

ECON 180 FALL 2022: PROJECT 6

→ **Due December 19, 2022 by 11:59 PM Victoria, B.C. time** ←

TO BE SUBMITTED VIA BRIGHTSPACE, AS USUAL

BECAUSE THIS IS TREATED AS A FINAL EXAM, **ABSOLUTELY NO EXTENSIONS¹,
EVEN BY ONE MINUTE, ARE AVAILABLE:** PLAN ACCORDINGLY.

Honor Code: I guarantee that this submission is **entirely my own work**. I have **cited any outside sources** in APA or IEEE style. **(You must accept this code to receive a mark.)**

Name or Signature for Honor Code: Arfaz Hossain

Last 3 digits of student number: 826

Please enter your answers in the spaces and tables provided. Your submission must be in either PDF or Microsoft 365 (Word, etc.) format, so Brightspace can read it properly.

Question		Marks
1	a	75
	b	75
	c	75
	d	75
	e	75
2	a-b (Average)	75
3	a	75
Q1 to Q3 = $(1.a+1.b+1.c+1.d+1.e+Q2+3.a)/7$		75
4 (Challenge)	a	5
	b	5
	c	5
	Q4 (Total)	15
Communication		10
Total (Q1 to Q3) + Q4 + Communication		100

¹ The only exceptions are those cases for which an extension or deferral would be offered for a final exam. Basically, treat this like you would treat a take-home final exam, even though it's not worth too much of your course mark.

Table of Contents

ECON 180 FALL 2022: PROJECT 6	1
Question 1: WBS, Gantt, Critical Path, Crashing.....	3
Source for this question	3
Data for Question 1	4
1.a Gantt Charts (Lecture 34)	5
1.b Activity on Node Diagram (Lecture 34)	7
1.c Finding the Critical Path (Lecture 34)	8
1.d Project Crashing (Lecture 35)	9
Work for question 1.d	10
1.e Work Breakdown Structure (Lecture 33)	11
Question 2: Payback Period.....	13
Data for Question 2	13
2.a Regular (non-discounted) Payback Period (Lecture 35)	13
2.b Discounted Payback Period (Lecture 35).....	14
Question 3: Financial Accounting.....	15
3.a Assets, Liabilities and Equity (Lecture 30)	15
Question 4: Monte Carlo Challenge Question.....	16
4.a Choose your distributions (Lectures 28, 29) (5 marks)	17
4.b Show me some numbers (Lectures 28,29) (5 marks)	18
4.c Create a Cost Acceptability Curve (Lectures 28, 29) (5 marks)	19

Question 1: WBS, Gantt, Critical Path, Crashing

Source for this question

The following questions are based on a published, real-world application. You may find it helpful to read through the article I used as a source:

Agyei, W. (2015). Project Planning and Scheduling Using Pert and CPM Techniques with Linear Programming Case Study. *International Journal of Scientific & Technology Research*, 4(8), 222-227. <https://ijstr.org/final-print/aug2015/Project-Planning-And-Scheduling-Using-Pert-And-Cpm-Techniques-With-Linear-Programming-Case-Study.pdf>

The original paper builds an Activity-on-Arrow diagram, finds the Critical Path, and performs crashing calculations.

To make this case study suitable for use as a final exam question, while keeping it as real-world relevant as possible, I've done the following:

- In several cases, I've consolidated what were originally separate activities in the original paper, into single activities. This kills two birds with one stone: it makes the problem slightly easier, and it means you can't just copy the answer from the original paper.
- I've converted their cost data from 2015 Ghanaian Cedi to 2022 Canadian dollars, using Canadian CPI inflation and the current exchange rate. This (hopefully) both makes the cost data more relevant to ECON 180 students, and makes it more difficult to simply copy the original paper's results.

Data for Question 1

Also available as a spreadsheet on Brightspace.

The following table describes the tasks involved in completing a 3-bedroom house in Ghana.

Task ID	Description	Predecessors	Un-crashed		Crashed	
			Duration (days)	Cost (CAD)	Duration (days)	Cost (CAD)
A	Clearing, Foundation, Block Laying	-	16	\$1,115.48	10	\$1,542.41
B	Roofing and Plastering	A	13	\$1,403.86	8	\$1,766.02
C	Plumbing	A	4	\$667.39	3	\$744.43
D	Electrical work	C	5	\$700.66	3	\$928.17
E	Fixing doors & windows, painting	B,C	11	\$1,030.02	7	\$1,347.68
F	Ceiling	A	7	\$545.27	5	\$663.36
G	Flooring	D,F	8	\$563.86	6	\$707.05
H	Interior Fixtures	G	4	\$633.66	3	\$694.51
I	Exterior Fixtures	G	5	\$450.71	3	\$626.33
J	Landscaping	H,I	6	\$490.95	3	\$660.78

Consistent with the lectures, and with the paper being used as a source, the Crashed durations and costs are *totals*. The correct way to interpret the above figures is therefore along the lines of:

- Under normal conditions, Activity A costs \$1,115.48 and takes 16 days.
- The shortest possible duration for Activity A (using overtime, etc.) is 10 days. Under these conditions, Activity A costs \$1,542.41, and takes 10 days.

1.a Gantt Charts (Lecture 34)

i. Show me you know how to put together a Gantt chart (minus the drawing bit)

Due to the long durations of some of the activities, I decided that drawing a Gantt chart for the full project would involve too much busywork on the part of the students. Instead, **please fill in the start/stop times for each activity, in the places provided below.** (For example, an activity that can start as soon as the project begins and has a duration of 10 days would have a 'START' time of 0 days, and a stop time of 10 days.) This question uses the *uncrashed* durations, so activity A has a duration of 16, activity J has a duration of 6, etc. **Remember that information on durations and predecessors can be found in the table in the 'Data for Question 1' section.**

Task ID	START	STOP
A	0	16
B	16	29
C	16	20
D	20	25
E	29	40
F	16	23
G	25	33
H	33	37
I	33	38
J	38	44

Hint: This is similar to the example on Slide 15 of the notes for Lecture 34.

ii. Show me you know how to draw a Gantt chart

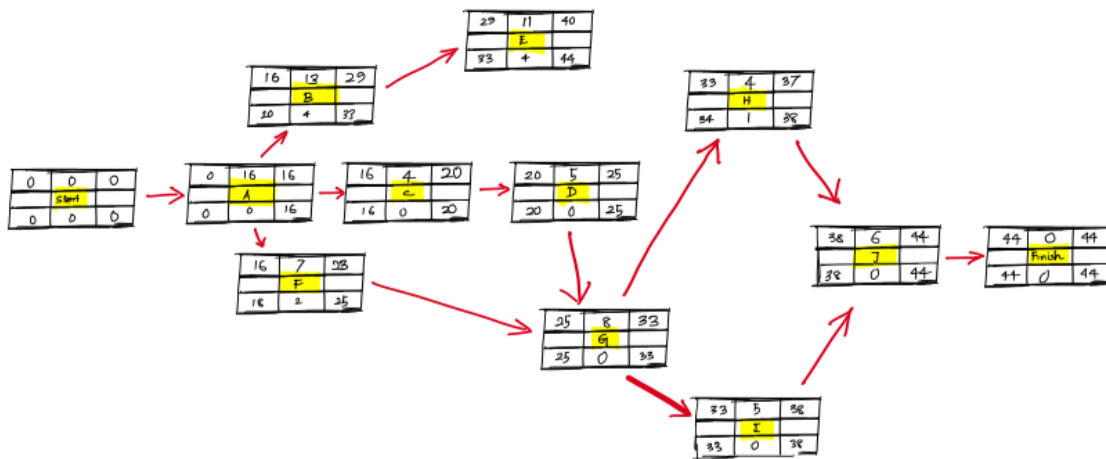
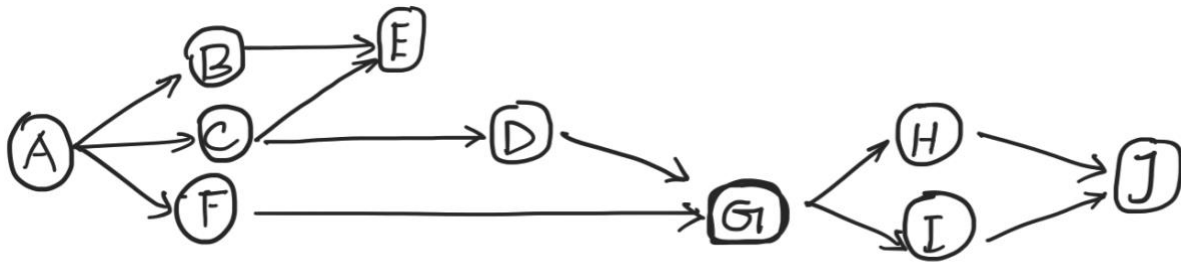
Using the information, you filled out above, draw a Gantt chart for *just* activities H, I and J. Use the earliest starting time among those activities as the 'start time' of your chart. For example, if H starts at 20, I start at 30, and J starts at 40, your chart should start at time 20.

[Draw your chart below. Use more space if you need to. It's fine to draw it by hand, drawing program, etc. Use whatever you're most comfortable with.]

	33	34	35	36	37	38	39	40	41	42	43	44
H												
I												
J												

1.b Activity on Node Diagram (Lecture 34)

Draw an Activity on Node diagram for the project. Use whatever technique you're most comfortable with. It's fine to do it by hand, Excel, drawing program, etc. **The nodes in your diagram should be clearly labeled with the Task ID they represent.** (So the node representing activity 'A' should have an 'A' on it, etc.). For this step, you're not being asked to include ES/EF, LS/LF information, though you may include it if you wish.



[IF DRAWING THIS IN MS OFFICE, PLEASE DO NOT JUST COPY AND PASTE FROM EXCEL OR POWERPOINT, AS THAT MAY BREAK THE IMAGE! COPY FROM EXCEL OR POWERPOINT AND 'PASTE SPECIAL', PREFERABLY AS PDF, GIF, PNG, JPG OR TIFF. IT'S ALSO FINE TO DRAW IT BY HAND AND INCLUDE (FOR EXAMPLE) A CELL PHONE PHOTO OR SCREENSHOT.]

1.c Finding the Critical Path (Lecture 34)

What activities are on the *critical path* of the uncrashed project? Show your work. Unsupported answers will receive no marks (i.e., you're mostly being marked on your work).

Activities on the critical path: A, C, D, G, I, J

[Show your work below. Use more room if you need it.]

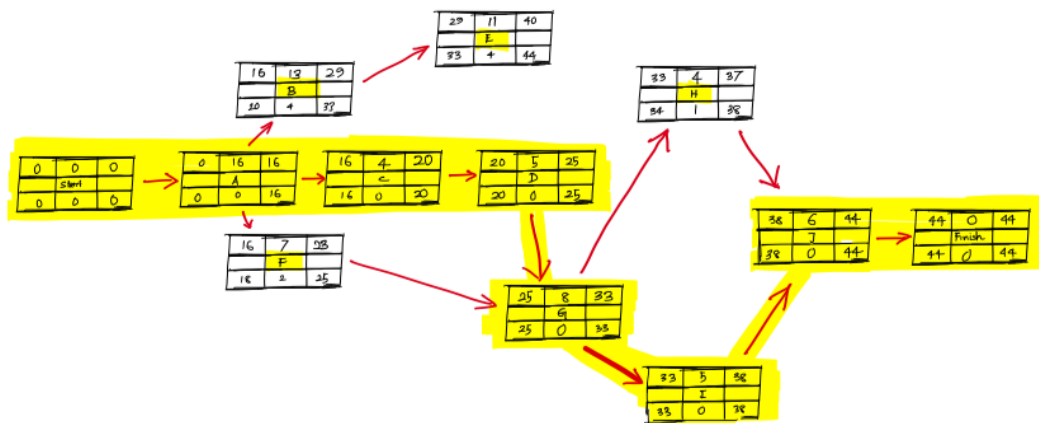


Figure: Critical Path Activities highlighted (yellow? ish)

The critical path (or paths) is the longest path (in time) from Start to Finish; it indicates the minimum time necessary to complete the entire project.¹ The path has been selected as this path determines the earliest possible start (ES) and earliest possible finish (EF) times for each activity. In all the path, the value of slack time (LF-EF or LS-ES) is zero.

1.d Project Crashing (Lecture 35)

Note: Crashing questions can get very messy. This question may be time-consuming. You may wish to leave it for last. If you absolutely have to, skipping some or all of this question will not hurt your mark by very much – it has the same weight as the Gantt chart question.

Suppose you are asked to reduce the duration of the project by 4 days, compared to its uncrashed duration.

- To achieve this 4-day reduction efficiently, which activities should be crashed, and by how many days? Show your work on the following page.

Task ID	Crashed by
A	1
B	0
C	1
D	0
E	0
F	0
G	1
H	0
I	0
J	1

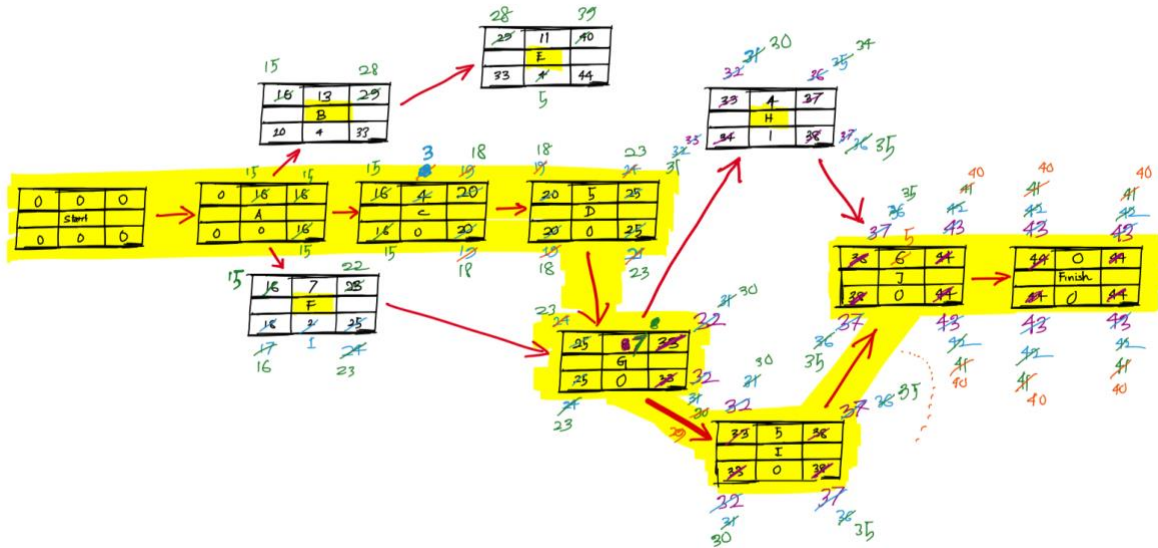
- Once the project has been reduced in duration by 4 days, using the method above, what nodes (tasks) are critical? Show your work on the following page.

What nodes are critical? A, C, D, G, I, J, as before.

- What is the total cost of the project when its duration has been reduced by 4 days, using the method above? Show your work on the following page.

Total cost of the project: \$7878.26

Work for question 1.d



Cost/Day Analysis:

Example for Activity A:

For 6 additional days, if it needs \$1,542.41: for 1 additional day of A activity, we will need $(\$1,542.41 - \$1,115.48) / (16 - 10) = \71.155 for each additional day of activity A.

END

Note: We took 4 days from the critical path and chose a cost-reductive way. We could have chosen the most cost-reductive way too (3 J's and 1 A's), but for this example, we didn't.

Activity	Initially				Run 1			Run 2			Run 3			Run 4		
	Normal Duration	Crash Duration	Cost / Day	TF	Days Saved	Dur	TF	Days Saved	Dur	TF	Days Saved	Dur	TF	Days Saved	Dur	TF
A	16	10	\$71.16	0	0	16	0	0	16	0	1	15	0	0	15	0
B	13	8	\$72.43	4	0	13	4	0	13	4	0	13	4	0	13	4
C	4	3	\$77.04	0	0	4	0	1	3	0	0	3	0	0	3	0
D	5	3	\$113.76	0	0	5	0	0	5	0	0	5	0	0	5	0
E	11	7	\$79.42	4	0	11	4	0	11	4	0	11	4	0	11	4
F	7	5	\$59.05	2	0	7	2	0	7	1	0	7	1	0	7	1
G	8	6	\$71.60	0	1	7	0	0	7	0	0	7	0	0	7	0
H	4	3	\$60.85	1	0	4	1	0	4	1	0	4	1	0	4	1
I	5	3	\$87.81	0	0	5	0	0	5	0	0	5	0	0	5	0
J	6	3	\$56.61	0	0	6	0	0	6	0	0	6	0	1	5	0
Cost - Savings	-				\$71.60			\$77.04			\$71.16			\$56.61		
Project Cost	\$7,601.86				\$7,673.46			\$7,750.50			\$7,821.65			\$7,878.26		
Project Duration	44				43			42			41			40		

1.e Work Breakdown Structure (Lecture 33)

i. Draw a visual WBS (Slides 20 & 31, Lecture 33 notes)

Draw a possible visual Work Breakdown Structure (tree diagram) for the project we are looking at in Question 1. There are multiple, possibly infinite, ways of doing this, as you will have to choose 'summary tasks' into which to organize the component activities, and there's no single right way to do that.

Note: As mentioned in the source paper, the main project deliverable is a completed 3-bedroom house at Nkororansa, in Ghana.

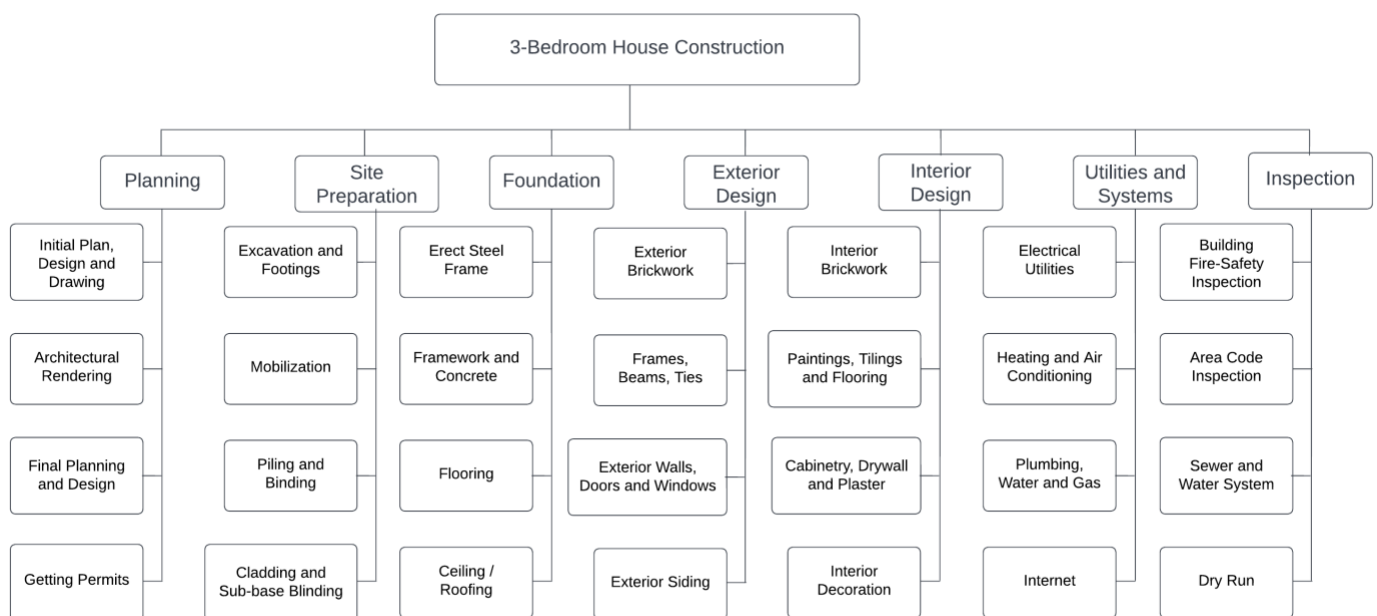


Figure: Work Breakdown Structure (WBS) of an ideal 3-Bedroom House in Ghana.

[IF DRAWING THIS IN MS OFFICE, PLEASE DO NOT JUST COPY AND PASTE FROM EXCEL OR POWERPOINT, AS THAT MAY BREAK THE IMAGE! COPY FROM EXCEL OR POWERPOINT AND 'PASTE SPECIAL', PREFERABLY AS PDF, GIF, PNG, JPG OR TIFF. IT'S ALSO FINE TO DRAW IT BY HAND AND INCLUDE (FOR EXAMPLE) A CELL PHONE PHOTO OR SCREENSHOT.]

ii. *Explain the choices you made in drawing the visual WBS (Slides 25 & 26, Lecture 33 Notes)*

Explain the steps you took to make your WBS consistent with best practices (Deliverables, No Gaps, No Overlap):

I divided the levels into several steps, divided the first level in chunks that wouldn't cause overlapping. However, some critical tasks/activities like plastering of all the interior and exterior walls as well as painting both inner and outer layers of the walls: these tasks do overlap in some of the sections in the first level such as in the Foundation Stage and both Interior and Exterior Design Stage. I decided to put those tasks into miniature tasks (Level 3 tasks) which I didn't include in my WBS Level 0 to 2.

To have a better understanding of a 3-Bedroom House Construction, I surfed around the internet for getting an idea about better deliverables and summary tasks for a single-family household construction to a retail-building construction looks like.^{1, 2} I appended my results into smaller chunks from the article and the goal of the project as well.

All items in the levels are mutually exclusive and exhaustive of one another, however in practice, some tasks might overlap (i.e., making a water, drainage, sewer system with inspecting the water and sewer system of the house).

Some stages in the first-level activities can be avoided for cost-reduction purposes, like first-level inspection and/or interior decoration in the second level.

[1] <https://www.smartsheet.com/content/construction-work-breakdown-structure>

[2] <https://www.smartsheet.com/sites/default/files/2021-01/IC-Sample-Construction-Work-Breakdown-Structure-for-Retail-Store.svg>

Question 2: Payback Period

Data for Question 2

It's been suggested that Canadian homeowners could save money by installing energy-efficient windows and lowering their energy bills. In this question, we'll use some ballpark figures to estimate how long it would take for such an installation to pay for itself. The figures we'll be using are based on information from [Canadian Choice Windows & Doors](#), and [The Cornwall Seeker](#).

- We're looking at a small home² with 10 (ten) windows.
- The cost³ of *one* energy-efficient window is \$650.
- Our hypothetical homeowner will replace *all* ten windows at once.
- Replacing the windows is expected to save⁴ \$288 per year.
- The home-owner's MARR⁵ is 6.45% per year.

2.a Regular (non-discounted) Payback Period (Lecture 35)

Calculate the (regular, non-discounted) payback period for replacing all ten windows. Give your answer in years and show your work. (If your answer would give a fractional number of years, it's fine to write "between 4 and 5 years," etc.)

Non-discounted payback period: between 22 and 23 years

Replacing all windows: \$6500 ($\650×10)

$\$288 \times 22 = \6336

$\$288 \times 23 = \6624

Between 22 and 23 years.

² The Cornwall Seeker says that a small home can have 10 to 12 windows.

³ Canadian Choice Windows & doors cites \$400-\$900. I've taken the average.

⁴ This figure is given by Canadian Choice Windows & Doors and represents 12% of an average annual energy bill.

⁵ This is the current prime rate in Canada at the time of writing.

2.b Discounted Payback Period (Lecture 35)

Calculate the discounted payback period for replacing all ten windows. Give your answer in years and show your work. (If your answer would give a fractional number of years, it's fine to write "between 4 and 5 years," etc.)

Discounted payback period: _____ years

[Show your work here]

Question 3: Financial Accounting

3.a Assets, Liabilities and Equity (Lecture 30)

Advanced Idea Mechanics (AIM) is an engineering services and clean energy company. Despite some health concerns, its best-selling product is the Terrigen™ clean fuel. Recently, the following transactions took place, in the order listed:

- AIM borrows \$13,000,000 in cash from Wilson Fisk, an independent money lender.
- AIM pays \$2,500,000 in cash to a former employee, George Tarleton, as part of a settlement.
- AIM receives a bill for \$8,500,000 in legal services from Goodman, Lieber, Kurtzberg & Holliway, a law firm.
- AIM buys a patent for a hover-wheelchair from a science company, Pym Technologies. AIM pays for the patent in two ways: a) it pays Pym Technologies \$1,000,000 in cash, and b) in addition, it gives Pym Technologies 30 kg of Terrigen™ fuel, from its existing inventory. Terrigen retails for \$3,500,000 per kg., and costs AIM \$1,250 per kg. to produce. After receiving the Terrigen™ and \$1,000,000, Pym Technologies considers itself paid in full for the patent.
- AIM sends a cheque for \$5,000,000 to Goodman, Lieber, Kurtzberg & Holliway as partial payment for their recent invoice. The cheque won't arrive for a week.

Calculate the TOTAL effect of the transactions above on AIM's Assets, Liabilities and Equity. Show your work.

Increase or decrease in Assets: \$ _____

Increase or decrease in Liabilities: \$ _____

Increase or decrease in Equity: \$ _____

Show your Work below (take more room if you need it):

Question 4: Monte Carlo Challenge Question

For this question, **run 1,000 (one thousand) trials of a Monte Carlo simulation of the present value of living and working in Montreal, using min/baseline/maximum information from Project 1. If you are doing this by hand, instead of with Excel, you may run 10 (ten) trials, instead.** I'll be making sure your curve looks like it should, and is properly labeled. You are also asked to post your 'headers' and first five trials.

The relevant equation is the same as in Project 4. This present value is represented by the following equation:

Your value of interest is the present value of working and renting a home in Montreal. From Project 2, we know the relevant formulas are as follow:

$$\text{NPV} = (\text{PV of Income}) - (\text{PV of Housing})$$

$$\text{PV of Income} = (S/4) \times (P/F, \text{MARR}, 3) + S \times (P/A, g, \text{MARR}, 40) \times (P/F, \text{MARR}, 2)$$

$$\text{PV of Housing} = R \times (P/A, \text{MARR}_{\text{monthly}}, 480) \times (P/F, \text{MARR}_{\text{monthly}}, 35)$$

- S = (Starting) yearly salary in Montreal (this is the 'salary' value you found in Project 1)
- $\text{MARR} = 5.45\%$ (per year)
- $g = 3.5\%$ (per year)
- R = Monthly rent (from Project 1)
- $\text{MARR}_{\text{monthly}} = (1 + 5.45\%)^{1/12} - 1$

You will notice that this is a function of only two parameters, S (starting yearly salary), and R (monthly rent).

After plugging in all the numbers, this equation becomes (approximately)

$$\text{NPV}(S, R) = S \times 22.47 - R \times 170.14$$

You may use the above as the equation for your Monte Carlo trials.

4.a Choose your distributions (Lectures 28, 29) (5 marks)

To generate your random numbers, you may wish to use the Excel sheet provided for that purpose (random.xls) in the manner discussed in the 'Probabilistic Sensitivity Analysis in Excel' lecture. **For each of your parameters, choose either a triangle, uniform or normal distribution, and briefly explain why you chose it.**

S = Salary when working in Montreal

R = Rent when living in Montreal

Variable	Distribution (Triangle/Normal/Uniform)	Reason
S		
R		

Any distribution choice is fine, as long as the reason is logical. For example, choosing the uniform distribution because there's a strong reason to believe that any number between MIN and MAX is equally likely.

For reference, please make sure to also write the minimum, baseline and maximum values of your parameters below.

Variable	Minimum	Baseline	Maximum
S			
R			

4.b Show me some numbers (Lectures 28,29) (5 marks)

First, show me the first ten rows of your calculations. The template below is only a suggestion. Feel free to use your own.

Trial	S	R	NPV(S,R)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Next, show me some statistics. Provide the median, mean, minimum, maximum and 95% confidence interval (or 60% confidence interval if doing this by hand). These statistics are for your *entire* data: 1,000 trials if using Excel, 10 trials if doing it by hand.

NPV Montreal (1,000 trials, or 10 trials if by hand)	
MEAN	
MEDIAN	
MIN	
MAX	
95% CONF (80% if by hand)	

Hint: If your ten values are 1,2,3,4,5,6,7,8,9,10, then 80% of those values are between 2 and 9. Your 80% confidence interval would be from 2 to 9. From that, you should be able to extrapolate for the case of 1,000 trials.

4.c Create a Cost Acceptability Curve (Lectures 28, 29) (5 marks)

Create a Cost Acceptability Curve for your data and include it below. I'll be checking to make sure it's labeled properly (see the lectures) and is consistent with your data.

[INSERT YOUR COST ACCEPTABILITY CURVE ABOUT HERE – PLEASE DO NOT JUST COPY AND PASTE FROM EXCEL, AS THAT MAY BREAK THE IMAGE! COPY FROM EXCEL AND 'PASTE SPECIAL', PREFERABLY AS PDF, GIF, PNG, JPG OR TIFF. IT'S ALSO FINE TO DRAW IT BY HAND AND INCLUDE (FOR EXAMPLE) A CELL PHONE PHOTO OR SCREENSHOT.]

Briefly explain the process by which you created the cost acceptability curve from your data:

[Insert your explanation here. Point form is fine.]