LON-CAPA-based Test Printing and Scoring

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- Historical background and objectives
- Test printing procedure
- Test scoring procedure
- Equipment and cost
- Tips

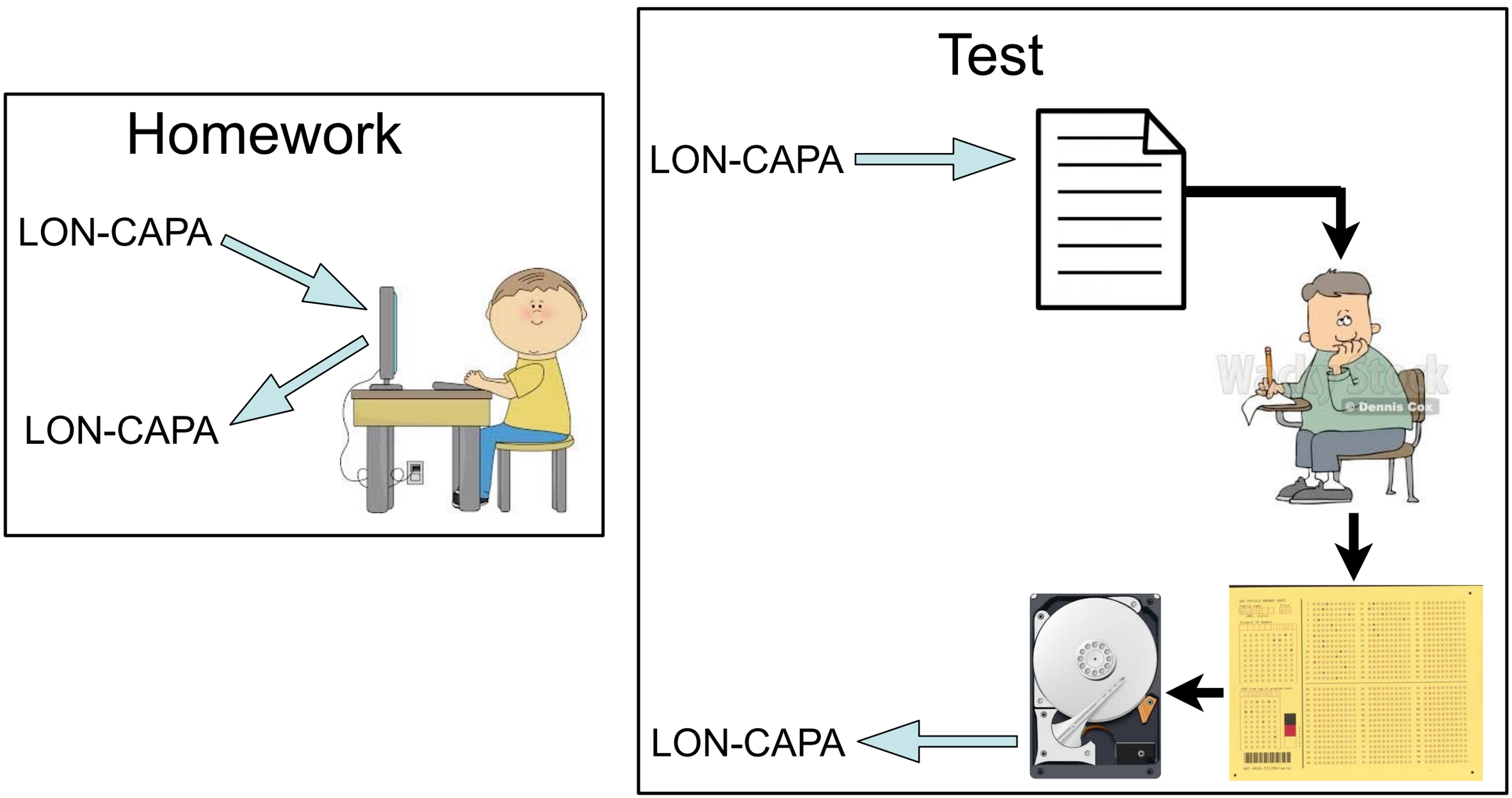
Historical Prolog

- USC started with CAPA-based automated assessment in 1998-99.
- The process was less labor intensive than hand grading, but it was far from quick and easy, and it was high-maintenance.
- In 2007 we started afresh with new tools, and our present system is an evolutionary descendant.
- No single overarching concept. The benefits accrue from a constellation of many features, many details.
- If you are not fully satisfied with your present assessment system, you may hear about one or two ideas that you would consider adopting.
- Otherwise, now might be a fine time to go on coffee break.

