WORKSHEET 5
REACTIONS & SHEAR FORCE DIAGRAMS

An introduction to the relationship between reactions and shear forces using the Push Me Pull Me models on Expedition Workshed

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INTRODUCTION

The shear force diagram shows how shear stresses develop along the beam as a result of the applied load.

If we know all the externally applied loads and the corresponding reaction forces, obtaining the shear force diagram should be quite straightforward for a number of simple structural configurations.

The shear force is one of the ways by which the applied load is transmitted through the beam and is dissipated at the supports. These are the internal shear stresses developing in order to keep adjacent cross-sections from sliding past each other.

REACTIONS & SHEAR FORCE DIAGRAMS

Looking at the simply supported beam opposite, internal shear forces can be seen when we model the structures as three free bodies. The middle free body has the externally applied load which is supported by the two shear forces at the two cuts (V1 and V2). The other two diagrams depict the rest of the beam from the cuts to the supports. At the cut the shear force is equal to the shear force on the adjacent free body but opposite in direction and is balanced by the reaction forces at the supports.

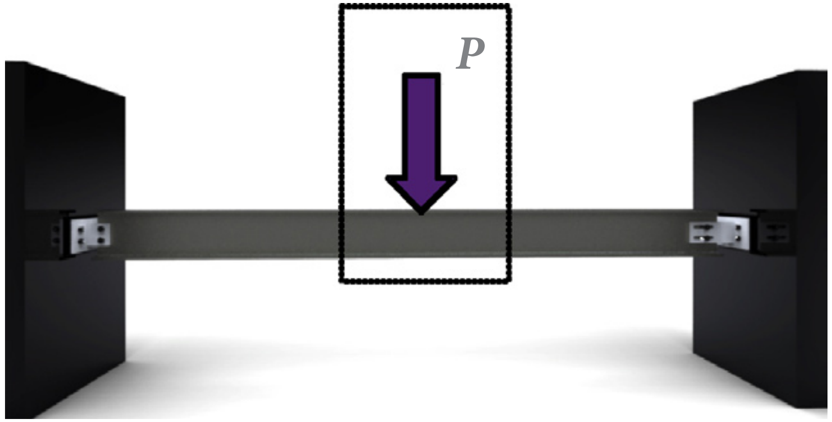

Fig. 1. Simply Supported Beam Push Me Pull Me Model with an applied central point load.

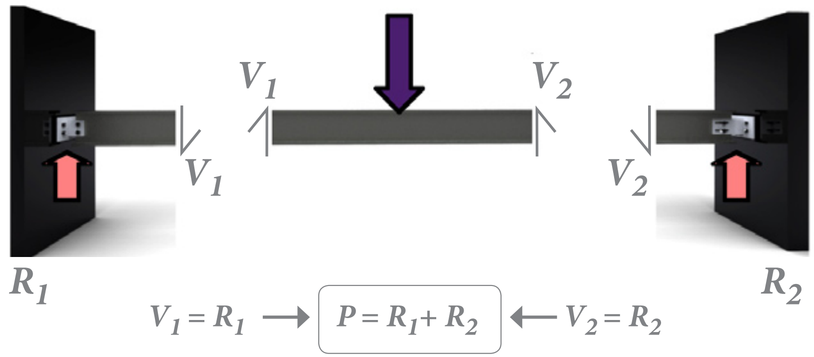

Fig. 2. A disection of the model, showing the structure as three free bodies with associated shear forces at the cuts. NB bending moment has not been considered in this diagram.

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DIAGRAMS

When a beam is subjected to a lateral load, shear stress resultants develop along the beam. Equally, when an axial force is applied, axial stresses develop.

The direction of the applied load (whether internal or external) with respect to the axis of the element dictates whether shear or axial stresses will develop in that element. Also, when two elements are not connected co-axially but at a different angle the distributions of shear and axial stresses change beyond the connection.

For example, looking at the frame opposite and applying a horizontal point load at the tip of the vertical member (Fig.4) leads to a shear force distribution that resists the rightward push from the applied load. Closing towards the top right joint, the shear stresses become dissipated into the horizontal beam which supports the vertical one. Since the shear force in the vertical beam is now aligned with the axis of the horizontal beam, the stress becomes axial (in fact tensile) and it is now preventing the beam from extending axially indefinitely. Finally, as this beam is attached on the wall the axial stress is being dissipated by a horizontal reaction.

