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Students' misconceptions in Dynamics:  
An interventionist approach using a  
computer simulation.

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Offered in partial fulfilment of the degree of  
Bachelor of Philosophy in Educational Technology

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## Statements

- I agree that this thesis may be made available for photocopying
- None of the contents of this thesis has been submitted to any university or other institute for a degree or any other qualification.
- Versions of some parts of this thesis have been published as a conference paper ('NEWLOGO: a programming language for simulating Newtonian motion and improving children's understanding of inertia', presented at GIREP '84, Utrecht).

## **Acknowledgements**

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## Abstract

NEWLOGO (NEWtonian LOGO) is a special-purpose, LOGO-like programming language for simulating motion with and without inertia, gravitation and friction. Its effect on student performance and understanding has been assessed by using a dynamics test that we developed, together with interviews and observation of NEWLOGO use.

The notion of 'misconceptions' in the area of dynamics is discussed, and related to the literature.



# Section 1: Review

## 1.0 Introduction

Does what we learn from our everyday observation of our environment provide us with the correct framework of ideas to understand physical reality? I have long suspected that the concepts that some students use are wrong, and more powerful ones are hidden from them by the complexity of the real world. In dynamics teaching, stroboscopes, special runways, air blowers, etc, are used to 'simplify' motion, so that the effects of gravity and friction are removed. This instructional design does not take sufficient account of students' intuitive misconceptions, and does not expose them to many examples of Newtonian motion, from which re-perception of how objects move may be possible.

## 1.1 Misconceptions in Physics

Do students have unrecognised misconceptions about Physics? It may seem reasonable to dismiss most of the wrong answers that they give as being the result of inadequate mathematical skill, or a misunderstanding of the question. However, from group to group, and from year to year there are some types of problems that consistently evoke unexpected and incorrect answers. This would seem to imply that such problems highlight misconceptions which would otherwise go unrecognised. DiSessa (1985) gives one example:

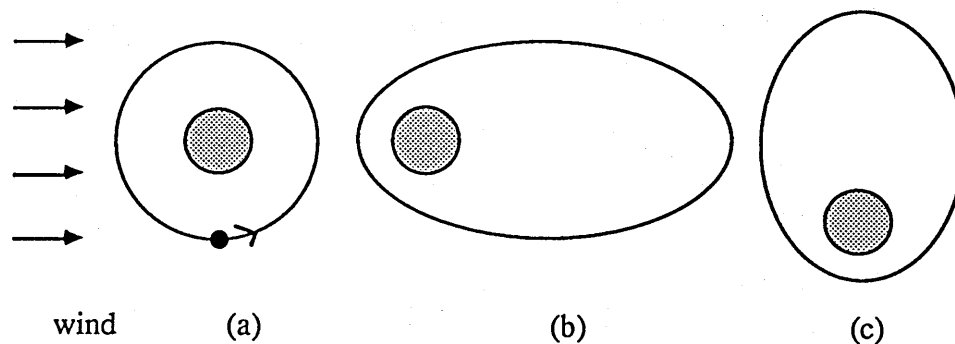


Figure 1. (a) A satellite in circular orbit blown by a "wind"  
 (b) Wrong prediction: orbit moves in direction of push  
 (c) Correct prediction

Several studies have investigated the errors which arise when students tackle such problems; those errors have been attributed to:

- A 'Natural', 'Intuitive' or 'Spontaneous' way of reasoning, independent of formal teaching. (Viennot 1980, Saltiel 1980);
- 'Naive Theories'- a set of rules evolved by informal, everyday observations, as distinct from systematic experimentation. (McCloskey 1980); and
- 'Alternative Conceptions' (Driver and Easley 1979).

One might reasonably ask how the idea of misconceptions is related to the idea of a 'concept'. Gilbert and Watts (1983) and Driver and Erickson (1983) exemplify two viewpoints: conjectural; and phenomenological. Gilbert and Watts have discussed the use of the term 'concept', identifying several meanings. They use the term 'alternative framework', which they distinguish from the term 'concept' by arguing that a 'framework' would be a mental structure, built of concepts. In the absence of a coherent, non-circular definition of the term 'concept', that differentiation is purely conjecture. Driver and Erickson use the terms 'conceptual framework' and 'alternative framework'. They describe

various studies of student performance as being somewhere on a scale between contextually (phenomenologically) framed and conceptually framed.

I now identify three possible uses of the term 'misconception':

- a) In studies that are contextually framed, 'misconceptions' are highly specific to a particular environment or situation, and are simply verbalizations of an observation.

For example, a statement like: 'The ball went where I kicked it' may be thought of as inaccurate. (It might be argued that the 'kick' would only be in the direction of motion of the ball if it had no initial sideways momentum relative to the kicker).

- b) Statements of the above sort could be grouped, in order to gain insight into students understanding (or misunderstanding).

The action of grouping the statements implies that an assumption has been made regarding the meaning of these statements. i.e. similar statements have the same meaning for different students, or for the same student at different moments. The grouping of statements also requires value judgments of what constitutes 'similar' statements. It may become necessary to take a statement that appears to be typical of the group, or to phrase a generalization to aid grouping. Here is an example of such a possible general statement:

*"If an object has no applied force acting on it, then it must be at rest"*

From an intuitive point of view, I feel that the above example is present in some students minds. I would use the 'misconception' label for this type of statement. Studies that use these generalizations or inferred rules in order to interpret the data have been described as being contextually framed. They still use the notion of a concept.

The rule itself might not have been said by a student, although some studies have tried to elicit verbalizations of misconceptions. These are conceptually framed investigations. The misconceptions are constructed by the investigator, who is already familiar with the notion of a physical law. In this case the misconceptions are convenient means of understanding students' responses. It is this level of misconceptions that has received attention in studies by Erickson (1979), Viennot (1980).

- c) It is possible to see these misconceptions as being symptoms of more fundamental 'misconceptions'.

Strike (1983) gives the example of the misconception 'The Earth is flat' as being created by the more fundamental concept of 'absolute up'. Some people remain 'Flat Earthers' even when apparently faced with evidence to the contrary. This feature of misconceptions, i.e. their robustness, supports the notion that they are produced by 'deeper feelings'. This suggests that the effort to investigate misconceptions, and to find ways of modifying them, must be directed away from the usual subject matter of science, and towards issues concerning the emotional state of the student.

These three alternative meanings for 'misconception' may of course be an over-simplification. The theoretical perspective adopted by a study of

student performance might allow for any of them, perhaps in a way that allows for the setting faced by the student. Driver (1984) has asked the question - what triggers intuitive reasoning? This is a recognition of the variability of student response. Ganiel and Idar (1984) have stated that 'superficial memorization of terminology' hides the understanding that the student actually has. This is a recognition of the unreliability of a student's response.

A useful analogy would be with crystallography. If the subject for investigation is the internal structure of a crystal, then the collection of data is aided by controlling and selecting the wavelength of the illumination. In the same way, students' responses to stimuli will depend on many factors, including their perception of the 'source' (e.g. an event occurring during experimentation, or a statement made by a teacher). In conventional science lessons, with conventional questioning, they may appear to have a classical Newtonian view of dynamics, giving correct answers to the questions. The wrong answers could be attributed to an incomplete understanding, or mathematical clumsiness. Entirely different, non-Newtonian views appear when the setting changes, or the questions become in some way unconventional.

No single fixed view of the mind is likely to take account of student behavior. To return to the crystal analogy, the diffraction pattern obtained from x-rays will depend on the orientation of the crystal. It is possible that students may enter a science lesson in a 'frame of mind' that is oriented in a way that results in entirely different views being expressed. For example, if a history lesson precedes the science lesson, students may have temporarily gained an interest in the idea of invention. This may lead to reflective thinking. Conversely, a sports lesson that follows may be absorbing their interest to the point that the physics lesson is regarded as a series of tasks to be performed as efficiently as possible. (I do not mean to imply that history is always good and sport is always bad.)

## Investigating Misconceptions

In the investigation of misconceptions, the type of question asked is of central importance. In a study by McDermot (1982), a typical question was:

*A bullet leaves the muzzle of a gun at a speed of 400 m/sec. The length of the gun barrel is 0.5 m. Assuming that the bullet is uniformly accelerated, what is the average speed within the barrel?*

By contrast, McCloskey (1980) used questions like:

*Draw the path of a ball when it is released from an aeroplane.*

This was accompanied by a diagram similar to the one shown in Question 6 of Appendix A.

McDermot tested groups of students and lecturers, identified as 'novices' and 'experts'. The differences in their observed performances were then evaluated not by using the notion of a misconception but by using the idea of memory limitations. In this case, the 'novices' were thought to have been unable to use their short-term memory in an efficient manner. The 'experts' had a way of recalling relevant concepts and facts from long term memory that McDermot likened to Information Retrieval in Computer Systems. (It is interesting that psychological interpretations often tend to be in terms of the current technology: e.g. hydraulic models, mechanical models, electrical models or computational models. In this thesis, I use 'short-term' and 'long term' without accepting any particular view of how the brain works.)

In support of his results, McDermot referred to studies involving the memory performance of expert chess players and non-players, which show how familiar patterns on a chess board are easily recalled by the

experts, but when the same chess pieces are presented in an arrangement that would not be met in normal play, the experts become as inefficient as the non-players at recalling the arrangement.

McCloskey (1980) used more open-ended questions than McDermot (compare the examples quoted above). His interpretation of the responses was that a significant proportion of students had similar misconceptions.

It is possible to claim that the misconceptions 'revealed' in such studies are an artefact of the questions asked, and that the students do not have any absolute misconceptions. A more convincing alternative view is that students do have quite persistent and absolute misconceptions, which give rise to consistent classes of error; in some cases, those errors can be predicted using a 'mal-rules' model (Preist, 1986)

## Common misconceptions

There have been investigations of misconceptions in many areas of science. (see Driver and Erickson, 1983). I concentrate now on the field of dynamics.

It is possible that all of the misconceptions in this field are products of a universally held concept of the type proposed by Strike (1983), but I now state three misconceptions, together with a question of the type that has produced some evidence for each.

1. *'An object will retain the main features of its motion until there has been time for changes in forces acting upon it to have effect'*

This misconception would appear to be held by many people who, in answer to the question: *"A ball is pushed through a curved tube. Draw*

*its path*", show the ball continuing to move in a curved path for some distance after it has left the tube. This could be called 'curvilinear' momentum.

2. *'The previous motion of any object does not affect its motion when it enters my "frame of reference"'*

(The term 'my frame of reference' could more accurately be called: 'the region in which I choose to perceive its motion'.) This misconception would appear to be held by many people, who, in answer to the question: *"A ball is released from an aeroplane. Draw its path"*, show the ball falling vertically.

3. *'An object will travel in the direction of the most recent impulse, independent of its previous motion'*

This misconception would appear to be held by many people who, in answer to the question: *"A ball is moving along a smooth table top. It is then hit from the side. Draw its path."*, show the ball moving in the direction of the hit.