LON-CAPA Assessment System Objectives

- Ease of scoring
- Rapid and comprehensive reporting to students
- Objectivity of scoring
- Suppression of cheating
- Answers via hardcopy to prevent disputes
- Rapid distribution of tests at test time
- Redundancy as a defense against catastrophe

The External Loop



Assessment Cycle

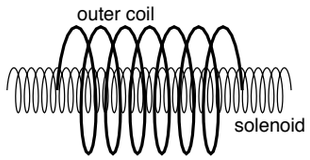
• Preparation of test questions	Instructor
• Preparation of ancillary materials	TA
– Bubble forms	
– Test-taking instructions	
– Formula sheets	
– Scratch sheets	
• Printing test packets	TA
• “Stuffing” test packets	TA
• Administration of the test	Instructor
• Unstuffing bubble forms	TA
• Scanning bubble forms	TA
• Processing scanned images	TA
• Uploading scores to LON-CAPA	TA

Test characteristics

- LON-CAPA algorithmically generates tests individualized for each student (anti-cheating).
- A six-digit code uniquely identifies each test.
- Typically questions come from a LON-CAPA library.
- Questions may come straight from the homework sets (at the instructor's discretion).
- Typically questions are 2/3 numeric, 1/3 qualitative
- Questions frequently include figures.
- LON-CAPA invokes LaTeX to generate printer-ready documents.
- Example:

Example Test

A very long solenoid with a circular cross section and radius r_1= 1.00 cm with n_s= 130 turns/cm lies inside a short coil of radius r_2= 3.60 cm and N_c= 29 turns.



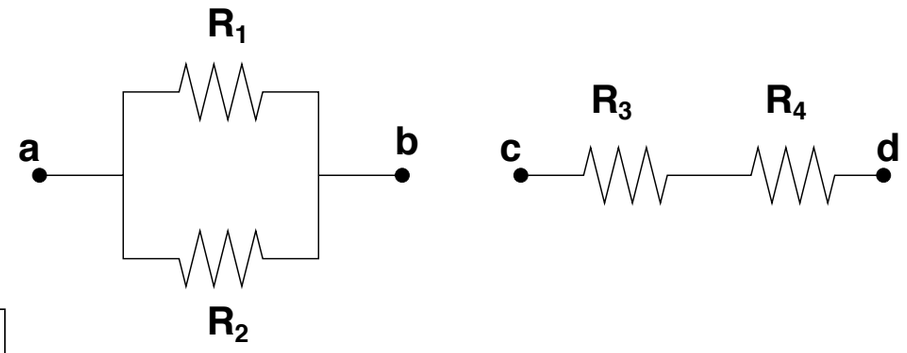
8 pt What is the mutual inductance between the solenoid and the short coil?

(in H*)*

6.A◯ 8.08×10^{-5} **B**◯ 9.13×10^{-5} **C**◯ 1.03×10^{-4}
D◯ 1.17×10^{-4} **E**◯ 1.32×10^{-4} **F**◯ 1.49×10^{-4}
G◯ 1.68×10^{-4} **H**◯ 1.90×10^{-4} **I**◯ 2.15×10^{-4}
J◯ 2.43×10^{-4}

8 pt

Consider two



8 pt

Consider the sections of two circuits illustrated above. Select True or False for all statements.

▷ After connecting **c** and **d** to a battery, the current through R_3 always equals the current through R_4.
12. **A**◯ True **B**◯ False

▷ After connecting **a** and **b** to a battery, the voltage across R_1 always equals the voltage across R_2.
13. **A**◯ True **B**◯ False

▷ R_{cd} is always less than or equal to R_3.
14. **A**◯ True **B**◯ False

▷ R_{ab} is always less than or equal to R_1.
15. **A**◯ True **B**◯ False

Bubble Forms History

- When we started CAPA-based testing, we bought a Scantron machine for about $3000.
- After a few years (~eight?) it was moribund.
- A replacement from Scantron would have cost about $7000.
- We rebelled and set off in a new direction:
  - Commodity raster image scanner and
  - Image processing software
- Disadvantages of Scantron forms
  - High cost
  - Need for inventory
  - No opportunity to choose the color of the paper
- We never looked back.

