Dynamics of Machinery (3151911)

IMP Questions – Chapter-wise, with Numerical Types ranked by frequency

GTU BE Semester 5 | Based on 9 papers: Winter 2022, 2023, 2024, 2025 and Summer 2022, 2023, 2024, 2025, 2026. Winter papers given extra weight.

★★★ 5+ papers – prepare FIRST ★★ Asked in 3–4 papers ★ Asked 1–2 times – only if time is left

1. Read this first

- Paper is **70 marks**. Each of Q.1 to Q.5 has parts (a) 3 marks, (b) 4 marks, (c) 7 marks. Q.2 to Q.5 have an OR choice.
- The **(c) part (7 marks) is almost always a numerical**. So about **35 of 70 marks** come from numericals. Learn numerical types, not random sums.
- Many numericals repeat with the **same numbers** in different years (see Section 4). Practise those exact sums first.
- **Chapter 8** (Vibration Monitoring: FFT, sensors, signal analysis) is new in the 2024-25 syllabus. It was never asked in old papers but carries about 15% weight. Keep short 4-mark theory ready. Summer 2026 already shows more “analyse / propose / examine” style questions.
- Syllabus weight (CO): Vibrations (Ch 5, 6, 7) = **35%**; Dynamic force + Flywheel (Ch 1, 2) = **20%**; Balancing (Ch 3) = **20%**; Monitoring (Ch 8) = **15%**; Gyroscope (Ch 4) = **10%**.

2. Numerical types – ranked (study in this order)

No.	Numerical type	Papers	What was asked / what to learn
1	**Damped free vibration (log decrement, damping factor, damped frequency, critical damping)**	8 of 9	Spring-mass with c given: find c_c, ω_d, δ (W24, S26). 30 kg, 20 kN/m, ζ = 0.25 (W24, S26). Successive amplitudes given: find ζ and ω_n (W23, S23, S25, S22, S24). Winter 2025 had damping as theory only. **Learn:** $\omega_n = \sqrt{(k/m)}$, $c_c = 2\sqrt{(km)}$, $\zeta = c/c_c$, $\omega_d = \omega_n\sqrt{(1-\zeta^2)}$, $\delta = \ln(x_1/x_2) = 2\pi\zeta/\sqrt{(1-\zeta^2)}$.
2	**Gyroscopic effect**	8 of 9	Ship turbine rotor: steering, pitching, rolling (W25, W24, W23, W22, S25, S24). Aeroplane half circle / turn (W25, S26). Four-wheeler on curve: load on each wheel / limiting speed (S23, S24). **Learn:** $C = I\omega\omega_p$, $I = mk^2$, ω_p for steering = v/R, pitching ω_p max (SHM), direction rules.
3	**Critical speed of shaft (Dunkerley, Rayleigh, whirling, eccentric rotor)**	7 of 9	Three discs, Dunkerley (W25, S25). Two discs/wheels with shaft mass (S24, S26). Eccentric rotor at mid-span: amplitude and bearing force (W24 ×2, W23). Cantilever shaft with disc: longitudinal + transverse frequency (W25, S24).
4	**Balancing of masses in different planes**	6 of 9	Four masses A, B, C, D (200, 300, 400, 200 kg) in planes X and Y (W25, W22 – same). Four masses P1–P4 (W23). P, Q, R, S find P (S23). Pulleys / rotor in planes (W24 OR, S24 OR). **Method:** couple polygon first, then force polygon (tabular method).
5	**Flywheel**	6 of 9	Turning moment areas +52, –124, +92, –140, +85, –72, +107: find flywheel mass (W25, S22 – same). Punching press 750 holes/h, 14000 Nm, 250/225 rpm: power and mass (W23, S25 – same). Engine flywheel mass / M.I. (W22 gas engine, S23 steam engine rim).
6	**Natural frequency of spring systems (series / parallel)**	6 of 9	K_1–K_6 with mass (W23); K_1–K_5, find m for 15 Hz (S22); pulley-spring (W22); lever with springs (S23); K_1 K_2 K_3, 10 kg (S25); two springs with block (W24). **Learn:** equivalent stiffness for series and parallel, then $\omega_n = \sqrt{(k_{eq}/m)}$.
7	**Forced vibration – rotating unbalance / transmissibility**	5 of 9	Unbalance 525 N at 6000 rpm, ζ = 0.3: amplitude and transmissibility (S25, S23 same type; W22 with 392 N, 3000 rpm). Compressor / engine on springs with damper: amplitude and phase (W23, S26).

