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ABSTRACT

This document is the sixth of seven units developed by the Math Network Curriculum Project. Each unit, designed to be a 2-week module, is a teacher's guide which includes detailed directions along with the courseware and software needed. Teacher intervention in the non-computer activities that begin each unit is required, and the consistent use of small-group instruction makes the units usable in a standard classroom if two microcomputers are present. In the Turtle Geometry Unit, students use a computer program called Turtleworks (developed by Bill Finzer), to learn a language for geometry. They use this language to construct drawings on the computer and to store them on the Network. When not making designs on the computer, students use Turtle-Tractors, devices similar to protractors, to make drawings on paper. Besides learning to express geometrical ideas in a computer language, students discover theorems about polygons, learn to command more than one turtle at a time, and become expert at seeing how a complex design is built of smaller parts. The computer program was developed for use on a Commodore PET Computer with at least 16K of RAM using 4.0 BASIC. (MNS)

Turtle Geometry

Teacher's Guide

Math Network Curriculum Project

San Francisco State University

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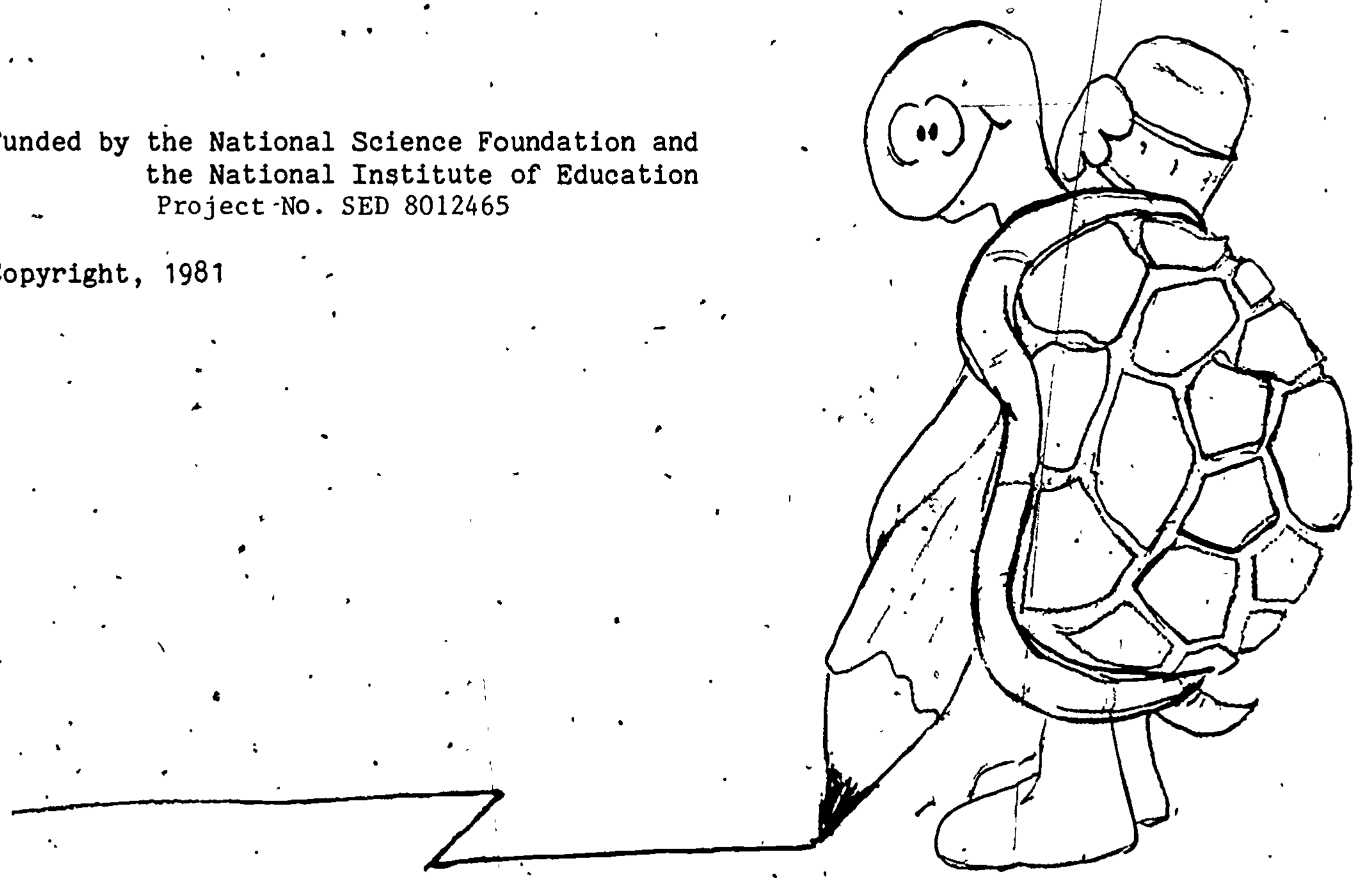

TURTLE GEOMETRY

TEACHERS' GUIDE

Math Network Curriculum Project

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Overview

Where Do Turtles Come From?

In the early 1960's my father read a Scientific American article about some small mechanical creatures designed by an Englishman named Grey Walter. These creatures would run around on the floor avoiding obstacles and searching for electrical outlets. My father wanted me to build one for a science project. (I never did.)

Perhaps this is why I was fascinated when I first heard about the work of Seymour Papert and the LOGO group at MIT. They had invented computer controlled 'turtles' which could either run around on the floor drawing lines as they went, or move around on the computer screen creating designs which were often very striking.[1] Their work with children from age three on up through college age has been an inspiration to educators all over the world and to this project in particular.

In this unit you will develop with your students a language called TURTLETALK, which is based on some of the 'Turtle Geometry' ideas of the MIT LOGO group.

Turtles live in a purely geometrical world, and yet it is a world filled with beauty and wonder. They understand a language, which is easily grasped by children and adults alike, with which we may command them to draw on the screen. Too often, learning the language of mathematics becomes a dry exercise in memorization for students. We have a new tool, the computer, which can make the language of mathematics not only accessible, but exciting and useful!

What Is Turtle Geometry About?

Turtle make possible a new way of looking at geometry[2]. To see what that new way is like, consider the following description of a square:

> A **square** is a closed figure with four straight sides of equal length such that each angle is a right angle.

That definition is probably close to the one you learned in school. It describes what a square **looks like**. In contrast, look at the definition below:

> A **square** is drawn by repeating four times the operation of going forward in a straight line a certain distance and then turning by a right angle.

In contrast to the first definition, the second definition **gives you a procedure for drawing a square**. The second definition is an **active** one; it involves you in the act of creating the square. Turtle Geometry takes the second approach, on the assumption that children will be more involved with and excited about geometry if they are as much creators as they are observers.

Turtle Geometry Teacher's Guide

Because we can make a computer understand simple 'languages,' we see that a geometry based on actions allows us to tell the computer how to create drawings. The computer screen becomes an arena for geometrical experimentation where geometrical 'truths' lie in wait to be discovered.

In doing Turtle Geometry with your students, you will find that geometry becomes a very concrete, hands-on subject. And, at the same time, you will find rich intellectual challenges for you and your students. Turtles, and the computers in which they live provide the medium for our students to reach out to the abstractions of geometry and make friends of them.

[1]Papert, Seymour, Mindstorms, Basic Books, N.Y., 1981. This is an inspiring book about the kinds of explorations kids can do using computers and especially the LOGO language.

[2]Abelson and DiSessa, Turtle Geometry, The Computer as a Medium for Exploring Mathematics, MIT Press, 1981. This book is aimed at college-level and beyond students with access to a Turtle language. The mathematics is very sophisticated.

How to Use This Guide

If the ideas presented here are new to you, this guide will probably not be sufficient introduction to allow you to teach the unit. Also, if you are a newcomer (as are most of us) to using computers in classrooms, then you will probably need help from the outside. This guide goes along with a course for teachers to serve as a reference for the classroom.

For What Level Student Is This Unit Appropriate?

Students in the upper elementary and junior high grades are at an optimal level for this unit. Younger children will be able to use the Turtletalk language, on the computer, to create interesting designs but will probably not grasp the symmetry concepts. Older students can take off on some of the proposed open-ended investigations. In Piagetian terms students will need to do the kind of thinking possible in the formal operational level, thinking that extends beyond concrete reality.

What You and Your Students Will Do

The work in this unit should consume about two weeks of 50 minutes/day class time. Some of the time you will find yourself talking to and discussing with the class as a whole, particularly in the early stages of the introduction of the TURTLETALK language. However, most of the activities are designed to be done by students working in small groups. There are many reasons for this:

- You probably don't have more than two or three computers in your classroom. Students will have more direct-interaction time with the computer if they work together in groups.

- A group of students at a computer work more efficiently than individuals; they are less likely to get 'stuck' forgetting some simple thing like hitting the RETURN key.

- Much of the interesting mathematics introduced is too difficult for most individuals, but can be easily handled by a group of minds working together.

- Social interaction is an essential ingredient for intellectual development and providing for it will help students grapple with the concepts presented in this unit.

- Students are often better at explaining concepts to each other than adults are. They learn by explaining.

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Summary of Activities and Materials

Total Time Required: about 2 weeks
Total Whole Class Time: between 3 1/2 and 6 1/2 periods
Independent Computer Time: 30 minutes per group of 3

1. **The Need for a Geometry Language**
   Format - Whole class and groups of two
   Time - 1/2 period
   Materials
   GRID PAPER

   Students try to communicate how to make simple drawings to each other using only verbal cues. Discussion leads toward standard words and phrases that will have the same meaning to everyone and can form the basis of a language for communicating geometrical concepts.

2. **Introduction of Turtletalk**
   Format - Whole class and groups of two
   Time - 1 to 2 periods
   Materials
   TURTLETALK WORKSHEET
   TURTLE-TRACTORS
   PUSHPINS
   CARDBOARD SHEETS FOR DRAWING
   CARDBOARD TURTLE
   OVERHEAD PROJECTOR
   PET COMPUTER(S) LOADED WITH TURTLEWORKS PROGRAM
   TURTLE COMMANDS SUMMARY SHEET

   Teacher introduces some of the basic terms of Turtletalk. Students learn how to measure angles with 'Turtle-tractors.'

3. **The Regular Polygon Family**
   Format - Groups of 3 at desks with computers available for checking
   Time - 1 to 2 periods
   Materials
   TURTLE-TRACTORS
   PUSHPINS
   CARDBOARD SHEETS FOR DRAWING
   REGULAR POLYGON FAMILY WORKSHEET

   Students work in groups with Turtle-tractors discovering laws about the angles of regular polygons. The concept of **total turning** is introduced as an intermediate to finding the **exterior angle** of a polygon.

*4. **Turtleworks Pictures**

Format - Groups of 3 at computers
Time - 30 minutes per group of students at the computer
Materials

PET COMPUTER(S) LOADED WITH TURTLEWORKS
MODEM CONNECTION TO AT LEAST ONE COMPUTER
TURTLEWORKS PICTURES WORKSHEET

Students test their understanding of TURTLETALK with some picture-drawing problems on the computer.

5. **Hook Problems**

Format - Groups of 3 at desks with computers available for checking
Time - (1 to 2 periods)
Materials

TURTLE-TRACTORS
PUSHPINS
CARDBOARD SHEETS
HOOK WORKSHEET

Treating a simple, bent-stick figure as a unit, students begin to explore some symmetry properties via the Turtletalk **MULTIPLYBY** command. Before students begin this worksheet, the teacher should introduce **MULTIPLYBY** as a way to talk to many turtles at once.

*** Note About Scheduling Computer Usage**
During Activity 4 (Turtleworks Pictures), students will need about 30 minutes per group of independent computer time. You will need to have other activities going on in the rest of the class during this time. You may elect either to start the rest of the class on the **Hook Problems** or you may prefer that those who are not working with the computer work on other topics.

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Activity 1
The Need for a Geometry Language

Format
Whole class discussion plus work in pairs

Time
1/2 class period

Materials Needed
Grid Paper

Background

Learning mathematics is, in many ways, like learning a foreign language. We learn any language most easily and rapidly when we find ourselves in situations where knowing that language allows us to communicate easily with others and to do useful things. And our motivation for learning a language is highest when we know that we need to know - that is, when we can see the payoffs of the learning in which we are about to engage. In this activity, your students are put in a situation where they must informally invent their own language for communicating geometrical ideas.

Purpose

- Students should be able to communicate what a simple drawing looks like to another student.

- They should also be able to follow the directions of another student well enough to make a reasonable facsimile of the other student's drawing.

Teacher Preparation

You need only make sure that you have grid paper on hand.

Activity

Students need to arrange themselves in pairs so that they cannot see what the other member of the pair is doing, but so that they can talk to each other in a low voice. If you have tables, then they can sit opposite each other with a wall of books between. Each student needs two pieces of grid paper.

Their task is to make a simple, non-pictorial drawing on the grid paper. The constraints on the drawings are that they be made up of only straight lines and that the places where the lines begin and end be on the intersections of the grid lines. It is important that the drawings they make be neither too

complex, nor too simple. If they make very complicated drawings, then the next phase will be frustratingly difficult and time-consuming. If the drawings are too simple, the ensuing communication will be over too soon and the students will miss the point. So, watch their work and stop them at the right moment - probably after 2-3 minutes.

Next, one student of each pair is to be the 'communicator' and the other is to be the 'drawer.' **Without** seeing each others' papers, the communicator is to instruct the drawer in drawing what he/she has just drawn. Either student can question the other about what they have done or what they mean. When finished, they should look at the results and trade roles.

You may need to remind them, a few minutes into the activity, that the communicator is not allowed to look at the drawer's paper.

When all have finished, group discussion should focus on general methods that they found useful and particular words that they found themselves using frequently. Examples of methods would be:

- "I told her where the points were and which ones to connect."
- "We ended up numbering the points lightly so that we could talk about them."
- "I pretended that he was driving a car and I was telling him where to turn."
- "We told each other the shapes to draw and how big to make them."