A reaction moment is also necessary to balance the couple due to the offset of the point and reaction forces.

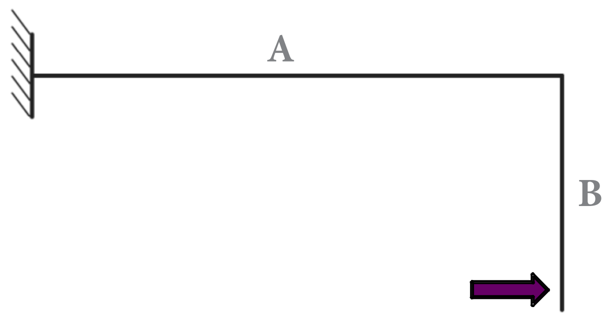

Fig. 3. Simply Supported Beam Push Me Pull Me Model with an applied central point load.

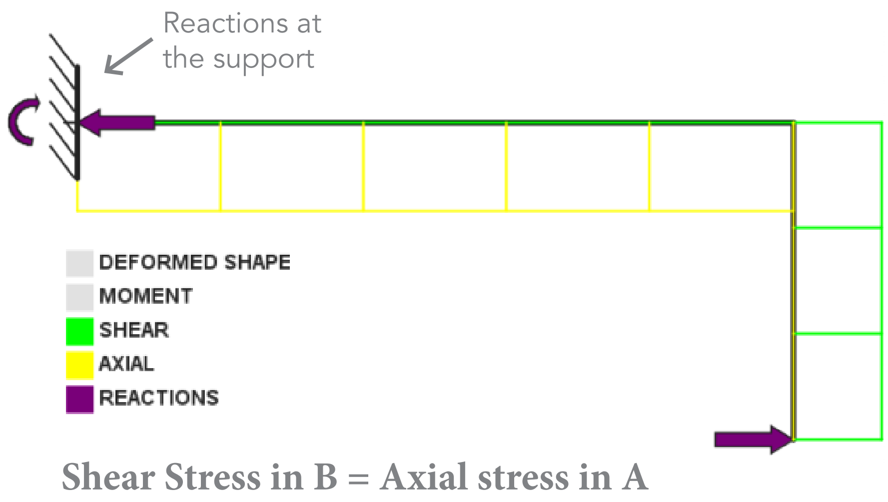

Fig. 4. A disection of the model, showing shear forces and reactons.

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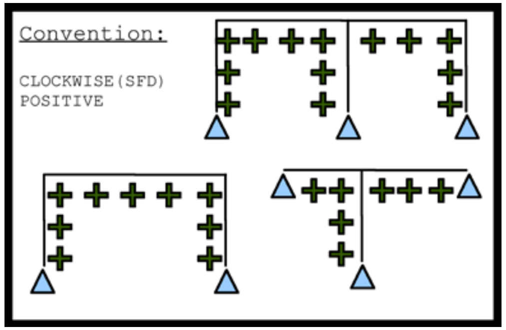
CONVENTIONS AND TIPS

The convention for plotting a shear force diagram is that clockwise shear forces are considered positive. How you plot positive shear force is left to the discretion of the engineer but it is always advisable to state your convention. These tutorials use the same convention and plotting style as Push Me Pull Me as shown below.



Tips on how to draw a shear force diagram

1) Suppose you have the following loading congfiugration. Starting from the LHS support or point load, draw a step in the opposite direction of the load.

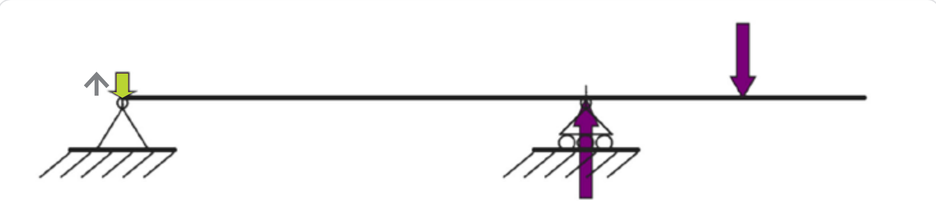


Fig 5. The apex of the line indicates the magnitude (and sense) of the shear force on the right of the support.

2) In the absence of any other applied load the shear force distribution remains constant, therefore extend a horizontal line until a point load or reaction is encountered.