Some reasonably firm evidence for the existence of these misconceptions, or variants of them, can be found in an increasing number of investigations (e.g. Driver, 1983). The findings from those studies, which accord with my informal observations as a science teacher, apply to diverse areas of Physics. For example, the 'Drift Velocity' that electrons have when travelling through a conductor is a concept that is difficult for some students, perhaps because they have no difficulty in accepting the misconception that a continuously applied force causes constant velocity ('Motion requires force'). The misconception will not be revealed by traditional examination questions, which are



answered correctly if students have declarative knowledge such as 'Energy is dissipated as heat', backed up by adequate mathematical skill. Even if teaching takes misconceptions into account, the modification of the misconception, and the internalization of more powerful concepts (i.e. Newton's Laws of Motion) may be rejected by students in favour of an easy way out- they are able to answer 'the questions in the textbook', so further thought and consideration of the concepts are not required, or even sensible, in view of the time available.

## 1.2 Implementations of LOGO for dynamics

Computer simulation offers an obvious way of generating large numbers of dynamic examples, from which students may be able to modify their misconceptions. What is more problematic is the role of the user in choosing the examples. Being able to control some aspects of a simulation will raise levels of concentration, but being able to control all aspects may be diversionary and so counter-productive. Three possibilities are:

- a low level of control (as with menu selection of a limited number of examples generated by a pre-written simulation program);
- complete control (a user can write all of a simulation program); and
- an intermediate but high level of control (a user can program some parts of a simulation).

LOGO, which is a general purpose programming language (Abelson and diSessa, 1981), is a common vehicle for creating controllable simulations of sub-sets of the physical world, termed 'microworlds' (e.g. Squires, 1985). It is more used for simulation in education than the BASIC programming language. Full implementations of LOGO are available on

8-bit and 16-bit computers. although some implementations used in schools are only a graphics subset (e.g. 'Turtle Graphics', for BBC-Acorn computers; 'LOGO Challenge', for Research Machines and BBC-Acorn).

There are more than twenty basic commands ('primitives') in LOGO, but the fundamental ones are *FORWARD n*, *LEFT n* and *RIGHT n*.

These control the movement of a graphics entity called a 'Screen-Turtle', and a wheeled, motorised plastic dome called a 'Floor-Turtle'. There is no accepted standard form for the other primitives, so that *TO*, *DEFINE* and *BUILD* all have the effect of starting the declaration of a procedure.

Students who carry out LOGO-based programming activities (e.g. 'Talking Turtle'), decide what the computer will do: they create and name groups of commands and generally adopt the role of an instructor, teaching the computer. Papert (1980) has made strong claims about the educational benefits which accrue from using the computer as an 'object to think with'. He claims that deeper learning results than from the more conventional, machine-led approach inherent in Skinner type teaching machines of the 1960's or authoring systems (e.g. the National Physical Laboratories' MICROTTEXT). It is also possible to see LOGO use as fulfilling the notion expressed by Woolnough (1984), that students benefit most from the learning environment where they can gain experience and apply 'tacit' knowledge to solve problems.

## Sprites

'SPRITES' are an additional feature included in some implementations of LOGO. These are graphic entities that can take on a velocity which can be set and reset under program control. For example, it is possible to program the movement of a picture of a hot air balloon so that it drifts diagonally across the screen. This is done by defining a balloon shape, and then setting its velocity.

The Screen-Turtle and the Sprite have their own 'Primitive' commands, although the sprite primitives all appear after the command *TELL*.

### Some Turtle 'Primitive' Commands

*FORWARD (FD) n*

*BACKWARD (BD) n (or BACK (BK) n)*

*RIGHT (RT) n*

*LEFT (LT) n*

*PENUP (PU) n*

*PENDOWN (PD) n*

### Some Sprite 'Primitive' Commands

*SETHEADING (SH)*

*SETSPEED (SS)*

These primitives allow for the production of dynamically changing screen displays, subject to restrictions of processing power (e.g. the turtle appears to pause at the end of each straight line that it draws, so that a

curve slows it down considerably). In general, speed cannot be assigned to the Turtle's movement; some versions of LOGO allow an optional *FAST* or *SLOW*, while a *HIDETURTLE* or *HIDE* command releases processing time to enable faster pattern drawing.

The turtle can perform any movement. The sequence for an L-shaped path, for example, is:

*FORWARD 20*

*LEFT 90*

*FORWARD 20*

In the case of the sprites, an L-shape path would be followed by giving the sequence:

*TELL 3 SETHEADING 0 SETSPEED 10*

*WAIT 20*

*TELL 3 SETHEADING 90 SETSPEED 10*

*WAIT 20*

In both cases, the previous motion of the graphic entity – Sprite or Turtle – is of no consequence in getting it to turn. A floor turtle moves slowly, at a fixed speed, on a surface with which it has (usually) high friction. This means that a continuous force must be supplied by the electric motors for it to maintain a constant velocity. At the end of completing a *FORWARD 20* command, it is decelerated by friction. (and by electromagnetic forces in the electric motor).

The floor turtle can turn, stop and start with no regard to its previous motion. This does not model the motion of everyday objects like cars, balls and people, which have inertia and move in a world affected by gravity and friction, nor does it model the motion of the objects often considered in science lessons, such as the Earth, Moon, Electron and ice puck.

## Dynaturtles

DiSessa (1981) has implemented a variant of the turtle with inertia; he has named it the 'Dynaturtle'. Its primitive commands are:

*KICKUP (KU)*

*KICKDOWN (KD)*

*KICKLEFT (KL)*

*KICKRIGHT (KR)*

*KICK (KK)*

The task of tracing an L-shape path is now more complicated, as it requires that momentum is taken into account. DiSessa made the *KICK* commands available for real-time use by causing keys on the computer keyboard to generate a *KICK* at the moment when the student touches them.

In the above discussion, the tracing of an L-shaped path was considered as an exemplar to provide a meaningful comparison between the control of the turtle, the sprite and the dynaturtle. It may have been just as useful to discuss other examples, such as the production of a triangular shape, or even a straight line of fixed length.

## **A problem with 'Immediate mode'**

The relationship between the user's perception of time and the display of events on the screen would seem to be critically important when dealing with dynamics. This means that 'immediate mode', in which the turtle responds to commands when they are typed in, would not provide a useful dynamical simulation. There are a number of other considerations that have to be made when attempting to extend LOGO into Newtonian mechanics, and these are discussed in the next section.

## **Summary**

The view that students have misconceptions has become widely accepted, and misconceptions in many areas are being investigated.

LOGO Graphics is a programming language that provides students with a means of controlling a 'turtle' that enables them to see the effects of moving and turning. The commands consist of a simple keyword, usually followed by a parameter.

## Section 2: Original Work

### 2.0 Introduction: the theoretical perspective

This work was initially motivated by some highly subjective hunches which I developed during five years of teaching at secondary level:

- students have misconceptions about dynamics;
- computer programming is intrinsically motivating; and
- programming can lead to marked changes in some students' attitude to work.

I had anecdotal support in each case, but wanted more objective evidence. I felt this could be obtained by devising a programming-like activity to challenge and possibly modify their supposed misconceptions (NEWLOGO, described later), then observing students' response to it.

My hypothesis was that an interventionist approach would provide insight into the nature of the misconceptions in mechanics, as well as providing a prototype of an instructional methodology. The theoretical model I adopted to describe the possible modification of misconceptions was the 'smooth change' model (e.g. Hewson, 1984). In this model, time must pass for conceptual change to take place (i.e. to allow a student to gradually reduce his or her reliance on a misconception). I hoped that shift would be triggered by the intervention caused by using NEWLOGO.

The testing of this model is inherently difficult, since during the change, students may not hold a misconception very strongly, and any attempt to probe their views would modify their viewpoint. Thus, testing or

interviewing would only provide evidence that a 'stepped' or even 'catastrophic' model of change was more appropriate. As an example, if students are interviewed or tested on a weekly basis, the repeated demand that this puts on them to consider the ideas that they have about the motion of objects is very likely to affect their answers. For example, a student may provide an incorrect answer for several weeks, but may become progressively more and more unsure of his answer. When his or her response finally changes, the superficial appearance is of a 'stepped' change, even though it may be the result of a 'smooth' change.

## 2.1 The Investigation

Bearing in mind the above considerations, we decided that the students were to be given a test, then exposed to NEWLOGO and given a chance to use it independently. Some time later the test was repeated, and then each student was interviewed in a manner that would deliberately try not to direct them to examine their ideas, but just to comment on the test. It was thought that by allowing a few months to pass between the NEWLOGO exposure and testing and interviewing, students should have time to complete any changes in the misconceptions that they might have.

The LOGO graphics programming language is oriented, at a superficial level, towards Geometry. Exposure to the LOGO environment has been claimed to cause the user to find out about Geometry for his-or-herself. In particular, the idea that a round trip along the sides of any polygon is exactly one full turn has been called the 'Total Turtle Trip Theorem' or 'TTTT' (Abelson 1981). It is intuitively appealing to believe that rote learning of the statement: 'The sum of the exterior angles of any polygon is 360 degrees' will not be as successful from the point of view of understanding Geometry as discovering 'TTTT' whilst at play with a turtle.



## Implementing NEWLOGO

It is part of LOGO's nature that it can be adapted to different environments, and with a sufficiently fully implemented LOGO it should be possible to create a subset specifically designed to focus on dynamics.

There are some limitations inherent in this approach, (discussed later) that, coupled with the technicalities involved in the computer hardware, firmware and software, make it necessary to create a programming language that is operated in a different manner to LOGO. The language I developed has similarities with LOGO, and it is because the turtle now obeys NEWtonian Mechanics, that it is called NEWLOGO.

### Aim of the study

The aim of this work was to investigate the suggestion:

*"NEWLOGO provides a learning environment in which dynamics concepts can be explored"*

The hypothesis formed in order to operationalise the investigation is:

*"The use of NEWLOGO improves the performance in answering certain types of dynamics questions of students who are also receiving conventional instruction in basic dynamics"*

Students' performance may have been modified in an indirect manner, possibly through a change in attitude towards the test. It was felt that

the test may be a way of gaining some insight into these changes, although it was designed to illuminate student misconceptions. The interviews had been intended to form a validation of the test, but they also provided an indication of student attitude.

Some indications of changes in student attitude have been gleaned from non-verbal clues exhibited by the students in their interviews. (I am not using the term 'attitude' in any precise way. It is a term that I have used to describe the kind of motivation that I perceive in students. It is a very subjective thing, based on the way that they respond to problems that they face in the learning situation.)

### **The use of the computer**

The way in which the student uses NEWLOGO, and the control of running programs and editing them was tested by providing students with a version of LOGO Graphics, which had been specially designed to function in a similar manner to the NEWLOGO language. The intention here was to test the assumptions made in the design. For example, in both languages the programming done by the student does not disappear from the screen. It was felt that this would remove the confusion shown by some students when attempting to program computers for the first time.

This LOGO Graphics version also provided us with first-hand experience of the effects reported by others involved in the provision of a LOGO environment for students, such as the intrinsically motivating nature of these languages.

