

# Writing Exams in (La)TeX for use with GRTEX

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March 23, 1997

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1. These are instructions for preparing exams in latex (or tex) in a way which will be compatible with the program GRTEX, which makes multiple versions, each containing selected questions with the questions and/or answers in permuted orders. But these instructions are formatted to look like an exam.
2. That way, the input for this file, called `examexample.tex`, can serve as an example as well as serving as instructions. You can copy `examex.template`, which is a template into which you can insert your own material.
3. You will see that the format provides several options for the style of questions, both with and without accompanying figures. One way to learn how to make an exam to your liking is to examine this example, select the styles you want to use, copy this file and change the text to say what you want.
4. You can also change from two column to one column, portrait style, by uncommenting the indicated line (see the source file). To print this file as a source file, type `enscript -G examexample.tex` (on a Sun, or whatever you use to print an ordinary ASCII file on other machines) rather than  $\LaTeX$ ing it. Another option you can choose is to have the pages numbered, by uncommenting a different line.
5. You will need a question file in a format like this one, which is suitable for  $\TeX$ ing or  $\LaTeX$ ing. It is also suitable for `grtex`, when taken together with a *want* file, which contains information for GRTEX such as which questions will be used and the style of permutation. The *want* file is described in detail in the GRTEX writeup. The program `grtex` will ask you for the names of these files and of the output files, one of which can then be  $\TeX$ ed or  $\LaTeX$ ed, and the other of which is an answer key input to GRAD or GRED.

Your name sticker with **exam code**

6. Most instructors like to have a cover page, and not have any exam problems on the first sheet. This leaves room for a page of instructions and a page of formulas and constants. In two column style, I call each column a page. To deliberately end the page, as I did after item 5, use `\eject` or `\vfill\eject`. To make sure to end the whole side, even in two column mode, use `\clearpage` instead.
7. Please note that  $\TeX$ ,  $\LaTeX$ , and emacs cannot be used directly on encrypted files. Unfortunately this means that the input and output will, at least temporarily, be on the disk in cleartext on the computer. Be very careful that exam files are secret in a subdirectory that is secret. They can be encrypted at all times except just around the  $\TeX$ ing and the printing.
8. This file requires  $\LaTeX$  and calls on the files `epsf.tex`, `exammac.tex` and `exammac2.tex`, which must be in the path searched by  $\LaTeX$ . On the public Suns this should be the case without your taking any action.
9. The available question formats are introduced starting with “Question” 1. The rules required for a good latex (or tex) file to be compatible with `grtex` are spelled out in “Question” 24. Hints for databases are in “Question” 33.

Elementary charge  $e = 1.6 \times 10^{-19}$  C,      Electron charge  $= -e$ .

$$\frac{1}{4\pi\epsilon_0} = 9 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2, \quad \epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{N} \cdot \text{m}$$

Mass of electron  $= 9.11 \times 10^{-31}$  kg

Mass of proton  $= 1.67 \times 10^{-27}$  kg

1 electron volt (eV)  $= 1.6 \times 10^{-19}$  J

1. The sections of these instructions are to be found as follows
  - a) Instructions for writing individual questions: “Question” 2
  - b) Instructions for the `grtex` input question file: “Question” 24
  - c) References to other documentation on `grtex`, `grad`, `grek`, *etc.*: “Question” 37
  - d) Suggestions for maintaining a database of questions: “Question” 33
  - e) Suggestions for getting started: The “tail” after “Question” 37
2. The programs `grtex`, `gread`, `gred`, and `grad` currently (Oct, 2003) support two kinds of exams. The traditional exam form permits up to 200 multiple choice questions. The newer form permits up to 15 numerical answer questions and up to 30 multiple choice questions.
  - a) The mark-sense forms for multiple choice questions and for numerical answer questions are totally different
  - b) Multiple choice questions are discussed beginning with “Question” 4
  - c) Multiple choice with accompanying pictures start with “Question” 11
  - d) Multiple choice with answer choices **on the pictures** start with “Question” 22
  - e) Numerical answer questions are discussed starting with “Question” 28

Finally we have some comments on things you can insert into all questions, starting with “Question” 32.

