HOW TO PLAY Dr. NIM*

HOW TO SET UP DR. NIM FOR EACH NEW GAME

1. PUT THE 15 MARBLES IN THE TOP ROW OF THE MACHINE.
2. SET THE FLIP-FLOPS SO THEY LOOK LIKE THIS.
3. FLIP THE EQUALIZER TO THE *START* POSITION, LIKE THIS.

HOW TO PLAY AGAINST DR. NIM

1. If you want to go first, flip the *TURN SWITCH* to player.
2. You may take 1 or 2 or 3 marbles on each turn.
3. The one who takes the *LAST* marble *LOSES.*
4. Next, *PUSH* the *TRIGGER* once for each of the 1 or 2 or 3 marbles you may want to take.
5. After your turn, flip the *TURN SWITCH* to *DR. NIM* . . . Then push the *TRIGGER* only *ONCE* and Dr. Nim will take his turn.
6. When he is finished, Dr. Nim will flip the *TURN SWITCH* back to *PLAYER* for your turn.
7. Repeat steps 4 and 5 until only *ONE MARBLE IS LEFT.*

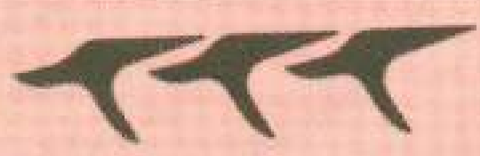
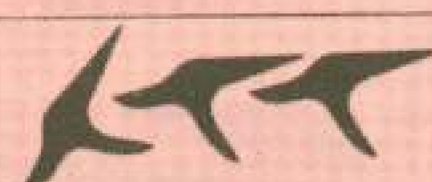
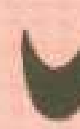
WHOEVER HAS TO TAKE THAT LAST MARBLE LOSES!

IF YOU SHOULD WANT TO LET DR. NIM GO FIRST, FLIP THE *TURN SWITCH* TO *DR. NIM* AND PLAY AS ABOVE.

If you play correctly, you can beat THE AMAZING DR. NIM, but remember, DR. NIM hates to lose . . . so don't make any mistakes.

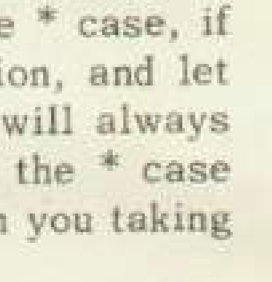
VARIATIONS ON THE GAME

You may play DR. NIM with any number of marbles. Only you must use different setups for the Flip-Flops. Here are the Starting Positions for some of the different numbers of marbles you may play with.

Number of Starting Marbles for "Last Marble Loses" Games	Starting FLIP-FLOP Positions	Starting EQUALIZER Positions
20 or 16 or 12		 START
19 or 15 or 11		 START
18 or 14 or 10		 START
*17 or 13 or 9		 START
18 or 14 or 10		OFF 

You should be able to beat DR. NIM for all these cases, whether you take the first turn or have DR. NIM take the first turn. From this table you can figure out the starting settings for more than 20 marbles. If you don't put the equalizer in the correct starting position, and let DR. NIM go FIRST, no matter how you play DR. NIM will always win, except in the case marked with an *. For the * case, if you don't put the equalizer in the correct starting position, and let DR. NIM go SECOND, no matter how you play DR. NIM will always win. Perhaps the hardest game for you to win would be the * case with the equalizer in the correct starting position and with you taking the first turn.

NOTE: To play with more than 15 marbles, simply add the necessary number of marbles back up to the top row from those already played at the bottom. For example, to play with 20 marbles, put the 15 marbles in the top row, then after 5 have been played, put them back up in the top row for a total of 20.

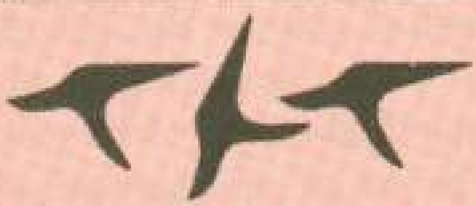
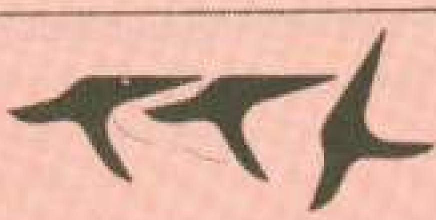


NOW FOR A WHOLE NEW SET OF GAMES

We will now change the rule so that the one who *TAKES THE LAST MARBLE WINS!*

To do this a different starting arrangement for the Flip-Flops is used. Everything else is the same as for the above games.

