國立台灣大學九十六學年度第二學期
機械工程學系教師課程教學規劃表

一、 課程基本資料

課程名稱	中文：波動力學				
	英文：Wave Propagation in Elastic Solids				
課程類別	□必修 □知識領域選修 ■一般選修 □大學部 ■研究所(組別：固體力學組)			班次	
授課教師	馬劍清			學分數	3
課程編號	522 M3060	每週上課時數	3	選修人數	30
上課時間	二 678	先修課程	線性彈性力學、工程數學	適修年級	碩博士班研究生

二、課程教學目標與預期成效

課程教學目標：

教導學生明瞭固體動態問題之基本知識及應力波傳所呈現之物理現象；傳授學生分析彈性材料受動態外力加載後變形與應力的方法與技巧，期使學生能將所學的知識應用於解釋與解決與固體承受動態負載相關的課題。

單元主題	預期教學成效	教學策略及方法	評量方式	養成核心能力
波動力學簡介	瞭解波動力學之基本知識及應用與其和固體力學相關課程之關係。	A 講述教學法 C 示範教學法 E 問題或專題教學法	a 考試 b 測驗 c 作業	U1,U2,U4; G1
彈性力學的基本理論與公式	明瞭應用張量來描述物理量之方式及其特性，並熟悉以簡潔的符號來描述複雜的數學系統及應用。熟悉應力應變及材料的本構方程並推導運動方程式。	A 講述教學法 C 示範教學法 E 問題或專題教學法	a 考試 b 測驗 c 作業	U1,U2,U4; G1
一維問題	明瞭一維動態問題的特性及數學解析方法，以及振動與波動問題之間的關連性。	A 講述教學法 C 示範教學法 E 問題或專題教學法	a 考試 b 測驗 c 作業	U1,U2,U4; G1
彈性動態問題的基本理	明瞭三圍彈性動態問題的基本理論及解析	A 講述教學法 C 示範教學法	a 考試 b 測驗	U1,U2,U4; G1

論與解析方法	方法，以及二維動態問題的控制方程推導。	E 問題或專題教學法	c 作業	
彈性波在無窮域的波傳	明瞭平面簡諧波的特性和數學表示式以及其在異向性及等向性材料的波傳。	A 講述教學法 C 示範教學法 E 問題或專題教學法	a 考試 b 測驗 c 作業	U1,U2,U4; G1,G2
平面簡諧波在半平面的波傳	明瞭平面簡諧波在兩種不同材料的波傳之入射，反射及折射現象及推導，並了解表面波的形成條件及特性。	A 講述教學法 C 示範教學法 E 問題或專題教學法	a 考試 b 測驗 c 作業	U1,U2,U4; G1,G2,G4
簡諧波的波導	明瞭簡諧波在兩平面間傳播的波導現象以及其頻散特性的探討，並具備推導頻散曲線之能力。	A 講述教學法 C 示範教學法 E 問題或專題教學法	a 考試 b 測驗 c 作業	U1,U2,U4; G1,G2,G4

三、課程教學大綱

Chap. 0. Introduction

1. Solid Mechanics
   general information, related courses
2. Wave Propagation in Elastic Solids
   general concept and application

Chap. 1. Index Notation and Basic Formulation of Linear Elasticity

1. Index Notation
   summation convention, calculus of Cartesian tensors
2. Basic Formulation of Linear Elasticity
   stress tensor and traction vector, deformation and strain tensor, stress and strain relation, restrictions on elastic moduli
3. Equations of Motion and Boundary Conditions

Chap. 2. One Dimensional Problems

1. Basic Governing Equations
   longitudinal strain, longitudinal stress, shear stress, the D'Alembert solution
2. One Dimensional Boundary Value Problem for a Semi-infinite Medium
   general solution method, Laplace transform method
3. Reflection and Transmission
   traction free boundary, interface boundary, the split Hopkinson pressure bar
4. Solutions for Infinite Bodies
   the initial value problem, domain of dependence, forced motion of an infinite body, the Green's function solution
5. Harmonic Waves

traveling waves, standing waves, modes of vibration

6. Dynamic Motion of a String
   the normal mode solution, Sturm-Liouville theory, boundary conditions for a string, the orthogonality of the normal modes, forced motions of a string
7. Dynamic Motion of a Finite Rod
   free vibration of a finite rod, forced vibration of a finite rod, impulse loading of a finite rod.
8. The String on an Elastic Foundation
   phase velocity, frequency spectrum and dispersion curve, group velocity
9. Flexural Waves in Bernoulli-Euler Beams
   propagation of harmonic waves, free vibrations of finite beams, orthogonality of normal modes, forced motions of beams, transient response of a simply supported beam