3. All of the questions on the exam must appear together, with no intermediate material, although there can be material before all the questions and after all the questions. Each question is a separate paragraph, that is, there is at least one blank line before and after each question.
  - a) MC next      b) MC pictures at 11      c) numerical at 28
  - d) file format at 24

4. Each of the multiple-choice questions must be given in a very particular form, with exactly the eight components described below. Each must start in the first column of a new line<sup>†</sup>. Comments may be placed as desired.\* Blank lines are ignored.(???) Each question appears as follows:

- a) The `TEX` command `\setup` with argument #1 containing the question number and #2 the correct answer: `\setup{27}{2}`. The initial `\` must be placed in column 1.
- b) The question, enclosed in braces, with the opening brace in column 1. If the question takes more than one line, it is recommended that following lines in the source code be indented for clarity. The final brace should be followed by a % and a newline.
- c) Five answers, enclosed in braces, with the opening brace in column 1. An argument’s closing `}` must be followed by a newline.
- d) A `TEX` command of the form `\xxxquest`, possibly followed by arguments, with the initial `\` in column 1.
- e) It is essential that the setup have exactly 8 arguments, and that there be no intermediate (uncommented) spaces or other material between them. The meanings of the arguments are given in the next question. The choices of `\xxxquest` are given in the question after that.

<sup>†</sup> Well, certainly not the second and third. What the true restrictions are needs to be clarified.

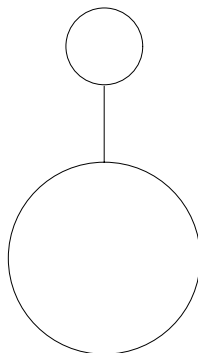
\* As of June, 1996, tex comments within questions were causing some problems.

5. The arguments to the `\setup` macro are
  - a) #1 is a number (integer) identifying the question in the “want” file. It will be replaced by GRTEX with the number to appear as the question number on the exam.
  - b) #2 is the correct answer, one of 1, 2, 3, 4, or 5
  - c) #3 is the text of the question, which may include any  $\text{\TeX}$  or  $\text{\LaTeX}$  code which makes sense. In all styles of question, this is set above the answers.
  - d) #4–#8 are the five answers, without a leading letter or number. There must be five arguments here even if you use a question format with fewer answer choices.
  
6. The first question was of the form `\stdquest`, which has no attached figure, has the question statement set above the answers, which are in an itemized list below the question. That particular question also had a footnote added with an `\undernote`, a feature added Nov. '96 to all forms of questions, and explained in question 27 below. The second question used `\fourquest` which is the same thing except the student is presented with only four answers. I don't encourage this, but it is available. The other forms of question available currently (May 11, 1993) are
  - a) `\lilquest`
  - b) `\ivlquest`
  - c) `\pixquest`
  - d) `\lpixquest`
  - e) `\fpixquest`

But in Nov. 1996 I added `\mvaquest` and `\lmvaquest`, and in Jan. 2003, I added the numerical question styles `numquest`, `numsidepix`, and `numbotpix`
  
7. This is an example of `\lilquest`.  
 Two large parallel conducting plates are 10 cm apart and carry equal but opposite charges on their facing surfaces. An electron placed midway between the plates experiences a force of  $3.2 \times 10^{-17}$  N. The potential difference between the plates is
  - a) 2000 V
  - b) 200 V
  - c) 40 V
  - d) 20 V
  - e) 10 V
  
8. Two capacitors have capacitances of  $7\mu\text{F}$  and  $5\mu\text{F}$  respectively. They are connected in parallel to a battery. After the battery has charged them, the  $7\mu\text{F}$ -capacitor has a stored energy of  $2.24 \times 10^{-4}$  J. What is the charge on the **other** capacitor, i.e. the  $5\mu\text{F}$ -capacitor?
  - a)  $40\mu\text{C}$
  - b)  $96\mu\text{C}$
  - c) Zero
  - d)  $56\mu\text{C}$
  - e) `\stdquest` questions are just so beautiful!
  
