Internal Forces of Frames

القوى الداخلية للهياكل

بسم الله الرحمن الرحيم

نسألكم الدعاء

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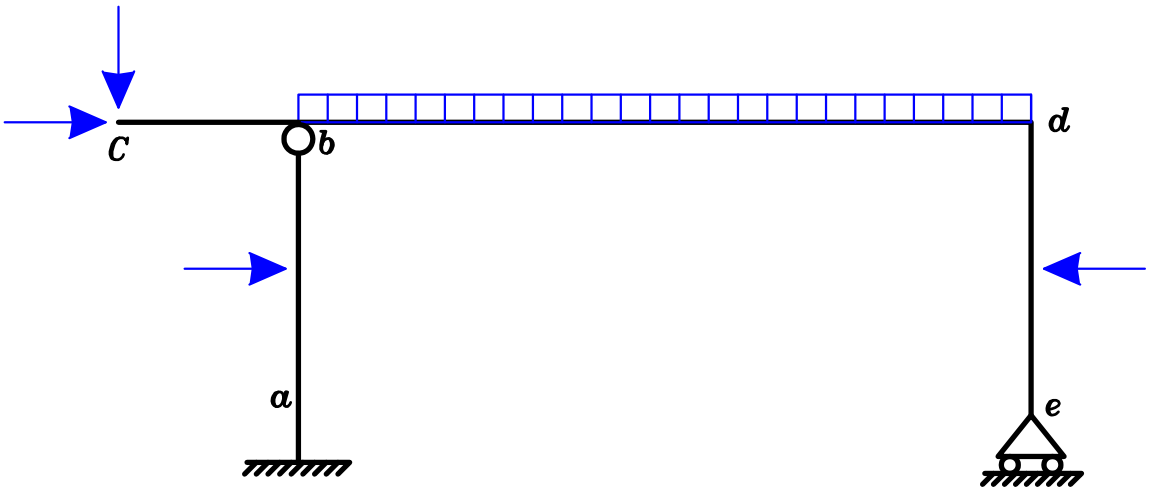
Drawing Internal Forces Diagrams



لرسم الـ *Internal forces diagrams* للـ *Frame* سنواجه مشكلتان

١ - الـ *Frame* يتكون من أكثر من *member* و ليس *member* واحد مثل الكمرة .

٢ - بعض الـ *members* فى الـ *Frame* ليس لها طرف حر على عكس الكمرة التى دائما ما يكون بها طرف حر .

و لحل المشكلة الاولى نقوم بفصل الـ *members* عن بعضها مع العلم بأن أى *member* يفصل عن *member* أخر يظهر ثلاث قوى عند مكان الفصل *(Normal , Shear , Moment)* فى حالة عدم وجود *Intrmediate Hinge* و تظهر قوتان فقط *(Normal , Shear)* فى حالة وجود الـ *Intrmediate Hinge* و هذه القوى تكون غير معروفة

و لحل المشكلة الثانية الـ *member* الذى له طرف حر نبدأ الحسابات منه و الذى ليس له طرف حر نقطع الـ *member* فى بدايته أو نهايته و نجمع الـ *Forces* من الناحية اللى قطعنا منها كما سنرى

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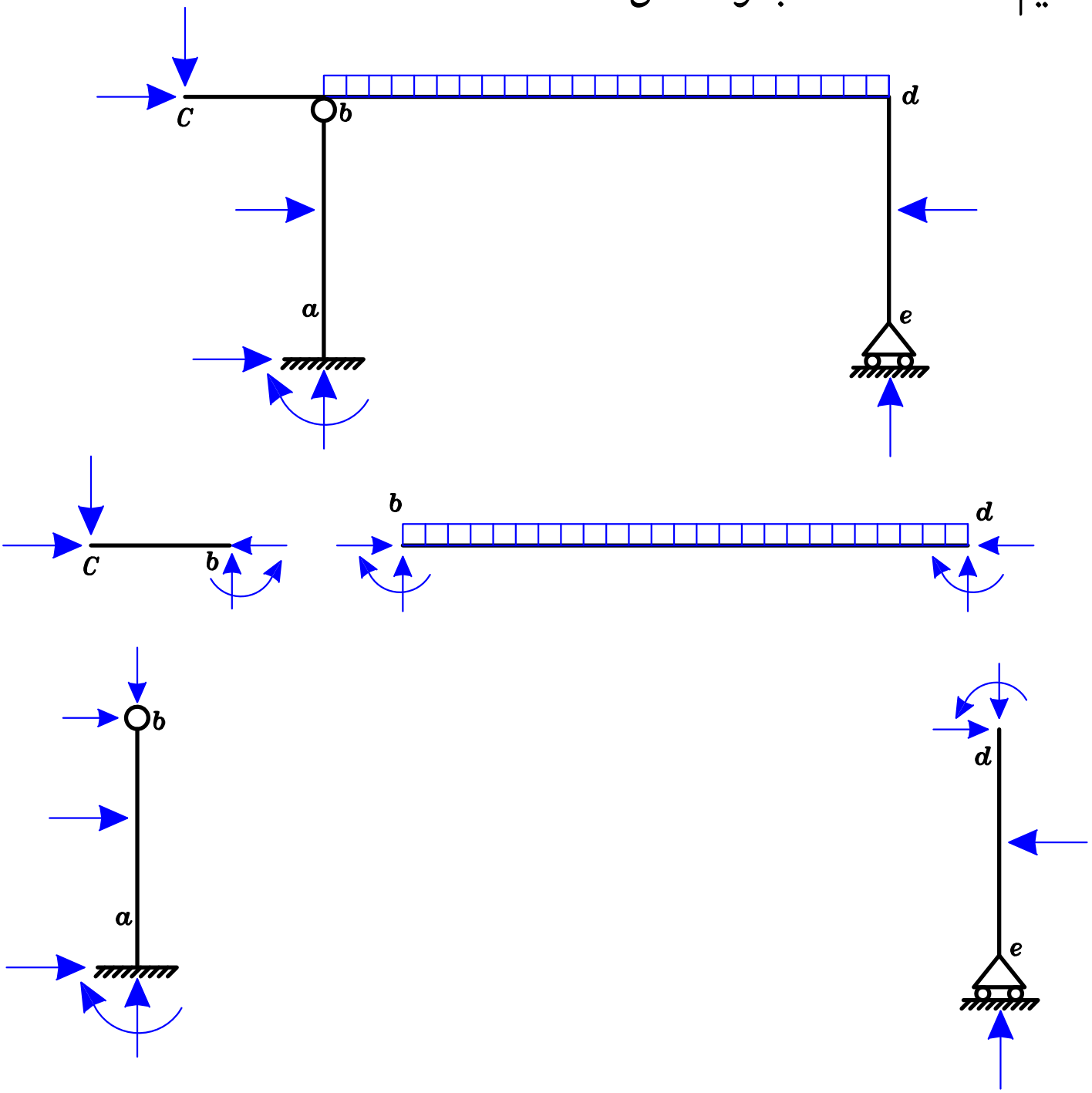
لتقسيم الـ *Frame* لمجموعة من الـ *members*



خد بالك القوى التى تظهر تكون غير معلومة و لذلك يجب عند حساب ورسم الـ *Internal forces diagrams* أن نبعد على قد نقدر عن الحساب من الناحية التى تظهر بها هذه القوى

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لرسم الـ N.F.D

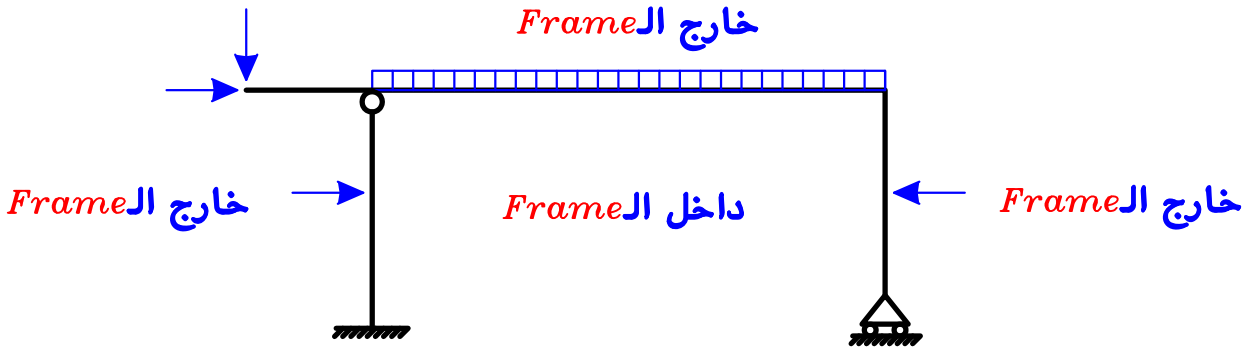
أ- اذا كان للـ member طرف حر

مثل (ab , Cb , de)

١- لا نرى سوى الـForces اللى بتعمل Normal على الـmember أى التى تكون فى اتجاه الـmember .

٢- نبدأ من الطرف الحر يمين أو شمال و نحدد اتجاه الـ Forces اللى بتعمل ضغط و اتجا ه اللى بتعمل شد .

٣- نبدأ برسم أول قوة نقابلها بحيث اذا كانت ضغط ترسم داخل الـ Frame وتكون سالبة و اذا كانت شد ترسم خارج الـ Frame و تكون موجبة مع العلم أنه فى حالة الـ N.F.D يمكن رسم الضغط خارج الـ Frame و الشد داخل الـ Frame المهم هو وضع اشارة +Ve على الشد و −Ve على الضغط .



٤- نتحرك مع الـmember وأى قوة نقابلها فى نفس اتجاه القوة الاولى نتحرك كما تحركنا فى القوة الاولى (داخل أو خارج الـ Frame) و أى قوة نقابلها عكس القوة الاولى نتحرك عكس اتجاه الحركة فى القوة الاولى .

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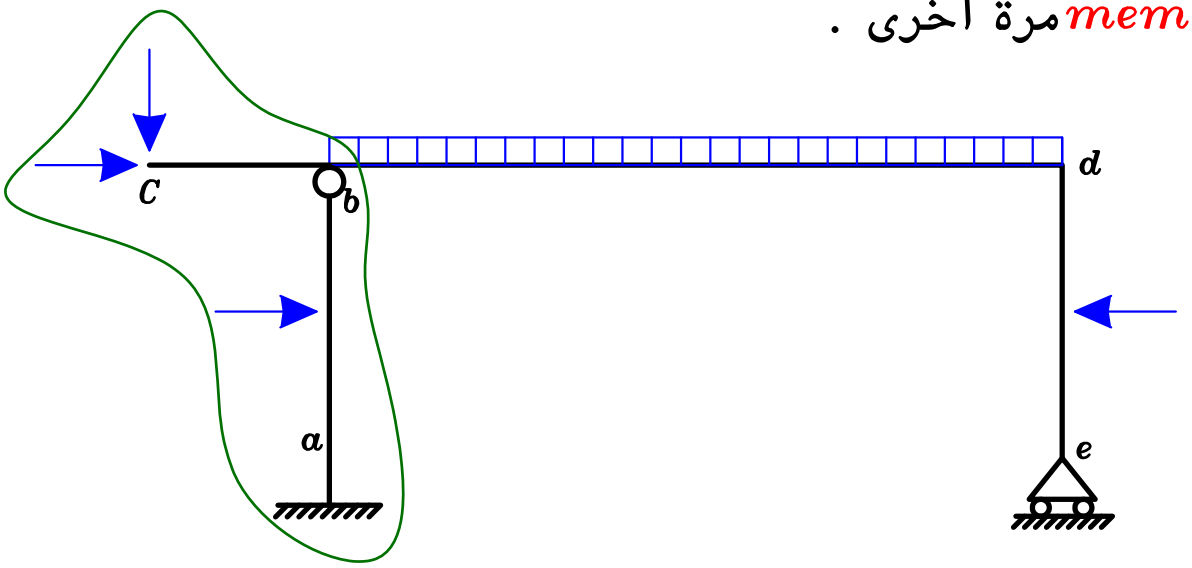
ب - اذا كان الـ member ليس له طرف حر مثل (bd)

١-نقطع الـmember فى بدايته أو نهايته مع التركيز على أن الـSection اللى بنقطع بيه لابد ألا يقطع أى member أخر ولا يقطع حتى نفس الـmember مرة أخرى .



٢-نجمع القوى اللى فى اتجاه الـ member (bd) من الجزء المقطوع فتكون هى الـ Normal force عند بداية الـmember و لو كانت داخلة على الـ member تكون ضغط و نضع لها اشارة سالبة و لو خارجة من الـmember تكون شد و نضع لها اشارة موجبة .

٣-نتحرك مع الـ member وأى قوة نقابلها فى نفس اتجاه القوة الاولى (القوى المجمعة) نتحرك كما تحركنا فى القوة الاولى و أى قوة نقابلها عكس القوة الاولى نتحرك عكس اتجاه الحركة فى القوة الاولى .

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أ- اذا كان للـ member طرف حر

مثل (ab , Cb , de)

١- لا نرى سوى الـ Forces اللى بتعمل Shear على الـ member أى التى تكون فى اتجاه عمودى على الـ member .

٢- نبدأ من الطرف الحر يمين أو شمال و نجمع الـ Forces العمودية على الـ member فتكون هى الـ Shear عند هذا الطرف الحر .

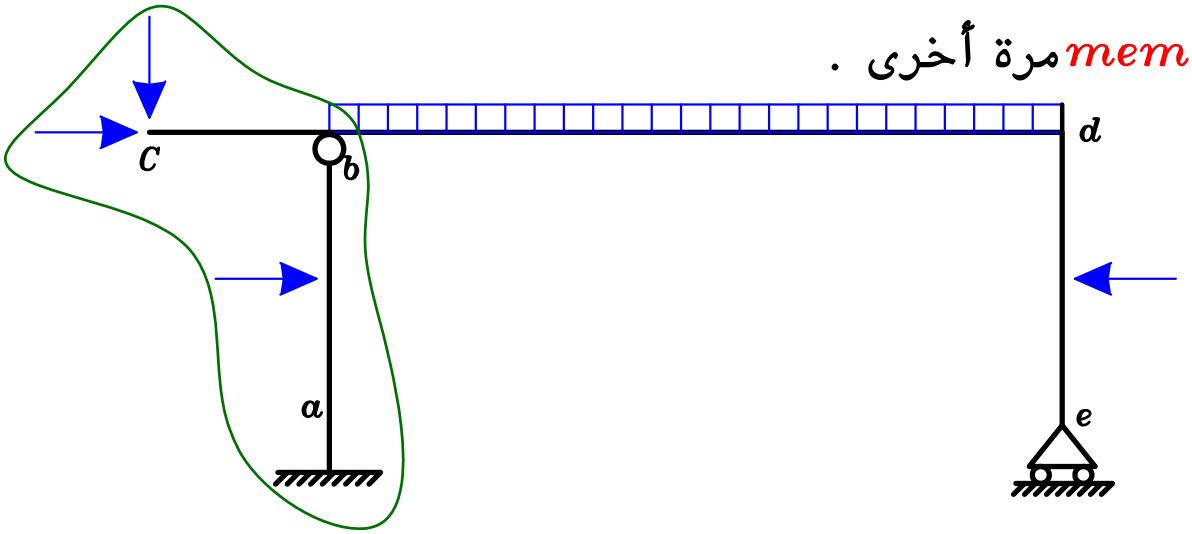
٣- نقف داخل الـ Frame وننظر الى الى الـ member اذا كان الطرف الحر الذى بدأنا منه الحسابات ناحية الشمال نرسم الـ Shear force فى نفس اتجاه القوى التى تم حسابها و اذا كان الطرف الحر يمين نرسم الـ Shear force فى عكس اتجاه القوى التى تم حسابها .

٤- نتحرك فى اتجاه الـ member ولو الطرف اللى بدأنا منه شمال أى قوة نقابلها نرسم الـ Shear force فى اتجاهها و لو الطرف اللى بدأنا منه يمين نرسم الـ Shear force فى عكس اتجاهها .

ب- اذا كان الـ member ليس له طرف حر

مثل (bd)

١- نقطع الـ member فى بدايته أو نهايته مع التركيز على أن الـ Section اللى بنقطع بيه لابد ألا يقطع أى member أخر ولا يقطع حتى نفس الـ member مرة أخرى .



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٢-نجمع القوى اللى فى الاتجاه العمو دى على member (bd) من الجزء المقطوع فتكون هى الـ Shear force عند بداية الـ member

٣- نقف داخل الـ Frame وننظر الى الـ member اذا كان الطرف الذى بدأنا منه الحسابات ناحية الشمال نرسم الـ Shear force فى نفس اتجاه القوى التى تم حسابها و اذا كان الطرف يمين نرسم الـ Shear force فى عكس اتجاه القوى التى تم حسابها .

٤- نتحرك فى اتجاه الـ member ولو الطرف اللى بدأنا منه شمال أى قوة نقابلها نرسم الـ Shear force فى اتجاهها و لو الطرف اللى بدأنا منه يمين نرسم الـ Shear force فى عكس اتجاهها .

الاشارات

داخل الـ Frame نضع اشارة سالبة و خارج الـ Frame نضع اشارة موجبة .

لرسم الـ B.M.D

نرسم لكل member على حدا .

يتم حساب العزوم عند اى قطاع من ناحية اليمين او اليسار و يتم الرسم ناحية زيل العزوم ثم نوصل بين القيم .

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النقط التى يتم حساب الـ B.M.D عندها

١ - بداية ونهاية الـ member

٢ - أى Support ٣ - أى Concntrated load

٤ - أى Concntrated moment قبله و بعده

٥ - بداية و نهاية الـ Distributed load

٦ - عند حدوث تغير فى قيمة الـ Distributed load

٧ - عند الـ Intermediate hinge قيمة الـ moment تساوى صفر

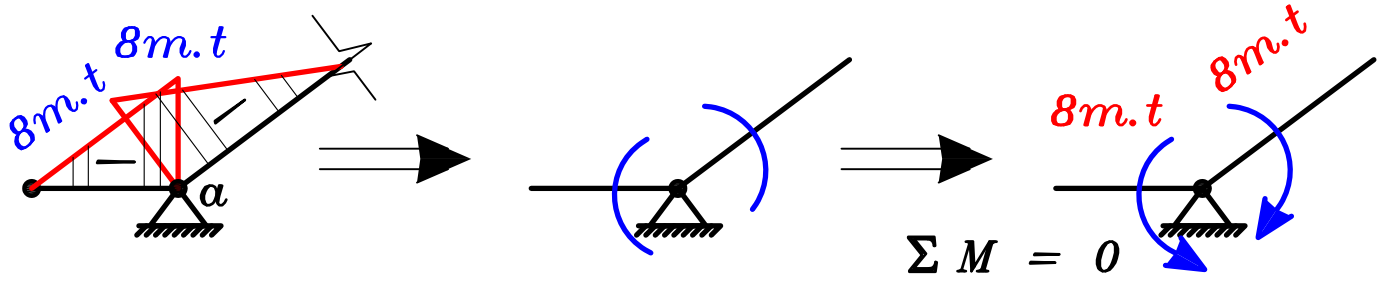
الاشارات

داخل الـ Frame نضع اشارة موجبة و خارج الـ Frame نضع اشارة سالبة .

خد بالك

عند وجود Joint بها 2 members و ليس عندها Conc. moment لابد أن يكون الـmoments على الـ 2 members متساوية و عكس بعض فى الدوران حتى تكون الـ Joint متزنة و يكون $\Sigma M = 0$ عند هذه الـ Joint .

و لنتأكد من أن الاتزان مظبوط نرسم الـ Joint أولا و نضع شكل الـ moment يلف بحيث يحزم الـ Joint بدون و ضع الذيل ثم نضع الذيل مكان رسم الـ B.M.D .



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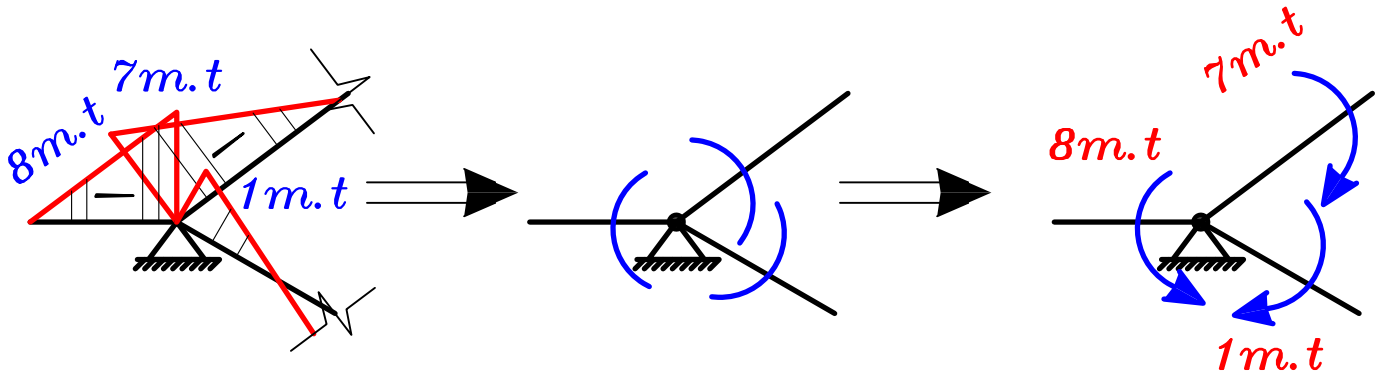
خد بالك

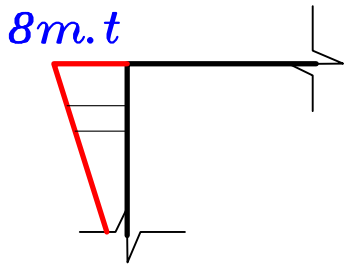
عند وجود *Joint* بها *3 members* و ليس عندها *Conc. moment* لابد أن يكون الـ*moments* على الـ *3 members* مجموعهم يساوى صفر حتى يكون $\Sigma M = 0$ عند هذه الـ *Joint* .

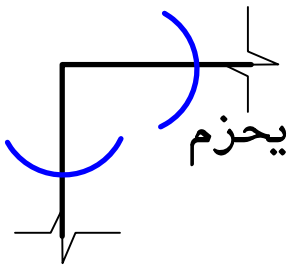
و لنتأكد من أن الاتزان مظبوط نرسم الـ *Joint* أولا و نضع شكل الـ *moment* يلف بحيث يحزم الـ *Joint* بدون و ضع الذيل ثم نضع الذيل مكان رسم الـ ***B.M.D*** .



$\Sigma M = 0$

و من الممكن استغلال اتزان الـ *Joint* فى توفير الوقت ففى حالة الـ *Joint* التى بها *2 members* بمعرفة الـ *moment* على احدهما يمكن استنتاج قيمة واتجاه الـ *moment* الاخر و رسمه





و لعمل اتزان لل *Joint* نضع اولا الـ *moment* يلف بحيث يحزم الـ *Joint* بدون وضع الذيل

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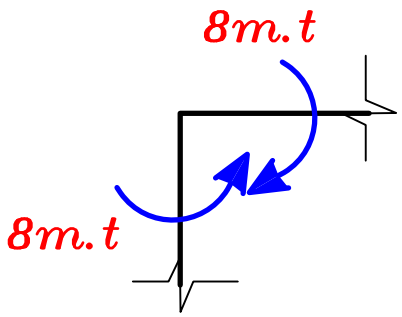
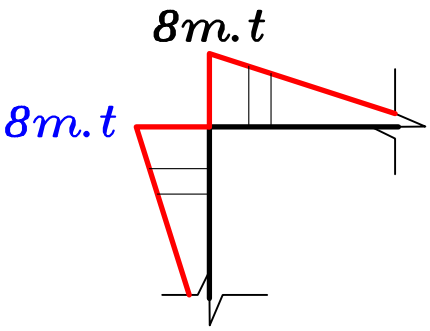
ثم نضع قيمة الـ moment المعلوم و اتجاه الذيل يكون ناحية رسم الـ Diagram

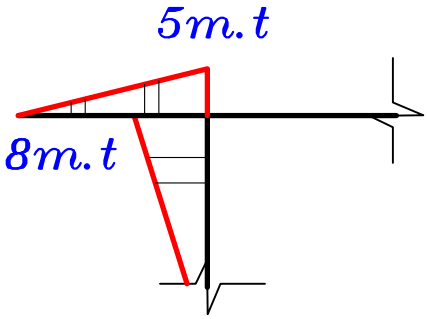
نعمل اتزان للـ Joint بحيث يكون $\Sigma M = 0$



ثم نرسم الـ B.M.D مكان ذيل السهم



و فى حالة الـ Joint التى بها 3 members بمعرفة الـ moment على 2 members يمكن معرفة الـ moment على الـ member الثالث



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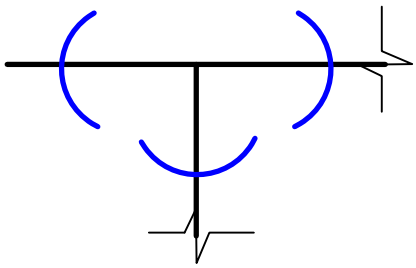
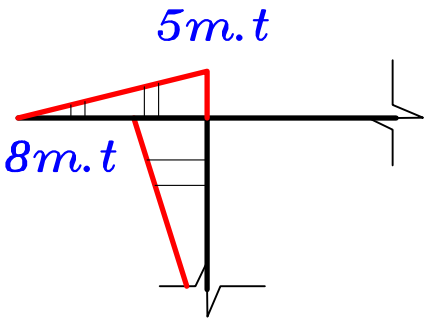
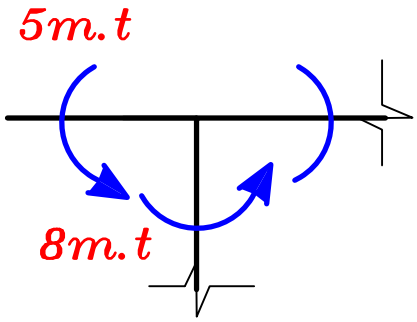
و لعمل اتزان للـ *Joint* نضع اولا الـ *moment* يلف بحيث يحزم الـ *Joint* بدون وضع الذيل

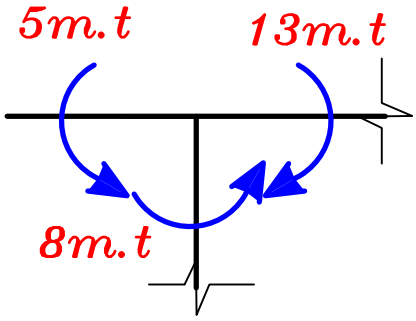


ثم نضع قيمة الـ *moment* المعلوم و اتجاه الذيل يكون ناحية رسم الـ *Diagram*

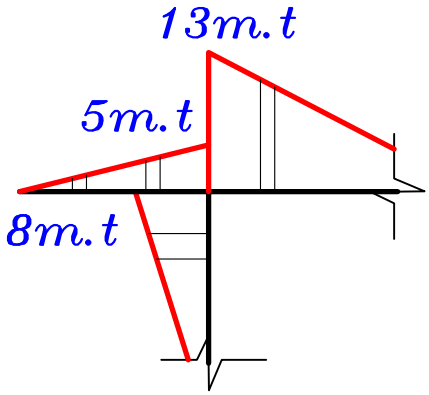




نعمل اتزان للـ *Joint* بحيث يكون $\Sigma M = 0$



ثم نرسم الـ ***B.M.D*** مكان ذيل السهم



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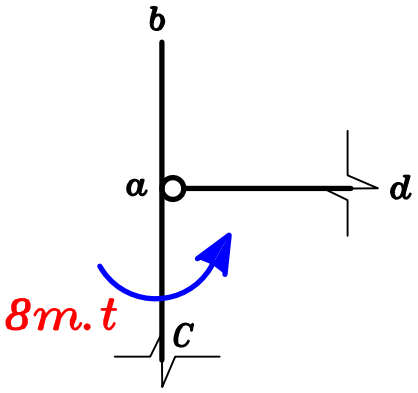
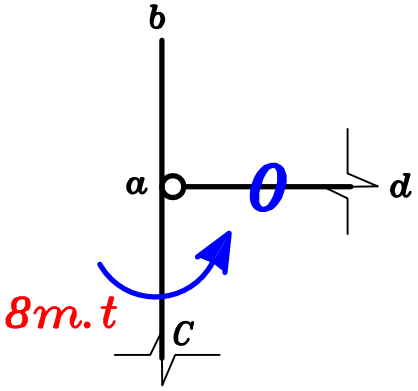
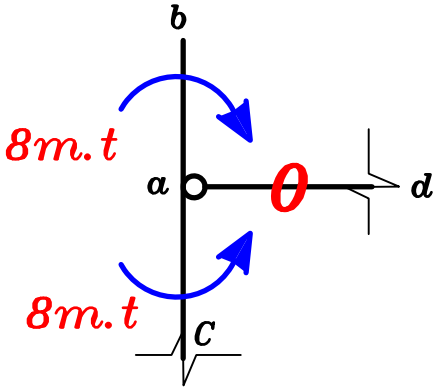
فى حالة وجود *Intrmediate hinge* عند نقطة فى *member* معين يكون الـ*moment* عند هذه النقطة فى هذا الـ*member* يساوى صفر

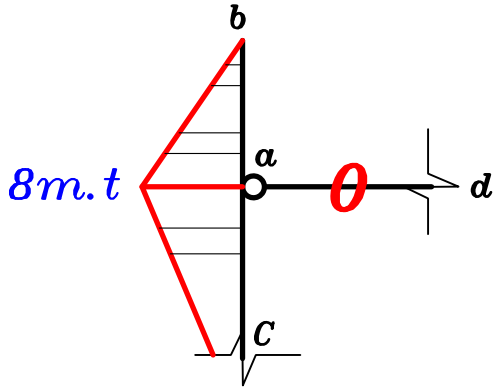


فى هذه الـ *Joint* يكون الـ*moment* عند نقطة فى الـ *ad* يساوى صفر



و بعمل اتزان للـ *Joint*





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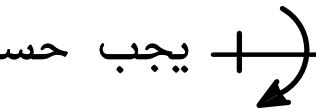
ملاحظات هامة جدا جدا

* العزوم عند أى طرف حر يساوى الصفر اذا لم يوجد عزم مركز عنده
* العزوم عند أى *Intrmediate hinge* يساوى صفر بدون حسابات
* اذا وجد عزم مركز  يجب حساب العزوم مرتين عند هذه النقطة مرة قبل العزم مباشرة و مرة بعده مباشرة و يجب حدوث *drop* فى رسمة الـ *Bending moment* عند هذه النقطة و تكون قيمة هذا الـ *drop* تساوى قيمة العزم المركز

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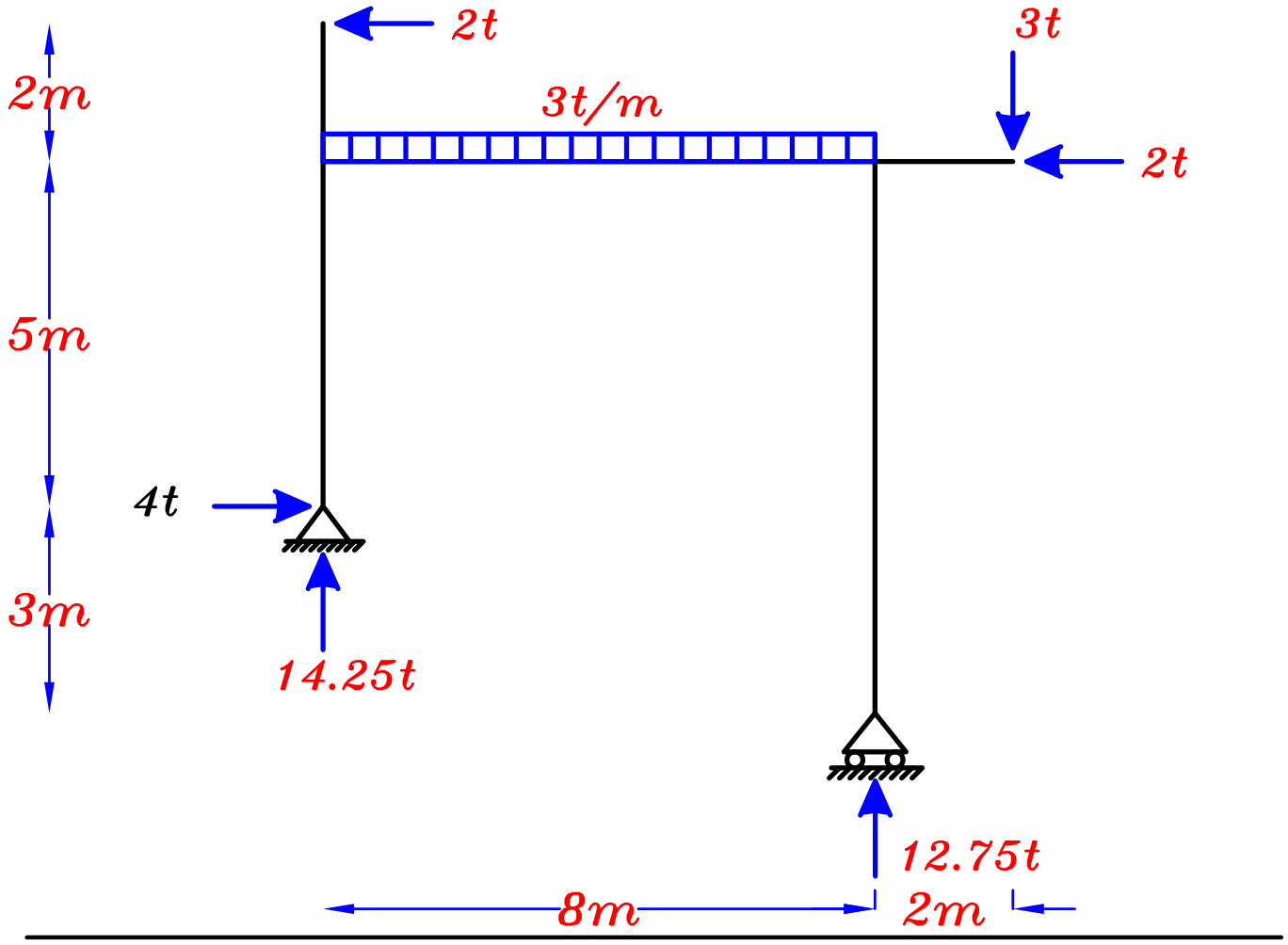
Example :

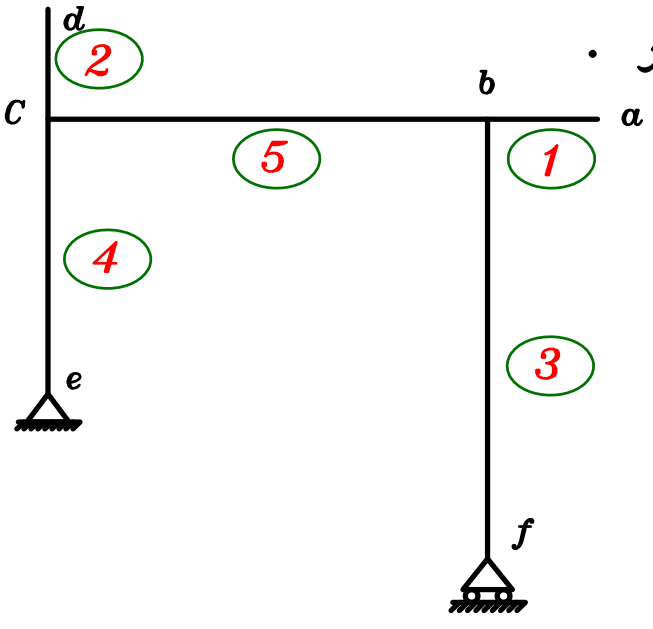
For the shown Frame draw N.F.D , S.F.D & B.M.D.

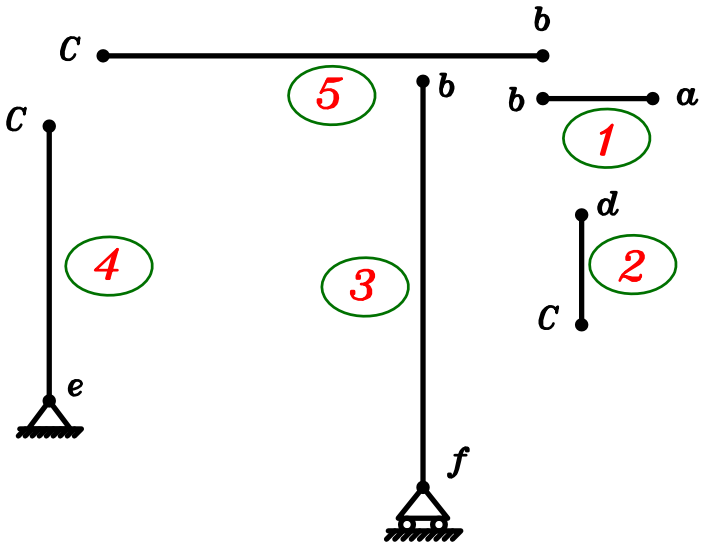


أ- نحدد الـ members .

والـmember يكون بين 2 Joints و الـ Joint هى عبارة عن Support

أو تقاطع member مع member أخر .





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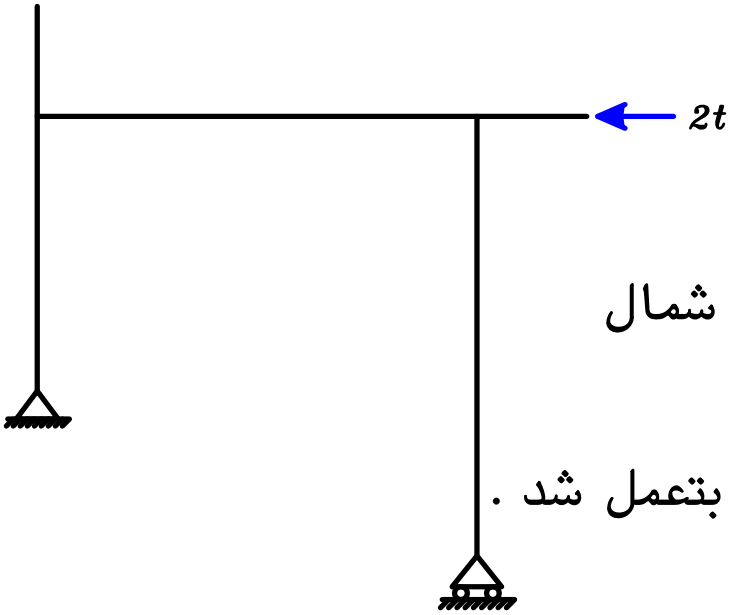
نبدأ بالـ members التى لها طرف حر

member (1)

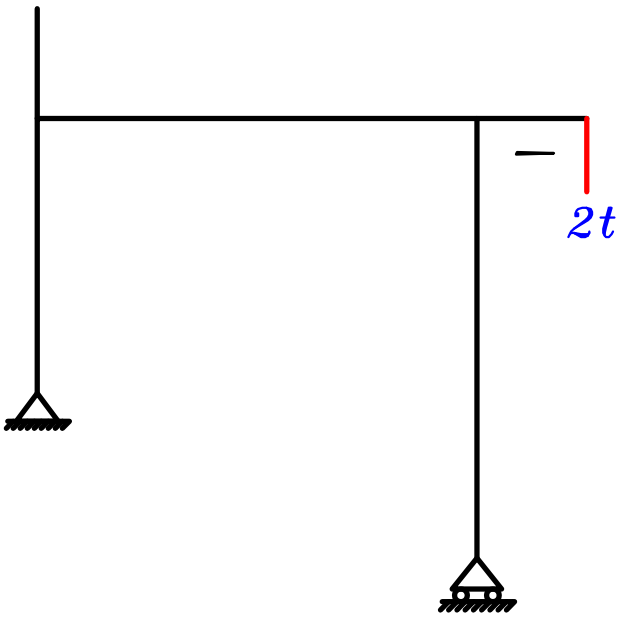
١- لا نرى سوى الـForces اللى بتعمل Normal على الـmember أى التى تكون فى اتجاه الـmember .



٢- نبدأ من الطرف الحر يمين أو شمال و نحدد اتجاه الـ Forces اللى بتعمل ضغط و اتجا ه اللى بتعمل شد .

(Tens.) (Comp.)

٣- نبدأ برسم أول قوة نقابلها بحيث اذا كانت ضغط ترسم داخل الـ Frame وتكون سالبة و اذا كانت شد ترسم خارج الـFrame و تكون موجبة



٤- نتحرك مع الـmember وأى قوة نقابلها فى نفس اتجاه القوة الاولى نتحرك كما تحركنا فى القوة الاولى (داخل أو خارج الـ Frame) و أى قوة نقابلها عكس القوة الاولى نتحرك عكس اتجاه الحركة فى القوة الاولى .

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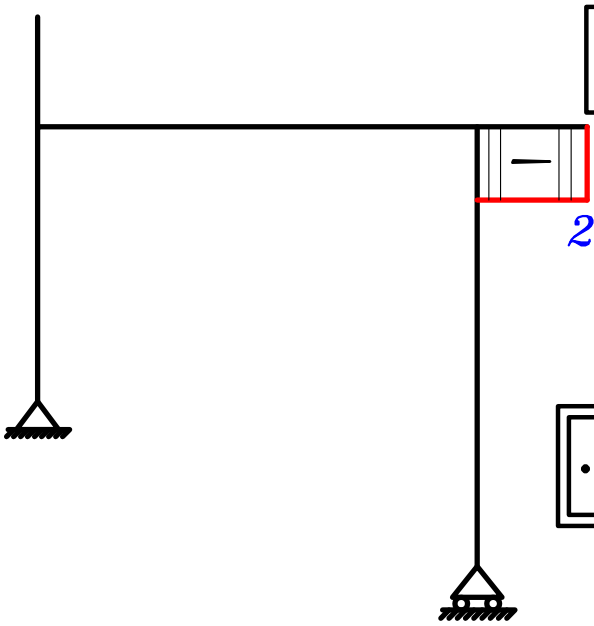
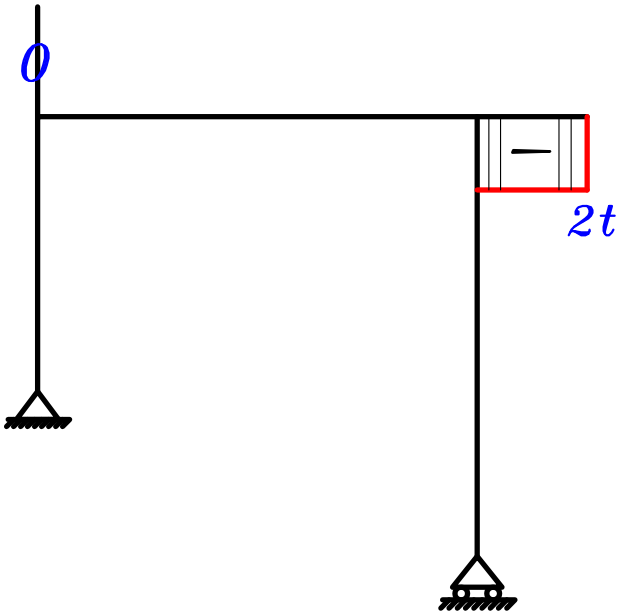
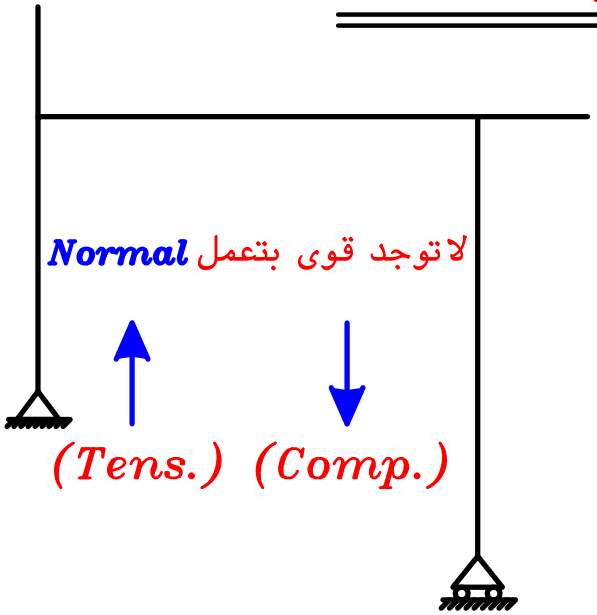
عندما نصل فى رسم *Diagram* الـ ***N.F.D*** أو الـ ***S.F.D*** الى نهاية الـ*member* و لم تكن طرف حر الـ*member* أى أنه يوجد *member* أخر مرتبط به نقفل الـ *Diagram* أى نوصله للـ *Zero* .

