Computers Unwrapped: An elementary curriculum exploring how computers work

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Overview

The City Technology Project, based at the City College of NY School of Education, has developed a new and unique computer curriculum. All or nearly all of the current K-12 Computer Science curriculum efforts in the US are focused on programing, often called coding. While this is an important skill, it is equally important that we demystify the computer by showing what's inside one. The materials described below have been used for teacher education at City College School Education. Pre-requisites for these materials are described in detail in a companion document, Computers Unwrapped – Elementary, which is available from the author. These materials consist of units on Circuits, Information, Computation, Communication and Control. Each unit is summarized below. The material that follows consists of a detailed Lesson Plan for each unit, including templates and worksheets.

Circuits

This unit begins with the construction of simple circuits including an LED and coin battery. Students are challenged to make the LED light up, and then to make and include switches in their circuits. They then explore the operation of this simple circuit using a circulating penguin toy as a model for explaining concepts of source, load, conductor, insulator, voltage and current. Finally, they create "electric puppets" whose two eyes light up when a hidden switch is closed.

Codes

Computer programming is commonly called coding, but what are codes and how are they used in computers? This unit begins with symbols, which are the components of codes. Students identify common graphic symbols, such as those found on common signs. A code is just a system of symbols. Examples of codes are Braille, ASL, sets of fabric care symbols, map legends, music notation, football referees' signals, text message abbreviations and emojis. A key is a translation of a code into everyday language. Students create keys for their favorite emojis. Computers operate using binary code, which uses only two symbols, 0 and 1, in contrast with decimal which has ten symbols. In the decimal system, the columns have place values of 1, 10, 100, etc., increasing by a factor of 10 from right to left. In the binary system, the place values are 1, 2, 4, 8, etc., increasing by a factor of two from right to left. Decimal and binary are base 10 and base 2 number systems, respectively. Mostly we use base 10, but sometimes also other bases, such as base 2 for measuring length and fluid volume; base 5 for counting by tally marks; and bases 12, 24 and 60 for time measurement. Students learn the binary system and use Binary Cards to translate their birthdates from decimal into binary by selecting the columns they need. They then represent these binary numbers using LEDs of different colors to represent 0 and 1.

Information

Computers use codes to represent information. The basic unit of information is the bit, which stands for binary digit, and could be either a 0 or a 1. The Information unit begins with examples of one-bit messages, such as a knock on the door. To add information, you can knock softly or loudly, once or repeatedly. Computers handle information in digital form, which has discrete possibilities, but there are other devices that use analog information, which can vary continuously. Light switches are digital, while dimmers are analog. Students look at a variety of devices, and sort them according to whether they handle information in analog or digital form. To measure the amount of information in a number, students play a guessing game to determine a secret number between 1 and 100. How many yes/no questions do you need? The instructor then plays the game against the class and finds the secret number by asking seven questions or less. The original number is translated into binary and then converted back to decimal.. Other examples of information representation are seven- and fourteen-segment displays found on digital clocks and microwaves, and 35-bit 5 x 7 arrays found on street signs, store displays, trains and buses. Students learn how this works by playing a game using counters to create numbers and letters on a 5 x 7 grid.

Communication

Here we develop the solution to the problem of getting data from one place to another. This task involves a source, a receiver and a channel, each of which may introduce errors. Redundancy is used in both ordinary life and computers to detect and or correct errors in transmission. Students send one another messages with letters or words removed. Is it still legible? Computers use parity bits to add redundancy. Students explore parity by learning a “magic trick” which uses row and column parity bits to find a secret error introduced by the students.

Circuits

Materials

(per student)

- 2 CR 2032 Coin batteries
- Cardboard rectangle, approx.. 3” x 4”

(per group)

- Assortment of LEDs: red, yellow, green and blue (at least 3 of each color)
- Roll of double-sided foam tape
- Roll of masking tape
- Scissors
- Ballpoint pens for poking holes (these do not have to write!)
- Set of materials for testing as conductors or insulators: buttons, coins, fabric, paper, aluminum foil, plastic wrap, pipe cleaners, chalk, crayons, washers, etc.

(per class)

- Blackboard or chart paper and amrkers
- Ducklings climbing stairs toy (assembled, and with batteries installed) – available for $8 or less from http://temu.com
- Sample switches: push button, rotary and slide (see Table 4, p. 7)
- Box of 100 1 ½ “ paper fasteners
- Assortment of Craft materials for customizing: pom-poms, feathers, pipe cleaners, stickers, etc., plus glue sticks for attaching them.

(to be projected on a screen, at various times, as indicated in the Procedure below).

- Circuit Drawings (p. 8)
- Circuit Diagrams (p. 9)
- Task Card for Making an Electric Puppet (p. 10)

Recommended vendors

LEDs

- https://protosupplies.com; Search on LED -- select 10mm, red, green and/or yellow; pack of 5 each @ $0.69
- https://www.adafruit.com/product/847 blue, pack of 25 @ $10
- www.digikey.com Search on Product # 5032-333296-ND Pack of 13@ $2.77 includes: 3x red, 3x blue, 3x green, 3x yellow, 1 white

Coin batteries:

- https://batteriesandbutter.com Maxell CR2032 @$0.35 each or less

Brass paper fasteners:

- www.officesupply.com Product # ODFN613332 1.5 inch fastener, box of 60 @$2.39

Procedure

1. Batteries and LEDs: Distribute 2 LEDs and 1 coin battery perstudent.

   Individual Activity: Turn on the LED. Record the following information:

   a) What do you notice about the battery and the LED?

b) When you try to turn it on, what works and what doesn't work (use diagrams).

c) What happens when you try to light more than one LED from the same battery?

d) Which combinations will light up together, and which ones will not?

2. Models

Class discussion

a) If you were able to make the LED light up, you created an electric circuit. How does it work? Unfortunately, we can't see inside the circuit to answer that question. To understand something that is too small, too big too fast or too slow, we use models.

b) Conduct a scavenger hunt for models. Examples are dolls, toy cars and globes. For each model, list the real thing it represents, what is similar between the model and the real thing and what is different. For example, a globe shows the continents and oceans of the earth, but is much smaller and does not show most details.

3. Ducklings Climbing Stairs Toy

Class discussion

Place the toy in a location where everyone can see it, and turn it on. This toy provides a convenient model of an electric circuit. Ask the class the following questions:

- In a circuit, what do you think is traveling around? In the toy, what do you see traveling around?
- In a circuit, what gives the electrons the energy they need to light up the LED, and what kind of energy is it?
- In the toy, where do the ducks get their energy, and of what kind is this energy?
- What would happen to the ducks if you disconnected one end of the ramp from the stairway? What would happen in the circuit if disconnected one wire from the LED

Complete a comparison chart showing the analogies between an electric circuit and the penguin toy (see Table 1, below).

Table 1: Duckling Toy vs. Electric Circuit

Issue	**Toy**	**Electric Circuit**
What is traveling around the loop?	ducklings	electrons
What keeps them in line?	the ramp	the wires
What gives them the energy they need?	the stairway	the battery
What kind of potential energy is it?	gravitational	electrical
How do they lose this energy to another form?	rolling down the ramp	by lighting the LED
How could you increase the energy?	make stairway higher	add another battery
Measuring the energy per duck	height of ramp	voltage
Flow rate of moving objects	ducks per minute	current

4. Why do some LEDs not work together?

   Class Discussion

   LED stands for Light Emitting Diode. A diode is a device that can conduct electricity in only one direction – somewhat like a fire exit that you cannot enter. This is the reasons why it will not turn on unless the long (+) wire of the LED is attached to the + side of the battery, and the short wire to the – side. Another property of a diode is that when it conducts, it limits the voltage across it. However, this limit is different for LEDs of different colors. Red LEDs use the least voltage, while blue LEDs use the most. Therefore, a red LED cuts off at a lower voltage, preventing the voltage from rising to the higher level needed to turn on the blue LED.

5. Conductors and Insulators

   Class Discussion

   Some materials can conduct electricity, while others cannot. Make a list of the available materials and predict which ones will conduct electricity. Then test each one by placing it between one side of an LED and the wire from the LED. If the LED still lights up, the material is a conductor; if not, it is an insulator. Project the Circuit Drawings page (p. 8, top only).

   Individual activity

   Make a list of the available materials, and predict which ones will conduct electricity. Then test each one by inserting it between the long wire of the LED and the plus side of the battery, as shown below. How will you be able to tell if the material is a conductor or an insulator?

6. Switch Hunt

   Class discusion:

   Nearly every electrical appliance has a component that has been missing from the circuits we made. You have to be able to turn it on or off. The device that does this is a switch, which is the basic control element in an electric circuit. To get an idea of the variety of switches, let's conduct a scavenger hunt for switches – Switch Hunt for short. For each switch you list, identify also what it controls, where you find it and how you operate it. List only switches that you operate by hand. Table 2 will get you started.