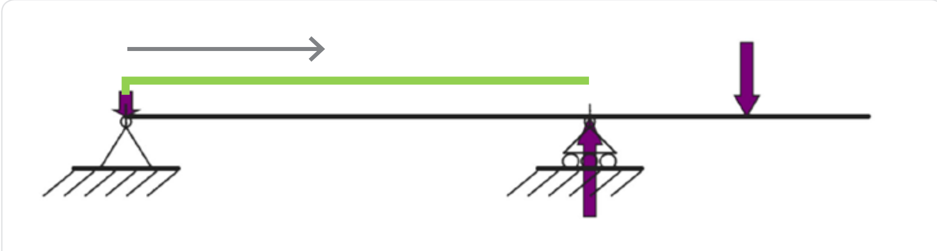


Fig 6. The shear force remains constant until another applied load or reaction.

3) At the support draw a vertical step opposite to the direction and equal in size with the reaction. The top of the step indicates the shear force on the left side of the support while the bottom indicates the shear force on the right hand side of the support.

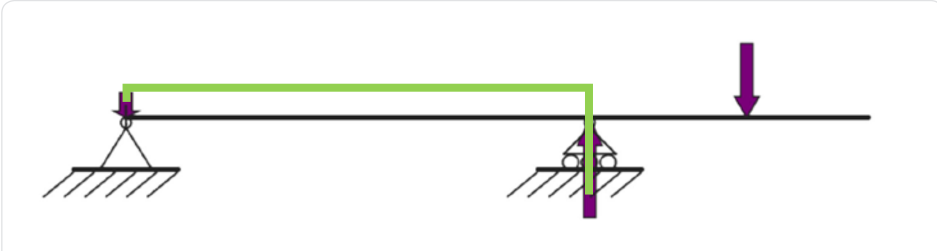


Fig 7. The shear force changes direction on meeting a force in the opposite direction.

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CONVENTIONS AND TIPS

4) As before, the distribution is constant and the line is extended horizontally until the next applied load.

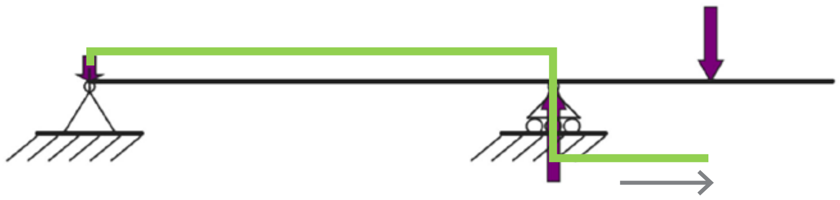

Fig 8. Again, the shear force line remains constant until it encounters another load or reaction.

5) When the last point load is reached, the shear force diagram closes as this shear force should be equal and opposite to the applied load.

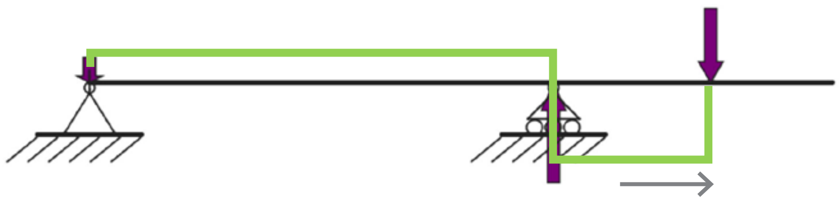

Fig 9. The shear force, as before, now moves with the same magnitude and opposite direction of the load it has encountered.

In the case of continuous or patch loads, the load along the distribution is no longer constant.

Uniform loading: linear shear force distribution

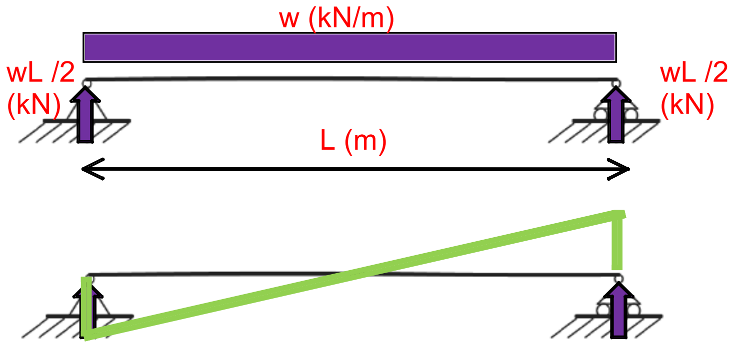

Fig 10. Loaded configuration diagram (top) and shear force diagram (bottom) for a uniformly distributed load.

