# UNIVERSITY OF BOLTON

# SCHOOL OF ENGINEERING

# MSC SYSTEMS ENGINEERING AND ENGINEERING MANAGEMENT

# SEMESTER 2 EXAMINATION 2022/2023

# MONITORING OF MECHANICAL SYSTEMS

# MODULE NO: EEM7018

**Date: Thursday 11th May 2023** **Time: 10:00am – 12:00pm**

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**INSTRUCTIONS TO CANDIDATES:**

**There are FOUR questions.**

**Answer ANY THREE questions.**

**All questions carry equal marks of 25.**

**Marks for parts of questions are shown in brackets.**

**All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.**

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**Question 1**

a) Fig. 1(a) shows a source with an internal voltage of $V_s$= 20 mV rms and an internal resistance of $R_s$= 500 Ω is connected to the input terminals of an amplifier having an open-circuit voltage gain of $A_{voc}$=100, an input resistance of $R_i$= 1 kΩ, and an output resistance of $R_o$= 2000 Ω. The load resistance of $R_L$= 500 Ω.

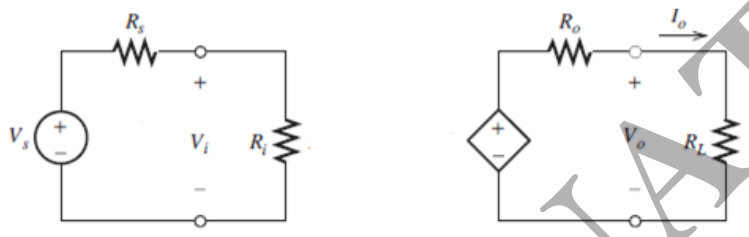


Fig.1(a): a source, amplifier and load circuits

(i) Find the voltage gain $A_{vs}$= $V_o/V_s$ and $A_V$= $V_o/V_i$

(14 marks)

(ii) Find the current gain and power gain.

(2 marks)

b) Find the overall simplified model for the cascade connection of Fig.1(b).

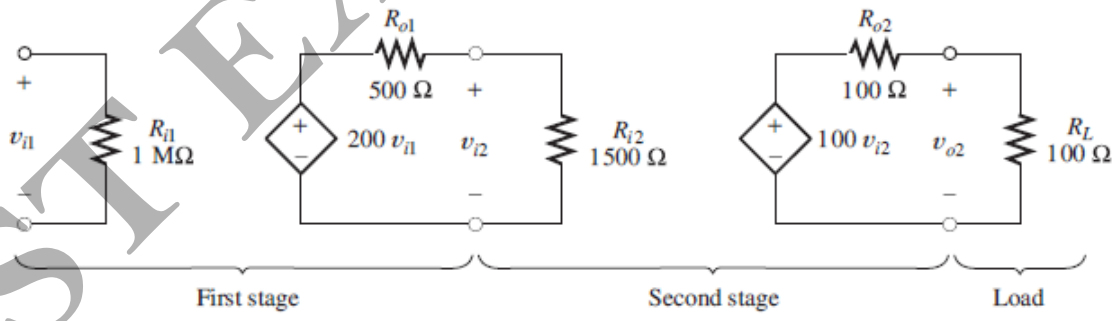


Fig.1(b): A cascaded amplifier circuit

(9 marks)

**Total 25 marks**

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**Question 2**

a) An operational amplifier has high input impedance and low output impedance. Briefly explain why this is desirable. (6 marks)

b) Fig.2b is a diagram of a summing inverting negative feedback operational amplifier circuit with two inputs V1 and V2 and an output Vo. What is the value of Vo if V1=2.5V and V2 = 5V (4 marks)

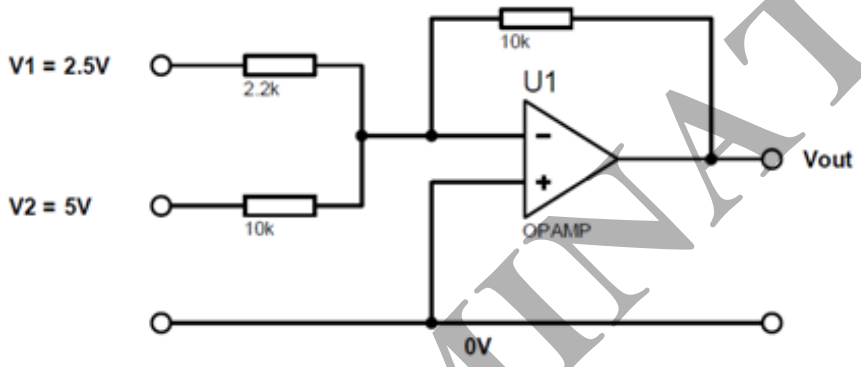


Fig.2(b): Summing amplifier

c) Briefly describe with the use of diagrams, the difference between amplitude and frequency modulation. (10 marks)

d) Explain, with the use of examples the difference between Analogue and Digital signals. (5 marks)

**Total 25 marks**

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**Question 3**

A mechanical engineering company intends to introduce the lean manufacturing into their company. TPM could be one of the key areas for success. The company owns four assembly machines You are asked by the management to investigate the effectiveness of the system. After inspecting the assembly machine for a week, you record the following, Table Q3(a) shows the reported failures:

- The assembly machines work a total of 48 hours over 6 days.
- Every noon all the operators have a 45-minutes lunch break.
- The standard time for the assembly process is 15 minutes.
- After assembling 200 parts, the tool needs to be checked and changed if necessary. 250 minutes required for each time.
- 11 defective parts have been detected.
- Detailed data was recorded on each failure and presented in Table Q3(a) (The normal processes time is from 9:00 am to 5:00 pm).
- The total assemblies made in the week were 100.