9. A parallel-plate capacitor is charged and then disconnected from the charging battery. A dielectric slab is inserted in the gap between the capacitor plates. As a result,
  - a) the capacitance stays the same, while the electric field decreases
  - b) the capacitance stays the same, while the electric field increases
  - c) the capacitance and electric field both increase
  - d) the capacitance increases, while the electric field decreases
  - e) the capacitance and electric field both decrease
  
10. This is a `\ivlquest`. Note `iv` is four, and `l` is for little.  
 A charge of  $+6.0$  nC is at the origin, and another charge of  $+6.0$  nC is on the x-axis at  $x = 1.0$  m. If the potential is chosen to be zero at infinity, what is the value of the potential on the y-axis at  $y = 1.0$  m?
  - a) 15.8 V
  - b) 108 V
  - c) 92.2 V
  - d) 85.4 V

11. Two conducting, hollow spheres have different radii. A thin, conducting wire connects the spheres. A charge  $Q$  is placed on the smaller sphere. Then,

- charge will flow until the spheres have equal potentials.
- charge will flow until the spheres have equal charges.
- all of the charge will flow to the larger sphere.
- charge will flow until the spheres have equal electric fields at their surfaces.
- There will be no flow of charge, so the charge  $Q$  will remain on the smaller sphere.

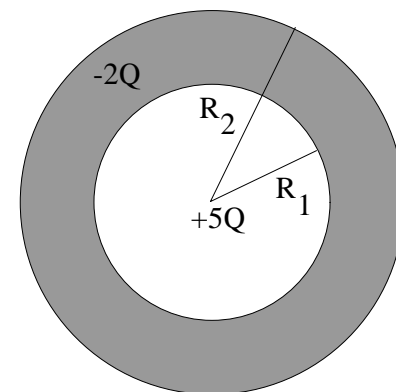


12. Note that the last question had a figure attached. It was a question of type `pixquest`, and had the 8 arguments to `\setup`, followed by `\pixquest{1in}{227f90h1.ps1}`.

- The `\pixquest` macro requires two arguments of its own, unlike `\stdquest`, `\fourquest`, `\lilquest` and `\ivlquest`, which didn't require arguments.
- The first argument is the width of the figure to be included. This should not be very large, or there will be insufficient room for the answers to format decently.
- The second argument is the name of a file containing a postscript figure to be inserted. Note that it has been given a unique name. This figure was the first figure on the first hour exam in 227 in fall, 1990.
- I hope that people will make their exams available to the department after giving them. I will try to put together a big file of questions. Once this file is large enough, people might reuse some of the questions.
- There are currently two other styles of questions with figures other than those with answers on them (Q22).

13. A charge of  $+5Q$  is at the origin. Concentric with it is a conducting spherical shell of inner radius  $R_1$  and outer radius  $R_2$ . This shell is given a **net** charge of  $-2Q$ . The distance  $r$  is measured from the origin. In the region  $r > R_2$ , the electric field is  $1/4\pi\epsilon_0$  times

- $[-2Q/r^2]\hat{r}$
- $[3Q/r^2]\hat{r}$
- $[5Q/r^2]\hat{r}$
- $[7Q/r^2]\hat{r}$
- Zero



14. In the preceding problem, the figure was to the right of everything, and both the question and the answers were set narrower than usual.

- It was set with `lpixquest`, where the `l` stands for long.
- `lpixquest` takes the same two arguments as `pixquest`.
- The decision which form to use depends on how high the picture will be, and how much space will be taken by the answers alone, and how much by the answers and question together.
- For the last problem, the figure was fairly tall, the answers didn't take much space, but the question statement together with the answers took as much vertical space as the figure. So `lpixquest` was just what was needed.

15. In the preceding problem, the charge on the surface of the shell at  $r = R_2$  is

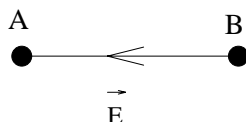
- Zero
- $\frac{5Q}{r^2}\hat{r}$
- $-\frac{2Q}{r^2}\hat{r}$
- $\frac{3Q}{r^2}\hat{r}$
- $\frac{7Q}{r^2}\hat{r}$

16. In the preceding problem, the charge on the surface of the shell at  $r = R_2$  is

a) Zero    b)  $-2Q$     c)  $-5Q$     d)  $+3Q$

17. Consider two points A and B. An electric field points from B towards A, and is constant in magnitude, so that  $E_B = E_A$ . How are the electric potentials at A and B related?

