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Preparing exam and homework material with `probsoln`

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1 Introduction

An important part of the job of a modern teacher is to prepare problem sheets, either for exams or for homeworks. This is particulary true for the math teacher, especially when you have many students and you want to prepare individual problem sheets. This becomes quite difficult and the teacher may feel it is a waste of time. A good idea would be to create a data base of problems and then write a Perl program, for instance, to select problems and include them in LaTeX files. Fortunately, you don't have to do this, because a nice LaTeX package, written by Nicola Talbot, is available and does the job for you, without requiring any knowledge of scripting languages.

It is the aim of this paper to describe this package, `probsoln`, and to provide a set of examples.

2 Basic philosophy

`probsoln` provides environments to describe problems and their solution. It works similar to the theorem-like environments, in the sense that you define a problem-like environment. However, this environment doesn't directly typeset the result. You will use the defined material to produce the problem/solution document.

The package is loaded, as usual, with a `\usepackage` command:

```
\usepackage{probsoln}
```

The package has several options:

- `answers` — when active, both the problems and their solutions are typeset;
- `noanswers` — when active, only the problems are typeset (default);
- `draft` — when active, the identification data of the problem are visible;
- `final` — when active, the identification data of the problem are invisible (default).

The options are global, but you can change some of them inside the text. For example, if you want to hide the answers, use the option `\hideanswers`. If you want to show them, use `\showanswers`.

The basic idea is to define a series of problems that are stored in containers called *data sets*. A data set is an internal element of the package. It only contains a list of labels (identifying the problems), separated by commas. The package comes equipped with a default data set, initially empty (and whose name is *default*, although we will never use it as such). Each time we define a new problem a label is added to a data set. As we shall see shortly, we can define the problems inside the main file, and then the labels are added to the default data set; or we can define the problems in an external file and later load them. In the latter case it is our choice whether the labels are added to the default data set or to a new data set.

3 Some new formatting commands

To help construct problems, the package provides several supplementary environments and commands:

- `solution`;
- `textenum`;
- `\correctitem`;
- `\incorrectitem`;

We shall see below how to use the `solution` environment. It is, essentially, similar to the `proof` environment from `amsthm`. Its name is provided by the command

\solutionname so that, if necessary, it can be changed with a \renewcommand. Beware that the package defines this environment only if it is not already defined by another package, so be very careful.

The environment textenum is a substitute for enumerate, to be used inside the text, when there are only a few items. For instance, the following source:

```
 I would like to buy:
 \begin{textenum}
\item a house;
\item an elephant;
\item a lake.
\end{textenum}
```

will produce

I would like to buy: 1. a house; 2. an elephant; 3. a lake.

which will take a lot less space than when we use the ordinary enumerate environment:

I would like to buy:

1. a house;

2. an elephant;

3. a lake.

The two new commands, \correctitem and \incorrectitem, are used to substitute the ordinary \item command in the enumerate environment. Suppose, for instance, we typeset the following sequence:

```
Which of the following numbers are integers?
\begin{enumerate}
\correctitem $\dfrac{10}{2}$;
\correctitem $\dfrac{9}{3}$;
\incorrectitem $\dfrac{3}{5}$.
\end{enumerate}
```

then, if the `answers` option is used, the result will be:

Which of the following numbers are integers?

$\boxed{1.}$ $\frac{10}{2}$;

$\boxed{2.}$ $\frac{9}{3}$;

3. $\frac{3}{5}$.

while if the `noanswers` is used, we would get:

Which of the following numbers are integers?

1. $\frac{10}{2}$;

2. $\frac{9}{3}$;

3. $\frac{3}{5}$.

i.e. the two new commands work exactly the same way as the ordinary `\item`.

4 Defining problems

There are two ways of defining a new problem. The first is through the environment `defproblem`. The syntax of this environment is

\begin{defproblem}[<*n*>]{<*label*>}<*definition*>\end{defproblem}.

