A Kinaesthetic Activity to Demonstrate Analogue to Digital Conversion

Created by TATSUMI Takeo, Tokyo University of Agriculture and Technology

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Summary:
A computer stores data as zeros and ones called digital data. How can we convert a simple set of data from an analogue format into digital format for this purpose? If we are to convert data between these formats, would there be loss of accuracy or errors in conversion? Are these errors more obvious in analogue or digital data?

Curriculum Links:
Mathematics: Number Level 2 and up. Explore numbers in other bases.

Skills:
Counting, Matching, Sequencing

Ages:
7 and up

Materials:

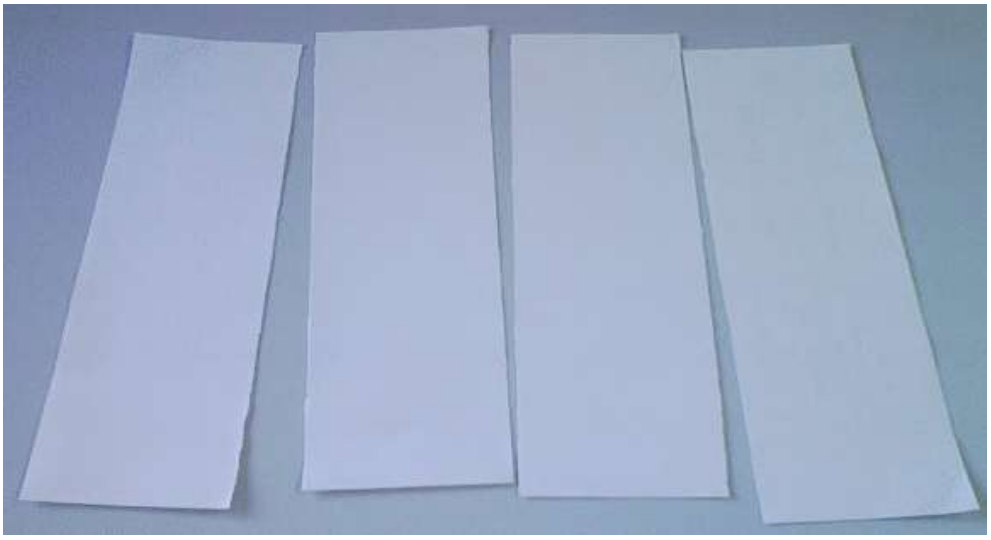
- Sheets of A4 or Letter size paper
- Scissors
- Pen or Pencil
- Eraser or Correction Fluid or Correction Pens

Introduction:
This activity is best done in pairs (at the least) for matching and comparison purposes. Each student starts with one set of the above materials required.

The activity is described both in text and images. We have used student 1 doing the encoding activity as the author himself (Takeo) and student 2 (Ken, referred to as a friend) doing the same activity. They will then compare and decode each other's conversion results.

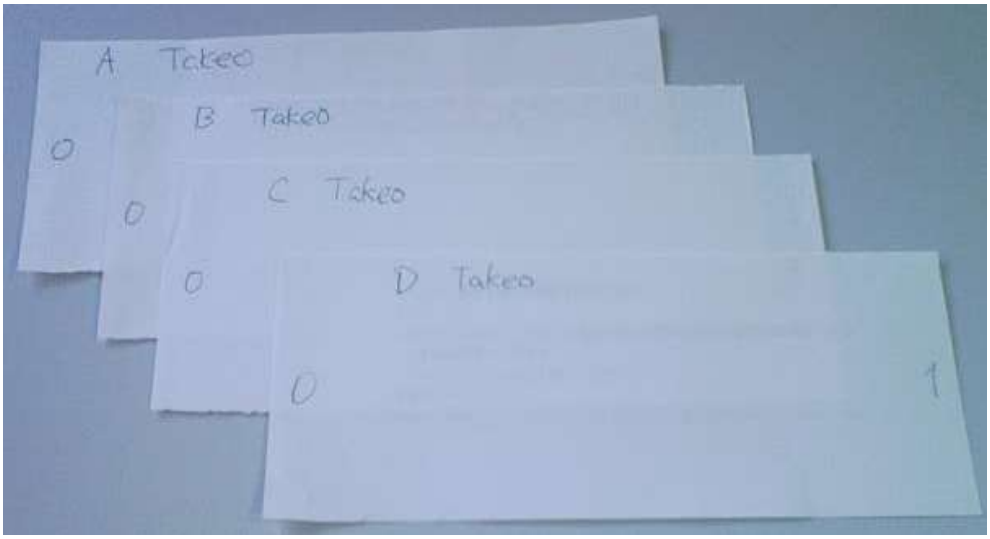
1. Take a sheet of paper (letter or A4 size)

2. Cut it into four equal parts

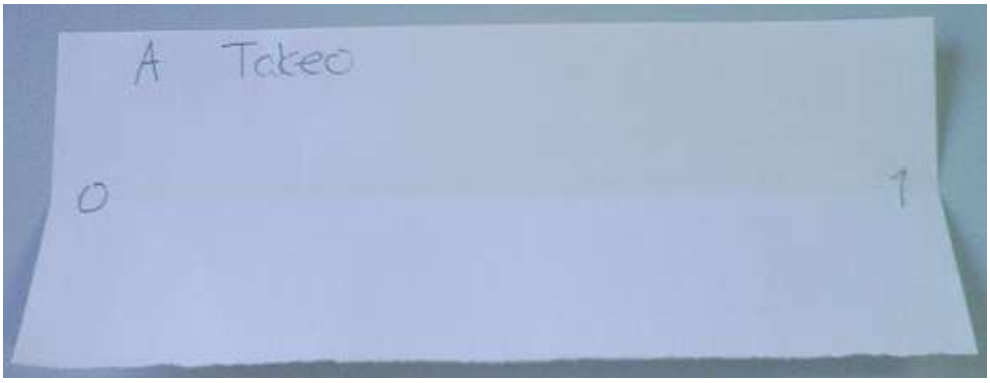


3. Label the parts A, B, C and D and write your name on the top-left end of all sheets. Write a "0" halfway down on the left and a "1" halfway down on the right.