Examples of words and phrases they might have found useful are:

> on the same line, next to, move forward, up, down, left, right, on the edge, do it again the same way, square, larger, smaller, upside down

Optional Extension

Tell the class that they are going to repeat the entire exercise, but this time, **no words are going to be allowed at all!** You will allow them 2 minutes to decide how they are going to communicate to each other before they begin making their drawings. Only whatever sign language they can invent will be allowed; no writing or speaking.

This optional activity gives them an experience in inventing a 'formal' language themselves and is different from the previous activity in that no 'explaining' can go on during the communication process.

Activity 2
Introduction of Turtletalk

Format
Whole Class and work in pairs

Time
1 - 2 class period

Materials Needed
turtle-tractors
pushpins
cardboard sheets for drawing
cardboard turtle
overhead projector
Pet computer(s) loaded with Turtleworks program
Turtle Commands Summary Sheet
Turtletalk Worksheet

Background

Mathematicians invent terms with special meanings to better communicate with each other. Your students experienced the need for such terms in the previous activity. Now it is time for everyone to agree on certain special terms. The agreed upon terms comprise a simple **language** which we will call **Turtletalk.** Turtletalk is also the language students will use with the computer in the next activity.

The words you are going to introduce are:

GO
TURN
PENUP
PENDN
REPEAT (with its abbreviation **RPT**)

It is through repeated use in the succeeding activities that students will come to grips with the ramifications of these Turtletalk words.

The description below is overly lengthy, trying to explain a process which will come naturally to you once you have tried introducing Turtletalk a couple of times. You will certainly evolve your own style suited to your way of teaching and your students.

Purpose

- Students should be able to use a turtle-tractor to create drawings specified by Turtletalk programs which use any of the above words.

Teacher Preparation

Load the 'Turtleworks' program into one computer before class. Loading takes about 5 minutes. Have ready a class set of **turtle-tractors.** These are originally produced by making transparencies from a transparency master. There are four turtle-tractors on each sheet. The very center of the turtle-tractor should be

strengthened with a piece of scotch tape. You may also need to cut up pieces of 8 1/2 x 11 cardboard to be used to allow students to stick pushpins through the turtle-tractors into their paper. Finally, the **Turtletalk Commands Summary** sheet should be ready to pass out to the students to serve as a reference for them.

Activity

MOTIVATION

You may be able to motivate the introduction of Turtletalk further with a story. You could tell about Papert's LOGO turtle (see Overview); or you could make up a story about a real turtle with a pen attached to its tail; or you could ask about the toy 'Big Trak,' which actually behaves a lot like the turtles we are going to use. You need a cardboard turtle to move around on the chalkboard or a clear plastic one to move around on the overhead. The kids need to get the idea that this 'turtle' understands certain words or commands and that you are now going to introduce some of these words.

Pose the question: 'What will the turtle do if it gets these commands?'

GO 10
TURN 90
GO 10
TURN 90
GO 10
TURN 90
GO 10
TURN 90

CONVENTIONS

There are three things the students have no way of knowing: 'How far will the turtle GO?'; 'In what direction will the turtle start?'; and 'Will the turtle turn left or right?' The answers to all these questions are decided by **convention.**

Introducing these conventions would be most easily done using an overhead with a **turtle-tractor** for measuring distances and angles.

The turtle **always starts out facing to the right.** (In mathematics, this direction is chosen as the **zero angle** direction.)

On the overhead and on paper, the unit of distance is the unit marked on the turtle-tractor. On the board, 5 centimeters would be reasonable.

The convention for turning is that turns are measured in **degrees** and when the angle is **positive** the turtle turns to the left. 90 degrees constitutes a right angle turn. This follows normal mathematical conventions. Students will be using **turtle-tractors** to measure angles. Turtle-tractors have two advantages over protractors for this work: they clearly indicate turns greater than 180 degrees; and it is easier to remember in which direction turns are measured.

USING A TURTLETRACTOR

Using the turtle-tractor to measure angles has **three steps.**

1. Place the dot in the middle of the turtle at the present position of the turtle and face the turtle in the direction it is presently going.

2. Pivot the turtle (this is easiest if you are working on cardboard and have stuck a pushpin through the turtle) so that the desired ray lies along **the last segment of the turtle's path.**

3. Measure the distance along the turtle's direction line and stick a pushpin through at that distance making a mark on the paper underneath.

After going through the above Turtletalk program for a square, it would be a good idea to have one of the students **act out** the role of the turtle by walking through the program.

TURTLETALK WORKSHEET

Pass out Turtletalk Worksheets, turtle-tractors, pushpins, and cardboard to each pair of students. Working together, they should go through the problems on the worksheet, taking turns being the one to move the turtle-tractor and draw the line.

As you move around the room to see how students are doing, watch for the following common problems:

- Some students may forget to actually move the turtle forward after drawing the line. Their work will look like a series of lines coming out from one point.
- The angle 270 degrees will cause trouble for some students. They will be reluctant to turn the turtle-tractor more than 180 degrees.
- When you find someone who has gotten hopelessly lost, ask them to start over, showing you their work as they go. Usually you can recognize their misconception after only a step or two.

The last two problems are meant for students who finish quickly. (You may want to assign them to the rest of the class for homework.)

COMPUTER DEMONSTRATION OF TURTLETALK

Perhaps the clinching motivation for Turtletalk is that the computer can be made to understand it and draw diagrams accordingly. Start the program with the computer in front of the class. Have one of the students type in the instructions for producing a square. Even from the back of the room, students will see that a square is being drawn on the screen.

Point out that this is a lot of typing and that there are **4 repetitions** of the commands **GO 10 TURN 90.** Since this is a common occurrence in turtle designs, there is a shortcut way to produce the same effect. It is

REPEAT 4 (GO 10 TURN 90)

They can test their understanding of **REPEAT** with the following program:

RPT 4 (GO 10 TURN 45)

where **RPT** is just an abbreviation for **REPEAT**. When they have finished, you can demonstrate what they should have gotten on the computer. To do this, you will have to introduce and execute the **CLEAR** command. **CLEAR** is really only useful on the computer.

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Activity 3
The Regular Polygon Family

Format

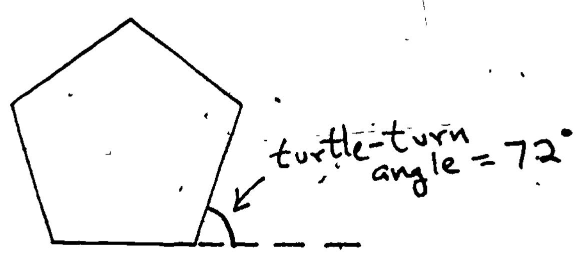
Groups of 3 at desks

Time
1 - 2 class periods

Materials Needed
- turtle-tractors
- pushpins
- cardboard sheets for drawing
- Regular Polygon Family Worksheet

Background

The regular polygons form a family of shapes starting from the equilateral triangle, proceeding through the square and regular pentagon, and heading toward regular polygons with so many sides they are indistinguishable from circles. In drawing polygons with turtles, we are not as interested in the **interior angle** of the shape (the interior angle of an equilateral triangle is 60 degrees and that of a regular pentagon is 108 degrees) as we are in the **exterior angle** or **turtle-turn angle**. It is the exterior angle that the turtle turns by when drawing the polygon. The turtle-turn angle of a regular pentagon is 72 degrees as shown in the drawing below. After five turns of 72 degrees, the turtle has turned 5 x 72 or 360 degrees.



Purpose

Students are asked to **discover** the exterior angles for the polygons by trying to draw them with their turtle-tractors. Each time they do so, they must compute the **total turning** that the turtle undergoes. **This total turning is always 360 degrees!** Having noticed that, one can work backward and formulate the rule

> **The exterior angle of an n-sided polygon is 360/n.**

Just how algebraically you treat this rule will depend on the sophistication of your class.

Teacher Preparation

Read through the worksheet and try drawing a polygon with the turtle-tractor. Load TURTLEWORKS on

your computers. Otherwise, you just need to have the materials available.

Activity

Students work in groups of 3. They should each make the figures on their own worksheets. When they come to try to discover the turning angles for the different polygons, they can each try a different angle. For example, if they are working on the equilateral triangle, one student might try 100 degrees while another is trying 110 degrees and the third is trying 120 degrees. When they have disagreements about what is the correct angle for a polygon, they can use the computer and TURTLEWORKS as an arbiter.

Circulate among the groups and make sure they are understanding the concept of **total turning** and that they are able to use their turtle-tractors correctly.

Check their Turtletalk programs to make sure they are using the **REPEAT** command properly.

Groups who finish early can try the optional polygons with 5, 7, and 10 sides. These are harder to discover since the turn angles (72 degrees, 51.4 degrees, and 36 degrees respectively) are not multiples of 10.

Class Discussion

When everyone has completed polygons with 3, 4, 6, 8, and 9 sides, a discussion of what they discovered will be appropriate. Questions to ask are:

- What did the 'total turning' come out to be? (There will probably be some disagreement here. Some students may insist that the turtle does not need to make the last turn to finish the polygon. Explain that things will be simpler if we arrange that the turtle end up facing the original direction.)

- Why 360 degrees for the total turning? (In watching a person walk through the drawing of a polygon, students can see

that the turtle has to turn all the way around, that is, through 360 degrees.)

- What is a rule for figuring out turn angle to produce a regular polygon of any given number of sides? (If there are **n** sides, then the turtle must turn through **360 / n** degrees on each turn.)

Ask the class how what would be the Turtletalk instructions to produce a regular 12-sided figure. Try out their suggestion on the computer. Ask the same question for other numbers of sides. Express this result in the general form

turn angle = 360 / (number of sides)

Activity 4
Turtleworks Pictures

Format
Groups of 3 at computers

Time
30 minutes at computer

Materials Needed
Pet Computer(s) loaded with Turtleworks
Modem connection for at least one computer
Turtleworks Pictures Worksheet

Background

We continue now with the learning of Turtletalk, introducing the **MULTIPLYBY** command (abbreviated as **MULT**). It is this command that will give students the ability to easily create complicated and beautiful designs. The idea is that the user of the Turtleworks program should be able to command many turtles at a time. The **MULTIPLYBY 4** command, for example, creates, for every turtle on the screen, 4 new turtles which are aimed symmetrically around the originals.

In addition, if you have networking capabilities, your students will begin to see what other students in other classrooms have done in the way of creating interesting designs with Turtleworks. Networking provides additional motivation for creating Turtletalk designs. Also, in looking at designs of other students in other classrooms, your students will gain new insights into the possibilities of Turtletalk and new appreciation for Turtle geometry (and, of course, regular geometry).

Purpose

- Students will get practice using the basic commands of Turtletalk on the computer.
- They will be able to use **MULTIPLYBY** to create symmetric designs.
- Finally, they will learn how to access the MNCP network to store and examine Turtletalk designs.

Teacher Preparation

Try the problems yourself so that you may anticipate some of the difficulties your students will have. In particular, you should try the **MULTIPLYBY**, **NETSAVE**, **NETNAMES**, and **NETLOAD** commands. Refer to your Turtleworks user manual for help using these commands. Have the Turtleworks program loaded in your computers before class begins. Have worksheet copies available.

Activity

CLASS DISCUSSION

The final command to be introduced is **MULTIPLYBY.** Turtles are social creatures and like to have company. Have one student stand up in front of the class and be a turtle. Then propose the command

MULTIPLYBY 4

and explain that after this command there will be 4 **active turtles.** Bring 4 more students to the front of the room and have them stand with their backs to the first student-turtle aimed in four right angle directions. Explain that these four new turtles are going to obey the next instructions.

```
GO 10 TURN 90
GO 10 TURN 90
GO 10
```

They can act this out and then you can go through the same sequence on the overhead. A practice program for them at their seats would be

```
MULT 3
GO 10 TURN 60 GO 10
```

Note: You may be wondering about the turtle in the middle. The reason for leaving this turtle around is that the **COLLAPSE** command causes the turtles which were created by the last **MULTIPLYBY** command to go away, reactivating the turtle(s) left behind. For example, try

```
MULT 3 GO 10 COLLAPSE GO 20
```

Demonstrate the **MULTIPLYBY** command on the computer. Then talk about how it would be nice to **save** pretty or interesting turtle designs somewhere so you would not have to type them everytime from the beginning and so that others could look at them. Explain that there it is possible to do this using the telephone connected to the computer. Demonstrate how to **NETSAVE** a design. Explain that other kids in other classrooms have already **saved** lots of turtle designs. Use the **NETNAMES** command to look at some of the names of these designs and then load in one design.

GROUPWORK

Students work in groups of three at the computer. As you observe them, make sure they are understanding how to interact with the computer program. They might need help using the **LIST** command and they will certainly need help using the **NETSAVE** and **NETLOAD** commands.

Activity 5
The Hook Family

Format

Groups of 3 at desks

Time
2 class periods

Materials Needed
turtle-tractors
pushpins
cardboard sheets for drawing
Hook Worksheet

Background

Complex shapes can be built up from repetition of a single, simple shape. The simple shape chosen here is called a **hook.** The idea is a powerful one. Two analogous ideas are:

- a complex problem can be solved from solutions to its simpler parts;
- a complex theory can be built upon simple axioms.

Purpose

Students get more practice with Turtletalk; in particular, they get deeper into the ramifications of **MULTIPLYBY** and **REPEAT.**

Teacher Preparation

As in all these activities, try them yourself ahead of time. Have available the usual turtle-tractor drawing materials.

Activity

Students work in groups of three at their seats solving the problems on **The Hook Worksheet.** There is not much opportunity for division of labor, but they should make sure that everyone in the group agrees about the answers before they go on to the next problem. The last two pages of problems are quite difficult but become accessible to groups that can brainstorm together. If the computer with Turtleworks is available, students can check their ideas on it.

