therefore, we say that air is a good conductor of heat.
If the underlined part of the sentence is correct, COPY it.
If the underlined part is incorrect, CHANGE it.

**IS NOT A GOOD CONDUCTOR OF HEAT**

46. **EDIT THIS SENTENCE**
We say heat is conducted when you heat one part of an object and the rest of the object stays cool.
If the underlined part of the sentence is correct, COPY it.
If the underlined part is incorrect, CHANGE it.

GETS HOT

47. Make up a sentence using all of the words below.
heat is conducted **HEAT IS CONDUCTED**
travels **WHEN HEAT TRAVELS**
from one end **FROM ONE END OF AN**
OBJECT TO THE OTHER **END**.

48. Heat travels very slowly through a piece of asbestos. Therefore, we say that asbestos is A POOR CONDUCTOR OF HEAT.

49. What do we mean by conduction? **HEAT TRAVELS THROUGH AN OBJECT.**

50. Give an example of an object which is a poor conductor of heat, and tell what happens to the object when you apply heat to part of it.
Your example can be any object which is a poor conductor of heat, for instance, asbestos, air, etc. When you apply heat to part of it, ONLY THE HEATED PART GETS HOT.

51. When heat is applied to the left side of a metal bar, the molecules at the left side start to move faster. Therefore, the left side starts to feel hotter **continues to feel hotter the same as before**

X

The right side of the bar will start to feel hotter, also, when the molecules at the right side start to move **continue to move the same as before**

X
52. When heat is applied to one part of a metal object, the molecules of that part start to move faster or slower.

\[
\begin{array}{ll}
\text{faster} & \text{slower} \\
\times & \_ \\
\end{array}
\]

They approach the slow-moving molecules next to them and make them start to move faster or stay the same speed as before.

\[
\begin{array}{ll}
\text{start to move} & \text{stay the same speed} \\
\times & \_ \\
\end{array}
\]

53. The fast-moving molecules in Area #1 approach the molecules in Area #2. The molecules in Area #2 start to move faster or stay the same speed as before.

\[
\begin{array}{ll}
\text{start to move} & \text{stay the same speed} \\
\times & \_ \\
\end{array}
\]

Therefore, Area #2 feels the same as before or hotter than before.

\[
\begin{array}{ll}
\text{the same as before} & \text{hotter than before} \\
\times & \_ \\
\end{array}
\]

54. After the fast-moving molecules in Area #1 make the molecules in Area #2 start to move faster, the fast-moving molecules in Area #2 approach the molecules in Area #3 and on Area #3 molecules make them move faster.

\[
\begin{array}{ll}
\text{approach the molecules in Area #3} & \text{on Area #3 molecules make them move faster} \\
\times & \_ \\
\end{array}
\]

Therefore, Area #3 feels the same as before or hotter than before.

\[
\begin{array}{ll}
\text{the same as before} & \text{hotter than before} \\
\times & \_ \\
\end{array}
\]

55. **EDIT THIS SENTENCE**

When part of an object is heated, the heated molecules do not increase the speeds of the molecules nearby.

If the underlined part of the sentence is correct, COPY it.

\[
\begin{array}{ll}
\text{THE HEATED MOLECULES DO INCREASE THE SPEEDS OF THE MOLECULES NEARBY.} \\
\times & \_ \\
\end{array}
\]

If the underlined part is incorrect, CHANGE it.

56. The molecules at one end of a metal wire do not move all the way to the other end of the wire, but they can still change the speeds of the molecules at the other end of the wire. Explain how.

\[
\begin{array}{ll}
\text{THE MOLECULES AT THE HEATED PART MOVE FASTER AND MAKE THE MOLECULES NEXT TO THEM MOVE FASTER, AND THEY MAKE THE MOLECULES NEXT TO THEM MOVE FASTER, AND SO ON, UNTIL ALL THE MOLECULES MOVE FASTER.} \\
\times & \_ \\
\end{array}
\]

57. The bottom of a metal pan is heated on the stove. At first only the molecules of the bottom start to move faster, but then the fast-moving molecules make the slow-moving molecules move faster or do not affect any other molecules.

\[
\begin{array}{ll}
\text{do not affect any other molecules} & \text{move faster} \\
\times & \_ \\
\end{array}
\]

When fast-moving molecules make slow-moving molecules move faster,

\[
\begin{array}{ll}
\text{heat travels} & \text{heat stays only in the bottom of the pan} \\
\times & \_ \\
\end{array}
\]
58. The top of a metal pole is heated. The molecules at the top start to move faster. When the fast-moving molecules at the top make the molecules next to them move faster, heat stays only in the top of the pole. heat is conducted through the pole. X

