

## Stochastic Models: Exercise 3

1. (i)  
(ii)

$$\begin{aligned}\mathbb{P}(N(9.5) - N(8.5) = 0) &= e^{-(m(9.5) - m(8.5))} \frac{m(9.5) - m(8.5)^0}{0!} \\ &= e^{-10}\end{aligned}$$

- (iii)

$$\begin{aligned}\mathbb{E}(\text{number of arrivals from 8:30AM-9:30AM}) &= \sum_{k=0}^{\infty} k \cdot e^{-(m(9.5) - m(8.5))} \frac{(m(9.5) - m(8.5))^k}{k!} \\ &= 10 \sum_{k=1}^{\infty} e^{-10} \frac{10^{(k-1)}}{(k-1)!} \\ &= 10\end{aligned}$$

- 2.

$$\begin{aligned}\mathbb{P}(N(I_1) = k_1, \dots, N(I_n) = k_n \mid N(U) = k) &= \frac{\mathbb{P}(N(I_1) = k_1, \dots, N(I_n) = k_n, N(u) = k)}{\mathbb{P}(N(U) = k)} \\ &= \left( \prod_{i=1}^n e^{-\lambda c_i} \frac{(\lambda c_i)^{k_i}}{k_i!} \right) \bigg/ e^{-\lambda c} \frac{(\lambda c)^k}{k!} \\ &= \frac{k!}{k_1! k_2! \dots k_n!} \left( \frac{c_1}{c} \right)^{k_1} \left( \frac{c_2}{c} \right)^{k_2} \dots \left( \frac{c_n}{c} \right)^{k_n}\end{aligned}$$

3. Let  $N_i$  denote the number of families with number of member of size  $i$  migrating to Batan Island over a  $t$  week(s) period and let such an event be called a type- $i$  event for  $i = 1, 2, 3, 4$ . Hence  $N_i(t)$  is a Poisson process and  $\mathbb{E}(N_i(t)) = \lambda t p_i = 10 p_i$ . Let  $M(t) = \sum_i i N_i(t)$  denote the number of individuals migrating during a  $t$ -week period.

$$\begin{aligned}\mathbb{E}(M(t)) &= \sum_i i \mathbb{E}(N_i(t)) \\ &= (1 + 4) \frac{10}{6} + (2 + 3) \frac{10}{3} \\ &= 25\end{aligned}$$

To find variance, we first find  $\mathbb{E}(N_i(t)^2)$

$$\begin{aligned}\mathbb{E}(N_i(t)^2) &= \sum_{n=0}^{\infty} n^2 e^{-\lambda t p_i} \frac{(\lambda t p_i)^n}{n!} \\ &= \sum_{n=2}^{\infty} e^{-\lambda t p_i} \frac{(\lambda t p_i)^{n-2}}{(n-2)!} + \sum_{n=1}^{\infty} e^{-\lambda t p_i} \frac{(\lambda t p_i)^{n-1}}{(n-1)!} \\ &= \lambda t p_i + (\lambda t p_i)^2\end{aligned}$$

and so  $\text{Var}(N_i(t)) = \lambda t p_i$ .

$$\begin{aligned}\text{Var}(M(t)) &= \sum_i i^2 \text{Var}(N_i(t)) \\ &= (1^2 + 4^2) \frac{10}{6} + (2^2 + 3^2) \frac{10}{3} = \frac{215}{3}\end{aligned}$$

- 4.

5. (i) (a) No. This can be show as follows, where  $m(t) = \int_0^t \alpha(u) du$

$$\begin{aligned}
\mathbb{P}(E_1 > t) &= \mathbb{P}(N(t) = 0) \\
&= e^{-m(t)} \\
&= \exp\left(-\int_0^t \alpha(u) du\right) \\
\mathbb{P}(E_2 > t \mid E_1 = s) &= \mathbb{P}(N(t+s) - N(s) = 0 \mid E_1 = s) \\
&= \mathbb{P}(N(t+s) - N(s) = 0), \quad \text{by independent increments} \\
&= e^{-(m(t+s)-m(s))} \\
&= \exp\left(-\int_t^{t+s} \alpha(u) du\right)
\end{aligned}$$

(b) From (a), we have  $\mathbb{P}(E_1 \leq t) = 1 - \exp\left(-\int_0^t \alpha(u) du\right)$

(ii)

6. (a) Let  $N_1(t)$  and  $N_2(t)$  be the type-I and type-II events where Irma Pince finds a misplaced book and fails to find a misplaced book respectively. Hence, the  $N_i$ s are independent Poisson process with rate  $\lambda p_i$  where  $i = 1, 2$ . This the misplacements found by Irma Pince follows a homogeneous Poisson process. For  $t = 100$ ,  $\mathbb{E}(N_1(100)) = 90\lambda$ .
- (b) For each shelf  $i$ , we can the classify the event of find a misplaced book in the shelf as a type-I event and not finding a misplaced book as a type-II event. Then the  $N_1(t)$  of shelf  $i$  is a Poisson process with rate  $\lambda p_i$ . Define  $N(t) = N_1(t) + N_2(t) + N_3(t)$  and we claim that it is a Poisson process with rate of process  $\lambda(p_1 + p_2 + p_3)$ . Hence the desired probability is,

$$\mathbb{P}(N(3) = 5) = e^{-\lambda(p_1+p_2+p_3)} \frac{(\lambda(p_1 + p_2 + p_3))^5}{5!}$$