Tribhuvan University

Institute of Science and Technology

Course Title: Mechanics — Full Marks: 50
Course No. : Math 402 — Pass Mark: 17.5
Level : B.Sc. — Year: IV
Nature of Course: Theory — Period per week: 5

Course Objectives: The objective of this course is to acquaint students with the concepts of Mechanics like coplanar forces, virtual work, common catenary, centre of gravity, kinematics in two dimensions, rectilinear motion, moments and products of inertia. It aims at enabling students to build a good knowledge in the subject of Mechanics.

Course Description: The course deals with the topics of both branches of Mechanics viz. Statics and Dynamics. It is a five unit course whose first three units consist of the topics of Statics whereas the last two those of Dynamics.

Detailed Course Contents:

Unit 1: Coplanar Forces and Virtual Work (20 Lectures)

a. Brief review of parallel forces, Moments and couples.
b. Resultant of coplanar forces.

Theorem: A system of forces consisting of any finite number of forces acting at different points in a plane of rigid body can be reduced to a single force through any given point in the same plane and a couple whose moment is equal to the algebraic sum of the moments of given forces about this point.

Theorem: (**Without Proof**) A system of forces acting in a plane of a rigid body at different points can be reduced to a single force or to a single couple.

c. Equation of the line of action of the resultant.
d. General conditions of equilibrium.

Theorem: A system of coplanar forces acting at different points of a rigid body is in equilibrium if the algebraic sums of the resolved parts of these forces in two mutually perpendicular lines in that plane are separately zero and the algebraic sum of their moments about any point in that plane is zero.

Theorem: A system of coplanar forces acting on a rigid body is in equilibrium if the algebraic sums of the moments of these forces about each of the three non-collinear points in that plane are zero.

e. Equilibrium of a rigid body under the action of three forces.

(i). Theorem: If three forces, acting in one plane of a rigid body, keep it in equilibrium, then either they must meet in a point or be parallel.

(ii) Two trigonometric results $(m+n)\cot\theta = m\cot\alpha - n\cot\beta$ and $(m+n)\cot\theta = n\cot A - m\cot B$ where symbols have their usual meanings. (**Without Proof**)

f. Work: introductory concepts.
g. Work done by the resultant.

Theorem: The algebraic sum of the works done by any number of coplanar forces acting on a particle for any displacement of the particle is equal to the work done by their resultant.

h. Concept of virtual displacement (v. d.) and virtual work. (v. w.)
i. Principle of virtual work for a system of coplanar forces acting on a particle and on a rigid body.

Theorem: (**Without Proof**) The necessary and sufficient condition that a particle acted upon by a number of coplanar forces be in equilibrium is that the algebraic sum of the virtual works done by these forces in an arbitrary small v.d. consistent with the geometrical conditions of the system is zero.

Theorem (**Without Proof**): The necessary and sufficient condition that a rigid body acted upon by a number of coplanar forces be in equilibrium is that the algebraic sum of the virtual works done by these forces in an arbitrary small v.d. consistent with the geometrical conditions of the system is zero.

j. List of forces that may be omitted while forming equation of virtual work, v.w. by tension of a string and thrust of a rod.

k. **Problems on the above topics**.

Unit 2: Catenary (12 Lectures)

a. Definition of a catenary and a common catenary.
b. The equation of a common catenary in intrinsic form.
c. The equation of a common catenary in Cartesian form.
d. Some definitions related to common catenary: vertex, axes, directrix, span, sag.
e. Properties of common catenary (various relations among the quantities s, x, y, ψ, T, c etc).
f. Approximation to the common catenary.
   To prove that a common catenary behaves approximately as a parabola for very small values of x and as an exponential curve for the large values of x.
g. Sag of a tightly stretched wire (i.e. sag of a telegraph wire)
h. **Problems on the above topics**.

