

# **FED 101D**

## **Industrial Engineering Module**

Stephen J. Tricamo  
Professor, Department of Industrial and Manufacturing Engineering  
New Jersey Institute of Technology  
Newark, NJ 07102-1982

This document contains a partial version of the FED Module for Industrial and Manufacturing Engineering. In addition to these notes, students also use the following supplements:

- M. Baxter, *Product Design*, Chapman & Hall Publishing Co., 1995.
- B. Thompson, *Creative Engineering Design, 4<sup>th</sup> edition*, Okemos Press, 1997.
- K. Ulrich and S. Eppinger, *Product Design and Development*, McGraw-Hill, 2000.

## COURSE INFORMATION

## I. OBJECTIVES

In this course you will learn at an early stage in your studies what engineers do and what the practice of engineering is about. This will be done by guiding you through all of the stages involved in completing a typical engineering design project. To successfully complete the project you will need to be actively involved in the learning process. You will need to gather and analyze technical information, organize your time, put together a management plan, use your creativity to design and construct a device meeting a given set of specifications, and learn to work in a group setting. You will need to communicate your results in oral and written form, and apply computer skills and resources to aid in completion of your project.

## II. STRUCTURE AND ORGANIZATION

The course meets once a week. Class activity will include exercises that will familiarize you with various activities you will be engaged in to complete your project. Students will work in teams of 4 or 5 members. There will be opportunities during class meetings to work on your project. During these times, I will work with each team to help them with their individual projects. It is likely that you will also have to devote some time outside of class to complete the required course activities.

Students will also be required to keep a personal log of their activities in the course. You will include this log in an appendix of the final project report you submit at the end of the course.

## III. PROJECT

The class will be given a description of a set of requirements that must be met by a device that they will design and build. Each group will work on their own solution. Each team will be working against the other teams in the class to come up with the best solution to the problem within the given guidelines stated in the project description. At the end of the semester, a contest will be held to determine which team's design is best.

## IV. GRADING

Each student will be given a grade reflecting their performance in the various activities of the class. To some degree, grades given to team efforts, such as the preparation of a final report, will affect individual grades but it is possible for members of the same team to get different grades. Your personal activities log will also be used to evaluate your performance and assign your grade. Your final grade will also be determined by the team competition at end of the semester. Members of the winning team will be assigned bonus points that will raise their individual final grade. The largest number of bonus points will be given to the winning team and proportionally fewer given the second and third place teams. The team finishing last will receive no bonus points.

## V. ATTENDANCE

Regular attendance is mandatory for all first year students. The university requires an attendance record to be kept. Excessive unexcused absence will result in failing the course.



Design Exercise:  
Construct a Flying Device

This exercise will require each team to design and construct a flying device. This device must meet the following two design specifications:

1. It must stay in the air as long as possible
2. It must get as close as possible to a given target.

The competition will be held at the rotunda of the ITC building. One member of the group will go to the second floor balcony and launch their device. The target will be the first floor center square of the rotunda. Time will be recorded from the moment the device is launched from the second floor until it hits the ground. The distance from the device to the target will then be measured. The score is a combination of longest flight time and closest landing to the target.

**Note, however, that flight time will represent 70% of the score and distance to target 30%.**

Each team will be given the following materials:

- several sheets of paper
- about 3 feet of tape
- a pair of scissors

Teams will have about 45 minutes to design and construct their device. Only one entry will be permitted for each team. Any testing must take place in the classroom. If time permits, teams will be allowed more than one run. All run results will be treated as a single set of data in determining the final scores for each group. The best of each group's scores will be used to determine the overall order of finish.

<u>Team/Trial</u>	<u>Time (sec)</u>	<u>Distance (in.)</u>	<u>Score</u>
1	1		
	2		
2	1		
	2		
3	1		
	2		
4	1		
	2		

\* Combine all trial runs into one data set.

