Creating and Automating Exams with LaTeX & Friends

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What's this talk about?

- As a lecturer I need to prepare exams
- Exams require significant amount of time:
  - not too simple, not too difficult
  - right amount of questions
  - unambiguous questions
- \LaTeX\ offers various packages to typeset exams and exercises, in this talk we cover `exam`
The exam document class

- Maintained by Philip Hirschhorn
- Current version 2.6 from November 2017
- Comes with a well-written manual
- Supports various types of questions, multiple choice questions, grading tables, etc.
A very basic example

\documentclass[12pt]{exam}
\begin{document}\Large
\begin{questions}
\question[10] Who was Albert Einstein?
\question[10] Compute \((e = m \cdot c^2)\)!
\end{questions}
\end{document}

Listing 1: A very basic exam example
1. (10 points) Who was Albert Einstein?
2. (10 points) Compute $e = m \cdot c^2$!
Localizing the exam-specific terms

Exam-specific terms can be localized, here’s an example for German:

\pointpoints{Punkt}{Punkte}
\bonuspointpoints{Bonuspunkt}{Bonuspunkte}
\renewcommand{\solutiontitle}{\noindent\textbf{Lösung:}\enspace}
\chqword{Frage}
\chpgword{Seite}
\chpword{Punkte}
\chbpword{Bonus Punkte}
\chsword{Erreicht}
\chtword{Gesamt}
\hpword{Punkte:}
\hsword{Ergebnis:}
\hqword{Aufgabe:}
\htword{Summe:}
Creating headers and footer

You can create headers and footers for the first resp. running pages.

\pagestyle{headandfoot}
\firstpageheadrule
\runningheadrule
\firstpageheader{<left>{<center>{John Doe \ Statistics 101 - 2019}}}
\runningheader{<l>{<c>{Statistics 101 - 2019}}}
\firstpagefooter{\today}{FOM Essen}{\thepage, /, \numpages}
\runningfooter{\today}{FOM Essen}{\thepage, /, \numpages}
\begin{document}\Large
\begin{questions}
\question[10] Who was Albert Einstein?
\question[10] Compute \((e = m \cdot c^2)\)!
\end{questions}
\end{document}

Listing 2: Setting header & footer

```tex
\pagestyle{headandfoot}
\firstpageheadrule
\runningheadrule
\firstpageheader{<left>{<center>{John Doe \ Statistics 101 - 2019}}}
\runningheader{<l>{<c>{Statistics 101 - 2019}}}
\firstpagefooter{\today}{FOM Essen}{\thepage, /, \numpages}
\runningfooter{\today}{FOM Essen}{\thepage, /, \numpages}
\begin{document}\Large
\begin{questions}
\question[10] Who was Albert Einstein?
\question[10] Compute \((e = m \cdot c^2)\)!
\end{questions}
\end{document}
```
1. (10 points) Who was Albert Einstein?

2. (10 points) Compute $e = m \cdot c^2$!
Dividing questions

• Questions can be further divided, exam provides the following environments:
  • parts
  • subparts
  • subsubparts

• Inside these environments individual questions are then added with
  • \part
  • \subpart
  • \subsubpart
Example for subdivided questions

\question[10] Who was Albert Einstein?
\begin{parts}
\part[1] Where was he born?
\part[4] What has he become famous for?
\begin{subparts}
\subpart[2] What does \(e=mc^2\) mean?
\subpart[2] What did he get the Nobelprice for?
\end{subparts}
\end{parts}
\end{questions}

Listing 3: Subdivisions \texttt{\part} and \texttt{\subpart}
1. (10 points) Who was Albert Einstein?
   (a) (1 point) Where was he born?
   (b) (4 points) What has he become famous for?
      i. (2 points) What does $e = mc^2$ mean?
      ii. (2 points) What did he get the Nobel price for?
Multiple choice and fill-In questions

• The \texttt{exam} class offers several environments for multiple choice and fill-in questions:
  • \texttt{choices} for vertical choices using letters
  • \texttt{checkboxes} for vertical checkboxes
  • \texttt{oneparchecboxes} for horizontally aligned checkboxes
  • with \texttt{\textbackslash fillin[solutiontext]} horizontal lines are created there, where the students are supposed to put their answer
Multiple choice and fill-In questions I

\begin{enumerate}
\item \question Who was not a Beatle?
\begin{choices}
\item John
\item Paul
\item George
\CorrectChoice Benedict
\end{choices}
\end{enumerate}
Multiple choice and fill-In questions II

Listing 5: Example for checkboxes

\begin{checkboxes}
\choice John
\choice Paul
\choice George
\CorrectChoice Benedict
\end{checkboxes}

\question Who was not a Beatle?
1. Who was not a Beatle?
   A. John
   B. Paul
   C. George
   D. Benedict

2. Who was not a Beatle?
   ○ John
   ○ Paul
   ○ George
   ○ Benedict

Figure 5: Resulting output
Multiple choice and fill-In questions III

\begin{onelargecheckboxes}
\choice John
\choice Paul
\choice George
\choice Ringo
\CorrectChoice Benedict
\end{onelargecheckboxes}

\question \fillin[James Bond][7em] has the \enquote{license to kill}.

