MACHAKOS UNIVERSITY

University Examinations 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF MECHANICAL AND MANUFACTURING ENGINEERING

FIFTH YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

EMM 500 SYSTEM RELIABILITY ENGINEERING AND PLANT MAINTENANCE

DATE: 22/7/2019 **TIME: 2.00-4.00 PM**

INSTRUCTIONS:

Answer Question One and Any Other Two Questions

All relevant tables and formulae have been provided on the question paper.

All symbols have usual meanings unless otherwise stated.

QUESTION ONE (30 MARKS)

a) Define the following terms: (6 Marks)

i. Reliability

ii. Availability

iii. Maintainability

b) Define the following two types of maintenance and state **two** advantages and **two** disadvantages for each.

i. Reactive maintenance (5 marks)

ii. Preventive maintenance (5 marks)

c) While conducting a system failure analysis, an iterative process is followed in order to determine the best design that will give a desired inherent reliability.

i. Define the phrase Inherent Reliability (1 mark)

ii. Show how system failures can be categorized (4 marks)

iii. List the five levels of failure probability occurrence that are critical in describing system safety (5 marks)

d) Given two reliability functions of two systems:

$$R(t)_1 = e^{-0.002t}; \qquad t \geq 0$$

$$R(t)_2 = \frac{1000 - t}{1000}; \qquad 0 \leq t \leq 1000$$

Determine:

i. Cumulative distribution function (2 Marks)

ii. Hazard rate function (4 Marks)

iii. The MTTF (2 Marks)

iv. The Reliability if the operating time is 400 hours (2 Marks)

v. Compare the reliability and MTTF for the systems (1 Mark)

e) Reliability (survivor) function of a component is given as

$$R(t) = \frac{1}{(0.2t+1)^2} \qquad \text{for } t \geq 0$$

Where the time t is measured in months, Calculate:

i) The probability density function. (3 marks)

ii) Failure rate function. (2 marks)

iii) Mean time to failure (MTTF). (2 marks)

f) The failure time of a certain component has a Weibull distribution with $\beta = 4$, $\theta = 2000$, and $\gamma = 1000$. Find the reliability of the component and the hazard rate for an operating time of *1500* hours. (4 marks)

g) A microwave transmitter has a constant failure rate of 0.00034 failures per hour. Determine

i. The MTTF (2 marks)

ii. The t_{med} (2 marks)

iii. The reliability R(t) for 30 days of continuous operation (2 marks)

iv. The design life if the reliability is 0.95 (2 marks)

QUESTION TWO (20 MARKS)

a) A fuel injection system is experiencing high failure rates. The reliability function has been found to be

$$R(t) = (t+1)^{-3/2}; \qquad t \geq 0$$

Where t is measured in years. The reliability over its intended life of 2 years is 0.19, which is unacceptable. Will a burn-in period of 6 months significantly improve upon this reliability? If so, by how much? (4 Marks)

b) Failure distributions are normally represented by Bathtub curve:

i) Draw a well labelled diagram of a Bathtub curve. (2 marks)

ii) Explain the characteristics, cause and how the three failure rates can be reduced in a Bathtub curve (6 Marks)

c) A rotary pump has a constant failure rate $\lambda = 4.28 \times 10^{-4}\,\text{hours}^{-1}$.

Calculate:

i) The probability that the pump survives one month (***t*** = 730 hours) in continuous operation (2 marks)

ii) Mean Time To Failure (MTTF) (2 marks)

iii) Suppose that the pump has been functioning without failure during its first 2 months (t_1=1460 hours) in operation. Calculate the probability that the pump will fail the next month (t_2=730 hours) (3 marks)

QUESTION THREE (20 MARKS)

a) Highlight the two categories of system functions used in developing maintenance programs under the RCM philosophy. (2 Marks)

b) A system is composed of two independent and active units, and at least one unit must work normally for the system success. The constant failure rates of units 1 and 2 are λ_1 = 0.004 failures per hour and λ_2 = 0.006 failures per hour, respectively.

