STUDY PROBLEMS #1 -- SOLUTIONS

1. Possible answers include:
   Architects – overall project design
   Engineers – mechanical and electrical systems (preliminary design and costs)
   Real estate brokers – land acquisition options
   Lawyers – preliminary agreements, land options, leases, etc.
   Politicians – public financial contributions
   Public relations / marketing – evaluate public support, naming rights, potential for sale of luxury boxes
   Bankers – financing.

2. Many possible answers.

3. "Controlled convergence" refers to the process of reducing the number of design options being considered in order to obtain a single solution. Typically this is accomplished either by combining multiple existing options or by eliminating options which are least suitable based on various criteria. See figure 1-12 (page 20).

4. The actual "need" could be reduction of air pollution in areas in which a large number of people rely on wood stoves for heating. Possible alternative solutions include (1) identification or development of cleaner burning fuels for existing stoves or (2) tax incentives to encourage use of alternative heating systems.

5. One possible solution:
   Objectives – light weight, low cost, secure latch, easily replaceable screen, doesn't "slam" on closing, reasonable forces to open/close
   Constraints – rust resistant materials, fits standard door frames

6. Machine A: $8500 initial cost, $4500/yr operating costs
   Machine B: $7000 initial cost, $4800/yr operating costs

   Annual rate of return = (Δ annual operating cost) / (Δ initial cost)
   = (4800–4500)/(8500–7000) = 300/1500 = 20.0%

   Note that this simplified solution ignores the 10-year life. In fact, at 20.0%, the $1500 would generate $300 per year forever, not just for 10 years. Instead, we could try to determine the interest rate that would allow a $1500 present value to generate $300 per year for only 10 years:

   (P/A, i%, n=10) = 1500/300 = 5 = $[(1+i)^{10} - 1] / [i(1+i)^{10}]$

   For i = 20%, P/A = $[1.20^{10} - 1] / [0.20\,(1.20)^{10}]$ = 4.19

   For i = 15%, P/A = $[1.15^{10} - 1] / [0.15\,(1.15)^{10}]$ = 5.02

   By interpolation, i = .15 + (.05) [(5.02 – 5.00) / (5.02 – 4.19)] = .151 = 15.1%

7. Initial cost: $40,000; Annual savings: $3000; Salvage value: $5000; Lifetime: 20 years; i = 15%

   Present value of annual savings = 3000 (P/A, 15%, 20) = 3000 $[1.15^{20} - 1] / [0.15\,(1.15)^{20}]$
   = 3000 (6.26) = 18,780

   Present value of salvage value = 5000 (P/F, 15%, 20) = 5000 $[1 / 1.15^{20}]$
   = 5000 (.061) = 305

   Total present value of savings plus salvage = 18780 + 305 = $19,085. Since this is less than the $40,000 initial (present) cost, this is not a good investment.

ECE 4000 -- Project Engineering & Professional Practice

8.

		Ajax ($1000)		Blaylock ($1000)	
		Future / Annual	Present Value	Future / Annual	Present Value
Initial Cost			30.00		20.00
Rebuilding	(P/F, 10%, 3) = 0.751			3.00	2.25
Salvage	(P/F, 10%, 5) = 0.621	-4.00	-2.48		
Maintenance	(P/A, 10%, 5) = 3.791	1.00	3.79	2.00	7.58
Productivity	(P/A, 10%, 5) = 3.791	-0.50	-1.90		
Electricity	(P/F_1, 10%, 5%, 5) = 4.151	3.00	12.45	3.50	14.53
TOTAL			41.86		44.36

9. If a limited amount of money is available at the present time, a decision may be based on lowest initial cost, even though the selected option has a higher present value of total life cycle cost.

   Although probably harder to justify from an economic perspective, lowest life-cycle cost (without adjusting for time value of money) may be used when the expenditures/savings occur at widely different times or when the affected group of people changes over time. For example, people may be unwilling to pay higher taxes now in order to produce savings (and, thus, lower taxes) for a potentially different group of people 25 years from now.