Here n is a number from 0 to 9 representing the number of arguments of the problem. If the number is 0, it can be absent. In the definition, the arguments are refered to by `#1`, . . . , `#9`.

The *definition* is the text of the problem and can contain any standard LaTeX commands, as well as the extra commands described previously. In particular, if you also want to provide the solution of the problem, this should be here as well, inside a `solution` environment.

Here is a first example:

```
\begin{defproblem}[1]{first}
Compute the derivative of the function $f(x)=e^{#1 x}$.
\begin{solution}
$f'(x)=#1 e^{#1 x}$.
\end{solution}
\end{defproblem}
```

To typeset this in your document, write

```
\useproblem{first}{2}.
```

which produces

Compute the derivative of the function $f(x) = e^{2x}$.
Solution: $f'(x) = 2e^{2x}$.

Note that the argument '2' following `\useproblem` replaces all occurrences of `#1` in the `defproblem` definition. In general, if the `defproblem` definition has n arguments, the `\useproblem` command will be:

`\useproblem{`<*label*>`}{`arg_1`}...{`arg_n`}`,

where the label is that of the problem we want to use and the arguments are the defined values.

In the example above the option `answer` is used in `\usepackage[answer]{probsoln}` and the solution is shown. If the `noanswers` option is used instead, the solution will not be given.

To use **Answer** rather then **Solution**, put the following in the preamble of the document:

```
\renewcommand{\solutionname}{Answer}
```

A nice feature of `probsoln` is that it allows you to typeset separately the text of the problem and that of the solution. The way to do it is through two environments: `onlyproblem` and `onlysolution`. These environments should be inside a `defproblem` environment. We can define the following problem:

```
\begin{defproblem}{test}
\begin{onlyproblem}
Compute the derivative of the function $f(x)=x^2$.
\end{onlyproblem}
\begin{onlysolution}
\begin{solution}
$f'(x)=2x$.
\end{solution}
\end{onlysolution}
\end{defproblem}
```

If the `noanswer` is active, then the corresponding `\useproblem` will produce

Compute the derivative of the function $f(x) = x^2$.

i.e. only the text of the problem is produced.

If, instead, the `answers` is active, we would get

Solution: $f'(x) = 2x$.

We mention that it is not necessary to use the two environments together. If, for instance, we don't put the problem inside the `onlyproblem`, then the text of the problem is always printed. Also, it is not necessary to put the `solution` inside the `onlysolution`, but if we don't, the text **Solution:** will not be printed.

The second way of defining a problem is through one of the commands `\newproblem` or `\newproblem*`. The syntax of the `newproblem` is

`\newproblem[<n>]{<label>}{<problem>}{<solution>}`.

This is, actually, just a shortcut for a specific `defproblem` environment, namely

```
\begin{defproblem}[<n>]{<label>}
<problem>
\begin{onlysolution}
\begin{solution}
<solution>
\end{solution}
\end{onlysolution}
\end{defproblem}
```

Another shortcut is `\newproblem*`, which contains only the text of the problem, and no solution. It has the syntax

`\newproblem*[<`*n*`>]{<`*label*`>}{<`*problem*`>}`

and is equivalent to the environment

```
\begin{defproblem}[<n>]{<label>}
<problem>
Problem statement $\dots$
\end{defproblem}
```

5 Using problems from external files

What we described so far is interesting, but not terribly useful. There is not much point of using `probsoln` for a couple of isolated problems. A package like `amsthm` would be more than enough. The advantage of using the `probsoln` package is to handle large lists of problems. Usually, it is preferable to put these problem sets in separate LaTeX files and it is a good policy to put only problems there (i.e. everything should be inside `defproblem` environments). Also, another good policy is to use, for each problem, both the `onlyproblem` and `onlysolution` environments (but without `solution` environments). Let us assume we already have such a file, called `dbase.tex`.

The external file can be made available by an `\include{dbase}` command. Alternatively, you can load problems from the file and make a new data set, or append them to a specified data set.

