國立成功大學機械工程學系

機械振動學(Mechanical Vibrations)

Spring Term 2022

QUIZ III

June 14 2022 (Tuesday)

13:10 – 15:10 PM (不延長)

RM. 91204

Note:

An A4 sheet of notes is permissible (請不要在 handout 上面黏貼其它的資料)

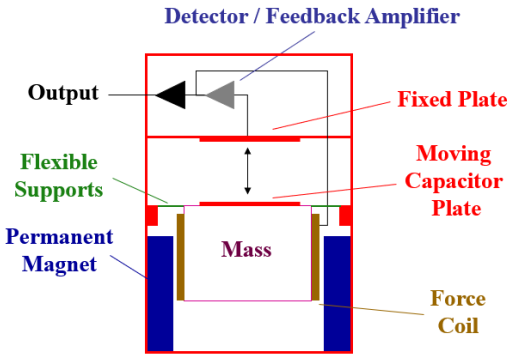
共 4 大題.　本次題目 (含此頁) 計 6 頁

Total 122 Points

Problem 1. Please briefly answer the following questions (Closed books/notes) 30 Pts (5 each)

A. 在課堂上 (Ch. 6) 我們提到了 inertia coefficient 方法, 藉由該方法探求系統的 mass matrix. 請用自己的話, 配合力學與數學, 說明該方法.

B. 在實驗振動力學部分, 我們介紹了如下圖所示之 force-feedback accelerometer, 請以自己的話, 說明該感測器之工作原理.

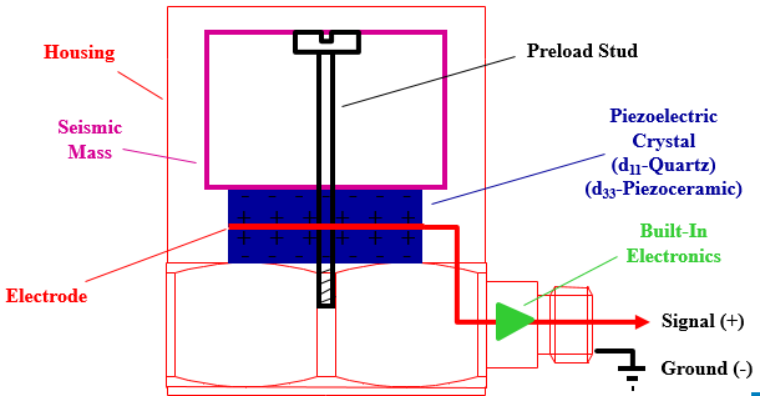


C. 在連續系統 (Ch. 8) 以及 MDOF systems (Ch.6), 我們都提到 Mode Shape 的正交 (Orthogonality) 特性. 請定義正交性, 以及說明模態正交性對振動分析的重要影響.

D. 請以自己的話, 說明 Swept Sine 測試的大概過程.

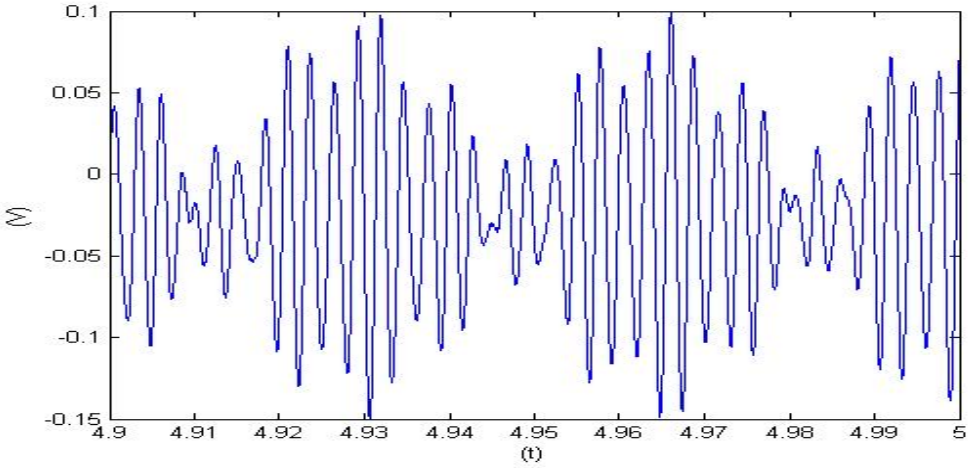
E. 在連續系統振動部分, 我們在上課以一個例題說明以 mode superposition 方式求解振動問題. 請用自己的話, 試著解釋該方法.