59. If heat is applied to the left side of a metal bar, the right side gets hot in a little while because the heated molecules the heated molecules make the others move to the other side faster. X

60. Heat is conducted through a brass handle because fast-moving molecules make slow-moving molecules move to the cool parts move faster. X

61. Make up a sentence using all of the words below. heat is conducted fast-moving molecules near the heat slow-moving molecules. HEAT IS CONDUCTED WHEN FAST-MOVING MOLECULES NEAR THE HEAT MOVE FASTER AND THEN MAKE THE SLOW-MOVING MOLECULES MOVE FASTER. X

62. A flame is applied to one end of a metal spoon. Explain fully how heat gets conducted through the spoon. HEAT MAKES THE MOLECULES NEAR THE FLAME MOVE FASTER, AND THESE MOLECULES MAKE THE SLOW-MOVING MOLECULES MOVE FASTER. X

63. Because copper molecules are spaced close together, a fast-moving copper molecule can come near many slow-moving only a few slow-moving copper molecules copper molecules. X

Therefore, a fast-moving copper molecule would be able to increase the speeds of many slow-moving only a few slow-moving copper molecules copper molecules. X

64. Because air molecules are spaced very far from each other, a fast-moving air molecule can approach many slow-moving only a few slow-moving air molecules air molecules. X

Therefore, a fast-moving air molecule could speed up many slow-moving only a few slow-moving air molecules air molecules. X
65. When we heat one end of a bar of aluminum, the molecules at that end move faster right away.

Since the molecules of aluminum are very close together, the fast-moving molecules make the slow-moving molecules move faster in a short time after a long time

X

66. Water molecules are not as close together as molecules of metal. Therefore, when heat is conducted, fast-moving molecules make slow-moving molecules move faster more quickly less quickly

in water in water

X

67. Write Q under the substance in which the faster movement of molecules caused by heating spreads quickly.

Write S under the substance in which the faster movement of molecules caused by heating spreads slowly.

oxygen gas that has aluminum that has molecules which are molecules which are far apart close together

S Q

68. Write 1 under the substance in which the faster movement of the molecules caused by heating spread fastest.

Write 2 under the substance in which the faster movement of the molecules spreads slowest.

Write 3 under the other substance.

milk molecules air molecules
which are far which are very apart far apart

lead molecules
which are very close together

1

69. Heat is conducted when fast-moving molecules make slow-moving molecules move faster. Therefore, heat is conducted slowly through oxygen gas because oxygen molecules are close together far apart

X

Heat is conducted quickly through copper because copper molecules are closely spaced widely spaced

X

70. Silver conducts heat fastest because silver molecules are very close together far apart

Air conducts heat slowest because air molecules are very close together far apart

X
71. EDIT THIS SENTENCE
An object conducts heat quickly if it has widely-spaced molecules.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

CLOSELY-SPACED MOLECULES

72. EDIT THIS SENTENCE
An object with widely-spaced molecules conducts heat slowly because the faster movement caused by heat spreads quickly.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

THE FASTER MOVEMENT CAUSED BY HEAT SPREADS SLOWLY.

73. Why does an object with closely-spaced molecules conduct heat fastest?

THE FASTER MOVEMENT FROM HEATING SPREADS QUICKLY.

74. How fast an object conducts heat depends on HOW CLOSE THE MOLECULES ARE.
SURFACE TENSION

1. If we place a needle in the center of water, it will
   sink float
   X

   But, if we place a needle on the surface of water, it will
   sink float
   X

2. A razor blade will float if it is placed
   on the surface in the center of the water
   X

   A razor blade will sink if it is placed
   on the surface in the center of water
   X

3. EDIT THIS SENTENCE
   A needle floats on water when it is placed beneath the surface.
   If the underlined part of the sentence is correct, COPY it.
   If the underlined part is incorrect, CHANGE it.
   ON THE SURFACE

4. Make up a sentence using all of the words below. Add any other words that you need.
   razor blade A RAZOR BLADE SINKS IN
   center of water THE CENTER OF WATER, BUT
   surface of water FLOATS ON THE SURFACE OF WATER.