Unit 3: Centre of Gravity (16 Lectures)

a. Some elementary concepts.
   Centre of mass, centre of gravity, the distinction between centre of mass and centre of gravity, uniqueness of centre of gravity, centers of gravity of some common bodies, the position of the centre of gravity of the particles lying in a plane.
b. Centre of gravity by integration.
c. Different cases of the centre of gravity.
   (i) Centre of gravity of an arc.
   (ii) Centre of gravity of a plane area.
   (iii) Centre of gravity of a solid of revolution.
   (iv) Centre of gravity of a surface of revolution.
   (v) Centre of gravity of the sum or difference of two bodies.
d. **Problems on the above topics**.

Unit 4: Kinematics in Two Dimensions (13 Lectures)

a. Motion in a plane and concept of velocity and acceleration for this motion.
b. Velocity and acceleration in Cartesian form.
c. Velocity and acceleration in polar form (radial and transverse components of velocity and acceleration).
d. Angular velocity and acceleration, relation between linear and angular velocity.
e. Tangential and normal components of velocity and acceleration (velocity and acceleration in intrinsic form).
f. **Problems on the above topics**.

Unit 5: Rectilinear Motion, Moments and Products of Inertia (14 Lectures)

a. Simple Harmonic Motion.
   Definition, expressions for velocity, acceleration and the position of a particle executing a SHM at any instant, some related definitions, a geometrical interpretation of SHM
b. Motion under inverse square law.
c. Motion under some other laws of force.
   (i). Under the repulsion from a fixed point varying as the distance from that point.
   (ii). Under the attraction from a fixed point varying inversely as the distance from that point.
d. Introduction of moments and products of inertia, their definitions, radius of gyration.
e. Moments and products of inertia of a plane lamina about the coordinate axes.
f. Moments and products of inertia of a body about the coordinate axes in space.
g. Moments of inertia in the following simple cases.
   (i) M.I. of a uniform rod about the line through its middle point perpendicular to its length.
   (ii) M.I. of a rectangular lamina about the axes through its centre parallel to sides and about an axis through its centre perpendicular to its plane.
   (iii) M.I. of a circular ring about a diameter and about the line through the centre perpendicular to the plane of the ring.
   (iv) M.I. of a uniform circular disc about any diameter and about the line through its centre perpendicular to its plane.
   (v) M.I. of a hollow sphere about any diameter.
   (vi) M.I. of any solid sphere about any diameter.
   (vii) M.I. of a spherical shell whose internal and external radii are given about any diameter.
h. **Problems on the above topics**.

Related Problems in the respective Units of Mechanics (Math 402)

Unit 1 **Coplanar Forces & Virtual Work** (20 Lectures)

a. Worked out examples on page 37 (No. 1, 2) and examples 4(a) (No. 1 to 8)
b. Worked out example on page43 and examples 4(b) (No. 1 to 5)
c. Worked out example on page 46 and page 49 (No. 2, 3) and examples 4 (c) (No. 1 to 7)
d. Worked out examples on page 55 (No.1) and examples 4 (d) (No. 1 to 7)
e. Worked out examples on page 163(No. 1, 2) and examples 9(a) (No. 1 to 12)

Unit 2 **Catenary** (12 Lectures)

a. Examples 10 (a) (1 to 7)
b. Illustrative examples on page 192 (No. 1, 2, 3) and example 10 (b) (No. 1 to 15)
c. Worked out example on page 200 (No.1, 2, 3) and Example 10 (c) (No. 1 to 7)
d. Example of chapter 10 (No. 1, 2, 4, 5, 6, 10, 13, 21)

Unit 3 **Centre of Gravity** (16 Lectures)

a. Examples 6 (a) (No. 1 to 4)
b. Worked out examples on page 102 (No. 1, 2) and examples 6 (b) (No. 1 to 5)
c. Worked out examples on page 106 (No.1, 2) and examples 6 (c) (No. 1 to 13)

d. Worked out examples on page 108 (No. 1) and Example 6 (d) (No. 1 to 6)
e. Worked out example on page 110 and examples 6 (e) (No.1 to 7)
f. Worked out example on page 112 (No. 1, 2) and examples 6(f) (No. 1, 2, 3)
g. Worked out example on page 116 (No. 1, 2, 3) and examples 6(g) (No. 1, 2)