- a.  $V_B = V_A$   
 b.  $V_B > V_A$   
 c.  $V_B < V_A$   
 d.  $V_B < V_A$  only if a positive charge is moved from B to A  
 e.  $V_B < V_A$  only if a negative charge is moved from B to A

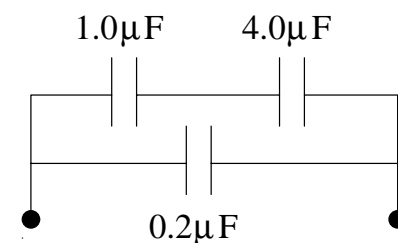


18. In the last problem, the figure was very short, and some of the answers long enough so they need to wrap when next to the picture. Note that the figure was set next to the first four answers, and the last one didn't need to wrap. The `\fpixquest` macro figured this out by itself. Permutation of the answers would still be treated properly, although if the current "d" and "e" were the first two, they would both wrap and there would be no advantage over `\pixquest`, except the picture would appear higher. `\fpixquest` proves that

- a) T<sub>E</sub>X is marvelously flexible.  
 b) T<sub>E</sub>X is overly complex.  
 c) Anyone who writes his exams using wordmark has no sense of quality.  
 d) Joel is **crazy** to have spent 8 hours getting `\fpixquest` to work.  
 e) All of the above.

19. The equivalent capacitance of the three capacitors is

- a)  $0.16\mu\text{F}$   
 b)  $0.19\mu\text{F}$   
 c)  $1.00\mu\text{F}$   
 d)  $5.20\mu\text{F}$   
 e)  $6.25\mu\text{F}$

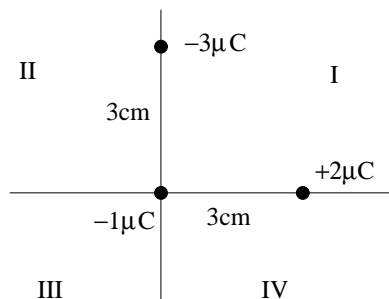


20. The `\pixquest` and `\lpixquest` can be called with `\empty.ps` as the second argument, as in `\pixquest{1in}{\empty.ps}`. This leaves space but does not insert a figure. If the shape is not right, you can edit the `BoundingBox` in `\empty.ps`. You can also use `\thinempty.ps`, which is 100 times higher than it is wide to set aside extra vertical space for a question. A width of 0.04in reserves 4 vertical inches for the question. Can this be done with `\fpixquest`?

- a) No  
 b) No!  
 c) No!!  
 d) No!!!  
 e) What would be the point?

21. A charge of  $+2.0\mu\text{C}$  is fixed on the x-axis at  $x = 3\text{ cm}$ , while a charge of  $-3.0\mu\text{C}$  is fixed on the y-axis at  $y = 3\text{ cm}$ . The force on a third charge of  $-1.0\mu\text{C}$  placed at the origin is of magnitude

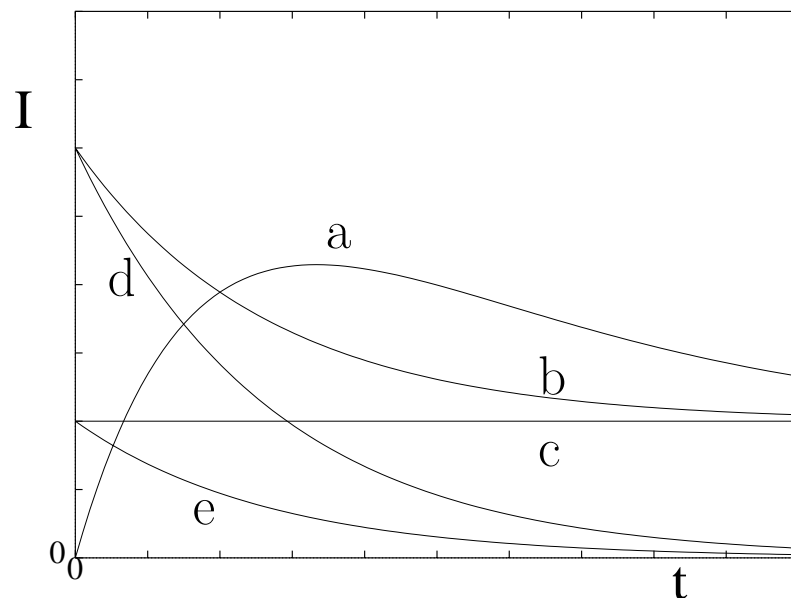
- a) 10 N
- b) 20 N
- c) 30 N
- d) 50 N
- e) 36.1 N



