Computational Mechanics

Group no: 5

Topic: MomentO

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BONAFIDE CERTIFICATE

This is to certify that the project report entitled “ MomentO ” submitted by Shashank Priyadarshi (Roll No:19060), Indraraj Biswas (Roll No:19034), Abhishek Singh (Roll No:19002), Gourav Singh Bajeli (Roll No:19031), Vishnu Vallabh Y(Roll No:19065), Sahitya Kandru (Roll No:19036), Venkat Appalabattula (Roll No:19014), Deepak Yadav (Roll No:19024), as a part of the internal evaluation process for the course 19PHY104 is a bonafide record of the work carried out by them under the guidance and supervision of me at the Department of Mechanical Engineering, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Amritapuri Campus.

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DECLARATION

We,Shashank Priyadarshi (Roll No:19060), Indraraj Biswas (Roll No:19034), Abhishek Singh (Roll No:19002), Gourav Singh Bajeli (Roll No:19031), Vishnu Vallabh Y(Roll No:19065), Sahitya Kandru (Roll No:19036), Venkat Appalabattula (Roll No:19014), Deepak Yadav (Roll No:19024), hereby declare that this project report entitled "Large number multiplication" is the record of the original work done by us under the guidance of Dr.Hariprasad M.P., Assistant Professor, Department of Mechanical Engineering, Amrita School of Engineering, Amritapuri.

Place: Amritapuri

Date:

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❑ AIM

The aim of our project is to compute the centroid and area moment of inertia of the given figures:

- Rectangular Channel
- Rectangular Channel with Slot
- MI and centroid of One Composite Section
- Triangle

about x -axis, y-axis and about any given axis using parallel axes theorem.

❑ THEORY

Centroid Of An Area

The centroid of an area is similar to the center of mass of a body. Calculating the centroid involves only the geometrical shape of the area. The center of gravity will equal the centroid if the body is homogenous i.e. constant density. Integration formulas for calculating the Centroid are:

$$C_x = \frac{\int x dA}{A} \qquad C_y = \frac{\int y dA}{A} \qquad A = \int f(x) dx$$

When calculating the centroid of a complex shape. Divide the shape into a combination of known shapes. Then use the following formula:

$$C_x = \frac{\sum_n A_n C_{x_n}}{\sum A_n} \qquad C_y = \frac{\sum_n A_n C_{y_n}}{\sum A_n}$$

The distance from the *y*-axis to the centroid is C_x
The distance from the *x*-axis to the centroid is C_y
The coordinates of the centroid are (C_x , C_y)
The centroid location of many common shapes is known.

RECTANGULAR CHANNEL:-

The moment of inertia of a channel section can be found if the total area is divided into three smaller ones, A, B, C, as shown in figure below. The final area, may be considered as the additive combination of A+B+C. Therefore, the moment of inertia I_x of the channel section, relative to centroidal x-y axis, is determined like this:

$$I_x = \frac{bh^3}{12} - \frac{(b-t_w)(h-2t_f)^3}{12}$$

where the channel height, the width of the flanges, t_f the thickness of the flanges and t_w the thickness of the web.

The moment of inertia I_{y0} of the double tee section, relative to non-centroidal y0-y0 axis, is readily available:

$$I_{y0} = \frac{(h-2t_f)t_w^3}{3} + 2\frac{t_f b^3}{3}$$

TRIANGLE

The moment of inertia of a triangle with respect to an axis passing through its centroid, parallel to its base, is given by the following expression:

$$I = \frac{bh^3}{36}$$

where b is the base width, and specifically the triangle side parallel to the axis, and h is the triangle height (perpendicular to the axis and the base).

The moment of inertia of a triangle with respect to an axis passing through its base, is given by the following expression:

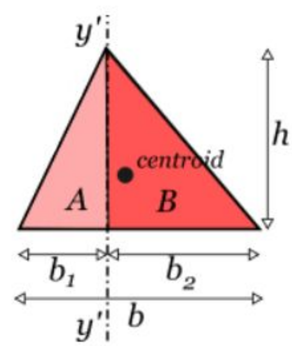
$$I_{y'} = \frac{h{b_1}^3}{12} + \frac{h{b_2}^3}{12} \qquad I = \frac{bh^3}{12}$$

This can be proved by application of the Parallel Axes Theorem (see below) considering that triangle centroid is located at a distance equal to h/3 from base.