5. At the top of all liquids there is a thin film called the surface film.
   If we place a razor blade on water, the surface film supports it lets it sink
   X

6. Although a needle is heavier than water, it floats because there is a surface film holding it up at the
   top of the liquid bottom of the liquid
   X

7. A bug can "skate" across the top of water because it is supported by a surface film pulled down by the surface film
   X
8. **EDIT THIS SENTENCE**

A hairpin floating on top of water is not supported by the surface film. If the underlined part of the sentence is correct, COPY it. If the underlined part is incorrect, CHANGE it. **IS SUPPORTED BY THE SURFACE FILM.**

9. Complete this sentence. A razor blade does not sink because **IT IS SUPPORTED BY A SURFACE FILM.**

10. When you stand on a trampoline, the trampoline
    bends remains stiff
    ____________________________
    X __________________________

    When you jump off the trampoline, the trampoline
    gets straight still remains bent
    ____________________________
    X __________________________

11. The surface film acts like a trampoline. When you place a razor blade on it, the surface bends remains stiff
    ____________________________
    X __________________________

    When you remove the blade, the surface
    gets straight still remains bent
    ____________________________
    X __________________________

12. Because the surface film bends, we could describe it as acting like a
    sheet of rubber sheet of steel
    ____________________________
    X __________________________

    That is, the surface film supports things because it bends and breaks easily does not break
    ____________________________
    ____________________________

13. A paper clip floats on top of the water because there is a surface film which bends but bends and does not break breaks easily
    ____________________________
    ____________________________

14. **EDIT THIS SENTENCE**

When you touch mercury with a pin and then release the pin, the surface gets straight again because the surface film bends and breaks easily.

If the underlined part of the sentence is correct, COPY it. If the underlined part is incorrect, CHANGE it. **SURFACE FILM BENDS AND DOES NOT BREAK EASILY.**

15. Make up a sentence using all of the words below. razor blade **A RAZOR BLADE FLOATS ON WATER** floats **BECAUSE THE SURFACE FILM BENDS** break easily **BUT DOES NOT BREAK EASILY.**
16. What will happen to a paper clip if we put it on top of a liquid? Explain why.

The paper clip will float because it is supported by a surface film which bends but does not break.

17. A child blows a soap bubble. When the child stops blowing, the air escapes and the bubble stays the same gets smaller.

18. When you stretch a rubber band it gets bigger stays the same shrinks.

But, when you let go of a rubber band it gets bigger stays the same shrinks.

19. Just like when you let go of a rubber band, or when you let air out of a bubble, the surface film of a liquid tends to shrink stay the same spread out.

20. The surface film of a liquid does not stay the same size, rather it tends to shrink spread out.

21. If you smear water on a table top, the film of water you leave on the table will shrink spread out.

22. When there is a thin film of water on a waxed automobile hood, the part which dries first is the outer edge center of the film.

23. When there is a film of water on an automobile hood, the outer edge of the film dries first because the film of water shrinks and spreads out and gets bigger.

24. If you wet an area with water, the water shrinks and gets smaller because the surface film pulls the water in toward the center out toward the edges.

25. Edit this sentence

When you wash a blackboard, the film of water on the board tends to get bigger.

If the underlined part of the sentence is correct, copy it.

GET SMALLER (SHRINK).
26. The surface film on top of the water in a glass acts the same as the film of water on a blackboard.

EDIT THIS SENTENCE
When water is in a glass, the surface film on the top of the water does NOT get smaller.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

THE SURFACE FILM ON THE TOP OF THE WATER DOES GET SMALLER.

27. Make up a sentence using all of the words below.
surface film THE SURFACE FILM stay the same size OF A LIQUID DOES NOT shrinks STAY THE SAME SIZE, BUT SHRINKS.

28. If you spread a film of water on the roof of a car, what will happen to the film of water? THE WATER SHRINKS AND GETS SMALLER.

29. If you wet a 10-inch circular area with water, the circle of water would become a 12-inch circle of water 8-inch circle of water

X

Explain why you chose that answer.
LIQUID TENDS TO SHRINK.

30. A magnet pulls particles of steel toward it because the magnet attracts steel repels steel

31. Just like a magnet, water molecules are pulled together because they attract each other repel each other

32. If two water molecules attract each other they will move together move apart

33. The molecules in a liquid attract each other. Therefore, they cling together move apart

34. The molecules in a liquid cling together because they attract each other repel each other

X
35. EDIT THIS SENTENCE

Because liquid molecules attract each other, they tend to move apart.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

36. Make up a sentence using all of the words below.

because water BECAUSE WATER MOLECULES molecules attract DO NOT MOVE APART.

move apart

37. A molecule in the center of a liquid is attracted by the molecules all around only from the top

39. A molecule on the surface of a liquid is only attracted sideways and downwards because there are no liquid molecules below it above it

40. Because there are no liquid molecules above it, a molecule on the surface of water is attracted in all directions but not down not up not sideways

41. A molecule on the surface of a liquid is only attracted sideways and downwards because there are no liquid molecules below it above it

42. Put X's below all the answers that tell in how many directions a molecule on the surface of a liquid is attracted by the other molecules.

sideways upwards downwards

43. EDIT THIS SENTENCE

The molecules at the surface of a liquid are being attracted in all directions.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

SIDWAYS AND DOWNWARDS BUT NOT UP
44. Make up a sentence using all of the words below.

surface molecules SURFACE MOLECULES ARE attracted ATTRACTION SIDEWARD AND upward direction DOWNWARD BUT NOT IN AN upward direction.

