

## 2.3 Solution

(a) Determine the equation of motion of the beam in Fig. 1 in terms of tip displacement  $v$ .

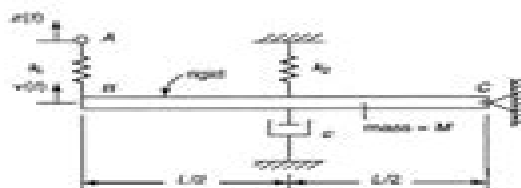


Figure 1



Figure 2

$$\sum M_C = I_C \ddot{\theta}$$

where

$$I_C = \frac{1}{3} M L^2$$

From the free-body diagram (Fig. 2 top),

$$f_{11} L - (f_{22} + f_{33}) \frac{L}{2} = I_C \ddot{\theta}$$

The constitutive relationships of the linear springs and the linear dashpot are:

$$f_{11} = k_1 [z(t) - v], \quad f_{22} = k_2 \frac{v}{2}, \quad f_{33} = c \frac{\dot{v}}{2}$$

From the deformation diagram (Fig. 2 bottom) and kinematics, for small  $\theta$ ,

$$v = L\theta, \quad \text{or} \quad \theta = \frac{v}{L}$$

Combining the above equations, we get

$$k_1 [z(t) - v] L - \left( k_2 \frac{v}{2} + c \frac{\dot{v}}{2} \right) \frac{L}{2} = \frac{1}{3} M L^2 \left( \frac{\ddot{v}}{L} \right)$$

Finally, the equation of motion of the beam in terms of displacement  $v$  is

$$4M\ddot{v} + 3c\dot{v} + (12k_1 + 3k_2)v = 12k_1 z(t) \quad \text{Ans. (a)}$$

(b) Determine the equation of motion of the beam in terms of the spring force  $f_{11}$ .

In the above answer to Part (a), substitute the force-deformation of spring 1 in the form

$$v = z(t) - \frac{f_{11}}{k_1}$$

Then, the equation of motion for  $f_{11}$  is

$$4M\ddot{f}_{11} + 3c\dot{f}_{11} + (12k_1 + 3k_2)f_{11} = k_1(4M\ddot{z} + 3c\dot{z} + 3k_2 z) \quad \text{Ans. (b)}$$

Although the left-hand sides of these two equations of motion have exactly the same form, the right-hand side of Ans. (b) is more complicated.

# Fundamentals Of Structural Dynamics

**Alvar M. Kabe, Brian H. Sako**



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