22. Sometimes the five answers might be best indicated by placing the (a), (b), *etc.* at the right locations on a figure. This is the function of the question style `mvaquest` (for “move answers”). The positions are indicated in place of textual answers in the five answer arguments to `setup`. For example, In this problem the first two answers are indicated by

```
{\placeit 100,152 }
{\placeit 180,97 }
```

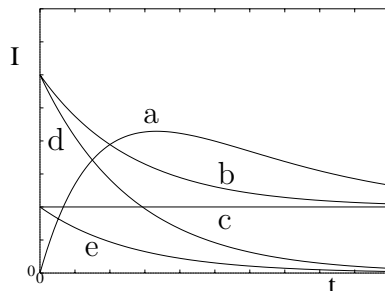
The spaces and lack thereof are essential — the two coordinates, given in points ( $1/72$  of an inch), must be separated by a comma and no spaces, and the second argument must be followed by a space.



This format requires adjustment by hand of the positions. These adjustments do not currently survive a switch from one column to two column mode. Any  $\text{\TeX}$  hackers are encouraged to fix this bug, and inform me.

Note `mvaquest` takes one argument, the file name of the picture, so this question ended with `\mvaquest{mvapix.eps}`

23. You also might want to have the figure on the right of the question, with the answers (a)—(e) appearing on the figure, as with `mvaquest`. This question is of that type. Note that the placement adjusted for one type is unlikely to work for the other. Note also that this format requires a width as well as the file name for the figure. This question ended with `\lmvaquest{2in}{mvapix.eps}`



24. Here are the rules for the format of the exam so that GRTEX will be able to do what it has to. Note they still permit immense flexibility

- The file begins with a latex header. This should include all the material needed to set things up, which does not need to be repeated for each version. It needs to be ended with a line that says exactly  
`%%End of header`
- Next should follow all the material before the questions, which is to be repeated on each version of the exam. It must not have the command `\setup` in it starting in column 1 or 2.
- Then follows any number of questions, separated by blank lines, each beginning with `\setup`, followed by exactly eight arguments, then followed by a question formatting macro `\???quest`, followed by the correct number of arguments for that style question.
- After all the questions follows any material which should follow the questions on each version.
- Finally, the file ends with

$$\left\{ \begin{array}{l} \text{\code{\bye} for } T_{EX} \\ \text{\code{\end{document}} for } E_{TEX} \end{array} \right.$$

25. There are other possible styles which should probably be developed.

- You could design additions to `exammac.tex`.
- You could find a student to do it for you.
- You could make do with the styles I've provided.
- You can include the picture directly in the question text. Note that the answers can also have figures included. These will move with the answer when permuted.
- You could give a clear description of the required style and a convincing argument for why I should spend the time creating it.

26. For a certain charge distribution, the potential as a function of  $r$  is given by

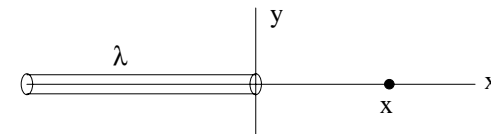
$$V(r) = \frac{Q(3R - r)}{8\pi\epsilon_0 R} \quad \text{for } r < R.$$

(The quantities  $Q$ ,  $R$ , and  $e$ ) are all constants). Then the electric field as a function of  $r$  (for  $r < R$ ) is

- $[+Q/4\pi\epsilon_0 r^2]\hat{r}$
- $[-Q/4\pi\epsilon_0 r^2]\hat{r}$
- $[-Q(3R^2 - 2r)/8\pi\epsilon_0 R^3]\hat{r}$
- $[-Qr/4\pi\epsilon_0 R^3]\hat{r}$
- $[+Qr/4\pi\epsilon_0 R^3]\hat{r}$

