

**Carleton University**  
**Department of Civil and Environmental Engineering**  
**Engineering Economics (ECOR 3800 B)**  
**Term Test, March. 13, 2013**

**One side information sheet is allowed**  
**Scientific calculator only (no programmable calculator)**

- (A) In order to design a cold –storage warehouse, the specification call for a maximum heat transfer through the warehouse walls of 30,000 joules per hour per square meter of wall when there is a 30° C temperature difference between the inside surface and the outside surface of the insulation. The two insulation materials being considered are listed below:

Insulation material	Cost per Cubic meter	Conductivity (J-m/m <sup>3</sup> – °C – hr)
Rock Wool	12.50	140
Foamed Insulation	14.00	110

The basic equation for heat conduction through a wall is

$$Q = K(\Delta T)/L$$

Where;

$Q$  = heat transfer, in J/hr/m<sup>2</sup> of wall

$K$  = conductivity in j-m/m<sup>3</sup> – °C – hr

$\Delta T$  = difference in temperature between the two surfaces in °C

$L$  = thickness of insulating material, in metres

**Which insulation material should be selected?**

**Required insulation thickness**

Rock wool     $30,000 = 140(30)/L$                        $\rightarrow$      $L = 0.14$  m

Foamed insulation     $30,000 = 110(30)/L$                        $\rightarrow$      $L = 0.11$  m

**Cost of insulation per square meter of wall**

Unit cost = cost/ m<sup>3</sup> x insulation thickness, in meter

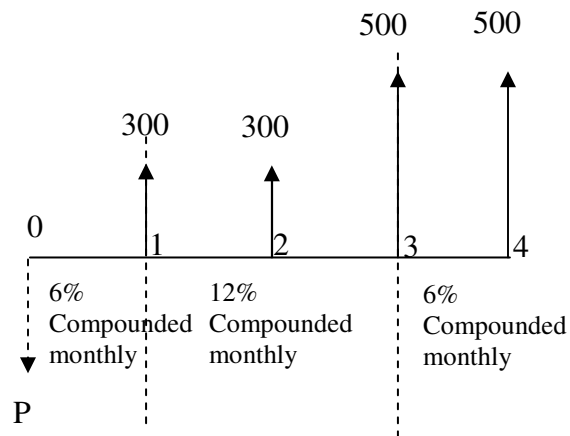
Rock wool    Unit cost = 12,5 x 0.14 = \$1.75/m<sup>3</sup>

Foamed insulation                                      Unit cost = 14 x 0.11 = \$1.54 /m<sup>3</sup>

**(B)**

Consider the cash flow transactions depicted in the cash flow diagram, with the changing interest rates specified.

- (a) If you deposit \$1123 now, would it be enough to withdraw \$300 at the end of year 1, \$300 at the end of year 2, \$500 at the end of year 3, and 500 at the end of year 4? If it is not enough, what will be the sufficient amount?
- (b) What is the single effective annual interest rate over 4 years?

**(a)**

$$P = 300(P/F, 0.5\%, 12) + 300(P/F, 0.75\%, 12) + 500(P/F, 0.75\%, 24) + 500(P/F, 0.5\%, 12) + 500(P/F, 0.5\%, 12) + 500(P/F, 0.75\%, 24) + 500(P/F, 0.5\%, 12)$$

$$= 1,305.26$$

**(b)**

$$1,305.26 = 300(P/A, i, 2) + 500(P/A, i, 2)(P/F, i, 2)$$

Using the formula instead of the factors required a trial and error solution at the end

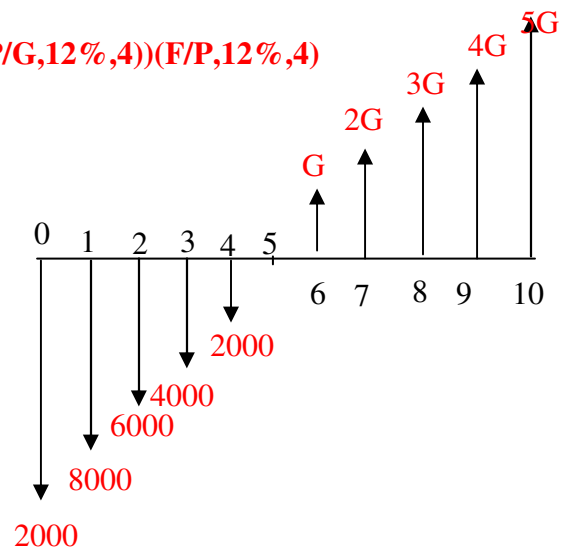
### Question 2 (20 Marks)

For the following transactions, draw the C.F.D and find the value of G that makes the deposit series equivalent to the withdrawal series at interest rate of 12%, compounded annually.