10. Divide problem into two phases: work and retirement.

   Work phase: First year deposit to savings: 5% of 45,000 = $2250
   Savings deposits increase 6% per year
   40 years, investment return = 10%

   Value of account at transition = (F/F_1, i=10%, g=6%, n=40) * 2250
   = (F/P, 10%, 40) * (P/F_1, i=10%, g=6%, n=40) * 2250
   = $(1.10)^{40} * [(1.10^{40} - 1.06^{40}) / ((.10 - .06)(1.10)^{40})] * 2250$
   = 45.26 * 5.68 * 2250
   = $578,572

   Retirement phase: First year withdrawal (F1) is the unknown
   Annual withdrawals increase 4% per year
   25 years, investment return = 8%

   Maximum first withdrawal = 578,572 / (P/F_1, i=8%, g=4%, n=25)
   = $578{,}572 / [(1.08^{25} - 1.04^{25}) / ((.08 - .04)(1.08)^{25})]$
   = 578,572 / 15.269
   = $37,893

Name: SOLUTION KEY Student #:

Problem 1. (~~16~~ 18 points)

For each of the following economic computations, (a) list the conversion factor to be used, specifying the parameter values, and (b) compute the result, showing your work. Write your answers on the blank lines on the right edge of this page; correct answers in other locations may not receive full credit. An example is provided.

EXAMPLE:

If you invest $100 in a bank account today, at an interest rate of 6.5%, how much will you have after five years?

(a) (F/P, 6.5%, 5)

(b) $ 137.01

$100 * (F/P, 6.5\%, 5) = 100 * (1 + 0.065)^5 = 100 * 1.3701 = 137.01$

A. (~~6~~ 4 points) How much would you need to invest annually, at an interest rate of 4%, in order to have $12,000 after 10 years?

(a) (A/F, 4%, 10)

(b) $ 999.49

$12000 * (A/F, 4\%, 10) = 12000 * \frac{.04}{(1+.04)^{10} - 1}$

$= 12000 * .0833 = 999.49$

B. (~~2~~ 4 points) A bond will be worth $50,000 in 30 years. At a discount rate of 8%, how much would you pay for that bond today?

(a) (P/F, 8%, 30)

(b) $ 4968.87

$50000 * (P/F, 8\%, 30) = 50000 * \frac{1}{(1+.08)^{30}}$

$= \frac{50000}{10.063} = 4968.87$

C. (~~8~~ ~~6~~ 5 points) A maintenance fund has been established that currently contains $8500. Assuming the fund earns 7% annually, how much can be spent each year if the fund is to last for 12 years?

(a) (A/P, 7%, 12)

(b) $ 1070.17

$8500 * (A/P, 7\%, 12) = 8500 * \frac{.07(1+.07)^{12}}{(1+.07)^{12} - 1}$

$= 8500 * \frac{.1577}{1.252} = 1070.17$

D. (~~4~~ 5 points) The first-year operating costs for a machine are estimated to be $5000 and are expected to increase 6% each year. What is the present value of the lifetime operating costs, assuming a useful life of 15 years and an interest rate of 10%?

(a) $(P/F_1, i=10\%, g=6\%, 15)$

(b) $ 53285.38

$5000 * \frac{(1+.1)^{15} - (1+.06)^{15}}{(.1-.06)(1+.1)^{15}} = 5000 * \frac{1.781}{.167} = 53285.38$

Name: SOLUTION KEY Student #:

Problem 2. (10 points)

A. (8 points) Two machinery options are described below. Complete the table below, indicating the present value of each of the items specified. Assume an interest rate of 6% and a useful lifetime of 8 years. Show all of the necessary work to calculate the values. If you need more space, use the back of this sheet.

You may find the following conversion factors to be useful:

(F/P, 6%, 8) =	1.5938	(P/F, 6%, 8) =	0.6274
(A/F, 6%, 8) =	0.1010	(F/A, 6%, 8) =	9.8975
(A/P, 6%, 8) =	0.1610	(P/A, 6%, 8) =	6.2098
(P/G, 6%, 8) =	19.8416		

OPTION 1: The initial purchase price of the machine is $25,000. The salvage value at the end of the useful life will be $5000. Maintenance costs are $2000 for the first year and are estimated to increase by $150 per year.

OPTION 2: The machine is leased for an initial payment of $2000 plus annual payments of $3500. There is no salvage value. A maintenance contract is purchased for a single payment of $10,000 at the start of the lease period.

(1) $-5000 * (P/F, 6\%, 8) =$

$-5000 * 0.6274 = -3137$

$2000 * (P/A, 6\%, 8) + 150 * (P/G, 6\%, 8)$

$= 2000 * 6.2098 + 150 * 19.8416$

$= 12419.60 + 2976.24 = 15395.84$

(2) $2000 + 3500 * (P/A, 6\%, 8)$

$= 2000 + 3500 * 6.2098$

$= 2000 + 21734.3 = 23734.3$

	Present Value of Item	
	OPTION 1	OPTION 2
Purchase/Lease	25000	23734
Salvage Value	(3137)	0
Maintenance	15396	10 000
TOTAL	37,259	33,734

B. (2 points) What is the equivalent annualized total cost, over the 8-year lifetime, for the machine with the lowest "present value of lifecycle cost"? Show your work.

