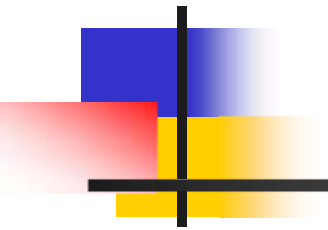


Introduction to Mechanical Vibrations

Before we get started…
Why Study Vibration ??

Earthquake-induced vibration ☹ **Bad Vibrations…..**

Before we get started…
Why Study Vibration ??

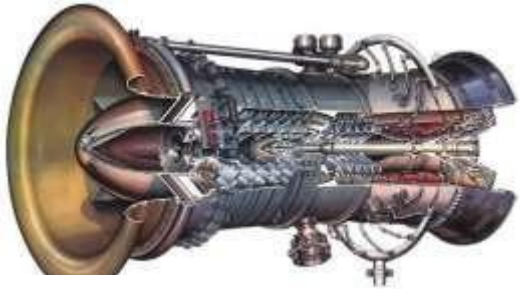
Wind-induced vibration

☹ **Bad Vibrations…..**

Tacoma Narrows bridge during wind-induced vibration. The bridge opened on July 1, 1940, and collapsed on November 7, 1940.

Before we get started…
Why Study Vibration ??

Other Examples



Jet Engines

Washing Machines

Compressors and Air Conditioners

Hard Drives

And so on….

Before we get started…
Is all Vibration Bad????

Good Vibrations

Musical Instruments

Vibration Testing of Civil Engineering Structures

Before we get started…
Is all Vibration Bad????

Good Vibrations

Vehicle Suspension Systems

Medical/Physiotherapy Applications

Before we get started…

So the Goals and the study areas

Goals of Vibration Engineering:

- **Suppress/eliminate bad vibrations**
- **Generate desired forms and levels of good vibration**

Areas of Study in Vibration:

1. **Modeling and Analysis**
2. **Design and Modification**
3. **Instrumentation**
4. **Monitoring and Experimentation**
5. **Control**

Before we get started…

Applicable Engineering Fields??

Mechanical Engineering: Reduced vehicle vibration

- **Improved performance**
- **ride quality and comfort**
- **reduced maintenance and repair Suspension design**
- **engine balancing**

Manufacturing Engineering: Machine tool vibration induces

- **Degrades product quality**
- **increases rate of wear**
- **frequency of malfunction**
- **creates noise and operator discomfort**

- **Proper design of machine tools and components**
- **Incorporation of vibration control, isolation….**

Before we get started…
Applicable Engineering Fields??

Aeronautical and Aerospace Engineering:

Design and development of aircraft and space craft (analyze and avoid excitation of resonances by engine, atmospheric, control surface excitations, etc.). …etc

Civil Engineering:

Design of bridges and buildings; Dynamic stability (to avoid catastrophic self-excited vibration)….

Electrical Engineering:

Hardware degrade/malfunction faster (e.g., components in PCs and control devices) …

Basic Concepts of Vibrations

Vibration : definitions

أي حركة تكرر نفسها بانتظام بعد مدة معينة من الزمن

- **Any motion that repeats itself after an interval of time.**
- **oscillations in mechanical dynamic systems**
- **in mechanical engineering is reserved for systems that can oscillate freely without applied forces**

Analysis, modelling and prediction of vibration behavior

The role of mechanical vibration analysis should be to use mathematical tools for modelling and predicting potential vibration problems and solutions, which are usually not obvious in preliminary engineering designs

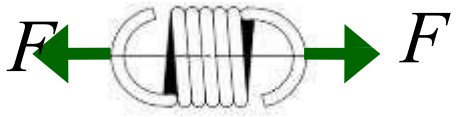
Basic Concepts of Vibrations

Modeling is usually 95% of the effort in real-world mechanical vibration problems;

For modelling, One needs elements capable of storing/dissipating various forms of energy:

قادرة على تخزين طاقة الوضع

Springs – capable of storing potential energy



قادرة على اكتساب طاقة الحركة

Masses – capable of acquiring kinetic energy

قادرة على امتصاص وتشتيت الطاقة

Damping elements –involved in the energy dissipation

عنصر قادر على التأثير بقوة خارجية على النظام لإحداث اهتزازات.

