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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2022/2023

COURSE NAME	:	VIBRATION
COURSE CODE	:	BDA 31103
PROGRAMME CODE	:	BDD
EXAMINATION DATE	:	JULY / AUGUST 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. **PART A:** ANSWER **ALL** QUESTIONS. **PART B:** ANSWER **ONE (1)** QUESTION **ONLY.** 2.THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK.** 3.STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **TWELVE (12)** PAGES

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PART A - ANSWER ALL QUESTIONS

Q1 (a) What is the relationship between the frequency and wavelength of a wave, and how does it affect the behaviour of a vibrating system? In your answer, provide the following:

- Definition of frequency and wavelength, and its unit of measurement.
- Relationship between frequency and wavelength, and how it is expressed mathematically.
- Explanation of the effect of frequency and wavelength on the behaviour of a vibrating system.

(7 marks)

(b) The time-domain and frequency-domain are two different approaches for analyzing vibration response.

i. Compare the time-domain and frequency-domain approaches for analyzing vibration response. In what practical situations each method are more appropriate? Provide some examples for both domains.

(8 marks)

ii. **Figure Q1** shows a time-domain response of a vibrating system that consists of 3 components. Sketch an approximate frequency-domain response to the system.

(4 marks)

(c) Given in **Table Q1(a)** is the vibration exposure data for a chainsaw operator over a 2-hour work in the *x*, *y*, and *z* axes. Check if the exposure exceeds the daily amount of vibration exposure which employers are required to take action to control exposure set by EC Directive 2002/44/EC as in **Table Q1(b)**.

Table Q1(a): Vibration exposure data for a chainsaw operator.

Axis of Vibration Exposure	x	y	z
a_w (m/s^2)	3.6	3.2	2.8

Table Q1(b): The limit values for the A(8) daily vibration exposure.

A(8) Limit Values	Hand-Arm Vibration	Whole-Body Vibration
Exposure Action Value (EAV)	2.5 m/s^2	0.5 m/s^2
Exposure Limit Value (ELV)	5 m/s^2	1.15 m/s^2

(6 marks)

Q2 (a) Choose and write the correct answer (either A or B) for each statements below:

i. Sound power or acoustic power is the sound energy ____________ per unit time.

A. emitted, reflected, transmitted, or received.

B. transmitted, reflected, or absorbed.

ii. Define the hearing range of humans.

A. 20 to 20,000 Hz

B. 20 to 2,000 Hz

iii. Intensity is the amount of energy passing through unit area per unit time.

A. True

B. False

iv. 90 dB(A) + 90 dB(A) = __________

A. 93 dB(A)

B. 96 dB(A)

v. 90 dB(A) – 80 dB(A) = 90 dB(A)

A. True

B. False

(5 marks)

(b) Calculate the wavelength difference between sound at frequency level of 500 Hz and 2,000 Hz travelling in air. Use 344 m/s as the speed of sound, c in air.

(3 marks)

(c) Define the definition of decibels (dB) scale and support with two (2) reasons why decibels (dB) scale is reliable compared to Pascal (Pa) scale.

(4 marks)

(d) Solve the case study below using suitable sound or noise mathematical formula:

i. The free field noise generated from Mitsubishi diesel generator produces 110 dB(A) measured from 1 meter distance. Determine whether or not the employee location at 4 meters exceeds the noise exposure limit of 85 dB(A)?

(3 marks)

ii. Shipyard grinder used their hand-held metal grinder for cumulative of 3 hours during eight (8) hours workday. The remaining cumulative of 5 hours are used for welding activities. The noise level during grinding activities is 94 dB(A) while noise level during welding activities is 85 dB(A). Evaluate the equivalent continuous noise level, L_{eq}.

(3 marks)

iii. Examine the dose exposure that obtained in question **Q2(c)ii**. Daily exposure duration limit for 85 dB(A) is 8 hours while 94 dB(A) is 1 hour.

