Bharath

INSTITUTE OF HIGHER EDUCATION AND RESEARCH

Declared as **Deemed-to-be-University** u/s 3 of the UGC Act, 1956

B.Tech Civil Engineering

U20PYBJ02 – Mechanics and Mechanics of Solids

Course File

School of Civil and Infrastructure Engineering

Vision and Mission of the Department

Vision

The Department of Civil Engineering is striving to become as a world class academic centre for quality education and research in diverse areas of civil engineering, with a strong social commitment.

Mission

Mission of the department is to achieve international recognition by:

M1: Producing highly competent and technologically capable professionals.

M2: Providing quality education in undergraduate and post graduate levels, with strong emphasis on professional ethics and social commitment.

M3: Developing a scholastic environment for the state – of –art research, resulting in practical applications.

M4: Undertaking professional consultancy services in specialized areas of civil engineering.

Program Educational Objectives (PEOs)

PEO1: PREPARATION

Civil Engineering Graduates are in position with the knowledge of Basic Sciences in general and Civil Engineering in particular so as to impart the necessary skill to analyze, synthesize and design civil engineering structures.

PEO2: CORE COMPETENCE

Civil Engineering Graduates have competence to provide technical knowledge, skill and also to identify, comprehend and solve problems in industry, research and academics, related to recent developments in civil and environmental engineering.

PEO3: PROFESSIONALISM

Civil Engineering Graduates are successfully work in various Industrial and Government organizations, both at the National and International level, with professional competence and ethical administrative insight so as to be able to handle critical situations and meet deadlines.

PEO4: SKILL

Civil Engineering Graduates have better opportunity to become a future researchers/ scientists with good communication skills so that they may be both good team-members and leaders with innovative ideas for a sustainable development.

PEO5: ETHICS

Civil Engineering Graduates are framed to improve their technical and intellectual capabilities through life-long learning process with ethical feeling so as to become good teachers, either in a class or to juniors in industry.

PROGRAMME OUTCOMES (POs)

On completion of B.Tech in Civil Engineering Programme, Graduates will have to

1) **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex civil engineering problems

2) **Design/Development of Solutions:** Design solutions for complex civil engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

3) **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

4) **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

5) **Problem analysis:** Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

6) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

7) **Communication:** Communicate effectively on complex engineering activities with the engineering community and with t h e society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

8) **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

9) **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

10) **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

11) **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

12) **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

Bharath INSTITUTE OF HIGHER EDUCATION AND RESEARCH
(Declared as Deemed - to - be - University under section 3 of UGC Act 1956)

COURSE FILE

FACULTY	**Dr. K.THIRUNAVUKKARASU**	**FACULTY DEPT**	**PHYSICS**
SUBJECT	**MECHANICS AND MECHANICS OF SOLIDS**	**SUBJECT CODE**	**U20PYBJ02**
YEAR	**2022 - 2023**	**SEMESTER**	**ODD**
DEG &BRANCH	**B.TECH (CIVIL/ MECH/ MECHATRONICS/ AM)**	**DURATION**	**90 Hours**

SL.NO	**DETAILS IN COURSE FILE**	**REMARKS**
1.	LEARNING OUTCOMES	✓
2.	LESSON PLAN	✓
3.	CO-PO MAPPING	✓
4.	INDIVIDUAL TIME TABLE	✓
5.	SYLLABUS WITH COURSE OUTCOMES	✓
6.	LECTURE NOTES (FOR ALL UNITS)	✓
7.	CLA I - QUESTION PAPER	✓
8.	CLA I - KEY	✓
9.	CLA I – SAMPLE ANSWER SHEETS	✓
10.	CLA II - QUESTION PAPER	✓
11.	CLA II - KEY	✓
12.	CLA II - SAMPLE ANSWER SHEETS	✓
13.	CLA III - QUESTION PAPER	✓
14.	CLA III - KEY	✓
15.	CLA III - SAMPLE ANSWER SHEETS	✓
16.	ASSIGNMENT QUESTIONS	✓
17.	SAMPLE ASSIGNMENTS	✓
18.	END SEMESTER QUESTION PAPER	✓
19.	END SEMESTER ANSWER KEY	✓
20.	TEXT BOOK AND REFERENCE BOOK	✓
21.	QUESTION BANK	✓
22.	STUDENT PERFORMANCE RECORD	✓
23.	STUDENT ATTENDANCE RECORD	✓
24.	COURSE END SURVEY	✓
25.	CO ATTAINMENT	✓

Course Coordinator

HOD

SCHOOL OF BASIC SCIENCES

DEPARTMENT OF PHYSICS

LEARNING OUTCOMES

Course Name: Mechanics and Mechanics of Solids
Course Code: **U20PYBJ02**

The learning of Mechanics and Mechanics of Solids helps the:

- The mechanics of rigid bodies is primarily concerned with the static and dynamic behaviour under external forces of engineering components and systems. Students can be able to understand the characteristics of materials and their interactions.
- Students can apply the principles of electrostatics to the solutions of problems relating to electric forces
- Students can solve the forces and motions associated with particles and rigid bodies
- Students can understand the basic principles of geometry of the components .

R. S. Lavan

1. Lesson Plan-MMOS- 21-22

S.No	Topic	CO	Reference	Teaching Tool	Proposed date	Completed date	Bloom's Taxonomy level
UNIT I							
1	Introduction to vector analysis	CO1	R1	T1	10.10.2022	10.10.2022	1
2	Scalar quantities and vector quantities	CO1	R1	T1	11.10.2022	11.10.2022	1
3	Transformation of scalars and vectors under rotational transformation	CO1	R1	T1	12.10.2022	14.10.2022	2
4	Newton's law and Invariance of Newton's second law	CO1	R1	T1, T4	13.10.2022	17.10.2022	2
5	Solving Newton's equations of motion in polar coordinates	CO1	R1	T1	14.10.2022	18.10.2022	2
6	Fundamentals of simple harmonic motion	CO1	R1	T1	17.10.2022	19.10.2022	1
7	Harmonic oscillator	CO1	R1	T1	18.10.2022	21.10.2022	2
8	Damped harmonic motion	CO1	R1	T1	19.10.2022	26.10.2022	2
9	Different cases over critically and lightly damped oscillators	CO1	R1	T1	20.10.2022	27.10.2022	2
10	Fundamentals of Vibrations	CO1	R1	T1	21.10.2022	28.10.2022	1
11	Vibration model	CO1	R1	T1	26.10.2022	29.10.2022	2
12	Forced oscillations and Magnification factor of forced oscillations	CO1	R1	T1	22.10.2022	30.10.2022	2
13	Resonance and Application of Resonance	CO1	R1	T1	23.10.2022	30.10.2022	2
14	Numerical problems related to oscillations and resonance	CO1	R1	T1	24.10.2022	31.10.2022	2
UNIT-II							
15	Definition and motion of a rigid body in the plane - Rotation in the plane	CO2	R1	T1	28. 10.2022	31. 10.2022	2
16	Kinematics in a coordinate system rotating and translating in the plane	CO2	R1	T1	01.11.2022	02.11.2022	3
17	Angular momentum about a point of a rigid body in planar motion	CO2	R1	T1	03.11.2022	04.11.2022	2
18	Describing rigid body motion	CO2	R1	T1	07. 11.2022	08. 11.2022	1
19	Euler's laws of motion and Independence of Euler's law from Newton's laws	CO2	R1	T1	09. 11.2022	09. 11.2022	2

20	Precession of a body and a spinning top	CO2	R1	T1	11. 11.2022	10. 11.2022	3
21	Introduction to three-dimensional rigid body motion	CO2	R1	T1	28. 10.2022	11. 11.2022	2
22	Distinction from two-dimensional motion in terms of angular velocity vector, its rate of change	CO2	R1	T1	29. 10.2022	11. 11.2022	2
23	Two dimensional motion in terms of moment of inertia tensor	CO2	R1	T1	30. 10.2022	12 11.2022	2
24	Three dimensional motion of a rigid body in coplanar manner	CO2	R1	T1	02. 11.2022	13. 11.2022	3
25	Rod executing conical motion with center of mass fixed	CO2	R1	T1	04. 11.2022	13. 11.2022	3
26	Failure of two-dimensional formulation	CO2	R1	T1	06. 11.2022	14. 11.2022	2
UNIT III							
27	Introduction to rigid body -	CO3	R2	T1	07. 11.2022	15. 11.2022	1
28	Free body diagrams with examples	CO3	R2	T4	08. 11.2022	16. 11.2022	3
29	Examples on modeling of typical supports and joints	CO3	R2	T1	09. 11.2022	17. 11.2022	3
30	Equilibrium of a rigid body in two dimensions and its conditions	CO3	R2	T1	10. 11.2022	18. 11.2022	2
31	Equilibrium of a rigid body in three dimensions and its conditions	CO3	R2	T1	11. 11.2022	15. 11.2022	2
32	Friction –limiting cases	CO3	R2	T1	11. 11.2022	16. 11.2022	2
33	Friction – non-limiting cases	CO3	R2	T1	12 11.2022	21. 11.2022	2
34	Force-displacement relationship	CO3	R2	T1	12 11.2022	22. 11.2022	2
35	Illustration of Force-displacement	CO3	R2	T1	13. 11.2022	23. 11.2022	3
36	Geometric compatibility of small deformations	CO3	R2	T1	14. 11.2022	24. 11.2022	3
37	Illustrations based on axially loaded members	CO3	R2	T1	16. 11.2022	25. 11.2022	3
38	Introduction to trusses	CO4	R2, R5	T1	18. 11.2022	28. 11.2022	1
39	Types of trusses	CO4	R2, R5	T1	20 11.2022	29. 11.2022	2
40	Method of joints and Method of section	CO4	R2, R5	T1	23 11.2022	30. 11.2022	3
UNIT IV							
41	Concept of stress at a point – plane stress	CO5	R2, R5	T1	24 11.2022	01.12.2022	2

42	Transformation of stress at a point	CO5	R2, R5	T1	25 11.2022	02. 12.2022	4
43	Principle stresses	CO5	R2, R5	T1	26. 11.2022	05. 12.2022	1
44	Mohr's circle-stress and Displacement field	CO5	R2, R5	T1	26. 11.2022	01.12.2022	2
45	Concept of strain at a point – plane strain	CO5	R2, R5	T1	27. 11.2022	02. 12.2022	2
46	Transformation of strain at a point	CO5	R2, R5	T1	29. 11.2022	05. 12.2022	4
47	Principle strains	CO5	R2, R5	T1	30. 11.2022	06. 12.2022	1
48	Mohr's circle-strain	CO5	R2, R5	T1	01. 12.2022	07. 12.2022	4
49	Rosette concepts of elasticity and plasticity	CO4	R2, R5	T1	02. 12.2022	08. 12.2022	2
50	Strain hardening and work hardening	CO4	R2, R5	T1	03. 12.2022	09. 12.2022	2
51	Concepts of fracture and yielding	CO4	R2, R5	T1	04. 12.2022	12. 12.2022	2
52	Idealization of one dimensional stress-strain curve	CO5	R2, R5	T4	05. 12.2022	11. 12.2022	4
53	Generalized Hooke's law with thermal strains for isotropic materials	CO4	R2, R5	T1	06. 12.2022	12. 12.2022	4
UNIT V							
56	Force analysis – axial force and shear force	CO4	R2, R3	T1	08. 12.2022	19. 12.2022	2
57	Bending moment and twisting moment diagrams of slender members	CO4	R2, R3	T1	10. 12.2022	20. 12.2022	3
58	Torsion of Circular shafts	CO4	R2, R3	T1	12. 12.2022	21. 12.2022	2
59	Definition torsion and effects of torsion	CO4	R2, R3	T1	14. 12.2022	22. 12.2022	2
60	Generation of shear stresses	CO5	R2, R4	T1	16. 12.2022	23. 12.2022	2
61	Torsion of thin walled tubes, Shear test by torsion of tube	CO5	R2, R4	T1	18. 12.2022	26. 12.2022	3
62	Moment curvature relation in pure bending of beams with symmetric cross-section	CO5	R2, R4	T1	20. 12.2022	27. 12.2022	3
63	Bending stress and shear stress-Cases of combined stresses	CO5	R2, R4	T1	23. 12.2022	28. 12.2022	3
64	Concept of strain energy – yield criteria	CO5	R2, R4	T1	25. 12.2022	29. 12.2022	2
65	Deflection due to bending	CO4	R2, R4	T1	29. 12.2022	30. 12.2022	3
68	Strain energy and complementary strain energy for simple structural	CO4	R2, R4	T4	30. 12.2023	02. 01.2023	2

	elements						
List of Experiments							
69	Determine acceleration due to gravity using Bifilar Pendulum	CO6	R6	T3	20.10.2022	20.10.2022	B
70	Determine rigidity modulus – torsional pendulum	CO3	R6	T3	24.11.2022		B
71	Determine Young's modulus – Uniform bending	CO3	R6	T3	10.11.2022		B
72	Determine Young's modulus – Non-uniform bending	CO3	R6	T3	17.11.2022		B
73	Determine static friction, Sliding friction and Rolling Friction	CO6	R6	T3	15.12.2022		B
74	Measurement of free fall-Dynamics method	CO3	R6	T3	05.01.2023		B
75	Mechanical conversion of Energy – Maxwell's wheel with measure dynamics	CO6	R6	T3	22.12.2022		B
76	Determine moment of inertia and angular acceleration -Gyroscope	CO6	R6	T3	27.10.2022	17.10.2022	B
77	Determine acceleration due to gravity – Compound bar Pendulum	CO6	R6	T3	01.12.2022		B
78	Determine Spring constant-Expansion of helical spring	CO6	R6	T3	08.12.2022		B
79	Newton's 2nd law – Demonstration track with measure dynamics	CO6	R6	T3	12.01.2023		B
80	Determine moment of inertia and angular acceleration with precision pivot bearing	CO6	R6	T3	29.12.2022		B

2. – EMT (2021 - 2022)

Hours	Topic	CO	Reference	Teaching Tool	Proposed Date	Completed Date	Blooms Level
UNIT 1- Electromagnetic wave							
1	Del, divergence, curl and gradient operations in vector calculus	CO1	R1, R2	T1	08.11.21	08.11.21	1
1	Gauss divergence and Stoke's theorem	CO1	R1, R2	T1	09.11.21	09.11.21	1
1	Electric field and electrostatic potential for a charge distribution	CO1	R1, R2	T1,T2	10.11.21	10.11.21	1
1	Gauss's law and its applications	CO1	R1, R2	T1	12.11.21	12.11.21	2
1	Laplace's equations for electrostatic potential	CO1	R1, R2	T1	15.11.21	15.11.21	2

1	Poisson's equations for electrostatic potential	CO1	R1, R2	T1	16.11.21	16.11.21	2
1	Concepts of electric current	CO1	R1, R2	T1,T2	17.11.21	17.11.21	2
1	Laws of magnetism	CO2	R1, R2	T1,T2	19.11.21	19.11.21	2
1	Faraday's law	CO2	R1, R2	T1	22.11.21	22.11.21	2
1	Ampere's law - Maxwell's equations	CO2	R1, R2	T1	23.11.21	23.11.21	2
1	Polarizations, permeability and dielectric constant	CO1	R1, R2	T1	24.11.21	24.11.21	2
1	Polar and non polar dielectrics - Types of polarization - Frequency and temperature dependence of polarization	CO1	R1, R2	T1	26.11.21	26.11.21	2
1	Internal field in Solids	CO1	R1, R2	T1	29.11.21	29.11.21	2
1	Clausius - Mossotti equation	CO1	R1, R2	T1	30.11.21	30.11.21	2
UNIT 2 – Magnetic Materials							
1	Magnetization	CO2	R1, R2	T1,T2	01.12.21	01.12.21	1
	Permeability and Susceptibility						
1	Classification of magnetic materials	CO2	R1, R2	T1	03.12.21	03.12.21	1
1	Concepts of ferromagnetic domains	CO2	R1, R2	T1	06.12.21	06.12.21	1
1	Hard and soft magnetic materials	CO2	R1, R2	T1	07.12.21	07.12.21	1
1	Energy product	CO2	R1, R2	T1	08.12.21	08.12.21	1
1	Ferrimagnetic materials	CO2	R1, R2	T1	10.12.21	10.12.21	3
1	Ferrites	CO2	R1, R2	T1	13.12.21	13.12.21	3
1	Regular spinel and inverse spinel	CO2	R1, R2	T1	14.12.21	14.12.21	3
1	Magnetic bubbles	CO2	R1, R2	T1	15.12.21	15.12.21	3
1	Magnetic thin films	CO2	R1, R2	T1,T2	17.12.21	17.12.21	3

2	Spintronics-GMR-TMR-CMR-Garnets	CO2	R1, R2	T1,T2	20.12.21	20.12.21	3
1	Magnetoplumbites	CO2	R1, R2	T1	21.12.21	21.12.21	4
1	Multiferroicmaterials-Applications of multiferroic materials	CO2	R1, R2	T1	22.12.21	22.12.21	4
UNIT 3 – Quantum Mechanics							
1	Introduction to Quantum mechanics	CO3	R1, R2,R3	T1	24.12.21	24.12.21	1
1	Explanation of wave nature of particles	CO3	R1, R2, R3	T1	27.12.21	27.12.21	1
1	Black body radiation	CO3	R1, R2, R3	T1	28.12.21	28.12.21	2
1	Concept of Photon-Photoelectric effect, Compton effect	CO3	R1, R2, R3	T1	29.12.21	29.12.21	2
1	Physical significance of wavefunction	CO3	R1, R2, R3	T1	31.12.21	31.12.21	2
1	Time independent Schrodinger's wave equation	CO3	R1, R2, R3	T1,T2	03.01.22	03.01.22	2
1	Particle in a 1 D box	CO3	R1, R2, R3	T1,T2	04.01.22	04.01.22	2
1	Normalization	CO3	R1, R2, R3	T1	05.01.22	05.01.22	2
1	Born interpretation of wave function	CO3	R1, R2, R3	T1	07.01.22	07.01.22	3
1	Verification of matter waves	CO3	R1, R2, R3	T1	10.01.22	10.01.22	3
1	Concept of harmonic oscillator	CO3	R1, R2, R3	T1	11.01.22	11.01.22	3
2	Quantum harmonic oscillator	CO3	R1, R2, R3	T1	12.01.22	12.01.22	3
1	Hydrogen atom problem	CO3	R1, R2, R3	T1,T2	18.01.22	18.01.22	3
UNIT 4 – Wave Optics							
1	Introduction to interference	CO4	R1, R2,R4	T1	19.01.22	19.01.22	2
2	Fraunhofer diffraction at single slit	CO4	R1, R2,R4	T1,T2	21.01.22	21.01.22	2

1	Fraunhofer diffraction at double slit	CO4	R1, R2,R4	T1	24.01.22	24.01.22	2
1	Fraunhofer diffraction at multiple slit	CO4	R1, R2,R4	T1	25.01.22	25.01.22	2
1	Diffraction grating	CO4	R1, R2,R4	T1	28.01.22	28.01.22	2
2	Characteristics of diffraction	CO4	R1, R2,R4	T1	31.01.22	31.01.22	2
2	Scattering of light	CO4	R1, R2,R4	T1	01.02.22	01.02.22	1
1	Circular polarization	CO4	R1, R2,R4	T1	02.02.22	02.02.22	3
1	Elliptical polarization	CO4	R1, R2,R4	T1	04.02.22	04.02.22	2
1	Fresner s relation	CO4	R1, R2,R4	T1	07.02.22	07.02.22	2
1	Brewster's angle	CO4	R1, R2,R4	T1	08.02.22	08.02.22	2
UNIT 5 – Laser							
1	Absorption and emission processes	CO5	R1, R2,R4	T1	09.02.22	09.02.22	2
1	Einstein's theory of matter radiation A and B coefficients	CO5	R1, R2,R4	T1	11.02.22	11.02.22	2
1	Characteristics of laser beams	CO5	R1, R2,R4	T1	14.02.22	14.02.22	2
2	Amplification of light by population inversion	CO5	R1, R2,R4	T1	15.02.22	15.02.22	2
2	Threshold population inversion	CO5	R1, R2,R4	T1	16.02.22	16.02.22	2
2	Essential components of laser system and pumping mechanisms	CO5	R1, R2,R4	T1	18.02.22	18.02.22	3
1	Nd: YAG laser	CO5	R1, R2,R4	T1	21.02.22	21.02.22	3
1	Semiconductor laser	CO5	R1, R2,R4	T1	22.02.22	22.02.22	3
1	CO_2 laser: Vibrational modes- CO_2 laser: energy level Optical fiber-physical structure	CO5	R1, R2,R4	T1	23.02.22	23.02.22	2
1	Physical structure-Total internal reflection	CO5	R1, R2,R4	T1	25.02.22	25.02.22	2
1	Optical fibers	CO5	R1, R2,R4	T1	28.02.22	28.02.22	2

LESSON PLAN (LAB)

Hours	Topic	CO	Reference	Teaching Tool	Proposed Date	Completed Date	Blooms Level
LIST OF EXPERIMENTS							
1	Determine wavelength – diffraction grating	CO3	R5	T1, T2	11.11.21	11.11.21	B
2	Determine Particle size using Laser	CO3	R5	T1	18.11.21	18.11.21	B
1	Calibrate Ammeter using Potentiometer	CO6	R5	T1	25.11.21	25.11.21	B
2	Study of I-V characteristics	CO3	R5	T1	25.11.21	25.11.21	B

	of LDR						
2	Determine wavelength of monochromatic light using Newton's ring	CO3	R5	T1, T2	02.12.21	02.12.21	B
1	Calibrate Voltmeter using Potentiometer	CO6	R5	T1	09.12.21	09.12.21	B
1	Determine Laser parameters- divergence and wavelength of a given laser source	CO3	R5	T1	16.12.21	16.12.21	B
2	Study of attenuation and propagation characteristic – optical fiber	CO3	R5	T1	23.12.21	23.12.21	B
2	Determine Planck's Constant	CO6	R5	T1, T2	06.01.22	06.01.22	B
2	Determine Magnetic Susceptibility - Quincke's method	CO6	R5	T1	20.01.22	20.01.22	B
2	Determine dielectric constant of the sample	CO6	R5	T1	20.01.22	20.01.22	B
2	Determine Coulomb's potential and Coulomb's field of metal spheres	CO6	R5	T1	03.02.22	03.02.22	B

REFERENCE CODE	**DESCRIPTION**
R1	David Jeffery Griffiths, Introduction to Electrodynamics, Revised Edition, Pearson 2013
R2	David Halliday, Fundamentals of Physics, 7th edition, John Wiley & Sons Australia, Ltd, 2004
R3	Eisberg and Resnick, Quantum Physics: Of Atoms, Molecules, Solids, Nuclei and Particles, John Wiley & Sons, 2nd Edition, 1985
R4	Ajay Ghatak, Optics, Tata McGraw 11111 Education, 5th Edition, 2012
R5	Physics Lab manual

TYPE CODE	TEACHING TOOL PLANNED
T1	Black Board
T2	Video Presentation
T3	Power Point Presentation
T4	Notes
T5	Models
T6	Tutorial & Problem solving
T7	Simulation/Practical

CO-PO MAPPING

Name of the School	: School of Basic Sciences
Name of the Department	: PHYSICS
Program Name/Code	: B.Tech. (IBT, GE, EEE, ECE, MECH, BME and MECHATRONICS)
Course Name/Code	: ELECTROMAGNETIC THEORY, QUANTUM MECHANICS, WAVE and OPTICS

Course Coordinator details

a. Name/ID : Dr. K.THIRUNAVUKKARASU
b. Designation : ASSOCIATE PROFESSOR
c. Department : Physics

List of POs:

Engineering Graduates will be able to:

PO1: Engineering knowledge: Graduates will demonstrate the ability to use basic knowledge in mathematics, science and engineering and apply them to solve problems specific to mechanical engineering. 3 Assignments and Exams

PO2: Problem analysis: Graduates will demonstrate the ability to design and conduct experiments, interpret and analyze data, and report results. 2 Assignments and Exams

PO3: Design/development of solutions: Graduates will demonstrate the ability to design any mechanical system or thermal that meets desired specifications and requirements. 2 Assignments and Exams

PO4: Conduct investigations of complex problems: Graduates will demonstrate the ability to identify, formulate and solve mechanical engineering problems of a complex kind. 1 Assignments and Exams

PO5: Modern tool usage: Graduates will be familiar with applying software methods and modern computer tools to analyze mechanical engineering problems.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and teamwork: Graduates will demonstrate the ability to function as a coherent unit in multidisciplinary design teams, and deliver results through collaborative research 3 Assignments and Exams

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions. 1 Assignments and Exams

PO11: Project management and finance: Graduate will be able to design a system to meet desired needs within environmental, economic, political, ethical health and safety, manufacturability and

management knowledge and techniques to estimate time, resources to complete project. PO12: Life-long learning: Graduates should be capable of self education and clearly understand the value of life-long learning. 2 Assignments and Exams

List of PSOs:

PSO 1

PSO 2 :

PSO n : ______________________________

CO-PO Mapping

CO No	COURSE OUTCOMES(COs)	Bloom's Taxonomy level
CO1	Identify the principle of Mechanics	2
CO2	Determine the resultants of force systems acting on rigid bodies	3
CO3	Establish and demonstrate the equations of equilibrium for a rigid body	3, B
CO4	Analyze the internal forces in engineering structures composed of simple trusses	4
CO5	Apply the concepts of stress and strain in different bodies	3
CO6	Apply the concepts of mechanics and mechanics of solids in real time applications	B

Mapping / Alignment of Cos with PO & PSO

(H/M/L indicates strength of correlation) H-High, M-Medium, L-Low

1	COs/PO & PSO	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PS O2	PS O3
2	CO1	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO2	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO3	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-
	CO4	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO5	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-
	CO6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Category	**Basics Science (BS)**														

Note: L – Low; M – Medium; H - High

CO-PSO Mapping

CO/PSO	PSO1	PSO2	PSO3
CO1			
CO2			
CO3			
CO4			
CO5			
CO6			

Note: L – Low; M – Medium; H - High

Prepared by	Course Coordinator **Dr. K.THIRUNAVUKKARASU**	Signature
Verified &Forwardedby	HoD **Dr. R. Velavan**	Signature R. Velavan

MECHANICS AND MECHANICS OF SOLIDS- DR. THIRUNAVUKARASU (SEC-L1)

Day/ Period	I 9.00 AM – 9.50 AM	II 9.50 AM – 10.40AM		III 10.50 AM – 11.40 AM	IV 11.40 AM – 12.30 PM		V 1.30 PM – 2.20 PM	VI 2.20 PM – 3.10 PM	VII 3.10 PM – 4.00 PM
MON	MMOS/L1								
TUE			B R	MMOS/L1		L U			
WED			E		MMOS/L1				
THUR			A K	MMOS/L1		N C		MMOS Lab Sec-L1	
FRI						H	MMOS/L1		

COURSE COORDINATOR

HOD

U20PYBJ01	**Mechanics and Mechanics of Solids (For B.Tech –IBT,GE, EEE, ECE, Mech, BME and Mechatronics)**	**L**	**T**	**P**	**C**
	Total contact hours - 90	3	1	2	5
	Prerequisite: +2				
	Course offered by – Department of Physics				
	Data Book/Codes /Standards : Periodic Table				

COURSE OUTCOMES(COs)

CO1	**Describe** the concepts of electrostatics and effects of charge dynamics **(Remember)**
CO2	**Explain the** magnetic and multi ferroic properties **(Apply)**
CO3	**Express** quantum mechanics to basic physical problems **(Understand)**
CO4	**Explain** the propagation of light and geometric optics (**Understand)**
CO5	**Identify** the application of lasers and fibre optics (**Understand)**
CO6	**Apply** the concepts electromagnetic theory and wave optics in real time applications (**Apply**)

Mapping of course outcomes with programme outcomes(POs)

(H/M/L indicates strength of correlation) H-High, M-Medium, L-Low

CO No	**COURSE OUTCOMES(COs)**	**Bloom's Taxonomy level**
CO1	Identify the principle of Mechanics	2
CO2	Determine the resultants of force systems acting on rigid bodies	3
CO3	Establish and demonstrate the equations of equilibrium for a rigid body	3, B
CO4	Analyze the internal forces in engineering structures composed of simple trusses	4
CO5	Apply the concepts of stress and strain in different bodies	3
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Mapping / Alignment of Cos with PO & PSO

(H/M/L indicates strength of correlation) H-High, M-Medium, L-Low

R. S. [illegible]

1	COs/PO & PSO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
2	CO1	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO2	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO3	3	-	-	3	-	-	-	-	-	-	-	-	-	-	-
	CO4	3	3	-	-	-	-	-	-	-	-	-	-	-	-	-
	CO5	3	-	3	-	-	-	-	-	-	-	-	-	-	-	-
	CO6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3	Category	**Basics Science (BS)**														

(Tick mark or level of correlation: 3-High, 2-Medium, 1-Low)

Part B- Content of the Course

1. Course Content

UNIT 1– Oscillations and Vibrations

Introduction to vector analysis-Scalar quantities and vector quantities - Transformation of scalars and vectors under rotational transformation - Newton's law and Invariance of Newton's second law - Solving Newton's equations of motion in polar coordinates - Fundamentals of simple harmonic motion - Harmonic oscillator - Damped harmonic motion - Different cases over critically and lightly damped oscillators - Fundamentals of Vibrations - Vibration model-Forced oscillations and Magnification factor of forced oscillations - Resonance and Application of Resonance**(Contact Hours – 14)**

UNIT 2– Rigid body equilibrium in 1D, 2D and 3D

Definition and motion of a rigid body in the plane - Rotation in the plane - Kinematics in a coordinate system rotating and translating in the plane - Angular momentum about a point of a rigid body in planar motion - Euler's laws of motion and Independence of Euler's law from Newton's laws - Describing rigid body motion - Precession of a body and a spinning top - Introduction to three-dimensional rigid body motion - Distinction from two-dimensional motion in terms of angular velocity vector, its rate of change - Two dimensional motion in terms of moment of inertia tensor - Three dimensional motion of a rigid body in coplanar manner - Rod executing conical motion with centre of mass fixed - Rod executing conical motion in two dimension and three dimension - Failure of two-dimensional formulation.**(Contact Hours – 14)**

UNIT 3– Introduction to Mechanics of solids

Introduction to rigid body - Free body diagrams with examples – Reactions at supports and connections for a two dimensional structure - Examples on modelling of typical supports and joints - Equilibrium of a rigid body in two dimensions – condition for equilibrium in two dimensions - Equilibrium of a rigid body in three dimensions – condition for equilibrium in three dimensions - Friction –limiting cases - Friction – non-limiting cases - Force-displacement relationship –simple illustration of Force-displacement - Geometric compatibility of small deformations - Illustrations based on axially loaded members - Introduction to trusses - Types of trusses - Method of joints and Method of section. **(Contact Hours – 14)**

UNIT 4– Stress and Strain

Concept of stress at a point – plane stress - Transformation of stress at a point – principle stresses - Mohr's circle-stress and Displacement field - Concept of strain at a point – plane strain - Transformation of strain at a point – principle strains - Mohr's circle-strain - Rosette concepts of elasticity and plasticity - Strain hardening and work hardening - Failure of materials - Concepts of fracture and yielding - Idealization of one dimensional stress-strain curve - Generalized Hooke's law with thermal strains for isotropic materials - Characteristics of elasticity - Complete equations of elasticity.

(Contact Hours – 14)

UNIT 5– Properties of solids

Force analysis – axial force and shear force - Bending moment and twisting moment diagrams of slender members- Torsion of Circular shafts - Definition torsion and effects of torsion - Generation of shear stresses - Torsion of thin walled tubes, Shear test by torsion of tube 0- Moment curvature relation in pure bending of beams with symmetric cross-section - Bending stress and shear stress - Cases of combined stresses - Concept of strain energy – yield criteria - Deflection due to bending - Integration of the moment curvature relationship for simple boundary conditions - Integration of the moment curvature relationship for method of superposition- Strain energy and complementary strain energy for simple structural elements. **(Contact Hours – 14)**

Experiments: (Contact Hours - 20)

1. Determine acceleration due to gravity using Bifilar Pendulum
2. Newton's second law – Demonstration track with measure dynamics
3. Determine acceleration due to gravity – Compound bar Pendulum
4. Determine Spring constant-Expansion of helical spring
5. Determine Static friction, Sliding friction and Rolling Friction
6. Determine moment of inertia and angular acceleration with precision pivot bearing
7. Determine moment of inertia and angular acceleration -Gyroscope
8. Measurement of free fall – dynamics method
9. Determine rigidity modulus – torsional pendulum
10. Mechanical conversion of Energy – Maxwell's wheel with measure dynamics
11. Determine Young's modulus – Uniform bending
12. Determine Young's modulus – Non-uniform bending

Learning Resources

i) Mahendra K Verma, Introduction to Mechanics, Universities Press(India) Pvt. Ltd., 2016

ii) E.P. Popov, Engineering mechanics of solids, Pentice Hall India learning Pvt. Ltd, 2nd Edition, 2002

6. Reference Books

iii) J. L. Meriam, Engineering Mechanics-Dynamics, 7th Edition, Vol. 2, Wiley Publishers, 2012

iv) J.P. Den Hartog, Mechanics, Dover Publications Inc., 1961

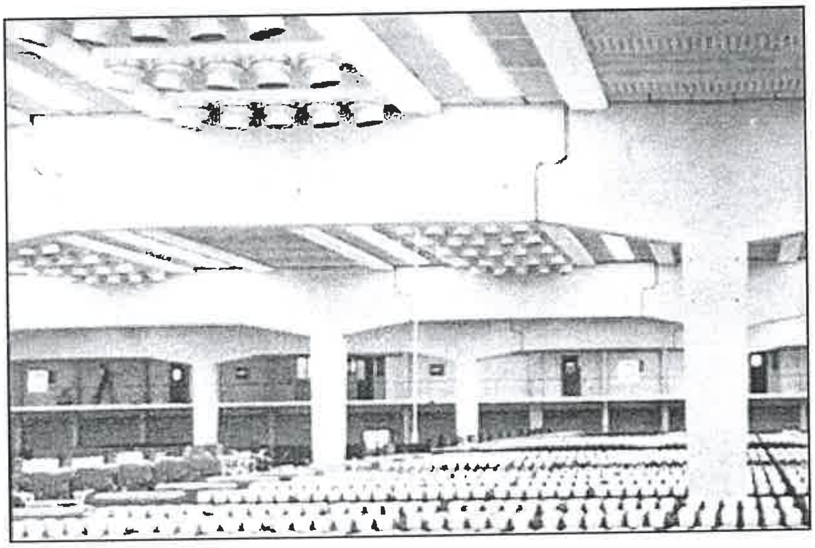
v) Bhavikatti S.S and Rajashekarappa K.G, engineering Mechanics, New age International (P) Limited Publishers (1998).

vi) Kumar K.L, Engineering Mechanics, 3rd Revised edition, Tata McGraw-Hill Publishing Company, New Delhi (2008).