You should look over their shoulders occasionally to check their ideas for solutions. Where you spot an error, you can suggest that they actually try out their program using turtle-tractors.

Solutions to worksheet problems:

```
4a) MULT 2 RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
b) MULT 3 RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
c) MULT 4 RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
5a) MULT 4 GO 5
      RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
b) MULT 4 PENUP GO 5 PENDN
      RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
c) MULT 3 PENUP GO 5 PENDN
      RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
d) MULT 6 PENUP GO 5 PENDN
      RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
e) MULT 24 PENUP GO 5 PENDN
      RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
6. a) RPT 3 (GO 10 TURN 60 GO 5 TURN 60)
b) MULT 2 RPT 3 (GO 10 TURN 60 GO 5 TURN 60)
c) MULT 3 RPT 3 (GO 10 TURN 60 GO 5 TURN 60)
d) MULT 2 GO 10 MULT 2
      RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
e) MULT 3 GO 10 MULT 2
      RPT 4 (GO 10 TURN 45 GO 5 TURN 45)
```

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Optional Activity

The Star Family

Background

You may want a challenge for those students that have a particularly good grasp of Turtletalk and the geometrical concepts of the preceding activities. The Star Family worksheet extends the ideas presented in the Regular Polygon Family worksheet.

Purpose

Students should discover the relation between the number of sides and the turning angle for various stars.

Teacher Preparation

Have the PETs loaded with Turtleworks.

Activity

The work involved here is fairly sophisticated. If you have had time to try the problems on the worksheet yourself, you can be of help to students. But you may simply want them to struggle with it on their own, knowing that it won't be easy.

Appendix

Turtle Geometry

Worksheets

TURTLETALK COMMANDS SUMMARY
Math Network Curriculum Project
San Francisco State University
March, 1982

HELP (abbreviated as H) - lists these commands.

GO - for example,

GO 10

sends all turtles forward 10 screen dots.

TURN - for example,

TURN 45

turns all turtles by 45 degrees in the counter-clockwise direction.

CLEAR - erases screen; gets rid of all turtles but one, and puts that turtle in the middle of the screen. Instructions in the main program are forgotten, but procedures are remembered.

REPEAT (abbreviated as **RPT**) - for example,

RPT 4 (GO 10 TURN 90)

causes the instructions **GO 10 TURN 90** to be repeated 4 times, thus drawing a square.

MULTIPLYBY (abbreviated as **MULT**) - for example,

MULT 6 GO 15

causes there to be **six** active turtles in place of every **one** that was there before. All of these new turtles now move forward 15 screen dots.

COLLAPSE - the opposite of MULTIPLYBY. The turtles will be returned to the state they were in just before the last MULTIPLYBY. The screen will not be affected.

PENUP - After issuing this command, when the turtles move, they will not draw lines.

PENDN - The turtles will now draw as they move.

QUIT - Ends the program. Be sure to end this way if you wish to make a copy of TURTLEWORKS on tape.

LIST - Show commands executed since last **CLEAR**.

DRAW (abbreviated as D) - Clear the screen and start executing commands.

TO - Begin a procedure definition. For example,

```
TO SQUARE
RPT 4 (GO 10 TURN 90)
TURN 45
END
```

will mean that the turtles understand SQUARE from then on (unless you stop the program and start over). In fact you can say SQUARE 8 which will repeat the procedure 8 times, making a very pretty design.

END – Signals the end of a procedure definition.

EDIT – allows editing of individual commands. By itself it brings up the first command. Use DEL to change and retype. When finished hit <return>. If you don't want to change the command, you can hit <return> (and the command will be executed) or hold down the <shift> key and type @ (in which case the line will be skipped over).

EDIT 4

allows editing of the 4th command.

EDIT SQUARE

brings up the first step in the SQUARE procedure for editing.

EDIT SQUARE 2

brings up the 2nd step in the SQUARE procedure for editing.

TAPESAVE – for example,

TAPESAVE FLOWER

will write your TURTLETALK commands on a tape with the name **FLOWER** for later retrieval.

TAPELOAD – for example,

TAPELOAD FLOWER

will load the TURTLETALK commands named FLOWER from a tape.

NETNAMES (requires modem connection to MNCP Network)

This command by itself will list the names of all the turtle creations to be found on the MNCP network. If you follow the command by a letter or letters, it will list the names of all turtle creations that **begin** with that letter or letters. For example,

NETNAMES FL

might produce the list

FLAGS
FLOWER
FLOWER2

NETSAVE (requires modem connection to MNCP Network) – for example,

NETSAVE BIGFLOWER

allows you to save your TURTLETALK commands on the MNCP Network under the name **BIGFLOWER** for later retrieval by you or someone else.

NETLOAD (requires modem connection to MNCP Network) – for example,

NETLOAD BIGFLOWER

allows you to load BIGFLOWER from the MNCP Network.

NETDELETE (requires modem connection to MNCP Network) – for example,

NETDELETE BIGFLOWER

allows you to delete BIGFLOWER from the MNCP Network.

Other notes:

- Holding down the **shift** key and typing @ will allow you escape from most operations.
- See the **Turtleworks User Manual** for a more detailed explanation of these commands.

Name
Partner
Date

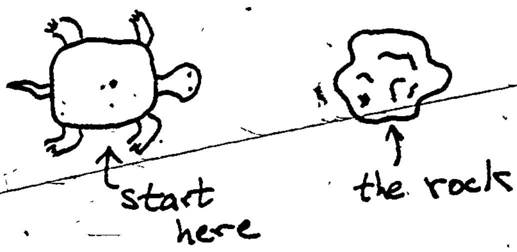
Turtletalk Worksheet

Materials: Turtletractor
Piece of Cardboard
Pushpin

1. Tellulah and the Rock

One day Tellulah Turtle was out for a stroll. But there was a rock in Tellulah's way. Here is how Tellulah moved:

```
GO 5
TURN 90
GO 5
TURN 270
GO 5
TURN 270
GO 5
TURN 90
GO 5
```

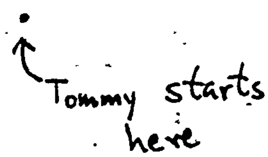


Show the path that Tellulah took.

2. Tommy's Triangles

Tommy Turtle is a great lover of triangles. He is also lazy. Here is how Tommy figured out how to make two triangles with very little effort.

```
GO 10
TURN 120
GO 10
TURN 120
GO 10
TURN 60
GO 10
TURN 120
GO 10
```



Draw Tommy's triangles.

Turtletalk Worksheet

3. Your Initial in Turtletalk

Draw your first initial here using only straight lines.

Write Turtletalk instructions to make a turtle draw that letter. Show both the instructions and their result in the space below.

Instructions | Result

More Triangles: (if you have time)
Figure out a way to have Tommy Turtle draw **three** triangles with only a few more instructions. (Then try **four** or **more**!)

Your Whole First Name: (if you have time)
Write Turtletalk instructions to draw your whole name. To do this, you will need to have the turtle stop drawing while you move between letters. The instruction to do this is **PENUP**. To get the turtle to start drawing again, use the instruction **PENDN**.

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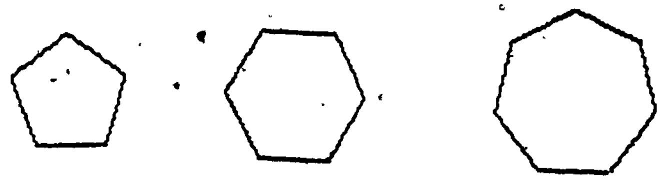
Name________________________

Group________________________

Date________________________



The Regular Polygon Family Worksheet

Materials: You will need paper, pencil, a 'turtle-tractor', and an 8 1/2 x 11 sheet of cardboard

You should already know the following Turtletalk commands:

GO
TURN
REPEAT (abbreviated as **RPT**)

1. Use your turtle-tractor to make the drawing produced by

RPT 6 (GO 5 TURN 60)

Your turtle had to turn 60 degrees 6 times. How many degrees did it have to turn altogether?__________

We call this number the **total turning** of the turtle.

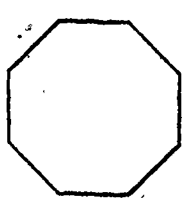
Did you end up drawing a six-sided figure with all sides equal? This figure is called a **hexagon**.

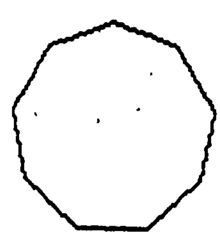
The Regular Polygon Family Worksheet

2. A hexagon is a kind of **polygon**. (The word 'polygon' literally means **many-sides.**) Polygons which have all sides equal and all angles equal like the hexagon you drew are called regular polygons.

Figure out how to draw the regular polygons listed in the chart below. For each one you draw, compute the total turning just like you did for the regular hexagon. Show in the chart the Turtletalk program you used to produce the polygon.

Number of sides	name of polygon	Turtletalk commands	Total Turning
3	triangle		
4	square		
6	hexagon	RPT 6 (GO 5 TURN 60)	360 degrees
8	octagon		
9	nonagon		





Name________________________

Date________________________

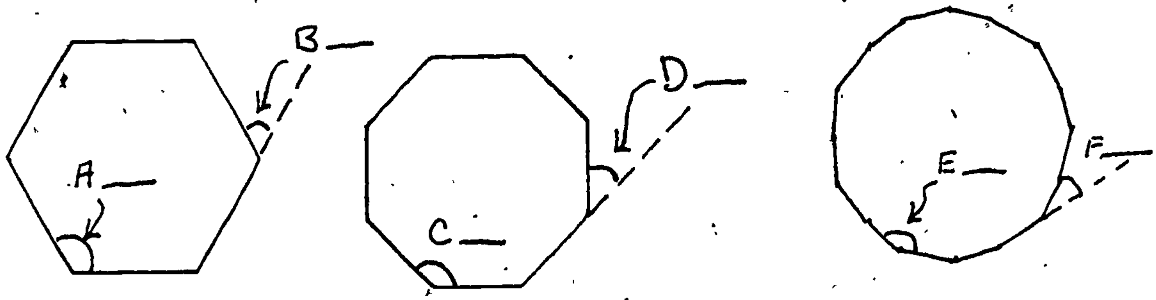
Homework on Regular Polygons

1. More Regular Polygons
   Write a Turtletalk program to make a turtle draw the following:

   a) a **regular dodecagon** (which has 12 sides)

   b) a **regular icosagon** (which has 20 sides)

2. Angles of Regular Polygons
   For each of the drawings shown below, tell how many degrees are in the indicated angles.



Name________________

Group________________

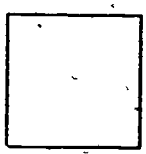
Date________________

Turtleworks Pictures Worksheet.

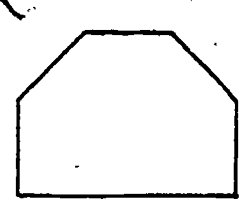
Materials: You need to be working in front of a PET computer.

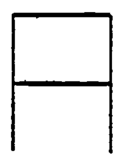
Find a way to draw each of the pictures below on the computer screen using Turtletalk. Write the program you end up using next to each picture. (You can use the **LIST** command to list your program.)

1.

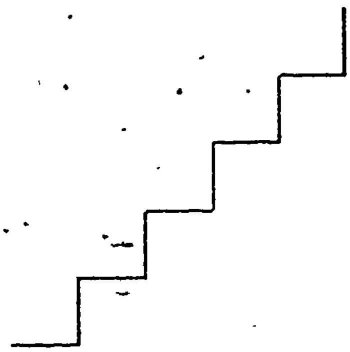


2. These pictures can be drawn with **one** turtle.

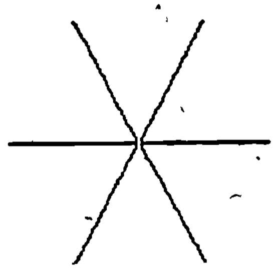


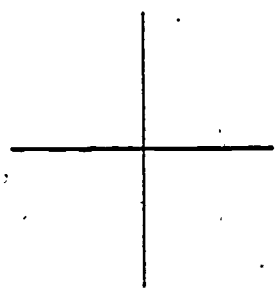


3. The **REPEAT** command will help here!

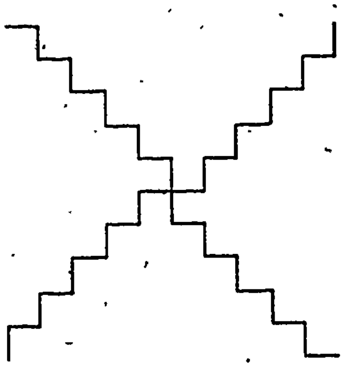


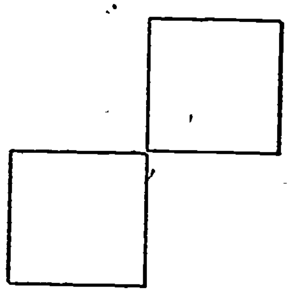
4. See if you can use **MULTIPLYBY** here.

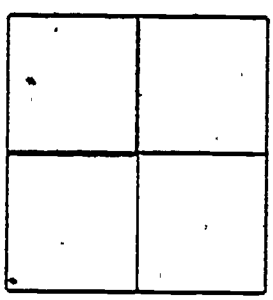




5. How about a combination of **MULTIPLYBY** and **REPEAT?**







Turtleworks Pictures Worksheet

Create a design of your own. Write the program here and make a sketch of what it produces. Save your design on the MNCP network.

Look at some of the designs other groups have saved on the MNCP network. Try to figure out how they made them. Sketch one design you liked here and show its Turtletalk commands.

