General Points:

At its most elementary level, the engineering report is a record of findings. However, a good report should convey information expeditiously, and in a form the reader can easily comprehend. The information must also be accessible; specific key points should be easy to find without reading the entire report (see 3 below). These purposes are as often compromised by excess as by deficiency. Excess verbiage, cluttered graphics, attempts to be cute, esoteric, erudite, artistic, etc. should be avoided unless they clearly aid the fundamental purposes of the report. This does not mean the report has to be boring; in fact, boring is an impediment itself.

1. Organization: The material should be presented in a logical fashion. Often this is in a chronological order; however, the chronology should be as if everything went correctly so that the sequence of events is easy for the reader to follow. Remember, a standard sequence is approachable by most readers and certainly aids accessibility and comprehension of the material.

2. Length: A report should never be longer than it has to be to accomplish its objectives. If you can put material in appendices or refer the reader to previous literature, do it! Repetitive information should be condensed. Show one example; then list only the bottom-line results of others. Points will be deducted for excessive length because length per se can reduce severely the efficiency of the report.

3. Accessibility: Does the reader have quick, painless and random access to the information? Accessibility requires, among other things, organization (e.g., text, tables and figures in the appropriate sections, thoughtful headings), attractiveness (adequate white space, large font, short paragraphs), readability (correct grammar, smooth sentence structure), stand-alone figures and tables, etc. (A stand-alone figure can convey essential information to the reader without reference to the text. A good test is a “yes” answer to the question: Can an engineer not connected with the study take the figure alone, project it on the screen and say something intelligent about it?) Number the pages and provide a table of contents for reports exceeding ~10 pages.

Specific points on various sections:

Abstract: The abstract is written last and looks back. Its first job is to tell the reader whether the report needs to be read or not. Abstracts are used for machine searches, and thus every word should count. It should describe briefly the subject system and/or substances, ranges of controlled and observed variables, important or unusual aspects of the equipment, key findings and finally the impact of the findings.

Introduction: The introduction tells what the situation was before you started the study. While previous work has always been done, there are invariably some problems with available knowledge. What is the problem, why is it important that it be solved, and what were your objectives at that juncture? (The latter refers to what your objectives should have been at that juncture.) As an example, an objective for the double-effect evaporator might be to find the set
of operating parameters that will give maximum steam efficiency for the production of distilled water.

Experimental: This section is the most straightforward. In an accurate but brief fashion, describe the materials and equipment used, and how you ran the experiments. Confine your discussion to the procedures that eventually produced the reported results; don't bother to describe all the mistakes you made. This section often has a drawing of the apparatus and a table describing the chemicals. It makes the most sense to the reader if you use past tense, because you have, at least in principle, finished the study. This can apply even to equipment that still exists. However, often standard operating procedures can be separated out and written in the present tense. (Historical note: the classical style for scientific papers was to write everything in the present tense. Today's readers of these reports find them confusing and pompous, as if the methods described are still the only proper ones.) Use proper abbreviations for units associated with numbers (e.g., “10 h” not “10 hours”; but “an hour”). The NIST website (nist.gov) has a comprehensive list of standard abbreviations.

Results and Discussion: The results are history, but their implications may be everlasting. Thus, this section is the hardest to word and requires care, thought and appropriate modesty. If your results do not allow a conclusion to be drawn, say as much in the discussion of these results. But don't stop there; tell the reader what could be done to arrive at more definitive answer. Sample text might be:

Table 2 lists (present tense) the mass-transfer coefficients ($K_{ga}$) found (past tense) in this study along with the corresponding values of vapor and liquid flow rates, and caustic concentration. Multivariable analysis of this data using the model described in Eq. 1 revealed (past tense, because the analysis was done in the past) that caustic concentration was (if you use "is," it implies that your result is the only possible one—very arrogant!) a significant factor under the conditions of our study (more humility), while the flow rates of vapor and liquid were not. Based on the results described by Smith et al. [2] [or Smith et al. (1990)] for a similar study, increasing the liquid flow rate was (or “is;” your choice) expected to increase $K_{ga}$. One hypothesis for the discrepancy is that the design and packing of the column used in our study allowed the fluid to channel at high flow rates, decreasing the effective transfer area. Introducing additional distribution plates into the column could check this hypothesis. (A concrete suggestion for the next engineer stuck with this horrible equipment.)

