ME370 KDOM LAB:

Second Order Systems: Vibrations of Two-Degree of Freedom Systems

In this experiment, you will learn to analyse a typical second order system, such as a mass-spring system or a combination of several such systems. A single mass-spring system ("M-K system") exhibits behaviour typical of a second order system, i.e. a system governed by an ordinary linear differential equation of the second order, where the highest order of the derivative is two. The 'free' vibration of any system is defined as its motion in response to initial conditions, and in the absence of sustained/continuous forcing. For the 'free' response of a single degree-of-freedom ('1-DoF') M-K system, the ODE governing its motion is

$$m\ddot{x} + kx = 0$$

where m and k are the mass and stiffness, and x is the displacement w.r.t equilibrium. Note that the RHS of the above ODE is zero for the 'free' response. The system oscillates at its natural frequency when it is displaced from its equilibrium, and this quantity is $\omega=\sqrt{k/m}$ for an M-K system.

In this experiment, you will start with experimentally identifying the natural frequency of a 1-DoF system and correlate it with its properties (here, the mass and stiffness). Then you will move on to 2-DoF systems, i.e. systems where two independent motions are possible.

The hardware for this experiment comprises the following:

- Two springs, of different spring stiffnesses $k1$ and $k2$
- Two masses (Mobile Phones), of mass $m1$ and $m2$
- A bar with holes for suspending springs and/or masses

<u>Tasks To Be Done: -</u>

1. Obtain the spring stiffnesses of each of the two springs: For either of the two springs, use the known values of the masses and the experimentally-determined value of the natural frequency to calculate the stiffness of that spring.

2. Free response of a 2-DoF translational system: Suspend one of the masses '*m1*' from the bracket using one of the springs '*k1*', and then suspend the other mass '*m2*' from the first mass using the second spring '*k2*'. This system will have two natural frequencies. Here both masses are mobile phone that will also be used to log the acceleration data using the Phyphox application.

- Displace both the masses '*m1*'and 'm2' by approximately same amount in the same direction and release. Note the time taken by any of the mass for its 10 or 20 complete oscillations. Find out the frequency of the system from this time.

- Now displace both the masses 'm1' and 'm2' by approximately same amount in the opposite direction and repeat the above procedure.

- Calculated the mode shapes (with help of assigned TA) for you measured mass and stiffness value and apply those values as initial displacement.

3. Comparison of experimental values with theoretical natural frequencies:
Use the signal processing method to find the natural frequencies of the experiment in all of these cases and verify it with the calculated 'eigenvalues. Mention the sources of discrepancies, if any, between the theoretical and experimental values.