Chapter 1

Problem 1.1

There are many possible correct answers to this question and it can be answered in varying levels of detail. The key steps that should be included for each process with typical required times are listed below. The project plan can be sketched using a spreadsheet or drawn up using a project planning tool such as MS Project (as in Problem 1.2).

a) A petrochemical process using established technology, to be built on an existing site. Since the technology is established, there will be no need to generate design concepts and carry out R&D. The steps are then:

   Set design basis (1 week)
   Evaluate economics, optimize and select design (typically 10-30 weeks, depending on project scope)
   Detailed design and equipment selection (typically six months to one year)
   Procurement and construction (typically one year)
   Shakedown and start-up (typically one month)

   These steps are usually more or less sequential, although some procurement of long lead-time items may be started during detailed design.

b) A process for full-scale manufacture of a new drug, based on a process currently undergoing pilot plant trials. Since the pilot plant is already operating the designer already has a good idea of the process flowsheet and the goal is to be prepared to ramp up production to full scale once the drug is approved. The steps are:

   Set design basis (1 week)
   Confirm performance/scale-up of pilot plant operations (2-20 weeks, depending on how smoothly pilot plant runs)
   Optimize and select design (10-20 weeks)
   Detailed design and equipment selection (about six months)

   In parallel to these process design activities there will be activities related to getting approval for the new drug:

   Conduct clinical trials (6 months to 2 years)
   Review clinical trial results (typically 3 to 6 months)
   Obtain FDA approval

   Some of the procurement and construction activities will be started as soon as the first clinical results look promising, but final construction and shakedown will not occur until the review of clinical trials is completed.

c) A novel process to convert cellulosic waste to fuel. The technology and flowsheet will need considerable development, so a schedule might be:

   Set design basis (1 week)
   Generate design concepts & carry out R&D (one to five years)
   Evaluate economics, optimize and select design (six months, but could run parallel to generating design concepts for up to five years)
   Detailed design and equipment selection (six months to one year)
   Procurement and construction (about one year)
   Shakedown and start-up (one month to one year, as there may be start-up hiccups with a new technology)

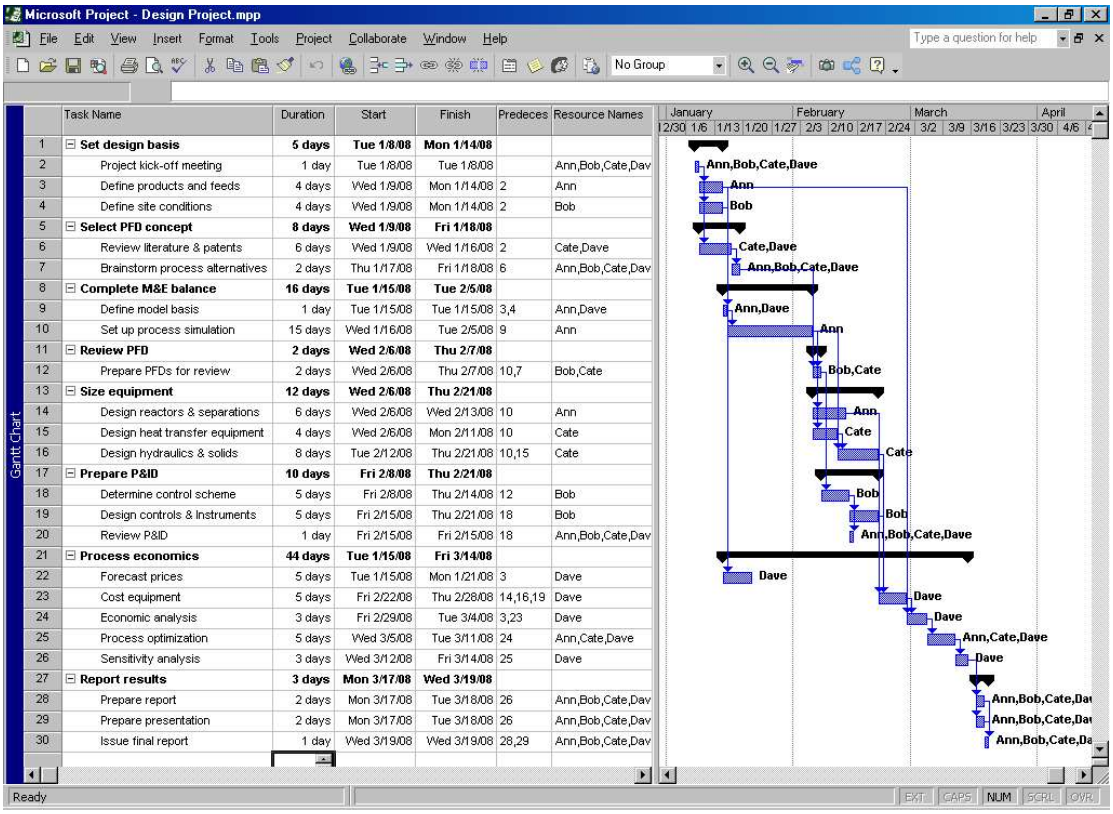
d) A spent nuclear fuel reprocessing facility. There is established technology for nuclear fuel reprocessing, but new processes are always possible. For an established technology the schedule would look much like problem (i) and for new technology it would look like problem (iv). All of the steps would probably take longer because of the scale of the plant and additional steps would be needed for obtaining local, state and federal permits and revising them after setting the design basis, selecting the design, and completing detailed design. The time taken to obtain permits could be several years and the total time to operation would probably exceed ten years.