1.

Lecture Notes

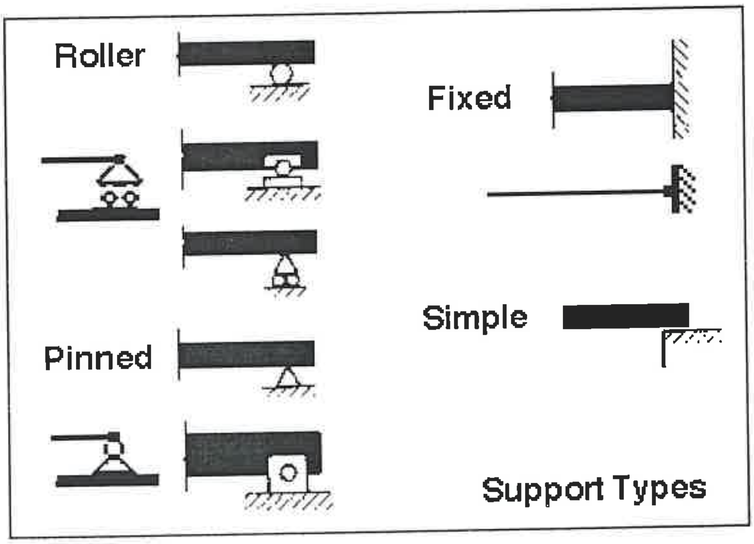
Support and Connection Types



Structural systems transfer their loading through a series of elements to the ground. This is accomplished by designing the joining of the elements at their intersections. Each connection is designed so that it can transfer, or support, a specific type of load or loading condition. In order to be able to analyze a structure, it is first necessary to be clear about the forces that can be resisted, and transfered, at each level of support throughout the structure. The actual behaviour of a support or connection can be quite complicated. So much so, that if all of the various conditions were considered, the design of each support would be a terribly lengthy process. And yet, the conditions at each of the supports greatly influence the behaviour of the elements which make up each structural system.

Structural steel systems have either welded or bolted connections. Precast reinforced concrete systems can be mechanically connected in many ways, while cast-in-place systems normally have monolithic connections. Timber systems are connected by nails, bolts, glue or by engineered connectors. No matter the material, the connection must be designed to have a specific rigidity. Rigid, stiff or fixed connections lie at one extreme limit of this spectrum and hinged or pinned connections bound the other. The stiff connection maintins the relative angle between the connected members while the hinged connection allows a relative rotation. There are also connections in steel and reinforced concrete structural systems in which a partial rigidity is a desired design feature.

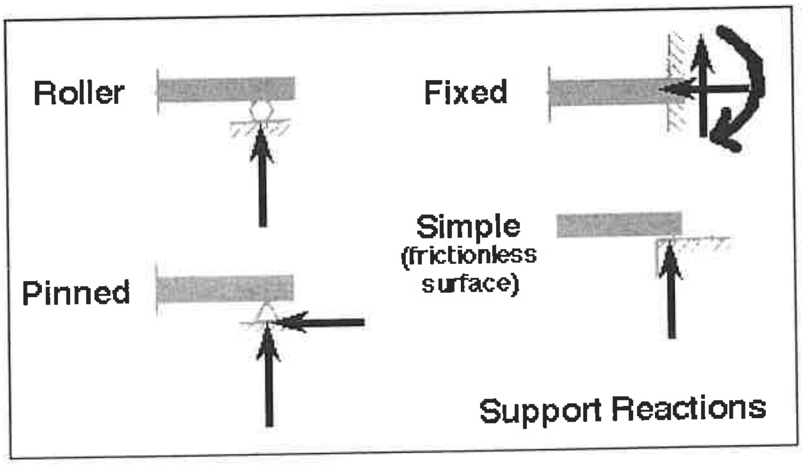
SUPPORT TYPES
The three common types of connections which join a built structure to its foundation are; **roller**, **pinned** and **fixed**.



Support Types

A fourth type, not often found in building structures, is known as a **simple** support. This is often idealized as a frictionless surface). All of these supports can be located anywhere along a structural element. They are found at the ends, at midpoints, or at any other intermediate points. The type of support connection determines the type of load that the support can resist. The support type also has a great effect on the load bearing capacity of each element, and therefore the system.

The diagram illustrates the various ways in which each type of support is represented. A single unified graphical method to represent each of these support types does not exist. Chances are that one of these representations will be similar to local common practice. However, no matter what the representation, the forces that the type can resist is indeed standardized.



REACTIONS

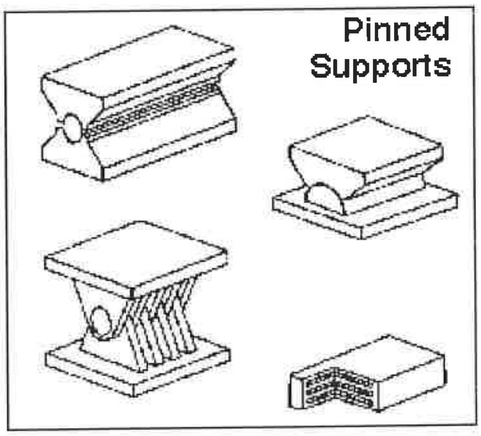
It is usually necessary to idealize the behaviour of a support in order to facilitate an analysis. An approach is taken that is similar to the massless, frictionless pulley in a physics homework problem. Even though these pulleys do not exist, they are useful to enable learning about certain issues. Thus, friction and mass are often ignored in the consideration of the behavior of a connection or support. It is important to realize that all of the graphical representations of supports are idealizations of an actual physical connection. Effort should be made to search out and compare the reality with the grpahical and/or numerical model.

The diagram to the right indicates the forces and/or moments which are "available" or active at each type of support. It is expected that these representative forces and moments, if properly calculated, will bring about equilibrium in each structural element.

ROLLER SUPPORTS

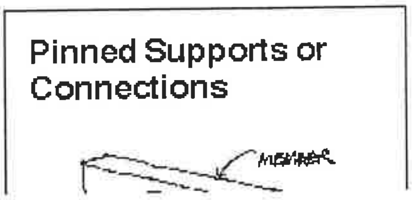
Roller supports are free to rotate and translate along the surface upon which the roller rests. The surface can be horizontal, vertical, or sloped at any angle. The resulting reaction force is always a single force that is perpendicular to, and away from, the surface. Roller supports are commonly located at one end of long bridges. This allows the bridge structure to expand and contract with temperature changes. The expansion forces could fracture the supports at the banks if the bridge structure was "locked" in place. Roller supports can also take the form of rubber bearings, rockers, or a set of gears which are designed to allow a limited amount of lateral movement.

A roller support cannot provide resistance to a lateral forces. Imagine a structure (perhaps a person) on roller skates. It would remain in place as long as the structure must only support itself and perhaps a perfectly vertical load. As soon as a lateral load of any kind pushes on the structure it will roll away in reponse to the force. The lateral load could be a shove, a gust of wind or an earthquake. Since most structures are subjected to lateral loads it follows that a building must have other types of support in addition to roller supports.



PINNED SUPPORTS

A pinned support can resist both vertical and horizontal forces but not a moment. They will allow the structural member to rotate, but not to translate in any direction. Many connections are assumed to be pinned connections even though they might resist a small amount of moment in reality. It is also true that a pinned connection could allow rotation in only one direction; providing resistance to rotation in any other direction. The knee can be idealized as a connection which allows rotation in only one direction and provides resistance to lateral movement. The design of a pinned connection is a good example of the idealization of the reality. A single pinned connection is usually not sufficient to make a structure stable. Another support must be provided at some point to prevent rotation of the structure. The representation of a pinned support includes both horizontal and vertical forces.

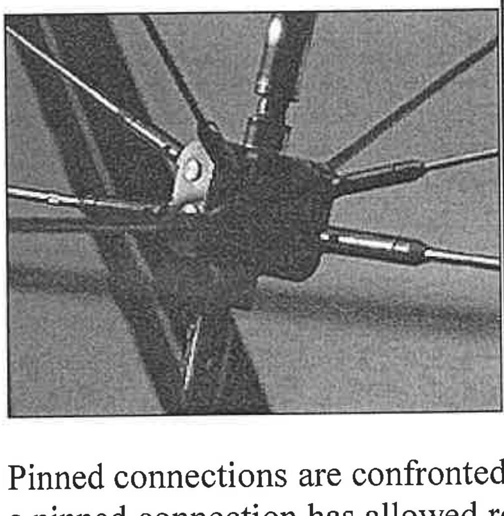


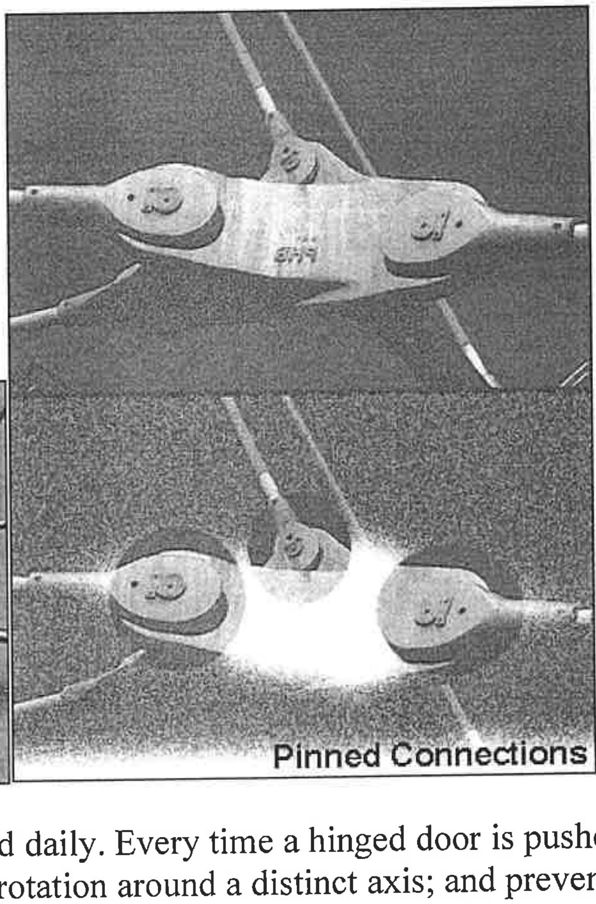
PINNED CONNECTIONS

In contrast to roller supports, a designer can often utilize pinned connections in a structural system. These are the typical connection found in almost all trusses. They can be articulated or hidden from view; they can be very expressive or subtle.

There is an illustration of one of the elements at the Olympic Stadium in Munich below. It is a cast steel connector that acts as a node to resolve a number of tensile forces. Upon closer examination one can notice that the connection is made of a number of parts. Each cable is connected to the node by an end "bracket" which is connected to a large pin. This is quite literally a "pinned connection." Due to the nature of the geometry of the bracket and pin, a certain amount of rotational movement would be permitted around the axis of each pin.

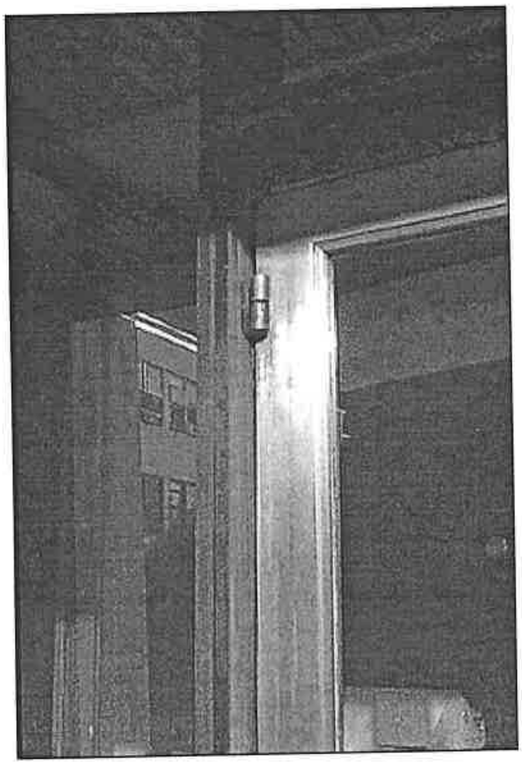
One of the connections from the pyramid of I.M. Pei's Loiuvre addition follows below. Notice how it too utilized pinned connections.

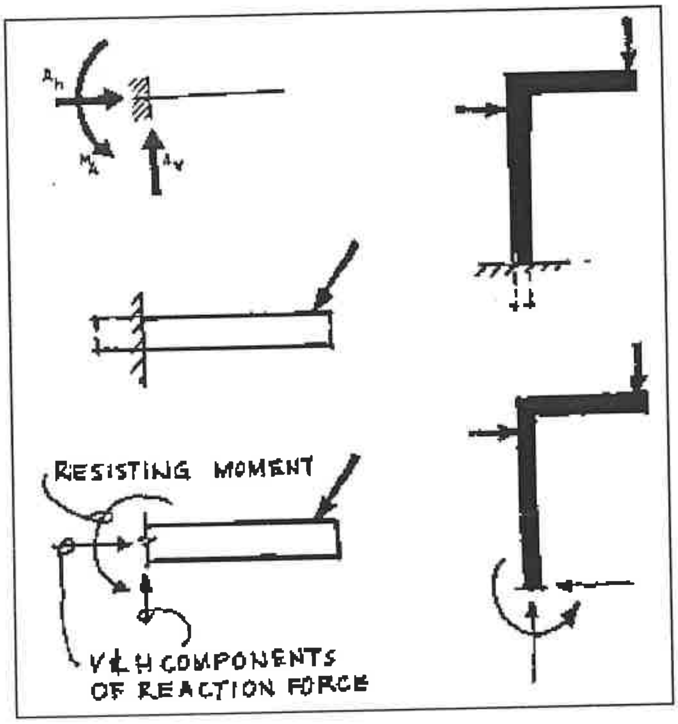




Pinned Connections

Pinned connections are confronted daily. Every time a hinged door is pushed open a pinned connection has allowed rotation around a distinct axis; and prevented translation in two. The door hinge prevents vertical and horizontal translation. As a matter of fact, if a sufficient moment is not generated to create rotation the door will not move at all.





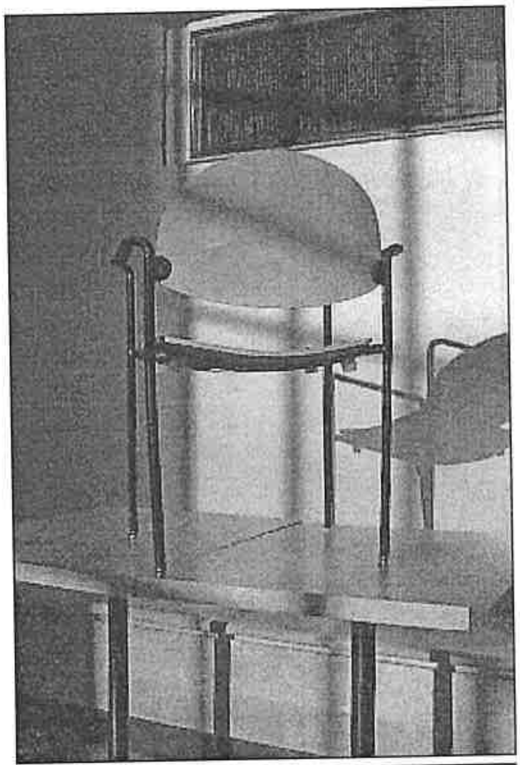
FIXED SUPPORTS

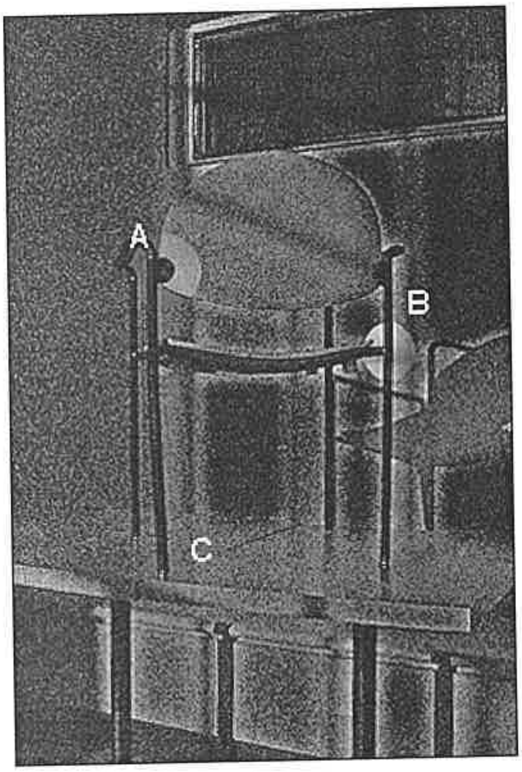
Fixed supports can resist vertical and horizontal forces as well as a moment. Since they restrain both rotation and translation, they are also known as rigid supports. This means that a structure only needs one fixed support in order to be stable. All three equations of equilibrium can be satisfied. A flagpole set into a concrete base is a good example of this kind of support. The representation of fixed supports always includes two forces (horizontal and vertical) and a moment.

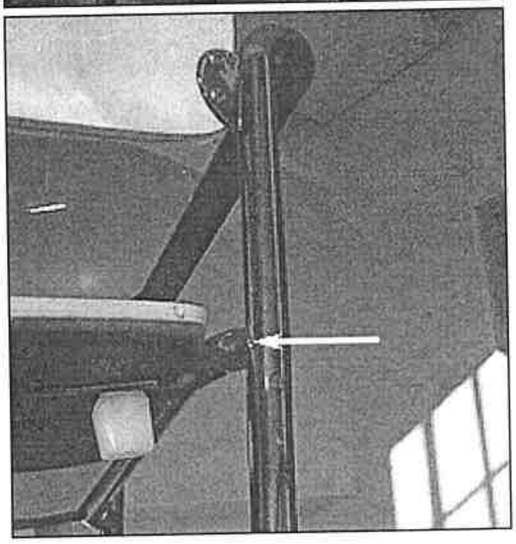
FIXED CONNECTIONS

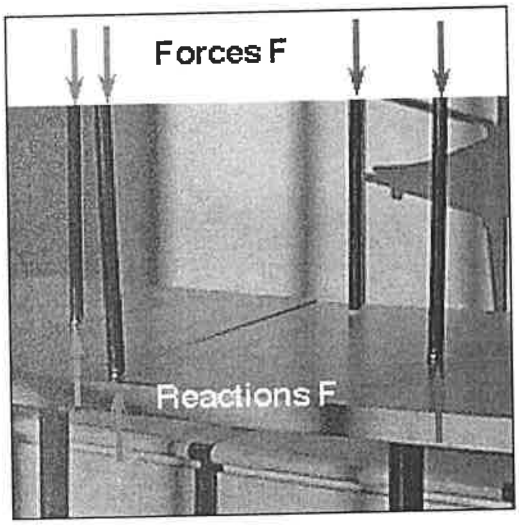
Fixed connections are very common. Steel structures of many sizes are composed of elements which are welded together. A cast-in-place concrete structure is automatically monolithic and it becomes a series of rigid connections with the proper placement of the reinforcing steel. Fixed connections demand greater attention during construction and are often the source of building failures.

Let this small chair illustrate the way in which two types of "fixed" connections can be generated. One is welded and the other is comprised to two screws. Both are considered to be fixed connections due to the fact that both of them can resist vertical and lateral loads as well as develop a resistance to moment. Thus, it is found that not all fixed connections must be welded or monolithic in nature. Let the hinges at locations A and B be examined in closer detail.



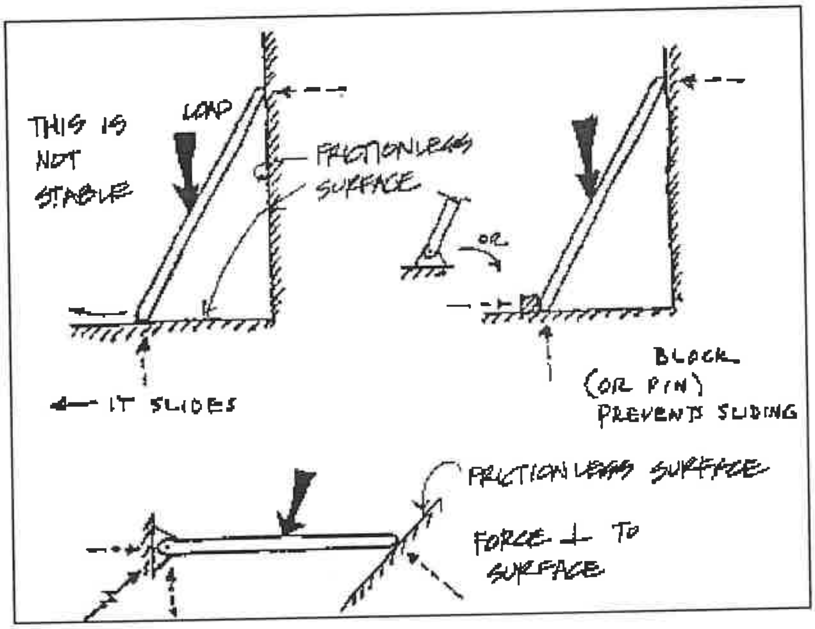


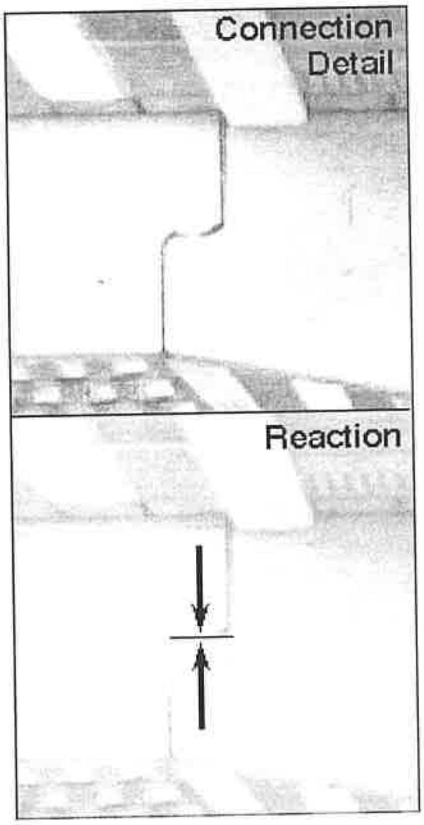




SIMPLE SUPPORTS

Simple supports are idealized by some to be frictionless surface supports. This is correct in as much as the resulting reaction is always a single force that is perpendicular to, and away from, the surface. However, are also similar to roller supports in this. They are dissimilar in that a simple support cannot resist lateral loads of any magnitude. The built reality often depends upon gravity and friction to develop a minimal amount of frictional resistance to moderate lateral loading. For example, if a plank is laid across gap to provide a bridge, it is assumed that the plank will remain in its place. It will do so until a foot kicks it or moves it. At that moment the plank will move because the simple connection cannot develop any resistance to the lateral loal. A simple support can be found as a type of support for long bridges or roof span. Simple supports are often found in zones of frequent seismic activity.





Equilibrium Analysis for a Rigid Body

For a **rigid body** in static equilibrium, that is a non-deformable body where forces are not concurrent, the sum of both the **forces** and the **moments** acting on the body must be equal to zero. The addition of moments (as opposed to particles where we only looked at the forces) adds another set of possible equilibrium equations, allowing us to solve for more unknowns as compared to particle problems.

Moments, like forces, are vectors. This means that our vector equation needs to be broken down into scalar components before we can solve the equilibrium equations. In a two dimensional problem, the body can only have clockwise or counter clockwise rotation (corresponding to rotations about the z axis). This means that a rigid body in a two dimensional problem has three possible equilibrium equations; that is, the sum of force components in the x and y directions, and the moments about the z axis. The sum of each of these will be equal to zero.

For a two dimensional problem, we break our one vector force equation into two scalar component equations.

$$\sum F=0$$

$$\sum F_x=0 \quad \sum F_y=0$$

The one moment vector equation becomes a single moment scalar equation.

$$\sum M=0$$

$$\sum M_z=0$$

If we look at a three dimensional problem we will increase the number of possible equilibrium equations to six. There are three equilibrium equations for force, where the sum of the components in the x, y, and z direction must be equal to zero. The body may also have moments about each of the three axes. The second set of three equilibrium equations states that the sum of the moment components about the x, y, and z axes must also be equal to zero.

We break the forces into three component equations

$$\sum F=0$$

$$\sum F_x=0 \quad \sum F_y=0 \quad \sum F_z=0$$

We break the moments into three component equations

$$\sum M=0$$

$$\sum M_x=0 \quad \sum M_y=0 \quad \sum M_z=0$$

Finding the Equilibrium Equations:

As with particles, the first step in finding the equilibrium equations is to draw a free body diagram of the body being analyzed. This diagram should show all the force vectors acting on the body. In the free body diagram, provide values for any of the known magnitudes, directions, and points of application for the force vectors and provide variable names for any unknowns (either magnitudes, directions, or distances).

Next you will need to choose the x, y, z axes. These axes do need to be perpendicular to one another, but they do not necessarily have to be horizontal or vertical. If you choose coordinate axes that line up with some of your force vectors you will simplify later analysis.

Once you have chosen axes, you need to break down all of the force vectors into components along the x, y and z directions (see the vectors page in Appendix 1 page for more details on this process). Your first equation will be the sum of the magnitudes of the components in the x direction being equal to zero, the second equation will be the sum of the magnitudes of the components in the y direction being equal to zero, and the third (if you have a 3D problem) will be the sum of the magnitudes in the z direction being equal to zero.

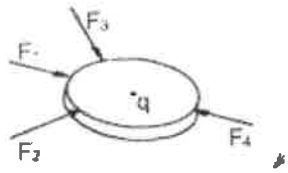
Next you will need to come up with the the moment equations. To do this you will need to choose a point to take the moments about. Any point should work, but it is usually advantageous to choose a point that will decrease the number of unknowns in the equation. Remember that any force vector that travels through a given point will exert no moment about that point. To write out the moment equations simply sum the moments exerted by each force (adding in pure moments shown in the diagram) about the given point and the given axis (x, y, or z) and set that sum equal to zero. All moments will be about the z axis for two dimensional problems, though moments can be about x, y and z axes for three dimensional problems.

Once you have your equilibrium equations, you can solve these formulas for unknowns. The number of unknowns that you will be able to solve for will again be the number or equations that you have.

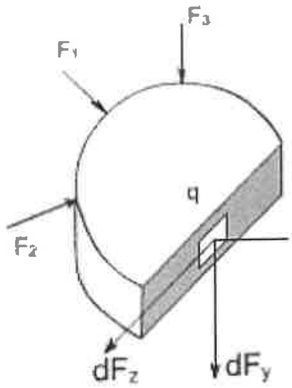
UNIT V

General State of stress at a point :

Stress at a point in a material body has been defined as some what ambiguous since it depends upon what area a point �q' in the interior of the body



Let us pass a cutting plane through a pont 'q' perpendic



The corresponding force components can be shown lik

$dF_x = \ _{xx}.\ da_x$

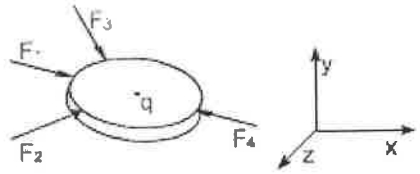
$dF_y = \ _{xy}.\ da_x$

$dF_z = \ _{xz}.\ da_x$

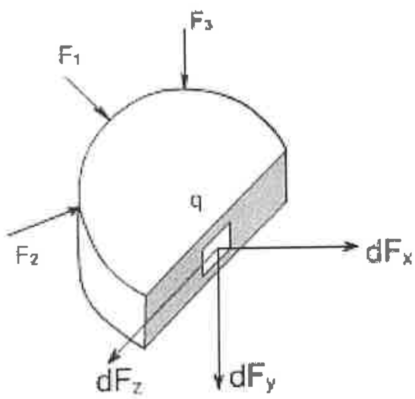
UNIT V

General State of stress at a point :

Stress at a point in a material body has been defined as a force per unit area. But this definition is some what ambiguous since it depends upon what area we consider at that point. Let us, consider a point �q' in the interior of the body



Let us pass a cutting plane through a pont 'q' perpendicular to the x - axis as shown below



The corresponding force components can be shown like this

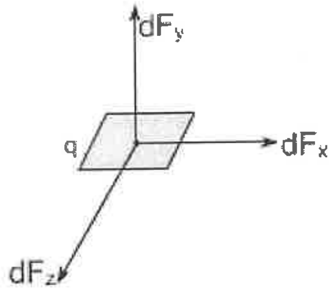
$dF_x = \square_{xx} . da_x$

$dF_y = \square_{xy} . da_x$

$dF_z = \square_{xz} . da_x$

where da_x is the area surrounding the point 'q' when the cutting plane □ ' is to x - axis.

In a similar way it can be assummed that the cutting plane is passed through the point 'q' perpendicular to the y - axis. The corresponding force components are shown below



The corresponding force components may be written as

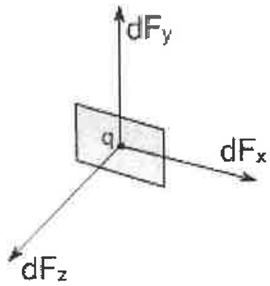
$dF_x = \square_{yx} . da_y$

$dF_y = \square_{yy} . da_y$

$dF_z = \square_{yz} . da_y$

where da_y is the area surrounding the point 'q' when the cutting plane $\square^{r}$ is to y - axis.

In the last it can be considered that the cutting plane is passed through the point 'q' perpendicular to the z - axis.



The corresponding force components may be written as

$dF_x = \square_{zx} . da_z$

$dF_y = \square_{zy} . da_z$

$dF_z = \square_{zz} . da_z$

where da_z is the area surrounding the point 'q' when the cutting plane $\square^{r}$ is to z - axis.

Thus, from the foregoing discussion it is amply clear that there is nothing like stress at a point 'q' rather we have a situation where it is a combination of state of stress at a point q. Thus, it becomes imperative to understand the term state of stress at a point 'q'. Therefore, it becomes easy to express astate of stress by the scheme as discussed earlier, where the stresses on the three mutually perpendiclar planes are labelled in the manner as shown earlier. the state of stress as depicted earlier is called the general or a triaxial state of stress that can exist at any interior point of a loaded body.

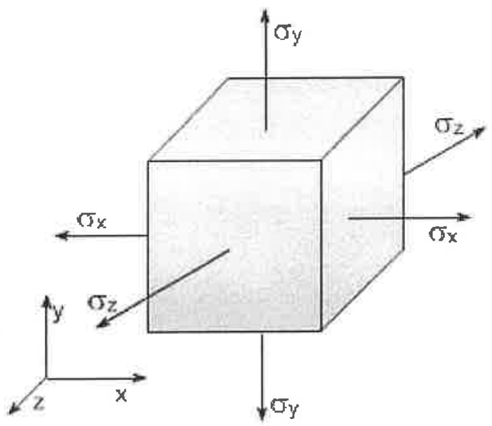
Before defining the general state of stress at a point. Let us make overselves conversant with the notations for the stresses.

We have already chosen to distinguish between normal and shear stress with the help of symbols □ and □ .

Cartesian - co-ordinate system

In the Cartesian co-ordinates system, we make use of the axes, X, Y and Z

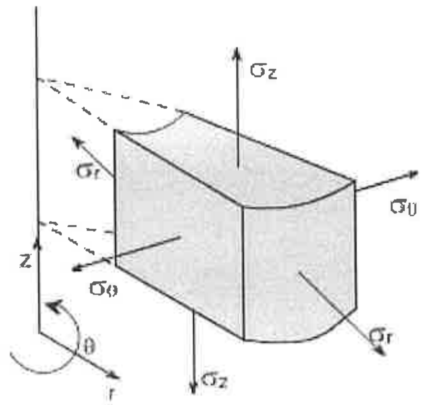
Let us consider the small element of the material and show the various normal stresses acting the faces



Thus, in the Cartesian co-ordinates system the normal stresses have been represented by $\square_x$, $\square_y$and $\square_z$.

Cylindrical - co-ordinate system

In the Cylindrical - co-ordinate system we make use of co-ordinates r, □ and Z.



