# GUJARAT TECHNOLOGICAL UNIVERSITY

**Program Name: Bachelor of Engineering**
**Level: UG**
**Branch: Mechanical Engineering, Automobile Engineering**
**Subject Code: BE05000301**
**Subject Name: Dynamics of Machinery**

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|---|---|
| w. e. f. Academic Year: | 2024-25 |
| Semester: | 5 |
| Category of the Course: | Professional Core Course |

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|---|---|
| **Prerequisite:** | • Basic knowledge of Engineering Mechanics<br>• Fundamentals of Theory of Machines (velocity & acceleration analysis)<br>• Elementary Strength of Materials (stiffness, elasticity)<br>• Engineering Mathematics (differential equations) |
| **Rationale:** | This course helps students understand the dynamic behavior of machines, including forces, vibrations, and stability. It enables analysis and control of unbalance, resonance, and vibrations, leading to safer, more efficient mechanical system design. It also forms a foundation for advanced areas like rotor dynamics, Noise Vibration and Harshness (NVH), and simulation-based design. |

**Course Outcomes:**

| Sr. No. | CO statement | Marks% weightage |
|---|---|---|
| CO-1 | Apply principles of dynamic force analysis for mechanisms, flywheels and reciprocating systems used in mechanical engineering applications. | 20 |
| CO-2 | Analyze and solve balancing problems related to rotating and reciprocating masses, multi-cylinder engines and linkages. | 20 |
| CO-3 | Evaluate gyroscopic effects and stability characteristics of automobiles, ships, aircraft and rotating systems. | 10 |
| CO-4 | Analyze free, damped and forced vibration behavior of mechanical systems, including torsional vibrations and critical speeds of shafts. | 35 |
| CO-5 | Apply vibration measurement, monitoring and signal analysis techniques in time, frequency and time-frequency domains for machinery condition monitoring and fault diagnosis. | 15 |

**Teaching and Examination Scheme:**

| Teaching / Learning Scheme (in Hours per semester) | | | | | Total Credits | Assessment Pattern and Marks | | | | | Total Marks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Theory | | Tutorial / Practical | | | |
| L | T | P | PBL | Total no of hours per semester | | ESE (E) | PA / CA (M) | PA/CA (I) | PBL (I) | ESE (V) | |
| 45 | 00 | 30 | 15 | 90 | 03 | 70 | 30 | 20 | 30 | 50 | 200 |

**** Problem-Based Learning (PBL) aims to accommodate learning beyond syllabus as per clause 9.4 of NBA manual.***

**Content:**

| Sr. No. | Topics and contents | Total Hrs. |
|---|---|---|
| 1 | **Dynamic force analysis of mechanisms:** Introduction, D'Alembert's principle, equivalent offset inertia force, dynamic analysis of four bar mechanism, dynamic analysis of slider crank mechanism, velocity & acceleration of piston, angular velocity & angular acceleration of connecting rod, engine force analysis, dynamically equivalent system, inertia forces in reciprocating engines. | **05** |
| 2 | **Turning moment diagrams and flywheel**: Turning moment diagrams for IC engines, fluctuation of energy and speed, coefficient of fluctuation, energy storage in flywheel, dimensions of flywheel rim, flywheel applications in punching presses. | **03** |
| 3 | **Balancing of rotating and reciprocating systems:** Static and dynamic balancing, balancing of several masses rotating in same and different planes, balancing of reciprocating masses, balancing of locomotives, effects of partial balancing in locomotives, secondary balancing, balancing of inline engines, balancing of 'V'-engines, balancing of radial engines, balancing machines. | **08** |
| 4 | **Gyroscope:** Angular velocity, angular acceleration, gyroscopic couple and torque, gyroscopic effects on ships, aircraft, stability of automobiles, stability of two-wheel vehicle. | **04** |
| 5 | **Free vibrations and damped free vibrations:** Types and elements of vibration systems, different methods of deriving equations of motion, free undamped vibrations, spring mass systems, equivalent stiffness, viscous damping, damping factor, under damped system, critically damped system, over damped system, logarithmic decrement, torsional vibrations - free torsional vibration of a two and three rotor system, torsionally equivalent shaft and geared system vibrations. | **09** |
| 6 | **Forced damped vibrations:** Analytical solution of forced damped vibration, vector representation of forced vibrations, Magnification factor, Frequency Response Functions (FRFs), force and motion transmissibility, forced vibration with rotating and reciprocating unbalance, forced vibration due to excitation of support. | **07** |
| 7 | **Critical speeds of shafts:** Critical speed of shaft carrying single rotor and having no damping, Critical speed of shaft carrying single rotor and having damping, secondary critical speeds in horizontal shafts, critical speed of shaft having multiple rotors. | **04** |
| 8 | **Vibration Monitoring and Analysis:** Condition monitoring, vibration measurement instruments and sensors, data acquisition systems, signal conditioning, time domain analysis, frequency domain analysis using FFT, spectrum and orbit analysis, time-frequency domain analysis using STFT and Wavelet Transform, vibration signatures for machinery fault diagnosis. | **05** |
| | **Total** | **45** |