27. A semi-infinite line charge of uniform density  $\lambda$  lies along the negative x-axis from  $x = 0$  to  $x = -\infty$ . The magnitude of the electric field at any point  $x$  on the positive x-axis is  $1/4\pi\epsilon_0$  times

- $\lambda/x$
- $\lambda/x^2$
- $2\lambda/x$
- $\lambda/2x$



- None of the other answers

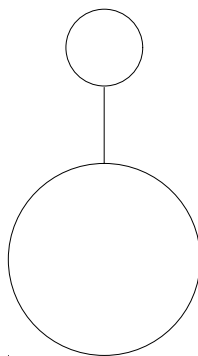
28. In 2002, Dick Plano introduced the possibility of giving questions which require numerical answers, rather than multiple choice. This requires a new exam form, with room for 15 numerical answer questions and 30 multiple choice questions. Answers are in scientific notation with three significant digits and an exponent of  $\pm$  two digits. So a question looks like:

What is the value of the physical constant  $e$ ?

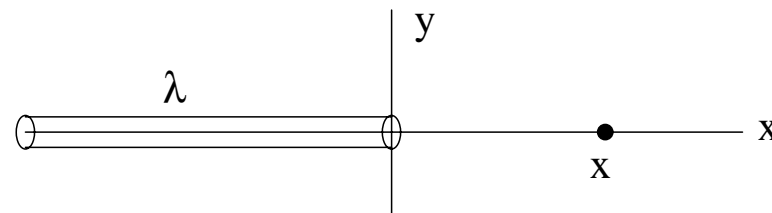
29. The numerical answer questions work differently than the multiple choice questions, in several ways. There is no setup command — the type of question, `numquest` or `numsidepix` or `numbotpix` determines the type of question at the beginning of the question. The arguments are

1. the question number
  2. two numbers, fixed or floating point, giving the points to give for a fully correct answer and for a “partially correct” answer
  3. the question statement, including some tex macros
  - 4-8 alternate definitions of the macros, including of `\answer`.
- `answer` is a set of 5 numbers, the correct answer, the lower end of the “fully correct answer” interval, the upper end of that interval, the lower end of the “partially correct answer” interval, and the upper end of that interval.

30. There are three forms of numerical question currently. These are `numquest`, which has no picture; `numsidepix`, which, like this question, has a picture on the side, and `numbotpix`, like the next question. The latter two have two additional arguments occurring before the question statement and after the point specification. The first of these is the width of the picture, with units, and the second is the filename of the picture.



31. This is a `numbotpix`



32. In November, 1996, I added the capability to add a footnote to each question — something which appears after the answers on a full line. As it is expected to be used rarely, I did not want to build a ninth argument into setup. So, if you want a question footnote

- a) You insert a tex command `\gdef\undernote{Text of footnote}` into the question statement.
- b) Then you follow the question statement, as usual, with the answers, the `\xxxquest`, and any arguments that form of question may have.
- c) This feature is now available with all the question styles.
- d) (A useless fourth comment.)

This is a question footnote.

33. In order to make a database of exam questions more useful, it is good to be able to track where the questions originated, what material is covered, how the students performed (including which wrong answers were popular), and why certain wrong answers were used as “distractors”. To do this, two tex macros, `\attrib` and `\explain` have been added to `exammac2.tex`.

[#33: #28 Joel Shapiro, not covered in Serway, 227f03h1:0 (16,13,18,51\*,3)]

- a) `\attrib` is intended to come at the end of the question statement. It should give the number (in the database) of the question, authorship, physics topic covered, exam used, and performance statistics.
- b) The above question statement ended with:  
to `{\tt exammac2.tex}`. `\attrib{\#28 Joel Shapiro, not covered in Serway, 227f03h1:0 (16,13,18,51*,3)}`
- c) The performance statistics should be a parenthesized list, of the percentage of students giving each answer, with the correct answer starred.
- d) Of course this needs to be turned off for the real exam. See the next question.

34. The `\explain` macro should appear in each **answer**.

- a) `\explain` is intended to tell why each answer is a good answer to present. [*like this*]
- b) The explanation in the last answer was included by ending the last answer with:  
to present.`\explain{like this}`
- c) Of course `explain` and `attrib` must be turned off for the real exam. When `\realexamtrue`, the `explain` and `attrib` commands, with their arguments, produce no output.
- d) To get the `attrib` and `explain` comments to show up, the command `\realexamfalse` needs to appear uncommented in the exam header.