Thus, in the Cylindrical co-ordinates system, the normal stresses i.e components acting over a element is being denoted by σ_r, σ_θ and σ_z.

Sign convention : The tensile forces are termed as (+ve) while the compressive forces are termed as negative (-ve).

First sub � script : it indicates the direction of the normal to the surface.

Second subscript : it indicates the direction of the stress.

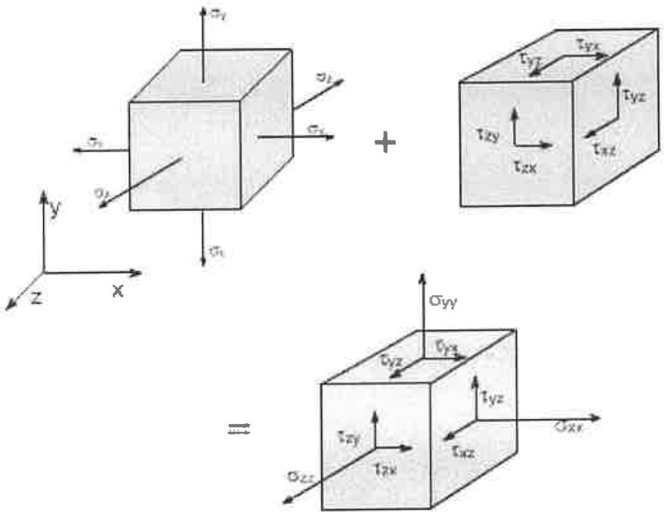
It may be noted that in the case of normal stresses the double script notation may be dispensed with as the direction of the normal stress and the direction of normal to the surface of the element on which it acts is the same. Therefore, a single subscript notation as used is sufficient to define the normal stresses.

Shear Stresses : With shear stress components, the single subscript notation is not practical, because such stresses are in direction parallel to the surfaces on which they act. We therefore have two directions to specify, that of normal to the surface and the stress itself. To do this, we stress itself. To do this, we attach two subscripts to the symbol ' τ ', for shear stresses.

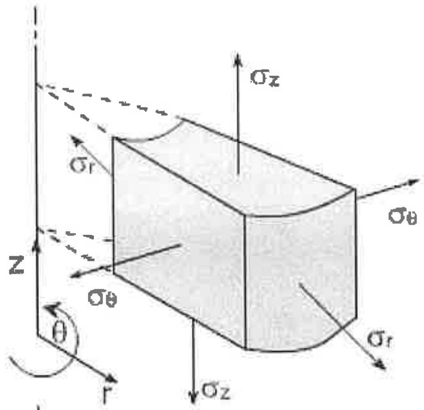
In cartesian and polar co-ordinates, we have the stress components as shown in the figures.

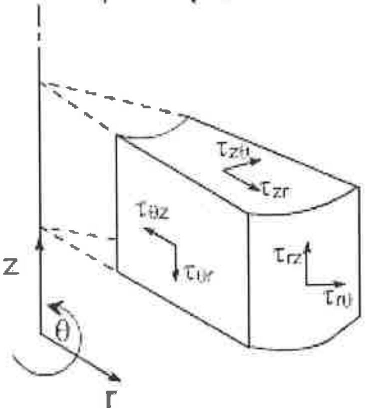
τ_{xy} , τ_{yx} , τ_{yz} , τ_{zy} , τ_{zx} , τ_{xz}

$\tau_{r\theta}$, $\tau_{\theta r}$, $\tau_{\theta z}$, $\tau_{z\theta}$,τ_{zr} , τ_{rz}

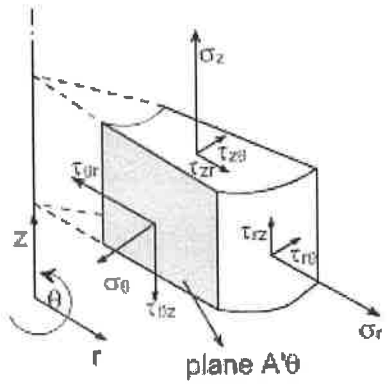


So as shown above, the normal stresses and shear stress components indicated on a small element of material seperately has been combined and depicted on a single element. Similarly for a cylindrical co-ordinate system let us shown the normal and shear stresses components separately.





Now let us combine the normal and shear stress components as shown below :



Now let us define the state of stress at a point formally.

State of stress at a point :

By state of stress at a point, we mean an information which is required at that point such that it remains under equilibrium. or simply a general state of stress at a point involves all the normal stress components, together with all the shear stress components as shown in earlier figures.

Therefore, we need nine components, to define the state of stress at a point

$\square_x$ $\square_{xy}$ $\square_{xz}$

$\square_y$ $\square_{yx}$ $\square_{yz}$

$\square_z$ $\square_{zx}$ $\square_{zy}$

If we apply the conditions of equilibrium which are as follows:

$\square\ F_x = 0\ ;\ \square\ M_x = 0$

$\square\ F_y = 0\ ;\ \square\ M_y = 0$

$\square\ F_z = 0\ ;\ \square\ M_z = 0$

Then we get

$\square_{xy} = \square_{yx}$

$\square_{yz} = \square_{zy}$

$\square_{zx} = \square_{xy}$

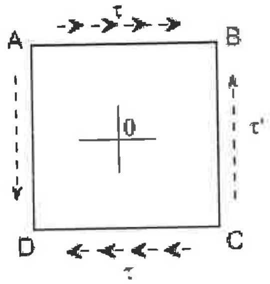
Then we will need only six components to specify the state of stress at a point i.e

$\square_{x}$, $\square_{y}$, $\square_{z}$, $\square_{xy}$, $\square_{yz}$, $\square_{zx}$

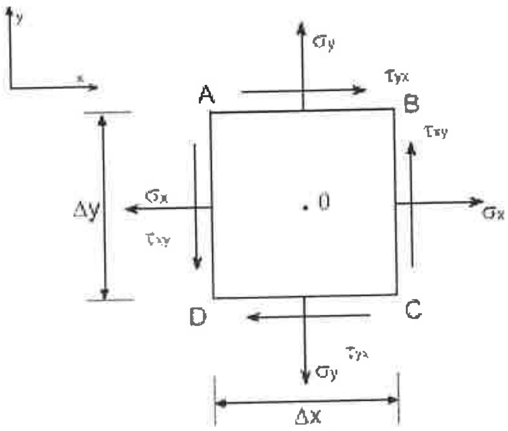
Now let us define the concept of complementary shear stresses.

Complementary shear stresses:

The existence of shear stresses on any two sides of the element induces complementary shear stresses on the other two sides of the element to maintain equilibrium.



on planes AB and CD, the shear stress □ acts. To maintain the static equilibrium of this element, on planes AD and BC, □ ' should act, we shall see that□ ' which is known as the complementary shear stress would come out to equal and opposite to the□ □ □ . Let us prove this thing for a general case as discussed below:



The figure shows a small rectangular element with sides of length □ x,□ y parallel to x and y directions. Its thickness normal to the plane of paper is □ z in z� direction. All nine normal and shear stress components may act on the element, only those in x and y directions are shown.

Sign convections for shear stresses:

Direct stresses or normal stresses

- tensile +ve

- compressive �ve

Shear stresses:

- tending to turn the element C.W +ve.

- tending to turn the element C.C.W � ve.

The resulting forces applied to the element are in equilibrium in x and y direction. (Although other normal and shear stress components are not shown, their presence does not affect the final conclusion).

Assumption : The weight of the element is neglected.

Since the element is a static piece of solid body, the moments applied to it must also be in equilibrium. Let �O' be the centre of the element. Let us consider the axis through the point �O'. the resultant force associated with normal stresses □$_x$ and □$_y$ acting on the sides of the element each pass through this axis, and therefore, have no moment.

Now forces on top and bottom surfaces produce a couple which must be balanced by the forces on left and right hand faces

Thus,

□$_{yx}$. □ x . □ z . □ y = □$_{xy}$. □ x . □ z . □ y

$$\boxed{\tau_{yx} = \tau_{xy}}$$

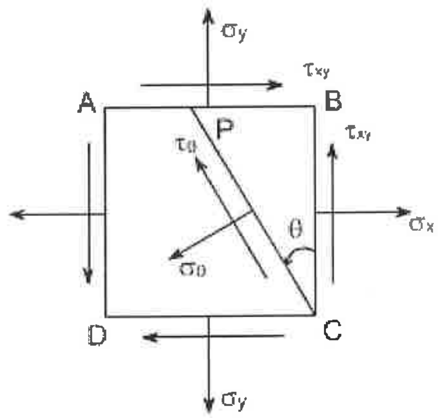
In other word, the complementary shear stresses are equal in magnitude. The same form of relationship can be obtained for the other two pair of shear stress components to arrive at the relations

$$\boxed{\begin{aligned} \tau_{zy} &= \tau_{zy} \\ \tau_{zx} &= \tau_{xz} \end{aligned}}$$

GRAPHICAL SOLUTION � MOHR'S STRESS CIRCLE

The transformation equations for plane stress can be represented in a graphical form known as Mohr's circle. This grapical representation is very useful in depending the relationships between normal and shear stresses acting on any inclined plane at a point in a stresses body.

To draw a Mohr's stress circle consider a complex stress system as shown in the figure



The above system represents a complete stress system for any condition of applied load in two dimensions

The Mohr's stress circle is used to find out graphically the direct stress □ and sheer stress□□ on any plane inclined at □ to the plane on which □$_x$ acts.The direction of □ here is taken in anticlockwise direction from the BC.

STEPS:

In order to do achieve the desired objective we proceed in the following manner

(i) Label the Block ABCD.

(ii) Set up axes for the direct stress (as abscissa) and shear stress (as ordinate)

(iii) Plot the stresses on two adjacent faces e.g. AB and BC, using the following sign convention.

Direct stresses � tensile positive; compressive, negative

Shear stresses � tending to turn block clockwise, positive

� tending to turn block counter clockwise, negative

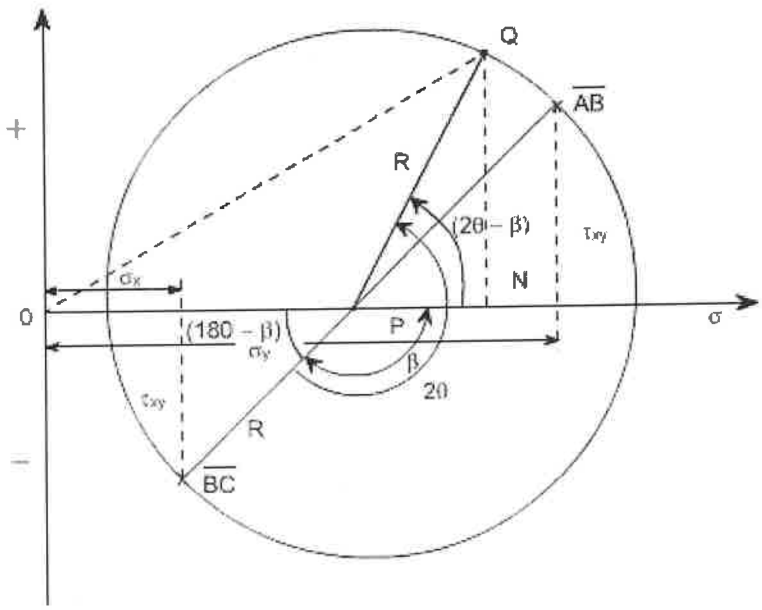
[i.e shearing stresses are +ve when its movement about the centre of the element is clockwise]

This gives two points on the graph which may than be labeled as $\overline{AB}$ and $\overline{BC}$ respectively to denote stresses on these planes.

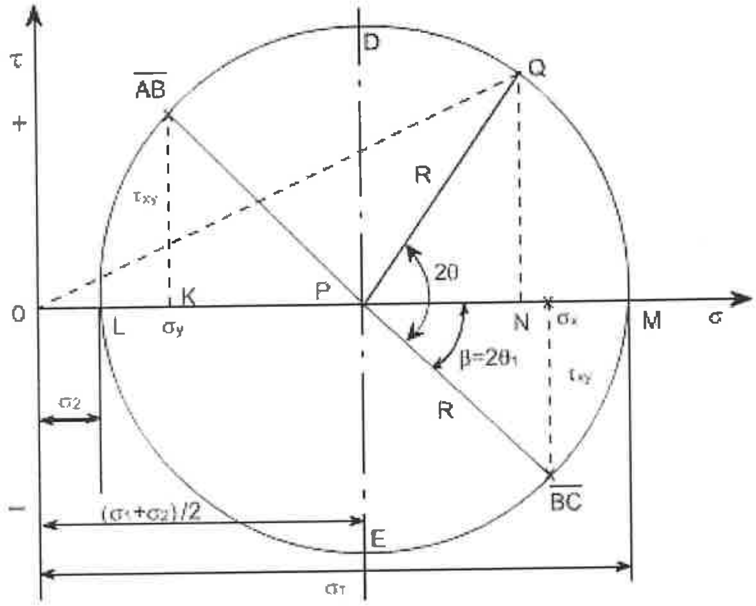
(iv) Join $\overline{AB}$ and $\overline{BC}$.

(v) The point P where this line cuts the s axis is than the centre of Mohr's stress circle and the line joining $\overline{AB}$ and $\overline{BC}$ is diameter. Therefore the circle can now be drawn.

Now every point on the circle then represents a state of stress on some plane through C.



Proof:



Consider any point Q on the circumference of the circle, such that PQ makes an angle 2□□with BC, and drop a perpendicular from Q to meet the s axis at N.Then OQ represents the resultant stress on the plane an angle □ to BC. Here we have assumed that □x □ □y

Now let us find out the coordinates of point Q. These are ON and QN.

From the figure drawn earlier

ON = OP + PN

OP = OK + KP

OP = □y + 1/2 (□x□y)

= □y / 2 + □y / 2 + □x / 2 + □y / 2

= (□x + □y) / 2

PN = Rcos(2□ □)

hence ON = OP + PN

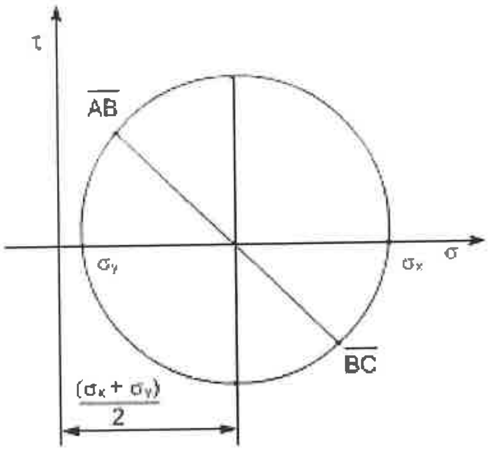
= (□x + □y) / 2 + Rcos(2□ □)

= (□□x + □y) / 2 + Rcos2□ cos□ + Rsin2□ sin□

now make the substitutions for Rcos□ and Rsin□ .

While the direct stress on the plane of maximum shear must be mid � may between □x and □y i.e

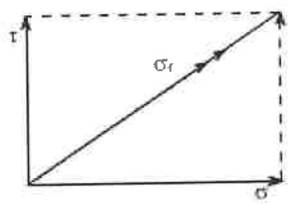
$$\frac{(\sigma_x + \sigma_y)}{2}$$



(4) As already defined the principal planes are the planes on which the shear components are zero.

Therefore are conclude that on principal plane the sheer stress is zero.

(5) Since the resultant of two stress at 90^0 can be found from the parallogram of vectors as shown in the diagram.Thus, the resultant stress on the plane at q to BC is given by OQ on Mohr's Circle.



(6) The graphical method of solution for a complex stress problems using Mohr's circle is a very powerful technique, since all the information relating to any plane within the stressed element is contained in the single construction. It thus, provides a convenient and rapid means of solution. Which is less prone to arithmetical errors and is highly recommended.

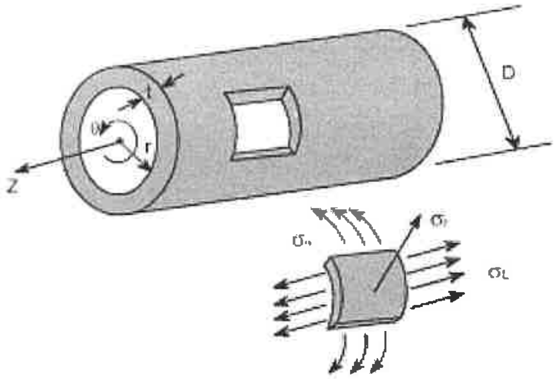
Pressurized thin walled cylinder:

Preamble : Pressure vessels are exceedingly important in industry. Normally two types of pressure vessel are used in common practice such as cylindrical pressure vessel and spherical pressure vessel.

In the analysis of this walled cylinders subjected to internal pressures it is assumed that the radial plans remains radial and the wall thickness dose not change due to internal pressure. Although the internal pressure acting on the wall causes a local compressive stresses (equal to pressure) but its value is neglibly small as compared to other stresses & hence the sate of stress of an element of a thin walled pressure is considered a biaxial one.

Further in the analysis of them walled cylinders, the weight of the fluid is considered neglible.

Let us consider a long cylinder of circular cross - section with an internal radius of R_2 and a constant wall thickness�t' as showing fig.



This cylinder is subjected to a difference of hydrostatic pressure of �p' between its inner and outer surfaces. In many cases, �p' between gage pressure within the cylinder, taking outside pressure to be ambient.

By thin walled cylinder we mean that the thickness�t' is very much smaller than the radius R_i and we may quantify this by stating than the ratio t / R_i of thickness of radius should be less than 0.1.

An appropriate co-ordinate system to be used to describe such a system is the cylindrical polar one r, □ , z shown, where z axis lies along the axis of the cylinder, r is radial to it and □ □ is the angular co-ordinate about the axis.

The small piece of the cylinder wall is shown in isolation, and stresses in respective direction have also been shown.

$$R\cos\beta = \frac{(\sigma_x - \sigma_y)}{2};\ R\sin\beta = \tau_{xy}$$

Thus,

$$ON = 1/2\,(\sigma_x + \sigma_y) + 1/2\,(\sigma_x - \sigma_y)\cos 2\theta + \tau_{xy}\sin 2\theta \qquad (1)$$

Similarly $QM = R\sin(2\theta - \beta)$

$$= R\sin 2\theta\cos\beta - R\cos 2\theta\sin\beta$$

Thus, substituting the values of $R\cos\beta$ and $R\sin\beta$, we get

$$QM = 1/2\,(\sigma_x - \sigma_y)\sin 2\theta - \tau_{xy}\cos 2\theta \qquad (2)$$

If we examine the equation (1) and (2), we see that this is the same equation which we have already derived analytically

Thus the co-ordinates of Q are the normal and shear stresses on the plane inclined at θ to BC in the original stress system.

N.B: Since angle $\overline{BC}$ PQ is 2θ on Mohr's circle and not θ it becomes obvious that angles are doubled on Mohr's circle. This is the only difference, however, as They are measured in the same direction and from the same plane in both figures.

Further points to be noted are :

(1) The direct stress is maximum when Q is at M and at this point obviously the sheer stress is zero, hence by definition OM is the length representing the maximum principal stresses σ_1 and $2\theta_1$ gives the angle of the plane θ_1 from BC. Similar OL is the other principal stress and is represented by σ_2

(2) The maximum shear stress is given by the highest point on the circle and is represented by the radius of the circle.

This follows that since shear stresses and complimentary sheer stresses have the same value; therefore the centre of the circle will always lie on the s axis midway between σ_x and σ_y . [since $+\tau_{xy}$ & $-\tau_{xy}$ are shear stress & complimentary shear stress so they are same in magnitude but different in sign.]

(3) From the above point the maximum sheer stress i.e. the Radius of the Mohr's stress circle would be

$$\frac{(\sigma_x - \sigma_y)}{2}$$

Type of failure:

Such a component fails in since when subjected to an excessively high internal pressure. While it might fail by bursting along a path following the circumference of the cylinder. Under normal circumstance it fails by circumstances it fails by bursting along a path parallel to the axis. This suggests that the hoop stress is significantly higher than the axial stress.

In order to derive the expressions for various stresses we make following

Applications :

Liquid storage tanks and containers, water pipes, boilers, submarine hulls, and certain air plane components are common examples of thin walled cylinders and spheres, roof domes.

ANALYSIS : In order to analyse the thin walled cylinders, let us make the following assumptions :

- There are no shear stresses acting in the wall.
- The longitudinal and hoop stresses do not vary through the wall.
- Radial stresses □$_r$ which acts normal to the curved plane of the isolated element are neglibly small as compared to other two stresses especially when $\left[\frac{t}{R_i} < \frac{1}{20}\right]$

The state of tress for an element of a thin walled pressure vessel is considered to be biaxial, although the internal pressure acting normal to the wall causes a local compressive stress equal to the internal pressure, Actually a state of tri-axial stress exists on the inside of the vessel. However, for then walled pressure vessel the third stress is much smaller than the other two stresses and for this reason in can be neglected.

Thin Cylinders Subjected to Internal Pressure:

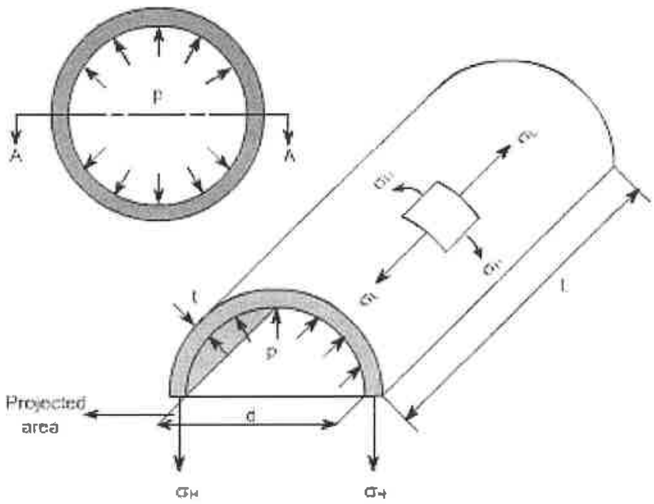
When a thin � walled cylinder is subjected to internal pressure, three mutually perpendicular principal stresses will be set up in the cylinder materials, namely

- Circumferential or hoop stress
- The radial stress
- Longitudinal stress

now let us define these stresses and determine the expressions for them

Hoop or circumferential stress:

This is the stress which is set up in resisting the bursting effect of the applied pressure and can be most conveniently treated by considering the equilibrium of the cylinder.



In the figure we have shown a one half of the cylinder. This cylinder is subjected to an internal pressure p.

i.e. p = internal pressure

d = inside diametre

L = Length of the cylinder

t = thickness of the wall

Total force on one half of the cylinder owing to the internal pressure 'p'

= p x Projected Area

= p x d x L

= **p .d. L** ------- (1)

The total resisting force owing to hoop stresses σ_H set up in the cylinder walls

= **2 .σ_H .L.t** ---------(2)

Because □ $\square_H$.L.t. is the force in the one wall of the half cylinder.

the equations (1) & (2) we get

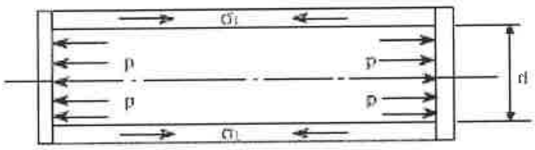
2 . $\square_H$. L . t = p . d . L

$\square_H$ = (p . d) / 2t

Circumferential or hoop Stress ($\square_H$) = (p .d)/ 2t

Longitudinal Stress:

Consider now again the same figure and the vessel could be considered to have closed ends and contains a fluid under a gage pressure p.Then the walls of the cylinder will have a longitudinal stress as well as a ciccumferential stress.



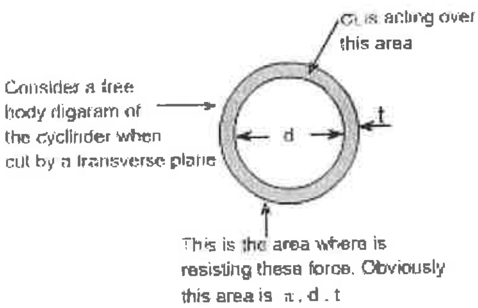
Total force on the end of the cylinder owing to internal pressure

= pressure x area

= p x □ □ d^2/4

Area of metal resisting this force = □ d.t. (approximately)

because □ d is the circumference and this is multiplied by the wall thickness



Hence the longitudnal stresses

$$\text{Set up} = \frac{\text{force}}{\text{area}} = \frac{[p \times \pi d^2/4]}{\pi dt}$$

$$= \frac{pd}{4t} \quad \text{or} \quad \sigma_L = \frac{pd}{4t}$$

or alternatively from equilibrium conditions

$$\sigma_L.(\pi dt) = p.\frac{\pi d^2}{4}$$

$$\text{Thus } \boxed{\sigma_L = \frac{pd}{4t}}$$

Energy Methods

Strain Energy

Strain Energy of the member is defined as the internal work done in defoming the body by the action of externally applied forces. This energy in elastic bodies is known as **elastic strain energy** :

Strain Energy in uniaxial Loading

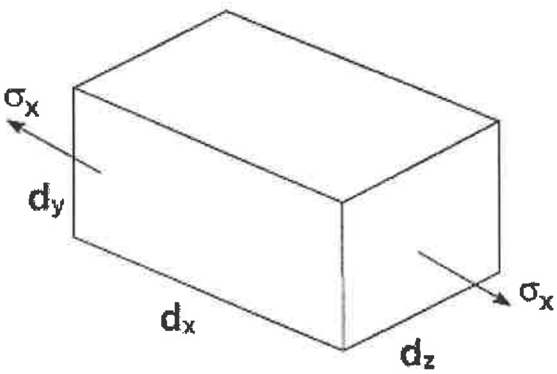


Fig .1

Let as consider an infinitesimal element of dimensions as shown in Fig .1. Let the element be subjected to normal stress $\square_x$.

The forces acting on the face of this element is $\square_x$. dy. dz

where

dydz = Area of the element due to the application of forces, the element deforms to an amount = $\square_x$ dx

□ $\square_x$ = strain in the material in x � direction

$$= \frac{\text{Change in length}}{\text{Orginal in length}}$$

Assuming the element material to be as linearly elastic the stress is directly proportional to strain as shown in Fig . 2.

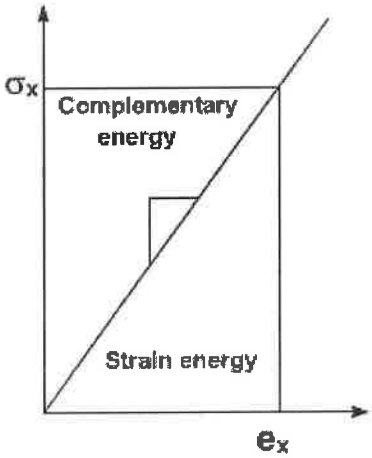


Fig .2

□ □ From Fig .2 the force that acts on the element increases linearly from zero until it attains its full value.

Hence average force on the element is equal to ½ $\square_x$. dy. dz.

□ Therefore the workdone by the above force

Force = average force x deformed length

= ½ $\square_x$. dydz . $\square_x$. dx

For a perfectly elastic body the above work done is the internal strain energy �du�.

$$\boxed{du = \frac{1}{2}\sigma_x dydz\, \epsilon_x\, dx} \qquad \text{.....(2)}$$

$$= \frac{1}{2}\sigma_x \epsilon_x\, dxdydz$$

$$\boxed{du = \frac{1}{2}\sigma_x\, \epsilon_x\, dv} \qquad \text{.......(3)}$$

where dv = dxdydz

= Volume of the element

By rearranging the above equation we can write

$$U_o = \boxed{\frac{du}{dv} = \frac{1}{2}\sigma_x \epsilon_x} \qquad \text{.....(4)}$$

The equation (4) represents the strain energy in elastic body per unit volume of the material its strain energy � density �u$_o$' .

From Hook's Law for elastic bodies, it may be recalled that

$$\boxed{\sigma = E\epsilon}$$

$$\boxed{U_o = \frac{du}{dv} = \frac{\sigma_x^2}{2E} = \frac{E\epsilon_x^2}{2}} \qquad \text{......(5)}$$

$$\boxed{U = \int_{Vol} \frac{\sigma_x^2}{2E} dv} \qquad \text{.......(6)}$$

In the case of a rod of uniform cross � section subjected at its ends an equal and opposite forces of magnitude P as shown in the Fig .3.

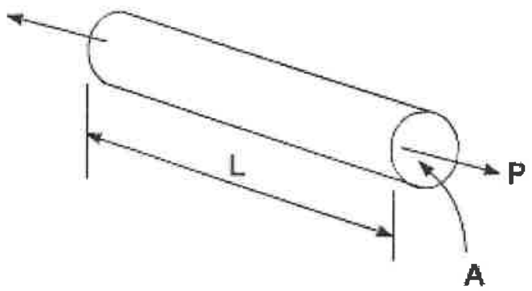


Fig .3

$$U = \int_{Vol}^{L} \frac{\sigma_x^2}{2E} dv \qquad \sigma_x = \frac{P}{A}$$

$$U = \int_0^L \frac{P^2}{2EA^2} A dx$$

$dv = Adx$ = Element volume

A = Area of the bar.
L = Length of the bar

$$\boxed{U = \frac{P^2 L}{2AE}} \qquad .....(7)$$

Modulus of resilience :

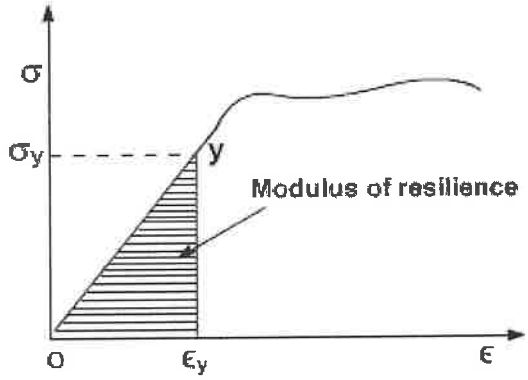


Fig .4

Suppose � σ_x� in strain energy equation is put equal to σ_y i.e. the stress at proportional limit or yield point. The resulting strain energy gives an index of the materials ability to store or absorb energy without permanent deformation

So $$\boxed{U_y = \frac{\sigma_y^2}{2E}} \qquad .....(8)$$

The quantity resulting from the above equation is called the Modulus of resilience

The modulus of resilience is equal to the area under the straight line portion �OY' of the stress � strain diagram as shown in Fig .4 and represents the energy per unit volume that the material can absorb without yielding. Hence this is used to differentiate materials for applications where energy must be absorbed by members.

Modulus of Toughness :

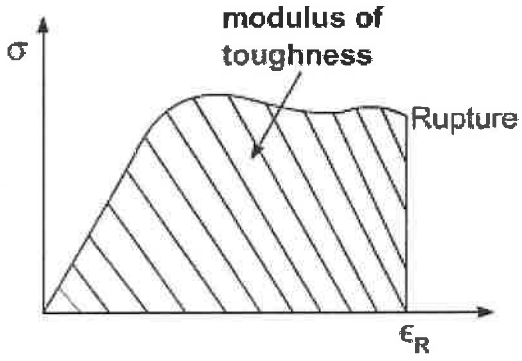


Fig .5

Suppose �□ ' [strain] in strain energy expression is replaced by□R strain at rupture, the resulting strain energy density is called modulus of toughness

$$U = \int_0^{\epsilon} E\epsilon_x \, dx = \frac{E\epsilon_R^2}{2} dv$$

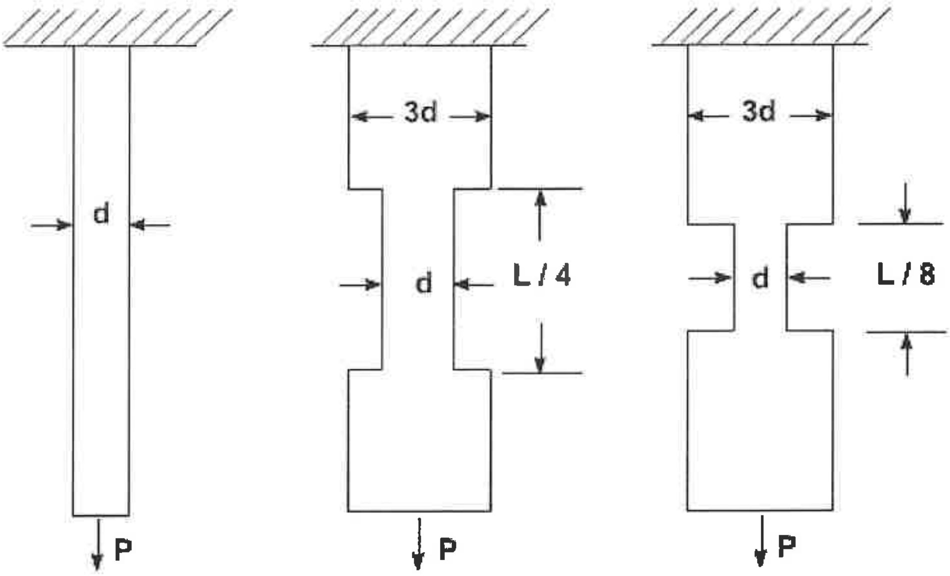
$$\boxed{U = \frac{E\epsilon_R^2}{2}} \qquad ......(9)$$

From the stress � strain diagram, the area under the complete curve gives the measure of modules of toughness. It is the materials.

Ability to absorb energy upto fracture. It is clear that the toughness of a material is related to its ductility as well as to its ultimate strength and that the capacity of a structure to withstand an impact Load depends upon the toughness of the material used.

