

MECHANICAL

DEPARTMENT

2023-24

EM



PREPARED BY
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Techno India NJR Institute of Technology



Course File

Engineering Mechanics (3ME3- 04)

Mr. Nishit Jain
(Assistant Professor)
Department of ME



RAJASTHAN TECHNICAL UNIVERSITY, KOTA

SYLLABUS

2nd Year - III Semester: B.Tech. (Mechanical Engineering)

3ME3-04: ENGINEERING MECHANICS

Credit: 2
2L+0T+0P

Max. Marks: 100 (IA:20, ETE:80)
End Term Exam: 2 Hours

Applicable to the students admitted from 2018-19 onwards

SN	Contents	Hours
1	<p>Statics of particles and rigid bodies: Fundamental laws of mechanics, Principle of transmissibility, System of forces, Resultant force, Resolution of force, Moment and Couples, Varignon's theorem, Resolution of a force into a force and a couple, Free body diagram, Equilibrium, Conditions for equilibrium, Lami's theorem.</p> <p>Plane trusses: Types of structures, Trusses, Support Conditions, Types of Loadings, Classification of trusses, Determinacy of trusses, Basic assumptions of truss analysis, Method of joints, Method of sections.</p> <p>Virtual work: Principle of Virtual Work, Active forces and active force diagram, Stability of equilibrium.</p>	5
2	<p>Centroid & Moment of inertia: Location of centroid and center of gravity, Moment of inertia, Parallel axis and perpendicular axis theorem, Radius of gyration, M.I of composite section, Polar moment of inertia, M.I of solid bodies.</p> <p>Lifting machines: Mechanical advantage, Velocity Ratio, Efficiency of machine, Ideal machine, Ideal effort and ideal load, Reversibility of machine, Law of machine, Lifting machines; System of pulleys, Simple wheel and axle, Wheel and differential axle, Weston's differential pulley block, Worm and worm wheel, Single purchase winch crab, Double purchase winch crab, Screw jack, Differential screw jack.</p>	5
3	<p>Friction: Types of Friction, Laws of friction, Angle of friction, Angle of repose, Ladder, Wedge, Belt Friction.</p> <p>Belt and Rope drive: Types of belts, Types of belt drives, Velocity ratio, Effect of slip on Velocity ratio, Crowing of pulleys, Length of belt, Ratio of tensions in flat belt drive, Power transmission by belt drives, Advantage and disadvantages of V-Belt over Flat Belt.</p>	5
4	<p>Kinematics of particles and rigid bodies: Velocity, Acceleration, Types of Motion, Equations of Motion, Rectangular components of velocity and acceleration, Angular velocity and Angular acceleration, Radial and transverse velocities and accelerations, Projectiles motion on plane and Inclined Plane, Relative Motion.</p> <p>Kinetics of particles and rigid bodies: Newton's second law, Equation of motion in rectangular coordinate, Equation of motion in radial and transverse components, Equation of motion in plane for a rigid body, D'Alembert principle.</p>	5
5	<p>Work, Energy and power: Work of a force, weight, spring force and couple, Power, Efficiency, Energy, Kinetic energy of rigid body, Principle of work and energy, Conservative and Non-conservative Force, Conservation of energy.</p>	6

Office of Dean Academic Affairs
Rajasthan Technical University, Kota



RAJASTHAN TECHNICAL UNIVERSITY, KOTA

SYLLABUS

2nd Year - III Semester: B.Tech. (Mechanical Engineering)

Impulse and momentum: Linear and angular momentum, Linear and angular impulse, Principle of momentum for a particle and rigid body, Principle of linear impulse and momentum for a particle and rigid body, Principle of angular momentum and Impulse, Conservation of angular momentum, Angular momentum of rigid body, Principle of impulse and momentum for a rigid body, Central impact, Oblique impact, System of variable mass, Rocket.	
TOTAL	26

Course Overview:

Engineering Mechanics is the practical application of mechanics concerned with the behaviour of bodies subjected to external forces or displacement. The main objective of this course to help student's development a thorough understanding of the theories and principle and thereby acquire analytical capability required to solve real life problems On successful completion of the course, the student will be able to, the i. Use scalar and vector analytic techniques for determining forces in statically determinate structure. ii. Apply fundamental concepts of kinetics and kinematics of particles for analysis of simple practical problem.