**Suggested Specification table with Marks (Theory):**

| Distribution of Theory Marks | | | | | |
|---|---|---|---|---|---|
| R Level | U Level | A Level | N Level | E Level | C Level |
| **08** | **17** | **50** | **15** | **05** | **05** |

**R: Remembrance; U: Understanding; A: Application, N: Analyze and E: Evaluate C: Create and above Levels (Revised Bloom's Taxonomy)**

Note: This specification table shall be treated as a general guideline for students and teachers. The actual distribution of marks in the question paper may vary slightly from above table.

**The syllabus of Dynamics of Machinery directly contributes to the following Sustainable Development Goals (SDGs):**

| SDG No. | SDG Title | Relevance to Course |
|---|---|---|
| SDG 7 | Affordable and Clean Energy | Efficient machine design, reduced energy loss due to vibrations and unbalance |
| SDG 8 | Decent Work and Economic Growth | Reliable and safe machinery improves industrial productivity and reduces failures |
| SDG 9 | Industry, Innovation and Infrastructure | Core alignment with mechanical system design, rotor dynamics, and advanced analysis |
| SDG 11 | Sustainable Cities and Communities | Noise and vibration control in urban infrastructure and transport systems |
| SDG 12 | Responsible Consumption and Production | Minimizing material failure, extending machine life, reducing maintenance and waste |
| SDG 13 | Climate Action | Energy-efficient and low-emission mechanical systems through better dynamic design |

**Reference Books:**

| Sr. No. | Title | Author(s) | Latest Edition | Publisher |
|---|---|---|---|---|
| 1 | *Theory of Machines* | S. S. Rattan | Latest Ed. | Tata McGraw-Hill |
| 2 | *Theory of Machines* | R. K. Bansal | Latest Ed. | Laxmi Publications |
| 3 | *Theory of Machines* | R. S. Khurmi & J. K. Gupta | Latest Ed. | S. Chand |
| 4 | *Theory of Machines: Kinematics and Dynamics* | Sadhu Singh | 3rd Ed. (2012) | Pearson India |
| 5 | *Dynamics of Machines* | Sadhu Singh | Reprint 2026 | S. K. Kataria & Sons |

| Sr. No. | Title | Author(s) | Latest Edition | Publisher |
|---|---|---|---|---|
| 6 | *Dynamics of Machines* | J. B. K. Das | Latest Ed. | Pearson / Cengage India |
| 7 | *Dynamics of Machines* | Anup Goel | Latest Ed. | Technical Publications |
| 8 | *Mechanical Vibrations* | Debabrata Nag | Latest Ed. | Wiley India |

**List of Experiments: (at least ten experiments from the following list should be performed)**

1. Static balancing of rotating masses.
2. Dynamic balancing of rotating masses in single plane.
3. Dynamic balancing of rotating masses in multiple planes.
4. Study of gyroscopic effect and determination of gyroscopic couple.
5. Determination of natural frequency of single degree of freedom (SDOF) system.
6. Study of free vibration of spring-mass system.
7. Determination of damping coefficient using logarithmic decrement method.
8. Study of damped free vibration characteristics.
9. Study of forced vibration and resonance in SDOF system.
10. Determination of transmissibility ratio for vibration isolation system.
11. Whirling of shaft experiment to determine critical speed.
12. Determination of natural frequency of torsional vibration system.
13. Vibration measurement using accelerometer/vibrometer.
14. Modal analysis of a beam using simulation software (ANSYS/MATLAB).
15. Harmonic response analysis of a mechanical system using simulation tools.

