

# Contents

PREFACE .....	11
<b>PART I. THEORETICAL MECHANICS I .....</b> 15	
<b>Chapter 1: Introduction .....</b> 17	
Lecture 1	
1.1. What is Mechanics? .....	17
1.2. Classification of Mechanics .....	17
1.3. Historical outline .....	19
1.4. Mechanics as a theory .....	20
1.5. Parts of Mechanics .....	22
1.6. Mechanical quantities and system of physical units .....	22
1.7. Useful knowledge preceding Mechanics .....	23
Review questions to Chapter 1 .....	24
<b>Chapter 2: Vectors and vector calculus .....</b> 25	
Lecture 2	
2.1. Scalars and vectors in Mechanics .....	25
2.2. Geometric and analytic description of vectors .....	25
2.3. Vector calculus .....	26
2.4. Vector functions of time .....	29
Review questions to Chapter 2 .....	34
<b>Chapter 3: Geometry of masses .....</b> 35	
Lecture 3	
3.1. What is geometry of masses? .....	35
3.2. First moments and center of mass of a multi-particle system and a body .....	36
3.3. Calculation of first moments and positions of mass centers of bodies .....	38
3.4. Pappus-Guldinus rules .....	46
Lecture 4	
3.5. Moments and products of inertia (second moments) .....	49
3.6. Calculation of second moments .....	53
3.7. Transformation of the second moments due to translation of reference frame .....	58

<b>Lecture 5</b>	
3.8. Transformation of second moments due to rotation of the reference frame .....	64
3.9. Principal axes and principal moments of inertia .....	68
3.10. Ellipsoid of inertia of a body at a point.....	73
Review questions to Chapter 3 .....	76
<b>Chapter 4: Statics of mechanical systems</b> .....	77
<b>Lecture 6</b>	
4.1. Subject, problems and methods of statics .....	77
4.2. Classification of forces (and free moments) in statics .....	80
4.3. Constraints and supports of mechanical systems.....	82
4.4. Equivalent reduction of forces and moments acting on a body .....	84
4.5. Geometric conditions of equilibrium of mechanical systems.....	92
<b>Lecture 7</b>	
4.6. Friction in statics of mechanical systems.....	96
4.7. Friction-induced zones of equilibrium and intervals of loads.....	98
4.8. Friction-induced static indeterminability .....	101
4.9. Duality of loss of equilibrium .....	102
4.10. Self-locking and jamming effects .....	108
<b>Lecture 8</b>	
4.11. Rolling resistance .....	114
4.12. Belt friction .....	117
4.13. Plane trusses .....	119
Review questions to Chapter 4 .....	125
<b>Chapter 5: Kinematics of a particle</b> .....	127
<b>Lecture 9</b>	
5.1. Geometric and analytic description of position of a particle .....	127
5.2. Path of a particle in space.....	129
5.3. Velocity and acceleration of a particle .....	135
5.4. Components of velocity and acceleration in the cylindrical reference frame .....	137
<b>Lecture 10</b>	
5.5. Components of velocity and acceleration in natural directions .....	141
5.6. Rectilinear motion of a particle.....	144
5.7. Curvilinear motion of a particle in a uniform field of acceleration.....	149
5.8. Motion of a particle in a central field of acceleration .....	150
Review questions to Chapter 5 .....	152
<b>Chapter 6: Dynamics of a particle</b> .....	153
<b>Lecture 11</b>	
6.1. Introduction to dynamics.....	153
6.2. Dynamics of a free particle .....	154
6.3. Motion of a particle under force dependent on position .....	155
6.4. Motion of a particle under force dependent on velocity .....	162

## Lecture 12

6.5. Motion of a particle under the Lorentz force .....	167
6.6. Motion of a particle under force dependent on time .....	169
6.7. Dynamics of a constrained particle .....	171
6.8. Linear momentum law of a particle .....	175
6.9. Angular momentum law of a particle.....	179

## Lecture 13

6.10. Work and power of a force acting on a particle .....	183
6.11. Kinetic energy of a particle and kinetic energy law .....	186
6.12. Kinetic energy law in a potential field of force .....	188
Review questions to Chapter 6 .....	194

<b>Chapter 7: Dynamics of multi-particle systems .....</b>	<b>195</b>
--	------------