45. Complete this sentence.

Liquid molecules at the surface are not attracted upward because THERE ARE NO LIQUID MOLECULES ABOVE THEM.

46. When rain falls it takes the shape of a sphere.

Put an X below the shape that is most like dripping water.

△ □ ○ X

47. We speak of rain "drops" because liquids tend to form cubes cones spheres

X

48. When a liquid shrinks it covers a bigger area smaller area

X

49. When liquids shrink, they cover a very small area.

Liquids form drops because the shape with the smallest area is a rectangle sphere triangle

X

50. If you spilled mercury, it forms tiny spheres. That is, the mercury takes the shape with the largest area smallest area

X

51. EDIT THIS SENTENCE

When water drips from a tap it forms spheres because a sphere covers the largest area.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

A SPHERE COVERS THE SMALLEST AREA

52. Complete this sentence.

When liquids shrink they form a sphere because A SPHERE COVERS THE SMALLEST AREA.

53. When water is in a glass it has a surface film. Liquids also have a surface film when they form a sphere are spilled on the floor both

X

B-17
54. When water is in a glass, the molecules at the surface are being attracted 
   sideways and downwards in all directions 
   
   When water forms a sphere, the molecules at the surface are still being attracted 
   sideways and downwards in all directions 
   
55. When water is spilled on the floor, the sideward and downward attraction of the surface molecules causes the water to 
   spread out and cover the biggest possible area; shrink and cover the smallest possible area 
   
   This happens because there is a sideward and downward attraction on the surface molecules 
   
56. The surface film of a liquid always shrinks to the smallest possible area; spreads the liquid out 
   
   This happens because there is no attraction on the surface molecules 
   
57. EDIT THIS SENTENCE 
   When you spill a drop of milk, the sideward and downward attraction of surface molecules causes the milk to spread out to the biggest possible area. 
   
   If the underlined part of the sentence is correct, COPY it. 
   
   If the underlined part is incorrect, CHANGE it. 
   
58. EDIT THIS SENTENCE 
   Water on a waxed table forms spheres because the molecules in the surface film are attracted upwards and downwards. 
   
   If the underlined part of the sentence is correct, COPY it. 
   
   If the underlined part is incorrect, CHANGE it. 
   
59. Because the molecules at the surface of a liquid are being pulled sideward and downward, what happens to the liquid? 
   
   IT SHRINKS TO THE SMALLEST POSSIBLE AREA. (IT FORMS A SPHERE.) 
   
60. Make up a sentence using all of the words below. 
   
   surface film THE SURFACE FILM DOES NOT spread out SPREAD OUT BECAUSE OF THE attraction of molecules ATTRACTION OF THE MOLECULES.
When you get out of a swimming pool, the water beads on your skin. Explain what happens to the molecules when water takes that shape. Because the surface molecules are attracted sideways and downwards, the water shrinks to the smallest possible sphere.
Visual Answer Booklet

1. Answer A  Answer B
Fast-moving molecules  Slow-moving molecules

2. Answer A  Answer B
Fast-moving molecules  Slow-moving molecules

3. Answer A  Answer B
Molecule continues to move slowly to move faster

4. Answer A  Answer B
Molecule continues to move slowly to move faster

5. Answer A  Answer B
Molecules far apart close together

6. Answer A  Answer B

7. Answer A  Answer B

8. Answer A  Answer B

9. Answer A  Answer B

10. Answer A  Answer B
Molecules all move fast at once At first only molecules near heat move fast, then it spreads

11. Answer A  Answer B
Fast movement spreads slowly Fast movement spreads quickly

12. Answer A  Answer B
Slow-moving molecules spaced close together Slow-moving molecules spaced far apart

*Students saw only "Answer A" and "Answer B" in their booklets. The phrases are descriptive of what they saw on the screen.*

B-20
**Visual Answer Booklet**

**HEAT - INDIRECT**

1. **Answer A**  
   Slow pinging  
   **Answer B**  
   Fast pinging

2. **Answer A**  
   Fast pinging  
   **Answer B**  
   Slow pinging

3. **Answer A**  
   Molecule continues to move slowly*  
   **Answer B**  
   Molecule starts to move faster*

4. **Answer A**  
   Molecule continues to move slowly*  
   **Answer B**  
   Molecule starts to move faster*

5. **Answer A**  
   Molecules far apart*  
   **Answer B**  
   Molecules close together*

6. **Answer A**  
   **Answer B**

7. **Answer A**  
   **Answer B**

8. **Answer A**  
   Fast moves through the water and turns the paper.