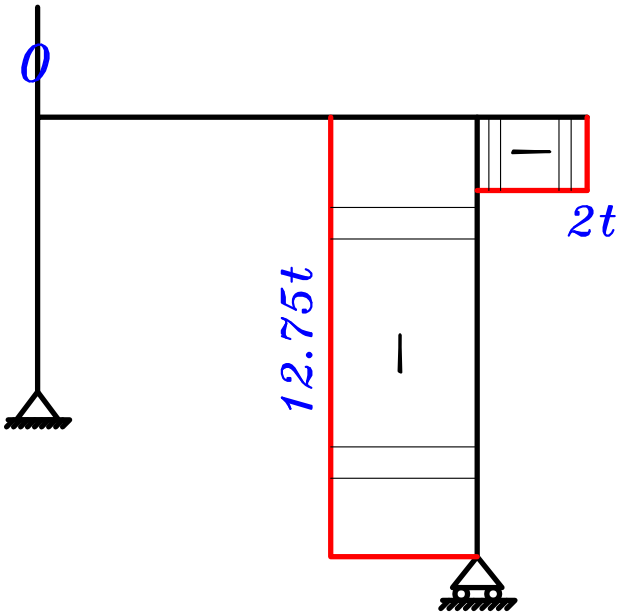


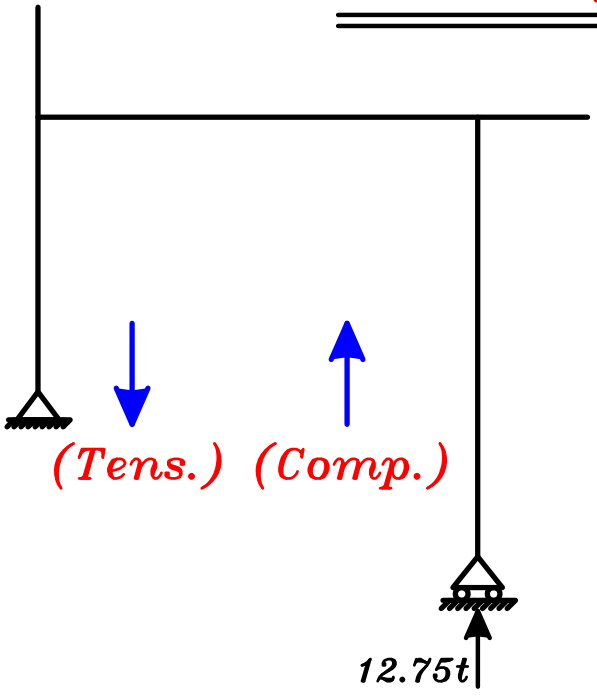
member (2)





member (3)





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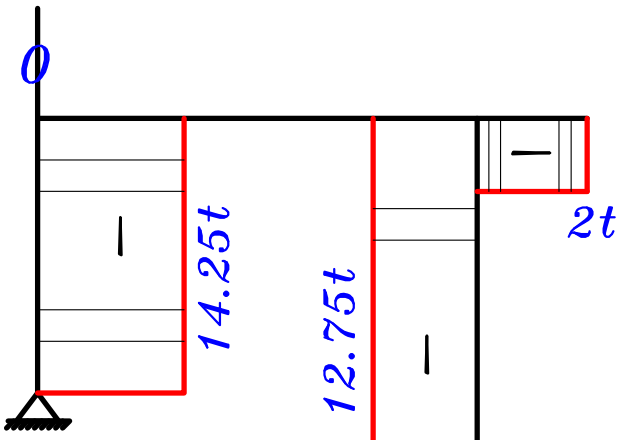
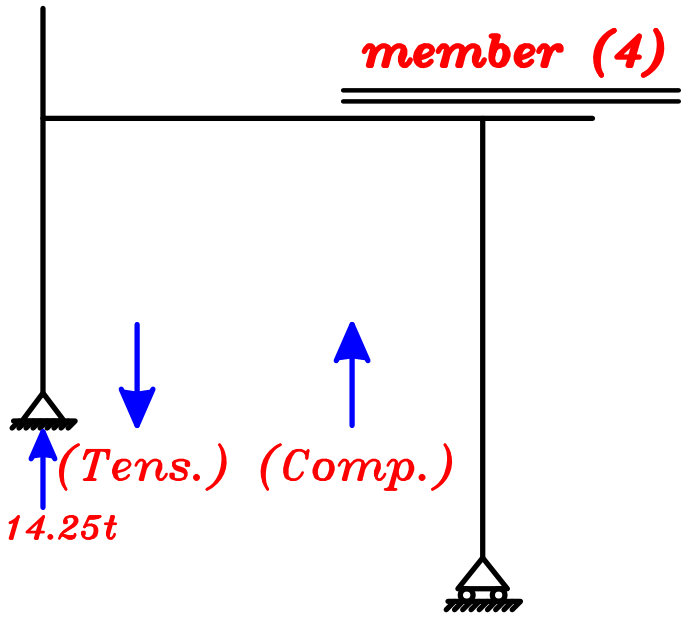
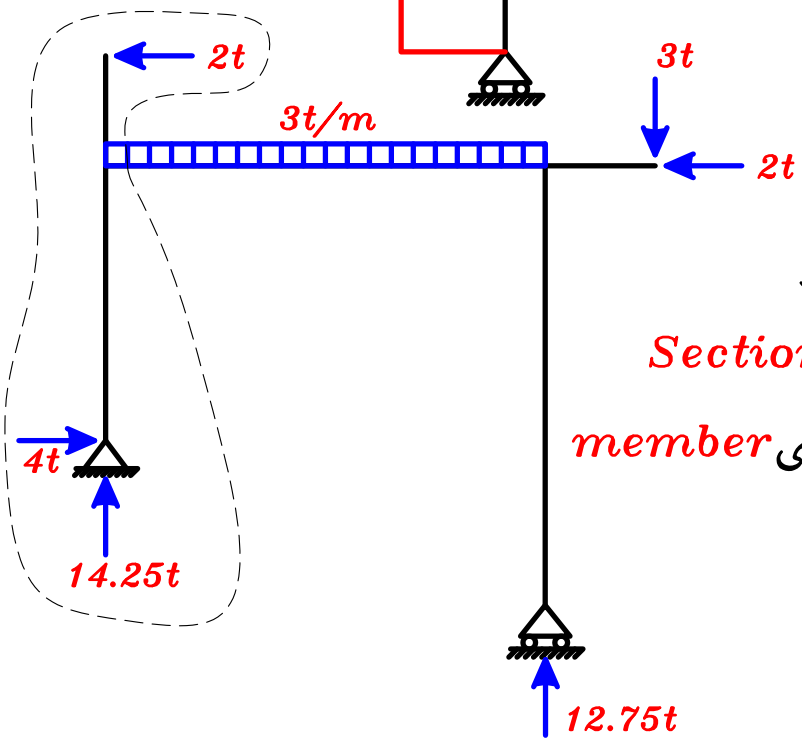


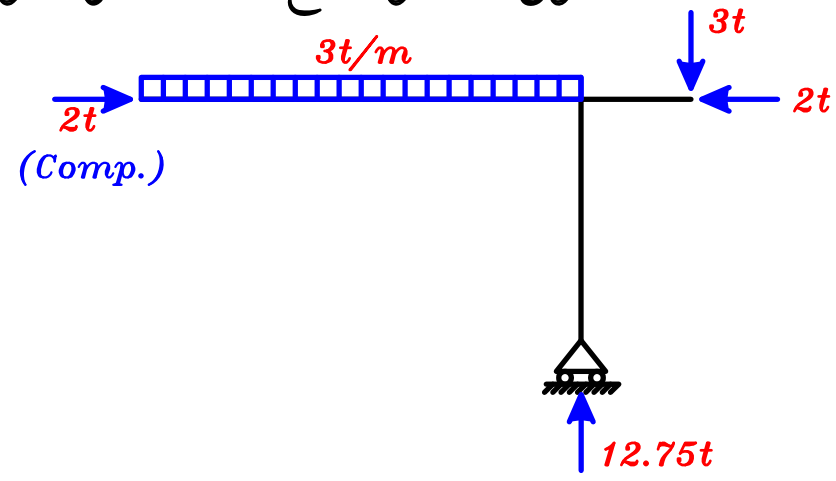




member (5)

١- نقطع الـ member فى بدايته أو نهايته مع التركيز على أن الـ Section اللى بنقطع بيه لابد ألا يقطع أى member أخر ولا يقطع حتى نفس الـ member مرة أخرى .

٢- نجمع القوى اللى فى اتجاه الـ member من الجزء المقطوع فتكون هى الـ Normal force عند بداية الـ member و لو كانت داخلة على الـ member تكون ضغط و نضع لها اشارة سالبة و لو خارجة من الـ member تكون شد و نضع لها اشارة موجبة .



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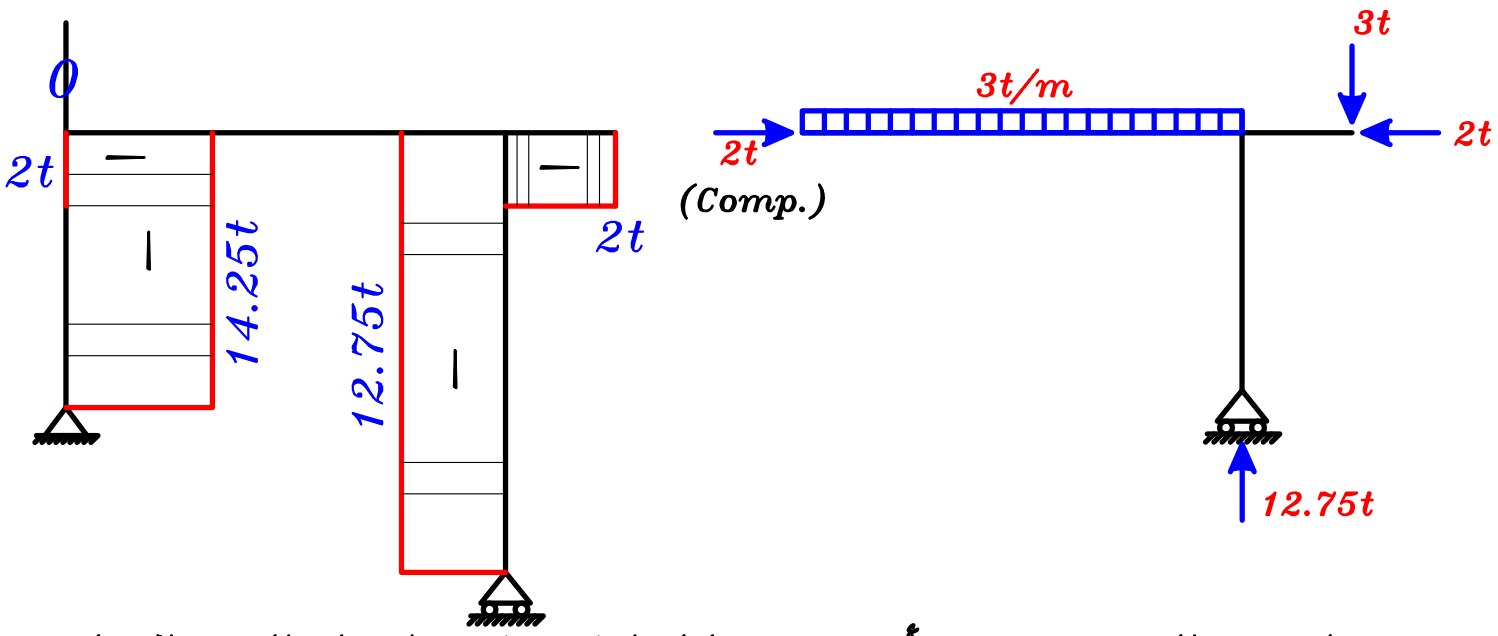
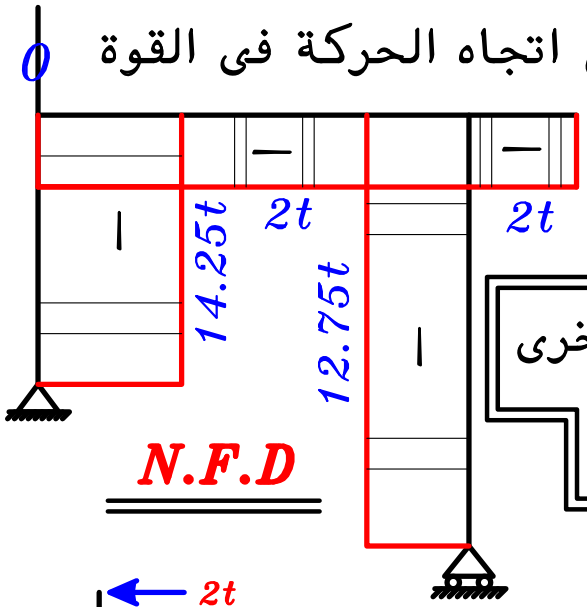
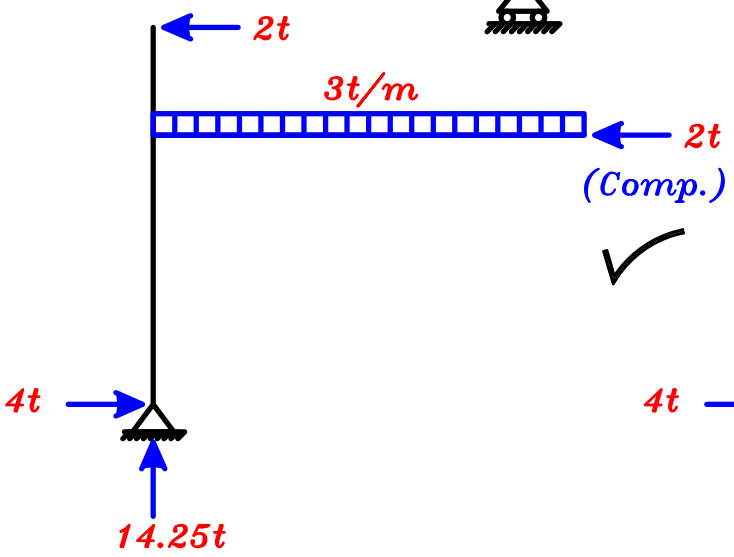


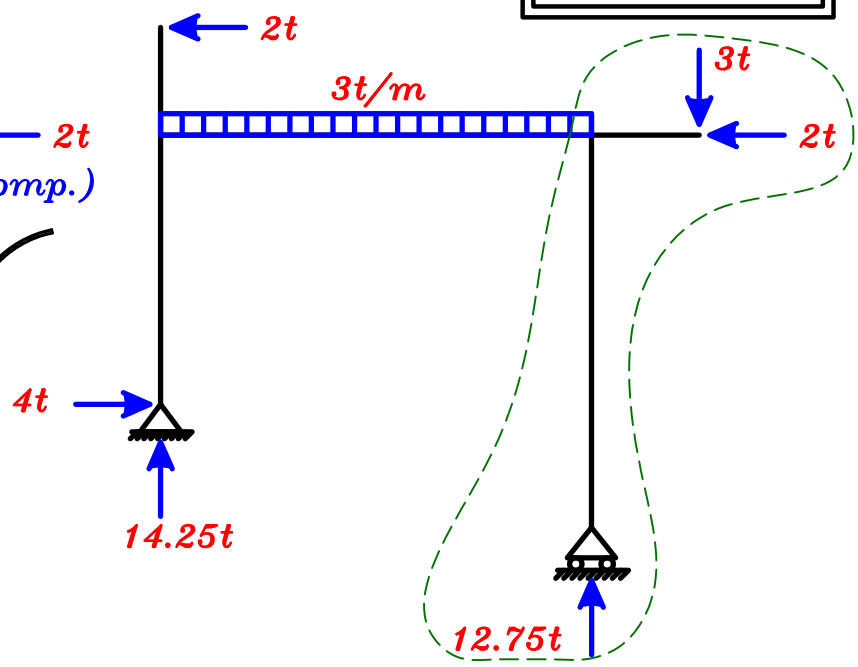
٣-نتحرك مع الـ *member* وأى قوة نقابلها فى نفس اتجاه القوة الاولى (القوى المجمعة) نتحرك كما تحركنا فى القوة الاولى و أى قوة نقابلها عكس القوة الاولى نتحرك عكس اتجاه الحركة فى القوة الاولى .



N.F.D

لعمل *Check* على أى *member* ممكن نقطع و نجمع الـ*Forces* من الناحية الاخرى لو أعطت نفس قيمة الـ*Diagram* يكون الحل صحيح .





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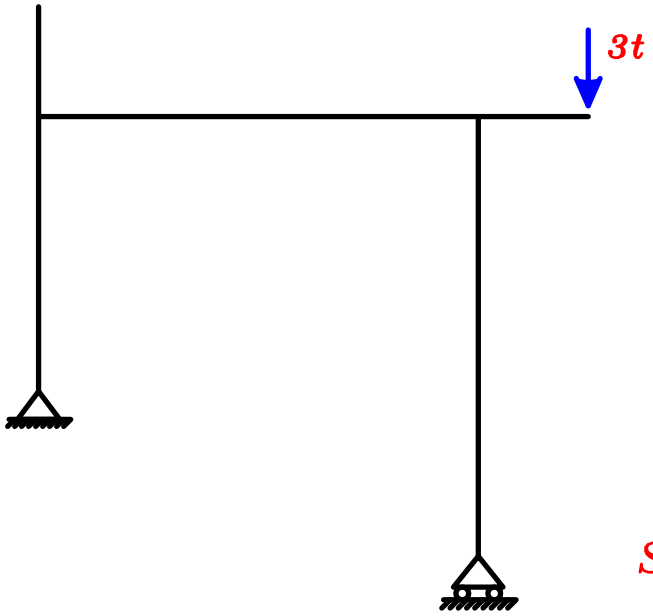
نبدأ بالـ members التى لها طرف حر

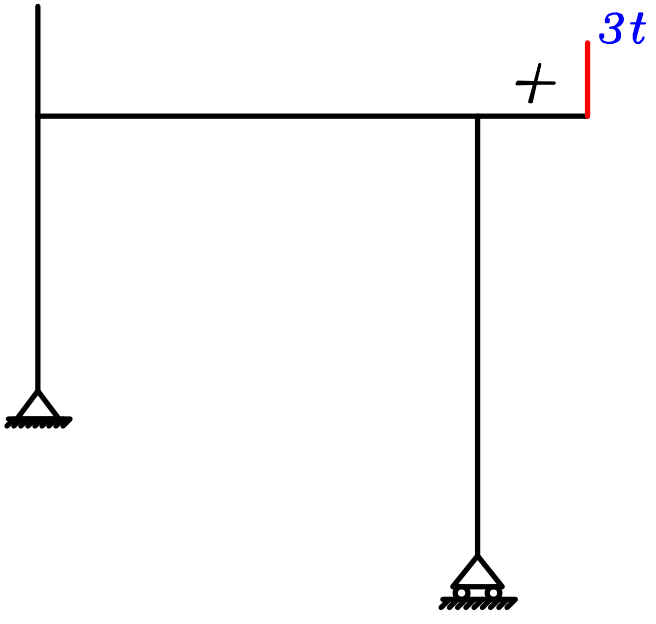
member (1)

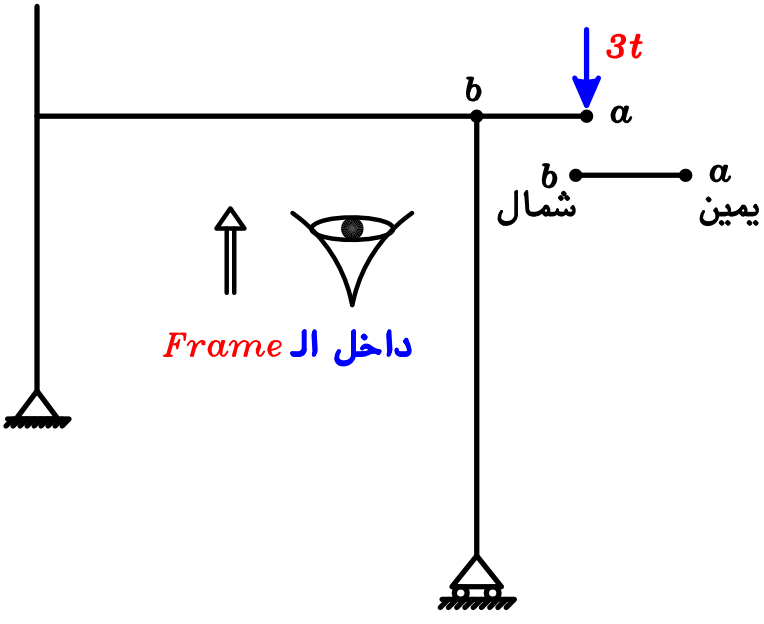
١- لا نرى سوى الـForces اللى بتعمل Shear على الـmember أى التى تكون فى اتجاه عمودى على الـ member .



٢- نبدأ من الطرف الحر يمين أو شمال و نجمع الـ Forces العمودية على الـ member فتكون هى الـShear عند هذا الطرف الحر .

٣- نقف داخل الـFrame وننظر الى الى الـmember اذا كان الطرف الحر الذى بدأنا منه الحسابات ناحية الشمال نرسم الـ Shear force فى نفس اتجاه القوى التى تم حسابها و اذا كان الطرف الحر يمين نرسم الـ Shear force فى عكس اتجاه القوى التى تم حسابها .





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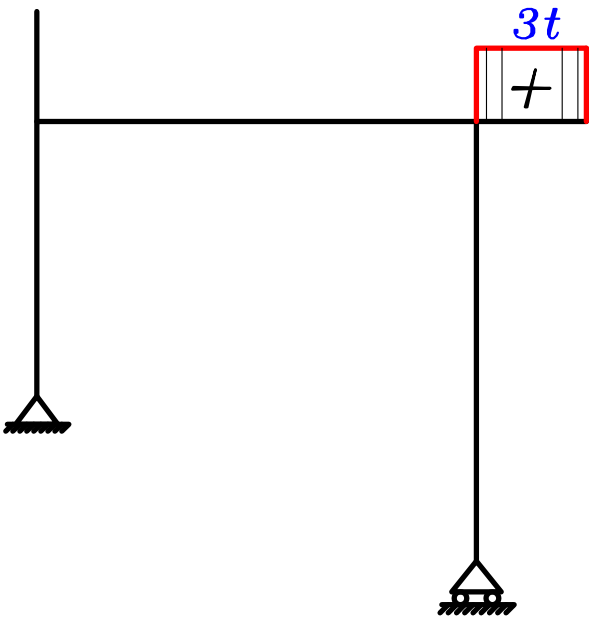
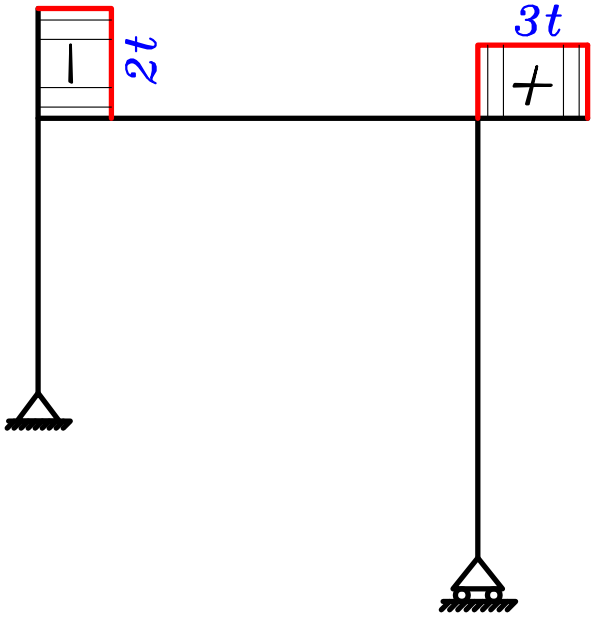
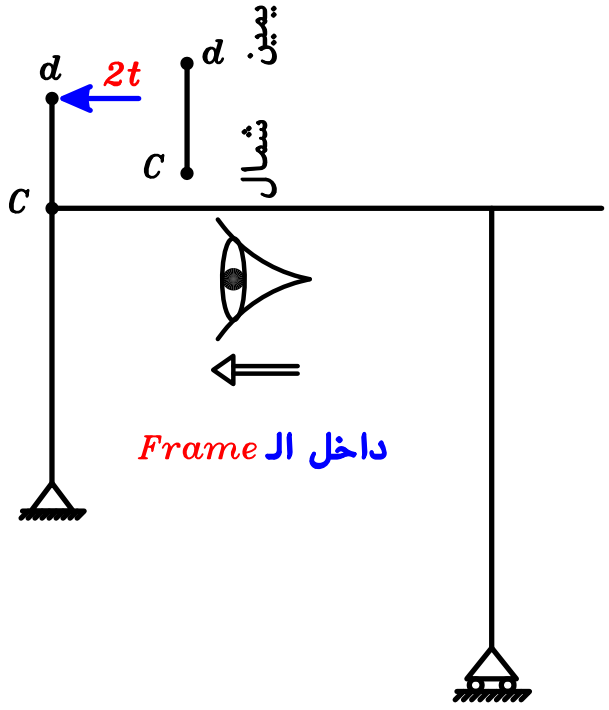
٤- نتحرك فى اتجاه الـmember ولو الطرف اللى بدأنا منه شمال أى قوة نقابلها نرسم الـ Shear force فى اتجاهها و لو الطرف اللى بدأنا منه يمين نرسم الـ Shear force فى عكس اتجاهها .



عندما نصل فى رسم Diagram الـ N.F.D أو الـ S.F.D الى نهاية الـmember و لم تكن طرف حر الـmember أى أنه يوجد member أخر مرتبط به نقفل الـ Diagram أى نوصله للـ Zero .

member (2)





داخل الـ Frame

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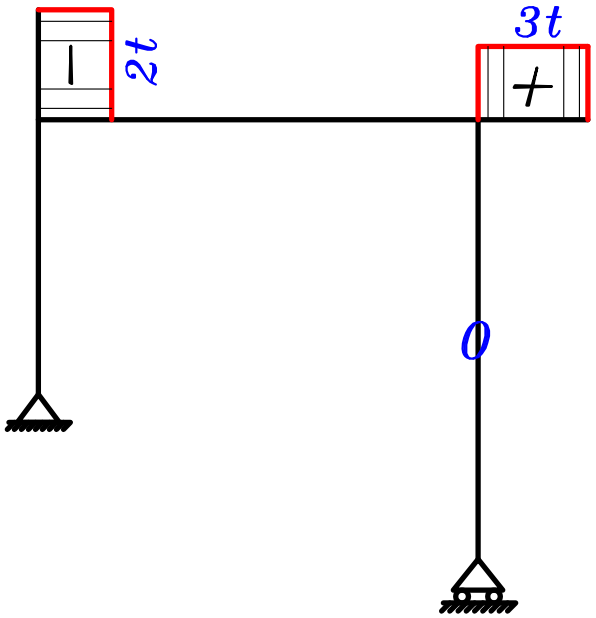
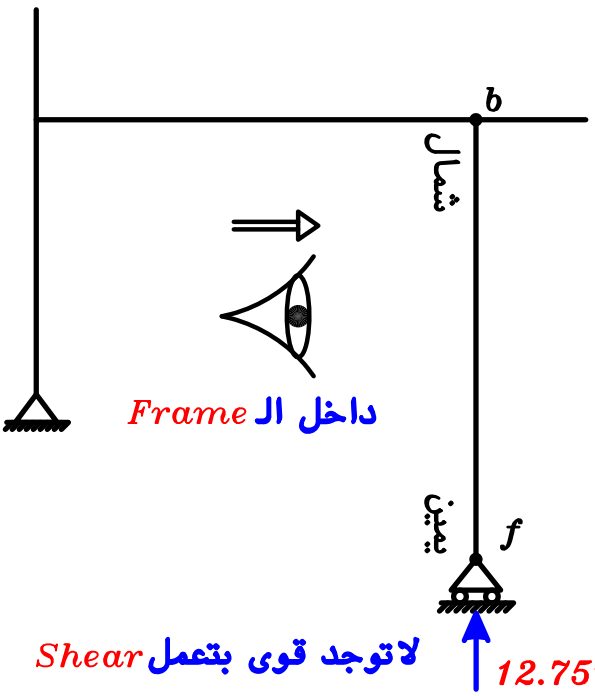
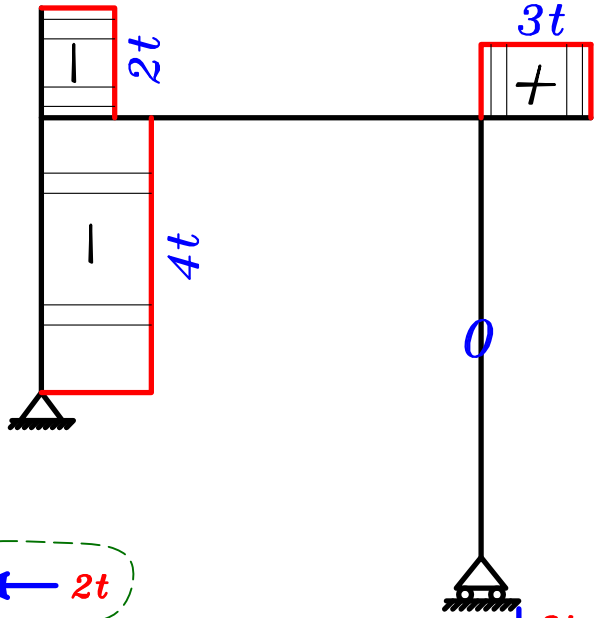
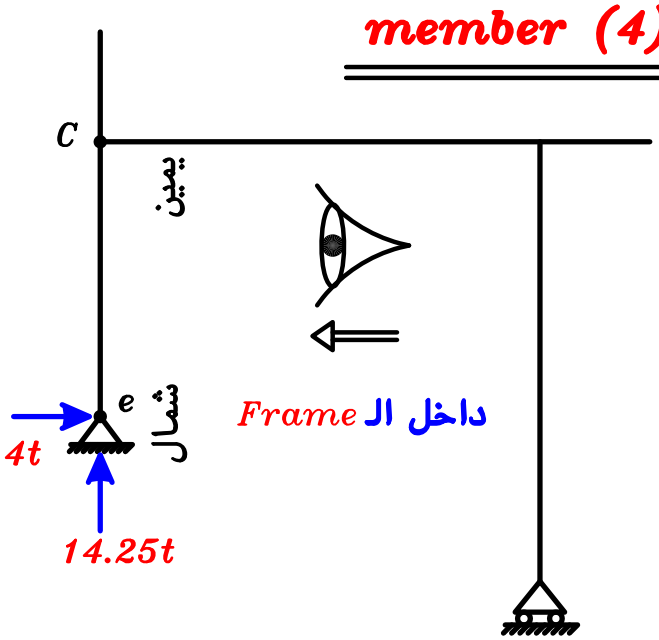
member (3)



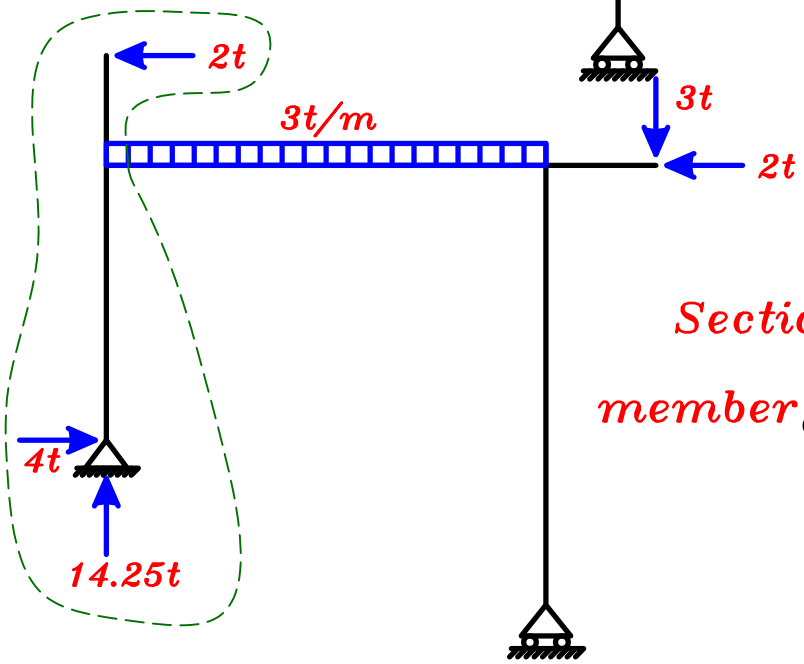


member (4)





member (5)



١- نقطع الmember فى بدايته أو نهايته مع التركيز على أن الSection اللى بنقطع بيه لابد ألا يقطع أى member أخر ولا يقطع حتى نفس الmember مرة أخرى .

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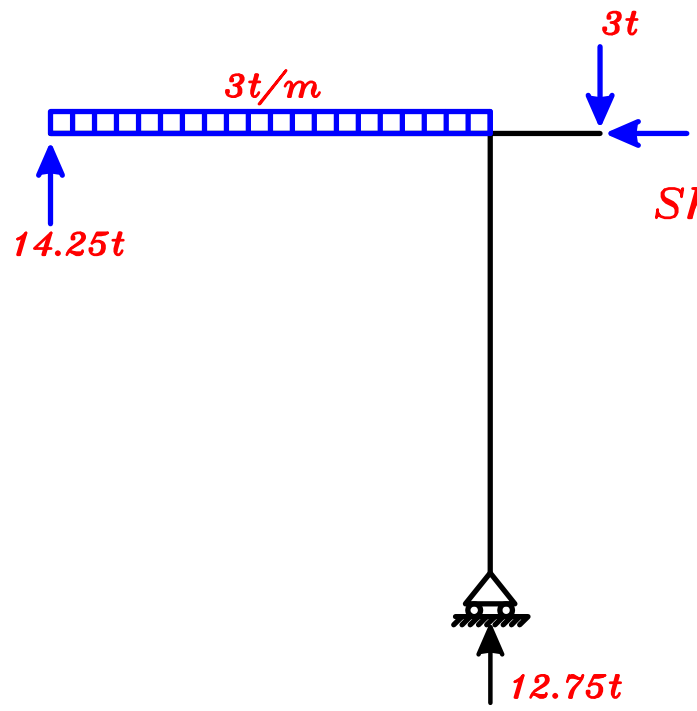
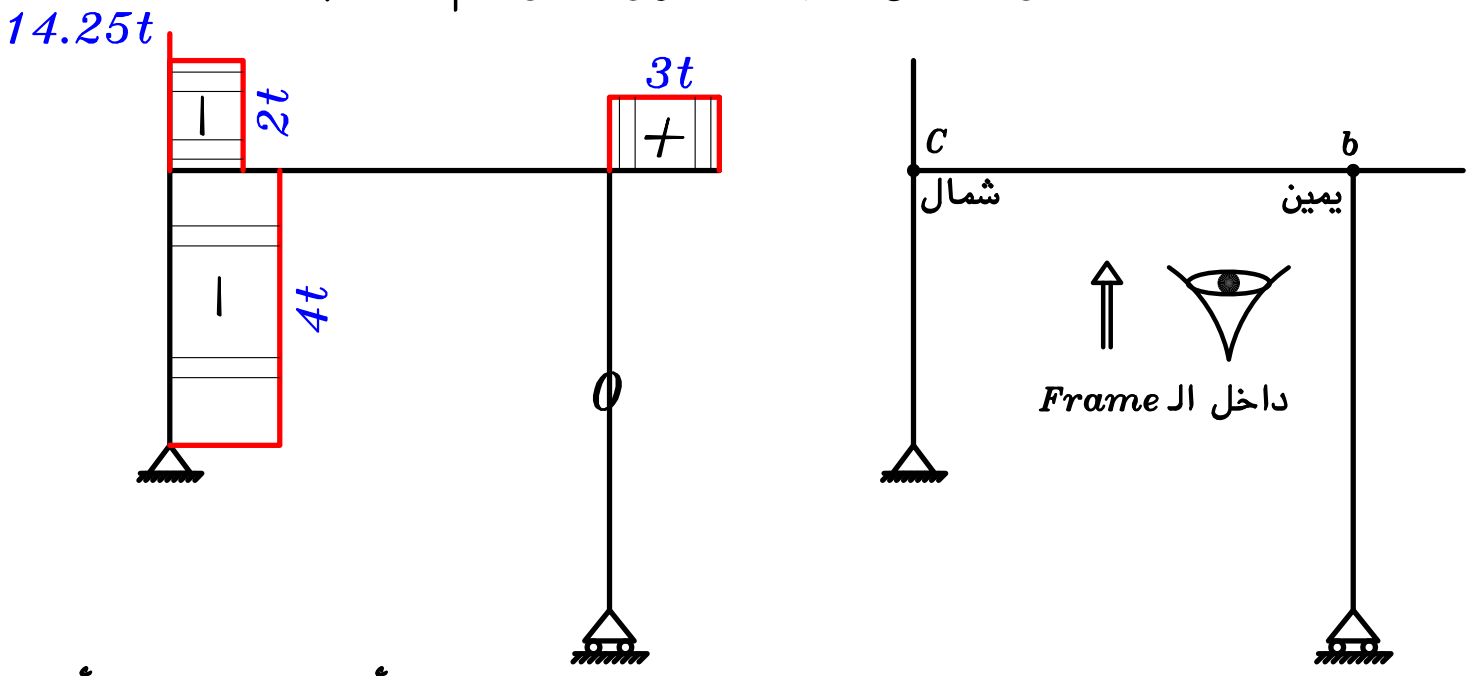
٢-نجمع القوى اللى فى الاتجاه العمودى على الـ member من الجزء المقطوع فتكون هى الـShear عند بداية الـmember



٣- نقف داخل الـFrame وننظر الى الى الـmember اذا كان الطرف الذى بدأنا منه الحسابات ناحية الشمال نرسم الـ Shear force فى نفس اتجاه القوى التى تم حسابها و اذا كان الطرف يمين نرسم الـ Shear force فى عكس اتجاه القوى التى تم حسابها .



٤- نتحرك فى اتجاه الـmember ولو الطرف اللى بدأنا منه شمال أى قوة نقابلها نرسم الـ Shear force فى اتجاهها و لو الطرف اللى بدأنا منه يمين نرسم الـ Shear force فى عكس اتجاهها .

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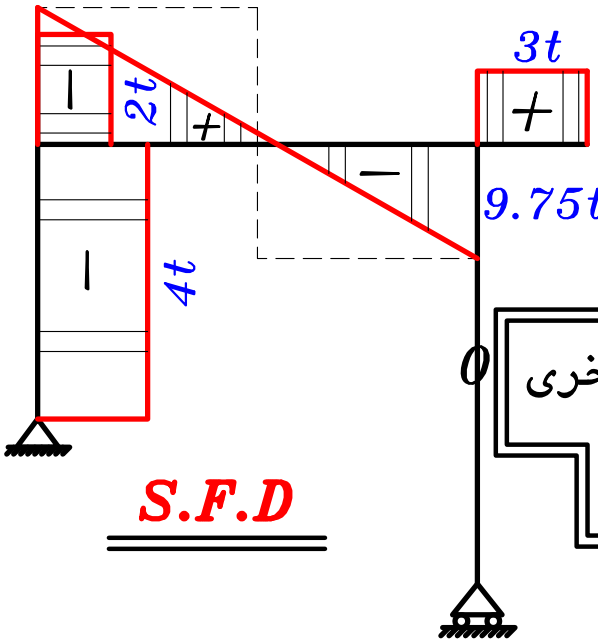
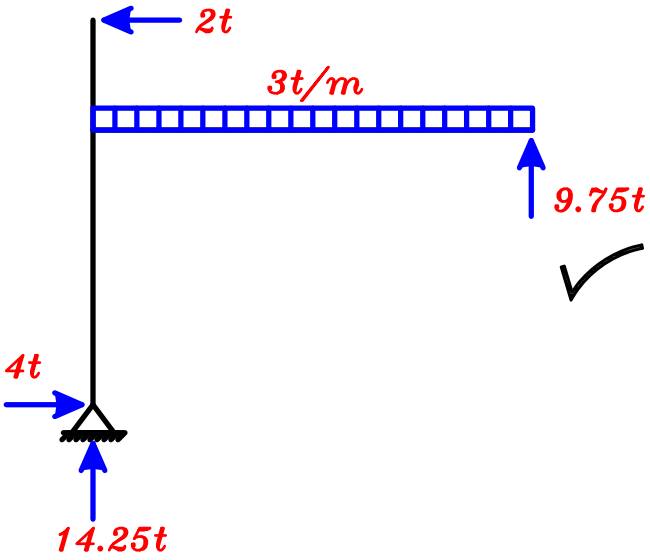
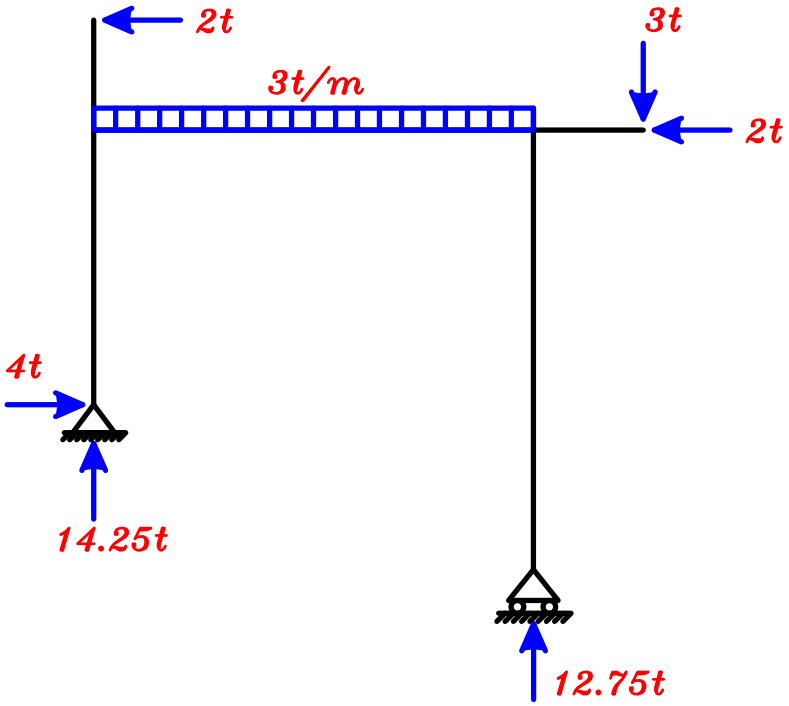
14.25t



S.F.D

لعمل Check على أى member ممكن نقطع و نجمع الForces من الناحية الاخرى لو أعطت نفس قيمة الDiagram يكون الحل صحيح .