Here are the starting conditions.

Number of Starting Marbles for "Last Marble Wins" Games	Starting FLIP-FLOP Positions	Starting EQUALIZER Positions
*20 or 16 or 12		 START
19 or 15 or 11		 START
18 or 14 or 10		 START
17 or 13 or 9		 START
17 or 13 or 9		OFF 

You should be able to beat DR. NIM for all of these cases. As before, if you forget to put the Equalizer in the correct starting position and DR. NIM goes first, then DR. NIM will always win!

From the above table you can figure out starting settings for more than 20 marbles.

STILL MORE GAMES TO PLAY WITH YOUR DR. NIM

1. You may use DR. NIM to *play against another person.* To do this, simply follow all the above rules, but leave the *TURN SWITCH* on *PLAYER* at all times.
2. Another game is to watch *DR. NIM play against himself.* To do this, flip the *TURN SWITCH* back to *DR. NIM* after each play. Call the first turn player DR. NIM Number 1 and the second turn player DR. NIM Number 2. Try this with the *EQUALIZER* in the *START* position. Then try the same game with the *EQUALIZER* in the *OFF* position. See who wins, DR. NIM Number 1, or DR. NIM Number 2, in each of these cases. Can you guess why this happens?

ABOUT THE GAME OF NIM

The basic game of NIM, of which DR. NIM plays a variation, is thought to have been played in the Far East, perhaps China, thousands of years ago. It is interesting to realize that this simple, but intriguing game has withstood the trials of time and has undoubtedly been played by millions of people over the centuries. E.S.R., Inc. hopes that you find it interesting and delightful to play DR. NIM and that you will have at least an insight into the workings of computers.

DR. NIM AND COMPUTERS

By now you have played against DR. NIM enough to respect and appreciate his ability. Does he really think? You certainly had to do a lot of thinking to beat him. Did he have to? You will probably say that DR. NIM does not "think" despite the fact that he plays a clever game of NIM. If this is your answer, you would also be convinced by more study that a large electronic computer does not "think" either. The large computer is more like DR. NIM in its capability than like a human. By the way, you *"PROGRAMMED"* DR. NIM each time that you positioned or set his elements at the beginning of each game.

So, let us leave this subject of "Can Machines Think" for the moment, and consider DR. NIM first from the computer machine point of view and then the computer programming point of view. Then we will come back to this question of thinking machines.

DR. NIM AS A COMPUTER MACHINE

DR. NIM is a "binary digital computer" specially designed to play the game of NIM. For a machine of such a simple design, containing only 6 moving logic elements, it might be argued that the word "computer" is an exaggeration, but consider some of its capabilities:

1. DR. NIM can repetitively count up to 4. (This is performed by the top 3 logic elements.)
2. DR. NIM can make logical decisions dependent upon the states of his logic elements. (He can decide whether to take another marble on his turn, whether to change the *TURN* to *PLAYER*, etc., dependent upon how the other player has played.)
3. DR. NIM can alter the states of his logic elements as the game progresses to represent the state of the game.
4. DR. NIM can "remember" the state of the game between his own and his opponent's play.
5. DR. NIM can gate impulses in the form of marbles to continue its play as required to play a winning game.

Counting, logical functions, altering internal states, memory, and gating impulses are all typical characteristics of a computer. They are combined in such a manner that the machine appears to play an "intelligent" game of NIM. By "intelligent" it is meant that it would be entirely reasonable for a person trying to win the game of NIM to play in an identical manner.

The word "digital" refers to the fact that the positions of the logic elements are always one of two possible positions which may be designated by the digits "0" and "1". Let us say, for example, that each of the 5 elements, other than the trigger button or the gating mechanism, is in the "0" position if it is to the right and in the "1" position if it is to the left. Also, let us say that the gating element is "0" if it is up and "1" if it is down. Now, any logical state of the machine may be described by giving the positions of its 6 elements as being "0" or "1".

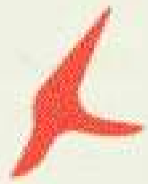
A number system having only the digits "0" and "1" is called a binary system. Any logic element that can take on exactly 2 different states denoted by the binary digits "0" and "1" is called a binary logic element or flip-flop. As DR. NIM uses only binary logic elements, he may be properly called a binary digital computer.