**Table 3(a)**

| Failure No. | Reported day and time | Machine handed back to production |
|---|---|---|
| **1** | Day 2 – 1:15 pm | Day 2 – 4:00 pm |
| **2** | Day 4 – 3:40 pm | Day 5 – 9:30 am |
| **3** | Day 5 – 2:00 pm | Day 5 – 3:15 pm |

a) Describing the procedure clearly, estimate the Availability, Performance Efficiency, Rate of Quality Products, and the Overall Equipment Effectiveness. (12 marks)

**Question 3 continued on the next page.**
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**Q3 continued**

b) Explain the basic elements involved in a vibration diagnosis system, a typical such system can be seen in Fig 3(b). (6 marks)

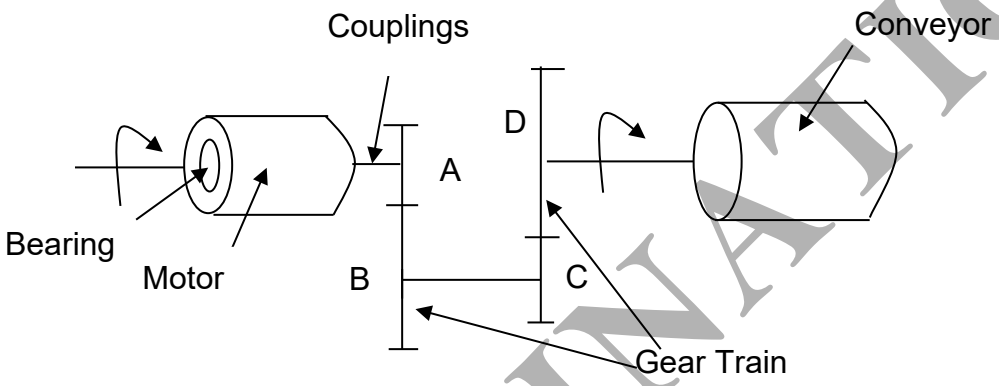


Fig 3(b) A conveyor system

Historical data collection by maintenance and operating workers shows that the individual reliabilities of each station are as follows:

- Station 1: 96.5%
- Station 2: 90.4%
- Station 3: 96.1%
- Station 4: 92.0%
- Station 5: 89.9%
- Station 6: 98.0%
- Station 7: 88.0%

Calculate and explain the reliability of the full production line. (3 marks)

c) A process engineer advises that a duplicate station be installed in Station 5, in parallel with the original one. What might be the effect(s) of this change on the reliability of the system (show your working)? What are the benefits and disadvantage of redundancy systems? (4 marks)

**Total 25 marks**

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**Question 4.**

(a) Critically discuss the strategic importance of maintenance for an organisation. (7 marks)

(b) Identify three commonly used maintenance strategies in industry and **explain** their benefits and applications and critically **analyse** the possible challenges of applying each of these maintenances. (12 marks)

(c) You are testing six air conditioning units for 1,000 hours. You collected the following data:

- AC 1 burned out after 422 hours.
- AC 2 burned out after 744 hours
- AC 3 burned out after 803 hours
- AC 4 burned out after 678 hours
- AC 5 remained operational for 1000 hours
- AC 6 burned after 999 hours

Calculate the following: (6 marks)

I. Failure rate (FR %)
II. Failure rate per hour (FR(N))
III. MTBF

**Total 25 marks**

**END OF QUESTIONS**

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**Appendix**

## FORMULA SHEET

These equations are given to save short-term memorisation of details of derived equations and are given without any explanation or definition of symbols; the student is expected to know the meanings and usage.

$$E_f = \frac{1}{2\pi}\int_{-\infty}^{\infty} |F(\omega)|^2 \, d\omega$$

**Butterworth Response Table**

| ORDER | ROLL-OFF DB/DECADE | 1ST STAGE | | | 2ND STAGE | | | 3RD STAGE | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | POLES | $DF$ | $R_1/R_2$ | POLES | $DF$ | $R_3/R_4$ | POLES | $DF$ | $R_5/R_6$ |
| 1 | −20 | 1 | Optional | | | | | | | |
| 2 | −40 | 2 | 1.414 | 0.586 | | | | | | |
| 3 | −60 | 2 | 1.00 | 1 | 1 | 1.00 | 1 | | | |
| 4 | −80 | 2 | 1.848 | 0.152 | 2 | 0.765 | 1.235 | | | |
| 5 | −100 | 2 | 1.00 | 1 | 2 | 1.618 | 0.382 | 1 | 0.618 | 1.382 |
| 6 | −120 | 2 | 1.932 | 0.068 | 2 | 1.414 | 0.586 | 2 | 0.518 | 1.482 |

**END OF PAPER**