## NEWLOGO - modes of use.

NEWLOGO is designed to assist the internalization of Newtonian concepts about momentum and the effects of impulses and forces on a free body. It is not specifically designed to be used in any particular environment, or in any particular way. It is very much just a tool for investigating motion.

There can be no simulation as exciting as the real thing. For example, actually feeling the force required to accelerate class-mate who is attempting to stand on ice must be far more memorable than having to adjust the parameter following the *FORWARD* command. However, many events are difficult to observe properly, or perhaps too dangerous or time consuming to perform.

It appears to be a very open-ended question as to how NEWLOGO could be used, but I mention here a few possibilities that may have been in mind during its conceptualization.

### 'Demonstration'

One might conceive of a learning scheme involving a variety of learning aids, and instructional techniques, with NEWLOGO included. For example, a conventional lesson might begin with a class discussion of the forces involved in the motion of an object dropping at its terminal velocity through a fluid. This might be followed by a simple experiment such as the delightful 'guinea and feather' experiment. NEWLOGO might then be used to create a simulation of motion at terminal velocity, which may hopefully stimulate further discussion, and perhaps some further experimentation.

### 'Directed use'

The use of worksheets is an integral part of the design of many physics courses, and it is obvious that several worksheets might be written to guide a student through particular topics in dynamics. The pupils are asked to perform specific tasks, and answer a set of questions. (In some cases it is quite possible that a student decides to use NEWLOGO in his own way, which may result in him discovering something for himself - see 'Free use') The programming difficulty should be no greater than that involved in the program 'LOGO Challenge' by Heather Govier, which has had many successes with young pupils.

### 'Free use'

The student might be given a short introductory demonstration of how to enter programs, and how to run and edit them. The only direction would be a cue that they are free to try what they like. Some students may not respond to this invitation, and so it may be necessary to offer a challenge, such as 'try to make the turtle move around'. Whether this challenge is necessary or not in order to encourage free experimentation is a value judgment that has to be made by the teacher. The teacher could arrange for the NEWLOGO to be used outside of normal lesson time, and this may remove some of the restrictions that students feel are imposed on them. However, it does not seem possible that one could be sure that there were no remaining restrictions in students' mind as to what is required.

The behavior of users at the keyboard must be affected by their needs, in the sense that they may be responding to a challenge. Students might evolve their own challenges. For example, one of them may attempt to

move the ball in a square path, other pupils may rise to the this challenge, or try to improve on it. I have often observed, and occasionally attempted to engineer, similar peer-group interaction in my teaching of computer programming.

## Summary

NEWLOGO is a version of LOGO graphics that gives the turtle inertia. Its effect on students misconceptions might be found through the use of a dynamics test.

## 2.2 NEWLOGO: Technical features & specifications

### Keywords

The Keywords in this language, their meanings and examples of how they form primitive commands are given here:

*TO* - Starts a Procedure definition

Examples

*TO ROLL D,SPEED*

*TO DROP*

(*ROLL* and *DROP* are procedure names provided by the user. *D* and *SPEED* are optional parameters, also provided by the user.)

*END* - Ends a procedure definition.

*WAIT* - Allows time to pass.

Examples

*WAIT 10*

*WAIT PAUSE*

(*10* is the duration of the time that is to be allowed to pass before the next instruction should take effect. *PAUSE* is a variable, the value for which can only be set when the procedure is called. The unit of time is the centisecond.)

*HIT* - Applies an impulse to the object.

Examples

*HIT 10 LEFT*

*HIT X UP*

*HIT 5 AT 45*

(*10*, *X* and *5* specify the magnitude of the impulse and *LEFT*, *UP* and *AT 45* its direction relative to the screen; *AT 45* means at 45 degrees to the horizontal. The unit of impulse depends on the mass of the object, and the size of the screen. One could make assumptions

about the meaning of distance on the screen, and how to interpret the time intervals. (When NEWLOGO was written the value for the mass was adjusted to provide reasonable speeds, for impulses given as numbers in the range 5 to 50. The value of the mass is fixed.)

*GRAVITY* - Puts gravitation on the object, acting downwards.

Example

*GRAVITY 20*

(20 is the magnitude of the (uniform) gravitational field.)

*FRICITION* - Puts a velocity-squared drag on the object.

Example

*FRICITION HIGH*

(*HIGH* is a user defined variable, giving the magnitude of the drag coefficient.)

*REPEAT* - Repeats the instructions as far as the next *END* statement.

Example

*REPEAT 4*

(4 is the number of times to repeat the instructions that follow it.)

## Structure

The procedures can call each other, so that it is possible to build complex sequences of motion, with a few instructions. As an example, it would be possible to define a procedure called *MOVELEFT N,S*:

*TO MOVELEFT N,S*

*HIT S LEFT*

*WAIT N/S*

*HIT S RIGHT*

*END*

NEWLOGO would respond to the command *MOVELEFT 10,2* by moving a distance of 10, at a speed of 2, and this command could be used within another procedure.

In versions of NEWLOGO developed more recently, it is possible to define the LOGO Graphics primitives *FORWARD n*, *LEFT n* and *RIGHT n*. The result of doing this would not be useful, but it might be an instructive exercise.

## Mathematical Functions

The functions *SQR*, *ABS*, *INT*, *SIN*, *COS* etc. can be used, together with mathematical expressions like  $2*SP-1$ .

## Defaults

If the values of the parameters following the keywords *WAIT*, *GRAVITY* and *FRICTION* are omitted, the value 5 is substituted automatically.

## Editing

This is accomplished by use of the cursor control keys. The text of the program does not scroll, and this imposes a limit of 20 lines to each program. This is not a constricting limit, as the usual NEWLOGO program is very short.

In the BBC-Acorn version, the program listing remains on the left-hand section of the screen throughout the whole duration of the session, in the PET version it re-appears after the program has been executed.



## **Control**

The <ESCAPE> key causes the routines on the screen to be compiled, and if a procedure has been named, it will be executed. <ESCAPE> can also be used to exit from execution, to return to editing at any time.

## **Display**

The motion is displayed as a ball-shape moving over the right-hand display area of the screen, leaving a trail of dots at regular time intervals (see examples below):

## **Demonstration**

There are two demonstration routines, called CLIFF and SHM. Each one can be stored on a function key of the BBC-Acorn microcomputer (see the section on 'keyboard', later), then recalled by touching the key.

CLIFF - This routine simulates a ball rolling off a cliff.

```

TO CLIFF
HIT 10 RIGHT
WAIT 10
GRAVITY 10
WAIT 30
END
CLIFF

```

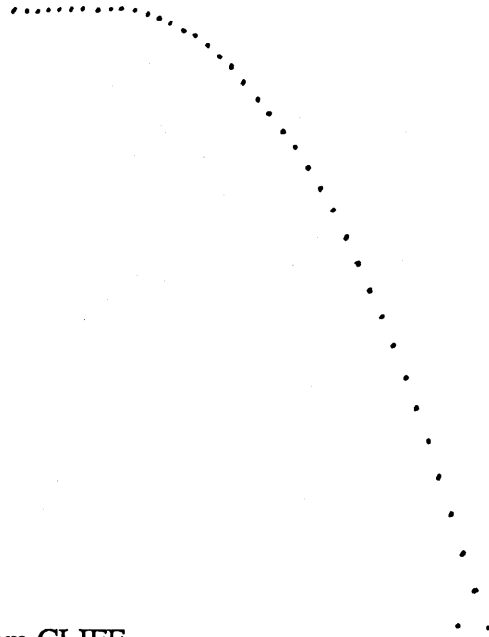


Figure 2. Screen dump of program CLIFF

SHM - This simulates an object moving with Simple Harmonic Motion.

```

TO SHM
HIT 30 LEFT
WAIT 10
HIT 20 UP
REPEAT 20
HIT Y DOWN
HIT X LEFT
WAIT 2
END
SHM

```

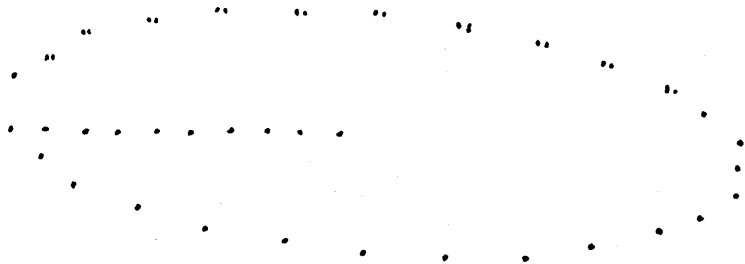


Figure 3. Screen dump of program SHM

## Example program

This program uses two procedures, called *START* and *FIRE*. *START* moves the object to the bottom left of the screen, *FIRE* sets it moving across the screen like a projectile in a viscous medium. *DO\_IT* is executed by typing *DO\_IT* at the end of the text.

<i>TO START</i>	<i>TO FIRE</i>	<i>TO DO_IT</i>
<i>HIT 10 LEFT</i>	<i>GRAVITY</i>	<i>START</i>
<i>WAIT 20</i>	<i>FRICTION</i>	<i>FIRE</i>
<i>HIT 10 RIGHT</i>	<i>HIT 20 AT 45</i>	<i>END</i>
<i>HIT 10 DOWN</i>	<i>WAIT 70</i>	
<i>WAIT 20</i>	<i>END</i>	
<i>HIT 10 UP</i>		
<i>WAIT 20</i>		
<i>END</i>		

## Choice of Computer

The hardware in my study was limited by financial considerations to 8-bit microcomputers. Although it may be considered desirable to use more elaborate and expensive hardware, this would considerably reduce the possibility of 'undirected' use of NEWLOGO by students on their own personal computers. It is expected that features inherent in these machines limit the achievable realism of simulations.

The Commodore PET 2001 was the machine originally used, and this was followed by the BBC-Acorn for the later part of the study.

### Constraints:

The following features of the systems used imposed constraints on the design of the NEWLOGO language and the way it operates.

### Backing Store:

The usual backing storage system found on low-cost microcomputers is an audio-cassette. This is considerably slower than disc systems, and in the entire study this became a cause of delay in the preparation of the lesson. It was not expected that any of the users would need to save their programs, and as the programs are only very short, they made their own notes whenever they felt it desirable. This is quite unlike the situation in LOGO GRAPHICS, where it is possible, and quite usual, to obtain hardcopy of the results of the program, and to save the program on backing store.

It may seem that the lack of backing store would be a great limitation, but the following points must be considered:

- hard-copy of the result of a program is not possible; and
- most programs would be very short, and the effort of keying them in is not great.

### Keyboard:

The QWERTY-type keyboard on the PET was used to enter programs, although purpose-built keypads (such as on BIG-TRAK) were considered, as were keyboard overlays. The single-key entry of programs, and two-letter abbreviations were also easily implemented possibilities. It was thought, however, that all these things were only

going to introduce more to learn about, and for the relatively short uses that can be made of NEWLOGO, they were rejected as not being helpful to the users.

On the BBC-Acorn computer there is a set of 11 keys which are additional to the QWERTY keys, called the user defined function keys. These provided a means of fast entry of keywords, and of whole demonstration programs (CLIFF and SHM). I labelled them as shown below.