Table 2: Switch Hunt

Where can you find it?	What does it control?	How do you operate it
Entrance of the room	lights	Flick it up or down

7. Make a switch.

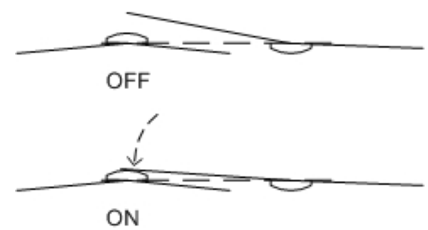
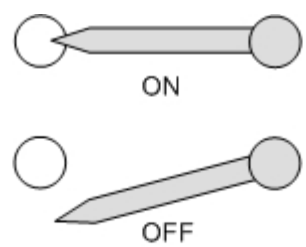
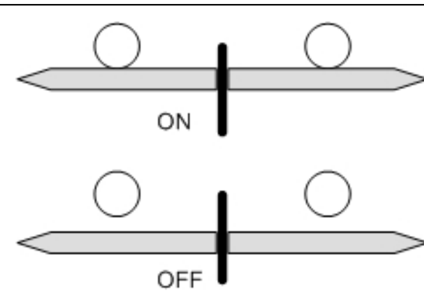
   Class Discussion:

   A switch works by touching two conductors together to turn something on, and separating the conductors by air, an insulator, to turn it off. Looking the results of the Switch Hunt we can see that some switches stay in place after you operate them, while others need to be held in place. Some switches have to be rotated, while others are operated by sliding them or pushing something. Common switches are shown in Table 3. Make and demonstrate a sample of each one (see Table 4)

Table 3: Basic Switch Types

Type of switch	**How you operate it**	**Typical use**
Push button	Push and hold it down	Keyboard
Toggle	Flick it	Light switch
Rotary	Turn it	Electric fan
Slide	Slide it	Penguin toy

Table 4: Ideas for making simple switches

Type	**Materials**	**How to make it**	**What it looks like**
Push-button	Two paper fasteners, cardstock	Attach the fasteners so that the leg of one can be pushed down to touch the head of the other, and so this same leg will spring back up when released.	
Rotary	Two paper fasteners, cardstock	Push both fasteners through the cardstock, about and inch apart. Keep one leg of one fastener on top. Rotate this leg so it is touching the top of the other fastener to turn the circuit on, and away to turn it off.	
Slide	Three paper fasteners, cardstock	Cut a slot for one paper fastener, and poke holes for the other two. Mount two paper fasteners through the holes with heads up, and mount the third though the slot with both legs up. The legs turn the circuit ON by touching the two heads, and OFF by sliding away from them.	

<u>Group activity</u>: Using cardstock and paper fasteners create a push button switch, a rotary switch and a slide switch.

8. Insert a switch in a circuit

   Class discussion:

   Now that you have a switch, you can add it to a circuit to control a LED. The switch should be put in a position where it breaks the flow of electricity when it is in the OFF position, and restores the follow when it is ON.

   The simplest idea is to use one of the wires of the LED as a pushbutton switch. See the Circuit Drawings page (p. 9, bottom only).

   Group activity: Insert your switch into a circuit so it can turn the LED ON or OFF.

9. Drawings and diagrams

   Individual activity: Make a drawing of your circuit.

   Gallery walk: Post all the drawings and ask the class to examine each one. They can use Post-Its to write comments or observations.

   Class discussion:
   - What did you notice about the drawings?
   - How were they different?
   - What features make a circuit drawing easier to understand?
   - Could you reproduce the circuit using only the drawing?

   Engineers use a common language for representing circuits, in order to create circuit diagrams. Project the Circuit Diagrams page (p. 9).

   Individual activity: Using the standard symbols and rules, create a schematic diagram that represents your circuit.

   Gallery walk: Post the diagrams and repeat the gallery walk.

   Class discussion:
   - How is a diagram different from a drawing?
   - What are the pros and cons of using diagrams instead of drawings?
   - What information does a diagram leave out, which a drawing might include?

10. Make an electric puppet

    Class Discussion: Project the Directions for Making an Electric Puppet (p. 10). Distribute cardboard rectangles, pens, LEDs, batteries, paper fasteners, masking tape and foam tape.

    Individual Activity: Make an electric puppet.

    Class discussion:

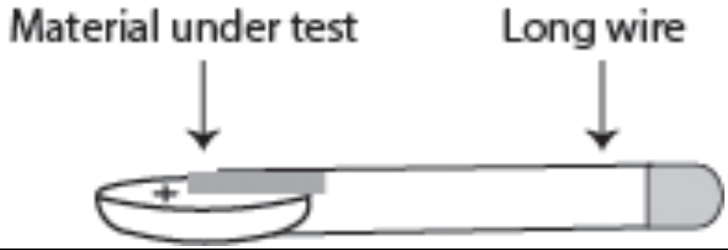
    After students have made their puppets, discuss how they could customize it. Ask:

    - Whay do we use the word customize instead of decorate?
    - What is the difference between them?
    - Which word gets at the idea of expressing yourself ?

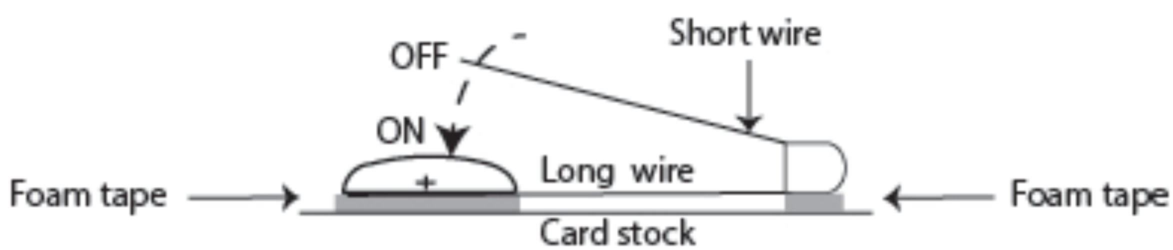
    Provide craft materials for customizing the puppets

Circuit Drawings

Conductor or Insulator?

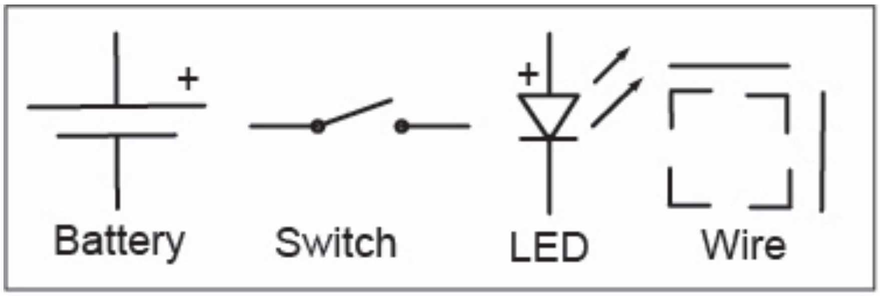


A circuit controlled by a switch



Circuit Diagrams

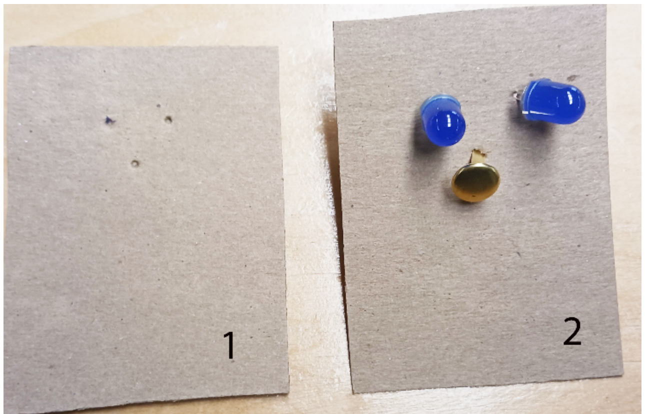
Symbols and Key

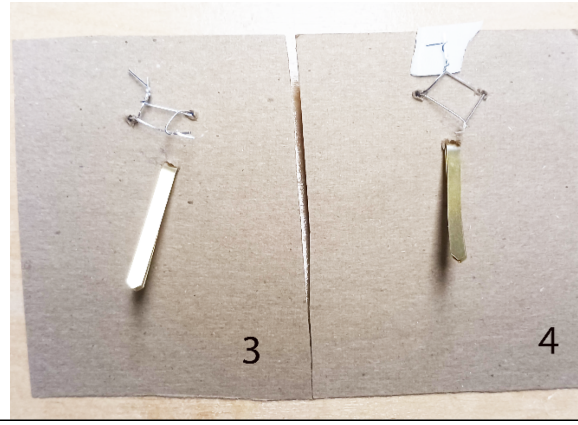


Rules for Making Circuit Diagrams

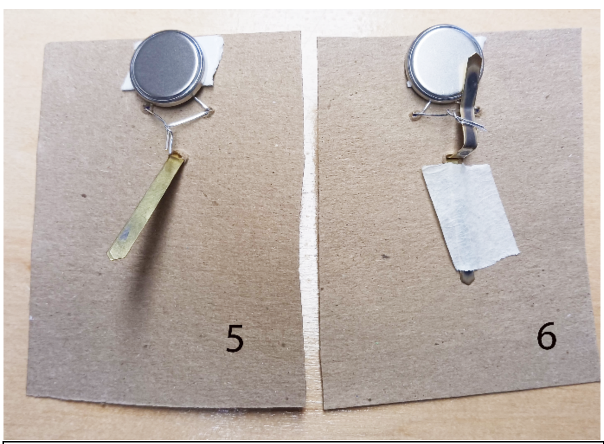
- Use horizontal or vertical straight lines to represent
- Use square corners between horizontal and vertical lines.
- Put the battery on the left and the LED on the right.
- Put switches on top.