End of period	Deposit	Withdrawal
0	\$2000	
1	8000	
2	6000	
3	4000	
4	2000	
5		
6		G
7		2G
8		3G
9		4G
10		5G

$$G(P/G, 12\%, 6) = 8000(F/A, 12\%, 4) + (2,000 - 2000(P/G, 12\%, 4))(F/P, 12\%, 4)$$

$$G = 3179.4308$$



### Question 3 (20 Marks)

Your firm is considering purchasing an old office building with an estimated remaining service life of 25 years. Recently, the tenants signed long-term leases, which leads you to believe that the current rental income of \$150,000 per year will remain constant for the first 5 years. Then the rental income will increase by 10% for every 5-year interval over the remaining life of the asset. For example, the annual rental income would be \$165,000 for years 6 through 10, \$181,500 for years 11 through 15, \$199,650 for years 16 through 20, and \$219,615 for years 21 through 25. You estimate that operating expenses, including income taxes, will be \$45,000 for the first year and that they will increase by \$3000 each year thereafter. You also estimate that razing the building and selling the lot on which it stands will realize a net amount of \$50,000 at the end of the 25-year period. If you had the opportunity to invest your money elsewhere and thereby earn interest at the rate of 12% per annum, what would be the maximum amount you would be willing to pay for the building and lot at the present time?

### Solution

Given: Estimated remaining service life = 25 years, current rental income = \$150,000 per year, O&M costs = \$45,000 for the first year increasing by \$3,000 thereafter, salvage value = \$50,000, and MARR = 12%.

Let  $A_0$  be the maximum investment required to break even.

$$\begin{aligned}
 PW(12\%) &= -A_0 + [\$150,000(F/A, 12\%, 25) + \$15,000(F/A, 12\%, 20) \\
 &\quad + \$16,500(F/A, 12\%, 15) + \$18,150(F/A, 12\%, 10) \\
 &\quad + \$19,965(F/A, 12\%, 5) + \$50,000](P/F, 12\%, 25) \\
 &\quad - \$45,000(P/A, 12\%, 25) - \$3,000(P/G, 12\%, 25) \\
 &= 0
 \end{aligned}$$

$\therefore$  Solving for  $A_0$  = yields

$$A_0 = \$793,113$$

**Question 4 (20 Marks)**

A large food-processing corporation is considering using laser technology to speed up and eliminate waste in the potato-peeling process. To implement the system, the company anticipates needing \$3 million to purchase the industrial-strength lasers. The systems will save \$1,200,000 per year in labor and materials. However, it will require an additional operating and maintenance cost of \$250,000. Annual income taxes will also increase by \$150,000. The system is expected to have a 10-year service life and will have a salvage value of about \$200,000. If the company's MARR is 12%, justify the economics of the project based on:

- (a) PE method
- (b) FE method
- (c) AE method

**Solution****(a)**

$$\begin{aligned} PE(12\%) &= -3,000,000 + [1,200,000 - 250,000 - \\ & 150,000](P/A, 12\%, 10) + 200,000(P/F, 12\%, 10) \\ &= 1584573 \end{aligned}$$

**(b)**

$$FE(12\%) = 1584573 (F/P, 12\%, 10)$$

**(c)**

$$AE(18\%) = 1584573 (A/P, 12\%, 10)$$

**Question 5 (20 Marks)**

Saskatchewan Environmental Consulting (SEC) Inc. designs plans and specifications for asbestos abatement (removal) projects in public, private and governmental buildings. Currently, SEC must conduct an air test before allowing the reoccupancy of a building from which asbestos has been removed. SEC subcontracts air-test samples to a laboratory for analysis by transmission electron microscopy (TEM). To offset the cost of TEM analysis, SEC charges its clients \$100 more than the subcontractor's fee. The only expenses in this system are the costs of shipping and air-test samples to the subcontractor and the labour involved in shipping the samples, with the growth of the business, SEC is having to consider either continuing to subcontract the TEM analysis to outside companies or developing its own TEM laboratory. With recent government regulation requiring the removal of asbestos, SEC expects about 1000 air-sample testing per year over eight years. The firm's MARR is known to be 12%.

**Subcontract option.** The client is charged \$400 per sample. Which is \$100 above the subcontracting fee of \$300. Labour expenses are \$1500 per year. And shipping expenses are estimated to be 0.50 per sample.

**TEM purchase option.** The purchase and installation cost for the TEM is \$415,000. The equipment would last for eight years, at which time it should have no salvage value. The design and renovation cost is estimated to be \$9500. the client is charged \$300 per sample. Based on the current market price. One full time manager and two part-time technicians are needed to operate the laboratory.

