

# OCR-Based Autograder for Handwritten Content

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# The Problem

Hand grading free-response questions for physics and math is a pain.

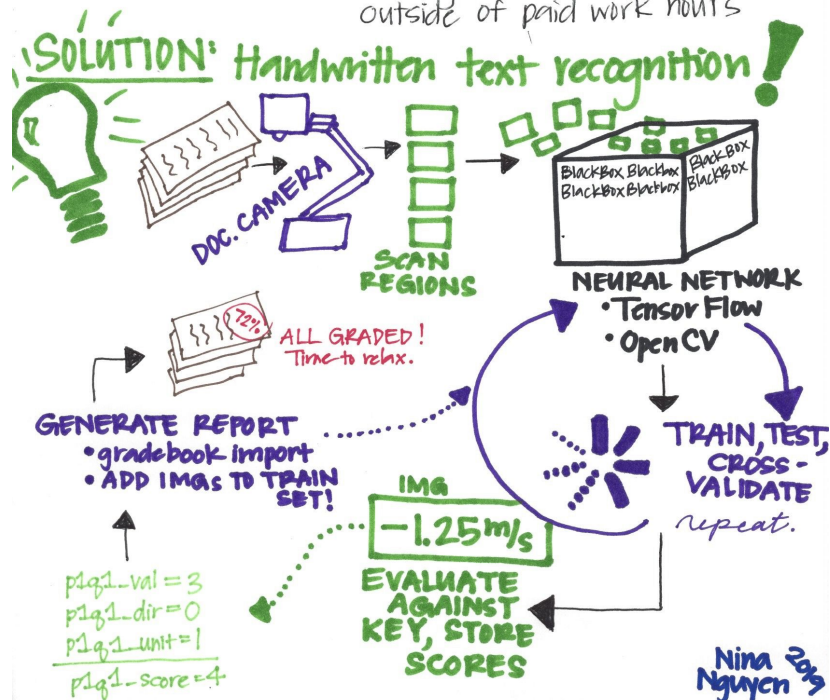
It is a monotonous process that can be automated due to limited characters and symbols, unlike English/history.

Why should a human do this when a computer can?

PROBLEM: "Not enough time, or red pens!"



- Task: hand-grade 150+ exams (free-response section)
- Magnitude: 10-15 parts per exam, evaluating 3 measures each (value, units, direction)
- Not Fun: scoring 4500-6750 items outside of paid work hours



# Inspiration

Illuminate has rendered ScanTron obsolete with OCR grading.

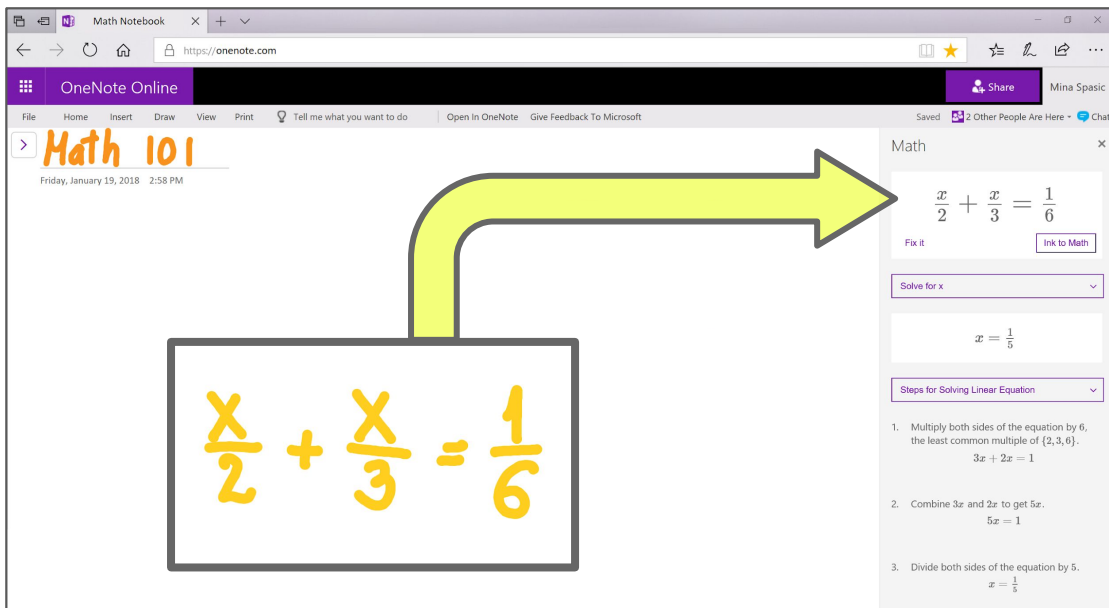
## Key Features:

- Test-specific forms
- Automatic gradebook entry
- Doc cam or webcam

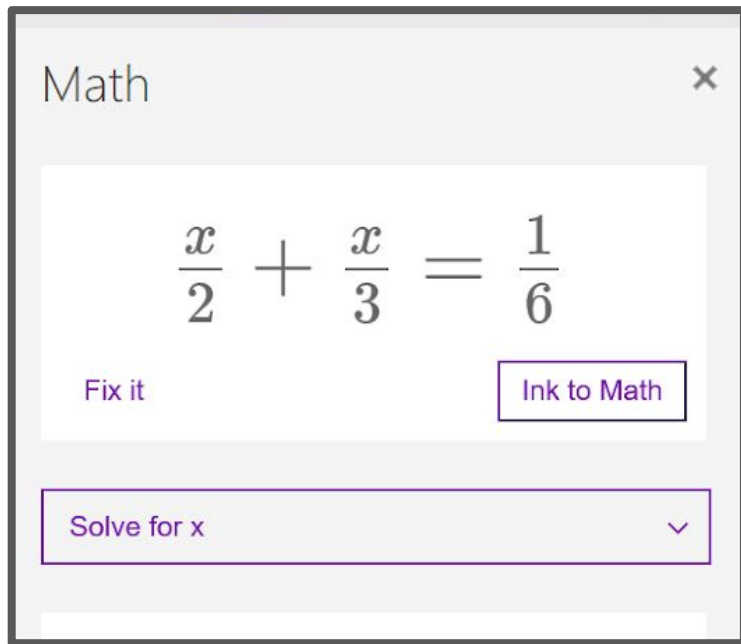


# Ink-spiration

Penstroke recognition by Microsoft



The screenshot shows the OneNote Online web interface. In the top left, there is a handwritten note titled "Math 101" with the date "Friday, January 19, 2018 2:58 PM". A large yellow arrow points from this note to a floating window titled "Math". This window contains the equation  $\frac{x}{2} + \frac{x}{3} = \frac{1}{6}$  and several interactive buttons: "Fix it", "Ink to Math", and "Solve for x". Below the equation, the solution  $x = \frac{1}{5}$  is displayed. At the bottom of the window, there is a section titled "Steps for Solving Linear Equation" with three numbered steps: 1. Multiply both sides of the equation by 6, the least common multiple of {2,3,6}. 2. Combine 3x and 2x to get 5x. 3. Divide both sides of the equation by 5.



This is a close-up of the floating "Math" window. It displays the equation  $\frac{x}{2} + \frac{x}{3} = \frac{1}{6}$  in a large font. Below the equation, there are three buttons: "Fix it", "Ink to Math", and "Solve for x". The "Solve for x" button is highlighted with a purple border and a dropdown arrow.



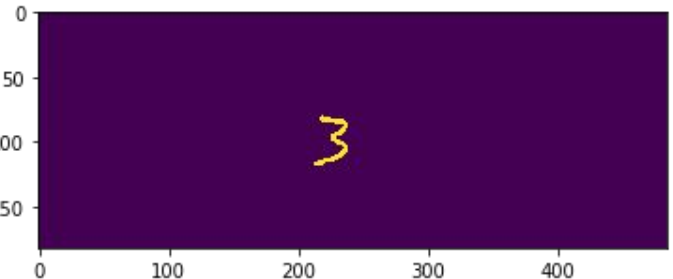
## 0) Convert InkML to .png

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InkML is a XML data type for digital ink data obtained from an electronic pen or stylus.