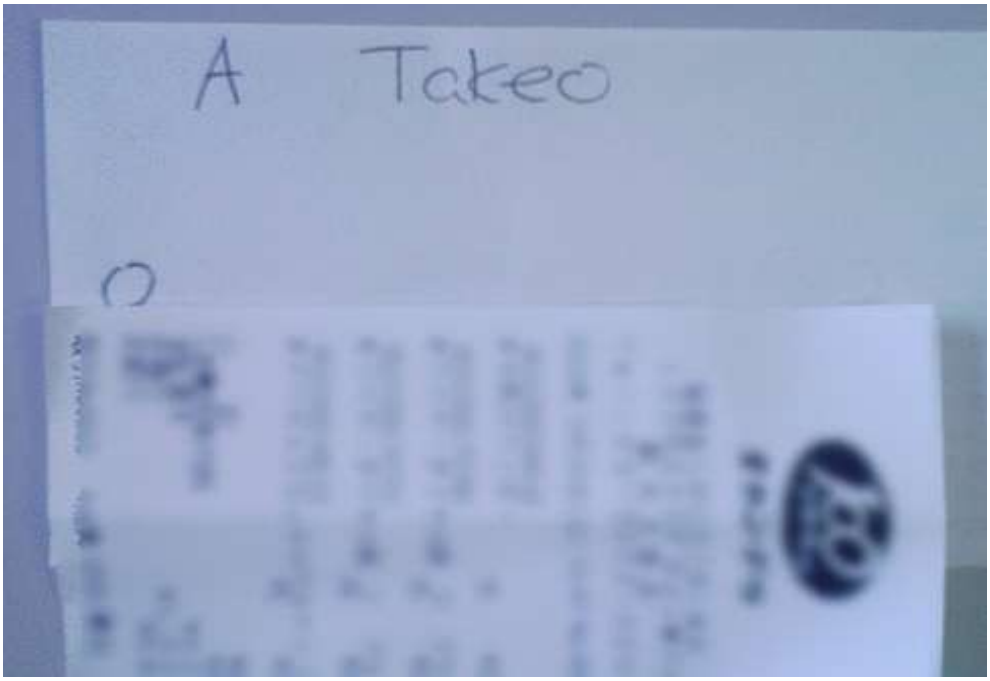
4. Prepare the parts as shown below (D is a spare in case you make a mistake)



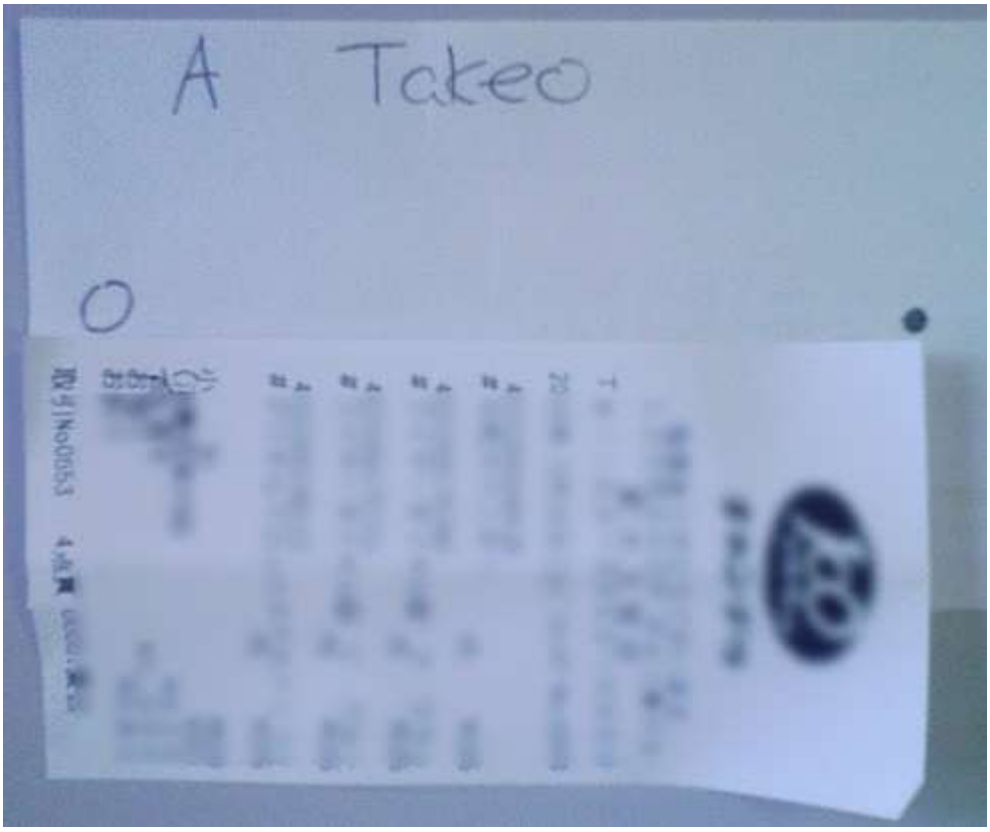
5. On part A: fold to make a crease along the middle (horizontally)



6. On the left side of Part A, place any object (e.g. a supermarket receipt) whose length is smaller than the sheet

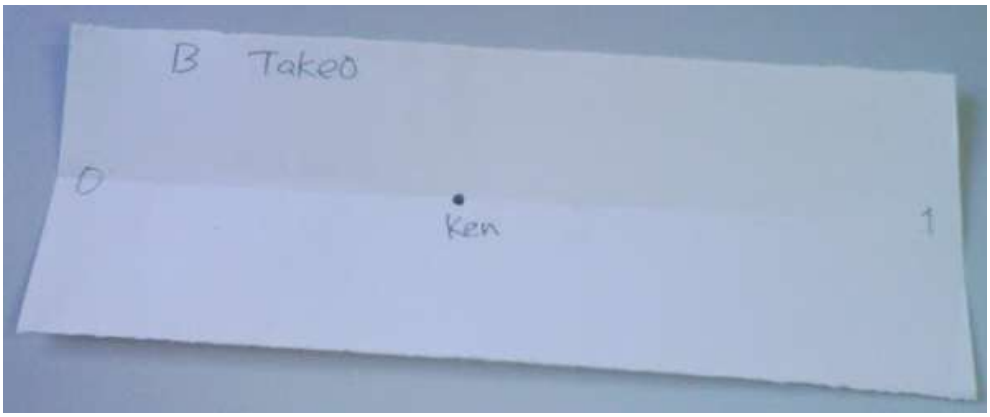


7. Draw a dot at the top right corner of the object on the crease on part A (this shows the length of the object from the left side of the paper).