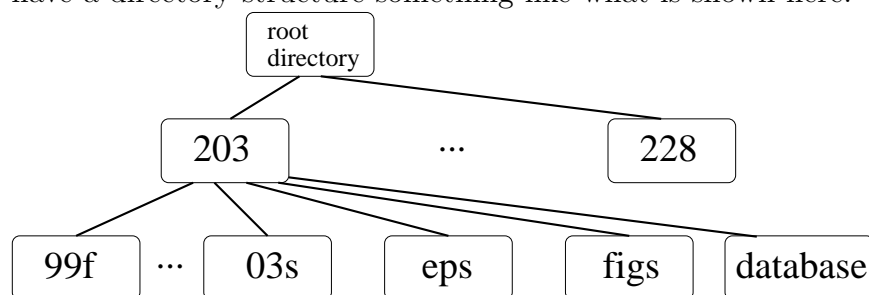
35. Here is an example:

A uniform surface charge density of  $+5.0 \text{ nC/m}^2$  is distributed over the entire  $xy$ -plane. Consider a spherical (radius = 0.050 m) surface centered on the origin. Determine the electric flux through this spherical surface.

[#35: #11; Question only from Saunders TestBank 24.6 on 24.2, edited slightly.  
227f96h1:6 (33\*,38,11,7,11)]

- a)  $4.44 \text{ Nm}^2/\text{C}$  [ $\pi r^2 \sigma / \epsilon_0$ ]
- b)  $17.74 \text{ Nm}^2/\text{C}$  [ $4\pi r^2 \sigma / \epsilon_0$ ]
- c)  $0.296 \text{ Nm}^2/\text{C}$  [ $4\pi r^3 \sigma / 3\epsilon_0$ ]
- d)  $45.0 \text{ Nm}^2/\text{C}$  [ $k_e \sigma$ ]
- e)  $1.8 \times 10^4 \text{ Nm}^2/\text{C}$  [ $k_e \sigma / r^2$ ]

36. The database for a course can get quite large, and some thought should be given to how to structure it. I believe it is useful to have a directory structure something like what is shown here:



- a) The “question” file for `grtex` would be in the `database` directory, and would contain all the questions. Any figures referred to in a question would be referenced as `{../eps/figurefile}`
- b) The question file would contain `\input cover.tex` and `\input tail.tex` in the appropriate places, before and after the questions. It might also contain an `input options.tex`.
- c) Each semester has its own directory, which will contain the files `cover.tex`, `tail.tex` and `options.tex` for the current exam. It also contains the “want” file for the exam.
- d) To make an exam, one changes directory to that for the current semester, and executes `grtex`. When asked for the FILE FOR Questions, give `../database/filename` so as to get the file from the database directory.
- e) Note that if you expect to share questions and figures among different courses, you might eliminate the course layer in the directory structure.

37. Here are some other documents relevant for computer assisted exams and record keeping.

[#37: As of Oct. 24, 2003]

- a) This file, the template, and the pictures used are in `/physics/doc/physics/grading/grtex` on the Suns.
- b) GRTeX, by Richard J. Plano, explains how to use the `grtex` program which produces multiple versions of the exam. It also discusses other aspects of the GREAD/GRED/GRAD/GREK assembly of programs.
- c) `/physics/doc/physics/grading/grek_unix` contains a number of files by Mohan Kalelkar explaining the use of GREK.
- d) `/physics/doc/physics/grading/grtex/grtex.*` contains older instructions by Joel Shapiro for using `grtex`. This predates the numerical questions and does not include them.

## Getting Started

The instructions above provide a very rich set, probably too rich, of options for a beginning `grtex` exam writer. I suggest you start by producing a simple exam. You could start with the template `examex.template`. If you have cover page material, enter it after the line

```
% enter your cover page material here, if you want one.
but if not, comment out the line \clearpage so it reads
```

```
% \clearpage
```

Then enter a set of questions after the line

```
% enter your exam questions here. #####
```

and before the line

```
% end of exam questions.
```

Finally, if you have material to go after all the questions, enter it just before the `clearpage` at the end of the file.