The moment of inertia of a triangle with respect to an axis perpendicular to its base, can be found, considering that axis y'-y' in the figure below, divides the original triangle into two right ones, A and B. These triangles, have common base equal to h, and heights b1 and b2

Taking into account that $b_2 = b - b_1$ and that centroidal parallel axis y-y is at a distance $\frac{2}{3}(\frac{b}{2} - b_1)$ from y'-y' makes possible to find the moment of inertia Iy, using the Parallel Axes Theorem (see below). After algebraic manipulation the final expression is:

$$I_y = \frac{hb}{36}(b^2 - b_1 b + {b_1}^2)$$



Parallel Axes Theorem:

The moment of inertia of any shape, in respect to an arbitrary, non centroidal axis, can be found if its moment of inertia in respect to a centroidal axis, parallel to the first one, is known. The *Parallel Axes Theorem* is given by the following equation:

$$I' = I + Ad^2$$

where I' is the moment of inertia in respect to an arbitrary axis, I the moment of inertia in respect to a centroidal axis, parallel to the first one, d the distance between the two parallel axes and A the area of the shape (=bh/2 in case of a triangle).

For the product of inertia Ixy, the parallel axes theorem takes a similar form:

$$I_{xy'} = I_{xy} + Ad_x d_y$$

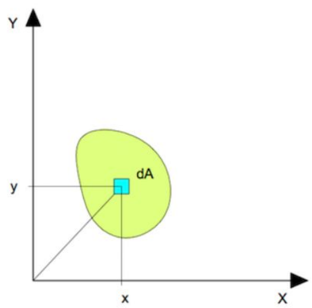
where Ixy is the product of inertia, relative to centroidal axes x,y, and Ixy' is the product of inertia, relative to axes that are parallel to centroidal x,y ones, having offsets from them d_x and d_y respectively.

Area Moment of Inertia:

The **area moment of inertia** is a property of a two - dimensional plane shape which characterizes its deflection under loading. It is also known as the second **moment** of **area** or second **moment of inertia**. The **area moment of inertia** has dimensions of length to the fourth power.

Difference between Mass moment of inertia and Area moment of inertia:

The basic **difference** being **is** that mass **moment of inertia is** concerned with rotating body whereas **area moment of inertia** concerned with the bending stresses developed **in the** body.
Mass **moment of inertia**: Resistance offered by a body to its rotation.



for bending around the x axis can be expressed as
$I_x = \int y^2 \, dA$

where

I_x = Area Moment of Inertia related to the x axis (m^4, mm^4, $inches^4$)

y = the perpendicular distance from axis x to the element dA (m, mm, inches)

dA = an elemental area (m^2, mm^2, $inches^2$)

The Moment of Inertia for bending around the y axis can be expressed as

$I_y = \int x^2 \, dA$ where I_x = Area Moment of Inertia related to the y axis (m^4, mm^4, $inches^4$)x = the perpendicular distance from axis y to the element dA (m, mm, inches

❑ ALGORITHM

Rectangular Channel -

Here for finding centroid of this figure we took coordinates of the edges from the user. Thereafter we will find centroids of individual figures (3 Rectangles separately) by the help of these coordinates, and then by the formula

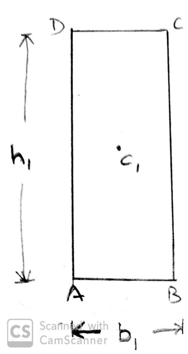
$$C_x = \frac{\sum_n A_n C_{x_n}}{\sum A_n} \qquad C_y = \frac{\sum_n A_n C_{y_n}}{\sum A_n}$$

So, for calculating centroid we used this formula-

For Rectangle 1 (r1) -

```
cx1 = (x12-x11)/2;
cy1 = (y14-y11)/2;
ar1 = (x12-x11)*(y14-y11);
b1  = cx1*2;
h1  = cy1*2;
```

