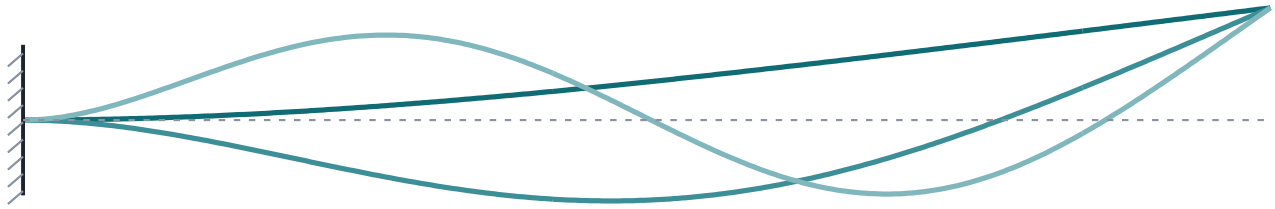
MECH3200 · ADVANCED DYNAMICS & VIBRATIONS

Hard-Topic Explainers

Deep dives on the three topics that cost the most marks: modal analysis from energy to response, continuous systems, and the approximate methods.



Built for: the current course (listed as Engineering Dynamics 2 from 2026, same code), final exam 50%, closed book, one handwritten A4 sheet, 40% hurdle

Picked by: going through the recent final exams question by question and the current syllabus week by week, then counting where the marks sit

Every number: re-checked in Python (NumPy and SciPy) by a different route: eigen-solvers, numerical integration and exact boundary-value solutions

Written by: a UQ mechatronics engineering graduate who took MECH3200 and tutored first-year engineering at UQ

Independent study notes. Not affiliated with or endorsed by The University of Queensland. All explanations, examples and diagrams are original. Course details are from the public course profile and can change, so check yours.

Why these three topics

The final is half your grade, and below 40% on it you cannot get more than a 3. So the topics worth deep work are the ones that carry the most exam marks and the most confusion.

Topic	Where it shows up in the exam	Why people lose marks
1. Modal analysis, energy to response	The long discrete-systems question every year: Lagrange, matrices, frequencies, modes, modal mass, then a damped or forced response. Plus multiple choice on orthogonality, damping and eigenvalues.	Long chain of steps. One early slip (a spring sign, a missing M) wrecks every later part.
2. Continuous systems	The long Part B question: string, rod or beam frequencies, mode-shape sketches, a forced beam, and "which model fits better". Plus multiple choice on boundary conditions and added masses.	Boundary conditions feel abstract, and string, rod and beam formulas get mixed up.
3. Approximate methods	Rayleigh, Dunkerley and Holzer turn up as calculations and as "which estimate is higher" and "how many modes" multiple choice.	Students memorise the formulas but not why they bound the answer, so the ordering questions become guesses.

Together they touch well over half the paper. The other topics (absorbers, isolation, measurement) are shorter and more formula-driven. They are covered in the worked problems pack and the exam sheet guide.

How each explainer works

- **Idea first, then the maths.** Each section starts with what is physically going on, because that is what the explain-and-pick marks test.
- **One running example per explainer,** with every number checked in Python.
- **Coloured boxes:** blue for how it gets examined, red for traps, green for what earns space on your A4 sheet.
- **A self-check at the end of each explainer.** Answers are at the back.

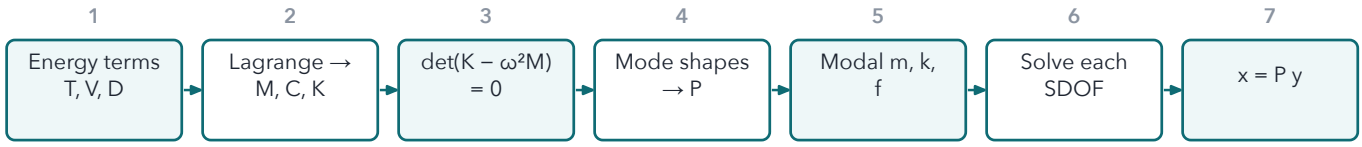
Contents

1 Modal analysis, energy to response
1.1 The chain in seven links
1.2 Energy terms without sign slips
1.3 Frequencies and modes
1.4 Orthogonality and modal mass
1.5 Getting into modal coordinates
1.6 Forced, damped response
1.7 Which damping method
2 Continuous systems
2.1 One equation, three systems
2.2 From boundary conditions to frequencies
2.3 Beams
2.4 String or beam?
2.5 Adding a mass
2.6 Forced beams by modes
3 Approximate methods
3.1 What each method gives you
3.2 Rayleigh's method
3.3 Dunkerley's method
3.4 Holzer's method
3.5 Finite elements in one page
– Self-check answers