## 2) Segmentation

### 3) Object isolation/processing

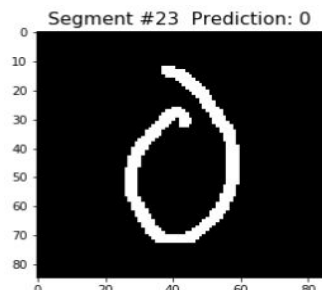
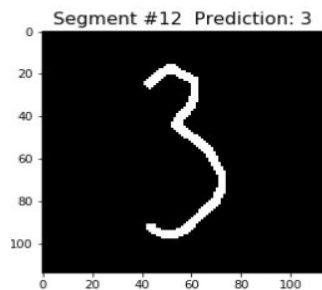


# Segmentation Challenges

How many segments do you see?

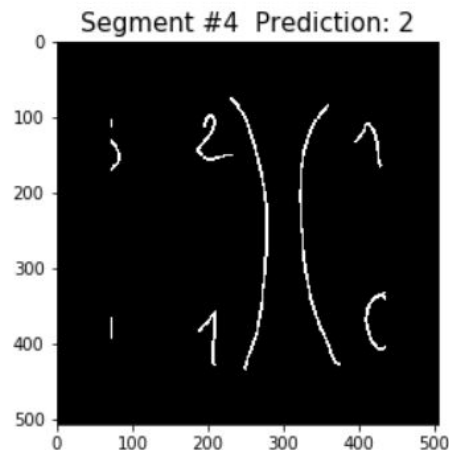
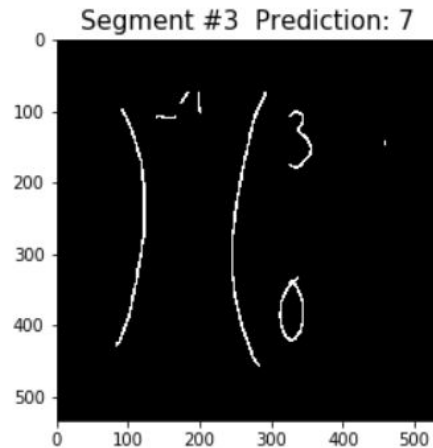
$$\begin{pmatrix} 3 & 0 \\ 0 & 1 \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & -1 \end{pmatrix}^{-1} \begin{pmatrix} 3 & 2 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 1 \\ 0 & -1 \end{pmatrix}$$

As expected, we get:



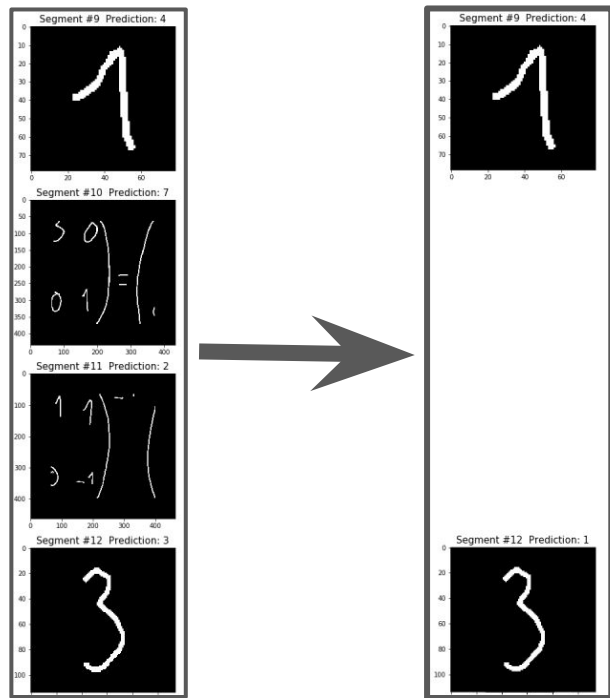
and so on...

.....But wait, there's more!