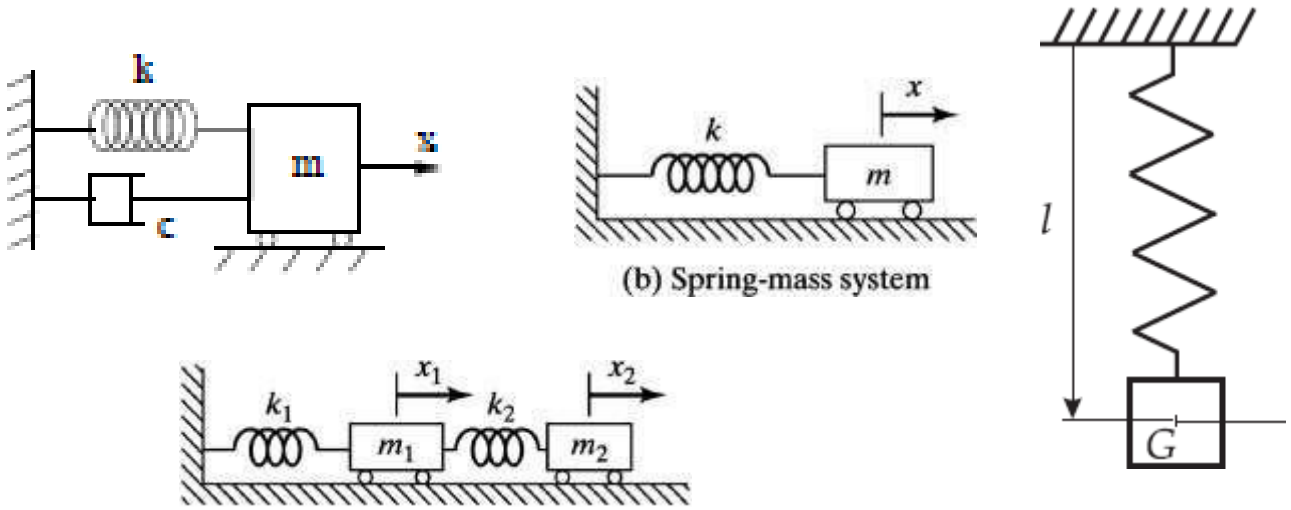
Actuators – the elements that apply an external forcing or impose a prescribed motion on parts of a system

Basic Concepts of Vibrations

So, A vibratory system model includes:

- **means for <u>storing potential energy</u> (springs or elasticity)**
- **means for <u>storing kinetic energy</u> (mass or inertia)**
- **means for <u>gradually losing energy</u> (damper).**

Examples of vibratory system model to be studied



Classification of Vibration

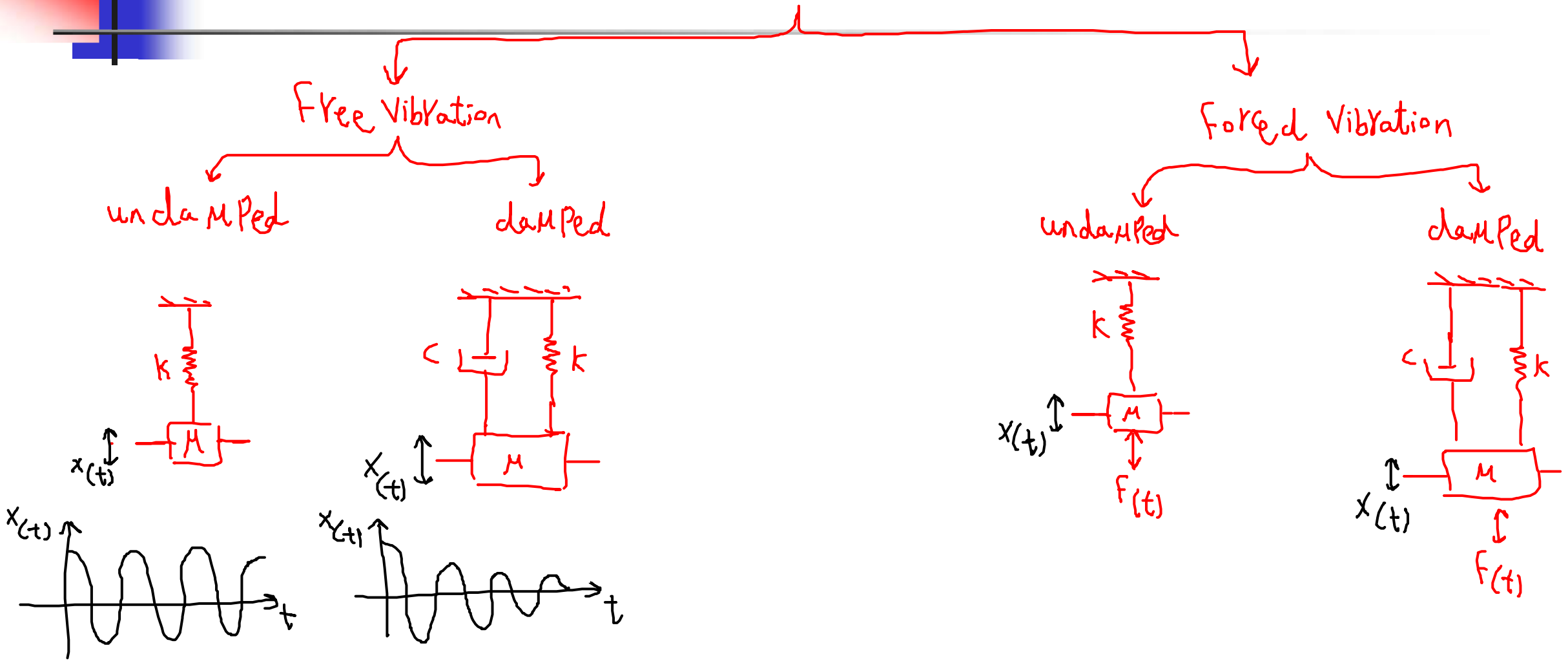
- **Free Vibration**: A system is left to vibrate on its own after an initial disturbance and no external force acts on the system. [E.g. simple pendulum]