Chap. 3. Elastodynamic Formulation and Theory

1. Displacement Equations of Motion
   Helmholtz decomposition of a vector, displacement potentials, dilatation and rotation waves, the relations of stress components and displacement potentials, the ideal fluid
2. Two-Dimensional Formulation
   anti-plane shear motion, in-plane motion, two-dimensional displacement potentials
3. Elastodynamic Theory
   kinetic energy and strain energy,uniqueness of solution, dynamic reciprocal identity
4. Wave Motion due to Body Forces
   the solution for point sources, the solution for distributed sources, elastodynamic solution due to body forces, steady-state time harmonic response, the singular solution of elastodynamic
5. Two-Dimensional Problems
   two-dimensional radiation problems, anti-plane line load, in-plane line load, boundary value problems

Chap. 4. Elastic Waves in an Unbounded Medium

1. Plane Waves
   in anisotropic elastic solid, acoustic tensor and characteristic equation, in transversely isotropic solid, in isotropic solid
2. Example
   uniform pressure on a spherical cavity

Chap. 5. Plane Harmonic Waves in Elastic Half-Space

1. Incident, Reflection and Refraction of Plane Waves
   reflection of incident longitudinal wave, reflection and refraction of incident SH shear wave
2. Surface Waves
   slowness diagram, Rayleigh surface wave, roots of function in the complex plane

Chap. 6. Harmonic Waves in Waveguides

1. SH Waves in an Elastic Layer
   SH shear wave, frequency equation and frequency spectrum, energy transport by SH wave in a layer, Love waves in a layered half-space
2. Plain Strain Waves in an Elastic Layer
   Rayleigh-Lamb frequency spectrum, longitudinal mode, Flexural mode

四、教科書及參考書目（書名、作者、出版者、出版日期）**及輔助教材**

教科書： **"Wave Propagation in Elastic Solids"**, J. D. Achenbach, North-Holland Publication Company, 1973.

參考書： (1) **"Wave Motion in Elastic Solids"**, K. F. Graff, Ohio State University Press, 1975.
(2) **"The Theory of Elastic Waves and Waveguides"**, J. Miklowitz, North-Holland Publication Company, 1978.

輔助教材：自編講義

五、課程說明與進度

波動力學是研習固體力學相關課程中有關動態問題的基礎課程，內容闡述了應力波在彈性固體中的波傳現象與數學解析，由於在動態問題中所有的物理量（包括應力、應變與位移）皆為時間相關，且在短時間內有劇烈的變化，所以動態問題的解析較以靜態問題為主的彈性力學為繁難，但也具有較多的有趣的物理現象與實際在工程及工業界的應用實例，如超音波非破壞檢測，固體受撞擊時的動態反應，地震波對於結構體的影響，地質的探勘，船艦的聲納系統，聲波的傳播與噪音防制等，這些實際的工程應用皆是以波動力學為基礎再作深入的研究發展而成的範例。

由於應力及應變並不是以往所熟知的純量以及向量場，而是更高階的物理量，所以本課程中首先以彈性力學為基礎說明這些物理量，並推導所需之基本方程式。本課程亦介紹以簡潔的符號系統來表示以及推導複雜的數學方程式，此符號系統將應用在本課程中以簡化一些繁複的數學推導以及方程式的表示式，修習的同學應熟悉此符號系統以利課程之學習。接著以較簡單的一維相關問題（如繩索、桿、樑）為例詳細說明波傳的基本特性及數學解析方法，再以連續體的理論模型為基礎建立三維波傳問題的控制方程式以及解析方法和動態問題基本特性探討。最後以平面簡諧波為例，詳細說明了其在無窮域及半平面的波傳和兩平面間的波導現象，並推導其中重要公式。

雖然本課程是固體力學相關研究領域動態問題的入門課程，但是本課程的內容及深度卻非一般大學部課程所可比擬，尤其有較多的數學推導以說明波傳的現象，故修習本課程的同學應具備良好的工程數學基礎以及彈性力學基本知識。希望同學們修習完這門課後能奠定良好的固體力學有關動態問題的知識基礎，以便將來能以正確的觀念來處理固體力學方面相關的問題，並在實際工程問題中得以應用。

本課程 96 學年度第二學期各週之授課進度暫訂如下：

週次	講授內容概要	教科書章節
1	**<u>Chap. 0. Introduction</u>** 1. Solid Mechanics general information, related courses 2. Wave Propagation in Elastic Solids general concept and application	講義
2	**<u>Chap. 1. Index Notation and Basic Formulation of Linear Elasticity</u>** 1. Index Notation summation convention, calculus of Cartesian tensors 2. Basic Formulation of Linear Elasticity stress tensor and traction vector, deformation and strain tensor, stress and strain relation, restrictions on elastic moduli	講義 Chapter 1 pp. 1-1 ~ 1-10
3	**<u>Chap. 1. Index Notation and Basic Formulation of Linear Elasticity</u>** 2. Basic Formulation of Linear Elasticity stress tensor and traction vector, deformation and strain tensor, stress and strain relation, restrictions on elastic moduli 3. Equations of Motion and Boundary Conditions	講義 Chapter 1 pp. 1-11 ~ 1-19
4	**<u>Chap. 2. One Dimensional Problems</u>** 1. Basic Governing Equations longitudinal strain, longitudinal stress, shear stress, the D'Alembert solution 2.One Dimensional Boundary Value Problem for a Semi-infinite Medium general solution method, Laplace transform method	講義 Chapter 2 pp. 2-1 ~ 2-12
5	**<u>Chap. 2. One Dimensional Problems</u>** 3. Reflection and Transmission traction free boundary, interface boundary, the split Hopkinson pressure bar 4. Solutions for Infinite Bodies the initial value problem, domain of dependence, forced motion of an infinite body, the Green's function solution	講義 Chapter 2 pp. 2-13 ~ 2-26