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ب - نرسم الـ B.M.D

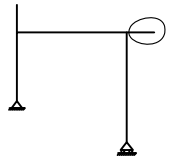
نبدأ بالـ **members** التى لها طرف حر

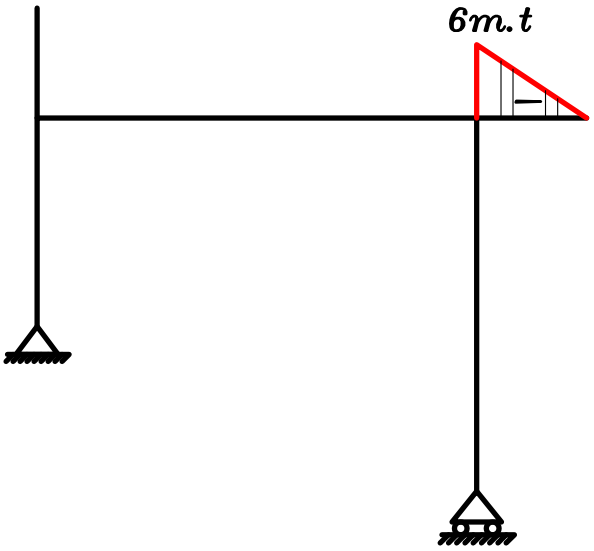
member (1)

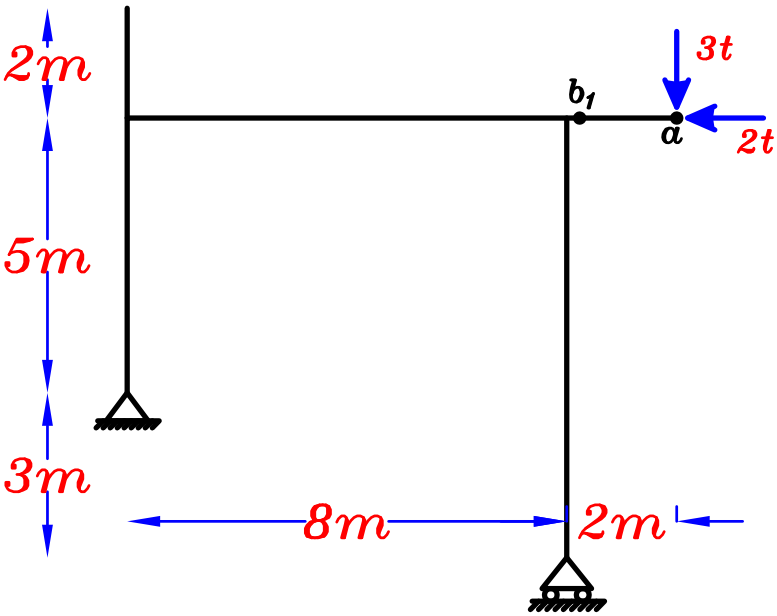
$M_a = 0$

$M_{b_1} = -3 \times 2 \curvearrowright$

$= -6 \ m.t \curvearrowright$







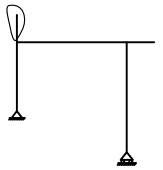
عند حساب الـ moment فى بداية ونهاية الـ member تكون بداية الـ member بعد الـ Joint مباشرة و نهايته قبل الـ Joint مباشرة

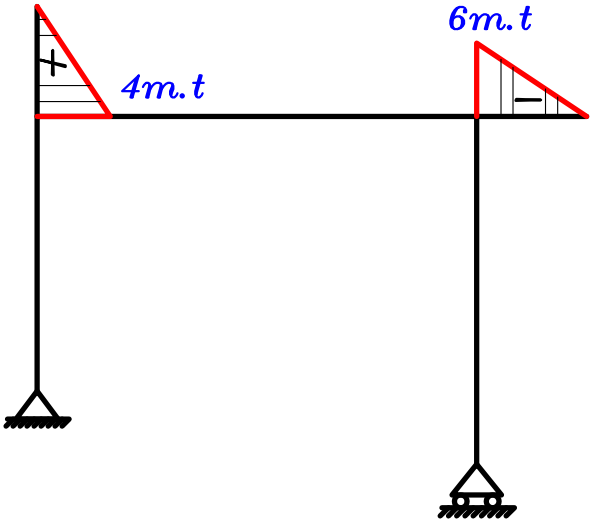
member (2)

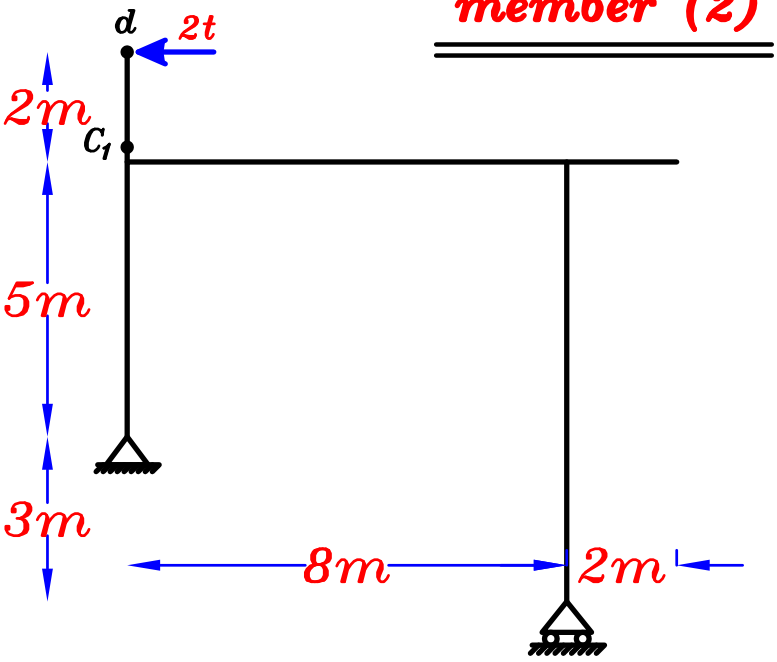
$M_d = 0$

$M_{C_1} = 2 \times 2 \curvearrowleft$

$= 4 \ m.t \curvearrowleft$







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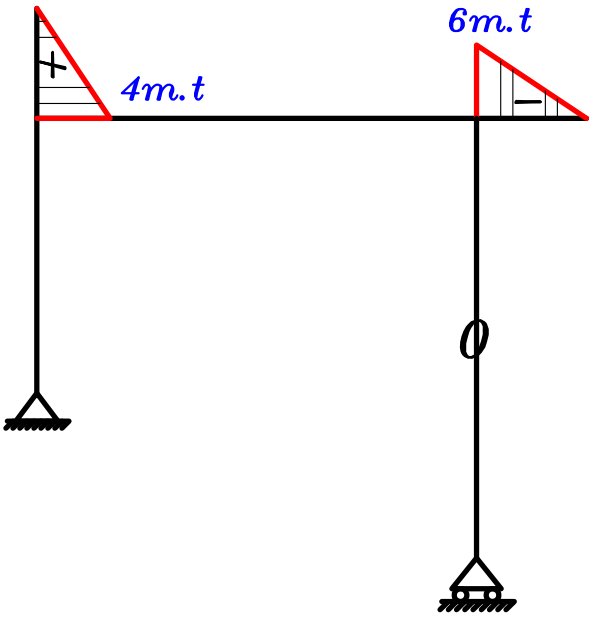
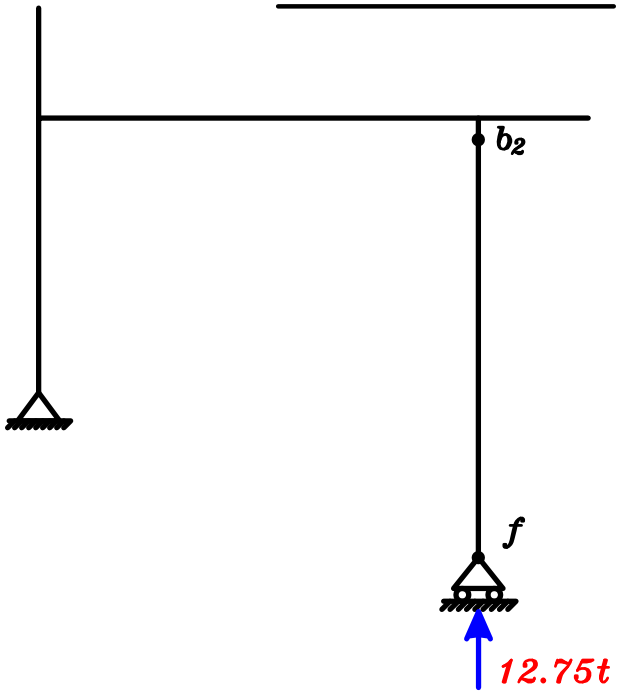
member (3)

$M_{b_2} = 0$

$M_f = 0$



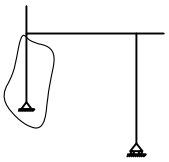


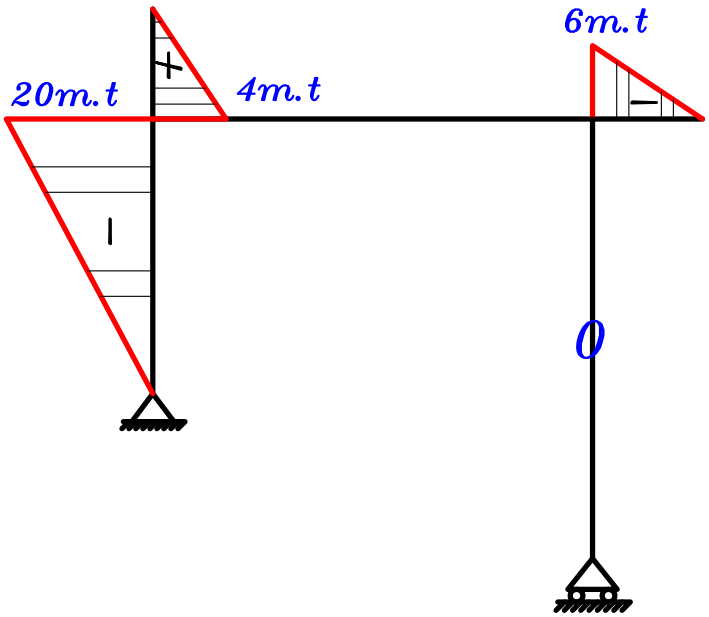
member (4)

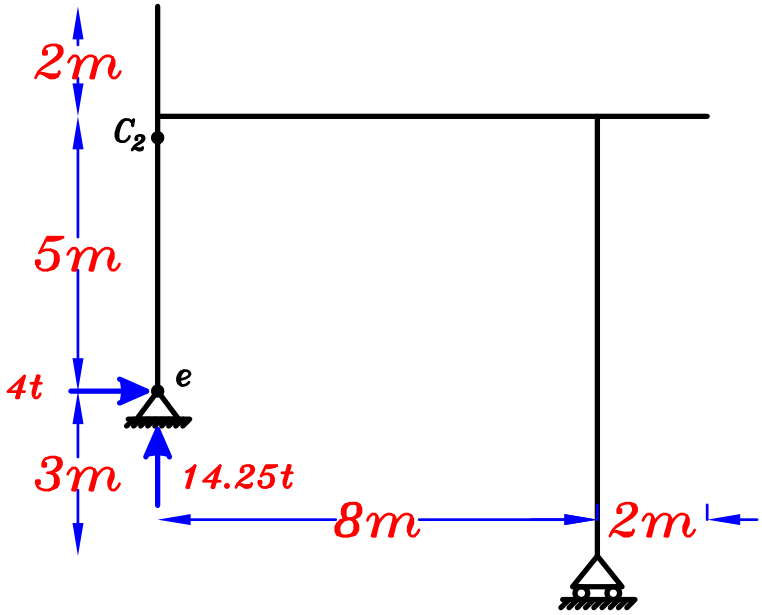
$M_e = 0$

$M_{C_2} = 4 \times 5 \curvearrowright$

$= 20 \text{ m.t} \curvearrowright$







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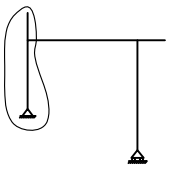
$M_{C_3} = -2 \times 2 \curvearrowleft$

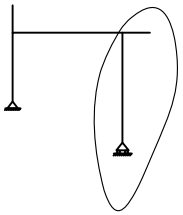
$- 4 \times 5 \curvearrowleft$

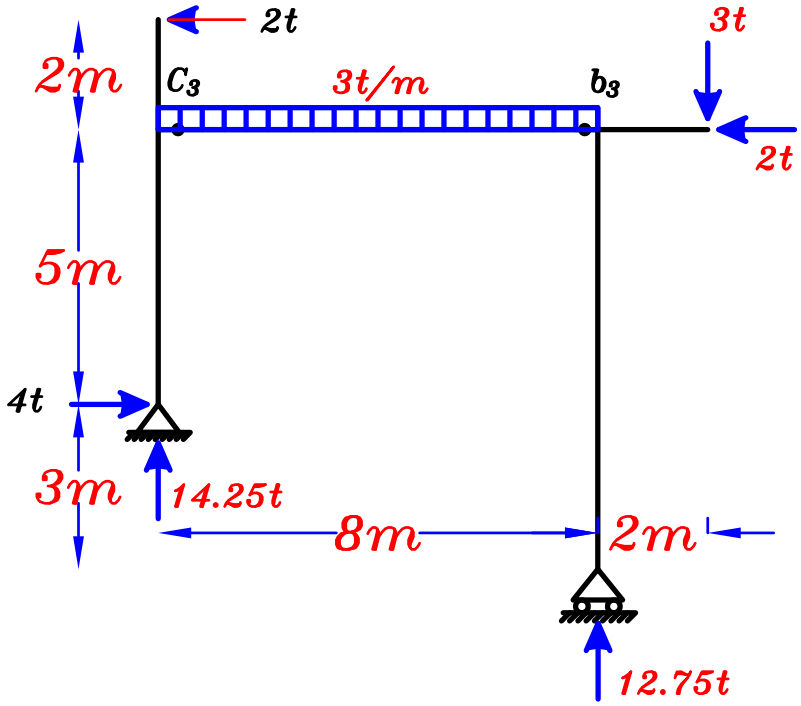
$= -24 \ m.t \curvearrowleft$

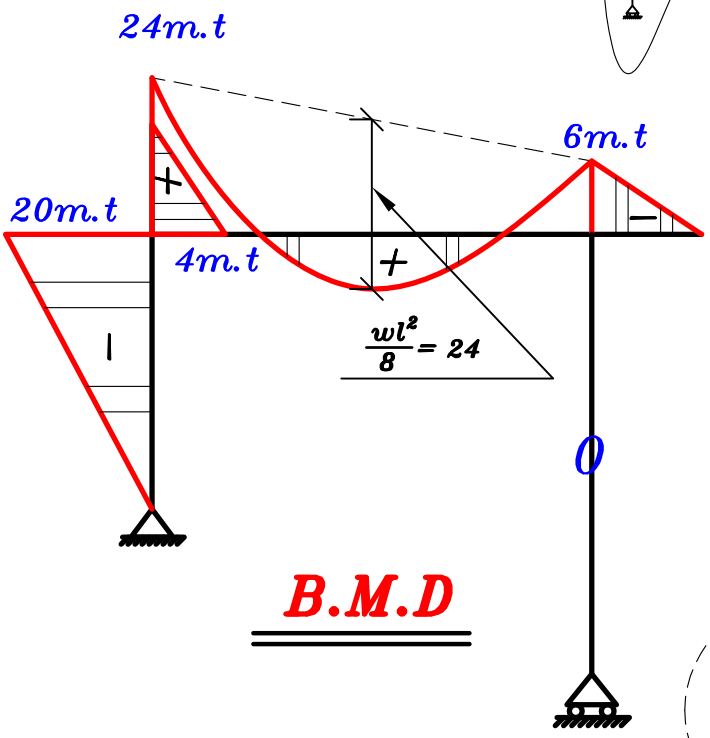
$M_{b_3} = -3 \times 2 \curvearrowright$

$= -6 \ m.t \curvearrowright$





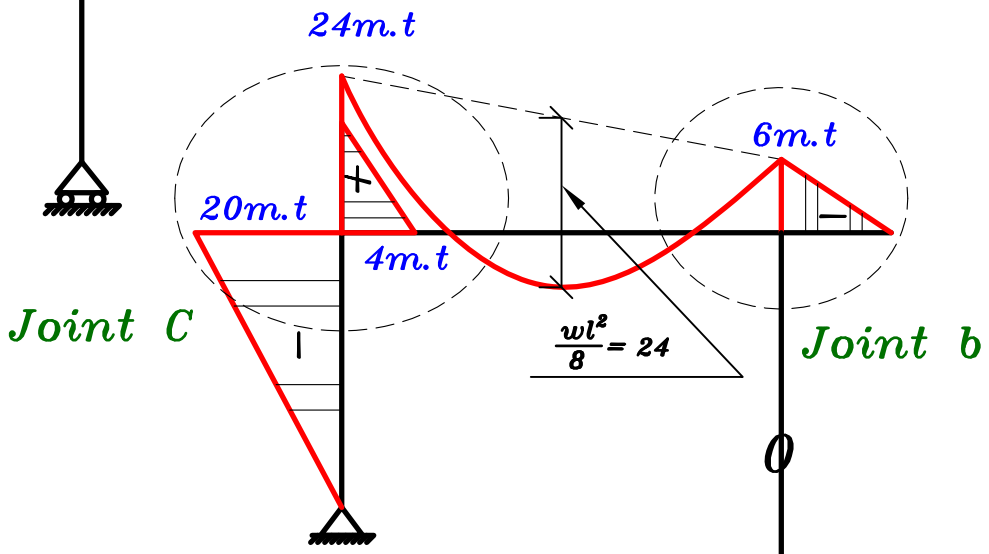




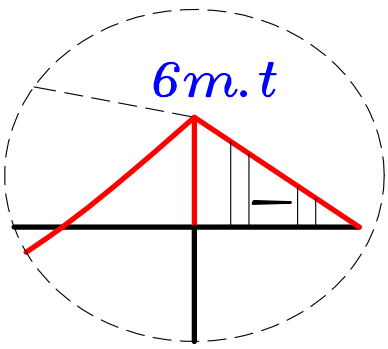
B.M.D

وللتأكد من أن الحل صحيح نعمل

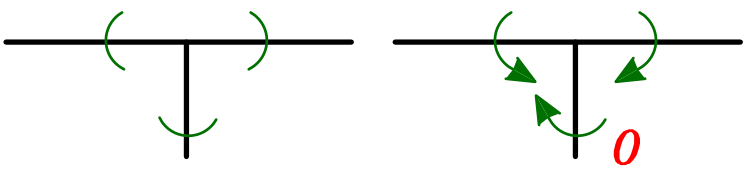
اتزان لـ Joint b و Joint C



Joint b



B.M.D



$\Sigma M = 0$

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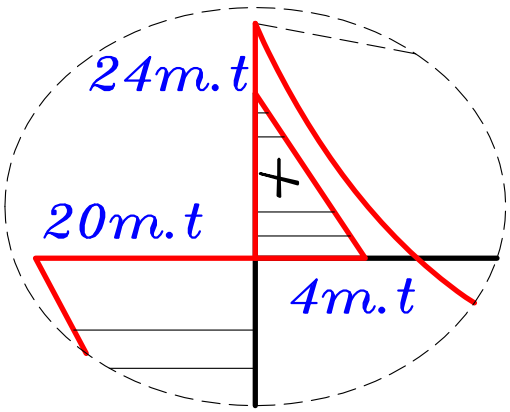
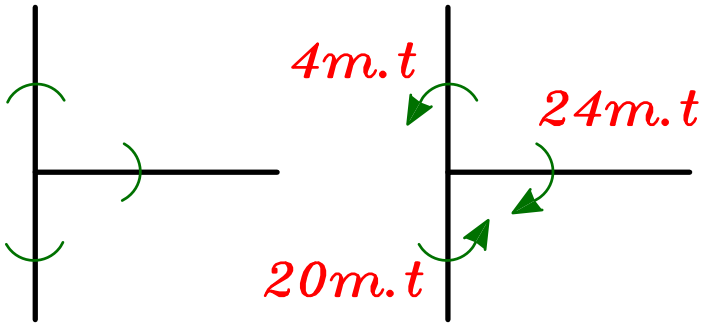
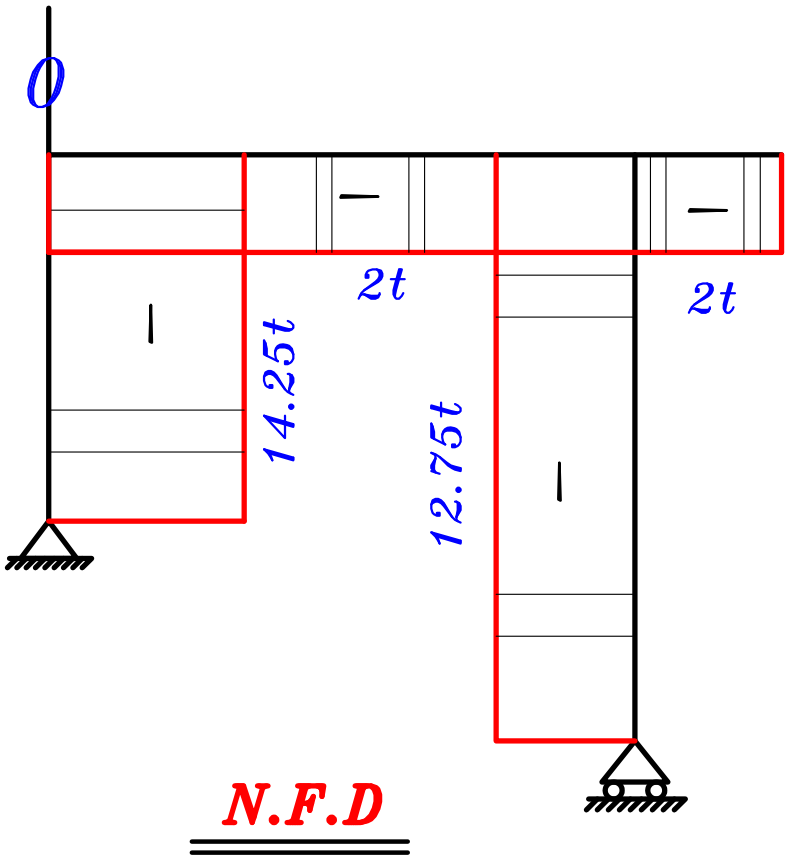
Joint C





$$\Sigma M = 0$$



N.F.D

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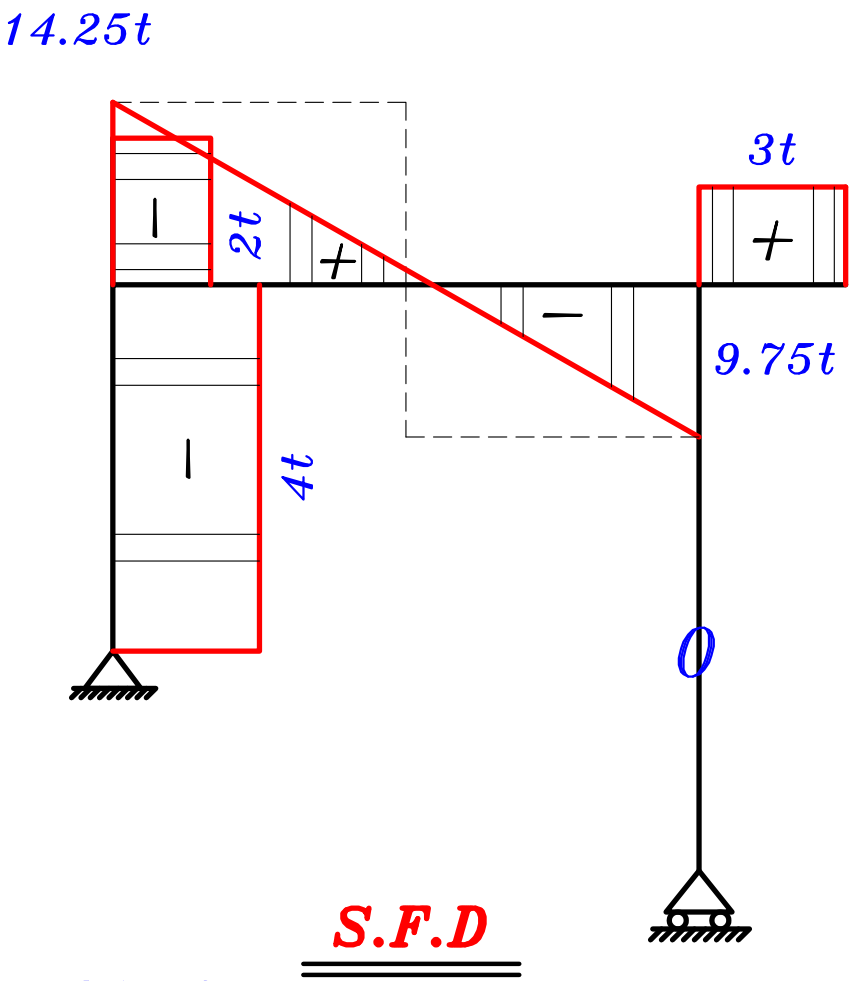
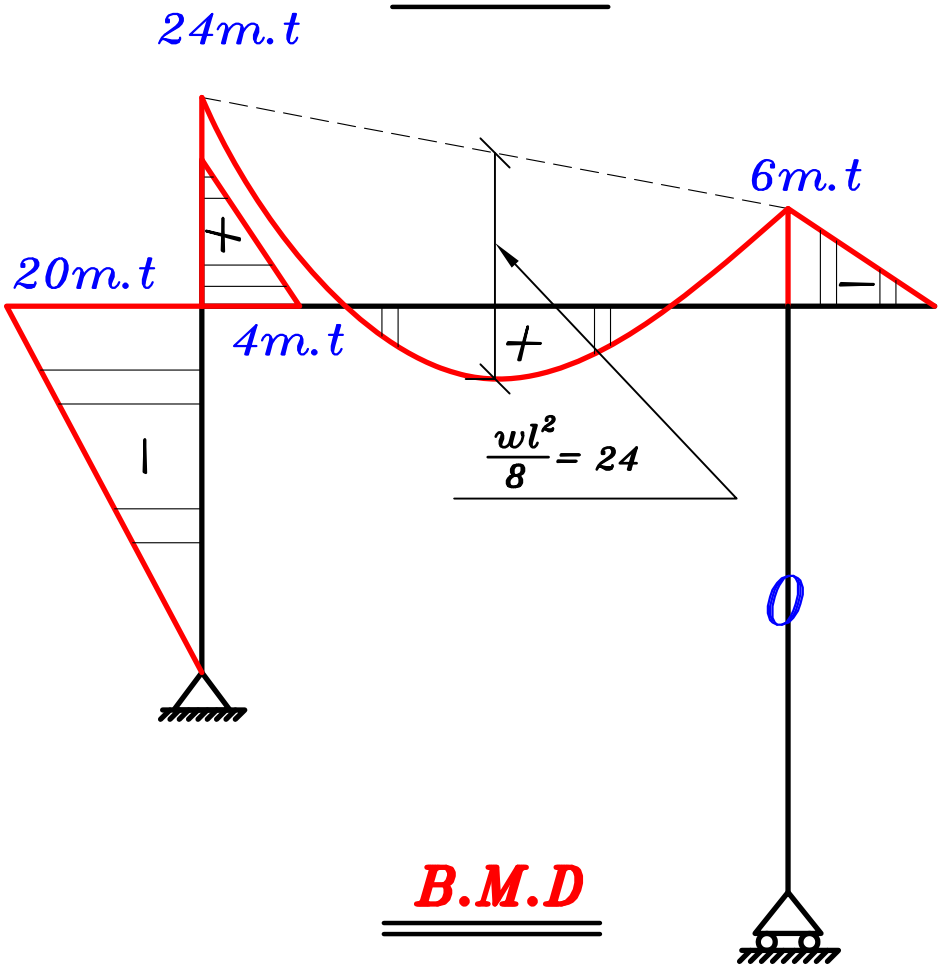


S.F.D



B.M.D

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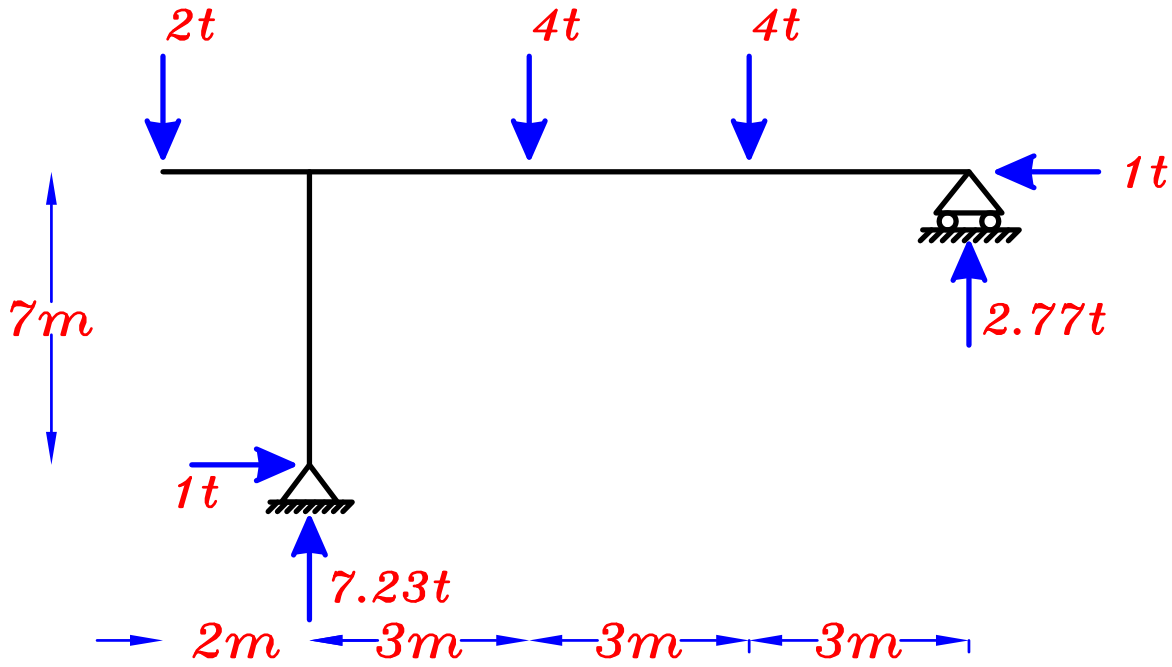
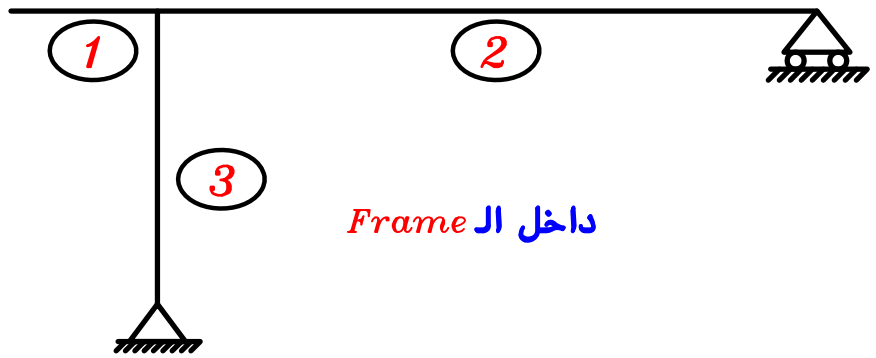
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.



نحدد الـ members .

والـmemberيكون بين 2 Joints و الـ Joint هى عبارة عن Support أو تقاطع member مع member أخر .



داخل الـ Frame

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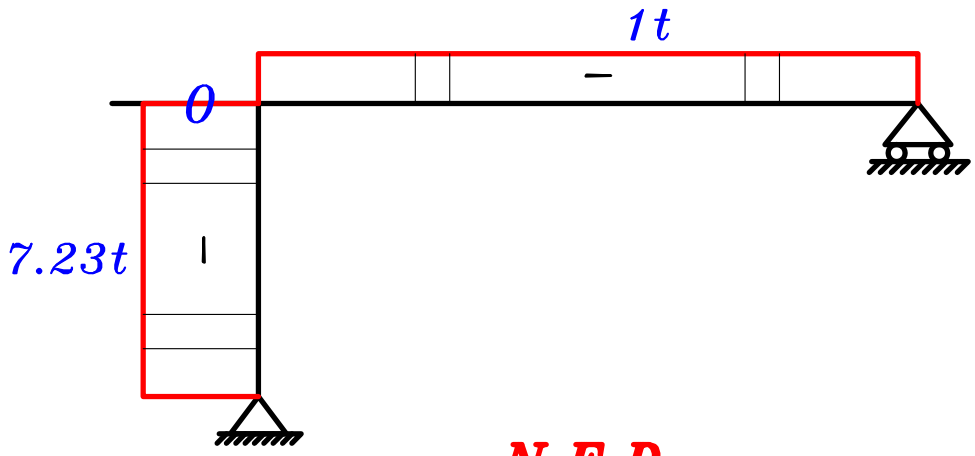
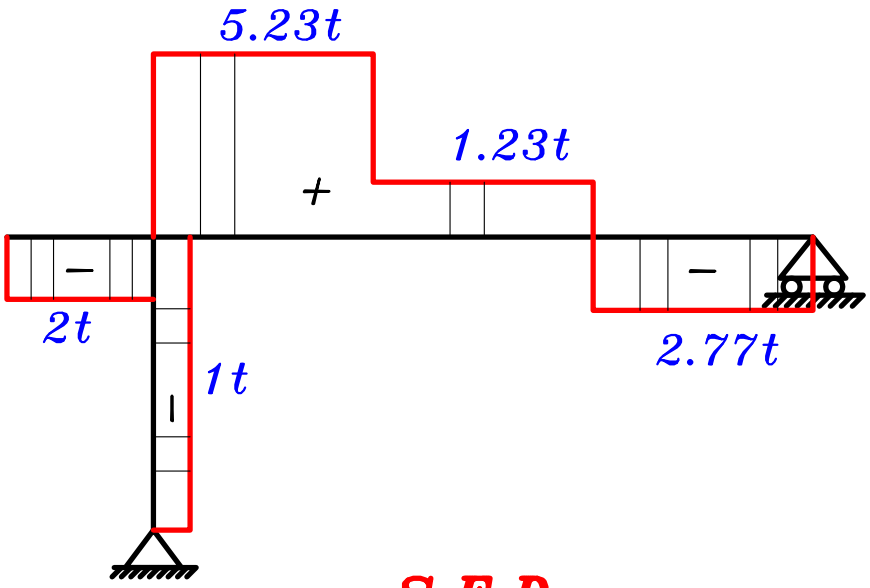
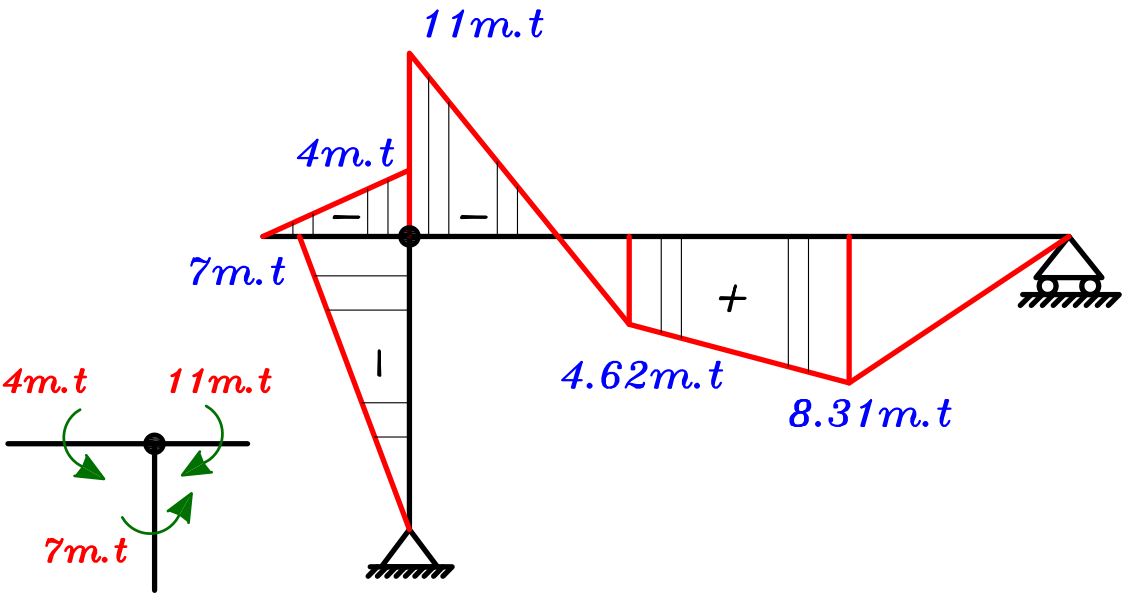


N.F.D



S.F.D



B.M.D

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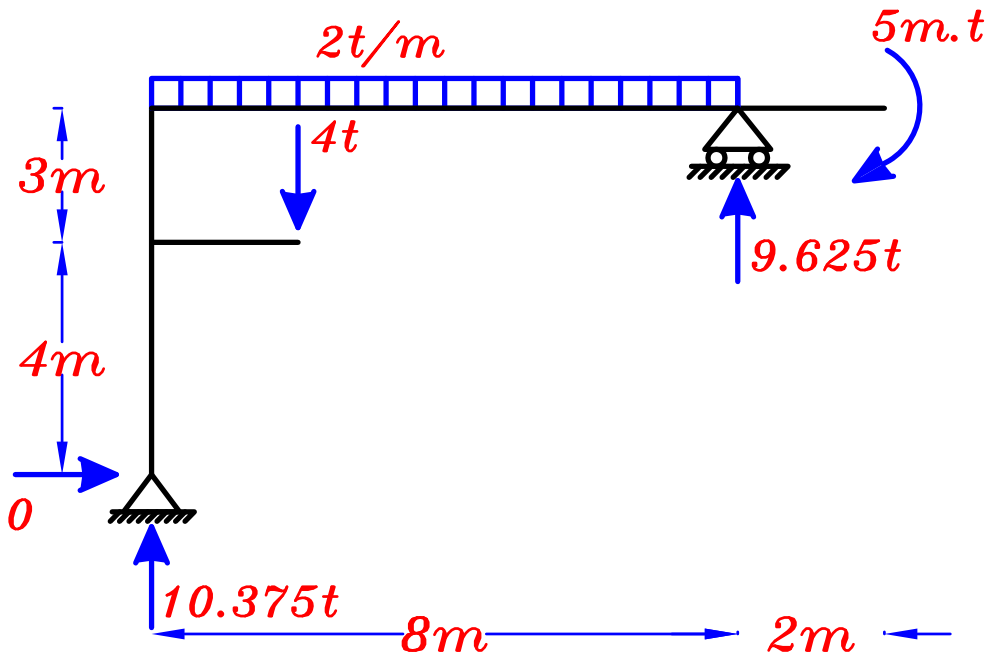
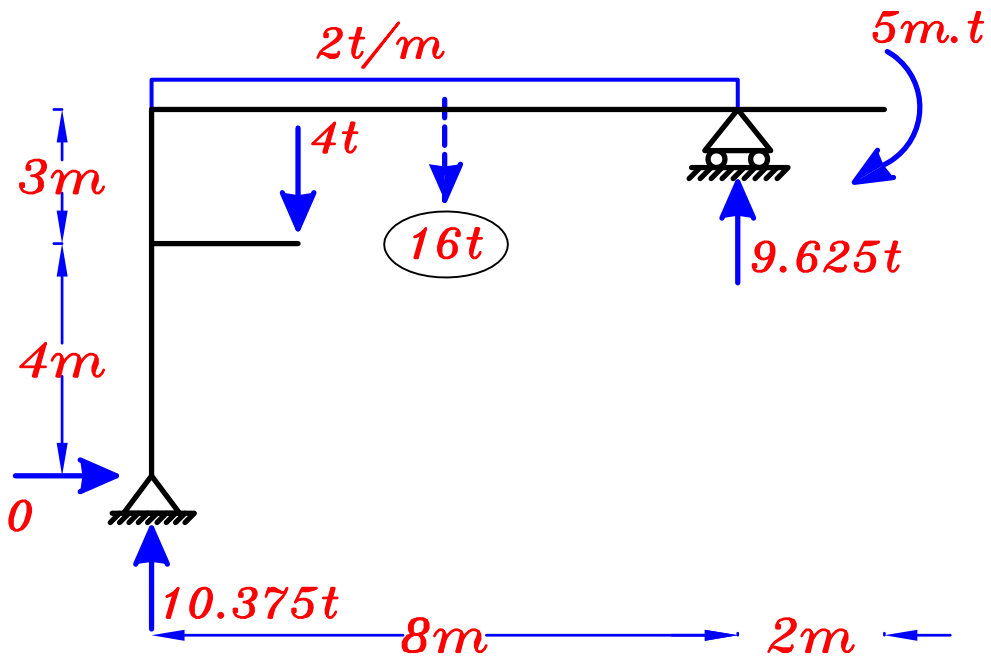
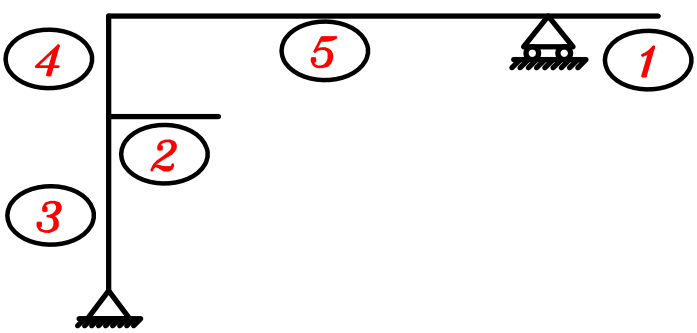
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.







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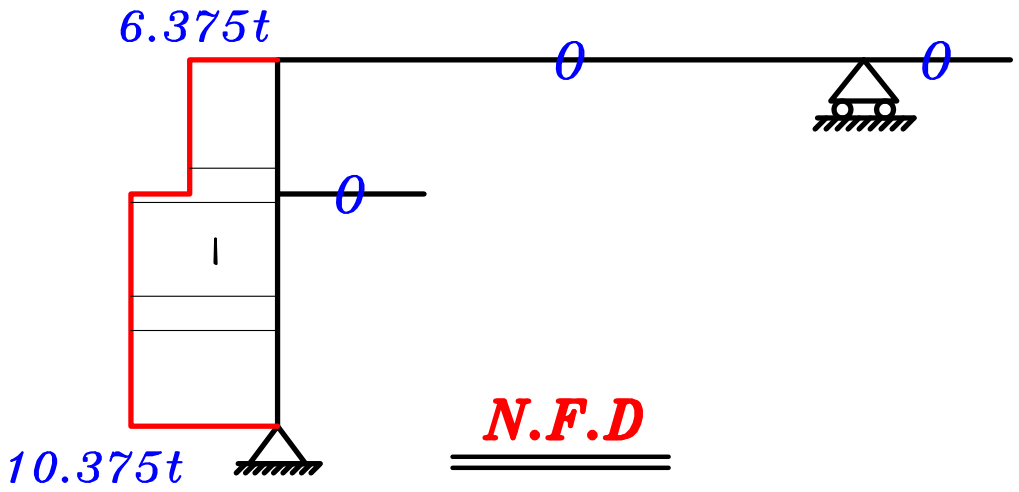
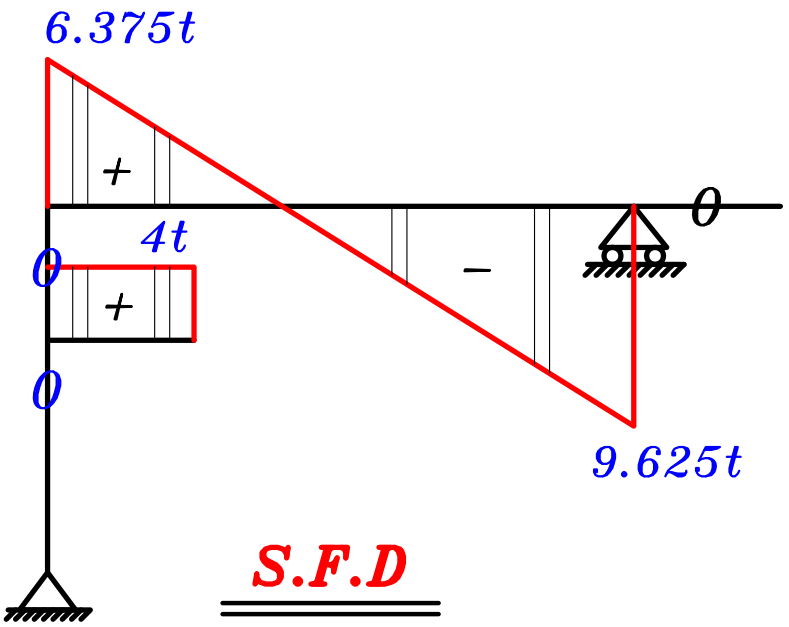
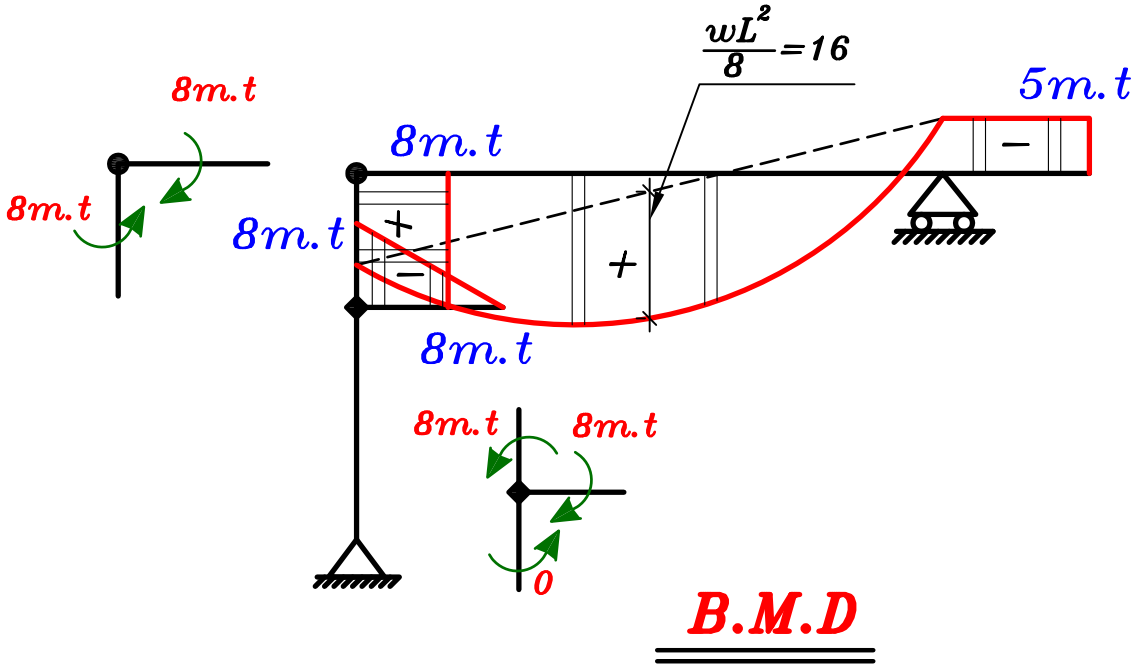


N.F.D



S.F.D



B.M.D

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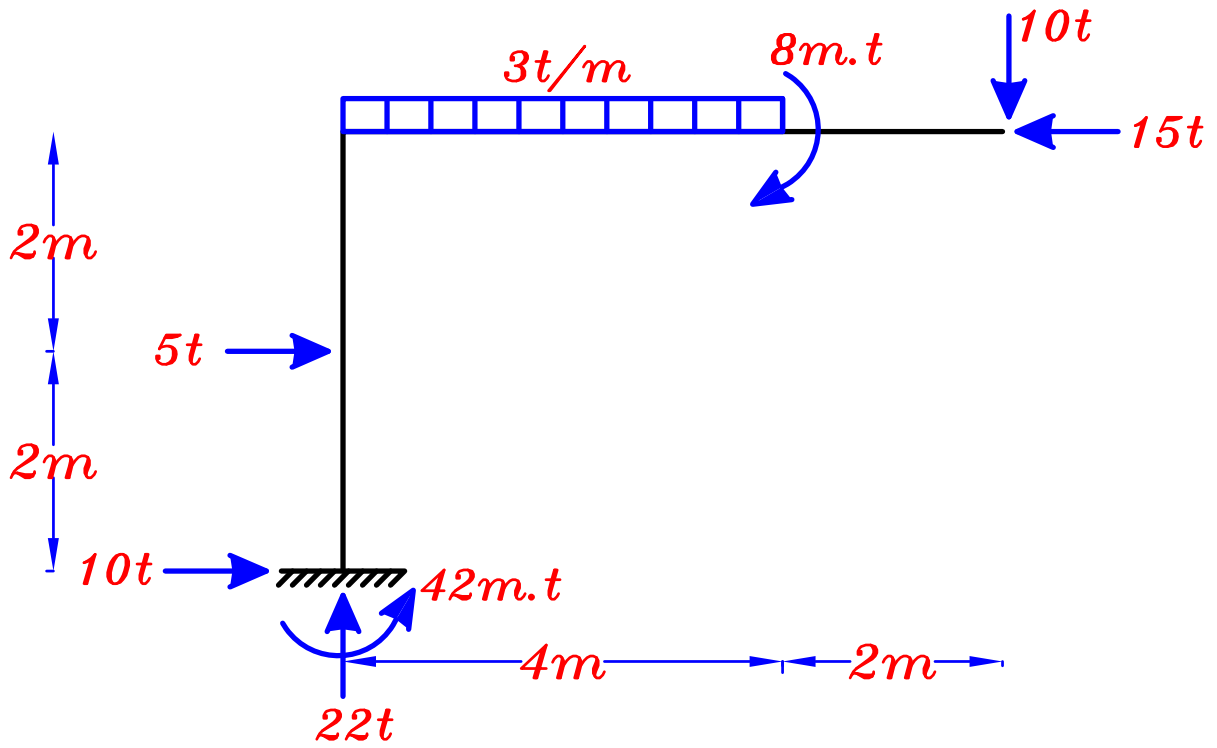
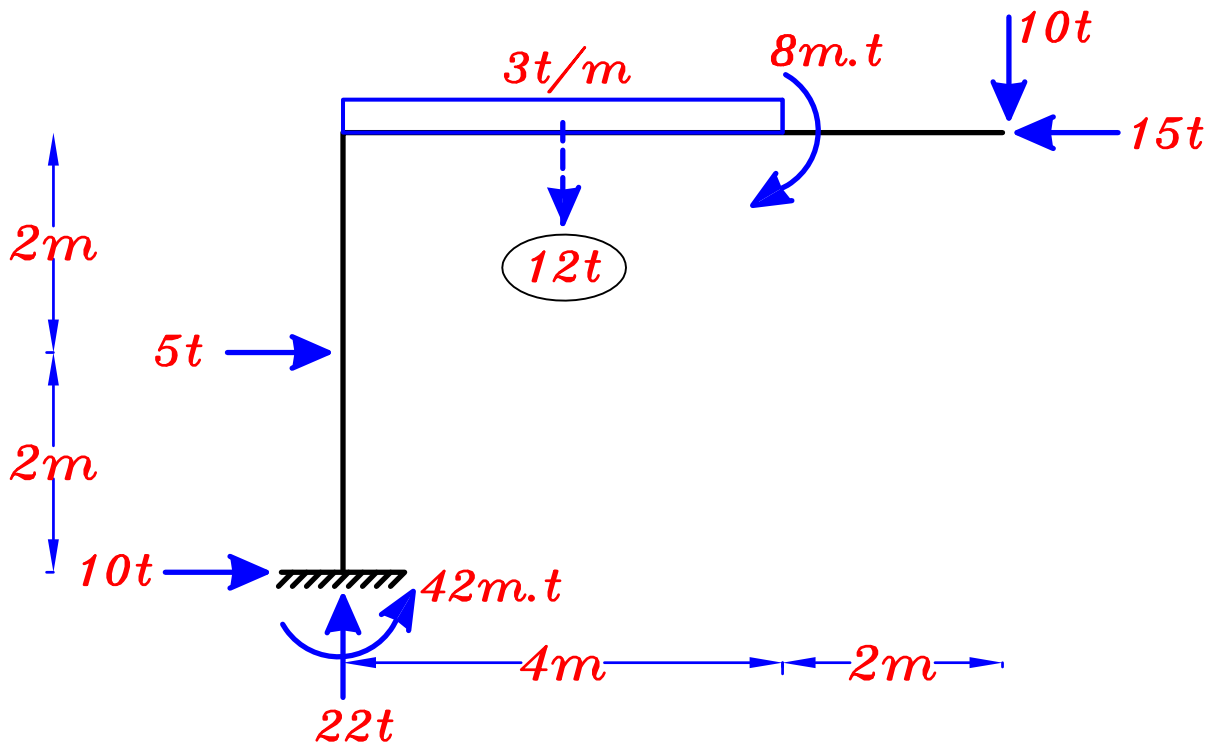
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.