Conclusions and Recommendations: These are the take-home messages for the reader. Generally, there is no need to summarize everything you did and found; restrict yourself to key findings. Some authors use list format here to remind themselves that the points made must be fully substantiated by the results. A conclusion might read as follows:

A parametric study of packed-column performance for the absorption of CO$_2$ into NaOH solutions gave $K_{ga}$ values ranging from 4.1 to 8.5 mol/(ft$^3$ h mmHg). Possibly because of channeling problems with the column and packing used, a dependency of $K_{ga}$ on either liquid or vapor flow rate could not be demonstrated.

On text, figures and tables:

Text
Use complete sentences and organize them by paragraphs. While a list (bullet) structure is allowed, make sure that the information can be handled best by a list. Prose, according to many
English instructors should be written in the first person with active voice. Many engineering firms prefer, or even insist, that prose be written in the third person, often with a passive voice, because engineers like to think that the action done is more important than exactly who did it (even though they insist on having the doer’s name on the report).

Active voice, 1st person: I (We) titrated the samples in random order.
Passive voice: The samples were titrated in random order.
Active voice, 3rd person (neuter): The titration procedure described previously yielded the results listed in Table 1.
Active voice, 3rd person: He (or Vincent) titrated the samples, which were drawn at the times indicated in Table 2.

The latter is rarely used unless one is referring to work done on the outside.

**Back to tense.** If the tense makes sense, don't worry about switching tense within a paragraph or even sentence. The easiest guide to tense is to imagine that you are writing the report a year after the end of the project, all the equipment has been torn down and discarded, the calculations were finished during the project. Thus while tables and figures are (present tense) in front of the reader right now and the results are listed in tables or depicted in the figures, they were derived from the data. (Remember, you derived the results; someone else doing the derivation in the future just might get a different answer! If you use the present tense, you are implying that your answer is the only possible answer, which is not necessarily the case.)

**Tables**

Table 1. Rate constants vs. temperature.

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Feed concentration</th>
<th>Rate constant, mL/(mol s)</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch</td>
<td>0.05 mol/L</td>
<td>2.5 x 10^-3</td>
<td>24 °C</td>
</tr>
<tr>
<td>Batch</td>
<td>0.05 mol/L</td>
<td>3.4 x 10^-3</td>
<td>30 °C</td>
</tr>
<tr>
<td>Batch</td>
<td>0.05 mol/L</td>
<td>5.6 x 10^-3</td>
<td>45 °C</td>
</tr>
<tr>
<td>Batch</td>
<td>0.05 mol/L</td>
<td>9.5 x 10^-3</td>
<td>53 °C</td>
</tr>
<tr>
<td>Tubular</td>
<td>0.05 mol/L</td>
<td>2.3 x 10^-3</td>
<td>28 °C</td>
</tr>
<tr>
<td>Tubular</td>
<td>0.05 mol/L</td>
<td>3.3 x 10^-3</td>
<td>32 °C</td>
</tr>
<tr>
<td>Tubular</td>
<td>0.05 mol/L</td>
<td>8.9 x 10^-3</td>
<td>54 °C</td>
</tr>
</tbody>
</table>
Table 2. Second-order kinetic results for isopropyl acetate saponification with stoichiometric feed concentrations of 0.05 mol/L.

<table>
<thead>
<tr>
<th>Reactor type</th>
<th>Temperature, °C</th>
<th>Rate constant, L/(mol s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batch</td>
<td>24</td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>45</td>
<td>5.6</td>
</tr>
<tr>
<td></td>
<td>53</td>
<td>9.5</td>
</tr>
<tr>
<td>Tubular a</td>
<td>28</td>
<td>2.3</td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>54</td>
<td>8.9</td>
</tr>
</tbody>
</table>

*Operated at Re = 4300, but interpreted with plug-flow equations.*

The purpose of a table is to present lists of numbers in an orderly fashion to provide the reader with a summary of quantitative or nominal variables. List values of independent variables, in order of increasing frequency of change, in the left-most columns. Dependent variables go to the right, with the final, fully polished results on the far right. If you find that you are repeating something within a column, stop; it belongs in the column heading (or possibly the title or a footnote), not in the column.

