Carleton University * Faculty of Engineering and Design

Mechanics I

ECOR 1101

Lecture 15

INTERNAL FORCES

Section 8.1

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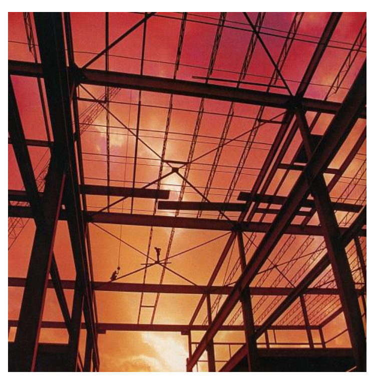
Objective:
Students will be able to:

Use the method of sections for determining internal forces in 2-D load cases.

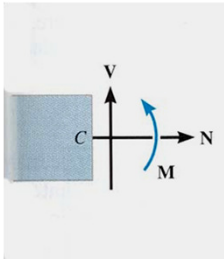


READING QUIZ

1. In mechanics, the force component V acting tangent to, or along the face of, the section is called the _________ .

   A) axial force   B) shear force

   C) normal force   D) bending moment



2. In a multiforce member, the member is generally subjected to an internal _________.

   A) normal force   B) shear force

   C) bending moment   D) All of the above.

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APPLICATIONS

These beams are used to support the roof of this gas station.

Why are the beams tapered? Is it because of the internal forces?

If so, what are these forces and how do we determine them?

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APPLICATIONS
(continued)

A fixed column supports this rectangular billboard.

Usually such columns are wider at the bottom than at the top. Why?

Is it because of the internal forces?

If so, what are they and how do we determine them?

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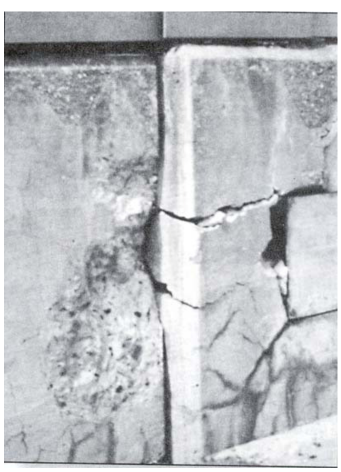
APPLICATIONS
(continued)



The concrete supporting a bridge has fractured.

What might have caused the concrete to do this?

How can we analyze or design these structures to make them safer?

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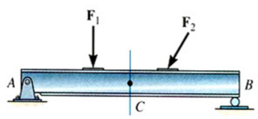
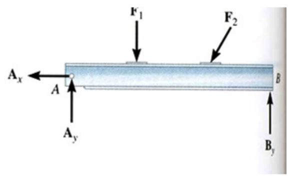
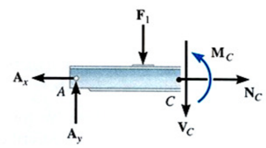
INTERNAL FORCES







The design of any structural member requires finding the forces acting within the member to make sure the material can resist those loads.

For example, we want to determine the internal forces acting on the cross section at C. First, we first need to determine the support reactions.

Then we need to cut the beam at C and draw a FBD of one of the halves of the beam. This FBD will include the internal forces acting at C. Finally, we need to solve for these unknowns using the E-of-E.

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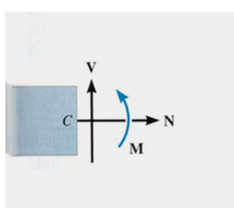
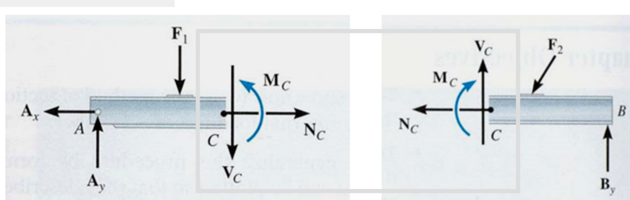
INTERNAL FORCES (continued)



In two-dimensional cases, typical internal loads are normal or axial forces (N, acting perpendicular to the section), shear forces (V, acting along the surface), and the bending moment (M).