ILLUSTRATIVE PROBLEMS

1. Three round bars having the same length �L' but different shapes are shown in fig below. The first bar has a diameter �d' over its entire length, the second had this diameter over one � fourth of its length, and the third has this diameter over one eighth of its length. All three bars are subjected to the same load P. Compare the amounts of strain energy stored in the bars, assuming the linear elastic behavior.



Solution :

1.The strain Energy of the first bar is expressed as

$$U_1 = \frac{P^2L}{2EA}$$

2.The strain Energy of the second bar is expressed as

$$U_2 = \frac{P^2(L/4)}{2EA} + \frac{P^2(3L/4)}{2E9A} = \frac{P^2L}{6EA}$$

$$\boxed{U_2 = \frac{U_1}{3}}$$

3.The strain Energy of the third bar is expressed as

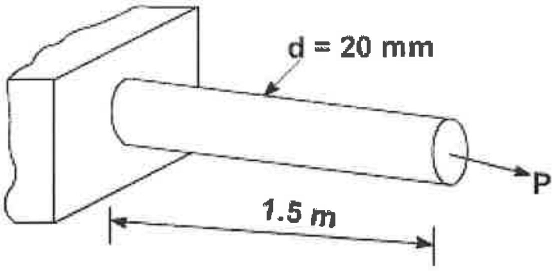
$$U_3 = \frac{P^2(L/8)}{2EA} + \frac{P^2(7L/8)}{2E(9A)}$$

$$U_3 = \frac{P^2L}{9EA}$$

$$\boxed{U_3 = \frac{2U_1}{9}}$$

From the above results it may be observed that the strain energy decreases as the volume of the bar increases.

2. Suppose a rod AB must acquire an elastic strain energy of 13.6 N.m using E = 200 GPa. Determine the required yield strength of steel. If the factor of safety w.r.t. permanent deformation is equal to 5.



Solution :

Factor of safety = 5

Therefore, the strain energy of the rod should be u = 5 [13.6] = 68 N.m

Strain Energy density

The volume of the rod is

$$V = AL = \frac{\pi}{4} d^2 L$$

$$= \frac{\pi}{4}\, 20 \times 1.5 \times 10^3$$

$$= 471 \times 10^3 \ mm^3$$

Yield Strength :

As we know that the modulus of resilience is equal to the strain energy density when maximum stress is equal to $\Box_x$.

$$U = \frac{\sigma_y^2}{2E}$$

$$0.144 = \frac{\sigma_y^2}{2 \times (200 \times 10^3)}$$

$$\boxed{\sigma_y = 200 \text{ Mpa}}$$

It is important to note that, since energy loads are not linearly related to the stress they produce, factor of safety associated with energy loads should be applied to the energy loads and not to the stresses.

Strain Energy in Bending :

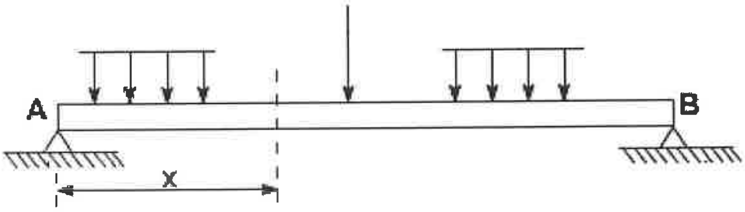


Fig .6

Consider a beam AB subjected to a given loading as shown in figure.

Let

M = The value of bending Moment at a distance x from end A.

From the simple bending theory, the normal stress due to bending alone is expressed as.

$$\boxed{\sigma = \frac{MY}{I}}$$

Substituting the above relation in the expression of strain energy

i.e. $U = \int \frac{\sigma^2}{2E} dv$

$= \int \frac{M^2.y^2}{2EI^2} dv$ .....(10)

Substituting dv = dxdA

Where dA = elemental cross-sectional area

$\frac{M^2.y^2}{2EI^2} \rightarrow$ is a function of x alone

Now substitiuting for dy in the expression of U.

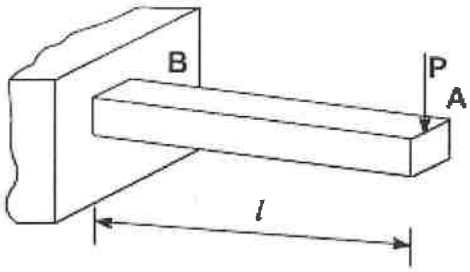
$$U = \int_0^L \frac{M^2}{2EI^2} \left(\int y^2 dA \right) dx \qquad .....(11)$$

We know $\int y^2 dA$ represents the moment of inertia 'I' of the cross-section about its neutral axis.

$$\boxed{U = \int_0^L \frac{M^2}{2EI} dx} \qquad .....(12)$$

ILLUSTRATIVE PROBLEMS

1. Determine the strain energy of a prismatic cantilever beam as shown in the figure by taking into account only the effect of the normal stresses.



Solution : The bending moment at a distance x from end A is defined as

$$\boxed{M = -Px}$$

Substituting the above value of M in the expression of strain energy we may write

$$U = \int_0^L \frac{P^2 x^2}{2EI} dx$$

$$\boxed{U = \int_0^L \frac{P^2 L^3}{EI}}$$

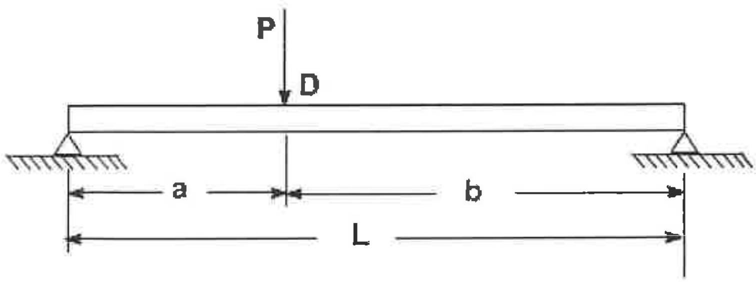
Problem 2 :

a. Determine the expression for strain energy of the prismatic beam AB for the loading as shown in figure below. Take into account only the effect of normal stresses due to bending.
b. Evaluate the strain energy for the following values of the beam

P = 208 KN ; L = 3.6 m = 3600 mm

A = 0.9 m = 90mm ; b = 2.7m = 2700 mm

E = 200 GPa ; I = 104 x 10^8 mm^4



Consider an inertial frame of reference 'S' fixed in space. a rigid body is rotating with angular velocity $\vec{\omega}$ about
Now consider another frame 'S'' fixed in the rigid (principal axes)
It will also rotate with the rotation of rigid body velocity $\vec{\omega}$ in space w.r.t. S.
then angular momentum of the rigid body principal axes is given by

$$\vec{L} = I_{xx}\,\omega_x\,\hat{i} + I_{yy}\,\omega_y\,\hat{j} + I_{zz}\,\omega_z\,\hat{k}$$

$$\Rightarrow \vec{L} = I_x\,\omega_x\,\hat{i} + I_y\,\omega_y\,\hat{j} + I_z\,\omega_z\,\hat{k}$$

where $I_x, I_y, I_z \rightarrow$ principal moments of inertia ar
But $\omega_x, \omega_y, \omega_z$ and $\hat{i}, \hat{j}, \hat{k}$ vary with time.

$\because$ frame S' fixed in the body is rotating

$$\therefore \frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d}{dt}\omega_y \hat{j} + I_z \frac{d}{dt}\omega_z \hat{k}$$

$$+ I_x \omega_x \frac{d\hat{i}}{dt} + I_y \omega_y \frac{d}{dt}\hat{j} + I_z \omega_z \frac{d\hat{k}}{dt}$$

Now we know that $\vec{v} = \vec{\omega} \times \vec{r}$

where $\vec{v} = \frac{d\vec{r}}{dt} \Rightarrow \frac{d\vec{r}}{dt} = \vec{\omega} \times \vec{r}$

$\Rightarrow \frac{d}{dt} = \vec{\omega} \times$

using relation (3) we get

$$\frac{d\hat{i}}{dt} = \vec{\omega} \times \hat{i}, \quad \frac{d\hat{j}}{dt} = \vec{\omega} \times \hat{j}, \quad \frac{d\hat{k}}{dt} = \vec{\omega} \times \hat{k}$$

Putting these values in eqn. (2)

$$\Rightarrow \frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d\omega_y}{dt}\hat{j} + I_z \frac{d\omega_z}{dt}\hat{k} + \Big[I_x \omega_x (\vec{\omega} \times \hat{i}) +$$

$$+ I_z \omega_z (\vec{\omega} \times$$

$$\Rightarrow \frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d\omega_y}{dt}\hat{j} + I_z \frac{d\omega_z}{dt}\hat{k}$$

$$+ \vec{\omega} \times \underbrace{\left(I_x \omega_x \hat{i} + I_y \omega_y \hat{j} + I_z \omega_z \hat{k} \right)}_{= \vec{L}}$$

$$\Rightarrow \quad \frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d\omega_y}{dt}\hat{j} + I_z \frac{d\omega_z}{dt}\hat{k} +$$

Consider $\vec{\omega} \times \vec{L} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \omega_x & \omega_y & \omega_z \\ I_x\omega_x & I_y\omega_y & I_z\omega_z \end{vmatrix} = \hat{i}\,(I_z \omega_y \omega_z - I_y \omega_y$

$- \hat{j}\,(I_z \omega_x \omega_z - I_x \omega$

$+ \hat{k}\,(I_y \omega_x \omega_y - I_x$

$$\vec{\omega} \times \vec{L} = -\Big[(I_y - I_z)\,\omega_y \omega_z \hat{i} + (I_z - I_x)\,\omega_x \omega_z \hat{j}$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d\omega_y}{dt}\hat{j} + I_z \frac{d\omega_z}{dt}\hat{k}$$

$$- (I_y - I_z)\,\omega_y \omega_z \hat{i} - (I_z - I_x)\,\omega_x \omega_z \hat{j} - (I_x - I_y)\,\omega_x \omega_y \hat{k}$$

$$\vec{\tau} = \frac{d\vec{L}}{dt} = \tau_x \hat{i} + \tau_y \hat{j} + \tau_z \hat{k}$$

$$\Rightarrow \tau_x \hat{i} + \tau_y \hat{j} + \tau_z \hat{k} = \left[I_x \frac{d\omega_x}{dt} - (I_y - I_z)\omega_y \omega_z \right] \hat{i}$$

$$+ \left[I_y \frac{d\omega_y}{dt} - (I_z - I_x)\omega_x \omega_z \right] \hat{j}$$

$$+ \left[I_z \frac{d\omega_z}{dt} - (I_x - I_y)\omega_x \omega_y \right] \hat{k}$$

Comparing the coeff. on both sides

we get

$$\boxed{\begin{aligned} \tau_x &= I_x \frac{d\omega_x}{dt} - (I_y - I_z)\omega_y \omega_z \\ \tau_y &= I_y \frac{d\omega_y}{dt} - (I_z - I_x)\omega_x \omega_z \\ \tau_z &= I_z \frac{d\omega_z}{dt} - (I_x - I_y)\omega_x \omega_y \end{aligned}}$$

$\Rightarrow$

Prove that if there is no force acting on a rig[id body]
with one pt. fixed, then total rotational K.E.

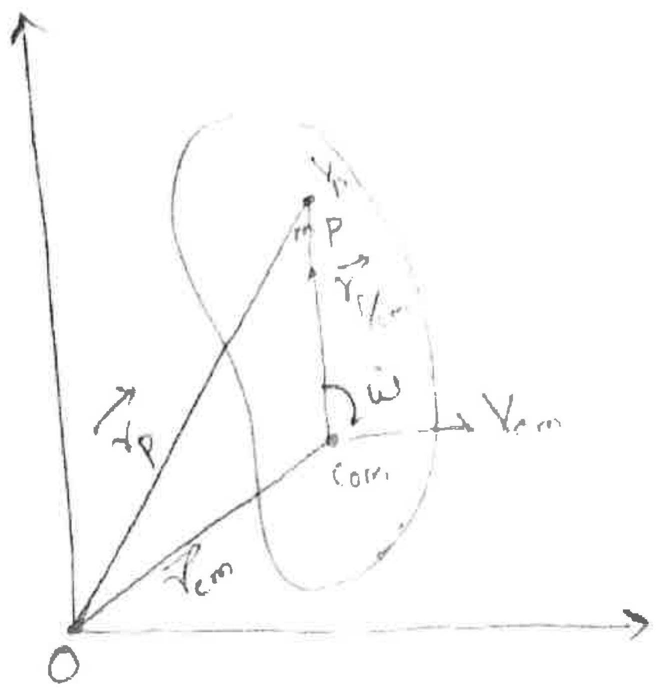
Also prove $\vec{\omega} \cdot \vec{L} = 2T = \text{const.}$

Angular Momentum(L) of a body under planar motion

$$L = \Sigma \vec{r_p} \times m\vec{V_p} \quad \text{———— (1)}$$

$$\vec{r_p} = r_{p/cm} + \vec{r_{cm}} \quad \text{———— (2)}$$

$$\vec{V_p} = V_{p/cm} + V_{cm} \quad \text{———— (3)}$$



Sub (2) & (3) in eqn (1)

$$L = \Sigma m \left(\vec{r}_{p/cm} + \vec{r}_{cm}\right) \times \left(\vec{V}_{p/cm} + \vec{V}_{cm}\right) \quad \text{———— (4)}$$

$$= \Sigma m\, \vec{r}_{p/cm} \times V_{p/cm} + \Sigma m\, \vec{r}_{p/cm} \times \vec{V}_{cm} + \Sigma m\, \vec{r}_{cm} \times \vec{V}_{p/cm} + \Sigma m\, \vec{r}_{cm} \times \vec{V}_{c}$$

$$L = \Sigma m\, \vec{r}_{p/cm} \times \vec{V}_{p/cm} + \left(\Sigma m\, \vec{r}_{p/cm}\right) \times \vec{V}_{cm} + \vec{r}_{cm} \times \Sigma m\, \vec{V}_{p/cm} + \left(\vec{r}_{cm} \times \vec{V}_{cm}\right) \Sigma \quad \text{--- (5)}$$

$$\vec{r}_{cm/g} = \frac{\Sigma m\, \vec{r}_{p/g}}{\Sigma m}$$

$$\vec{r}_{cm/cm} = \frac{\Sigma m\, \vec{r}_{p/cm}}{\Sigma m}$$

here $\vec{r}_{cm/cm} = 0$

$$\therefore \quad \Sigma m\, \vec{r}_{p/cm} = 0 \quad \text{--- (6)}$$

$$\vec{V}_{cm/g} = \frac{\Sigma m\, \vec{V}_{p/g}}{\Sigma m}$$

$$\vec{V}_{cm/cm} = \frac{\Sigma m\, \vec{V}_{p/cm}}{\Sigma m}$$

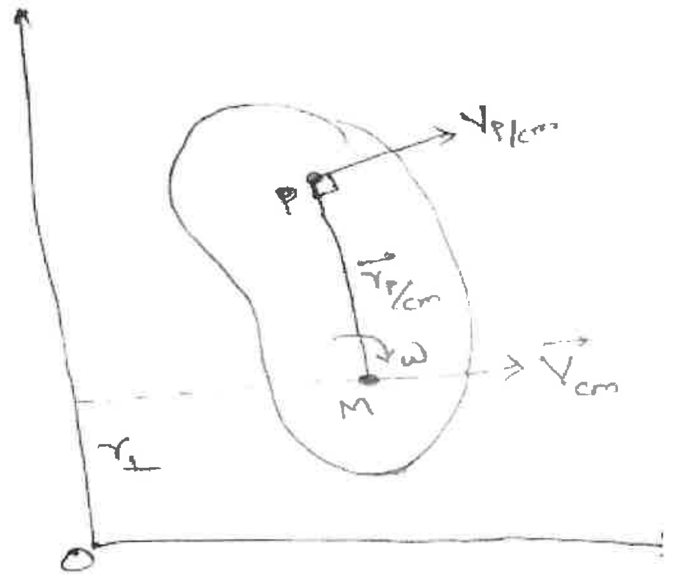
here $\vec{V}_{cm/cm} = 0$

$$\therefore \quad \Sigma m\, \vec{V}_{p/cm} = 0 \quad \text{--- (7)}$$

Sub (6) eq (7) in (5) ∴

$$L = \sum m\, \vec{r}_{p/cm} \times \vec{V}_{p/cm} + \left(\sum m\, \cancel{\vec{r}_{p/cm}}^{\,0}\right) \times \vec{V}_{cm} + \vec{r}_{cm} \times \sum m\, \cancel{V_{p/cm}}^{\,0} + \left(\vec{r}_{cm} \times \vec{V}_{cm}\right) \sum m$$

$$L = \sum \left(m\, \vec{r}_{p/cm} \times \vec{V}_{p/cm}\right) + \left(\vec{r}_{cm} \times \vec{V}_{cm}\right) M \qquad (8)$$



$$\vec{V}_{p/cm} = \vec{r}_{p/cm}\, \omega$$

$$\vec{L} = \sum m\, r_{p/cm}^2\, \omega \sin 90^\circ + M r_{cm} r_\perp$$

$$\boxed{\vec{L} = I_{cm}\, \omega + M V_{cm}\, r_\perp}$$

↓ Rotation ↓ Translation.

Mechanics:

Mechanics is a branch of physics concerned with the motion of bodi action of forces, including the special case in which a body remains at concern in the problem of motion are the forces that bodies exert on This leads to the study of such topics as gravity, electricity, and according to the nature of the forces involved.

Classical Mechanics:

Classical mechanics describes the motion of macroscopic objects, fron to parts of machinery, and astronomical objects, such as spacecraft, p and galaxies.

Quantum Mechanics:

Quantum mechanics is a fundamental theory in physics that provides a of the physical properties of nature at the scale of atoms and subatomic

Motion:

- Motion, in physics, change with time of the position or orientation of a body.

- Motion along a line or a curve is called translation. Motion that cha orientation of a body is called rotation. In both cases all points in the body same velocity (directed speed) and the same acceleration (time rate of c velocity).

Newton's Laws:

First law: states that every object will remain at rest or in uniform motion in line unless compelled to change its state by the action of an external force.

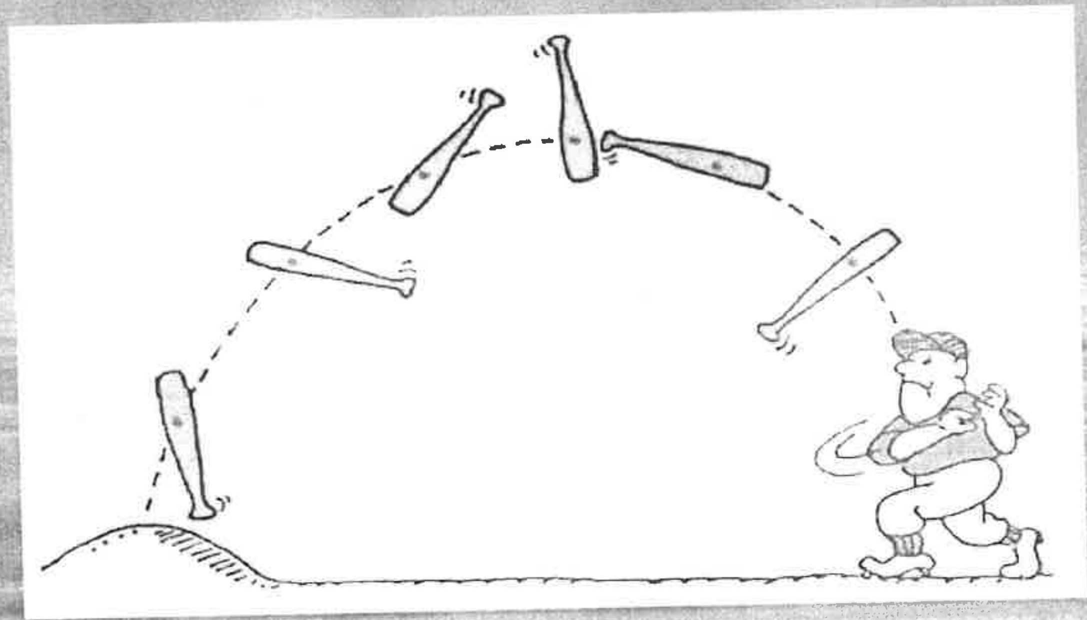
Second law: states that the rate of change of momentum of a body is proportional to the force applied, and this change in momentum takes pla direction of the applied force.

states that for every action (force) in nature there is an equal and reaction.

Let's learn some basic terms regarding rotational motion:

- Particle
- System of particles
- Linear motion
- Translational motion
- Circular motion
- Rotational motion
- Moment of inertia

- **Centre of Mass:** Centre of mass of a system of particles(rigid body) is point where complete mass of the body can be considered as concentra
- Centre of mass of a body is a point such that, if sum of force is applied point it will have the same effect as if the forces are applied at different



Kinematics:

Kinematics is the branch of mechanics concerned with the motion of o reference to the forces which cause the motion.

Kinetics:

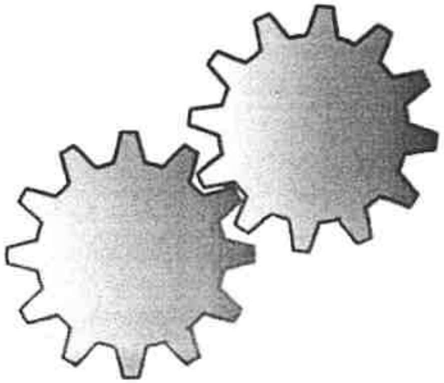
- Deals with the forces and their effects on moving bodies.

Rigid body:

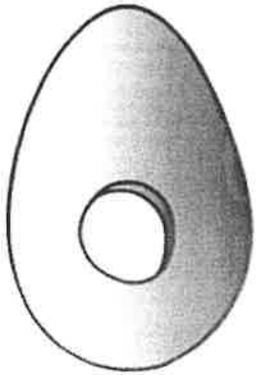
-In physics, a rigid body is a solid body in which deformation is zero or so neglected. The distance between any two given points on a rigid body rema time regardless of external forces exerted on it.

[illegible] between rigid and non-rigid body:

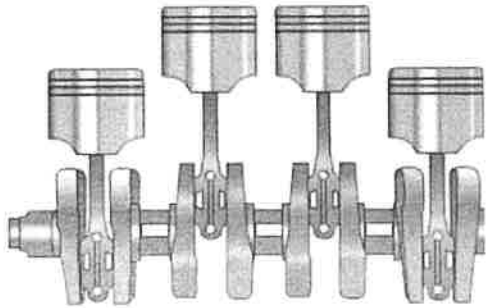
When force is applied on a **rigid body**, there will be no change in the sh the **rigid body**. In case of **a non rigid body** the force will distort shape the body.



Gears



Cams



Mechanisms

RIGID BODY MOTION

- A rigid body is said to be in motion, if the position of any particle of the body or the o
of any line drawn on the body is changed during a finite time interval.

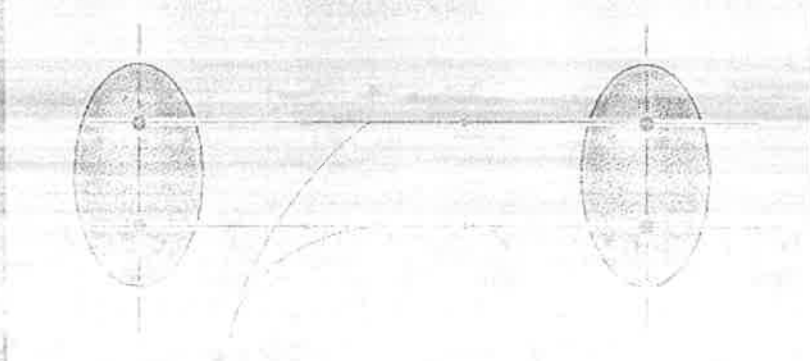
- When all the particles of a rigid body move along paths which are equidistant from a fix
the body is said to undergo planar motion.

- There are three types of planar motion:

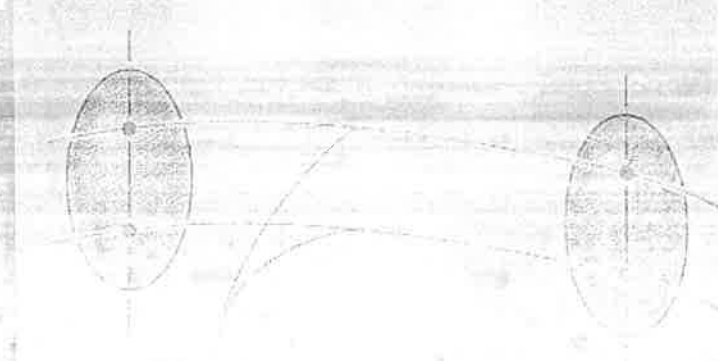
  - General Plane Motion

TRANSLATION:

- Translation occurs if any line segment on the body remains parallel to its original direc motion
- When the paths of motion for any two particles of the body are along equidistant straig motion is called rectilinear translation
- If the paths of [illegible] called translation

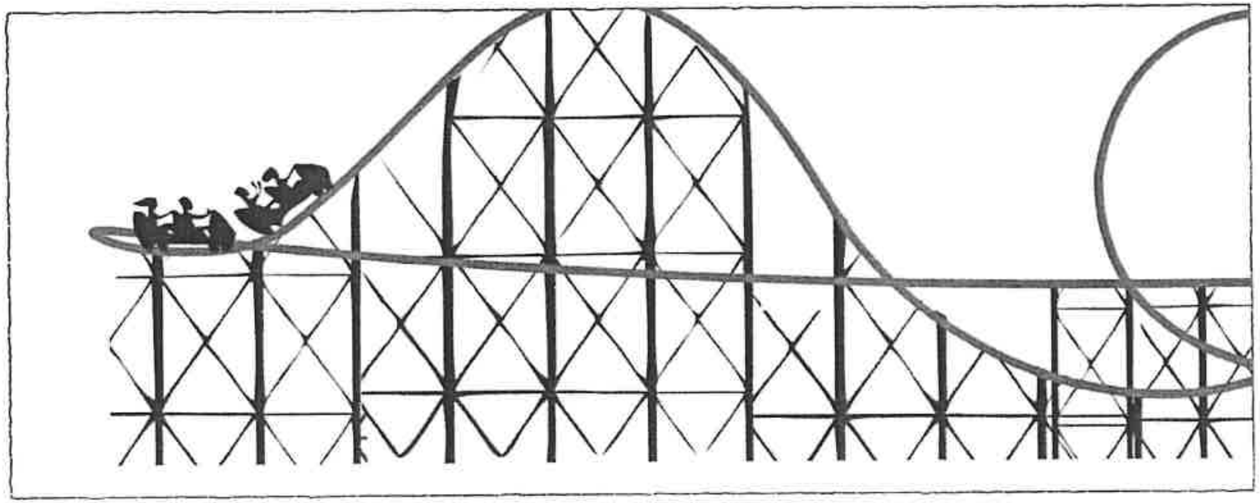


Path of rectilinear translation

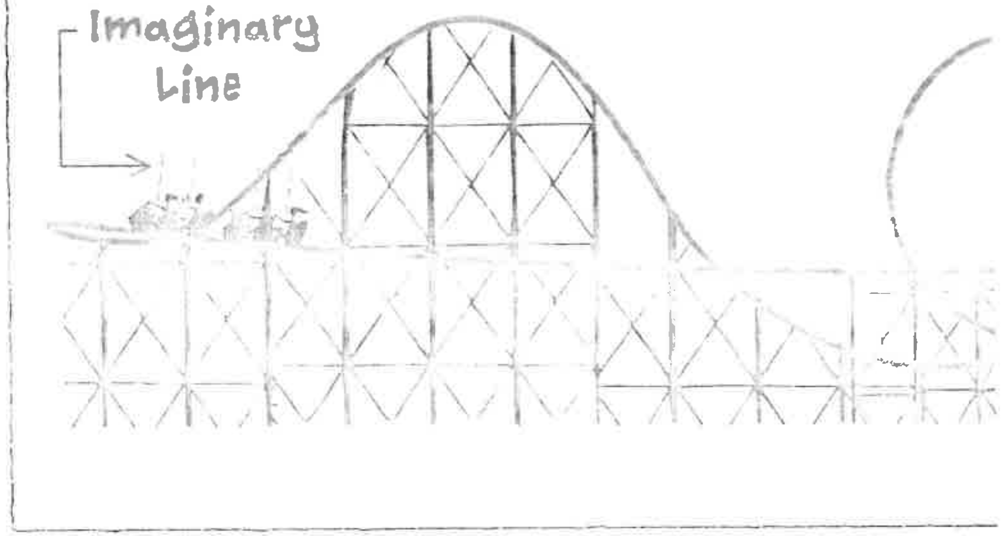


Path of curvilinear translation

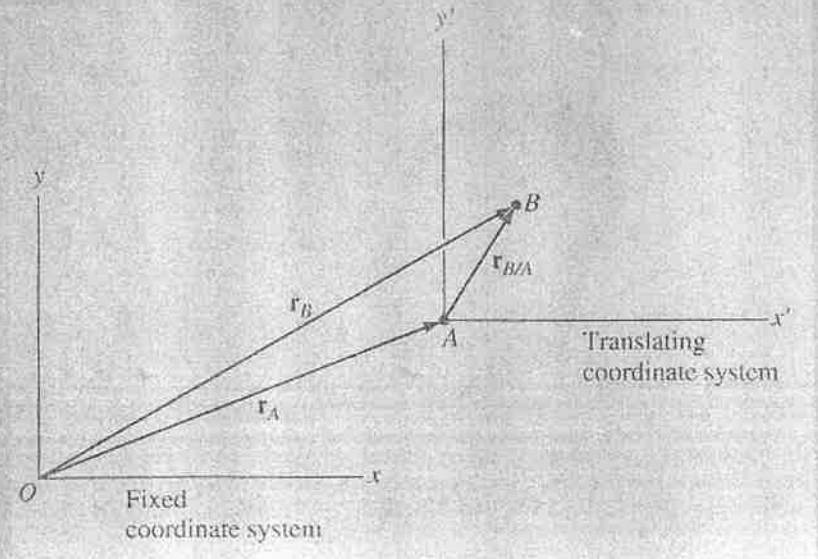
Translation Motion



Translatory Motion



TRANSLATION

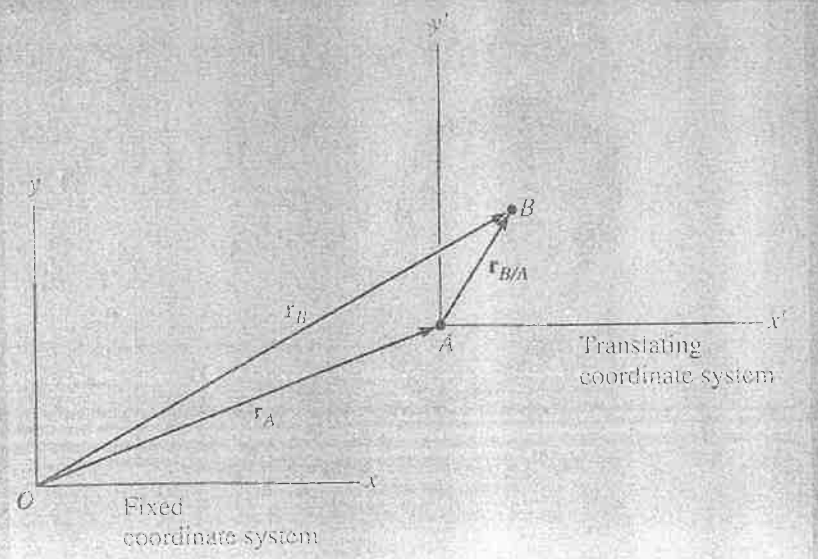


- Consider a rigid body which is subject to either rectilinear or curvilinear translation in th [illegible]

Position

[illegible] points A [illegible] by using

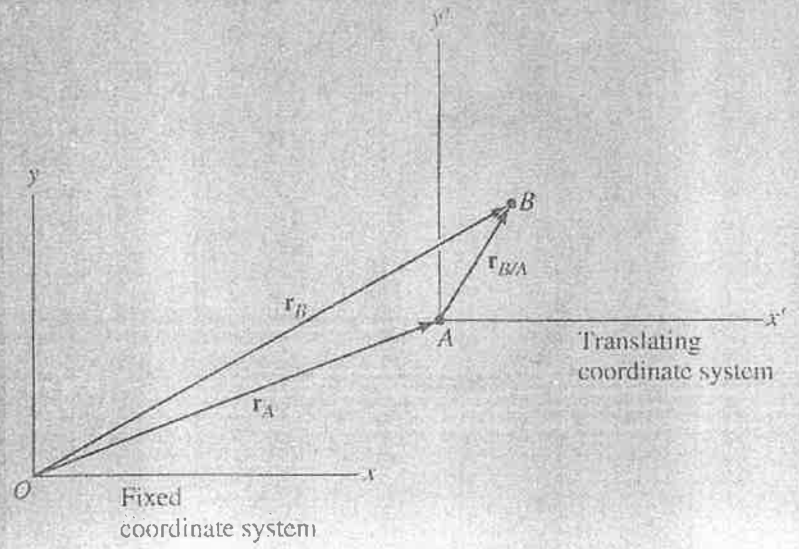
TRANSLATION



Velocity:

- A relationship be[illegible] velocities of [illegible] obtained by taking the time derivative of th[illegible] position equation[illegible]