$33734 * (A/P, 6\%, 8) = 33734 * 0.1610 = \boxed{5431.17}$

Name: SOLUTION KEY Student #:

Problem 3. (12 points)

A 1. (4 points) Match each of the following terms to its definition. On the blank line in front of each term, write the letter corresponding to the best definition. In the definitions, "item" may refer to a component, element, module, system, etc.

d	Hierarchy	a.	dividing a single item at a particular level of abstraction into a set of items, typically at that same level of abstraction
b	Modularity	b.	describing items in such a way as to reduce interactions between items and increase self-containment and potential re-use
a	Partitioning	c.	dividing an item at one level of abstraction into multiple items at a lower level of abstraction
c	Decomposition	d.	a multi-level description in which an item at one level of abstraction is generally composed of multiple items at the next-lower level

B 2. (2 points) List two specific examples of the benefits of increased modularity. One example should relate to the design portion and one example should relate to the manufacturing portion of the product lifecycle.

- REDUCED DESIGN TIME, SINCE THE MODULE IS USED MULTIPLE TIMES, BUT IS ONLY DESIGNED ONCE
- REDUCED INVENTORY COST, SINCE THERE ARE FEWER DISTINCT ELEMENTS IN THE DESIGN

C 3. (6 points) Briefly describe how partitioning would be used in the following examples of steps in the product design process. For each example, briefly explain the basis on which partitioning would occur, the principal expected benefit(s) of partitioning, and a significant potential disadvantage or weakness of partitioning at that step in the design process.

Preliminary design of a new automobile

- PARTITIONED BASED ON FUNCTIONAL AREAS (BODY, ENGINE, ELECTRICAL SYSTEMS, FRAME, ETC.)
- REDUCED TIME DUE TO PARALLEL EFFORTS; SPECIALIZED KNOWLEDGE OF EACH TEAM
- COMMUNICATION OVERHEAD + MULTIPLE ITERATIONS, SINCE CHANGES LIKELY TO AFFECT MORE THAN ONE GROUP

Detailed circuit-level design of a large electronic system

- PARTITIONED BY TECHNOLOGY (ANALOG, DIGITAL, POWER SUPPLY) OR PROBABLE IMPLEMENTATION (MULTIPLE CIRCUIT BOARDS)
- REDUCED DESIGN TIME DUE TO PARALLEL EFFORTS
- EACH MODULE OPTIMIZED INDEPENDENTLY, RATHER THAN OPTIMIZING TOTAL DESIGN

Name: SOLUTION KEY Student #:

Problem 4. (10 points)

1. (4 points) During the design process, a product may be described at various levels of abstraction. For each of the following statements, check the appropriate box indicating if the statement more accurately describes a high-level or low-level product description.

	High-level	Low-level
The description emphasizes product functionality or behavior, rather than implementation.	X	
It is relatively easy to determine specific product characteristics such as cost, timing, or component count.		X
The description is usually shorter, but may be ambiguous or incomplete.	X	
It is relatively easy to modify the product description to reflect changes in user desires or expectations.	X	

2. (6 points) Sustainability can be defined as doing things in a way that minimizes the negative effects on future generations. One approach to sustainability is to design products so that components can be re-used or recycled, rather than thrown away, at the end of their useful lifetime. Briefly discuss the effect of emphasizing re-use/recycling on the design process. Potential issues: What is difference between re-use and recycling? What key design decisions will most likely be affected? How does the expected product lifetime affect re-use or recycling? Be as specific as possible in your answer, including examples where possible.

Write your answer in the space remaining at the bottom of this page. Your answer is limited to this space only. **DO NOT** write (or continue) your answer on the back of this page or anywhere else on this exam.

- RE-USED: COMPONENT USED AGAIN (ALTERNATOR OR WATER PUMP IN CAR)
  RECYCLING: MATERIALS IN COMPONENTS SEPARATED AND USED INSTEAD OF ~~NEW~~ RAW MATERIAL TO CREATE NEW ITEMS (GLASS, STEEL, ALUMINUM
- RE-USE REQUIRES EARLY DESIGN DECISIONS TO IDENTIFY POTENTIAL COMMON ELEMENTS AND CONTROL DESIGN TO MAINTAIN COMPATIBILITY
- RECYCLING AFFECTS IMPLEMENTATION DECISIONS ON MATERIALS (SEPARABLE VS. COMPOSITES)
- RE-USE DIFFICULT W/ LONG PRODUCT LIFE-TIMES SINCE DESIGN LIKELY TO CHANGE OVER TIME.