Linearly varying loading: quadratic shear force diagram

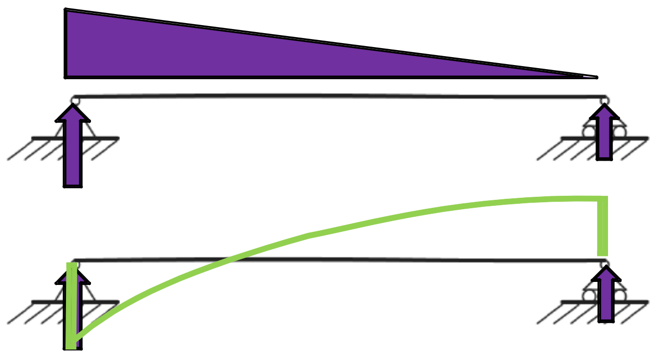

Fig 11. Loaded configuration diagram (top) and shear force diagram (bottom) for a linearly varying load.

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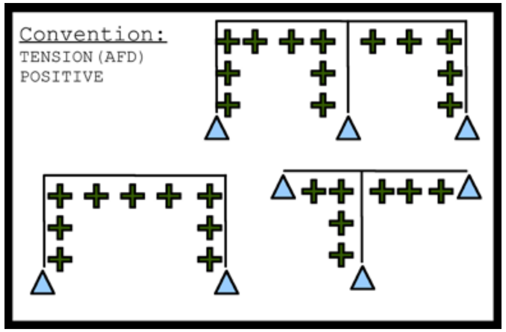
CONVENTIONS AND TIPS

Axial Force Diagrams (AFD) indicate the level of axial stress in a structural element. In this case (as it is usually done for steel structures),tension is considered positive and follows the same convention as for the bending moment and shear force.



Axial Force Diagrams (AFD) indicate the level of axial stress in a structural element. In this case (again, as it is usually done for steel structures), tension is considered positive and follows the same convention as for the bending moment and shear force.

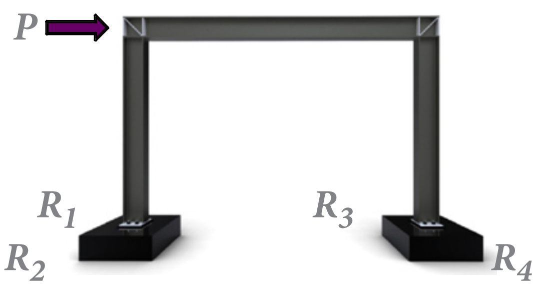
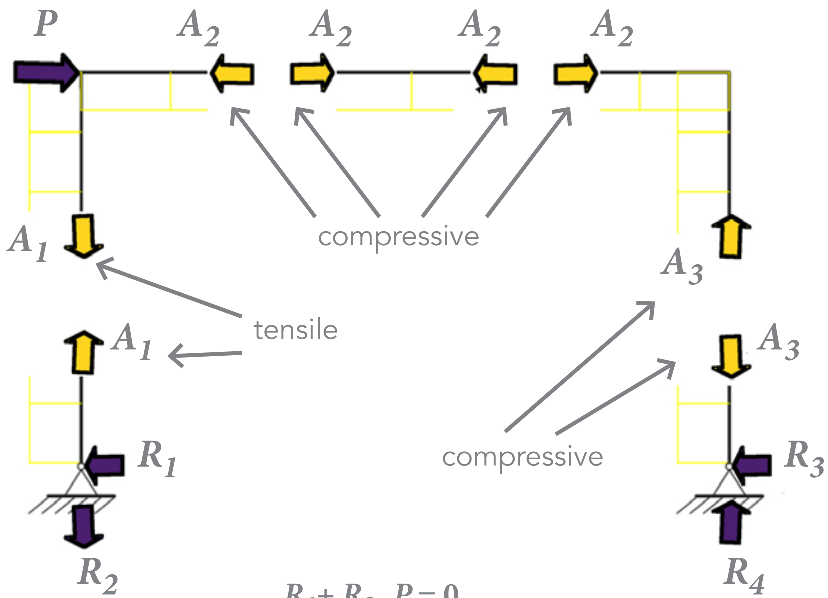


Fig 12. Push Me Pull Me Portal Frame Model with a horizontal load applied in the top left hand corner.



$$R_1 + R_3 - P = 0$$
$$R_2 - A_1 = 0$$
$$R_4 - A_3 = 0$$

Fig 13. This diagram shows the frame from Fig. 12 broken down into five free bodies in order to show the associated axial forces and shear forces in play when the load P is applied. Beneath are shown the equilibrium equations that can be deduced from this diagram.