Here, cx1 = x centroid
cy1 = y centroid
ar1 = area of r1
b1 = base of r1
h1 = height of r1



$c_1 = [h_1/2 , b_1/2]$

For Rectangle 2 (r2) -

```
cx2 = x12 + (x22-x12)/2;
cy2 = (y23 - y22)/2;
ar2 = (x22 - x12)*(y23 - y22);
b2  = (x22-x12);
h2  = cy2*2;
```

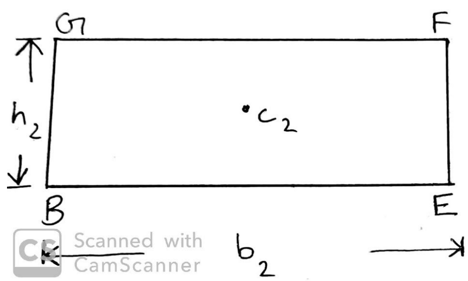
Here, cx2 = x centroid

cy2 = y centroid

ar2 = area of r1

b2 = base of r1

h2 = height of r1



$C_2 = \left[h_2/_2 , b_2/_2 \right]$

For Rectangle 3 (r3) -

```
cx3 = x22 + (x32 - x22)/2;
cy3 = (y33 - y32)/2;
r3  = (x32 - x22)*(y33 - y32);
b3  = (x32 - x22);
h3  = cy3*2;
```

Here, cx3 = x centroid

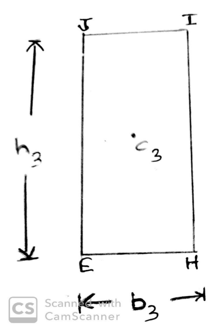
cy3 = ycentroid

ar3 = area of r1

b3 = base of r1

h3 = height of

r1

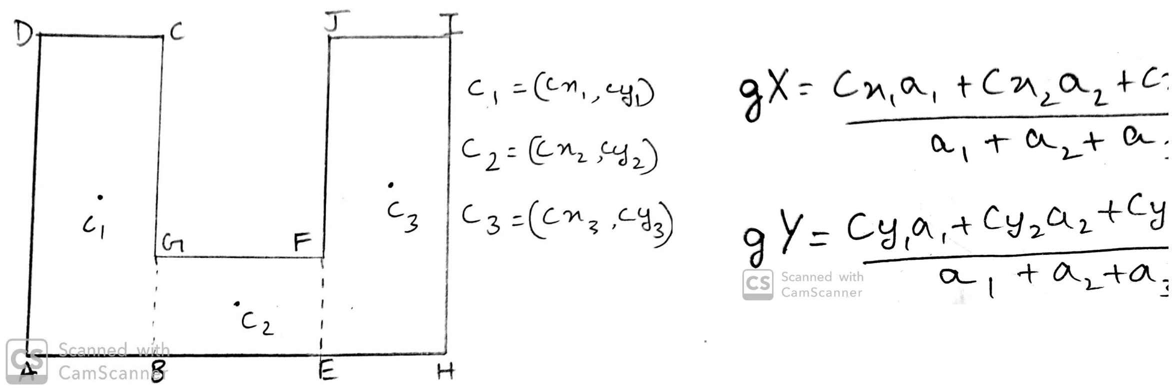


$c_3 \left[h_3/_2 , b_3/_2 \right]$

So after combining this all,

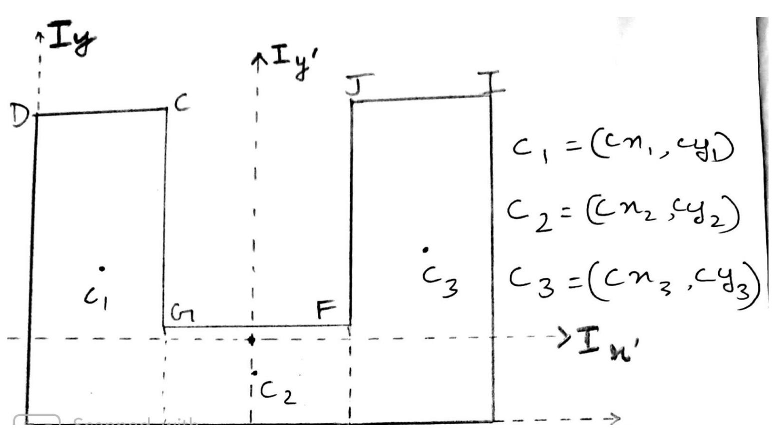
```
gX = ((ar1)*(cx1) + (ar2)*(cx2) + (ar3)*(cx3))/(ar1 + ar2 + ar3);
gY = ((ar1)*(cy1) + (ar2)*(cy2) + (ar3)*(cy3))/(ar1 + ar2 + ar3);
```

