BMM3553 Mechanical Vibrations

Chapter 1: Introduction to Vibrations

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Chapter Description

- Expected Outcomes
  - Identify the different types of element of vibration
  - Identify the different types of vibration
  - Analyze the series and parallel of stiffness and damping element

- References

  - Singiresu S. Rao. Mechanical Vibrations. 5th Ed
  - Abdul Ghaffar Abdul Rahman. BMM3553 Mechanical Vibration Note. UMP.
  - Md Mustafizur Rahman. BMM3553 Mechanical Vibration Lecture Note. UMP

ELEMENTARY PARTS OF VIBRATING SYSTEMS

A general vibratory system includes means:

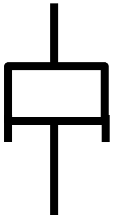
(1)For storing potential energy (elasticity)

Spring element

(2) For storing kinetic energy (mass, inertia)

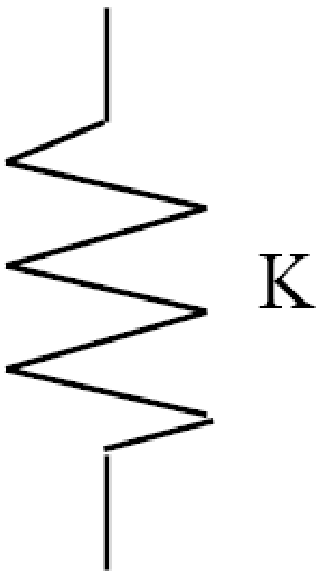
Mass element

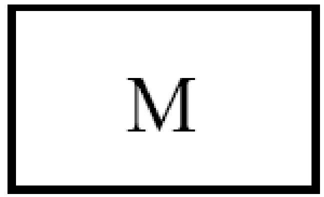
(3) By which energy is lost (damping)



Damping element

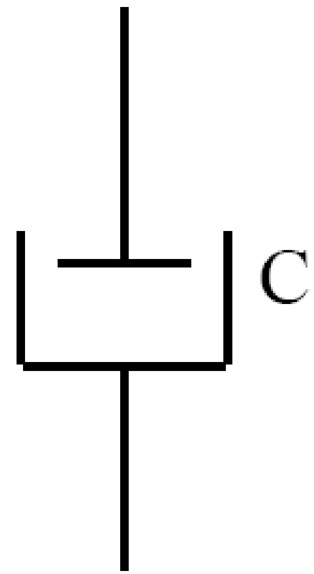
Vibrating Systems : Translational Elements





Mass

Inertia (Kinetic Energy)



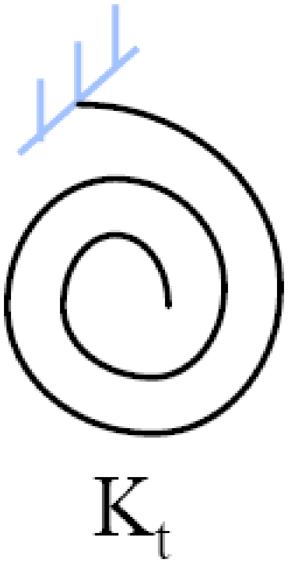
Spring

Storage (Potential Energy)

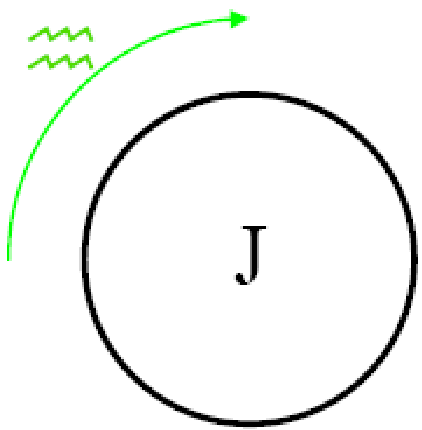
Damper

Dissipative (Energy Loss)