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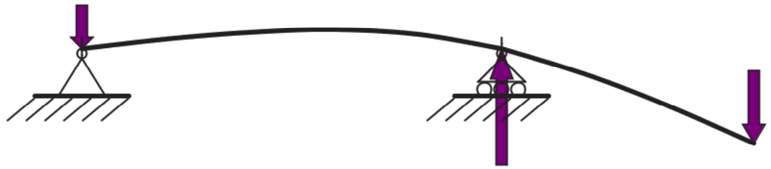
QUESTION TIME

1. Given the deflected shapes and reactions draw the approximate Shear force and Axial force diagrams where appropriate. Use Push Me Pull Me to verify your results.

a.

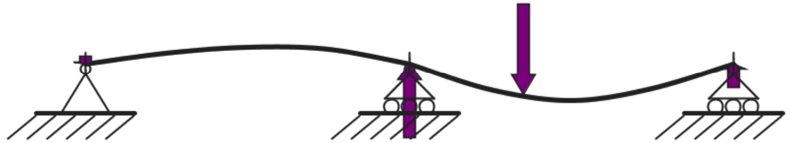
b.

c.



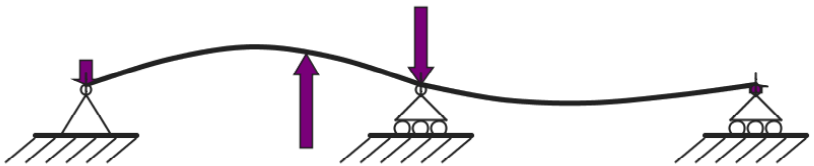
d.

e.

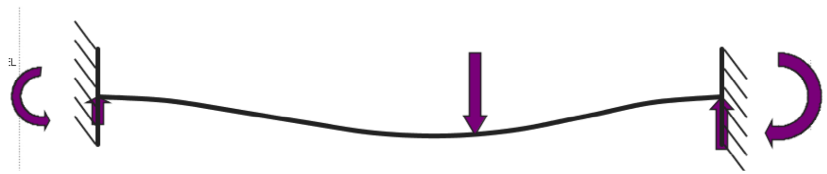


QUESTION TIME

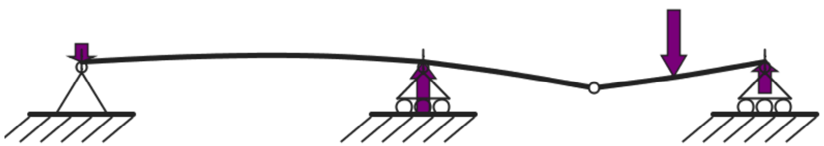
f.



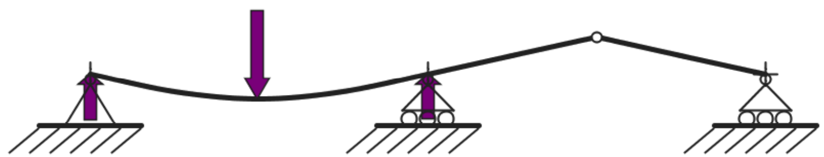
g.



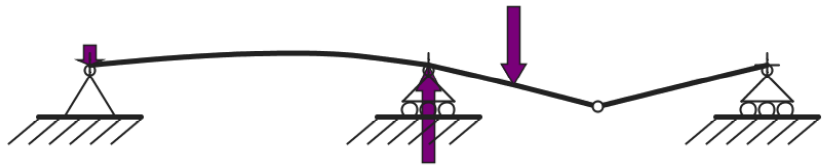
h.



i.



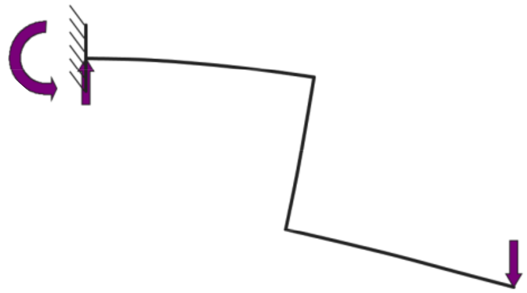
j.