USC PHYSICS ANSWER SHEET

Family name First

(ABC… style)

Student ID Number

0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 1 1 1
2 2 2 2 2 2 2 2 2
3 3 3 3 3 3 3 3 3
4 4 4 4 4 4 4 4 4
5 5 5 5 5 5 5 5 5
6 6 6 6 6 6 6 6 6
7 7 7 7 7 7 7 7 7
8 8 8 8 8 8 8 8 8
9 9 9 9 9 9 9 9 9

CODE from top of problem sheet

0 0 0 0 0 0
1 1 1 1 1 1
2 2 2 2 2 2
3 3 3 3 3 3
4 4 4 4 4 4
5 5 5 5 5 5
6 6 6 6 6 6
7 7 7 7 7 7
8 8 8 8 8 8
9 9 9 9 9 9

G9101 8M

1 A B C D E F G H I J 16 A B C D E F G H I J 31 A B C D E F G H I J
2 A B C D E F G H I J 17 A B C D E F G H I J 32 A B C D E F G H I J
3 A B C D E F G H I J 18 A B C D E F G H I J 33 A B C D E F G H I J
4 A B C D E F G H I J 19 A B C D E F G H I J 34 A B C D E F G H I J
5 A B C D E F G H I J 20 A B C D E F G H I J 35 A B C D E F G H I J
6 A B C D E F G H I J 21 A B C D E F G H I J 36 A B C D E F G H I J
7 A B C D E F G H I J 22 A B C D E F G H I J 37 A B C D E F G H I J
8 A B C D E F G H I J 23 A B C D E F G H I J 38 A B C D E F G H I J
9 A B C D E F G H I J 24 A B C D E F G H I J 39 A B C D E F G H I J
10 A B C D E F G H I J 25 A B C D E F G H I J 40 A B C D E F G H I J
11 A B C D E F G H I J 26 A B C D E F G H I J 41 A B C D E F G H I J
12 A B C D E F G H I J 27 A B C D E F G H I J 42 A B C D E F G H I J
13 A B C D E F G H I J 28 A B C D E F G H I J 43 A B C D E F G H I J
14 A B C D E F G H I J 29 A B C D E F G H I J 44 A B C D E F G H I J
15 A B C D E F G H I J 30 A B C D E F G H I J 45 A B C D E F G H I J

46 A B C D E F G H I J 61 A B C D E F G H I J 76 A B C D E F G H I J
47 A B C D E F G H I J 62 A B C D E F G H I J 77 A B C D E F G H I J
48 A B C D E F G H I J 63 A B C D E F G H I J 78 A B C D E F G H I J
49 A B C D E F G H I J 64 A B C D E F G H I J 79 A B C D E F G H I J
50 A B C D E F G H I J 65 A B C D E F G H I J 80 A B C D E F G H I J
51 A B C D E F G H I J 66 A B C D E F G H I J 81 A B C D E F G H I J
52 A B C D E F G H I J 67 A B C D E F G H I J 82 A B C D E F G H I J
53 A B C D E F G H I J 68 A B C D E F G H I J 83 A B C D E F G H I J
54 A B C D E F G H I J 69 A B C D E F G H I J 84 A B C D E F G H I J
55 A B C D E F G H I J 70 A B C D E F G H I J 85 A B C D E F G H I J
56 A B C D E F G H I J 71 A B C D E F G H I J 86 A B C D E F G H I J
57 A B C D E F G H I J 72 A B C D E F G H I J 87 A B C D E F G H I J
58 A B C D E F G H I J 73 A B C D E F G H I J 88 A B C D E F G H I J
59 A B C D E F G H I J 74 A B C D E F G H I J 89 A B C D E F G H I J
60 A B C D E F G H I J 75 A B C D E F G H I J 90 A B C D E F G H I J

