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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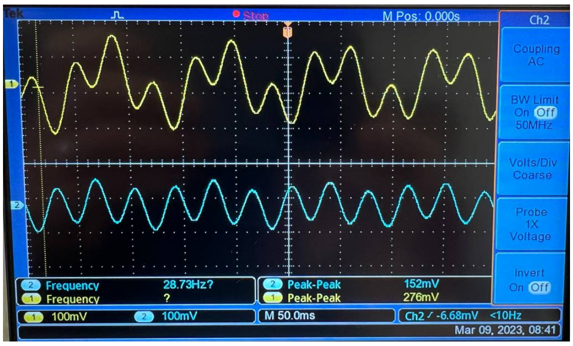
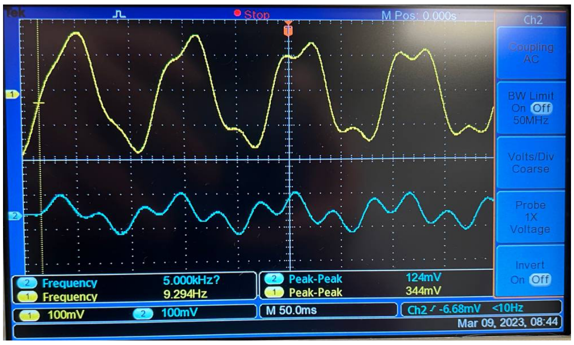
6 RESULTS & DISCUSSION

Experiment 1: Free Vibration of Two-DOF System

Present the printed results for Experiment 1 and discuss Questions 1, 2 and 3.



Strike Mass 1



Strike Mass 2

Question 1: Does the system vibrate harmonically? Why not?

The system did not vibrate harmonically but displayed an irregular waveform. A system that vibrates harmonically will have a sine or cosine wave that has a fixed amplitude and fixed frequency.

The results above show the frequency of mass 1 (Channel 1) and mass 2 (Channel 2) on the oscilloscope when the masses are hit respectively. However, the results obtained showed irregular amplitudes and frequencies of the waves produced by both masses. This could be due to the difference in the natural frequency of the supporting beams and the masses.

Question 2: Does striking on mass 1 and mass 2 produce similar vibration waveforms? Explain your answers.

Striking on mass 1 and mass 2 does not produce similar vibration waveforms.

$$x_1 = r_1 B_1 \sin(\omega_1 t + \phi_1) + r_2 B_2 \sin(\omega_2 t + \phi_2)$$
$$x_2 = B_1 \sin(\omega_1 t + \phi_1) + B_2 \sin(\omega_2 t + \phi_2)$$

From the equations above, we can deduce that x_1 and x_2 will have different waveforms. This is because the amplitude of wave 1 is multiplied by a factor of r_1 and r_2 respectively.

Question 3: Can you use the vibration amplitude against time plots to measure the natural frequencies of the system? How do you measure it?

No. The waveforms consist of different sine and cosine waves of different natural frequencies. However, we can use Fast Fourier Transform to determine the natural frequencies of the system.

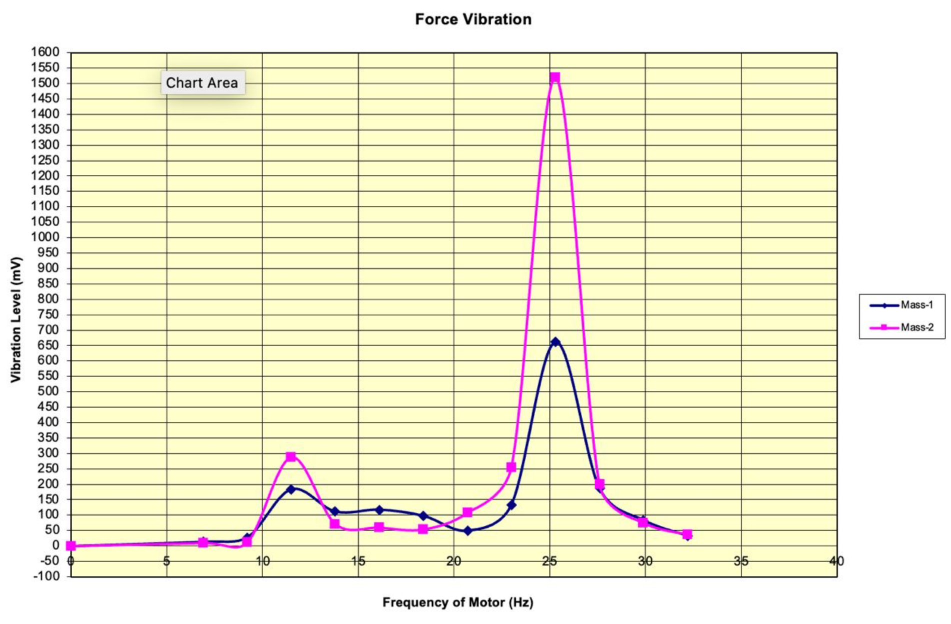
The use of computer software for Fast Fourier Transform can help to convert the signal from a time domain into a frequency domain, allowing us to determine the vibration amplitude and measure the natural frequencies of the system.