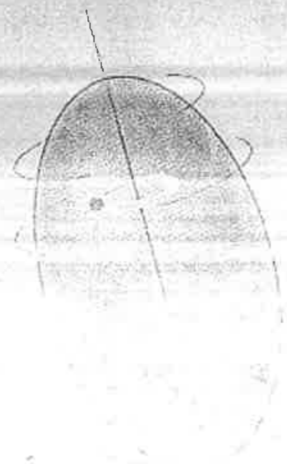
TRANSLATION



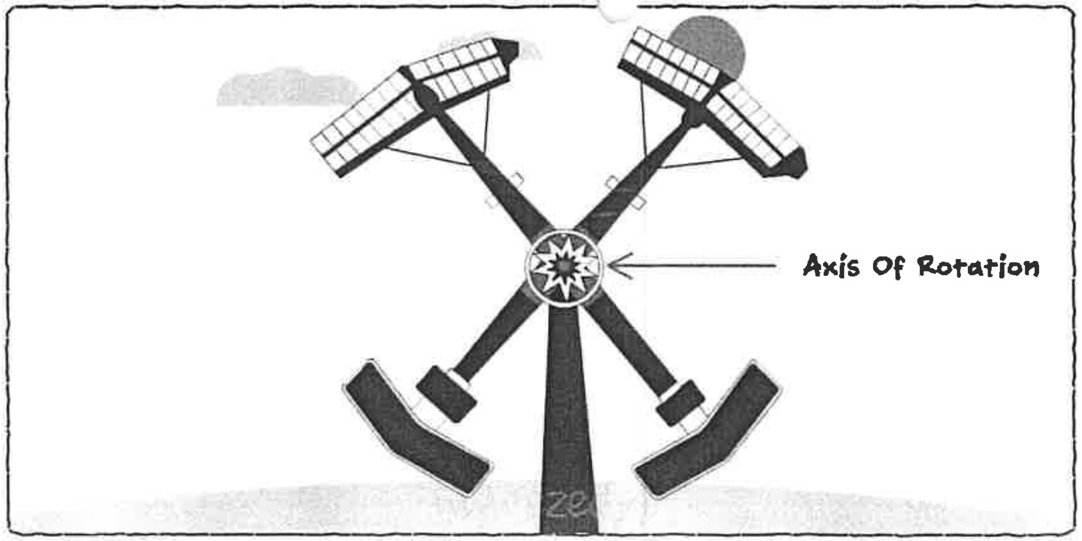
- Acceleration:

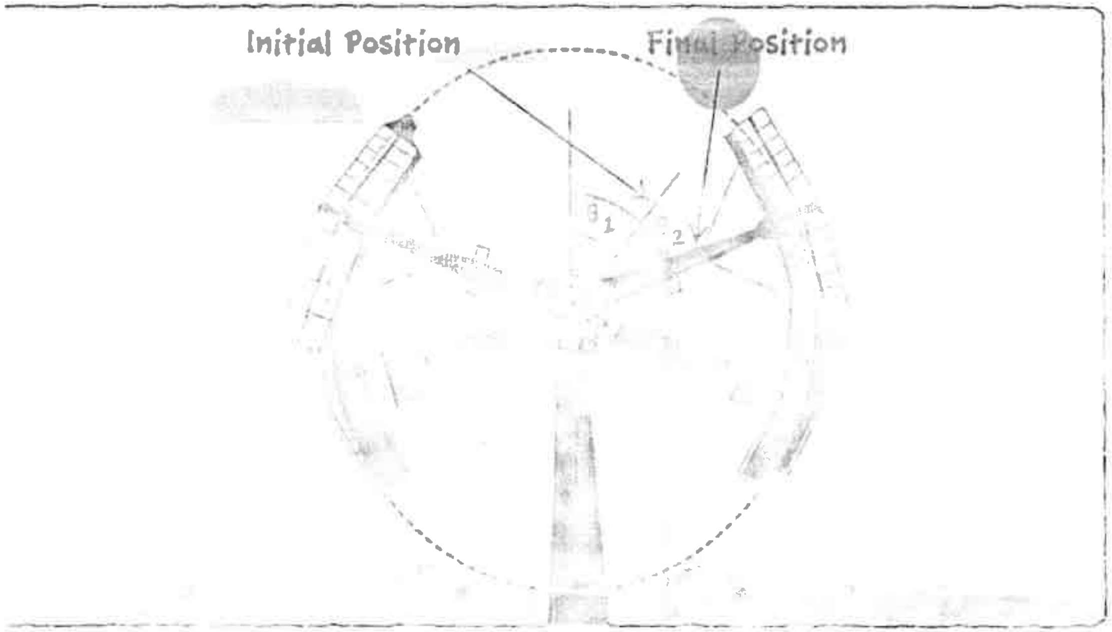
ROTATION ABOUT A FIXED AXIS:

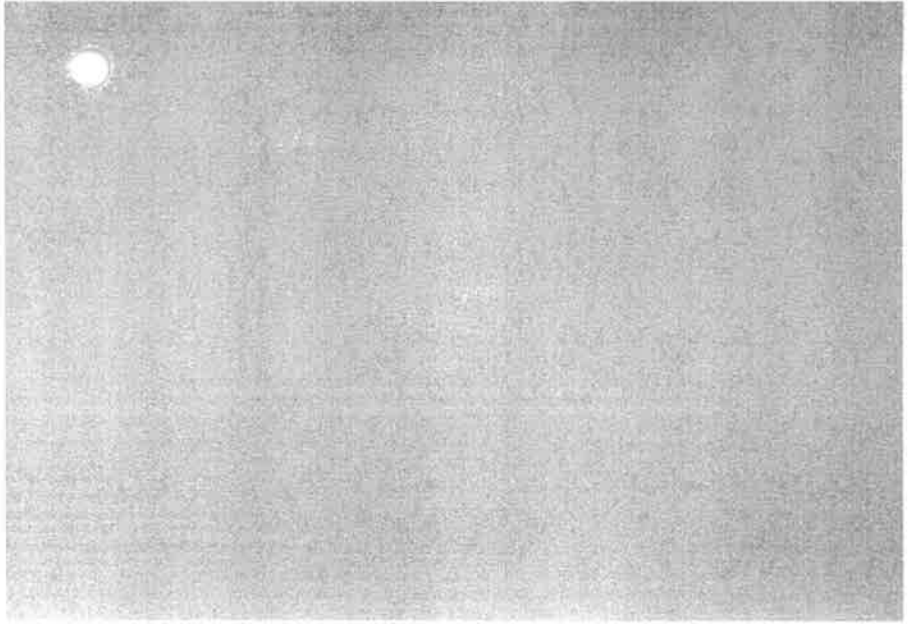
- A rigid body is said to be in rotation, if all the particles of the body move along circles fixed axis of rotation. The planes of the circular paths are perpendicular to the axis of r



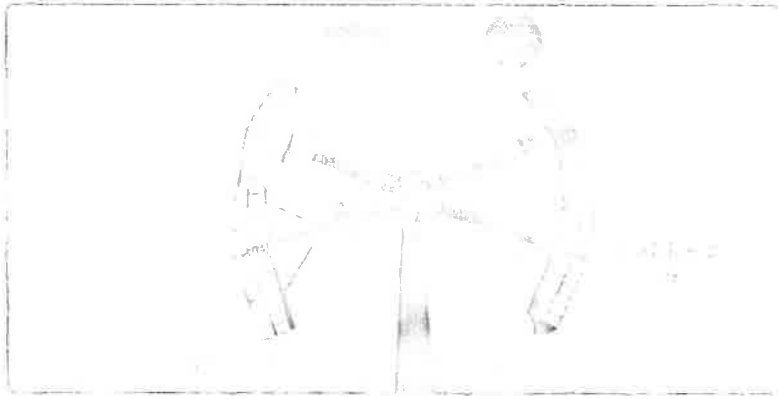
Rotation About Fixed Axis







Rotation About Fixed A



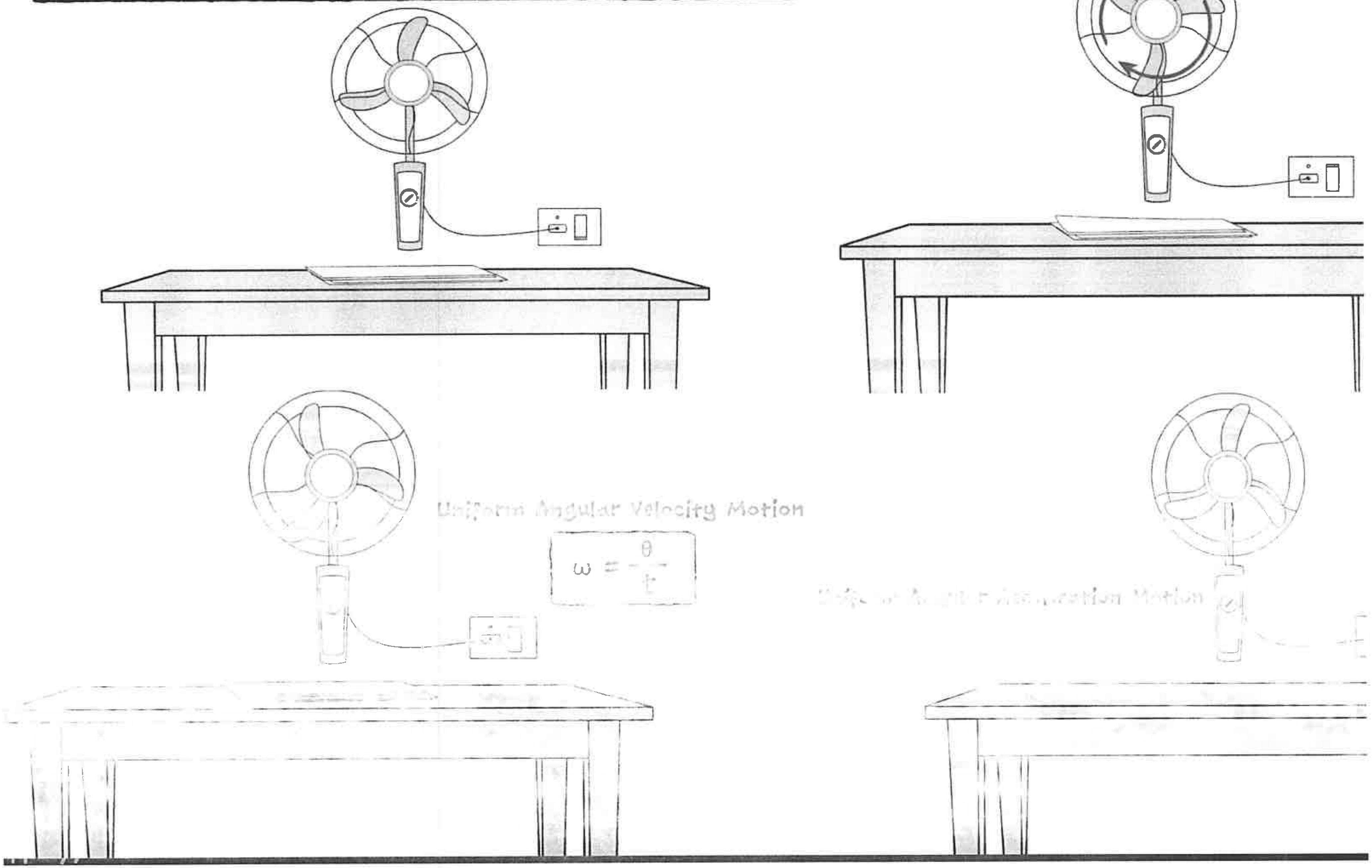
1.

2.

3.

4.

Types Of Rotation Motion About Fixed Axis



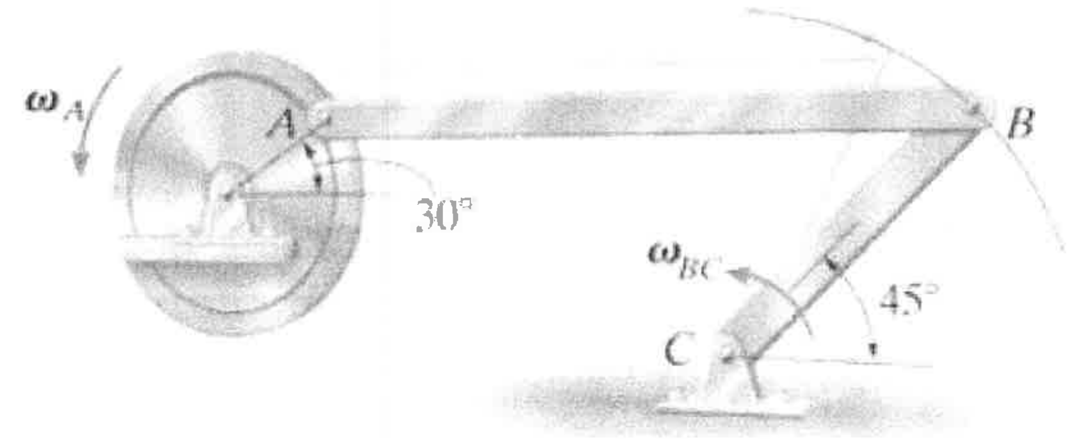
$s \rightarrow \theta$, $v \rightarrow \omega$, $a \rightarrow \alpha$, $F \rightarrow \tau$, $m \rightarrow$ I

Rectilinear Motion	Formulae	Rotational Motion	Fo
Linear Velocity	$v = \frac{ds}{dt}$	Angular Velocity	
Acceleration	$a = \frac{dv}{dt}$	Angular Acceleration	
Force	$F = ma$	Torque	
Work	$W = \int F\,ds$	Work	
Power	$P = F.v$	Power	
Kinetic Energy	$K.E = \frac{1}{2} mv^2$	Kinetic Energy	

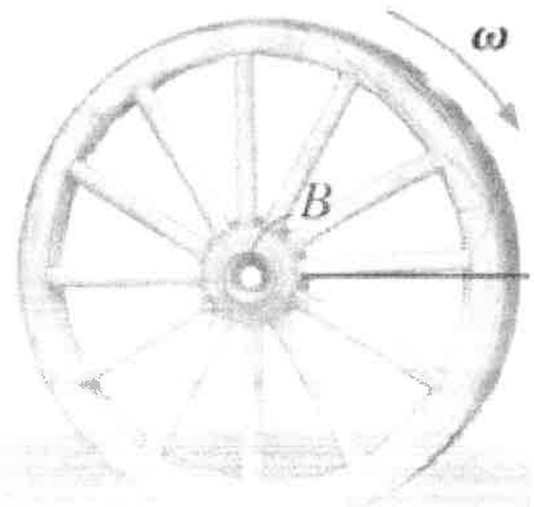
RIGID BODY MOTION

GENERAL PLANE MOTION (COMPLEX MOTION):

- When a body is subjected to general plane motion, it undergoes a combination of t
and rotation
- The translation occurs within a reference plane, and the rotation occurs about an ax
perpendicular to the re

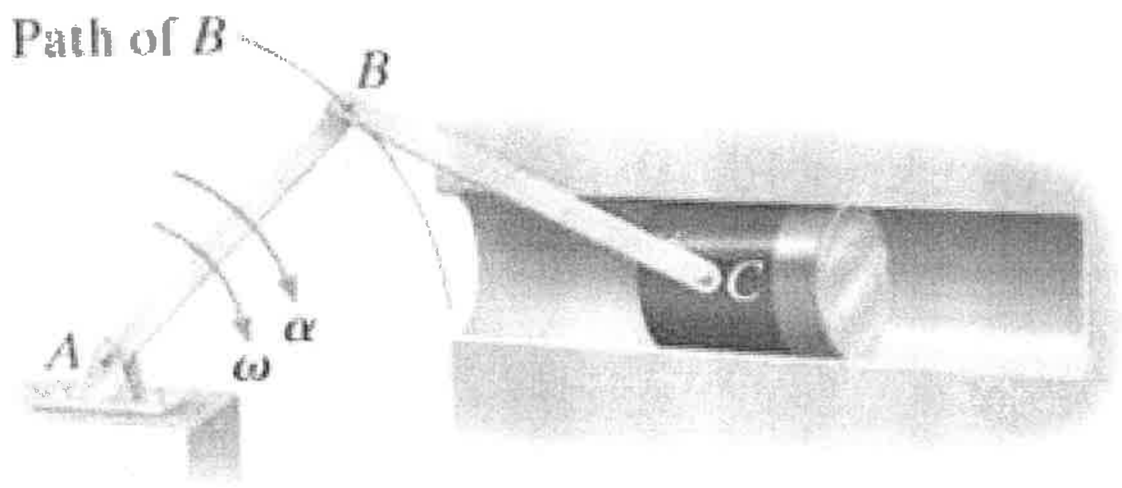


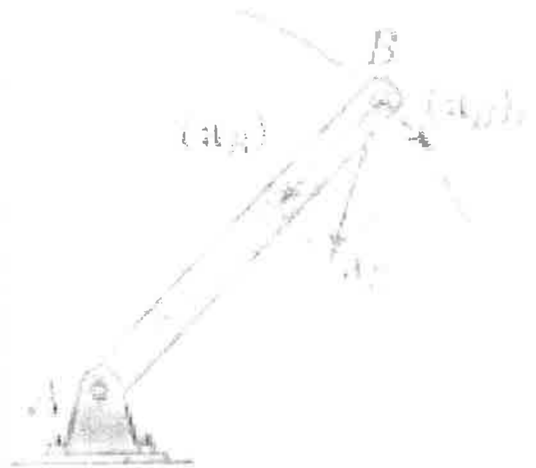
ω_A
A
30°
B
ω_BC
45°
C



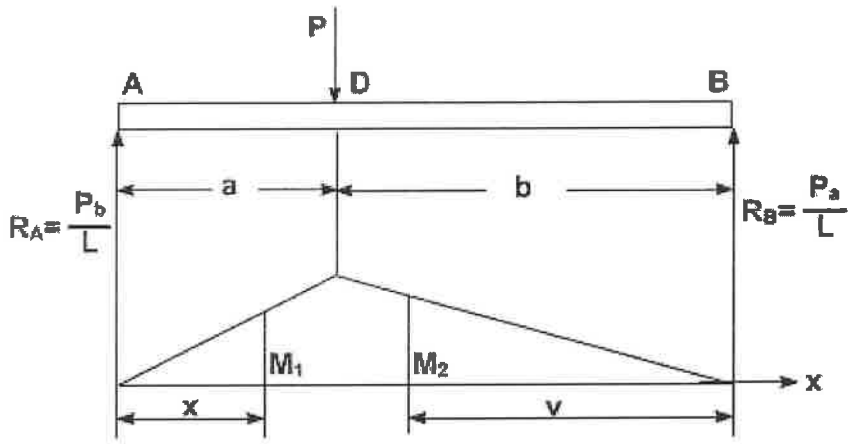
ω
B

A
B


Path of B
B
A
ω
α
C


B
A

Solution:



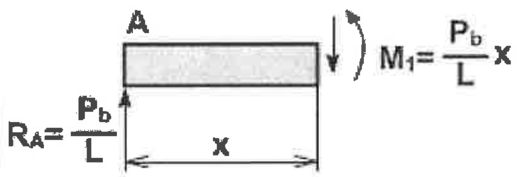
a.

Bending Moment : Using the free � body diagram of the entire beam, we may determine the values of reactions as follows:

$R_A = P_b / L$ $R_B = P_a / L$

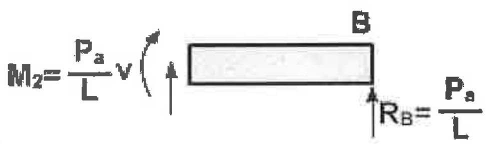
For Portion AD of the beam, the bending moment is

$\boxed{M_1 = \frac{P_b}{L} x}$



For Portion DB, the bending moment at a distance v from end B is

$\boxed{M_2 = \frac{P_a}{L} x}$



Strain Energy :

Since strain energy is a scalar quantity, we may add the strain energy of portion AD to that of DB to obtain the total strain energy of the beam.

$$U = U_{AD} + U_{DB}$$

$$= \int_0^a \frac{M_1^2}{2EI} dx + \int_0^b \frac{M_2^2}{2EI} dv$$

$$= \frac{1}{2EI} \int_0^a \left(\frac{P_b}{L} x \right)^2 dx + \frac{1}{2EI} \int_0^b \left(\frac{P_a}{L} v \right)^2 dx$$

$$= \frac{1}{2EI} \frac{P^2}{L^2} \left(\frac{b^2 a^3}{3} + \frac{a^2 b^3}{3} \right)$$

$$\boxed{U = \frac{P^2 a^2 b^2}{6EIL^2}(a + b)}$$

Since$(a + b) = L$

$$\boxed{U = \frac{P^2 a^2 b^2}{6EIL}}$$

b. Substituting the values of P, a, b, E, I, and L in the expression above.

$$U = \frac{(200 \times 10^3)^2 \times (900)^2 \times (2700)^2}{6(200 \times 10^3) \times (104 \times 10^6) \times (3600)} = 5.27 \times 10^7 \text{ KN.m}$$

Problem

3) Determine the modulus of resilience for each of the following materials.

a. Stainless steel . E = 190 GPa σ_y = 260MPa

b. Malleable constantan E = 165GPa σ_y = 230MPa

c. Titanium E = 115GPa σ_y = 830MPa

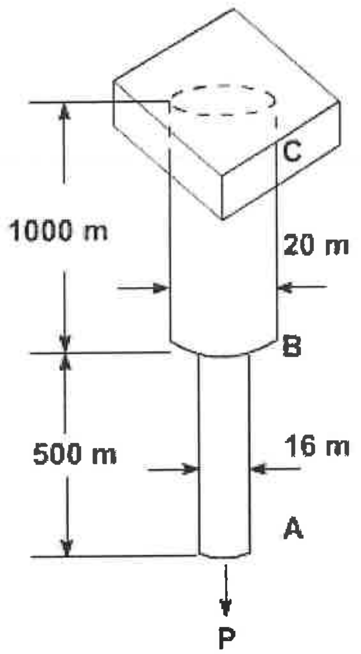
d. Magnesium E = 45GPa σ_y = 200MPa

4) For the given Loading arrangement on the rod ABC determine

(a). The strain energy of the steel rod ABC when

P = 40 KN.

(b). The corresponding strain energy density in portions AB and BC of the rod.



UNIT V

ANALYSIS OF STRESSES IN TWO DIMENSIONS

PART-A (2 Marks)

1. Distinguish between thick and thin cylinders.
2. Define Principal planes and principal stress.
3. Define: Thin cylinders. Name the stresses set up in a thin cylinder subjected to internal fluid pressure.
4. What is Mohr's circle & name any the situations where it is used?
5. Define principal planes and principal stresses.
6. Draw Mohr's Circle for given shear stress q.
7. What is the necessary condition for maximum shear stress?
8. Define Obliquity.
9. Define Strain energy and resilience.
10. Define proof resilience and modulus of resilience.

PART- B (16 Marks)

1. A Thin cylindrical shell 3 m long has 1m internal diameter and 15 mm metal thickness. Calculate the circumferential and longitudinal stresses induced and also the change in the dimensions of the shell, if it is subjected to an internal pressure of1.5 N/mm2 Take E = 2x105 N/mm2 and poison's ratio =0.3. Also calculate change in volume.

2. A closed cylindrical vessel made of steel plates 4 mm thick with plane ends, carries fluid under pressure of 3 N/mm2 The diameter of the cylinder is 25cm and length is 75 cm.

Calculate the longitudinal and hoop stresses in the cylinder wall and determine the change in diameter, length and Volume of the cylinder. Take E =2.1x105 N/mm2 and 1/m = 0.286.

3. A rectangular block of material is subjected to a tensile stress of 110 N/mm2 on one plane and a tensile stress of 47 N/mm2 on the plane at right angle to the former plane and a tensile stress of 47 N/mm2 on the plane at right angle to the former. Each of the above stress is accompanied by a shear stress of 63 N/mm2 Find (i) The direction and magnitude of each of the principal stress (ii) Magnitude of greatest shear stress

4. At a point in a strained material, the principal stresses are100 N/mm2 (T) and 40 N/mm2 (C). Determine the resultant stress in magnitude and direction in a plane inclined at 600 to the axis of major principal stress. What is the maximum intensity of shear stress in the material at the point?

5. A rectangular block of material is subjected to a tensile stress of 210 N/mm2 on one plane and a tensile stress of 28 N/mm2 on the plane at right angle to the former plane and a tensile stress of 28 N/mm2 on the plane at right angle to the former. Each of the above stress is accompanied by a shear stress of 53 N/mm2 Find (i) The direction and magnitude of each of the principal stress (ii) Magnitude of greatest shear stress

6 A closed cylindrical vessel made of steel plates 5 mm thick with plane ends, carries fluid under pressure of 6 N/mm2 The diameter of the cylinder is 35cm and length is 85 cm. Calculate the longitudinal and hoop stresses in the cylinder wall and determine the change in diameter, length and Volume of the cylinder. Take E =2.1x105 N/mm2 and 1/m = 0.286.

7. At a point in a strained material, the principal stresses are 200 N/mm2 (T) and 60 N/mm2 (C) Determine the direction and magnitude in a plane inclined at 600 to the axis of major principal stress. What is the maximum intensity of shear stress in the material at the point

8. At a point in a strained material, the principal stresses are 100 N/mm2 (T) and 40 N/mm2 (C) Determine the direction and magnitude in a plane inclined at 600 to the axis of major principal stress. What is the maximum intensity of shear stress in the material at the point

RIGID BODY

In physics, a **rigid body** (also known as a **rigid object**) is a solid body in which deformation is zero or so small it can be neglected. The distance between any two given points on a rigid body remains constant in time regardless of external forces or moments exerted on it. A rigid body is usually considered as a continuous distribution of mass.

Kinematics

1.The linear position or position of the body, namely the position of one of the particles of the body, specifically chosen as a reference point (typically coinciding with the center of mass or centroid of the body), together with

2.The angular position (also known as orientation, or attitude) of the body.

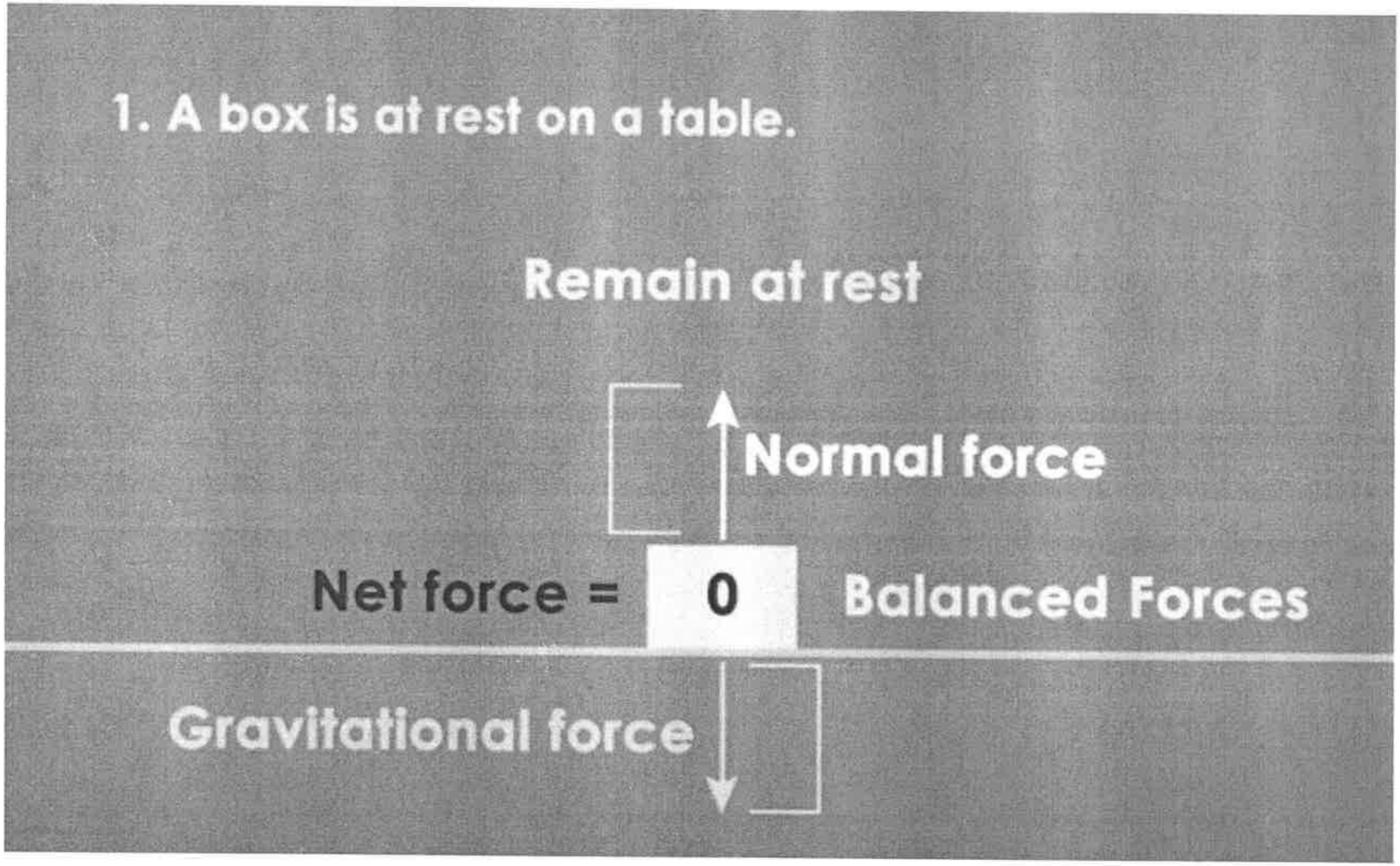
3. Linear and angular velocity

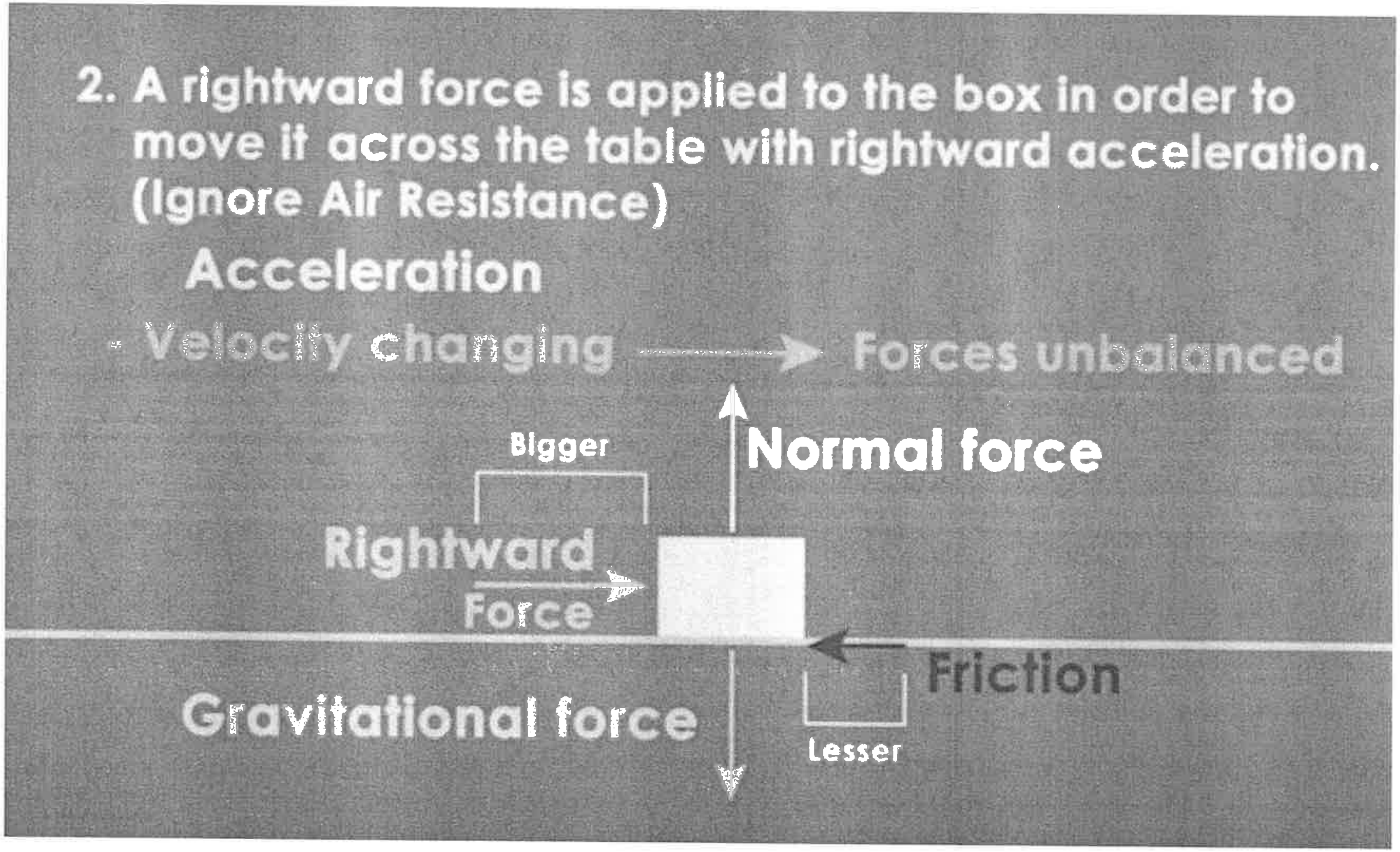
Kinetics

- Centre of mass
- Linear momentum
- Angular momentum
- Kinetic energy

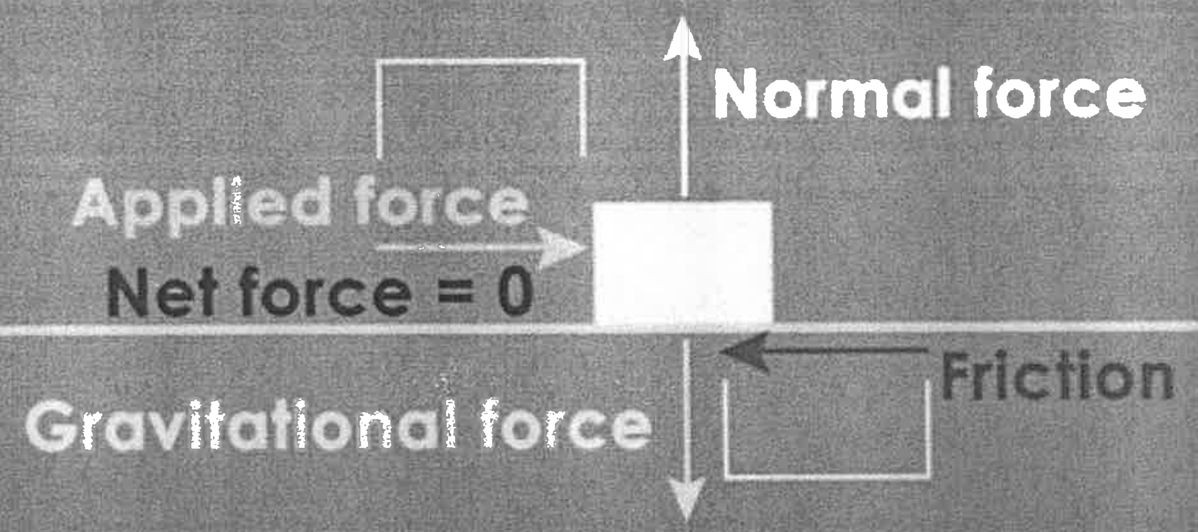
Free Body Diagram (FBD)

- A free body diagram is a diagram which indicates the object, the forces action on the object with their directions
- While drawing the free body diagram all the supports of the body are removed and replaced with the reaction forces acting on it
- FBD makes the problem easier by eliminating unwanted surroundings


1. A box is at rest on a table.
Remain at rest
Normal force
Net force = 0
Balanced Forces
Gravitational force


2. A rightward force is applied to the box in order to move it across the table with rightward acceleration. (Ignore Air Resistance)
Acceleration
Velocity changing
Forces unbalanced
Normal force
Bigger
Rightward Force
Friction
Lesser
Gravitational force

3. A box on the table is moving towards the right at constant velocity. (Ignore Air Resistance)



1. A flying squirrel is gliding (no *wing flaps*) from a tree to the ground at constant velocity. Consider air resistance. Diagram the forces acting on the squirrel.