(3 marks)

iv. From the monitoring conducted, worker was exposed to noise at 85 dB(A) measured by noise dosimeter. Determine the effective duration, T_e if the measurement is not taken during lunch break. Evaluate the daily noise exposure level, L_{EX} and daily personal noise dose, D for 8 hours whether it exceeds the noise exposure limit as per stated in Regulation 6 Occupational Safety & Health (Noise Exposure) Regulations 2019. Detail work schedule are as below:

Working hours: 12 hours
Morning break: 20 minutes
Lunch break: 1 hour
Tea break: 20 minutes

(4 marks)

Q3 The cable of electrical transmission tower is designed to withstand a steady-state wind operating speed between 1000 and 2000 rpm. Unfortunately, due to a loose installation in the cable connection, a large violent vibration occurs at around 1500 rpm. An initial vibration absorber design as shown in **Figure Q3** is implemented with a mass of 2 kg tuned to 1500 rpm. This, however, causes the combined system natural frequencies to occur at $\Omega_1 = 1250$ rpm and $\Omega_2 = 1800$ rpm.

(a) Interpret the phenomena occurred at 1500 rpm.

(2 marks)

(b) Determine the mass of the transmission line/cable.

(8 marks)

(c) Evaluate the new design of the vibration absorber by taking the result of the first new natural frequency of the system, $\Omega_{1,new}$ at 900 rpm as a benchmark. Provide the answer in terms of mass, $m_{a,new}$ at and stiffness, $k_{a,new}$ of the absorber.

(8 marks)

(d) Based on **Q3(c)**, please justify your answer whether the re-design vibration absorber is safe for operation?

(7 marks)

PART B - ANSWER ONE QUESTION ONLY

Q4 **Figure Q4** shows a rally car that has just jumped off a cliff in one of the World Rally Challenge. The car consists of two suspensions system (front and rear) which have different stiffness value. The front suspension system has stiffness coefficient value, $k_1 = 33\ \text{kN/m}$ while the rear suspension stiffness coefficient value, $k_2 = 37\ \text{kN/m}$. The distance of each suspension system to the center of gravity is $l_1 = 1.1$ m and $l_2 = 1.4$ m respectively. The mass of the car is given as $m = 1{,}350$ kg while the radius of gyration, $r_G = 1.2$ m. By neglecting the damping coefficient of the suspension system:

(a) Sketch the free body diagram by considering the problem as mass spring damper system.

(2 marks)

(b) Develop the equation of motion complete with all values.

(5 marks)

(c) Evaluate the natural frequencies of the system.

(9 marks)

(d) Estimate the mode shape of the system complete with its mode shape diagram.

(9 marks)

Q5 (a) **Figure Q5** demonstrates the simplified model of a lathe machine. Using Lagrange's equations with x and θ as generalized coordinates, prove that the equation of motion for the system as :

$$\begin{bmatrix} m & 0 \\ 0 & J_0 \end{bmatrix} \begin{Bmatrix} \ddot{x} \\ \ddot{\theta} \end{Bmatrix} + \begin{bmatrix} (k_1 + k_2) & (k_2 l_2 - k_1 l_1) \\ (k_2 l_2 - k_1 l_1) & (k_1 l_1^2 + k_2 l_2^2) \end{bmatrix} \begin{Bmatrix} x \\ \theta \end{Bmatrix} = \begin{Bmatrix} 0 \\ 0 \end{Bmatrix}$$

(10 marks)

(b) The following data tabulated in **Table 5** is given to the equation of motion derived in **Q5 (a)**. Evaluate:

Table 5: Parameter of the lathe machine

Parameter	Values
Mass, m	500 kg
Radius of gyration, r_G	0.6 m
Distance between front spring and C.G (l_1)	0.8 m
Distance between rear spring and C.G. (l_2)	1.2 m
Front spring stiffness, (k_1)	5 kN/m
Rear spring stiffness (k_2)	8 kN/m

i. The natural frequencies of the system

(10 marks)

ii. Mode shape of the system (no need to draw mode shape diagram)

(5 marks)

-END OF QUESTION-

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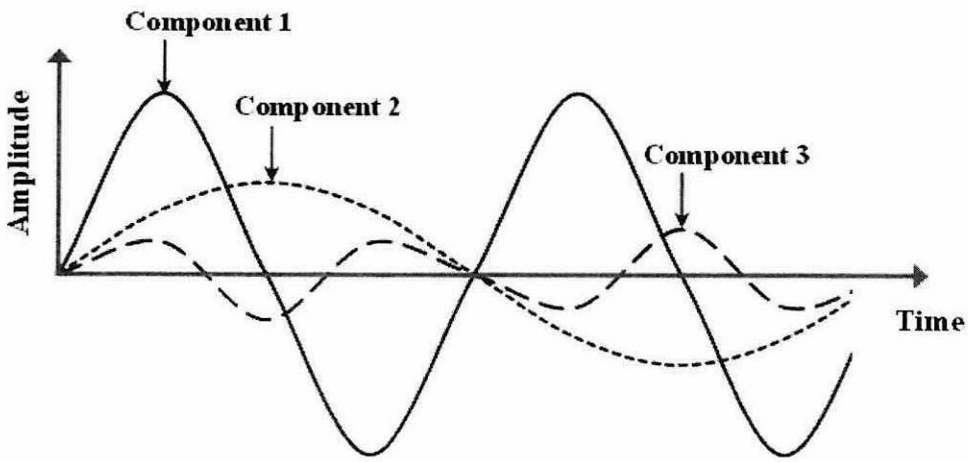