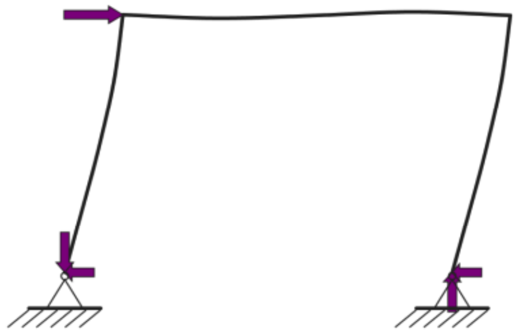
QUESTION TIME

2. As (1) but for frames. Use Push Me Pull Me to verify your results.

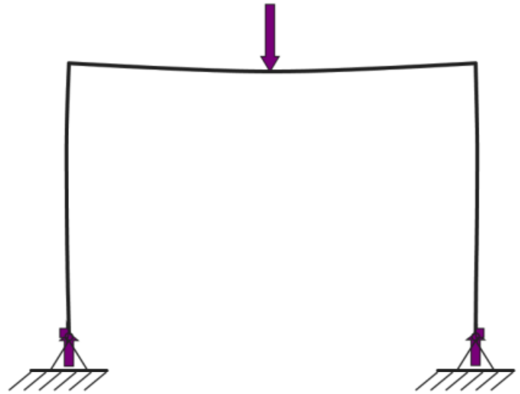
a.



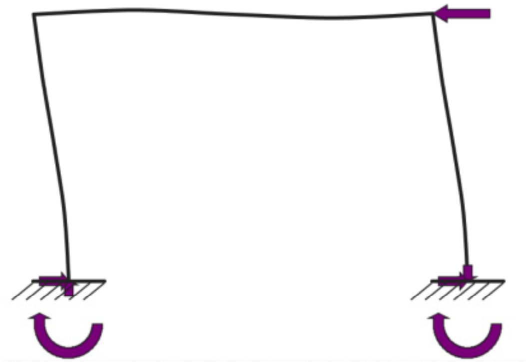
b.



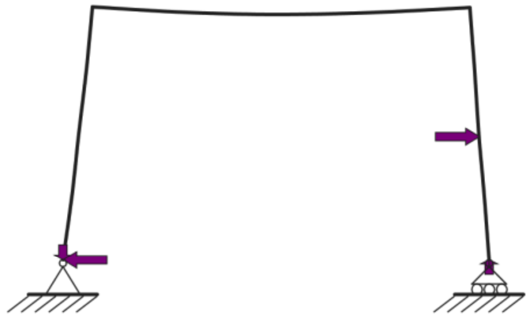
c.



d.

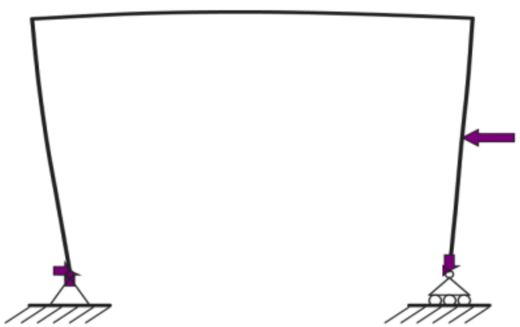


e.



QUESTION TIME

f.