2. A rightward force is applied to a book in order to move it across a desk with a rightward acceleration. Consider frictional forces. Neglect air resistance. Diagram the forces acting on the book.

3. A rightward force is applied to a book in order to move it across a desk at constant velocity. Consider frictional forces. Neglect air resistance. Diagram the forces acting on the book.

4. A college student rests a backpack upon his shoulder. The pack is suspended motionless by one strap from one shoulder. Diagram the vertical forces acting on the backpack.

5. A skydiver is descending with a constant velocity. Consider air resistance. Diagram the forces acting upon the skydiver.

6. A force is applied to the right to drag a sled across loosely packed snow with a rightward acceleration. Neglect air resistance. Diagram the forces acting upon the sled.

7. A football is moving upwards towards its peak after having been *booted* by the punter. Neglect air resistance. Diagram the forces acting upon the football as it rises upward towards its peak.

8. A car is coasting to the right and slowing down. Neglect air resistance. Diagram the forces acting upon the car

PROBLEMS

- A girl is to walk across a high wire strung horizontally between two buildings 12.0 m apart. The sag in the rope when she is at the midpoint is 10.0 degree. If her mass is 56.0 kg, what is the tension in the rope at this point?
- The distance between two telephone poles is 50.0m. When a 1.00kg bird lands on the telephone wire midway between the poles, the wire sags 0.200m. How much tension does the bird produce in the wire? Ignore the weight of wire.
- A 50-N box is slid straight across the floor at constant speed by force of 25 N at 40 degree (a) How large a friction force impedes the motion of the box? (b) How large is the normal force; (c) Find the coefficient friction between the box and the floor?

What is Precession?

Precession, phenomenon associated with the action of a gyr
a spinning top and consisting of a comparatively slow rotation o
of rotation of a spinning body about a line intersecting the spin
smooth, slow circling of a spinning top is precession, the uneven
is nutation.

What is spinning?

A rotation is a circular movement of an object around a center o
The geometric plane along which the rotation occurs is called th
plane, and the imaginary line extending from the center and perp
to the rotation plane is called the rotation axis. If the rotation ax
internally through the body's own center of mass, then the body
be spinning.

PRECESSION OF SPINNING TOP

A rapidly spinning top will precess in a direction deter
the torque exerted by its weight

The precession angular velocity is inversely proportio
spin angular velocity, so that the precession is faster ar
pronounced as the top slows down.

The direction of the [illegible] can be visualize
the help of the right-hand rule.

This process involves a considerable number of physical
mathematical concepts.

The angular momentum of the spinning top is given by it
of inertia times its spin speed but this exercise requires a
understanding of it's vector nature.
A torque is exerted about an axis through the top's suppo
by the [illegible] of the top acting on its [illegible] with
[illegible] with respect to that support point.

Since torque is equal to the rate of change of angular mo
this gives a way to relate the torque to the precession pro

From the definition of the angle of precession, the rate of
of the precession angle θ can be expressed in terms of the
change of angular momentum and hence in terms of the t

The expression for precession angular velocity is valid on
the conditions where the spin angular velocity ω is much
than the precession angular velocity ω_p.

When the top slows down, the top begins to wobble, an i
that more complicated types of motion are coming into pl

Gyroscope

A gyroscope is a device used for measuring or maintaining orientation and angular v
is a spinning wheel or disc in which the axis of rotation (spin axis) is free to ass
orientation by itself. When rotating, the orientation of this axis is unaffected by
rotation of the mounting, according to the conservation of angular momentum.

GYROSCOPIC EFFECT:

7. A spinning rotor has an axis of spin.
8. A couple acting about this axis can only ever cha[illegible]
the spinning speed
9. To change the direction of the axis of spin the onl[illegible]
remaining possibility is to apply a couple at right
angles to the spinning axis.
10. The axis of spin will deviate so as to direct the
direction of the applied couple. This is called
"Gyroscopic Precession".
11. More precisely, *"the angular momentum changes in
the direction of the applied couple"*. Angular momentum is
a measure of how fast the rotor is spinning.

Spinning symmetric tops are prolonged or oblated b
a cylindrical or discrete rotational symmetry, whirling
their symmetry axis $\mathbf{e}_m$, having one point fixed, or at l
restricted to move on a surface.

The symmetry axis coincides with the principal axle

magnitude.

One of the characteristic phenomena exhibite
spinning tops is ***precession***. This term is used
to several phenomena having different physic
origins.

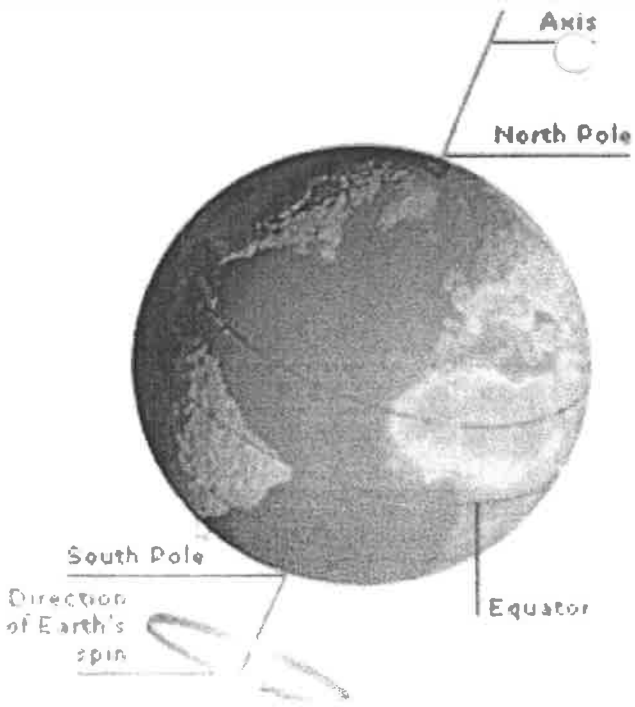
Torque-free precession occurs when no external co forces is acting on the top; its symmetry axis will sw around the mantle of a cone with opening angle ϑ, hereinafter ***nutation angle***, while the total angular momentum **L** of the system, which determines the a the cone, is conserved.

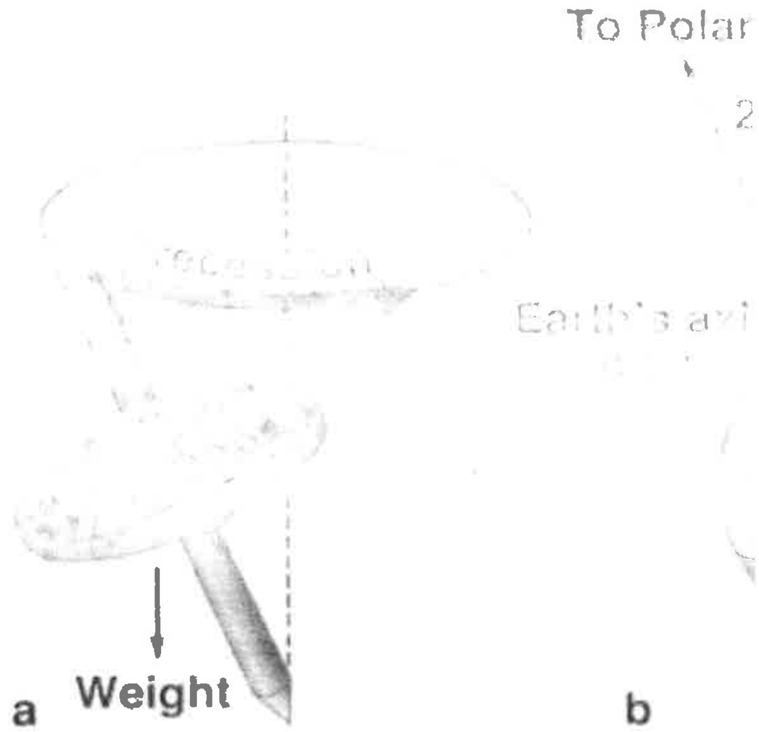
momentum as *precession*.

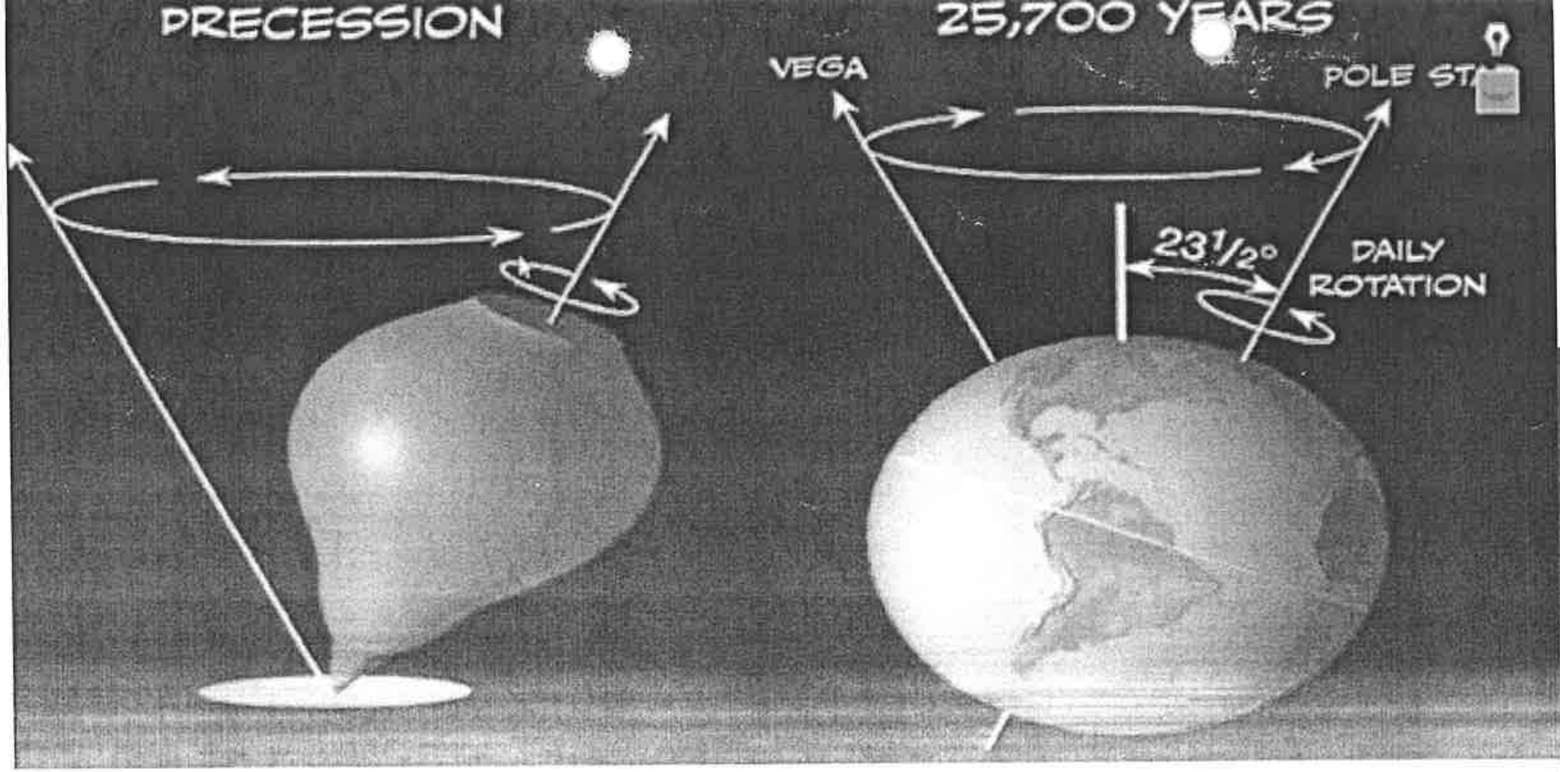
Note that different points of a freely precessing body are subjected to acceleration which varies in space and time, therefore mechanical tensions will arise within precessing free tops. This phenomenon has a major importance in planetary physics.

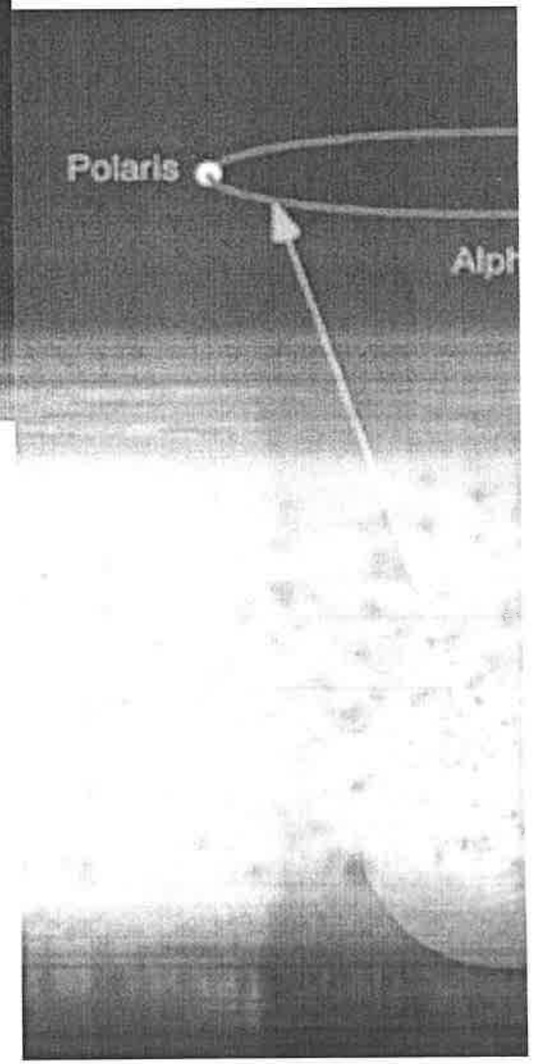
Torque-induced precession takes place if a spinning t[illegible] [illegible] cylindrical or at least [illegible] rotational symmetry, spinning around this [illegible] and subjected to a torque follows a regular trajectory.

Here the smooth change of the ***precession angle*** of th spinning (and symmetry) axis, that is, the ***precession***, accompanied by ***nutation***, a regular "***nodding***" of the angle. It is important to mention that asymmetric tops typically show chaotic behaviour. Presence of dissipat lead to exotic dynamics like the inversion of the tippe [illegible] precession [illegible], nutation [illegible] [illegible] "heavy" tops), w [illegible] dissipation is neglected.


Axis
North Pole
South Pole
Direction of Earth's spin
Equator


To Polar
2
Weight
a
b


PRECESSION
25,700 YEARS
VEGA
POLE ST
23½°
DAILY
ROTATION


Polaris

Let's derive equation for $\vec{a}$

$$\vec{a} = \frac{d\vec{v}}{dt} = \frac{d}{dt}(r\dot{\theta}\hat{\theta}) = r\frac{d}{dt}(\dot{\theta}\hat{\theta})$$

$$= r\left(\frac{d\dot{\theta}}{dt}\hat{\theta} + \dot{\theta}\frac{d\hat{\theta}}{dt}\right)$$

$$= r\left(\ddot{\theta}\hat{\theta} + \dot{\theta}\frac{d}{dt}(-\sin\theta\hat{i} + \cos\theta\hat{j})\right)$$

$$= r\left(\ddot{\theta}\hat{\theta} + \dot{\theta}\dot{\theta}(-\cos\theta\hat{i} - \sin\theta\hat{j})\right)$$

$$= r\left(\ddot{\theta}\hat{\theta} - \dot{\theta}\underbrace{(\cos\theta\hat{i} + \sin\theta\hat{j})}_{\hat{r}}\right)$$

$$\boxed{\vec{a} = r\ddot{\theta}\hat{\theta} - r\dot{\theta}\hat{r}}$$

$$fg = f'g + fg'$$

Newton's 2nd law

$$\vec{F} = m\vec{a}$$

$$= m(r\ddot{\theta}\hat{\theta} - r\dot{\theta}\hat{r})$$

$$\boxed{\vec{F} = mr\ddot{\theta}\hat{\theta} - mr\dot{\theta}^2\hat{r}}$$

In r-direction

$\vec{F}_r = -mr\dot{\theta}^2$ → radial force

In θ-direction

$\vec{F}_\theta = mr\ddot{\theta}$ → angular force

CONTINUOUS LEARNING ASSESSMENT - I

Mechanics and Mechanics of solids– U20PYBJ02

Date : 07-11-2022
Academic Year / Semester : 2022-2023/ODD
Duration : 1 hour 30 mins
Instructions : Answer all the questions (1 to 5) and answer either (a) or (b) from 6 to 8

Q.No	PART – A Answer All the Questions (5*2 = 10)	Weightage	CO	Bloom's Level
1	State Newton's second law of motion.	2	CO1	2
2	Give an example for damped harmonic motion.	2	CO1	2
3	What is Eulers law from newtons law?	2	CO2	2
4	State Eulers law of motion.	2	CO2	2
5	What is meant by precession?	2	CO2	3
	PART – B Answer all questions (2*4 = 08)			
6	(a) Explain Newton's equations of motion in polar coordinates **(or)** (b) Explain Newtons laws of motion with examples.	4	CO1	2
07	(a) Explain the rotation in plane. **(or)** (b) Explain the angular momentum in plane.	4	CO2	3
	PART – C Answer all questions (1*12 = 12)			
08	(a) Derive the equations of simple harmonic motions **(or)** (b) How to solve newtons laws of motion in polar coordinates.	12	CO1	2

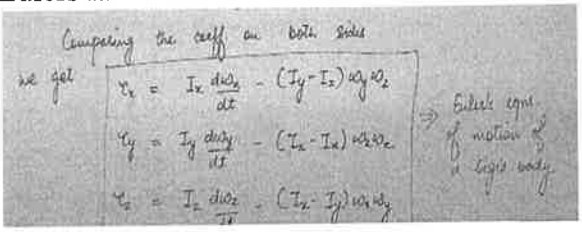
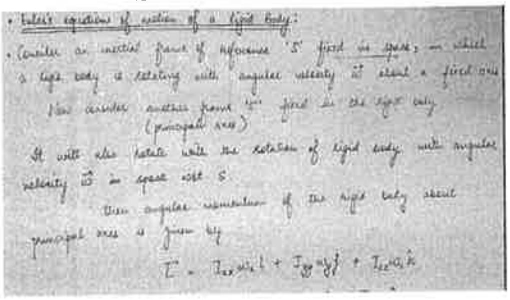
CO	Weightage
CO1	20
CO2	10
CO3	-
CO4	-
CO5	-
CO6	-
Total	30

Prepared by	Dr. K.Thirunavukkarasu	Signature	
Verified by	HOD	Signature	

CONTINUOUS LEARNING ASSESSMENT - I

Mechanics and Mechanics of solids– U20PYBJ02

Answer Key

Q.No	PART – A Answer All the Questions (5*2 = 10)
1	Newton's second law of motion. F=ma
2	Pendulum clock-example for damped harmonic motion.
3	Eulers law from newtons law-  Comparing the coeff on both sides we get $\tau_x = I_x \frac{d\omega_x}{dt} - (I_y - I_z)\omega_y\omega_z$ $\tau_y = I_y \frac{d\omega_y}{dt} - (I_z - I_x)\omega_z\omega_x$ $\tau_z = I_z \frac{d\omega_z}{dt} - (I_x - I_y)\omega_x\omega_y$ $\Rightarrow$ Euler's eqns of motion of a rigid body
4	State Eulers law of motion.  • Euler's equations of motion of a rigid body: • Consider an inertial frame of reference 'S' fixed in space, in which a rigid body is rotating with angular velocity $\vec{\omega}$ about a fixed axis Now consider another frame S' fixed in the rigid body (principal axes) It will also rotate with the rotation of rigid body with angular velocity $\vec{\omega}$ in space w.r.t S Then angular momentum of the rigid body about principal axes is given by $\vec{L} = I_{xx}\omega_x\hat{i} + I_{yy}\omega_y\hat{j} + I_{zz}\omega_z\hat{k}$
5	**Precession**-phenomenon associated with the action of a gyroscope or a spinning top and consisting of a comparatively slow rotation of the axis of rotation of a spinning body about a line intersecting the spin axis
	PART – B Answer all questions (2*4 = 08)
6	(a) Explain Newton's equations of motion in polar coordinates **(or)** (b) Explain Newtons laws of motion with examples.

$\vec{r} = \vec{r}' + vt \Rightarrow \vec{r}' = \vec{r} - vt$

$\therefore \vec{r} = x + y + z, \quad \vec{r}' =$

$x' = x - vt$ — (2)

$y' = y$ — (3)

$z' = z$ — (4)

$t' = t$ — (5)

Let's differentiate eqn (1) w.r.t tim

$$\frac{d\vec{r}'}{dt} = \frac{d\vec{r}}{dt} - \frac{d}{dt}(vt)$$

$\vec{u}' = \vec{u} - \vec{v}$ — (6)

This equation shows that, velocity
(i.e not absolute) under

Now, differentiate eqn (6) w.r.t "

$$\frac{d\vec{u}'}{dt} = \frac{d\vec{u}}{dt} - \frac{d\vec{v}}{dt} \quad (\because \text{ val}$$

$\Rightarrow \vec{a}' = a - 0.$ This shows

$\boxed{\vec{a}' = a}$ — (7) invariant

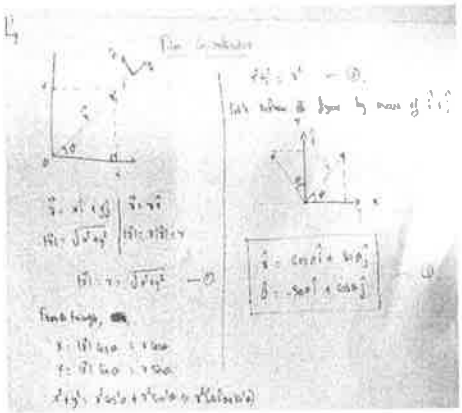
Let us multiply "m" on both

$\Rightarrow m\vec{a}' = m\vec{a} \quad (\because$

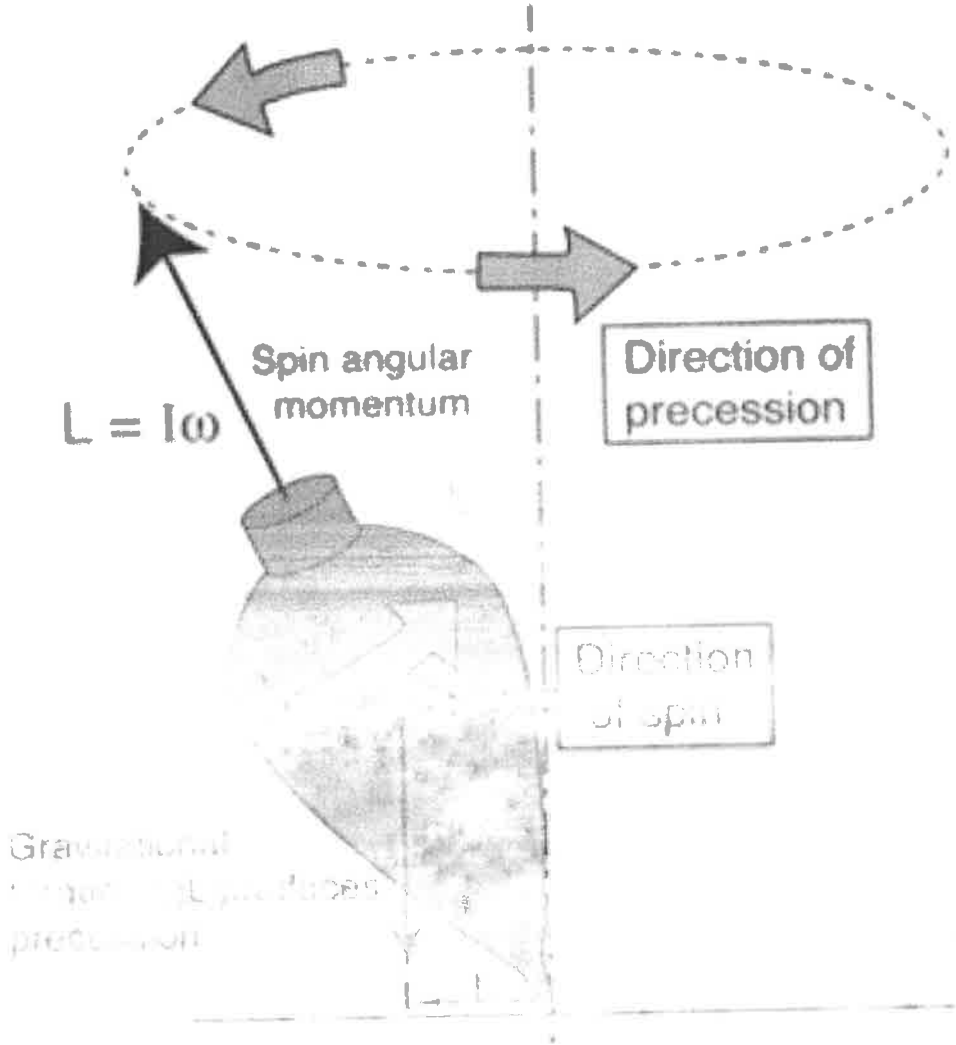
$\therefore \boxed{\vec{F}' = \vec{F}}$ — (8).

This shows that Newton's second
same form in all inertial

07	(a) Explain the rotation in plane. **(or)** (b) Explain the angular momentum in plane.



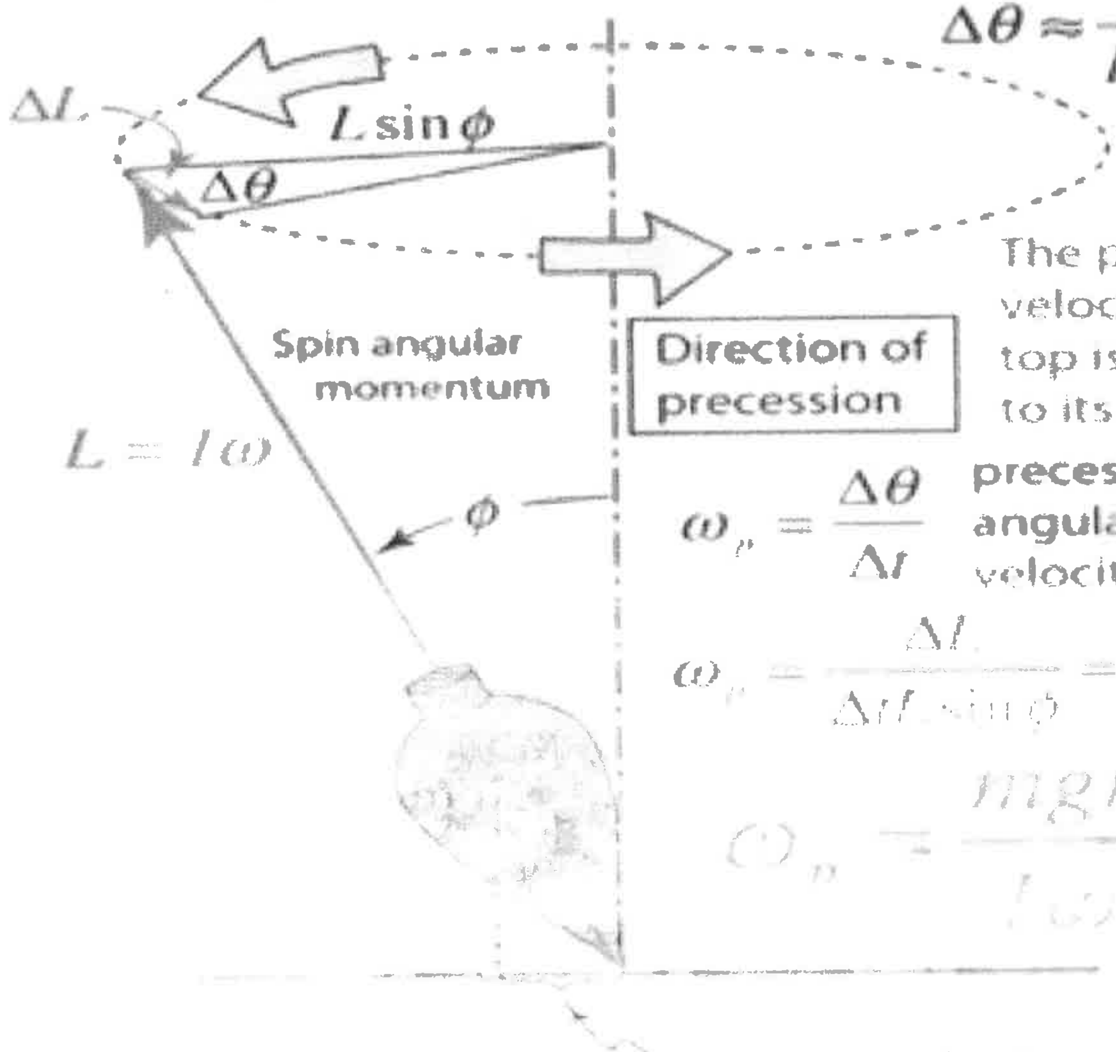
	PART – C Answer all questions (1*12 = 12)
08	(a) Derive the equations of simple harmonic motions **(or)** (b) How to solve newtons laws of motion in polar coordinates.


Direction of precession
Spin angular momentum
$L = I\omega$

Spin a top on a flat surface, and you will see it's top en revolve about the vertical direction, a process called *pr* As the spin of the top slows, you will see this precessic faster and faster.

It then begins to bob up and down as it precesses, and falls over.