Figure Q1

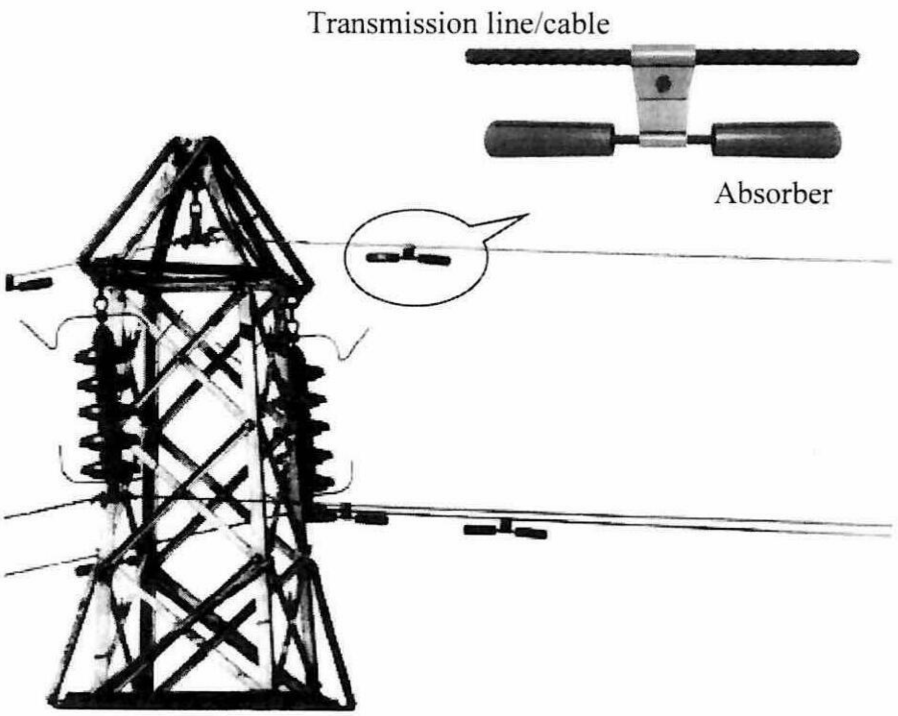

Figure Q3

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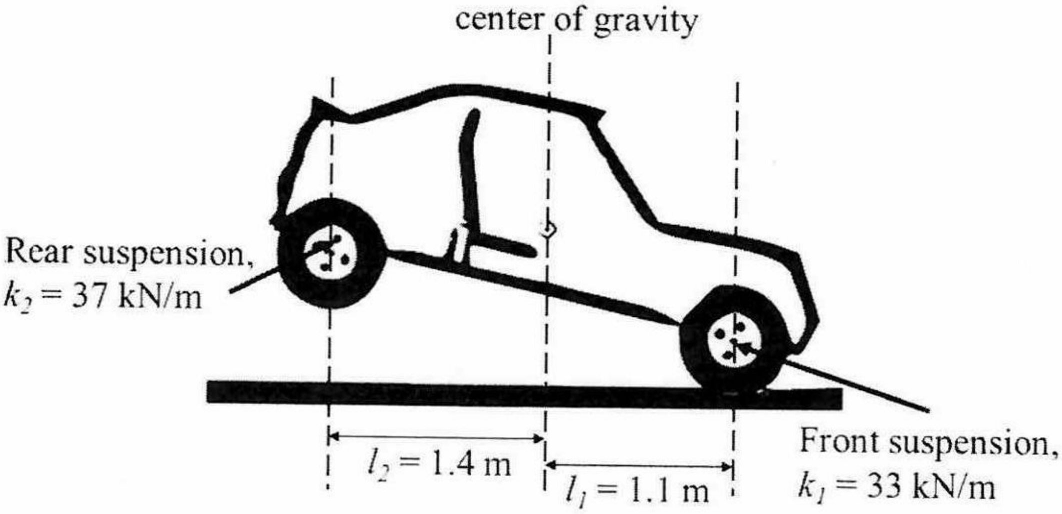