1 Modal analysis, energy to response

The long discrete-systems question is one chain of steps. Get each link right and the marks stack up. Break one link and everything after it goes wrong, even if your method is perfect.

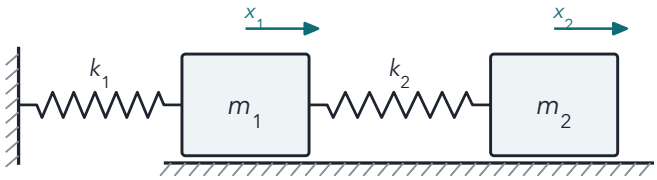
1.1 The chain in seven links



Every question in this family is some slice of that chain. "Show that the equations of motion are..." is links 1 and 2. "Find the natural frequencies and modes" is 3 and 4. "Find the steady response of each mode" is 5 to 7. Knowing where you are in the chain tells you what the marker wants written down.

The running example

A two-storey frame: floor masses $m_1 = 3000$ kg (first floor) and $m_2 = 1500$ kg (roof). The first-storey columns give $k_1 = 6$ MN/m and the second-storey columns $k_2 = 2$ MN/m. Coordinates x_1, x_2 are sideways floor displacements. It is the same picture as a two-mass chain standing on its end.



1.2 Energy terms without sign slips

Lagrange's equation for coordinate q_i, with Rayleigh's dissipation function D and generalised force Q_i:

$$\frac{d}{dt}\left(\frac{\partial T}{\partial \dot{q}_i}\right) - \frac{\partial T}{\partial q_i} + \frac{\partial V}{\partial q_i} + \frac{\partial D}{\partial \dot{q}_i} = Q_i$$

The safest habit is to write the **stretch of every spring** in words before writing V. Then square it.

Element	Energy term	Note
Mass moving at $\dot{x}$	$T = \frac{1}{2}m\dot{x}^2$	Use the velocity of the centre of mass
Rigid body turning	$T = \frac{1}{2}J_G\dot{\theta}^2$	Or $\frac{1}{2}J_O\dot{\theta}^2$ about a fixed pivot O only
Spring between two points	$V = \frac{1}{2}k(\text{stretch})^2$	Stretch $= x_j - x_i$ or $y + a\theta$: write it first
Torsional spring	$V = \frac{1}{2}k_t(\theta_j - \theta_i)^2$	Through gears, refer everything to one shaft first
Gravity on a pendulum	$V = mgL(1-\cos\theta) \approx \frac{1}{2}mgL\theta^2$	Keep the θ^2 term when you linearise
Viscous damper	$D = \frac{1}{2}c(\text{stretch rate})^2$	Same pattern as the spring, with velocities

For the frame, the first-storey columns stretch by x_1 and the second by $x_2 - x_1$:

$$T = \tfrac{1}{2}m_1\dot{x}_1^2 + \tfrac{1}{2}m_2\dot{x}_2^2, \qquad V = \tfrac{1}{2}k_1x_1^2 + \tfrac{1}{2}k_2(x_2 - x_1)^2$$

$$\mathbf{M} = \begin{bmatrix} 3000 & 0 \\ 0 & 1500 \end{bmatrix}, \qquad \mathbf{K} = \begin{bmatrix} k_1 + k_2 & -k_2 \\ -k_2 & k_2 \end{bmatrix} = \begin{bmatrix} 8 & -2 \\ -2 & 2 \end{bmatrix} \times 10^6$$

TRAP

If your K is not symmetric, or a diagonal term is negative, a stretch was written wrongly. M and K from Lagrange are always symmetric, and the diagonal of K is always positive for a stable system.