Let us review DR. NIM's structure. He is made up of three Flip-Flops, the turn setting element, a Clock Pulser (the Trigger) and several different paths for the marbles to take. The marbles are analogous to the impulses that are carried through an electronic computer. The elements are like the memory of the computer. They are asked questions by the impulses and they are changed, dependent upon the answers.

Consider how these elements should be connected. Each Flip-Flop is a two-state device. It is either open to permit a marble to go through or it is closed and does not permit a marble to pass through, but makes it go to the next Flip-Flop. As we said above, DR. NIM is a binary digital computer, its logic elements having only two states.

Suppose we name the three Flip-Flops A, B, and C, with the left one A, the center one B and the right one C. Then, also, we could call the "turn" switch D and the "equalizer" E.

If one of the Flip-Flops is open like this,



for instance, the A Flip-Flop, then we will put a bar over the A, writing it $\bar{A}$. Also, suppose we put a bar over the D when the "turn" switch is set to "DR. NIM", ($\bar{D}$), and over the E when the "equalizer" is set to "start" ($\bar{E}$).

Now we can re-write the starting positions table on Page 4 using these symbols instead of the pictures.

Number of Starting Marbles for "Last Marble Loses" Game	Starting FLIP-FLOP Positions	Starting EQUALIZER Positions
20 or 16 or 12	A $\bar{B}$ C	E
19 or 15 or 11	A B $\bar{C}$	$\bar{E}$
18 or 14 or 10	A B C	E
17 or 13 or 9	$\bar{A}$ B C	$\bar{E}$
18 or 14 or 10	$\bar{A}$ B $\bar{C}$	E

Now that we have this shorthand at our disposal, let us play a Game of NIM on paper. Suppose we play the game of "Last Marble Loses", with 15 marbles and DR. NIM goes first.

No. of Marbles Left	Flip-Flop Setting	Turn Switch Setting	Equalizer Setting
15	A B $\bar{C}$	$\bar{D}$	$\bar{E}$

DR. NIM will take one and stop. (Note that D and E change states.) Then it's the player's turn and the settings are:

14	A B C	D	E

Suppose he takes 2.

13	$\bar{A}$ B C	D	E
12	A $\bar{B}$ C	$\bar{D}$	E

Now it's DR. NIM'S turn again and he will take 3.

11	A B $\bar{C}$	$\bar{D}$	E
10	A B C	$\bar{D}$	E
9	$\bar{A}$ B C	D	E

The player takes 2.

8	A $\bar{B}$ C	D	E
7	A B $\bar{C}$	$\bar{D}$	E

This time DR. NIM will take 2.

6	A B C	$\bar{D}$	E
5	$\bar{A}$ B C	D	E

The Player takes 3.

4	A $\bar{B}$ C	D	E
3	A B $\bar{C}$	D	E
2	A B C	$\bar{D}$	E

And DR. NIM will take 1.

1	$\bar{A}$ B C	D	E

The Player takes 1 and loses.

0	A $\bar{B}$ C	D	E

LET'S WRITE THIS GAME IN THE FORM OF EQUATIONS.

$$
\begin{aligned}
15 &= A\ B\ \overline{C}\ \overline{D}\ \overline{E} \\
14 &= A\ B\ C\ D\ E \\
13 &= \overline{A}\ B\ C\ D\ E \\
12 &= A\ \overline{B}\ C\ \overline{D}\ E \\
11 &= A\ B\ \overline{C}\ \overline{D}\ E \\
10 &= A\ B\ C\ \overline{D}\ E \\
9 &= \overline{A}\ B\ C\ D\ E \\
8 &= A\ \overline{B}\ C\ D\ E \\
7 &= A\ B\ \overline{C}\ \overline{D}\ E \\
6 &= A\ B\ C\ \overline{D}\ E \\
5 &= \overline{A}\ B\ C\ D\ E \\
4 &= A\ \overline{B}\ C\ D\ E \\
3 &= A\ B\ \overline{C}\ D\ E \\
2 &= A\ B\ C\ \overline{D}\ E \\
1 &= \overline{A}\ B\ C\ D\ E
\end{aligned}
$$

The first thing we should notice is that the A, B & C Flip-Flops form a counter. Every fourth equation has the same setup for A, B & C. (For instance, whether there are 1, 5, 9, or 13 marbles left, the terms are $\overline{A}$ B C.)