Bubble Forms

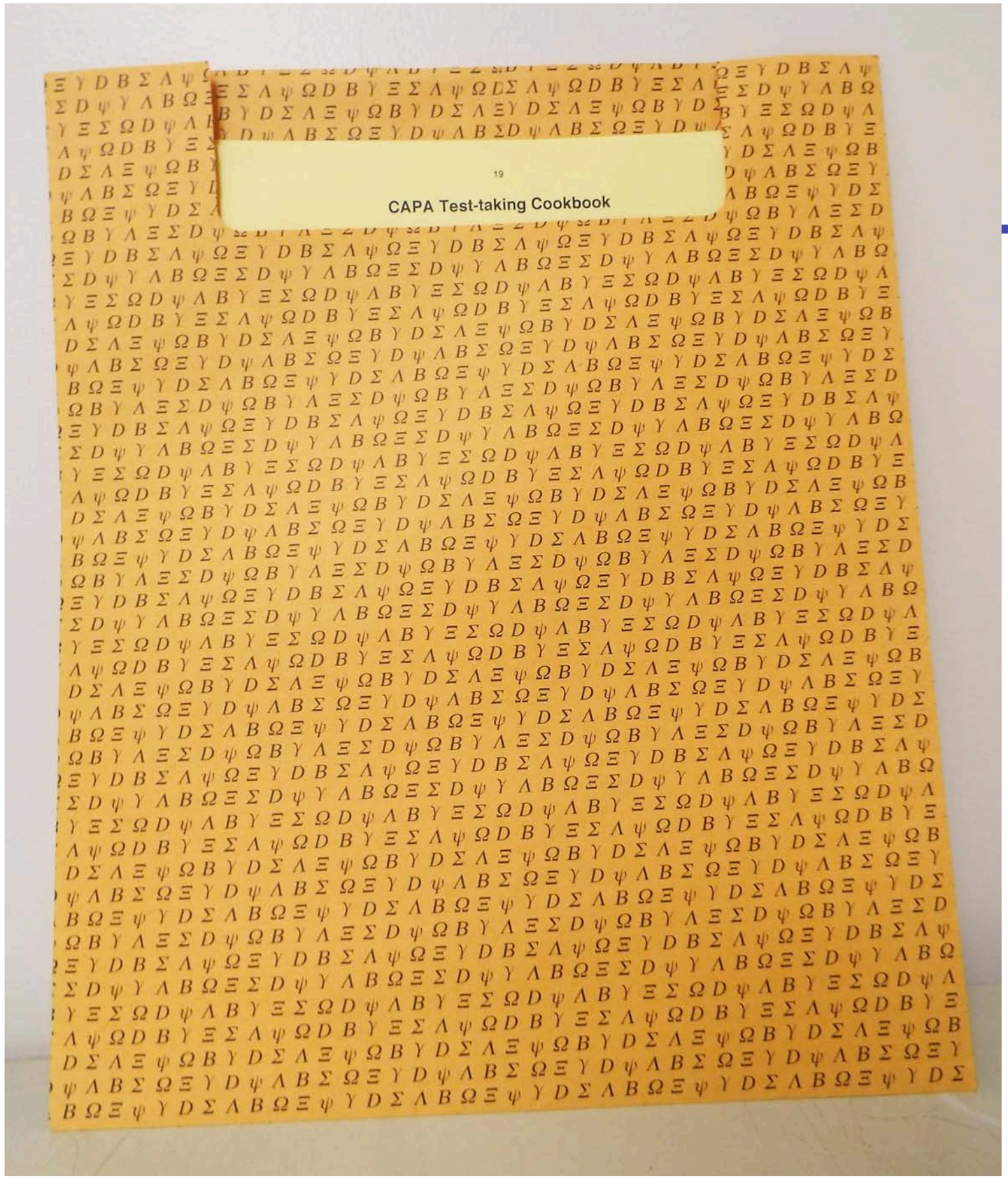
- Custom design(s), printed in house.
  - Less expensive than commercial Scantron forms.
  - Created on a Mac using commodity software (Numbers and EazyDraw).
- Printed as part of test packet preparation – no inventory.
- Designed for compatibility with Remark Office OMR software.
- Form includes corner fiducials used in the image processing to register the form.
- Bubble labels are internal to the bubbles.
  - Allows high bubble density.
  - Physics form has 90 rows of 10 bubbles for answers.
- Forms are printed on a color printer. Labels are magenta or cyan.
  - Image processing depends on color to “erase” the labels.
- Printed on colored paper with color selected for each test “randomly” from a universe of ten colors (anti-cheating).
- Forms are oversize, 8.5x11.375 in, to facilitate post-test separation from the packet.