- **Forced Vibration**: A system that is subjected to a repeating external force. [E.g. oscillation arises from diesel engines]

- **Undamped Vibration**: When no energy is lost or dissipated in friction or other resistance during oscillations

- **Damped Vibration:** When any energy is lost or dissipated in friction or other resistance during oscillations

Classification of Vibration



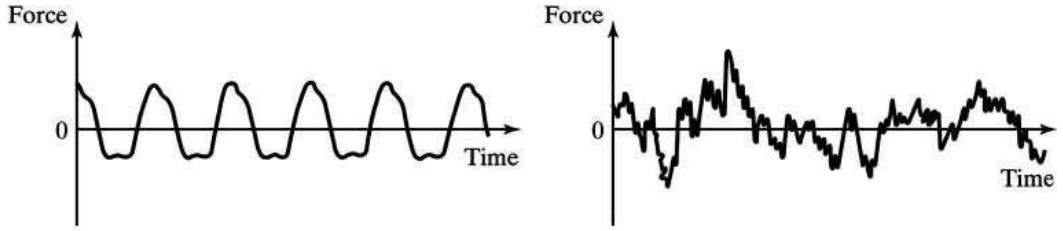
Classification of Vibration

- **Linear Vibration:** When all basic components of a vibratory system, i.e. the spring, the mass and the damper behave linearly

- **Nonlinear Vibration**: If any of the components behave nonlinearly

- **Deterministic Vibration**: If the value or magnitude of the excitation (force or motion) acting on a vibratory system is known at any given time

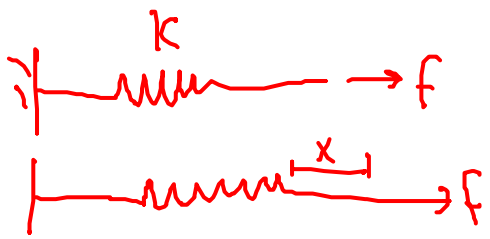
- **Nondeterministic or random Vibration:** When the value of the excitation at a given time cannot be predicted



(a) A deterministic (periodic) excitation (b) A random excitation

vibratory systems : Basic elements

Spring Elements



Spring Constant

$F = K X$

$K \rightarrow \left(\frac{N}{m}\right)$

Linear spring is a type of mechanical link that is generally assumed to have negligible mass and damping.

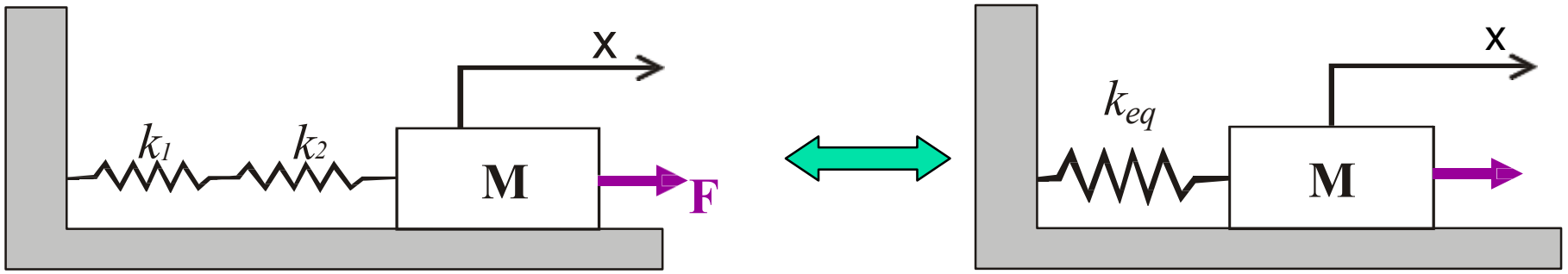
Spring force is given by: $F = k.x$

طاقة الوضع $U = \frac{1}{2} k x^2$

F = spring force, k = spring stiffness or spring constant, and x = deformation (displacement of one end with respect to the other)

Work done (U) in deforming a spring or the strain (potential) energy is given by: $U = \frac{1}{2} K.X^2$