9. **Answer A**  
   **Answer B**

10. **Answer A**  
    Molecules all move fast at once*  
    **Answer B**  
    At first only molecules near heat move fast, then it spreads*

11. **Answer A**  
    Fast movement spreads slowly*  
    **Answer B**  
    Fast movement spreads quickly*

12. **Answer A**  
    Slow-moving molecules spaced far apart*  
    **Answer B**  
    Slow-moving molecules spaced close together*

*Students saw only "Answer A" and "Answer B" in their booklets. The phrases are descriptive of what they saw on the screen.*

B-21
Visual Answer Booklet - Surface Tension (Direct)
Visual Answer Booklet - Surface Tension (Indirect)

- Spread out
- Stay the same
- Observe

Page 6

Page 7

Page 8

A

B

C

B-26
Visual Answer Booklet - Surface Tension (Indirect)

A

B

C

Page 9

Page 10

Page 11

Page 12

B-27
HEAT

PART I

1. The left side of a metal bar is heated. Explain how heat is conducted through the metal bar so that the right side also becomes hot.

2. Different substances conduct heat differently. Some substances conduct heat easily and quickly. Others conduct heat slowly or not at all. What determines how easily heat is conducted?

3. Describe two conditions which are necessary if the movement of one molecule is to change the movement of another molecule.

4. Describe two conditions under which the movement of one molecule will not change the movement of another molecule.

5. What effect does cooling an object have on the molecules that make up the object?
Achievement Test - Heat

PART II

1. a. Circle the substance which conducts heat the slowest.

   metal   water   air

   b. Why does that substance conduct heat the slowest?

   ____________________________________________________________

   ____________________________________________________________

2. a. When one part of the substance is heated, the molecules at that part change speeds. Circle the substance in which the change in speed spreads slowest from molecule to molecule.

   metal   water   air

   b. Why does it spread slowest in that substance?

   ____________________________________________________________

   ____________________________________________________________

3. Circle the substance in which molecules approach each other most often.

   metal   water   air

   b. Why do molecules approach each other most often in that substance?

   ____________________________________________________________

   ____________________________________________________________

B-29
SURFACE TENSION

1. a. Some objects which are heavier than water can, nevertheless, still float on top of the water. How is this possible?

b. When the same objects are placed below the top of the water, they sink. What difference is there between the top of the water and the middle of the water?

c. Using the word "molecules" in your answer explain why there is a difference between the top and middle of the water.

2. When it rains, in what shape does rain come down? Explain why the rain takes on this shape.

3. After you spill some pop on your clothes, the wet spot begins to dry. Describe which part of the spot dries first and explain why it dries first.

4. What causes a surface film to be formed in a glass of soda pop?

5. Describe the ways in which surface films act.
1. All substances like iron, wood, water, air, aluminum, etc. can be broken down into tiny pieces which we call "atoms." Atoms are the smallest pieces of the largest pieces. 

2. The picture shows the atoms that make up salt. Salt is made up of one kind of atom. 

3. Carbon dioxide is made up of: (a) 1 atom 2 atoms 3 atoms (b) oxygen carbon oxygen and carbon atom atom atom (c) one kind two kinds (d) one carbon atom two carbon atoms 

4. Which examples have the same number of atoms? 1 & 2 1 & 3 2 & 3 

5. The two gases carbon monoxide and carbon dioxide are different because they have different kinds of atoms. They are similar because they have the same kinds of atoms. 

*The frames reproduced here are those which were presented to the subjects as confirmation frames after they had made their own responses. X's are used to indicate the correct multiple choice responses.*
6. **Gold**

   **Water**

   **EDIT THIS SENTENCE**

   Substances are made up of only one kind of atom.

   If the underlined part of the sentence is correct, **COPY** it.

   If the underlined part is incorrect, **CHANGE** it.

