Theory exam in Structural Dynamics 2020-03-06 kl.10-12

The test consists of 6 questions giving the maximum of 20 points. 7 points are required to pass the exam (and the course). Each question should be answered on a separate paper. No helping aids are permitted on this test, except calculator. Do not forget to write your name on each submitted paper.

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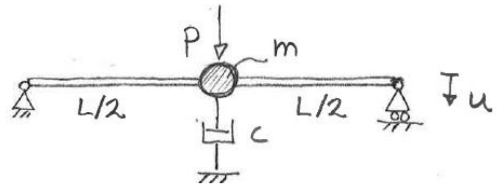
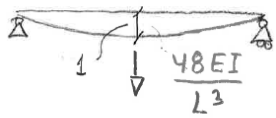
1) (2 p)

A concentrated mass *m* is welded to a light beam of steel according to the figure. It is loaded by a force *p* and the damping in the system is represented by a viscous damper.



a) Determine by using free body diagrams the equation of motion for the structure in terms of the mass vertical displacement.
Use the unit displacement case shown.



b) Calculate the natural angular frequency ω_n, natural frequency f_n , and the natural period time T_n .
The beam is a thin-walled pipe with diameter *D* and wall thickness *t* giving $I=\pi D^3 t/8$.
Data: L=3m, D=50mm, t=2mm, E=210GPa, and m=50kg.

Hint: T_n is about 0.2s

2) (3 p)

Use the deformation response factor

$$R_d = \frac{1}{\sqrt{[1-(\omega/\omega_n)^2]^2 + [2\zeta(\omega/\omega_n)]^2}}$$

to determine the steady state vibration amplitude u_0 in 1) for a damping of c =30Ns/m and a force amplitude p_0 =100N. Calculate a) the quasi-static vibration amplitude and b) the amplitude at resonance.

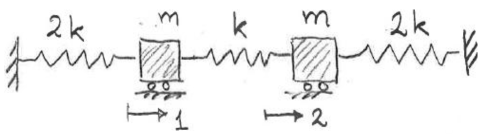
c) Calculate also the static deflection of the beam.

Hint: Standard form of the left hand side of the eq. of motion is: $\ddot{u} + 2\zeta\omega_n\dot{u} + \omega_n^2 u$

3) (5 p)

Consider the two dof system with matrices defined as

$$\mathbf{m} = \begin{bmatrix} m & 0 \\ 0 & m \end{bmatrix} \qquad \mathbf{k} = \begin{bmatrix} 3k & -k \\ -k & 3k \end{bmatrix}$$



The mode shapes for the system are: $\boldsymbol{\phi}_1 = \begin{bmatrix} 1 \\ 1 \end{bmatrix}$, $\boldsymbol{\phi}_2 = \begin{bmatrix} 1 \\ -1 \end{bmatrix}$

a) Determine the natural frequencies f_1 and f_2.

b) Show m- and k-orthogonality.

c) Obtain the uncoupled (diagonal) system (i.e. determine $\boldsymbol{M}^{\phi}$ and $\boldsymbol{K}^{\phi}$).

d) Determine the free vibration response if $u_1(0)=u_0$ and $u_2(0)=0$.

4) (3p)

This question concerns reduction and solution methods. Describe briefly in words and with formulas:

a) How is the system reduction done when using modal reduction, generalized SDOF and Ritz vector approach, respectively?

b) Describe some major advantages with using modal truncation in a time stepping solution. Is there any drawback?

c) Describe briefly the semi-analytical procedure for solving linear dynamic equations. How can this procedure be used for solving systems with several degrees of freedom?

5) (3 p)

This is about earth quake response analysis:

a) What is the basic assumption in defining a spectrum of buildings and to use pseudo variables?

b) Define the three pseudo variables and show how they are connected.

c) Explain how it is possible to put a building on rubber bearings and thereby protect it from earth quakes.

6) (4 p)

Finally some questions from different fields:

a) Describe the advantages and disadvantages with having a vibration isolator made from a highly damping material.

b) You have a vibration problem caused by a resonance at 12Hz. If you have a steel spring with stiffness k=5kN/m. How can solve the problem by using the spring in a tuned damper and how big is the mass you need to use?

c) Define the deformation response factor used for pulse loading. Show in a diagram what is put on the horizontal and vertical axis.

d) What is dynamic stiffness for a dynamically loaded component?