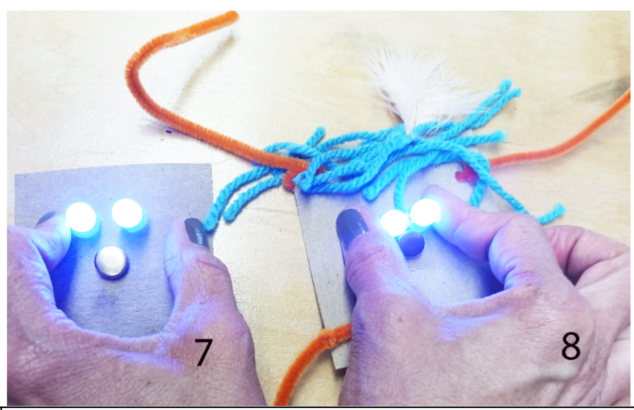
Task Card for Making an Electric Puppet





1.Take a piece of cardboard, at least 3” x 4”. Using a ballpoint pen, poke three holes in the pattern of two eyes and a nose about ½ “apart. 2.Push an LED through each of the top holes and a paper fattener through the bottom hole.	3. Flip the cardboard over, press the two long LED wires together towards the top and the two short wires towards the bottom. Then twist each pair of wires together. Bend the legs of the paper fastener down. 4. Place a small square of double-sticky mounting tape under the long leads and press them onto the tape





5. Press the flat (+) side of the coin battery on the tape, so it touches the long wires. 6. Bend one leg of the paper fastener towards the battery. Wrap the two short wires around this leg. Use masking tape to secure the other leg, and make a better connection with the wires	7. Flip the cardboard over again and press down. If the leg of the paper fastener touches the battery, the LED eyes will light up! 8. Customize your electric puppet using craft materials.

Codes

Materials

(per student)

- Template for Making Binary cards, photocopied onto light-colored cardstock– See P.19 (If cardstock is not available, Che template can be printed on plain paper, cut into five separate rectangles and glued onto index cards.)
- Cardboard sheet, approx. 5 ½ x 8"
- 4 LEDs
- 4 CR 2032 coin batteries

(per group)

- 2 or 3 rulers
- Double-sided foam tape
- Masking tape
- Craft materials for customizing

(per class)

- Paper fasteners, 2 boxes of 100 each

(to be projected on a screen, at various times, as indicated in the Procedure below)

- Sample Symbols (p. 15)
- Sample Codes (p. 16)
- Non-decimal Number Systems (p. 17)
- Decimal and Binary Number Systems (p. 18)

Procedure

1. Symbols:

   Class discussion: Project the Sample Symbols What are they? Why do we use them? How do we use them? Project the Sample Symbols page (p. 15)

   Individual Activity:

   - Draw each symbol and explain what it means.
   - What other symbols can you think of? Write each one down and share it with the class.

2. Codes: A code is a system of symbols. To help us understand a code, there is usually a key, which translates the symbols in a code into a familiar language. Project the Sample Codes page (p.16).

   Individual activity:
   - Where can you find these symbols?
   - Look inside your clothing or lunch box, on a cell phone, advertisement, business card, wall notice or flyer.
   - What does each type of symbol used for?

3. Emojis

   Class discussion: "Emoji" means "picture-word" in Japanese, and emojis are based on Manga characters. Ask:

- Are the emojis a code?
- What do you use them for?

Individual activity: Write down a few of your favorite emojis, and create a key that explains what each one means.

4. Positional number systems:

   Class Discussion: Positional systems These use a small number of symbols, and create larger numbers by adding columns. The number of symbols is called the number base. The amount each column represents s called its place value.

   Individual Activity:
   - Add 4 + 10 in decimal.
   - Add IV + X in Roman numerals. These represent 4 + 10.
   - What goes wrong?

5. Number bases other than 10

   Class discussion:

   a) Distribute rulers. Ask students:
   - What do the numbers on a ruler represent?
   - Why is there a big line next to each number?
   - Suppose you're measuring something smaller than 1 inch. How much of an inch does the next largest line represent?
   - What about the next largest line and the next one after that. How much of an inch does each one represent?
   - Look at your answers to the previous questions.
   - What number do you have to divide by to get from one to the next to the next?

   The fact that you always divide by 2 means the divisions on a ruler use a number system other than decimal. This system is called binary, because its number base is 2.

   b) Project the Non-Decimal Number Bases page (p. 17). To find the number base, look at how many how many symbols you use before you start over again, or the number you divide by to get from one measurement to the next. Project the Non-decimal Number Systems page (p. 17). Help students identify the number base used in each of the following systems:
   - The Chinese abacus (see https://www.youtube.com/watch?v=22NdwzuEZi4)
   - The tally system (How many marks do you make before you start over again?)
   - Subdivisions of a gallon (How many cups are there in a pint? Pints in a quart? Quarts in a half gallon? Half gallons in a gallon?)
   - Measurement of time (How many seconds are there in a minute? Minutes in an hour? Hours in a day? Days in a week?)

6. Introduction to binary: The decimal system uses 10 symbols, and is therefore a base-10 number system.Each switch in a computer has only two possibilities: ON or OFF. These are represented by the numbers 0 and 1. Since there are only two symbols, this is a base-2 or binary number system.

   Class Discussion:
   - How many symbols does the Binary System use?

- What number do you get up to when you run out of symbols in binary?
- Express this number in both binary and decimal.:

7. Place value

Class Discussion: Place value is the meaning of each column in a positional number system. Project the Place value tables at the top of the Decimal and Binary Systems page (p. 18)

- In the number 13 in decimal, what number does tahe 3 represent? What does the 1 represent?

A humorous Abbott and Costello routine shows Costello calculating 7 x 13 = 28, by ignoring place value. This routine is available at https://www.youtube.com/watch?v=01wIU1PNvo0

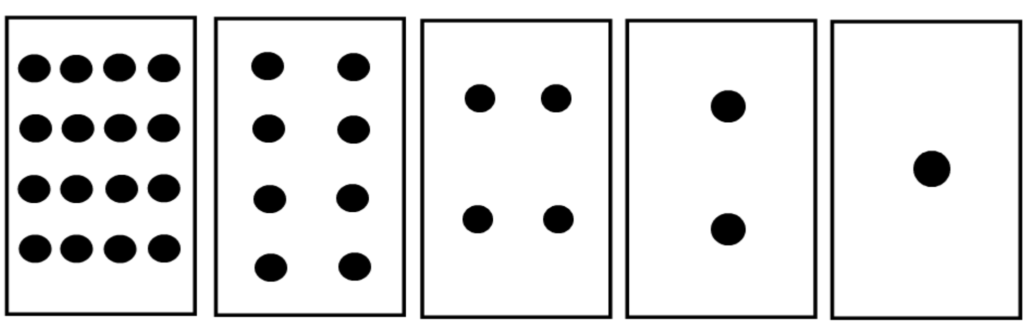
- What are the first four decimal place values, reading from right to left?
- How are the decimal place values related to each other as you move from right to left?
- To get to the next decimal place value to the left what number do you multiply by?
- How many symbols does the decimal system use? Be sure to include 0, but exclude 10, which consists of two symbols, not one.
- What are the first four binary place values, reading from right to left?
- How are the binary place values related to each other as you move from right to left?
- To get to the next binary place value to the left what number do you multiply by?
- How many symbols does the binary system use? Be sure to include 0, but exclude 10, which consists of two symbols, not one.
- What does 11 represent in binary? (Add the place values of the first two columns)
- What does 101 represent in binary? (Add the place values of the first and third columns)

8. Binary number cards: Distribute the Template for Making Binary Cards (p.19), one per student, plus scissors for cutting the cards apart.

Individual Activity: Ask each student to create his or her own set of Binary Cards.

- If the templates are printed on cardstock, simply cut the cards apart.
- If the templates are printed on plain paper, distribute glue sticks and index cards. The students then cut the cards apart and then glue each one onto its own index card.

Class Discussion: Demonstrate how to lay the cards out as shown below:

Number	16	8	4	2	1
Binary cards					

Ask:

- What do you think the number of dots on each card represents? Students should recognize the binary pace values.
- Why did I lay out the cards in this order?

These cards will help you convert from decimal to binary and back again.

9. Binary Birthdates

Class Discussion: Next you will convert your birthdate (day of the month only) from decimal to binary. To do this, identify the cards you need to build up to the decimal number of your birthdate. Leave these cards face up, and turn the others face down. Then write a 1 below the cards you need to make your decimal number, and 0 for those that are turned over, and read the binary number from left to right. Project the Converting between Binary and Decimal section of the Deimal and Binary Systems page (p. 19) it shows you how to use the binary cards to convert from 19 in decimal to 10011 in binary.

