1 Free Vibration of Single Degree-of-freedom Systems

1.1 Solved Problems

Problem 1:

For the mechanical system shown to the right, the uniform rigid bar has mass m and pinned at point O. For this system:

- a) find the equations of motion;
- b) Identify the damping ratio and natural frequency in terms of the parameters m, c, k, and ℓ.
- (c) For:

$$m = 1.50$$
kg, $\ell = 45$ cm,
 $c = 0.125$ N/(m/s), $k = 250$ N/m,

find the angular displacement of the bar $\theta(t)$ for the following initial conditions:

$$\theta(0) = 0$$
, $\dot{\theta}(0) = 10 \text{rad/s}$.

Assume that in the horizontal position the system is in static equilibrium and that all angles remain small.



Solution:

a) In addition to the coordinate θ identified in the original figure, we also define x and y as the displacment of the block and end of the bar respectively. The directions i and j are defined as shown in the figure.

A free body diagram for this system is shown to the right. Note that the tension in the cable between the bar and the block is unknown and represented with T while the reaction force F_B is included, although both its magnitude and direction are unspecified. In terms of the identifed coordinates, the angular acceleration of the bar α_s and the linear acceleration of the block a_G are

$$\alpha_{\sigma} = \tilde{\theta} \, k$$
, $a_{\sigma} = \tilde{x} \, j$.

We can also relate the identified coordinates as

$$x = \frac{\ell}{2}\theta$$
, $y = \ell \theta$.

The equations of motion for this system can be obtained with linear momentum balance applied to the block and angular momentum balance aout O on the bar. These can be



Mechanical Vibration Solved Problems

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