Printing the Test Packets

(Bubble forms, problems, instructions, etc.)

- Printing utilizes a custom script (AppleScript) that collates the pages of a packet and sends the packets to a paused print queue at a rate of around one per second.
- The printer draws stock paper from a cassette and preprinted bubble forms from the multi-purpose feed slot.
- At packet print time a barcode representation of the test ID code is added to the bubble form.
- The TA redistributes the print jobs to four active print queues.
- The four printers are low-cost (~$400) HP models.
  - Individually they print at about 10 s/page, collectively at 2.5 s/page.
  - A 100-packet eight-page test prints in about 35 min.
- The TA stuffs finished packets into custom envelopes, and at that point they are ready for deployment. No other collating required.


HP Color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CAPA Test-taking Cookbook

Scanning

- The students return their tests in the original envelopes.
  - Between semesters we return the envelopes to stock for reuse.
- The TA removes the bubble forms from the envelopes (aided by the extra length of the forms) and orients them.
- The TA loads the forms on a commodity scanner and scans them to 24-bit/300-dpi TIFF files. These files are each 25 MB.
- The desirable properties of the scanner are
  - At least 300 dpi,
  - At least USB 2 connectivity,
  - A capacious input hopper,
  - High speed.

Scan Specifications

Scanner Type: Flatbed color image scanner with ADF

Optical Sensor: 1200 dpi 4 line color line sensor (RGB & Black)

Optical Resolution:

- Flatbed: 1200 dpi
- ADF: 600 dpi

Hardware Resolution:

- Flatbed: 1200 x 1200 dpi with Micro Step Drive™ technology
- ADF: 600 x 600 dpi Micro Step Drive™ technology

Color Bit Depth: 48-bits per pixel internal / external

Grayscale Bit Depth: 16-bits per pixel internal / external

Maximum Scan Area:

- Flatbed: 8.5" x 11.7"
- ADF: 8.5" x 40"

Light Source: ReadyScan LED

Scanning Speed:

200 dpi

- B/W: Up to 40 ppm / 80 ipm with ADF
- Color: Up to 40 ppm / 80 ipm with ADF

300 dpi

- B/W: Up to 40 ppm / 80 ipm with ADF
- Color: Up to 40 ppm / 80 ipm with ADF

600 dpi

- B/W: Up to 8 ppm / 16 ipm with ADF
- Color: Up to 8 ppm / 16 ipm with ADF

Type: Sheet fed 1-pass , duplex scanning

Capacity: 100 pages (80 g/m^2)

Document Sizes:

- A4, Letter, Legal, B5, A5
- Max. Size 8.5" x 40"
- Min. Size 4" x 6"

Paper Weight: Thickness 50 – 128 g/r ²

Epson WorkForce DS-7500

Features

Software:

- Epson Scan
- EPSON Event Manager (Mac onl
- ABBYY FineReader Sprint
- Document Capture Pro (Windows only)
- ISIS Driver (Web Distribution)

Connectivity

Scanner Interface:

- Hi-Speed USB 2.0
- Optional Network Module(RJ45, 10BaseT / 100Base TX)

Scantron iNSIGHT 4ES

Much higher cost than the Epson DS-7500.

Much worse performance for raster image scanning (as opposed to OMR).