Individual activity: Use the binary cards to express your birthdate (day of the month only) in binary.

Class discussion: Ask each student to state his or her birthday in binary. As the rest of the class to convert this number back to decimal. Then ask the first student if that is the correct birthdate. Help students correct any errors. Ask:

- Is there any birthdate that cannot be translated to a five binary 1's or 0's?
- Which five-bit binary number does not translate into a possible birthdate?

10. Binary birthdates lit (pre-requisite: Electric Puppets, p. 10)

Individual activity:

Using the same method as for Electric Puppets, but using only one LED per coin battery, create an LED display showing your birthdate in binary. The numbers 0 and 1 could be represented by using different color LEDs, or LEDs ON and OFF. The lights should come on when the board is pressed down on a table. The photo below shows an example.

Binary birthdate lit, made by a fourth grader. Her birthdate is 01111, or 15 in decimal

Sample Symbols

Sample Codes

- Internet WiFi signal
- Cell phone signal
- FaceTime call
- Screen is recording
- Camera is off
- Microphone is off
- device is locked
- An alarm is set
- Battery is charged
- Battery is charging

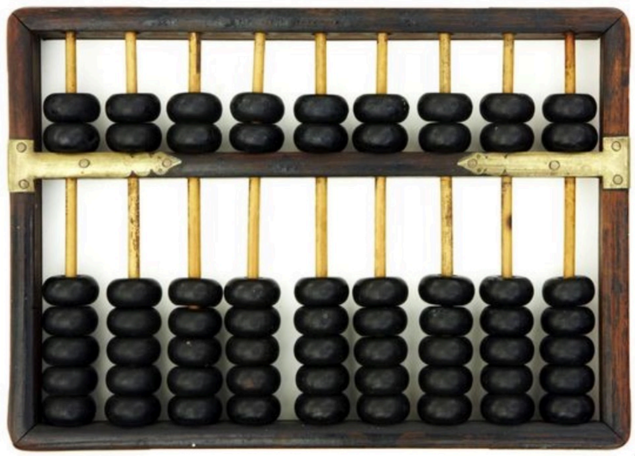
- Machine Wash Normal
- Machine Wash Permanent Press
- Machine Wash Gentle
- Hand Wash
- Do Not Wash

- Tumble Dry Normal
- Tumble Dry Normal - No Heat
- Tumble Dry Permanent Press
- Tumble Dry Gentle
- Tumble Dry Gentle - No Heat

0 55653 63010 4

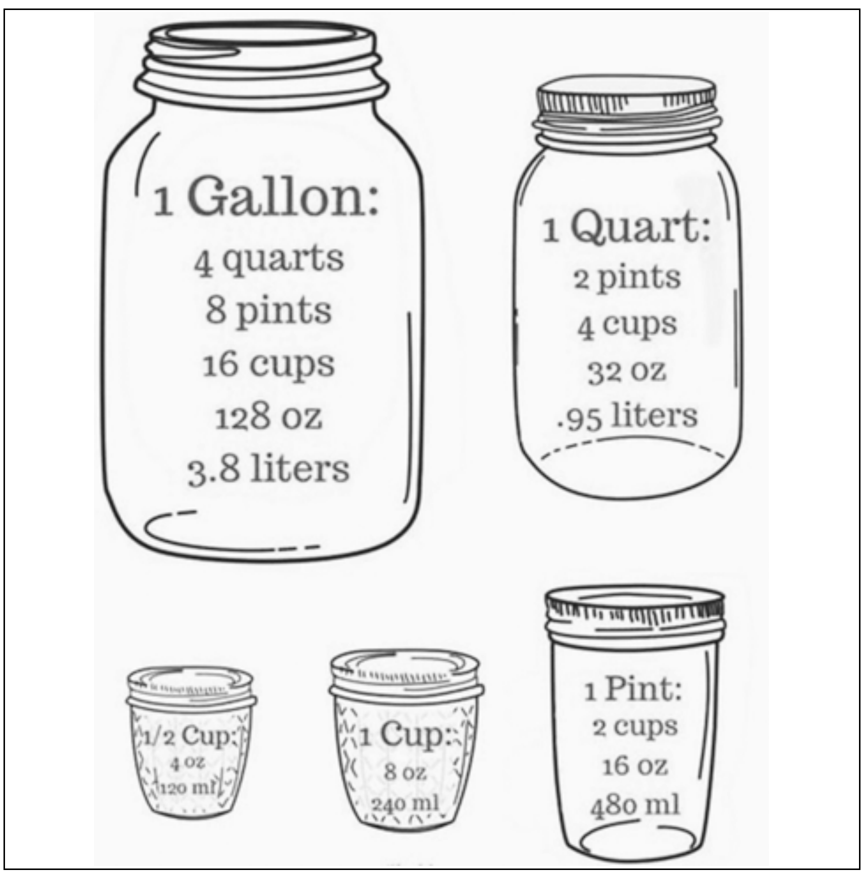
Non-decimal number bases

Chinese Abacus



Tally systems

Liquid Measures



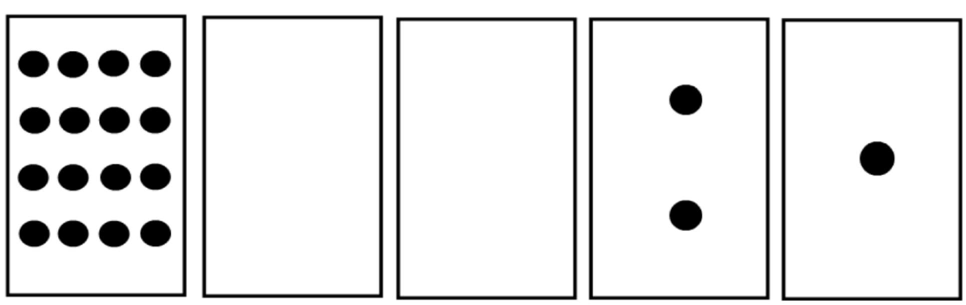
Decimal and Binary Number Systems

Place Values

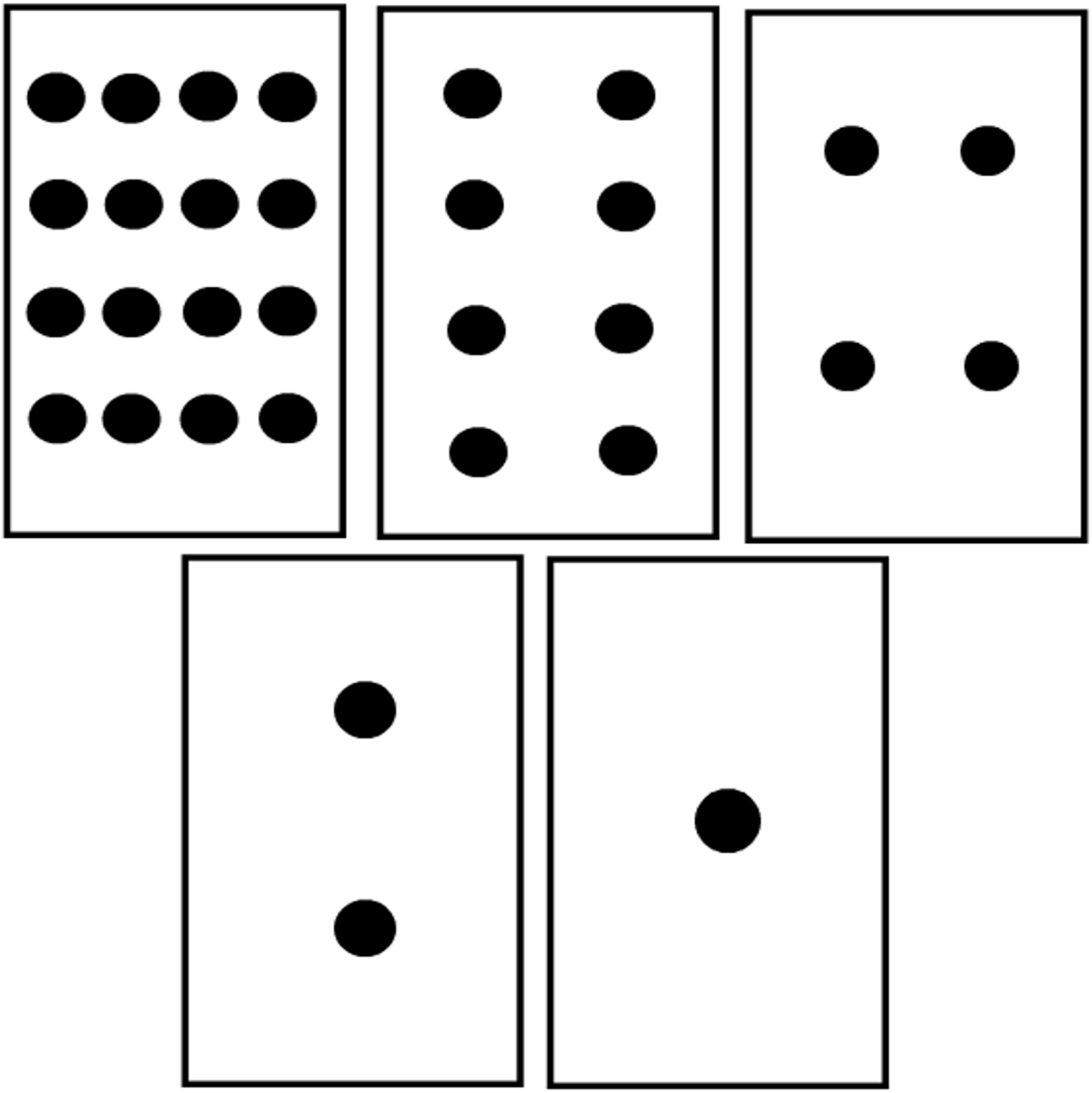
Decimal place value of each column					Decimal number
10,000	**1000**	**100**	**10**	**1**	
0	0	0	0	1	1
0	0	0	1	0	10
0	0	1	0	0	100
0	1	0	0	0	1000
1	0	0	0	0	10,000