- a) Relevance to Branch: The subject has the significance to understand & develop intuitive understanding of the subject to present a wealth of real world engineering examples to give students a feel of how engineering mechanics is useful in engineering practices.
- b) Relevance to Society: Providing an adequate information about the mechanics which are beneficial to the society development and comfort to the occupant.
- c) Relevance to self-knowledge: Understand concept of mechanical behavior of materials and calculations of same using appropriate equations.
- d) Relevance to an environment: Engineering mechanics is the discipline devoted to the solution of mechanics problems through the integrated application of mathematical, scientific, and engineering principles. Special emphasis is placed on the physical principles underlying modern engineering design

Course Outcomes:

CO. NO.	Cognitive Level	Course Outcome
1	Analysis	Students will be able to demonstrate knowledge of mathematics and mechanics with logics in resolution and composition of force systems
2	Synthesis	Students will be able to demonstrate the ability to relate kinematics with kinetic equations on linear displacement, velocity and acceleration
3	Design	Students will be able to develop the confidence for self learning in application of equilibrium conditions for co-planar and non co-planar force system.
4	Application	Students will be able to correlate power; work and energy to solve practical problems.
5	Analyze	Students will be able to solve practical examples related to curvilinear motion

Prerequisites:

1. To demonstrate knowledge of mathematics and mechanics with logics in resolution and composition of force systems
2. to demonstrate the ability to relate kinematics with kinetic equations on linear displacement, velocity and acceleration
3. To develop the confidence for self learning in application of equilibrium conditions for co-planar and non co-planar force system..
4. correlate power; work and energy to solve practical problems.
5. solve practical examples related to curvilinear motion.

Course Outcome Mapping with Program Outcome:

Engineering Mechanics															
Course Outcome	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO233.1	2	2	2	2	0	1	1	0	0	0	0	1	1	1	1
CO233.2	2	2	2	2	1	1	0	0	0	1	0	0	1	1	1
CO233.3	2	2	2	1	2	2	2	2	1	1	2	1	1	1	1
CO233.4	2	2	2	1	2	2	2	2	1	1	2	1	1	1	1
CO233.5	2	2	2	1	1	2	2	2	2	1	2	1	1	1	1
CO233 (AVG)	2	2	2	1.5	1.25	1.5	1.25	1	0.5	0.75	1	0.75	1	1	1

Course Coverage Module Wise:

Lecture No.	Unit	Topic
1	1	Student should be able to understand Fundamental laws of mechanics, Principle of transmissibility, System of forces, Resultant force, Resolution of force.
2	1	Student should be able to understand Moment and Couples, Varignon's theorem, Resolution of a force into a force and a couple, Free body diagram, Equilibrium, Conditions for equilibrium, Lami's theorem.
3	1	Student should be able to understand Plane trusses: Types of structures, Trusses, Support Conditions, Types of Loadings, Classification of trusses.
4	1	Student should be able to understand Determinacy of trusses, Basic assumptions of truss analysis, Method of joints, Method of sections.
5	1	Student should be able to understand Virtual work: Principle of Virtual Work, Active forces and active force diagram, Stability of equilibrium.
6	2	Student should be able to Location of centroid and center of gravity, Moment of inertia, Parallel axis and perpendicular axis theorem.