Their combined annual salaries will be \$50,000. Material required to operate the lab includes carbon rods, copper grids, filter equipment, and acetone. The costs of these materials are estimated at \$6000 per year. Utility costs, operating and maintenance costs, and the indirect labour needed to maintain the lab are estimated at \$18,000 per year. The extra income- tax expense would be \$20,000.

- (a) Determine the cost of an air-sample test by the TEM (in-house)  
 (b) What is the required number of air samples per year to make the two options equivalent?

(a) Determine the unit profit of air sample test by the TEM (in-house).

- Subcontract Option:

$$\text{Unit profit} = \$400 - \$300 - \$0.50 - \$1,500/1,000 = \$98$$

- TEM Purchase Option:

$$\begin{aligned} \text{AEC (12\%)} &= (415,000 + 9,500)(A/P, 12\%, 8) + (50,000 + 6,000 + 18,000 + 20,000) \\ &= 179453.1 \end{aligned}$$

$$\text{Unit cost} = \text{AEC (12\%)} / 1000 = 179453.1 / 1000$$

$$\text{Unit profit} = 300 - \text{Unit cost} = 179.453$$

(b) Let  $X$  denote the break-even number of air samples per year.

$$400 - (300 + 0.5 + (1,500/X)) = 300 - (\text{AEC}/X)$$

$$400 - (300 + 0.5 + (1,500/X)) = 300 - (179453.1/X)$$

Solving for  $X$  yields

$$X = 903 \quad \text{air samples per year}$$

*Note:* If SEC's goal is simply to minimize per unit *cost* of sampling, then the break-even point would be calculated without including the revenue:

$$(300 + \$0.50 + (\$1,500/X)) = -179453/X$$

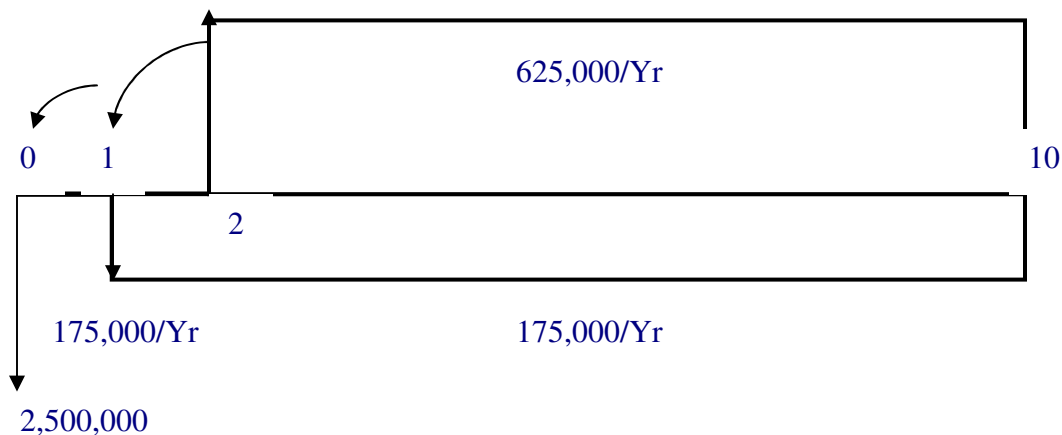
Solving for  $X$  yields:  $X = 600$  air samples per year

**Question 6 (20 Marks)**

A municipal city is trying to decide whether to build a parking garage. An engineering plan calculates that the building will cost \$2.5 million and that it will cost \$175,000 per year to operate. Our analysis of operating revenue determines that the garage will start to earn revenue of \$625,000 per year *starting from the end of second year*. The city is interested in knowing whether this project will be profitable over the next ten years at 12%. If not, how long the city has to wait to breakeven

**Solution:**

Given:  $I = \$2,500,000$ , annual revenue = \$625,000, annual operating cost = \$175,000,  $i = 12\%$



NPW for 10 years:

$$I = 2,500,000$$

$$\text{Cash in (P)} = 625,000(P/A, 12\%, 9)(P/F, 12\%, 1) = 2,973,354$$

$$\text{Cash out (P)} = 2,500,000 + 175,000(P/A, 12\%, 10) = 3,488,789$$

$$\begin{aligned} \text{NPW (12\%)} &= \text{Cash in (P)} - \text{Cash out (P)} = 2,973,354 - 3,488,789 \\ &= -515,435 \quad (\text{not profitable yet}) \end{aligned}$$

**Break-Even:**

- At  $N = 14$  yrs

$$\text{Cash in (P)} = 625,000(P/A, 12\%, N)(P/F, 12\%, 1) = 3,488,789$$

**Solve for N**

$$(P/A, 12\%, N) = 6.25$$

**$N \approx 13$  years**