AML733-DYNAMICS
AML734-ADVANCED DYNAMICS

9-10 AM: TUE, WED, FRI

LH 416

DR. S. PRADYUMNA

DEPARTMENT OF APPLIED MECHANICS

IIT DELHI

COURSE OBJECTIVE

- Introduce basic and advanced topics of mechanical vibrations
- Illustrate significant applications to determine dynamic response of components/ structures.

BASIC DYNAMICS

- Revision of Single degree of freedom systems

  Undamped and damped vibrations

  Free and forced vibration response
- Linear and nonlinear systems
- Harmonic motion of the support

COURSE CONTENTS

- *Free vibration of single-degree-of –freedom (SDOF) linear systems*
  - Discrete system, differential equation of motion, free vibration of undamped and damped systems, Logarithmic decrement, Coulomb damping
- *Forced response of SDOF linear systems*
  - Response of first-order systems to harmonic excitation, rotating unbalanced mass, whirling of rotating shafts, harmonic motion of the support, energy dissipation
  - Response to periodic excitation, impulse response, vibration under general forcing conditions, analysis through the time and frequency domains
- *Two-degree-of-freedom systems*
  - Equations of motion, free vibration of undamped systems, orthogonality of modes, beat phenomenon.

COURSE CONTENTS

- *Multi-degree-of-freedom systems*
  - Newton's equations of motion, matrix formulation, undamped free vibration, eigenvalue problem, modal analysis
- *Continuous systems*
  - Discrete vs continuous systems, free vibration, axial and bending vibration of bars
- *Analytical dynamics*
  - Work and energy, principle of virtual work, Lagrange's equations of motion
- *Approximate methods*
  - Rayleigh's energy method, Rayleigh-Ritz method. Symmetric and antisymmetric modes

SELF STUDY COMPONENT

☹ Not covered in class but will be part of exams! ☹

- Kinematics of rigid bodies,
- Dynamics of rigid bodies: 3-dimensional motion of a rigid body
- Fourier transforms
- Vibration control methods
- Numerical integration methods,
- Dynamic analysis using Finite Difference and finite element methods
- Vibration of isotropic and composite plates

REFERENCES

- **Text Book**

  Mechanical Vibrations, S.S. Rao, Pearson Education, 4e, 2006.

- **Additional References**

  Dynamics of Structures, R.W. Clough and J. Penzien, McGraw-Hill International, 2e, 1993.

  Structural Dynamics, Mario Paz, Theory and Computation, CBS Publishers, 2e, New Delhi, 2004.

  Elements of Vibration Analysis, Leonard Meirovitch, McGraw-Hill International, 2e, 1986.

  Engineering Mechanics: Dynamics, J.L. Merium and L.G. Kraige, John Wiley and Sons, Singapore, 2002.

ASSESSMENT

Minor Test- I	:	20%
Minor Test-II	:	20%
Major Test	:	40%
Tut/Assignments/Quiz	:	20%

Minimum of 40% marks required for passing

There will be no make-up tests.

One minor test (with complete course syllabus!), only for those who are absent from any of the minor tests due to valid medical reasons, will be given towards the end of the semester

Assignments to be submitted before the deadline. Delayed submission will carry reduced/zero weightage.

Any plagiarism/unfair means in assignments/exams - "F" grade and Institute level action

VIBRATION

- Any motion that repeats itself after an interval of time is called *vibration* or *oscillation*

  The swinging of a pendulum

  The motion of a plucked string

- The theory of vibration deals with the study of oscillatory motions of bodies and the forces associated with them.

- Question: What is the difference between *vibration* and *oscillation*?

  Vibration: If the reciprocating motion involves deformation of the body

  Oscillation- Rigid body movement without involving its deformation

APPLICATIONS

- Earthquake Engineering
- Wind Engineering
- Offshore Engineering (Wave- and flow-induced vibrations)
- Blast and Impact Engineering
- Foundation Engineering

DYNAMIC ANALYSIS

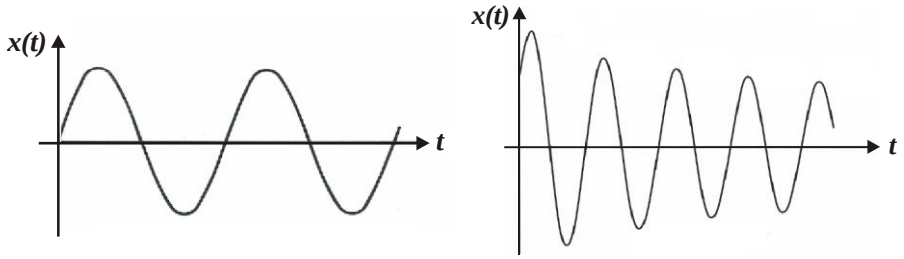
- Most of the loads applied on structural components are dynamic
- Dynamic analysis necessary when