F. 請說明如下圖所示之 compression type piezoelectric accelerometer 之工作原理



Problem 2. 實驗振動力學 (35 Pts)

A. 下圖為過去我們測試成功大學校鐘的振動響應. 請由圖的數據大略估計其振動頻率 (橫軸單位為秒). Notes: it may have more than 1 natural frequency (5 Pts)

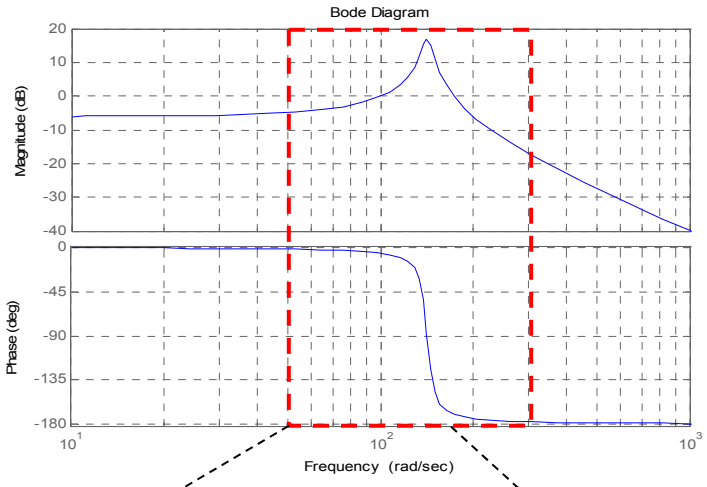


B. A transfer function Bode plot (i.e., *output voltage (volts) / input acceleration (m/s^2)*) of an accelerometer is shown below. Note:上圖之縱軸為 dB scale, 為便於觀察, 紅色區域被放大為下圖, 且其縱軸改成 linear scale. **(10 Pts)**

i. Please estimate its damping ratio. (5 Pts)

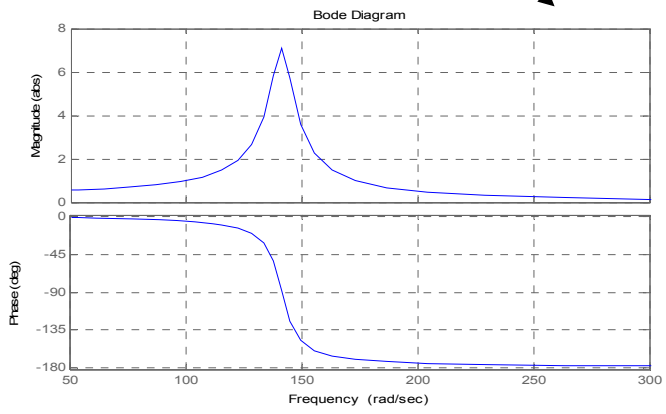
ii. Suppose you have performed an acceleration measurement and the accelerometer output *A(t) = 2 cos(10t) + 3 cos(140t) + 5 cos(500t) (Volts)*. Please estimate the real acceleration signals. (5 Pts)

dB scale !

