

**ORDRE DES INGÉNIEURS DU QUÉBEC**  
**November 2019 SESSION**

All documentation is permitted  
Calculators: allowed models only  
Exam duration: 3 hours

**14-CI-A7 Construction Project Management**

**Question 1 (5 points)**

Define the following terms:

- a. Bid Bond (Cautionnement de soumission). (3 points)
- b. Commitment letter (Lettre d'engagement). (1 point)
- c. Company resolution (Résolution de compagnie). (1 point)

**Question 2 (8 points)**

The amount of the overhead of a project was estimated at \$ 160,000. This amount is distributed as follows:

- An amount of \$ 40,000 depending on the duration of the project estimated at eight (8) months.
- An amount of \$ 80,000 depending on the value of the project estimated at \$ 1,400,000 **including** the overhead.
- A fixed amount of \$ 40,000 for mobilisation and demobilisation.

After introducing the latest corrections, the submission totaled \$ 1,380,000 **not including** the overhead and the duration was estimated to be nine (9) months. What is the new amount of the project overhead?

### Question 3 (20 points)

Using the data in Table 1, draw the Precedence Diagram Method (**PDM**) also called AON (**Activity-On-Node**) diagram and indicate the critical path.

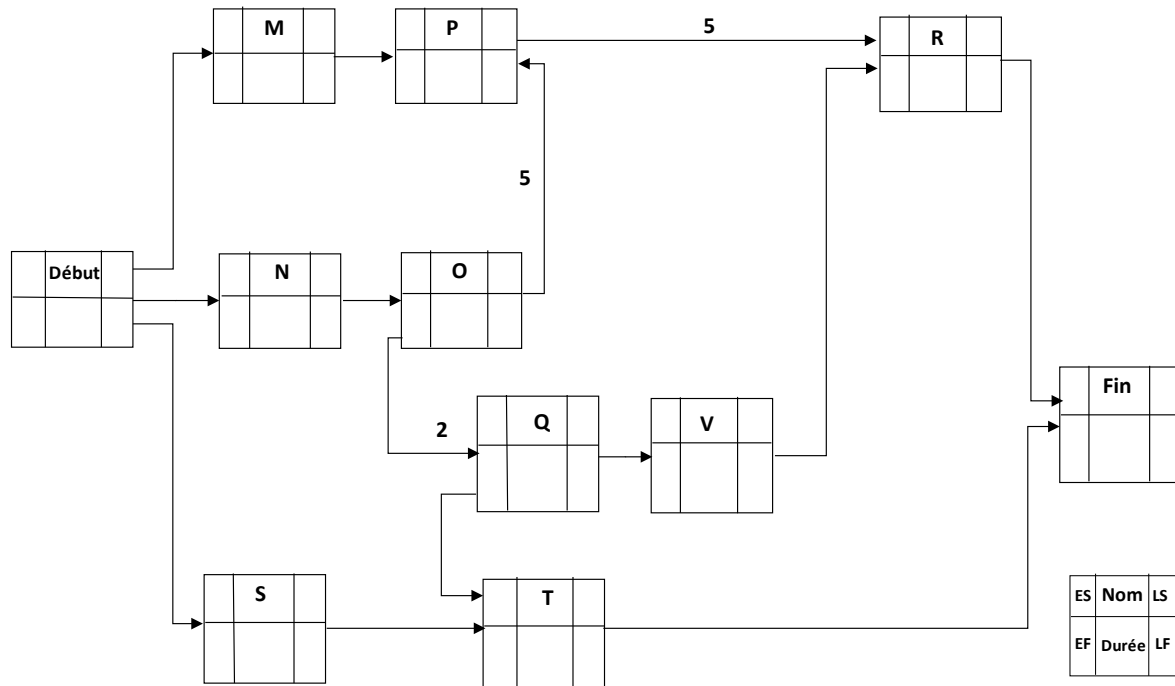
Indicate the Early Start (ES), the Early Finish (EF), the Late Start (LS), the Late Finish (LF), the total Float (TF), and the Free Float (FF).

**Table 1**

| Activity | Duration | Relations                   |                           |
|----------|----------|-----------------------------|---------------------------|
|          |          | Start                       | End                       |
| A        | 12       |                             |                           |
| B        | 12       | After the End of A          |                           |
| C        | 15       | After the End of A          | 5 days after the End of G |
| D        | 12       |                             |                           |
| E        | 10       | 4 days after the Start of D |                           |
| F        | 4        | After the End of B          |                           |
| G        | 12       | After the End of F          |                           |
| H        | 15       | After the End of C          |                           |
| J        | 8        | 4 days after the Start of E |                           |

#### Question 4 (15 points)

Figure 1 shows the schedule of a project using the **PDM** method, also called AON diagram (Activity-On-Node).



**Figure 1 – Project Schedule**

Table 2 shows the optimistic, pessimistic and most likely durations for each activity of this project.

- Calculate and indicate, on table 2, the expected duration TE and the variance  $\sigma^2$  and the standard deviation  $\sigma$  for each activity. (5 points)
- Calculate the project total duration. (2 points)
- Calculate the project variance. (2 points)
- Calculate the probability to complete the project within 68 days. (3 points)
- Calculate the probability to complete the project within 55 days. (3 points)

**Table 2**

| Activity | Optimistic Duration | Most Likely Duration | Pessimistic Duration | Te | $\sigma^2$ | $\sigma$ |
|----------|---------------------|----------------------|----------------------|----|------------|----------|
| M        | 16                  | 20                   | 24                   |    |            |          |
| N        | 24                  | 28                   | 44                   |    |            |          |
| O        | 6                   | 10                   | 14                   |    |            |          |
| P        | 15                  | 18                   | 33                   |    |            |          |
| Q        | 3                   | 4                    | 11                   |    |            |          |
| R        | 10                  | 10                   | 10                   |    |            |          |
| S        | 4                   | 11                   | 12                   |    |            |          |
| T        | 10                  | 10                   | 10                   |    |            |          |
| V        | 8                   | 10                   | 12                   |    |            |          |

| <b>z</b>    | <b>0</b> | <b>0.01</b> | <b>0.02</b> | <b>0.03</b> | <b>0.04</b> | <b>0.05</b> | <b>0.06</b> | <b>0.07</b> | <b>0.08</b> | <b>0.09</b> |
|-------------|----------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| <b>+0</b>   | .50000   | .50399      | .50798      | .51197      | .51595      | .51994      | .52392      | .52790      | .53188      | .53586      |
| <b>+0.1</b> | .53983   | .54380      | .54776      | .55172      | .55567      | .55966      | .56360      | .56749      | .57142      | .57535      |
| <b>+0.2</b> | .57926   | .58317      | .58706      | .59095      | .59483      | .59871      | .60257      | .60642      | .61026      | .61409      |
| <b>+0.3</b> | .61791   | .62172      | .62552      | .62930      | .63307      | .63683      | .64058      | .64431      | .64803      | .65173      |
| <b>+0.4</b> | .65542   | .65910      | .66276      | .66640      | .67003      | .67364      | .67724      | .68082      | .68439      | .68793      |
| <b>+0.5</b> | .69146   | .69497      | .69847      | .70194      | .70540      | .70884      | .71226      | .71566      | .71904      | .72240      |
| <b>+0.6</b> | .72575   | .72907      | .73237      | .73565      | .73891      | .74215      | .74537      | .74857      | .75175      | .75490      |
| <b>+0.7</b> | .75804   | .76115      | .76424      | .76730      | .77035      | .77337      | .77637      | .77935      | .78230      | .78524      |
| <b>+0.8</b> | .78814   | .79103      | .79389      | .79673      | .79955      | .80234      | .80511      | .80785      | .81057      | .81327      |
| <b>+0.9</b> | .81594   | .81859      | .82121      | .82381      | .82639      | .82894      | .83147      | .83398      | .83646      | .83891      |
| <b>+1</b>   | .84134   | .84375      | .84614      | .84849      | .85083      | .85314      | .85543      | .85769      | .85993      | .86214      |
| <b>+1.1</b> | .86433   | .86650      | .86864      | .87076      | .87286      | .87493      | .87698      | .87900      | .88100      | .88298      |
| <b>+1.2</b> | .88493   | .88686      | .88877      | .89065      | .89251      | .89435      | .89617      | .89796      | .89973      | .90147      |
| <b>+1.3</b> | .90320   | .90490      | .90658      | .90824      | .90988      | .91149      | .91308      | .91466      | .91621      | .91774      |
| <b>+1.4</b> | .91924   | .92073      | .92220      | .92364      | .92507      | .92647      | .92785      | .92922      | .93056      | .93189      |
| <b>+1.5</b> | .93319   | .93448      | .93574      | .93699      | .93822      | .93943      | .94062      | .94179      | .94295      | .94408      |
| <b>+1.6</b> | .94520   | .94630      | .94738      | .94845      | .94950      | .95053      | .95154      | .95254      | .95352      | .95449      |
| <b>+1.7</b> | .95543   | .95637      | .95728      | .95818      | .95907      | .95994      | .96080      | .96164      | .96246      | .96327      |
| <b>+1.8</b> | .96407   | .96485      | .96562      | .96638      | .96712      | .96784      | .96856      | .96926      | .96995      | .97062      |
| <b>+1.9</b> | .97128   | .97193      | .97257      | .97320      | .97381      | .97441      | .97500      | .97558      | .97615      | .97670      |
| <b>+2</b>   | .97725   | .97778      | .97831      | .97882      | .97932      | .97982      | .98030      | .98077      | .98124      | .98169      |
| <b>+2.1</b> | .98214   | .98257      | .98300      | .98341      | .98382      | .98422      | .98461      | .98500      | .98537      | .98574      |
| <b>+2.2</b> | .98610   | .98645      | .98679      | .98713      | .98745      | .98778      | .98809      | .98840      | .98870      | .98899      |
| <b>+2.3</b> | .98928   | .98956      | .98983      | .99010      | .99036      | .99061      | .99086      | .99111      | .99134      | .99158      |
| <b>+2.4</b> | .99180   | .99202      | .99224      | .99245      | .99266      | .99286      | .99305      | .99324      | .99343      | .99361      |
| <b>+2.5</b> | .99379   | .99396      | .99413      | .99430      | .99446      | .99461      | .99477      | .99492      | .99506      | .99520      |
| <b>+2.6</b> | .99534   | .99547      | .99560      | .99573      | .99585      | .99598      | .99609      | .99621      | .99632      | .99643      |
| <b>+2.7</b> | .99653   | .99664      | .99674      | .99683      | .99693      | .99702      | .99711      | .99720      | .99728      | .99736      |
| <b>+2.8</b> | .99744   | .99752      | .99760      | .99767      | .99774      | .99781      | .99788      | .99795      | .99801      | .99807      |
| <b>+2.9</b> | .99813   | .99819      | .99825      | .99831      | .99836      | .99841      | .99846      | .99851      | .99856      | .99861      |
| <b>+3</b>   | .99865   | .99869      | .99874      | .99878      | .99882      | .99886      | .99889      | .99893      | .99896      | .99900      |
| <b>+3.1</b> | .99903   | .99906      | .99910      | .99913      | .99916      | .99918      | .99921      | .99924      | .99926      | .99929      |
| <b>+3.2</b> | .99931   | .99934      | .99936      | .99938      | .99940      | .99942      | .99944      | .99946      | .99948      | .99950      |
| <b>+3.3</b> | .99952   | .99953      | .99955      | .99957      | .99958      | .99960      | .99961      | .99962      | .99964      | .99965      |
| <b>+3.4</b> | .99966   | .99968      | .99969      | .99970      | .99971      | .99972      | .99973      | .99974      | .99975      | .99976      |
| <b>+3.5</b> | .99977   | .99978      | .99978      | .99979      | .99980      | .99981      | .99981      | .99982      | .99983      | .99983      |
| <b>+3.6</b> | .99984   | .99985      | .99985      | .99986      | .99986      | .99987      | .99987      | .99988      | .99988      | .99989      |
| <b>+3.7</b> | .99989   | .99990      | .99990      | .99990      | .99991      | .99991      | .99992      | .99992      | .99992      | .99992      |
| <b>+3.8</b> | .99993   | .99993      | .99993      | .99994      | .99994      | .99994      | .99994      | .99995      | .99995      | .99995      |
| <b>+3.9</b> | .99995   | .99995      | .99996      | .99996      | .99996      | .99996      | .99996      | .99996      | .99997      | .99997      |
| <b>+4</b>   | .99997   | .99997      | .99997      | .99997      | .99997      | .99997      | .99998      | .99998      | .99998      | .99998      |

### Question 5 (20 points)

Your company has planned to implement the following project according to the schedule shown in figure 1, in 23 days.

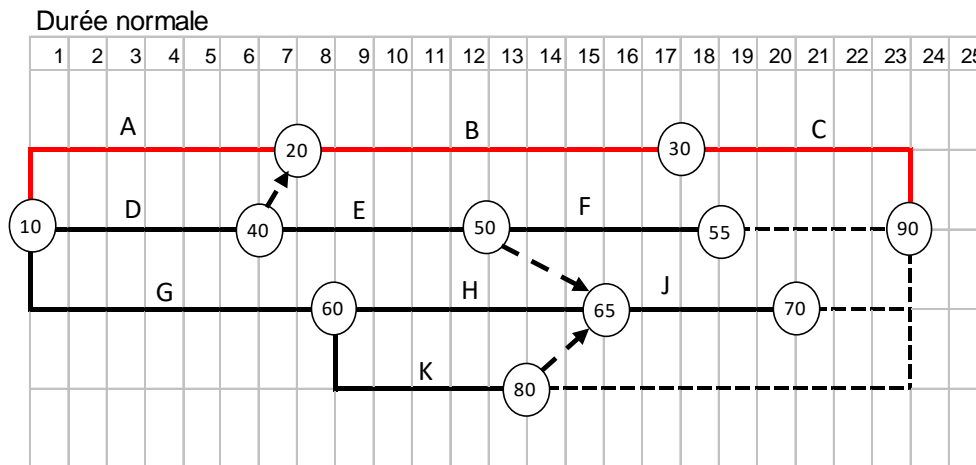


Figure 1. Project schedule

The project includes **fixed overhead of \$ 3000** which will be spent on the first day of the project and **variable overhead of \$ 500 / day**.

The project data are in Table 3 below:

Table 3

| Activity | Predecessors | Normal   |       | Compressed |      |
|----------|--------------|----------|-------|------------|------|
|          |              | Duration | Cost  | Duration   | Cost |
| A        |              | 7        | 3200  | 5          | 3600 |
| B        | A, D         | 10       | 2000  | 8          | 2800 |
| C        | B            | 6        | 1800  | 4          | 2400 |
| D        |              | 6        | 3500  | 6          | 3500 |
| E        | D            | 6        | 4000  | 4          | 4200 |
| F        | E            | 6        | 1500  | 3          | 3000 |
| G        |              | 8        | 3000  | 7          | 3600 |
| H        | G            | 7        | 2000  | 4          | 2600 |
| J        | E, H, K      | 5        | 2000  | 3          | 2600 |
| K        | G            | 5        | 1000  | 5          | 1000 |
| Total    |              |          | 24000 |            |      |

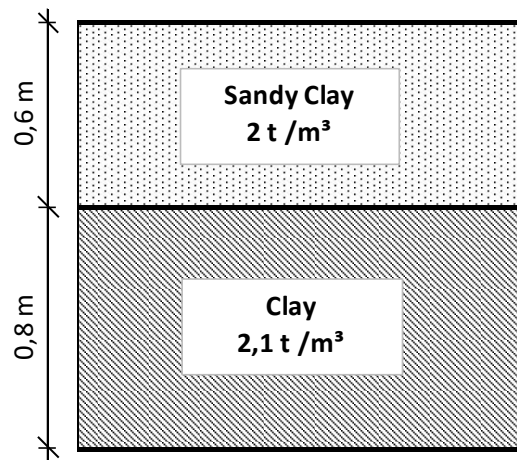
You have been asked to:

1. Compress the project duration to the maximum by demonstrating all the compression steps and calculate the minimum duration of the project after compression (7 points);
2. Draw the direct costs-duration curve for this project (2 points);
3. Calculate the indirect costs at each compression and draw the indirect costs-duration curve for this project (5 points);
4. Draw the total cost-duration curve (2 points);
5. Calculate the optimum duration for this project and the relative cost for this duration (4 points).

### Question 6 (12 points)

Your employer wants to determine the number of trucks, he must deploy on site to ensure continuous work of the excavator, required for an activity of mass excavation for a building foundation. He gives you the following information:

1. The land is rectangular with dimensions of 150 m (length) x 120 m (width).
2. The total excavation depth is 1.4 m.
3. The surveys indicate that there are two types of soil whose thicknesses and densities in their natural state are shown in the figure 3 below.
4. The percentage of swelling is 25% for the Sandy Clay and 30% for the clay.
5. The production of the excavator is  $90 \text{ m}^3 / \text{h}$  for the sandy clay and  $85 \text{ m}^3 / \text{h}$  for the clay.
6. The excavator works 8 h / day.
7. The soil was loaded on trucks of 10 tons. Each truck has one (1) cycle per hour (Load, travel to the dump site, unload, return to the loading unit).



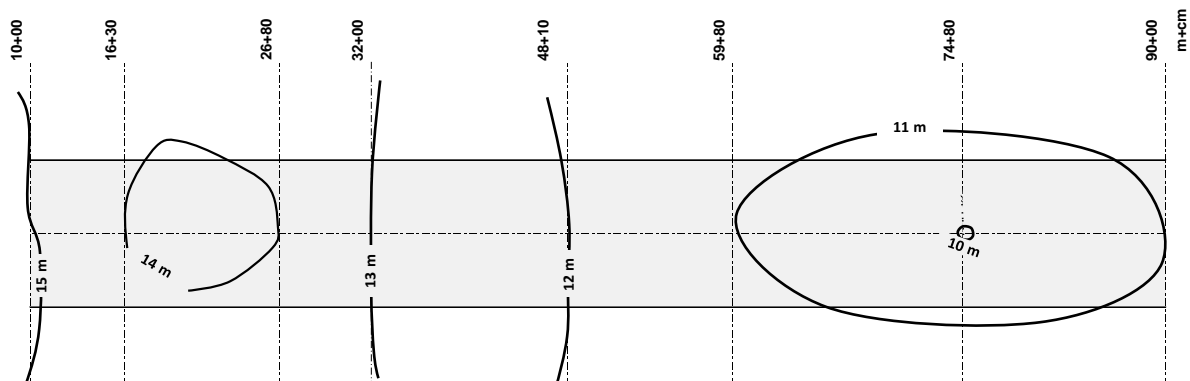
**Figure 3 - Geotechnical Studies - Vertical cross section**



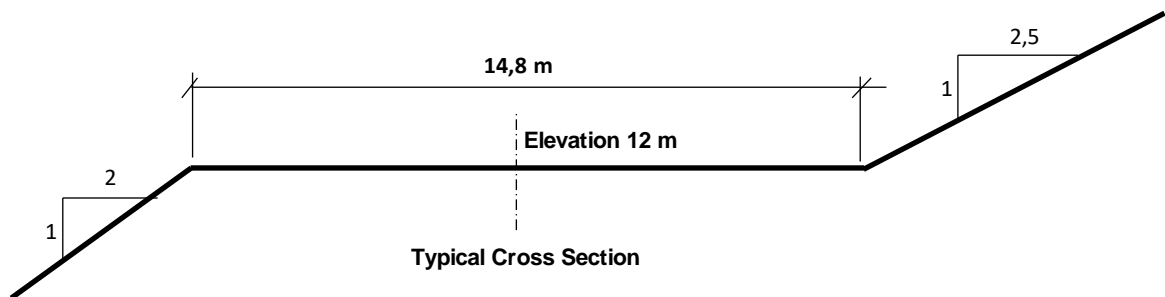
### Question 7 (20 points)

For the road St-Peter illustrated in Figure 4, you should perform the following tasks:

- 1 - Draw the longitudinal section (2 pts)
- 2 - Draw the cross sections at each chaining (5 pts)
- 3 - Calculate the areas of the cross sections (5 pts)
- 4 - Using the cross sections method (Sections en Travers), calculate the volumes of excavation and backfilling required for the layout of the road (8 pts)



Plan view



Typical Cross Section

Figure 4. Plan view and typical cross-section of the road St-Peter