The next thing we should notice is when DR. NIM decides he has had enough; that is when he changes the "turn" switch from "DR. NIM" to "Player". In our equations it would be when $\overline{D}$ is changed to D. When there are 15, 10, 6 or 2 marbles left, he will take one more and stop.

Except for the first time, when there were 15 marbles, DR. NIM stopped when there was one more than a multiple of 4 marbles (when there were 1, 5 or 9).

This could all be expressed in a language called Boolean Algebra. It is the basis for all digital computer operation; whether it be an elementary one like DR. NIM or a giant electronic brain.

To illustrate the basic ideas involved in using Boolean Algebra, suppose we look back at the equations on Page 9. DR. NIM should end his turn when there is one marble left.

DR. NIM stopped when there were 1, or 5, or 9 or 14. That is, when the Flip-Flops were in the states described by the following equation:

$$\text{STOP} = \overline{A} \text{ and } B \text{ and } C \text{ and } D \text{ and } E \qquad (1)$$

Or

$\bar{A}$ and B and C and D and E (5)

Or

$\bar{A}$ and B and C and D and E (9)

Or

A and B and C and D and E (14)

In the shorthand of Boolean Algebra, the word "OR" is replaced by the addition sign (+) and the word "AND" is replaced by the multiplication sign (·). Using this shorthand, then, the equations above may be rewritten as follows:

$$\begin{aligned} STOP = & \left[\bar{A} \cdot B \cdot C \cdot D \cdot E\right] + \left[\bar{A} \cdot B \cdot C \cdot D \cdot E\right] \\ & + \left[\bar{A} \cdot B \cdot C \cdot D \cdot E\right] + \left[A \cdot B \cdot C \cdot D \cdot E\right] \end{aligned}$$

The second and third terms (groups) can be neglected since they are the same as the first term. Thus;

$$STOP = \left[\bar{A} \cdot B \cdot C \cdot D \cdot E\right] + \left[A \cdot B \cdot C \cdot D \cdot E\right]$$

This brings out an interesting question. Why did DR. NIM stop on 14 ($A \cdot B \cdot C \cdot D \cdot E$) when in every other case, he kept going until he got to the $\bar{A} \cdot B \cdot C \cdot D \cdot E$ state, (which would be 13)? The answer is that DR. NIM, being a true gentleman, purposely makes a mistake on his first move to give the player a chance. That is what the "Equalizer" is for. If you forget to set it to "Start" and "DR. NIM" goes first, you can't win, except in the * case. In the * case if DR. NIM goes second and you forget to set it to "START", DR. NIM will always win.

Try writing more equations which describe DR. NIM's decision making process. For instance, you could, by following the same procedure, discover when DR. NIM will take another marble. By doing this you can see how the various Flip-Flops are connected by OR gates. (There are several different paths a marble could take and still accomplish the same end result.)

The key to beating DR. NIM is to do what he would do, before he gets a chance. If you study the equations and the machine carefully, you should learn how to beat THE AMAZING DR. NIM at his own game.

But DR. NIM could be designed by following the above discussion and working out the mathematical relationships as they have been here. In other words, you have been shown how a simple computer could be designed to satisfy a certain set of logical requirements. This is all that is done for a giant computer, except that there are many, many more equations and hence elements. But the basic principle is the same. A rather complete discussion of computer logic, including AND and OR gates, binary arithmetic and boolean algebra is given in the Advanced Manual for E.S.R.'s DIGI-COMP I.

DR. NIM AND COMPUTER PROGRAMMING

We have referred to DR. NIM as a binary digital computer and have said that he was specially designed to play the game of NIM. NIM playing is indeed his specialty and he can do this to near perfection, but, alas . . . his special talent is also his only talent. It is for this reason that he must be called a "special purpose" rather than a "general purpose" computer. His NIM playing ability is "built into the circuitry" so to speak. It is possible to have machines in which this is not true. It was necessary for you to set DR. NIM's logic elements to the correct initial position before playing the game. Otherwise, DR. NIM would play all wrong. We referred to this initial setting of his elements as "programming" DR. NIM and this is true but only in a limited sense compared to a "general purpose" computer.

Large general purpose digital computers can perform an enormously varied set of functions. Not only can they play games much more complicated than NIM, such as checkers and chess, but they can also do complicated mathematical calculations, control complicated machines and factories, keep all kinds of accounting records for industry, translate languages, forecast coming events based on experience, schedule the use of valuable resources to minimize waste, simulate complicated and costly operating procedures, and perform a host of other difficult and useful functions far too numerous to mention.