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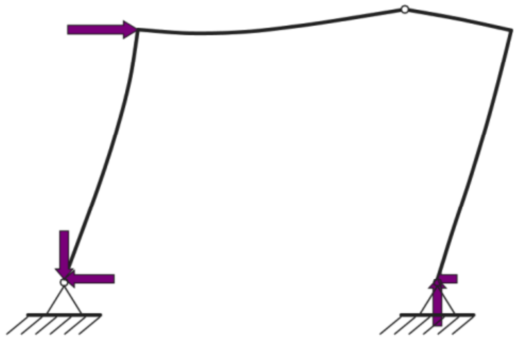
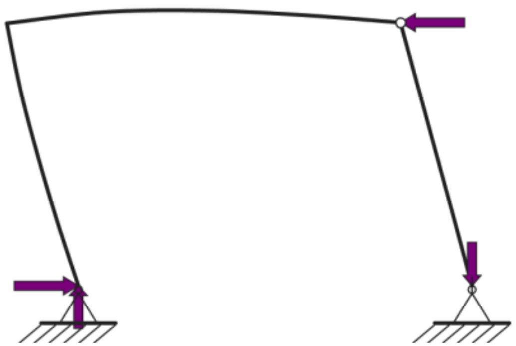
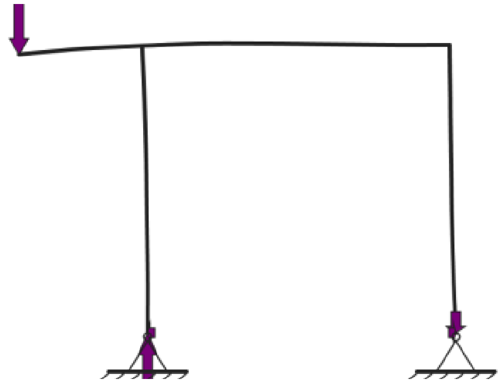


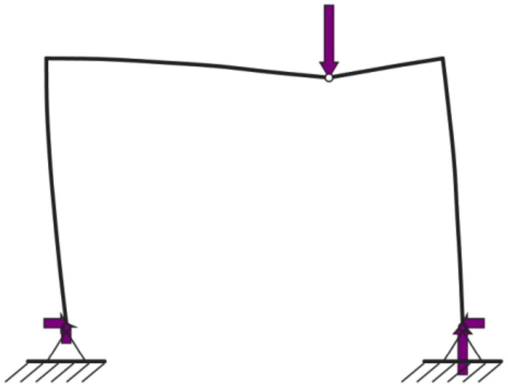
g.



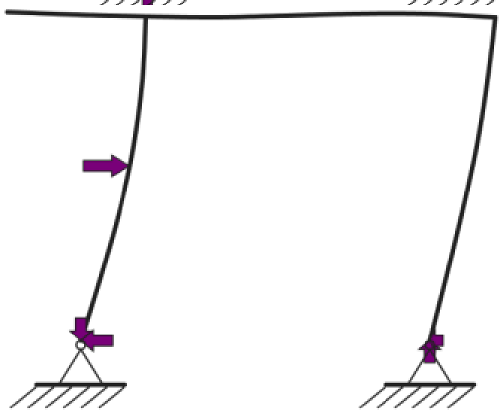
j.



h.



k.



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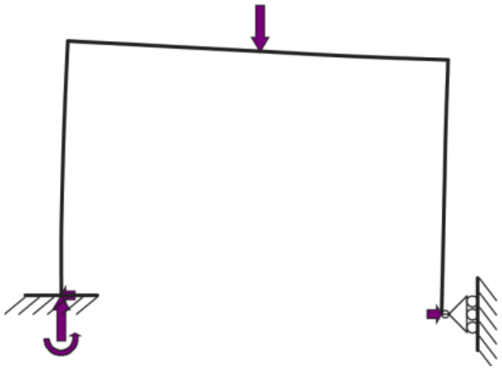
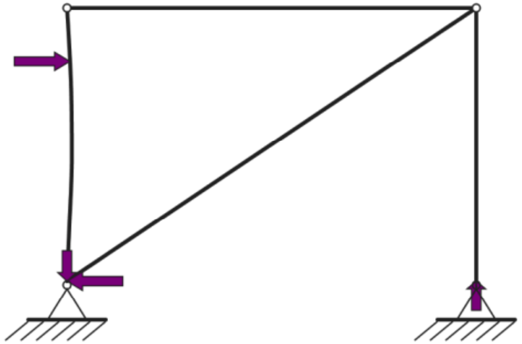
QUESTION TIME

l.

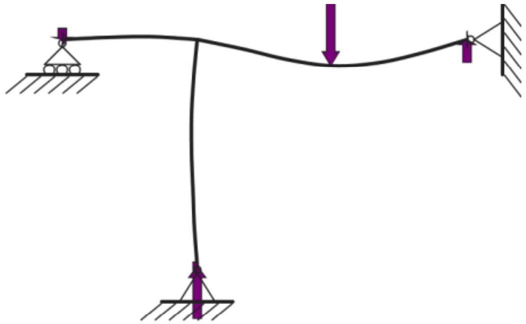


o.



m.

p.



n.