Experiment 2: Forced Vibration

Tabulate the measurement results for forced vibration. Plot a graph by using the vibration levels for mass 1 and mass 2 as the *y*-axis and the corresponding motor speed as the *x*-axis. Discuss Question 4.

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	14	6.9	10
4.0	9.2	28	9.2	12
5.0	11.5	184	11.5	288
6.0	13.8	112	13.8	72
7.0	16.1	118	16.1	60
8.0	18.4	98	18.4	54
9.0	20.7	50	20.7	108
10.0	23	134	23	256
11.0	25.3	661	25.3	1520
12.0	27.6	187	27.6	200
13.0	29.9	84	29.9	76
14.0	32.2	34	32.2	38



Question 4: Suppose the test rig represents a two-storey building. By installing a motor on the roof (mass 1), discuss the potential vibration problems and recommend actions to reduce the vibration level. (The discussion must refer to the measurement results).

Installing a motor on the roof of a two-storey building can lead to potential vibration problems, especially if the motor is not properly supported or balanced. The vibrations can cause the building to sway along one axis vigorously which can lead to discomfort and noise for the occupants of the building. Moreover, the vigorous vibrations will cause stress and strain to the structure of the building especially if the natural frequency of the building matches the motor's frequency which causes resonance to occur at 11Hz and 25Hz based on our test rig experimental data. These vibrations will eventually result in structural damage to the pillars over time and cause the building to lose its structural integrity.

To reduce the vibration levels caused by the motor, the following actions can be taken:

1. Install shock absorbers beneath the motor: This will help to absorb any vibrations produced by the motor and prevent them from being transmitted to the building structure.
2. Balance the motor: If the motor is balanced properly, it will reduce the amount of vibration generated when it is running. An unbalanced motor can cause excessive vibration and lead to premature wear and tear on the equipment as well as unwanted vibrations to the building.

Experiment 3: Vibration Modes

Question 5: Would the vibration level increase, decrease or remain unchanged if the motor is installed at mass 2? Explain your answer for motor speed close to the resonances.

GIVEN: $m_1 = 1.40\text{kg}$, $m_2 = 1.06\text{kg}$

$k_1 = 8800\text{N/m}$, $k_2 = 8520\text{N/m}$

MOTOR AT MASS 1

$$A_{top} = \frac{m_0\Omega^2 e\,[2(k_1+k_2) - \Omega^2 m_2]}{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}$$

$$A_{bottom} = \frac{2m_0\Omega^2 e k_1}{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}$$

$$\left|\frac{A_{below}}{A_{top}}\right| = \frac{\dfrac{2\cancel{m_0\Omega^2 e}k_1}{\cancel{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}}}{\dfrac{\cancel{m_0\Omega^2 e}\,[2(k_1+k_2) - \Omega^2 m_2]}{\cancel{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}}}$$

$$= \frac{2k_1}{2(k_1+k_2) - \Omega^2 m_2}$$

$\therefore$ For frequency 1 (11.5Hz), $\left|\frac{A_{below}}{A_{top}}\right| = 0.605_{\#}$

For frequency 2 (25.3Hz), $\left|\frac{A_{below}}{A_{top}}\right| = 2.241_{\#}$

MOTOR AT MASS 2

$$B_{top} = \frac{2m_0\Omega^2 e k_1}{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}$$

$$B_{bottom} = \frac{m_0\Omega^2 e\,[2k_1 - \Omega^2 m_1]}{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}$$

$$\left|\frac{B_{below}}{B_{top}}\right| = \frac{\dfrac{\cancel{m_0\Omega^2 e}\,[2k_1 - \Omega^2 m_1]}{\cancel{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}}}{\dfrac{2\cancel{m_0\Omega^2 e}k_1}{\cancel{m_1 m_2 (\Omega^2-\omega_1^2)(\Omega^2-\omega_2^2)}}}$$

$$= \frac{2k_1 - \Omega^2 m_1}{2k_1}$$

$\therefore$ For frequency 1 (11.5Hz), $\left|\frac{B_{below}}{B_{top}}\right| = 0.585_{\#}$

For frequency 2 (25.3Hz), $\left|\frac{B_{below}}{B_{top}}\right| = 1.010_{\#}$

From the calculations, we can conclude that the vibration levels will decrease if the motor were to be installed on mass 2 for both frequencies 11.5Hz and 25.3Hz.