## Lecture 14

7.1. Definition and basic properties of a multi-particle system.....	195
7.2. Equations of motion of a multi-particle system .....	198
7.3. Linear momentum law of a multi-particle system .....	203
7.4. Law of motion of the mass center of a multi-particle system .....	205

## Lecture 15

7.5. Angular momentum law of a system of particles.....	210
7.6. Kinetic energy law of a system of particles .....	213
7.7. Kinetic energy law in case of potential forces .....	215

Review questions to Chapter 7 .....	222
-------------------------------------	-----

<b>PART II. THEORETICAL MECHANICS II.....</b>	<b>223</b>
---	------------

<b>Chapter 8: Kinematics of a rigid body.....</b>	<b>225</b>
---	------------

## Lecture 1

8.1. Description of the position of a body in space .....	225
8.2. Classification of motions of a rigid body .....	231
8.3. Velocity of points of a body in arbitrary motion .....	233

## Lecture 2

8.4. Acceleration of points of a body in arbitrary motion .....	236
8.5. Velocity and acceleration of points of a body in translatory motion.....	240
8.6. Velocity and acceleration of points of a body in rotation about a fixed point.....	242

## Lecture 3

8.7. Velocity and acceleration of points of a body in plane motion .....	248
8.8. Velocity and acceleration of points of a body in screw motion .....	256

Review questions to Chapter 8 .....	258
-------------------------------------	-----

<b>Chapter 9: Resultant motion of a particle .....</b>	259
<b>Lecture 4</b>	
9.1.    Description of motion of a particle in different reference frames .....	259
9.2.    Velocity and acceleration of a particle in resultant motion .....	262
<b>Lecture 5</b>	
9.3.    Dynamics of a particle in relative motion .....	269
Review questions to Chapter 9 .....	280
<b>Chapter 10: Dynamics of a rigid body .....</b>	281
<b>Lecture 6</b>	
10.1.    Kinetic energy of a rigid body.....	281
10.2.    Kinetic energy law of a rigid body.....	286
<b>Lecture 7</b>	
10.3.    Linear momentum of a body and linear momentum law .....	291
10.4.    Angular momentum of a body and angular momentum law .....	294
10.5.    Equations of motion of a body resulting from linear and angular momentum laws .....	300
10.6.    Dynamics of a body in translatory motion .....	301
<b>Lecture 8</b>	
10.7.    Dynamics of rotation of a body about a fixed axis.....	304
10.8.    Reactions in bearings of a body rotating about a fixed axis.....	307
<b>Lecture 9</b>	
10.9.    Dynamics of a body in rotation about a fixed point .....	316
10.10.    Gyroscopic phenomenon.....	322
10.11.    Dynamics of a body in plane motion.....	324
<b>Lecture 10</b>	
10.12.    Dynamics of a rolling wheel .....	327
10.13.    Dynamics of vehicles .....	331
Review questions to Chapter 10 .....	336
<b>Chapter 11: Elements of analytical mechanics.....</b>	337
<b>Lecture 11</b>	
11.1.    Motivation for studies of analytical mechanics.....	337
11.2.    Constraints and generalized coordinates of a multi-particle system .....	338
11.3.    Virtual displacements in a multi-particle system .....	341
11.4.    Principle of virtual work.....	343
11.5.    Principle of virtual work in case of a rigid body.....	349
<b>Lecture 12</b>	
11.6.    D'Alembert's principle.....	351
11.7.    Lagrange's equations.....	355
Review questions to Chapter 11.....	366

<b>Chapter 12: Elementary impact theory .....</b>	367
<b>Lecture 13</b>	
12.1. Impact forces.....	367
12.2. Dynamics of a particle under impact force .....	368
12.3. Collision of a particle with a resting body .....	370
12.4. Collision of two particles .....	374
12.5. Effect of impact on a rigid body.....	377
<b>Lecture 14</b>	
12.6. Effect of impact on a body rotating about a fixed axis.....	380
12.7. Collision of two bodies in plane motion .....	385
Review questions to Chapter 12 .....	392
<b>Chapter 13: Dynamics of a particle of continuously varying mass .....</b>	393
<b>Lecture 15</b>	
13.1. Equation of motion of a particle of variable mass .....	393
13.2. Dynamics of a rotating body with a variable moment of inertia.....	399
13.3. Equation of motion of a rocket.....	401
Review questions to Chapter 13 .....	404
REFERENCES .....	405