  Forces change with respect to time

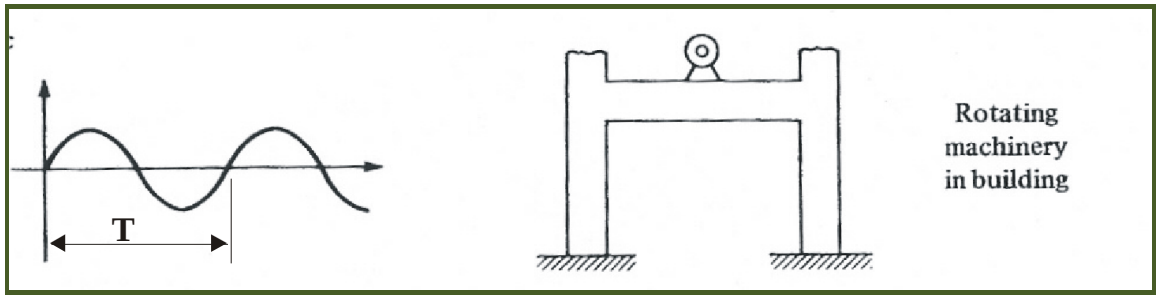
  Applied force cause acceleration and inertial forces are significant
- Dynamic analysis mandatory for
  - Structures like bridges subjected to moving loads
  - Machine foundation supporting reciprocating machines
  - Buildings in earthquake sensitive places
  - High-rise structures subjected to wind gusts (wind-induced vibrations)

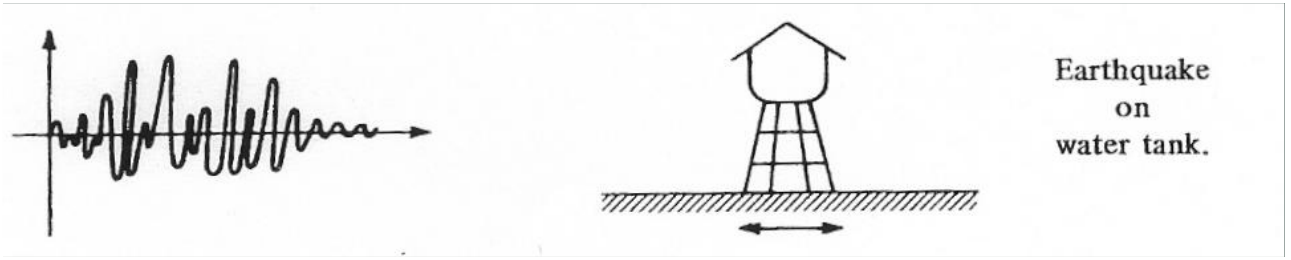
TYPES OF VIBRATION

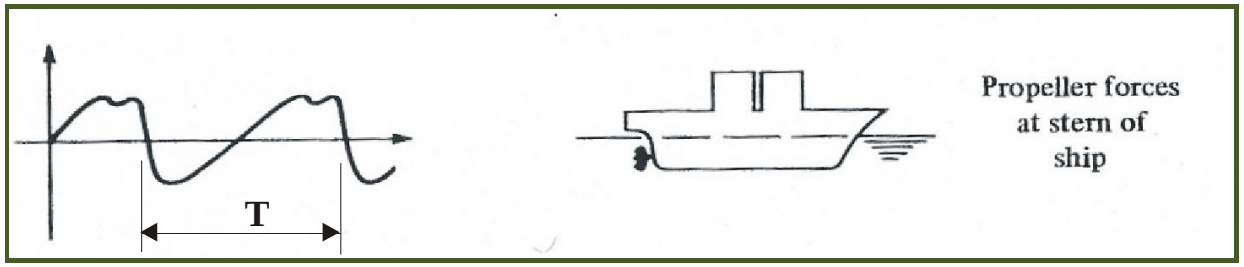
- **Free Vibration:** If a system, after an initial disturbance, is left to vibrate on its own, the ensuing vibration is known as *free vibration*.
- **Forced Vibration:** If a system is subjected to an external force (often, a repeating type of force), the resulting vibration is known as *forced vibration*.
- **Undamped vibration:** If *no energy is lost or dissipated* in friction or other resistance during oscillation
- **Damped vibration:** energy is lost during vibration
- **Linear and Nonlinear Vibration**