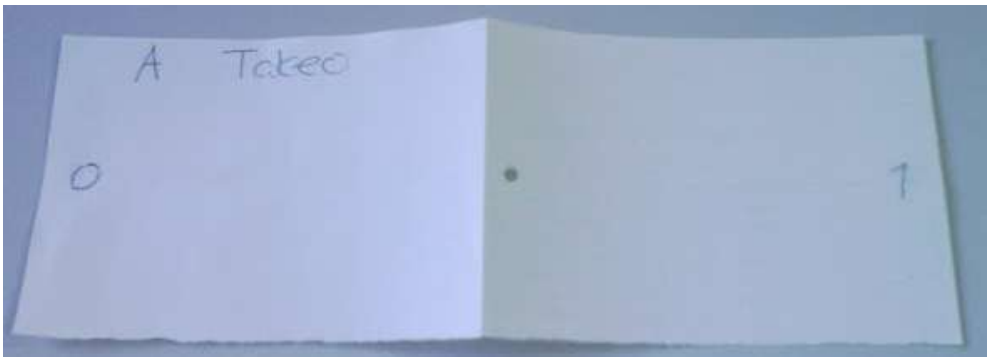


8. At this stage, your friend would have done the same as you with another object.
   In this example, your friend Ken has made a dot for a different object on his paper.
   You look at it, and try to estimate its position *from a distance*.

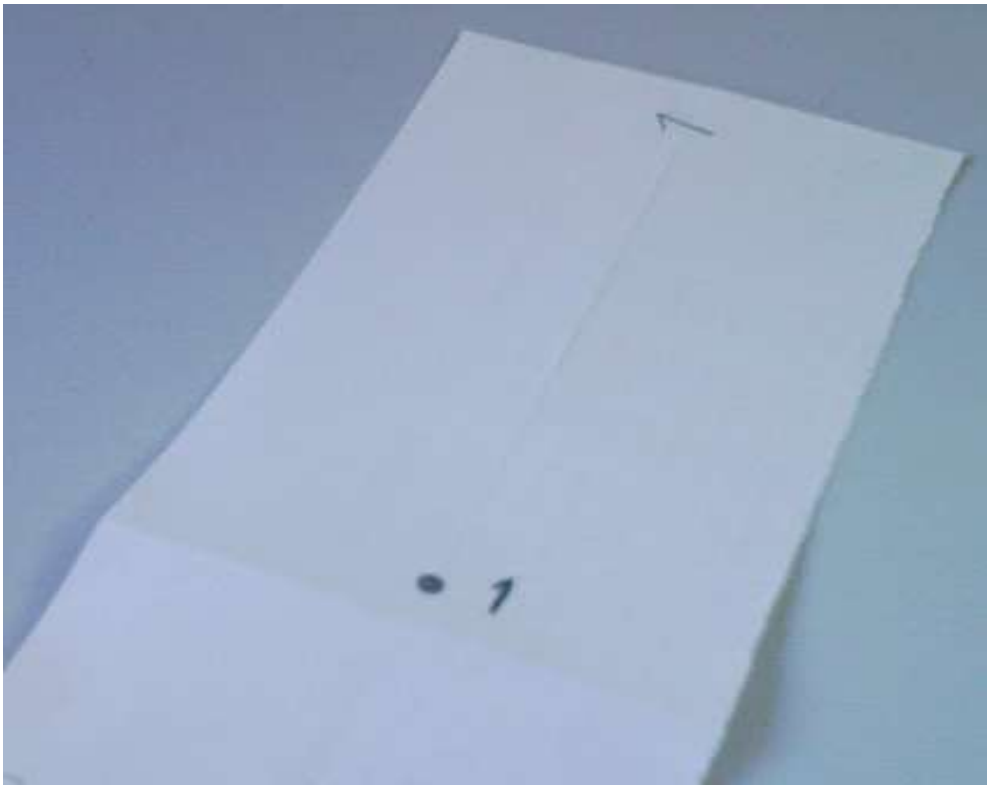
9. On your **part B**: put the dot where you estimate that Ken's dot is.
   This is a rough (analogue) estimate you are making by eyesight and at a distance!



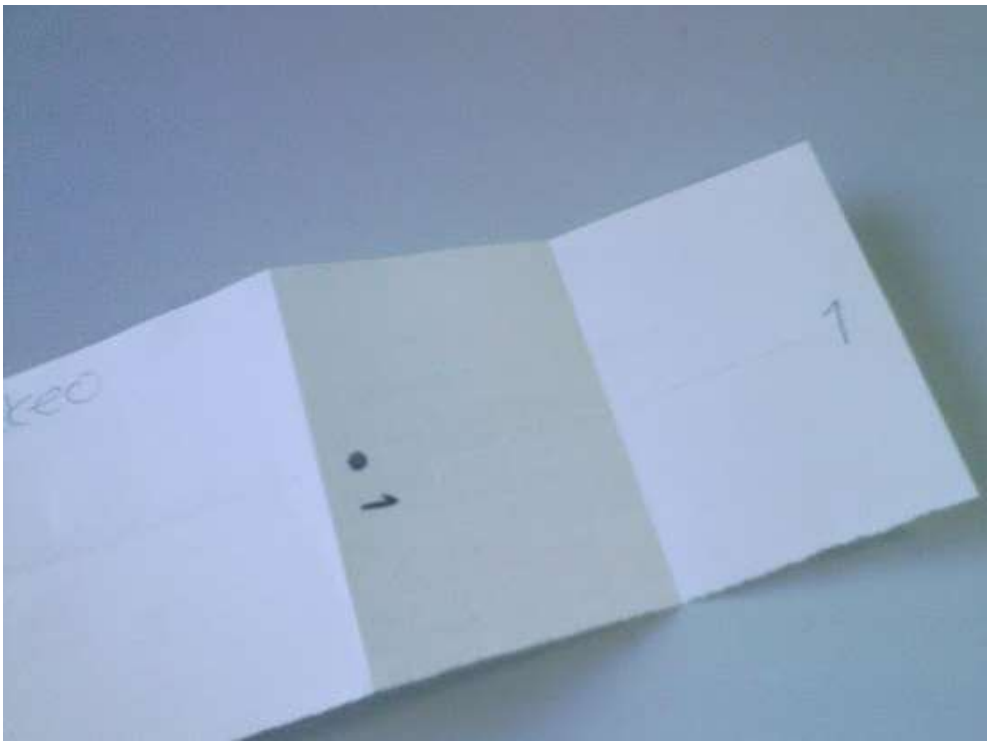
10. Come back to your **Part A**. On your part A: fold a crease in the middle (vertically)