HIT	LEFT	RIGHT	REPEAT	GRAVITY	FRICITION	WAIT	DOWN	SHM (Program)	CLIFF (Program)	RESTART
-----	------	-------	--------	---------	-----------	------	------	------------------	--------------------	---------

To minimise the risk that some users would be confused by the existence of the function keys, I left them out of the introduction to a short 'directed' use session. (As later experience indicated, the judgment about other program entry methods not being helpful may have been wrong, as the labelled user-defined keys were apparently very useful.)

Both PET and BBC-Acorn computers have special editing keys which were active in NEWLOGO, and required very little explanation.

### Memory:

The internal memory that was available to the user was 8K Bytes, which is very small by the comparison with more recent microcomputers, and was dictated by cost. This memory would have to be shared out between the screen-editor, main program and user workspace. This was one of the three main factors that suggested that the program would have to be implemented in BASIC. (This follows from the need to use the BASIC Interpreter's floating point arithmetic routine, and the screen editor routines, which are not so easily accessed from user-supplied routines)

The other factors were the need to respond quickly to any problems found by the users, and the need for a realistically fast and continuous movement of the dynamically moving ball.

### Display:

The TV monitors have a resolution of 1024 by 625 pixels, but the microcomputers I had available are more limited:

- The PET has 40 by 30 Character positions, and although this can be split into an 8 times better resolution horizontally OR vertically; the best that can be achieved in 2 dimensions is 80 by 60 pixels. This is very limiting for LOGO GRAPHICS, for which lines are displayed as staircases, very noticeable at small angles to the horizontal or vertical. It is not such a problem for NEWLOGO, which does not have to display every position visited in order to give the impression of movement.
- The BBC-Acorn has a choice of graphic modes, and the one chosen provides 319 by 192 pixels. The 'staircase' is still noticeable, but the

impression of movement is considerably better, and the path that the object follows is well represented as a series of dots, much in the same way as the ticker-tape or strobe-photographs used in school kinetics experiments

It is only on the BBC-Acorn version that the program and the display can be left on the screen together, so that the less 'computerate' do not have to become accustomed to the idea of a hidden memory containing a copy of a program. (It has been noticed that some computer novices re-type the program if the screen clears, despite instruction in this matter.)

#### Firmware:

The Operating System and Language Read-Only Memories within the microcomputers contain useful routines. By using the technique of translating the NEWLOGO into BASIC, and then executing the BASIC through the BASIC Interpreter, these routines are used and much programming effort is saved. It also becomes possible to fit the software into the available Random Access Memory. Despite the obvious appeal of this reasoning, the original motivation for using this approach stems from a feature of LOGO Graphics:

One of the features of some versions of LOGO GRAPHICS is a slight pause as the Turtle finishes one straight line and starts the next. This is caused by the time it takes to interpret the next instruction. The effect becomes quite noticeable when the turtle follows a curved path. In NEWLOGO the realism of the movement is destroyed if the 'turtle' pauses in what should be a simulation of continuous movement. This is especially important when it is by no means certain that the screen representation is accepted as being relevant to real objects.

## Development Machine:

The development of NEWLOGO would have been possible using a more powerful computer, which could provide better software tools. The BBC-Acorn could be fairly claimed to be its own development machine, and if this project had started two years later it may well have been that NEWLOGO would have been implemented using a more suitable language than BASIC, for example BCPL, or PASCAL or perhaps LOGO.



## 2.3 Use of NEWLOGO

### Outline of the study

A Commodore PET-based version of NEWLOGO was tried in 1981-2 by 24 fourth-year (14-15 year-old) pupils in two physics classes. Few PETs were available, so pupils were limited in their use of NEWLOGO to a maximum of three 20-minute group sessions during lessons, or they could try it individually outside normal lesson times. The group was of average ability; at the end of the following year, just over 50% of them obtained examination passes in C.S.E. or G.C.E 'O'-level or its equivalent. Some weeks before they were shown NEWLOGO they were given a short test on Newton's Laws: they had to sketch the paths that they considered would be taken by a ball under various circumstances. The test was based upon items used elsewhere (McCloskey, Caramazza & Green, 1980; Sutton, Lefrere et al, 1974). Later interviews revealed ambiguities in some test items, so the questions were improved and converted into multiple-choice format to use with the next year's pupils. There was no opportunity to retest the 1981-2 pupils with either the new or the original questions.

The PET implementation of NEWLOGO involved the students in frequent re-typing of keywords, this was a major reason for developing the Acorn version.

The Acorn version of NEWLOGO and the revised test were tried in 1982-3. The test was given to 63 fourth-year pupils of average ability and to 26 third-year pupils of above-average ability, most of whom went on to study physics in the fourth year.

Both groups were given a short demonstration of NEWLOGO, as a part of a normal Physics lesson. They were then told to use the computer in groups of two or three, and were set a challenge to make the object move to the left and then move up the screen. The programs they wrote were recorded, and their discussions were noted.

These initial sessions were subject to the constraints imposed by school lessons; the time available was roughly twenty minutes; the motivation for the work could be described as extrinsic, and the target was set by a teacher. This was not the case subsequently, when NEWLOGO was made available to them during their dinner-breaks. Some students made frequent use of this, writing programs which they spent hours running and debugging, others only observed the work.

Prior to this they had all been given the revised multiple choice test. This test was repeated two months later, and 8 of the third-year students were interviewed in an attempt to assess the validity of the test, and to provide more insight into the nature of their supposed misconceptions.

## The development of the dynamics test

The design of a test to uncover misconceptions poses the problem of the test designers own beliefs about misconceptions. It may be possible to 'prove' that misconceptions exist, simply by making the questions vague or ambiguous. I felt that even a conscious awareness of this could not guarantee the creation of a truly discriminatory test, and that the best strategy would be to adapt questions from other studies, and to evaluate them by using a trial group.

Students' responses to the trial test uncovered the difficulty of assessing the meaning of the answers given, in light of the critical importance of the straight line in this topic. In particular, the free-hand sketching by some students of what they had intended to be a straight line may be more curved than the intended curve produced by other students. The value-judgments required to interpret the test may be subject to the same bias towards a belief in misconceptions as the value-judgments involved in test design.

The responses to this trial form of the test were used to produce the final version, which had multiple choice questions. The choices offered were those that had been given by the trial group, with the addition of some extra distractors to make up the number to five for each question. This procedure was followed in an attempt to achieve objectivity.

There are three main types of question in this test; each group is intended to detect a particular misconception.

#### *Questions 1,2,3,7 (Appendix A2)*

These are all answered with a straight line. The concept needed is Newton's first law. The curve path responses would indicate that the student has not fully understood the implications of Newton's first law, and may be using the misconception that has been referred to as 'curvilinear momentum'.

There is the possibility that the student has misunderstood the orientation of the diagram; this would be indicated if the responses given to the first three questions consistently show the ball curving downwards. There is the further possibility that the student may interpret the word 'smooth' in the question to mean that the table was flat, but not friction-free. A spinning ball would not slip on the surface,

but would react with the surface in a way that may result in a curved path. These questions may therefore be assessing the difficulties that students have in accepting the notion of a friction-free surface.

### *Questions 4,5,6*

These require some degree of understanding of frames of reference. It would appear that some incorrect responses may be a result of a confusion between reference frames. It may be that a student may be describing the path seen from the carrier (plane and pendulum) or that the 'my frame now' misconception is being used.

### *Questions 8,9,10*

The 'most recent impulse' misconception is being tested here.

### *Questions 11,12*

These questions are not intended to test for any particular misconception. They are intended as they would appear to have 'obvious' answers, and as such they might provide some insight into the students' abilities.

## **The Third-year group's background**

### *The Physics lessons.*

The group had been given an informal preparation for Newtonian dynamics, following the third year Nuffield physics course, during which they had all been actively involved in experiments using dynamics trolleys. They had been directed to observe and record the motion of these trolleys rolling down slopes and being pulled along runways. They also observed the motion of thrown objects, and entered into directed discussions on relevant topics.

All students had been issued with text books (*The Revised Third Year Nuffield Physics*) which they used as a substitute for workcards to direct them in their experiments and activities, and as a source of questions for homework.

The group did appear to gain familiarity with the physics equipment, some of them contriving to build their own models of hovercraft and such-like. The entire group would appear to have appreciated that words like 'speed' and 'force' have a precise meaning in a scientific context, as they used them in answering written questions. It may be that some students use these words as empty jargon, not aware of their significance.

Most of these students would expect to be continuing their study of physics into the following school years, and it was not expected that they would all attain a full grasp of Newtonian mechanics during these early sessions.

I felt that several of the group were starting to think about basic ideas of inertia and motion, as they had been asking questions that would indicate this.

The course that these students were following would seem to be typical of third-year physics lessons in many schools. The standard of work of the individuals within the group varied, and their attitudes towards learning also varied.

These purely subjective observations are only mentioned to indicate the nature of the classroom situation.

### *Other influences.*

The validity of any conclusions drawn from the testing may be affected by other experiences that the students have. I assume that the following events and situations have very little effect on this study, and I have made no attempt to quantify or evaluate them:

- the group were receiving instruction in other subjects, including Chemistry, Biology and Mathematics;
- the group had been split into small groups of two, three and four students and had been directed to use a version of LOGO graphics for approximately ten minutes; this continued for one session only, and it became apparent that they had little difficulty mastering the keyboard skills required;
- some of the group owned microcomputers, or had frequent access to their friends' microcomputers; and
- two members of this group had parents who have taught science, other students have older brothers or sisters who have passed examinations in science.

## **The Fourth-year group's background**

The system of offering choice within a curriculum has affected the type of student within this group. Some were taking physics out of interest, others had had their choice made for them. In many cases the choice had been affected by their like or dislike of particular teachers. (This became clear during the discussion sessions that preceded grouping, when they could not be informed which teacher they would have, as this would depend on how the group was divided.)

The group had been divided into a single 'G.C.E. O-Level' group, and two 'C.S.E.' groups of lower ability. The examinations were used to adjust the content of each group, so that they could be prepared for the appropriate external examinations. The 'C.S.E.' groups were not graded, so that in practice the only adjustment that took place was the movement of four students out of the 'O-level' group, and one student into it.

It is very difficult to characterise these groups, as the students varied in their performance and attitude.

## The NEWLOGO Sessions

NEWLOGO had been introduced during the time that had normally been set aside for Physics. It had not been presented as part of other work, either theoretical or practical. The intention here was to set the NEWLOGO experience in isolation, in an attempt to evaluate it.

It would have been possible to provide worksheets, and to direct discussion on the topic of how things move in response to impulses and friction. The use of the computer would then have been as a means of providing a reward, and most readers would agree that the NEWLOGO program might just as well have been an arcade game.

Another source of 'noise' is the effect on the students of the teacher's expectations: students would feel under pressure to make extra effort if they realised that the NEWLOGO program was written by the teacher, and that the teacher intended the authoring effort to result in better learning. I had learning gains in mind when I introduced NEWLOGO, and I feel sure that they did not realise that I wrote it. (I was asked much later, after the post-test, where the NEWLOGO came from.)