The loads on the left and right sides of the section at C are equal in magnitude but opposite in direction. This is because when the two sides are reconnected, the net loads are zero at the section.

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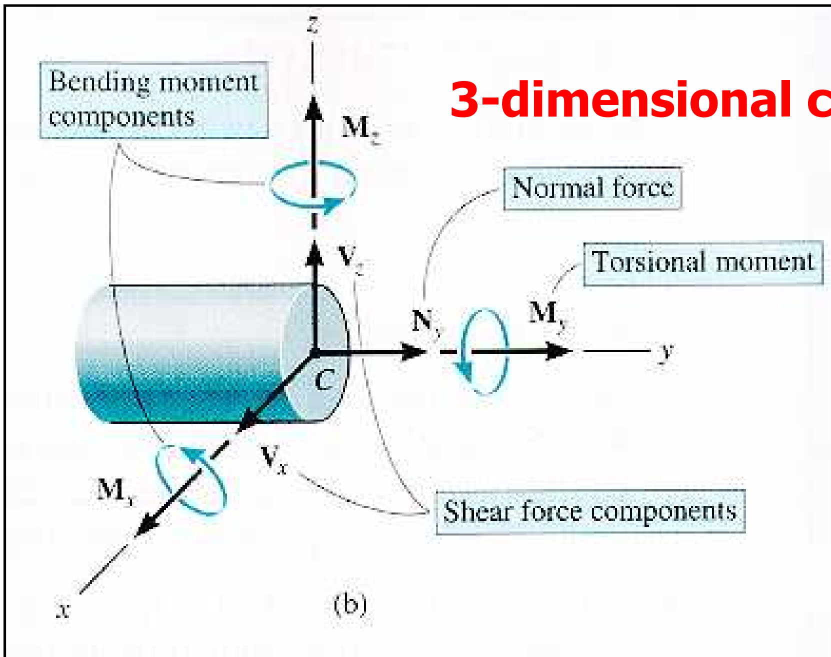
3-dimensional cases



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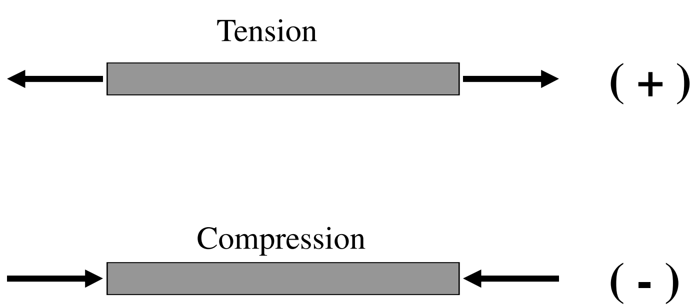
Sign Convention (N)



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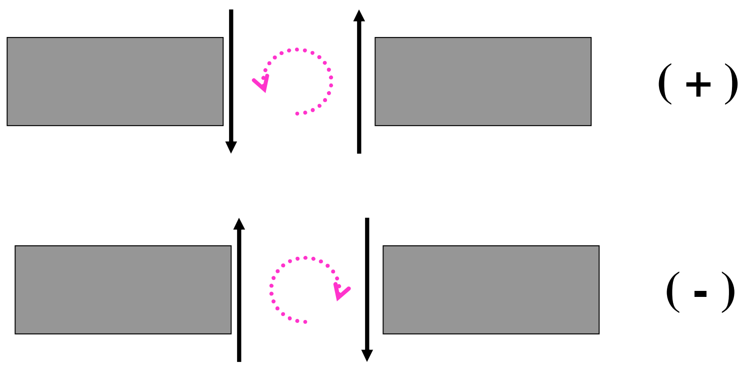
Sign Convention (V)