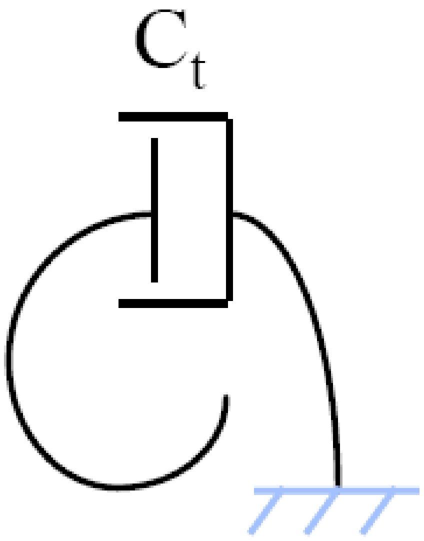
Vibrating Systems : Rotational Elements



Torsional Spring



Rotating Inertia



Torsional Damper

Spring Elements

- Linear spring is a type of mechanical link that is generally assumed to have negligible mass and damping
- Stiffness force is work to bring the mass back to the position of equilibrium.
- Stiffness force is given by:

$$F = kx$$

F = Force,
k = spring stiffness
x = Spring deformation

Spring Elements

- For a cantilever beam, static deflection of a beam is given by:

$$\delta_{st} = \frac{Wl^3}{3EI}$$

W = mg is the weight applied to the beam,
E = Modulus of elasticity
I = polar moment of inertia of beam (cross-section)

- Spring Constant is given by:

$$k = \frac{W}{\delta_{st}} = \frac{3EI}{l^3}$$

Spring Elements

Stiffness for Beam and Rod

for fixed – fixed beam with load at the middle,

$$k_{eq} = \frac{192EI}{l^3}$$

for simply supported beam with load at the middle,

$$k_{eq} = \frac{48EI}{l^3}$$

for cantilever beam with end load, $k_{eq} = \frac{3EI}{l^3}$

Rod under axial loading , $k_{eq} = \frac{AE}{l}$

Spring Elements

- Combination of Springs:

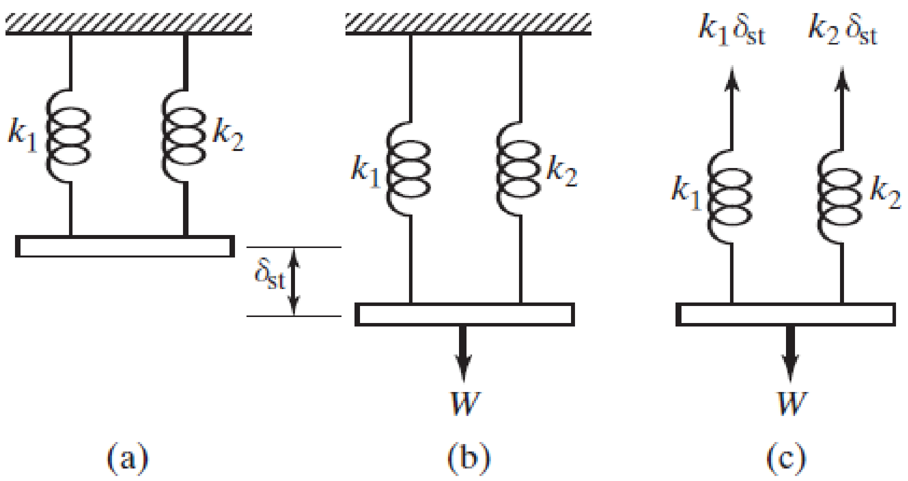
  1) Springs in parallel – For the n parallel spring with stiffness of k_1, k_2, …, k_n, the equivalent spring stiffness, k_{eq} is equal to:

$$k_{eq} = k_1 + k_2 + \ldots + k_n$$

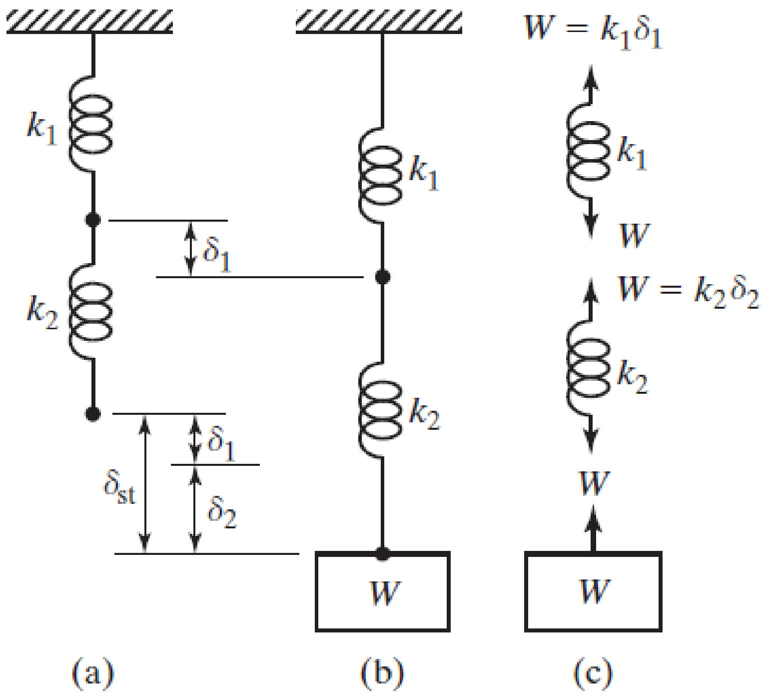
- Combination of Springs:
- *2) Springs in series* – For the n series spring with stiffness of k_1, k_2, …, k_n ,the equivalent spring stiffness, k_{eq} is equal to:

$$\frac{1}{k_{eq}} = \frac{1}{k_1} + \frac{1}{k_2} + \ldots + \frac{1}{k_n}$$

Spring Elements



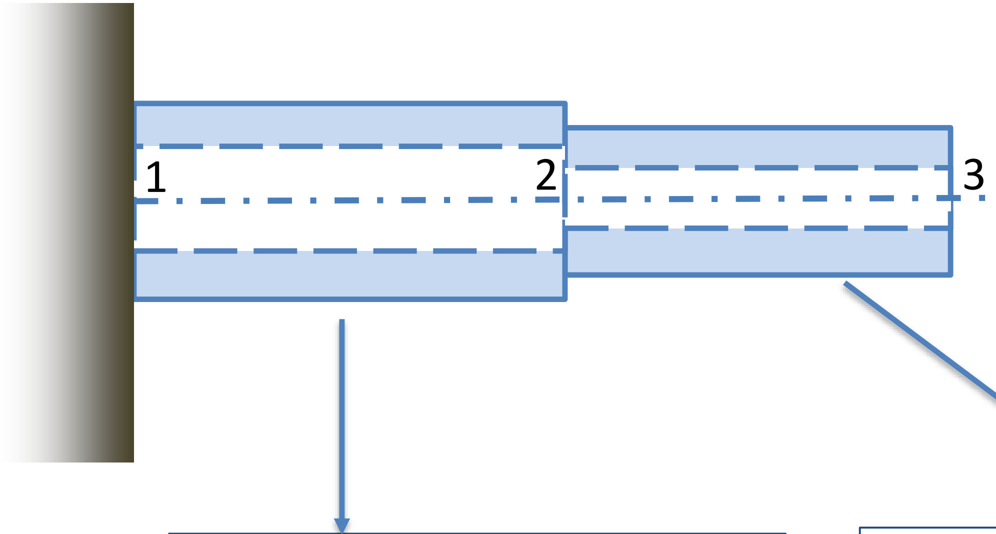
Parallel spring



Series spring

Spring Elements

Torsional Spring Constant of a Hollow Shaft



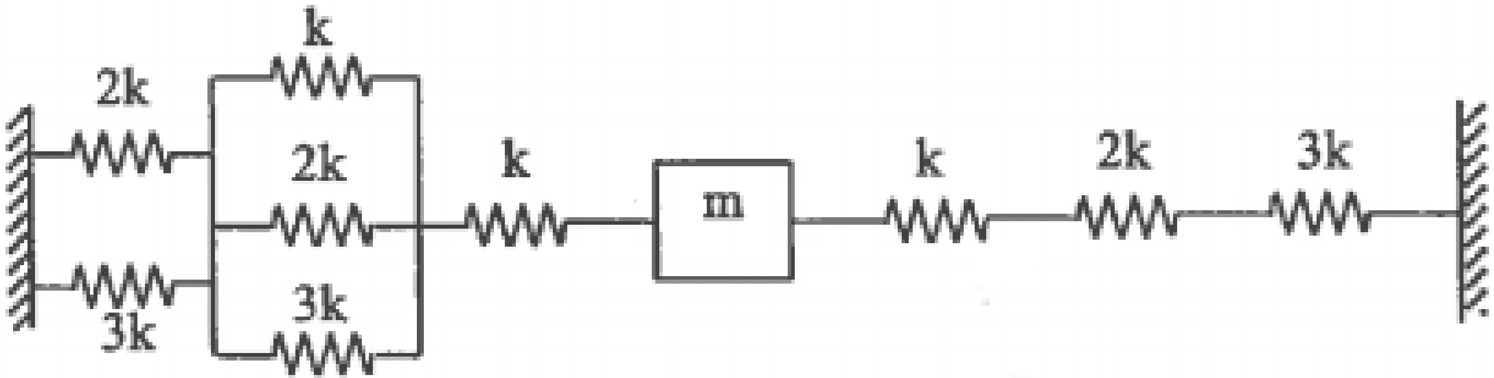
$$\frac{1}{k_{eq}} = \frac{1}{k_{t1}} + \frac{1}{k_{t2}}$$

$$k_{t_{12}} = \frac{GJ_{12}}{l_{12}} = \frac{G\pi(D_{12}^4 - d_{12}^4)}{32 l_{12}}$$

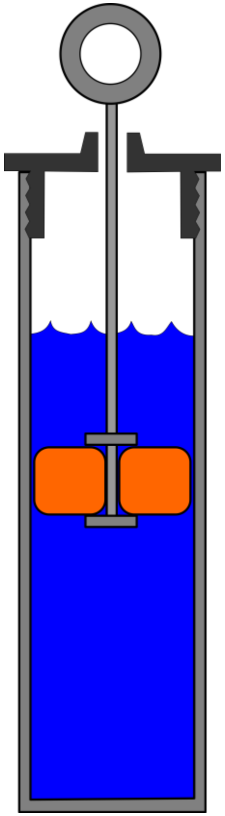
$$k_{t_{23}} = \frac{GJ_{23}}{l_{23}} = \frac{G\pi(D_{23}^4 - d_{23}^4)}{32 l_{23}}$$

Spring Elements: Exercise

Determine the equivalent spring constant for the system shown in **Figure below**



Damping Elements

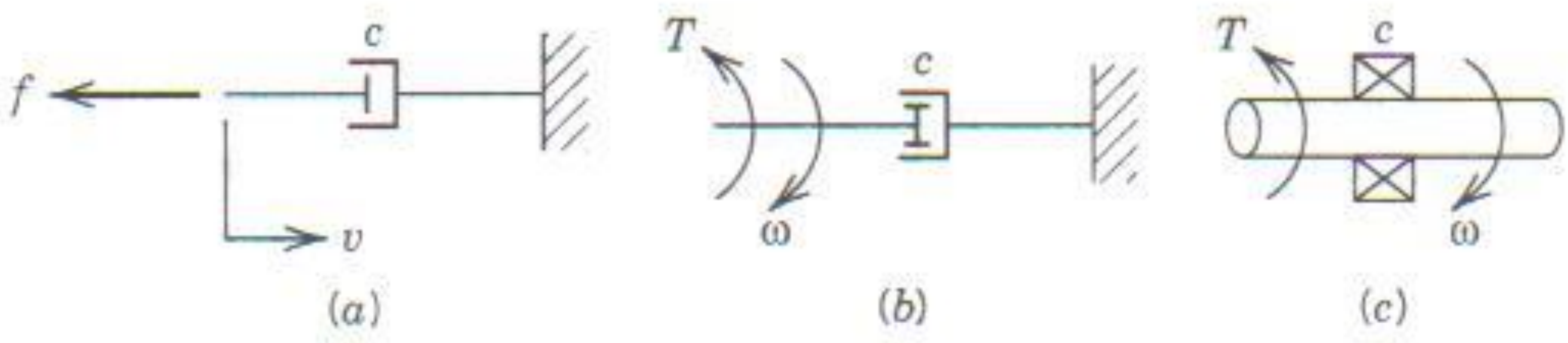


Dashpot

- Damping is very important element in mechanical system to calculate vibration response of the system accurately.
- Damping element resulting resistant to **relative velocity** of the system.
- **Damping force** is **proportional** to **velocity**