The package provides three commands for loading problems from the external file. The first command is

```
\loadallproblems[<data set>]{<filename>}
```

The effect of this command is that all the problems from the external file are loaded and saved in the specified data set. If the data set does not exist, it will be created. If the data set is not specified (i.e. the optional argument is not present), the default data set will be used. For instance, in our case, we can use something like

```
\loadallproblems[new]{dbase}
```

The second command is

```
\loadselectedproblems[<data set>]{<labels>}{<filename>}
```

The difference from the previous command is that, this time, only a list of problems (identified by their label) are loaded. For instance, the command

```
\loadselectedproblems[new]{1,3,5}{dbase}
```

will only load the problems with the labels 1, 3 and 5, and the rest of the problems will not be available.

Finally, we can use the command

```
\loadrandomproblems[<data set>][<n>]{<filename>}
```

to load, randomly, n problems from the external file. Of course, the file has to contain at least n problems.

You can use the same data set several times, with the same external file, or different files. Every time, the new added problems are appended to the existing one. Usually, however, we prefer to create different data sets.

Now that we have learned how to load problems from an external file, it is time to also learn how to use them. Assume we loaded a number of problems from our file:

```
\loadselectedproblems[new]{1,3,5}{dbase}
```

Now we can use these problems by using `\useproblem` (specifying the data set, of course):

```
\useproblem[new]{3}
```

The equatorial plane intersects the horizontal plane through a line perpendicular to vertical and the polar axis. It follows that this line is perpendicular to the meridian line (North-South) and it cuts the horizon at the points East and West.

gives

If we have a large number of problems or they are loaded randomly, it is difficult to use this approach. Fortunately, the package provides commands to overcome this difficulty and to generate nice problem lists by iterating through the data sets.

The first, and, maybe, the most important command is `\foreachproblem`, with the syntax

```
\foreachproblem[<data set>]{<body>}
```

This simply means that for each problem in the data set, the commands from the *<body>* are executed. You can use, in particular, the command `\thisproblem`, to access the current problem and `\thisproblemlabel` to access the label of the current problem.

Let us assume we want to prepare a homework for a student. To this end, first we load, randomly, 5 problems from the external database:

```
\loadrandomproblems[John]{5}{dbase}
```

Now, use these problems to create the list (be careful, use `\hideanswers`, otherwise you will get the solutions):

```
\begin{enumerate}
\foreachproblem[John]{\item\thisproblem}
\end{enumerate}
```

Homework for John

1. A comet has the equatorial coordinates $\alpha = 81°48'.7$, $\delta = +68°28'$. What are its ecliptical coordinates λ and β ($\epsilon = 23°27'26''$)?

2. On an autumn morning a hunter goes into the woods in the direction of the Pole Star. He returns after sunrise. If he uses the position of the Sun as a guide, what direction must he take to return?

3. Show that the equator intersects the horizon at points which lie at 90° to the points North and South (*i.e.* at the points East and West).

4. The two brightest stars in the northern hemisphere of the sky are Vega (α= 18 hr 34 min) and Capella (α= 5 hr 10 min). In what sector of the sky (in the western or the eastern) and at what hour angle will they appear, at the moment of upper culmination of the point of the Vernal Equinox? At the moment of the lower culmination of the same point?

5. The two brightest stars in the northern hemisphere of the sky are Vega (α= 18 hr 34 min) and Capella (α= 5 hr 10 min). What is the hour angle of Capella at the moment of the upper culmination of Vega? What is it at the moment of its lowest culmination?

If you also want to generate the solutions, use the same command, but this time use `\showanswers` first:

Solutions for John

1. The conversion between equatorial and ecliptical systems is given by

$$\sin\beta = \cos\epsilon \cdot \sin\delta - \sin\epsilon \cdot \cos\delta \cdot \sin\alpha$$

and

$$\tan\lambda = \frac{\tan\delta \cdot \sin\epsilon + \cos\epsilon \sin\alpha}{\cos\alpha},$$

where ϵ is the obliquity of the ecliptic.