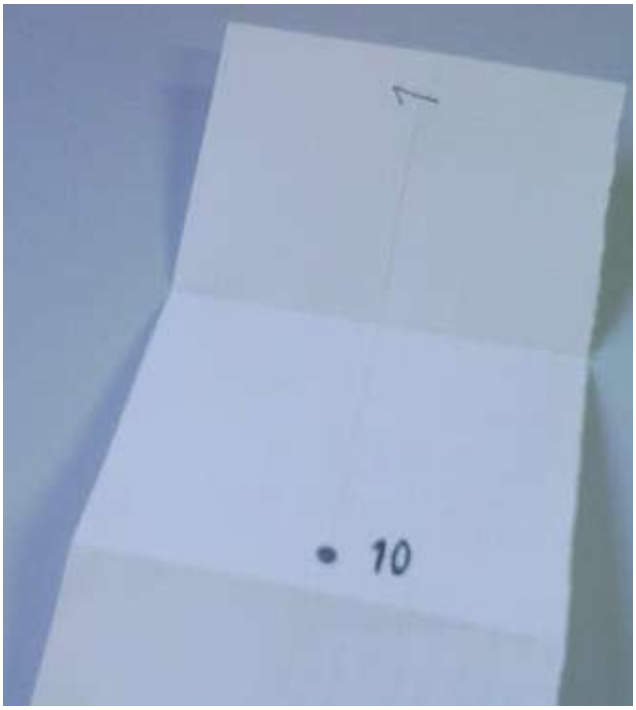
11. On part A: if your dot is to the left of the crease, write "0", otherwise write "1".



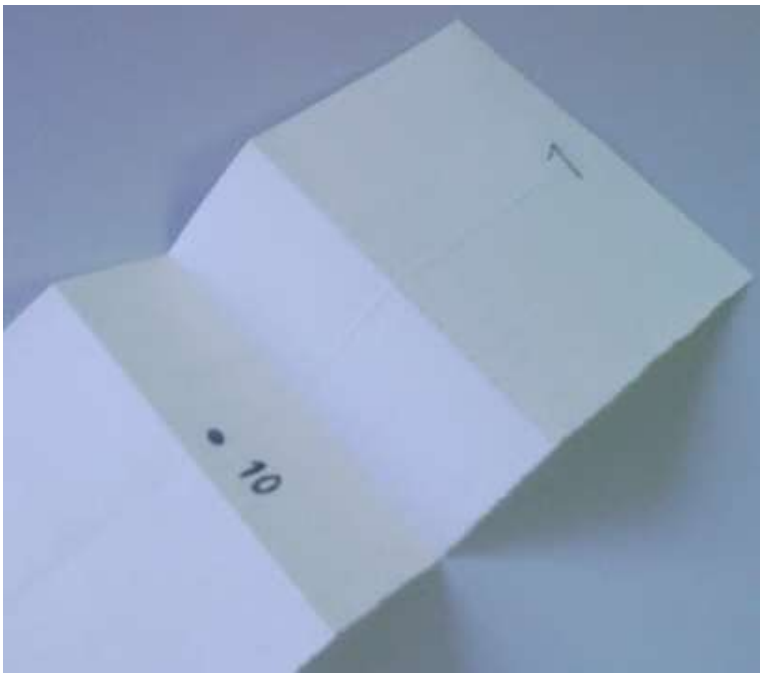
12. On part A: on the half that has the dot, fold a crease in the middle of that half.



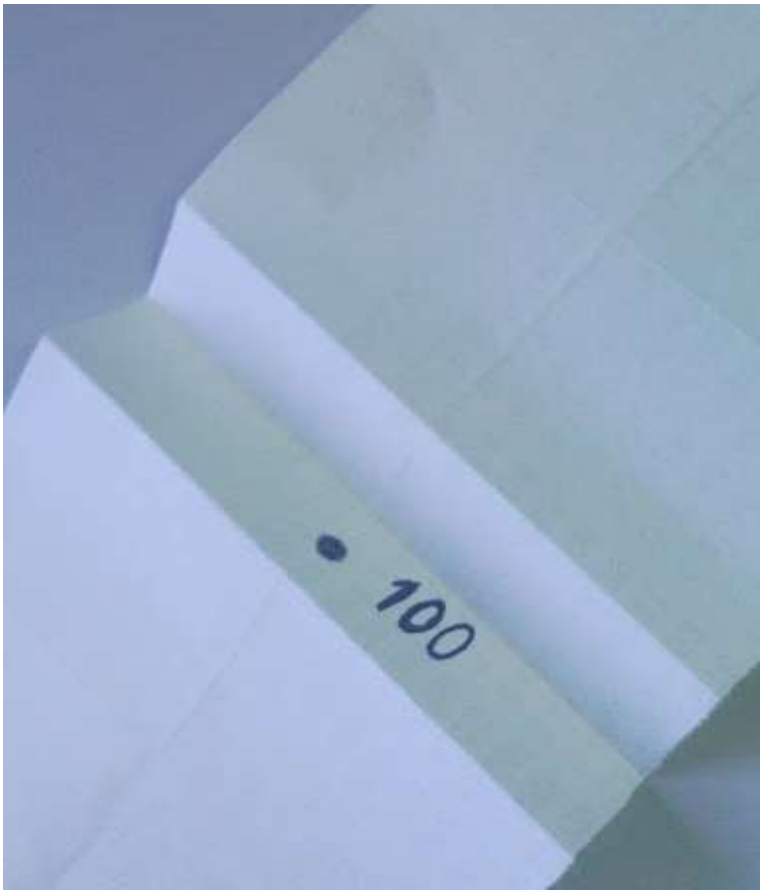
13. On part A: if your dot is on the left half of the half, write a "0", otherwise write "1".