Technical Specifications

Physical Description	Length: 21.25” Width: 14.5” Height: 9” Weight: 17 lbs
Environment	Operating Temperature: 60° to 85°F (16°C to 29°C) Humidity: 40% to 60%, non-condensating
Power	100-240 volt operation: 100-240 volts AC (-10%, +6%): 50-60 Hz; US 3-prong plug; 15 amp dedicated circuit
Communications	USB 2.0 connection—Image or OMR processing
Operation	• Dual Read Heads: 200 dots per inch (dpi) resolution, up to 256 levels of grayscale per pixel; pencil and ink read capabilities • Pencil or ink forms may be used • Scanning Rate: 2,800 sheets per hour in OMR mode, 2,300 sheets per hour in OMR with imaging mode. • Forms: 2.5” x 5” to 9” x 14” (60-100 lb. Offset). Uses both Mark Reflex B and Trans-Optic® forms • Form Input Capacity: Auto-feed, 100 sheets • Output Stacker Capacity: 100 sheets main stacker, 100 sheets select stacker (if present) • Controls: Two Push button programmable switches • Message Display: 40 character, alphanumeric • Multi-feed detection • Integrated ES/ScanMark™ Emulation Mode
Options	• A programmable interactive printer • Select stacker separates forms that fail edit checks • Bar code reader • SelfScore® option for classroom test scoring and surveys

USC PHYSICS ANSWER SHEET

Family name: Budd

First: Ka

(ABC... style)

Student ID Number: 1103

CODE from top of problem sheet: 220407

Question	Marked
1	D
2	C
3	I
4	B
5	E
6	F
7	A
8	C
9	C
10	G
11	F
12	A
13	H
14	C
15	F
16	B
17	A
18	D
19	I
20	B
21	B
22	C

Questions 23–90: A B C D E F G H I J (no marks)

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Image Processing A

- Phase 1: Registration and color reduction by application of custom macros in ImageJ. (ImageJ began life as NIH Image and is maintained by a staff member at NIH.)
- Requires about 3 s per form.
- The grayscale format of the output allocates eight bits to each pixel notwithstanding that each pixel takes one of just two values.
  - Output files are 8.4 MB.

USC PHYSICS ANSWER SHEET

Family name: Budd

First: Ka

(ABC… style)

Student ID Number: 1103

CODE from top of problem sheet: 220407

G9101 8M

407-4036-P212Morawiec

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

31 32 33 34 35 36 37 38 39 40 41 42 43 44 45

46 47 48 49 50 51 52 53 54 55 56 57 58 59 60

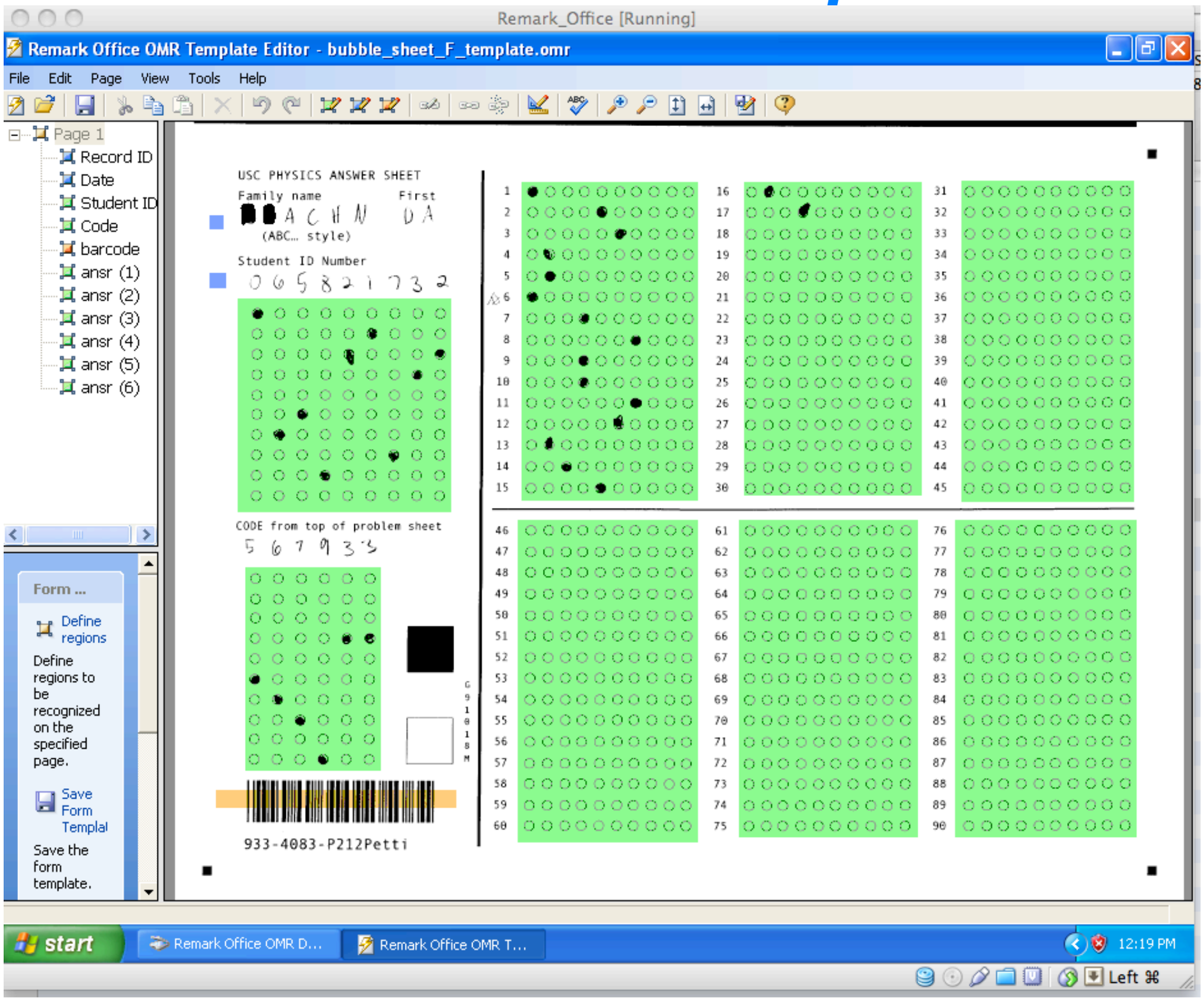
61 62 63 64 65 66 67 68 69 70 71 72 73 74 75