For the given comet the ecliptical longitude equals $85°45'1.''9$ and its ecliptical latitude $45°7'49''$.

2. When the hunter goes out from the woods it has to go to South, because when he went into the woods he had gone in the North direction (following the Pole Star). The Sun rises in autumn from East, so the hunter should have the rising Sun to left.

3. The equatorial plane intersects the horizontal plane through a line perpendicular to vertical and the polar axis. It follows that this line is perpendicular to the meridian line (North-South) and it cuts the horizon at the points East and West.

4. To find out the hour angle of the star we use the relation:

$$\theta = H + \alpha\,.$$

At the moment of upper culmination of the point of the Vernal Equinox its hour angle equals 0 hr. Then $H_{Capella}$ = 18 hr 50 min and the star appears in the eastern hemisphere of the sky. The hour angle of Vega equals 5 hr 26 min and the star appears in the western hemisphere of the sky.

When the point of the Vernal Equinox is at lower culmination its hour angle equals 12 hr, Capella's hour angle is 6 hr 50 min and the star appears in the western hemisphere of the sky. The hour angle of Vega is 17 hr 26 min and Vega appears in the eastern hemisphere of the sky.

5. The relation between the sidereal time, hour angle and right ascension of the star is

$$\theta = H + \alpha \,.$$

When Vega is at upper culmination the sidereal time is equal with its right ascension. The hour angle of Capella is then equal with 13 hr 24 min.

When Vega is at its lowest culmination its hour angle is 12 hr, and the hour angle of Capella is equal with 1 hr 24 min.

Sometimes you want to produce several lists of problems, in different parts of the documents, but you want the solution to be put in the same place (for instance, at the end of the document). To do that, we will create, first, several data sets, one for each list of problems, even if they are loaded from the same external file. We will explain, in the sequel, how we can do that. First, we load the problems and create the data sets.

6 A nice list of problems

6.1. If we lose one solar day on a journey round the world, traveling from west to east do we also lose a sidereal day?

6.2. On an autumn morning a hunter goes into the woods in the direction of the Pole Star. He returns after sunrise. If he uses the position of the Sun as a guide, what direction must he take to return?

6.3. Show that the equator intersects the horizon at points which lie at 90° to the points North and South (*i.e.* at the points East and West).

6.4. The two brightest stars in the northern hemisphere of the sky are Vega (α= 18 hr 34 min) and Capella (α= 5 hr 10 min). In what sector of the sky (in the western or the eastern) and at what hour angle will they appear, at the moment of upper culmination of the point of the Vernal Equinox? At the moment of the lower culmination of the same point?

6.5. The two brightest stars in the northern hemisphere of the sky are Vega (α= 18 hr 34 min) and Capella (α= 5 hr 10 min). What is the hour angle of Capella at the moment of the upper culmination of Vega? What is it at the moment of its lowest culmination?

7 Another nice list of problems

7.1. How far from the eye must a coin of diameter 1.7 cm be held, so that it just covers the disc of the Sun or the Moon?

7.2. On an autumn morning a hunter goes into the woods in the direction of the Pole Star. He returns after sunrise. If he uses the position of the Sun as a guide, what direction must he take to return?

7.3. Show that the equator intersects the horizon at points which lie at 90° to the points North and South (*i.e.* at the points East and West).

7.4. The two brightest stars in the northern hemisphere of the sky are Vega (α= 18 hr 34 min) and Capella (α= 5 hr 10 min). In what sector of the sky (in the western or the eastern) and at what hour angle will they appear, at the moment of upper culmination of the point of the Vernal Equinox? At the moment of the lower culmination of the same point?

7.5. The two brightest stars in the northern hemisphere of the sky are Vega (α= 18 hr 34 min) and Capella (α= 5 hr 10 min). What is the hour angle of Capella at the moment of the upper culmination of Vega? What is it at the moment of its lowest culmination?