How can a general purpose computer perform such a staggering variety of tasks? The secret of its generality lies in the fact that a different set of instructions, called a program, can be stored (magnetically) in the computer's memory for every different function it is required to perform. All the "intelligence" required for the task is built into this program of instructions, *not* into the machine. The computer is built to know only how to follow a set of instructions one by one. The program is written to know how to perform the desired task.

It is for this reason that many programmers (people who write the programs) refer to the general purpose computer as a "giant idiot" not a "giant brain." The machine in its own simplemindedness will dutifully follow any sequence of instructions, however stupid or however in error. If the computer behaves cleverly we must admire the program, not the machine. If it makes errors or appears stupid, again it is the program (and therefore the Programmer) not the machine that is at fault. (In DR. NIM's case, if we wrote the wrong program and did not set his flip-flops correct initially, it would be our fault, not his, that he did not play a perfect game.)

Isn't it remarkable that the general purpose digital computer has allowed man to vastly extend his mental abilities in thousands of different directions by virtue of its very ignorance? Isn't it also amazing that the complicated logical capability that the machine exhibits is a function only of the set of instructions stored in its memory? The machine is clever only in its ability to follow instructions. The program of instructions is clever in its ability to do the required task.

We may illustrate this point further by demonstrating a program of instructions that has been written to play the game of NIM in the manner that DR. NIM plays the game. The program has been written so that a person can easily obey the commands instead of having a machine follow them. It is convenient to write them mostly in English for a person. The same set of instructions could easily be coded for a computer with no change of logic, but they would be coded as numbers that the machine could follow rather than English statements.

The program has been written such that 4 numbers need be changed repeatedly and be remembered as the game progresses. We will call these numbers:

M = the number of marbles still left in the game (15 to start).

R = a remainder number needed by the program.

P = the number of marbles the PLAYER chooses on a given TURN.

N = the number of marbles the Program chooses on a given TURN.

M	R	P	N

In order to remember these numbers as the game progresses get a blank sheet of paper and write the given letters at the top of 4 different columns as above.

During the course of the game several different numbers will be written in each column. Only the last number written in a column is taken to be the current value of the letter at the top of the column.

In following the program you must begin at Instruction 1 and follow the instructions consecutively downward until you are instructed to do otherwise. If you are instructed to jump to a different instruction out of sequence, do so and again follow the instructions consecutively downward from that point, etc.

Some of the instructions will tell you to change a number in a column, as for example, Instruction 7 says to, "Subtract 'P' from 'M' and write back in 'M'." This means to subtract the last number in column "P" from the last number in column "M" and write the result in column "M" under the last number.

Other instructions will ask a question and based on the answer will either tell you to jump to another instruction or to go on to the next instruction. For example, instruction 3 says, "If you wish to take the first turn go to instruction 6." If you do not want to take the first turn it is implied that you go to the next instruction, instruction 4.

It is very easy to make an error following the instructions, either by forgetting to write something down or by going to the wrong instruction. You will also be impressed with how tedious the procedure is and what a great number of instructions must be followed to play this game. Of course, the computer can follow a lengthy tedious set of instructions very rapidly and never make a mistake. This is one of the great advantages of the machine.

PROGRAM TO PLAY DR. NIM AGAINST A PERSON

(Whoever takes last marble, loses.)

Instruction Number	Instruction
1	Let's start a new game with 15 marbles.
2	Write a 15 in Column "M" and a 2 in Column "R".
3	If you wish to take first turn, go to Instruction 6.
4	I will take 1 marble, write a "1" in Column N, subtract "1" from "M" and write back in Column "M". Also subtract "1" from "R" and write back in Column "R".
5	If "M" is now zero go to Instruction 15. Otherwise continue.
6	How many marbles do you wish to take? Write answer in Column "P".
7	Subtract "P" from "M" and write back in "M".
8	If "M" is now zero go to 16. Otherwise continue.
9	If "P" is less than or equal to R go to 11.
10	Add 4 to "R" and write back in "R".
11	Subtract "P" from "R" and write back in "R".
12	If "R" is not equal to zero go to 14. Otherwise continue.
13	Write a "4" in "R". Go to 4.
14	I will take "R" marbles. Write "R" in "N". Write "4" in "R". Subtract N from M. Go to 6.
15	You win! Go to 1.
16	You lose! Go to 1.

In comparing DR. NIM with the computer program we would say that DR. NIM'S logic is built into the circuitry of the machine. As a result DR. NIM's circuitry is simple by comparison to the general purpose computer with NIM-playing program, but DR. NIM has sacrificed generality for this simplicity.