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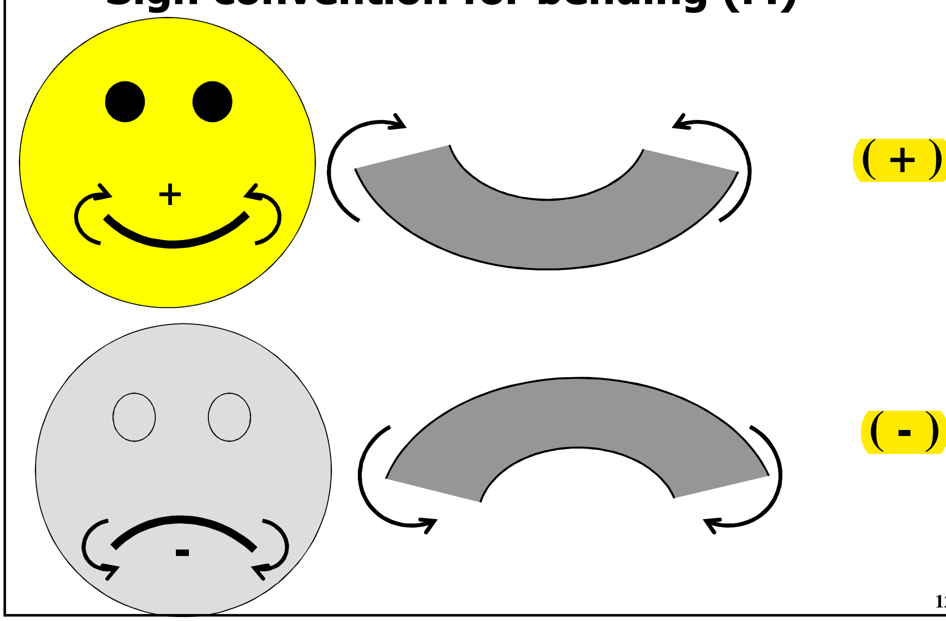
Sign convention for bending (M)



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STEPS FOR DETERMINING INTERNAL FORCES

1. Take an imaginary cut at the place where you need to determine the internal forces. Then, decide which resulting section or piece will be easier to analyze.
2. If necessary, determine any support reactions or joint forces you need by drawing a FBD of the entire structure and solving for the unknown reactions.
3. Draw a FBD of the piece of the structure you've decided to analyze. Remember to show the N, V, and M loads at the "cut" surface.
4. Apply the E-of-E to the FBD (drawn in step 3) and solve for the unknown internal loads.

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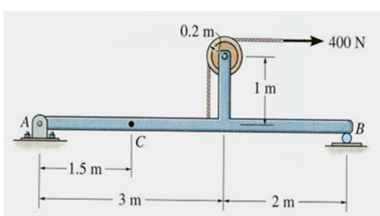
EXAMPLE



Given: The loading on the beam.

Find: The internal forces at point C.

Plan: Follow the procedure!

Solution

1. Plan on taking the imaginary cut at C.
   It will be easier to work with the left section (point A to the cut at C) since the geometry is simpler.

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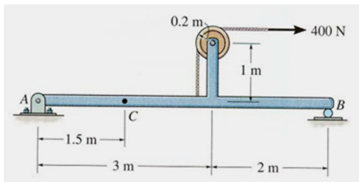
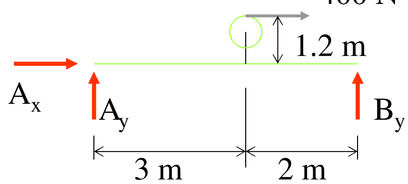
2. We need to determine A_x and A_y using a FBD of the entire frame.





Applying the E-of-E to this FBD, we get

$\rightarrow + \Sigma F_x = A_x + 400 = 0$; $A_x = -400$ N

$\circlearrowleft + \Sigma M_B = -A_y(5) - 400\,(1.2) = 0$; $A_y = -96$ N

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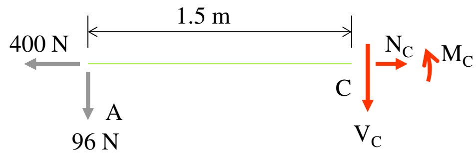
EXAMPLE (continued)