e) A solvent recovery system for electronics production. This is a relatively small project, so the steps would be:

   Set design basis (1 – 2 days)
   Generate design concepts (1 to 2 months)
   Evaluate economics, optimize and select design (ten weeks or less)
   Detailed design and equipment selection (2 to 3 months)
   Procurement and construction (3 to 6 months)
   Shakedown and start-up (one month)

Problem 1.2

This requires a more detailed breakdown than problem 1.1. A sample project plan is given in the lecture slides and shown below (in MS Project format):



	Task Name	Duration	Start	Finish	Predeces	Resource Names
1	**Set design basis**	**5 days**	**Tue 1/8/08**	**Mon 1/14/08**		
2	Project kick-off meeting	1 day	Tue 1/8/08	Tue 1/8/08		Ann,Bob,Cate,Dav
3	Define products and feeds	4 days	Wed 1/9/08	Mon 1/14/08	2	Ann
4	Define site conditions	4 days	Wed 1/9/08	Mon 1/14/08	2	Bob
5	**Select PFD concept**	**8 days**	**Wed 1/9/08**	**Fri 1/18/08**		
6	Review literature & patents	6 days	Wed 1/9/08	Wed 1/16/08	2	Cate,Dave
7	Brainstorm process alternatives	2 days	Thu 1/17/08	Fri 1/18/08	6	Ann,Bob,Cate,Dav
8	**Complete M&E balance**	**16 days**	**Tue 1/15/08**	**Tue 2/5/08**		
9	Define model basis	1 day	Tue 1/15/08	Tue 1/15/08	3,4	Ann,Dave
10	Set up process simulation	15 days	Wed 1/16/08	Tue 2/5/08	9	Ann
11	**Review PFD**	**2 days**	**Wed 2/6/08**	**Thu 2/7/08**		
12	Prepare PFDs for review	2 days	Wed 2/6/08	Thu 2/7/08	10,7	Bob,Cate
13	**Size equipment**	**12 days**	**Wed 2/6/08**	**Thu 2/21/08**		
14	Design reactors & separations	6 days	Wed 2/6/08	Wed 2/13/08	10	Ann
15	Design heat transfer equipment	4 days	Wed 2/6/08	Mon 2/11/08	10	Cate
16	Design hydraulics & solids	8 days	Tue 2/12/08	Thu 2/21/08	10,15	Cate
17	**Prepare P&ID**	**10 days**	**Fri 2/8/08**	**Thu 2/21/08**		
18	Determine control scheme	5 days	Fri 2/8/08	Thu 2/14/08	12	Bob
19	Design controls & instruments	5 days	Fri 2/15/08	Thu 2/21/08	18	Bob
20	Review P&ID	1 day	Fri 2/15/08	Fri 2/15/08	18	Ann,Bob,Cate,Dav
21	**Process economics**	**44 days**	**Tue 1/15/08**	**Fri 3/14/08**		
22	Forecast prices	5 days	Tue 1/15/08	Mon 1/21/08	3	Dave
23	Cost equipment	5 days	Fri 2/22/08	Thu 2/28/08	14,16,19	Dave
24	Economic analysis	3 days	Fri 2/29/08	Tue 3/4/08	3,23	Dave
25	Process optimization	5 days	Wed 3/5/08	Tue 3/11/08	24	Ann,Cate,Dave
26	Sensitivity analysis	3 days	Wed 3/12/08	Fri 3/14/08	25	Dave
27	**Report results**	**3 days**	**Mon 3/17/08**	**Wed 3/19/08**		
28	Prepare report	2 days	Mon 3/17/08	Tue 3/18/08	26	Ann,Bob,Cate,Dav
29	Prepare presentation	2 days	Mon 3/17/08	Tue 3/18/08	26	Ann,Bob,Cate,Dav
30	Issue final report	1 day	Wed 3/19/08	Wed 3/19/08	28,29	Ann,Bob,Cate,Dav

Suitable intermediate deliverables could include:

The design basis
A completed PFD (or PFD review)
A completed process simulation
A completed PID (or review)

Problem 1.3

a) The list of product requirements will be somewhat qualitative and depend on the preferences of the "customer" group. The required properties of the dough must consider properties of the dough itself, as well as properties of the final (home-baked) product. Some properties of the dough that might be considered include:
   - Shelf life
   - Calorie content
   - Chocolate chip content
   - Stiffness (do you scoop it or is it preformed in cookie shapes?)
   - Baking time

   Properties of the end cookies are perhaps more obvious:
   - Chewiness
   - Crunchiness
   - Sweetness
   - Saltiness
   - Mouth feel
   - Serving size (if pre-formed)

b) The product specifications could include the following:
   - Composition of major ingredients (see any cookie dough: flour, fat or oil, water, etc.)
   - Composition of chocolate chips

- Size of chocolate chips
- Composition of minor flavors (salt, vanilla, etc.)
- Composition of baking soda?
- Type and composition of sweetening agent
- Type and composition of preservatives, stabilizers
- Type and composition of viscosity modifiers?
- Mixing order
- Mixing time, speed, temperature
- Dough aging / forming processes (extrusion, cutting, rolling, etc.)