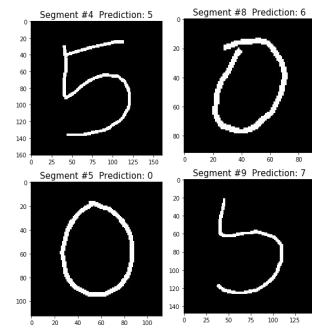
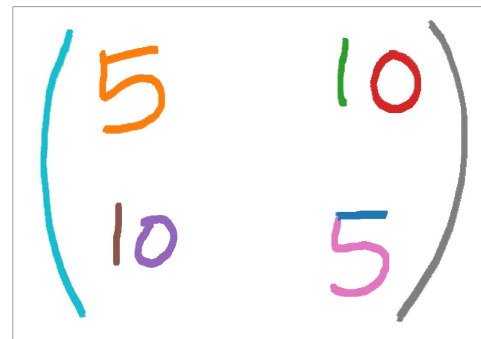
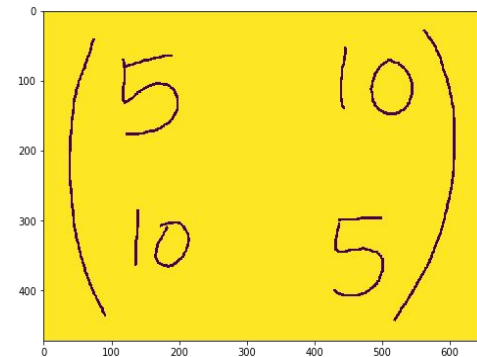


# Segmentation Challenges

Write code to ignore such segments before isolation.



...which helps most things,  
but can cause other issues.



Simplify the Problem at Hand:  
Generate Test Images

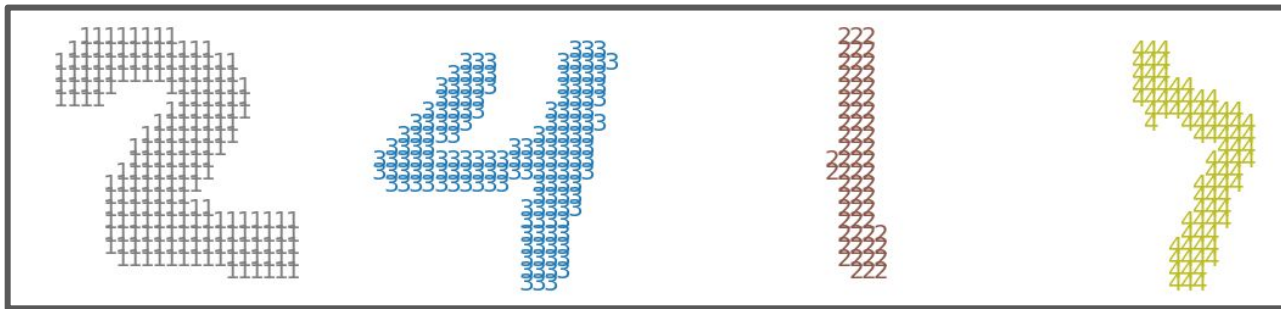


# Process

## 1) Raw Image Creation

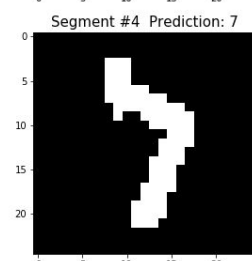
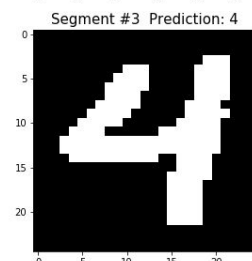
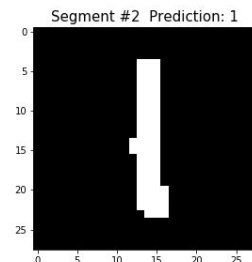
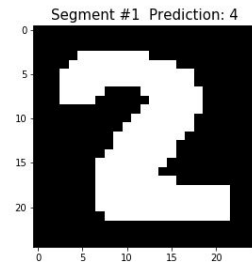