3. Now draw a FBD of the left section. Assume directions for V_C, N_C and M_C.



4. Applying the EofE to this FBD, we get

$\rightarrow + \Sigma F_x = N_C - 400 = 0$; $N_C = 400$ N

$\uparrow + \Sigma F_y = -V_C - 96 = 0$; $V_C = -96$N

$\circlearrowleft + \Sigma M_C = 96\,(1.5) + M_C = 0$; $M_C = -144$ N m

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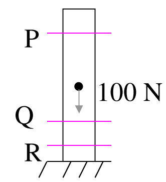
CONCEPT QUIZ

1. A column is loaded with a vertical 100 N force. At which sections are the internal loads the same?

   A) P, Q, and R B) P and Q

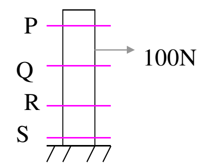
   C) Q and R D) None of the above.



2. A column is loaded with a horizontal 100 N force. At which section are the internal loads largest?

   A) P B) Q

   C) R D) S



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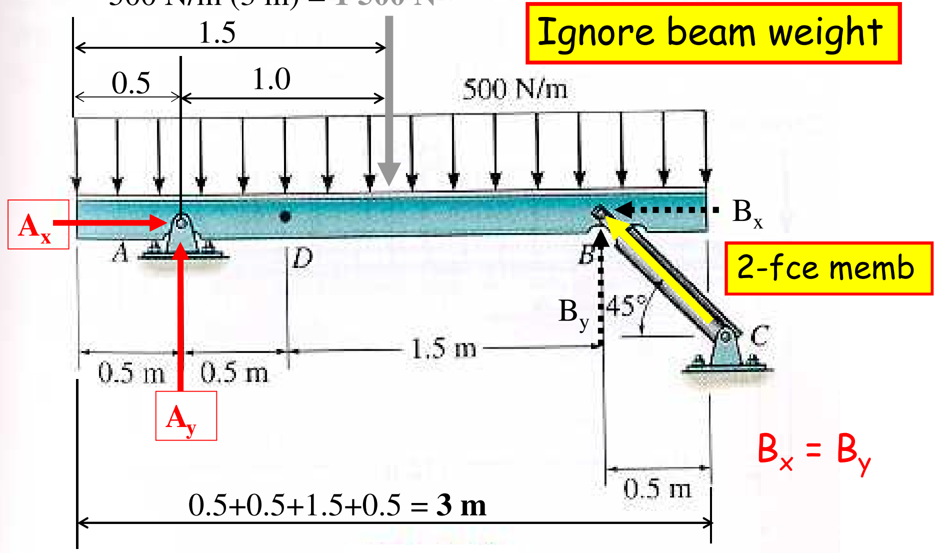
Determine the internal normal force, shear force, and moment at point *D* of the beam.



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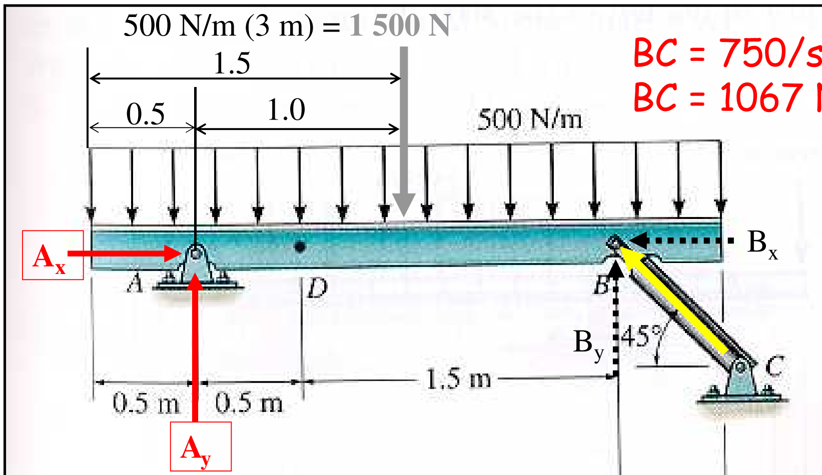