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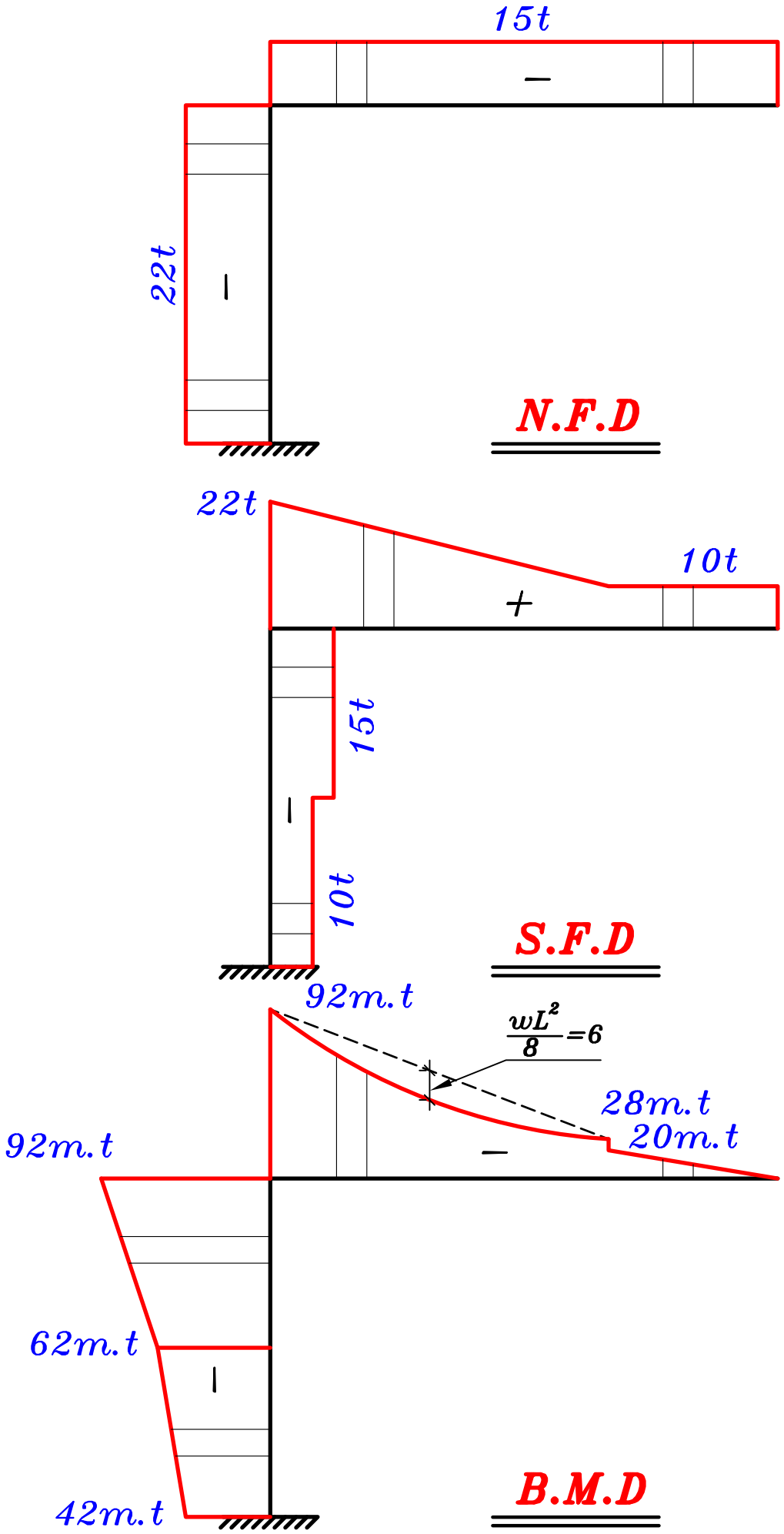

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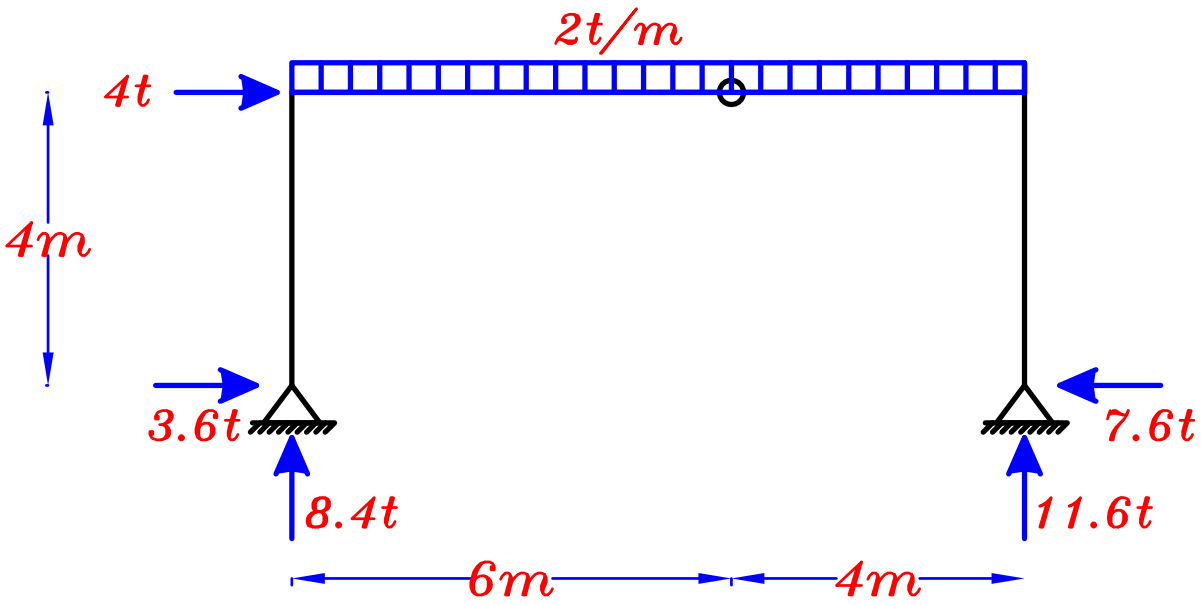
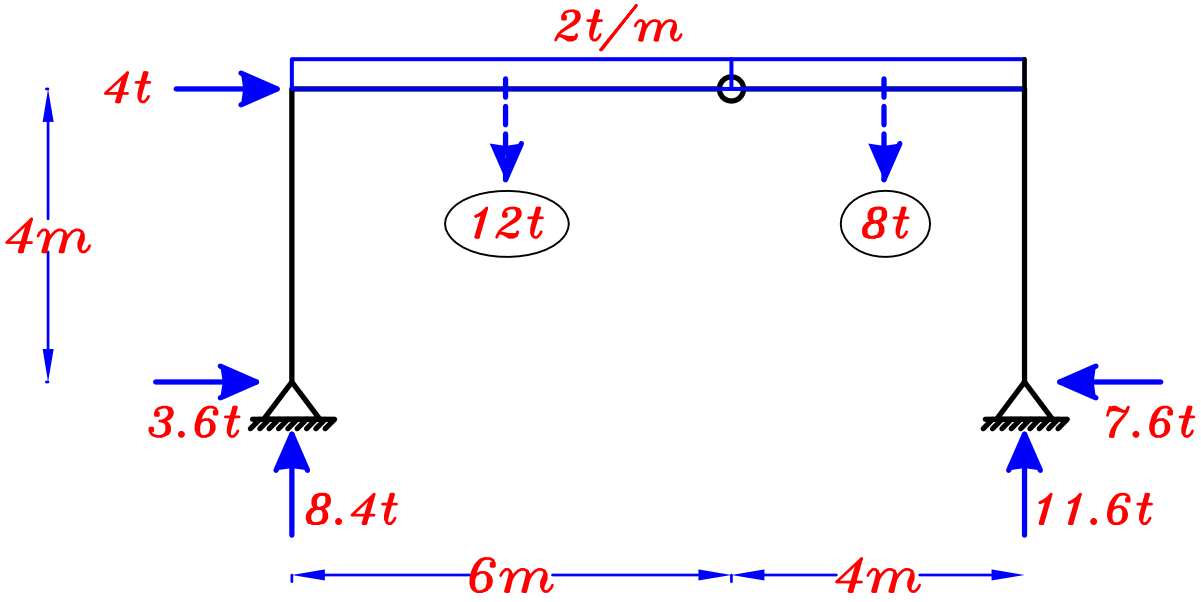
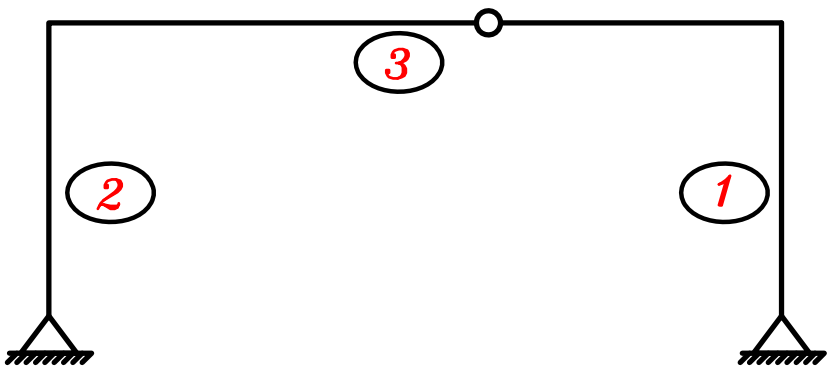
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.







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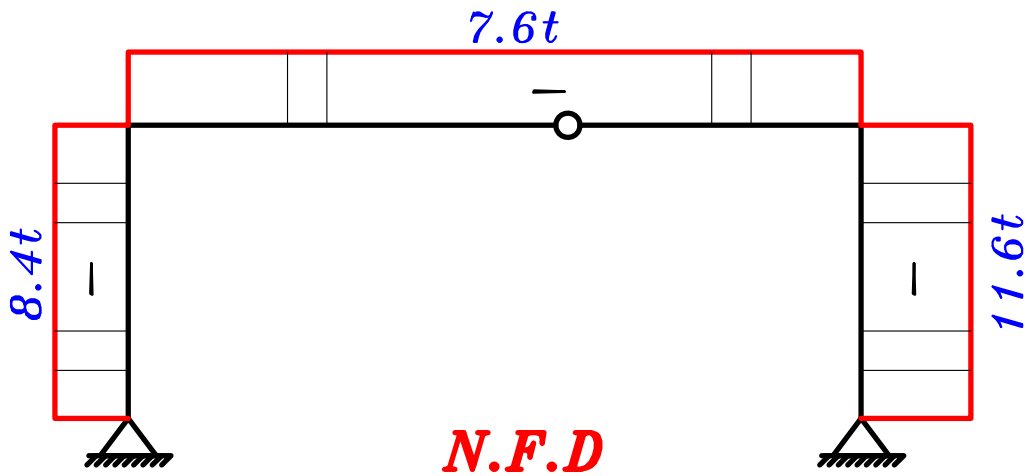
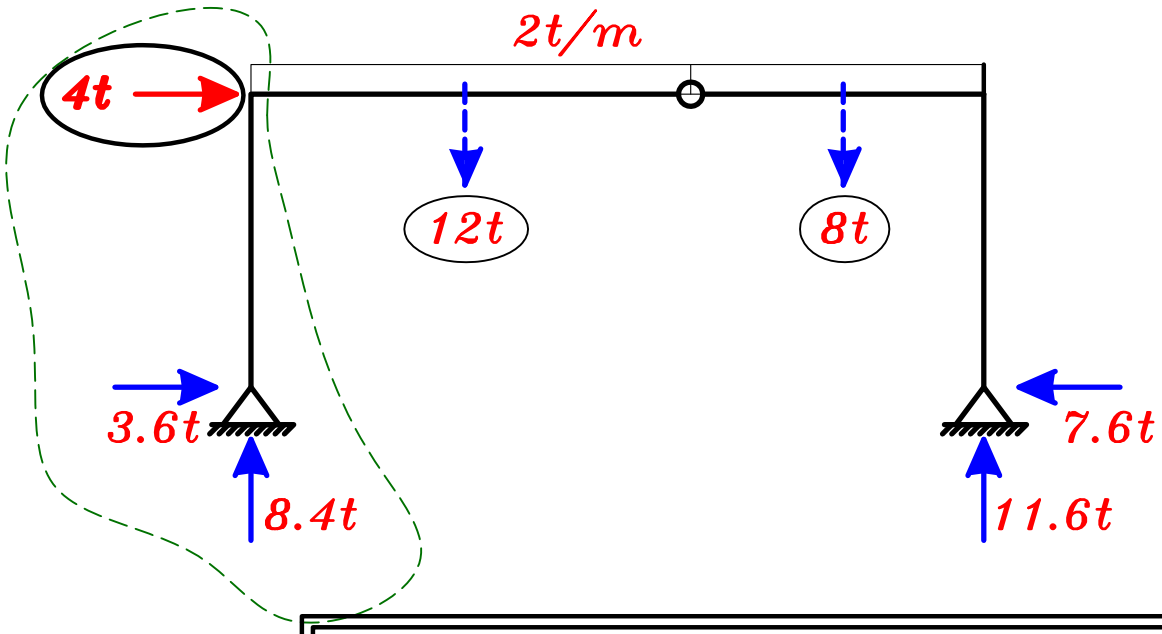


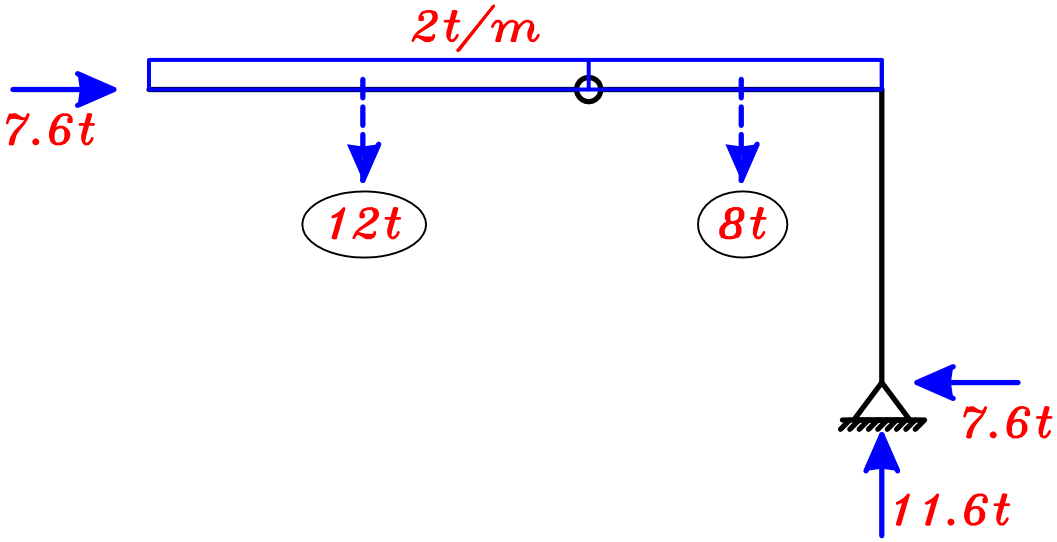
N.F.D

لرسم الـ *N.F.D* فى *member(3)* لابد أن نقطع فى الـ*member* ونجمع الـ *Forces* من الناحية اللى قطعنا منها .



خد بالك الـ *4t* دخلت معنا فى الحسابات

ولكن قيمة الـ*Normal* فى الـ*member* ليست *4t*



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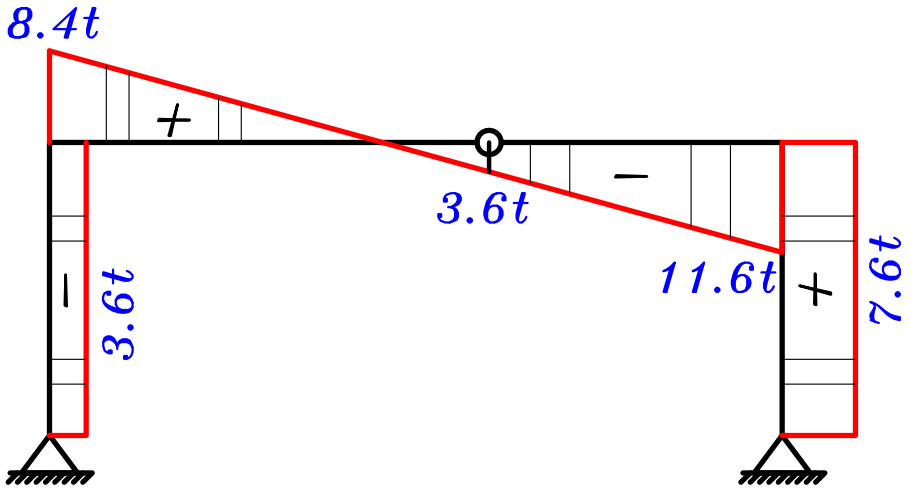
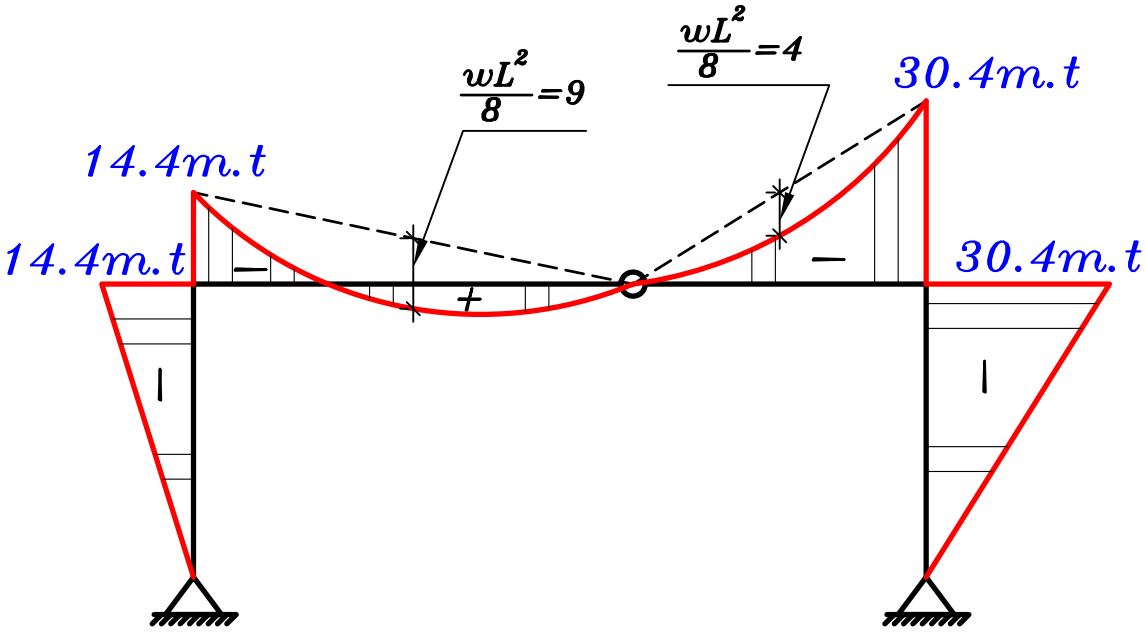


S.F.D



B.M.D

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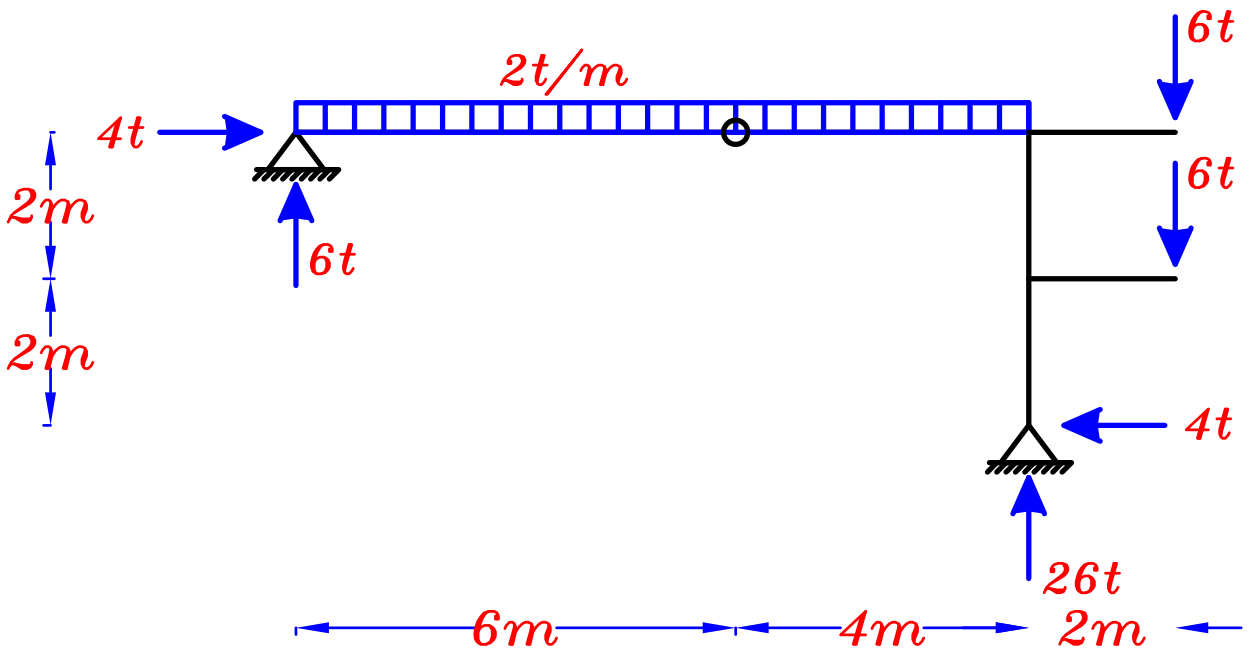
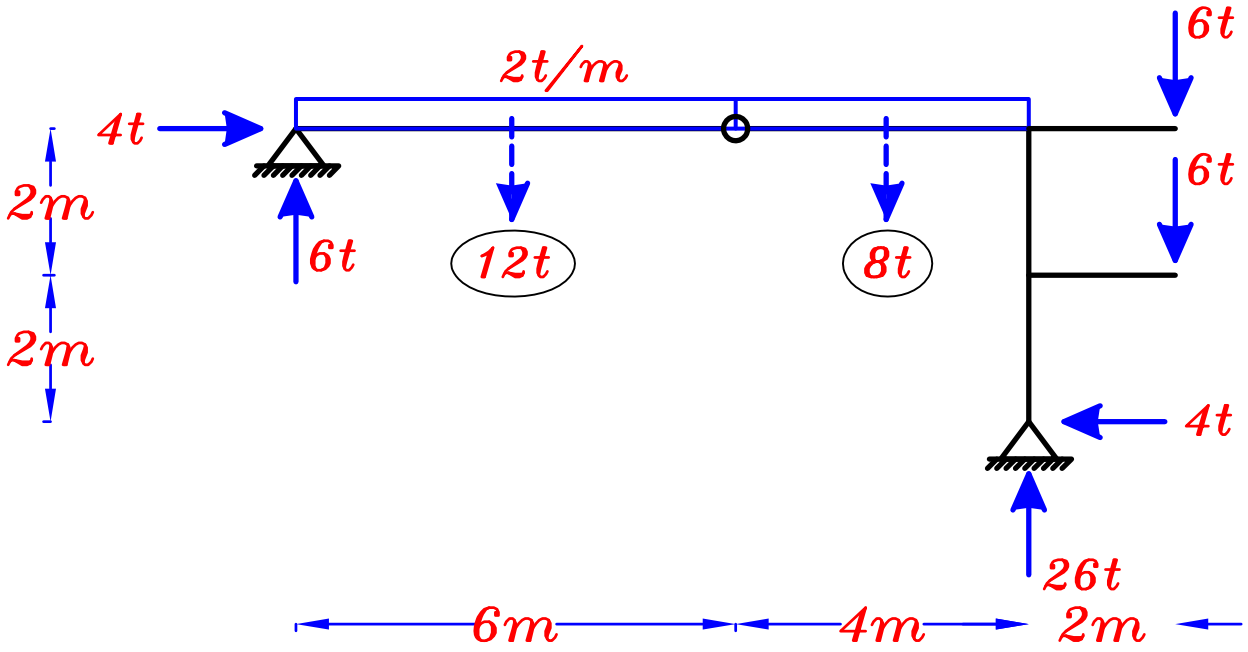
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.





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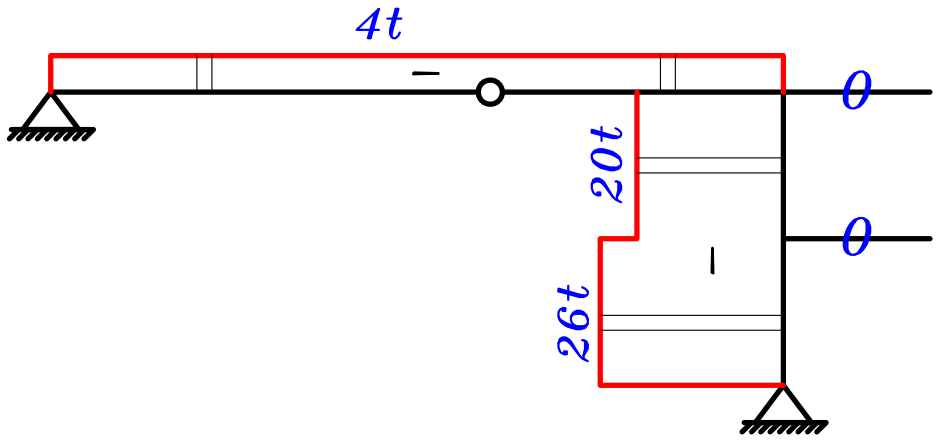
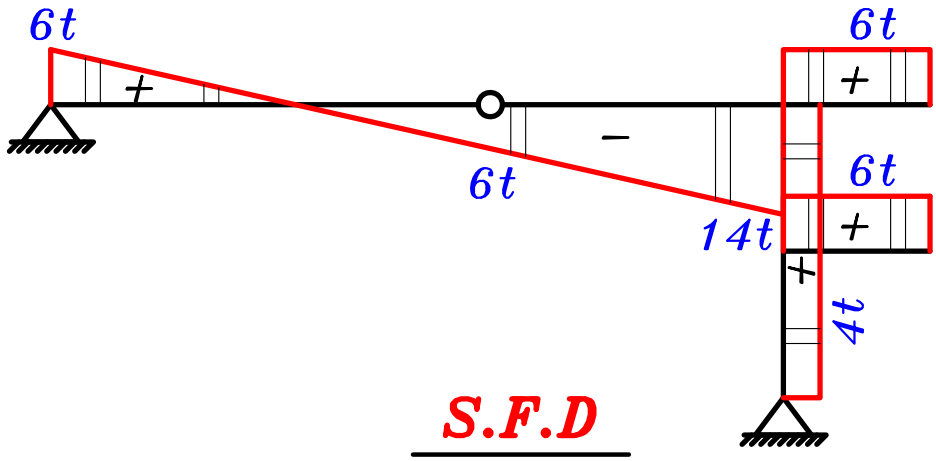
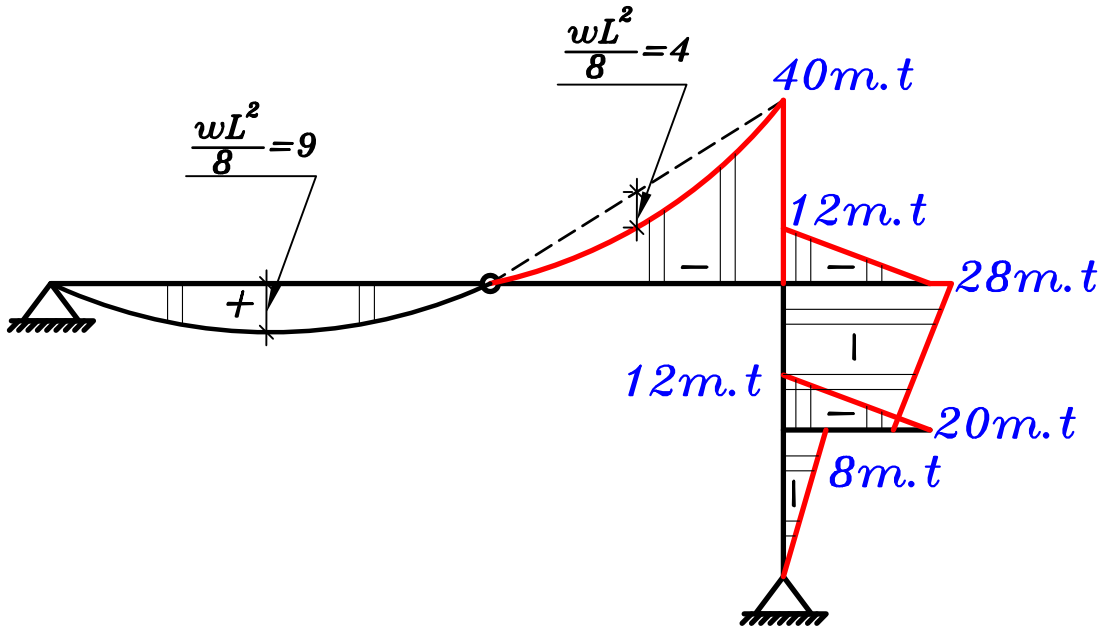


N.F.D



S.F.D



B.M.D

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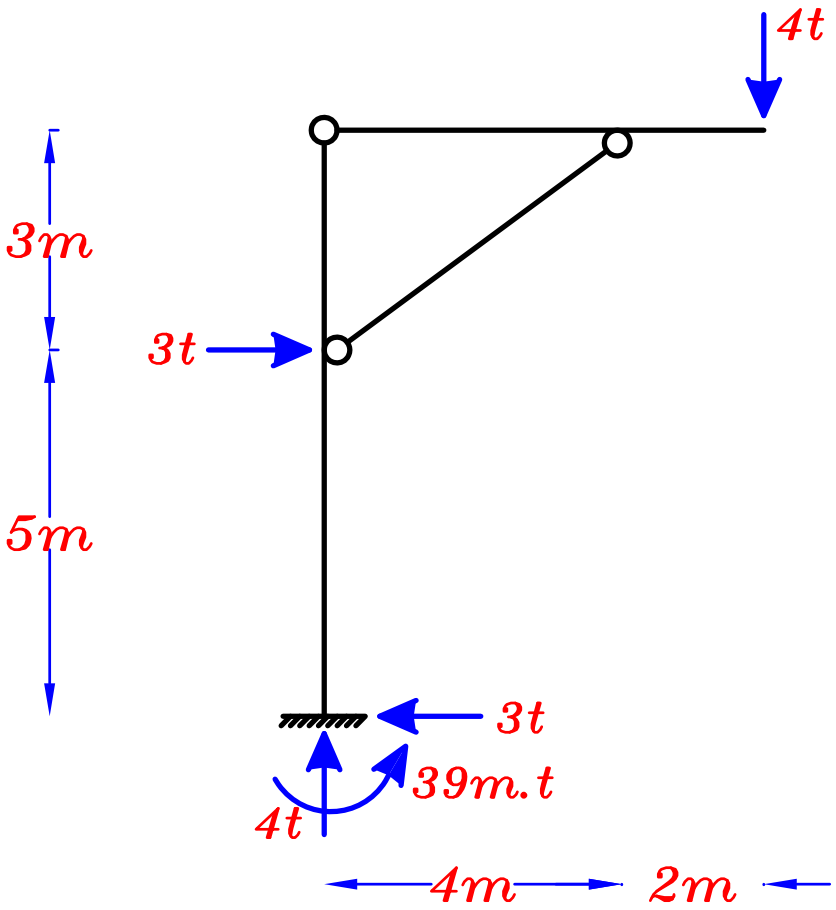
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.



ملحوظة هامة جدا جدا

فى حالة الClosed Frame لابد من فك الFrame (فتح الـ Frame)
و ايجاد الForces الناتجة من الفتح ثم نقوم بعد ذلك
برسم الInternal Forces diagrams .

و لفتح هذا الـ Frame لابد من قطع الLink member و ايجاد القوة اللى فيه .

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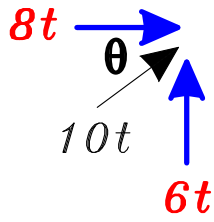
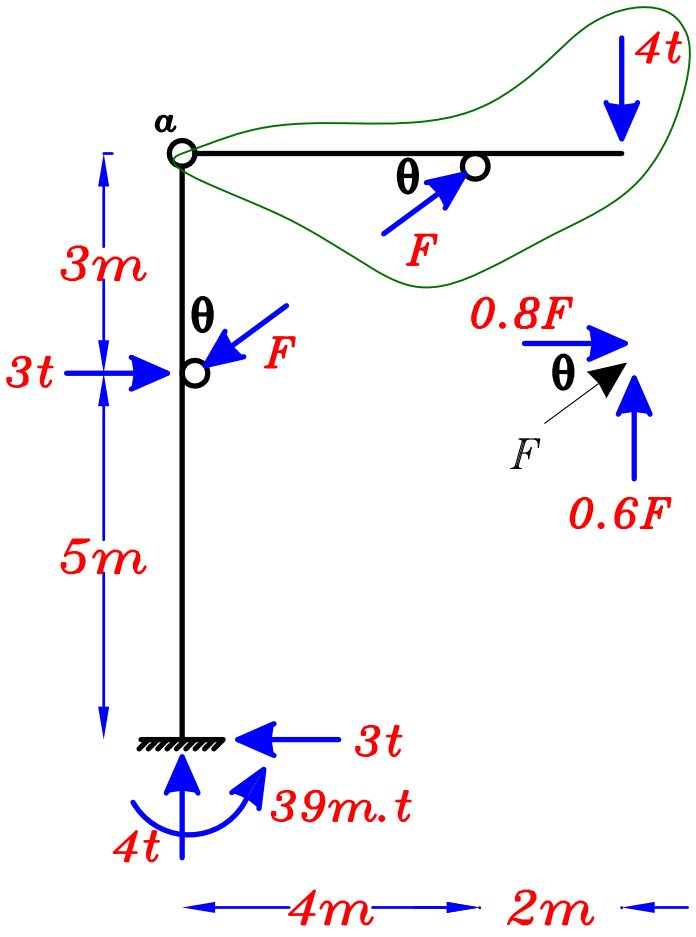
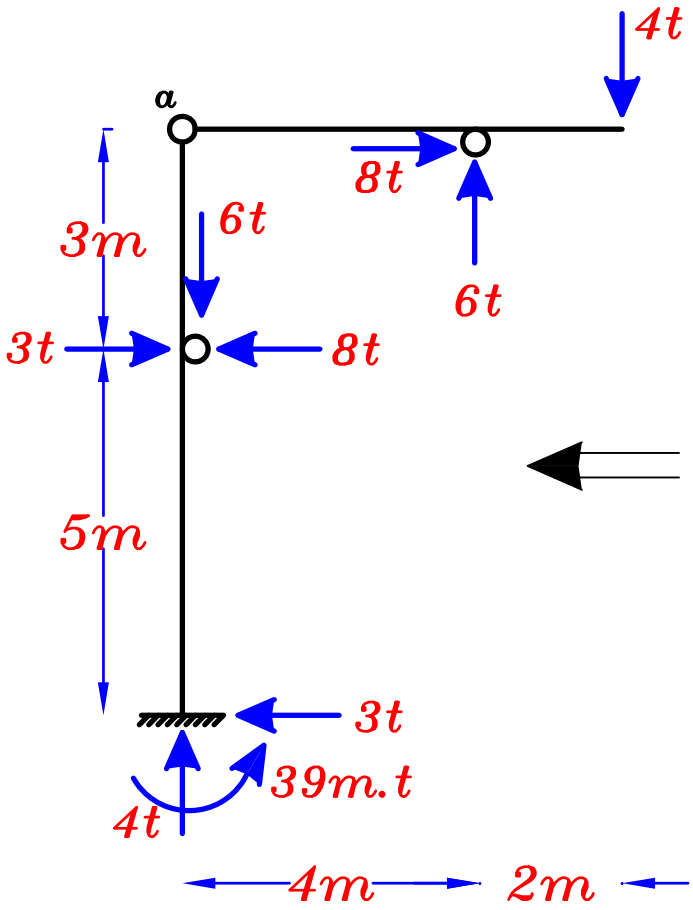
$$\Sigma M \ @ \ a \ right = 0$$

$$4 \ x \ 6 - 0.6F \ x \ 4 = 0$$

$$\boxed{F = 10 \ t}$$







هذا الـ *Frame* هو الذى

نرسم منه الـ *Diagrams*

ملحوظة هامة جدا جدا

عند رسم الـ *Internal Forces diagrams* لابد من رسم الـ *Link*

و كالعادة يكون الـ *Link member* مرسوم عليه قوة فى الـ *N.F.D* فقط

و يكون فى الـ *S.F.D* و الـ *B.M.D* مرسوم و لكن عليه .

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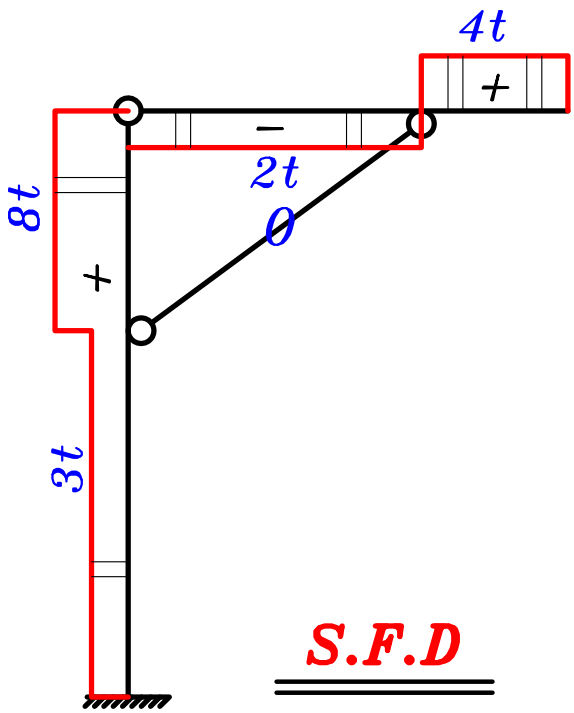
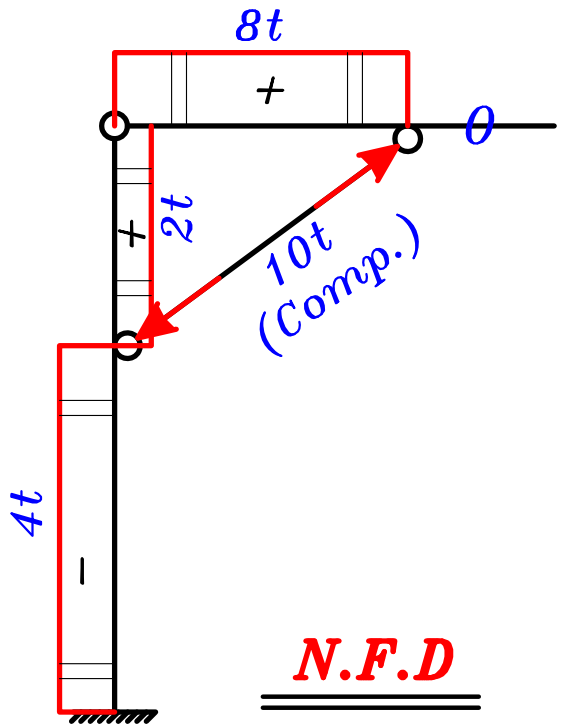
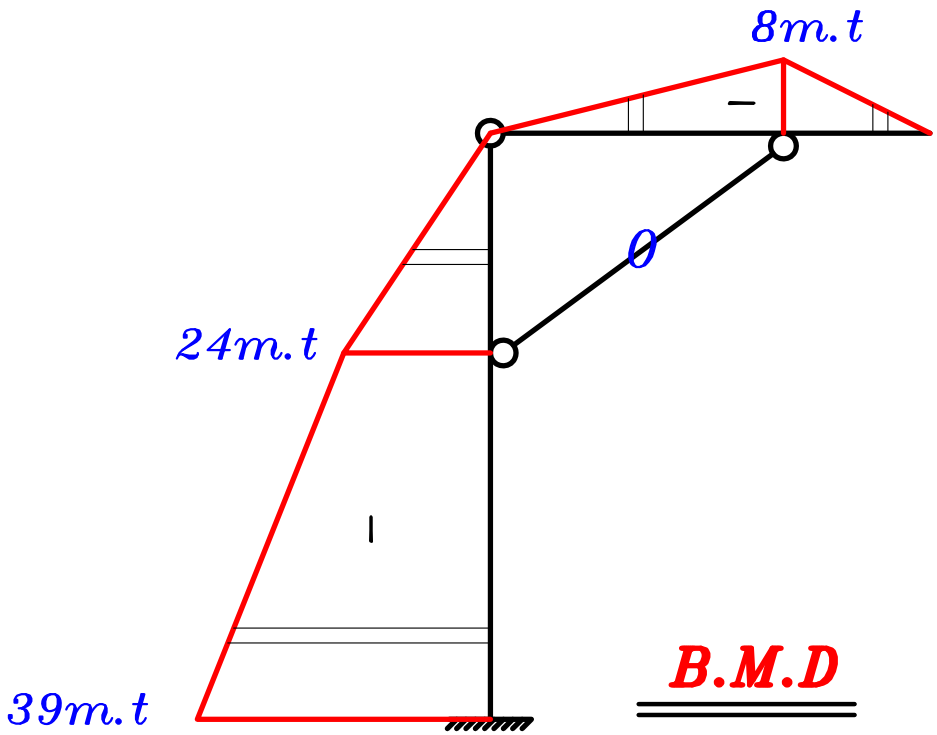


S.F.D



N.F.D



B.M.D

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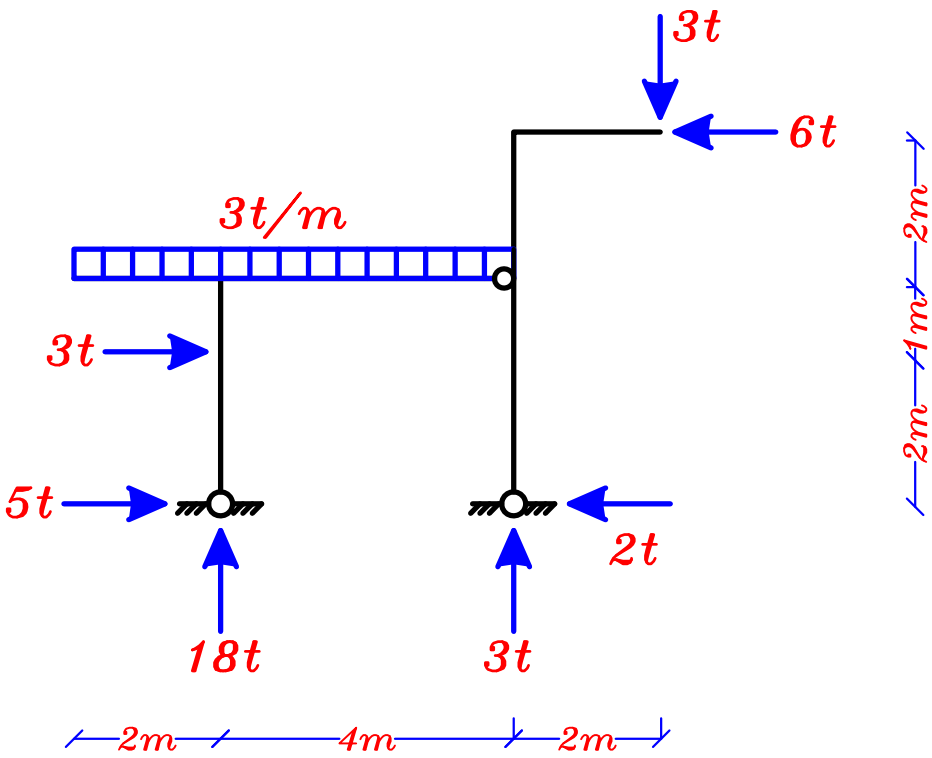
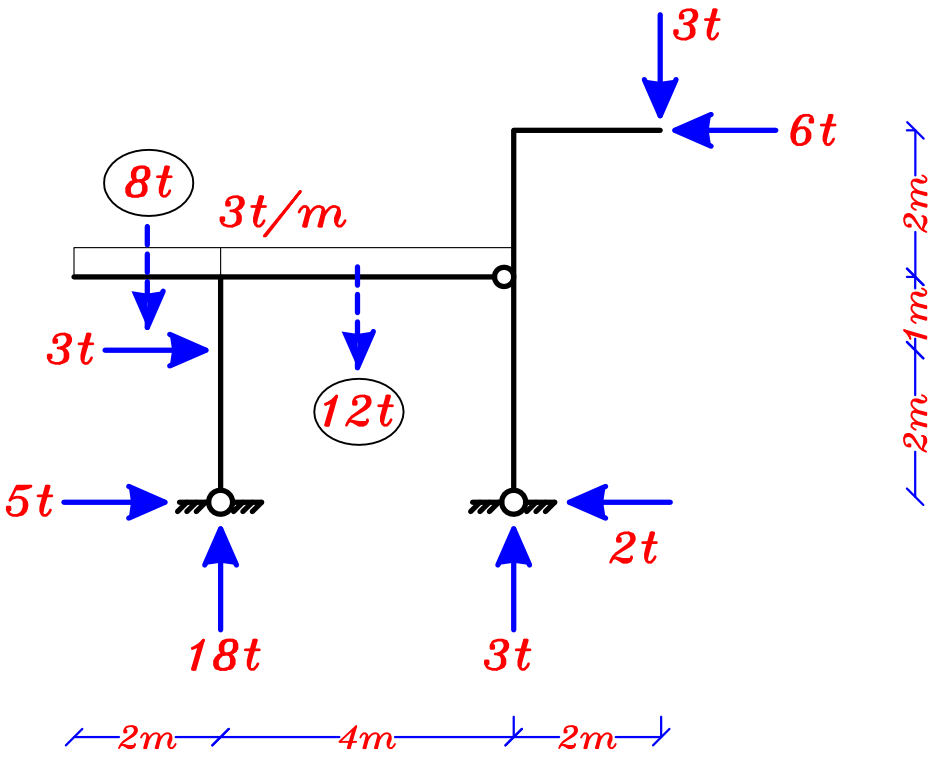
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.