Scoring

A) Time : 
$$\frac{([\text{Team's time}] - \text{shortest time})}{(\text{Longest time} - \text{shortest time})} \times 70 =$$

B) Accuracy : 
$$\frac{(\text{Longest distance from target} - [\text{Team's distance}])}{(\text{Longest distance from target} - \text{Shortest distance from target})} \times 30 =$$

Note: Bring stopwatch and tape measure to determine time & distance

## Project Planning Process

## I. Managing the Project

- Prepare a written description of the project and the objectives to be achieved
- Write an outline of the project plan that describes:
  - all tasks to be performed
  - when each task will be completed
  - who is responsible for each task
- Appoint a project manager responsible for:
  - keeping the project on schedule
  - scheduling team meetings
  - maintaining a written record of the team's progress, problems, and work done by each team member
- Collect and summarize all data
- Prepare written report and oral presentation

## II. Carrying Out the Project

- Prepare a specification of the project or product, listing what you are going to do and what you are going to produce or deliver
- Gather information about all known solutions, products, facts, and requirements about the project or product
- Determine required and desirable characteristics for product
- Generate as many alternate solutions as possible
- Reduce number of alternate solutions to two or three best choices
- Analyze best choices and pick one
- Prepare detailed design or solution to your project
- For design of a product, include industrial design and manufacturing process design
- Fabricate prototype and test
- Document all steps of the project implementation and include in written report.

#### **A. Description of Objective:**

Many manufacturing processes involve the use of hazardous liquids that require proper collection and disposal after use. A company in this area is exploring feasible options for transporting such material from a factory collection point to a disposal collection point. The company is asking students to contribute to this development by designing a device that meets the following requirements:

1. Design and develop a system capable of safely transferring 250ml (8oz) of water between two identical containers 2m (79 in) apart.
2. Initially 300ml will be in a standard 355ml (12oz) styrofoam cup, and 250 plus or minus 15ml must be transferred to the second styrofoam cup.
3. The system is to be powered by a small DC motor and gear set running off of a battery. No additional energy sources are permitted. One such drive will be provided for each group.
4. When the system is ready to begin the transfer, a 'go' signal will be given and the time to complete the transfer will be measured. During the transfer each and every spill of liquid will be assessed a time penalty of five (5) seconds. A spill is defined as any liquid that ends up on the surface holding the cups.
5. The design objective is to transfer the liquid as rapidly as possible without any spills.
6. Once the system has been put into operation, no further contact or guidance by contestants is permitted. The system must stop automatically when the transfer is complete.
7. The entire operation must be completed within five minutes, but the winner will be determined on the basis of transfer time.

#### **B. Determining a Winner**

The score for each valid run is computed as follows:

$$\text{SCORE} = T + 5 * N_s + V$$

where:

- T = the transfer time measured in seconds (rounded to the nearest tenth).
- N<sub>s</sub> = the number of "spills"
- V = the amount of liquid outside of the containers at the completion of the run  
= 300 - (total volume in both cups measured in ml).
- The lowest score wins.

If there is more than one trial, the best score for each team will be used.