here , gX = global x centroid
gY = global y centroid



Moment of Inertia -

For finding MOI, we first declare the origin then by using this algorith we will find the MOI about any axis by applying parallel axis theorem.



$$I' = I + Ad^2$$

Here,
I' = Moment of inertia about any axis

A = total area

d = distance b/w cx1 and new origin.

Here,

Ix1 and Iy1 = MOI of r1 about given axis

Ix2 and Iy2 = MOI of r2 about given axis

Ix3 and Iy3 = MOI of r3 about given axis

```
double Ix1 = (b1*(Math.pow(h1,3)))/12 + ar1*Math.pow(Math.abs(cy1-y),2);
double Ix2 = (b2*(Math.pow(h2,3)))/12 + ar2*Math.pow(Math.abs(cy2-y),2);
double Ix3 = (b3*(Math.pow(h3 , 3)))/12+ar3*Math.pow(Math.abs(cy3-y),2);
Ix = Ix1 + Ix2 +Ix3 ;
```

Composite shape-

Part 1 :

Only Four Sided

In this program I have taken eight entries from a user that are the X and Y coordinates of the four sided figure.

Giving The X And Y Coordinates The Centroid Was Computed And Also The Are By Applying The Formula For The Moment Of Inertia By Given In The Code Below I Found Out The Moment Of Inertia About Any Axis And Then By Parallel Axis Theorem Found The Moment Of Inertia About Any Axis.

Part 2 :

Four Sided,Triangle

For the four sided I did the same thing as the part 1 and for the triangle I took 6 inputs ,I.E, X and Y coordinates of the vertices.Using them I Found The Centroid and the area which then I used them with four sided centroid and area of four sided figure to calculate common centroid of the whole figure using momentum of inertia formula I found the moment of inertia of triangle then added It with four sided figure To get momentum of inertia of the whole figure about any axis.

Part 3 :

After Repeating The Part 2 I got the moment of Inertia of 4 sided and The Triangle ,Then I Will Calculate Moi Of Circle Using The Given Formula I Will Find The Centroid And Moment Of Inertia And Area Then Find Out The Common Centroid For The Whole Figure And The Moment Of Inertia Of The Whole Figure About Any Axis

Part 4 :

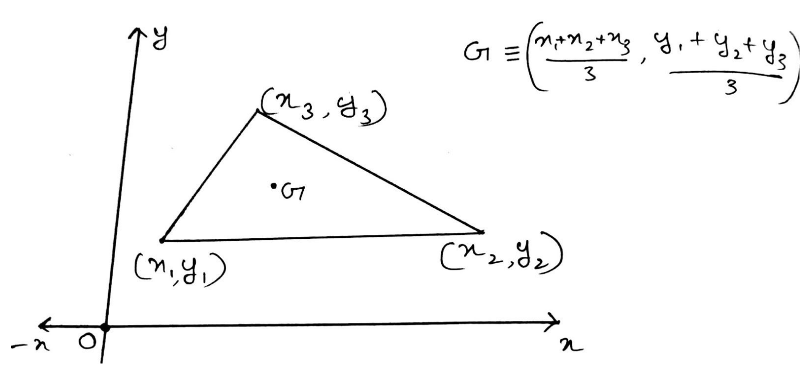
After Repeating The Above Steps We Have The Moment Of Inertia Of The 4 Sided , Triangle, Circle And Their Centroids And Area Then I Will Take 4 Inputs From The User 3 X And Y Coordinates And 1 Raidus Using The Radius And Coordinates I Can Find The Centroid And The Area Then By Applying The Common Centroid Formula We Can Find The Common Centroid Of The Whole Figure And Then Ufind Out Moi By Using Moi Of The Four Figures By Adding Them About Any Axis

Note: If A User Wants Circle And Semicircle Only He Can Give Input 0 For Other Figures So The Moi Of The Other Figure Would Be Zero

Triangular -

Here for finding centroid of triangular geometry I used the coordinates again, as we know that centroid of triangle-

$C_x = (x1 + x2 + x3)/3$ $C_y = (y1 + y2 + y3)/3$



For finding moment of inertia about centroidal axis we used the formula and parallel axis theorem.

b = base = AB

h = height

```java
double centroidX = (x1+x2+x3)/3;
double centroidY = (y1+y2+y3)/3;
```

For finding height

As, we know that area = ½(base*height)

$$I_x = \frac{bh^3}{36}$$

$$I_y = \frac{b^3h - b^2ha + bha^2}{36}$$

I.e.

$$area = \left| \frac{A_x(B_y - C_y) + B_x(C_y - A_y) + C_x(A_y - B_y)}{2} \right| = ½(AB*h)$$

Here,

$A_x = x1$, $A_y = y1$, $B_x = x2$, $B_y = y2$, $C_x = x3$, $C_y = y3$

As, by the help of coordinate we will find the area and then by the help of area we will find height then by applying moment of inertia formula we can find MOI.

```java
double centroidX = (x1+x2+x3)/3;
double centroidY = (y1+y2+y3)/3;
double breadth = Math.sqrt((Math.pow((y2-y1),2)+Math.pow((x2-x1),2)));
double area = (x1*(y2-y3)+x2*(y3-y1)+x3*(y1-y2))/2;
double height = (2*area)/breadth;
double a = x3-x1;
double Ixc = (breadth*Math.pow(height,3))/36;
double Iyc = (Math.pow((breadth),3)*height-Math.pow((breadth),2)*height*a+breadth*height*Math.pow((a),2))/36;
double Ix = Ixc + area*Math.pow((centroidY-oy),2);
double Iy = Iyc + area*Math.pow((centroidX-ox),2);
```

Rectangular Channel with slot (Rectangle, Square,Triang Circle)

Here for finding centroid of this figure we took coordinates of the edges from the user. Thereafter we will find centroids of individual figures (3 Rectangles separately) by the help of these coordinates, and then by the formula. For slot we find the centroid of that slot and then finally we subtracted the value.

$$C_x = \frac{\sum_n A_n C_{x_n}}{\sum A_n} \qquad C_y = \frac{\sum_n A_n C_{y_n}}{\sum A_n}$$

If the rectangle/square/triangle is slot then we find the centroid as we found previously and if the slot is circle then we took centre and its radius as input then by the help of parallel axis theorem and centroid formula we found the answer. This all algorithm is valid for any axis.

Flowchart -

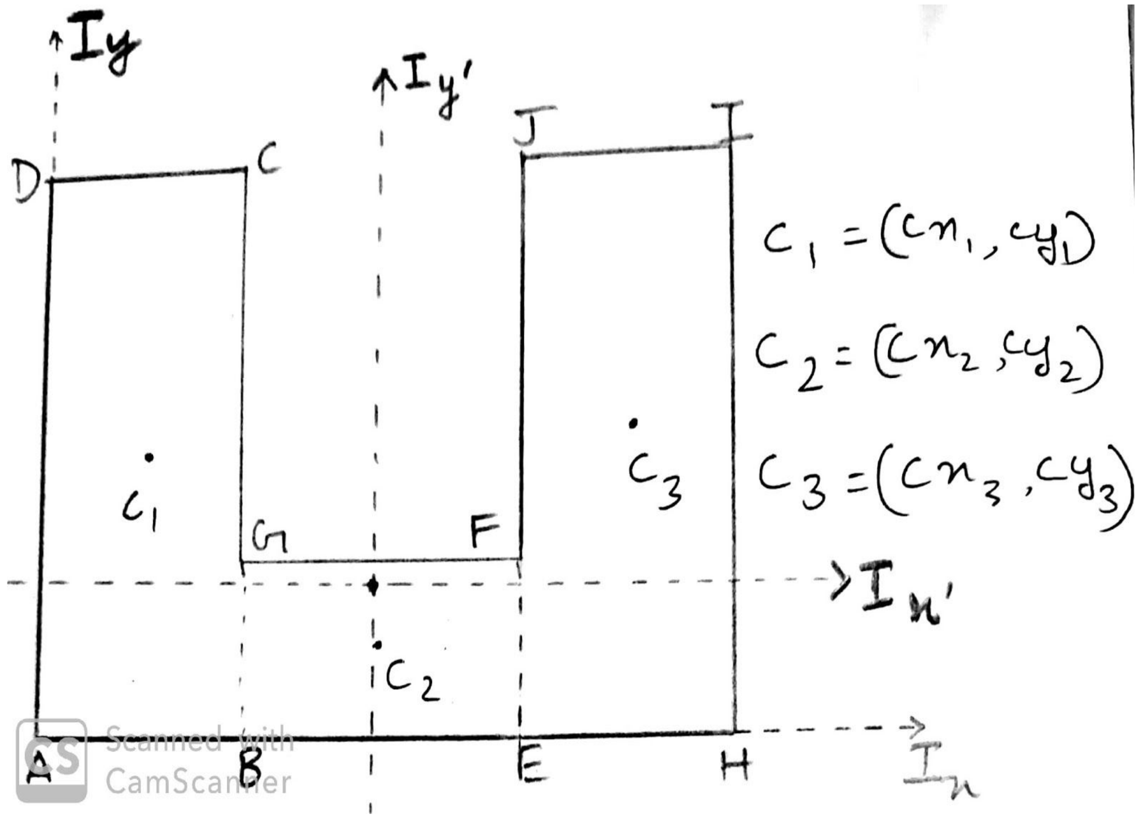
First in out application their is page which contains three buttons i.e. features, documentation and exit. If we press feature button then new interface will open which contains four options i.e for rectangular channel, rectangular channel with slot, composite shape and triangular shape.

For rectangular channel we just took the coordinates as input then next by our formula we found centroid and MOI.

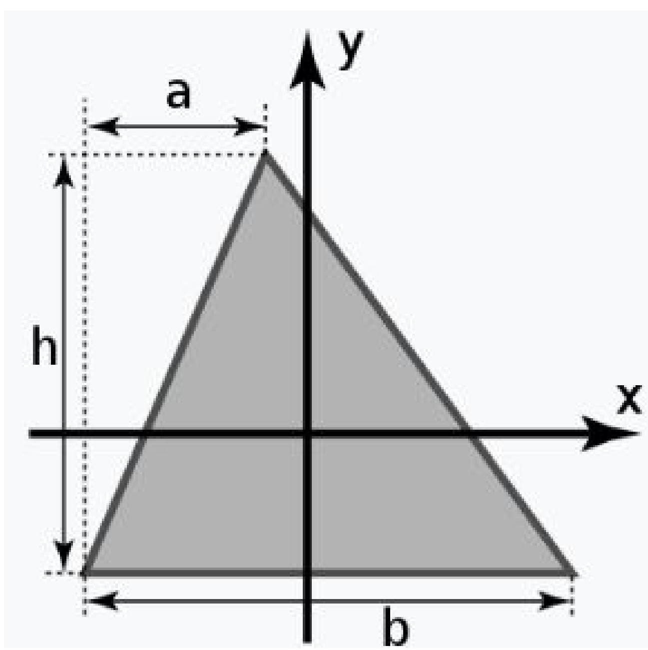
For rectangular channel with slot we just took the coordinates of channel and slots as input then next by our formula we found centroid and MOI.

For triangular we just took the coordinates as input then next by our formula we found centroid and MOI.

And then the next button contains documentation which is hyperlinked to a webpage which contains all documents.



Iy
Iy'
D
C
J
I
c1 = (cx1, cy1)
c2 = (cx2, cy2)
c3 = (cx3, cy3)
c1
c3
G
F
Ix'
c2
A
B
E
H
Ix



y
a
h
x
b