Calculate the system mean time to failure. (5 Marks)

c) FMEA and FMECA utilize categories and levels of failure to show the criticality of a given malfunction.

i) Describe the four failure categories used in FMECA. (4 Marks)

ii) What are failure levels used for? (1 Mark)

d) State and explain **four** probable causes of system failure which a reliability design engineer must properly understand for adequate design. (8 Marks)

QUESTION FOUR (20 MARKS)

a) Define TPM, and state **four** main objectives in maintenance (6 marks)

b) Distinguish between serviceability and reparability (2 Marks)

c) Name and explain three fault diagnostics (troubleshooting) methods. (6 Marks)

d) Tests performed on a self-diagnostic module for a complex electronic system resulted in correct diagnostics of a known fault 98% of the time, with only a 1% false reading when it was known there were no faults present. The probability of a failure (fault) occurring over the rest period is 0.005. How reliable is the self-diagnostic module? (6 marks)

QUESTION FIVE (20 MARKS)

a) Define the following terms as used in Maintenance: (2 Marks)

i) Planning

ii) Scheduling

b) While planning for a scheduled maintenance shutdown, it is important to define the scope of work to be performed. Describe **four** sources of information input into the planning process. (8 Marks)

c) Distinguish between Routine and Non-Routine Maintenance. (4 Marks)

d) Identify any **six** key features of a Computerized Maintenance Management System (CMMs) (6 Marks)

USEFUL FUNCTIONS

$$\begin{aligned}
F(t) &= \int_0^t f(t')dt';\; R(t) = \int_t^\infty f(t')dt' \\
R(t) &= 1 - F(t);\; f(t) = \frac{-dR(t)}{dt} = \frac{dF(t)}{dt} \\
\lambda(t) &= \frac{f(t)}{R(t)};\; R(t) = exp\left[-\int_0^t \lambda(t')dt'\right] \\
MTTF &= \int_0^\infty R(t)dt;\; MTTF(T_0) = \frac{1}{R(T_0)}\int_{T_0}^\infty R(t')dt' \\
R(t|T_0) &= \frac{R(t+T_0)}{R(T_0)} \\
\sigma^2 &= \int_0^\infty t^2 f(t)dt - (MTTF)^2 \\
p_n(t) &= \frac{e^{-\lambda t}(\lambda t)^n}{n!};\; R_s(t) = \sum_{n=0}^{s} p_n(t)
\end{aligned}$$

$$R_{\mathrm{ps}} = 1 - (1 - R_1)(1 - R_2)(1 - R_3)\ldots(1 - R_n)$$

$$R_{ps}(t) = 1 - \prod_{i=1}^{n}(1 - e^{-\lambda_i t})$$

$$R_{ps} = 1 - (1 - R_1)(1 - R_2)(1 - R_3).....(1 - R_n)$$

CFR:

$$\begin{aligned}
R(t) &= \exp[-\lambda t];\; f(t) = \lambda \exp[-\lambda t] \\
MTTF &= \frac{1}{\lambda};\; \sigma^2 = \frac{1}{\lambda^2} \\
R(t) &= \prod_{i=1}^{n} R_i(t);\; \lambda(t) = \sum_{i=1}^{n} \lambda_i(t) \\
p_n(t) &= \frac{e^{-\lambda t}(\lambda t)^n}{n!};\; R_s(t) = \sum_{i=1}^{s} p_n(t) \\
R(t) &= 2e^{-\lambda t} - e^{-2\lambda t}
\end{aligned}$$

Time Dependent failure models:

$$
\begin{aligned}
\lambda(t) &= \frac{\beta}{\theta}\Big(\frac{t}{\theta}\Big)^{\beta-1};\ R(t) = \exp\Big(-\frac{t}{\theta}\Big)^{\beta} \\
MTTF &= \theta\Gamma\Big(1+\frac{1}{\beta}\Big);\ \sigma^2 = \theta^2\Big\{\Gamma\Big(1+\frac{2}{\beta}\Big) - MTTF^2\Big\} \\
R(t|T_0) &= \exp\Big[-\Big(\frac{t+T_0}{\theta}\Big)^{\beta} + \Big(\frac{T_0}{\theta}\Big)^{\beta}\Big];\ \Big[\sum_{i=1}^{n}\Big(\frac{1}{\theta_i}\Big)\Big]^{-1/\beta} \\
F(t) &= Pr\{T \le t\} = Pr\Big\{z \le \frac{t-\mu}{\sigma}\Big\} = \Phi\Big(\frac{t-\mu}{\sigma}\Big) \text{ - Normal} \\
F(t) &= \Phi\Big(\frac{1}{s} ln \frac{t}{t_{med}}\Big) \text{ - Lognormal}
\end{aligned}
$$

Weibull Distribution

$R(t) = e^{-\left(\frac{t-\gamma}{\theta}\right)^{\beta}}$ for $t > \gamma > 0,\ \beta > 0,\ \theta > 0$

$h(t) = \dfrac{\beta\left(t-\gamma\right)^{\beta-1}}{\theta^{\beta}}$ for $t > \gamma > 0,\ \beta > 0,\ \theta > 0$