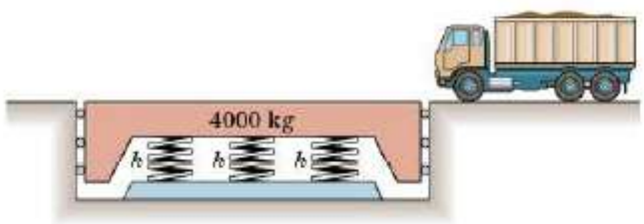
UNIVERSITY OF ZAMBIA

SCHOOL OF ENGINEERING

EEE3112 ELECTRICAL ENGINEERING PRACTICE

ASSIGNMENT 4 DUE WEDNESDAY, 12TH MAY, 2015

1. During the design of the spring-support system for the 4000kg weighing platform at Kafue Weigh Bridge, it was decided that the frequency of free vertical vibration in the unloaded condition shall not exceed 3 cycles per second.
   (a) Determine the maximum acceptable spring constant k for each of the three identical springs
   (b) For this spring constant, what would be the natural frequency f_n of vertical vibration of the platform loaded by the 40Mg truck?
   (c) Define resonance of a forced vibration system, what is the effect of viscous damping on resonance amplitude?



Hand in Question 1 as Assignment 4

TUTORIAL 4

Determination of Damping by Experiment

We often need to experimentally determine the value of the damping ratio ζ for an underdamped system. The usual reason is that the value of the viscous damping coefficient c is not otherwise well known. To determine the damping, we may excite the system by initial conditions and obtain a plot of the displacement x versus time t, such as that shown schematically in Fig. 8/7. We then measure two successive amplitudes x_1 and x_2 a full cycle apart and compute their ratio

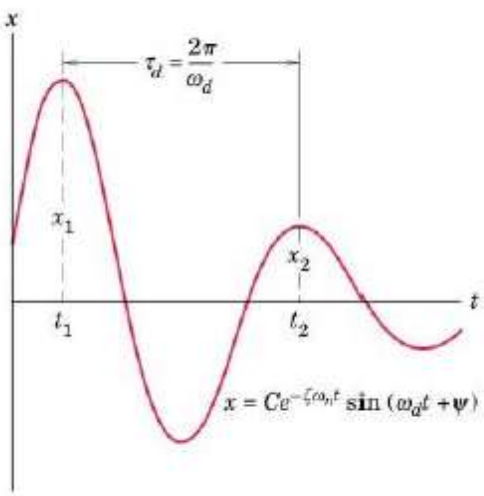
$$\frac{x_1}{x_2} = \frac{Ce^{-\zeta\omega_n t_1}}{Ce^{-\zeta\omega_n(t_1+\tau_d)}} = e^{\zeta\omega_n\tau_d}$$

The *logarithmic decrement* δ is defined as

$$\delta = \ln\left(\frac{x_1}{x_2}\right) = \zeta\omega_n\tau_d = \zeta\omega_n\frac{2\pi}{\omega_n\sqrt{1-\zeta^2}} = \frac{2\pi\zeta}{\sqrt{1-\zeta^2}}$$

From this equation, we may solve for ζ and obtain

$$\zeta = \frac{\delta}{\sqrt{(2\pi)^2 + \delta^2}}$$



Applications

Vibration-measuring instruments such as seismometers and accelerometers are frequently encountered applications of harmonic excitation. The elements of this class of instruments are shown in Fig. 8/14a. We note that the entire system is subjected to the motion x_B of the frame. Letting x denote the position of the mass *relative* to the frame, we may apply Newton's second law and obtain

$$-c\dot{x} - kx = m\frac{d^2}{dt^2}(x + x_B) \qquad \text{or} \qquad \ddot{x} + \frac{c}{m}\dot{x} + \frac{k}{m}x = -\ddot{x}_B$$

where $(x + x_B)$ is the inertial displacement of the mass. If $x_B = b \sin \omega t$, then our equation of motion with the usual notation is

$$\ddot{x} + 2\zeta\omega_n\dot{x} + \omega_n{}^2x = b\omega^2 \sin \omega t$$

which is the same as Eq. 8/13 if $b\omega^2$ is substituted for F_0/m.

Again, we are interested only in the steady-state solution x_p. Thus, from Eq. 8/20, we have

$$x_p = \frac{b(\omega/\omega_n)^2}{\{[1 - (\omega/\omega_n)^2]^2 + [2\zeta\omega/\omega_n]^2\}^{1/2}} \sin(\omega t - \phi)$$

If X represents the amplitude of the relative response x_p, then the nondimensional ratio X/b is

$$X/b = (\omega/\omega_n)^2M$$

where M is the magnification ratio of Eq. 8/23. A plot of X/b as a function of the driving-frequency ratio ω/ω_n is shown in Fig. 8/14b. The similarities and differences between the magnification ratios of Figs. 8/14b and 8/11 should be noted.

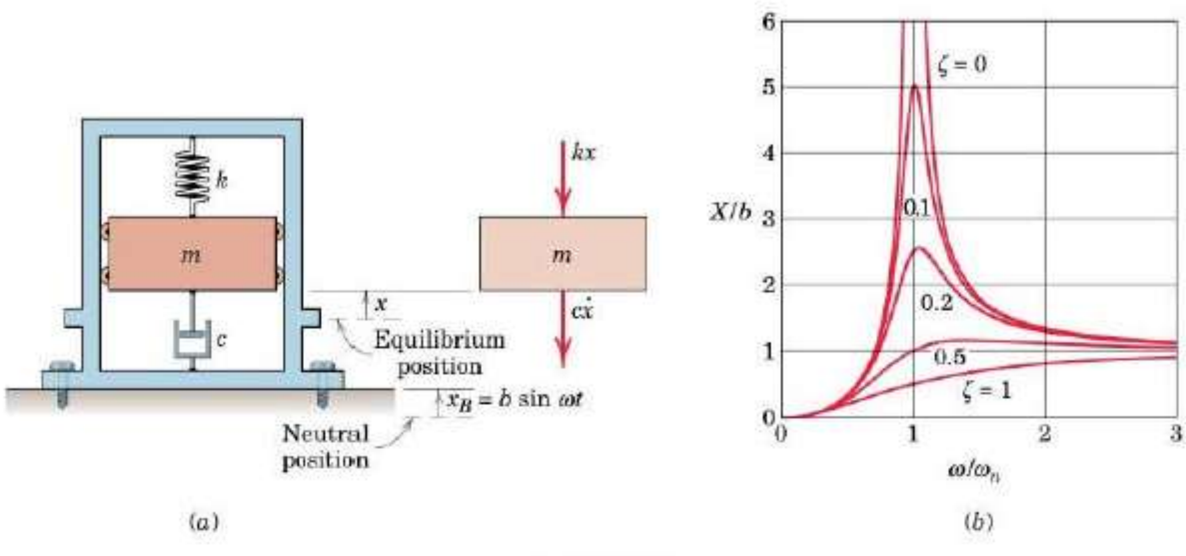


Figure 8/14

Prepared by: K.H. Moonga, May, 2015