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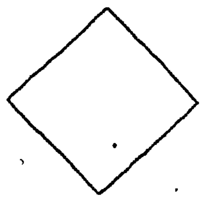
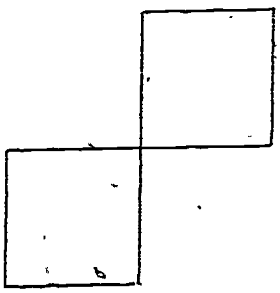
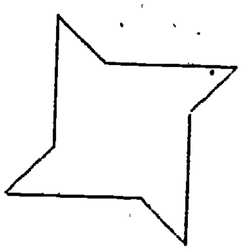
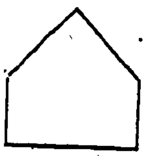
Turtleworks Pictures Worksheet

Here are some additional designs for you to try if you have time.





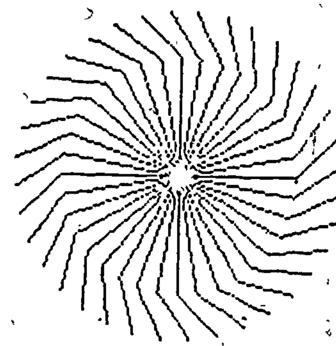




Name________________

Group________________

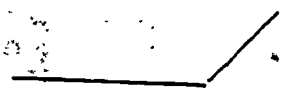
Date________________



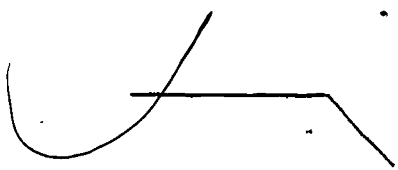
The Hook Worksheet

Materials: You need paper, pencil, and a **Turtle-Tractor.**

1. a) Below is a **hook** drawn by a turtle. Write the Turtletalk program which would draw the hook.



b) Suppose the hook goes the other way. Now what would the Turtletalk program be?



2. a) The Turtletalk program below puts 4 **hooks** together. Draw the figure using your Turtle-Tractor.

RPT 4 (GO 6 TURN 45 GO 3 TURN 45)

b) Find out what happens if you send the turtle the other direction.

RPT 4 (GO 6 TURN 315 GO 3 TURN 315)

The Hook Worksheet

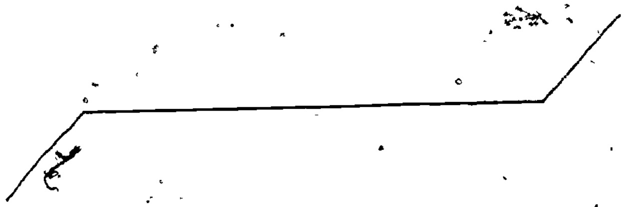
3. Below are some figures drawn with hooks and some Turtletalk programs. **Draw lines from each figure to its program.**

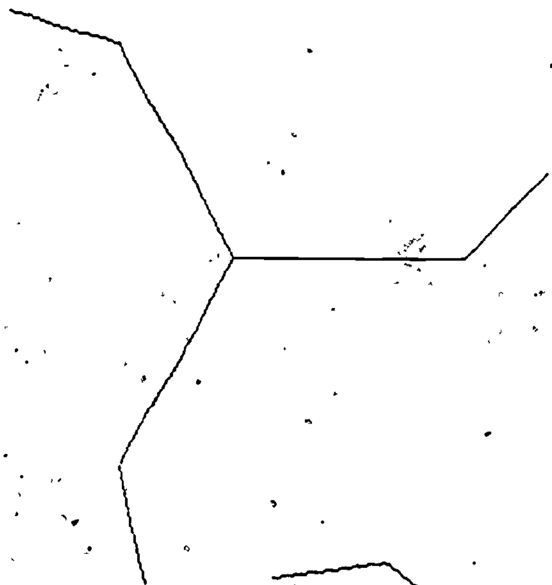
   a) MULT 3 GO 6 TURN 45 GO 3 TURN 45

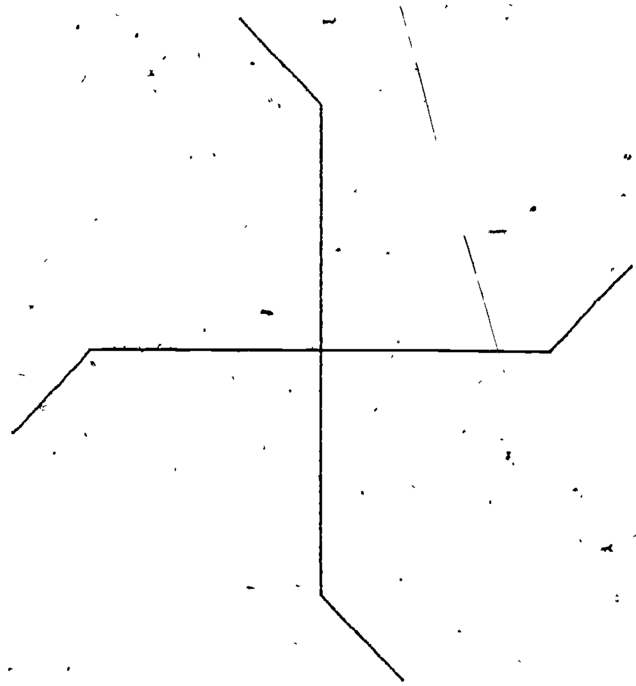
   b) MULT 2 GO 6 TURN 45 GO 3 TURN 45

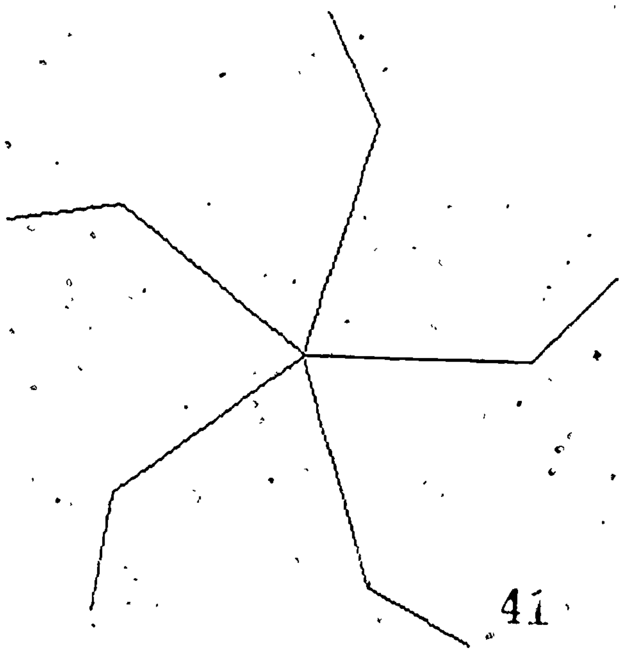
   c) MULT 5 GO 6 TURN 45 GO 3 TURN 45

   d) MULT 4 GO 6 TURN 45 GO 3 TURN 45



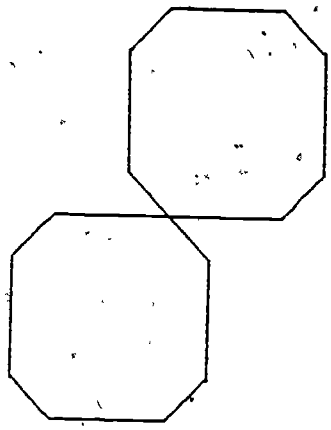




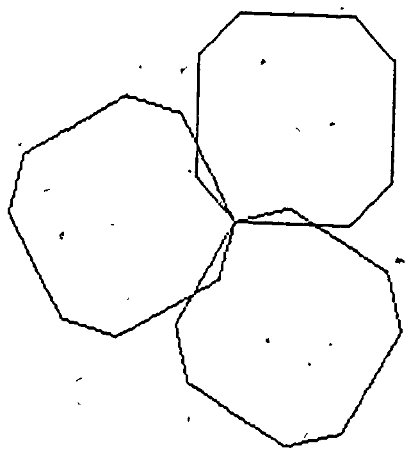


4. Combining the ideas of problems 2 and 3, we can get figures like those drawn below. Next to each figure, write its Turtletalk program. You do not need to use your turtle-tractor to actually make the drawing.

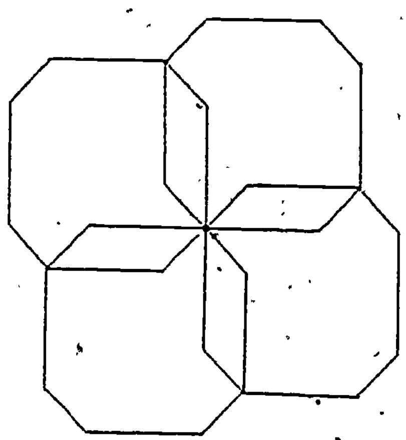
a)



b)



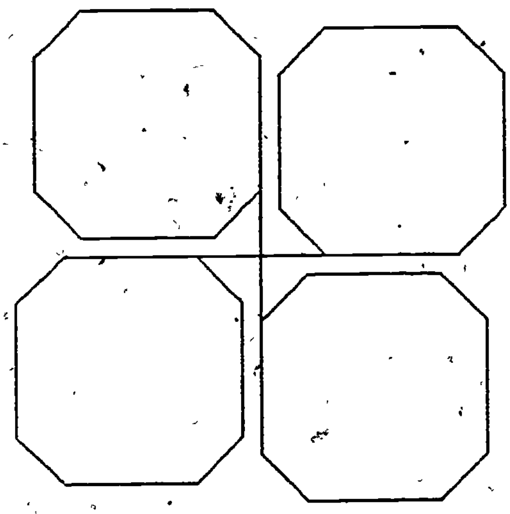
c)



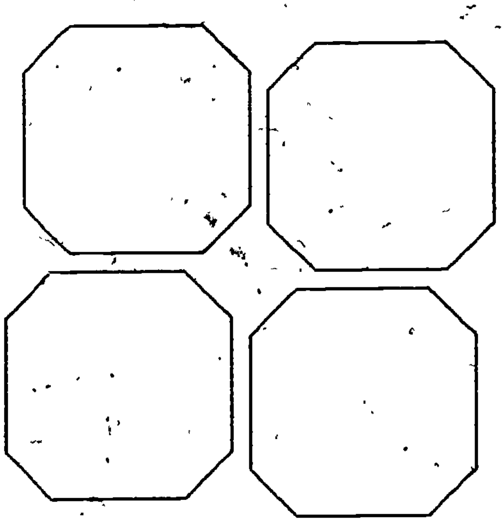
5. **IF YOU HAVE TIME**
On the following pages are some more figures made with hooks. For as many of them as you can, write a Turtletalk program that could draw them.

Also, you might enjoy making up some **HOOK FIGURES** of your own.

a)



b)



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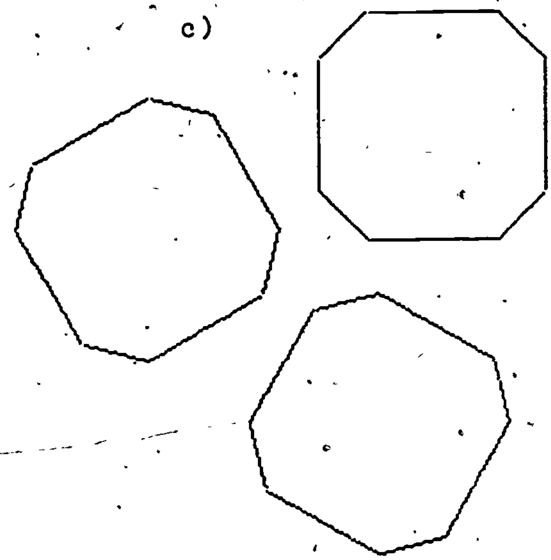
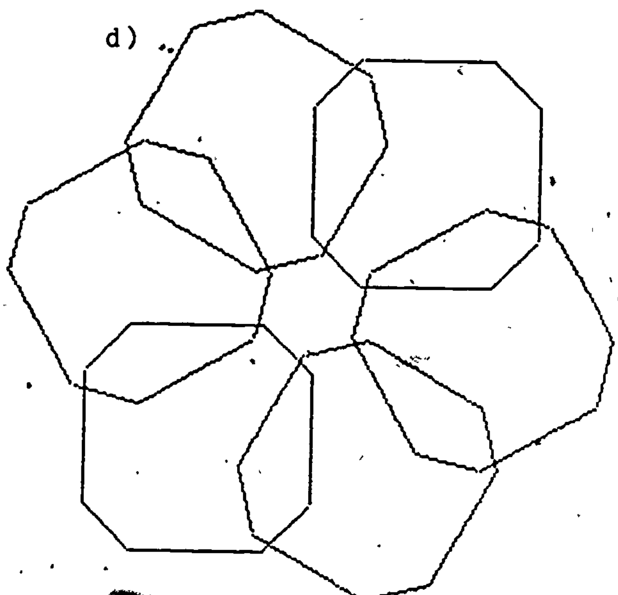
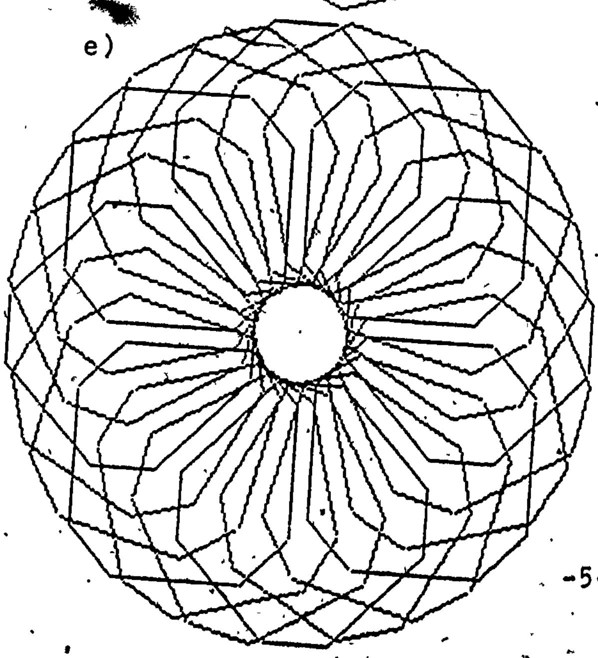
c)



d)