	Binary place value of each column					Decimal equivalent
32	**16**	**8**	**4**	**2**	**1**	
0	0	0	0	0	1	1
0	0	0	0	1	0	2
0	0	0	1	0	0	4
0	0	1	0	0	0	8
0	1	0	0	0	0	16

Converting between Binary and Decimal

Place values	16	8	4	2	1
Binary cards					
Binary number	1	0	0	1	1
Decimal number	16			2	1

Template for making binary cards



Information

Materials

(per student)

- Set of 15 counters or pennies
- 7 x 7 Grid Template (p. 30), printed on Cardstock or glued to cardstock or cardboard
- Worksheets: i) Guess my Number (p. 26); ii) 7-segment display (p. 27); iii) 14-segment display (p. 28); iv) 7 x 5 grid (p. 29)

(per group)

- Collection of common analog or digital devices, such as switches, eye droppers, spring scales, tweezers, clothespins, hole punchers, bottle caps, tape measures (one set per group)
- Box of crayons, enough for at least seven crayons per student

(to be projected on screen, when indicated in Procedure below)

- Encoding Letters and Numbers (p.24)
- 7 x 5 Grid Displays of Letters and Punctuation (p. 25)

Procedure

1. What is information?

   Class discussion

   Information is carried by any meaningful change or difference in the environment. Examples: knock on the door, a doorbell, an alarm clock, a light switch, a horn, a nod or a shake of the head. Each of these has two possible conditions, on or off. Each one contains the most basic unit of information: YES or NO. Each one can be represented by one binary digit, 0 or 1, which is also called one bit of information.

   Group Activities:

   - Identify other or actions that contain only one bit of information.
   - Modify each one so it contains more than one bit.

   Class discussion:

   - How can silence convey information?
   - Think of some common hand gestures. What information does each one send?
   - How do teachers send information to the class?
   - How do students send information to the teacher?

2. Analog vs. digital information

   Class discussion:

   Analog devices can change continuously, such as a dimmer switch, volume control or joystick. A digital device has only two states, ON or OFF, such an ON/OFF.

   - Look at a clock or watch. Is it analog or digital?
   - How can you tell?

Group activity:

Provide each group with a similar set of analog and digital devices. Their task is to sort these items according to whether they are analog or digital. List each group's results on a sheet of chart paper, and ask the groups to defend their choices, especially when there are disagreements between groups.

Class Discussion:

- What other examples can you find of analog devices or digital devices?

(This could also be a homework assignment.)

3. Guess my Number Game (pre-requisite: Introduction to binary and Binary number cards Pp. 12-14).

Class Discussion: Here is a game that reveals how to measure the amount of information in a number. It is measured by the number of bits needed to cover all the possibilities. For example, when we created binary birthdates, we needed five bits, because all possible birthdates are from 1-31, and five bits can represent any number from 0 – 31. The Guess my Number Game explores how many YES or NO questions, or bits, is contained in a number that can vary from 1 – 100.

Group Activity: Playing the Game within each group

a) Students work in groups of three. Each group member gets a different role: i) the Secret Keeper, ii) the Questioner and iii) the Recorder.

b) The Secret Keeper in each group picks a number from 1 to 100, writes it down, but doesn't tell the others what the number is.

c) The Questioner asks the Secret Keeper series of YES/NO questions until he or she determines the secret number. The goal of the game is to find out the number using the least number of questions.

d) The Recorder writes down each of the questions, plus the Secret Keeper's answer.

e) Once each group has played the game, the groups share the number of questions needed by each questioner. Put these numbers up on chart paper.

Class Activity:

a) The teacher plays the game against the class. The teacher steps outside the door for a moment, while the class chooses a number that the teacher does not know, and every student writes this number down.

b) To keep track of each step, students use the Guess my Number Worksheet on p. 25. The teacher asks, "Is the number odd?" If the answer is YES, her or she writes a 1 on a chart, otherwise a 0.

c) If the number was even, the teacher tells the class to divide the number by 2 If it was odd, the class is told to subtract 1 and then divide by 2.

d) Next the class looks at the result of doing step b and asks "Is the result odd?" If so the teacher writes a 1 in the next line; if not, he or she writes a 0.

e) If the number was even, the teacher tells the class to divide the number by 2 If it was odd, the class is told to subtract 1 and then divide by 2.

f) The class repeats steps d) and e) until the number goes down to 0, Then the games ends.

g) The instructor then informs the class of the secret number by writing the binary number from left to right, starting at the bottom, and translating it into decimal. See the bottom of the Worksheet for an example.

Class Discussion:

- What number system did I use to unlock the mystery?
- What number system did I change it, in order to give you back your number?
- How many questions did I need to find the number?
- How does this last number compare with the number of questions you used when you played the game against each other?

The teacher never needs more than 7 questions to find the number. This number is typically less than the number the students used when they played the game against each other. Seven is the maximum number of questions needed for the teacher's method, because each question divides the answers into nearly equal possibilities, so there is no wasted information. Because only seven binary numbers can represent a number from 1 to 100 tells us that a number from 1 to 100 contains seven bits of information.

Group Activity: Use the teacher's method to play the game against each other. .

4. Morse code

Class discussion: Project the page Encoding Letters and Numbers (p. 23). A key to Morse code is at the top of the page. Morse code was invented along with the telegraph in the 1800's. Today it has been mostly replaced by much more useful computer codes. As you can see from the screen, Morse Code consists of dots and dashes.

Group activity: Provide each group with a different task:

- In written English, how do we separate letters?
- How do separate words?
- What symbol do we use to separate sentences?
- How do we indicate the beginning of a new paragraph?

Class discussion:

You might be wondering how the same issues are addressed in Morse Code. Here is how:

- A short pause – the length of a dash – indicates a space between letters.
- A longer pauses – three dashes – indicates a space between words.
- The end of a sentence is indicated by the word STOP.
- Morse Code has no way to separate paragraphs

Group Activity: Write a short message and translate it into Morse Code. Then exchange messages with another group. Can they decode your message?

5. Displaying letter and number symbols:

   Class Discussion:

   Digital displays of numbers and letters are all around us. You can find them on kitchen appliances, clocks, computer equipment, food trucks, trains, buses and store windows. Project the bottom part of the page Encoding Letterand Numbers (p. 24) to remind students of what the simplest displays look like. Then ask:

   - Where can you see these displays?
   - Does each one use 7 segments, 14 segment, 7 x 5 grids or something more complicated?
   - What information does each one convey?

   (This could also be a homework assignment.)

   a) Seven-segment displays:

      Individual Activity: Use crayons to represent each of the ten number symbols numbers by arranging them in the shape of a seven-segment display. Record the results by darkening the appropriate rectangles a-g, on the Seven-segment Worksheet.

      - Show how each of the number symbols, 0 through 9, can be represented using seven segments.
      - What upper-case letters can you also represent?
      - What letters can't you represent? What goes wrong?

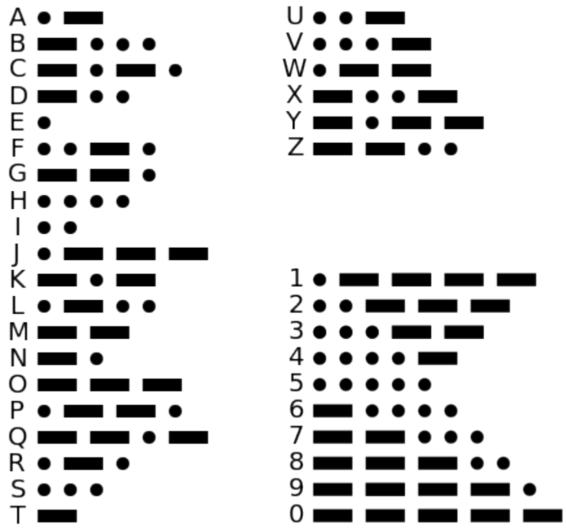
   b) The 14-segment display uses twice as many segments to display a character. Use the 14-Segment Worksheet to explore what letters and numbers it can display.

      Individual Activity: Represent as many numbers and letters as you can using the 14-Segment Display worksheet.