$BC = 750/\sin 45$

$BC = 1067$ N

$\Sigma M_A = 0$	$-1500\,(1) + B_y(2) = 0$
$\Sigma F_y = 0$	$-1500 + A_y + B_y = 0$
$\Sigma F_x = 0$	$A_x - B_x = 0$

$B_y = 750$ N
$B_x = 750$ N
$A_x = 750$ N
$A_y = 750$ N

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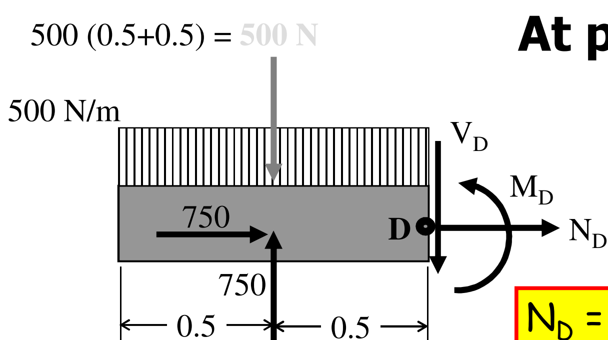
At point D



$N_D = -750$ N (Comp)
$V_D = 250$ N (+)
$M_D = 125$ N m ☺

$\Sigma F_x = 0$	$750 + N_D = 0$
$\Sigma F_y = 0$	$750 - 500 - V_D = 0$
$\Sigma M_D = 0$	$-750(0.5) + 500(0.5) + M_D = 0$

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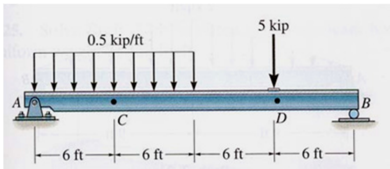
PROBLEM SOLVING



Given: The loading on the beam.

Find: The internal forces at point C.

Plan: Follow the procedure!!

Solution

1. Plan on an imaginary cut at C.
   Why will it be easier to work with segment AC?

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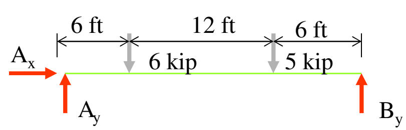
PROBLEM SOLVING (continued)

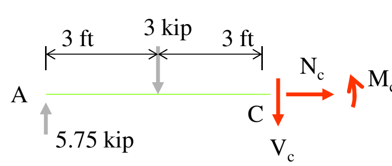
2. We need to determine A_x and A_y using a FBD and the EofE for the entire frame.



$\rightarrow + \Sigma F_x = A_x = 0$

$\circlearrowleft + \Sigma M_B = -A_y(24) + 6\,(18) + 5\,(6) = 0\ ; \quad A_y = 5.75 \text{ kip}$

3. A FBD of section AC is shown to the right.



4. Applying the E-of-E to the FBD, we get

$\rightarrow + \Sigma F_x = N_c = 0$

$\uparrow + \Sigma F_y = 5.73 - 3 - V_c = 0\ ; \quad V_c = 2.75 \text{ kip}$

$\circlearrowleft + \Sigma M_C = 3\,(3) - 5.75\,(6) + M_c = 0\ ; \quad M_A = 25.5 \text{ kip·ft}$

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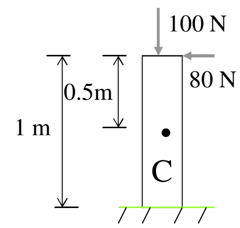
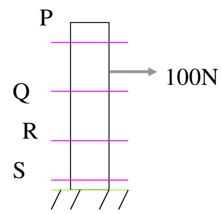
ATTENTION QUIZ

1. Determine the magnitude of the internal loads (normal, shear, and bending moment) at point C.



   A) (100 N, 80 N, 80 N·m)
   B) (100 N, 80 N, 40 N·m)
   C) (80 N, 100 N, 40 N·m)
   D) (80 N, 100 N, 0 N·m)

2. A column is loaded with a horizontal 100 N force. At which section are the internal loads the lowest?



   A) P B) Q
   C) R D) S

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"Would you happen to have a coathanger with you? I think I left the keys in the ignition!

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