   **SUBSTANCES ARE MADE UP OF DIFFERENT KINDS OF ATOMS.**

7. **Carbon**

   **Hydrogen**

   **Oxygen**

   **EDIT THIS SENTENCE**

   Substances are made up of the same number of atoms.

   If the underlined part of the sentence is correct, **COPY** it.

   If the underlined part is incorrect, **CHANGE** it.

   **SUBSTANCES ARE MADE UP OF DIFFERENT NUMBERS OF ATOMS.**

8. **Carbon**

   **Hydrogen**

   **Oxygen**

   **EDIT THIS SENTENCE**

   There is a difference between carbon dioxide and water. Make up a sentence using the words below telling what the difference is.

   - Carbon dioxide and water are different because they are made up of a different number of atoms and of different kinds of atoms.

9. Atoms join together and form tiny clumps, called molecules.

   - An atom is part of a molecule
   - A molecule is part of an atom

   **X**

10. Since atoms joined together make up molecules, we can say that

    - a molecule contains one or more atoms
    - an atom contains one or more molecules

   **X**

11. The molecule in this picture is the whole clump of circles.

    - a smaller circle

   **X**

12. If the big clump is a molecule, the small circles are atoms.

13. This picture shows the smallest particles in a drop of water. The atoms are the small circles.

    - groups of circles

   **X**

   The molecules are the clumps of circles.

   - smaller circles labelled "water"
   - labelled "hydrogen" and "oxygen"
14. **EDIT THIS SENTENCE**

A molecule contains one or more atoms.

If the underlined part of the sentence is correct, COPY it.

A MOLECULE CONTAINS ONE OR MORE ATOMS.

If the underlined part is incorrect, CHANGE it.

15. Atoms of chloride joined with atoms of sodium make salt. However, atoms of chloride joined with atoms of hydrogen make a gas. Salt and the gas are different because they are made up of the same atoms \( \text{Cl}_2 \) \( \text{Na}_2 \) joined together joined together

\[ \text{Cl}_2 \text{Na}_2 \]

16. Some things, called elements, are made of only one kind of atom. Gold is an element; it is made up of

one kind of atom \( \text{Au} \)

different kinds of atoms \( \text{X} \)

Therefore, gold is made up of only gold atoms \( \text{Au} \) and other kinds of atoms \( \text{X} \)

17. Iron is an element. If we broke iron into its smallest pieces, we would find many atoms but they would be

different kinds of atoms \( \text{Fe} \) \( \text{X} \)

18. **Molecule of Rust** **Molecule of Iodine**

Study these pictures of molecules. You can tell that

\( \text{O}_2 \text{H}_2 \) \( \text{I}_2 \)

- Rust is an element
- Iodine is an element

19. Because salt can be broken down into two kinds of atoms, we know it is not an element \( \text{X} \) \( \text{O} \)

20. Water is made up of hydrogen atoms and oxygen atoms. Water is an element not an element \( \text{X} \)

21. **EDIT THIS SENTENCE**

An element is something made up of different kinds of atoms.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

AN ELEMENT IS SOMETHING MADE UP OF ONLY ONE KIND OF ATOM.
22. Make up a sentence. Include all the words below, and add any other words that you need.

**element** AN ELEMENT IS different kinds of NOT MADE UP OF DIFFERENT KINDS OF ATOMS.

23. In an element, the atoms in each molecule are of only one kind different kinds x

24. A molecule of various substances can contain one atom or several atoms. Often the atoms are of a different kind. When the atoms are of the same kind we know the material is not an element an element x

25. Make up a sentence, using all the words below.

**molecule** A MOLECULE OF SILVER **silver** CONTAINS ONLY ONE ATOM.

26. Since silver is an element, it contains different kinds only one kind of atom of atom x

Thus, the molecules in silver contain different kinds of atoms only a silver atom x

27. The picture shows a molecule of chalk. By looking at the different kinds of atoms in the molecule we can tell that chalk is an element is not an element x

28. Each molecule of water has the same number of hydrogen atoms as the other molecule the same number of oxygen atoms as the other molecule x

Both answers are correct x

Both molecules of water have 2 hydrogen 1 oxygen both answers atoms atom are correct x
29. SODIUM → CHLORIDE
   Molecule of salt
   Molecule of salt

These two molecules of salt are the same because they both contain the same kinds of atoms in the molecules and have the same number of each kind of atom in the molecules. Both answers are correct.

30. OXYGEN ← HYDROGEN
    HYDROGEN ← OXYGEN

These two molecules are similar because they are made up of the same kind of atom in the molecules and the same number of each kind of atom.