**Additional Information About Class Project**

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1. **Where is the system permitted to start in relation to the two containers?**  
There are no restrictions on where the system is placed provided no part of the system is touching either container at the start.
2. **Is there a required finish or out-of-bounds zone?**  
There are no restrictions on the final placement of your system provided nothing is touching the destination container or the contained liquid at the completion of the transfer.
3. **What is the condition (roughness/flatness) of the surface like?**  
The containers will be centered on a 1" thick 4'x8' sheet of grade 'A' plywood lying on a flat surface. Slight surface imperfections, dirtiness, wetness, and nonflatness are possible but will not be intentional.
4. **"Are the containers affixed to the surface in any way?"**  
No.
5. **Are there dimension restrictions on the containers?**  
The approximate dimensions of the cups will be: base diameter = 53 mm, rim diameter = 89 mm, height = 117 mm. The cups will be provided and will be standard readily available 12 oz styrofoam cups; for example, the 12 oz StyroCUP brand made by WinCup (Phoenix, AZ).
6. **In Item 4 it states that "the contestant is not allowed to touch the styrofoam cups at any time." Is it okay for the transfer mechanism to touch or move the cups?**  
Yes, provided the destination container is standing no more than 1 cm from its initial position at the completion of the run.
7. **Will a small short splash-type spill of 1 ml be penalized the same amount as a large long sustained trickle-type spill of 65 ml (provided the remaining 235 ml is transferred to the destination container)?**  
No. In addition to the 5 sec per spill penalty, a 1 sec penalty will be assessed for each ml of liquid not contained by either container at the completion of the run. At the completion of a run, the liquid in the destination container will be measured and if the volume is not within the 235 ml to 265 ml range, the run is unsuccessful. If the run is successful, any liquid remaining in the source container is added to the transferred liquid. This total volume is then measured and subtracted from 300 ml, and a 1 sec penalty is assessed for each ml in the difference. For example, if a system delivers 255 ml of liquid to the destination container in 20 sec, and if 30 ml were left in the source container, and if the judges decide that 2 separate spills occurred, the resulting score would be 45 ( $20 + (300 - 255 - 30) + 2 \cdot 5$ ).
8. **Can energy storage devices (e.g., springs, rubber bands, capacitors) be used if they provide no net power output to the system?**  
Yes. However, each energy storage device must end the run with the same or more energy than at the beginning of the run.
9. **Does inserting a hose into a cup constitute touching the cup?**  
No, provided it only touches the liquid. No part of your system may touch either cup at the start. Also, at the completion of the run, no part of the system may touch the destination cup or the liquid it contains.
10. **How will spills be counted?**  
Any occurrence which results in water landing on the surface will be counted and penalized as a spill. Since determining the number of spills can be extremely subjective, here are some guidelines to help further define a "spill":

- A "messy splash," even though it may result in many puddles, should only be counted as 1 spill. However, each obviously distinct splash should be counted as a separate spill.
- A constant or intermittent "dripping" or "leaking" from one location on the system, even if the leak or drip point is moving should only be counted as 1 spill. However, each obviously distinct drip or leak point should be counted as a separate spill.

In summary, only obvious distinct spills should be penalized since the amount of volume spilled will also be penalized.

- 11. Can the contestants place something in the cup(s) if they do not touch the cup(s)?**  
Yes, realizing that this "something" is considered to be part of the system. Refer to Q&A #10.
- 12. If a pump is used, can it be primed before timing begins?**  
No.
- 13. Item 7 of the problem description states that once the system is started "no further communication of any kind is allowed to be transmitted." Does this prohibit all interaction with the system during the run?**  
Yes. Once the system is started, no external communication, interaction, or influence of any kind is allowed. In other words, the system must be completely autonomous and stop by itself without any external assistance whatsoever.
- 14. Can any part of the system leave the board during the transfer?**  
No.
- 15. Can the system or part of the system be temporarily fastened to the board with tape or thumb tacks before the run?**  
Yes, provided everything is easily and completely removed from the board at the completion of the run. Fasteners such as nails or screws which could result in significant damage to the board will not be allowed.
- 16. Is there a penalty if liquid is spilled during the setup?**  
Yes. If any liquid is spilled before starting your system, one 5 second spill penalty will be assessed. The amount spilled will also be penalized based on Q&A #8.
- 17. What is the penalty for touching the cup or knocking it over during setup?**  
There is no penalty for touching the cups during setup provided that no part of the system is touching either cup at the start. Also, the cups must be centered in their indicated positions, 2 m apart, at the start. If the cup containing the liquid is knocked over, the attempt is disqualified. Multiple attempts will be allowed if time permits.
- 18. What is the penalty if too little or too much liquid is transferred?**  
The attempt is disqualified.
- 19. Does the time stop when the motor stops or when the water stops flowing between the cups?**  
The time stops when water stops flowing both out of the source cup and into the destination cup.  
**Is the one motor and one battery the only devices allowed in the system to provide power and actuation?**  
Yes.
- 20. Can the first styrofoam cup be picked up and moved without returning it to its original position?**  
Yes.
- 21. Can the first styrofoam cup be cut, punctured or crushed?**  
No. Neither cup may be damaged in any way.
- 22. Can a chemical be added to the water to aid in its pumpability?**  
No.
- 23. Can the source cup be in physical contact with the system at the end of the run even if such contact prevents the source cup from touching the plywood?**  
Yes, given Q&A #10 and Q&A #12.
- 28. Can a solid be in the source cup, which would be removed at the time of water measurement?**  
Yes, given Q&A #10 and Q&A #12.