Figure Q4

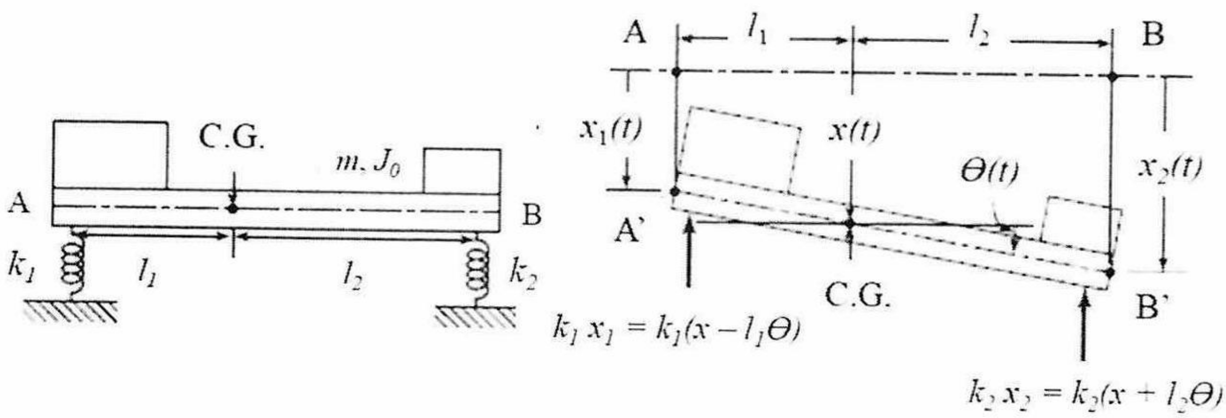

Figure Q5

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USEFUL FORMULAS:

Vibration total value:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

Daily Vibration Exposure:

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}}$$

Noise – distance relationship:

$$dL = 20\ log\left(\frac{R_2}{R_1}\right)$$

$$dL = Lp_1 - Lp_2$$

Equivalent continuous noise level, L_{eq}:

$$L_{eq} = 10\log\{(t_1 \times 10^{L1/10} + t_2 \times 10^{L2/10} + \cdots + t_n \times 10^{Ln/10})/T\}$$

Dose exposure :

$$Dose = 100 \times (\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots + \frac{C_n}{T_n})$$

Daily exposure duration limit:

Noise level, dB(A)	Daily exposure duration limit (hours)
85	8
88	4
91	2
94	1

Daily noise exposure level, L_{EX}:

$$L_{EX,8h} = L_{eq,Te} + 10\log\left(\frac{T_e}{T_0}\right)$$

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USEFUL FORMULAS:

Daily personal noise dose:

$$Dose_{8h} = 100 \times \left(\frac{T_e}{T_0}\right) \times 10^{(L_{eq}-85)/10}$$

Natural frequencies of system with attached vibration absorber:

$$\left.\begin{matrix}(r_1)^2 \\ (r_2)^2\end{matrix}\right\} = \left[1+\frac{\mu}{2}\right] \mp \sqrt{\left[1+\frac{\mu}{2}\right]^2 - 1}$$

where $r_1 = \frac{\Omega_1}{\omega_2}$, $r_2 = \frac{\Omega_2}{\omega_2}$, $\mu = \frac{m_2}{m_1}$

Mass ratio, μ :

$$\mu = \left(\frac{r_1^4 + 1}{r_1^2}\right) - 2$$

Moment of Inertia, I_0 @ J_0 :

$$I_0 = mr_G^2$$

Cramer's Rule:

$$\begin{vmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{vmatrix} = 0 \qquad (A_{11})(A_{22}) - (A_{21})(A_{12}) = 0$$

Harmonic motion:

$$x = A\sin(\omega t + \emptyset)$$

Lagrange Equation for n degree of freedom:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_j}\right) - \frac{\partial T}{\partial q_j} + \frac{\partial V}{\partial q_j} = Q_j^{(n)}, j = 1,2,\ldots,n$$

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USEFUL FORMULAS:

Kinetic energy of spring mass system, T :

$$T = m\dot{x}^2$$

Potential energy of spring mass system, V :

$$V = \frac{1}{2}kx^2$$