For example, in Table 1, the 3rd column has the units listed throughout; the advantages of a table are clearly not being exploited! The second column is totally repetitive; the entire column should be eliminated in favor of a single number in a footnote or the caption. (If you like to use columns filled with constants for your spreadsheet computations, then hide these columns before copying the table into your report.) The 4th column contains a common multiplier; eliminate this with a standard unit multiplier as shown in Table 2 (preferred) or a common arithmetic multiplier in the heading. The formatting in Table 2 saves ink, saves time, and yet gets the information across with no clutter. Note that the repetition of the nominal variable in the 1st column is not needed. Also, the caption has been reworded to provide more information and eliminate redundancy. The independent variable temperature has been relocated to the left of the results to provide a logical flow of information. Minimum ruling would consist of lines under each column heading, but ruling style is a secondary issue as long as the columns and rows are clear. All tables must be numbered to allow easy reference from the text and provided with a caption (title, same thing) so that the reader can figure out what is listed without having to wade through pages of text. Titles of tables traditionally go on top of the table, while for figures, the caption goes underneath. Symbols or entries that need clarification should be footnoted at the bottom of the table, as shown in Table 2.
Figures

Figures are often the key expression of an engineering report, and the writer should strive to create figures that have impact and lasting value. While there is definitely an aspect of artistry in a good figure, many items can be reduced to the routine, as follows: Include figure number and title, for the same reasons as for tables. Both (or all) axes must have a scale and a label. If the scale is dimensional, the label must carry the units written using correct abbreviations. Do not extend the scale to physically impossible values of the variable. Do not bury the axis in the middle of the data. (Yes, one can move the axis location in Excel.) Use consistent style throughout the report, so that the reader does not have to pause at each figure to decode symbols, etc. Use legible text and symbols that are no smaller than 1/30 of the biggest dimension of the plotted area. (An easy-to-remember rule of thumb for the size of the tick and axes labels is to multiply the largest dimension of the graph in inches by 4 to get the point size. Other text can be 2 to 4 points smaller. If this rule is followed, the text will be legible at large reductions or when projected. Data points should be about the same size, although smaller if there are many points.)

Use great care with curves describing what you think the data should really do; it’s usually better to let the data speak for themselves unless you have an appropriate theory that can be used to describe the data. (Do not throw straight lines or polynomials willy-nilly through the data; polynomials have some extremely poor characteristics, and are usually physically meaningless.) Label the curve with the theory (e.g., Arrhenius theory) or the equation used to generate the curve. Remember, curves are depictions of functions, which are defined everywhere in the figure. Curves are not a series of straight–line segments traveling from one calculated point to another. If your graphing software does not calculate a large set of plotting points automatically for a given function, you must force it to do this in separate columns.

With multiple data sets in the same figure, label each with the appropriate value of the factor that has been changed to arrive at each response. Use a separate key only if it is impossible to identify the sets directly. Distinguish data points with different symbols and corresponding curves with different textures. Unless you have color reproduction equipment, and want to pay for it, avoid depending on color to distinguish curves (although color is very helpful on slides). If you use both the darker colors and distinctive texture, you probably will be safe regardless of the method of reproduction. Attempt to be consistent with the meaning of lines and symbols, figure to figure, to save the reader time.

Figure 1. Arrhenius plot of second-order rate constants derived from batch saponification reactions using equimolar amounts (0.05 mol/L) of NaOH and isopropyl acetate.
Bar graphs are fine when a nominal variable (e.g., men vs. women) is being depicted on the abscissa. (However, this information is almost always presentable in a more accessible fashion in a table, at least for engineers.) Never use bar graphs for quantitative independent variables, as the analogy between spatial position of the bar and the value of the independent variable is normally lost. Be very careful with the use of bar graphs for multiple data sets, as the analogy between bar height and value of the variable can be very confusing to the reader. In addition, the shading can become illegible when xeroxed. The latter also applies if separate bars are used for each set. Do not use shadowing, as the position of the bar’s top becomes obscured. Figures (or tables) with highlighting or colored backgrounds usually copy very poorly and can become completely illegible.

An example of acceptable figure (although the data are not the best!) is shown in Figure 1. (A recommended change would be to remove the $R^2$, as it is not very helpful and can possibly be misleading, as it is in this case.) Note that the labels of both axes, even the ordinate with the log scale, feature units with the variable name. Common delimitators between the variable symbol and the unit abbreviation include the comma (shown), a space, a slash, and a parenthesis mark. Each has some advantages; use what is most comfortable, but be consistent. If the variable symbol is not obvious from common usage, the units, and the context, either spell out the variable or define it in the caption.