Image source: https://commons.wikimedia.org/wiki/File:Dashpot.svg

Damping Element



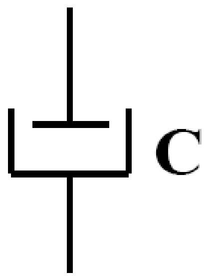
Symbol of damper

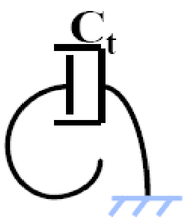
Damping force,

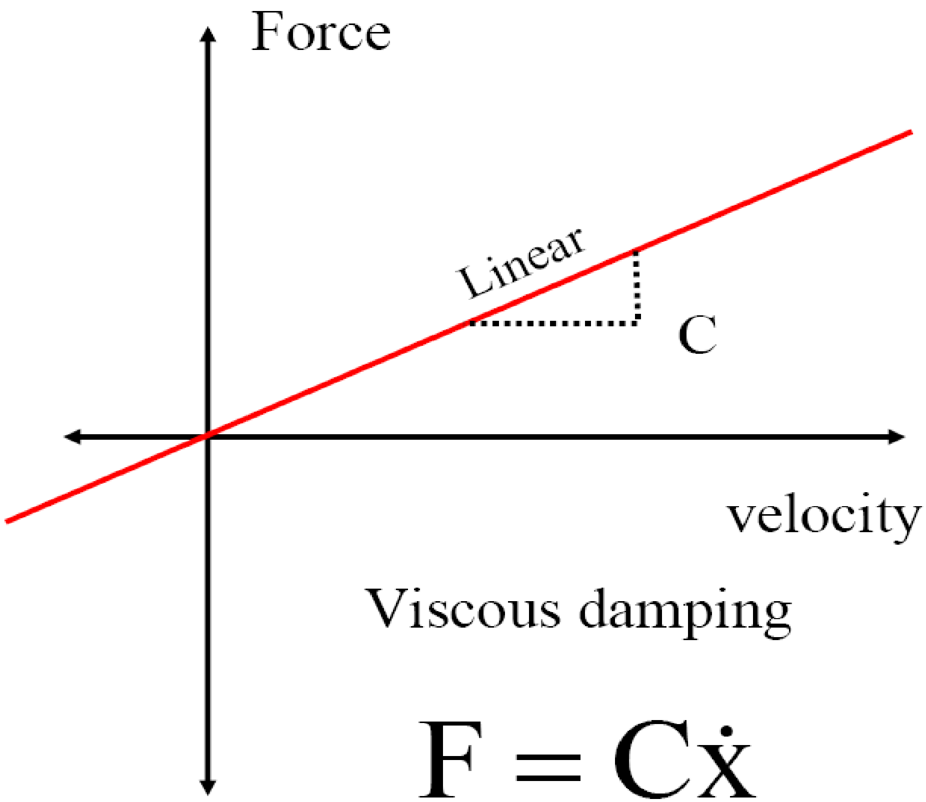
$$F_0 = cv = c\dot{x} = c\frac{dx}{dt}$$

Damping constant or damping coefficient

Damping Element







$$F = C\dot{x}$$

Classification of Vibration

- **FREE VIBRATION**:

System vibrate by its own with initial disturbance applied to the system. System oscillate without any external force. E.g. spring-mass system, pendulum

- **FORCED VIBRATION:**

System vibrate under the excitation of repeating external force. E.g. Rotating unbalanced, car engine

  - ***RESONANCE*** occurs when the excitation frequency coincides with one of the natural frequencies of the system which resulting high vibration phenomena.

Classification of Vibration

UNDAMPED VIBRATION:

- System oscillate with constant amplitude
- No amplitude decay and energy lost

DAMPED VIBRATION:

- Lost of energy due to friction or other resistance.
- Amplitude of oscillation decrease with time

Thank You

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