

Vibrations and Acoustics

3. Vibration isolation

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Outline of the chapter

- *Direct vibration isolation
 - Isolation factor and isolation domain
 - Examples
- *Inverse vibration isolation
 - Transmissibility and isolation domain
 - Examples



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How can I reduce vibration from my washing machine or home gym travelling into the floor below?

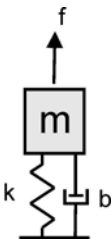


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Vibration transmission



Vibration isolation



$$m\ddot{x} + b\dot{x} + kx = f \quad x(t) = Xe^{i\omega t}$$

$$\rightarrow (k - \omega^2 m + j\omega b)X = F$$

$$|F| = \sqrt{(k - \omega^2 m)^2 + (\omega b)^2} |X|$$

Force transmitted to the ground:

$$F_T = kx + b\dot{x} = (k + j\omega b)X$$

$$|F_T| = \sqrt{k^2 + (\omega b)^2} |X|$$

Isolation factor:

$$\frac{|F_T|}{|F|} = \frac{\sqrt{k^2 + (\omega b)^2}}{\sqrt{(k - \omega^2 m)^2 + (\omega b)^2}}$$

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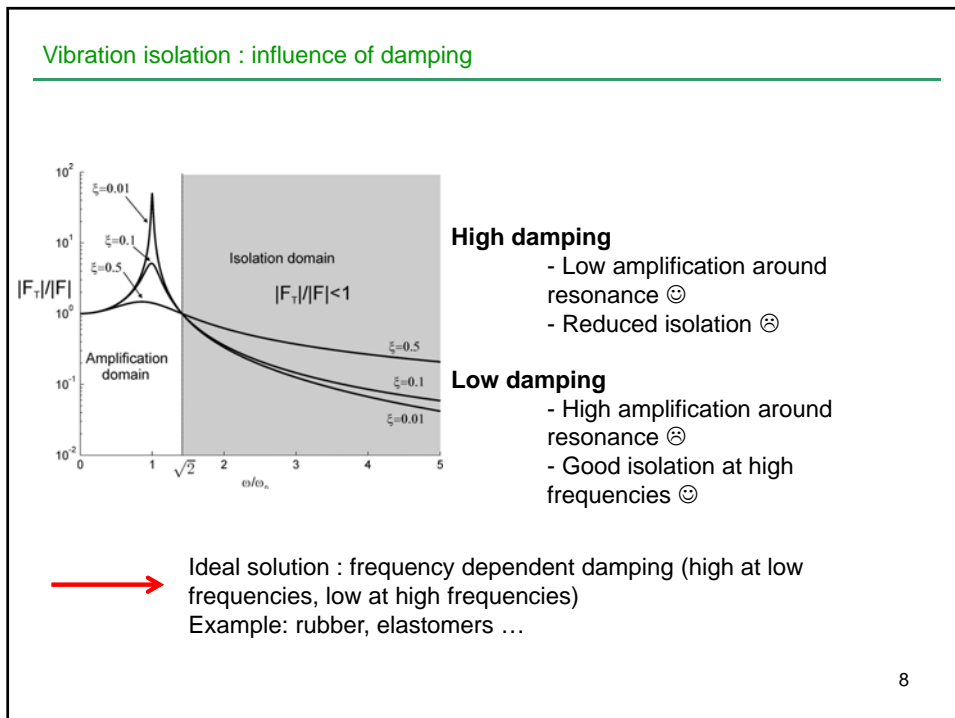
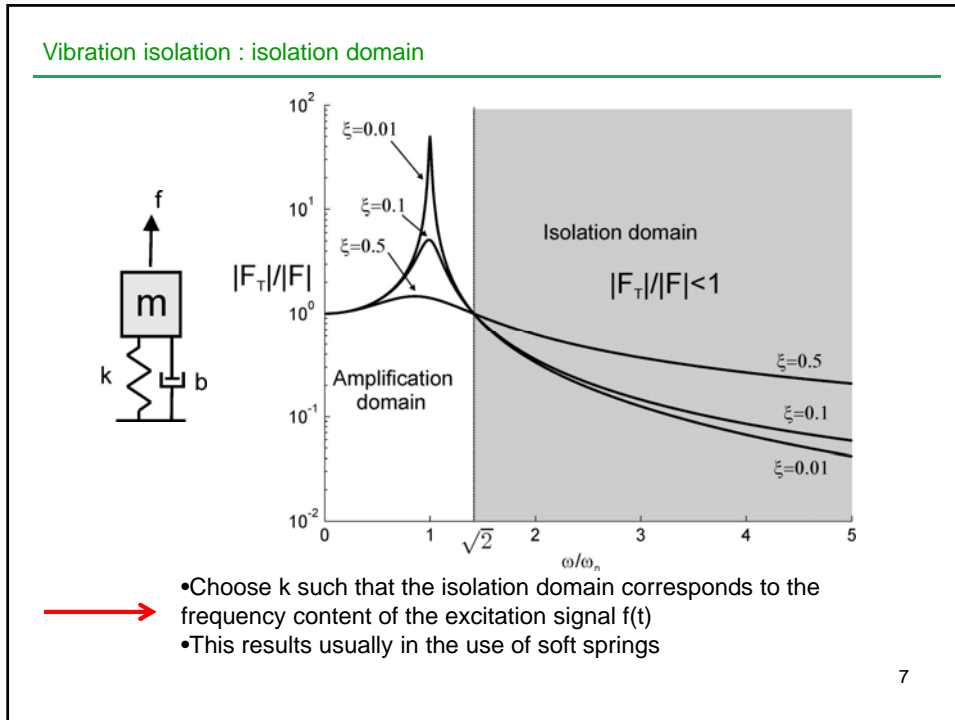
Vibration isolation