**Major Equipment:**

The laboratory shall be equipped with a Universal Vibration Apparatus capable of performing experiments on single and multi-degree of freedom systems, including free, damped, and forced vibrations, resonance, and transmissibility studies and for torsional system analysis. In addition, the lab should include a static and dynamic balancing machine for single and multi-plane balancing, a gyroscope apparatus to study gyroscopic effects, a whirling of shaft apparatus for determination of critical speeds. For measurement and analysis, a vibration measurement system consisting of accelerometers, displacement sensors, and an FFT analyzer along with a data acquisition (DAQ) system for real-time signal processing is optional. The laboratory may also be supported by computer systems equipped with simulation software such as ANSYS and MATLAB for numerical and validation studies. Optionally, advanced facilities like a rotor dynamics test rig, impact hammer modal testing setup, and non-contact measurement systems such as laser displacement sensors may be included to enhance research and analysis capabilities.

**List of Open-Source Software/learning website:**

1. OpenModelica – Modeling and simulation of dynamic systems
2. Scilab – Numerical computing and vibration analysis
3. Code_Aster – Finite element analysis for structural dynamics
4. CalculiX – Structural and thermal simulation

5. SALOME – Pre- and post-processing platform for simulations
6. Elmer FEM – Multiphysics and vibration analysis
7. Siconos – Simulation of mechanical systems with impacts and friction
8. OpenTorsion – Torsional vibration analysis
9. k-Wave – Acoustic and wave propagation simulation
10. FreeCAD – CAD modeling with basic simulation capability

**Open-Source Learning Websites / Platforms**

1. NPTEL – Online courses on Theory of Machines, Vibrations
2. SWAYAM – Government of India online learning platform
3. MIT OpenCourseWare – Free courses on dynamics and vibrations
4. Coursera – Online courses (free audit)
5. edX – Courses from global universities
6. Khan Academy – Basic mathematics and physics concepts
7. YouTube – Educational lectures and experiment demonstrations
8. GitHub – Open-source codes and simulation projects
9. ResearchGate – Research papers and technical resources
10. Coursera Project Network – Hands-on guided projects

**List of Relevant Indian Standards (IS Codes):**

Faculty members are required to give introduction about various Indian standards related to the course of Dynamics of Machinery during theory and/or practical sessions. Students may be asked to prepare a report on one or more related Indian standards under PBL.

1. IS 2974 (Part 1–5) – Code of practice for design and construction of machine foundations
2. IS 12075 – Mechanical vibration of rotating and reciprocating machinery – Requirements
3. IS 4729 – Methods for measurement of vibration in rotating electrical machines
4. IS 13364 (Part 1 & 2) – Mechanical vibration – Evaluation of machine vibration by measurements on non-rotating parts
5. IS 13573 – Mechanical vibration of machines with operating speeds from 10 to 200 rev/s
6. IS 14280 – Balancing of rotating rigid bodies – Vocabulary and procedures
7. IS 14386 – Mechanical vibration – Balancing – General guidelines
8. IS 15336 – Mechanical vibration and shock – Evaluation of human exposure to whole-body vibration
9. IS 15999 (Part 1 & 2) – Mechanical vibration – Measurement and evaluation of vibration of machines
10. IS 14817 – Mechanical vibration – Rotordynamics terminology and analysis

**List of suggested activities for Problem-based Learning (PBL):**

| Sr. No. | PBL category | Name of the activity | No. of hours | Evaluation Criteria |
|---|---|---|---|---|
| 1. | Complex Problem-Solving targeting relevant SDGs / Mini Project | Mini Project | 10h for a mini project report and presentation. | Based on the novelty of project, technical understanding, report quality and presentation |
| 2. | Case Study Analysis / Seminar | Seminar | 5h for a seminar report and presentation. | Based on the quality of report and presentation, technical understanding |