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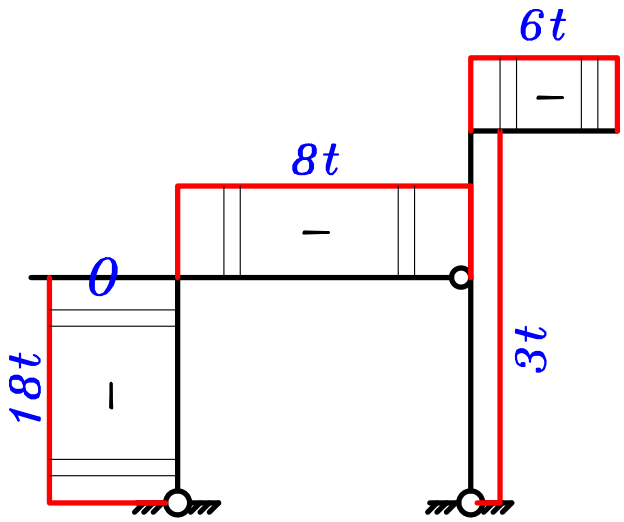
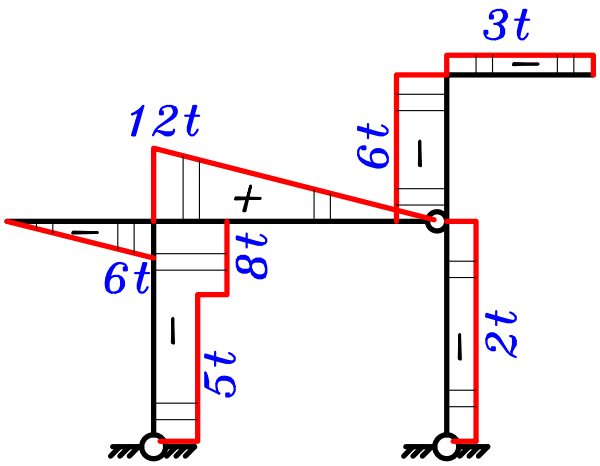
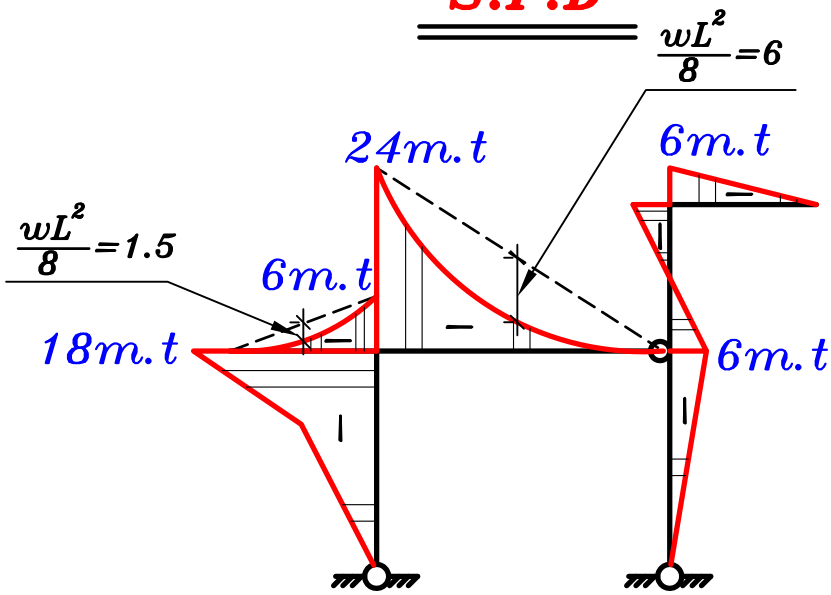


N.F.D



S.F.D



B.M.D

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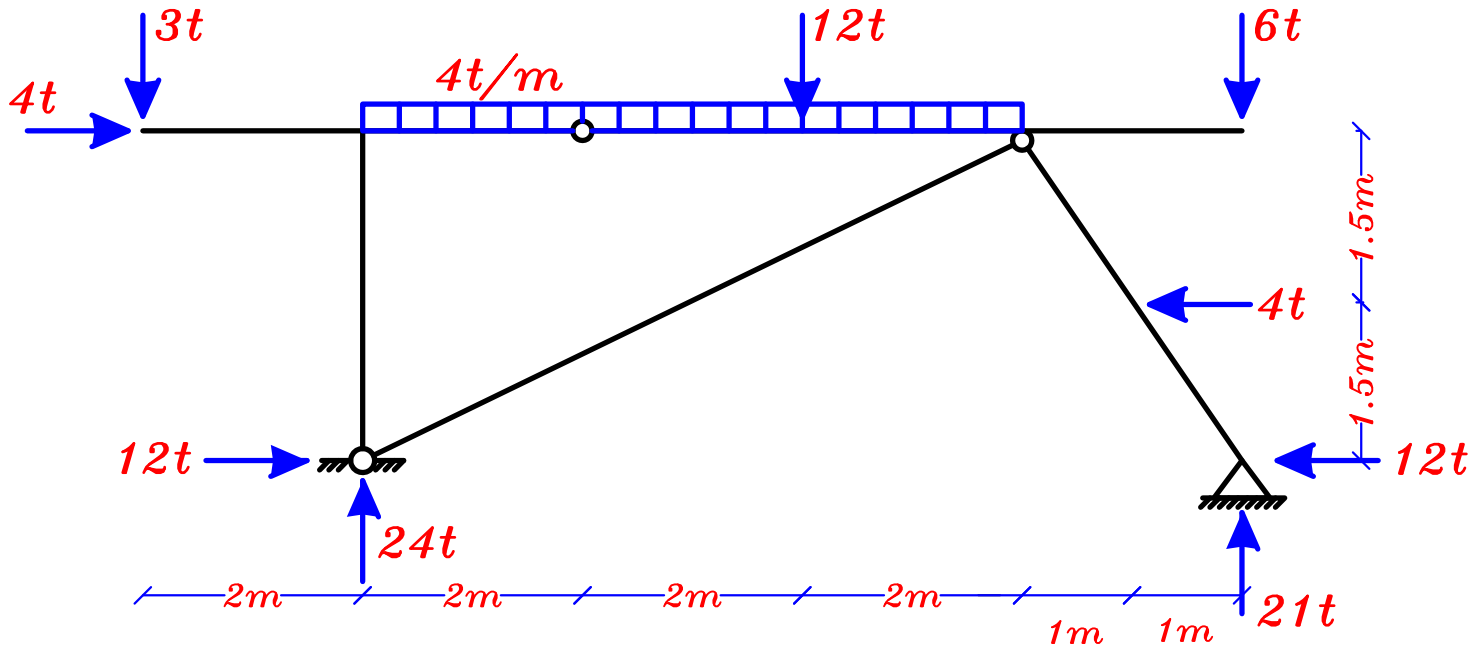
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.



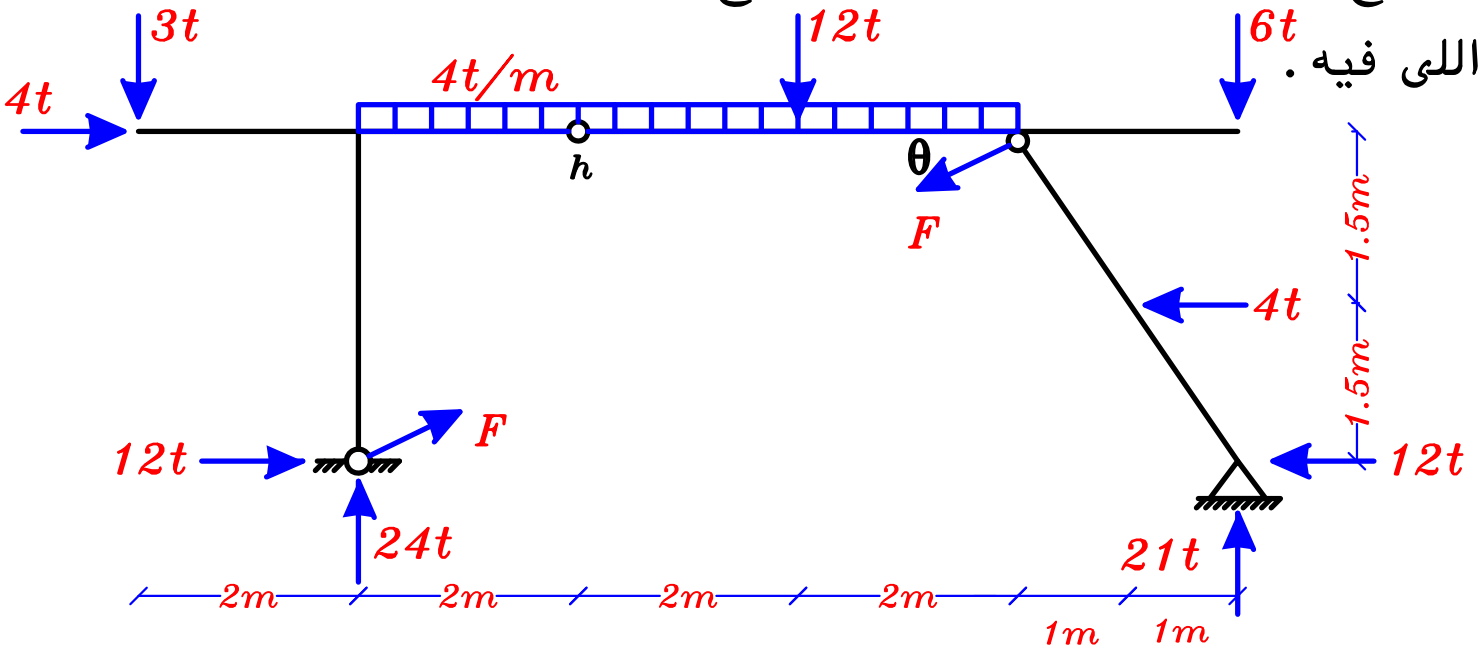
ملحوظة هامة جدا جدا

فى حالة الClosed Frame لابد من فك الFrame (فتح الـ Frame)

و ايجاد الForces الناتجة من الفتح ثم نقوم بعد ذلك

برسم الInternal Forces diagrams .

و لفتح هذا الـ Frame لابد من قطع الLink member و ايجاد القوة اللى فيه .



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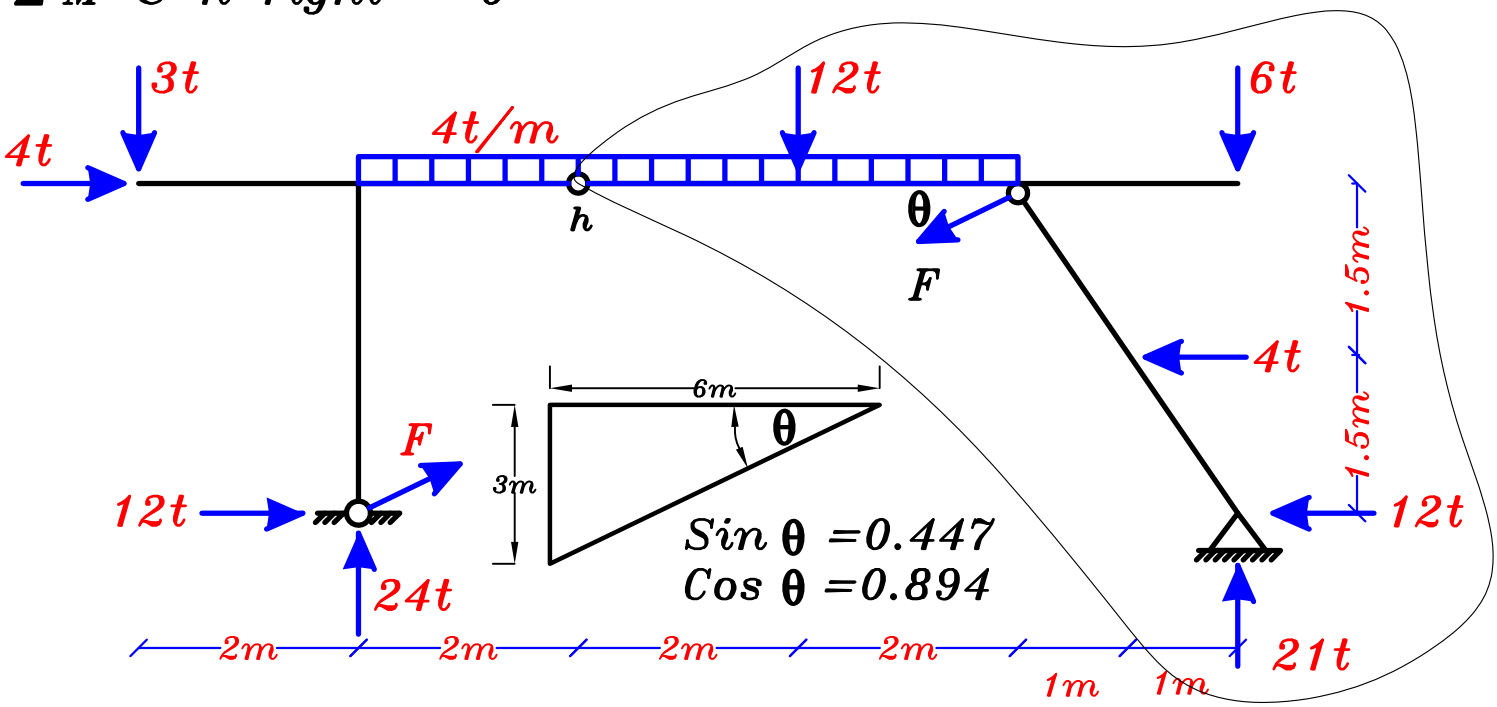
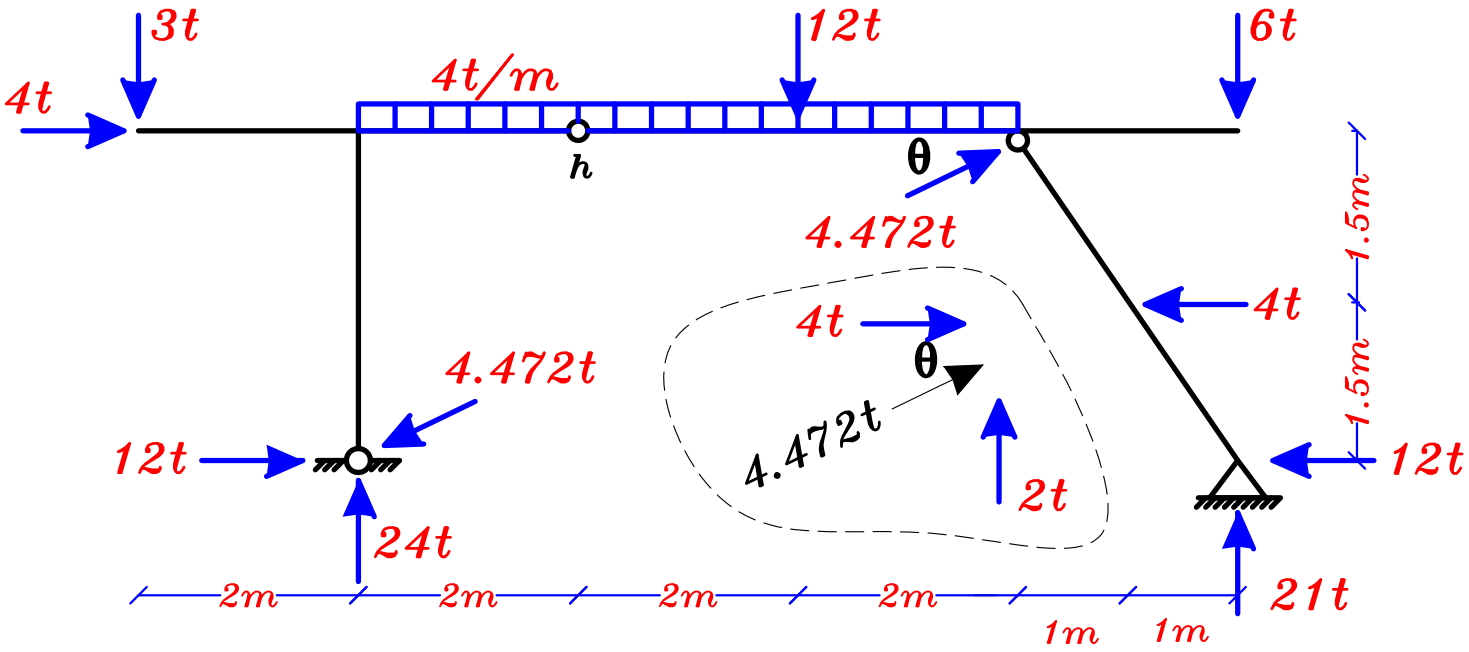
ΣM @ h right $= 0$



$12 \times 2 + 4 \times 4 \times 2 + F \sin \times 4 + 6 \times 6 + 4 \times 1.5$

$+12 \times 3 - 21 \times 6 = 0$

$F = -4.472$ (comp.)



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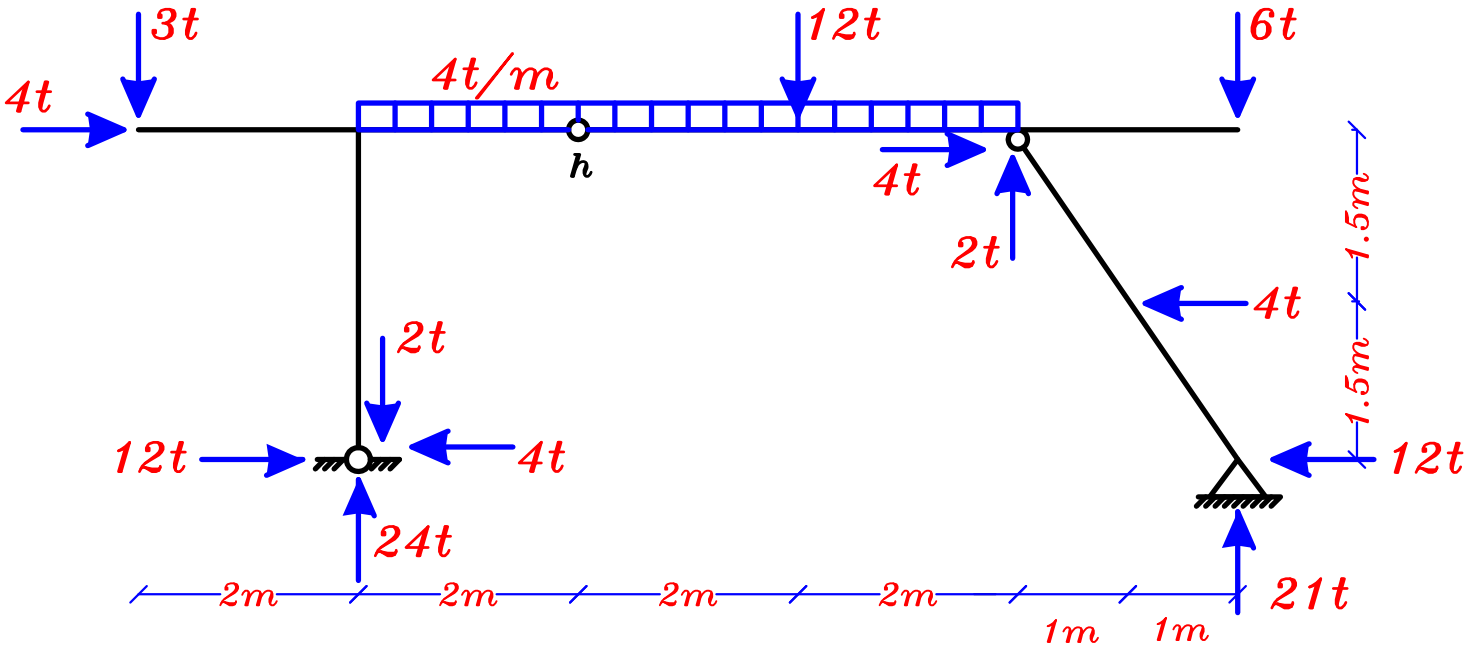

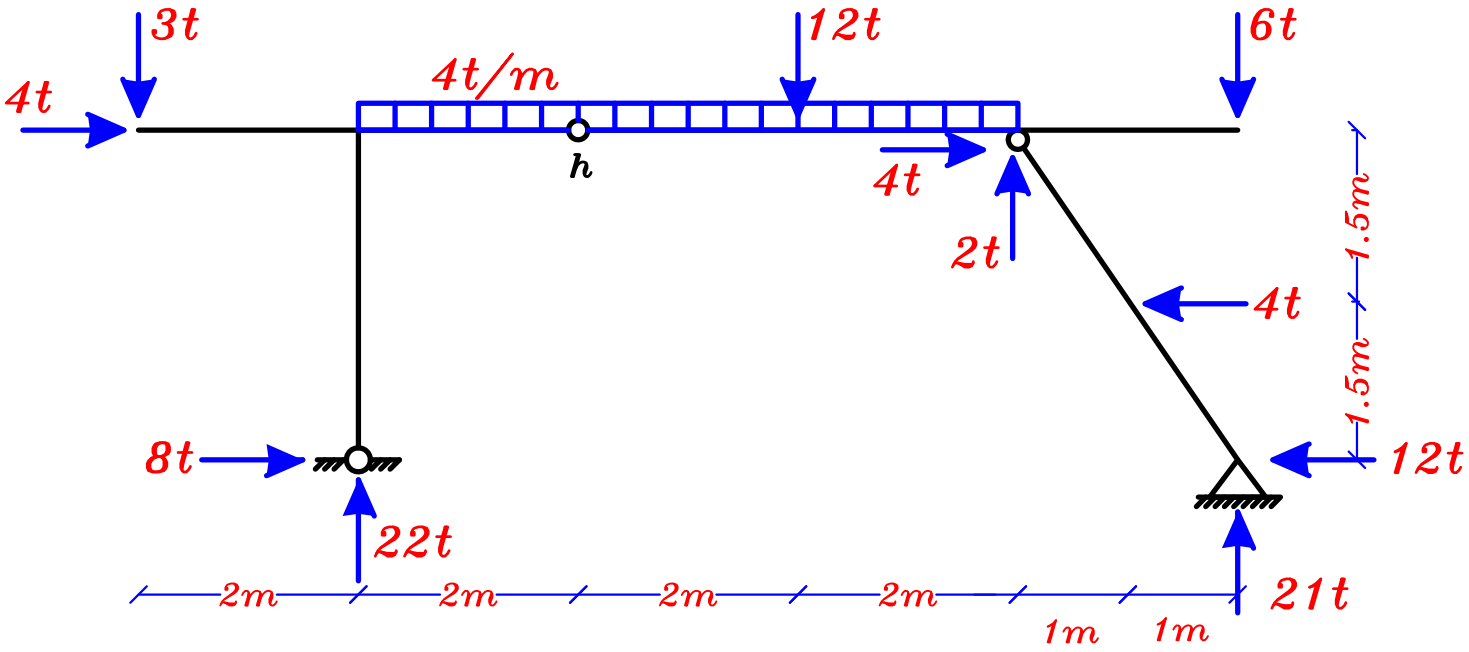

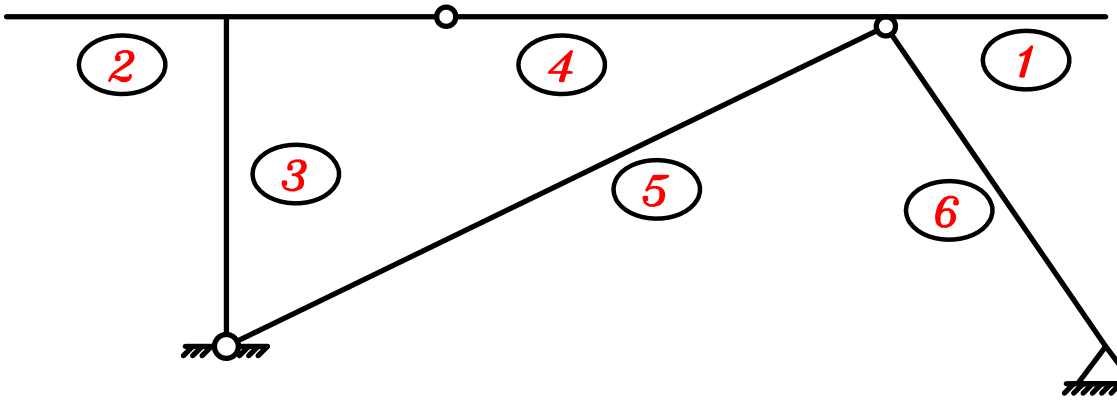

نرسم الـ $N.F.D$ و الـ **S.F.D** و الـ **B.M.D** على الـ members من 1 الى 5

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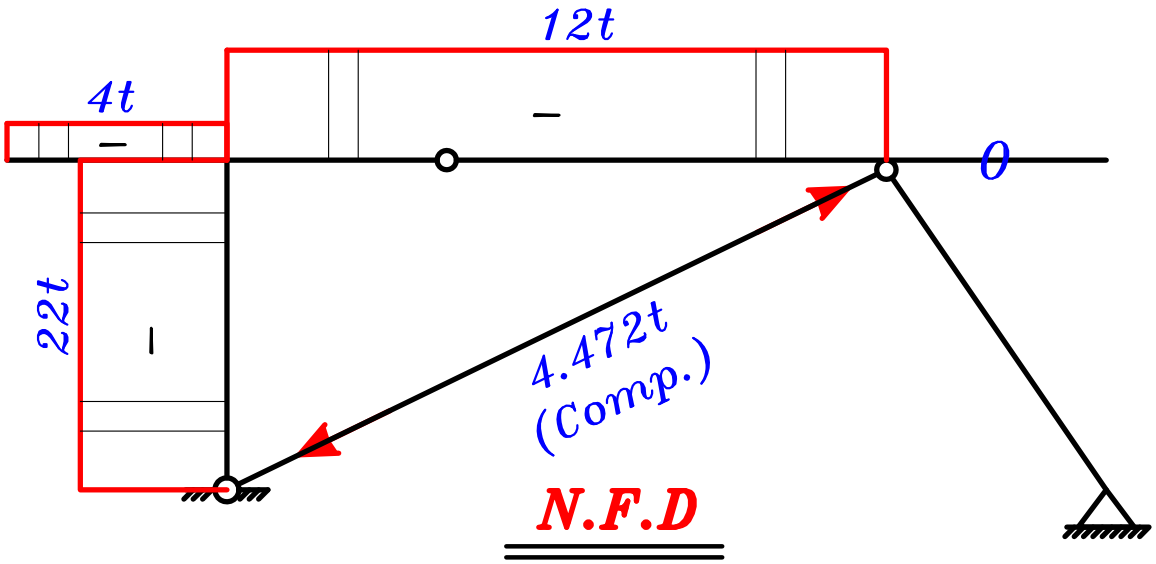
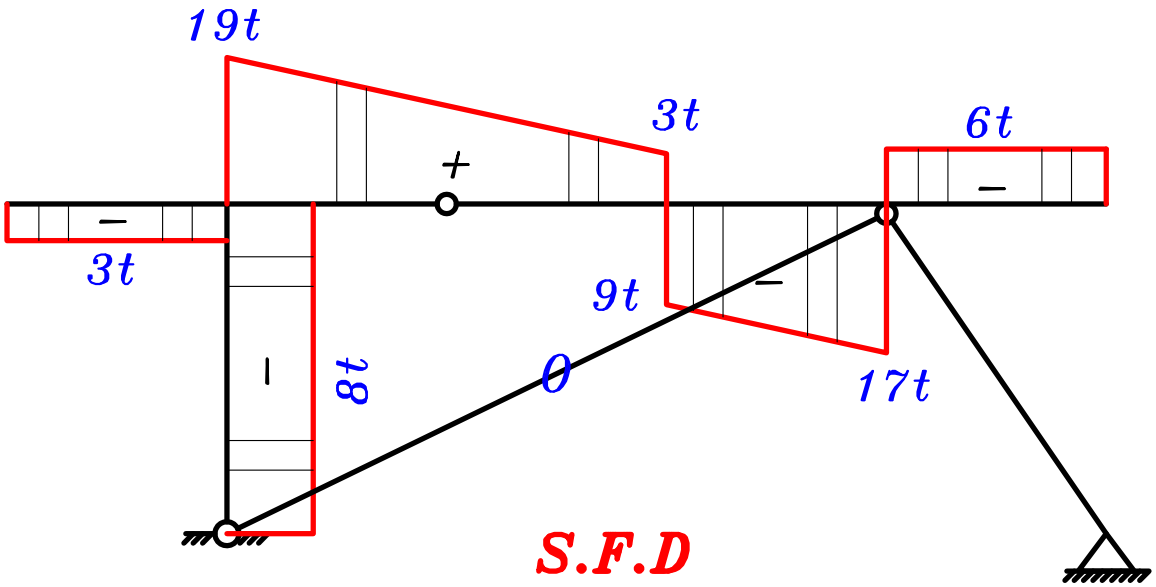
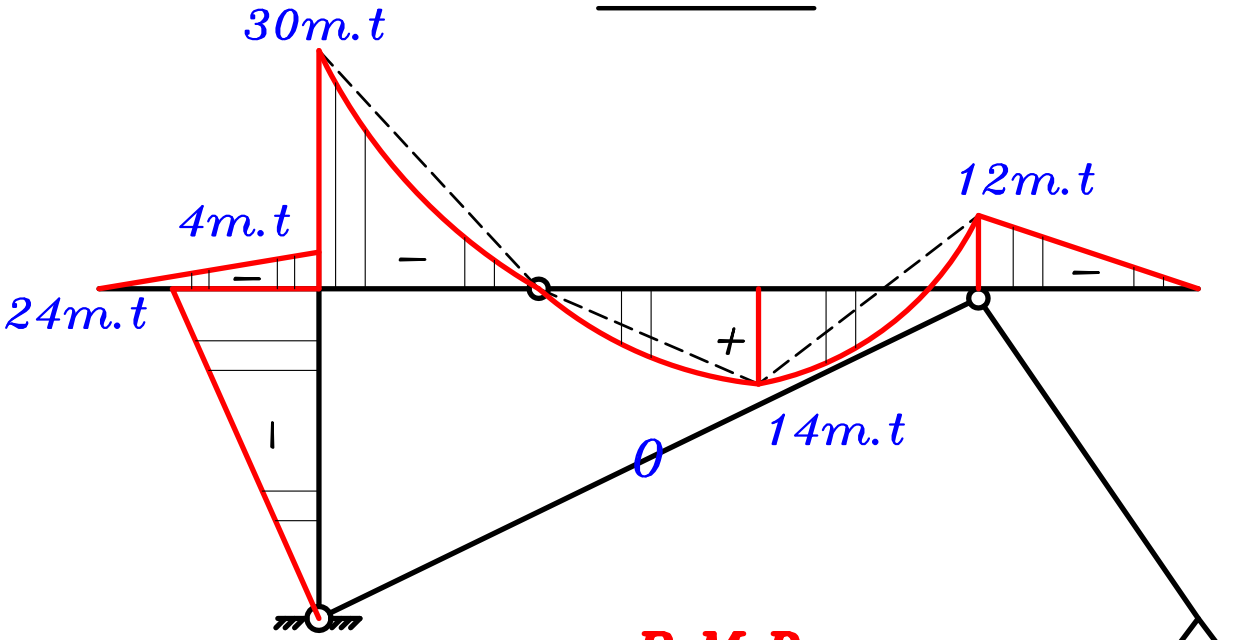


N.F.D



S.F.D



B.M.D

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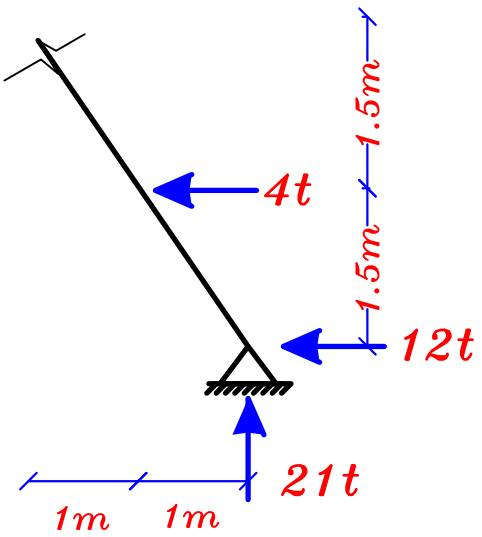
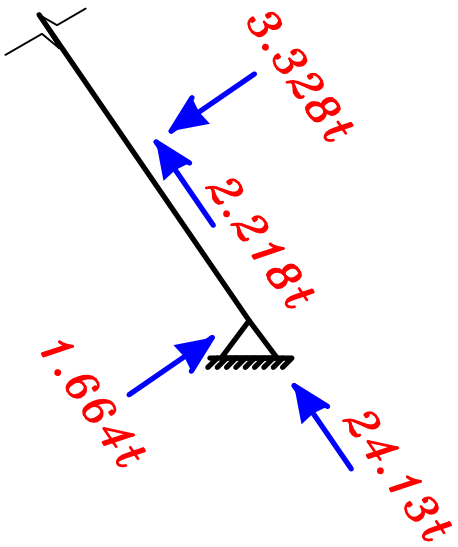
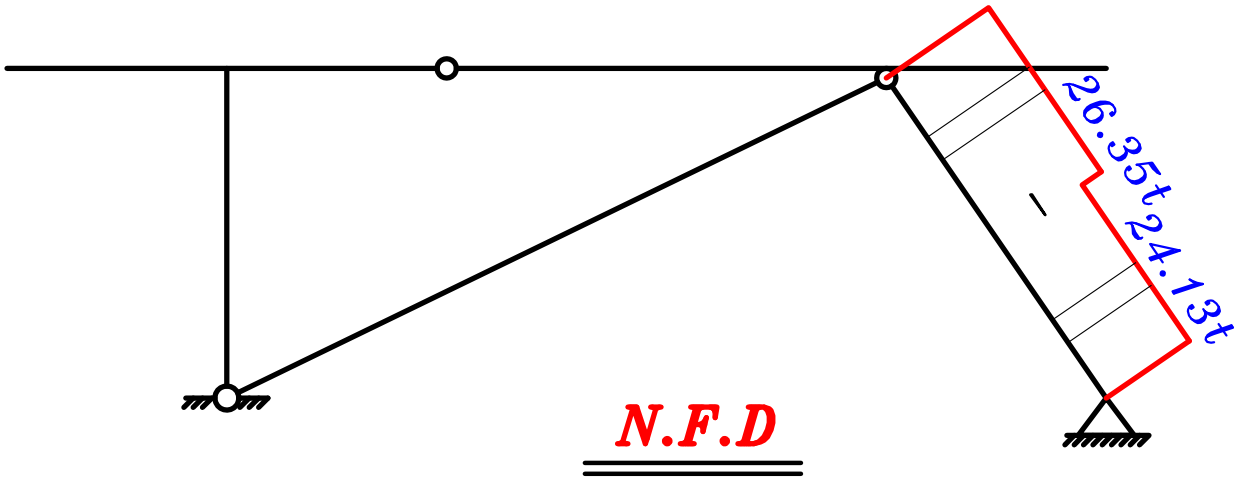
ثم نرسم الـ **N.F.D** و الـ **S.F.D** و الـ **B.M.D** على *member 6*

و لانه *member* مائل و له طرف حر لابد من تحليل القوى فى اتجاه الـ *member* و فى الاتجاه العمودى عليه .

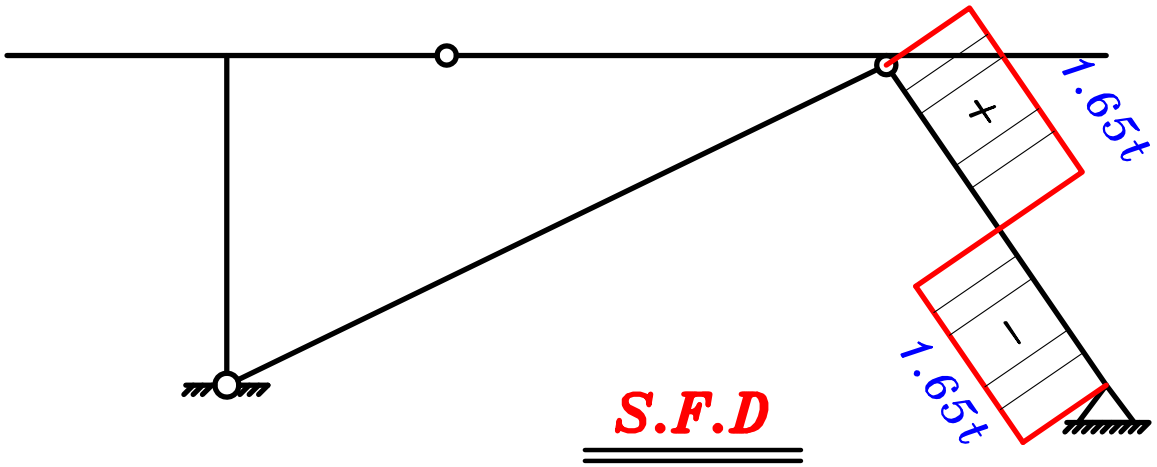




و طبعا عند الرسم نبدأ من الطرف الحر .



N.F.D



S.F.D

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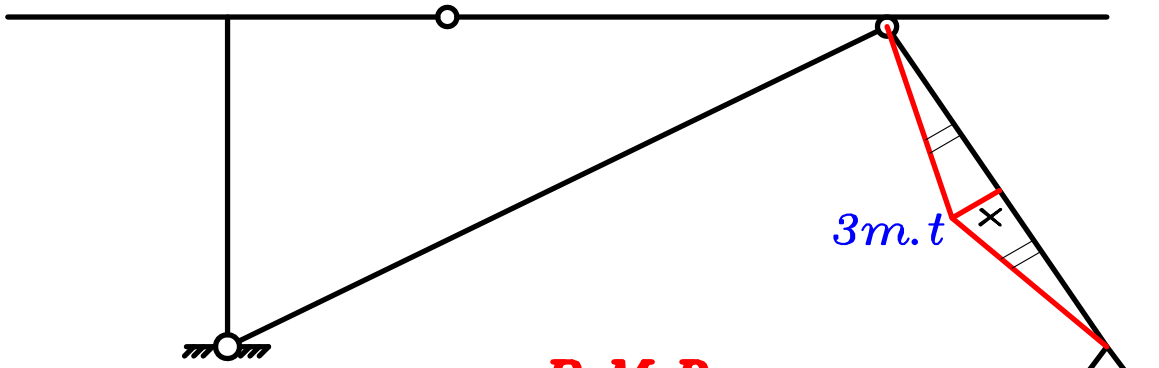
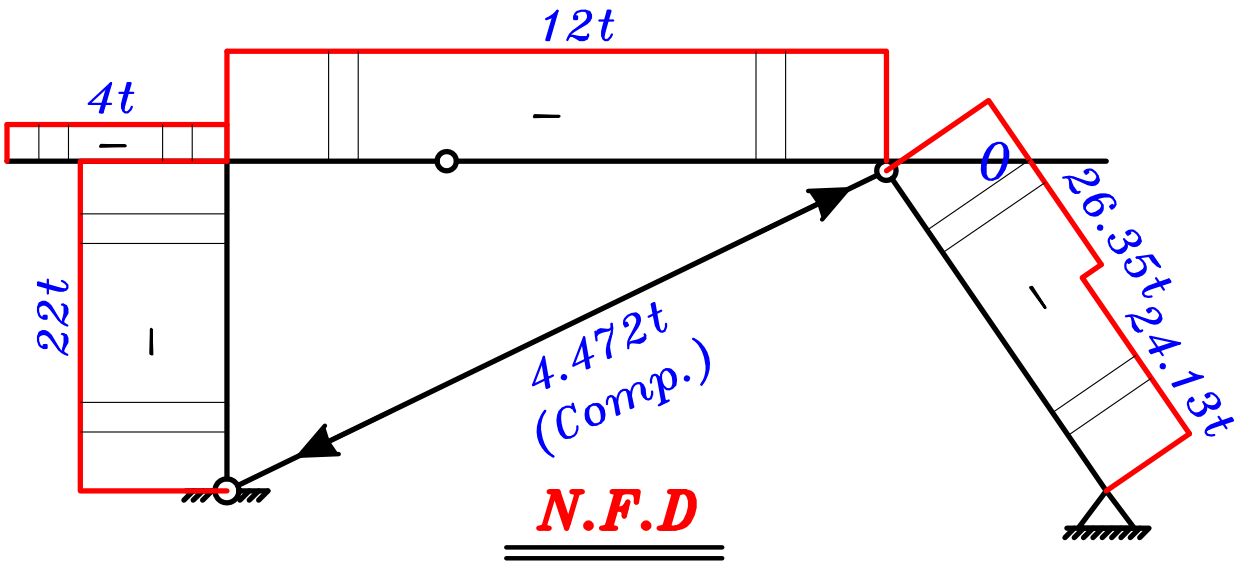
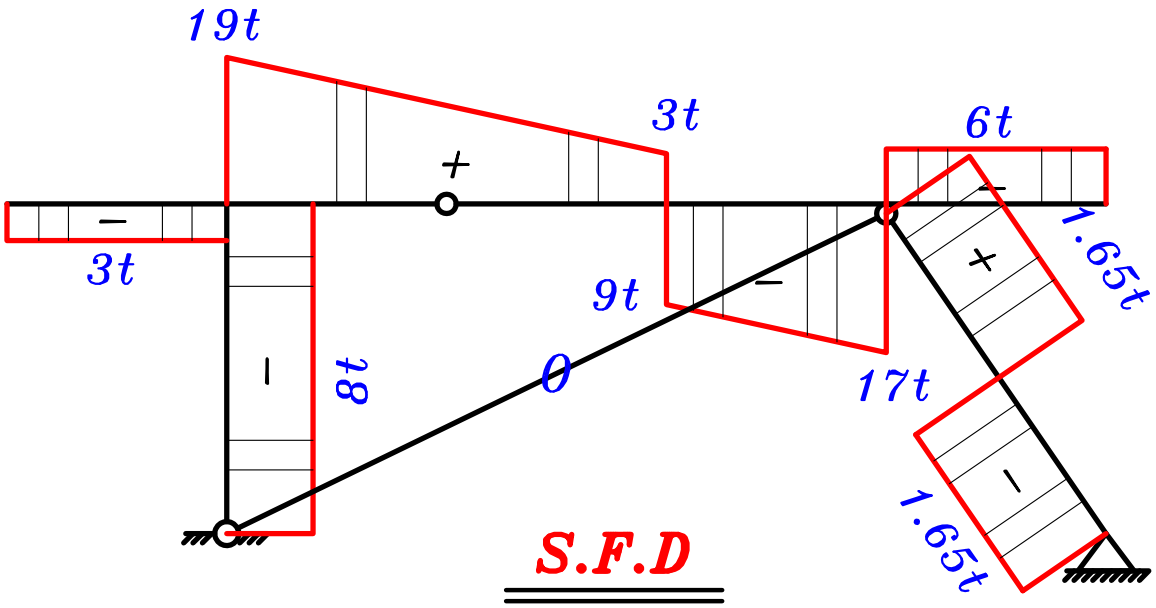


B.M.D

و بالتالى يكون شكل الـ *Diagrams* الاخير :



N.F.D



S.F.D

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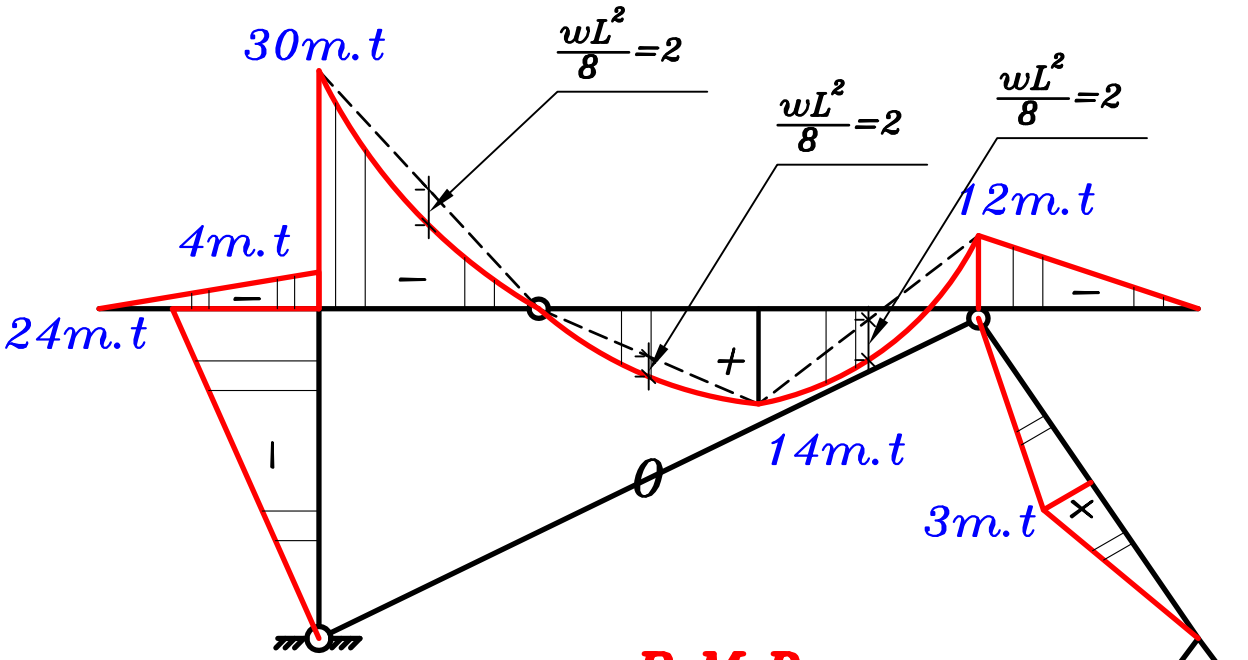