31. CARBON ← OXYGEN
    CARBON ← OXYGEN

These two molecules are different because they are made up of different kinds of atoms. Carbon monoxide and carbon dioxide are different because their molecules are made up of different kinds of atoms and different numbers of atoms. Both answers are correct.

32. EDIT THIS SENTENCE

What a thing is depends on the kinds of atoms it contains and the number of each kind of atom in the molecule.

If the underlined part of the sentence is correct, copy it.

KINDS OF ATOMS NUMBER OF EACH KIND OF ATOM IN THE MOLECULE

If the underlined part is incorrect, change it.

33. Complete the sentence below using the words on the left to help you.

Flour and butter molecules could be different for either of two reasons; either because kinds of atoms they contain different kinds of atoms or because number of each kind of atom they contain a different number of the same kinds of atoms.
34. The reason that water and peroxide are different is because they contain the same kinds of atoms, but the number of atoms in their molecules are different.

35. Although we cannot see them, scientists have found that the tiny molecules are always moving. Even in solid objects, the molecules are always moving.

36. It is easy to imagine the molecule in water moving, but it is also true that the molecules in a block of wood are also moving.

37. The molecules that make up the air are always moving in all substances.

38. Molecules move in all substances. Molecules are always moving in all of these things:

39. Leather and silver are different substances. However, the molecules move in neither of these substances, both of these substances.

40. Molecules are always moving only in some substances.

41. Make up a sentence, using all the words below.

42. Molecules are arranged differently in different types of materials. Comparing molecules in wood and water, you can see that in wood the molecules are closer together and farther apart.
Comparing water molecules with air molecules, air molecules are
farther apart  closer together

Mark the words below 1, 2, 3 in order of the closeness together of the molecules.

1 - solid
2 - liquid
3 - gas

In solids, the molecules are usually moderately close together and very far apart.

In liquids, the molecules are usually moderately close together and far apart.

In gases, the molecules are usually far apart.

Look at the drawings below. Then, depending on how close together the molecules are, write in below the appropriate drawings with the words solid, liquid, or gas.

In solids, the molecules are usually moderate close together.

In liquids, the molecules are usually moderately far apart.

In gases, the molecules are usually far apart.

EDIT THIS SENTENCE

The more solid a substance is, the further apart are the molecules.

If the underlined part of the sentence is correct, COPY it.

If the underlined part is incorrect, CHANGE it.

THE CLOSER TOGETHER ARE THE MOLECULES
49. Complete the table below by putting check marks in the correct squares.

<table>
<thead>
<tr>
<th></th>
<th>Molecules very far apart</th>
<th>Molecules moderately far apart</th>
<th>Molecules close together</th>
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</thead>
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<td></td>
</tr>
<tr>
<td>Liquids</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>Gases</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

50. Describe the molecules in:
- gas: MOLECULES ARE FURTHEST APART
- liquid: MOLECULES ARE MODERATELY FAR APART
- solid: MOLECULES ARE CLOSE TOGETHER

51. Describe the molecules in:
- solid iron: SINCE IRON IS A SOLID, THE MOLECULES ARE CLOSE TOGETHER.
- milk: SINCE MILK IS A LIQUID, THE MOLECULES ARE MODERATELY FAR APART.
- iodine gas: SINCE IODINE GAS IS A GAS, THE MOLECULES ARE VERY FAR APART.

52. The moving molecules are like children playing tag in a playground, always pushing and pulling at each other. The closer together they are, the more strongly they push and pull each other. 
Stay still

53. Magnets can pull towards each other or away. The closer they are together, the more strongly they push or pull. Similarly, the closer molecules are together, the

more strongly they push and pull less strongly they push and pull

54. Since molecules in solids are closest together furthest apart

- molecules in solids push and pull each other the least push and pull each other the most

55. The farther apart molecules are

The less strongly they push and pull more strongly than less strongly-than

Gas molecules push and pull

More strongly than less strongly-than liquid molecules liquid molecules

X
56. Complete the table below by putting check marks in the correct squares.

<table>
<thead>
<tr>
<th>Molecules push and pull most</th>
<th>Molecules push and pull least</th>
<th>Molecules push and pull each other the most</th>
<th>Molecules push and pull each other the least</th>
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</thead>
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<tr>
<td>Gas</td>
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</tr>
</tbody>
</table>

57. **EDIT THIS SENTENCE**

When molecules are closest together, they push and pull the least.

If the underlined part of the sentence is correct, **COPY** it.

If the underlined part is incorrect, **CHANGE** it.