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|---|---|---|---|---|
| 3. | Micro project | Micro project | 5h for a micro project report and demonstration. | Based on the novelty of project, technical understanding, quality of report and demonstration |
| 4. | Industry/Research laboratory visit | Industry/Research laboratory visit | Visit = 5h,<br>Report preparation = 5h<br>Total = 10h | Based on report submitted. Report should contain observations and calculations based on industry/ lab data. |
| 5. | Video Based Learning | Technical video-based learning related to the subject | Duration of video = 5h<br>Report preparation = 5h<br>Total = 10h | Report /presentation based on the video learning outcomes. |
| 6. | Assignment / Technical Writing / Research Writing | Assignment writing. Numerical based assignment is preferable. | 5 assignments of 4 h each<br>Total = 20h | Based on the correctness of submitted assignment |
| 7. | Group Discussion / Quiz / Simulation | Problem solving/Coding using C, C++, MATLAB, Python, SCILAB, modeling and Analysis software or any other software | 5 small coding-based assignment of 2h each<br>Total = 10h | Based on the coding solution submitted. |
| 8. | Video Based Learning | Self-learning online course | Minimum duration of the course should be 10h | Examination based assessment at the end of course. Based on the certificate produced. |
| 9. | Complex Problem-Solving targeting relevant SDGs / Mini Project | Identification and solution of Complex problem | Maximum 2 problems.<br>Study of the problem and solution finding,<br>Total = 10h | Based on the depth of the solution submitted. |
| 10. | Video Based Learning | Videos on Industrial safety/Disaster Management aspects based on subject | Duration of video = 5h<br>Report preparation = 5h<br>Total = 10h | Based on quiz/report submitted |
| 11. | Research Paper Review / Analysis | Technical paper reading and summarization of research papers based on relevant subject | 5 research papers = 20h | Summarize research paper and evaluation critical parameters |
| 12. | Poster / Chart / PowerPoint presentation | Poster/chart/power point preparation on technical topics | Duration = 6h | Based on poster/chart preparation and presentation skills |
| 13. | Industry/Research laboratory visit | Industrial exposure for 2-3 days to observe and provide tentative solutions on society/environment/health/sustainability/any other issue | Duration = 15h for industrial exposure<br><br>Problem identification and tentative solution = 10h<br>Total = 20h | Based on evaluation of critical problems and solutions |
| 14. | Group Discussion / Quiz / Simulation | Group Discussion on emerging/trending technical topics based on subject | Duration = 1h – 3h per topic | Based on performance in group discussion, technical depth, knowledge etc. |

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|---|---|---|---|---|
| 15. | Case Study Analysis / Seminar | Real world case studies-based learning | Duration of data collection/study = 5h<br>Report preparation = 5h<br>Total = 10h | Based on in-depth study, technical depth, data collected, fact finding, etc. |
| 16. | Group Discussion / Quiz / Simulation | Application/Software development | Duration = 10h | Depending on the complexity of the Application/Software |
| 17. | Assignment / Technical Writing / Research Writing | Research paper publication | Duration = 10h | Based on submission of proof of publication |
| 18. | Micro project | Upgradation/Reverse engineering studies of existing equipment of the laboratory | Duration 10h | Based on the performance of the equipment |
| 19. | Industry/Research laboratory visit | Expert lecture/session | Duration 3h<br>For attending the lecture/session– 2h and for report writing 1h | Based on the proof of attendance<br>and report submitted |
| 20. | Video Based Learning | Annotated Video Explanation of Concept/Problem | 10h (Preparation + Recording + Submission) | Based on accuracy of explanation, clarity, and presentation style. |
| 21. | Assignment / Technical Writing / Research Writing | Patent Search and Innovation Gap Identification | 10h (Search + Report) | Based on number of relevant patents analyzed and identification of innovation scope. |
| 22. | Assignment / Technical Writing / Research Writing | Preparation of a report on Indian Standard(s) | 10h (study of Indian Standard(s) + report | Based on report quality and understanding of the relevant Indian Standard(s). |

Note:

1. In alignment with Outcome-Based Education (OBE) and NBA accreditation requirements, the subject Dynamics of Machinery compulsorily incorporates Micro Project 5 Marks and Seminar – 10 Marks as PBL activities.
   These activities are incorporated as integral Project-Based Learning (PBL) components. These activities are designed to foster experiential learning, encourage innovation, and strengthen problem-solving skills by engaging students in practical applications of power converter design, simulation, and analysis. The inclusion of PBL ensures that learners develop higher-order cognitive abilities mapped to Bloom's taxonomy, while simultaneously enhancing teamwork, communication, and research competencies essential for professional engineering practice.
2. The hours allocated to specific activities should be proportionate to the total no. of PBL hours and marks.
3. All the suggested activity should be related to the subject.
4. The number of hours is suggestive. Faculty can sub-divide the number of hours based on the activity. However, total number of hours is fixed.
5. Rubrics for the evaluation can be prepared by the faculty.
6. Subject teacher can add the relevant activities other than those listed above, with the consent of head of the department and DQAC.

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