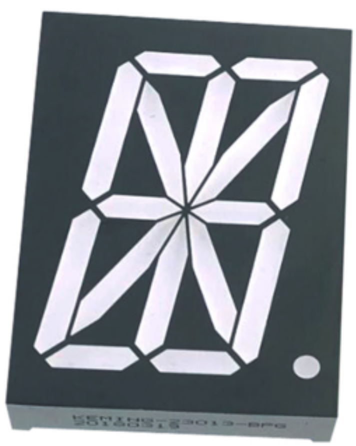
   c) The 7 x 5 grid array. These displays use dots in a grid to display letters and numbers.

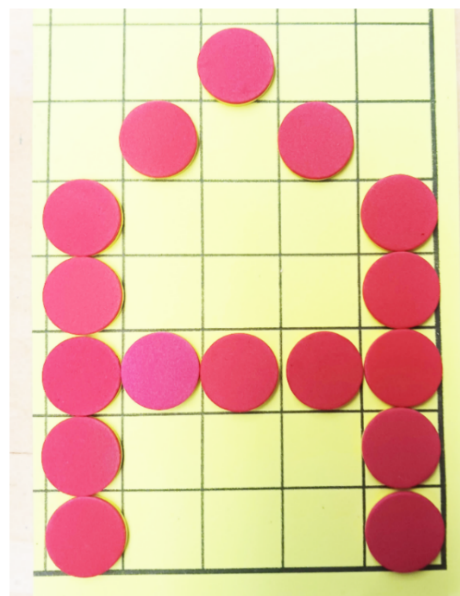
      Individual Activity: Use the five middle columns of the 7 x 7 grid sheets. Place counters or pennies in the squares you need to represent as many letters as you can. to find out what characters you can show using a 7 x 5 array. Then transfer the results for each letter or number to the 7 x 5 Grid Worksheet.

Encoding Letters and Numbers



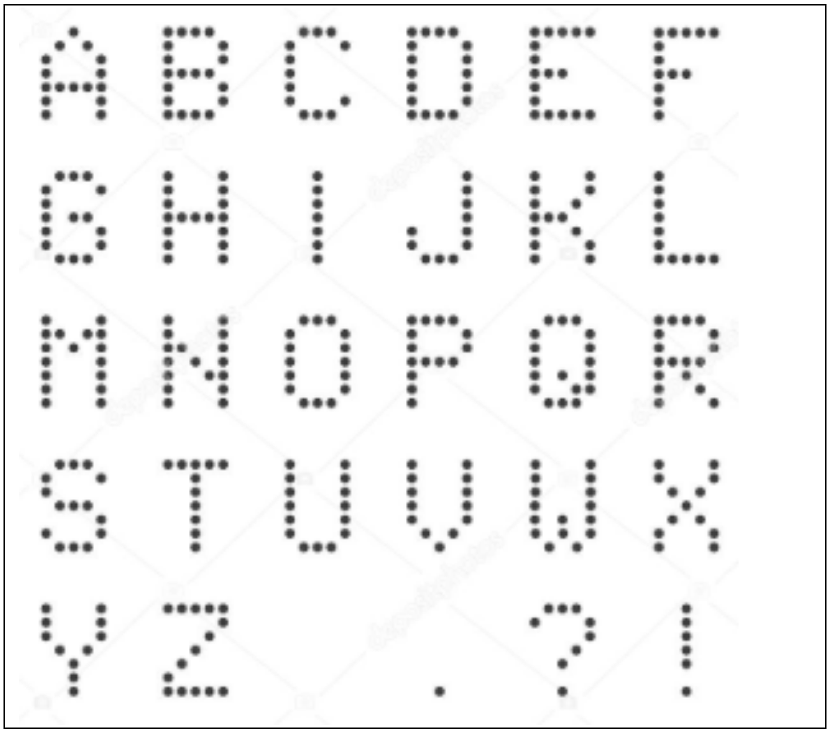
Morse Code





7- and 14-Segment Displays   7 x 5 grid display of the letter A

7 x 5 Grid Displays of Letters and Punctuation



Guess My Number Worksheet and Example

Directions: There are spaces below for three games, A, B & C**.** Ask the secret keeper if their number is odd. If they say YES, write a 1 in the YES = 1 column and then ask them to subtract 1 from the number and divide the result by 2. If they say NO, write a 0 in the NO = 0 column, and ask the secret keeper to just divide by 2. In either case, the secret keeper will have a new number for you to test in the same way. Write the results in Row 2. Continue recording the YES'es & NO's and 1's or 0's in each row, until the number reaches 0. At that point, the game is over

Game A			**Game B**		**Game C**	
Row	**Is the number odd? YES or NO**	**YES =1 NO = 0**	**Is the number odd? YES or NO**	**YES =1 NO = 0**	**Is the number odd? YES or NO**	**YES =1 NO = 0**
1						
2						
3						
4						
5						
6						
7						

Converting the **Binary** column to Decimal

1. Write the 0's and 1's from the **YES =1, NO =0** column. Use the shading code to align the numbers from top to bottom above in the cells from right to left below.
2. Add the place values in the bottom row that have 1's above them that have 1's above them. Ignore the 0's in the Binary Row.

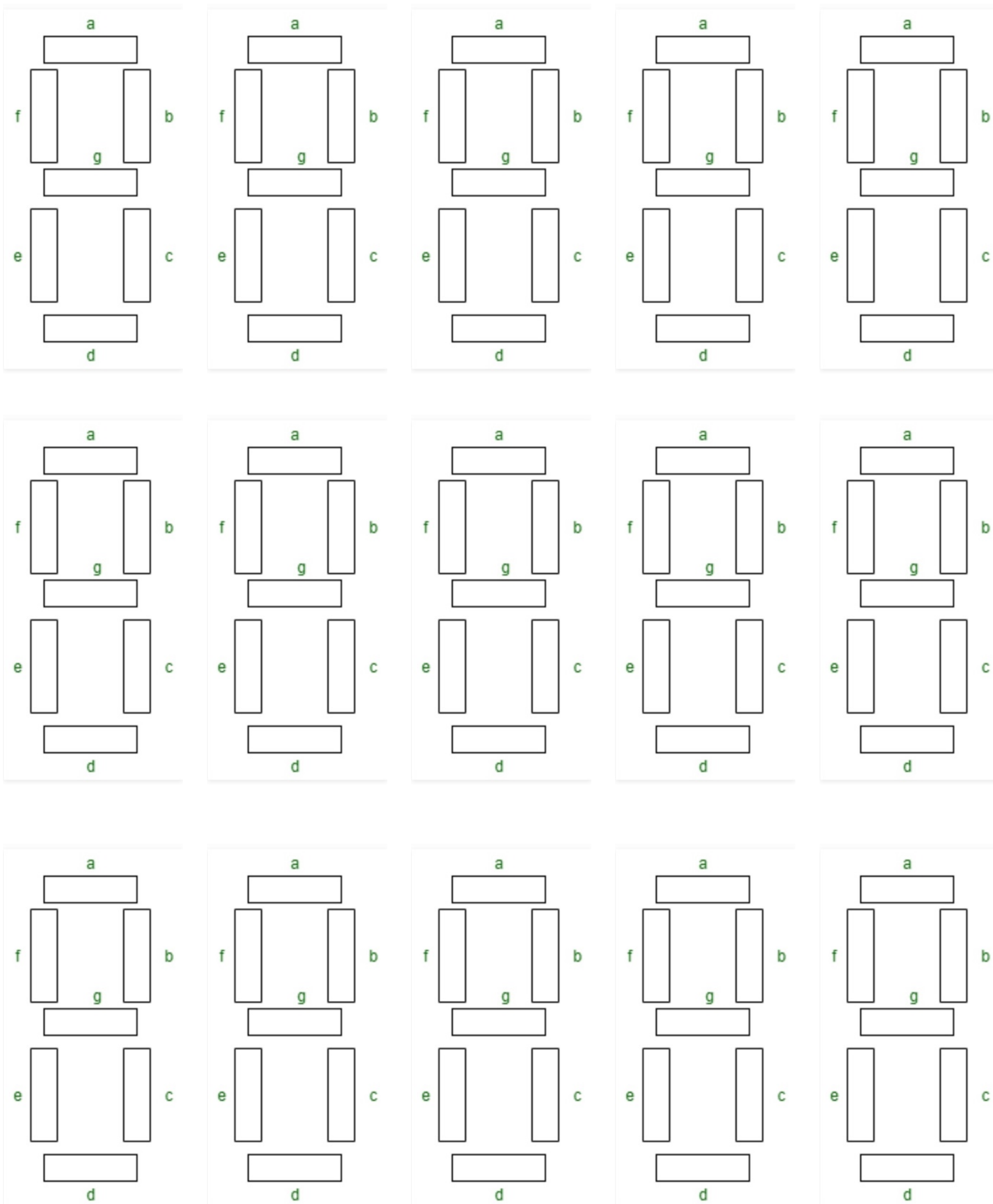
Place value	64	32	16	8	4	2	1
Game A							
Game B							
Game C							

Example: If the number in the Binary Column is 0 1 1 0 1 0 1 from top to bottom, the table above would look like this