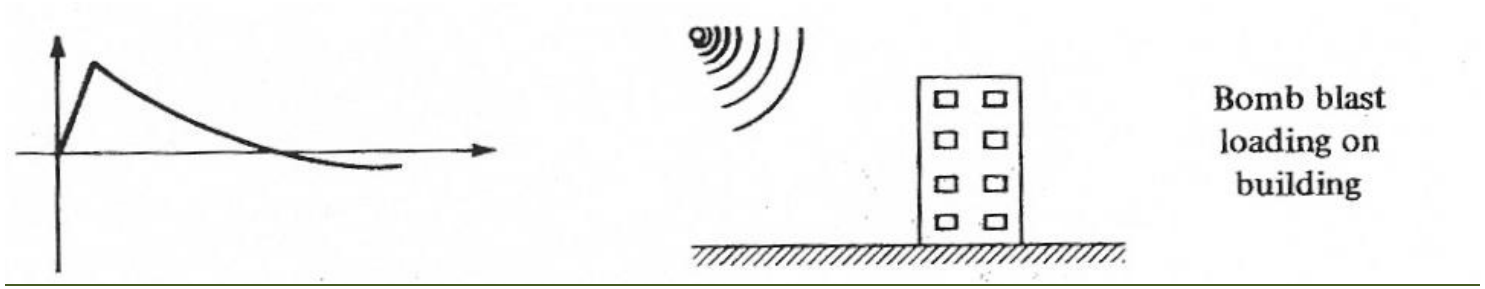


TYPES OF EXCITATION









VIBRATION

- A vibratory system, in general, includes

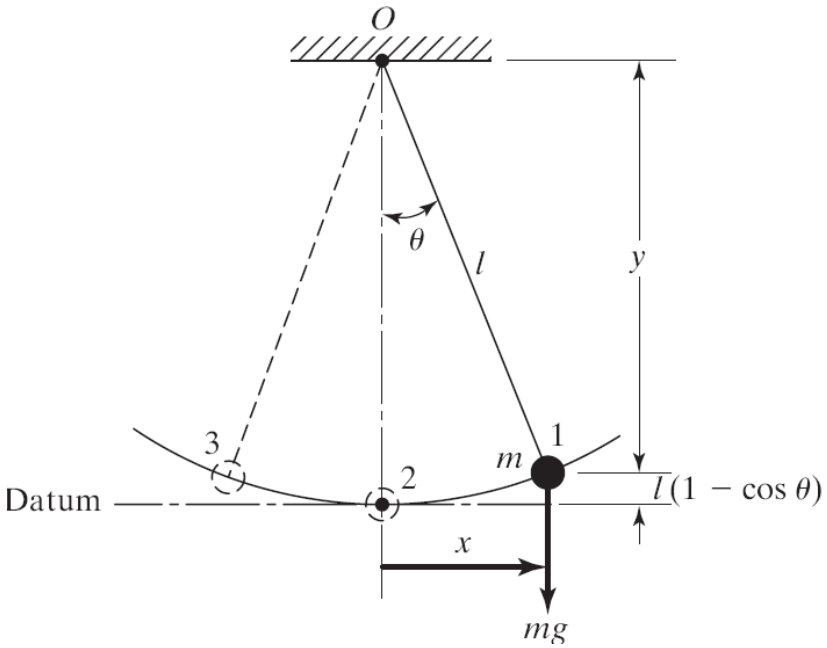
  a means for storing potential energy (spring or elasticity)

  a means for storing kinetic energy (mass or inertia)

  a means by which energy is gradually lost (damper)

- The vibration of a system involves the transfer of its potential energy to kinetic energy and of kinetic energy to potential energy, alternately.
- If the system is damped, some energy is dissipated in each cycle of vibration and must be replaced by an external source if a state of steady vibration is to be maintained.