Showing that the precession speed gets faster as the spi [illegible] problem in mechanics. The proc [illegible] summarized in the illustration below.



$$\Delta\theta \approx \frac{\Delta L}{L\sin\phi}$$

The precession angular velocity of a spinning top is inversely proportional to its spin speed.

$$\omega_p = \frac{\Delta\theta}{\Delta t}$$ precesion angular velocity

$$\omega_p = \frac{\Delta L}{\Delta t L\sin\phi} = \frac{\tau}{L\sin\phi} = \frac{mgr\sin\phi}{L\sin\phi}$$

$$\omega_p = \frac{mgr}{I\omega}$$

lever arm = $r\sin\phi$

torque $\tau = mgr\sin\phi = \frac{\Delta L}{\Delta t}$

CONTINUOUS LEARNING ASSESMENT - 2

U20PYBJ02–Mechanics and Mechanics of Solids (Theory)

Date : 27.12.2022

Academic Year / Semester : 2021-2022/odd

Duration : 90 mins

Instructions : Answer all the questions from 1 to 5. Answer either (a) or (b) from 6 to 8

Q.No	Question	Weightage	CO	Bloom's Level
	Part-A **5 x 2 = 10**			
1	Define joints and supports.	2	CO2	2
2	What is free body diagram?	2	CO3	2
3	Define Trusses	2	CO3	2
4	What is meant by Rolling friction?	2	CO3	2
5	State the types of frictions.	2	CO3	2
	Part-B **2 x 4 = 8**			
6	(a) Demonstrate different Friction phenomenon with special cases. **or** (b) Illustrate the concept of trusses based on the various types.	4	CO2	3
7	(a) Apply the equilibrium conditions of a rigid body in two dimensions. **or** (b) Apply the equilibrium of a rigid body in three dimensions with condition.	4	CO2	3
	Part -C 1 x12 =12			
8	(a) Establish kinematics in a coordinate system rotating and translating in the plane **or** (b) Apply the Newton's second law of motion to prove the independence of Euler's equations	12	CO3	3

CO	Weightage
CO1	
CO2	10
CO3	20
CO4	
CO5	
CO6	
Total	30

Prepared by	Staff Name Dr.K.THIRUNAVUKKARASU	Signature
Verified by	HoD	Signature

CONTINUOUS LEARNING ASSESMENT - 2

U20PYBJ02–Mechanics and Mechanics of Solids (Theory)

CLA-2 ANSWER KEY

Q.No	Question
	Part-A **5 x 2 = 10**
1	joints and supports-The method of joints is one of the simplest methods for determining the force acting on the individual members of a truss because it only involves two force equilibrium equations.
2	free body diagram- A Free-Body Diagram is a basic two or three-dimensional representation of an object used to show all present forces and moments
3	Trusses-A truss is a structure that consists of members assembled into connected triangles so that the overall assembly behaves as a single object.
4	Rolling friction-the frictional force that occurs when one object rolls on another, like a car's wheels on the ground
5	Types of frictions-Static Friction. Sliding Friction. Rolling Friction. Fluid Friction.
	Part-B **2 x 4 = 8**
6	different Friction phenomenon with special cases ▪ static Friction occurs between two objects which are not movable. Even if a large amount of force is applied to the objects, they will not move. ▪ Kinetic friction occurs between moving objects, that is when one object moves on another object. A good example is when you ride a bicycle on a road. The wheels of the bicycle move on the road. The bicycle will slow down until it comes to a halt. The two types of kinetic friction are sliding friction and rolling friction. ▪ Fluid friction is a type of friction which acts between the layers of a viscous fluid; these layers move relative to each other. Liquids and gases are included in fluids. (a)

	or (b) concept of trusses based on the various types. Truss members will carry only the axial forces The nodes i.e the connections of the members are designed as pinned joints so that moments won't be transferred to the members of the truss All the external loads and the reactions are act only on the nodes Generally, the truss should be in a plane
7	Equilibrium conditions of a rigid body in two dimensions- rigid body in a two dimensional problem has three possible equilibrium equations; that is, the sum of force components in the x and y directions, and the moments about the z axis. The sum of each of these will be equal to zero **or** (a) equilibrium of a rigid body in three dimensions with condition. The first condition of equilibrium is that there must be no net external forces acting on the body, and the second condition is that there must be no net external torques from external forces. For equilibrium to exist, these two conditions must be satisfied concurrently.
	Part -C 1 x12 =12
8	Establish kinematics in a coordinate system rotating and translating in the plane $F_{net} = 0$ The above condition is true for both static equilibrium, where the object's velocity is zero, and dynamic equilibrium, where the object moves at a constant velocity. (a) **or**

	(b) Newton's second law of motion to prove the independence of Euler's equations This alternative derivation should serve two purposes. One is that it doesn't matter which point we use to find angular momentum. The second is that use of foresight, in this case choosing the center of mass of the system so that the final velocity does not contribute to the angular momentum, can prevent extra calculation

BHARATH INSTITUTE OF SCIENCE AND TECHNOLOGY
Department of Physics

CONTINUOUS LEARNING ASSESMENT - 3

U20PYBJ02–Mechanics and Mechanics of Solids (Theory)

Date	:	03.02.2023
Academic Year / Semester	:	2022-2023/odd
Duration	:	90 mins
Instructions	:	Answer all the questions from 1 to 5. Answer either (a) or (b) from 6 to 8.

Q.No	Question	Weightage	CO	Bloom's Level
	Part-A **5 x 2 = 10**			
1	Mention the effects of torsion.	2	CO4	4
2	Explain Mohr's circle.	2	CO4	2
3	List out Hooke's formula.	2	CO4	2
4	a) Define Principal stress b) Write the formula of principal stress.	1 1	CO4 CO5	2 3
5	Distinguish between bending moment and twisting moment.	2	CO5	3
	Part-B **2 x 4 = 08**			
6	(a) Justify the reason for failure of the materials. **or** (b) Analyze the concept of torsion in circular shafts	4	CO4	4
7	(a) Examine the Rosette concepts in elasticity and plasticity **or** (b) From work hardening mechanism, how you interpret strain hardening.	4	CO4	4
	Part –C 1 x12 =12			
8	(a) Apply the concepts of Mohr's circle to identify plane stress **or** (b) Deduce the equations of generalized hook's law for isotropic materials.	12	CO5	3

CO	Weightage
CO1	
CO2	
CO3	
CO4	15
CO5	15
CO6	
Total	30

Prepared by	Staff Name Dr. K.Thirunavukkarasu	Signature
Verified by	HoD Dr. R. Velavan	Signature

CLA -3 ANSWER KEY

Q.No	Question
	Part-A **5 x 2 = 10**
1	Effects of torsion-Torsional force is used in several medical and general applications for performing various complex tasks.
2	Mohr's circle-Two-dimensional graphical representation of the transformation law for the Cauchy stress tensor.
3	Hooke's formula- stress/ strain= constant
4	principal stress- Principal stress is the maximum or minimum normal stress which may be developed on a loaded body formula of principal stress. Equations for Principal Stress and Princpal angles **Principal Stresses** $\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$ **Principal Angles** defining the **Principal Planes** $\tan 2\theta_p = \frac{2\tau_{xy}}{\sigma_x - \sigma_y}$
5	Distinguish between bending moment and twisting moment. The bending moment causes the section to bend, and the Torque moment causes the section to twist. Torsion is the moment that acts about the transverse axis of the body, and bending is the moment that acts about the longitudinal axis of the body
	Part-B **2 x 4 = 08**
6	(a) Justify the reason for failure of the materials. **or** (b) Analyze the concept of torsion in circular shafts 1. The shaft's material is uniformly homogeneous and isotropic. 2. After loading, the shaft's circular cross-section stays circular. 3. The shaft has a consistent amount of twists throughout its length. 4. There are no stresses on the shaft that exceed the elastic

CLA-3 ANSWER KEY

	limit. 5. After twisting, the transverse parts are still unaltered. 6. The separation between two normal cross-sections is unaffected by the application of torque.
7	(a) Examine the Rosette concepts in elasticity and plasticity An object or material is elastic if it comes back to its original shape and size when the stress vanishes. In elastic deformations with stress values lower than the proportionality limit, stress is proportional to strain. When stress goes beyond the proportionality limit, the deformation is still elastic but nonlinear up to the elasticity limit. An object or material has plastic behavior when stress is larger than the elastic limit. In the plastic region, the object or material does not come back to its original size or shape when stress vanishes but acquires a permanent deformation. Plastic behavior ends at the breaking point. **or** (b) From work hardening mechanism, how you interpret strain hardening.
	Part –C 1 x12 =12
8	(a) Apply the concepts of Mohr's circle to identify plane stress **or** (b) Deduce the equations of generalized hook's law for isotropic materials. (c) The generalized Hooke's Law also reveals that strain can exist without stress. For example, if the member is experiencing a load in the y-direction (which in turn causes a stress in the y-direction), the Hooke's Law shows that strain in the x-direction does not equal to zero. This is because as material is being pulled outward by the y-plane, the material in the x-plane moves inward to fill in the space once occupied, just like an elastic band becomes thinner as you try to pull it apart

CLA-4

Assignment Questions-Sec L1

Batch: 2022-23
Sem: ODD

Max.Marks:10

U20PYBJ02- MECHANICS AND MECHANICS OF SOLIDS

Assignment Questions:-

1. What is Mohr cycle and draw necessary diagram **(CO2)** **(4 MARKS)**

2. How will you measure shear test by torsion of tube? **(CO4)** **(6 MARKS)**

Submit these 2 assignments on or before Jan 20th.

COURSE COORDINATOR

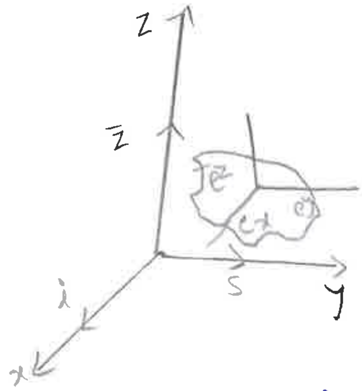
HOD

DEAN

Nam: T.Shivanadha Reddy
sec:- A1
Reg no: U22OE038

①

Euler's Eq Equation of Motion



consider a inertia frame 'S' fixed in space & the rigid body rotating with angular velocity $\bar{\omega}$ not a ASced axis

Now consider another frame 's'' Axed in the rigid body (principal axis) body fixed coordinate system

It will also also rotate with the rotation a rigid body with $\vec{\omega}$ in space wrt 's'

Thus angular moment of the rigid body abt principal axis

$$\vec{L} = I_{xx}\, \omega_x\, \hat{e}_x + I_{yy}\, \omega_y\, \hat{e}_y + I_{zz}\, \omega_z\, \hat{e}_z$$

$$\vec{L} = I_x\, \omega_x\, \hat{e}_x + I_y \omega_y\, \hat{e}_y + I_z \omega_z\, \hat{e}_z \quad -①$$

I_x, I_y and I_z are principle momentum of Inertia and are constant

do not vary with time

But ω_x, ω_y & ω_z & $\hat{p}_x, \hat{p}_y, \hat{p}_z$ vary with time

$$\frac{d\bar{L}_3}{dt} = d\bar{L} + \vec{\omega} d't$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt} \hat{p}_x + I_x\, \omega_x \frac{d\bar{p}_x}{dt} + I_y \frac{d\omega_y}{dt} \hat{p}_y -$$

$$I_y \omega_y \frac{d\vec{p}_y}{dt} + I_z \frac{d\omega_z}{dt} \hat{p}_z + I_z \omega_z \frac{d\vec{p}_3}{dt} \quad -②$$

Body Axed coordinate system

$\vec{\omega}_t = \vec{\omega}_s = \vec{\omega}$; $\vec{v}_n = \vec{\omega}_0 \times \vec{r}_n$ $\quad \vec{v}_n = \frac{d\vec{r}_n}{dt}$

$$\frac{d\vec{e}_x}{dt} = \vec{\omega} \times \vec{e}_x = \frac{dx}{dt}\hat{p}_x + \frac{dy}{dt}\vec{p}_y + \frac{dz}{dt}\hat{e}_z$$

$$\frac{d\vec{r}_s}{dt} = \frac{d\vec{r}_n}{dt} + (\vec{\omega} \times \vec{r}_n)$$

$$\frac{d\vec{A}}{dt} = \vec{\omega} \times \vec{A} \quad \text{— (3) for infi}$$

$$\frac{d\vec{e}_x}{dt} = \vec{\omega}_x \vec{e}_x, \quad \frac{d\vec{p}_y}{dt} = \vec{\omega} \times p_y; \quad \frac{d\vec{p}_x}{dt} = \vec{\omega} \times \vec{e}_z$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{p}_x + I_x \omega_x (\omega \times \hat{e}_x) + I_y \frac{d\omega_y}{dt} \hat{\Delta}\omega + I_y \omega_y (\omega \times \hat{e}_y) +$$

$$I_z \frac{d\omega_y}{dt}\hat{e}_z + I_x \omega_x (\vec{\omega} \times \hat{e}_z)$$

$$= I_x \frac{d\omega_x}{dt}\hat{e}_x + I_y \frac{d\omega_y}{dt}\hat{e}_y + I_z \frac{d\omega_z}{dt}\hat{e}_z$$

$$+ \vec{\omega}_x \, \cancel{(I_x} \, \omega_x \hat{e}_x + I_y \omega_y \hat{e}_y + I_z \omega_z \hat{e}_z)$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{e}_x + I_y \frac{d\omega_y}{dt}\hat{e}_y + I_z \frac{d\omega_z}{dt}\hat{e}_z +$$

$$\vec{\omega} \times \vec{L} = \begin{vmatrix} \hat{p}_x & \hat{p}_y & \hat{p}_z \\ \omega_x & \omega_y & \omega_z \\ I_x\omega_x & I_y\omega_y & I_z\omega_z \end{vmatrix} \begin{aligned} &+ \hat{e}_x (I_z \omega_y \omega_z - I_y \omega_y \omega_z) \\ &+ \hat{e}_z (I_y \omega_x \omega_y - I_x \omega_x \omega_y) \\ &+ \hat{e}_y (I_z \omega_x \omega_z - I_x \omega_x \omega_z) \end{aligned}$$

Euler's Eq of motion

$$\frac{d\vec{L}_I}{dt} = \frac{d\vec{L}}{dt} + (\vec{\omega} \times \vec{L})$$

$$(\vec{\omega} \times \vec{L}) = \left[(I_y - I_z)\omega_y \omega_z \hat{e}_x + (I_z - I_x)\omega_x \omega_z \hat{e}_y + (I_x - I_y)\omega_x \omega_y \hat{e}_z \right]$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt} \hat{e}_x + I_y \frac{d\omega_y}{dt} \hat{p}_y + I_z \frac{d\omega_z}{dt} \hat{p}_z$$

$$= [(I_y - I_z]\omega_y \omega_z \hat{e}_x + (I_z - I_x)\omega_x \omega_z \hat{e}_y + (I_x - I_y)\hat{e}_z]$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt} \hat{e}_x + I_y \frac{d\omega_y}{dt} \hat{p}_y + I_z \frac{d\omega_z}{dt} \hat{p}_z$$

$$= -(I_y - I_z) = \omega_y \omega_z \hat{p}_x - (I_z - I_x)\omega_x \omega_z \hat{p}_y$$

$$(I_x - I_y)\omega_x \omega_y \hat{p}_z$$

$$\tau_x \hat{p}_x + \tau_y \hat{p}_y + \tau_z \hat{p}_z = [(I_x \frac{d\omega_x}{dt} - (I_y - I_z)\omega_y \omega_z] \hat{p}_x +$$

$$[I_y \frac{d\omega_y}{dt} - [I_z - I_x]\omega_x \omega_z)\hat{p}_y +$$

$$[I_z \frac{d\omega_z}{dt} - (I_x - I_y]\omega_x \omega_y]\hat{p}_z$$

Comparing the cofficient on both sides

$$\tau_x = I_x \frac{d\omega_x}{dt} - (I_y - I_z)\omega_y \omega_z$$

$$\tau_y = I_y \frac{d\omega_y}{dt} - (I_z - I_x)\omega_x \omega_z$$

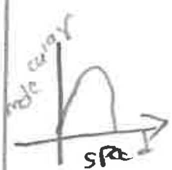
$$\tau_z = I_z \frac{d\omega_z}{dt} - (I_x - I_y)\omega_x \omega_y$$

This is a Euler's equation of motion of motion of rigid body.

Explain Maxwell - Boltzmann distribution Drive the mean square speed the realation for mean, Root & most probable velocity.

Maxwell Boltzmann Distribution

Speed of the Molecules are distributed for an ideal gas



Defination

In a system of distinguisnable particles the total no of particles in the system is n

The total volume of the system is fixed and given by v

The total amount of energy is fixed & it is v

The total energy levels available within system

The total energy levels available within system

The no of Particles sitting at each energy is variable $m_1, m_2, m_3 \ldots m_n$

$$w = \frac{m!}{m_0! m_1! m_2! \cdots n_n!} \quad (1)$$

To Maximise the value of w / lnw

$$\ln w = \ln m! - \sum_{i=0}^{i=r} \ln n_i! \quad (2)$$

$$\ln n! = x \ln x - x$$

$i = n$

$\ln w = \Sigma_{i=0}$ $m_i \ln m_i - i n \times \frac{1}{n_i}$

$i = l$

$\Sigma_{i=0}$ $d\, n_i = 0 - (5)$

$i = 0$

To energy of system should be considered

$\Sigma_{i=v}$ $\Sigma p n_i = v =$ constant
$i = 0$

$\Sigma_{i=l}$ $\Sigma i n_i = V =$ constant
$i = 0$

$\Sigma_{i=l}$ $\Sigma i n_i = v$ constant
$i = 0$

$\ln n_i - \alpha + B \Sigma i = 0$

$n_i = e^{-\alpha} e^{-Be_i}$

$i =>$ $n_i = e^{-\alpha} \Sigma_{i=0}^{i=l} e^{-Bl} = n$

$\Sigma i = 0$

$n_i = \frac{n}{p} e^{-BE_i}$ — (8)

$B = \frac{-1}{KBT}$ $\quad n_p = \frac{n}{p} e^{-\frac{e_i}{KBT}}$

The speed expressions can be derived from the Max-well Boltzmann distribution

The average speed ~~& the root~~

$\frac{dF(c)}{dc}$ $!\ c_{mp} = 0$

which is

$c_{mp} = \sqrt{\frac{2RT}{m}}$

The average speed is the sum of the speed of all molecules by the no of molecules

$c_{avg.} = \sqrt{\frac{8RT}{m\pi}}$

The root mean square speed

$$C_{rms} = \sqrt{\frac{3RT}{M}}$$

wheres

R is the gas constant

T is the temperature

M is the Molecular mass of gass

$$\sum_{i=0}^{i=R} J\, m_i = 0 \rightarrow (5)$$

The Total energy of the system should be constant

$$\sum_{T=0}^{T=n} \varepsilon_1 M_i = V = \text{constant}$$

$$\sum_{i=0}^{i=n} \varepsilon_i d n_i = V = 0 \rightarrow (6)$$

$$d n\, n_i + \alpha + \beta\, \varepsilon_i = 0$$

$$n_i = e^{\alpha} s c e^{-\beta \varepsilon i}$$

$$\sum_{i=0}^{i=n} n_i = e^{-a} \sum_{i=0}^{i=n} e^{-\beta \varepsilon i} = n$$

$$e^{-\alpha} = \frac{n}{\sum_{i=0}^{i=n} e^{-\beta \varepsilon i}}$$

$$n_i = \frac{n}{P} e^{-\beta \gamma i} — (8)$$

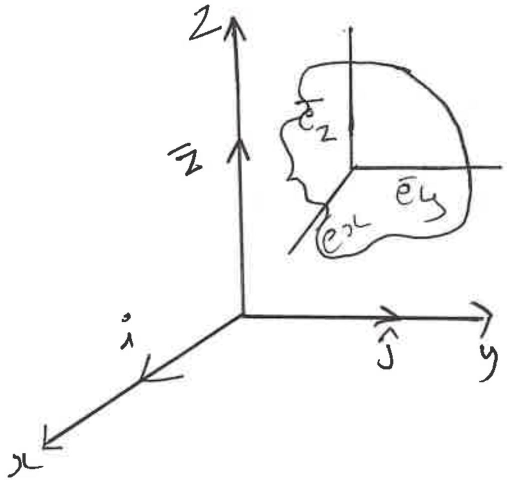
$$\beta = \frac{-1}{k d T}$$

$$n_i = \frac{n}{P} P^{\frac{-\varepsilon i}{KBT}}$$

1

Euler's Equation of Motion

Name : Surya Teja
Sec : A1
Reg no : U22~~AB~~027
Adm no : 8216



Consider a inertia frame 's' fixed in space and the rigid body rotating with angular velocity $\bar{\omega}$ not a fixed axis.

Now consider another frame 's' fixed in the rigid body (principal axis) body fixed coordinate system.

It will also rotate with the rotation of a rigid body with $\vec{\omega}$ in space wrt 's'

Thus angular momentum of the rigid body abt principal axis.

$$\vec{L} = I_{xx} \omega_x \hat{e}_x + I_{yy} \omega_y \hat{e}_y + I_{zz} \omega_z \hat{e}_z$$

$$\vec{L} = I_x \omega_x \hat{e}_x + I_y \omega_y \hat{e}_y + I_z \omega_z \hat{e}_z \quad -①$$

$$\frac{d\vec{e}_x}{dt} = \vec{\omega} \times \vec{e}_x, \quad \frac{d\vec{p}_y}{dt} = \vec{\omega} \times \vec{p}_y; \quad \frac{d\hat{p}_x}{dt} = \vec{\omega} \times \vec{e}_z$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt} \hat{p}_x + I_x \omega_x (\omega \times \hat{e}_x) + I_y \frac{d\omega_y}{dt} \hat{A}\omega + I_y \omega_y (\omega \times \hat{e}_y) +$$

$$I_z \frac{d\omega_y}{dt} \hat{e}_z + I_x \omega_x (\vec{\omega} \times \hat{e}_z)$$

$$= I_x \frac{d\omega_x}{dt} \hat{e}_x + I_y \frac{d\omega_y}{dt} \hat{e}_y + I_z \frac{d\omega_z}{dt} \hat{e}_z + \vec{\omega} \times (I_x \omega_x \hat{e}_x + I_y \omega_y \hat{e}_y + I_z \omega_z \hat{e}_z)$$

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt} \hat{e}_x + I_y \frac{d\omega_y}{dt} \hat{e}_y + I_z \frac{d\omega_z}{dt} \hat{e}_z + (\vec{\omega} \times \vec{L}) \quad \text{— (4)}$$

$$\vec{\omega} \times \vec{L} = \begin{vmatrix} \hat{p}_x & \hat{p}_y & \hat{p}_z \\ \omega_x & \omega_y & \omega_z \\ I_z\omega_x & I_y\omega_y & I_z\omega_z \end{vmatrix} \begin{matrix} + \hat{e}_x (I_z \omega_y \omega_z - I_y \omega_y \omega_z) \\ + \hat{e}_z (I_y \omega_x \omega_y - I_x \omega_x \omega_y) \\ + \hat{e}_y (I_z \omega_x \omega_z - I_x \omega_x \omega_z) \end{matrix}$$

<u>Euler's</u> <u>eq</u> of <u>motion</u>:

$$\frac{d\vec{L}_1}{dt} = \frac{d\vec{L}}{dt} + (\vec{\omega} \times \vec{L})$$

$$(\vec{\omega} \times \vec{L}) = -\left[(I_y - I_z)\omega_y \omega_z \hat{e}_x + (I_z - I_x)\omega_x \omega_z \hat{e}_y + (I_x - I_y)\omega_x \omega_y \hat{p}_z\right]$$

Comparing the coefficient on both sides

$$I_x = I_x \frac{d\omega_x}{dt} - (I_y - I_z)\,\omega_y \omega_z$$

$$I_y = I_y \frac{d\omega_y}{dt} - (I_z - I_x)\,\omega_x \omega_z$$

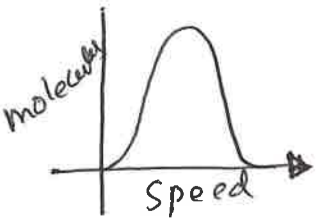
$$I_z = I_z \frac{d\omega_z}{dt} - (I_x - I_y)\,\omega_x \omega_y$$

$\therefore$ This is a Euler's equation of motion of motion of rigid body.

* Explain Maxwell - Boltzmann distribution. Derive the realation for mean, Root mean Square speed and Most probable velocity.

Maxwell Boltzmann Distribution

Speed of the molecules are distributed for an ideal gas.



Defination:

In a System of distinguishable particles.

The total number of particles in the System is n

The total volume of the System is fixed and given by V.

The total amount of energy is fixed & it is U.

The total energy levels available within System

The number of particles sitting at each energy is variable, $m_1, m_2, m_3 \ldots m_n$

$$\omega = \frac{m!}{m_0!\, m_i!\, m_2! \ldots n_n!} \quad (1)$$

To maximise the value of $\omega / \ln \omega$

$$\ln \omega = \ln m! - \sum_{i=0}^{i=r} \ln n_i! \quad - (3)$$

$$\ln x! = x \ln x - x$$

$$\ln \omega = \sum_{i=0}^{i=n} \delta m_i \ln m_i - i n_i \times \frac{1}{n_i}$$

The averge speed and the root

$$\frac{dF(c)}{dC} ! c_{mp} = 0$$

which is

$$C_{mp} = \sqrt{\frac{2RT}{m}}$$

The average speed is the Sum of the speeds of all molecules by the number of molecules

$$C_{avg} = \sqrt{\frac{8RT}{M\pi}}$$

The root mean Square Speed,

$$C_{rms} = \sqrt{\frac{3RT}{M}}$$

where
R is the gas constant
T is the temperature
M is the molecular mass of gas.

$$\sum_{i=0}^{i=\Omega} \delta m_i = 0 \quad (5)$$

The total energy of the System should be Constant $\sum_{T=0}^{T=\Omega} \varepsilon_i M_i = V = \text{Constant}$

$$\sum_{i=0}^{i=\Omega} \varepsilon_i \delta n_i = V = 0 \quad (6)$$

FINAL SEMESTER EXAMINATION

U20PYBJ02 – Mechanics and Mechanics of Solids

Date :

Academic Year / Semester : 2020-2021/ODD

Duration : 180 mins

Instructions : Answer all the questions.

Q.No	Question	Weightage	CO	Bloom's Level
	Part-A **10 x 2 = 20**			
1	The system returns to equilibrium as quickly as possible without oscillating a) Critically damped b) Over damped c) Under damped d) Undamped	2	CO1	2
2	A particle executes S.H.M. of amplitude 25 cm and time period 3 seconds. What is the minimum time required for a particle to move between two points located at a distance of 12.5 cm on either side of the mean position? a) 0.3 s b) 0.4 s c) 3 s d) 4 s	2	CO1	2
3	If the whole truss is in equilibrium, then all the joints which are connected to that truss is in equilibrium. This is known as__________ a) Method of joints b) Section method c) Scalar field method d) Vector equilibrium method	2	CO3	2
4	__________ is a structure made of slender members which are joined together at their end points. a) Truss b) Beam c) Pillar d) Support	2	CO3	1
5	Principal plane is the plane in which __________ a) Shear stress is maximum b) Normal stress is zero c) Shear stress is zero d) It doesn't depend upon stresses	2	CO4	1
6	Two suffixes in the normal stress notation represents a) Plane b) Direction c) Both plane & direction d) None	2	CO4	1
7	_______ produces a decrease in length per volume of the body a) Normal stress b) Compressional stress	2	CO5	1

	c) Tensile stress d) Tangential stress			
8	Strain is the relative change in configuration due to the application of _______________ a) Forces b) frictional forces c) compressive forces d) deforming forces	2	CO5	2
9	A hollow shaft with diameter ratio 3/5 is required to transmit 450 kW at 120 rpm. The shearing stress in the shaft must not exceed 60 N/mm^2 and the twist in a length of 2.5 m is not to exceed 10. Calculate the minimum external diameter of the shaft. Take C = 80 k N/mm^2. a) 1.66 mm b) 16.6 mm c) 166 mm d) 0	2	CO5	3
10	In a shear stress, the stress components will be _______ to the surface a) Perpendicular b) Parallel c) Tangential d) none of the above	2	CO5	2
	Part-B **5 x 6 = 30** **Answer any 5 questions**			
11	Discuss the fundamentals of vibrations.	6	CO1	2
12	Explain kinematics in a coordinate system rotating and translating in the plane	6	CO2	2
13	Explain the importance of rosette concept in analyzing elasticity and plasticity.	6	CO4	4
14	Differentiate between plane stress and principle stress	6	CO4	4
15	How do you study stress analysis in bending with the help of combined stresses? Explain.	6	CO5	3
16	A 50-N box is slid straight across the floor at constant speed by force of 25 N at 40 degree (a) How large a friction force impedes the motion of the box? (b) How large is the normal force; (c) Find the coefficient friction between the box and the floor?	6	CO3	3
17	Write note on three dimensional rigid body motion with examples.	6	CO2	2
	Part-C **5 x 10 = 50** **Answer either (a) or (b)**			
18	(a) Discuss damped harmonic motion and its different cases. (or) (b) Show the invariance of Newton's second law under Galilean transformation.	10	CO1	2
19	(a) Show that if there is no force acting on a rigid body with one point fixed, then total rotational kinetic energy is constant. Also, prove w.J =2T = constant. (or)	10	CO2	3

	(b) Derive Euler's equations of motion of a rigid body.			
20	(a) Explain various types of supports and connections with examples. (or) (b) Establish the force-displacement relationship for a double spring piston.	10	CO3	3
21	(a) Analyze plane stress using Mohr's circle. (or) (b) Deduce the equations of generalized hook's law for isotropic materials.	10	CO4	4
22	(a) Explain the concept of strain energy due to torsion. (or) (b) Illustrate moment curvature relation in pure bending of beams with symmetric cross-section	10	CO5	3

CO's	**Marks (Theory)**
CO1	20
CO2	16
CO3	14
CO4	26
CO5	24
Total	100

Prepared by	Staff Name Dr. K.Thirunavukkarasu	Signature
Verified by	HoD Dr. R. Velavan	Signature R. Velavan

GFINAL SEMESTER EXAMINATION

U20PYBJ02 – Mechanics and Mechanics of Solids

Answer key.

Q.No	Question
	Part-A **10 x 2 = 20**
1	The system returns to equilibrium as quickly as possible without oscillating a) Critically damped b) Over damped c) Under damped d) Undamped
2	A particle executes S.H.M. of amplitude 25 cm and time period 3 seconds. What is the minimum time required for a particle to move between two points located at a distance of 12.5 cm on either side of the mean position? a) 0.3 s b) 0.4 s c) 3 s d) 4 s
3	If the whole truss is in equilibrium, then all the joints which are connected to that truss is in equilibrium. This is known as_____________ a) Method of joints b) Section method c) Scalar field method d) Vector equilibrium method
4	___________ is a structure made of slender members which are joined together at their end points. a) Truss b) Beam c) Pillar d) Support
5	Principal plane is the plane in which ____________ a) Shear stress is maximum b) Normal stress is zero c) Shear stress is zero d) It doesn't depend upon stresses
6	Two suffixes in the normal stress notation represents a) Plane b) Direction c) Both plane & direction d) None
7	_______ produces a decrease in length per volume of the body a) Normal stress b) Compressional stress c) Tensile stress d) Tangential stress
8	Strain is the relative change in configuration due to the application of ________________ a) Forces b) frictional forces

	c) compressive forces d) deforming forces
9	A hollow shaft with diameter ratio 3/5 is required to transmit 450 kW at 120 rpm. The shearing stress in the shaft must not exceed 60 N/mm^2 and the twist in a length of 2.5 m is not to exceed 10. Calculate the minimum external diameter of the shaft. Take C = 80 k N/mm^2. a) 1.66 mm b) 16.6 mm c) 166 mm d) 0
10	In a shear stress, the stress components will be _______ to the surface a) Perpendicular b) Parallel c) Tangential d) none of the above
	Part-B **5 x 6 = 30** **Answer any 5 questions**
11	Discuss the fundamentals of vibrations.
12	Explain kinematics in a coordinate system rotating and translating in the plane
13	Explain the importance of rosette concept in analyzing elasticity and plasticity.
14	Differentiate between plane stress and principle stress
15	How do you study stress analysis in bending with the help of combined stresses? Explain.
16	A 50-N box is slid straight across the floor at constant speed by force of 25 N at 40 degree (a) How large a friction force impedes the motion of the box? (b) How large is the normal force; (c) Find the coefficient friction between the box and the floor?
17	Write note on three dimensional rigid body motion with examples.
	Part-C **5 x 10 = 50** **Answer either (a) or (b)**
18	(a) Discuss damped harmonic motion and its different cases. (or) (b) Show the invariance of Newton's second law under Galilean transformation.
19	(a) Show that if there is no force acting on a rigid body with one point fixed, then total rotational kinetic energy is constant. Also, prove w.l =2T = constant. (or) (b) Derive Euler's equations of motion of a rigid body.
20	(a) Explain various types of supports and connections with examples. (or) (b) Establish the force-displacement relationship for a double spring piston.

21	(a) Analyze plane stress using Mohr's circle. (or) (b) Deduce the equations of generalized hook's law for isotropic materials.
22	(a) Explain the concept of strain energy due to torsion. (or) (b) Illustrate moment curvature relation in pure bending of beams with symmetric cross-section

6. Text Books

i) Mahendra K Verma, Introduction to Mechanics, Universities Press(India) Pvt. Ltd., 2016

ii) E.P. Popov, Engineering mechanics of solids, Prentice Hall India learning Pvt. Ltd, 2nd Edition, 2002.

7. Reference Books

i) J. L. Meriam, Engineering Mechanics-Dynamics, 7th Edition, Vol. 2, Wiley Publishers, 2012

ii) J.P. Den Hartog, Mechanics, Dover Publications Inc., 1961

iii) Bhavikatti S.S and Rajashekarappa K.G, Engineering Mechanics, New Age International (P) Limited Publishers, 1998.

iv) Kumar K.L, Engineering Mechanics, 3rd Revised edition, Tata McGraw-Hill Publishing Company, New Delhi, 2008.

Question Bank

U20PYBJ02 – Mechanics and Mechanics of solids

Unit – 1 Oscilations and Vibrations

Part – A (2 Marks)

1. What is meant by vector and give example?
2. Differentiate coplanar and collinear forces.
3. Define scalar and give examples.
4. A body of mass 7.5 kg is moving with a velocity of 1.2 m/s. If a force of 20N is applied on the body determine its velocity after 3s.
5. What is a Resonance?
6. State Newton's second law.
7. List out the names of all the forces present in nature.
8. What are polar co-ordinates?
9. What is vibration?
10. What are harmonic oscillator?