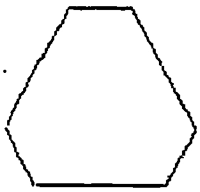


e)

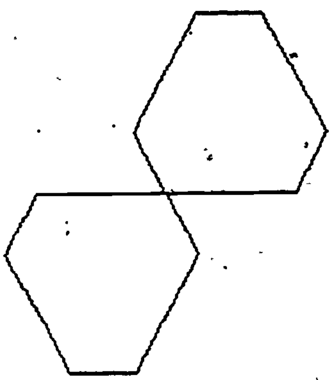


6. Still More Hooks

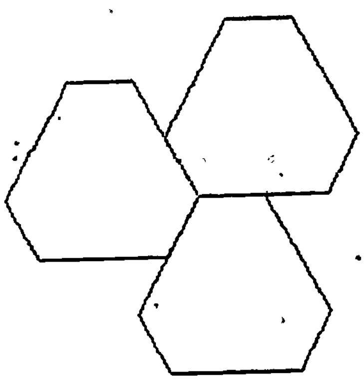
a)



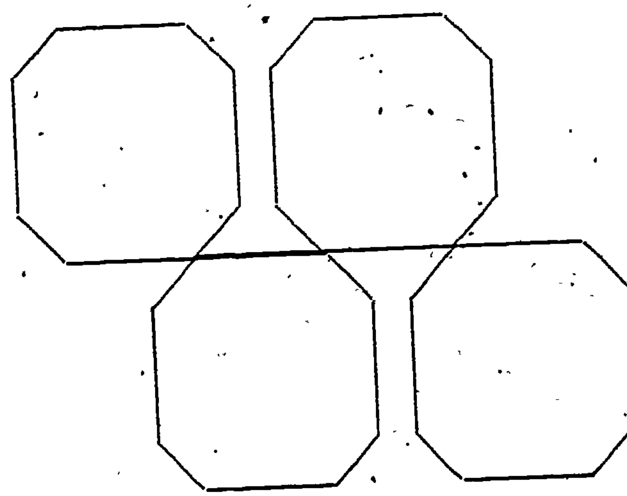
b)



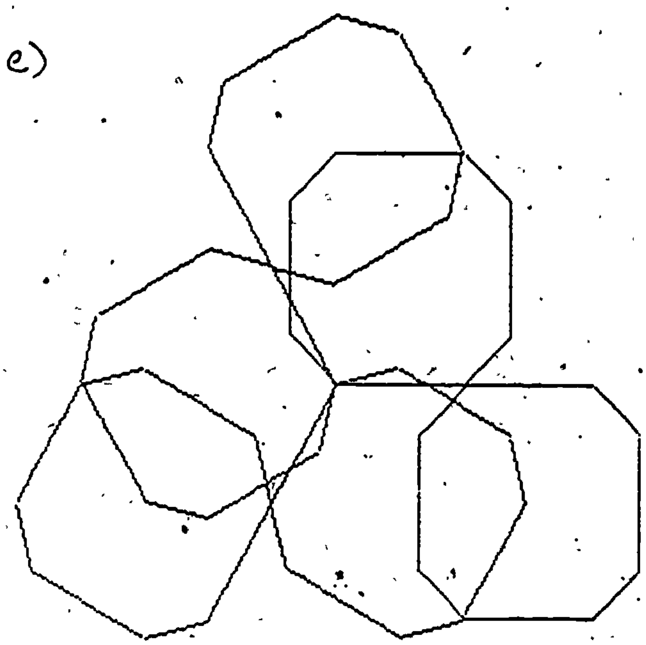
c)



d)



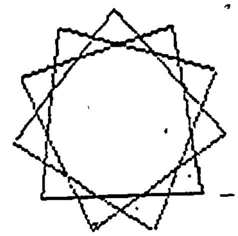
e)



Name________________________

Group_______________________

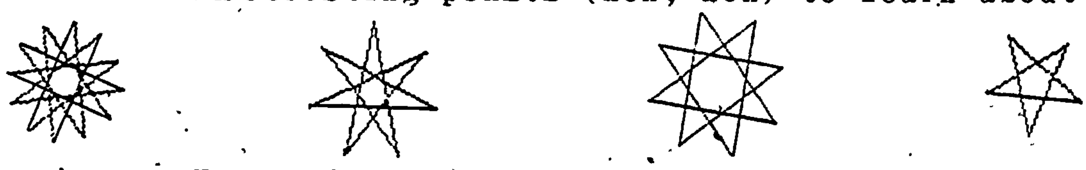
Date________________________

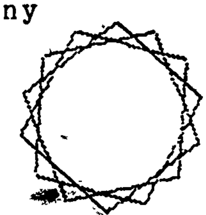


The Star Family Worksheet

Materials: You will need a PET computer loaded with the TURTLEWORKS program.

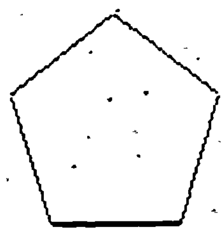
This worksheet is about **STARS** and how to draw them in TURTLETALK. We hope that you will find there are many interesting **points** (heh, heh) to learn about stars.





You and your group should be sitting around a PET all loaded up with the TURTLEWORKS program and ready to receive your typed commands.

1. You would probably like to jump right in and make the 5-pointed star which is the usual one we see. **But first**, as preparation, write a Turtletalk program to draw a **regular pentagon**. It looks like this:



Write your program here:

Star Family Worksheet

Now I'm going to ask you two questions after every figure you draw. You may think it silly, but if you look closely at your answers, you will eventually see a neat (and very mathematical) pattern.

The first question is:

How many degrees did the turtle have to turn at each corner (the proper word is vertex) of the pentagon?______

(If you didn't get 72 degrees, try it now. This angle is called the '**exterior angle**' of the pentagon.) The second question is:

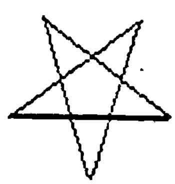
How many degrees did the turtle turn altogether?______

(Did you get 360? The turtle turned 72 degrees five times. Five times 72 is 360 degrees.)

2. Of course there are many ways to get the pentagon drawn in Turtletalk and I haven't any idea how you did it. But here is a very short way to do it. You just have to fill in the right numbers in the blank places.

RPT _____ (GO 10 TURN _____)

3. Finally, try for a 5-pointed star!



Write your program here:

(Did you find a short way to do it?)

Here are the two questions again:

How many degrees did the turtle have to turn at each corner (or vertex) of the star? (What is the 'exterior angle'?) ______

How many degrees did the turtle turn altogether?______. Let's call this the 'total **turning**' of the turtle.

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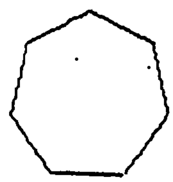
Star Family Worksheet

4. Now let's shoot for bigger money. Seven-pointed stars are much less often seen than the 5-pointed variety (however, sheriffs' badges have seven points!) But actually there are **two** seven pointers you can make. Start with the regular seven-sided polygon and then do each of the stars.

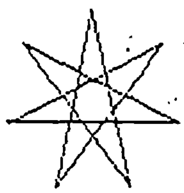
Program for regular heptagon:



exterior angle?______

total turning?______

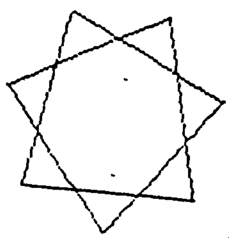
Program for skinny star:



exterior angle?______

total turning?______

Program for fat star:



exterior angle?______

total turning?______

Star Family Worksheet

5. I'll bet your wondering why we skipped six-pointed stars. Well, try to make one! But **please** obey this rule:

use the program

RPT _____ **(GO 10 TURN** _____**)**

where you can fill in the blanks with whatever numbers you like

This program **'defines'** the **STAR FAMILY** for us.

Write about what you found out here:

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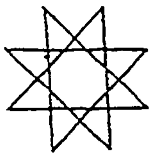
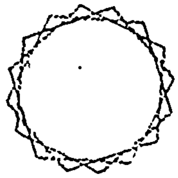
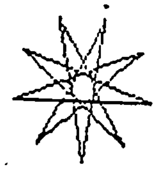
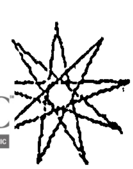
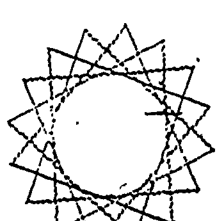
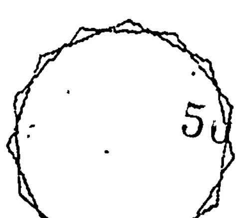
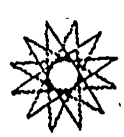
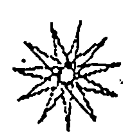
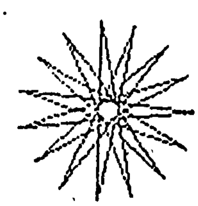





6. There is a lot more to find out. But I don't want to lead you by the nose through it. Below is a big table, mostly empty. You should fill in what you have already learned and then set about investigating more stars.

Number of Points	Exterior angle	Total turning	Is it a star?
3	120	360	no
4	90		
5	72	360	no
5	144	720	yes
6	60	360	no
7			no
7			yes
7			yes

The Hard Question: Even a computer would have trouble finding out how many stars there are with say 377 points. You certainly would not want to try by drawing! But can figure out how many there are using the patterns you have discovered?

Turtleworks User Manual

Math Network Curriculum Project

San Francisco State University
March, 1982

Overview of the Program

The world is full of wonderful symmetries, from the mirror-symmetry of our bodies, to the many-fold, rotational symmetry of flowers, to the fundamental symmetries underlying the structure of matter. The computer is a tool which, through its graphics capabilities, can give us ways to 'play' with symmetry. This program will give you some tools for producing rotationally symmetric drawings on the computer screen.

The way you will draw on the screen is based on the idea of a 'turtle'[1] which can be made to move around on the screen. The turtle has a 'pen' which, when down, produces a line on the screen as the turtle moves. You will address the turtle with the simple commands outlined below.

What has drawing with lines got to do with making symmetrical designs? The answer is that one of the things you can say to a turtle is '**MULTIPLYBY 4**.' In this case you get **four** turtles moving on the screen instead of one. These four turtles are 'aimed' symmetrically around the one turtle that was there before. All these turtles will now 'listen' simultaneously to your subsequent commands. You will automatically get drawings with a 'four-fold' or 'square' symmetry to them. (Other numbers will give you other symmetries.)

But the best way for you to understand all this is to experience it yourself! Try going through this manual sitting in front of a computer with the program loaded so that you can try all the commands as you encounter them here.

TURTLEWORKS COMMANDS

When **TURTLEWORKS** begins running, you will see the message

TURTLES ARE GETTING READY

appear at the top of the screen. After a brief pause, the screen will clear and you will see a white line at the top of the screen with a flashing gray cursor. The command line will be empty except for

D 1:.

Now the turtles are ready to listen to **you**.

Note about 'shift @': There will be times when you wish to 'escape' from something that is happening. Usually, holding down the **'shift'** key and pressing the @ key will accomplish this for you. For example, if the turtles are drawing a complicated design that is taking too long, **'shift @'** will allow you to 'escape' from that drawing (without 'forgetting' how to do it, though). Or, if you have just typed in a long command and realize that you made a typing error at the beginning of the line, **shift @** will erase the whole line for you. (Or you could use the **DEL** key as a backspace key as you normally would.)

Here is a list of all the commands that the turtle, or turtles, on your screen understand:

Getting Help

HELP (abbreviated as H)

This command will simply list, as a reminder, all the commands that the turtles understand. But you will need this manual to explain how the commands work. Note that asking for **HELP** erases whatever drawing you had. You can get all or some of it back using the **DRAW** command (see below). HELP isn't really much help except to remind you of the commands listed here.

Moving the Turtles

GO

This is the command that moves the turtles, and the only one that visibly adds to your drawing. You must tell the turtles **how far** to move forward by following the command with a number. For example,

GO 10

would move all turtles forward by 10 screen dots.

The space after **GO** is important and the program will complain at you if you leave it out.

The screen on which you can draw is 80 dots wide and 48 dots high. You can move the turtles outside of this area, but, of course, you won't see anything appear on the screen.

TURN

Making the turtles move forward would not be of much use unless you can make them change directions. You accomplish this with the **TURN** command. If you type

TURN 45

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all turtles will turn 45 degrees counter-clockwise (i.e. to their left). Of course, you won't see anything happen on the screen until you give them another **GO** command.

CLEAR

By now your screen may be pretty messy. You need a way to erase everything and start over again. **CLEAR** does this. It brings you back to the beginning with one turtle in the middle of the screen facing to the right. (Note that any 'memory' of lines you have typed in will be wiped out also. For more about this see the **LIST** command below.

REPEAT (abreviated as **RPT**)

Computers are very good at repetition. So it makes sense that there would be some way to tell the turtles to do something over and over again. Look at this example:

REPEAT 4 (GO 10 TURN 90)

Can you guess what it will do? The turtles will repeat the two commands inside the parentheses **four times**. If there happens to be just one turtle, it will draw a square.

> **Note about multiple commands on a line:** You may have already figured out that you can keep typing on the command line until you fill it up. Nothing happens until you hit the [**RETURN**] key and the program executes one command after another until it reaches the end of the line. So,
>
> **GO 10 TURN 90 GO 10**
>
> will produce a right angle bend only after you hit <**RETURN**>.

