[1.4절]

1.80 statics $J = \frac{1}{2}mr^2$, kinematics $x = r\theta$, $\dot{x} = r\dot{\theta}$

spring $\Delta l = (r+a)\theta$

$$T = \frac{1}{2}m\dot{x}^2 + \frac{1}{2}J\dot{\theta}^2 = \frac{1}{2}m(r\dot{\theta})^2 + \frac{1}{2}(\frac{1}{2}mr^2)\dot{\theta}^2 = \frac{3}{4}mr^2\dot{\theta}^2$$

$$U = 2\ [\frac{1}{2}k\ (\Delta l)^2\ ] = k\,[(r+a)\theta]^2 = k\,(r+a)^2\,\theta^2$$

$$\frac{d}{dt}(T+U) = \frac{d}{dt}[\frac{3}{4}mr^2\dot{\theta}^2 + k\,(r+a)^2\,\theta^2]$$

$$= [\frac{3}{2}mr^2\ddot{\theta} + 2k\,(r+a)^2\,\theta]\ \dot{\theta} = 0\ , \quad \dot{\theta} \neq 0$$

equation of motion $\frac{3}{2}mr^2\ddot{\theta} + 2k\,(r+a)^2\,\theta = 0$,

natural frequency $\omega_n = \sqrt{\frac{4k(a+r)^2}{3mr^2}} = 2\frac{a+r}{r}\sqrt{\frac{k}{3m}}$