29. **Is potential energy considered an energy storage device?**  
Yes.
30. **Given that potential energy is considered an energy storage device, if part of our system goes down do we have to put it back up?**  
Strictly speaking, if the center of gravity (CG) of your system ends up at a lower height at the end of the transfer as compared to the CG height when the system was started, then your attempt will be disqualified. However, the CG of the system will not be measured before and after the transfer, so this will involve a judgement call. You will definitely be disqualified if you are obviously using a potential energy effect to aid the transfer (e.g., using a large mass falling over a distance to provide energy to a pump). If, on the other hand, some side effect in your system causes the CG to be lower at the end of the transfer, but the change in potential energy was obviously not utilized in the transfer (e.g., a piece of your system falls onto the board without imparting energy to the rest of the system), then the attempt will not be disqualified.
31. **Can the motor be disassembled and altered in any way?**  
No.
32. **What weight does originality, reliability, and clarity of written summary have in the final score as compared to the example of scoring given in Answer 8 of Update Bulletin No. 1?**  
The score is determined as described in Q&A # 8. The lowest score wins and the other criteria will be used only to break a tie.
33. **Q&A # 20 states that the contestant can touch the cup during setup. Does this mean that we can pick up the cup and set our machine around it as long as we put the cup back in the same spot and no part of the system is touching the cup?**  
Yes.
34. **Can the fluid in the first cup be transferred to a third container and can fluid remain in the third container at the completion of the transfer?**  
Yes, but the liquid in the third container will be penalized based on Q&A # 8.
35. **Can the cups be capped and/or pressurized?**  
Yes, provided the system does this automatically under the power of the single battery once the "go" signal is given. Also, see Q&A #'s 1, 10, and 16.
36. **Can we change motors and batteries between trials?**  
Yes.
37. **Is the battery power supplied at the competition?**  
Yes.
38. **What will be the temperature of the water?**  
Typical room temperature, approximately.
39. **What kind of water will be used (tap, distilled, etc.)?**  
Whatever is readily available at the contest; but most likely, tap water.
40. **Can the first cup be completely emptied?**  
Yes, but this will be penalized based on Q&A # 8.
41. **Will there be standard environmental conditions (no wind, extreme temperature, strong magnetic field concentration, etc.)?**  
There will be typical indoor conditions.
42. **Does the system have to be reusable or can it be designed to break itself (e.g., burning up the motor)?**  
It can break itself.
43. **Is there a weight limit to the system?**  
No.
44. **If water is no longer flowing out of the source cup and no longer flowing into the destination cup, but the system is leaking liquid onto the board, does the time stop (see Q&A # 22)?**  
No. The time stops only when all water flow has ceased.

45. **If the system is still dripping liquid after the apparent completion of the transfer, does the transfer time clock keep running?**

Any dripping will be considered "flow" (see Q&A # 44) and the time will continue to run until the drip rate slows below 1 drip per second (i.e., when the time interval between drips exceeds 1 second).