MULTIPLYBY (abbreviated as **MULT**)

This command is the one that makes it simple to create interesting patterns. It gives you more turtles! Try the following:

MULTIPLYBY 6 GO 15

You should see six spokes emerge from the center of the screen. What has happened is that the single turtle that was sitting at the center has been 'multiplied' into six turtles which get aimed symmetrically around the original point.

Now add the line

MULT 4 GO 10

The surprising design you get is caused by each of the six turtles multiplying into 4. There are now 24 turtles obeying your commands!

COLLAPSE

This is the opposite of **MULTIPLYBY**. After you say **COLLAPSE**, things will be taken back to the state just as they were before you last said **MULTIPLYBY**. Nothing will be erased on the screen, but there will be fewer turtles ready to respond to your **next** command. (This is best understood by experiment.)

PENUP

There will be times when you really don't want the turtles to draw a line. Just tell them **PENUP** and they won't draw anything until you tell them **PENDN**.

PENDN

This stands for 'Pendown', the counterpart to **PENUP**. Use it when you want the turtles to begin drawing again. When the program first starts, the pen is down.

Some TopLevel Commands

QUIT

Here is a graceful way to leave the Turtle World. If you are wanting to make a copy of the program, it is essential that you first **QUIT** so that internal pointers in the PET will be reset properly so that you can save the program on tape.

LIST

You may not have been aware that the program is remembering commands that you have typed in. When you type **LIST**, the commands you have issued since the last **CLEAR** command will be printed on the screen. (Note that this will mess up your drawing.)

DRAW (abreviated as D)

Since the program is remembering your commands, it should be able to do them again! When you type **DRAW**, the program first clears the screen and then re-draws using your instructions.

Making Your Own Procedures

TO

follow this command by a word which names the routine that you are about to define. For example,

TO SQUARE

will mean that you are about to say what is involved in the routine SQUARE. The commands that you type in now will be executed as normal but will not become part of the main routine. Instead, they will be remembered as part of SQUARE. This will continue until you type

END

Then you will be able to include the SQUARE routine (or whatever you

called it) in your main routine. For example,

SQUARE 6

included in the main routine would cause the turtles to SQUARE six times.

END

Use this instruction to signal the end of the definition of a routine.

Editing Your Routines

EDIT

Often you will want to change one or more of the instructions in the set of drawing commands. Just typing

EDIT

will bring the first line of the main routine into the command line at the top of the screen. You can use the <DEL> key to backspace this command and then retype what you want. Press return any time you are happy with what you see on the command line.

Typing

EDIT 5

will bring up the 5th line of the main procedure to be edited.

Typing

EDIT FLOWER

will cause the first step of the the FLOWER routine to appear, ready to be edited. (You will have to step through to the end of the routine and type END to return to the main routine.)

Typing

EDIT FLOWER 3

will bring up the 3rd step (if there is one) of the FLOWER routine for editing.

Saving and Loading From Tape or Network

TAPESAVE

If you find yourself enjoying creation of designs with the Turtleworks, you may wish you had a way to store your designs for later retrieval. That is the function of **TAPESAVE**. After you type this command the following will happen:

a) You will see a listing of all your procedures and the main commands you typed in since the last **CLEAR**. In the command line you will see

SAVE THESE COMMANDS?

If the list of commands is indeed what you wish to save on tape, then you should now position a blank, rewound tape (**Not the program tape, please!** in the tape recorder and type **Y** and **[RETURN]**. You will see the instruction to

PRESS PLAY ON TAPE #1

which you should now do.

b) If you answer **N** to the question about saving these commands, then you will simply be left where you were with nothing changed except that your design has been messed up by the list of commands. You can get your design back, as usual, by typing **DRAW**.

c) Often it will be helpful to save a sequence of commands with a name. You can do that by adding the name of your design to the **TAPESAVE** command. For example,

TAPESAVE FLOWER

would save your creation under the name FLOWER. This is most useful if you want to save a whole set of creations on one tape. It is just like saving BASIC programs with names. You don't have to, but it is often useful.

TAPELOAD

Clearly, it is no good to you to be able to save your creations on tape unless you can **read** them back. You can load creations by their names or simply in the sequence in which they appear on the tape. For example

TAPELOAD FLOWER

would cause the program to search your tape for a Turtleworks creation called FLOWER. Just using the command

TAPELOAD

would cause the **next** creation on whatever tape you have inserted to be loaded. You should position your tape **before** typing this command.

If you get stuck trying to load a creation that is not there, then you will have to stop the program by pressing the **[RUNSTOP]** key. After that you can restart Turtleworks by typing **RUN**.

Note: The next four commands apply only if you are set up to access the MNCP NETWORK. See the **Network User's Guide** for basic setup information.

NETSAVE

It is possible to save your creation on the MNCP Network via the phone lines. This makes it possible for you to share your work (or play) with others who can access the network. You must give a name to your creation (so that you can retrieve it later). For example, you might type

NETSAVE BIGFLOWER

Now the program will ask you for your name. It does this so that your name can be stored along with your creation. This will be a protection so that no one else can **NETDELETE** your creation. (See below for more about this.)

If you had not already dialed on to the MNCP Network, you will see in the command line

PLEASE DIAL

followed by the network telephone number. After you dial and are (hopefully) connected, the command lines of your creation will be stored out one at a time (up to 10, as usual).

NETNAMES

You need to know the names that you and others have used to store Turtleworks creations on the Network. This is the command that lists these for you. If you have not already connected with the Network, you will have to go through the same sequence outlined above under **NETSAVE** before the names appear.

NETLOAD

This is the command that lets you look at yours and others' Turtleworks creations that are stored on the network. You must specify the name of the creation that you wish to load into your computer. So, for example, you might type

NETLOAD BIGFLOWER

This would bring back the flower creation that you previously saved.

If you have not already connected to the Network, you will be asked to do so as outlined above.

As each command is brought over the telephone the turtles on your screen go about recreating your drawing. Afterward, you could, if you wished, **LIST** the commands that were used to make this drawing.

NETDELETE

Sometimes you may store a creation on the network which you later decide you don't want to be there any more. (Perhaps you have a better looking one, or a better way to create the same design.) Suppse, for example, that you wished to get rid of BIGFLOWER. Then you would type

NETDELETE BIGFLOWER.

Now the program asks you for your name. You must type in your name just as you did at the time you **NETSAVed BIGFLOWER.** If the program finds BIGFLOWER on the network and finds that it was saved there by you, it will delete it and you will see the message

SUCCESSFUL DELETE.

displayed on the command line. If you see any other message, it means that something has gone wrong with the delete process.

At certain times, the network will fill up with Turtleworks creations. At this time, the MNCP Network Manager will have to get rid of some of them. You will see a Bulletin announcing that this is about to happen. At this time, you might want to save your creations on tape.

[1] We are indebted to Seymour Papert and the MIT LOGO group for many of the ideas in this program. Turtle graphics came from their work and they have seen many of the possibilities of using computers in euducation. For an excellent introduction in this area, see Mindstorms, by Seymour Papert, Basic Books, N.Y., 1981.

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Star Family Worksheet

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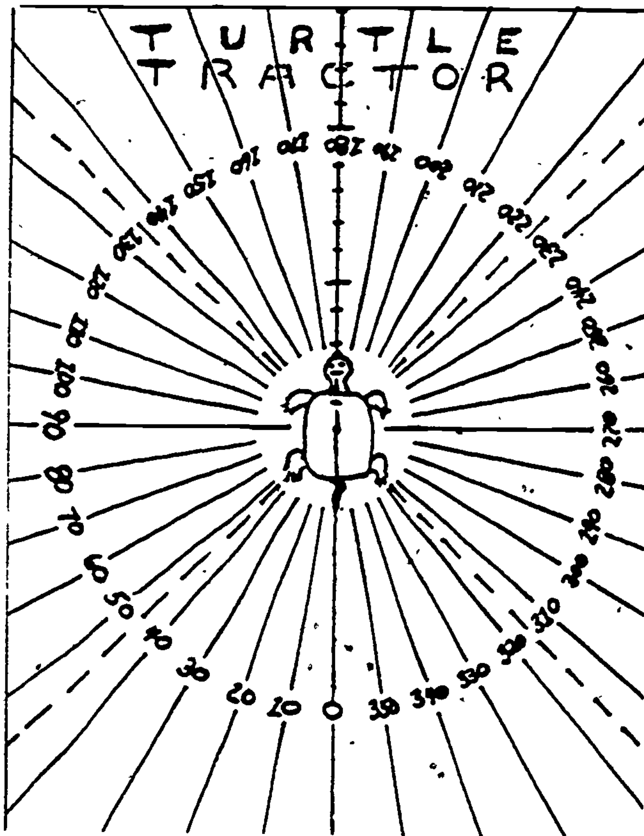
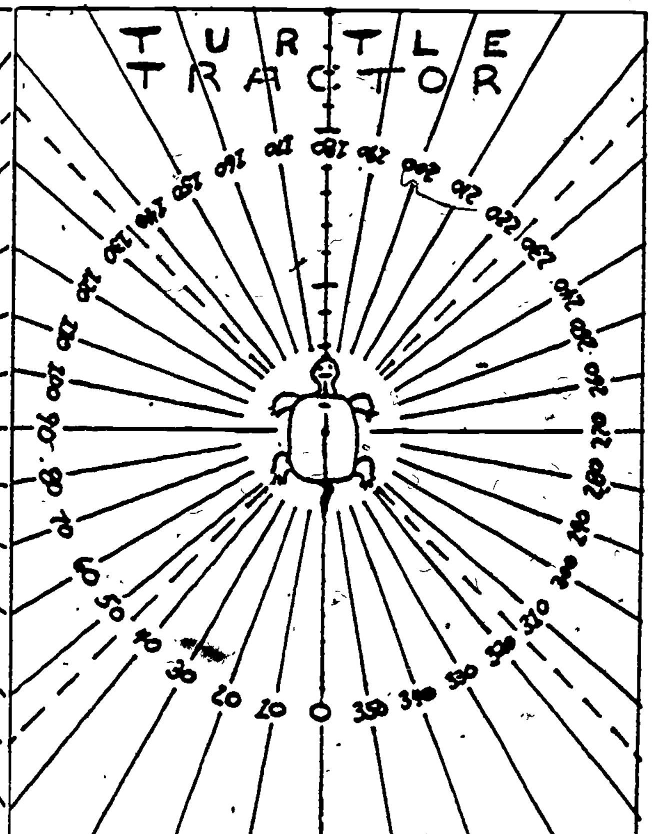

TURTLE
TRACTOR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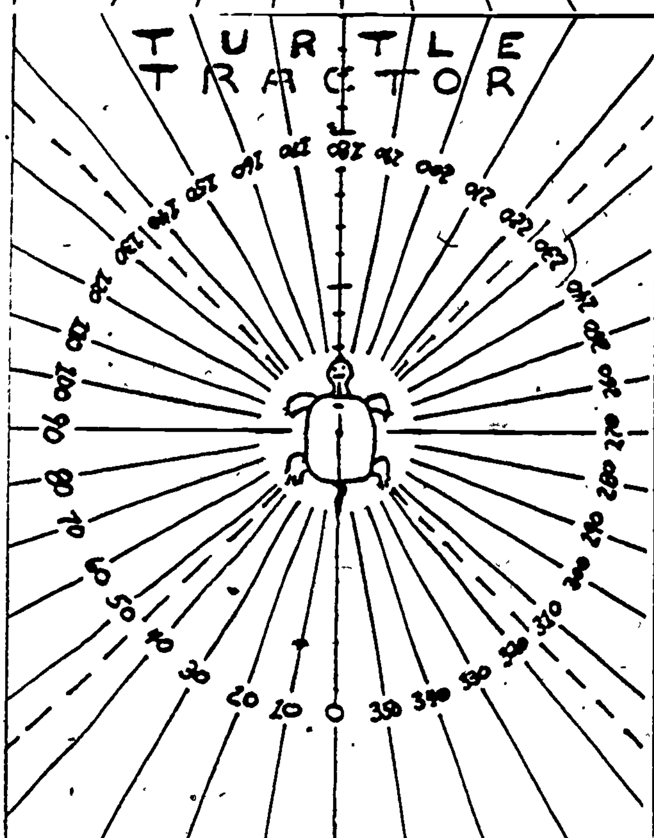
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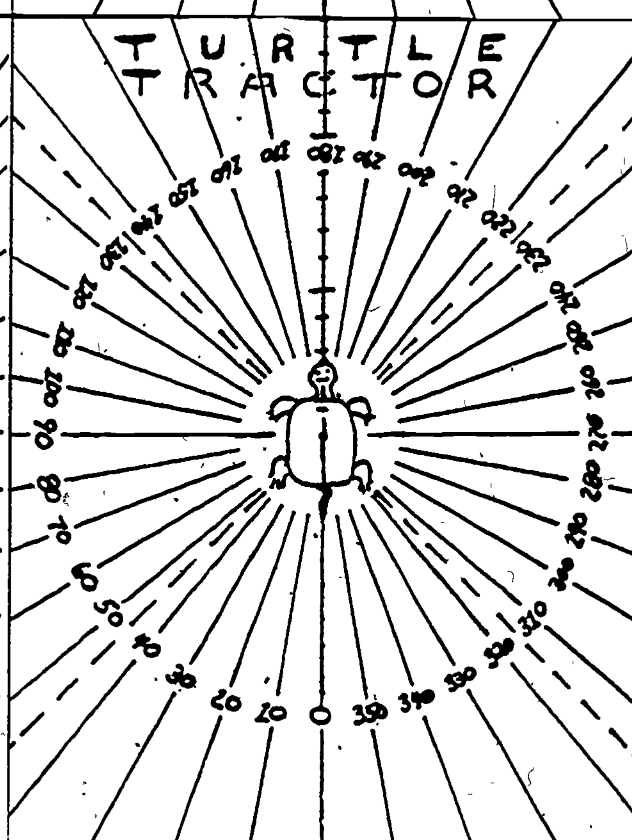
TRACTOR