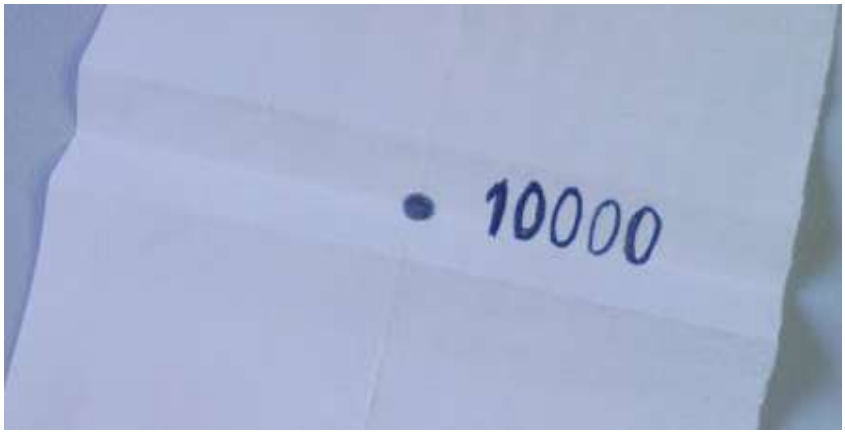
14. Again, fold the section with the dot in half.



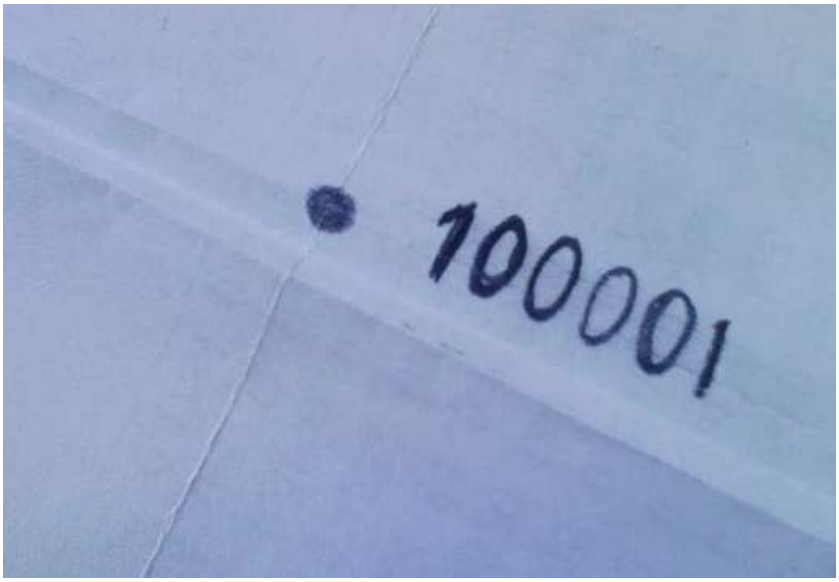
15. On part A: if your dot is on the left half of this quarter, write "0", otherwise write "1" again.



16. Continue to halve the section that contains the dot, writing "0" or "1" if the dot is on the left or right side of the crease respectively.