Listing 6: oneparcheckboxes and fillin
1. Who was not Beatle?
   - John
   - Paul
   - George
   - Ringo
   - Benedict

2. James Bond has the “license to kill”.
### Using the “answers” class option

<table>
<thead>
<tr>
<th>1. Who was not Beatle?</th>
</tr>
</thead>
<tbody>
<tr>
<td>○ John</td>
</tr>
<tr>
<td>○ Paul</td>
</tr>
<tr>
<td>○ George</td>
</tr>
<tr>
<td>○ Ringo</td>
</tr>
<tr>
<td>✓ Benedict</td>
</tr>
</tbody>
</table>

2. **James Bond** has the “license to kill”.

---

**Figure 7:** Resulting output
Creating space for answers

\begin{verbatim}
% simple vertical space
\vspace*{<length>}

% vertical space to the end of the page
\vspace*{\stretch{1}}
\newpage

% empty framed box
\makeemptybox{<length>}

% empty framed box to the end of the page
\makeemptybox{\stretch{1}}
\newpage
\end{verbatim}
More space for answers

\fillwithlines{<length>} \% for lines
\% Remark: \linefillheight for the inter-line spacing

\fillwithdottedlines{<length>} \% for dotted lines
\% Remark: distance in \dottedlinefillheight

\fillwithgrid{<length>} \%
\% \setlength{\gridsize}{5mm}
\% \setlength{\gridlinewidth}{0.1pt}

\answerline[answer] \% for short answers
1. Give a short overview of whatever!

__________________________________________________________________________________

__________________________________________________________________________________

__________________________________________________________________________________

__________________________________________________________________________________

2. (5 points) Describe the general theory of relativity!

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

...........................................................................................................................................

Figure 8: Resulting output
1. Give a short overview of whatever!

2. (5 points) When was Henry VIII born?

2. ________

Figure 9: Resulting output
Printing solutions

- Global option `answers` controls printing of solutions
- `solution-environment` after each `\question`

```latex
\begin{solution}
  Some text containing the solution.
\end{solution}
```

- Some environments for the solution space
  - `solutionorbox`
  - `solutionorlines`
  - `solutionordottedlines`
  - `solutionorgrid`
Example for the solution environment

\begin{questions}
\question[1] How much does lead (Pb) weigh?

\begin{solution}
Pb weighs \SI{11,342}{\gram\per \centi\meter^3}
\end{solution}

\end{questions}

Listing 7: Multiple choice

\end{document}
1. (1 point) How much does lead (Pb) weigh?

Solution: Pb weighs 11.342 g/cm³
\question[5] Draw the function $3x^2+4x+5$!

\begin{solutionorgrid}[8cm]
\begin{tikzpicture}[baseline]
\begin{axis}[
axis y line=center, axis x line=middle, grid=both, xmax=5, xmin=-5, ymin=0, ymax=10, xlabel=$x$, ylabel=$y$, xtick={-5,...,5}, ytick={0,...,11}, anchor=center
\]
\addplot[smooth, blue, thick, samples=100]{3*x^2+4*x+5} ;
\end{axis}
\end{tikzpicture}
\end{solutionorgrid}
1. (5 points) Draw the function $3x^2 + 4x + 5$!

Figure 11: Resulting output
1. (5 points) Draw the function $3x^2 + 4x + 5!$

Solution:

Figure 12: Resulting output with class option “answers”
Printing grade tables

- exam supports the output of grade tables
- grade tables can be arranged per page or question

1. `\gradetable[v][questions]` vertically per question
2. `\gradetable[h][questions]` horizontally per question
3. `\gradetable[v][pages]` vertically per page
4. `\gradetable[h][pages]` horizontally per page
Example for `\gradetable`

```
\begin{questions}
\question[2] What’s the specific weight of air?
\question[2] What’s the specific weight of air?
\end{questions}

\gradetable[h][questions]
```

Listing 9: Grade table
1. (2 points) What’s the specific weight of air?
2. (2 points) What’s the specific weight of air?