TURTLE
TRACTOR

TURT 2.2 DCAT

```
READY.

 10 SYS1039:RUN
READY.

READY.

 1 GOTO16000
 2 REM COPYRIGHT 1981, BILL FINZER, SFSU
 200 REM-NETIN-
 210 IN$="":D$="R"
 220 GOSUB300:IF(PEEK(SS)ANDRF)<>RFTHEN220
 230 SYS RX
 240 A$=CHR$(PEEK(RB)):IFA$=RT$THENPRINT"█ ▌";:SYSSD:RETURN
 250 IN$=IN$+A$:GOTO220
 300 REM-BLINK D$-
 310 IFDTHENPRINT"▣"D$"▌";:D=FA:RETURN
 320 PRINT"█"D$"▌";:D=TR:RETURN
 400 REM--NET OUT--
 405 SYSI1
 410 D$="S"
 420 FORI=1TOLEN(OUT$):GOSUB300:POKEXB,ASC(MID$(OUT$,I)):SYS TX
 430 NEXT
 435 POKEXB,13:SYSTX:PRINT"█ ▌";
 440 GOTO200
 500 REM-GET TK$--
 510 RE=FA:TK$="":IFLEN(LI$)=0THENRETURN
 515 IFASC(LI$)<>TTTHEN530
 520 LI$=MID$(LI$,2):IFLEN(LI$)=0THENRETURN
 525 GOTO515
 530 TK$=TK$+LEFT$(LI$,0):LI$=MID$(LI$,2)
 535 IFLEN(LI$)=0THENRE=TR:RETURN
 540 IF(ASC(LI$)<>TT)ANDLEFT$(LI$,0)<>"("THEN530
 545 RE=TR
 590 RETURN
 600 REM-GET STRNG-
 620 GOSUB800:A=ASC(A$)
 640 IFB$=""ANDA=20THEN620
 650 IFB$=""ANDA=13THENRETURN
 660 IFA=13THENPRINT:RETURN
 662 IFRE$=ES$THENPRINT:RETURN
 670 IFA=20ANDLEN(B$)<2THENPRINT"▌ ▌";:B$="":GOTO620
 680 IFA=20THENPRINT"▌ ▌";:B$=LEFT$(B$,LEN(B$)-1):GOTO620
 690 IFA<32OR(A>127ANDA<161)THEN620
 715 IFLEN(B$)=LLTHEN620
 720 PRINTA$;:B$=B$+A$
 725 IFA$=CHR$(34)THENPRINTCHR$(34)"▌";
 740 GOTO620
 800 REM-SNGLE CH--
 810 T=TI:RES$=""
 820 IFTI<T+30THENPRINT"▒▌";:GOTO850
 830 IFTI<T+60THENPRINT" ▌";:GOTO850
 840 T=TI
 850 GETA$:IFA$=""THEN820
 857 IFA$=ES$THENRE$=A$
 858 IFA$=RT$THENRE$=A$
```

```
860 PRINT" ▮"::RETURN
900 REM---LKUP TK$--
910 RE=FA
920 FORI=0TONK-1:IFTK$=KE$(I)THENRE=TR:PS=KP%(I):I=NK-1
930 NEXTI
940 IFNOTRETHENGOSUB14200
950 RETURN
1000 REM-GEN TG--
1002 GETA$:IFA$=ES$THENER=8
1005 IFERTHENRETURN
1010 IFTG=CGTHENGOSUB2000:RETURN
1020 SK=TG:GOSUB1800
1030 SK=M%(TG):GOSUB1800
1050 GOSUB1900:RA=SK
1060 GOSUB1900:TG=SK
1065 IFRA=0OR ERTHENRETURN
1070 GOSUB1200
1080 RA=RA-1
1090 SK=TG:GOSUB1800:SK=RA:GOSUB1800
1100 TG=TG+1:GOSUB1000
1110 GOTO1050
1190 RETURN
1200 REM-COMPTE TRNS-
1210 R=2*π/M%(TG)*RA:U(Z,Z)=COS(R):U(O,O)=U(Z,Z):U(O,Z)=SIN(R):U(Z,O)=-U(O,Z)
1260 U(2,Z)=-X(TG)*(U(Z,Z)-1)-Y(TG)*U(O,Z)
1270 U(2,O)=X(TG)*U(O,Z)-Y(TG)*(U(Z,Z)-O)
1290 FORI=ZTO2:FORJ=ZTOO
1310 T(TG+O,I,J)=U(I,Z)*T(TG,Z,J)+U(I,O)*T(TG,O,J)-(I=2)*T(TG,I,J):NEXT:NEXT
1390 RETURN
1600 REM-PUSH STR-
1620 SK$(SP)=SK$:SP=SP+1:RETURN
1700 REM-POP STR-
1720 SP=SP-1:SK$=SK$(SP):RETURN
1800 REM-PUSHNUM-
1820 SK(SN)=SK:SN=SN+1:RETURN
1900 REM-POPNUM
1920 SN=SN-1:SK=SK(SN):RETURN
2000 REM-MOVE TRT-
2010 X1%=OX*T(TG,0,0)+OY*T(TG,1,0)+T(TG,2,0)
2020 Y1%=OX*T(TG,0,1)+OY*T(TG,1,1)+T(TG,2,1)
2030 X2%=NX*T(TG,0,0)+NY*T(TG,1,0)+T(TG,2,0)
2040 Y2%=NX*T(TG,0,1)+NY*T(TG,1,1)+T(TG,2,1)
2050 REM-CLIP-
2060 X%=X1%:Y%=Y1%:C1%=FNC(0)
2070 X%=X2%:Y%=Y2%:C2%=FNC(0)
2080 IF(C1%=0)AND(C2%=0)THENSYS(DR):RETURN
2090 IF(C1%ANDC2%)<>0THENRETURN
2100 C%=C1%:IFC%=0THENC%=C2%
2110 IF(1ANDC%)=0THEN2130
2120 Y%=Y1%+(Y2%-Y1%)*(LF-X1%)/(X2%-X1%):X%=LF:GOTO2165
2130 IF(2ANDC%)=0THEN2145
2140 Y%=Y1%+(Y2%-Y1%)*(RT-X1%)/(X2%-X1%):X%=RT:GOTO2165
2145 IF(4ANDC%)=0THEN2155
2150 X%=X1%+(X2%-X1%)*(BTM-Y1%)/(Y2%-Y1%):Y%=BT:GOTO2165
2155 IF(8ANDC%)=0THEN2165
2160 X%=X1%+(X2%-X1%)*(TP-Y1%)/(Y2%-Y1%):Y%=TP
2165 IFC%=C1%THENX1%=X%:Y1%=Y%:C1%=FNC(0):GOTO2080
2170 X2%=X%:Y2%=Y%:C2%=FNC(0):GOTO2080
2600 REM--GET NEXT NUMBER---
2610 GOSUB500:IFNOTREORVAL(TK$)=0THENLI$=TK$+LI$:TK$="1"
```

```
2620 P=VAL(TK$):RETURN
2800 REM-EXEC--
2810 GOSUB3000:IFER=FATHEN2840
2820 GOSUB10400:IFPFTHENCC=CC-1
2830 CM$(CC,NR)=PL$:RETURN
2840 GOSUB500:IFNOTRETHENRETURN
2850 GOSUB900
2855 IFNOTRETHENCC=CC-1:CM$(CC,NR)=PL$:ER=3:GOSUB10400:CC%(NR)=CC:RETURN
2860 GOTO2810
3000 REM--EXEC LNE-
3010 GETA$:IFA$=ES$THENER=8:RETURN
3020 ER=FA
3030 ONPSGOTO3400,3600,3800,5600,5800,4000,4600,14000,4400,10000,5000
3040 ONPS-11GOTO5400,13000,13200,7000,7200,7400,7600,7800,8200,11000,14400
3190 RETURN
3400 REM-MVE TRTS FRWRD-
3420 GOSUB500:IFNOTREORVAL(TK$)<=0THENER=6:RETURN
3450 LN=VAL(TK$):OX=X(CG):OY=Y(CG)
3460 NX=OX+LN*COS(FNR(A(CG))):NY=OY+LN*SIN(FNR(A(CG))):IFPETHENTG=0:GOSUB1000
3495 X(CG)=NX:Y(CG)=NY
3500 RETURN
3600 REM-TRN TURTS-
3610 GOSUB500
3620 IFNOTRESTHENER=3:RETURN
3630 A(CG)=A(CG)+VAL(TK$)
3640 RETURN
3800 REM-MULT TURTS--
3810 GOSUB500
3820 IFNOTREORVAL(TK$)=0THENER=3:RETURN
3840 IFCG=MGTHENER=2:RETURN
3850 M%(CG)=VAL(TK$)
3860 CG=CG+1
3870 X(CG)=X(CG-1):Y(CG)=Y(CG-1):A(CG)=A(CG-1)
3990 RETURN
4000 REM-CLLPSE--
4010 IFCG=0THENER=4:RETURN
4020 CG=CG-1
4030 RETURN
4200 REM-INITRT-
4210 CG=0:X(0)=CX:Y(0)=CY:A(0)=0:M%(0)=1
4220 PEN=TR
4290 RETURN
4400 REM-INIT ALL--
4405 FORI=0TOCC%(0):CM$(I,0)="":NEXT
4410 CC=0:LI$="":NR=0:CC%(0)=0
4420 GOSUB4800
4430 RETURN
4600 REM-RPT-
4610 GOSUB500
4620 IFNOTREORVAL(TK$)<1THENER=5:RETURN
4640 SK=VAL(TK$):GOSUB1800:GOSUB9800
4655 IFNOTRETHENER=5:RETURN
4660 SK$=MID$(LI$,P2+1):GOSUB1600
4670 SK$=MID$(LI$,P1+1,P2-P1-1):GOSUB1600:CN=1
4690 GOSUB1700:LI$=SK$:GOSUB1600:SK=CN:GOSUB1800
4700 GOSUB500:IFNOTRETHEN4720
4705 GOSUB900:IFNOTRETHENER=3:RETURN
4710 GOSUB3000:IFER=FAAND(LI$<>"")THEN4700
4712 IFER=8THENRETURN
4715 IFERTHENER=5:RETURN
```

```
4720 GOSUB1900:CN=SK+1
4730 GOSUB1900:IFCN<=SKTHENGOSUB1800:GOTO4690
4750 GOSUB1700:GOSUB1700:LI$=SK$
4760 RETURN
4800 REM-CLEAR-
4810 PRINT"□"
4820 GOSUB4200
4830 RETURN
5000 REM-LIST-
5010 IF(CC%(0)=0)ANDRR=0THENER=21:RETURN
5015 PRINT"■■
5020 FORR=0TORR:FORI=0TOCC%(R)-1:IFI>CC%(R)-1THEN5050
5030 PRINTR$(R);I+1;"■: "CM$(I,R)
5050 NEXTI,R
5100 RETURN
5400 REM-DRAW-
5420 IFCC%(NR)=0THENER=10:TK$="":RETURN
5425 GOSUB4800
5430 FORCP=0TOCC%(NR)-1
5440 LI$=CM$(CP,NR)
5445 GOSUB500:IFNOTRETHEN5470
5450 GOSUB900:IFNOTRETHEN5470
5455 GOSUB3000:IFLI$=""THEN5470
5457 IFERTHENCP=CC%(NR)-1:GOTO5470
5460 GOTO5445
5470 NEXTCP
5480 RETURN
5600 REM PENUP
5610 PE=FA:RETURN
5800 REM PENDN
5810 PE=TR:RETURN
7000 REM-TPESAVE-
7005 IFRR=0ANDCC%(0)=1THENER=12:TK$="":RETURN
7010 GOSUB500
7020 GOSUB5000
7030 P$="SAVE THESE COMMANDS? ":GOSUB17200
7070 GOSUB800:IFA$<>"Y"ANDA$<>"N"THEN7070
7080 PRINTA$"■";:IFA$="N"THENRETURN
7090 OPEN1,1,1,TK$
7095 PRINT#1,RR
7100 FORR=0TORR:PRINT#1,R$(R):PRINT#1,CC%(R)
7110 FORCP=0TOCC%(R)-1:PRINT#1,CM$(CP,R):NEXTCP,R
7120 CLOSE1:ER=0:RETURN
7200 REM-TPELOAD-
7205 GOSUB500
7210 P$="SEARCHING ":IFTK$<>""THENP$=P$+"FOR "+TK$
7215 GOSUB17200
7220 OPEN1,1,0,TK$:GOSUB4400
7222 FORR=0TORR:FORI=0TOCC%(R)-1:CM$(I,R)="":NEXTI,R:RR=0
7230 P$="FOUND "+TK$:GOSUB17200
7240 PRINT
7250 INPUT#1,RR
7260 FORR=0TORR
7270 INPUT#1,R$(R):INPUT#1,CC%(R)
7280 FORCP=0TOCC%(R)-1:INPUT#1,CM$(CP,R):NEXTCP,R
7385 CLOSE1:GOSUB5000:CC=CC%(0)
7390 RETURN
7400 REM-NETNMS-
7405 GOSUB500
7410 IFNOTNFTHENGOSUB8800
```

```
7420 OU$="DMN000"+TK$
7430 CN=0:ER=FA
7440 GOSUB400
7460 IFMID$(IN$,4,1)<>"T"THENRETURN
7470 PRINTTAB(-CN*20)MID$(IN$,8);:CN=NOTCN
7480 IFNOTCNTHENPRINT
7485 GETA$:IFA$=ESC$THENRETURN
7490 OU$="DMN"+MID$(IN$,5,3)+TK$:GOTO7440
7600 REM-NETSVE-
7602 IFRR=0ANDCC%(0)=1THENER=12:TK$="":RETURN
7605 GOSUB500:IFNOTRETHENER=14:TK$="NETSAVE":RETURN
7607 IFLEN(TK$)>16THENTK$=LEFT$(TK$,16)
7610 IFNOTNFTHENGOSUB8800
7620 P$="YOUR NAME? ":GOSUB17200:LL=16:B$="":GOSUB8400:IFRE$=ES$THENRETURN
7625 GOSUB8000
7630 OU$="DMA"+A$+B$+TK$:GOSUB400
7640 IFIN$="DMAF"ORLEN(IN$)<7THENER=15:TK$="":RETURN
7650 IFLEFT$(IN$,4)<>"DMAT"THENER=13:TK$="":RETURN