76 77 78 79 80 81 82 83 84 85 86 87 88 89 90

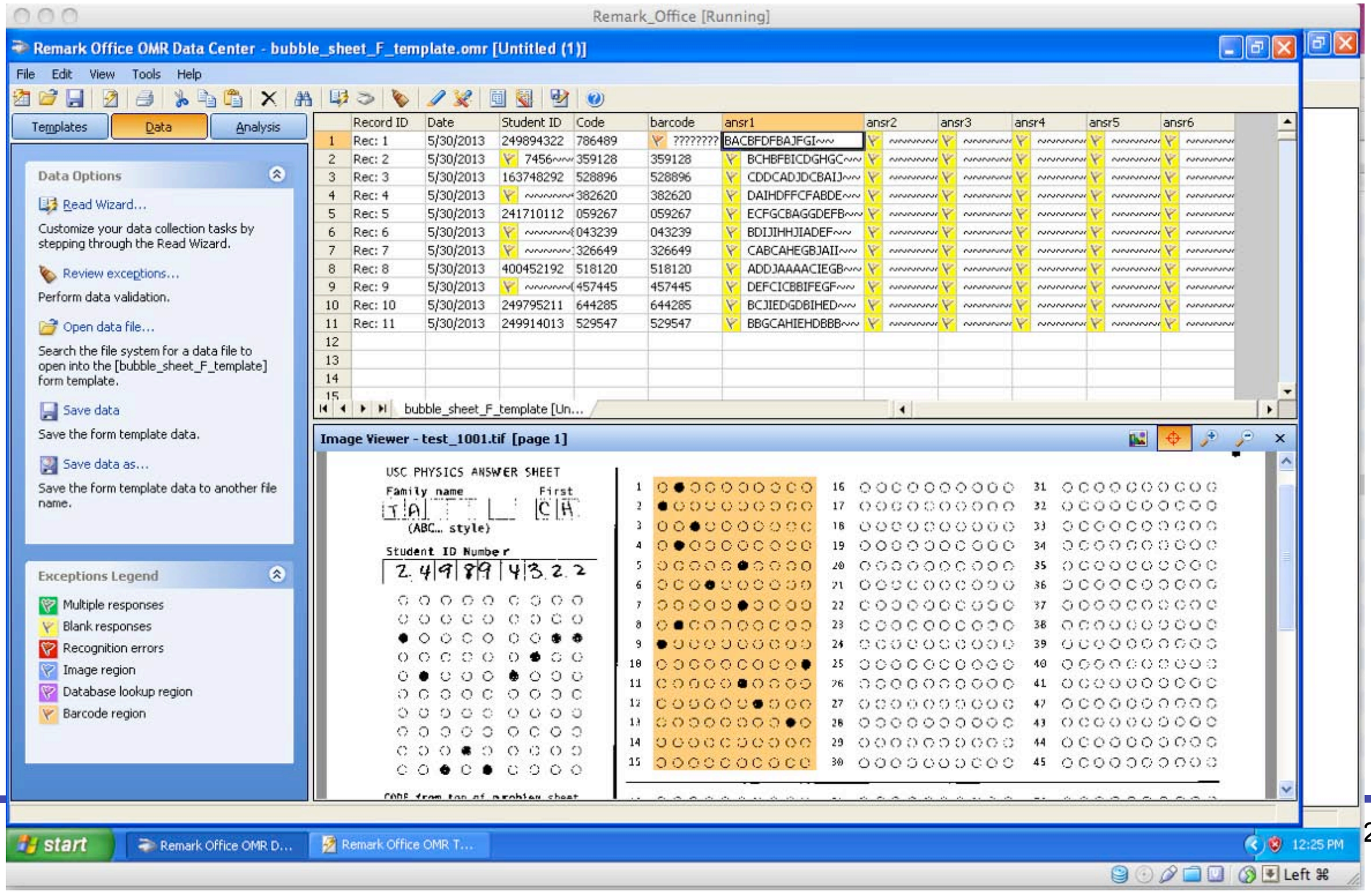
Image Processing B

- Phase 2: Recompression via GraphicConverter.
  - Reduces the final image file to one bit per pixel.
  - 8.4 MB -> 1.0 MB.
  - Remark Office copes better with B/W than with grayscale.
- Phase 3: Processing by Remark Office OMR.
  - Runs on a Mac in a MS Windows Virtual Box VM.
  - USC Physics is still using Ver. 6 (2005); current is Ver. 8.
  - Result is an Excel worksheet containing for all students
    - Student ID info
    - Test ID
    - Student's answers

Remark Office Template



Remark Office Processing



Data Format Conversion

- Phase 4: Conversion of spreadsheet data to a text file meeting the requirements for upload to LON-CAPA.
  - Done by conventional formulae in an Excel spreadsheet.
  - Matches the Student IDs from the bubble forms to the Student IDs of enrollees in the course.
  - Corrects single-digit errors in the Student ID.

Printing Components

- Mac with two displays and HD backup, $1300.
- One color laser printer, $1000.
- Four low-cost monochrome printers, $1600.
- Custom envelopes, 6000 for $3000.
- Adobe Acrobat X or later, $120.
- MS Excel, $$?
- Custom scripts (priceless).
- User manual (priceless).

Scoring Components

- Computer with HD backup, $1200.
  - But printing computer can serve at no additional cost.