### *The initial NEWLOGO sessions*

The first group to use NEWLOGO were those in 1981, and these used the Commodore PET microcomputer. The students experienced some difficulties with the equipment, mainly through not leaving spaces between keywords and parameters (e.g. *HIT10 LEFT*). The machines had audio-cassettes as backing storage, which involved me in a rather lengthy preparation for the sessions.

In the following year, the BBC-Acorn version had been developed, and NEWLOGO was given to the fourth year group. They were limited by examination pressure, and did not make much use of the NEWLOGO outside of a short couple of 20 minute sessions. During this time, two sixth-form physics students had become interested in using NEWLOGO. They spent a few hours each on the computer, and subsequently appeared to become interested in computer programming.

It had become apparent to me by this time that using NEWLOGO was an interesting experience for most students. It was also apparent that there was a need for an element in the assessment of the effects of NEWLOGO that could provide a different perspective than that provided by the tests.

### *The Third Year Sessions.*

The students were split into groups of their own choice. The monitoring of their initial activities was made easier by there being only one computer available. (Seven other computers were available during the dinner-times)



Here is an account of one group's experience:

(16th June 1983 9.30 a.m. - 10.00 a.m.) John, Dean and Brendan were given the 'corner' challenge. They tried:

*TO CO*

*HIT 20 LEFT*

*WAIT 20*

*HIT 20 UP*

*END*

They tried increasing the *HIT 20 UP* to *HIT 30 UP*, but then there was some interference from another class member who said: "Here you've got to hit it *10 RIGHT* - that amount of energy is going to stop it dead". (This boy was clearly delighted to show off his knowledge). The three users later tried an eleven-line program, which they tried to debug.:

*TO CO*

*HIT 20 LEFT*

*WAIT 20*

*HIT 20 RIGHT*

*HIT 20 UP*

*WAIT 20*

*HIT 20 RIGHT*

*WAIT 20*

*HIT 20 DOWN*

*WAIT 20*

*END*

They were trying to achieve a square path, but although the first corner of the square was good, they could not achieve the second. I then interviewed each of them separately:

*Interview with Dean*

Q. "What did you try?"

Dean: "We were going to hit back - but we didn't think it would work, we were trying all the other things."

Q. "What does HIT 20 RIGHT do?". (Here I am attempting to discover what he had made of the uninvited help given by Gary.

Dean: "It stops it"

*Interview with Brendon*

Q. "Dean has told me what you did, but what do you think HIT 20 RIGHT does?"

Brendon: "Like hitting a brick wall"

Q. "So that dot on the screen really is like a ball-bearing" (Here I am interested in his perception of the graphic as a real object)

Brendon: "Yes, but that would bounce off a wall"

*An overall pattern*

The above excerpt is typical of a session with NEWLOGO, in that it is rich in variety, and does not yield an easily quantified outcome. However, it would seem that there are some commonly occurring tactics, and I now give an idealised version of the other sessions, that are started with the corner challenge.

First attempt:

```

TO TURN
HIT 20 LEFT
WAIT 8
HIT 20 UP
WAIT 8
END
TURN

```

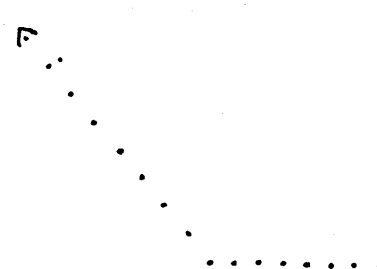


Figure 4. Screen dump of first 'corner challenge' attempt

This is an 'obvious' thing to try, especially if you have a LAST-HIT misconception. The result is not believed, and there are a number of things which are tried; in some cases the results are ignored and more statements are tacked onto the end of the program, in apparently aimless play.

Second attempt:

```

TO TURN
HIT 20 LEFT
WAIT 8
HIT 20 RIGHT
HIT 20 UP
WAIT 8
END
TURN

```

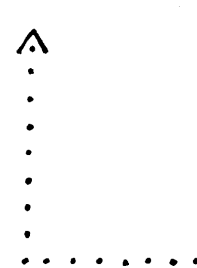


Figure 5. Screen dump of second 'corner challenge' attempt

This is successful, and is discovered by some groups (To what extent each group member contributes is difficult to ascertain.)

Here is another way of answering the corner challenge, which was tried by the older pupils:

```

TO TURN
HIT 20 LEFT      ^
WAIT 8           .
HIT 28 AT 45    .
WAIT 8           .
END              .
TURN            . . . . .

```

Figure 6. Screen dump of third 'corner challenge' attempt

The values of the magnitude and direction of the impulse in *HIT 28 AT 45* was found by trial and error. (It is easily calculated, of course.)

## The Test results

The results of the pre and post tests, for twenty of the third year pupils are given in Appendix B. In the following matrices the students answers to the PRE-test are given across, and the POST-test answers are shown going down. The correct answer is marked \*.

As an example, in question 4 it can be seen that 2 students gave 'B' in the pre-test, followed by 'C' in the post-test. A matrix showing an even, or random spread of numbers would indicate that the students hold no particular views. A matrix showing a high total along the diagonal from top left to bottom right indicates that students views were fixed.

The first three questions are about a ball travelling in a circular path. The total correct answers in the pre test are 12, and in the post test 20. This indicates a decrease in the 'curvilinear momentum' misconception.

*Question Number 1*

	A	B	C	D	E
			*		
A	1	1	1		
B	1	3	1	3	
C*		2	<u>1</u>	1	
D		1		2	
E					1

*Question Number 2*

	A	B	C	D	E
			*		
A	1	1			
B	3	3	3	1	
C*		4	<u>2</u>		1
D					
E					

*Question Number 3*

	A	B	C	D	E
				*	
A					
B					
C	2		5	3	
D*		1	6	<u>1</u>	1
E					

The next four have different presentations of the same basic question, about a ball being dropped. The total correct in the pretest is 27, in the post test 34. This indicates a decrease in the second misconception.

*Question Number 4*

	A	B	C	D	E
			*		
A					
B		1			
C*		2	16		
D					
E					

*Question Number 5*

	A	B	C	D	E
				*	
A					
B		3		2	
C					
D*	2	2		8	2
E					

*Question Number 6*

	A	B	C	D	E
					*
A	1	2			
B		5			
C	1	4	1	1	
D			1	1	
E*					1

The following matrix shows that 5 students gave the correct response in the pretest, but only 3 in the post-test. It may be significant that this question is a close re-working of a question posed in the Physics text book that the students were using. It would be wrong to read too much into this result, but it may be that the higher number of correct responses in the pre-test is a result of the students having recently answered the similar question in the text-book. Perhaps some students then forget the correct answer that they learned in a superficial way.

*Question Number 7*

	A	B	C	D	E
		*			
A	5	3			
B*		2	1		
C			4		
D	1		1	2	
E					

The next three questions are about balls being hit. They have 24 correct pre-test answers, and 23 correct post-test answers. This indicates an increase in the third misconception, and it might be taken to indicate that the experience of using NEWLOGO has increased this misconception.

*Question Number 8*

	A	B	C	D	E
			*		
A	1	1		1	
B		2	1	1	
C*		4	4	1	
D			1	1	
E		1			

*Question Number 9*

	A	B	C	D	E
					*
A	5	2			1
B		1			1
C	1				
D	1				1
E*	1	1			4

*Question Number 10*

	A	B	C	D	E
			*		
A			1		
B		2	7		
C*	1	4	3		
D					
E					

The following question shows an improvement from 6 to 14 in the correct answers.

*Question Number 11*

	A	B	C	D	E
				*	
A		1			
B					
C			2		
D*		2	7	5	
E	1				1



The final question has been quite well answered.

### *Question Number 12*

	A	B	C	D	E
					*
A		1	1		2
B					
C			1		1
D					
E*	2		2		9

The total number of correct answers for all questions changes from 86 to 107, which is a 24% improvement.

The interpretation of these matrices is open to discussion, but I feel that the following points are true:

- The students' views are not firmly fixed.
- Since there are clear indications of changes, the NEWLOGO experience may have affected their understanding of dynamics.

## The interviews

Eight of the third-year students, selected at random, were interviewed in an attempt to assess the validity of the test and to gain more insight into the nature of their supposed misconceptions. They were shown the answers that they gave to the post-test and asked if they would like to say anything about them. In some cases the student was prompted further. I now give some extracts from the transcriptions.

### *Interview with Helen.*

Helen offers some 'explanations', of the 'that is just how things are' type.

I: *I see you have chosen a straight line there.* (Question 1) *Why haven't you got a straight line there?* (Question 2)

Helen: *Because that's not quite a circular one.*

I: *So if it's been in a spiral tube then it might curve.. Is that what you are saying?*

Helen: *Yes.*

### *Interview with Bernadette.*

Bernadette confirms her answers, but offers no explanation for the first three questions. She has chosen curved paths for Questions 1,2,3 and 7

I: *Going in a curve... Comment?* (Pointing at her answer to question 7)

Bernadette: *It just slings off that way.*

### *Interview with Shelley.*

Shelley confirms her answers with no comment on them. I let a short moment pass to pressure her slightly, and she shrugs and says '*I don't really know what to say*'.

*Interview with Sarah.*

I: *Comment?* (Pointing to Question 1)

Sarah: *I just thought it would go like that.*

*Interview with Surinder.*

Surinder has given straight lines for the first three questions, but a curve for question 7

I: *Comment* (points to questions 1,2 and 3)

Surinder: *You know, you expect the ball to come shooting out like a bullet and not go in a curl.*

I: *Comment* (Points to question 7)

Surinder: *Because it's going around in a circle when it's let go it would have kept on going in a circle.*

*Interview with Mark.*

Mark has given curves for the first three questions.

Mark: *Yes, well when they come out, at the end of the tube, they are used to going in a curve, going around the curve...*

I: *Do you want to comment about your answer to number 7?*

Mark: *When it comes off it's then going in a curve, when it's released it's still got part of the curve going into the force, and as it's released it goes... carries on in a curve.*

*Interview with Harjinder.*

Harjinder has given curves for the first three questions.

I: *Comment?* (points to questions 1,2,3)

Harjinder: *I thought that they would come off in a curve because they are in a curve already and there is some sort of... there is some spin which is carrying them through the... and it may take some time before they go to a straight line or stop, so for the first part of their journey they would probably stay in a curve.*

*Interview with Gary.*

Gary gave straight lines for the first three questions.

Gary: *I just thought when it come out it would be going that way, so it would carry on going straight, instead of the curve motion.*

The interviews continued for approximately five minutes each. Those students who had 'explanations' for the first three questions also gave some comments for the other questions, in other words they remained 'true to form'.