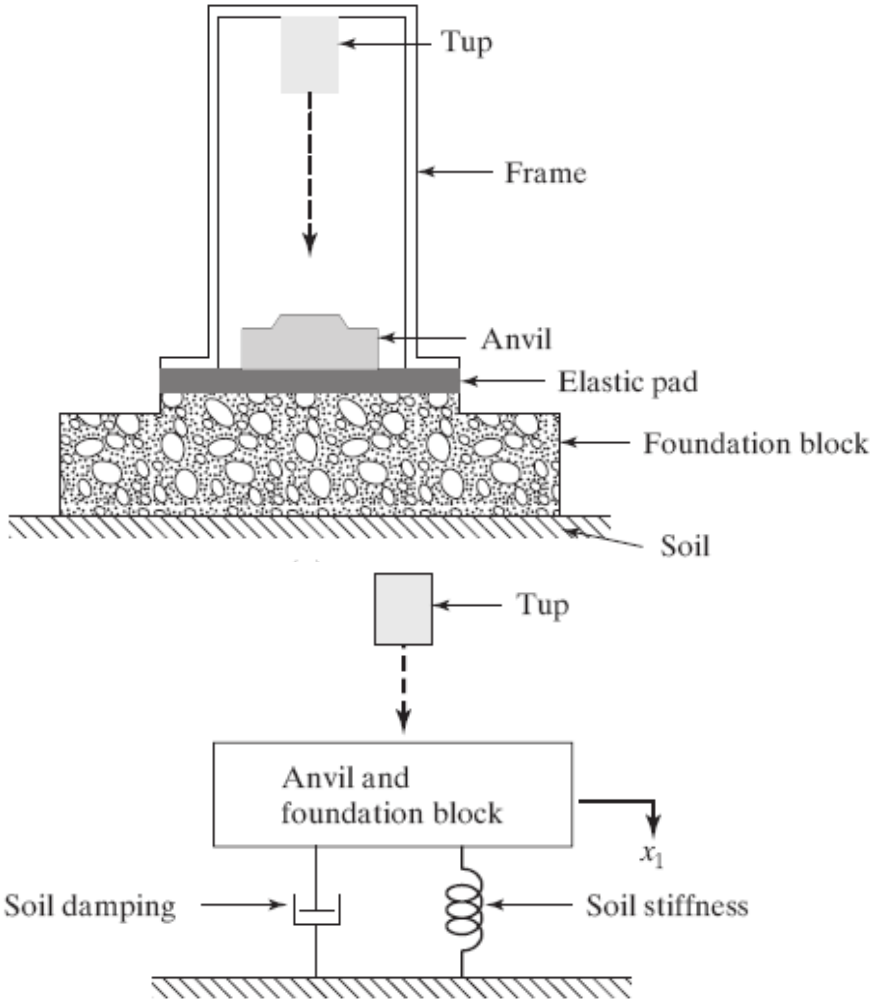
SIMPLE PENDULUM

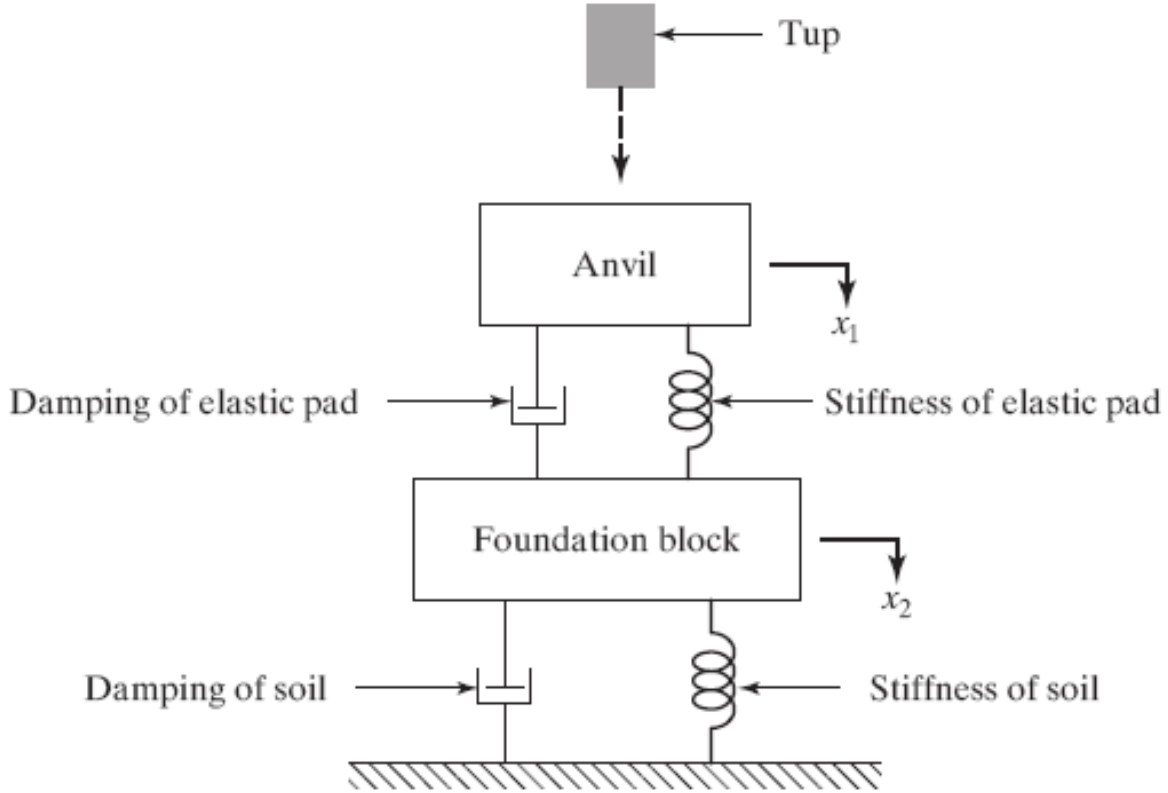


Source: SS Rao, Mechanical vibrations, Pearson, 5e

- At position 1 the velocity (hence KE is zero)
- PE = $mgl(1 - \cos\theta)$ with respect to 2
- At position 2, all KE is converted into PE and won't stop at 2
- Again at 3 the PE is maximum and KE is zero
- For undamped case, the oscillation continues
- In practice the motion stops due to interaction with air. (Some energy dissipated due to damping by the air)

DISCRETE AND CONTINUOUS

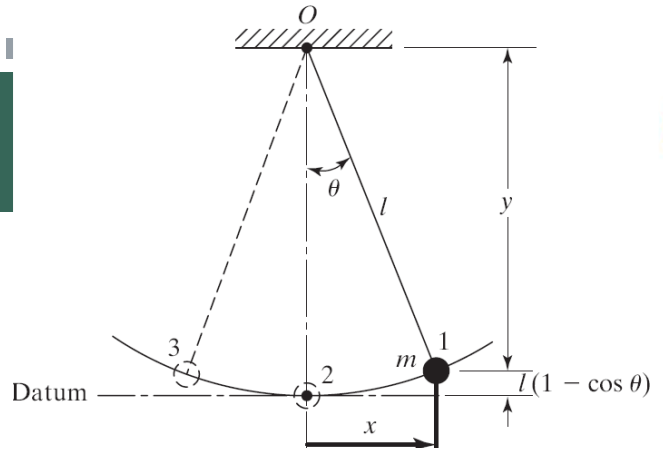


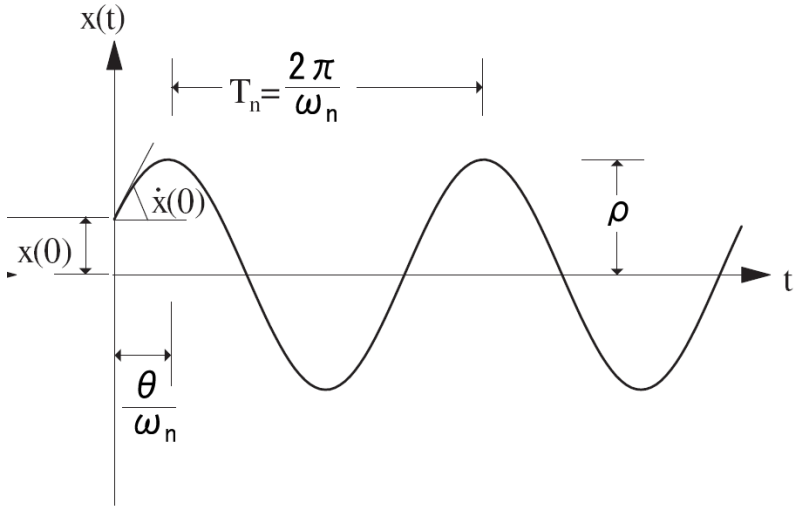


Source: SS Rao, Mechanical vibrations, Pearson, 5e

DEFINITIONS AND TERMINOLOGY

- **Cycle:** Equilibrium->Extreme position(1)->Equilibrium -> Ext. Position (2)-> Equilibrium
- **Amplitude:** The maximum displacement of a vibrating body from its equilibrium position
- **Period of oscillation:** The time taken to complete one cycle of motion
- **Frequency of oscillation:** The number of cycles per unit time
- **Natural frequency:** If a system, after an initial disturbance, is left to vibrate on its own, the frequency with which it oscillates without external forces





WHAT NEXT?

- Spring-mass system
- Equation of motion
- Undamped Free vibration response of Single Degree of Freedom (SDOF) system