

# 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:

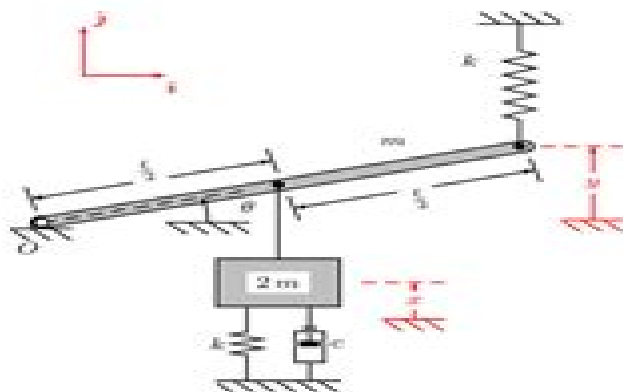
- find the equations of motion;
- Identify the damping ratio and natural frequency in terms of the parameters  $m$ ,  $c$ ,  $k$ , and  $\ell$ .
- For:

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

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

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

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



### Solution:

- In addition to the coordinate  $\theta$  identified in the original figure, we also define  $x$  and  $y$  as the displacement of the block and end of the bar respectively. The directions  $\hat{i}$  and  $\hat{j}$  are defined as shown in the figure.

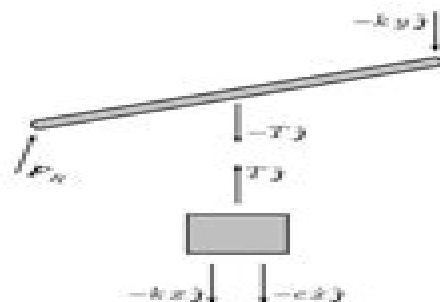
A free body diagram for this system is shown to the right. Note that the tension in the cable between the bar and the block is unknown and represented with  $T$  while the reaction force  $\mathbf{F}_R$  is included, although both its magnitude and direction are unspecified. In terms of the identified coordinates, the angular acceleration of the bar  $\alpha_\theta$  and the linear acceleration of the block  $\mathbf{a}_c$  are

$$\alpha_\theta = \ddot{\theta} \hat{k}, \quad \mathbf{a}_c = \ddot{x} \hat{j}.$$

We can also relate the identified coordinates as

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

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



# Mechanical Vibration Solved Problems

**Michael Hoelscher**



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