No.	Numerical type	Papers	What was asked / what to learn
8	**Engine force analysis (inertia force, thrust, torque)**	5 of 9	Thrust on connecting rod, side thrust, tangential force, bearing load at a crank angle (W24, W23). Inertia torque at a crank angle (S25). Slider-crank 150/600 mm, 60°, 450 rpm: velocity and acceleration of piston, ω and α of rod (S23, S22 – same).
9	**Torsional vibration (two / three rotor, equivalent shaft, node)**	4 of 9	Two rotors on stepped shaft, node and frequency (S22, W25). Motor-pump with gearing (S26). Equivalent length of shaft (W23).
10	**Locomotive and multi-cylinder engine balancing**	4–5 of 9	Locomotive: balance masses and hammer blow / wheel lift-off speed (S26, S25, S23). Four-crank engine primary balance + secondary force (W24, S24); six-cylinder in-line (W23); V-engine secondary force (S26 OR).

Shaded rows = Ranks 1–5: together they give about 25–30 marks.

3. Chapter-wise IMP questions

Chapter 1 – Dynamic Force Analysis of Mechanisms (about 5 hrs)

Priority	Question	Asked in	Marks
★★★	State D'Alembert's principle and explain its use / application.	W23, W22, S26, S25, S23, S22	3 / 4
★★	Difference between piston effort, crank effort and crank-pin effort; derive turning moment in terms of piston effort.	W22, S23, S24	4 / 7
★★	Dynamically equivalent system of two masses (requirements / conditions).	W22, S24	3 / 4
★	Define inertia force and inertia couple.	W22, S22	3
★	Significance of inertia forces in reciprocating engines; why correction couple is applied.	W24	3 / 4
★	Lami's theorem with example (W25); why crank is shaped like a bulb (W23).	W25, W23	3

Numerical: see Rank 8 (engine force analysis, slider-crank velocity and acceleration).

Chapter 2 – Turning Moment Diagram and Flywheel (about 3 hrs)

Priority	Question	Asked in	Marks
★★★	Turning moment diagram of four-stroke IC engine and of multi-cylinder engine.	W23, S22, S23, S26	3 / 4
★★★	Define fluctuation of energy, fluctuation of speed, coefficient of fluctuation of speed and of energy.	W25, W22, W23, S23	3 / 4
★★	Role of flywheel in punching press.	S26	4
★	Flywheel in two-wheeler and how it differs from governor.	S25	4

Numerical: see Rank 5 (flywheel).

Chapter 3 – Balancing (about 8 hrs) – highest theory + numerical weight

Priority	Question	Asked in	Marks
★★★	Static balancing vs dynamic balancing, with examples and conditions.	W25, S26, S25, S24, S23, S22	3 / 4
★★★	Why balancing of rotating parts is necessary, especially for high-speed machines; effects of unbalance.	W25, W23, W22, S22	3 / 4
★★★	Balancing of V-engines; derive secondary unbalanced force; primary force magnitude and direction.	W23, W22, S24, S26	4 / 7
★★★	Primary and secondary unbalanced forces – compare; imaginary crank; partial balancing of primary force; why only part of reciprocating force is balanced.	W24, W22, S26, S24, S22	3 / 4 / 7
★★	Locomotive terms: tractive force variation, swaying couple, hammer blow (derive).	W25, W24, W23, S23	3 / 4 / 7
★★	Balancing of inline engines – procedure.	S25, S23	4 / 7
★	Why leading and trailing wheels of locomotive are coupled (S25); criteria for reference plane (S24); several masses in same plane (S22); three masses in different planes (S25).	S25, S24, S22	3 / 4

Numerical: see Rank 4 and Rank 10.

Chapter 4 – Gyroscope (about 4 hrs)

Priority	Question	Asked in	Marks
★★★	Derive gyroscopic couple formula $C = I\omega\omega_p$.	S23, S22	3 / 4
★★★	Effect of gyroscopic couple on ship during steering, pitching and rolling; define steering, pitching, rolling.	W25, W22, S23	3 / 4
★★	Effect on aeroplane while taking a turn (nose up / down).	W23, W22, S25	4
★★	Active and reactive gyroscopic couple; define axis of spin, plane of precession, axis of gyroscopic reaction.	W25, W23	3 / 4
★★	Effect of gyroscopic couple on stability of two-wheeler and on four wheels of vehicle on a curve.	S26, S22, S23	3 / 7

Numerical: see Rank 2 (ship turbine, aeroplane, four-wheeler).