B.M.D

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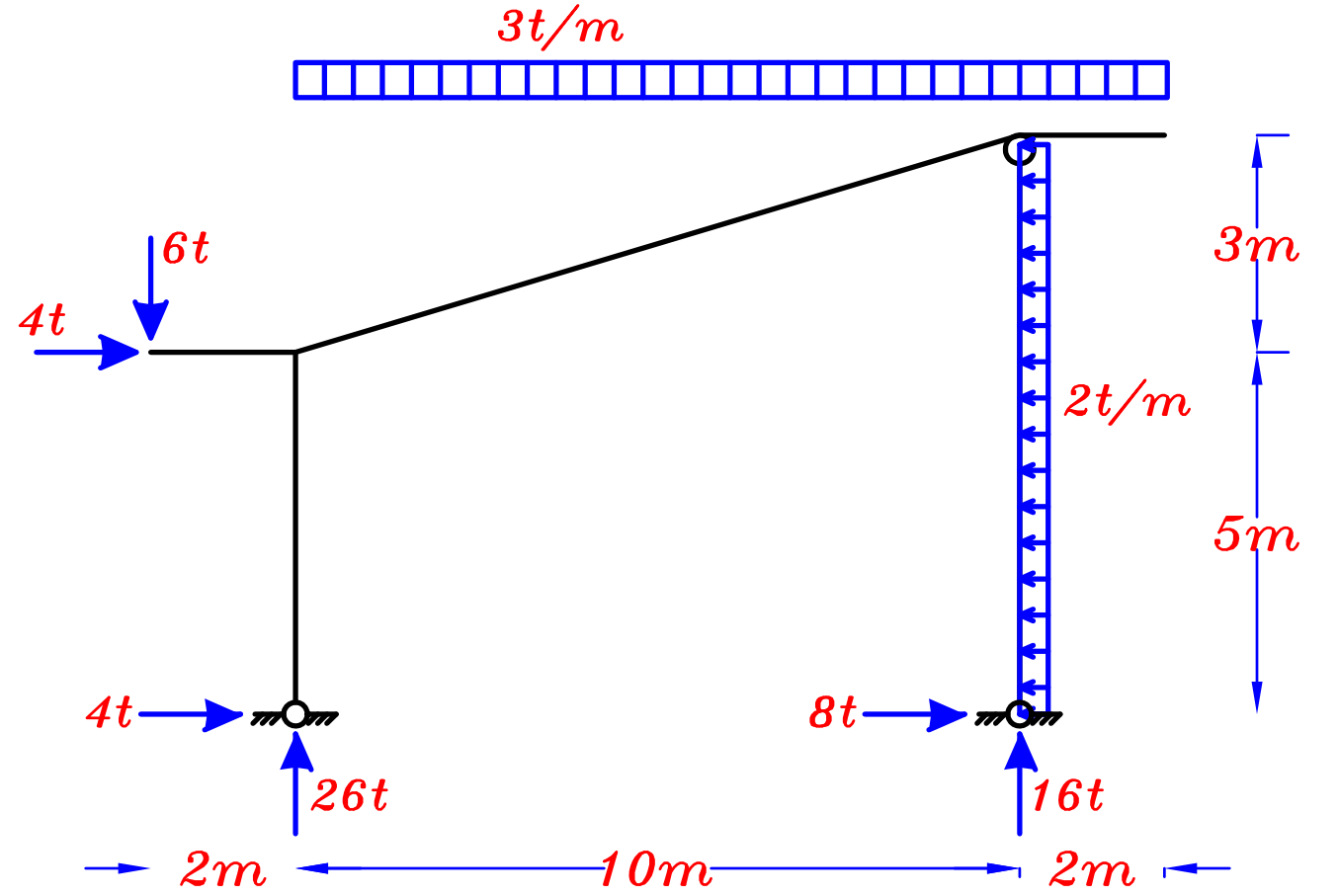
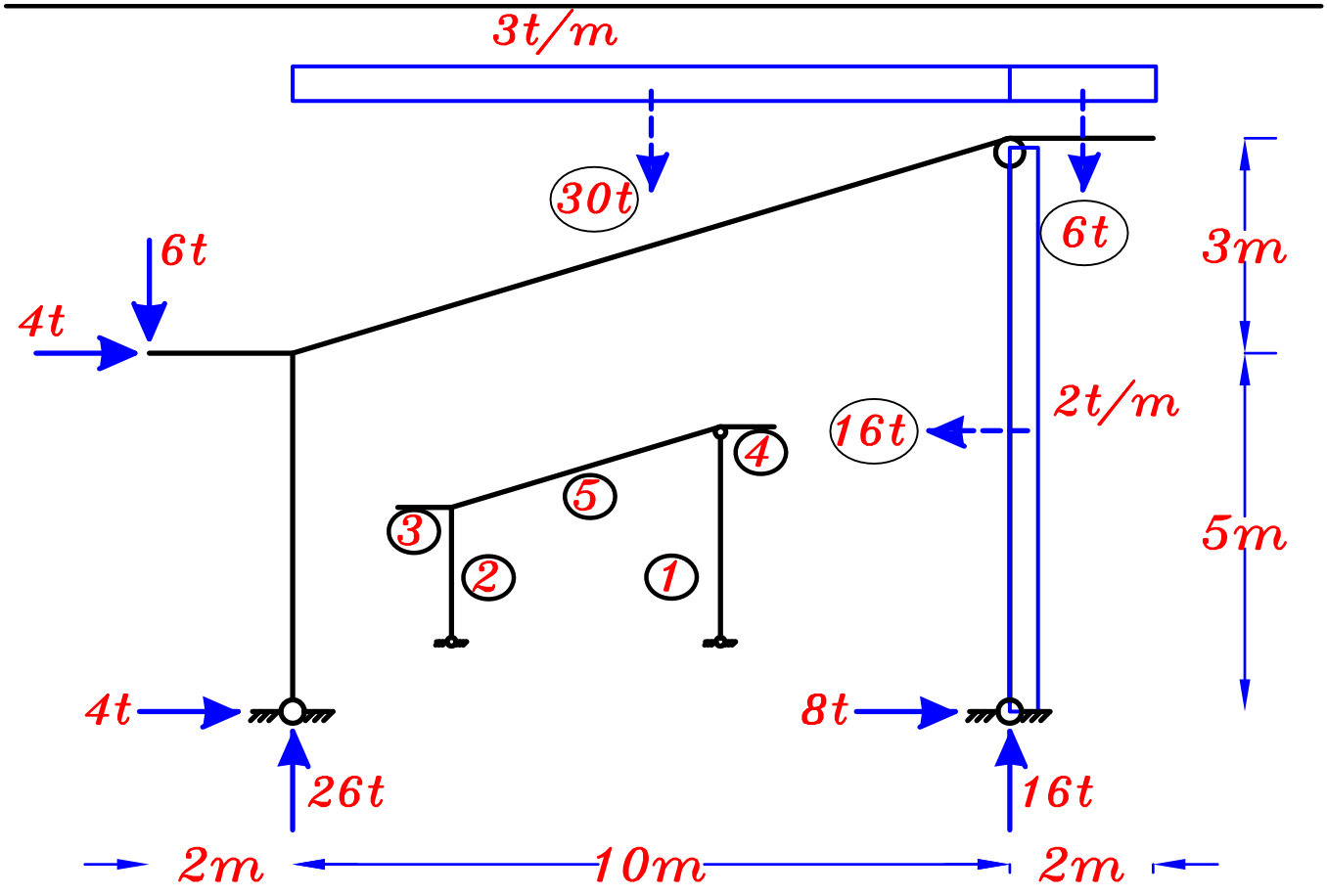
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.





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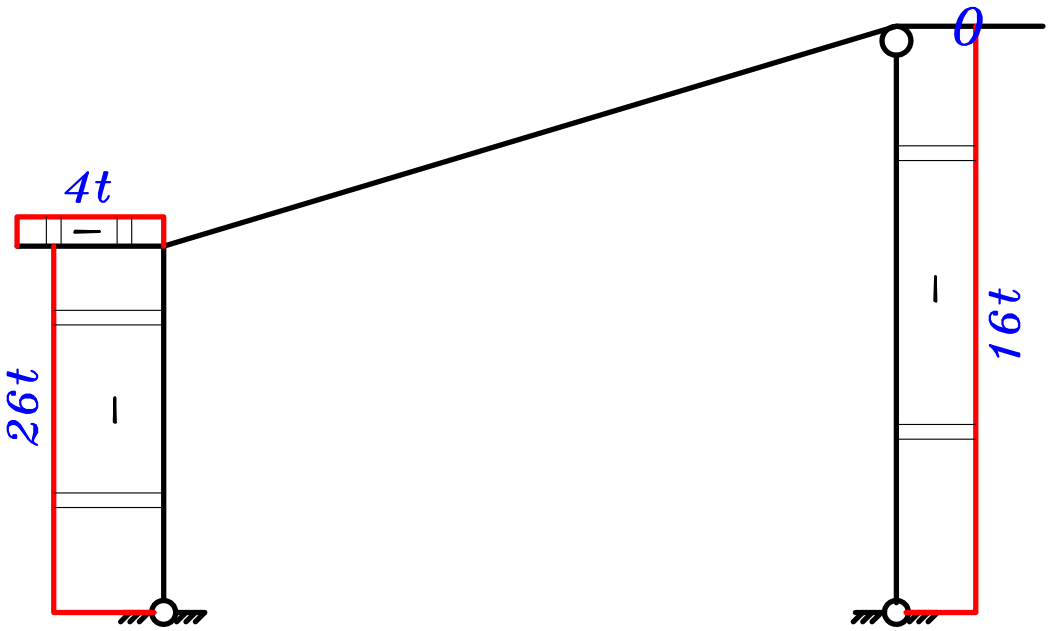
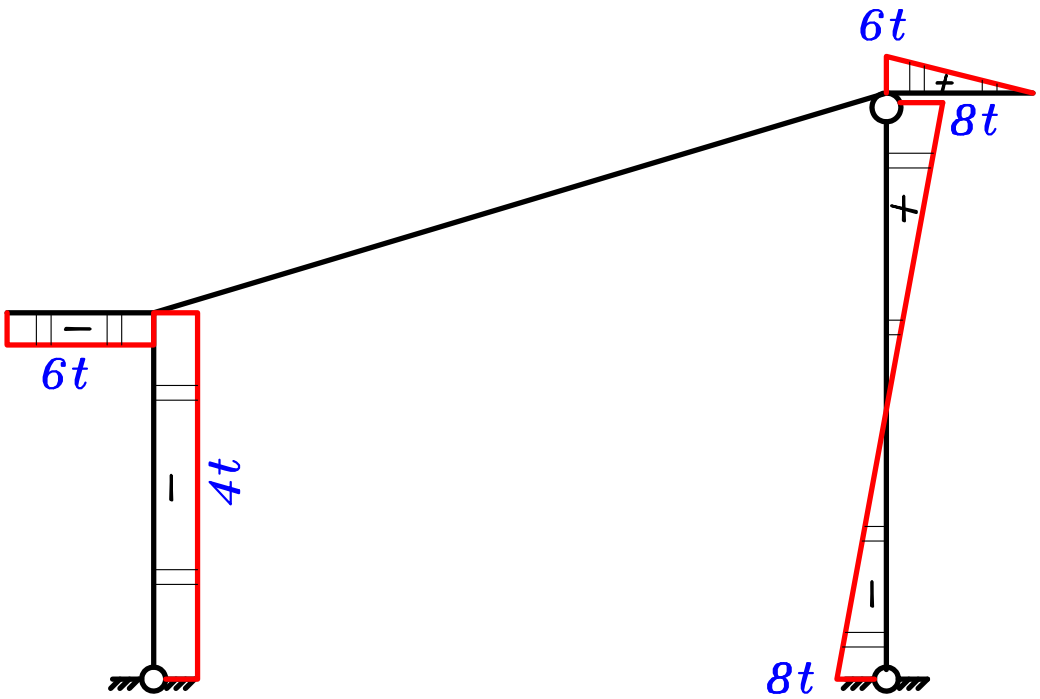
نرسم الـ ***N.F.D*** و الـ ***S.F.D*** و الـ ***B.M.D*** على الـ *members* من *1* الى *4*



N.F.D



S.F.D

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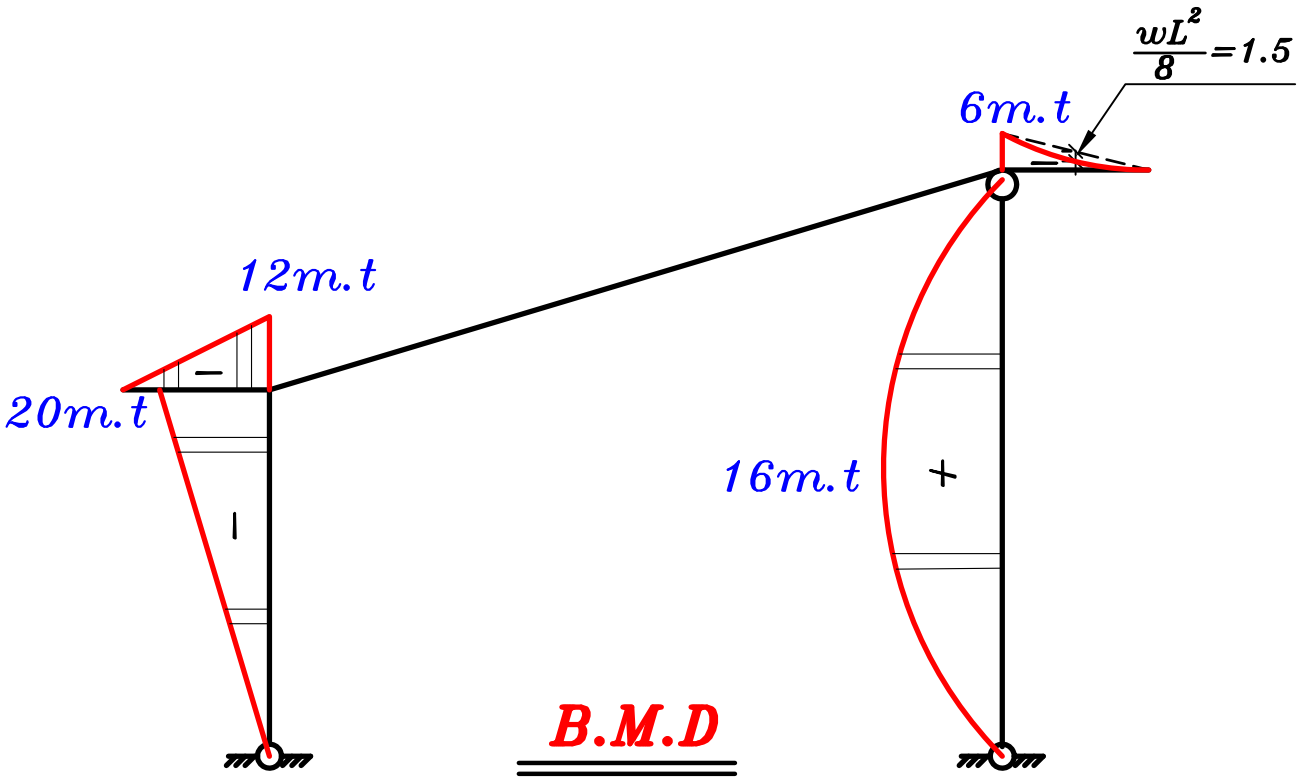
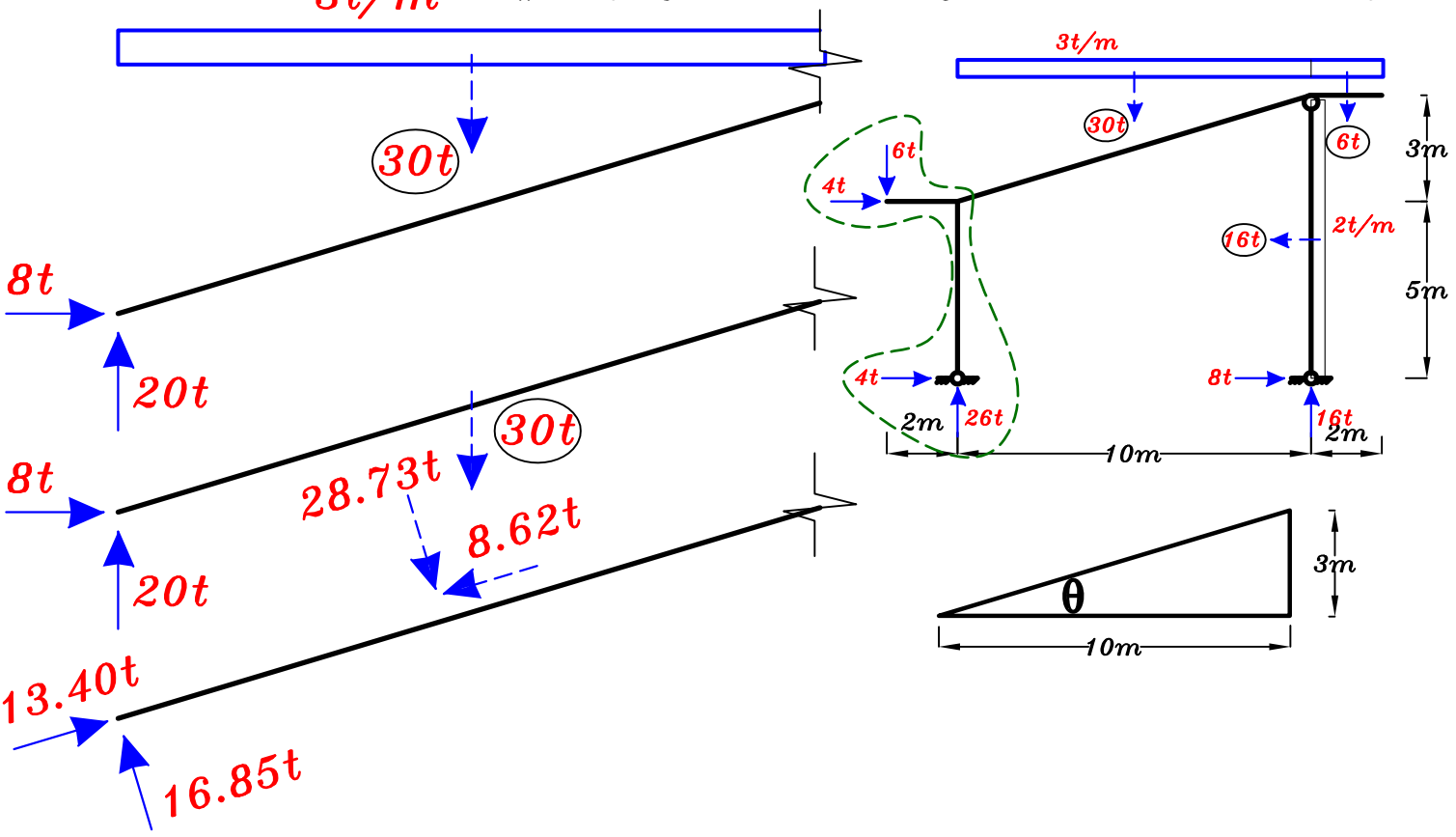


ثم نرسم الـ **N.F.D** و الـ **S.F.D** على member 5

و لانه member مائل و ليس له طرف حر لابد من قطع الـmember من احد الناحيتين و تجميع القوى فى اتجاه X , Y ثم تحليلها فى فى اتجاه الـmember و الاتجاه العمودى عليه .



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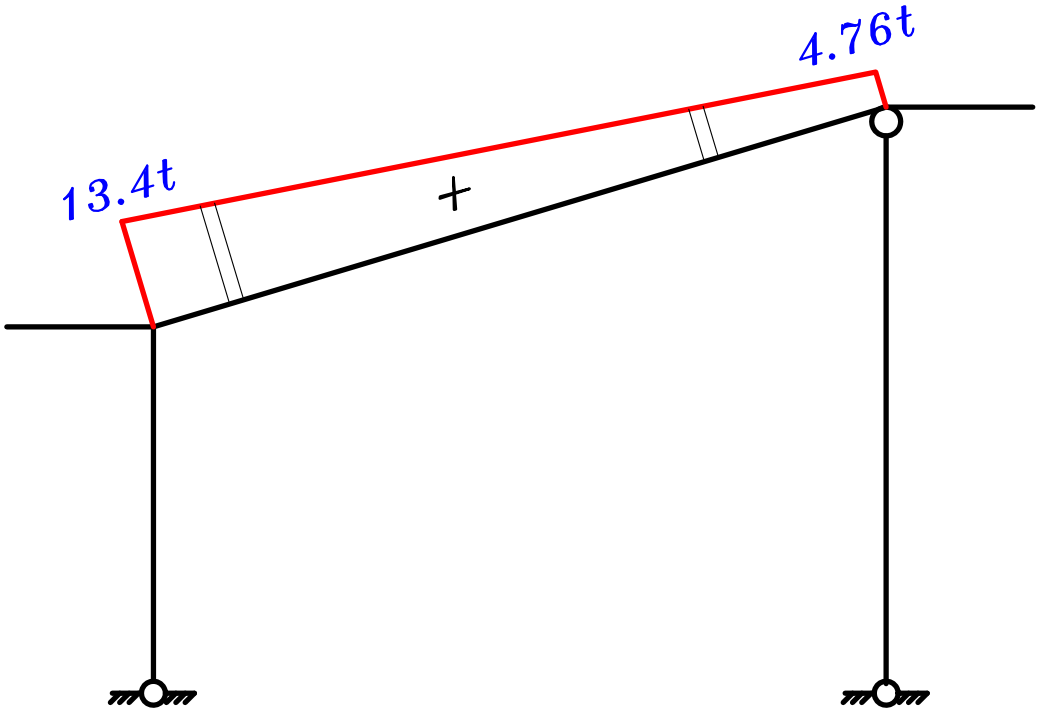
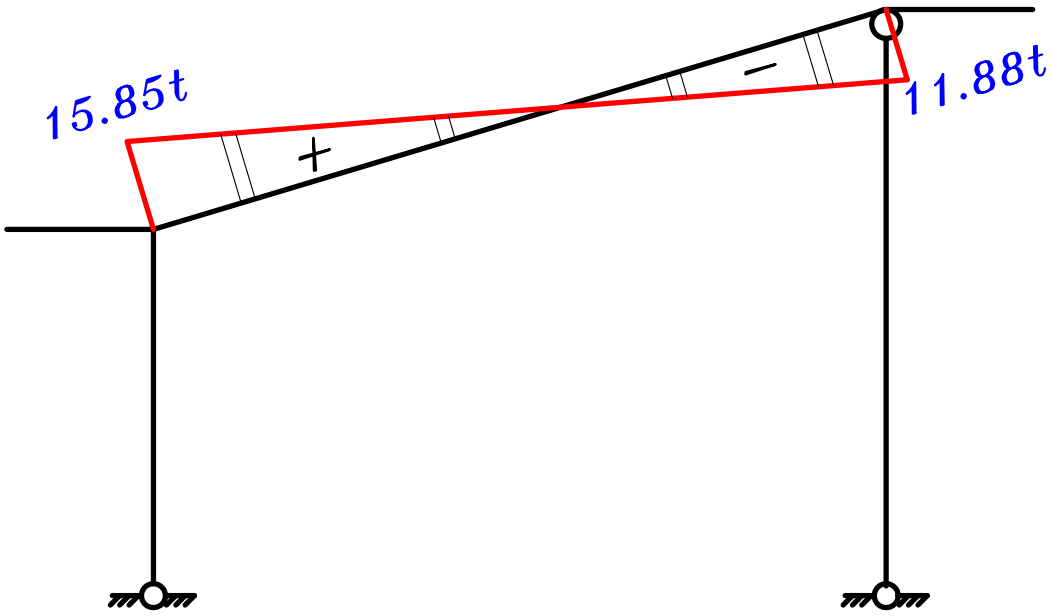


N.F.D



S.F.D

و يفضل رسم الـ ***B.M.D*** من الـ *Forces* قبل التحليل

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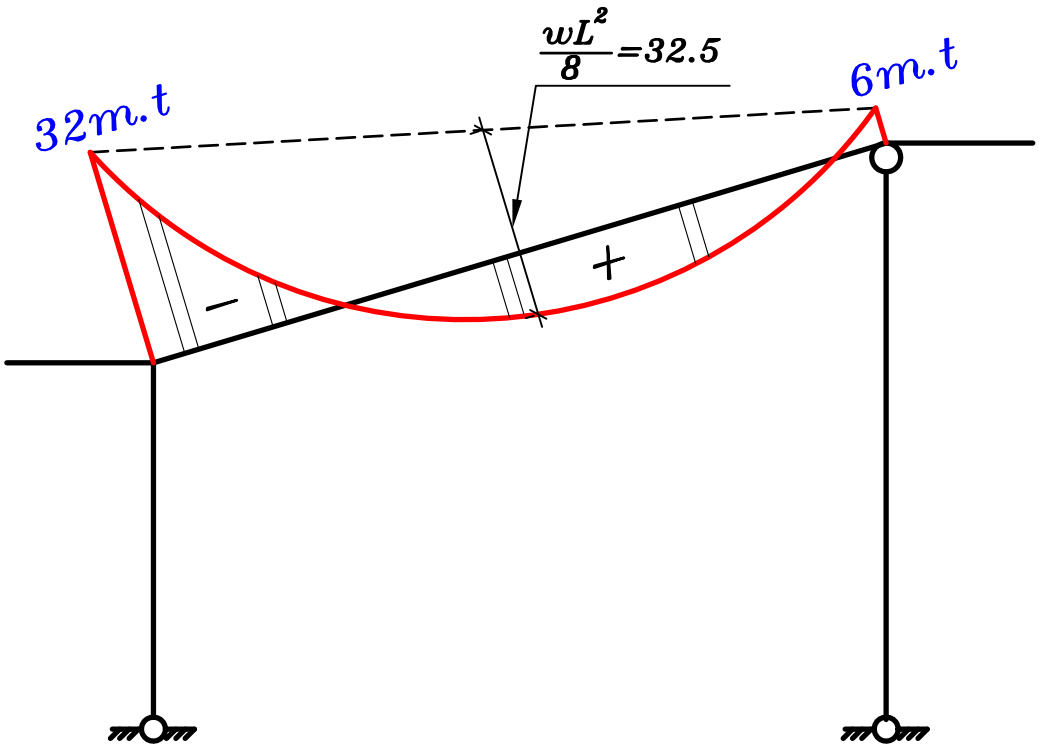
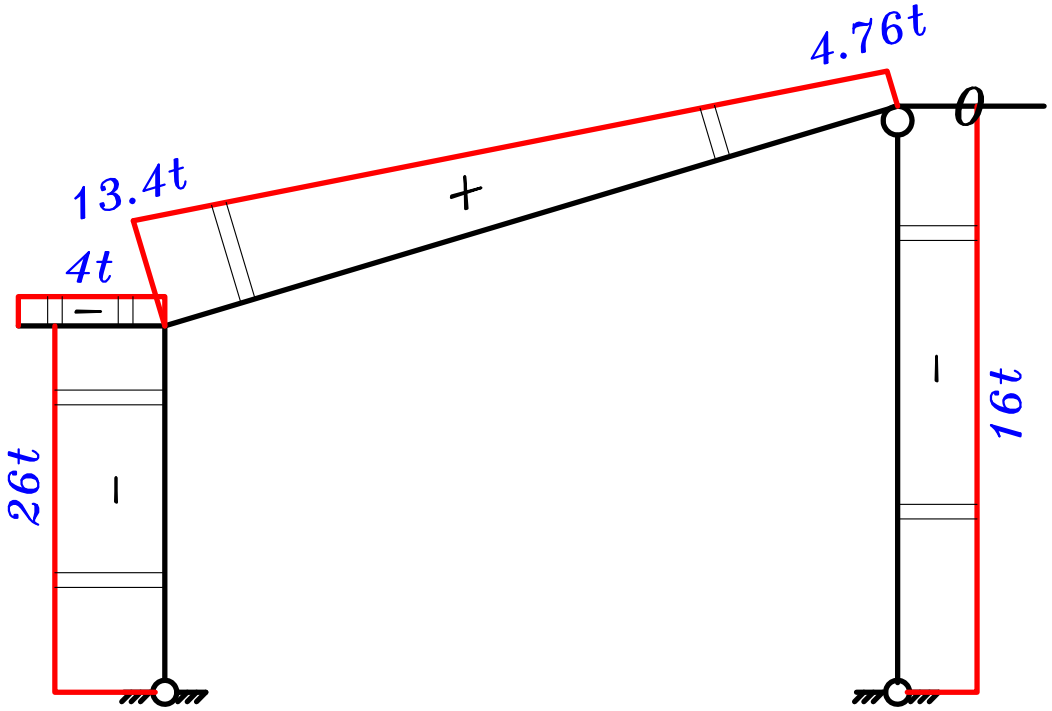


B.M.D

و بالتالى يكون شكل الـ ***Diagrams*** الاخير :



N.F.D

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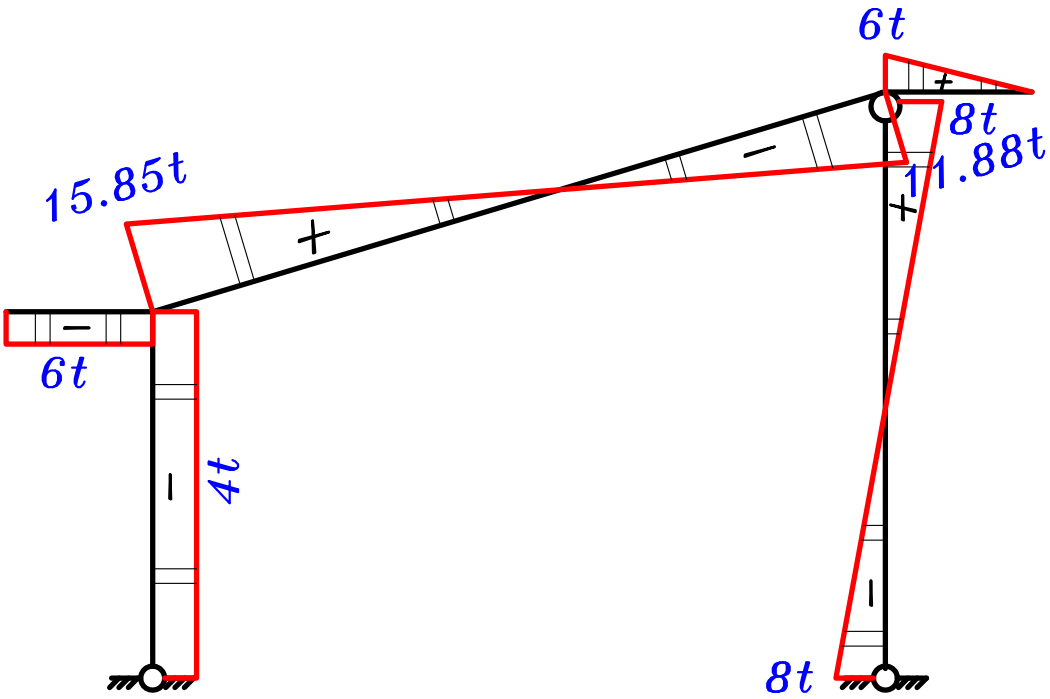
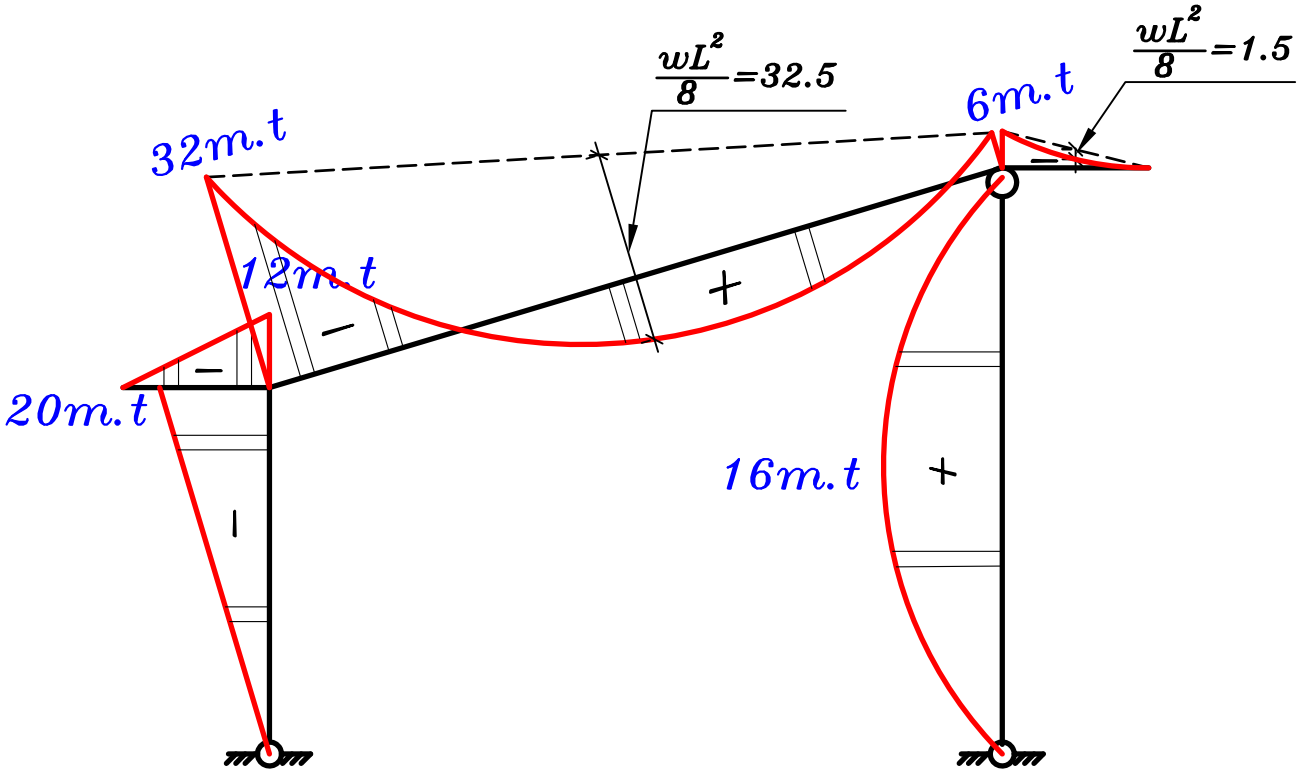


S.F.D



B.M.D

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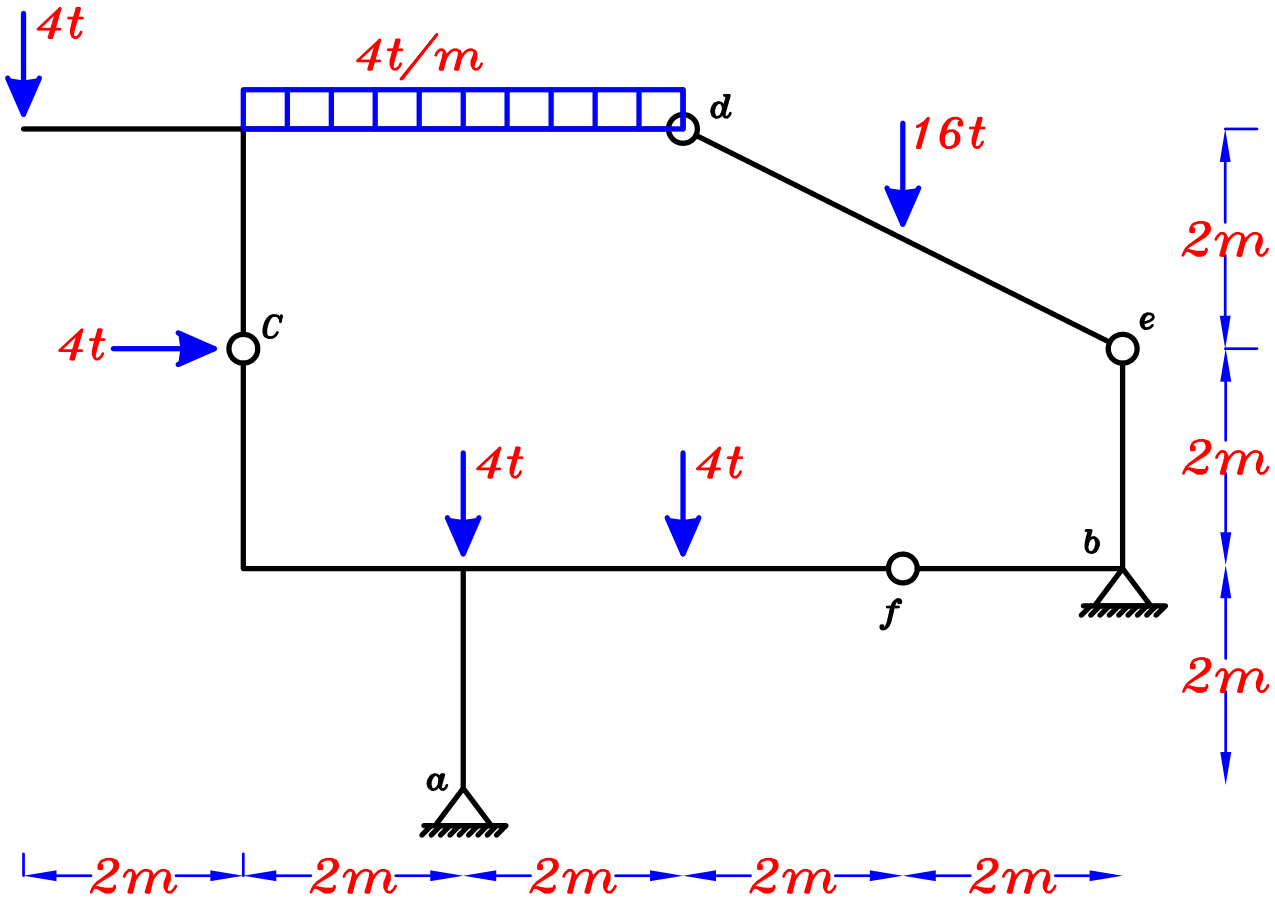
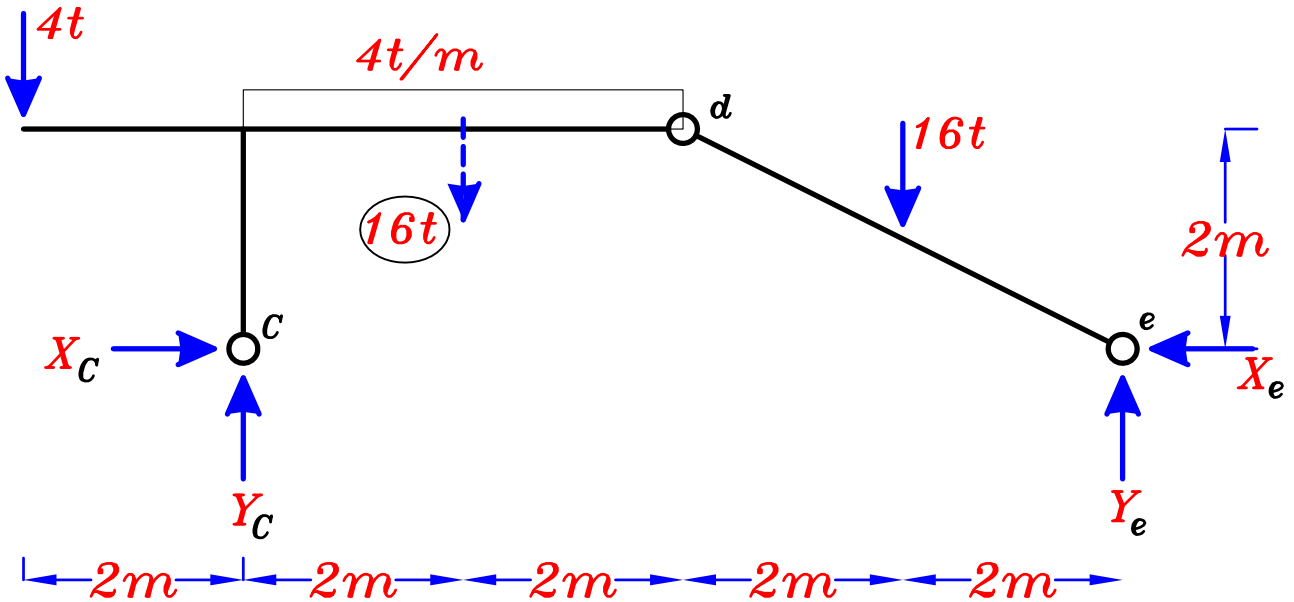
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.



لحل هذا الـ *Frame* نفك الـ *3 hinged frame* ونحله ثم نعكس الـ *Reactions* الناتجة منه على الجزء المتبقى من الـ *Frame* .