Bottom-line tables and figures should appear near the place they are first cited in the text. It’s OK, and often easier, to place figures and tables on separate pages, but still near the first citation. If you imbed the figure in the text as an image, make sure it is readable! (With MS Word, the least frustrating and memory-intensive method is to Paste Special/Picture/Fix (or in line) directly from an image copied onto the clipboard from the graphing application.) Do not fill up the body of the report with repetitive plots of raw data. It is the author’s job to process raw data and present it in a summary form, e.g., $f$ vs $Re$ for pressure drops in diverse pipes, or as equations that model the entire set of data. Precious space in the report body should be reserved for figures that carry the key messages. At times this might include a sample of raw data, as there could be something unusual about this data that needs discussing.

**Equations**

An important aspect of engineering communications is mathematical expression. Many engineers have grave problems understanding a quantitative concept without the help of an equation. Text such as “the mass-transfer coefficients taken at different vapor and liquid flow rates were shifted onto one straight line” is quite a bit less satisfying than an explanation involving an equation such as:

\[ K_g a = \alpha V^\beta L' \]  \hspace{1cm} (1)

where $K_g$ is the mass-transfer coefficient; $a$ is the packing area per unit column volume, $V$ and $L$ are the vapor and liquid flow rates, respectively; and $\alpha$, $\beta$ and $\gamma$ are parameters determined by the fitting process. (A fine point is the use of italics for the symbols; note how this saves puzzling about the isolated variable $a$ when it appears in the text.) It is important to use standard algebraic notation including full subscripts for compound variable symbols. For example, $K_g$ is a single variable, $K_g$ means $K$ times $g$, and $K^*g$ means $K^*$ times $g$. This applies to equations anywhere: tables, figures, text etc., but not to verbatim listings of computer code. The equations should be numbered to provide easy reference from other parts of the report, and all symbols must be defined. (This rule can be relaxed if the symbol and its context are highly universal, such as the $R$ in $k = k_0 \exp(-E^*/RT)$. ) Short in-line equations or expressions like the one in the last sentence...
are fine if they are not used or cited elsewhere in the report. Eschew programming code style unless you are directly discussing code. Symbols can be defined in a separate nomenclature list, which has the added advantage of forcing the writer to use consistent notation throughout. However, refer the reader to this list immediately below the first equation, at least. There is nothing wrong with using both methods, as long as the two are consistent.

**Sample calculations**

Complex spreadsheet calculations can be very difficult for the reader to understand and check, especially when they do not have access to the file to check the formulas. Thus, clarify the first row of a calculation spreadsheet by providing a sample calculation based on the data in the first row. This calculation can be done neatly by hand in a style similar to a homework problem solution. Include sketches, as appropriate, and symbol definitions. If you do these calculations before you set up the spreadsheet, they can guide the coding of the spreadsheet and help you to avoid serious errors. For the reader, however, the sample calculation may be the only way he or she can verify that the answers are correct. A less desirable alternative is to provide a complete and verbatim listing of the formulas used for each cell, along with a key to any variable symbols. (Note: a “listing” is a printout of the actual code used for the calculation—not a summary of what you thought you used.) The reason a listing is less desirable is that it is easy to forget to include the units of the dimensional numbers listed in the spreadsheet. Append the sample calculations to the report in a distinguishable fashion and cite them in a footnote on the related table. Very simple sample calculations can be footnoted directly on the table.

**Page numbering**

Pages in a report must always be numbered for reference. To keep life simple, however, minimize references to page numbers in the text of the report, as the page numbering may change at a moment’s notice. (Those familiar with Word’s “Insert Reference” can ignore this.) Page numbers are used for indexing (not needed in most engineering reports), the table of contents, and for conversations and communications about the report. A time-saving practice is to use section numbering in conjunction with the pages (e.g., A-1, A-2, …, B-1, B-2 etc.) especially for appendices. This allows the writer to insert or delete pages in a section without renumbering everything. For the lab reports, the appendices may be numbered by hand. If you have a scanner (and the time!) you may scan sheet material and insert images into your electronic document, in which case page numbering can be done automatically.