Part – B (4 marks)

1. Explain newtons first law with example.
2. Demonstrate newtons second law of motion with example
3. Explain newton's laws and its completeness in describing a particle motion.
4. Derive Newtons law of equations.
5. Write a short note on simple harmonic motion.
6. What are damped harmonic motion and explain with example.
7. What are salient features of the fundamentals of vibrations.
8. Explain resonance and give its applications.
9. How to solve newtons law in polar coordinates.
10. Describe Forced oscillations.

Part-C (12 marks)

1. What is a polar co-ordinate system? Derive equations using newtons law.
2. How do you determine a position, velocity and acceleration of a particle in a polar co-ordinate system? Explain.
3. Derive the expressions for velocity and acceleration in a spherical co-ordinate system.
4. Explain the following in detail with examples. (i) Newtons first law (ii) Newtons second law.
5. Explain damped oscillator with necessary cases.
6. What are forced oscillations and explain magnification factor.
7. How will you transform vector and scalar under rotational transformation?

Unit – 2 Rigid body equilibrium in 1D,2D,3D

Part – A (2 marks)

1. Define motion of a rigid body.
2. What is rotation in the plane?
3. What do you mean by equipotential surface?
4. What is a conservative force?
5. Define torque.
6. Define Angular momentum.
7. State the principle of Conservation of Angular Momentum.
8. Define moment of inertia.
9. What is angular velocity?
10. What is Tensor?

Part -B(4 Marks)

1. Explain kinematics in a coordinate system.
2. Explain in detail with roation in plane.
3. What are angular momentum about a point.

4. Define rigid body equilibrium in 1D and 3D.

5. Explain conservative and non-conservative forces with example.

6. Explain the properties of equipotential surface.

7.Explain precession of a body

8. Demonstrate spinning top .

9. Write a short note on three dimensional rigid body motion.

10.How the rod executing conical motion in 2d.

Part- C(12 Marks)

1. Prove that potential energy function F = -Grad V.

2. Prove two and three dimensional motion of a rigid body

3. Discuss Precession of a body and spinning top.

4. What is angular momentum? Explain the principle of conservation of angular momentum.

5. Explain Eulers laws of motion from newtons law.

6. Demonstrate kinematics in a coordinate system

7. What are moment of inertia tensor and mention the failures of two dimensional formulation.

UNIT-III Introduction to Mechanics of solids

Part-A(2 Marks)

1. Define free body diagram.

2. What are typical supports?

3. What is meant by friction?

4. What are the cases of friction?

5. What is restoring force?

6. What are the equilibrium of a rigid body?

7. Define Joints.

8. What are trusses?

9. What is rigid body motion?

10. What is deformation?

Part -B(4 Marks)

1. Explain free body diagram with example.
2. Discuss force- displacement relation.
3. Write a short note on method of joints.
4. Explain different methods of sections.
5. What do you meant by compatibility of deformation. Explain.

6. Explain the equilibrium of rigid body in two dimension.

7. Explain the concept of the equilibrium of rigid body in three dimension.

8.What is meant by friction and explain different types.

9. Demonstrate joints and sections with necessary diagram.

10.Demonstrate axial loaded members in deformations.

Part – C (12 Marks)

1. Explain the equilibrium of rigid body in two and three dimension.
2. Explain the following, (i) Force (ii) Displacement.(iii) Trusses and (iv) joints.
3. Prove force –displacement relation with example.
4. What are different types of joints with necessary diagrams.
5. Draw necessary diagrams of different types of trusses
6. prove the condition of equilibrium in three dimension.
7. Illustrate the deformation on axially loaded members.

UNIT-IV Stress and strain

Part-A(2 Marks)

1. Define Stress.
2. Define strain.
3. What are plane stress?

4. What is yielding?
5. Define thermal stress.
6. What is thermal strain?
7. What do you mean by elasticity?
8. When does fracture forms?
9. What is work hardening?
10. Define mohr's circle.

Part-B(4 Marks)

1. Explain concept of stress at a point.
2. Briefly explain the characteristics of elasticity.
3. Explain strain hardening with example.
4. Demonstrate idealization of one dimensional stress.
5. Write short notes on general plane motion.
6. Elucidate the transformation of stress at a point.
7. State the concept of strain at a point.
8. Derive the equations of elasticity.
9. Explain the work hardening mechanism.
10. Explain the concept of rosette elasticity.

Part-C (12 marks)

1. Briefly explain the Rosette concept of elasticity and plasticity.
2. Briefly explain the generalized concept of Hooke's law.
3. Explain the following terms with necessary diagrams.
   (i) Mohr's circle
   (ii) thermal strain and stress
   (iii) Strain and Work Hardening
4. Discuss the various types elasticity and plasticity with neat diagram.
5. Demonstrate the concept of Mohr's circle with stress, strain and draw relevant diagrams.
6. How will you transform stress and strain in elasticity and plasticity concept with relevant example.
7. How to idealize stress and strain in one dimensional motion?

UNIT-V Properties of solids

Part-A(2 Marks)

1. Define axial force.
2. What is bending moment?
3. Define shear force.
4. Define twisting moment.
5. What are moment of curvature?
6. What do you meant by symmetry cross section?
7. Give any two examples for combined stresses.
8. Write the formula of moment of curvature.
9. What is meant by shear test?
10. Define force analysis.

Part-B(4 Marks)

1. Explain the effects of torsion.
2. Explain the concept of circular shafts.
3. Demonstrate the concept of strain energy.
4. Explain in detail of combined stresses.
5. Derive the equation for deflection in bending.
6. Explain the complementary strain energy.
7. Derive the relation of bending of beams.
8. What are the methods of shear test?
9. Explain the principle behind the superposition.
10. Explain twisting moment with neat diagram.

Part-C(12 Marks)

1. Explain the Moment of torsion of thin walled tubes.
2. Arrive at an expression for deflection in bending with symmetric cross section.
3. Discuss the concept of strain and complementary energy
4. Demonstrate the bending moment and twisting moment.
5. Derive the moment of curvature relationship with boundary conditions.

6. How will you generate shear stresses with necessary diagram.
7. Derive the relation of bending stress and shear stress with relevant diagram.

Bharath
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(Vide Notification No. F.9-5/2000 - U.3, Ministry of Human Resource Development, Govt. of India, dated 4th July 2002)
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SL NO.	REG.NO	CLA 1 (30)	CLA 2 (30)	CLA 3 (30)	CLA 4 (10)	Attendance%
1	U22CE001	28	23	10	10	86
2	U22CE002	AB	30	AB	10	94
3	U22CE003	26	26	25	10	70
4	U22CE004	27	17	15	10	67
5	U22CE005	28	24	22	10	85
6	U22CE007	24	18	18	10	67
7	U22CE008	22	21	17	10	91
8	U22CE010	19	22	20	10	93
9	U22CE011	AB	23	18	10	88
10	U22CE012	AB	10	7	10	79
11	U22CE013	AB	24	26	10	64
12	U22CE014	4	16	15	10	83
13	U22CE015	20	22	15	10	54
14	U22CE016	AB	5	15	10	83
15	U22CE017	AB	26	30	10	59
16	U22CE018	22	21	29	10	75
17	U22CE019	18	AB	19	10	80
18	U22CE020	AB	5	8	10	83
19	U22CE021	AB	28		10	73
20	U22CE022	26	10	15	10	84
21	U22CE023	22	22	11	10	80
22	U22CE024	23	22	25	10	56
23	U22CE025	AB	AB	10	10	68
24	U22CE026	AB	AB	11	10	6
25	U22CE027	20	15	20	10	84
26	U22CE028	25	24	26	10	86
27	U22CE029	26	20	25	10	83
28	U22CE030	25	12	13	10	69
29	U22CE031	AB	30	AB	10	40
30	U22CE032	23	8	AB	10	33
31	U22CE033	15	24	25	10	86
32	U22CE034	24	25	25	10	67
33	U22CE035	15	20	29	10	74
34	U22CE036	28	18	24	10	88
35	U22CE037	20	15	15	10	72
36	U22CE038	25	23	28	10	68
37	U22CE039	26	20	13	10	64
38	U22CE040	25	21	20	10	74
39	U22CE041	AB	12	15	10	73
40	U22CE042	AB	AB	26	10	88

41	U22CE043	AB	8	AB	10	57
42	U22CE044	AB	24	25	10	86
43	U22CE045	AB	25	25	10	58
44	U22CE046	26	20	22	10	64
45	U22CE047	25	17	15	10	74
46	U22CE048	AB	3	15	10	73
47	U22CE049	5	AB	AB	10	88
48	U22CE050	20	AB	15	10	57
49	U22CE051	AB	20	20	10	86
50	U22CE052	AB	22	15	10	58
51	U22CE053	AB	22	20	10	74
52	U22CE054	AB	15	20	10	83
53	U22CE055	AB	AB	AB	10	65
54	U22CE056	AB	25	16	10	95
55	U22CE057	20	AB	15	10	25
56	U22CE058	AB	10	17	10	64
57	U22CE059	29	AB	17	10	91
58	U22CE060	12	AB	15	10	52
59	U22CE061	AB	22	20	10	89
60	U22CE062	28	AB	AB	10	69
61	U22CE063	AB	AB	AB	10	94
62	U22CE064	26	AB	AB	10	65
63	U22CE065	18	17	15	10	85
64	U22CE066	26	AB	24	10	7
65	U22CE067	AB	25	24	10	53
66	U22CE068	AB	26	26	10	7
67	U22CE069	26	30	15	10	72
68	U22CE070	25	9	7	10	59
69	U22CE071	27	15	8	10	77
70	U22CE072	26	21	10	10	9
71	U22CE073	0	15	20	10	78
72	U22CE074	15	AB	18	10	46
73	U22CE075	17	AB	AB	10	83
74	U22CE076	23	AB	16	10	73

R. Selavan

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SCHOOL OF SCIENCE AND HUMANITIES
I YEAR, B. TECH - 2022 - 2023

Subject Name: Mechanics and Mechanics of Solids

Subject Code: U20PYBJ02

Sl No.	Reg. No	Name	Punctuality	Audibility	Coverage of syllabus and clarification of doubts	Communication	Encouraged questions	Quality-based information beyond the syllabus
1	U22CE008	NAIDU VENKATESH	5	5	5	5	4	5
2	U22CE010	POPPURU TEJESWAR REDD	2	5	2	5	5	5
3	U22CE011	SATHISH KUMAR G	5	2	5	2	2	5
4	U22CE012	YAMSANI GOUTHAM KUM	2	5	2	5	5	2
5	U22CE023	BHARATH P	5	5	5	2	5	5
6	U22CE024	BHARATHRAJ	5	5	5	5	5	2
7	U22CE025	CHIRRA VENKATA SAI	5	5	5	5	5	5
8	U22CE026	CHITTURI DHUSHYANTH	5	5	5	5	5	5
9	U22CE027	DASARI DANIEL PREM KUN	5	5	5	2	5	5
10	U22CE032	GADDAM MAHENDHAR	5	3	5	5	3	5
11	U22CE033	GADDAM REVANTH REDDY	3	5	3	5	5	5
12	U22CE034	GANNI AJAY	5	3	5	5	3	5
13	U22CE035	GLENN GRIFTON	3	5	3	5	5	3
14	U22CE056	LAKSHMI NARASIMMAN V	5	3	5	5	3	5
15	U22CE057	LOKKU VENU SAI L	3	3	3	5	3	3
16	U22CE058	MADHANAGOPAL	3	3	3	3	3	5
17	U22CE059	MANEESH	5	5	5	5	5	3
18	U22CE063	MOHAMEDRAWOOF	5	3	5	3	3	3
19	U22CE064	MUTHUKUMAR A	5	3	5	5	3	5
20	U22CE065	NANDHA KUMAR K	5	5	5	3	5	5
21	U22CE066	P DEVANANDHAN	5	5	5	3	5	5
22	U22CE067	PASUPATHI R	5	5	5	5	5	5
23	U22CE068	PENDYALA ANIL	5	5	5	5	5	5
24	U22CE069	PRASATH	5	5	5	5	5	5
25	U22CE071	SANTHOSH P	5	5	5	5	5	5
26	U22CE072	SARATH S	5	5	5	5	5	5
27	U22CE073	SHAKTHYESWARAN S P	5	5	5	5	5	5
28	U22CE074	SIVAMANI	3	5	5	5	5	5

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Subject Name: Mechanics and Mechanics of Solids

Subject Code: U20PYBJ02

Sl No.	Reg. No	Name	CO1	CO2	CO3	CO4	CO5	Average
1	U22CE001	AMY HYNNIEWTA	93	100	91	89	90	92
2	U22CE002	BANAGOLLA MADHUKAR YADAV	90	92	85	85	90	88
3	U22CE003	DEVANABOINA YASHWANTH	88	100	88	91	90	91
4	U22CE004	KATHIRAVAN S	88	97	88	89	82	89
5	U22CE005	KHAGOKPAM ULLEN	90	92	97	85	95	92
6	U22CE007	MOOD NAIK	88	100	88	87	90	91
7	U22CE008	NAIDU VENKATESH	90	97	88	94	85	91
8	U22CE010	POPPURU TEJESWAR REDDY	90	86	88	98	97	92
9	U22CE011	SATHISH KUMAR G	93	97	79	83	95	89
10	U22CE012	YAMSANI GOUTHAM KUMAR	90	97	91	91	87	91
11	U22CE013	**ABIRAMI**	93	100	91	89	90	92
12	U22CE014	AKALYA B	90	92	85	85	90	88
13	U22CE015	AKSHAY KUMAR	88	100	88	91	90	91
14	U22CE016	AMPOLU BHARATH KUMAR	88	97	88	89	82	89
15	U22CE017	ANIGA SUJITH REDDY	90	92	97	85	95	92
16	U22CE018	ANKIT KUMAR	88	100	88	87	90	91
17	U22CE019	ARIVAZHAGAN	90	97	88	94	85	91
18	U22CE020	ASHWINKARTHICK	90	86	88	98	97	92
19	U22CE021	AYYANAR	93	97	79	83	95	89
20	U22CE022	BALAJI	90	97	91	91	87	91
21	U22CE023	BHARATH P	93	100	91	89	90	92
22	U22CE024	BHARATHRAJ	90	92	85	85	90	88
23	U22CE025	CHIRRA VENKATA SAI	88	100	88	91	90	91
24	U22CE026	CHITTURI DHUSHYANTH	88	97	88	89	82	89
25	U22CE027	DASARI DANIEL PREM KUMAR	90	92	97	85	95	92
26	U22CE028	DHANALAKOTA	88	100	88	87	90	91
27	U22CE029	DHILIPAN	90	97	88	94	85	91
28	U22CE030	DINESH	90	86	88	98	97	92
29	U22CE031	ENIYANBALAJI	93	97	79	83	95	89
30	U22CE032	GADDAM MAHENDHAR	90	97	91	91	87	91
31	U22CE033	GADDAM REVANTH REDDY	93	100	91	89	90	92
32	U22CE034	GANNI AJAY	90	92	85	85	90	88
33	U22CE035	GLENN GRIFTON	88	100	88	91	90	91
34	U22CE036	GOKUL RAJ	88	97	88	89	82	89

35	U22CE037	GOKULA PRASANNA N	90	92	97	85	95	92
36	U22CE038	GOPINATH	88	100	88	87	90	91
37	U22CE039	GURUMOORTHI	90	97	88	94	85	91
38	U22CE040	HAJANAJIMUDEEN	90	86	88	98	97	92
39	U22CE041	HARIHARAN	93	97	79	83	95	89
40	U22CE042	HARIKRISHNAN	90	97	91	91	87	91
41	U22CE043	HARISH	93	100	91	89	90	92
42	U22CE044	HEMANATHAN P	90	92	85	85	90	88
43	U22CE045	JAGANNATHAN	88	100	88	91	90	91
44	U22CE046	JEEVENDRAN	88	97	88	89	82	89
45	U22CE047	JITTA MANIKANTA	90	92	97	85	95	92
46	U22CE048	KAILASA SANKARA SELVAM	88	100	88	87	90	91
47	U22CE049	KARTHEESWAR	90	97	88	94	85	91
48	U22CE050	KARTHIK	90	86	88	98	97	92
49	U22CE051	KARTHIKEYAN	93	97	79	83	95	89
50	U22CE052	KAVIN	90	97	91	91	87	91
51	U22CE053	KONAR	93	100	91	89	90	92
52	U22CE054	KUMARAN	90	92	85	85	90	88
53	U22CE055	LAKAVATH SAI ASHISH NAYAK	88	100	88	91	90	91
54	U22CE056	LAKSHMI NARASIMMAN V	88	97	88	89	82	89
55	U22CE057	LOKKU VENU SAI L	90	92	97	85	95	92
56	U22CE058	MADHANAGOPAL	88	100	88	87	90	91
57	U22CE059	MANEESH	90	97	88	94	85	91
58	U22CE060	MANI	90	86	88	98	97	92
59	U22CE061	MANIGANDAN	93	97	79	83	95	89
60	U22CE062	MANIRAJ	90	97	91	91	87	91
61	U22CE063	MOHAMEDRAWOOF	93	100	91	89	90	92
62	U22CE064	MUTHUKUMAR A	90	92	85	85	90	88
63	U22CE065	NANDHA KUMAR K	88	100	88	91	90	91
64	U22CE066	P DEVANANDHAN	88	97	88	89	82	89
65	U22CE067	PASUPATHI R	90	92	97	85	95	92
66	U22CE068	PENDYALA ANIL	88	100	88	87	90	91
67	U22CE069	PRASATH	90	97	88	94	85	91
68	U22CE070	SAKTHI SARAVANAN V	90	86	88	98	97	92
69	U22CE071	SANTHOSH P	93	97	79	83	95	89
70	U22CE072	SARATH S	90	97	91	91	87	91
71	U22CE073	SHAKTHYESWARAN S P	93	100	91	89	90	92
72	U22CE074	SIVAMANI	90	92	85	85	90	88
73	U22CE075	SRI MARUTHI RAM	88	100	88	91	90	91
74	U22CE076	YESHWANTH G	88	97	88	89	82	89
AVERAGE			**90**	**96**	**89**	**89**	**90**	

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BHARATH INSTITUTE OF HIGHER EDUCATION AND RESEARCH

SCHOOL OF SCIENCE AND HUMANITIES

I YEAR, B. TECH - 2022 - 2023

CO attainment through students Performance

Department of Physics

Course Name - Mechanics and Mechanics of Solids

Course Code - U20PYBJ02

Direct Attainment						
	CO1	CO2	CO3	CO4	CO5	CO6
Average Mark	90	96	89	89	90	0
No.of students above average	70	71	67	69	71	0
Total no. of students	74	74	74	74	74	0
% CO attainment	**95**	**96**	**91**	**92**	**96**	**0**

CO INDIRECT ATTAINMENT – SURVEY REPORT

CO	No. of 5's	No. of 4's	No. of 3's	No. of 2's	No. of 1's	CO%
CO1	30	12	21	10	1	91
CO2	12	21	30	8	3	94
CO3	28	14	21	4	7	91
CO4	21	12	10	15	16	90
CO5	14	28	10	11	11	92
CO6						

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BHARATH INSTITUTE OF HIGHER EDUCATION AND RESEARCH
SCHOOL OF SCIENCE AND HUMANITIES
I YEAR, B. TECH - 2022 - 2023

Subject Name: Mechanics and Mechanics of Solids
Subject Code: U20PYBJ02

	PO1	PO2	PO3	PO4	PO5
CO1	3	3		-	-
CO2	3	3	-	-	-
CO3	3	-	-	3	-
CO4	3	3	-	-	-
CO5	3	-	3	-	-
CO6	-	-	-	-	-
AVERAGE	3	3	3	3	-
	PO1	PO2	PO3	PO4	PO5
CO1	89.2	89.2		-	-
CO2	88.0	88	-	-	-
CO3	87.1	-	-	87.1	-
CO4	89.2	89.2	-	-	-
CO5	89.7	-	89.7	-	-
CO6	-	-	-	-	-
AVERAGE	88.6	88.8	89.7	87.1	-
	PO1	PO2	PO3	PO4	PO5
ATTAINMENT	**88.6**	**88.8**	**89.7**	**87.1**	-

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SCHOOL OF SCIENCE AND HUMANITIES

I YEAR, B. TECH - 2022 - 2023

DEPARTMENT OF PHYSICS

Course Name - Mechanics and Mechanics of Solids

Course Code - U20PYBJ02

	MARKS ALLOTTED					MARKS OBTAINED						END SEMESTER EXAM								
CO	AT1	AT2	AT3	A1	A2	AT1	AT2	AT3	A1	A2	CO ATTAINMENT AVERAGE FROM ASSESSMENT TEST	MARKS ALLOTTED	MARKS OBTAINED	CO ATTAINMENT AVERAGE FROM END SEMESTER EXAM	DIRECT CO ATTAINMENT	INDIRECT CO ATTAINMENT (OBTAINED FROM EXIT SURVEY)	TOTAL CO ATTAINMENT (%)	TARGET [CLASS AVERAGE] (%)	CO ATTAINMENT GAP [TARGET - ATTAINMENT](%)	Actions Proposed to bridge the Gap (Gap >0)	Modification of Target when achieved(Gap <=0)
CO1	20					17					85	20	19	93	89	91	89	85	-4	Target Attained	Target Increased to 85
CO2	10	10		4		8	8.5		4		85	16	14	88	86	94	88	86	-2	Target Attained	Target Increased to 80
CO3		20					18				90	14	12	82	86	91	87	85	-2	Target Attained	Target Increased to 88
CO4			15		6			12		6	86	26	24	92	89	90	89	84	-5	Target Attained	Target Increased to 85
CO5			15					13			87	24	22	92	89	92	90	86	-4	Target Attained	Target Increased to 86
CO6																					

Name-: U.Rajani Kanth Naidu.

Section-: AM-A1

REG NO: U22[illegible]004

Subject: Mechanics & Mechanics of Solids

Date-: 07/11/2022

ASSESSEMENT TEST-I

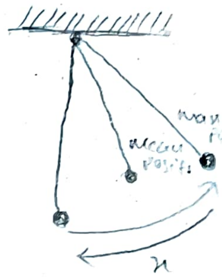
Invigilator Sign
V. Vet[illegible]
07/11/22

Part-B

9b) **Simple Harmonic motion.**

Simple Harmonic motion.-: If a body said to be simple Harmonic motion, a body moves to and fro about its mean position and it the restoring force is directly propotional to the displacement from the mean position and opposite directed of displacement.

We know that Newton's second law



$$F = ma \rightarrow (1)$$

$$F = -kx \rightarrow (2)$$

$$ma = -kx \quad [\text{From eq (1) \& (2)}]$$

$$a = \left(\frac{-k}{m}\right)x.$$

$$a = -\omega^2 x \quad [k/m = \omega^2]$$

$$\boxed{\omega = \frac{2\pi}{T}, \; \omega = \theta/t}$$

$$\frac{d^2x}{dt^2} = -\omega^2 x \quad \left[a = \frac{d^2x}{dt^2}\right]$$

$$\boxed{\frac{d^2x}{dt^2} + \omega^2 x = 0}$$

26½
30

The simple Harmonic motion only has sine (or) cosine functions. The equations are.

$$x = A\sin\omega t$$
$$x = A\cos\omega t$$
$$x = A\sin\omega t + B\cos\omega t$$
$$x = A\cos\omega t + B\sin\omega t$$

Differential equations of SHM :-

$$x = A\sin(\omega t + \phi)$$
$$x = A\cos(\omega t + \phi)$$
$$x = A\sin(\omega t + \phi) + B\cos(\omega t + \phi)$$

$\Rightarrow$ $x = A\sin\omega t$.

differentiation w.r.to time.

$$\frac{dx}{dt} = \frac{d}{dt}A\sin\omega t$$

$$\frac{dx}{dt} = \omega A\cos\omega t$$

$$\frac{d^2x}{dt^2} = -\omega^2 A\sin\omega t$$

$$\frac{d^2x}{dt^2} = -\omega^2 x \quad [x = A\sin\omega t)$$

$$\boxed{\frac{d^2x}{dt^2} + \omega^2 x = 0}$$

5½

10) a) Rigid body :- When a force acting on an object then its shape or size are not change is called as Rigid body. so ideally body does not exist.

* consider a interial frame reference as 's'.
* Fixed in space in which rigid body moving with angular velocity ($\vec{\omega}$) among fixed axis.
* consider another frame ('s'') in which rigid body moving with angular velocity ($\vec{\omega}$) among fixed axis in the fixed space w.r.to 's'.
* The angular momentum of the principal axis is

$$\vec{L} = I_{xx} \omega_x \hat{i} + I_{yy} \omega_y \hat{j} + I_{zz} \omega_z \hat{j}$$

$$\vec{L} = I_x \omega_x \hat{i} + I_y \omega_y \hat{j} + I_z \omega_z \hat{j} \rightarrow (1)$$

* The 's' frame fixed in the body ~~then~~ ('s'') ~~with respective~~ 's'' then body moving with respective to 's'' frame.

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt} \hat{i} + I_y \frac{d\omega_y}{dt} \hat{j} + I_z \frac{d\omega_z}{dt} \hat{k} + I_x \frac{d\hat{i}}{dt} \omega_x$$
$$+ I_y \frac{d\hat{j}}{dt} \omega_y + I_z \frac{d\hat{k}}{dt} \omega_z' \rightarrow (2)$$

* We know that the relation between linear velocity and angular velocity.

$$\vec{v} = \vec{\omega} \times \vec{r}$$

$$\frac{d\vec{r}}{dt} = \vec{v}$$

IIly
$$\frac{d\hat{i}}{dt} = \vec{\omega} \times \hat{i}$$
$$\frac{d\hat{j}}{dt} = \vec{\omega} \times \hat{j}$$
$$\frac{d\hat{k}}{dt} = \vec{\omega} \times \hat{k}$$

The values subtitute in eq (2).

$$\frac{d\vec{L}}{dt} = I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d\omega_y}{dt}\hat{j} + I_z \frac{d\omega_z}{dt}\hat{k} + I_x(\vec{\omega}\times\hat{i})\omega_x + I_y(\vec{\omega}\times\hat{j})\omega_y + I_z(\vec{\omega}\times\hat{k})\omega_z.$$

$$= I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d\omega_y}{dt}\hat{j} + I_z \frac{d\omega_z}{dt}\hat{k} + \vec{\omega}(I_y\omega_y\hat{j} + I_x\omega_x\hat{i} + I_z\omega_z\hat{k})$$

$$= I_x \frac{d\omega_x}{dt}\hat{i} + I_y \frac{d\omega_y}{dt}\hat{j} + I_z \frac{d\omega_z}{dt}\hat{k} + \vec{\omega}\times\vec{L} \quad [\because \text{From eq (1)}]$$

$$\vec{\omega}\times\vec{L} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \omega_x & \omega_y & \omega_z \\ I_x\omega_x & I_y\omega_y & I_z\omega_z \end{vmatrix}$$

$$= \hat{i}[\omega_y I_z \omega_z - \omega_z \omega_y I_z] + \hat{j}[\omega_x I_z \omega_z - I_x\omega_x \omega_z] + \hat{k}[\omega_x I_y \omega_y - I_x\omega_x\omega_y]$$

$$= -\left[\hat{i}[\omega_y I_z \omega_z - \omega_z\omega_y I_z] + \hat{j}[\omega_z\omega_x I_x - \omega_x\omega_z I_z] + \hat{k}[\omega_x I_y \omega_y - I_x \omega_x \omega_y]\right]$$

$$= -\omega_y\omega_z[I_y - I_z]\hat{i} - \omega_x\omega_z[I_x - I_z]\hat{j} - \omega_x\omega_y[I_x - I_y]\hat{k}.$$

$$= I_x\frac{d\omega_x}{dt}\hat{i} + I_y\frac{d\omega_y}{dt}\hat{j} + I_z\frac{d\omega_z}{dt}\hat{k} - \hat{i}[\omega_y\omega_z](I_y - I_z) - \hat{j}[\omega_z\omega_x(I_x - I_z)] - \hat{k}[\omega_x\omega_y][I_x - I_y] \quad (3)$$

$$\vec{\tau} = \frac{d\vec{L}}{dt} = \tau_x\hat{i} + \tau_y\hat{j} + \tau_z\hat{k} \rightarrow (4)$$

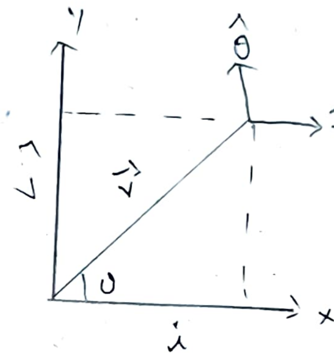
equating co-efficient $\hat{i}, \hat{j}$ & $\hat{k}$ of eq (3) & (4)

$$\boxed{\begin{aligned} \tau_x &= I_x\frac{d\omega_x}{dt} - \omega_y\omega_z(I_y - I_z) \\ \tau_y &= I_y\frac{d\omega_y}{dt} - \omega_x\omega_z(I_x - I_z) \\ \tau_z &= I_z\frac{d\omega_z}{dt} - \omega_x\omega_y[I_x - I_y] \end{aligned}}$$

∴ These are Euler's equations.

PART-C

(11a) Polar coordinates



$$\vec{r} = x\hat{i} + y\hat{j}$$

$$|\vec{r}| = \sqrt{x^2+y^2}.$$

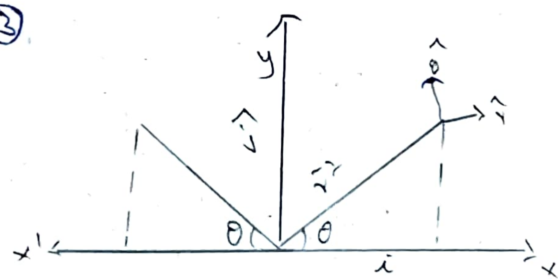
$$\vec{r} = r.\hat{r}$$

$$|\vec{r}| = r.|\hat{r}| = r.$$

$$|\vec{r}| = r = \sqrt{x^2+y^2} \rightarrow (1)$$

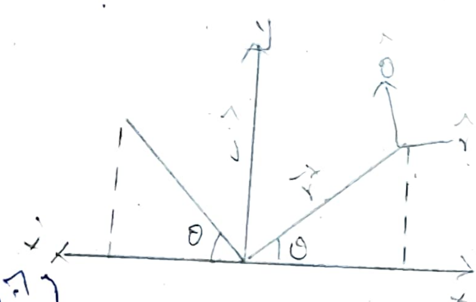
Let redraw the diagram for $\hat{i} + \hat{j}$

$$\boxed{\begin{aligned}\hat{r} &= \cos\theta\,\hat{i} + \sin\theta\,\hat{j}\\ \hat{\theta} &= -\sin\theta\,\hat{i} + \cos\theta\,\hat{j}\end{aligned}} \rightarrow (3)$$



* If the point 'p' has constant magnitude then value of $\hat{r}$ and $\hat{\theta}$ are changes.

* $r.\hat{r} = |\vec{r}| = \text{constant}$



$$\vec{v} = \frac{d|\vec{r}|}{dt} = r.\frac{d\hat{r}}{dt}$$

$$= r.\frac{d}{dt}\left(\cos\theta\,\hat{i} + \sin\theta\,\hat{j}\right)$$

$$= r.\left[-\sin\theta\,\hat{i}.\frac{d\theta}{dt} + \cos\theta\,\hat{j}.\frac{d\theta}{dt}\right]$$

$$= r.\frac{d\theta}{dt}\left[-\sin\theta\,\hat{i} + \cos\theta\,\hat{j}\right]$$

$$= r.\dot{\theta}.\hat{\theta} \rightarrow (4)\ [\because \text{From eq } (3)]$$

let derive the for the acceleration

$$\vec{a} = \frac{d}{dt}(r \cdot \dot{\theta}\,\hat{\theta})$$

$$= r \cdot \frac{d}{dt}(\dot{\theta} \cdot \hat{\theta})$$

$\boxed{(uv)' = uv' + vu'}$

$$= r \cdot \left[\frac{d\dot{\theta}}{dt} \cdot \hat{\theta} + \frac{d\hat{\theta}}{dt}\,\dot{\theta}\right]$$

$$= r \cdot \left[\ddot{\theta}\,\hat{\theta} + \dot{\theta}\frac{d}{dt}(-\sin\theta\hat{i} + \cos\theta\hat{j})\right]$$

$$= r \cdot \left[\ddot{\theta}\,\hat{\theta} + \dot{\theta}\left[-\cos\theta\hat{i} - \sin\theta\hat{j}\right]\right]$$

$$= r \cdot \left[\ddot{\theta}\,\hat{\theta} - \dot{\theta}\left[\cos\theta\hat{i} + \sin\theta\hat{j}\right]\right]$$

$$= r \cdot \left[\ddot{\theta}\,\hat{\theta} - \dot{\theta}\left[\hat{r}\right]\right] \quad [\because \text{from eq (3)}]$$

$$\vec{a} = r\ddot{\theta}\,\hat{\theta} - \dot{\theta}\, r \cdot \hat{r}$$

We know that Newton's second law.

$$F = ma$$

$$= m(r\ddot{\theta}\,\hat{\theta} - \dot{\theta}\, r\,\hat{r})$$

$$= mr\ddot{\theta}\,\hat{\theta} - mr\dot{\theta}\,\hat{r}$$

9½

In $\hat{\theta}$ direction

$F_\theta = mr\ddot{\theta}$ (angular force)

In $\hat{r}$ direction

$F_r = -mr\dot{\theta}$ (radial force)

PART - A

1) c
2) ~~B~~ b
3) b
4) d
5) a
6) a
7) c
8) a

6

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