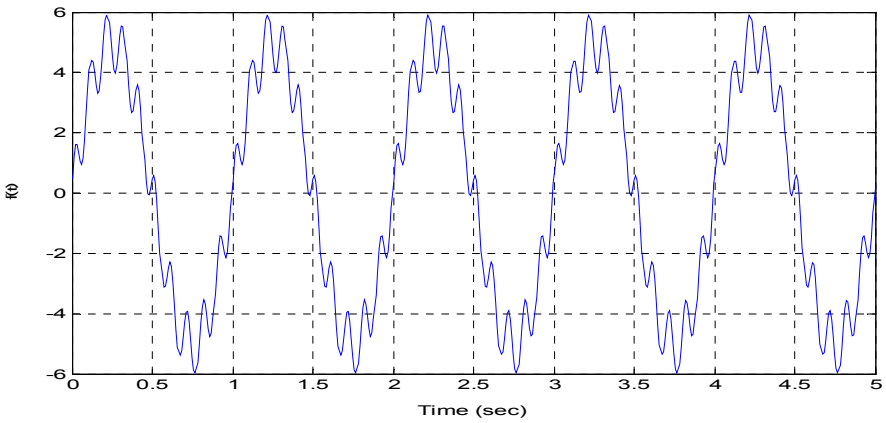


Enlarged View

Linear scale !



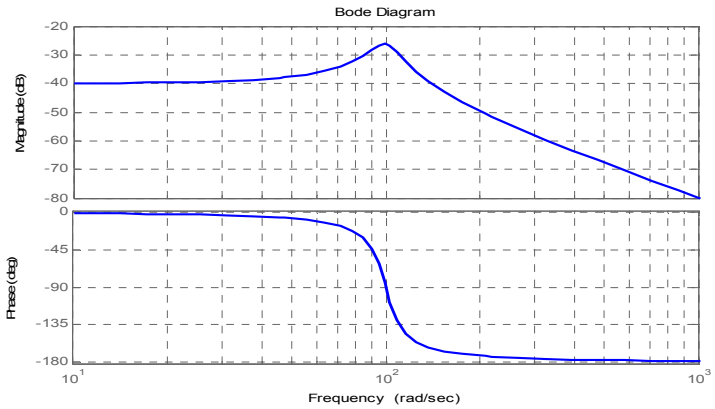
C. Consider the following signal, please briefly show its power spectrum (請大略畫出形狀, 頻率, 以及重要的 spectrum level). (5 Pts)



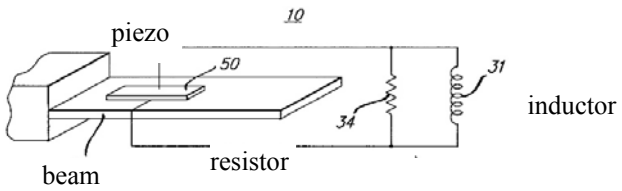
D. 若一個加速規之轉移函數被定為加速規輸出之訊號除上輸入之加速度 (即每單位加速度輸入可產生的電壓輸出). 典型之轉移函數如下圖所示: 請以該圖為基準, 回答下列問題:

1. 請問該加速規之可操作頻率範圍與靈敏度, 並說明理由 (5 Pts)

2. 假設若要量測地震, 其靈敏度必須提昇 10 倍. 請問你如何在設計上修正? (僅限改變 m 與 k) 反之, 若要量測汽車衝擊引發之振動, 其頻寬必須要提升五倍, 請問你如何在設計上修正? (僅限改變 m and k) (5 Pts)



E. Please state the working principle of shear damper, shunt piezo damper (see below), 以及 turn mass damper (TMD). 上述三種 damper 挑兩種說明即可. 不要全寫, 否則寫錯的部分當成是你的"一定"選項 **(5 Pts)**



Problem 3. Lagrange's Equation (18 Pts)