THEY PUSH AND PULL THE MOST

58. Make up a sentence, using all the words below.

molecules **WHEN MOLECULES ARE** furthest apart **FURTHEST APART, THEY** push and pull **PUSH AND PULL THE LEAST.**

59. Compare the pulling of molecules in hydrogen chloride and in ammonium sulfide.

THE Molecules IN AMMONIUM SULFIDE ARE CLOSER TOGETHER AND THEREFORE PUSH AND PULL MORE.

60. When molecules are close together, the spaces between them are small. The spaces between molecules are smallest in a

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</table>

61. You will remember that the molecules push and pull most when they are closest together. This also means that the molecules push and pull most when the spaces between them are

largest smallest

<p>| | |</p>
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</table>

62. Liquid oxygen is used in rockets. Gaseous oxygen is a gas. Compare the spaces between liquid oxygen molecules and gaseous oxygen molecules. The spaces between gaseous oxygen molecules are

larger the same smaller

<p>| | | |</p>
<table>
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The molecules push and pull each other more in

gaseous oxygen liquid oxygen

<p>| | |</p>
<table>
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<tbody>
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</table>

63. **EDIT THIS SENTENCE**

The amount of push and pull among molecules depends on the amount of space between the molecules.

If the underlined part of the sentence is correct, **COPY** it.

**AMOUNT OF SPACE BETWEEN THE MOLECULES**

If the underlined part is incorrect, **CHANGE** it.
64. Make up a sentence, using all the words below.
pushing and pulling among molecules depends on the amount of space between them.

65. Molecules do most pushing and pulling in a solid. This is because in this substance the spaces between the molecules are smallest.

66. EDIT THIS SENTENCE
The closer the molecules are to each other the less they push and pull each other.

If the underlined part of the sentence is correct, COPY it. If the underlined part is incorrect, CHANGE it.

67. Hot steam is a gas. Below, explain why the molecules push and pull each other less in steam than in water.
The molecules in steam are further apart or the spaces between steam molecules are larger.

68. Let's see what you remember.
An element contains different kinds of atoms.

In elements and all other materials, one or more atoms form molecules or fragments.

69. What makes things different is only the kinds of atoms they contain in the molecules.
Both answers can be correct.

70. Molecules are always moving. Below, explain why they push and pull each other less in steam than in water.
The molecules in steam are further apart or the spaces between steam molecules are larger.

71. Molecules are usually closest together in solids. Below, explain why they push and pull each other less in steam than in water.
The spaces between molecules are usually largest in solids.
72. Molecules push and pull each other most when they are closest together and the spaces between them are the largest.

73. Below, write what you know about what decides the amount of pushing and pulling among molecules.

1. THE AMOUNT OF PUSHING AND PULLING AMONG MOLECULES DEPENDS ON THE AMOUNT OF SPACE BETWEEN THEM.
2. THE AMOUNT OF PUSHING AND PULLING AMONG MOLECULES DEPENDS ON HOW CLOSE THEY ARE TOGETHER.

74. Compare how the molecules of water push and pull each other: (1) at the surface of a pool of water and (2) in the middle of a pool of water.

1. AT THE SURFACE THEY PUSH AND PULL ONLY SLIGHTLY AND DOWNWARDS.
2. IN THE MIDDLE OF THE POOL, THEY PUSH AND PULL IN ALL DIRECTIONS.
### Table 1
Summary of Analysis of Variance for the Matching of Ss for:
Work Rate

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Significance levels: * = .05; ** = .01; *** = .001

### Table 2
Summary of Analysis of Variance for the Matching of Ss for:
Otis IQ

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Significance levels: * = .05; ** = .01; *** = .001
Table 3

Summary of Analysis of Variance for the Matching of Ss for:
Pretest Scores - Heat

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Table 4

Summary of Analysis of Variance for the Matching of Ss for:
Pretest Scores - Surface Tension

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### Table 5
Summary of Analysis of Variance:
Errors - Heat

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### Table 6
Summary of Analysis of Variance:
Errors - Surface Tension

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B-44
### Table 7
**Summary of Analysis of Variance:**
Visual Booklet - Heat

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### Table 8
**Summary of Analysis of Variance:**
Visual Booklet - Surface Tension

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### Table 9
Summary of Analysis of Variance:

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Summary of Analysis of Variance:

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### Table 11
Summary of Analysis of Variance:
Posttest - Heat

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### Table 12
Summary of Analysis of Variance:
Posttest - Surface Tension

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### Table 13
Summary of Analysis of Variance: Retention Test - Heat

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Summary of Analysis of Variance: Retention Test - Surface Tension

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