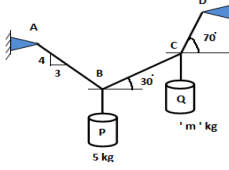
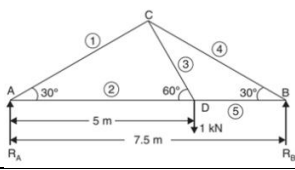
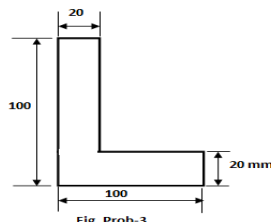
7	2	Student should be able to understand Radius of gyration, M.I of composite section, Polar moment of inertia, M.I of solid bodies.
8	2	Student should be able to understand Mechanical advantage, Velocity Ratio, Efficiency of machine, Ideal machine, Ideal effort and ideal load, Reversibility of machine, Law of machine.
9	2	Student should be able to understand Lifting machines; System of pulleys, Simple wheel and axle, Wheel and differential axle, Weston's differential pulley block.
10	2	Student should be able to understand Worm and worm wheel, Single purchase winch crab, Double purchase winch crab, Screw jack, Differential screw jack.
11	3	Student should be able to understand Types of Friction, Laws of friction, Angle of friction.
12	3	Student should be able to understand Angle of repose, Ladder, Wedge, Belt Friction.
13	3	Student should be able to understand Belt and Rope drive: Types of belts, Types of belt drives, Velocity ratio, Effect of slip on Velocity ratio
14	3	Student should be able to understand Crowing of pulleys, Length of belt, Ratio of tensions in flat belt drive..
15	3	Student should be able to understand Power transmission by belt drives, Advantage and disadvantages of V-Belt over Flat Belt.
16	4	Student should be able to understand Velocity, Acceleration, Types of Motion, Equations of Motion, Rectangular components of velocity and acceleration.
17	4	Student should be able to understand Angular velocity and Angular acceleration, Radial and transverse velocities and accelerations.
18	4	Student should be able to understand Projectiles motion on plane and Inclined Plane, Relative Motion.
19	4	Student should be able to understand Kinetics of particles and rigid bodies: Newton's second law, Equation of motion in rectangular coordinate, Equation of motion in radial.
20	4	Student should be able to understand Equation of motion in Transverse components, Equation of motion in plane for a rigid body, D'Alembert principle.
21	5	Student should be able to understand Work of a force, weight, spring force and couple, Power, Efficiency, Energy, Kinetic energy of rigid body.
22	5	Student should be able to understand Principle of work and energy, Conservative and Non-conservative Force, Conservation of energy.
23	5	Student should be able to understand Impulse and momentum: Linear and angular momentum, Linear and angular impulse, Principle of momentum for a particle and rigid body,
24	5	Student should be able to understand Principle of linear impulse and momentum for a particle and rigid body, Principle of angular momentum and Impulse.

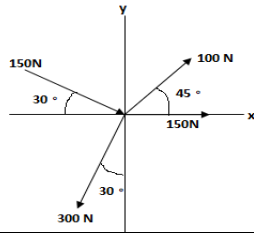
25	5	Student should be able to understand Conservation of angular momentum, Angular momentum of rigid body, Principle of impulse.
26	5	Student should be able to understand Principle of momentum for a rigid body, Central impact, Oblique impact, System of variable mass, Rocket.

TEXT/REFERENCE BOOKS

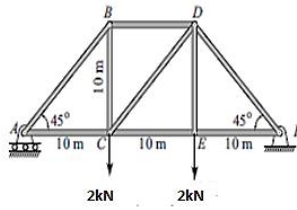
1. Vector Mechanics for Engineers, Beer and Johnston, Tata McGraw-Hill.
2. Engineering Mechanics, Hibbeler, Pearson Education.
3. Engineering Mechanics, Meriam and Kraige, John Wiley & Sons.
4. Engineering Mechanics, Timoshenko and Young, Tata McGraw-Hill.
5. Engineering Mechanics, Shames, Pearson Education.