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$\Sigma M @ C = 0$

$-4 \times 2 + 4 \times 4 \times 2 + 16 \times 6 - 8 Y_e = 0$

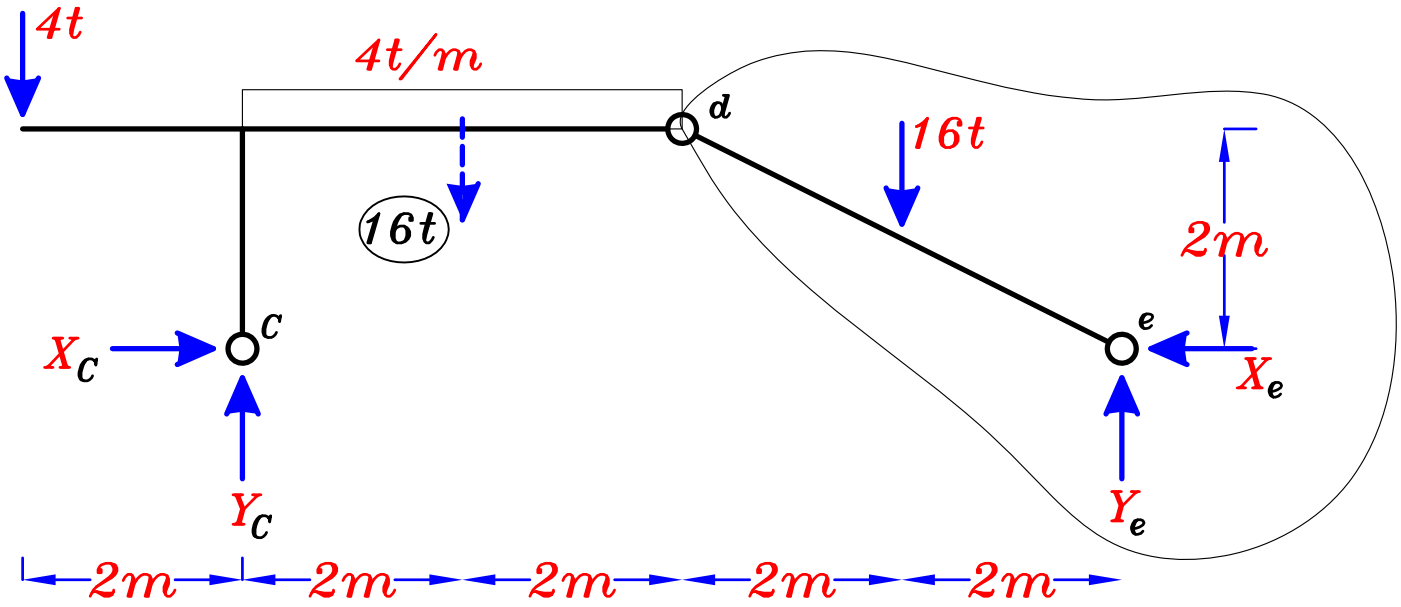
$\boxed{Y_e = 15 \text{ t}}$

$\Sigma Y = 0$

$Y_C + 15 - 4 - 4 \times 4 - 16 = 0$

$\boxed{Y_C = 21 \text{ t}}$

$\Sigma M @ d \text{ (right)} = 0$

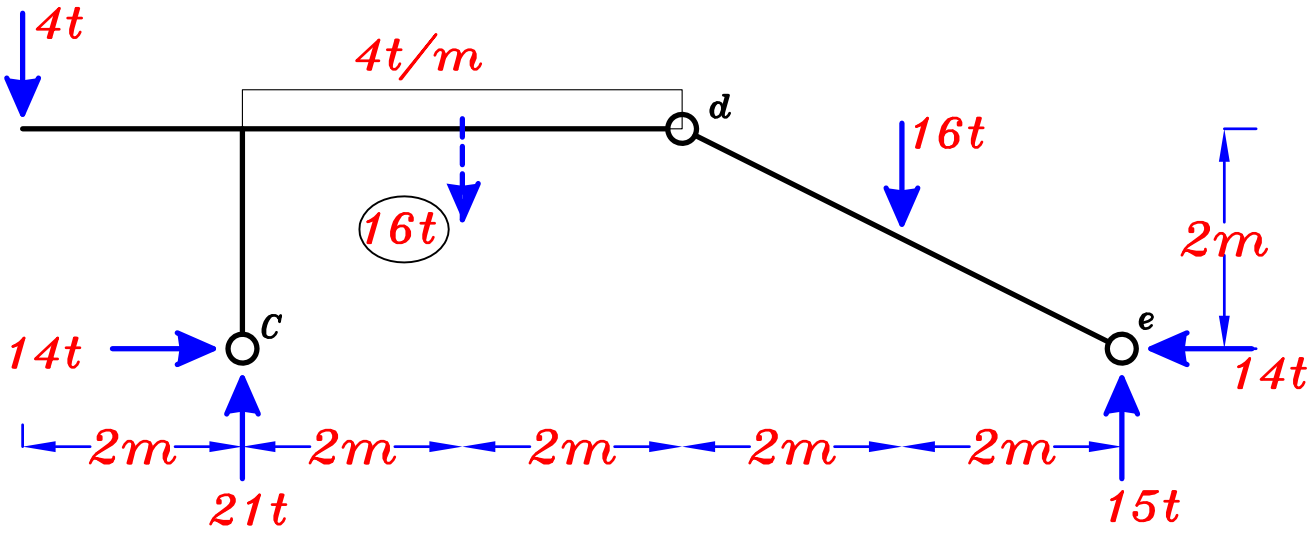


$16 \times 2 + 2 X_e - 15 \times 4 = 0$

$\boxed{X_e = 14 \text{ t}}$

$\Sigma X = 0$

$\boxed{X_C = 14 \text{ t}}$



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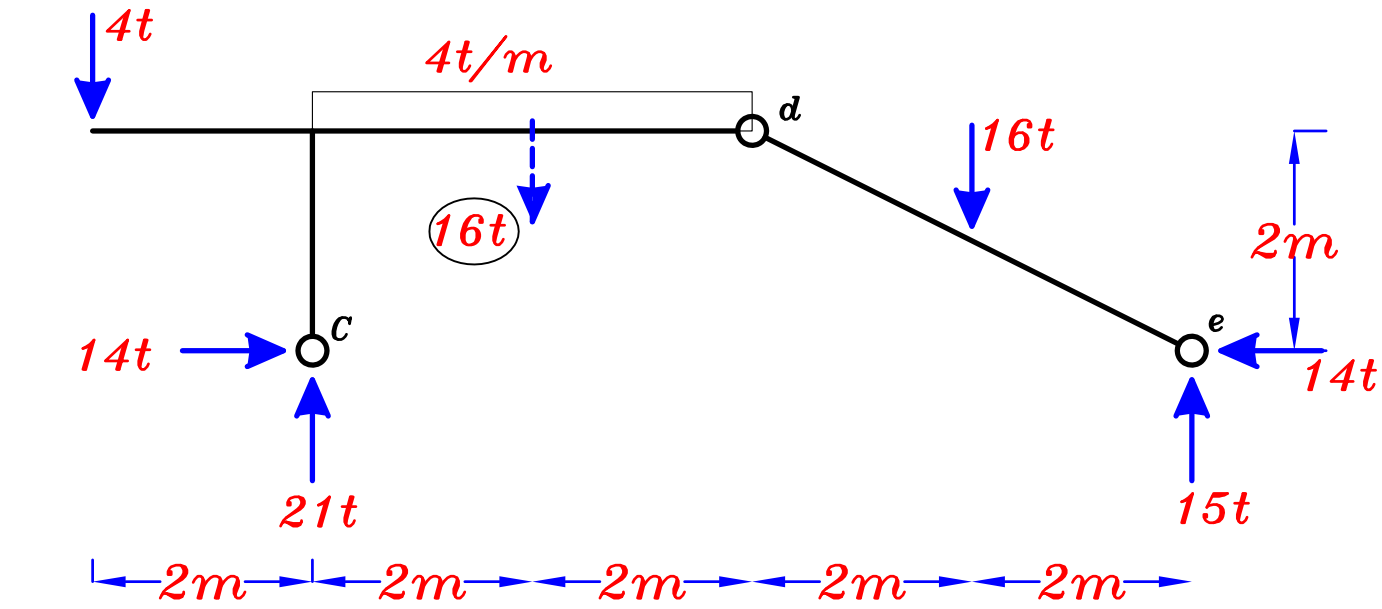

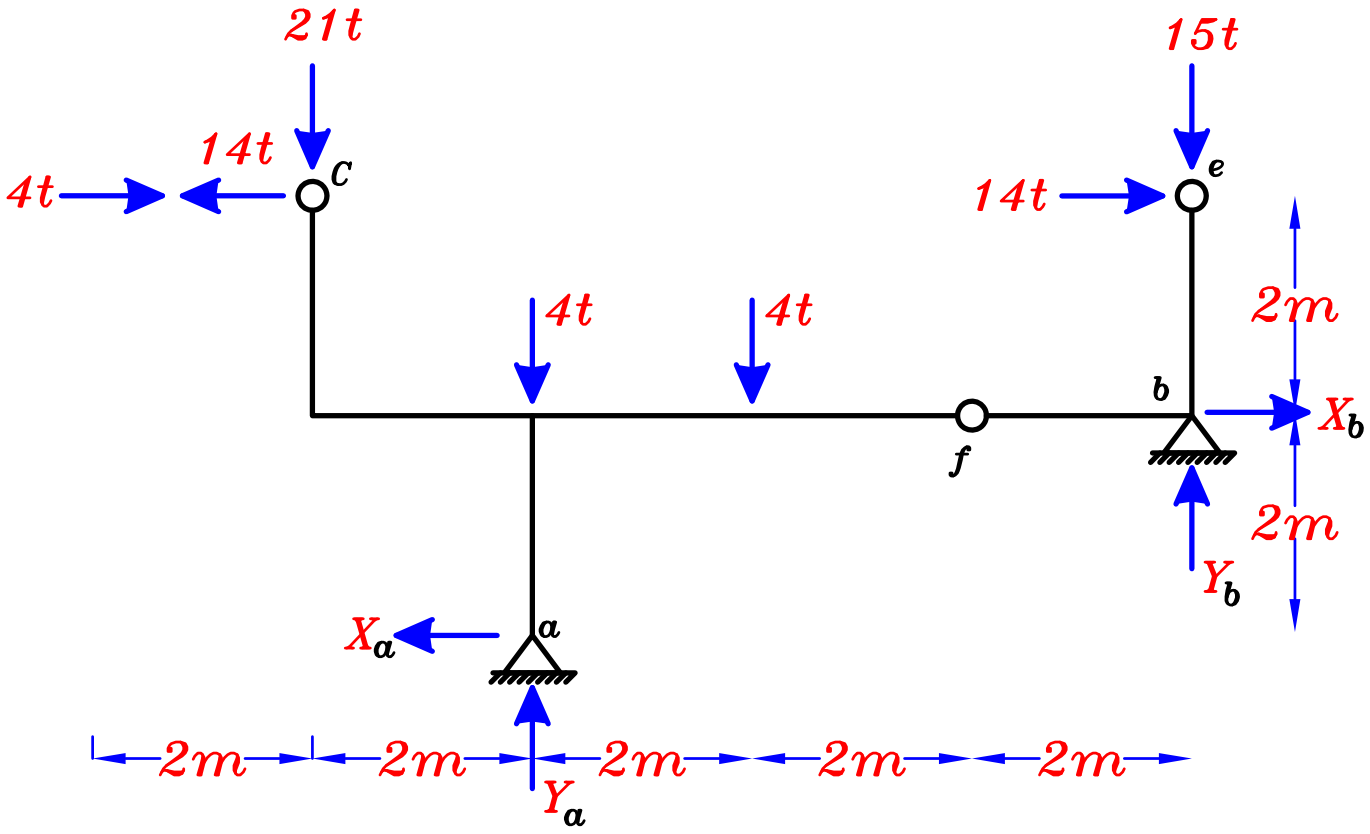

ΣM @ f (right) $= 0$

$15 \times 2 + 14 \times 2 - 2\, Y_b = 0$

$\boxed{Y_b = 29 \text{ t}}$

$\Sigma Y = 0$

$Y_a + 15 + 29 - 21 - 4 - 4 - 15 = 0$

$\boxed{Y_a = 15 \text{ t}}$

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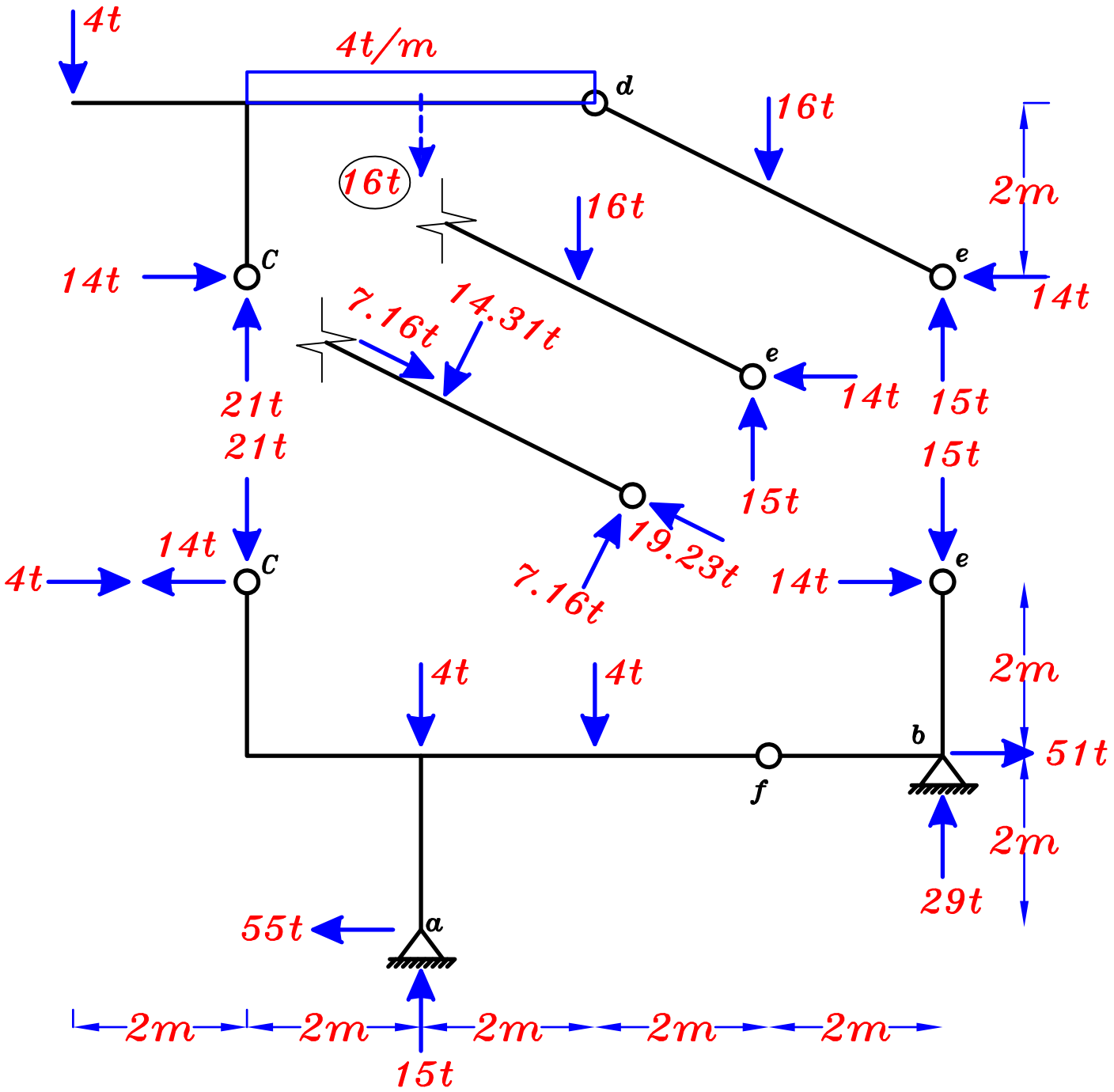
$\Sigma M @ f (right) = 0$

$4 \times 2 + 4 \times 4 - 15 \times 4 + 21 \times 6 + 10 \times 2$

$- 2 \quad X_a = 0$ $\quad \boxed{X_a = 55\ t}$

$\Sigma X = 0$ $\quad \boxed{X_b = 51\ t}$



نرسم الـ *Internal forces diagrams* لكل *Frame* على حدا

ولكن لابد من تجميع الرسم فى النهاية فى رسمة واحدة لكل *Diagram*

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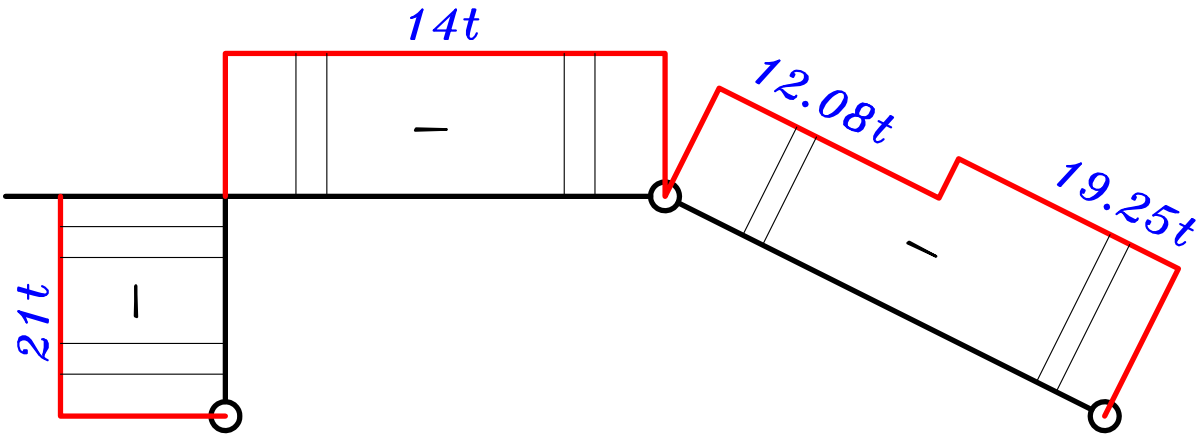

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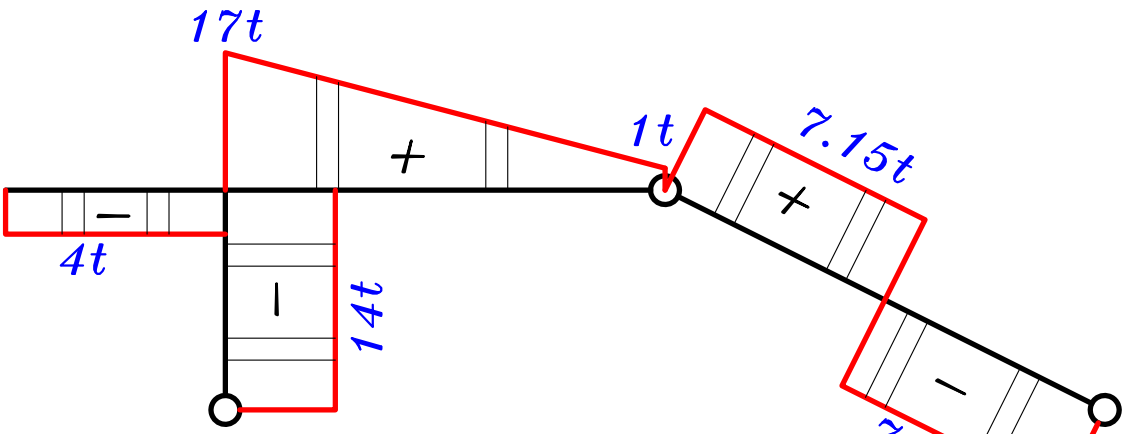

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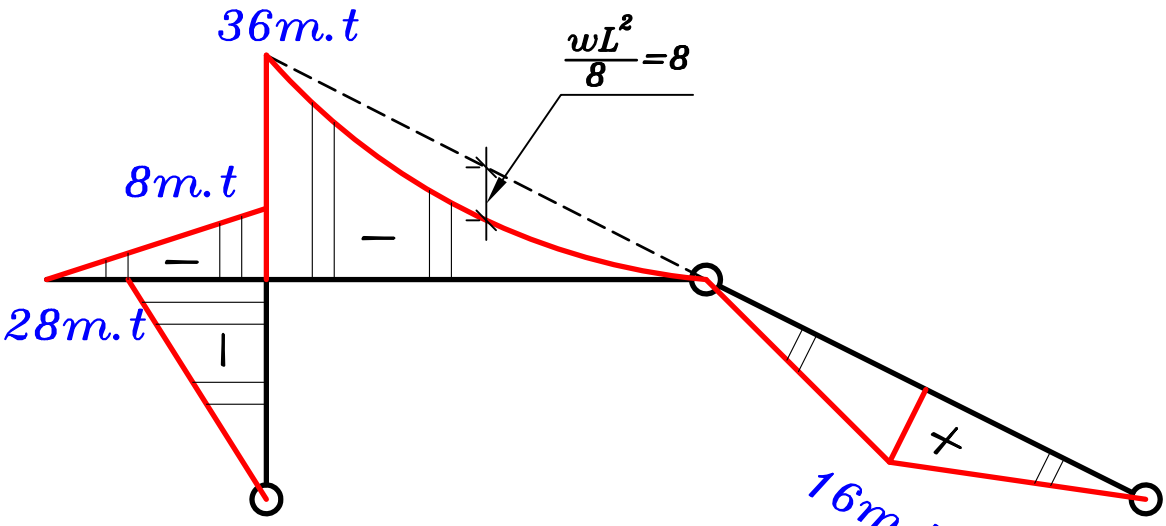

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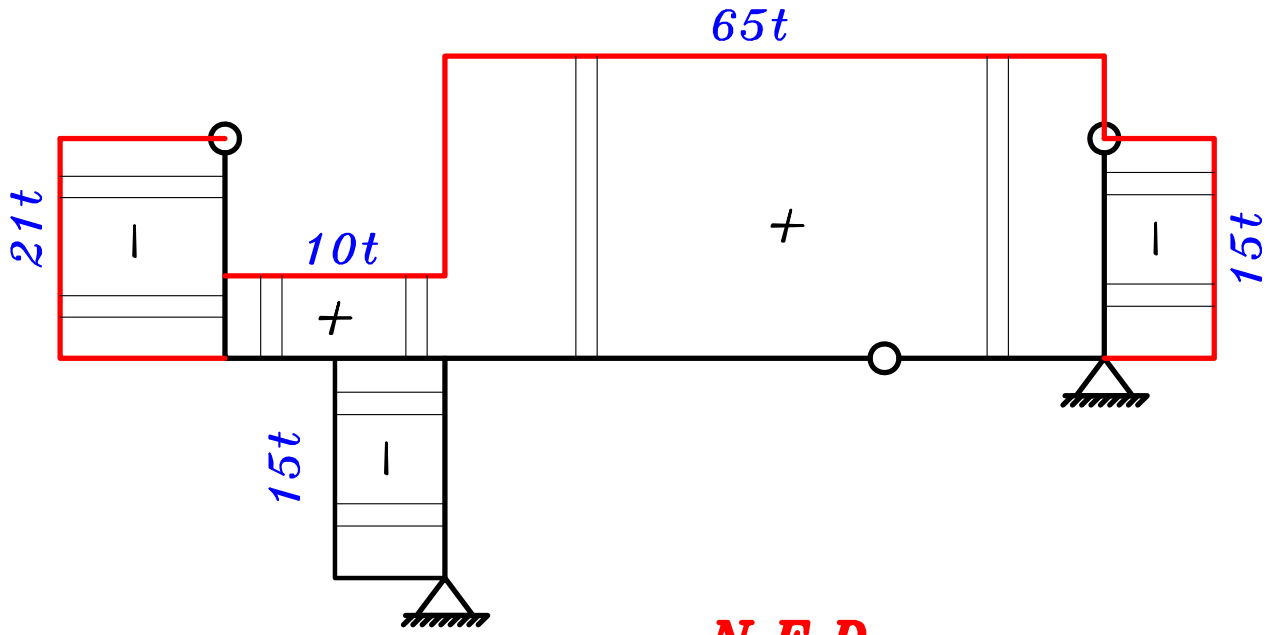

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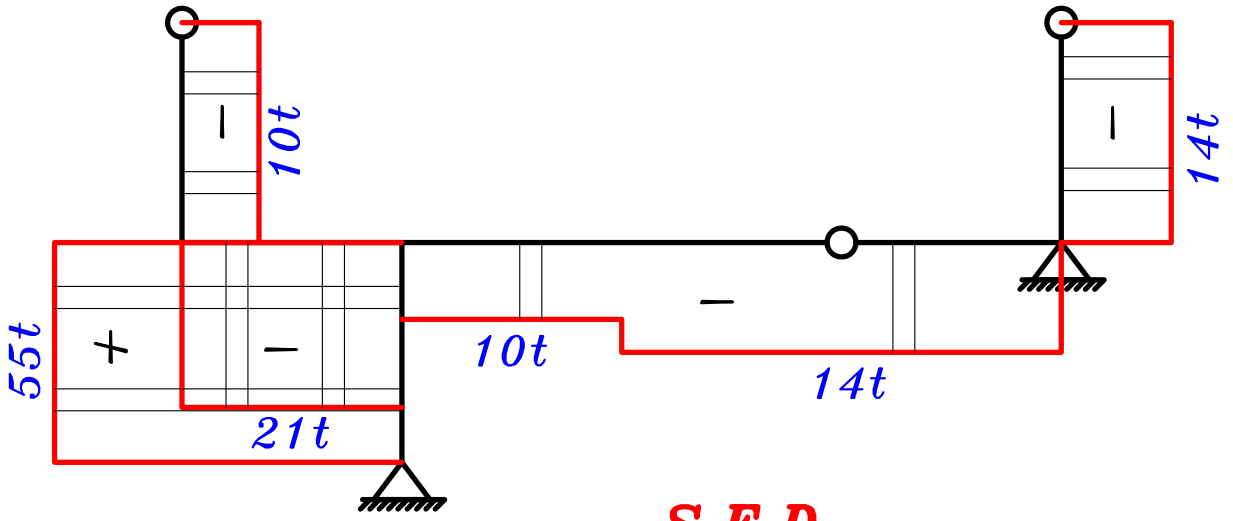

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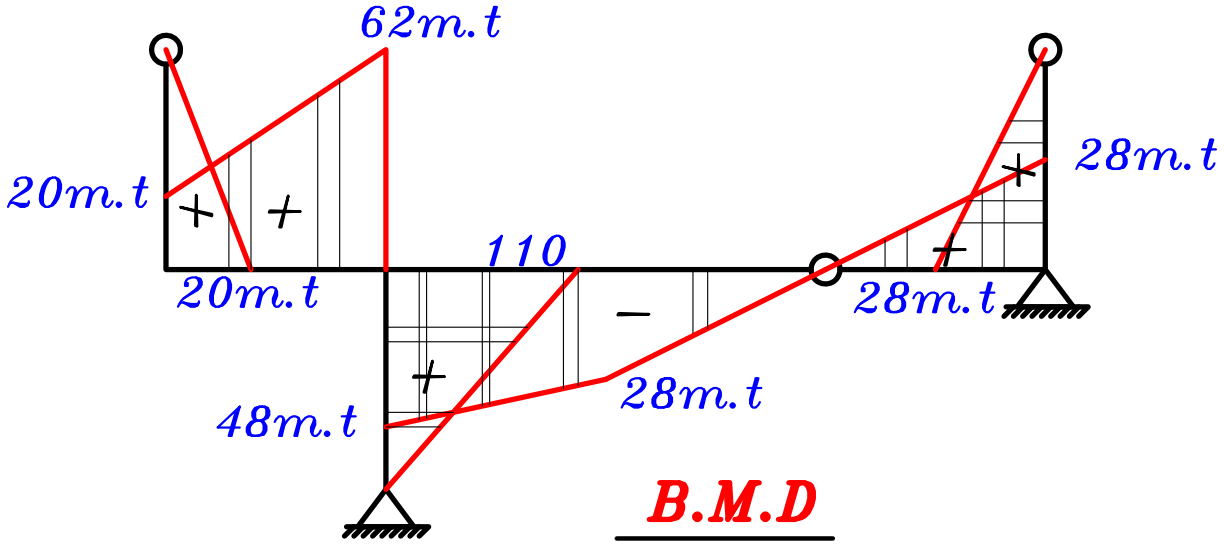

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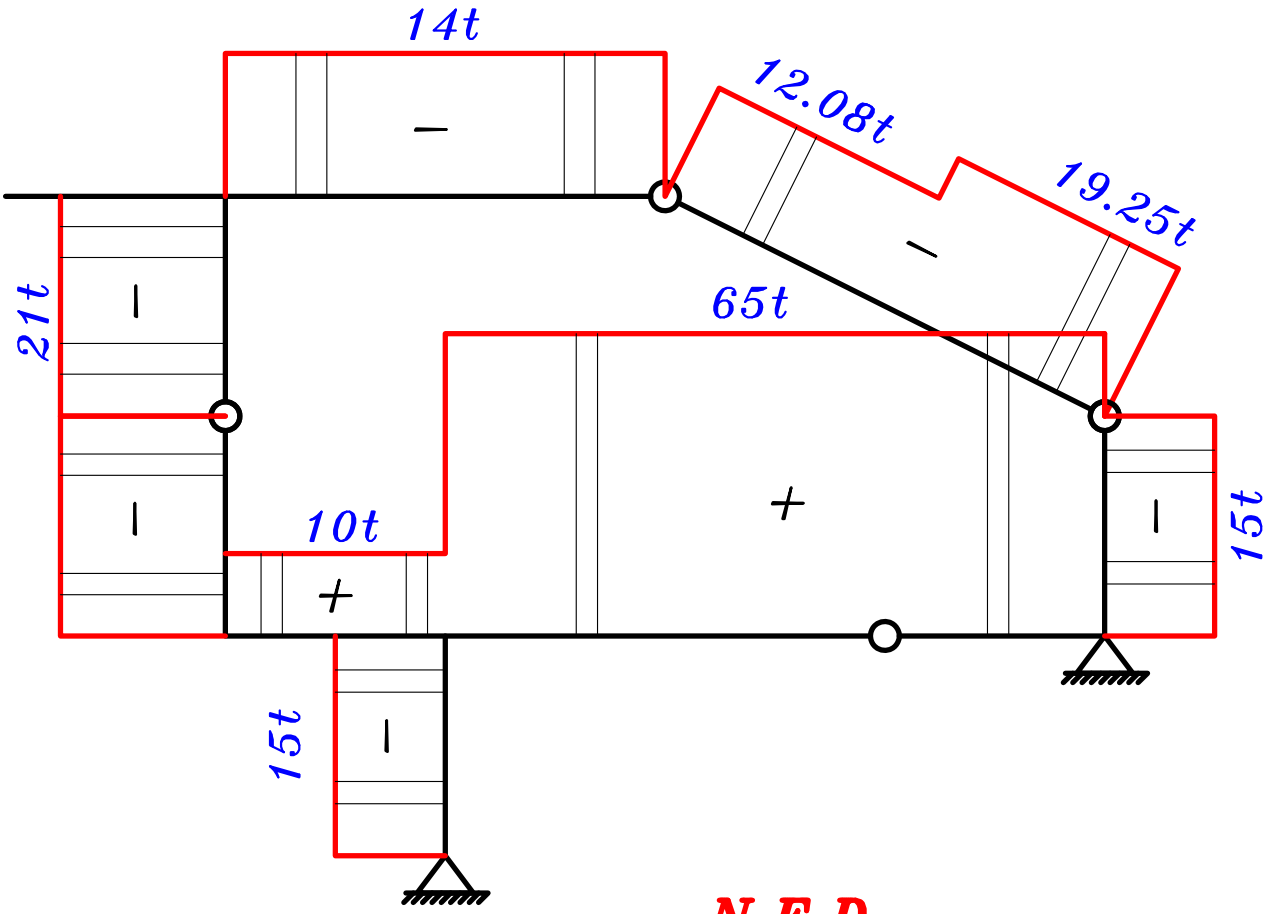

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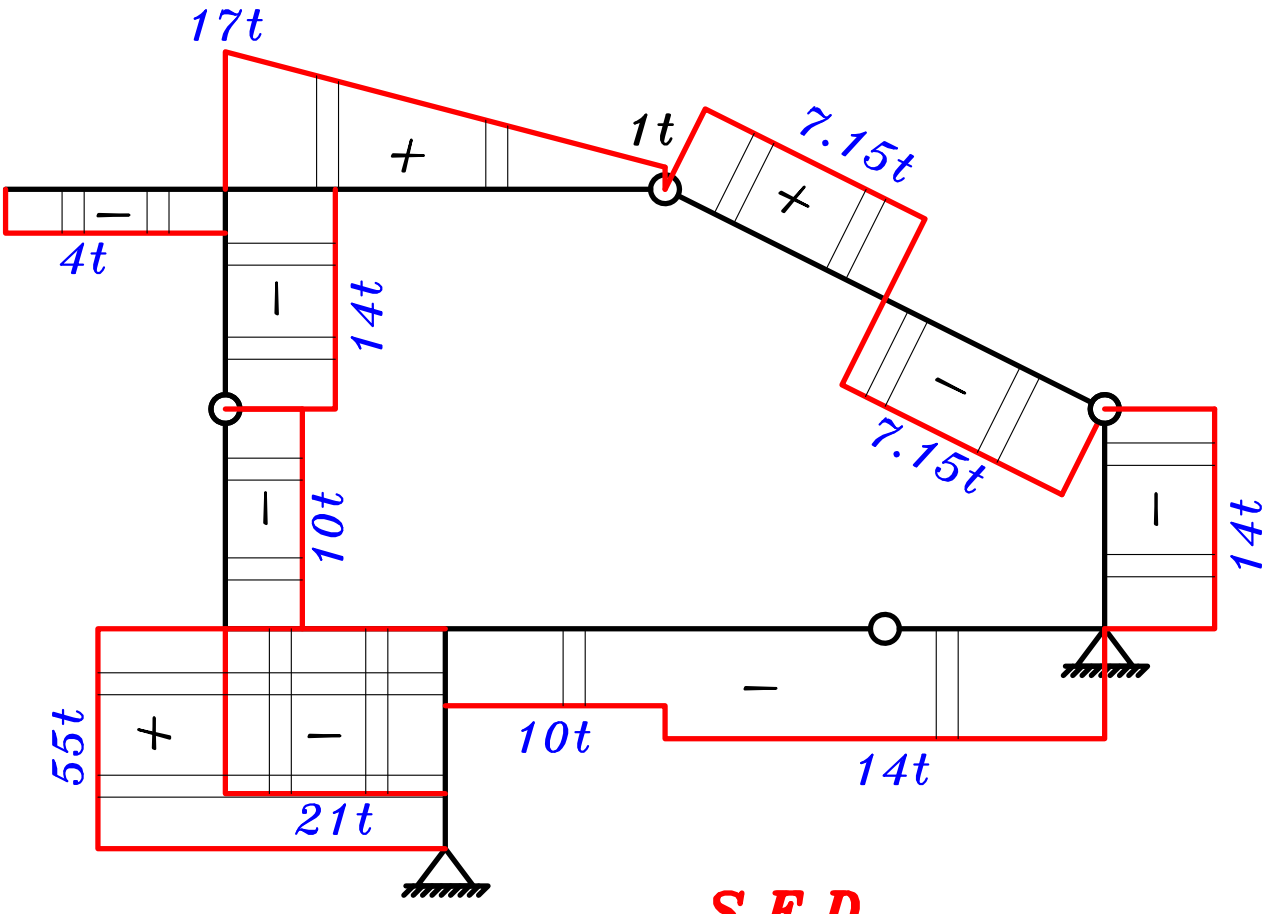

S.F.D

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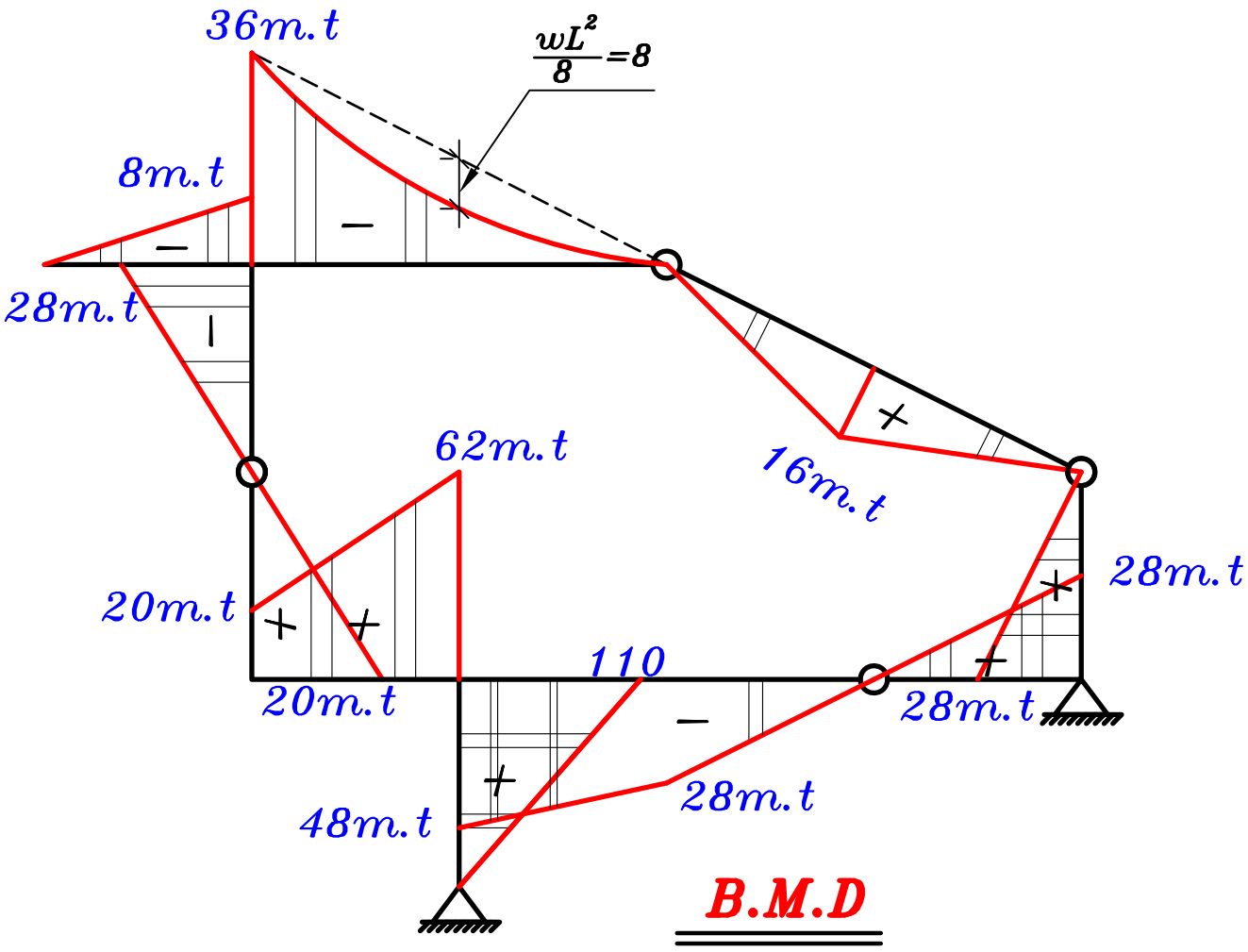

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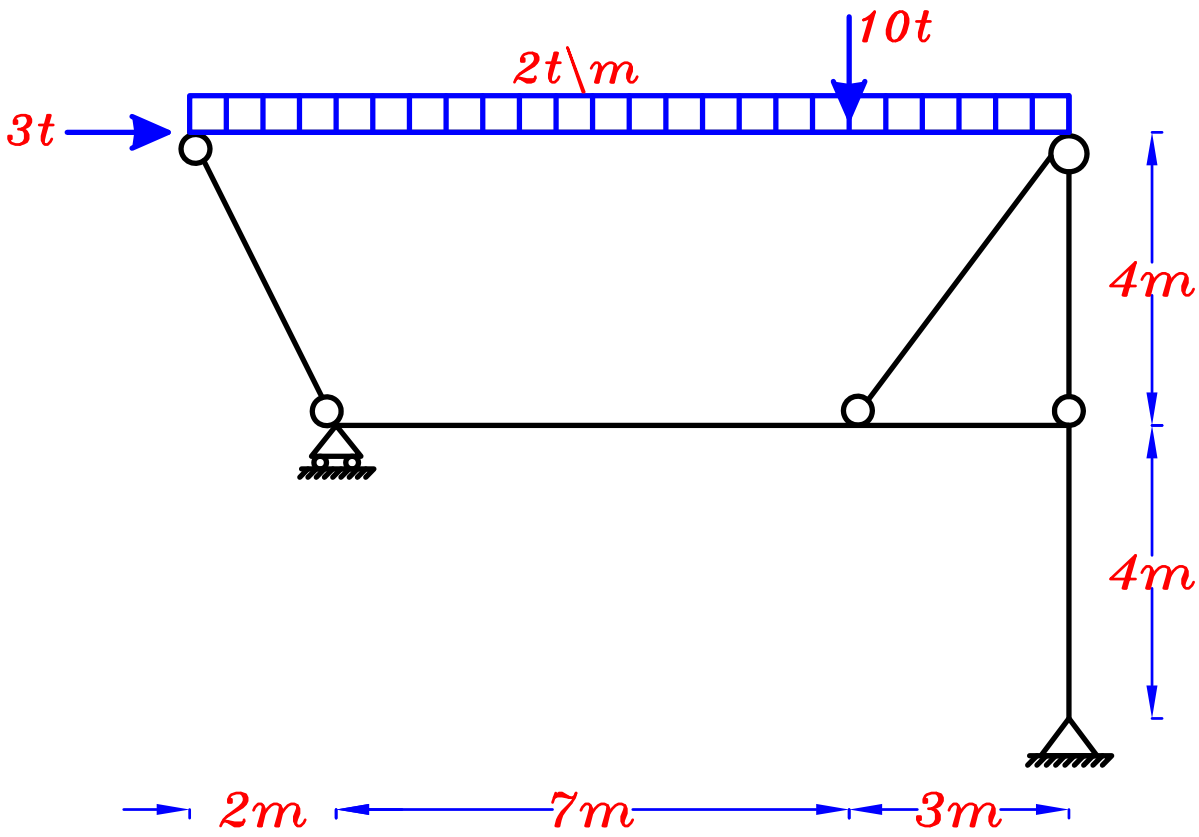
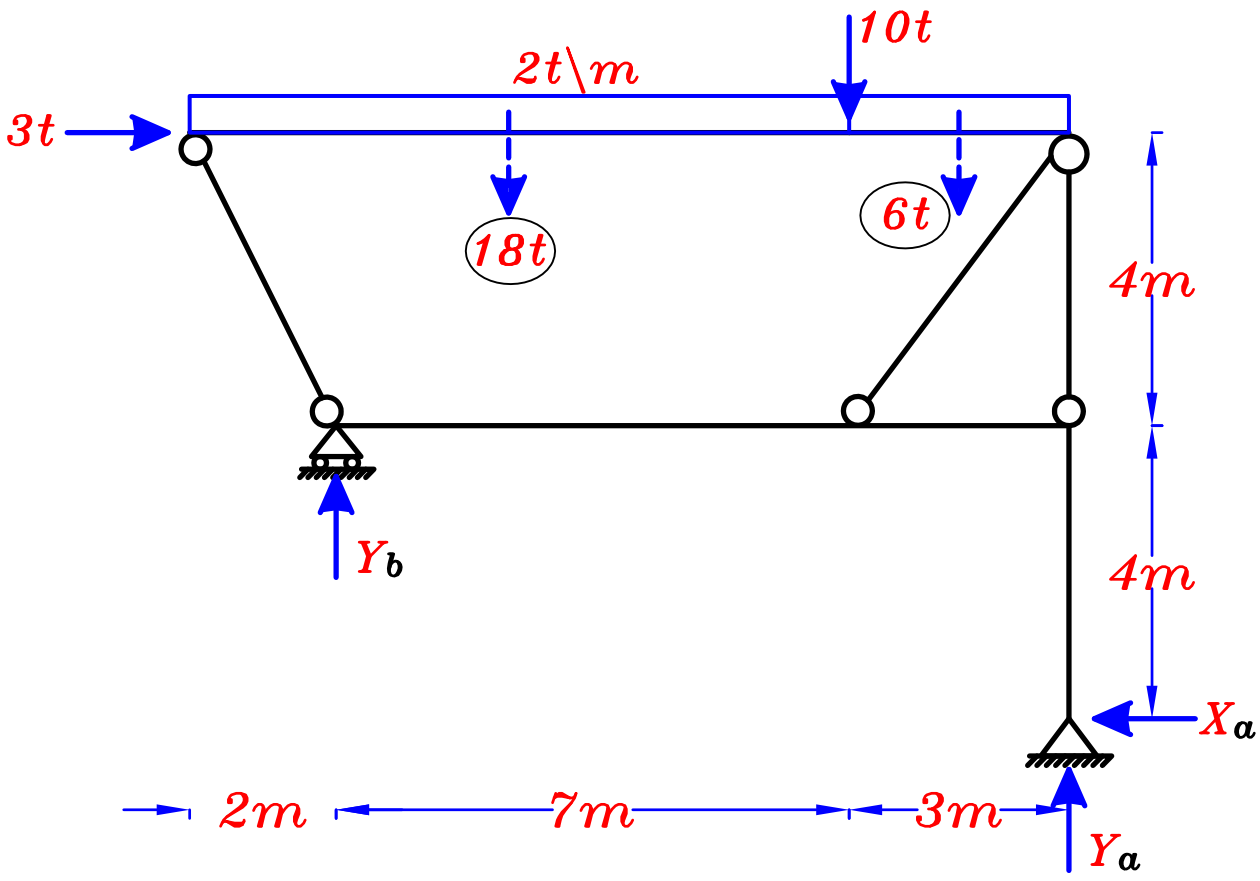
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.





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من الممكن حساب الـ Reactions بدون فك الـ Frame .

$$\Sigma X = 0$$

$$X_a - 3 = 0 \qquad \boxed{X_a = 3\,t}$$

$$\Sigma M @ \ a \ = 0$$

$$6 * 1.5 + 10 * 3 + 18 * 7.5 - 3 * 8 - Y_b * 10 = 0$$

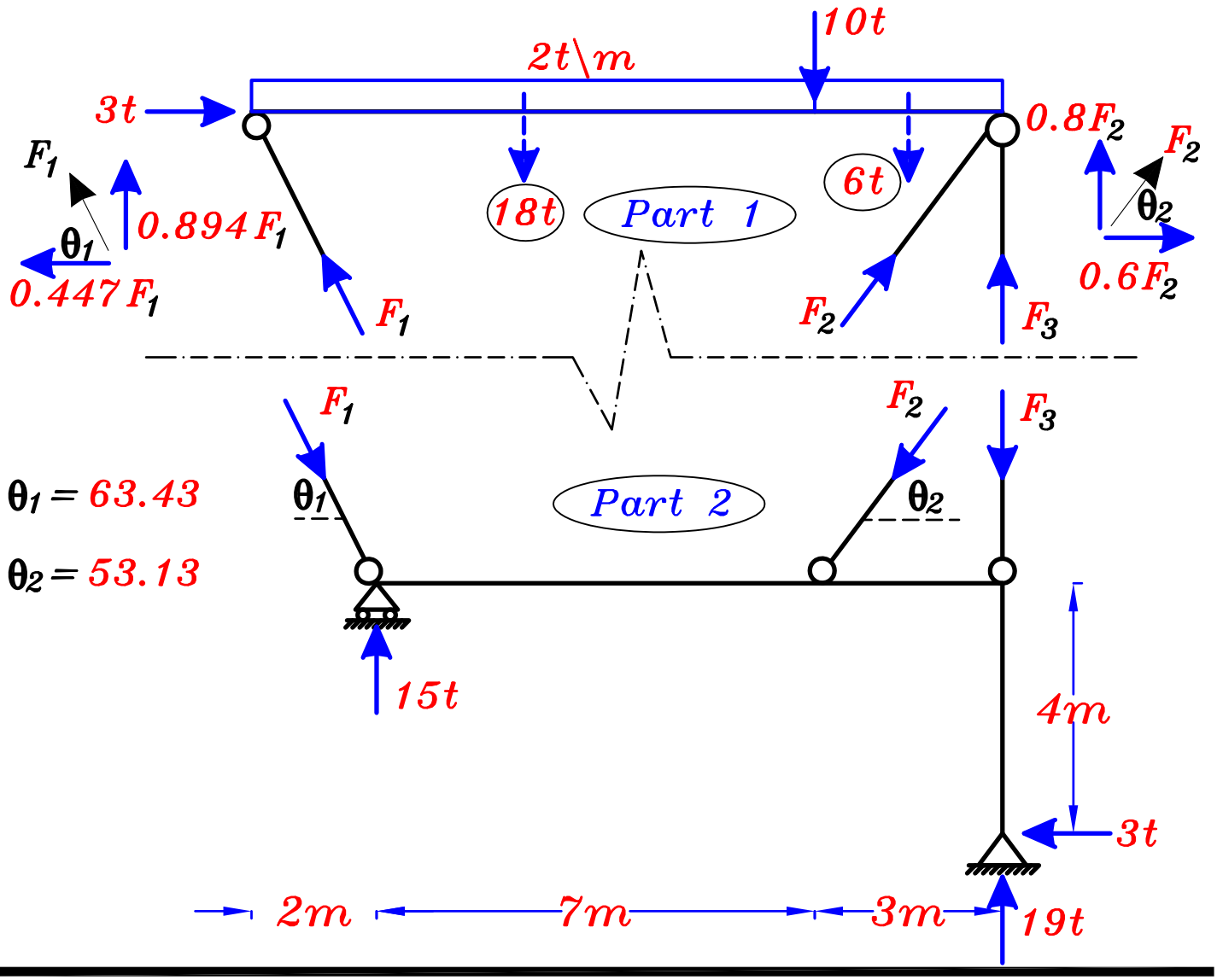
$$\boxed{Y_b = 15\,t}$$

$$\Sigma Y = 0$$

$$Y_a - 6 - 10 - 18 + 15 = 0 \qquad \boxed{Y_a = 19\,t}$$

و لرسم الـ Internal forces diagrams نحتاج الى فتح الجزء الـ Closed من الـ Frame .

و فى هذه المسألة من الممكن أن نقطع فى الـ Link members .



