

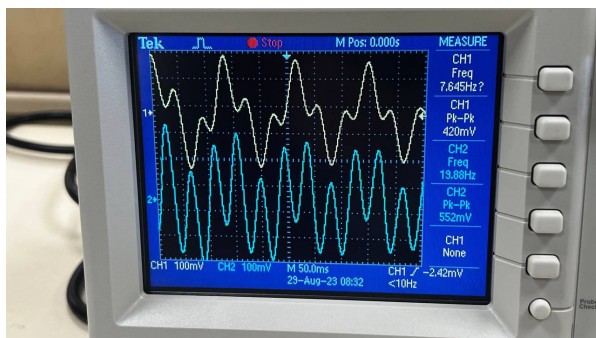
NANYANG TECHNOLOGICAL UNIVERSITY
School of Mechanical and Aerospace Engineering

EXPERIMENT E3.2: VIBRATION OF A TWO-DEGREE OF FREEDOM SYSTEM
LOG SHEET

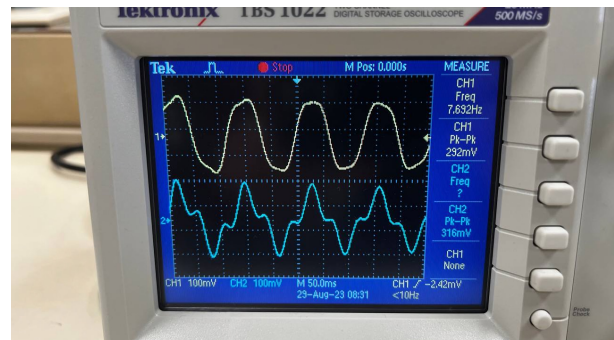
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Strike at mass 1

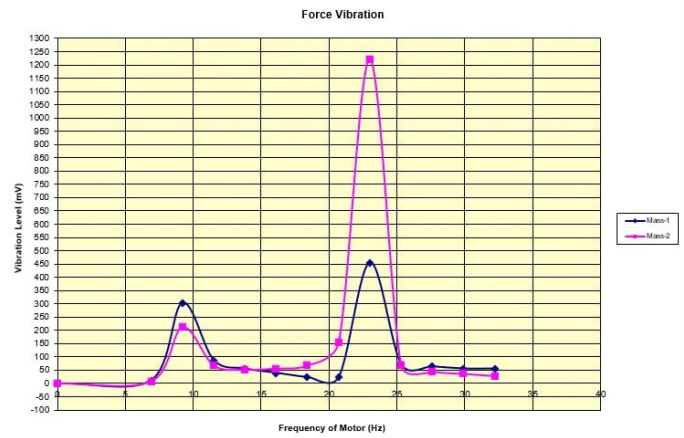


Strike at mass 2

1. The system does not vibrate harmonically. This is because based on the graph, it can be seen that the amplitude of the graph does not stay constant and the periodic oscillations are irregular. However, for system to vibrate harmonically the sine or cosine wave has a fixed amplitude and fixed frequency. Therefore, the system does not vibrate harmonically and this can be caused by the difference in the natural frequency of the supporting beams and the masses.
2. It does not produce similar vibration waveform. This is because based on the equations (18) and (19),
$$x_1 = r_1 B_1 \sin(\omega_1 t + \phi_1) + r_2 B_2 \sin(\omega_2 t + \phi_2),$$
$$x_2 = B_1 \sin(\omega_1 t + \phi_1) + B_2 \sin(\omega_2 t + \phi_2),$$
we can see that x_1 and x_2 will have different waveforms. This is due to the amplitude of wave 1 is multiplied by r_1 and r_2 respectively.
3. No, the vibration amplitude cannot be used against time plots to measure the natural frequencies of the system. The waveforms consist of different sine and cosine waves of the different natural frequencies. We can use Fourier Transform to determine the natural frequencies of the system. Using software for Fast Fourier Transform can help to convert the signal from a time domain into a frequency domain, which allow us determine the vibration amplitude and measure the natural frequencies of the system.