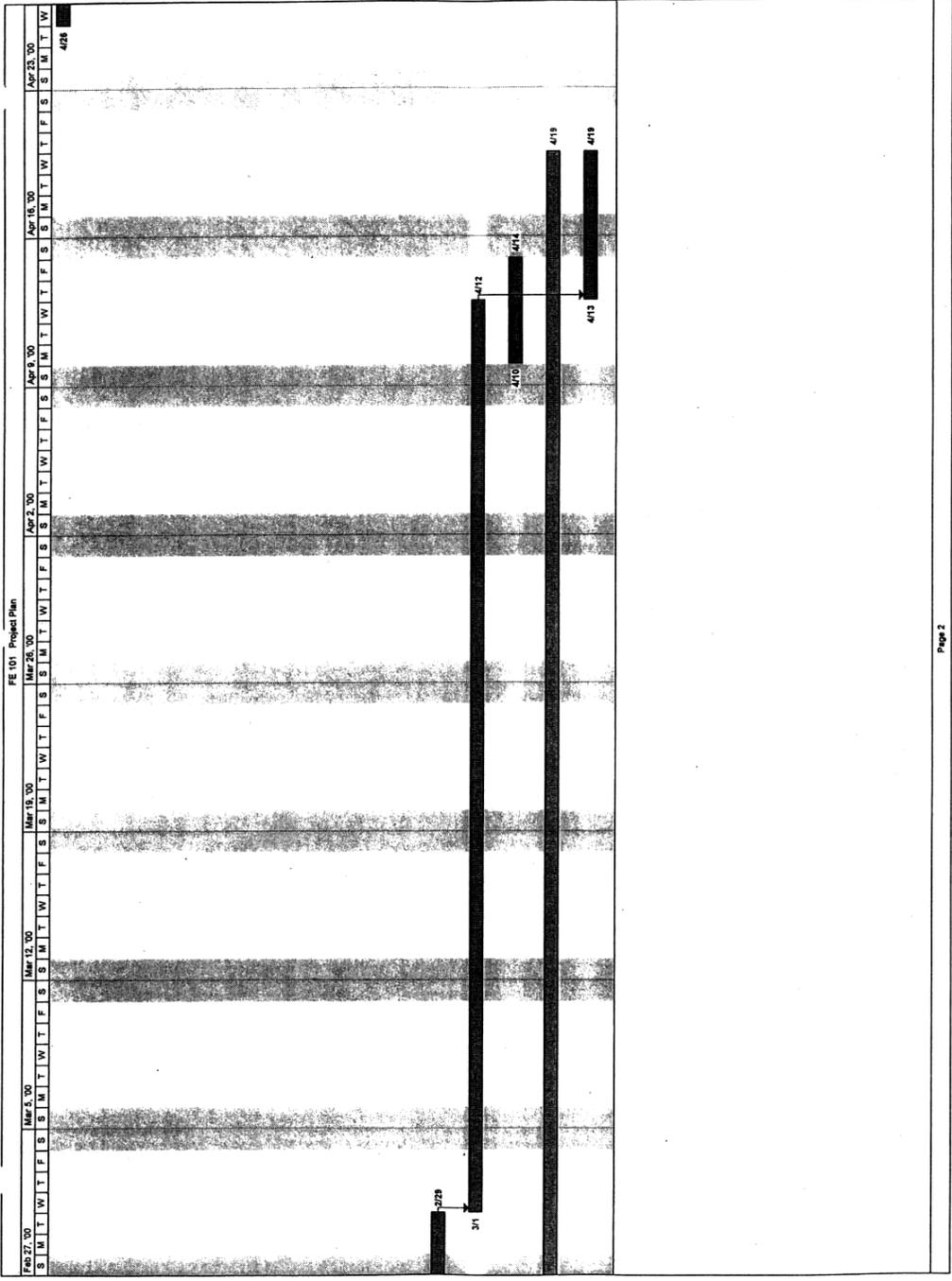
46. **Will a system that uses the change in vertical position of a float to trigger an event be disqualified since it is utilizing potential energy? What about a spring in a mechanical timer which is pre-wound?**

The float is OK since it does not actively provide power to the system and since it does not actively control the system. Instead, the float is just passively reacting and triggering an event in response to the liquid transfer process. Also refer to Q&A # 30. The pre-wound mechanical timer, on the other hand, is using the stored energy to actively control the device. Therefore, the system would be disqualified.

## Brain Teasers

1. The Chompem Cannibals of Drybone Island (shown left) have the annoying habit of eating each other. In fact, Grandpa Chompem went missing only last week, and it was thought he'd lost his way home until his bits and pieces were found on the beach. One evening, the Chompems threw a dinner party, one of those bring-a-friend get-togethers. Six cannibals turned up and they decided to eat each other in turn. So someone was selected for everyone to eat (except the victim!), and when he had been eaten, someone else was selected, and so on. If it took one cannibal two hours on his own to devour one person, how long was it before just one consumer remained?
  