Unit 4 **Kinematics in two Dimensions** (13 Lectures)

a. Worked out examples on page 3 (No. 1 to 4) and examples I (A) (No. 1, 2, 3)
b. Worked out examples on page 11 (No. 4 to 8) and examples I (B) (No. 1 to 4)
c. Worked out examples on page 17 (No. 11 to 17) and examples I (C) (No. 1 to 8)
d. Miscellaneous worked out examples on page 34 (No. 29, 31)
e. Examples I (E) (No. 3, 4, 7,8,10, 11, 12, 13)

Unit 5 **Rectilinear Motion, Moments & Product of Inertia** (14 Lectures)

a. Worked out example on page 50 (No.9, 11, 12, 13) and examples II (C) (No.1 to 6)
b. Worked out examples on page 73 (No. 25, 26, 27, 28, 29, 30)
c. Examples II (G) (No.1, 2, 3, 4) and examples XI (A) (No. 1(a to f))

Text/ Reference Books:

1. R.S. Verma; *Text Book on Statics,* Pothishala Pvt. Ltd. Allahabad, India
2. M.Ray; *Text Book on Dynamics*, S. Chand & Company Ltd. India
3. C.M. Joshi, J.C. Joshi & R.D. Joshi ; *A Text Book on Mechanics*, Buddha Academic Publishers & distributers, Kathmandu.

Guidelines to the question setters

There will be 5 questions each carrying 10 marks and there will be a head, a tail and middle part if possible. All the questions are compulsory. There will be **two** OR choices in any question number from the same unit. The examination period of Math 402 will be 2 hours.

On the basis of the guidelines mentioned, we enclose one set of model question for Mechanics (Math 402)

MODEL QUESTION

Tribhuvan University

Bachelor Level / IV year/ Sc. & Tech. Full Marks: 50

Mechanics (Math 402) Time: 2 Hours

Attempt ALL the questions

1. Define Catenary. Find the Cartesian equation of the catenary. A and B are two points in the same horizontal line distant 2a apart, AO, OB are two equal heavy strings tied together at O and carrying a weight at O. If l is the length of each string, and d is the depth of O below AB, show that the parameter c of the catenary in which either strings is given by $l^2-d^2= 4c^2 \sinh^2 a/2c$. [1+3+6]
2. What is the line of action of resultant? Three forces P, Q, R act along the sides the triangle forsmed by the lines x+ y= 1, y- x= 1, y= 2. Find the equation of the line of action of their resultant. [2+8]

   OR

   Define tension of the string . Four uniform rods are freely joined at their extremities and form a parallelogram ABCD which is suspended by the joint A, and is kept in shape by a string AC. Prove that the tension of the string is equal to half the whole weight. [2+8]
3. Define centre of gravity of a body. Find the centre of gravity of the area of a loop of the curve r= a $\cos 2\theta$. [2+8]
4. Define simple harmonic motion. Give the geometrical representation of the S.H. M. . In a S. H. M., prove that x= a $\cos\sqrt{\mu}$ t, v= -a $\sqrt{\mu}$ $\sin\sqrt{\mu}$ t, T = $2\pi/\sqrt{\mu}$ where the symbols have their usual meaning. [2+2+6]

   OR

   A particle falls from an infinite distance towards the earth surface and goes to the centre of earth through a fixed hole. Discuss the motion. [10]
5. Define tangential and normal components of acceleration. A particle is moving in a plane curve. Find components of its acceleration along the tangent and the normal to the curve at any instant. What are tangential and normal acceleration if a particle is moving in a circle of radius a? [2+6+2]