7655 B$="DML"+MID$(IN$,5)
7660 OU$=B$+STR$(PR):GOSUB9000:IFERTHENRTURN
7670 FORR=0TORR:OU$=B$+R$(R):GOSUB9000:IFERTHENRETURN
7680 OU$=B$+STR$(CC%(R)):GOSUB9000:IFERTHENRETURN
7690 FORCP=0TOCC%(R)-1:OU$=B$+CM$(CP,R):GOSUB9000:IFERTHENRETURN
7700 NEXTCP,R
7790 ER=9:RETURN
7800 REM-NETLOAD-
7805 GOSUB500:IFNOTRETHENER=16:TK$="NETLOAD":RETURN
7810 IFNOTNFTHENGOSUB8800
7830 OU$="DMR"+TK$:GOSUB400
7835 IFIN$="DMRF"THENER=17:TK$="NETLOAD "+TK$:RETURN
7837 IFLEN(IN$)<7THENER=13:RETURN
7838 GOSUB4400
7840 GOSUB9200:IFERTHENRETURN
7850 PR=VAL(MID$(IN$,9))
7860 FORR=0TORR:GOSUB9200:IFERTHENRETURN
7870 R$(R)=MID$(IN$,9):PRINTR$:GOSUB9200IFERTHENRETURN
7880 CC%(R)=VAL(MID$(IN$,9))
7890 FORCP=0TOCC%(R)-1:GOSUB9200:IFERTHENRETURN
7900 CM$(CP,R)=MID$(IN$,9)
7905 PRINTCM$(CP,R)
7910 NEXTCP,R
7920 GOSUB5000:ER=FA
7990 RETURN
8000 REMB$ TO LEN B$
8010 A$=MID$(STR$(LEN(B$)),2)
8020 IFLEN(A$)<2THENA$="0"+A$
8030 RETURN
8200 REM NET DLTE
8210 GOSUB500:IFNOTRETHENER=18:RETURN
8220 IFNOTNFTHENGOSUB8800
8230 P$="YOUR NAME? ":GOSUB17200:LL=16:B$="":GOSUB8400:IFRE$=ES$THENRETURN
8240 GOSUB8000
8250 OU$="DMD"+A$+B$+TK$:GOSUB400
8255 TK$="NETDELETE "+TK$
8260 IFIN$="DMDF"THENER=17:RETURN
8270 IFIN$="DMDC"THENER=19:RETURN
8280 IFIN$<>"DMDT"THENER=13:RETURN
8290 TK$="":LI$="":ER=20:RETURN
8400 REM-NON-EMPTY STRNG-
8410 REM POKE158,0
```

```
8420 GOSUB600
8422 IFPE$=ES$THEN8440
8430 IFB$=""THEN8420
8440 RETURN
8600 REM CC>MC
8610 ER=22:GOSUB10400:CC=CC-1:RETURN
8800 REM-DIAL NET--
8810 P$="PLEASE DIAL 469-2125":GOSUB17200
8820 OU$="HELLO FROM MULTITURTS"
8830 GOSUB400
8850 P$=IN$:GOSUB17200:TM=2:GOSUB9600
8860 PRINT:NF=TR
8890 RETURN
9000 REM--NETSAVE CHECK
9010 ER=0:GOSUB400:IFIN$<>"DMLT"THENER=13
9020 RETURN
9200 REM NETLOAD GET LINE
9210 B$=MID$(IN$,5,4):OU$="DMS"+B$:GOSUB400
9220 ER=0:IFIN$="DMSF"ORLEN(IN$)<6THENER=13
9225 GETA$:IFA$=ES$THENER=13
9230 RETURN
9400 REM-ERRORS
9420 DATAEDIT WHAT?,TOO MANY SYMMETRY POINTS
9440 DATAI DON'T UNDERSTAND,CAN'T COLLAPSE LAST TURTLE
9460 DATAINCORRECT REPEAT STATEMENT,HOW FAR TO GO?
9480 DATAFINISHED TAPESAVE,USER STOPPED DRAWING
9500 DATAFINISHED NETSAVE,NO COMMANDS DRAW WITH
9520 DATAFINISHED TAPESAVE,NO COMMANDS TO SAVE
9530 DATANET ERROR,NETSAVE MUST HAVE NAME
9550 DATANAME IN USE,MUST LOAD BY NAME
9565 DATANO PROGRAM BY THAT NAME,NETDELETE WHAT?
9575 DATAILLEGAL NAME,SUCCESSFUL DELETE
9585 DATANOTHING TO LIST,TOO MANY COMMANDS
9590 DATAEND
9600 REM--WAIT
9610 T=TI
9620 IFTI<T+TM*60THEN9620
9630 RETURN
9800 REM-FND MTCHING PARENS--
9820 RE=FA
9830 IFLEN(LI$)=0THENRETURN
9840 P2=0:C=0
9845 P1=1
9847 IFMID$(LI$,P1,1)=" "THENP1=P1+1:IFP1<=LEN(LI$)THEN9847
9848 IFMID$(LI$,P1,1)<>"("THEN9980
9850 FORI=P1+1TOLEN(LI$)
9855 T$=MID$(LI$,I,1)
9880 IFT$="("THENC=C+1:GOTO9970
9890 IFCANDT$=")"THENC=C-1:GOTO9970
9900 IFNOTCANDT$=")"THENP2=I:I=LEN(LI$)
9970 NEXT
9980 RE=(P1<>0)AND(P2<>0)AND(P2-P1>1)
9990 RETURN
10000 REM-HELP-
10010 PRINT"  HERE ARE THE WORDS THE TURTLES
10015 PRINT"      UNDERSTAND:
10018 PRINTTAB(5)" HELP
10020 PRINTTAB(5)" GO
10025 PRINTTAB(5)" TURN
10030 PRINTTAB(5)" PENUP
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```
10035 PRINTTAB(5)"■PENDN
10040 PRINTTAB(5)"■REPEAT■  (OR ■RPT■)
10045 PRINTTAB(5)"■CLEAR
10050 PRINTTAB(5)"■MULTIPLYBY■  (OR ■MULT■)
10055 PRINTTAB(5)"■COLLAPSE
10057 PRINTTAB(5)"■TO
10058 PRINTTAB(5)"■END
10060 PRINTTAB(5)"■QUIT
10065 PRINTTAB(5)"■LIST
10070 PRINTTAB(5)"■DRAW
10075 PRINTTAB(5)"■EDIT
10080 PRINTTAB(5)"■TAPESAVE
10085 PRINTTAB(5)"■TAPELOAD
10090 PRINTTAB(5)"■NETSAVE
10095 PRINTTAB(5)"■NETNAMES
10100 PRINTTAB(5)"■NETLOAD
10105 PRINTTAB(5)"■NETDELETE
10190 RETURN
10400 REM-ERRORS-
10410 P$=ER$(ER)
10415 IFER=3THENP$=P$+" "+TK$:GOTO10420
10420 GOSUB17200
10430 TM=1:GOSUB9600
10445 SN=0:SP=0
10450 RETURN
11000 REM-QUIT--
11010 P$="GOODBYE FROM ALL TURTLES!"
11020 GOSUB17200
11035 POKE40,1:POKE41,4
11040 END
12800 REM--KEYS---
12805 DATAGO,/,TURN,/,MULTIPLYBY,MULT,/,PENUP,/,PENDN,/,COLLAPSE,/
12810 DATAREPEAT,RPT,/
12815 DATA ENDPS
12820 DATA CLEAR,/,HELP,H,/,LIST,/,D,DRAW,/,TO,/,END,/,TAPESAVE,/,TAPELOAD,/
12825 DATA NETNAMES,/,NETSAVE,/,NETLOAD,/,NETDELETE,/,QUIT,/,EDIT
12840 DATA ENDALL
12900 REM-INIT KEYS--
12910 I=1:DIMER$(22)
12920 READ A$:IF A$<>"END"THENER$(I)=A$:I=I+1:GOTO12920
12930 MK=30:DIMKEYS$(MK),KP%(MK)
12940 NK=0:KP=1
12950 READK$
12960 IFK$="/"THENKP=KP+1:GOTO12950
12970 IFK$="ENDPS"THENKP=KP+1:NP=KP:GOTO12950
12980 IFK$="ENDALL"THENRETURN
12990 KE$(NK)=K$:KP%(NK)=KP:NK=NK+1:GOTO12950
13000 REM-DEF RTNE-
13010 GOSUB500:IFNOTREORVAL(TK$)>0THENER=1:RETURN
13015 GOSUB14200:IFRETHENNR=R:CC=0:RETURN
13020 RR=RR+1:IFRR>MRTHENRR=1
13025 FORI=0TOCC%(RR):CM$(I,RR)="":NEXTI
13030 NR=RR:CC%(NR)=0:CC=0
13040 R$(NR)=TK$:RETURN
13200 REM-END RTNE DEF-
13210 CC%(NR)=CC:CC=CC%(0):NR=0:RETURN
14000 REM EXEC ROUTINE---
14010 GOSUB2600:SK$=LI$:GOSUB1600
14020 SK=P:GOSUB1800:SK=0:GOSUB1800:SK=R:GOSUB1800
14030 GOSUB1900:R=SK:GOSUB1900:IN=SK
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```
14040 IFIN>=CC%(R)THEN14150
14050 SK=IN+1:GOSUB1800:SK=R:GOSUB1800
14060 LI$=CM$(IN,R)
14065 GOSUB500:IFNOTRETHEN14130
14070 GOSUB900:IFNOTRETHEN14130
14080 GOSUB3000:IFER=FATHEN14065
14120 IFER=8THENRETURN
14130 GOTO14030
14150 GOSUB1900:P=SK-1:IFP>0THEN14020
14160 GOSUB1700:LI$=SK$:RETURN
14200 REM---LKUP ROUTINE--
14205 RE=FA:FORI=0TORR:IFTK$=R$(I)THENRE=TR:R=I:I=RR:PS=NP-1
14210 NEXT:RETURN
14400 REM--EDIT---
14410 GOSUB500:IFNOTRETHENNR=0:CC=0:RETURN
14420 IFVAL(TK$)<1THEN14430
14422 CC=VAL(TK$)-1:IFCC>CC%(NR)THENCC=CC%(NR)
14424 RETURN
14430 GOSUB14200:IFNOTRETHENER=1:RETURN
14440 NP=P:GOSUB500:IFNOTRETHENCC=0:RETURN
14450 IFVAL(TK$)<1THENER=1:RETURN
14452 CC=VAL(TK$)-1:IFCC>CC%(NR)THENCC=CC%(NR)
14590 RETURN
16000 REM--MAIN PROG--
16010 GOSUB16200
16025 GOSUB4400
16030 GOSUB17000
16032 IFRE$=ES$ANDCC=CC%(NR)THEN16030
16033 IFRE$=ES$THENCC=CC+1:GOTO16030
16035 PL$=LI$:CM$(CC,NR)=""
16037 GOSUB500:IFNOTRETHEN16030
16040 GOSUB900
16045 IFNOTRETHENCM$(CC,NR)=PL$:ER=3:GOSUB10400:GOTO16030
16050 PF=FA:IFPS<NPTHENCM$(CC,NR)=PL$:CC=CC+1:PF=TR
16055 IFCC>MCANDPFTHENGOSUB8600:GOTO16030
16060 IFCC%(NR)<CCTHENCC%(NR)=CC
16070 GOSUB2800
16100 GOTO16030
16200 REM--INIT--
16204 X1%=0:Y1%=0:X2%=0:Y2%=0:Z=0:O=1:I=0:J=0:OX=0:OY=0:NX=0:NY=0:TT=32
16205 C1%=0:C2%=0:ER=0:SK=0:SN=0:SK$=""
16207 POKE59468,12
16208 DEFFNC(X)=-(X%<LF)-2*(X%>RT)-4*(Y%<BTM)-8*(Y%>TP)
16215 LF=0:RT=79:BT=0:TP=47
16225 BL$="                                        "
16226 ES$="-":RT$=CHR$(13)
16227 PRINT"□":P$="    WELCOME TO TURTLEWORKS":GOSUB17200
16250 MG=5
16260 CX=(RT-LFT)/2:CY=(TP-BTM)/2
16280 DIMT(MG,2,1),U(2,1),X(MG),Y(MG),A(MG),M%(MG)
16315 TR=-1:FA=0:SS=0
16320 GOSUB4200
16332 T(0,0,0)=1:T(0,1,1)=1
16335 MS=20
16340 DIM SK$(MS),SK(MS)
16360 DEFFNR(A)=2*π*A/360
16370 DR=1586
16380 MC=30:MR=10:DIMCM$(MC,MR),R$(MR):NR=0:R$(NR)="D"
16382 NF=FA
16384 BS=1048:SS=BS+15:RB=BS+17:XB=BS+18:I1=BS+0:TX=BS+9:RX=BS+6:RF=1:SD=BS+3
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```
16387 GOSUB12900
16390 RETURN
17000 REM-GET B$--
17010 P$=R$(NR)+STR$(CC+1)+":":LL=39-LEN(P$)
17020 P$=P$+CM$(CC,NR):B$=CM$(CC,NR):GOSUB17200:GOSUB8400
17030 IFERTHENCM$(CC,NR)="":ER=0
17040 LI$=B$
17050 RETURN
17200 REM-PNT P$-
17210 PRINT"SR"BL$"S"P$;
17220 RETURN
READY.
```