<table>
<thead>
<tr>
<th>Question:</th>
<th>1</th>
<th>2</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points:</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Score:</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 13: Resulting output
Automating exams
Automating the exam class

- Wouldn’t it be nice to randomize exercise values?
- Each student could have his or her own exam, no more cheating!
- To simplify correcting, can’t we use e.g. bar codes to assist correcting the exam?

Yes, we can!
Preparing the \LaTeX-Code

Listing 10: Some simple exercise...

\begin{questions}
\question[5] Calculate!
\begin{parts}
\part[1] \((12345 + 67890 = \quad)\ \fillin[80235]\)
\end{parts}
Use `\usepackage{qrcode}` for qrcode support

```
\begin{questions}
\question[5] Calculate!
\begin{parts}
\part[1] (12345 + 67890 = \_) \fillin[80235] \qrcode
{80235}
\end{parts}
```

Listing 11: Adding the qrcode
Preparing the \LaTeX-Code III

\begin{questions}
\question[5] Calculate!

\begin{parts}
\part[1] \(12345 + 67890 = \) \fillin[80235] \hfill\qrcode{80235}
\vspace{2em}
\part[1] \(12345 + 67890 = \) \fillin[80235] \hfill\qrcode{80235}\vspace{2em}
\end{parts}

Listing 12: Adjust formatting...
1. (5 points) Calculate!

(a) (1 point) 12345 + 67890 = ____________

(b) (1 point) 12345 + 67890 = ____________

(c) (1 point) 12345 + 67890 = ____________

(d) (1 point) 12345 + 67890 = ____________

(e) (1 point) 12345 + 67890 = ____________

**Figure 14:** Resulting output (excerpt)
Preparing the Python-Code I

Generate a string adding two random numbers

```python
from random import randrange

print(randrange(1000, 10000, 1), ' + ', 
      randrange(1000, 10000, 1))
```

Listing 13: Multiple choice

1 5274 + 2654
Refactor to get the result of the addition

```python
from random import randrange

a = randrange(1000, 10000, 1)
b = randrange(1000, 10000, 1)
c = a + b

print(a, '+', b, '=' , c)
```

Listing 14: Multiple choice

1. 9183 + 9351 = 18534
Create a callable function from the code

```python
from random import randrange

def gen_exercise():
    a = randrange(1000, 10000, 1)
    b = randrange(1000, 10000, 1)
    c = a + b
    print(a, '+', b, '=' , c)

gen_exercise()
```

Listing 15: Creating a function

```
9183 + 9351 = 18534
```
from random import randrange

def gen_exercise():
    a = randrange(1000, 10000, 1)
    b = randrange(1000, 10000, 1)
    c = a + b
    a = str(a)
    b = str(b)
    c = str(c)
    print(r'\(' + a + ' + ' + b + ' = \fillin[' + c + '] \hfill\qrcode{' + c + '}\vspace*{2em}')

gen_exercise()
Listing 17: Load `pythontex`, import `randrange`

\usepackage{pythontex}
\begin{document}
\pyc{from random import randrange}
\begin{questions}
\question[5] Calculate!
\begin{parts}
\part[1] \((12345 + 67890 = \)) \fillin[80235] \hfill\text{\qrcode{80235}}\vspace{2em}
\end{parts}
\end{questions}
Combining LaTeX and Python

Listing 18: Add the function

```python
\texttt{\texttt{from random import randrange}}

\begin{pycode}
def gen_exercise():
a = randrange(1000, 10000, 1)
b = randrange(1000, 10000, 1)
c = a + b

a = str(a)
b = str(b)
c = str(c)

return '\(' + a + ' + ' + b + ' = \) \fillin[' + c + ']
\hfill\qrcode{' + c + '}\vspace*{3em}'
\end{pycode}
```
Combining \LaTeX{} and Python

Listing 19: Add the code to generate the exercise.
1. (5 points) Calculate!

(a) (1 point) \( 5989 + 5087 = \) _____________

(b) (1 point) \( 7065 + 1500 = \) _____________

(c) (1 point) \( 6694 + 9484 = \) _____________

Figure 15: Resulting output (excerpt)
Summary

• Creating exams in \LaTeX{} is easy ✓
• The exam class offers rich set of functions ✓
• Generating individual exams per group/student can be done ✓
• For questions and comments please contact me

ziegenhagen@gmail.com
• Clicking file and file opens the example files (at least in Adobe Reader)
• \LaTeX-source
• Document class: Beamer
• Document theme: Metropolis
• Font: IBM Plex Sans