## 2) Segmentation

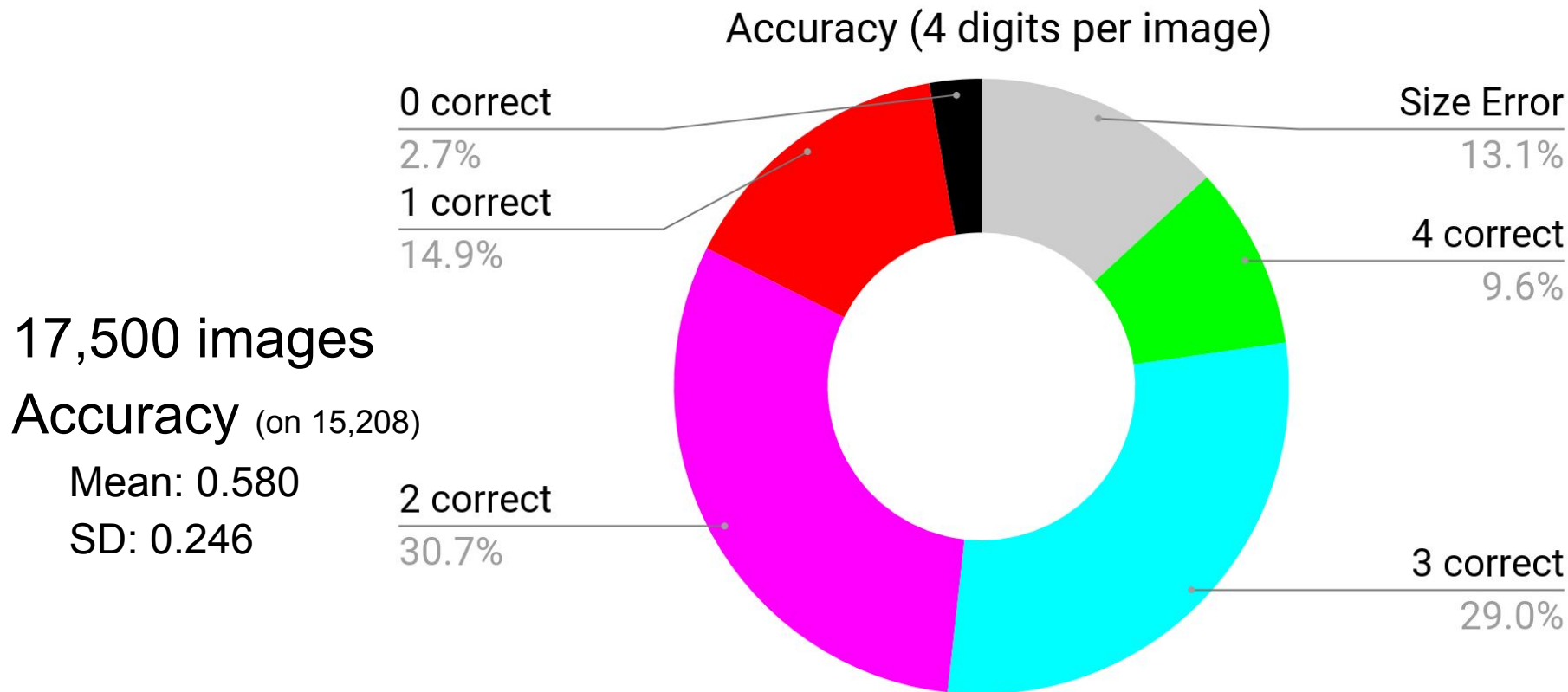


## 3) The Fun Part

- a) Isolate objects
- b) Make square (non-trivial task)
- c) Resize to 28x28
- d) Make individual predictions



