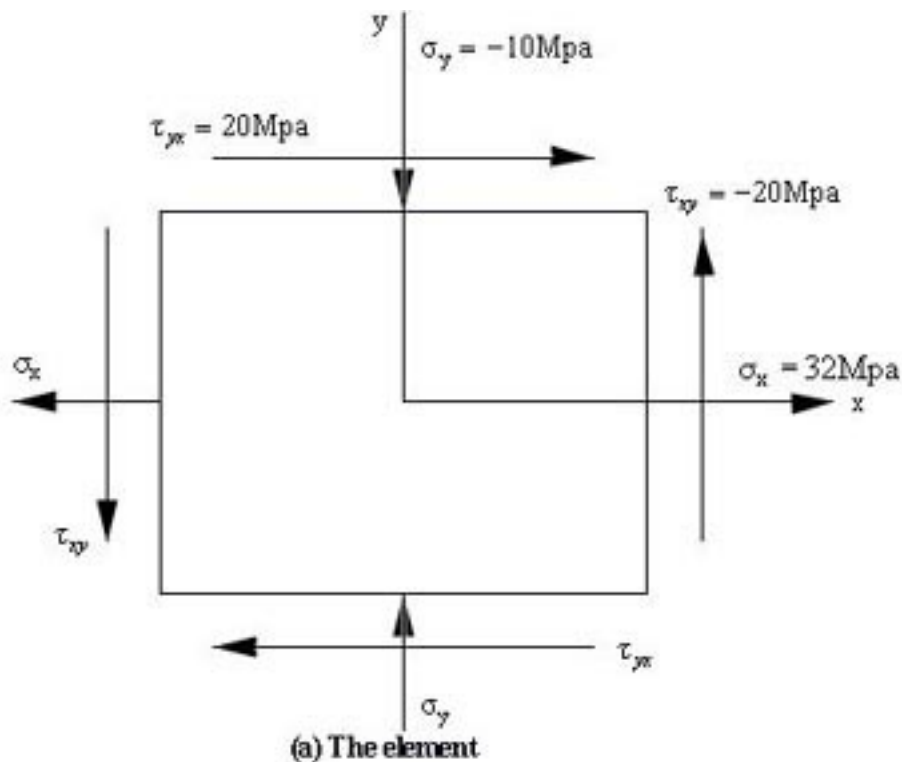


## 10429 Mohr's Circle

An approach of representing the stresses (force per unit area) on a body is the Mohr's Circle - devised by Otto Mohr in 1882. It's a very nice method of representing the stresses and analyze where they occur, so it's used widely. In this problem we are not concerned with the details of the theory, we will just know how to use this device at work.

### Drawing Mohr's Circle

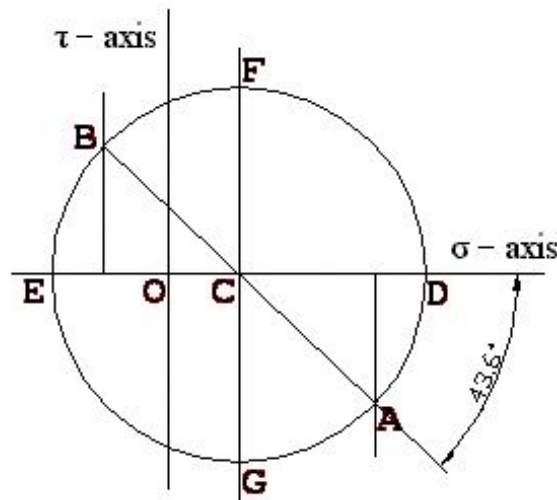
Let a stress state is described by two principle stresses (Load which tries to compress or elongate)  $\sigma_x$ ,  $\sigma_y$  and two torsional stresses (Load which tries to twist)  $\tau_{xy}$ ,  $\tau_{yx}$  as shown in the example below, *Figure a*. As  $\tau_{yx}$  is always equal to  $\tau_{xy}$  but in reverse direction, in the input these will be given as  $\sigma_x$ ,  $\sigma_y$  and  $\tau_{xy}$ . Thus input for the following condition is (32, -10, 20, CCW).



**Step 1 :** Draw two perpendicular line indicating horizontal line as  $\sigma$  axis and the vertical line as  $\tau$  axis. The point of intersection is the center point (0,0) and both the stresses is zero there. See *Figure b* below.

**Step 2 :** Locate points  $(\sigma_x, \tau_{xy})$  and  $(\sigma_y, \tau_{yx})$  and connect them with a straight line. Indicated by point A (32, -20) and B (-10, 20) respectively in *Figure b*.

**Step 3 :** Draw a circle with the line AB as the diameter and the intersection of the line AB and DE ( $\sigma$  axis) as the center (point C).



(b) The Mohr's Circle Diagram

Now for maximum normal stress condition:

- Maximum normal stress angle = half of angle ACD =  $43.6 / 2 = 21.8$  degree. Angle ACD will not be greater than 90 degree only for current problem.
- Maximum and minimum normal stress = OD and OE respectively = 40 and -18 respectively.

For maximum shear stress condition

- Maximum shear stress angle = half of angle ACD + 45 =  $21.8 + 45 = 66.8$  degree
- Maximum shear stress = CF = 29
- Normal stress at this condition = OC = 11

Remember, on the ordinate clockwise (**CW**) shear stresses are plotted up; counterclockwise (**CCW**) shear stresses are plotted down. Moreover  $\tau_{yx}$  always has the same value as  $\tau_{xy}$  but inverse in direction, i.e.  $\tau_{yx} = -\tau_{xy}$ .

### Input

First line of input will contain a stress state with three numbers  $\sigma_x$ ,  $\sigma_y$  and  $\tau_{xy}$  (all in the range of -1000 MPa to 1000 MPa) followed by a string ('CW' or 'CCW') stating the direction of the torsional stress if not zero (i.e. The string will not appear if  $\tau_{xy}$  is zero).

### Output

For each system, First of all output angle ACD, then the value OD and OE on the next line. Then print a blank line.

After that print maximum shear stress angle as stated in the example above (angle ACD + 45). On the next line print the value of CF, followed by the value of CO.

Each real number must be rounded to the nearest 2 digits after the decimal point. Consider the format of the sample output below while printing the values. Output a blank line between two consecutive output set.

**Sample Input**

32 -10 20 CCW  
80 -40 0

**Sample Output**

Element : 1

Position of maximum normal stresses : 21.80 deg

Maximum normal stresses : 40.00 MPa and -18.00 MPa

Position of maximum shear stresses : 66.80 deg

Maximum shear stress (xy plane) : 29.00 MPa

Normal stress at this condition : 11.00 MPa

Element : 2

Position of maximum normal stresses : 0.00 deg

Maximum normal stresses : 80.00 MPa and -40.00 MPa

Position of maximum shear stresses : 45.00 deg

Maximum shear stress (xy plane) : 60.00 MPa

Normal stress at this condition : 20.00 MPa