- Commodity color scanner, $1100.
- ImageJ (no cost).
- GraphicConverter, $40.
- Remark Office OMR, $600 (edu price in 2007).
- MS Excel.
- Custom ImageJ macros (priceless).
- User manual (priceless).

Test-making Tips

- The first question of a test provides bonus points for good faith bubblers.

CODE - 022271 - 2014 Sp, Phys 212H(Rosenfeld) 1
Test 2

Name:

3 pt Did you enter your name at the top of this sheet?
Did you enter your name and VIP ID on the answer sheet and bubble in your VIP ID with opaque marks?
Did you enter the six-digit CODE at the top of this sheet in the CODE field on the answer sheet and bubble it in with opaque marks?

1. **A**◯ I did, I did, I did.
   B◯ Not yet.

- On numeric problems award one point for no answer. (A correct answer earns eight points.) Very effectively suppresses guessing, which tends to undermine the utility of difficult questions.
- On T/F problems score as Value * (# correct - # wrong)/(# of leaves) but never < 0. Likewise suppresses guessing.
- The above two strategies require use of the LON-CAPA “spreadsheet” for calculating scores.

Wrap-up

- The system we describe above has been evolving at U South Carolina for 16 years.
- It processes about 4000 tests / semester.
- It has now reached a state of near perfection, and needs only occasional maintenance.
- Perhaps some features will be of interest to other domains.

Finis