8 Solutions for the nice lists of problems

The first list

6.1 Yes, for this we consider the Earth is divided in 24 zones of sidereal time.

6.2 When the hunter goes out from the woods it has to go to South, because when he went into the woods he had gone in the North direction (following the Pole Star). The Sun rises in autumn from East, so the hunter should have the rising Sun to left.

6.3 The equatorial plane intersects the horizontal plane through a line perpendicular to vertical and the polar axis. It follows that this line is perpendicular to the meridian line (North-South) and it cuts the horizon at the points East and West.

6.4 To find out the hour angle of the star we use the relation:

$$\theta = H + \alpha \, .$$

At the moment of upper culmination of the point of the Vernal Equinox its hour angle equals 0 hr. Then $H_{Capella}$ = 18 hr 50 min and the star appears in the eastern hemisphere of the sky. The hour angle of Vega equals 5 hr 26 min and the star appears in the western hemisphere of the sky.
When the point of the Vernal Equinox is at lower culmination its hour angle equals 12 hr, Capella's hour angle is 6 hr 50 min and the star appears in the western hemisphere of the sky. The hour angle of Vega is 17 hr 26 min and Vega appears in the eastern hemisphere of the sky.

6.5 The relation between the sidereal time, hour angle and right ascension of the star is

$$\theta = H + \alpha \, .$$

When Vega is at upper culmination the sidereal time is equal with its right ascension. The hour angle of Capella is then equal with 13 hr 24 min.
When Vega is at its lowest culmination its hour angle is 12 hr, and the hour angle of Capella is equal with 1 hr 24 min.

The second list

7.1 The coin has to be held at approximately 400 cm far from the eye.

7.2 When the hunter goes out from the woods it has to go to South, because when he went into the woods he had gone in the North direction (following the Pole Star). The Sun rises in autumn from East, so the hunter should have the rising Sun to left.

7.3 The equatorial plane intersects the horizontal plane through a line perpendicular to vertical and the polar axis. It follows that this line is perpendicular to the meridian line (North-South) and it cuts the horizon at the points East and West.

7.4 To find out the hour angle of the star we use the relation:

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At the moment of upper culmination of the point of the Vernal Equinox its hour angle equals 0 hr. Then $H_{Capella}$ = 18 hr 50 min and the star appears in the eastern hemisphere of the sky. The hour angle of Vega equals 5 hr 26 min and the star appears in the western hemisphere of the sky. When the point of the Vernal Equinox is at lower culmination its hour angle equals 12 hr, Capella's hour angle is 6 hr 50 min and the star appears in the western hemisphere of the sky. The hour angle of Vega is 17 hr 26 min and Vega appears in the eastern hemisphere of the sky.

7.5 The relation between the sidereal time, hour angle and right ascension of the star is

$$\theta = H + \alpha\,.$$

When Vega is at upper culmination the sidereal time is equal with its right ascension. The hour angle of Capella is then equal with 13 hr 24 min. When Vega is at its lowest culmination its hour angle is 12 hr, and the hour angle of Capella is equal with 1 hr 24 min.

We used two different external files here. You always have to be careful in these situations. The two data sets should not contain identical problem labels, otherwise your lists of solutions (more specifically their identification numbers) will be messed up.

9 Iterating through all the data sets

So far we iterated individually through each data set. Sometimes we want to generate, in the same place, the problem solutions from *all* data sets. This is possible by using the command `\foreachdataset`, as in the following example:

```
\begin{enumerate}
\foreachdataset{\thisdataset}{%
\foreachproblem[\thisdataset]{\item\thisproblem}}
\end{enumerate}
```

This may be useful, for instance, when we write a book. We produce a list of problems for each chapter and then, at the end, we provide the solutions for all of the problems.

References

[1] Nicola Talbot — *probsoln v3.0: creating problem sheets optionally with solutions*, 2008, available from CTAN