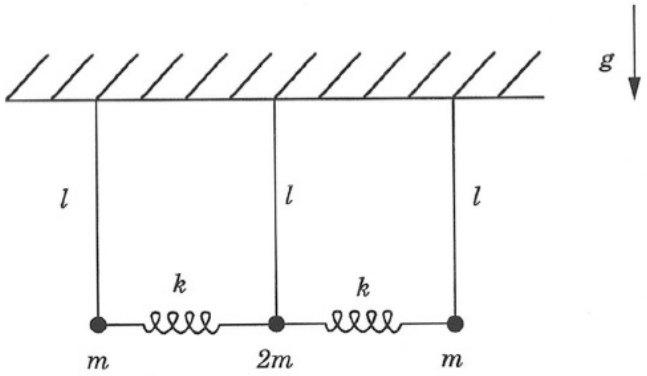
Three pendulums, all of length ***l***, are symmetrically arranged as shown in the figure. The center bob, of mass ***2m***, is connected by ideal springs of force constant ***k*** to the outer bobs, each of mass ***m***. Please use swing angles of each pendulum as the generalized coordinates.

(a): Assuming small motion, please find the ***Lagrangian*** of the system. (6 Pts)

(b): Assuming small motion (i.e., swing angles are very small), please find the equations of motion of the system. (6 Pts)

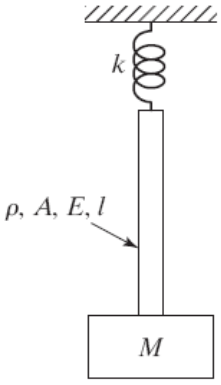
(c): What are the natural frequencies and the corresponding natural modes of the system? (6 Pts)

[Caution: for part c, a little physical insight will save a lot of algebra in this problem.]

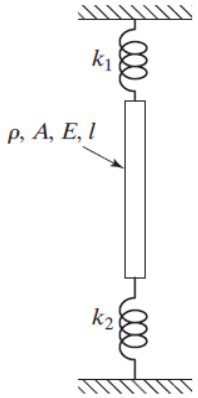


Problem 4. Continuous Vibrations (39 Pts)

A. Consider a bar (桿子，不是樑) with axial vibration shown below, please write the boundary condition for its axial vibration. **(5 Pts)** 忽略重力

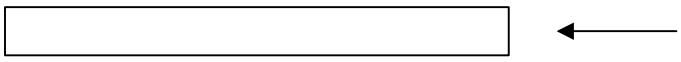


B. Consider the bar shown below. Please find its corresponding frequency equation. 忽略重力 (10 Pts)



C. The cord of a musical instrument is fixed at both ends and has a length 2 m, diameter 0.5 mm, and density 7800 Kg/m^3. Find the tension required in order to have a fundamental frequency of 1 Hz. (8 Pts)

D. 如下圖所示，一根鋼的桿件 (bar) (E=200 GPa, ρ=8000 Kg/m^3, 桿件兩端均為 free)，其中一端遭到一個衝擊，致使桿子產生軸向變形. 假設其軸向變形 $u(x,t) = u_0 \sin(\omega x/c)\sin(\omega t)$. 其中ω= 1000 rad/s. 請問該桿子所受到的最大應力以及該應力傳遞至另一自由端所須之時間為何? (提示: c 值為何? 應變與位移之關係為何? 應力/應變關係為何?) (6 Pts)



假設桿之長度為 L

E. 考慮一根矩形截面鋼懸臂樑 (長度 L, 寬度 W, 厚度 H)(鋼 E= 210 Gpa, ρ=7820 Kg/m^3)，它的最低共振頻率為ω_1. 若我們將此樑之材料換成鋁 (E= 70 GPa, ρ=2700 Kg/m^3), 並將其厚度由 H 變為 2H, 長度由 L 變為 2L, 寬度不變, 但該鋁樑變成是 fixed-fixed beam. 試估計新的 ω_1. (5Pts)

F. As shown below, a beam is simply supported at both ends. However, at the left end, a torsional spring with spring constant $\boldsymbol{k_t}$ is connected with. On the other hand, at the right end, a linear spring with spring constant $\boldsymbol{k}$ is connected with. Please tell us the boundary conditions (5 Pts)