

Test Paper of Wuhan University of Technology (A)

2018-2019 Academic Year 1st Semester, Course: _____,

Closed-book Exam

Time: 120mins, Class hours: _____ Credits: _____ Total Points: 100, Percent in final evaluation

result: _____ % Date: _____

No.	一 I	二 II	三 III	四 IV	五 V	六 VI	七 VII	八 VIII	九 IX	十 X	合计 Total	Teacher
Full score											100	
Score	8	18	20	30	14						90	

得分 Score	8
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I. Single-choice questions (2 points * 5=10 points)

1. (A) The basic characteristics of elastic elements are
- A. the elements that represent the relationship between force and displacement
 - B. the elements that represent the relationship between force and speed
 - C. the elements that represent the relationship between force and acceleration
 - D. the elements that represent the relationship between displacement and speed

2. (A) For the forced vibration under the simple harmonic excitation of the single-degree-of-freedom system, the magnitude of the response amplitude in the low-frequency zone, resonance zone and high-frequency zone mainly depends the system's

- A. spring stiffness, damping and inertia
- B. damping, spring stiffness and inertia
- C. inertia, spring stiffness and damping
- D. inertia, damping and spring stiffness

3. (B) The function that best reflects the correlation of random variables at different times in different random processes is

- A. autocorrelation function
- B. cross-correlation function
- C. auto-spectrum
- D. frequency response function

4. (C) There are mainly three kinds of vibration problems. Besides vibration analysis and prediction of vibration environment, what is the other vibration problem?

- A. vibration prediction
- B. vibration modeling
- C. system identification
- D. modal analysis

5. (D) The function that cannot reflect the inherent characteristics of the system is

- A. autocorrelation function
- B. impulse response function
- C. frequency response function
- D. natural frequency

得分 Score	18
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II. Explanation of phases (5 points * 5=25 points)

6. Sample function

随机过程中各种可能发生的情况, 各随机互不影响的函数曲线

7. Multi-degree-of-freedom vibration system

用多个物理量来表示的振动系统, 包括二自由度振动系统

8. Power spectrum

在频域上描述系统的平均功率与相关函数互功率谱密度变换对

9. Spectral analysis

对不同频率谐波振幅的分析

10. Principle of dynamic vibration absorber

动力吸振器是把弹性元件连接在系统上,利用辅助元件的振动使其与主系统抵消,而不依靠动能消耗的装置。

得分
Score

20

III. Short-answer questions (10 points * 2 = 20 points)

11. Give examples to illustrate the similarities and differences between active vibration isolation and passive vibration isolation.

相同点: 将自由度系统变为二自由度系统, 增加阻尼器件使一个振动系统变为另一个振动系统

不同点: ①主动隔振的震源是机器本身, 例如汽车发动悬置
被动隔振的震源来自地面, 例如汽车的悬架系统

②主动隔振效果表示形式是隔振系数

被动隔振效果表示形式是位移传递率

12. What are the concepts of impulse response function and frequency response function and their relationship?

脉冲响应函数: 单位脉冲函数为激励下, 系统作出响应的函数表示

频率响应函数: 在不同频率谐波激励作用下, 系统作出的响应的函数表示

$$H(\omega) = |H(\omega)| e^{-j\varphi}$$

脉冲响应函数和频率响应函数为傅里叶变换对

$$Y(\omega) = H(\omega) X(\omega)$$

$$H(\omega) = \frac{Y(\omega)}{X(\omega)}$$

得分
Score

30

IV. Calculation (10 points * 3 questions = 30 points)

13. The probability density function of random variable X is $p(x) = ae^{-b|x|}$, of which a and b are constants. Find the relationship between a and b, and when a = 1, determine the distribution function F(x).

解: 概率密度函数 $p(x) = ae^{-b|x|}$

$$\int_{-\infty}^{\infty} p(x) dx = \int_{-\infty}^{\infty} ae^{-b|x|} dx = 1$$

$$\int_{-\infty}^0 ae^{bx} dx + \int_0^{\infty} ae^{-bx} dx = 1$$

$$\int_0^{\infty} ae^{-bx} dx = \frac{1}{2}$$

$$-\frac{a}{b} e^{-bx} \Big|_0^{\infty} = \frac{1}{2} \quad 0 - (-\frac{a}{b}) = \frac{1}{2} \quad \frac{a}{b} = \frac{1}{2} \quad b = 2a$$

$$\text{若 } a=1, \text{ 则 } b=2 \quad p(x) = e^{-2|x|}$$

$$\text{当 } x \leq 0, p(x) = e^{2x}, F(x) = \int_{-\infty}^x e^{2x} dx = \frac{1}{2} e^{2x}$$

$$\text{当 } x > 0, F(x) = \int_{-\infty}^0 e^{2x} dx + \int_0^x e^{-2x} dx = 1 - \frac{1}{2} e^{-2x}$$

$$F(x) = \begin{cases} \frac{1}{2} e^{2x}, & x \leq 0 \\ 1 - \frac{1}{2} e^{-2x}, & x > 0 \end{cases}$$