# Decision Tree Classifier



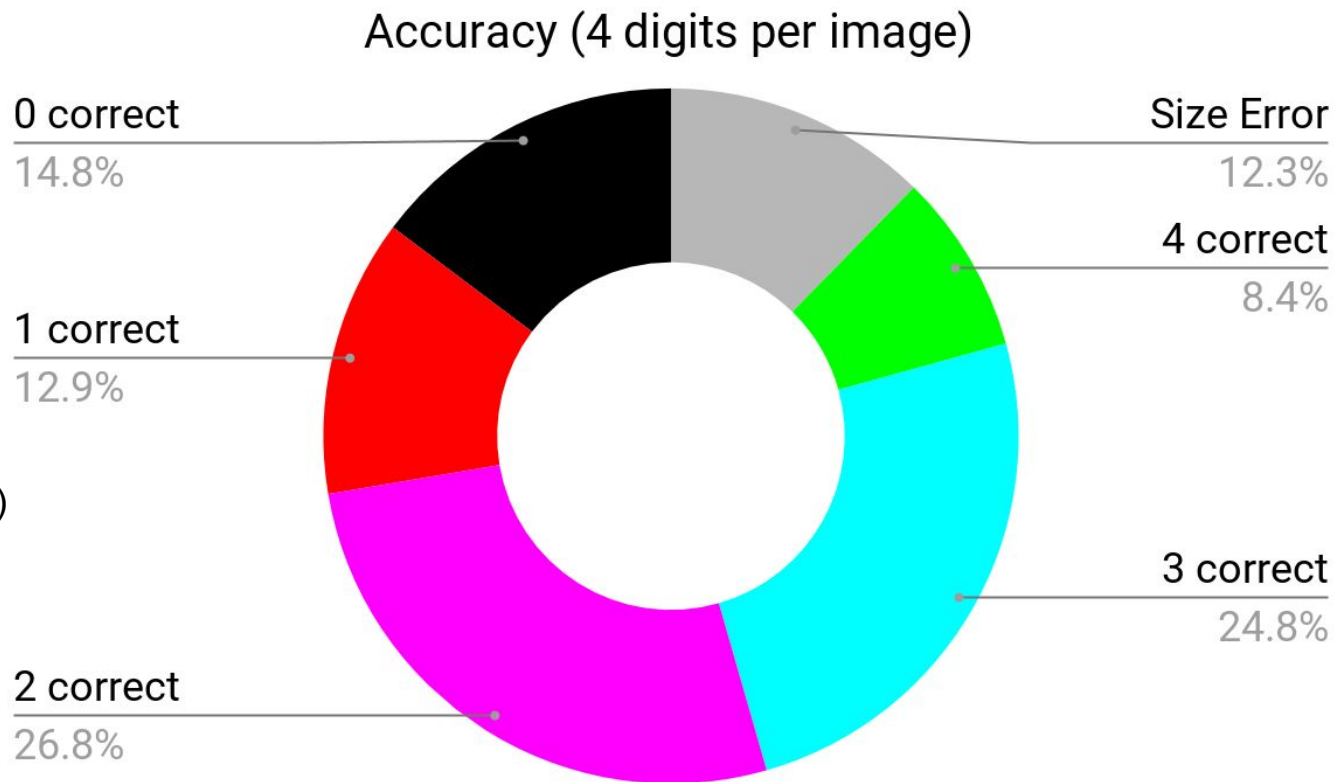
# SVM Classifier

17,500 images

Accuracy (on 15,042)

Mean: 0.579

SD: 0.246



# Results

Size Error results needs a deeper look.

image	truth	predict	correct
/merge_4_7____3982.png	[3, 9, 8, 2]	[3, None, 2, 8, 2]	False
/merge_4_8____1551.png	[1, 5, 5, 1]	[1, 2, 2, 8, 8]	False
/merge_4_17____9373.png	[9, 3, 7, 3]	[8, 3, 2, None, None]	False
/merge_4_21____0245.png	[0, 2, 4, 5]	[5, 2, 4, None, None, 2]	False
/merge_4_25____1037.png	[1, 0, 3, 7]	[8, 0, 3, 2, None]	False
...	...	...	...
/e_4_17477____5949.png	[5, 9, 4, 9]	[5, 8, None, None, 8]	False
/e_4_17479____4067.png	[4, 0, 6, 7]	[4, 0, 6, None, 8]	False
/e_4_17485____5881.png	[5, 8, 8, 1]	[None, 4, 8, 8, 1]	False
/e_4_17488____3085.png	[3, 0, 8, 5]	[3, 0, 8, None, 4]	False
/e_4_17489____3093.png	[3, 0, 9, 3]	[3, 0, 8, None, None]	False