6	**<u>Chap. 2. One Dimensional Problems</u>** 5. Harmonic Waves traveling waves, standing waves, modes of vibration 6. Dynamic Motion of a String the normal mode solution, Sturm-Liouville theory, boundary conditions for a string, the orthogonality of the normal modes, forced motions of a string	講義 Chapter 2 pp. 2-27 ~ 2-39
7	**<u>Chap. 2. One Dimensional Problems</u>** 7. Dynamic Motion of a Finite Rod free vibration of a finite rod, forced vibration of a finite rod, impulse loading of a finite rod. 8. The String on an Elastic Foundation phase velocity, frequency spectrum and dispersion curve, group velocity	講義 Chapter 2 pp. 2-40 ~ 2-56
8	**<u>Chap. 2. One Dimensional Problems</u>** 9. Flexural Waves in Bernoulli-Euler Beams propagation of harmonic waves, free vibrations of finite beams, orthogonality of normal modes, forced motions of beams, transient response of a simply supported beam	講義 Chapter 2 pp. 2-57 ~ 2-71
9	期中考試	
10	**<u>Chap. 3. Elastodynamic Formulation and Theory</u>** 1. Displacement Equations of Motion Helmholtz decomposition of a vector, displacement potentials, dilatation and rotation waves, the relations of stress components and displacement potentials, the ideal fluid 2. Two-Dimensional Formulation anti-plane shear motion, in-plane motion, two-dimensional displacement potentials	講義 Chapter 3 pp. 3-1 ~ 3-11
11	**<u>Chap. 3. Elastodynamic Formulation and Theory</u>** 3. Elastodynamic Theory kinetic energy and strain energy,uniqueness of solution, dynamic reciprocal identity 4. Wave Motion due to Body Forces the solution for point sources, the solution for distributed sources, elastodynamic solution due to body forces, steady-state time harmonic response, the singular solution of elastodynamic	講義 Chapter 3 pp. 3-12 ~ 3-22

12	**<u>Chap. 3. Elastodynamic Formulation and Theory</u>** 4. Wave Motion due to Body Forces the solution for point sources, the solution for distributed sources, elastodynamic solution due to body forces, steady-state time harmonic response, the singular solution of elastodynamic 5. Two-Dimensional Problems two-dimensional radiation problems, anti-plane line load, in-plane line load, boundary value problems	講義 Chapter 3 pp. 3-23 ~ 3-32
13	**<u>Chap. 4. Elastic Waves in an Unbounded Medium</u>** 1. Plane Waves in anisotropic elastic solid, acoustic tensor and characteristic equation, in transversely isotropic solid, in isotropic solid 2. Example uniform pressure on a spherical cavity	講義 Chapter 4 pp. 4-1 ~ 4-12
14	**<u>Chap. 4. Elastic Waves in an Unbounded Medium</u>** 2. Example uniform pressure on a spherical cavity **<u>Chap. 5. Plane Harmonic Waves in Elastic Half-Space</u>** 1. Incident, Reflection and Refraction of Plane Waves reflection of incident longitudinal wave, reflection and refraction of incident SH shear wave	講義 Chapter 4 pp. 4-13 ~ 4-16 講義 Chapter 5 pp. 5-1 ~ 5-7
15	**<u>Chap. 5. Plane Harmonic Waves in Elastic Half-Space</u>** 1. Incident, Reflection and Refraction of Plane Waves reflection of incident longitudinal wave, reflection and refraction of incident SH shear wave 2. Surface Waves slowness diagram, Rayleigh surface wave, roots of function in the complex plane	講義 Chapter 5 pp. 5-8 ~ 5-23
16	**<u>Chap. 6. Harmonic Waves in Waveguides</u>** 1. SH Waves in an Elastic Layer SH shear wave, frequency equation and frequency spectrum, energy transport by SH wave in a layer, Love waves in a layered half-space	講義 Chapter 6 pp. 6-1 ~ 6-12
17	**<u>Chap. 6. Harmonic Waves in Waveguides</u>** 2. Plain Strain Waves in an Elastic Layer Rayleigh-Lamb frequency spectrum, longitudinal mode, Flexural mode	講義 Chapter 6 pp. 6-13 ~ 6-17
18	期末考試(依照學校規定時間)	

六、評分及考試

成績評量方式：

1. 期中考 (40%)， 期末考 (40%)。
2. 作業(20%)。

七、授課教師與助教

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