It should now be clear that very lengthy and involved programs can be written, even to play such complicated games as checkers and chess. In the game of NIM it is possible to follow a simple mathematical rule to play correctly throughout. In checkers or chess no such simple rule exists.

One might consider it possible, given the exceptionally high speed of computers, to explore every possible move and countermove for many moves ahead, perhaps even to the conclusion of the game, as a method of having the machine select and play an intelligent game. It turns out that the number of alternatives grow so rapidly even with 2 or 3 moves, however, that impossible delays would be imposed in looking only a few moves ahead in this manner.

As a result checker and chess playing programs attempt to reduce the number of reasonable alternatives by following the kinds of strategies that would seem promising and look for alternatives among these. With these restrictions the program can look a few moves ahead without imposing undue delays. The programs play only a "good" game, not a perfect game.

The checker playing program written by Dr. Samuels has the added wrinkle of learning to play a better game with experience. Experience is used to change the weights of the many conflicting strategies that the program can adopt based on its record of achievements.

CAN MACHINES REALLY THINK?

This question is indeed thought provoking. It raises all kinds of additional questions such as –

1. What is thought?
2. Is thought composed of many factors, at least a few of which machines share?
3. Can the higher animals, such as chimpanzees and gorillas, think?

4. If so where does one draw the line? Can frogs think? Can one-celled animals think?

5. Can newborn babies think? If not, when and how does thought first begin in children? Does it begin gradually or all of a sudden?

6. Is language necessary to thought? Are deaf mutes, who never learn a language, capable of thought?

7. What are the mental capabilities that humans have that machines cannot duplicate?

8. Is the brain really a mechanism which could be imitated electronically if we fully understood how it works?

9. What kinds of tests could we propose that if a machine were capable of passing we would agree that the machine were capable of thought?

10. Can machines approximate the mental capabilities of lower animals?

DR. NIM

DR. NIM has shown us how an extremely simple machine can perform with seeming intelligence in the restricted area of playing the game of NIM. We cannot help but wonder how such an elementary machine can do so well at outwitting us in this simple game, yet we are convinced that DR. NIM cannot think.

If DR. NIM were a human opponent we could well imagine him saying to himself, "Now let me see . . . on my first turn I will take so many and after that if the other player takes such and such I will take so and so, but if he takes some other amount I will take such and such else . . . ," etc. We would, no doubt, say that he was reasoning. Yet we are certain that DR. NIM does not reason. What is the difference? Without trying to answer this question let us consider the capabilities of machines which are used by man primarily to supplement and extend his own intellect.

Virtually all important inventions and engineering advancements in the first half of this century and before were directed toward extending man's physical capabilities or catering directly to his physical needs. Very suddenly, in the first decade of the second half of this century, a technical revolution began which is still rapidly unfolding.

Man became widely and seriously interested in designing and using machines to extend his mental as well as his physical capabilities. His interest centered on the development of the general purpose electronic digital computer and extended outwards to all kinds of other automata such as the analogue computer, electro-mechanical control systems, electronic analogies to neurological networks, etc. We now still stand on the brink of this revolution. Since 1950 machines have been built and programmed which can, for example,

1. Make many of the decisions necessary to running a business;
2. Play complicated games better than most people but not as well as some;
3. Prove complicated theorems in mathematics better than most people but not as well as some.
4. Compose interesting music and poetry;
5. Perform complicated logical and mathematical functions at hundreds of times the speeds that man can perform them;
6. Sense and control factory processes such as steel making;

and perform thousands of other tasks far too numerous to mention.

Machines have been built which can recall information from memory associatively in a manner similar to the way man's memory seems to work. Others have been built which can be taught rather than programmed, to perform a simple task such as recognizing each of several geometrical shapes placed at varying orientations in and distances from its "visual field." In machines of this nature, a conscious attempt has been made in the design to imitate the functions of biological nerve cells called neurons. Machines have been built which can recognize printed words and a limited number of spoken words such as the numbers zero through nine.

In the near future machines will no doubt carry on reasonable conversations with us in selected topics; indeed they can do this within limits already. They will read our printing or writing, understand a wider vocabulary of our spoken words, speak back to us appropriately, not by selecting a recorded sentence, but by forming appropriate sentences logically from recorded words. We will be able to teach them more complicated patterns of behavior by example and by trial and error rather than by feeding them long detailed lists of instructions. We will increasingly ask them "What if . . .?" type questions and play games with them which will teach us how to react to environments as yet not experienced.