2. Scatterbrain the Treasurer was a bit of a ... well, scatterbrain, and he had forgotten how many gold, silver and bronze coins were kept in the town vaults. So he decided to ask the three guards, each of whom guarded one type of coin, how many coins were in his charge. However, the guards were uncooperative, and the best that Scatterbrain could get from each was a statement about the numbers of coins in the other two vaults. Dimwit, who was guarding the gold, said there were 3000 silver and 5000 bronze coins; Thickplank, who was in charge of the silver, said there were 3000 gold and 5000 bronze; while Beefbrain, who was protecting the bronze, said there were 4000 gold and 3000 silver. Unfortunately, only one guard was being truthful, each of the other two stating at least one false amount. If there were 12000 coins altogether, how many of each type were there?

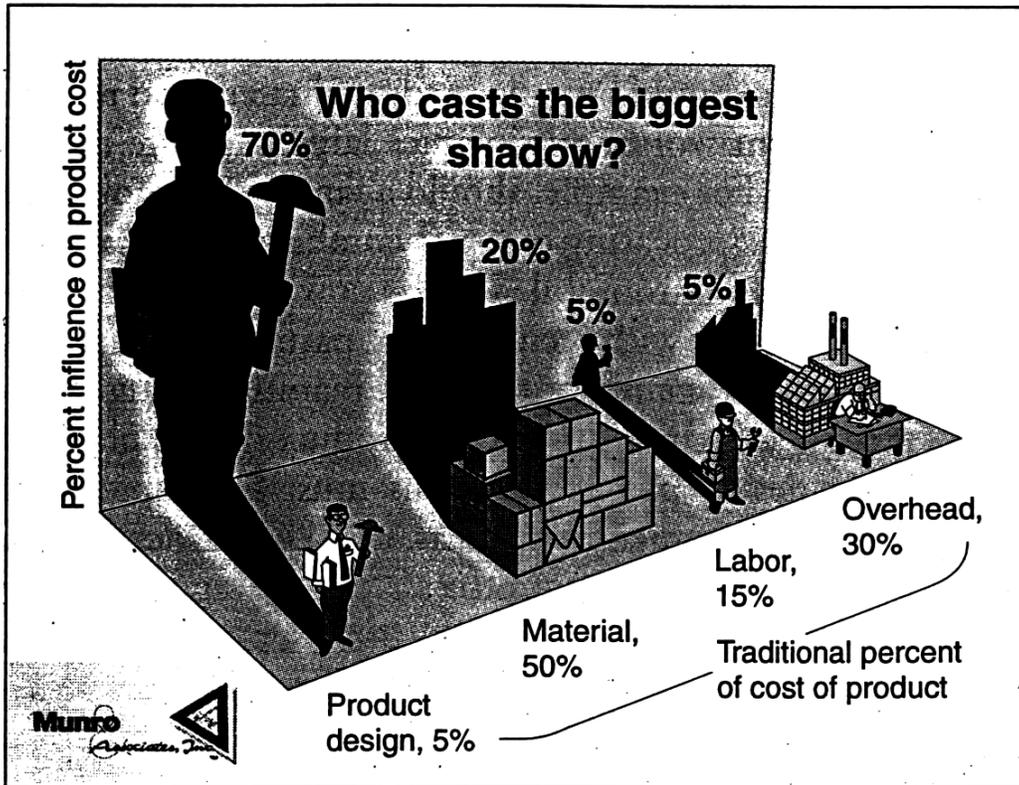






Developing a new product means very different things to different companies [1]

