**Please type your answers below each question and describe how you get to the final answer.**

**Q1 (12 points)** The network diagram of a project is shown below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Normal time (days) | Normal Cost ($) | Crash time (days) | Crash Cost ($) | Daily Crash Cost ($/day) |
| A | 7 | 10 | 4 | 28 |  |
| B | 3 | 30 | 1 | 36 |  |
| C | 4 | 20 | 2 | 30 |  |
| D | 5 | 20 | 3 | 40 |  |

1. Use two-pass method to determine the critical path (you can show the different times in the above diagram). **(4 points)**
2. What is the project duration? **(1 point)**
3. What is the slack time of activity F? **(1 point)**
4. Activities A, B, C, D can be crashed. The normal time, crash time, normal cost and crash cost are shown in the table below. What is the daily crash cost of each activity? **(2 points)**
5. The project needs to be completed in 22 days. How can you achieve this goal at minimum cost? Please report your crashing steps in the table below. (The table size does not imply the number of steps that will be needed.) **(4 points)**

|  |  |  |  |
| --- | --- | --- | --- |
| Project Duration  (days) | Critical Paths | Crashable Tasks on Critical Paths  [daily crash cost, crashable # days] | Best Option [days to crash] |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

**Q2 (11 points)** A cafeteria serving line has a single coffee urn from which customers serve themselves. Arrivals at the urn follow a Poisson distribution at the rate of three per minute. In serving themselves, customers take on average about 15 seconds with exponentially distributed serving times.

a. How much time, on average, does it take before a customer can drink coffee? **(5 points)**

Prepare for VUT calculation

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **a** (avg. inter-arrival time) | **p** (avg. service time) | **m** (number of servers) | **u** (avg. utilization) |  | CVa (coef. of var.- arrival) | CVp (coef. of var.- service) |
|  |  |  |  |  |  |  |

Show VUT calculation and final answer to the question:

b. How many customers on average would you expect to be waiting in line for their coffee? **(3 points)**

c. Instead of the customers serving themselves from the coffee urn, suppose that the cafeteria installs an automatic vendor that dispenses a cup of coffee in a constant time of 15 seconds. How does this change your answer to part b? **(3 points)**

**Q3 (7 points)** All patients who arrive to the Emergency Department (ED) of Cleanland Clinic first go to Registration and then to Triage. Triage is staffed by two nurses: Gary and Elena. Triage is operated using **a single line** and patients are served on a first-come-first-serve basis.

Gary

Elena

1. Patients arrive at an average of one every 30 minutes, and their requests take on average 20 minutes to be processed at Triage. Assume Poisson arrivals and exponential service times. What is the average waiting time for a patient? **(5 points)**

Prepare for VUT calculation

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **a** (avg. inter-arrival time) | **p** (avg. service time) | **m** (number of servers) | **u** (avg. utilization) | CVa (coef. of var.- arrival) | CVp (coef. of var.- service) |
|  |  |  |  |  |  |

Show VUT calculation and final answer to the question:

(b) Triage is considering creating **two separate lines**, the first for patients with surnames starting with a letter in the range A-M, the second for N-Z. Each line would have a Triage nurse dedicated to serve only that line of patients. What effect do you think creating these dedicated lines will have on the average waiting time experienced by patients at Triage? (i.e., will the waiting time remain the same, increase or decrease?) You may assume that the average patient arrival rates to each line is equal to each other. Justify your answer. **(2 points)**