E3.2 - Experiment 2

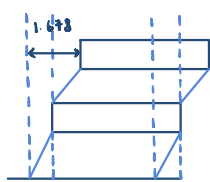
Voltage	Mass-1		Mass-2	
	Freq (Hz)	Vib Level (mV)	Freq (Hz)	Vib Level (mV)
0.0	0	0	0	0
3.0	6.9	12	6.9	8
4.0	9.2	304	9.2	212
5.0	11.5	88	11.5	68
6.0	13.8	56	13.8	52
7.0	16.1	40	16.1	56
8.0	18.4	24	18.4	68
9.0	20.7	24	20.7	156
10.0	23	456	23	1220
11.0	25.3	72	25.3	68
12.0	27.6	64	27.6	44
13.0	29.9	56	29.9	36
14.0	32.2	56	32.2	28



4. By installing a motor on the roof can lead to potential vibration problems, especially when the motor is not properly supported or balanced. The vibrations can cause the building to shake in one direction (one axis) vigorously which can cause to discomfort and noise for people in the building. In addition, vibration will cause stress and strain on the building structure if the natural frequency of the building matches the motor's frequency which lead to resonance to occur at 9.2 Hz and 23 Hz. based on the data collected in experiment 2. Also, these vibration will result in structural damage to the pillars over time and cause the building to lose its structural durability over time.

There are several actions to take to reduce the vibration levels caused by the motor. First is to install shock absorber beneath the motor. This will absorb the vibration produced by the motor and prevent them from transmitting to the building structure. Second is to balance the motor, it will reduce the amount of vibration generated when it is operating. The unbalanced motor can cause excessive vibration and lead to wear and tear on the equipment as well as unwanted vibrations to the building

5.

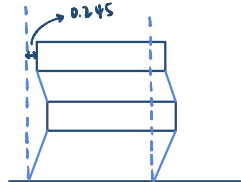


$$\text{At 4V}$$

$$\frac{A}{B} = \frac{[2(k_1 + k_2) - \omega^2 m_2]}{2k_1}$$

$$= 1.678$$

$$A = 1.678$$



$$\text{At 10V}$$

$$\frac{A}{B} = \frac{[2(k_1 + k_2) - \omega^2 m_2]}{2k_1}$$

$$= 0.245$$

$$A = 0.245$$

$$\begin{bmatrix} 2k_1 - \omega^2 m_1 & -2k_1 \\ -2k_1 & 2(k_1 + k_2) - \omega^2 m_2 \end{bmatrix} \begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} 0 \\ m_2 \omega^2 e \end{bmatrix}$$

$$m_1 = 1.4 \text{ kg}, m_2 = 1.06 \text{ kg}, k_1 = 8800, k_2 = 8520$$

$$\begin{bmatrix} a & b \\ c & d \end{bmatrix}^{-1} = \frac{1}{\det} \begin{bmatrix} d & -b \\ -c & a \end{bmatrix}$$

$$\begin{bmatrix} 2k_1 - \omega^2 m_1 & -2k_1 \\ -2k_1 & 2(k_1 + k_2) - \omega^2 m_2 \end{bmatrix}^{-1} = \frac{1}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} \begin{bmatrix} 2(k_1 + k_2) - \omega^2 m_2 & -2k_1 \\ 2k_1 & 2k_1 - \omega^2 m_1 \end{bmatrix}$$

$$= \begin{bmatrix} \frac{2(k_1 + k_2) - \omega^2 m_2}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} & \frac{2k_1}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} \\ \frac{2k_1}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} & \frac{2k_1 - \omega^2 m_1}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} \end{bmatrix}$$

$$X = A^{-1}B$$

$$\begin{bmatrix} A \\ B \end{bmatrix} = \begin{bmatrix} \frac{2(k_1 + k_2) - \omega^2 m_2}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} & \frac{2k_1}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} \\ \frac{2k_1}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} & \frac{2k_1 - \omega^2 m_1}{m_1 m_2 (\omega^2 - \omega_1^2)(\omega^2 - \omega_2^2)} \end{bmatrix} \begin{bmatrix} 0 \\ m_2 \omega^2 e \end{bmatrix}$$

First resonance

$$\omega = 60.13 \text{ rad/s}$$

$$\frac{A_{\text{new}}}{A_{\text{old}}} = 0.57 < 1$$

$$\frac{B_{\text{new}}}{B_{\text{old}}} = 0.71 < 1$$

Second resonance

$$\omega = 146.46 \text{ rad/s}$$

$$\frac{A_{\text{new}}}{A_{\text{old}}} = 1.48 > 1$$

$$\frac{B_{\text{new}}}{B_{\text{old}}} = -0.71 < 1$$

∴ We can conclude that the vibration levels will decrease if the motor were to be installed on mass 2 for both frequencies 9.2 Hz and 23 Hz.