The overall impressions that I obtained were that four of the interviewees appeared to be interested in explaining their answers to the test, and appealed to 'intuitive' models of motion. The other interviewees (Helen, Bernadette, Shelley and Sarah) were puzzled that one could have an 'explanation' for how objects move. It seems that even after conventional lessons on Newton's Laws, and an opportunity

to use NEWLOGO, those students did not appreciate that what they were taught at school relates to the motion of real objects, and can provide a means of describing and predicting how objects move. As another researcher has observed, 'One of the difficulties with much of our educational process is that it concentrates only on the later phases of the learning cycle and never deals with the experiential component [so cannot overcome...] the wrong insights which come out of the natural environment' (Bork, 1981)

The three students who made most frequent use of NEWLOGO also gave the most verbose answers in interview. For these students NEWLOGO seems to have provided more effective discrepant events, and although much work would have to be done to establish a correlation between the use of NEWLOGO and a deeper understanding of dynamics, we feel that a first step in conceptual change is taken by students who decide to use NEWLOGO.

## Section 3: Conclusion & discussion

### The effect on student performance

The timing of the tests was chosen so that any superficial learning that took place would be forgotten, and so that the testing should not be seen by the students as part of NEWLOGO. The students answers would be more likely based on the more permanent intuitive ideas that they may have adopted.

I thought that this would be a more objective way of investigating than giving the pre- and post-tests at close intervals. (It would be an extremely naive evaluation technique to ask a question, show the correct answer and ask the same question again, all within a short period of time.)

The questions in the dynamics test that have the most obvious relevance to NEWLOGO (i.e. 8, 9 and 10) might have been most strongly affected, comparing the pre and post tests. Since there has been no such effect, I form the following conjectures, any or all of which may be true:

- The misconceptions are being acquired over a period of time.
- Students recall that objects do not travel in the direction of the last impulse, which is what they expected. Unfortunately they only recall that objects travel in an unexpected direction. They have rejected their misconception, but have not replaced it with a more powerful idea. (They have been taught that they cannot do Physics!)
- Conventional teaching techniques and instructional practices have not been stringently tested, and it might well be possible to find some that actively produce misconceptions.

## The 'control' group

The use of a control group is of great importance, and a 'placebo' programming activity was devised (I wrote a TURTLETALK interpreter that was identical with NEWLOGO in its operation, except that the primitives were different, giving a standard turtle instead of a Newtonian one.)

It had been originally thought desirable to use NEWLOGO with half of a group, and the conventional graphics subset of LOGO (TURTLETALK) with the other half. This might then have provided a form of standardisation.

However, it became apparent that achieving a separation within a single teaching group under the circumstances of allowing free use of NEWLOGO or TURTLETALK was not practicable. I also rejected the idea of comparing one teaching group with another, as the differences in the lessons would have made any conclusions to be drawn highly suspect. (One could not claim that the differences between the groups were only attributable to the split between NEWLOGO and TURTLETALK.)

The interviews indicate that the whole procedure of dynamics testing is not to be taken as a direct indicator. The students did not confirm that they gave reasoned answers, and in many cases did not seem to realise that there could be reasons. They appear to be treating school physics questions as part of a game, and not as part of real life. So when they are faced with questions that are not firmly placed within the context of a physics lesson, they start to use intuitive ideas.

## Pedagogical implications

The use of NEWLOGO would appear to be valuable in focusing attention on basic concepts of motion. It would seem that a few minutes of introduction followed by about twenty minutes of free use is sufficient to cause the student to become uncertain about intuitive ideas of motion.

This is a first step towards learning Newtonian mechanics. The students that are sufficiently self-motivated to continue using NEWLOGO may adopt the more powerful Newtonian concepts of motion. They will at very least be in a more ready state to accept that their intuitive ideas are not correct.

NEWLOGO could be introduced to any dynamics course, used as a 'catalyst'. It could be set up simply as one of several activities, with no particular task set. Alternatively it is possible to provide worksheets containing a series of challenges, which lead to other, non-programming activities such as direct experimentation. In this way it could form a significant part of a dynamics course.

## Correcting wrong insights

Little research of either a practical or a theoretical kind seems to have been done on remedying misconceptions through computer simulations (Hewson 1983a,b; Hewson & Hewson, 1984), as distinct from devising simulations. Even less attention seems to have been paid to the possible effects of incompatibility between simulations, perhaps because it is easy to forget that users meet other programs. For example, a 'Newtonian motion' simulation will have to compete with computer games (most of which have screen displays that do not obey Newton's laws of motion) and computer displays in mathematics classes.



Conventional teaching and testing may highlight isolated errors, rather than help to remedy the underlying, more global misconceptions. Some of those misconceptions may be consistent with primitive and intuitive models of the world. To improve our physical understanding we may need to make a transition to a more sophisticated mode of thought, that is, undergo some conceptual change. Sometimes this will come about by exposure to a single event which challenges our existing world-view. A single event is rarely enough; more often it is ignored or accommodated as a special case within an existing naive theory. Change is more likely if we meet a series of discrepant events.

It seems from the literature on conceptual change (Hewson, 1983a,b; Hewson & Hewson, 1984) that effective discrepant events satisfy the following criteria:

- all aspects of the events must be perceivable by students within their existing frameworks (e.g. by telling learners what they will see);
- each event cannot be explained fully using a primitive theory;
- each event must be readily explicable using a more powerful theory;
- learners must be 'ready' to understand the more powerful theory which is required to explain the event;
- events should pose one problem at a time (not be multi-faceted);
- events must be challenging enough to be noticed and to require explanation (from learners or teachers); and
- events must not be too challenging (either in content or by being presented too quickly).

NEWLOGO and other LOGO-like computer simulations could satisfy the above criteria. However, at the moment they tend not to be used for long enough to generate sufficient examples nor are they incorporated into a curriculum in any principled way.

I feel that the important task has already been accomplished by NEWLOGO- the student has been triggered into using intuitive ideas, and these have been challenged by NEWLOGO. What may be needed next is an episode of repeated alternations between conventional teaching and NEWLOGO use.

(One technique might be to use the computer monitor to display television programs of the type produced by the Open University for the foundation course in physical science, edited so as to prompt the student to try using NEWLOGO.)

Now that microcomputers are available that can run full versions of LOGO, It may be possible to configure a NEWLOGO environment (microworld) that produces an acceptable dynamic display.

The present implementation contains no error messages, and these should not be added as an afterthought, but as an integral part of the way that NEWLOGO works. It is my experience with most high-level language Interpreters and Compilers that error messages frequently mis-lead users. This may be just tolerable when the task is to produce functional software, but with NEWLOGO, the inappropriate error message would cause a diversion that would destroy the original teaching objective.

## A post-script

At the date of final printing (December 1986), there is available a version of NEWLOGO that forms part of an ILEA CAL system that runs in Microsoft Windows.

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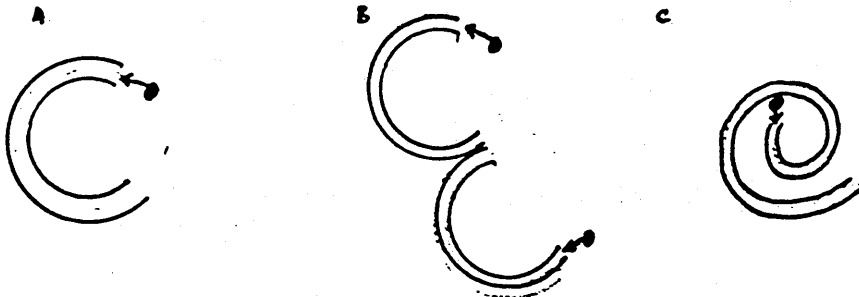
Appendix A The tests

DYNAMICS TEST

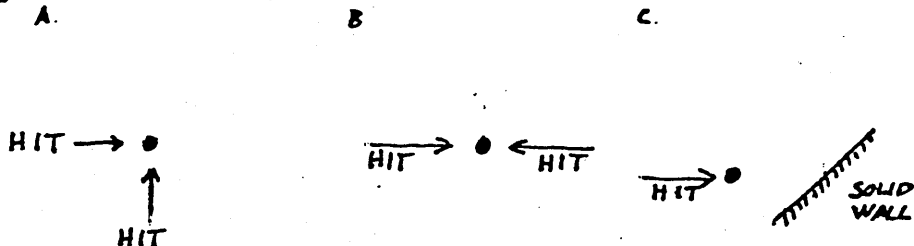
NAME \_\_\_\_\_

TO ANSWER THESE QUESTIONS, JUST DRAW THE PATHS THAT THE BALL MUST FOLLOW.  
THE FIRST SIX VIEWS ARE FROM ABOVE OF OBJECTS ON A FLAT TABLE.

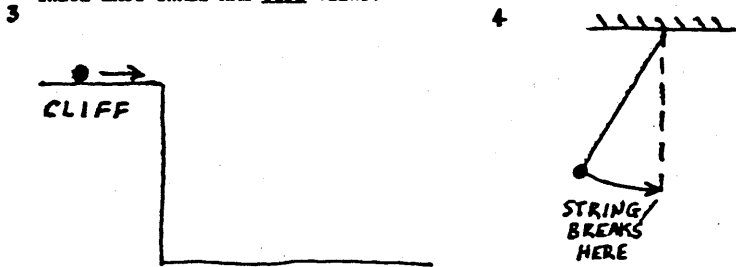
1. HERE ARE SOME HOLLOW TUBES, THE BALL IS PUSHED INTO EACH TUBE, AND GOES AROUND AND OUT.



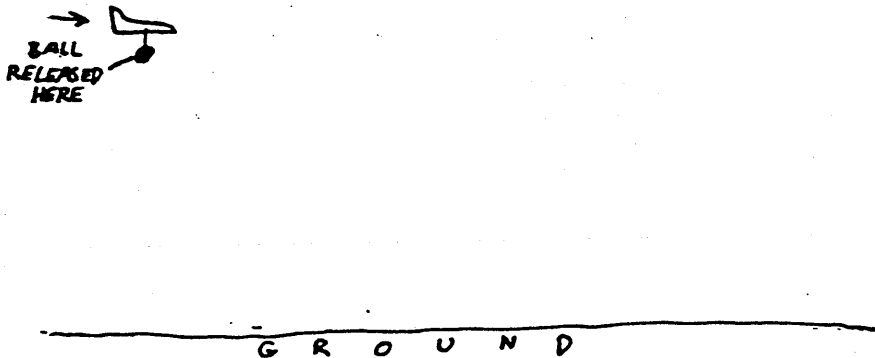
2. HERE THE BALL IS HIT EQUALLY IN THE DIRECTION SHOWN.



THESE LAST THREE ARE SIDE VIEWS.



5. A PLANE CARRIES THE BALL, AND RELEASES IT. DRAW THE PATH OF THE BALL, AND THE POSITION OF THE PLANE WHEN THE BALL HITS THE GROUND.