Chapter 5 – Free and Damped Free Vibrations (about 9 hrs) – biggest chapter

Priority	Question	Asked in	Marks
★★★	Define natural frequency, damping, free / forced vibration, resonance, period, cycle, frequency.	W25, W24, W23, W22, S25, S23, S22	3 / 4
★★★	Logarithmic decrement – define, derive expression, use.	W25, W24, W22, S26, S22, S24	3 / 4
★★★	Under-damped, critically damped, over-damped systems – compare curves; derive equation for critically damped system.	W25, W24, W22, S25, S24, S23	3 / 4
★★	Types of vibration – longitudinal, transverse, torsional (with sketches).	W25, W24, W22, S24	3 / 4
★★	Methods to find natural frequency – energy method, Rayleigh's method.	W25, W24, S24	3 / 4
★★	Types of damping / ways of providing damping; dry friction damping.	W23, W22, S25, S23	3 / 4
★★	Torsionally equivalent shaft; torsional vibration of one, two and three rotor systems.	W22, W23, S23, S22	4 / 7
★	Effect of inertia of shaft (W24); causes and effects of vibration (W25).	W24, W25	3

Numerical: see Ranks 1, 6 and 9.

Chapter 6 – Forced Damped Vibrations (about 7 hrs)

Priority	Question	Asked in	Marks
★★★	Vibration isolation and force transmissibility; transmissibility curve with regions of control.	W23, W22, S26, S25, S23, S22	3 / 4
★★★	Magnification factor (dynamic magnifier) – define, expression, role; frequency ratio.	W25, W24, W22, S25, S24, S23, S22	3 / 4
★★	Forced vibration due to rotating unbalance; vector / graphical representation of forced damped vibration; effect of damping on amplitude.	W24, W22, S26, S24, S22	3 / 4 / 7
★	Materials used for isolation and their uses.	W23	4

Numerical: see Rank 7.

Chapter 7 – Critical Speeds of Shafts (about 4 hrs)

Priority	Question	Asked in	Marks
★★★	Derive critical (whirling) speed of shaft with single rotor, without damping.	W25, W23, W22, S25	4 / 7
★★	Explain whirling speed; prove whirling speed = natural frequency of transverse vibration.	W25, W23, S24	3 / 7
★★	Dunkerley's method – derive / demonstrate for several loads.	W25, S24	4 / 7
★	Effect of damping on critical speed; safety near critical speed; design changes to avoid resonance (S26); half-frequency whirl (W25); why soldiers break step on bridges (S25).	S26, W25, S25	3 / 4 / 7

Numerical: see Rank 3.

Chapter 8 – Vibration Monitoring and Analysis (about 5 hrs) – new in syllabus

Priority	Question	Asked in	Marks
★★	Vibrometer and accelerometer – working principle with sketch; classify vibration measuring instruments.	S22, S25, W22, S23	3 / 4
★	Measurement of displacement and velocity of vibrating body.	W23, S25	3 / 4

Also prepare short answers (new syllabus, not yet asked): condition monitoring, sensors and data acquisition, FFT / frequency-domain analysis, time-domain analysis, vibration signatures for faults.

4. Repeated questions – do these exact questions first

- Four masses A, B, C, D (200, 300, 400, 200 kg) balancing in planes X and Y – **W25 and W22**
- Turning moment diagram with areas +52, –124, +92, –140, +85, –72, +107 – **W25 and S22**
- Punching press, 750 holes/hour, 14000 Nm – **W23 and S25**
- Spring 350 N/m, mass 0.35 kg, damping 14 Ns/m – **W24 and S26**
- Mass 30 kg, k = 20 kN/m, damping factor 0.25 – **W24 and S26**
- Slider-crank 150 mm / 600 mm, 60°, 450 rpm – **S23 and S22**
- Rotating unbalance 525 N at 6000 rpm, damping factor 0.3 – **S25 and S23**
- Cantilever shaft 50 mm dia, 300 mm long, 100 kg disc – **W25 and S24**
- Aeroplane half circle (50 m or 60 m radius) – **W25 and S26**
- Ship turbine rotor (steering, pitching, rolling) – appears almost every year with new numbers.

5. Suggested order for last-minute preparation

1. Numerical Ranks 1 to 5 (damped vibration, gyroscope, critical speed, balancing in planes, flywheel) – about 25 to 30 marks.
2. All ★★★ theory in Chapters 3, 4, 5, 6 (3 and 4 mark answers).
3. Numerical Ranks 6, 7, 8.
4. ★★ theory, then Chapter 8 short notes.
5. Remaining numericals (torsional, locomotive, multi-cylinder).