UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	VIBRATION AND NOISE IN RAILWAY
COURSE CODE	:	BNT 20303
PROGRAMME CODE	:	BNT
EXAMINATION DATE	:	DECEMBER 2019 / JANUARY 2020
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

Q1 A number degree of freedom system depend on the number of mass and number of movement either translation, rotation or torsional at each axis. A system is said to undergo free vibration when it's oscillates only under an initial disturbance with no external forces acting after initial disturbance.

(a) Demonstrate the free vibration response of $5\ddot{x} + 150x = f(t)$ in the form of $x(t) = A_1 \cos \omega_n t + A_2 \sin \omega_n t$ with initial condition of; $x\,(1) = 0.01\ m$ and $\dot{x}(1) = -0.5\ m/s$.

(4 marks)

(b) Differentiate between three types of free vibration damped system with roots formula condition and diagram.

(6 marks)

(c) Test the amplitude of steady state motion for single degree of freedom with harmonic excitation with different value of damped system which is c = 500 Ns/m and c = 0 Ns/m. The value of spring stiffness, k is 1000 N/m, mass, m is 100 kg and harmonic excitation, F is $100\cos 5t$. Please draw the diagram system.

(6 marks)

(d) Examine the natural frequencies and mode shapes for the torsional system shown in **Figure Q1(d)**. The value for J_1 = 10 kgm^2, J_2 = 20 kgm^2 and $k_{t1} = k_{t2}$ = 1 N/m. Assume harmonic motion of $\theta(t) = A \sin(\omega t + \phi)$.

(9 marks)

Q2 **Figure Q2** illustrates a schematic model of seismograph system: device to records earthquakes. Assuming that θ is too small for the model, and given g = 9.81 m/s^2 and the initial conditions of the system are (0) = 0.2 m, $\dot{x}(0) = \theta\,(0) = \theta(0) = 0$:

(a) By using Lagrange formula, derive the equations of motion of the system in matrix form with complete values. $[M]\begin{Bmatrix}\ddot{x}\\ \ddot{\theta}\end{Bmatrix}+[K]\begin{Bmatrix}x\\ \theta\end{Bmatrix}=\begin{Bmatrix}0\\ 0\end{Bmatrix}$

(10 marks)

(b) Analyze the natural frequencies of the system.

(5 marks)

(c) Determine the free vibration responses of the system, $x(t)$ and $\theta(t)$ by including all the given initial conditions.

(10 marks)

Q3 A motor-generator set, weighing 200 kg is designed to operate in the speed range of 2900 to 3300 rpm. However, the generator set is found to vibrate violently at a speed of 3000 rpm due to a slight unbalance in the rotor. As an engineer, you have been instructed to design an undamped vibration absorber attached to the system to eliminate the problem. The trial mass of vibration absorber given to you is 5 kg.

(a) Analyze the vibration absorber performance whether it can eliminate the vibration induced by motor-generator set or not. Please justify your answer.

(12 marks)

(b) If you are required to re-design the vibration absorber by taking an upper natural frequency 3400 rpm (which fall outside the operating speed range of motor-generator set) as a benchmark, evaluate the new parameters of vibration absorber by specifying its mass and stiffness. Please justify your answer whether the re-design vibration absorber is safe to be used or not?

(13 marks)

Q4 (a) Any motion that repeats itself after an interval of time is called vibration or oscillation. Demonstrate **TWO (2)** typical examples of vibration and interpret general energy conservation concept of vibratory systems.

(5 marks)

(b) The minimum number of independent coordinate required to determine completely the positions of all parts of a system at any instant of time defines the number of degrees of freedom of the system. Distinguish between linear and angular coordinate for single, two and three degree of freedom systems with diagram explanation.

(6 marks)

(c) The measurement of the input and the resulting output vibration characteristics of a system helps in identifying the system in term of its mass, stiffness and damping. Illustrate the basic features of a vibration measurement scheme.

(5 marks)

(d) Hand arm vibration is a physical hazard which transmitted to worker hand during operating hand held machine

(i) During occupational vibration monitoring, a workers from grinding operation had been exposed to hand arm vibration with the acceleration value of 6.30 m/s^2 at x-axis, 2.59 m/s^2 at y-axis and 2.67 m/s^2 at z-axis. Examine the vibration total value, *ahv* and daily vibration exposure, A(8) if the worker only expose to vibration for a duration of 2 hours per day. Assume the working duration per day is 8 hours. Justify whether the daily vibration exposure exceed exposure limit value of 5 m/s^2?

(7 marks)

(ii) Describe **TWO (2)** types of occupational disease related to exposure of hand arm vibration?

(2 marks)

Q5 (a) Identify the correct match for the items in the two columns below:

1. Peak action level of the Noise at Work Regulations 1989	a. 344 m/s
2. Unit of sound pressure	b. Watt
3. Unit of sound power	c. 140 dB
4. Speed of sound	d. Pa

(4 marks)

(b) Three boilers located next to each other give individual sound pressure levels of 108, 96 and 111 dB, respectively.

(i) Determine the total sound pressure level when all of the boilers are switched on together

(3 marks)

(ii) Noise measurement was made at 1 m from the noise source with a reading of 105 dB. If the workstation is located at 4 m from the noise source, estimate the sound pressure level received by the workers at the workstation. The workers needs to be at the workstation for 8 hours daily.

(6 marks)

(iii) Based from your answer in **Q5 (b)(ii)**, suggest the allowable exposure time the workers can be at the workstation daily according to 3 dB exchange rate.