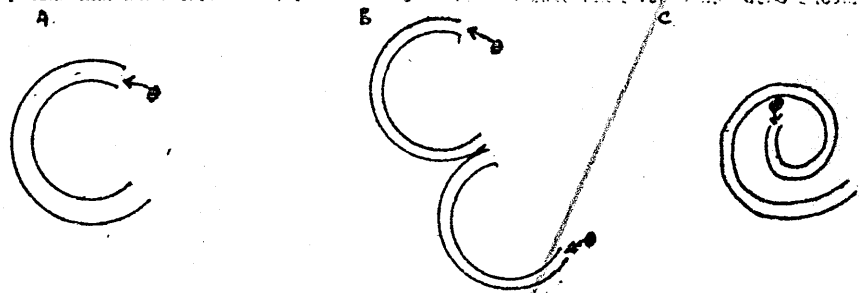


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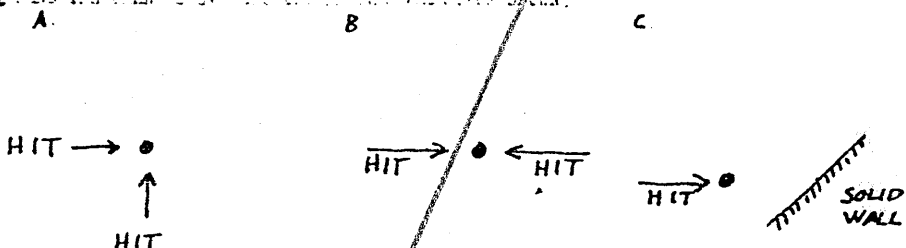
Appendix A The tests

TO ANSWER THESE QUESTIONS YOU MUST FIRST READ THE PARTS THAT THE BALL MUST FOLLOW.  
THE BESSER YOU UNDERSTAND THE PARTS OF THE TESTS ON A FLAT TABLE

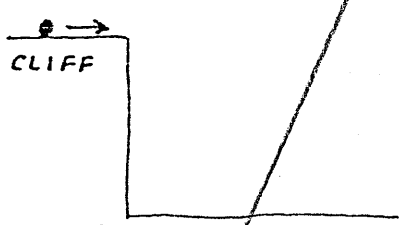
1 HERE ARE SOME TESTS TO SEE IF A BALL WILL GO AROUND AND OUT. THE BALL GOES AROUND AND OUT.



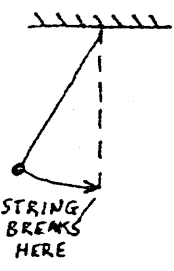
2 HERE ARE SOME TESTS TO SEE IF A BALL WILL GO AROUND AND OUT.



3 HERE ARE SOME TESTS TO SEE IF A BALL WILL GO AROUND AND OUT.



4 HERE ARE SOME TESTS TO SEE IF A BALL WILL GO AROUND AND OUT.



5 HERE ARE SOME TESTS TO SEE IF A BALL WILL GO AROUND AND OUT.



G R O U N D

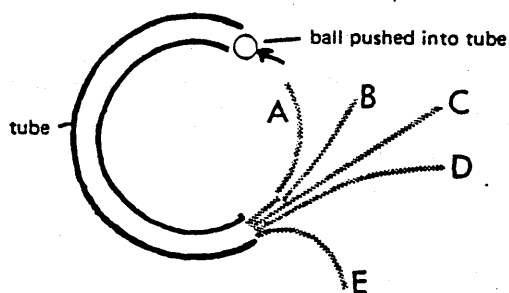


## TEST

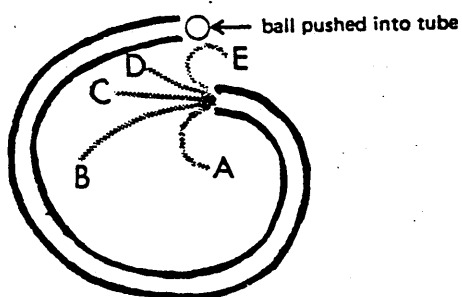
Here are some pictures of the paths followed by a ball – but only one path in each question is correct.

Give your answer by *circling around the letter* next to the correct path.

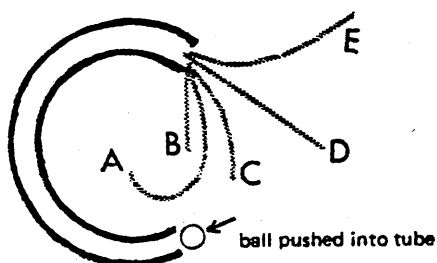
1. Looking DOWN onto a flat surface



2. Again, looking DOWN onto a flat surface



3. And again, looking DOWN onto a flat surface



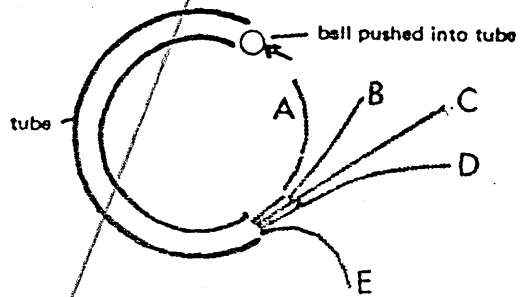
TEST

Here are some pictures of the paths followed by a ball – but only one path in question is correct.

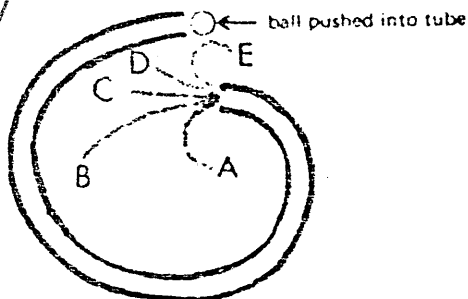
Give your answer by *circling around the letter* next to the correct path.

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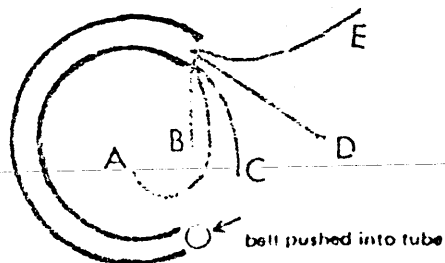
1. Looking DOWN onto a flat surface



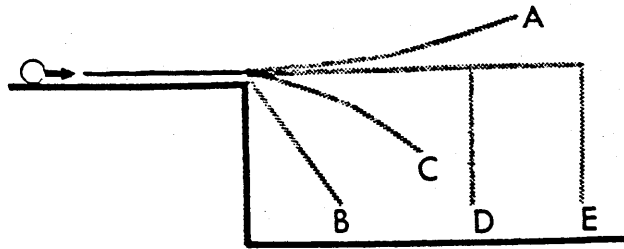
2. Again, looking DOWN onto a flat surface



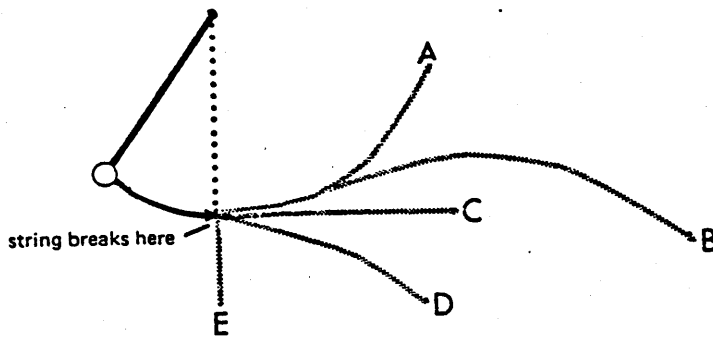
3. And again, looking DOWN onto a flat surface



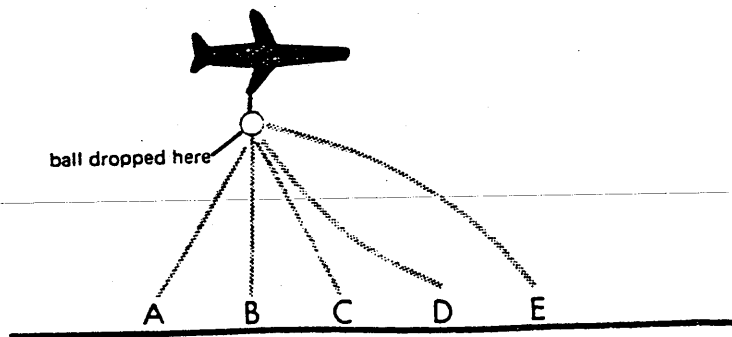
4. Looking at a cliff – from one side



5. Looking at a pendulum – from one side

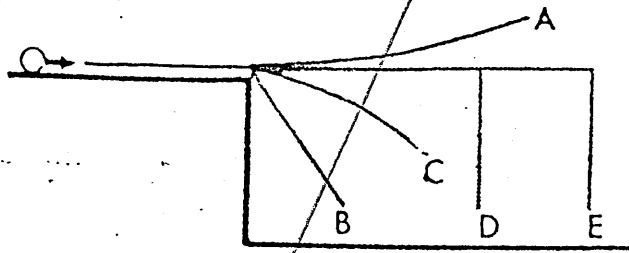


6. Looking at a plane – from one side

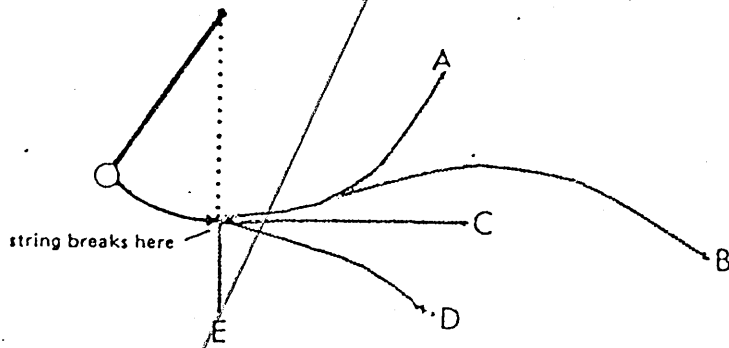


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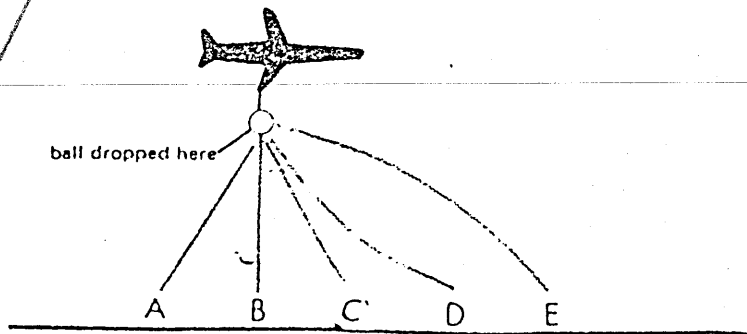
4. Looking at a cliff – from one side



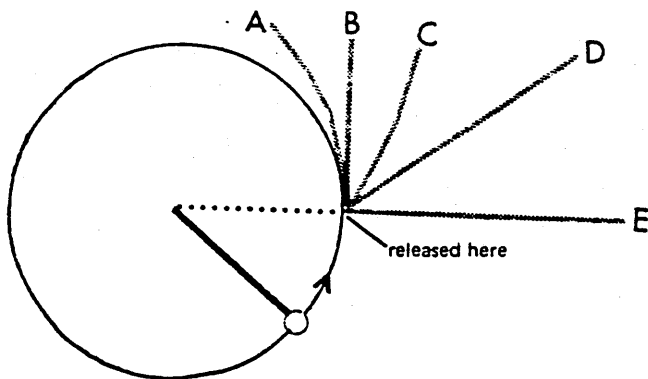
5. Looking at a pendulum – from one side