Course Level Problems (Test Items):

CO.NO.	Problem description
1	<p>A. Explain various types of system of forces with suitable examples.</p> <p>B. In the figure shown below, masses P and Q are suspended with inelastic strings, and are in static equilibrium. Determine the mass of block Q.</p>  <p style="text-align: center;">PROBLEM - 1(B)</p> <p>C. Determine the support reactions and force in all members of the Truss shown below.</p> 
2	<p>A. Compute the centroid of area shown in figure below and find moment of inertia of area about horizontal axis passing through its centroid</p>  <p style="text-align: center;">Fig. Prob-3</p> <p>B. State and prove law of parallelogram of forces</p> <p>C. Determine the magnitude and direction of the resultant of force system shown in figure below.</p>



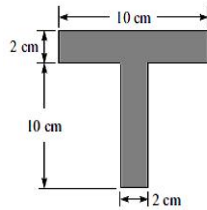
A. Determine the support reactions and forces in members AB, BD and



CD, of the Truss shown below.

3

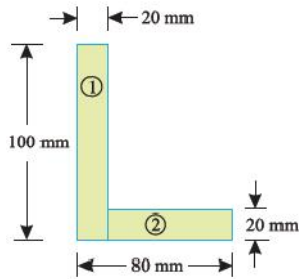
B. Compute the centroid of the area shown in figure below. Then find its moment of inertia about the horizontal centroidal axis. All dimensions in 'cm'.



C. Prove the parallel axes theorem for moment of inertia

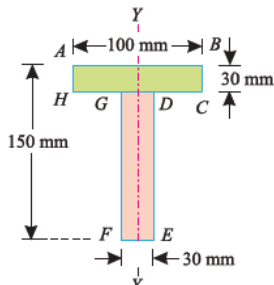
A. Prove the perpendicular axes theorem for moment of inertia.

A. Find the Centroid of following plane figures:-



4

B. Find the Centroid of following plane figures:-



Assessment Methodology:

1. Practical exam in lab where they have to analyze problem statement. (Once in a week)
2. Assignments one from each unit.
3. Midterm subjective paper based on topics as mentioned in the modules. (Twice during the semester)
4. Final paper at the end of the semester subjective.

Teaching and Learning resources unit-wise:

A. INTRODUCTION: Objective, scope and outcome of the course.

Video Tutorials: https://youtu.be/Vb1aMHC1_BM

Theory concepts: <https://pe.gatech.edu/courses/introduction-engineering-mechanics#:~:text=Engineers%20are%20the%20ultimate%20problem%20solvers.&text=It%20addresses%20the%20modeling%20and,and%20physics%20covering%20classical%20mechanics>.

Sample Quiz: <https://jamdbokhtier.com/introduction-to-engineering-mechanics-quiz-answer/>

B. Plane Trusses and frame.

Video Tutorials: <https://youtu.be/3-4wNORPjXY>

Theory concepts: https://academic.csuohio.edu/duffy_s/511_07.pdf

Sample ppt: <https://www.sanfoundry.com/engineering-mechanics-questions-answers-simple-trusses/>

C. Centroid and MOI.

Video Tutorials: <https://youtu.be/TqOVBD4OrNo>

Theory concepts: https://web.iit.edu/sites/web/files/departments/academic-affairs/academic-resource-center/pdfs/Moment_Inertia.pdf

Sample Quiz: https://edurev.in/course/quiz/attempt/-1_Test-Centroid-Of-A-Body/8efd846d-d943-4906-8bcb-c9b6806a977b

D. Simple Stress and Strain

Video Tutorials: https://youtu.be/KGCyT2oVa_A

Theory concepts: <https://www.jntua.ac.in/gate-online-classes/registration/downloads/material/a158938439610.pdf>

Sample Quiz: <https://testbook.com/objective-questions/mcq-on-simple-stress-and-strain--5eea6a0b39140f30f369de96>

E. Work Energy and Power

Video Tutorials: <https://youtu.be/65Ytcr-KweQ>

Theory concepts: <https://www.physicsclassroom.com/class/energy>

Sample Quiz: <https://www.sparknotes.com/physics/workenergypower/review/quiz/>

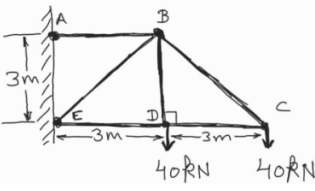
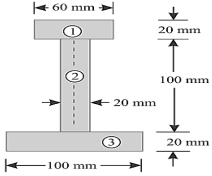
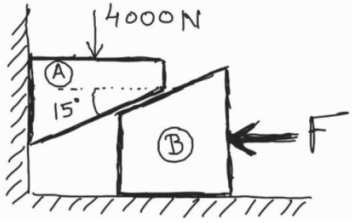
F. Friction

Video Tutorials: <https://youtu.be/4ygO9lonVKY>

Theory concepts: <https://en.wikipedia.org/wiki/Friction>

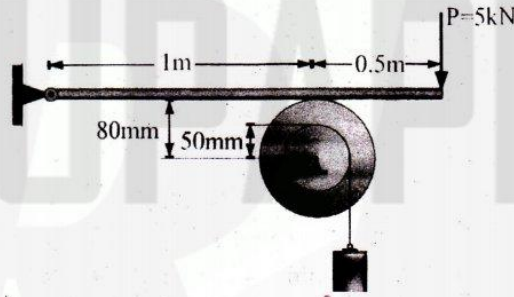
Sample Quiz: https://www.ducksters.com/science/quiz/friction_questions.php

Important Question:

Q.No	Questions	CO
1.	<p>Find the forces in all members of the truss shown in figure below. Also state whether the forces are compressive or tensile in nature. Use method of joints.</p> 	
2.	<p>Find the moment of inertia of the section shown in figure below, about the horizontal axis passing through its centroid. Given: considering the bottom edge of lamina as reference, the location of centroid is: $(\bar{y}) = 60.8 \text{ mm}$.</p> 	
3.	<p>A load of 4000 N is placed on wedge A (see figure given below). Find the force F (applied on wedge B) that is required to lift the loaded wedge A. Both the wedges have no weight of their own. The coefficient of friction on all surfaces is 0.2.</p> 	
4.	<p>The resultant of the two forces, when they act at an angle of 60° is 14 N. If the same forces are acting at right angles, their resultant is $\sqrt{136}$ N. Determine the magnitude of the two forces.</p>	

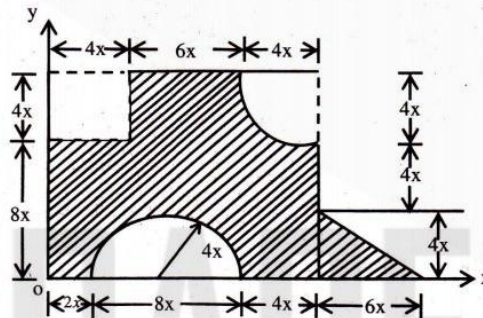
OR

- Q.1 (a) Explain the principal of virtual work? [8]
- (b) What is the maximum load W that a force will hold up, if the coefficient of friction between lever and pulley is 0.2 in the arrangement shown in Figure? Neglect the weight of lever. [8]



UNIT - II

- Q.2 (a) Determine the moment of inertia of a thin elliptical disk of mass m , having axial radius of a and b . [8]
- (b) Determine the centroid of the composite figure about x - y coordinate. Take $x = 40$ mm. [8]

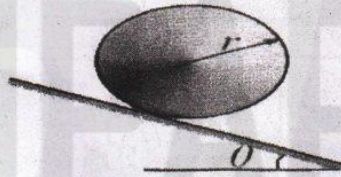


OR

- Q.2 (a) Explain the reversibility and law of machine. [8]
- (b) The number of teeth on the worm wheel of a single worm and worm wheel is 60. Calculate the velocity ratio if the diameter of effort wheel is 25 cm and that of load drum is 12.5 cm. The effort required to lift a load of 600 N by this machine is 20 N. Find the efficiency of the machine. [8]

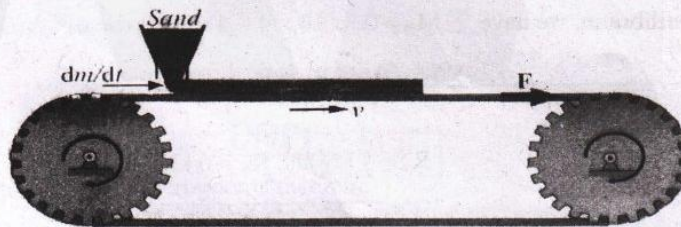
UNIT - III

- Q.3 (a) Define the angle of friction and angle of repose. [8]
 (b) Find the minimum value of the coefficient of friction between a body and a plane, so that the body may roll without slipping. The radius of gyration and radius of body are k and r , respectively [Fig.] [8]



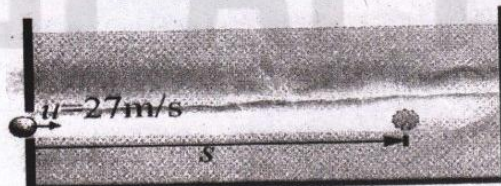
OR

- Q.3 (a) Derive an expression for the limiting ratio of tension in a V-belt over pulley. [8]
 (b) Sand drops continuously from a hopper on to a moving belt as shown in Figure. What force and power are required to keep the belt moving at a constant speed? [8]



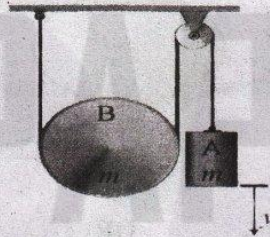
UNIT - IV

- Q.4 (a) Find Range, time of flight and maximum height for a projectile motion. [8]
 (b) A sphere is fired horizontally into a viscous liquid with an initial velocity of 27 m/s [Fig.] If it experiences a deceleration $a = -6t \text{ m/s}^2$, where t is in seconds, determine the distance traveled before it stops. [8]



OR

- Q.4 (a) Define and explain Newton's law of motion for rotational motion. [8]
 (b) If the system shown in figure is released from rest, find
 (i) velocity v of the falling block A as a function of y , and [4]
 (ii) tensions of the string. [4]

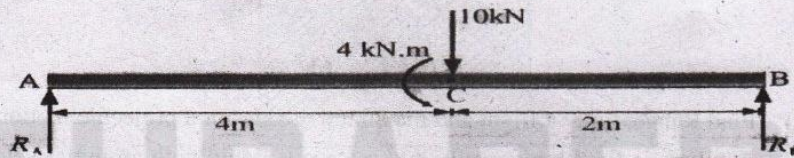


UNIT - V

- Q.5 (a) Explain the principal of work and energy. [8]
 (b) By transferring a load 10 kN at C by a force 10 kN and a moment 4 kNm, we draw free body diagram of the beam [Fig.] and applying equations of equilibrium, we have $\sum M_A = 0 \Rightarrow 10 \times 4 - 4 - R_B \times 6 = 0$ [8]

$$\sum F_y = 0 \Rightarrow R_A + R_B - 10 = 0$$

$$R_A = 4 \text{ kN and } R_B = 6 \text{ kN}$$



OR

- Q.5 Write short note on:
 (a) Conservation of Energy [8]
 (b) Conservation of angular momentum [8]

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2E2005

B.Tech. II Semester (Main/ Back) Examination, June/July - 2016
205 Engineering Mechanics

Time : 3 Hours

Maximum Marks : 80
Min. Passing Marks : 26

Instructions to Candidates:

Attempt any **five** questions, selecting **one** question from each unit. All questions carry **equal** marks. (Schematic diagrams must be shown wherever necessary. Any data you feel missing suitably be assumed and stated clearly. Units of quantities used/calculated must be stated clearly.

Unit - I

1. a) Describe force and State its application. Give a detailed classification of system of force. (6)
- b) A light string ABCDE whose extremity A is fixed, has weights W_1 and W_2 attached to it at B and C. It passes round a small smooth peg at D carrying a weight of 300 N at the free end E as shown in the Fig. (i) If in the equilibrium position, BC is horizontal and AB and CD make 150° and 120° with BC, find : (i) Tensions in the portions AB, BC and CD of the string and (ii) Magnitudes of weights W_1 and W_2 . (6+4)

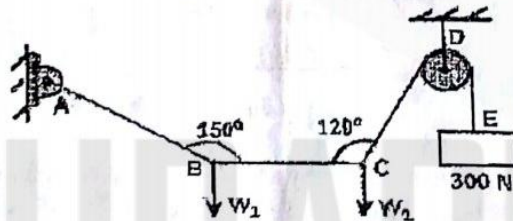


Fig. (i)

OR

1. a) State and Prove Lami's Theorem. (8)

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(1)

[Contd....

- b) Two beams AC and CD are hinged at C and are supported by rollers at A and D and a hinge support is provided at B as shown in Fig. (ii). Using principle of virtual work, determine the reactions at the hinge C and at support B, when a load of 600 N is acting at point E. (8)

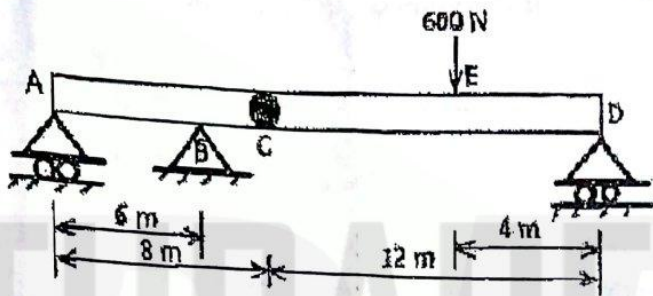


Fig. (ii)

Unit - II

2. a) State the law of machine. Derive an expression for the efficiency of a machine. (6)
- b) Find the moment of inertia about the horizontal and vertical axis (X-X and Y-Y) passing through the centroid of the section shown in Fig. (iii). (6+4)

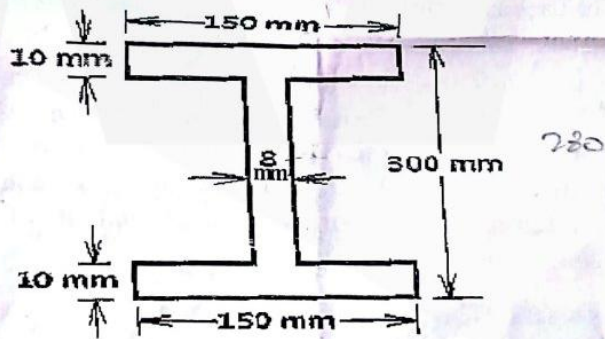


Fig. (iii)

OR

2. a) A machine lifts a load of 250 N by an effort of 160 N, at another instant the same machine lifts the load of 375 N by an effort of 175 N. If the velocity ratio of the machine is 20, determine :
- Law of machine,
 - Efficiency of the machine at 375 N &
 - Efforts lost in friction at 250 N load.

(2+2+2)

- b) A uniform lamina as shown in fig. (iv) consists of a rectangle, a semicircle and a triangle. Determine the centroid of the lamina. All dimensions are in mm. (10)

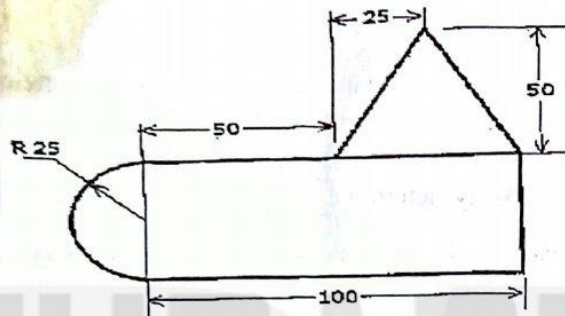


Fig. (iv)

Unit - III

3. a) Define angle of repose. Show that the angle of repose is equal to angle of static friction. (6)
- b) A uniform ladder 3 m long weighs 200 N. It is placed against a wall making an angle of 60° with the floor. The co-efficient of friction between the wall and the ladder is 0.25 and that between the ladder and the floor is 0.35. The ladder in addition to its own weight has to support a man of 1000 N at its top. Calculate:
- The horizontal force P to be applied to the ladder at the floor level to prevent slipping.
 - If the force P is not applied, what should be the minimum inclination of ladder with the horizontal, so that there is no slipping of it? (5+5)

OR

3. a) Derive an expression for the ratio of belt tensions on the tight side and slack side for a flat belt passing over a fixed pulley in terms of co-efficient of friction and angle of contact of belt over pulley. (8)
- b) A ladder of weight 390 N and 6 m long is placed against a vertical wall at an angle of 30° with wall. The co-efficient of friction between the ladder and the wall is 0.25 and that between ladder and floor is 0.38. Find how high a man of weight 1170 N can ascend, before the ladder begins to slip. (8)

Unit - IV

4. A stone is thrown vertically upwards with a velocity 20 m/s from the top of the tower of 25m height. Make calculations for the following parameters :
- The maximum height to which the stone will rise in its flight. (2+2+2)
 - Velocity of the stone during its downward travel at a point in the same level as the point of projection.
 - Time required for the stone to reach the ground.

What is Projectile motion? Derive the expression for the horizontal range, maximum height and time of flight. (4+3+3)

OR

4. a) Two guns are pointed at each other, one upwards at an angle of 30° and the other at the same angle of depression. The muzzles of the guns are 40 m apart. If the guns are shot with velocities of 350 m/s upwards and 300 m/s downwards respectively, determine when and where the shots will meet. (8)

b) A particle moves along horizontal direction and its position at any instant is prescribed by the relation $X = 3t^3 - 5t^2$, where X is in m and t is in seconds, determine: (2+2+2+2)

- i) Displacement during $t = 2$ sec. to 5 sec.
- ii) Average velocity during $t = 2$ sec. to 5 sec. and instantaneous velocity at $t = 2$ sec.
- iii) Average acceleration during $t = 2$ sec. to 5 sec. and instantaneous acceleration at $t = 5$ sec.
- iv) Distance travelled in first 5 sec.

Unit - V

5. a) Explain the principle of work and energy and derive an expression for the same. (8)

b) A pile hammer of 250 kg mass is made to fall freely on a pile from a height of 6 m. If the hammer comes to rest in 0.012 sec, determine (i) the change in momentum, (ii) impulse and (iii) average force. (3+2+3)

OR

5. a) State impulse momentum relation. A shell of mass 60 kg is fired horizontally with a velocity of 250 m/s by a gun of 3000 kg mass. Make calculations for:

- i) The velocity with which the gun recoils, (2+2+2+2)
- ii) The uniform force required to stop the gun in 0.5 m distance, and
- iii) The time required to stop the gun. It may be presumed that momentum of the system comprising the gun and the shell is conserved.

b) From what height, must a heavy elastic ball be dropped on a floor, so that after rebounding thrice it will reach a height of 9 meters? Take $e = (0.5)^{1/3}$. (8)