

## Chapter 3

### Harmonically Excited Vibration

3.1 (a)  $\delta = \frac{W}{k} = \frac{40}{4000} = 0.01 \text{ m}$   
 (b)  $\delta_{st} = \frac{F_0}{k} = \frac{40}{4000} = 0.01 \text{ m}$   
 (c)  $\omega_n = \sqrt{\frac{k}{m}} = \left( \frac{4000 \times 9.81}{40} \right)^{1/2} = 31.3049 \text{ rad/sec}$   
 $\omega = 2 \pi \times 15 = 94.2478 \text{ rad/sec}$   

$$X = \delta_{st} \left| \frac{1}{1 - \left( \frac{\omega}{\omega_n} \right)^2} \right| = 0.01 \left| \frac{1}{1 - \left( \frac{94.2478}{31.3049} \right)^2} \right| = 0.0187 \text{ m}$$

3.2  $T_1 = \frac{2\pi}{\omega_n - \omega} = \frac{2\pi}{31.4159 - 25.1327} = 5 \text{ sec}$

3.3  $k = 4000 \text{ N/m}$ ,  $m = 10 \text{ kg}$ ,  $F(t) = 400 \cos 10t \text{ N}$   
 $F_0 = 400 \text{ N}$ ,  $\omega = 10 \text{ rad/s}$   
 $\omega_n = \sqrt{\frac{k}{m}} = 20 \text{ rad/s}$ ,  $\frac{\omega^2}{\omega_n^2} = \frac{10}{40} = 0.25 < 1$   
 Response is given by Eq. (3.9):  

$$x(t) = \left( x_0 - \frac{F_0}{k - m\omega^2} \right) \cos \omega_n t + \left( \frac{\dot{x}_0}{\omega_n} \right) \sin \omega_n t + \frac{F_0}{k - m\omega^2} \cos \omega t \quad (E-1)$$

(a)  $x_0 = 0.1$ ,  $\dot{x}_0 = 0$ :

Eq. (E-1) becomes

$$x(t) = \left\{ 0.1 - \frac{400}{4000 - 10(100)} \right\} \cos 20t + \frac{400}{4000 - 10(100)} \cos 10t$$

$$= -0.033333 \cos 20t + 0.133333 \cos 10t \quad (E-2)$$

(b)  $x_0 = 0$ ,  $\dot{x}_0 = 10$ :

Eq. (E-1) becomes

$$x(t) = \left\{ 0 - \frac{400}{4000 - 10(100)} \right\} \cos 20t + \frac{10}{20} \sin 20t$$

$$+ \left\{ \frac{400}{4000 - 10(100)} \right\} \cos 10t$$

$$= -0.133333 \cos 20t + 0.5 \sin 20t + 0.133333 \cos 10t \quad (E-3)$$

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