14. It is already known that $R(x) = 25e^{-4|t|} \cos \omega t + 16$, work out $\mu(x)$, σ_x^2 , $S_x(\omega)$.

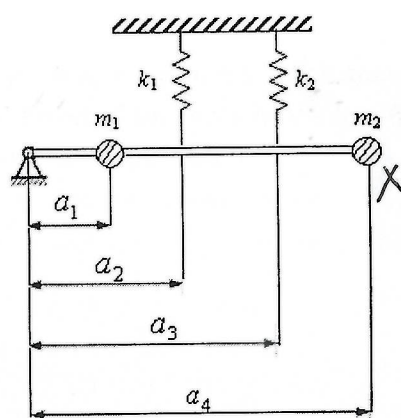
解: $\mu(x) = \lim_{t \rightarrow \infty} R(t) = \lim_{t \rightarrow \infty} 25e^{-4|t|} \cos \omega t + 16 = 16$

$E(x) = \lim_{t \rightarrow 0} R(t) = \lim_{t \rightarrow 0} 25e^{-4|t|} \cos \omega t + 16 = 41$

$\sigma_x^2 = E(x) - \mu^2(x) = 41 - 16 = 25$

$S_x(\omega) = F(25e^{-4|t|} \cos \omega t + 16)$
 $= F(25e^{-4|t|} \cos \omega t) + F(16)$
 $= \frac{25}{4} \frac{\omega^2 + 8}{\omega^2 + 4} + 32\pi \delta(\omega)$

15. Take the linear displacement of m_2 as the coordinates of motion to determine the equivalent stiffness k_B and equivalent mass m_B of the system and natural frequency of vibration. Each value in the figure is known, regardless of the mass of the horizontal lever and the distributed mass of the elastic element.



解: 等效刚度 k_B
 $U_a = \frac{1}{2} k_1 \left(\frac{x}{a_4} a_1 \right)^2 + \frac{1}{2} k_2 \left(\frac{x}{a_4} a_2 \right)^2$

$U_e = \frac{1}{2} k_B x^2$

$U_a = U_e$
 $k_B = \frac{k_1 a_1^2 + k_2 a_2^2}{a_4^2}$

等效质量 m_B

$T_a = \frac{1}{2} m_1 \left(\frac{x}{a_4} a_1 \right)^2 + \frac{1}{2} m_2 \dot{x}^2$

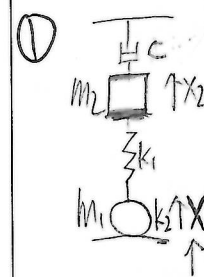
$T_e = \frac{1}{2} m_B \dot{x}^2$

$T_a = T_e$
 $m_B = m_1 \frac{a_1^2}{a_4^2} + m_2$

$p = \sqrt{\frac{k_B}{m_B}} = \sqrt{\frac{k_1 a_1^2 + k_2 a_2^2}{m_1 a_1^2 + m_2 a_4^2}}$

得分 14 V. Comprehensive problem-solving questions (15 points)

16. There are two methods to simplify the car into a two-degree-of-freedom vibration system model in the course. Draw the diagrams of two-degree-of-freedom vibration system models under the two methods; write down their respective assumptions for simplification and explain the physical meaning of each value in the diagrams. If you want to analyze the deformation and dynamic load of suspension and tire under irregular road (displacement) excitation, which two-degree-of-freedom model is best used? Deduce the corresponding vibration differential equation of this model.

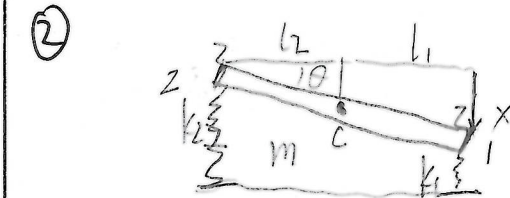


简化假设条件:

汽车的 前后悬架质量系数为1, 即汽车的四个轮子均是有质量的

各量的物理意义

m_2 : 汽车车身质量
 m_1 : 车轮质量
 c : 悬架阻尼系数 k_1 : 弹簧刚度
 k_2 : 车轮 轮胎的刚度
 q : 路面的激励



忽略汽车横向振动和侧倾角影响, 隔离车身悬架只考虑车轮轮胎弹簧

θ : 车身纵向倾角
 x : 车前部分线位移
 k_1 : 车前轮弹簧刚度
 k_2 : 车后轮弹簧刚度
 m : 悬架质量
 l_1 : 车前轮到质心的距离
 l_2 : 车后轮到质心的距离

选择第二种两自由度模型, 振动微分方程为

$$\begin{cases} m\ddot{x}_2 + c(\dot{x}_2 - \dot{x}_1) + k_1(x_2 - x_1) = 0 \\ m_1\ddot{x}_1 + c(\dot{x}_1 - \dot{x}_2) + k_2(x_1 - x_2) + k_1(x_1 - q) = 0 \end{cases}$$