Springs Acting in Series

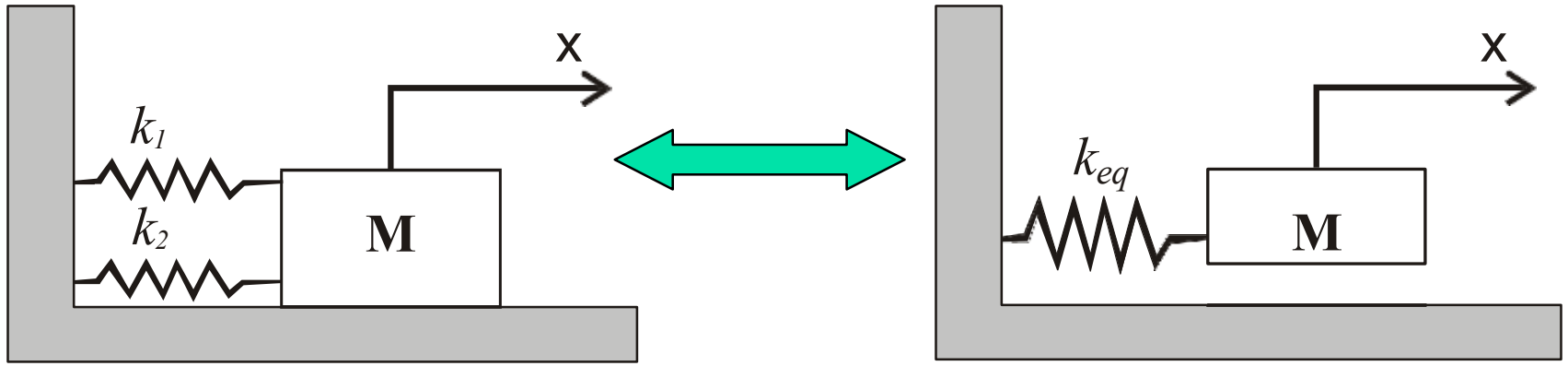


the equivalent spring constant k_{eq} is such that:

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

The idea is that you want to determine one abstract spring that has k_{eq} that deforms by the same amount when it's subject to F.

Springs Acting in Parallel



Note that two springs are in parallel when:

a) They experience the same amount of deformation

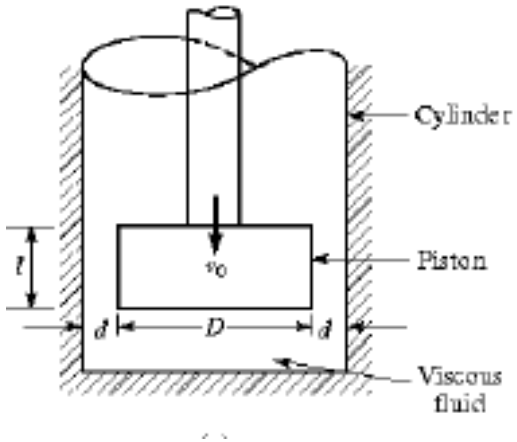
b) You'd add up the force experienced by each spring to come up with the total force F

the equivalent spring constant k_{eq} is such that:

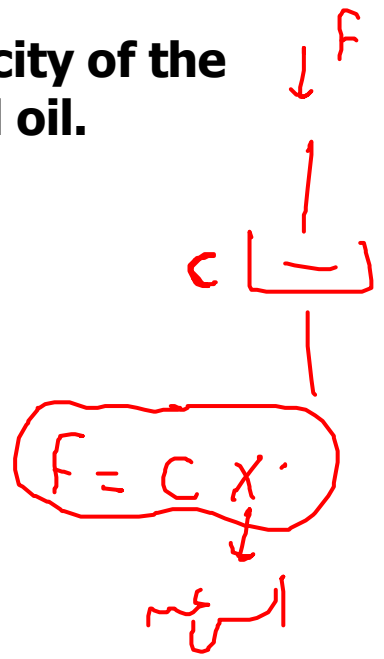
$$k_{eq} = k_1 + k_2$$

Basic Concepts of Vibrations

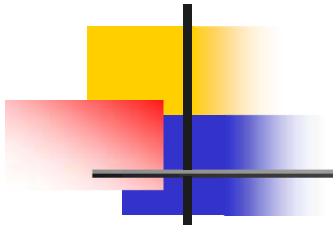
·**Viscous Damping: Damping force is proportional to the velocity of the vibrating body in a fluid medium such as air, water, gas, and oil.**



$$F = cv$$



·**Coulomb or Dry Friction Damping: Damping force is constant in magnitude but opposite in direction to that of the motion of the vibrating body between dry surfaces**



The course will focus primarily on the derivation of equations of motion, free response and forced response analysis, and approximate solution methods for vibrating systems.