Company	Stanley	Hewlett-Packard	Chrysler	Boeing
Product	Jobmaster Power Screwdriver	DeskJet 500 Printer	Concorde Automobile	777 Aeroplane
No. of Unique Parts	3	35	10 000	130 000
Development Time	1 year	1.5 years	3.5 years	4.5 years
Development Team	3 people	100 people	850 people	6800 people
Development Costs	\$150 000	\$50 million	\$1 billion	\$3 billion
Sales Price	\$30	\$365	\$19 000	\$130 million
Annual Production	100 000	1.5 million	250 000	50
Sales Lifetime	4 years	3 years	6 years	30 years
Devel. Costs/Lifetime Sales	1.2%	3%	3.5%	1.5%



**Figure 5.2**

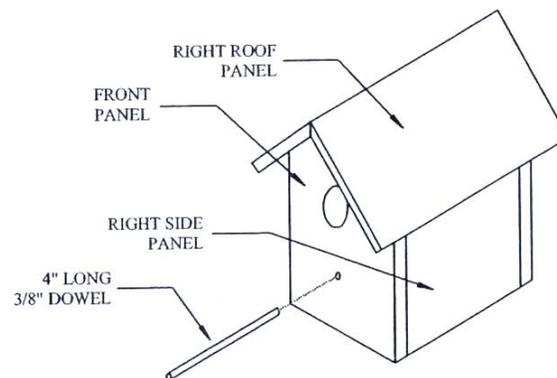
*Product costs: a comparison of traditional accounting practice and the influence of these costing components on the total cost of a product. (Based upon an illustration by Munro & Associates, Troy, Michigan. Copyright 1989. Used by permission.)*

Exercise in Project Planning and Scheduling:  
"Build a Birdhouse"

Each group will create a project plan and schedule, using the Gantt chart format provided, to construct a typical wooden birdhouse such as that shown below. The project is to be completed over a three-day period with approximately four hours each day devoted to the project.

You should describe the tasks to be done, the sequence of steps, and the time for each task. You should include in the plan a list of materials to be purchased and the tools that will be required to complete the task.

When completed, your plan should be able to be followed by someone who knows very little about the details of constructing a birdhouse but has enough basic skill to complete the project.



Build a Bird House					
ID	Build a Bird House 4 hours per day for 3 days	Task	Mon Oct 23 M	Tue Oct 24 T	Wed Oct 25 W
1	Step 1				
2	Step 2				
3	Step 3				
4	Step 4				
5	Step 5				
6	Step 6				
7	Step 7				
8	Step 8				
9	Step 9				
10	Step 10				
11					

Tools Required :

### **PAPER TOWER**

**Objective:**

Build the tallest tower from a single sheet of 8 1/2" x 11" sheet of paper. The tower must stand alone for 1 minute.

**Supplies:**

1 - 8 1/2" x 11" sheet of 20 weight paper  
Transparent tape  
Scissors

**Time:**

You have 40 minutes to complete your tower.  
Winners will be determined by height of tower and ability to stand alone for designated time.  
Towers that can not stand will be disqualified.

FED 101D-023

Group \_\_\_\_\_

**Competition: Ideas For This Semester's Project**

**Your group is to sketch and/or describe each idea or design concept that could be used to carry out the objective of this semester's project - the design of a liquid transport system. Start below and continue on the pages that follow. List two ideas on each page. The group with the highest number of feasible, different designs will win.**

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Concept 1:

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Concept 2:

---

Concept No. \_\_\_\_\_

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Concept No. \_\_\_\_\_

### Detailed Project Design

By now, you should have chosen the final design for your project. To this point you have sketched out the overall configuration of the device. Now you need to a detailed plan on how to manufacture and assemble the parts needed to build your project

To do this, you need to decide the following:

- what are the parts needed to build the overall project
- what are the dimensions of each part
- what materials will be used to produce the parts
- what tools are needed to make the parts.

On the first page of the attached graph paper, draw a detailed view of your entire device. Include dimensions, all parts and other necessary components and what materials will be needed to produce the parts. Under the drawing, describe how the device is intended to work.

On the pages that follow, make a detailed drawing of each part you need to make, including materials, dimensions, and method of manufacture.

Group \_\_\_\_\_

Detailed View of Entire Device:

Description of how the device is intended to work: