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## Question: 120 Dynamics of Structures 4.2 Compute the vertical motion o...

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## 120 Dynamics of Structures

- 4.2 Compute the vertical motion of the car shown schematically in Figure 4.32 when it is crossing a bridge at a velocity of 60 km/h. The spring stiffness was evaluated by a test during which the measured vertical displacement of the car was 2.5 mm when its weight was increased by 500 N. The bridge profile is idealized by a sinusoidal curve with a wave length of 12 m and a half-amplitude of 30 mm. Consider a damping ratio of 50% of critical.

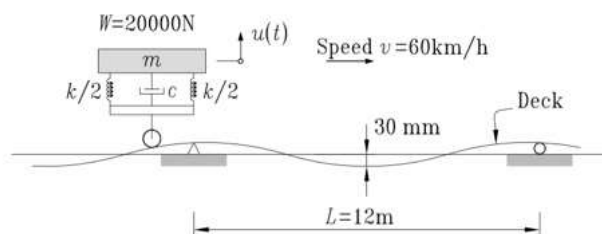


Figure 4.32. Problem 4.2

[Show transcribed image text](#)

## Expert Answer



Anonymous answered this  
353 answers

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### Given;

$$v = 60 \text{ kmph}$$

$$\Delta F = 500 \text{ N}$$

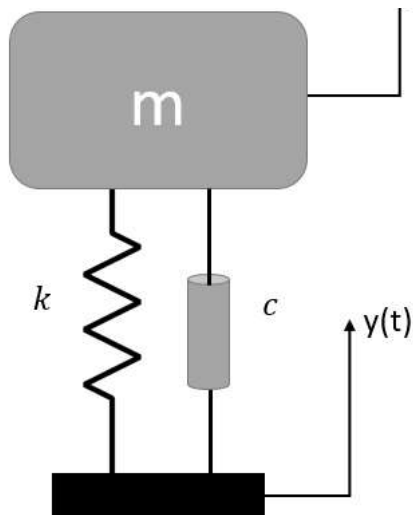
$$\Delta x = 2.5 \text{ mm}$$

$$W = 20000 \text{ N}$$

$$\lambda = 12 \text{ m}$$

$$A = 30 \text{ mm}$$

### Solution



$$m = \frac{W}{g} = \frac{20000}{9.81} = 2038.736 \text{ kg}$$

$$k = \frac{\Delta F}{\Delta x} = \frac{500}{0.0025} = 2 \times 10^5 \text{ N/m}$$

$$c = \zeta c_c = 0.5(2\sqrt{km}) = 20192.751 \text{ Ns/m}$$

**Road profile:**

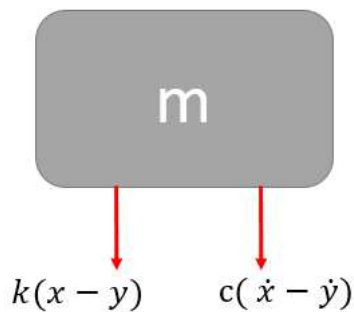
$$\text{Vehicle velocity} = 60 \text{ kmph} = 16.67 \text{ m/s}$$

$$\text{Frequency of base excitation, } \omega = \frac{2\pi v}{\lambda} = \frac{2\pi(16.67)}{12} = 8.7284 \text{ rad/s}$$

$$\text{Amplitude of base excitation} = 0.06 \text{ m.}$$

$$\text{Therefore, } y(t) = 0.03 \sin(8.7284t)$$

**Free body diagram**



Using Newton's law of motion,

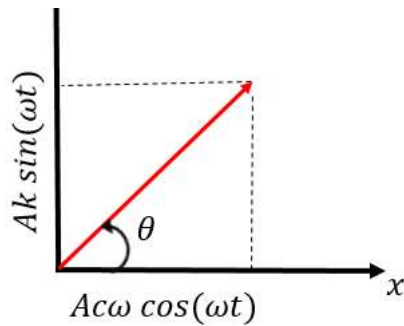
$$-k(x - y) - c(\dot{x} - \dot{y}) = m\ddot{x}$$

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

Substituting  $y(t)$ , we get,

$$m\ddot{x} + c\dot{x} + kx = Ak \sin(\omega t) + Ac\omega \cos(\omega t)$$

Using properties of vectors,



$$m\ddot{x} + c\dot{x} + kx = A\sqrt{k^2 + (c\omega)^2} \sin(\omega t + \theta)$$

$$\theta = \tan^{-1} \left( \frac{k}{c\omega} \right)$$

$$m\ddot{x} + c\dot{x} + kx = (0.3)\sqrt{(2 \times 10^5)^2 + 176250.41^2} \sin(8.7284t + \theta)$$

$$m\ddot{x} + c\dot{x} + kx = (52997.534) \sin(8.7284t + \theta)$$

$$\text{Let } F_o = 7997.3612N$$

Therefore this equation will be of the form,

$$m\ddot{x} + c\dot{x} + kx = F \dots (1)$$

To solve this differential equation let us assume,

$$x = X e^{i\omega t}$$

Therefore,

$$\dot{x} = i\omega X e^{i\omega t}$$

$$\ddot{x} = i^2 \omega^2 X e^{i\omega t} = -\omega^2 X e^{i\omega t}$$

$$F = F_o e^{i\omega t}$$

Substituting in the equation we get,

$$(-m\omega^2 + i\omega c + k) X e^{i\omega t} = F_o e^{i\omega t}$$

$$X = \frac{F_o}{(k - m\omega^2) + i(\omega c)}$$

$$|X| = \frac{F_o}{\sqrt{(k - m\omega^2)^2 + (\omega c)^2}}$$

$$|X| = \frac{7997.3612}{\sqrt{(2 \times 10^5 - 2038.736 \times 8.7284^2)^2 + (8.7284 \times 20192.751)^2}}$$

$$|X| = 0.9716m$$

Therefore,

$$x(t) = (0.04398) e^{i(8.7284)t} \quad m$$

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A: [See answer](#) 100% (2 ratings)

Q: When water is heated, the temperature eventually reaches a constant value and forms a plateau on the graph. What does the plateau indicate ?

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