image	truth	predict	correct	score
17460____0414.png	[0, 4, 1, 4]	[0, 4, 1, 4]	[True, True, True, True]	1.00
17461____8443.png	[8, 4, 4, 3]	[8, 4, 4, 3]	[True, True, True, True]	1.00
17463____2446.png	[2, 4, 4, 6]	[2, 4, 4, 8]	[True, True, True, False]	0.75
17464____7761.png	[7, 7, 6, 1]	[2, 2, 6, 8]	[False, False, True, False]	0.25
17465____4866.png	[4, 8, 6, 6]	[4, 8, 6, 8]	[True, True, True, False]	0.75
17466____1170.png	[1, 1, 7, 0]	[1, 1, 2, 0]	[True, True, False, True]	0.75
17468____0351.png	[0, 3, 5, 1]	[0, 2, 5, 1]	[True, False, True, True]	0.75
17470____9106.png	[9, 1, 0, 6]	[3, 8, 0, 0]	[False, False, True, False]	0.25
17473____6187.png	[6, 1, 8, 7]	[0, 7, 8, 5]	[False, False, True, False]	0.25
17474____9427.png	[9, 4, 2, 7]	[8, 4, 2, 2]	[False, True, True, False]	0.50
17475____0976.png	[0, 9, 7, 6]	[0, 8, 2, 8]	[True, False, False, False]	0.25
17476____3694.png	[3, 6, 9, 4]	[3, 6, 8, 8]	[True, True, False, False]	0.50
17478____7058.png	[7, 0, 5, 8]	[8, 0, 5, 8]	[False, True, True, True]	0.75
17480____9618.png	[9, 6, 1, 8]	[8, 6, 1, 8]	[False, True, True, True]	0.75
17481____9693.png	[9, 6, 9, 3]	[8, 0, 8, 3]	[False, False, False, True]	0.25
17482____8660.png	[8, 6, 6, 0]	[8, 0, 8, 0]	[True, False, False, True]	0.50
17483____4302.png	[4, 3, 0, 2]	[8, 3, 0, 2]	[False, True, True, True]	0.75

# Nitty Gritty

## Text Recognition Areas

area = IDs

response areas

Free Response

To receive full credit, you must include units in your final answer. Write answers in the boxes.

1) A rope is used to pull a 4.75-kg bucket of water out of a deep well. What is the acceleration of the bucket when the tension in the rope is 52.5 N?

2) A 2000-kg car heading right is skidding to a stop along a horizontal surface. The car starts off at a speed of 52.7 m/s and comes to rest in 3.10 seconds. What is the acceleration?

3) Mira and Tariq are lab partners. They have determined that the 2.15-kg brick is experiencing a leftward tension force of 12.8 N and a friction force of 6.4 N as it is accelerated across the table top. Using the box below, construct a free-body diagram depicting the types of forces acting upon the brick. Assume that the right and up directions are positive.

a. What is the force due to gravity (aka. weight) of the brick?

b. What is the net force in the x-direction?

c. What is the net force in the y-direction?