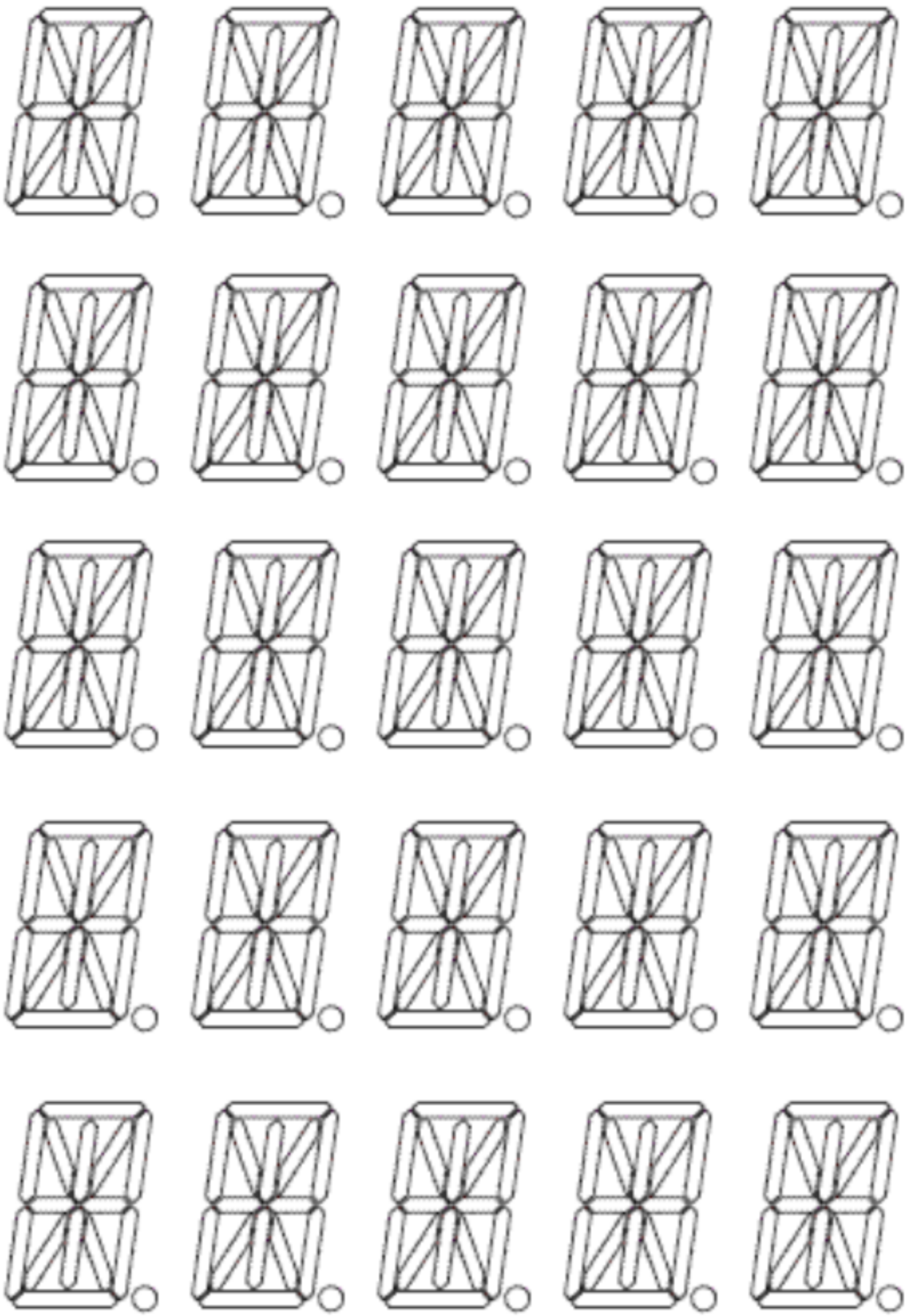
Place value	64	32	16	8	4	2	1
Binary row	1	0	1	0	1	1	0

To find the result in decimal, add the place values of the columns with 1's underneath. In this example, the result would be (from left to right): 64 + 16 + 4 + 2 + 0 = 82

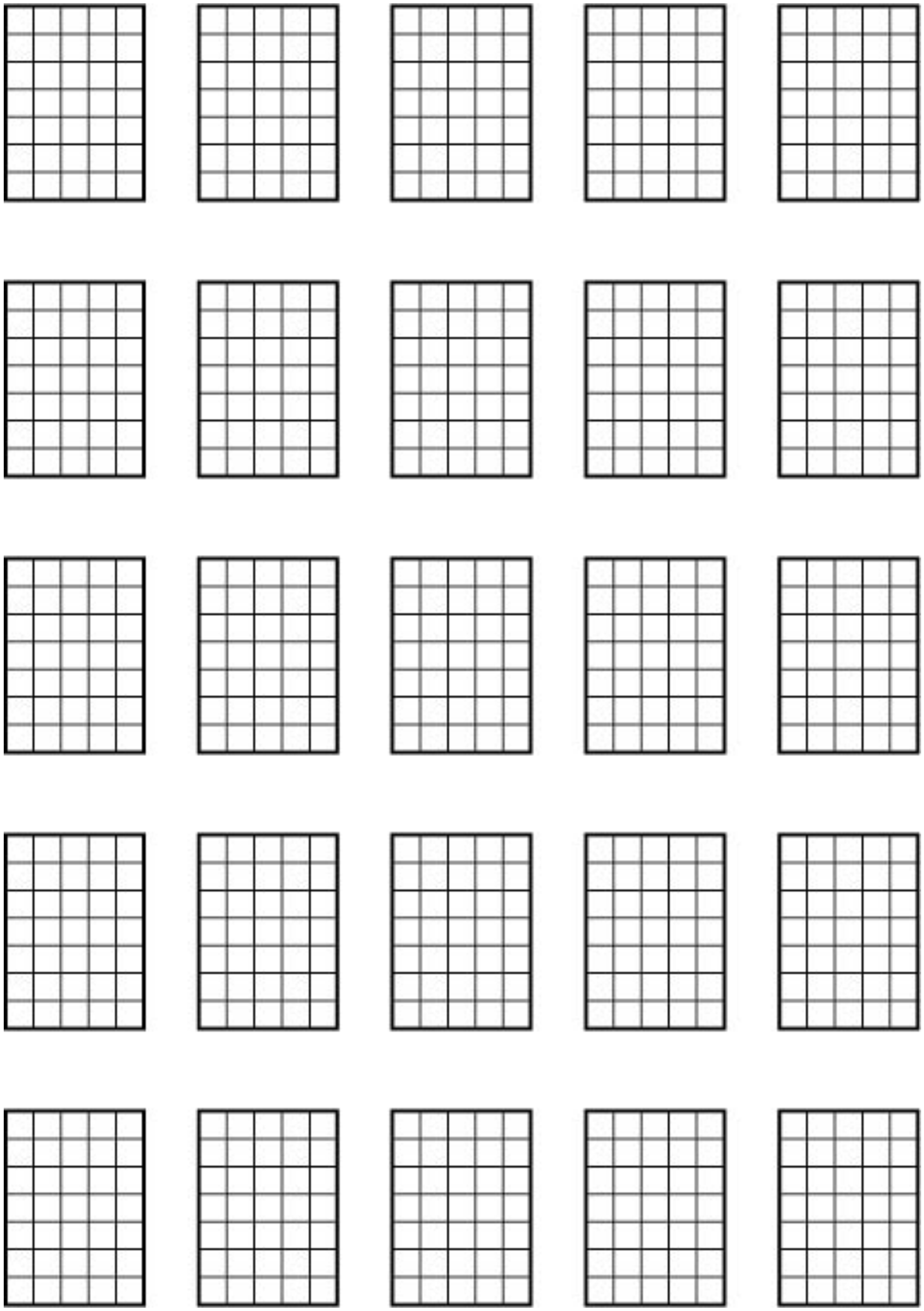
Seven-segment Display Worksheet



14-segment Display Worksheet



7 X 5 Grid Worksheet



Template for making 7 x 7 grid sheet with 1” squares

Communication

Materials

(per group)

- Set of 35 Two-color counters (one set per group)
- 7 x 7 grid sheet, printed on cardstock from template on p. 30

(per class)

- 40 small Post-its, with an X or O written one each one
- Blackboard or chart paper and markers

(to be projected on a screen, at various times, as indicated in the Procedure below)

- Parity Trick Example (p. 34)

Procedure

1. What is the purpose of communication?

   Class Discussion: Develop the idea that communication is what happens when information travels from one place to another.

2. Communication without technology:

   Class Discussion:
   - What are the ways we can communicate between people?
   - What are the five senses?
   - How can we use each of these senses to get information from one person to another?

3. Source, receiver and channel:

   Class discussion: Every form of communication requires a source (that sends the information), a receiver (that receives the information) and a channel (that carries the information from source to receiver). For example, while I am talking to you now:
   - The source is my voice, which comes from my vocal cords;
   - The receiver consists of your ears, which hear what I am saying;
   - The channel consists of sound waves that travel from me to you.