Still with all this added capability and more, we will be inclined to say that they do not think. We will admit that they recognize, recall, associate, abstract, generalize, deduce, analyze, calculate, learn, synthesize, decide, infer, solve, create, etc., to varying degrees without admitting that they think. They will seem very clever and even intelligent to us in certain areas. They will also seem quite stupid to us in others. They will be able to perform feats that humans could not hope to do in a lifetime in some areas, yet they will be incapable of duplicating some of our most commonplace mental accomplishments in others.

It is interesting to consider some of the things that machines cannot do either at all or very well, in comparison with humans. A machine cannot, for example, be given a photograph and asked what it "sees" in the picture. On the other hand, a child can easily look at the picture and tell us that there is perhaps a street, several people whom he could name, so many trees, a house with a mail box in front of it, so many windows and doors in the house, etc. Yet, of course, the child could not play chess, prove the theorems, translate from Russian to English, or solve differential equations. The machine again cannot begin to understand the spoken vocabulary the child understands. A machine, even if it could be greatly reduced in size, could not control a human like mechanism with arms, hands, legs, head, mouth, eyes, etc., to balance on its legs and walk or run over uneven territory avoiding obstacles in its path.

In view of the fact that some things, such as chess playing, theorem proving and mathematical calculation have been considered the very hallmarks of human intelligence in the past, it is very odd that a machine can perform these functions better than most people. Also, it is odd that there are moronic tasks, such as recognizing people or animals, friends or strangers, etc., that even a dog can do but the machine cannot do independent of their distance and orientation in a visual field. It is as if some of our most intelligent behavior of which we are most proud requires comparatively little in the way of logical circuitry but some of our easiest and simplest behavior is exceedingly complex logically.

It should not be inferred, however, that machines can easily do any mental tasks that we find difficult and vice-versa. Machines cannot pose different and important new problems for solution. They cannot push forward scientific discoveries without man's direction. The chess playing program, for instance, could not have been suggested and programmed by another program unless possibly that program in turn were conceived and written by a man. Even the cleverest of programs seems hopelessly singleminded compared to the multi-facets of man's intellect. Man could and would be thinking about all kinds of other things besides chess as he played.

Man has a stream of consciousness, an identity, he thinks about himself, he philosophizes one minute and proceeds to solve a problem the next. He has a huge recognition memory that functions effortlessly. Having met a person only once, for example, and seen him from only one angle, he recognizes him again in a different position. Of course, he has difficulty recalling his name, but his memory seems to be designed primarily for recognition, not recall. If he goes into a movie in the middle, he recognizes immediately the point at which he came in because he recognizes that he has seen and heard this part of the film before. Yet he cannot recall what the actors are going to say next. When they say the next sentences, he recognizes immediately that he has seen and heard before, however.

Man's brain is apparently organized in a completely different way from that of a general purpose digital computer, and yet there is some similarity. The reaction time of an electronic computer is measured in millionths of a second. The reaction time of man's nerve cells is measured in tenths of seconds. The computer executes instructions one at a time consecutively. Man's brain works in parallel with many thousands of neurons "firing" and passing on impulses all at the same time. Man's parallel circuitry, if it can be called that, permits him to see, for example, a very fine grained visual field all simultaneously without repeatedly scanning it sequentially in lines as a computer would have to do.

Yet man, somewhat like a computer in the execution of a program, has only one stream of conscious thought. He cannot simultaneously focus his thought on two conscious processes at the same time. Nevertheless, he can perform certain mental tasks simultaneously. He can walk and avoid obstacles directing his feet over complicated terrain while he thinks about something else and perhaps even whistles or hums a tune in the "back of his mind" at the same time.

Chances are his walking and whistling are completely unconscious, but his thoughts may be interrupted or changed by what he sees or hears.

Man is able to integrate his thoughts from widely different areas as he attempts to analyze a situation or solve a problem. He is able to think by the aid of analogies and associations drawn from vastly different fields.

The complex workings of his mind can be duplicated in part and in some area by machines but virtually not at all in many other areas. On the other hand, the machine can do whatever it does much better than man in certain areas.