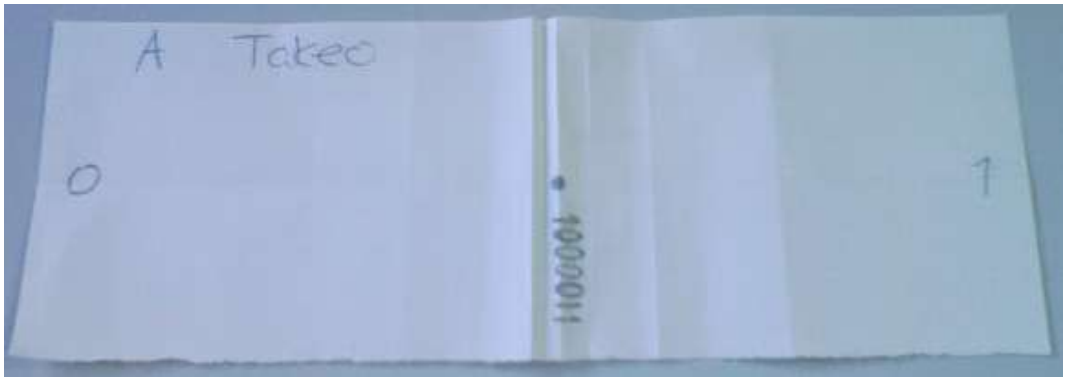


17. Continue this process.

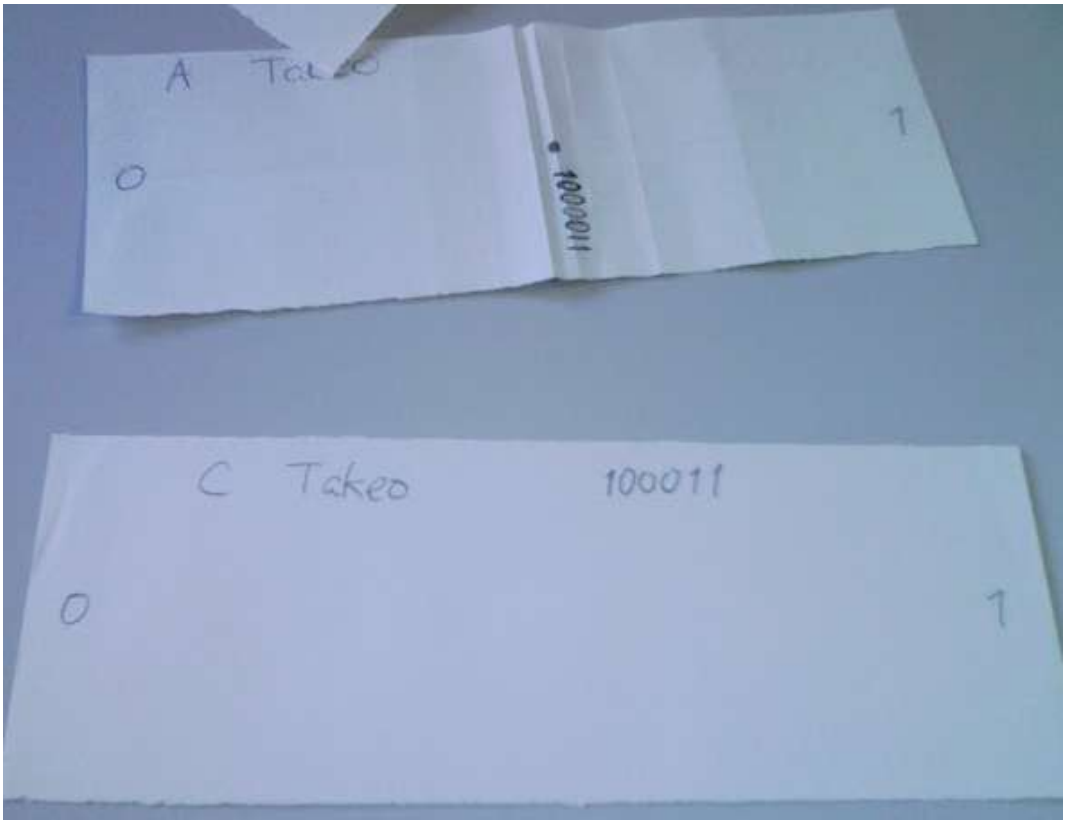


18. The goal in this activity is to get 7 bits written down.

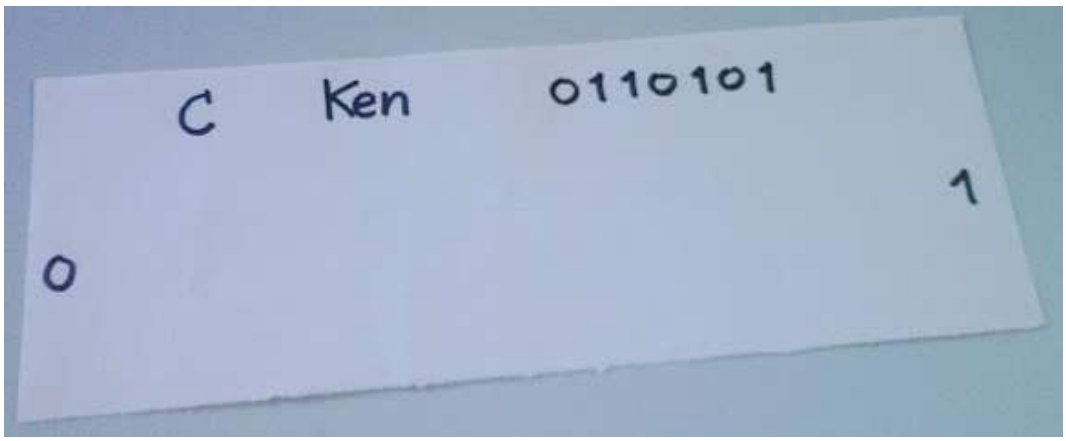
19. You've now written a 7 bit binary expression that locates the dot.



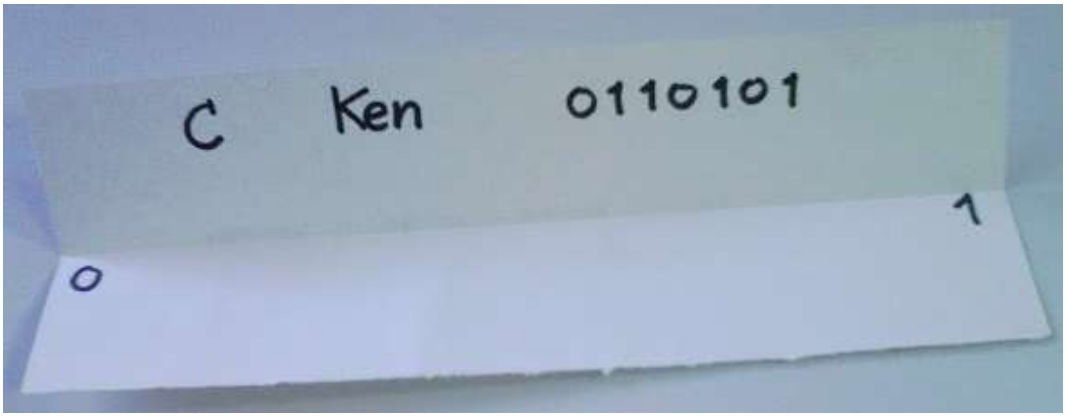
20. On **part C**: write only the 7 bits (without any folding) and give this paper to your friend Ken.



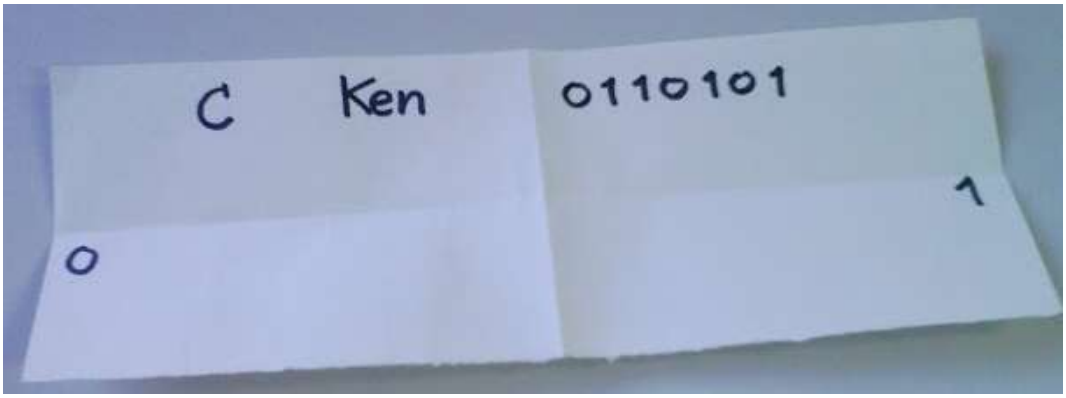
21. Now ask Ken for **his piece of part C**. Note that he has done the same steps as you.



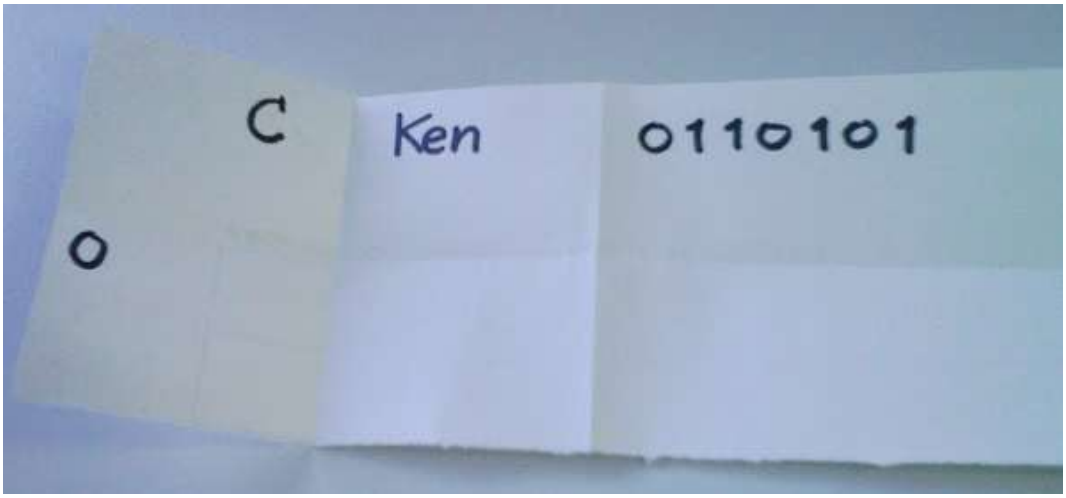
22. With **Ken's part C**: fold a horizontal crease on it (as you did with your part A)