   Group activity:

   Divide into pairs. One person will send some information, and the partner will receive it. Then the partners exchange roles. Each pair answers these questions:
   - What was the source of the information that was sent?
   - What was the receiver I that picked it up?
   - What was the channel that carried it from the source to the receiver??

   Class activity: Make a chart showing the an swers from each group.

4. Errors in everyday communication.

   Class Discussion: What are some ways communication can go wrong? Here are some examples:
   - Errors in speaking and listening:

     (i) Source issues: speaker speaks too softly, speaker ses the wrong words, speaker uses poor grammar, speaker skips words or uses a foreign language.

(ii) Channel issues: there is too much background noise; speaker and listener are too far apart, so sound waves die out

(iii) Receiver issues: listener is not paying attention; listener is hearing impaired

5. Detecting and correcting errors in communication

   Class discussion: An error in communication is not so serious if you can detect that there was an error. Better yet, sometimes you can not only detect an error, but also correct it, so the original message could come back. Ask:

   - Think about some of the messages you sent or received today.
   - What could have gone wrong between the source and receiver?
   - How could you tell (detect) that there was an error?
   - How could you correct the error, to get back the original message?

   Group Activity:. Students work in groups of three. Identify one member of the group as the source, the second as the channel, and the third as the receiver.

   a) On a piece of paper, the source writes a short message in pencil.

   b) The channel erases one or more words from the message, or rewrites the message without some words.

   c) The receiver tries to interpret the message with the words missing, and checks with the source to see if he or she got it right.

   Class discussion:

   - How did you detect that there was an error?
   - How did you correct it?
   - What strategies do we use to make sure messages are received correctly?

6. Redundancy. Repeating the same message more than once, or saying the same thing in a different way, are strategies for making it easy to detect and/or correct errors in communication. This strategy is called the use of redundancy, because it adds extra information to the message to make it harder to get wrong.

   Class discussion: Ask for examples of redundancy in everyday communication, for example:

   - As a teacher, when do I repeat my instructions to the class, or add extra information to make them clearer?
   - When someone asks you your name or address, what extra information might you add so they don't get it wrong?

7. Introduction to Parity

   (pre-requisites: Introduction to binary, Binary cards, Binary birthdates, Pp. 12 – 14)

   Class discussion

   Parity is a form of redundancy that computers add to information to make it possible to detect errors, and sometimes even correct them. Here is how parity works:

   - Suppose you want to send someone your binary birthdate . Recall that it takes five 0's and 1's to express a birthdate in binary These five numbers, which could each be 0 or 1, are called bits.

- To guard against errors, you add an extra bit at the end, called a parity bit.
- To create the parity bit, count the number of 1's within the five-bit message. If the count is odd, make the parity bit a 1. If the count is even, make the parity bit a 0.
- For example, if your birthdate was 01010, your parity bit at the end, would be 0, giving 010100, because the number of 1's was 2, and even number.
- If you wanted to send 11100, the total number of 1's is 3, an odd number, so the parity bit is 1, giving 111001.

Individual Activity:

Add a parity bit to your birthdate in binary, and share the new message with the class. Is the total number of 1's now even or odd? Ask another student to change one of the bits from 1 to 0 or 0 to 1, and give the new code back to you. How can you tell that there was an error?

8. Parity Magic Trick.

Class activity:

a) Demonstrate the trick.
   - On a blackboard or chart paper, draw a 5 x 5 array of cells, so that each cell is large enough to fit one of the Post-its you marked with an X or an O.
   - Ask a student to use 25 Post-its to randomly put an X or an O in each cell of the 5 x 5 array.
   - Create a 6th row and a 6th column each five cells long.
   - Count the number of X's in each row and column.
   - Place an X or a O in each of the 10 new cells, to force the number of X's in each row and each column to be an even number. These additional X' and O's are the parity bits for each column and each row.
   - Look the other way, or leave the room, while a student changes one of the 25 original cells from an X to an O, or an O to an X. This change is the error.
   - As a result of the error, there should now be one row and one column in which the number of X's (parity) is odd rather than even.
   - Look for cell where this row and this column intersect. Tell the students that is the cell where the X or the O was changed.
   - Correct the error by replacing the X with at O or the O with an X in the cell that was changed.

   Students are likely to be amazed that you found the error they introduced without looking while they did it!

b) Explain how you did the trick:
   - Project the page Parity Trick Revealed (p. 35).
   - Item 1 (top left) shows the original array, using double-sided counters instead of X's and O's
   - Item 2 shows the parity bit added to each column and row.
   - Item 3 shows where the error was introduced.
   - Item 4 shows how the error was detected, and how it could be corrected.

Group Activity: Distribute 35 two-color counters and a grid sheet to each group of four.

- The students in each group should play four different roles: Source, Channel, Receiver and Recorder.
- The Source lays out red and yellow counters randomly on a 5 x 5 grid.
- The Receiver adds the 10 parity bits, one for each column and each row.
- The Channel flips one of the counters in the original 5 x 5 array.
- The Receiver than detects and corrects the error by looking for the row and column that no long have even parity.
- The Recorder draws the original array, circles the error, and shows how the Receiver detected and corrected the errror

If students have difficulty with any of these tasks, call their attention to the Parity Trick Revealed page you've projected and/or help them understand the steps.

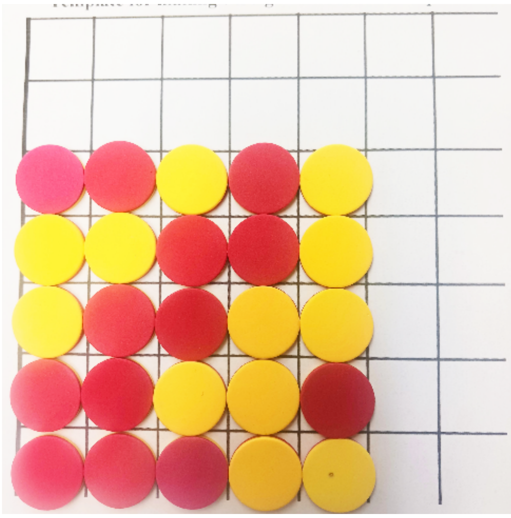
9. Exploring further: How well would the parity method would work if there were two errors instead of one?

   Group activity:

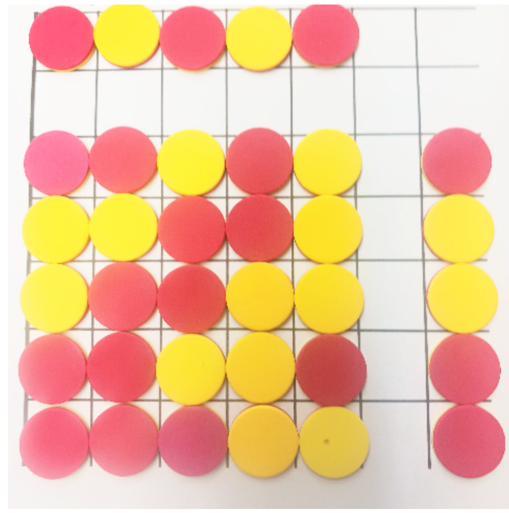
   a) Suggest that the Channel makes two errors in the array. What happens when the Receiver tries to detect and/or correct both errors.

   b) Suggest that students vary the locations of the two errors with respect to each other. For example, what happens if the two errors are in the same row or column. What goes wrong?

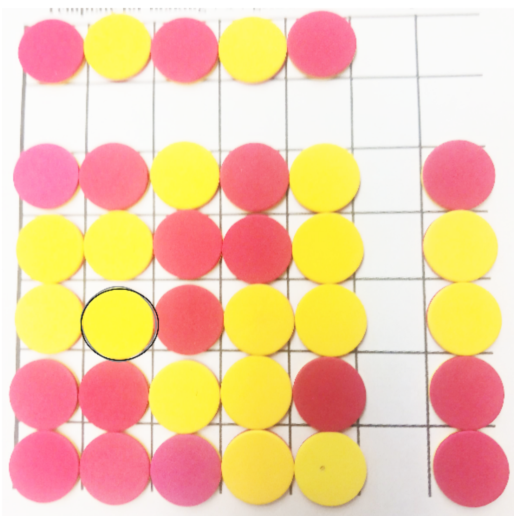
Parity Trick Revealed



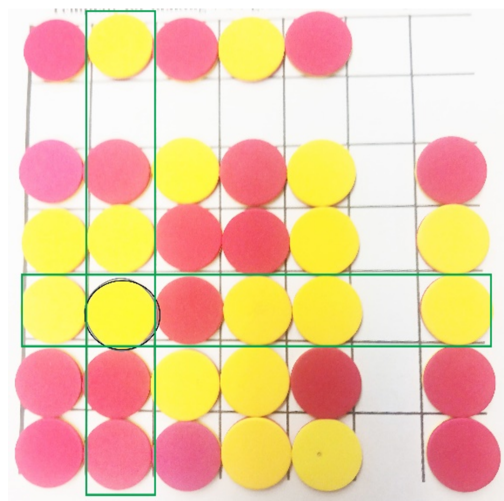
1. Original pattern



2. Parity bits added



3. Error introduced (circled)



4. Error identified (row and column intersect)