$$\frac{|F_T|}{|F|} = \frac{\sqrt{k^2 + (\omega b)^2}}{\sqrt{(k - \omega^2 m)^2 + (\omega b)^2}} \quad \xi = b/(2\sqrt{km})$$

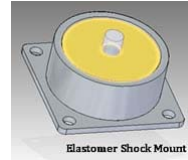
$$\omega_n = \sqrt{k/m}$$

$$\frac{|F_T|}{|F|} = \frac{\sqrt{1 + (2\xi \frac{\omega}{\omega_n})^2}}{\sqrt{(1 - (\frac{\omega}{\omega_n})^2)^2 + (2\xi \frac{\omega}{\omega_n})^2}}$$

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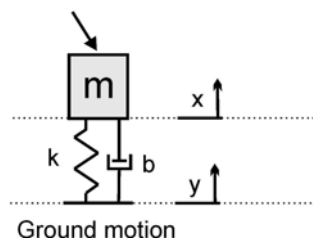


Vibration isolation : examples



Inverse vibration isolation

Building,
Sensitive equipment



$$m\ddot{x} + b\dot{x} + kx = b\dot{y} + ky$$

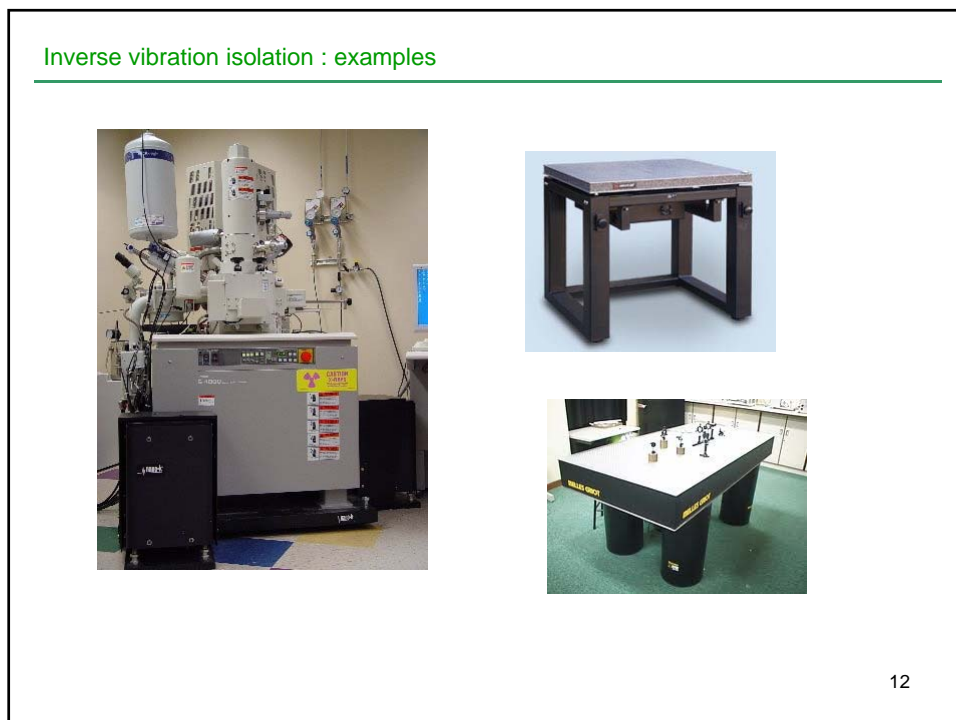
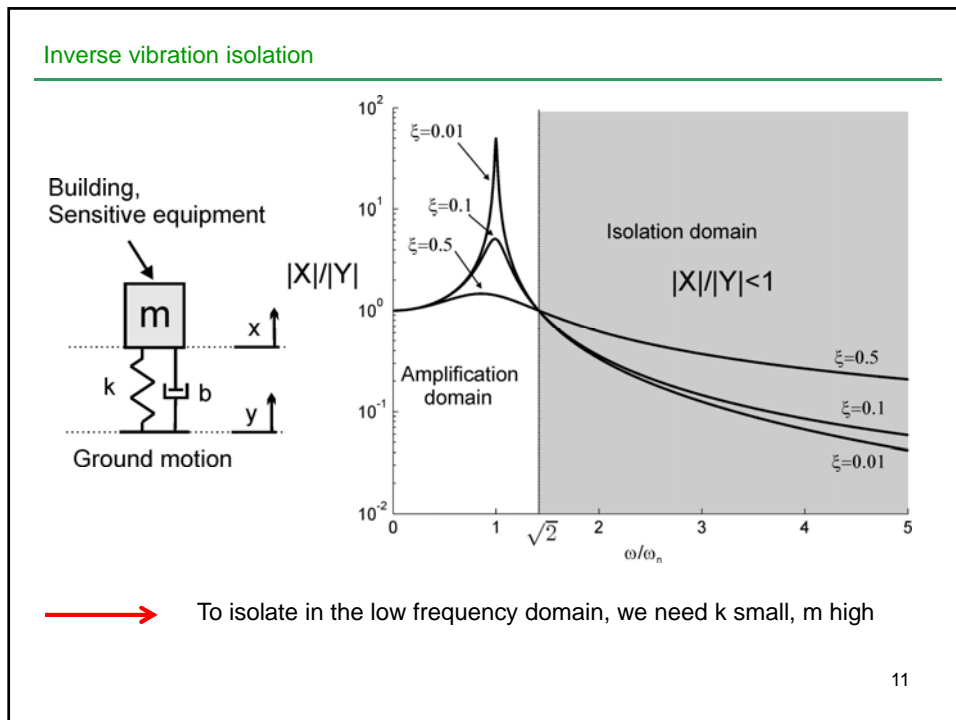
$$x(t) = Xe^{i\omega t}$$

$$y(t) = Ye^{i\omega t}$$

$$(k - \omega^2 m + j\omega b)X = (k + j\omega b)Y$$

Transmissibility : $\frac{|X|}{|Y|} = \frac{\sqrt{k^2 + (\omega b)^2}}{\sqrt{(k - \omega^2 m)^2 + (\omega b)^2}}$

The transmissibility is equal to the isolation factor previously defined



Inverse vibration isolation : examples



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Inverse vibration isolation : precision microscope



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Inverse vibration isolation : camera



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Inverse vibration isolation : wine glass on isolation table



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