23. Crease the paper in the middle (vertically)

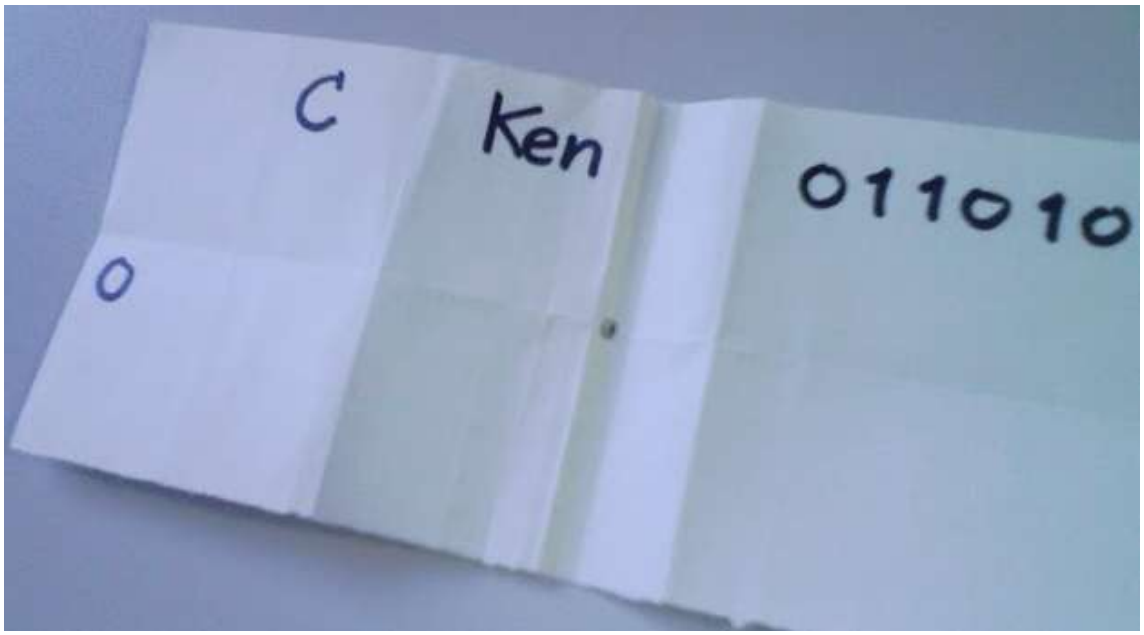


24. Because Ken's first bit is "0", you should crease the *left* half side in the middle.

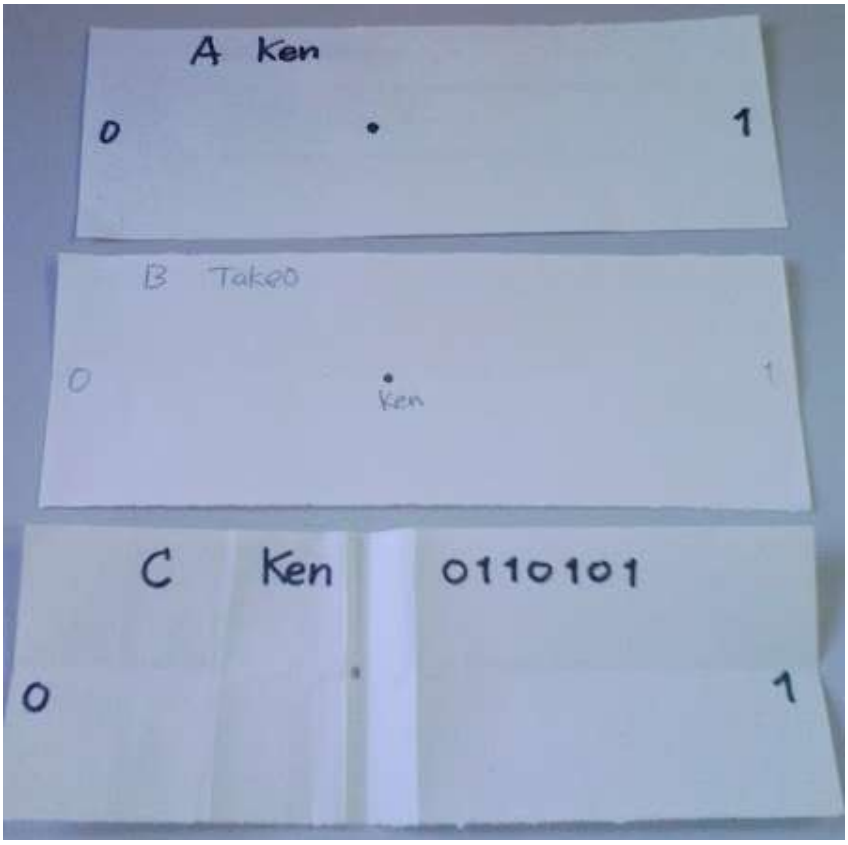


25. Because the second digit is "1", you crease the *right* half of the left half side.

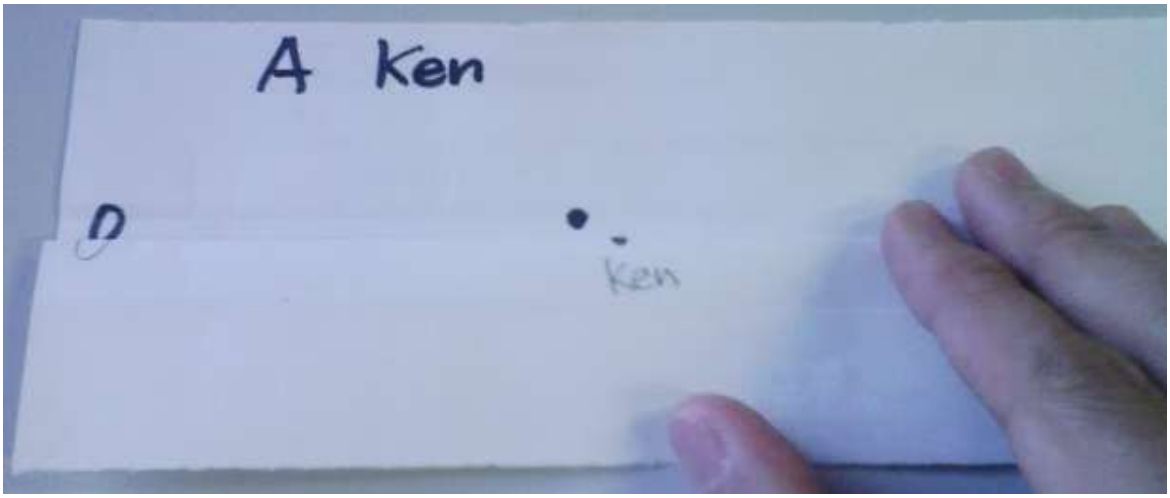
26. Carry on like this for each bit, choosing the left half for a “0” and the right half for a “1”. Now place a dot *on the last crease*.



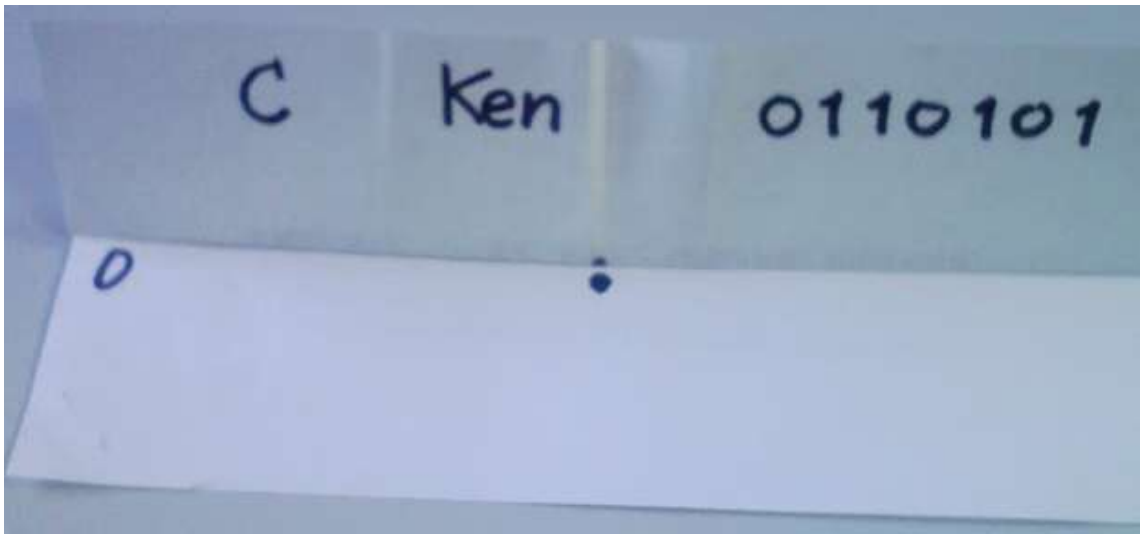
27. Now ask for **Ken's piece of part A**.



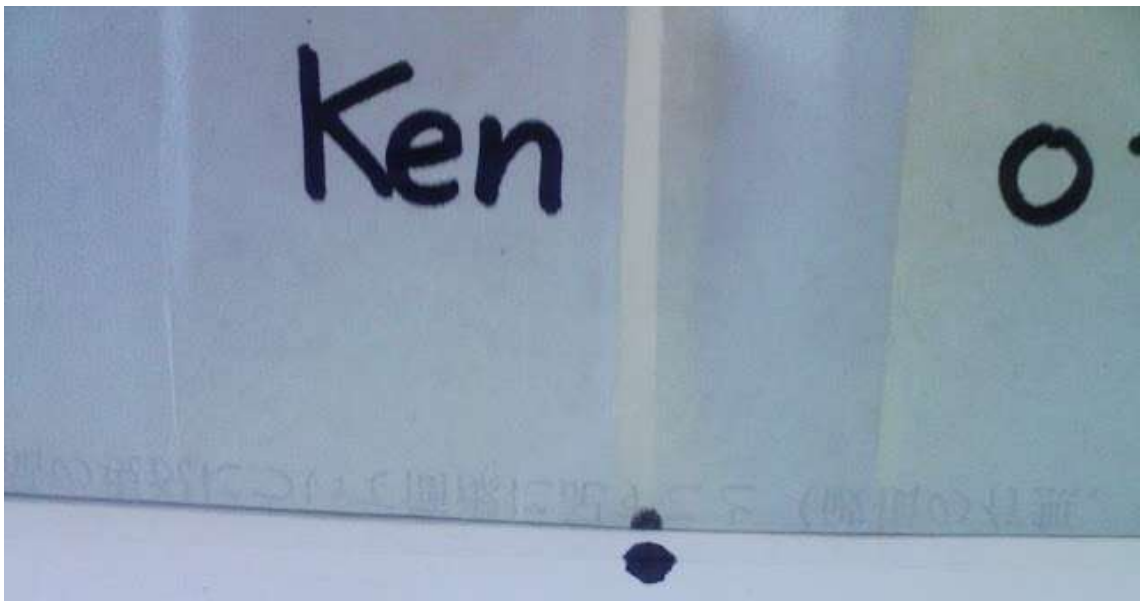
28. Compare the position of the dot on **Ken's piece of part A** (original) to **your part B** (the estimate you worked out yourself).
    You'll mostly find that your analogue measurement is not accurate. Remember this estimate was done merely by eyesight and is rough.



29. Now compare the dot on **Ken's piece of part A** (original) to **your part C**.
The digital (binary) representation should be more accurate!



30. Even then *it isn't exactly the same*. Why is this? (You should try to work this out for yourself.)



Note to Teachers:
At the end of the activity it becomes obvious that the analogue measurement used for estimation is not so accurate, however the digital measurement done in binary bits is more accurate. This quantization error is further amplified if only a 5 bit binary expression is used instead of a 7 bit one.

Extension: Decimal to Binary Conversion
Make the pieces of paper to be 32cms long and draw a dot for the number x (0 – 31) at x + 0.5cm; 5 folds will give you the binary number and vice versa.