B. Sc. Engg. (CEE)/ 2nd Sem. 14 May 2024 (Morning)

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Semester Final Examination **Summer Semester: 2022 - 2023**
Course No.: CEE 4201 **Full Marks: 200**
Course Title: Analytic Mechanics **Time: 3 Hours**

There are **10 (TEN)** questions. Answer all questions. The symbols have their usual meaning. Assume any missing data.

1(a) Why is the linear velocity at the instantaneous center of a rolling disk always zero? Briefly explain with a diagram. **CO1 PO1** **20**

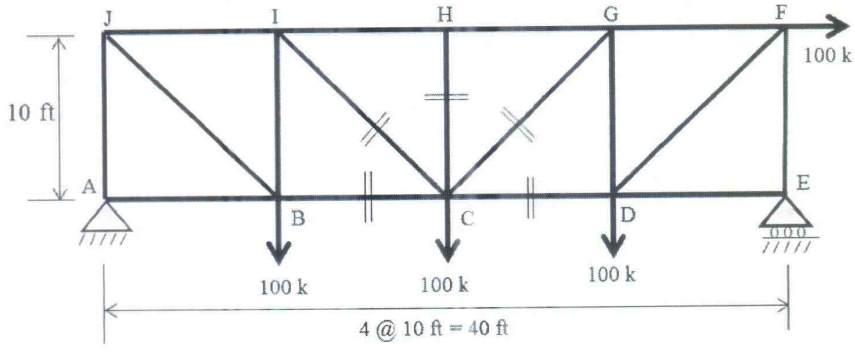
(b) Explain the difference between limiting static frictional force and kinetic frictional force with friction versus load diagram.

(c) Write down the differences between two-force member, multi-force member, and zero-force member. Show qualitative free-body diagrams for these members in order to explain your answer.

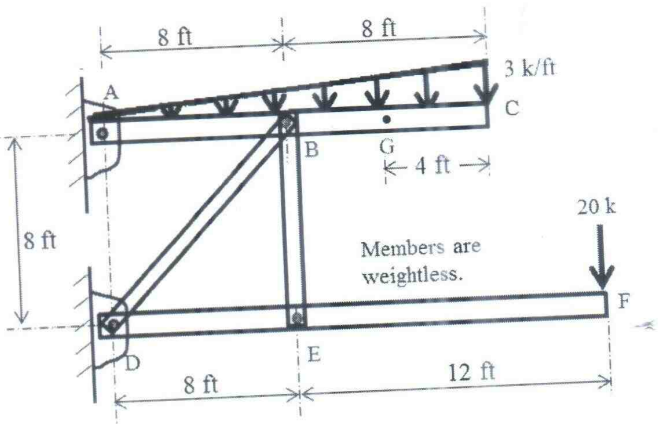
(d) Explain the physical significance of the radius of gyration of an area.

2(a) Determine the internal forces in the members adjacent to joint C of the following truss using the Method of Sections. Indicate tension and compression members. **CO2 PO2** **20**

(b) Verify your results from the free-body diagram of joint C.



3(a) Determine the horizontal and vertical components of the reactions at A and D for the frame shown in the following figure. **CO2 PO2** **20**

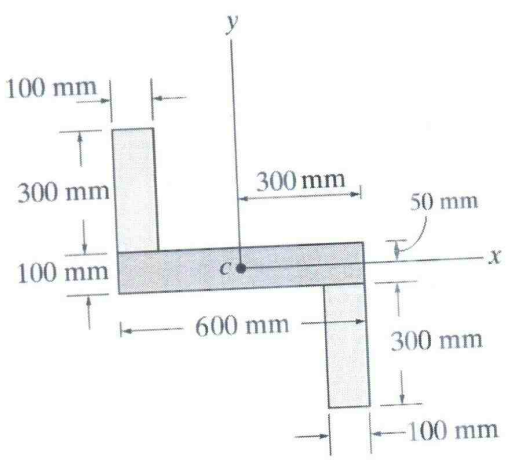


(b) The frame is composed of four members (AC, BD, BE, and DF). Identify the two-force and multi-force members. Determine the internal forces of the two-force members. Indicate if the two-force members are in tension or compression.

(c) Determine the internal normal force, shear force, and bending moment at point G of the member AC.

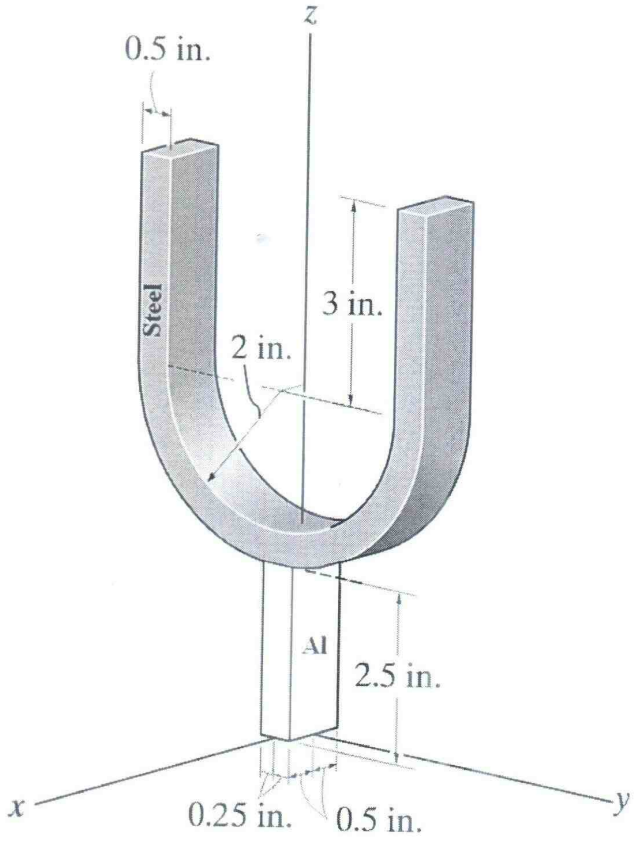
4(a) Find the orientation (θ) of the principal axes for the area shown in the following figure with respect to axis x passing through the centroid C. **CO2 PO2** **20**

(b) Determine the least radius of gyration of the area for axes passing through the centroid.

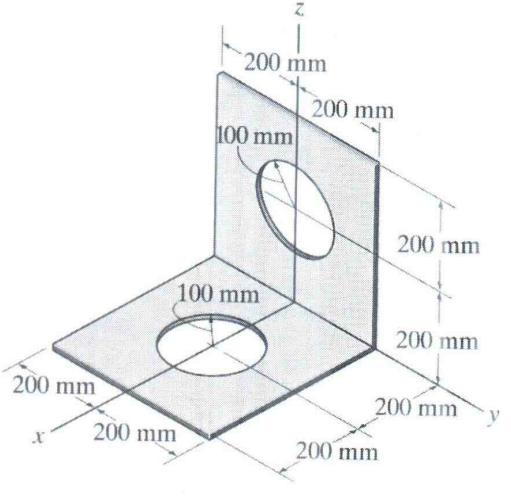


5(a) For the coordinate system shown in the following figure, locate the centroid and the center of gravity of the tuning fork. The U-shaped top part of the fork is made from steel (ρ_{steel} = 15.1 slug/ft^3) and the stem at the bottom is made from aluminum (ρ_{Al} = 5.2 slug/ft^3). **CO2 PO2** **20**

(b) How much would the centroid and the center of gravity of the tuning fork change, if the entire tuning fork was made from steel?

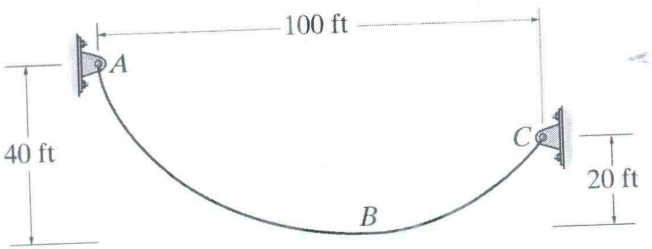


6 The thin-plate object shown in the following figure has a mass per unit area of 10 kg/m^2. Determine its mass moment of inertia about the z axis. **CO2** **PO2** **20**

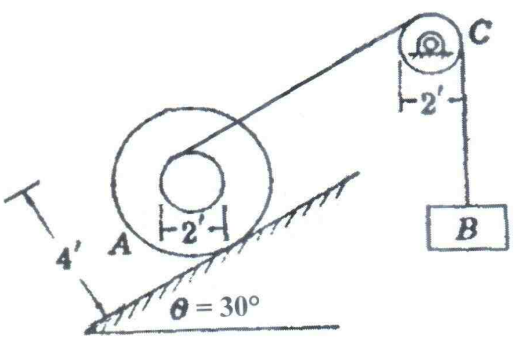


7(a) The flexible cable shown in the following figure is subjected to a load of 850 lb/ft. B is the lowest point in the cable. Determine the minimum tension in the cable and the tension at points A and C. **CO2 PO2** **20**

(b) Draw the free body diagram for the segment AB of the cable and verify your results for the minimum tension and the tension at A [hint: check if $\sum F_x$ and $\sum F_y$ are equal to zero for the segment].



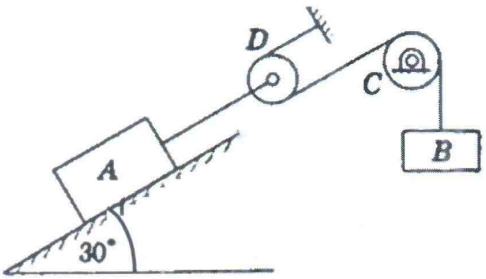
8(a) The 4-ft cylinder (denoted as A) has a central 2-ft groove about which is wound a weightless inextensible cord. This cord passes parallel to the 30° incline and over a 2-ft smooth pulley (denoted as C), thence vertically downward to a body (denoted as B) of weight 70 lb. The displacement of B is 25 ft. Consider, W_A = 80 lb, k_A (radius of gyration of A) = 1.4 ft, and W_C = 20 lb. If the system starts from rest, calculate the final speed of the center of gravity of A and B. Use the Work-Energy Principle for your calculation. **CO2 PO2** **20**



(b) Verify your result for the final speed of object B from its free-body diagram by using the Impulse-Momentum Principle.

(c) From the free-body diagram of cylinder A, show that the Impulse-Momentum equations are equivalent to those of Kinetics.

9 In the following figure, $W_A = 400$ lb, $W_B = 160$ lb, and the pulleys C and D are to be considered as smooth and weightless. Determine the minimum coefficient of static friction required between A and the incline to prevent B from falling downward. Use Virtual-Work Method for your calculation. CO2 PO2 20



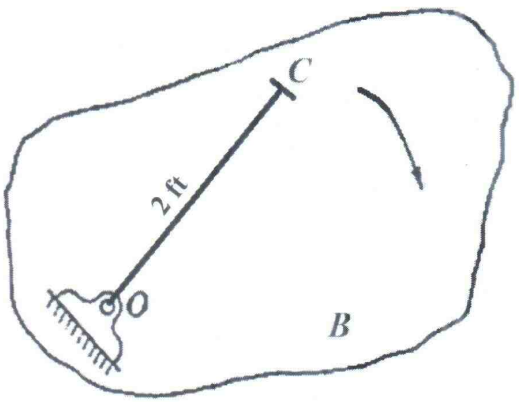
10(a) Body B, shown in the following figure, is rotating about a hinge at O. The angular motion of the body follows the equation below for 10 sec. CO2 PO2 20

$$\theta = 2t^3 + 4t^2$$

where θ is angular displacement in radians and t is time in seconds.

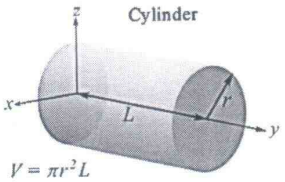
After 10 sec, the angular acceleration becomes constant. Construct the relationship between θ and t, which the rotating body will be following after 10 sec.

(b) Calculate the angular displacement, angular velocity, angular acceleration of the body at 15 sec. At the same instant, also calculate the tangential acceleration and normal acceleration of point C on the body which is located at a distance of 2 ft from point O.



Centroids of Solids

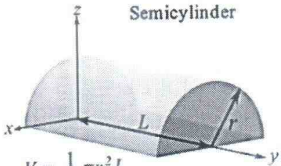
Cylinder



$V = \pi r^2 L$

$\bar{x} = 0, \bar{y} = \frac{L}{2}, \bar{z} = 0$

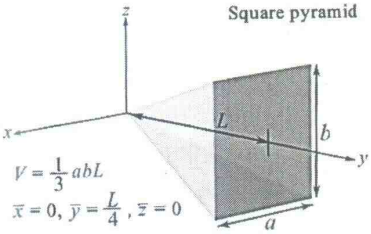
Semicylinder



$V = \frac{1}{2}\pi r^2 L$

$\bar{x} = 0, \bar{y} = \frac{L}{2}, \bar{z} = \frac{4}{3\pi} r$

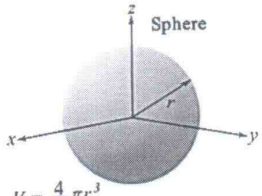
Square pyramid



$V = \frac{1}{3} abL$

$\bar{x} = 0, \bar{y} = \frac{L}{4}, \bar{z} = 0$

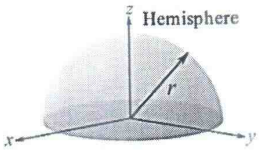
Sphere



$V = \frac{4}{3}\pi r^3$

$\bar{x} = 0, \bar{y} = 0, \bar{z} = 0$

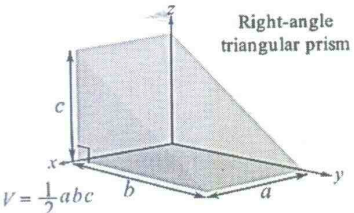
Hemisphere



$V = \frac{2}{3}\pi r^3$

$\bar{x} = 0, \bar{y} = 0, \bar{z} = \frac{3}{8} r$

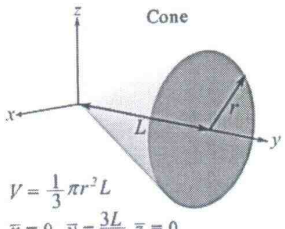
Right-angle triangular prism



$V = \frac{1}{2} abc$

$\bar{x} = \frac{a}{2}, \bar{y} = \frac{b}{3}, \bar{z} = \frac{c}{3}$

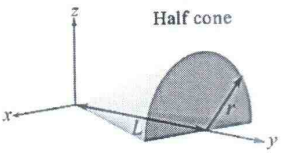
Cone



$V = \frac{1}{3}\pi r^2 L$

$\bar{x} = 0, \bar{y} = \frac{3L}{4}, \bar{z} = 0$

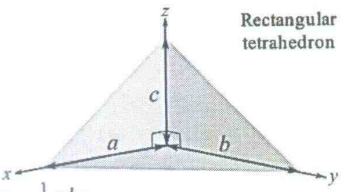
Half cone



$V = \frac{1}{6}\pi r^2 L$

$\bar{x} = 0, \bar{y} = \frac{3L}{4}, \bar{z} = \frac{r}{\pi}$

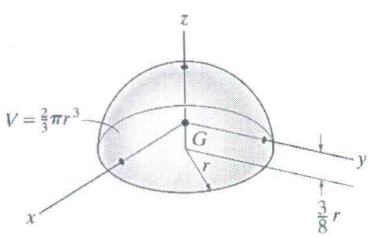
Rectangular tetrahedron



$V = \frac{1}{6} abc$

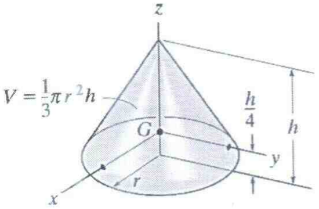
$\bar{x} = \frac{a}{4}, \bar{y} = \frac{b}{4}, \bar{z} = \frac{c}{4}$

Mass Moment of Inertia of Solids



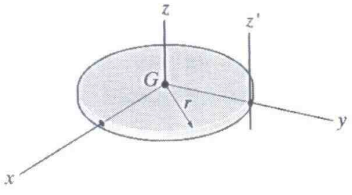
Hemisphere

$I_{xx} = I_{yy} = 0.259\, mr^2 \quad I_{zz} = \frac{2}{5} mr^2$



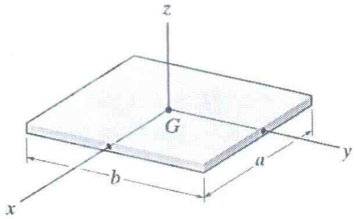
Cone

$I_{xx} = I_{yy} = \frac{3}{80} m(4r^2 + h^2) \quad I_{zz} = \frac{3}{10} mr^2$



Thin Circular disk

$I_{xx} = I_{yy} = \frac{1}{4} mr^2 \quad I_{zz} = \frac{1}{2} mr^2 \quad I_{z'z'} = \frac{3}{2} mr^2$



Thin plate

$I_{xx} = \frac{1}{12} mb^2 \quad I_{yy} = \frac{1}{12} ma^2 \quad I_{zz} = \frac{1}{12} m(a^2 + b^2)$