What conclusions can we draw? First, it must be recognized that our conclusions are only speculative in nature. Without being able to define thought with any degree of precision how can we hope to answer whether machines think? Our conclusions must be considered as only opinion, not fact. Your opinion on this matter is every bit as good as ours. You may consider that our opinion merely helps to define what we mean by "thought" and sheds very little factual light on a matter that must still be regarded as philosophical. That is, no doubt, largely true. Still, you might be interested in our opinion.

IN OUR OPINION . . .

1. The gulf between what machines are capable of doing electronically and what humans are capable of doing with their brains is far too great to consider that machines "think."
2. The differences between humans and higher animals, such as apes, are much less in the matter of thought than between humans and machines.
3. A language is a great asset but not necessary to thought.
4. The mental activity of certain animals is sufficiently similar to man's to say they "think", although at a lower level and without man's language.
5. The mental activities of the lowest forms of animals can be largely duplicated by machines.
6. Biological intelligence is primarily oriented towards "pattern recognition", that is, recognizing extremely subtle similarities in the way things look, sound or feel and associating them with concepts such as friends, enemies, food, warmth, and danger, despite gross surface dissimilarities. Spoken words, for example, are easily recognized by man and some higher animals despite differences in inflection, pitch, timber, accent, timing, intensity, etc.
7. Biological intelligence is generally very poor in recall and logical deduction. These capabilities have become of consequence only to man. Even man cannot do certain mental tasks which would otherwise be simple because of his shockingly poor ability to

recall information. It is no trick for a machine to perfectly recall two 5-digit numbers which it has been given and all the intermediate results necessary to multiply them and get a 10-digit answer. But, man cannot multiply two 5-digit numbers in his head because he cannot keep them in mind! Long chains of "if then" type deductions leading to multiple cases to be examined easily defeat man's poor capability in this area. Machines can do this at least as good and probably much better.

8. Despite the fact that recall and logical deduction are "unnatural" to most biological organisms, including man to a considerable extent, it is in precisely this area that man has improved his brain over other animals. It is in conjunction with this new capability that languages have been developed. This improvement has bought, through a culture, enormous advantages for a relatively small advance in mental capability.

9. Much of man's supposedly higher forms of intellectual capability are not really complicated functions. They appear impressive only relative to animals. Machines, many orders of magnitude simpler than man's brain, can perform these functions with little difficulty. This accounts for why machines can play chess, prove theorems, etc.

10. Pattern recognition and association, such as recognizing people, places, situations, settings, facial expressions, gaits, etc., is an extremely complicated mental function which we do so easily and effortlessly that we are inclined to dismiss it as being simple. It is much too complicated for even our most sophisticated and highest speed computers to do as well as most animals, let alone man. During the millions of years of animal evolution this type of intelligence was the only type of importance. With the recent advent of man, and man's language, deductive logic and recall became important to survival for the first time. Its evolutionary development has been short but its results have been impressive.

11. Man uses his pattern recognition capability to great advantage in combination with his new but limited recall and deductive ability. One part of a problem reminds him of a similar situation in which he approached it in such and such a manner. Extremely subtle similarities, despite gross dissimilarities, allow him to associate possible courses of action wildly different but in some important respect, similar. He, thus, achieves imagination and creativity not available to a machine.

12. The simplicity of machines, like DR. NIM, expose man's limited deductive power. The complication of the design computers pay

tribute to his imagination and creativity which seems to be born of a mixture of pattern recognition, deduction and many other factors, both identified and unidentified.

13. The strides that man has made in the last 15 years in developing machines that extend and supplement his thinking are truly astounding. Who can say what enormous strides will take place in the next 15 to 30 years?

14. Man's written and spoken language permits him to communicate his thoughts, his manner of thinking, his conclusions, his conjectures, his knowledge, etc. to his fellow man both in existence and yet to come. We call this accrued social knowledge our culture. Our culture has assumed a seeming intelligence that transcends man's intelligence by several orders of magnitude. No single man designs or builds our cultural products. Our computers, space vehicles, communication systems, energy conversion and distribution systems, etc., are of necessity the product of many men's brains working in concert.

It is as if the culture "thinks" independent of any given man or small numbers of men. Scientists, engineers, administrators and planners of all types bear an analogy in our culture to the brain cells of man. As in the case of our brain, our cultural "thoughts" would suffer little from the absence or presence of any particular cells. But if we consider that our culture "thinks," its manner of thinking is grossly different than man's thinking. With the fast pace of technological development it is possible that this difference will ultimately be as great as the difference between the rudimentary reactions of brain cells and human thought. It may ultimately seem appropriate to say that mankind, in conjunction with its electronic machines, "thinks".