name per

Name: John Doe Period: 4

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① parse p1q1

p1q1 score = 4

#2: value = 3  
dir = 0  
unit = 0 ∴ p1q2 score = 3

#3a: val = 3  
dir = 0  
unit = 1 ∴ p1q3 score = 4

#3b: val = 0  
dir = 1  
unit = 1 ∴ p1q4 score = 2

#3c: val = 3  
dir = NULL  
unit = 1 ∴ p1q5 score = 4

17

21.07 N

4.6 N ←

0 N

② acceptable answers

0/1 p1q1-dir: {+, ↑, up}

3/3 p1q1-val: {1.25,  $\frac{5}{4}$ , 1.3}

1/1 p1q1-unit: { $\frac{m}{s^2}$ ,  $ms^{-2}$ }

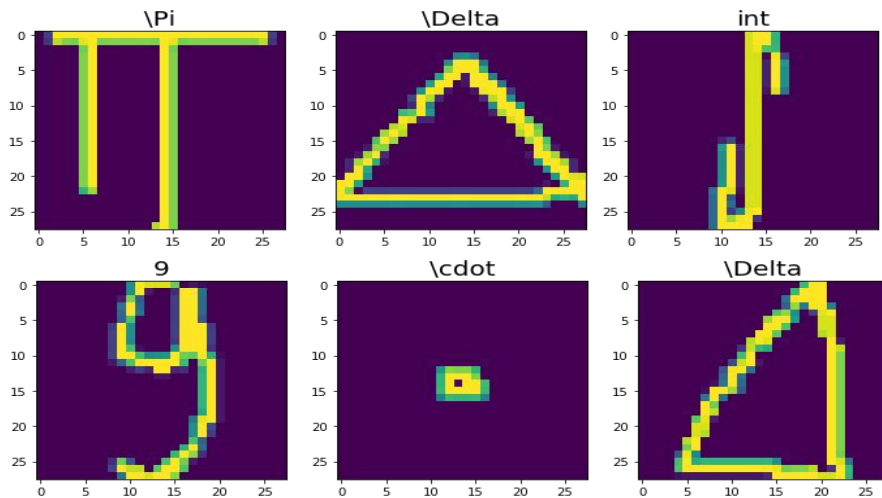
③ assign score given predeclared weight

④ page total p1 = 17 (max 24) p1q1-score = 4



# Future Directions

- 1) Units & direction
- 2) Organic chemistry
- 3) OCR + NLP



Name: \_\_\_\_\_ Period: \_\_\_\_\_

- 4) Kelli and Jarvis are members of the stage crew for the talent show. Between acts, they must quickly move a Baby Grand Piano onto the stage. After the curtain closes, they exert a sudden rightward force of 617 N to budge the piano from rest. The 220-kg piano experiences 508 N of friction. What is the piano's acceleration during this phase of its motion?

Free-body diagram for the piano:

$$F_{app} = 617 \text{ N} \rightarrow$$

$$F_f = 508 \text{ N} \leftarrow$$

$$F_g \downarrow$$

$$F_N \uparrow$$

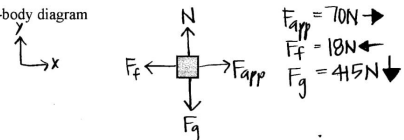
$$\sum F_x = F_{app} - F_f = 617 - 508 = 109 \text{ N} \rightarrow$$

$$a = \frac{F}{m} = \frac{109}{220} = 0.495 \text{ m/s}^2 \rightarrow$$

or  $+0.50 \text{ m/s}^2$

- 5) It's Friday night and Skyler has been assigned the noble task of baby-sitting Casey, his 2-year old brother. He puts a crash helmet on Casey, places him in the red wagon and takes him on a stroll through the neighborhood. As Skyler starts across the street, he exerts a 70 N rightward force on the wagon. There is a 18 N friction force and the wagon and Casey have a combined weight of 415 N. Construct a free body diagram depicting the types of forces acting upon the wagon. Then determine the net force, mass and acceleration of the wagon.

- a. Free-body diagram



- b. What is the net force in the x-direction?

$$\sum F_x = F_{app} - F_f = 70 - 18 = 52 \text{ N} \rightarrow$$

or  $+52 \text{ N}$

- c. What is the net force in the y-direction?

$$\sum F_y = N - F_g = 0 \text{ N}$$

0 N

- d. What is the mass of the wagon?

$$F_g = w = mg$$

$$415 = m(9.8)$$

$$m = \frac{415}{9.8} = 42.35 \text{ kg}$$

42.35 kg

- e. BONUS: Find the acceleration of the wagon.

$$a = \frac{F}{m} = \frac{52}{42.35} = 1.23 \text{ m/s}^2 \rightarrow$$

or  $+1.23 \text{ m/s}^2$