(2 marks)

(c) The dose measured for 8 hours is given as 440 %. Estimate the equivalent sound level (L_{eq}) for actual working time duration. Show the result of L_{eq} in **THREE (3)** and **FIVE (5)** exchange rate. Conclude whether the noise level exceed permissible exposure limit (PEL > 90 dB(A)) as per mention in Factories and Machinery (Noise Exposure) Regulation 1989. List below is the detail information during noise personal monitoring:

Work shift start from 7.00 am to 4.30 pm

- Morning tea break start from 10.00 am to 10.15 am
- Lunch break start from 12.00 pm to 1.00 pm
- Evening tea break start from 3.00 pm to 3.15 pm

(10 marks)

- **END OF QUESTIONS** -

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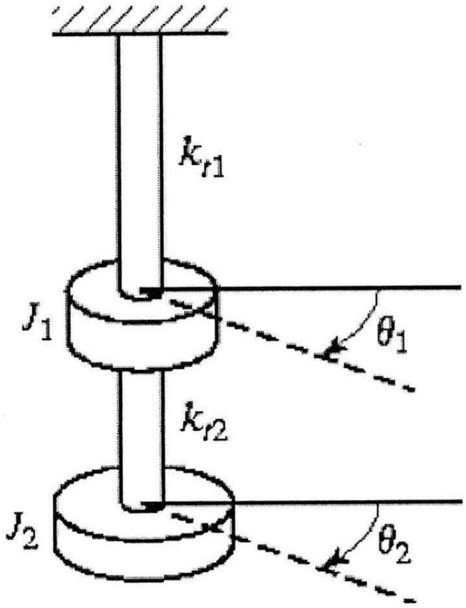

Figure Q1 (d)

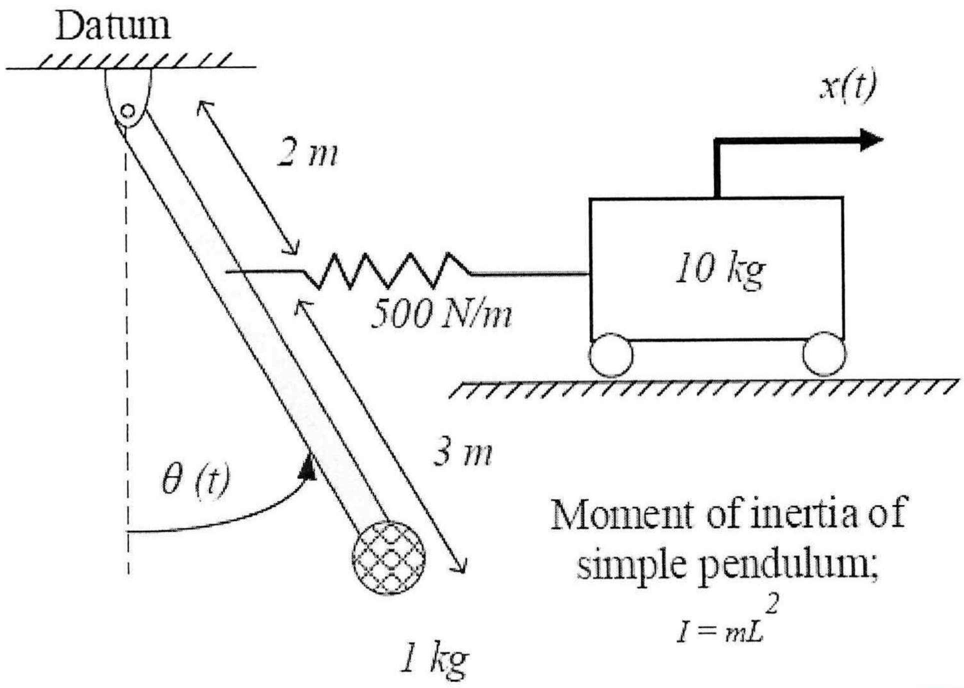

Figure Q2

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USEFUL FORMULAS:

Vibration total value:

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

Daily Vibration Exposure:

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

Total sound pressure level:

$$L_p = 10\log\left[\left(10^{L1/10}\right) + \left(10^{L2/10}\right) + \cdots\left(10^{Ln/10}\right)\right]$$

Difference in sound pressure level (Inverse Square Law):

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

$$dL = Lp_1 - Lp_2$$

Relationship between Dose and L_{eq} for 3dB exchange rate:

$$Leq_{\ 8} = 90 + 9.97\ log\left(\frac{D}{100}\right)$$

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USEFUL FORMULAS:

Allowable exposure time for 3 dB exchange rate:

3 dB Exchange Rate	
dB	**Exposure time (hours)**
87	16
90	8
93	4
96	2

Allowable exposure time for 5 dB exchange rate:

5 dB Exchange Rate	
dB	**Exposure time (hours)**
85	16
90	8
95	4
100	2

Roots for underdamped system:

$$S_1 = \left(-\xi\omega_n + i\omega_n\sqrt{1-\xi^2}\right)$$
$$S_2 = \left(-\xi\omega_n - i\omega_n\sqrt{1-\xi^2}\right)$$

Roots for underdamped system:

$$S_1 = S_2 = \frac{-C_c}{2m} = -\omega_n$$

Roots for overdamped system:

$$S_1 = \left(-\xi + \sqrt{\xi^2 - 1}\right)\omega_n$$
$$S_2 = \left(-\xi - \sqrt{\xi^2 - 1}\right)\omega_n$$

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USEFUL FORMULAS:

Damping ratio:

$$\xi = \frac{C}{2m\omega_n}$$

List of maximum amplitude for different cases:

$$|X| = \frac{F_0}{k - m\omega^2}$$

$$|X| = \frac{F_0}{[(k - m\omega^2)^2 + c^2\omega^2]^{1/2}} \qquad \phi = \tan^{-1}\left(\frac{c\omega}{k - m\omega^2}\right)$$

Lagrange Equation for n degree of freedom:

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

Natural frequencies of system with attached vibration absorber:

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