Name: SOLUTION Student #:

Problem 1. (12 points)

For this problem, place your final numerical answers in the boxes at the right margin. You MUST show your work (formulas and numeric values) to justify your answers. Correct answers without supporting work will not receive full credit.

A. (4 points) A piece of manufacturing equipment costs $27,000. Assuming a useful lifetime of six (6) years, a salvage value of $8,000, and an interest rate of 5.0% per year, what is the annualized cost? If the company expects to produce an average of 1000 widgets per month, how much does this piece of equipment contribute to the cost of a widget?

$PV \text{ OF SALVAGE} = 8000\,(1.05)^{-6} = 5969.72$

$A = (27000 - 5969.72) \cdot A/P(.05,6)$

$= 21030.28 \left[\frac{.05\,(1.05)^6}{(1.05)^6 - 1}\right]$

$= 21030.28\,(0.197) = 4143.33$

$CPW = 4143.33/(12 \cdot 1000) = 0.345$

Annualized Cost: **4143.33**

Cost per Widget: **0.345**

B. (8 points) A company has offered you two different payment plans for purchasing a product:

Option 1: 15% down payment and 10 annual payments of $1200.

Option 2: no down payment and 12 annual payments of $1500.

Treat the down payment as occurring at the end of year 0, with the annual payments occurring at the end of years 1 though n. Assume an interest rate of 5.0% per year. What is the total sale price (present value) for each option? What is the present value of the last annual payment under Option 2?

$.85\,SP_1 = 1200 \cdot P/A(.05,10)$

$= 1200 \cdot \left[\frac{(1.05)^{10} - 1}{.05\,(1.05)^{10}}\right] = 1200\,(7.72)$

$= 9266.08$

$SP_1 = 10,901.27$

Option 1

Total Sale Price: **10,901.27**

$SP_2 = 1500 \cdot P/A(.05,12)$

$= 1500 \cdot \left[\frac{(1.05)^{12} - 1}{.05\,(1.05)^{12}}\right] = 1500\,(9.86)$

$= 13,294.88$

Option 2

Total Sale Price: **13,294.88**

$PV = 1500 \cdot P/F(.05,12) = 1500\left(\frac{1}{(1.05)^{12}}\right)$

Present Value of Final Payment: **835.26**

Briefly explain why someone might choose the option that has the larger sale price.

DOESN'T REQUIRE INITIAL EXPENDITURE FOR THE DOWNPAYMENT

Name: Student #:

Problem 3. (15 points)

This QFD diagram maps customer desires into engineering characteristics for a cellular phone.

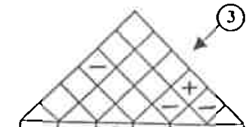
A. (6 points) Complete the three indicated sections of this QFD diagram by doing the following:

(1) Precede each engineering characteristic by a "+" ("–") sign if it is generally desirable to increase (decrease) the value of that characteristic. This may not apply to some characteristics.

(2) Place a "+" ("–") sign in the rectangular matrix to indicate that improving the engineering characteristic will improve (diminish) customer satisfaction in the indicated area.

(3) Place a "+" ("–") sign in the triangular matrix to indicate that improving one engineering characteristic will improve (diminish) the other engineering characteristic.

ANSWERS MAY VARY



	Transmit power output	Battery charge storage	Transmission mode (analog, digital, GSM)	Power consumption	Features (memory, clock, messaging, etc.)	Circuit size and complexity
(1)	+	+		–	+	–
Large coverage area	+		+			
Long battery life	–	+		+	–	
Short recharge time		–				
Advanced capabilities					+	–
Sound clarity	+		+			
Low cost		–			–	

(2) (3)

In the space below, or on the back of *this page*, answer the following questions about this QFD diagram.

B. (3 points) Identify two customer desires that are in conflict. Explain how this conflict is revealed in the QFD diagram. If there are no conflicting customer needs/desires, state so.

C. (3 points) Based on the entries in your QFD diagram, what do you anticipate will be the most significant trade-off between two engineering characteristics? Explain the impact of this trade-off on the overall product design. If there are no engineering characteristics that involve trade-offs, state so.

D. (3 points) Based on this QFD diagram, which engineering characteristic is probably the most important in determining overall success in satisfying customer desires? Why? How will determining the value for this characteristic affect other aspects of the design?

B. LONG BATTERY LIFE / LARGE COVERAGE AREAS (OTHERS)

C.: POWER CONSUMPTION / TRANSMIT POWER

D. BATTERY CHARGE STORAGE (SIZE/TYPE)