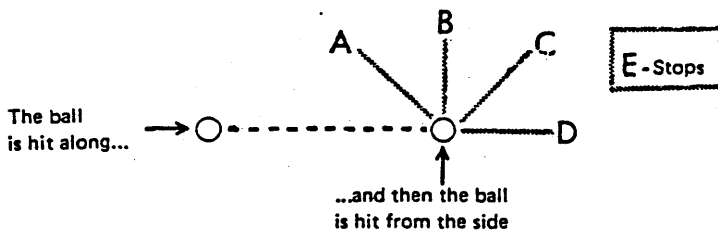
6. Looking at a plane – from one side



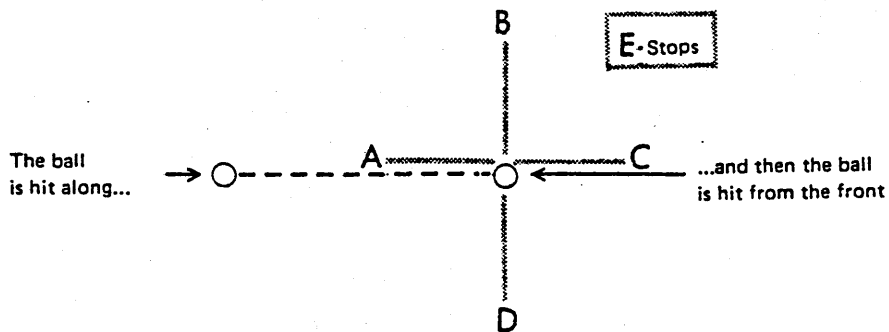
7. Looking DOWN on a ball being whirled around



8. Looking DOWN onto a flat surface

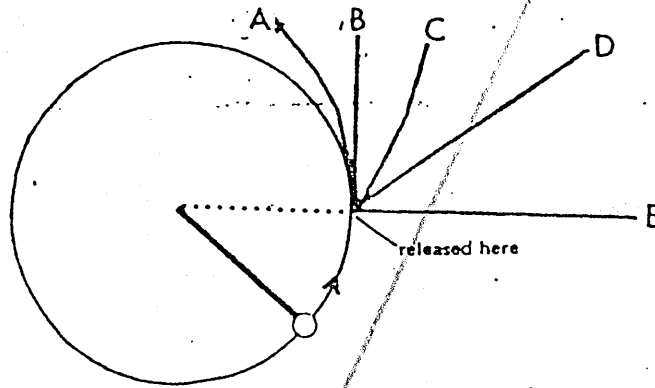


9. Looking DOWN onto a flat surface

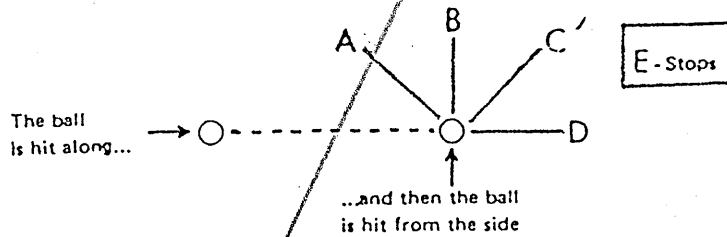


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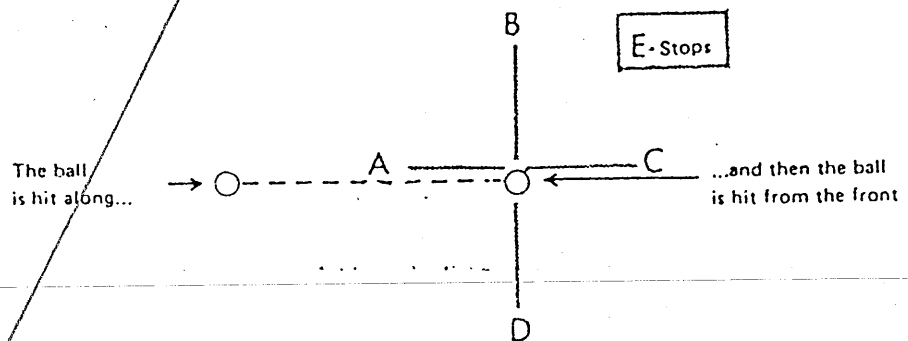
7. Looking DOWN on a ball being whirled around



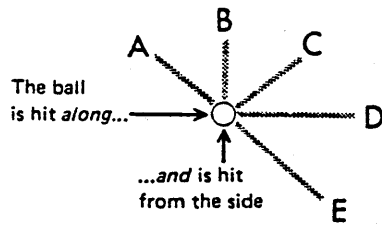
8. Looking DOWN onto a flat surface



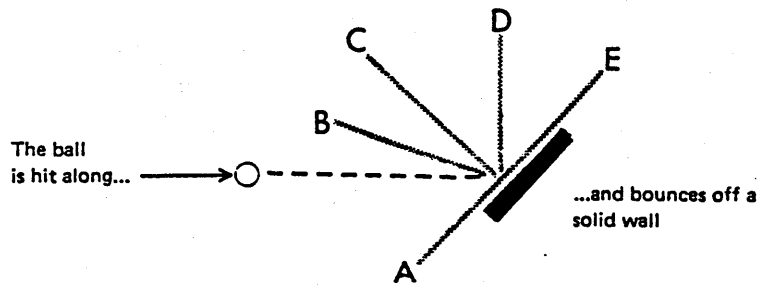
9. Looking DOWN onto a flat surface



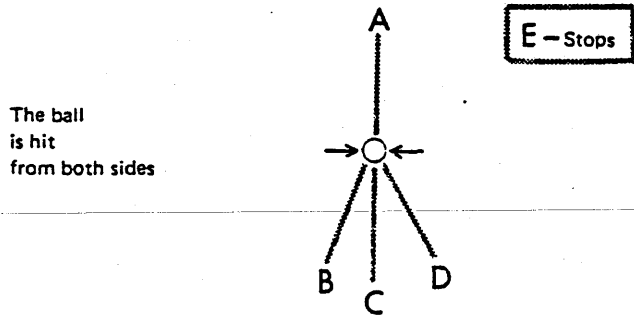
10. Looking DOWN onto a flat surface



11. Looking DOWN onto a flat surface

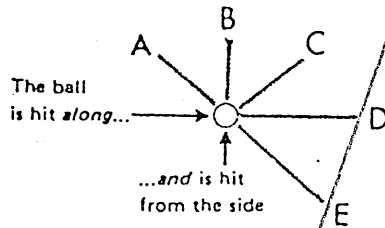


12. Looking DOWN onto a flat surface

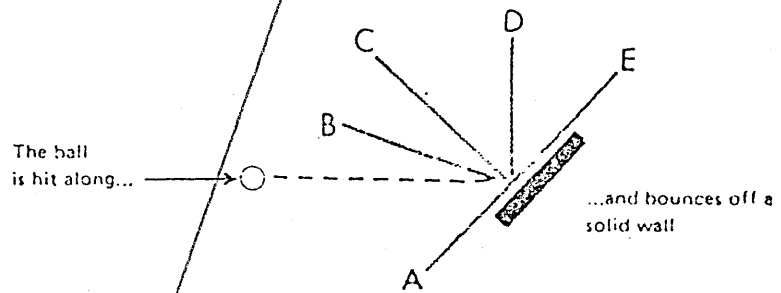


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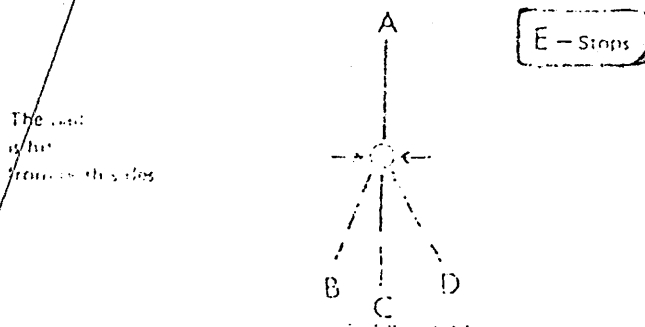
10. Looking DOWN onto a flat surface



11. Looking DOWN onto a flat surface



12. Looking DOWN onto a flat surface





## Appendix B Some test results

The correct sequence is CCDCDEBCECDE

Each pair of lines is for one student, the first is the PRE-test, the second is the POST-test.

BCCCEAABBECE  
CCDCDEABAADA

CBDCDBDBECDE  
BCCDBDCEBDE

DCCDBBDECCE  
CBCCDBABEBDE

BCDCDBBBACCE  
CCDCDCACABDE

BCDBBBDACDE  
BCCBDBDECDE

CCACDBACACCB  
ABCCDAADDCDA

BBDCDCCBABAC  
BCCDDDCACEC

ECCBABACECCA  
ECCBDBACDCCE

BACDBBCECBE  
ABCCDCACEBDA

AACCBABBBCCCE  
BBDCBABCABDE

CBCCDBCABABDE  
CCDCDCCECBDC

ABCCABABBBBC  
AADCDAAAACAA

DDACBCCDBCCC  
BBCCDCCCEBDE

DACCBACBABDE  
DBDCBCCBACDE

DBBCBBADAABC  
BCDCDBAAACDE

BBCBDBDCECCE  
DCDCBBDCEBDE

DBCCDDCCECDE  
BBCCDCCCEAEE

BBECEBCABBCCA  
BBDCDCBABCCE

DACCDEACABDE  
DACCBEDBABDE

CBCCBDBCECDE  
BCDCBDBCECDE

## Appendix B Some test results

REPLACEMENT COPY  
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The correct sequence is CCDCDEBCECDE

Each pair of lines is for one student, the first is the  
PRE-test, the second is the POST-test.FPCCEAABEFCE  
CCDCDEABAADADCCDEBDEECCE  
CBCCDBABESDEBCDRBDEBACDE  
BCCRBDEECDEBBDCDCCBABC  
BCCDBDCACECBACCDBFCECE  
ABCCDCACHDACBCCDBCFABDE  
CCDCDCCLEBDCDDACBCCBCC  
BCCDCCCEBDEDEBDBPADAABC  
BDCDBAAACDEDBCCDCCCECDE  
BCCDCCCEAEEDACCDEACABDE  
DACCBEDBARDECBDCDBDBECDE  
BCCDBDCERDEBCDCDFBBACCE  
CCDCDCACABDECCACDBACACCB  
ABCCDAADDCDAECCBABACECCA  
ECCBDBACDCCEAACCBAEBBCCE  
BDCBASCABDEABCCABABBBBC  
AADCDAAAACAADACCBAABABDE  
DBDCBCCBACDEBCEBDBCECCE  
DCDCBBDCBBDEBBECEBCABBCA  
BDCDCBABCCECBCCBDBCECDE  
BCDCBDBCECDE