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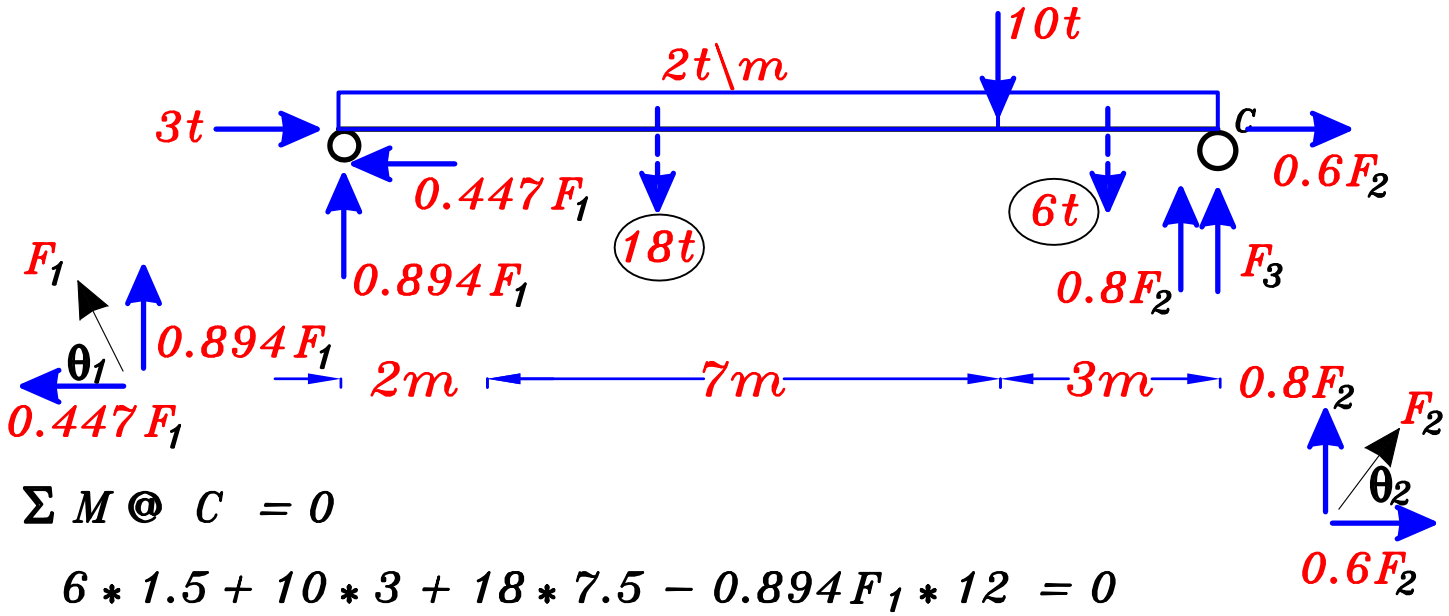
Part 1



$\Sigma M @ C = 0$

$$6 * 1.5 + 10 * 3 + 18 * 7.5 - 0.894 F_1 * 12 = 0$$

$$F_1 = \mathbf{16.21}\ t\ (Comp.)$$

$\Sigma X = 0$

$$0.447 * 16.21 - 3 - 0.6 * F_2 = 0$$

$$F_2 = \mathbf{7.07}\ t\ (Comp.)$$

$\Sigma Y = 0$

$$0.894 * 16.21 - 18 - 10 - 6 + 0.8 * F_2 + F_3 = 0$$

$$F_3 = \mathbf{13.85}\ t\ (Comp.)$$

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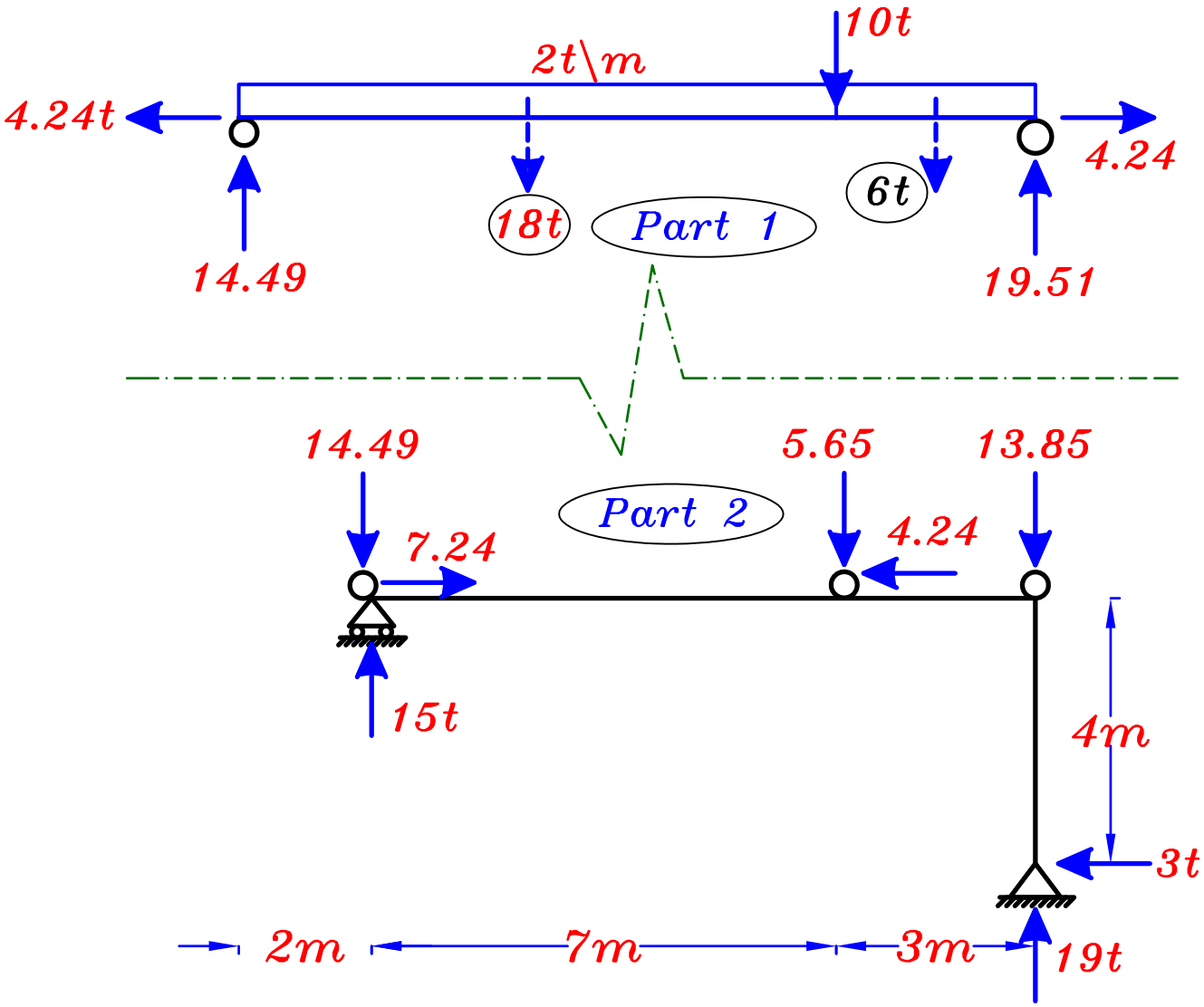
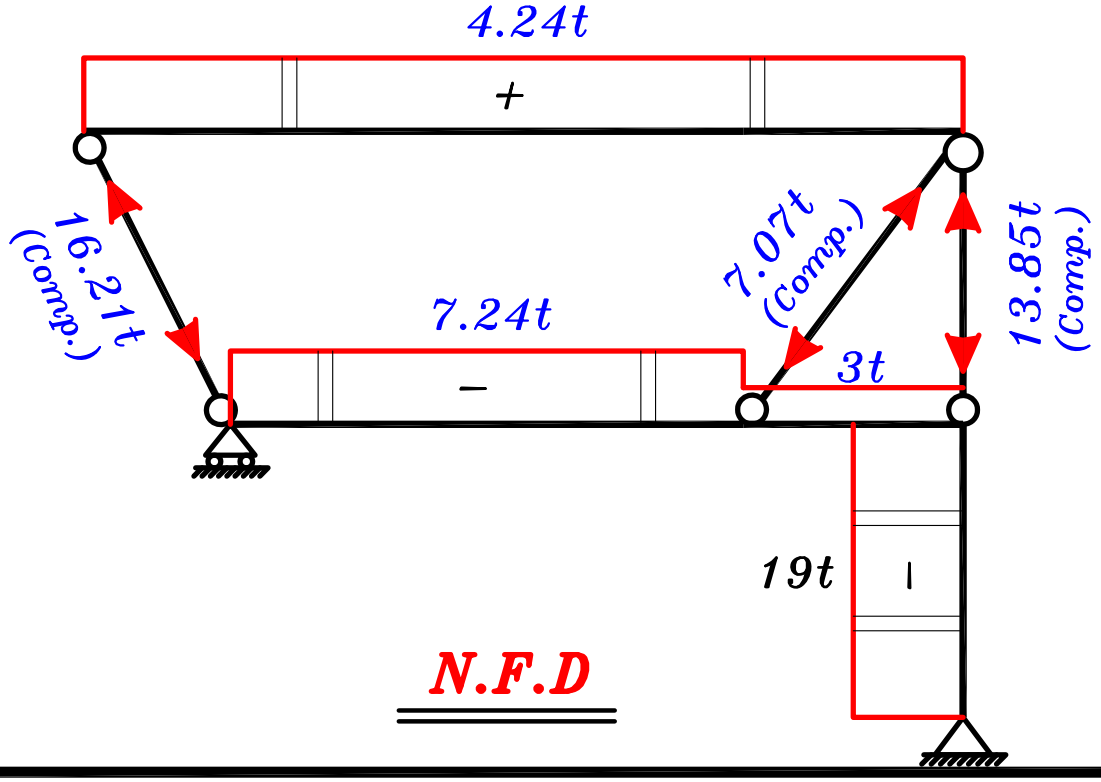


و الان من الممكن رسم الـ *Internal forces diagrams* لكل جزء على حدا و الـ *Forces* فى الـ *Link members* معروفة .



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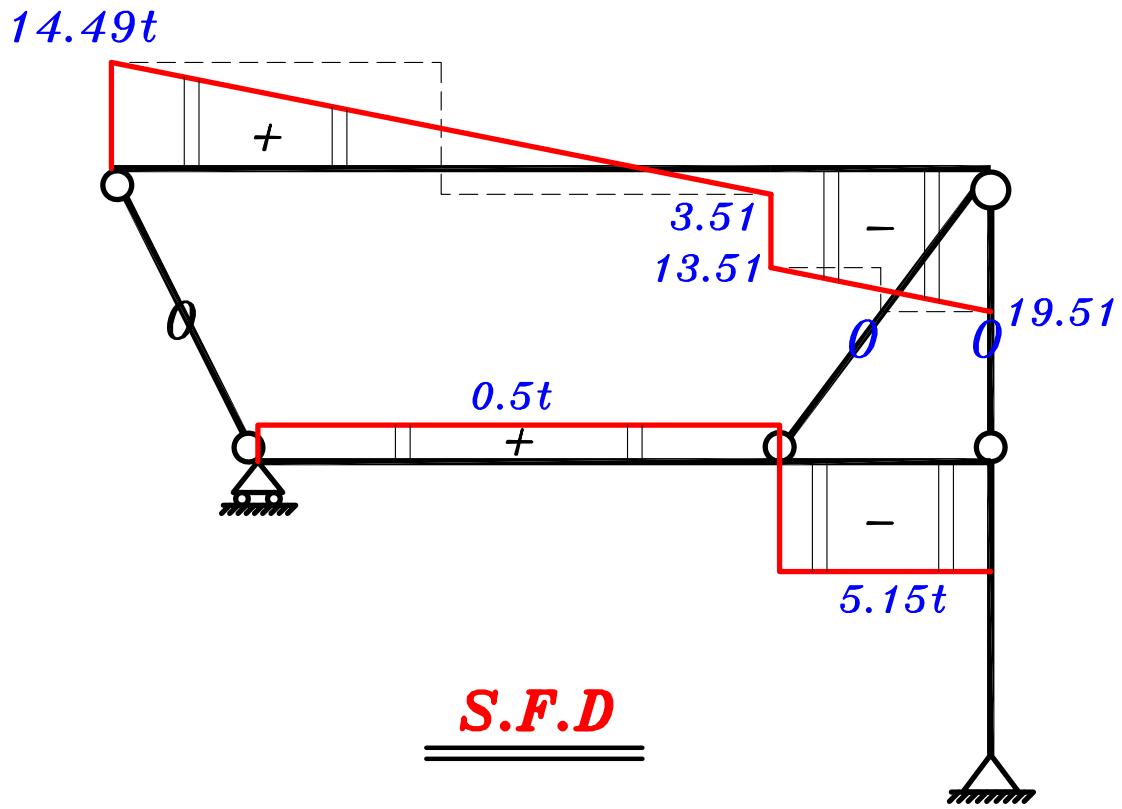
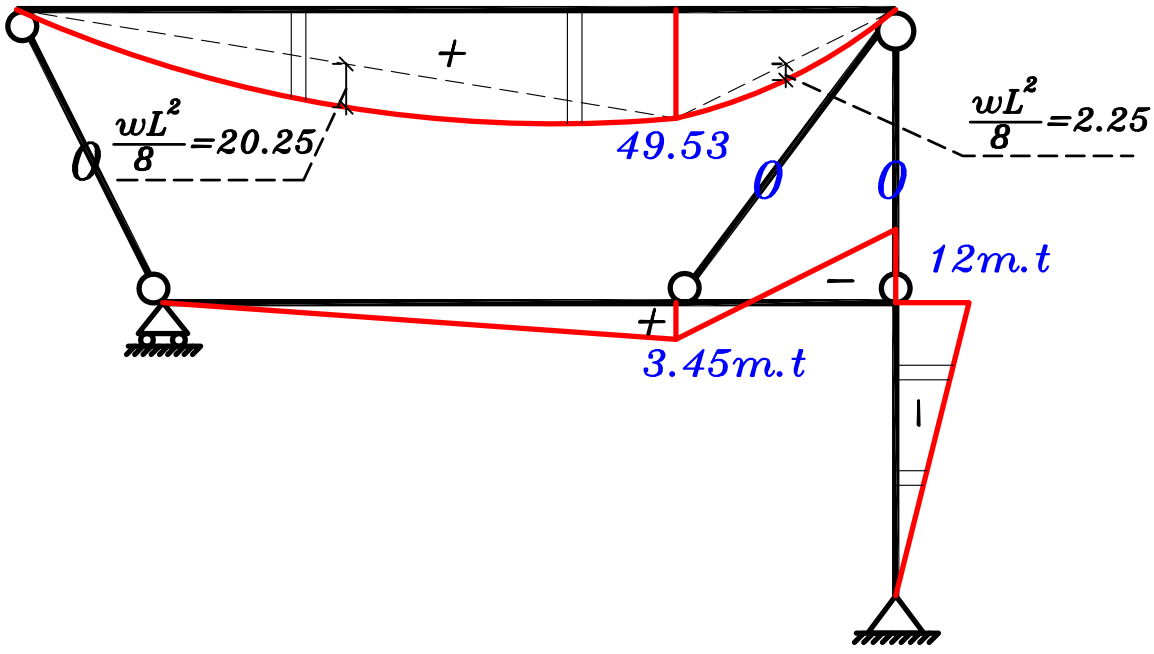


S.F.D



B.M.D

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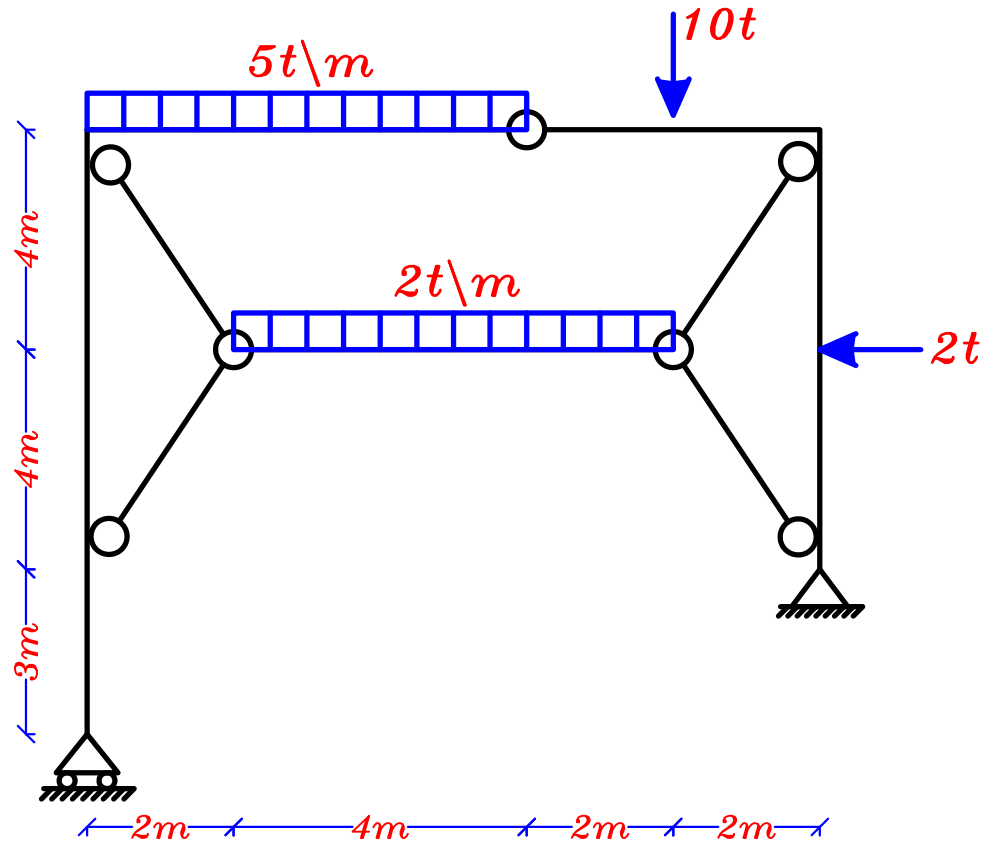
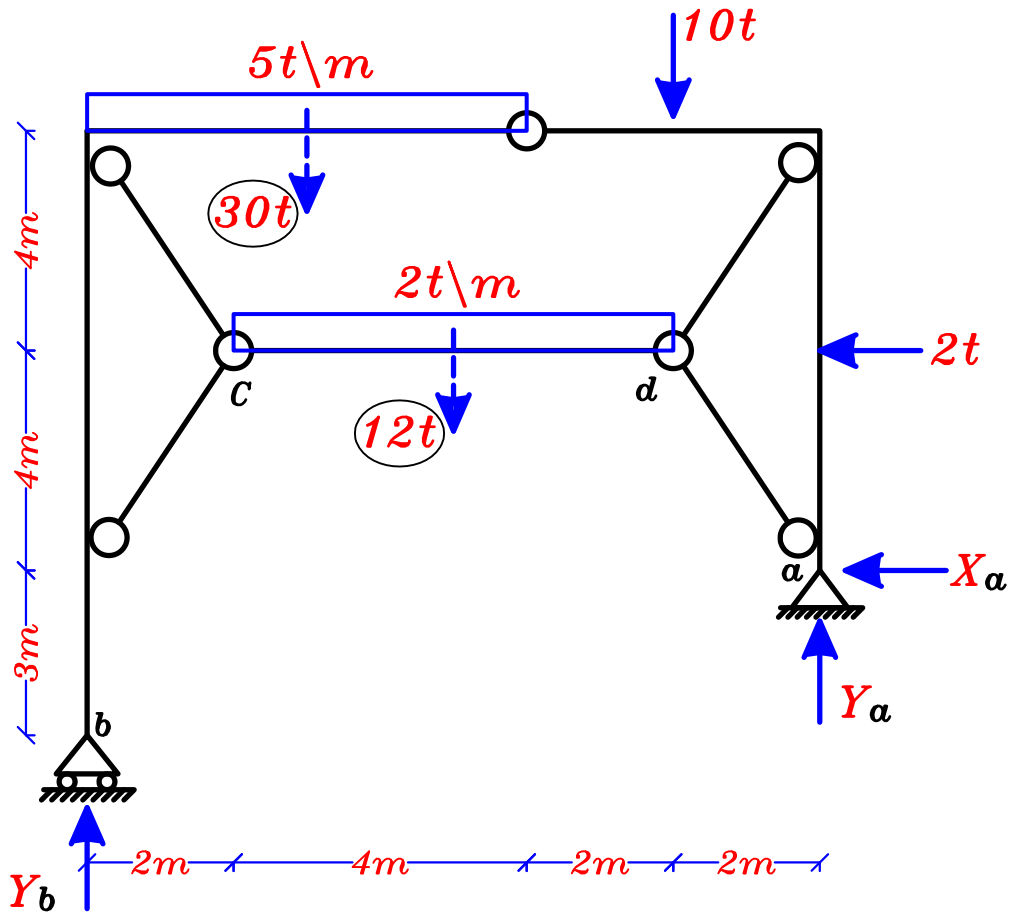
Example :

For the shown Frame draw N.F.D , S.F.D & B.M.D.





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من الممكن حساب الـ *Reactions* بدون فك الـ *Frame* .

$$\Sigma X = 0$$

$$X_a + 2 = 0 \qquad \boxed{X_a = -2\,t} \qquad \text{عكس الاتجاه}$$

$$\Sigma M @ \ a \ = 0$$

$$10 * 2 + 12 * 5 + 30 * 7 + 2 * 4 - Y_b * 10 = 0$$

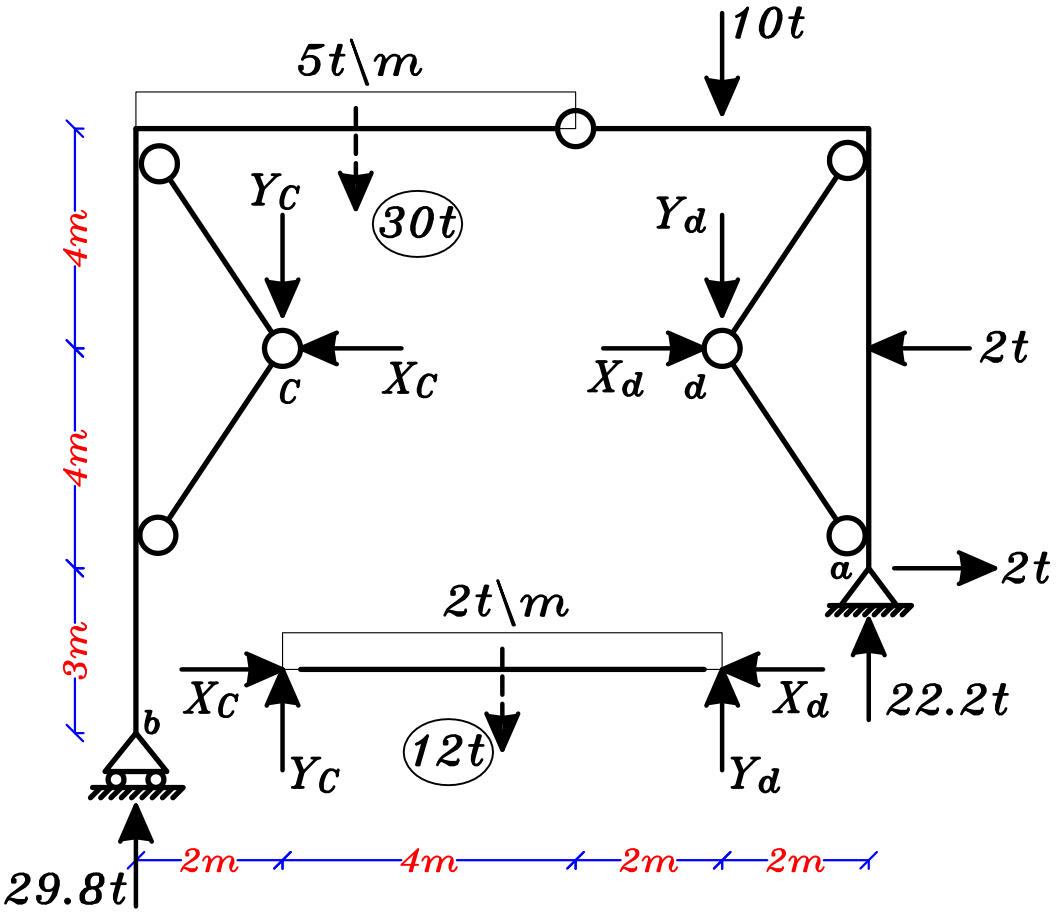
$$\boxed{Y_b = 29.8\,t}$$

$$\Sigma Y = 0$$

$$Y_a - 12 - 10 - 30 + 29.8 = 0 \qquad \boxed{Y_a = 22.2\,t}$$

و لرسم الـ *Internal forces diagrams* نحتاج الى فتح الجزء الـ *Closed* من الـ *Frame*

وفى هذه المسألة نأخذ الـ *Simple beam Cd* لوحدها نحلها ثم نرجع الـ *Reactions* الرأسية لها على الـ *Frame* .



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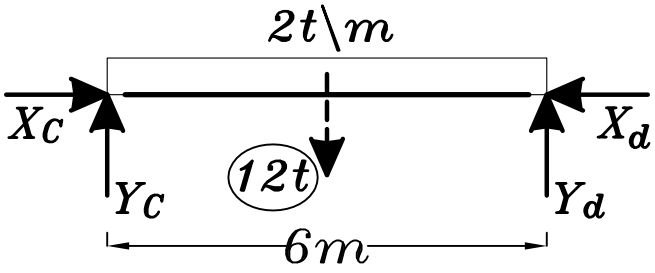


$$\Sigma M @ d = 0$$

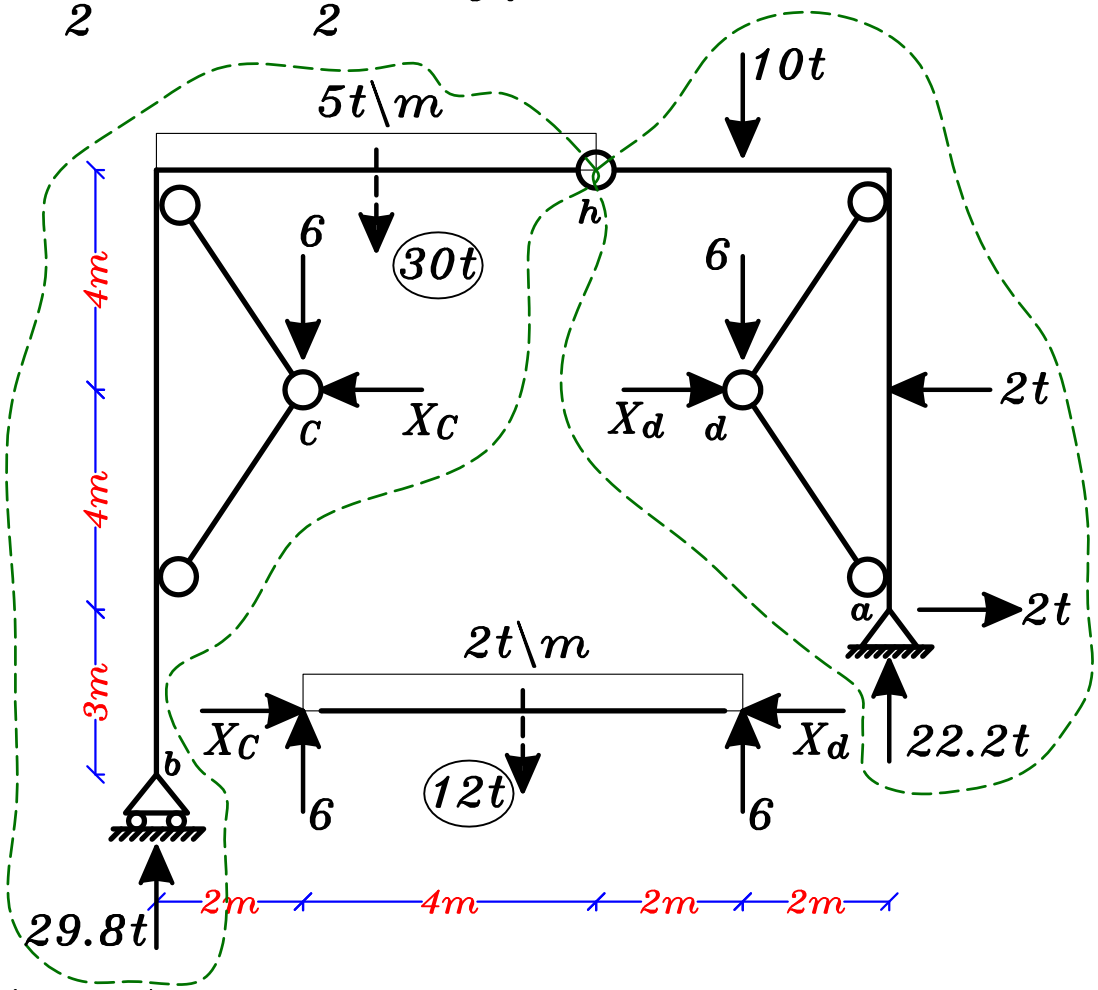
$$12 * 3 - Y_C * 6 = 0 \qquad \boxed{Y_C = 6\ t}$$

$$\Sigma Y = 0$$

$$Y_d - 12 + 6 = 0 \qquad \boxed{Y_d = 6\ t}$$

و من الممكن لان الكمرة متماثلة أن نحسب الـ Reactions الرأسية كالتالى

$$Y_C = Y_d = \frac{\Sigma\ Load}{2} = \frac{12}{2} = 6\ t$$



$$\Sigma M @ h\ (right) = 0$$

$$10 * 2 + 6 * 2 + 2 * 4 - 2 * 8 - 22.2 * 4 - X_d * 4 = 0$$

$$\boxed{X_d = -16.2\ t}$$

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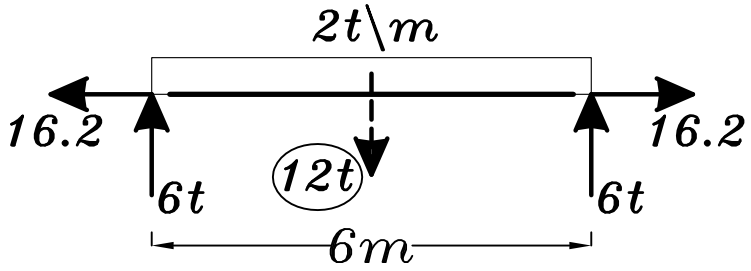
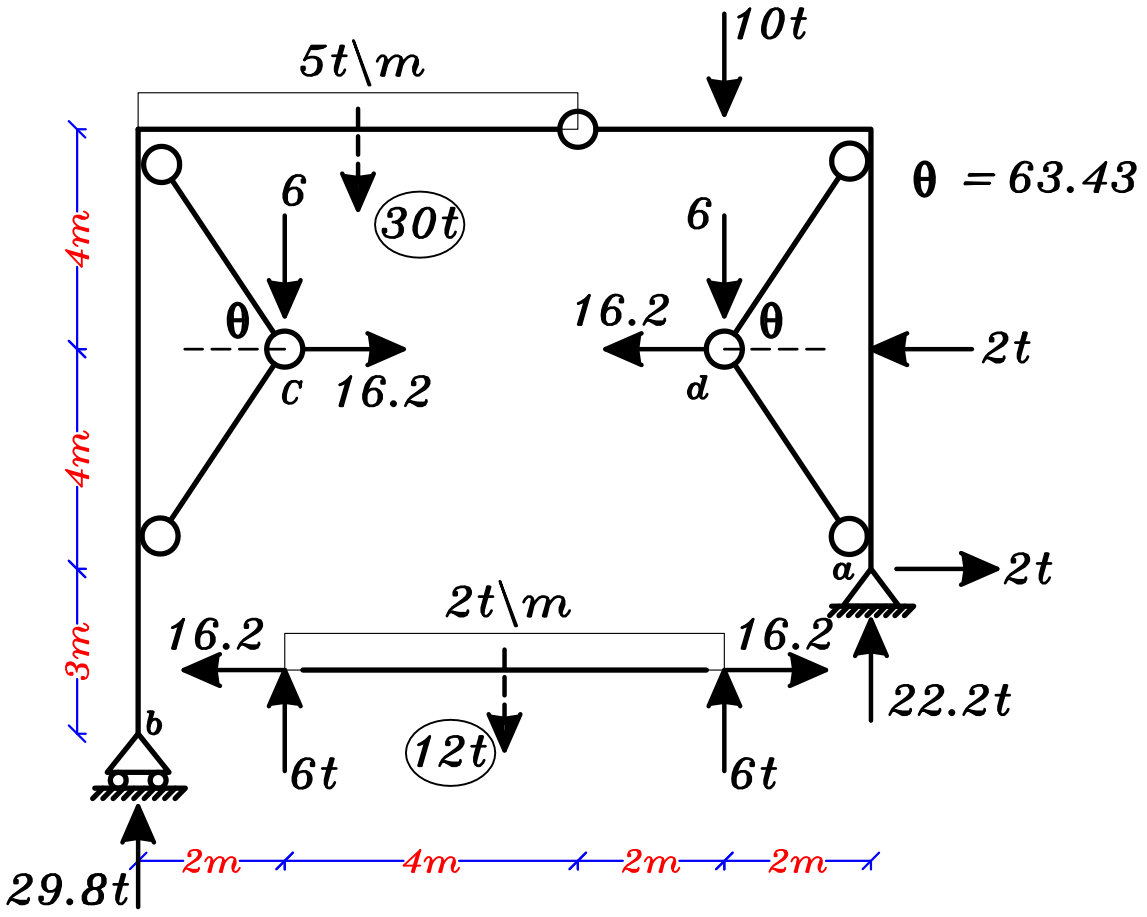
$$\Sigma M @ h \ (left) = 0$$

$$30 * 3 + 6 * 4 - 29.8 * 6 - X_C * 4 = 0$$

$$\boxed{X_C = -16.2 \ t}$$

و من الممكن عمل Check بأخذ $\Sigma X = 0$ للكمرة Cd

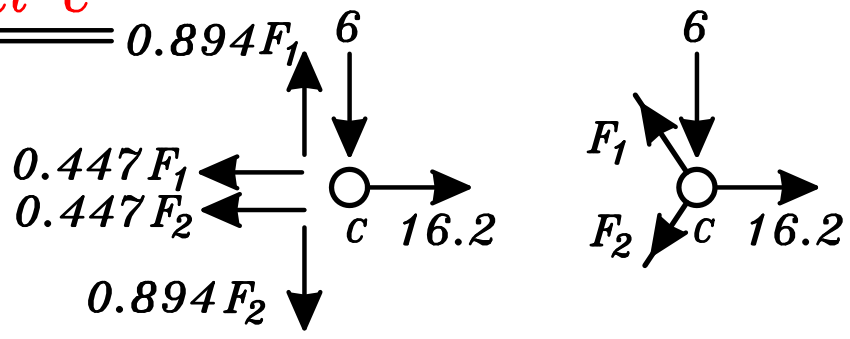




Equilibrium of joint C

$$\Sigma X = 0$$

$$0.447F_1 + 0.447F_2 - 16.2 = 0 \Longrightarrow Eq.1$$



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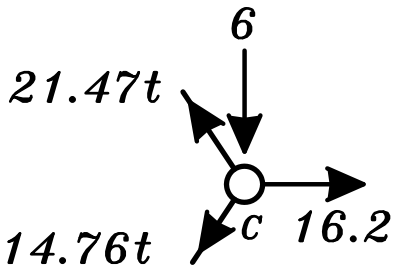
$$\Sigma Y = 0$$

$$0.894F_1 - 0.894F_2 - 6 = 0 \Longrightarrow Eq.2$$

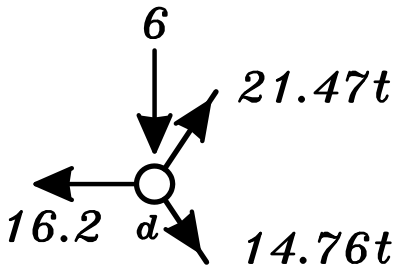
Solving the two equations

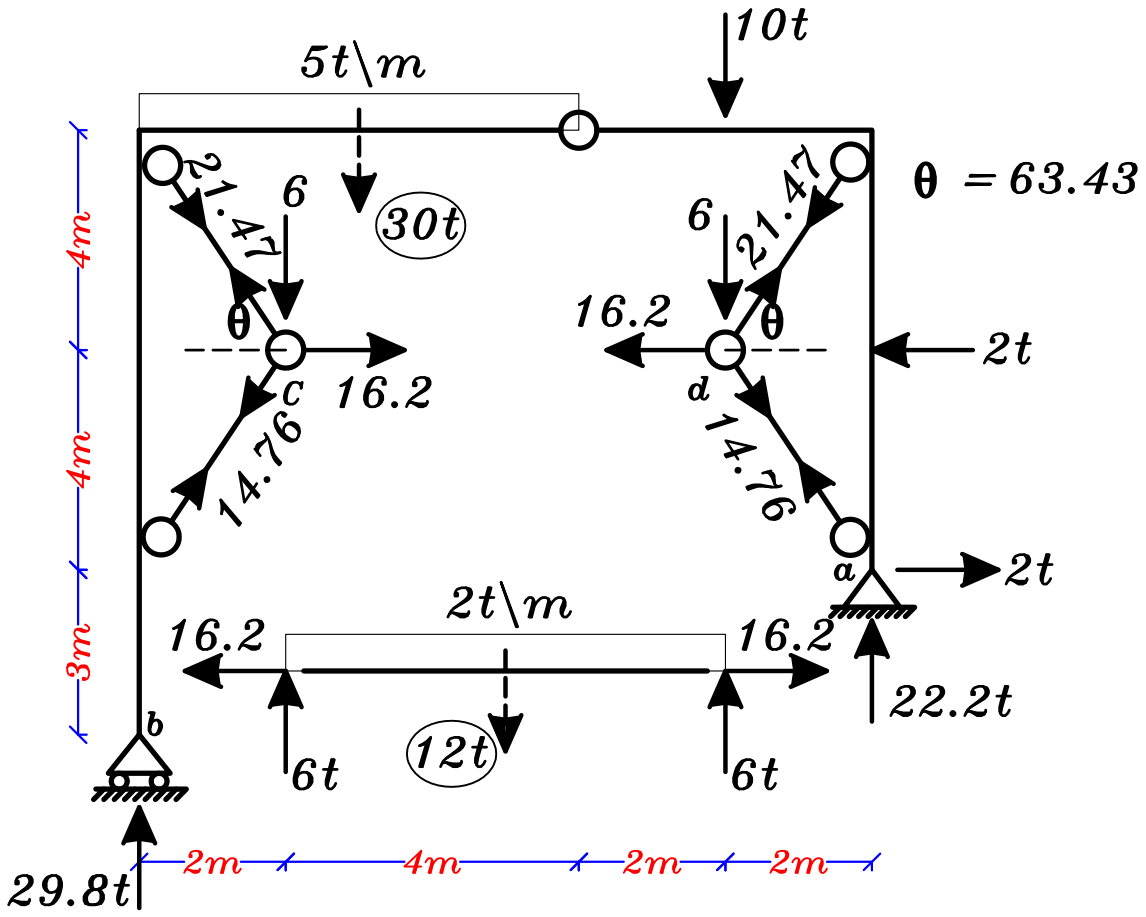
$F_1 = 21.47\,t$ (Tens.)

$F_2 = 14.76\,t$ (Tens.)



وبالمثل Joint d و من الممكن عدم حلها لانها متماثلة





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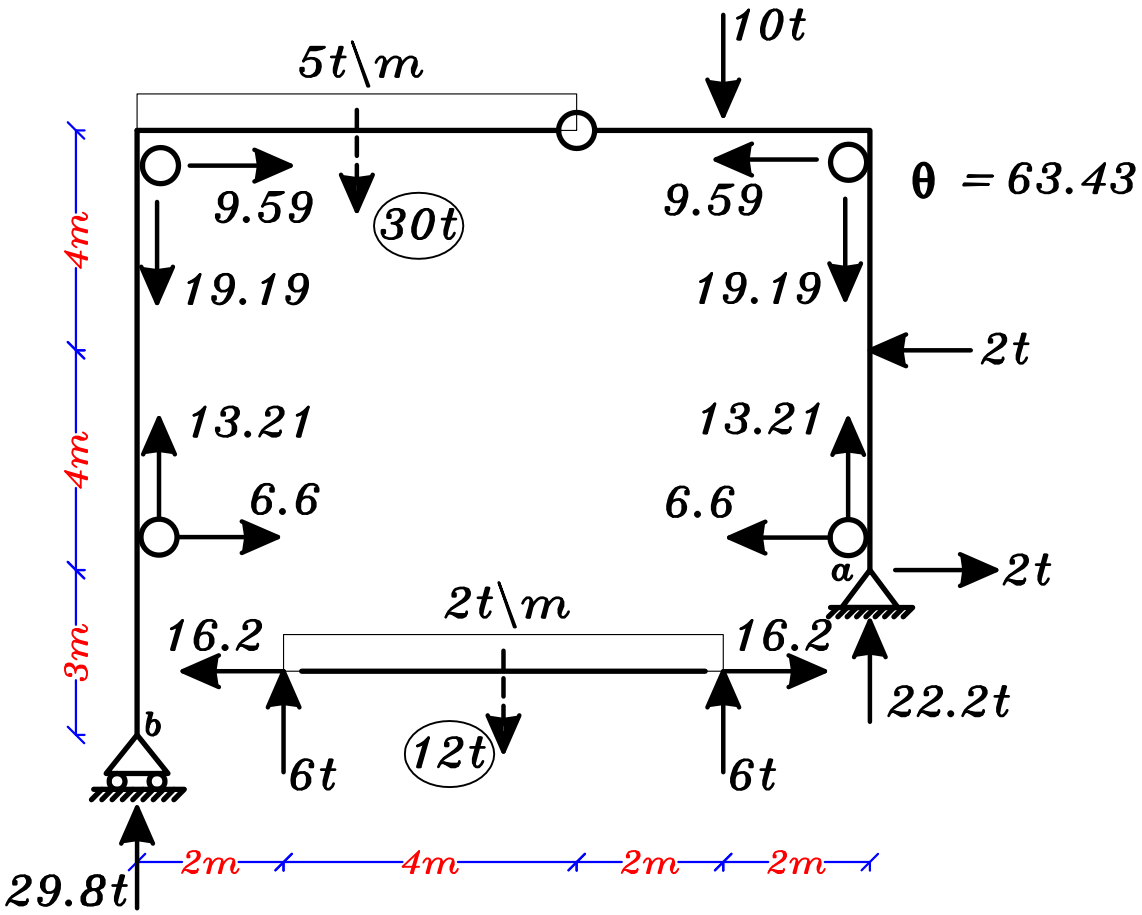

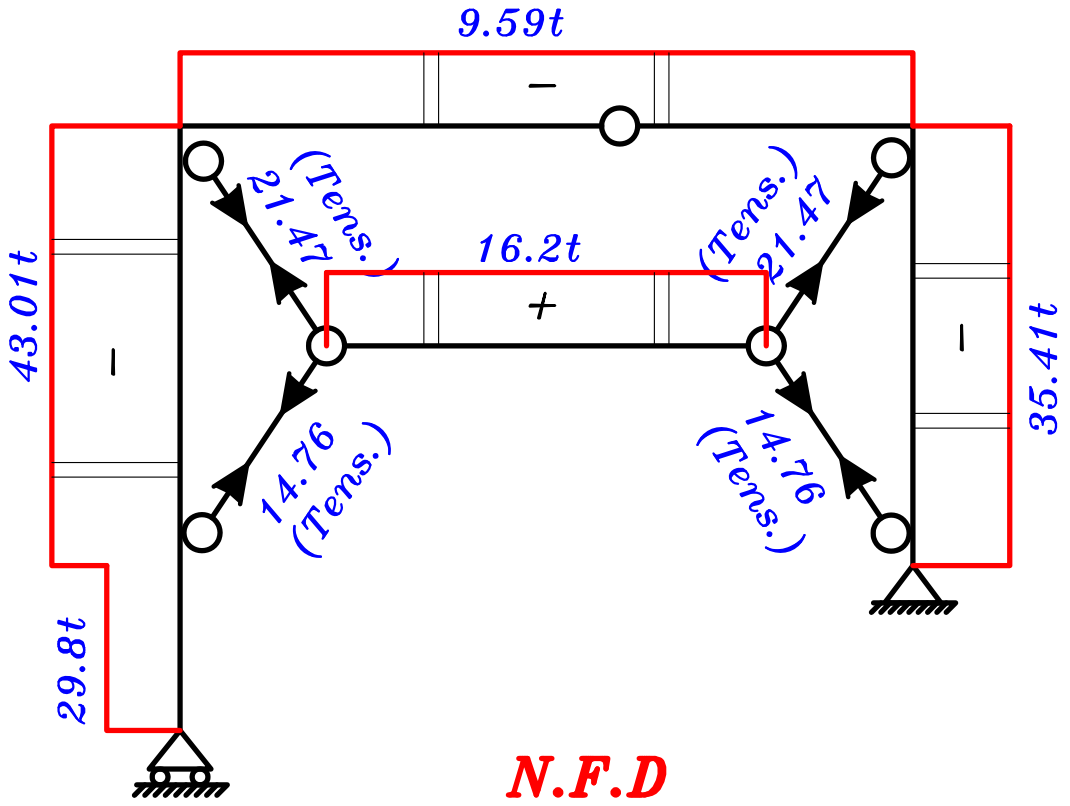

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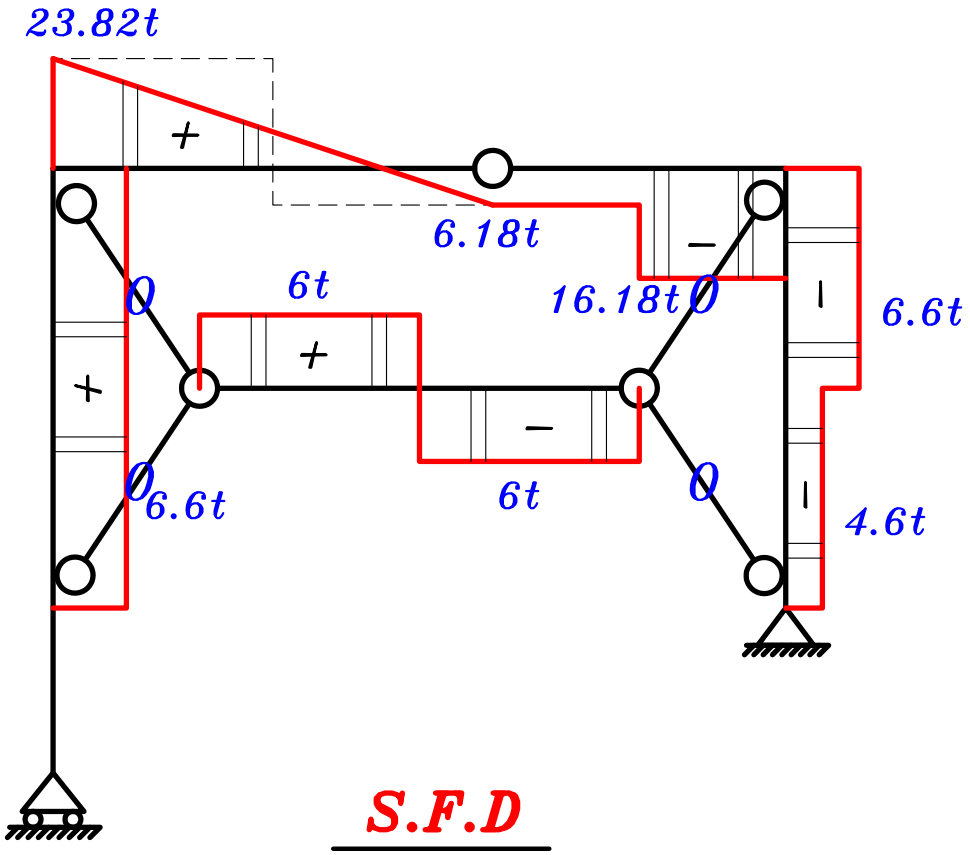
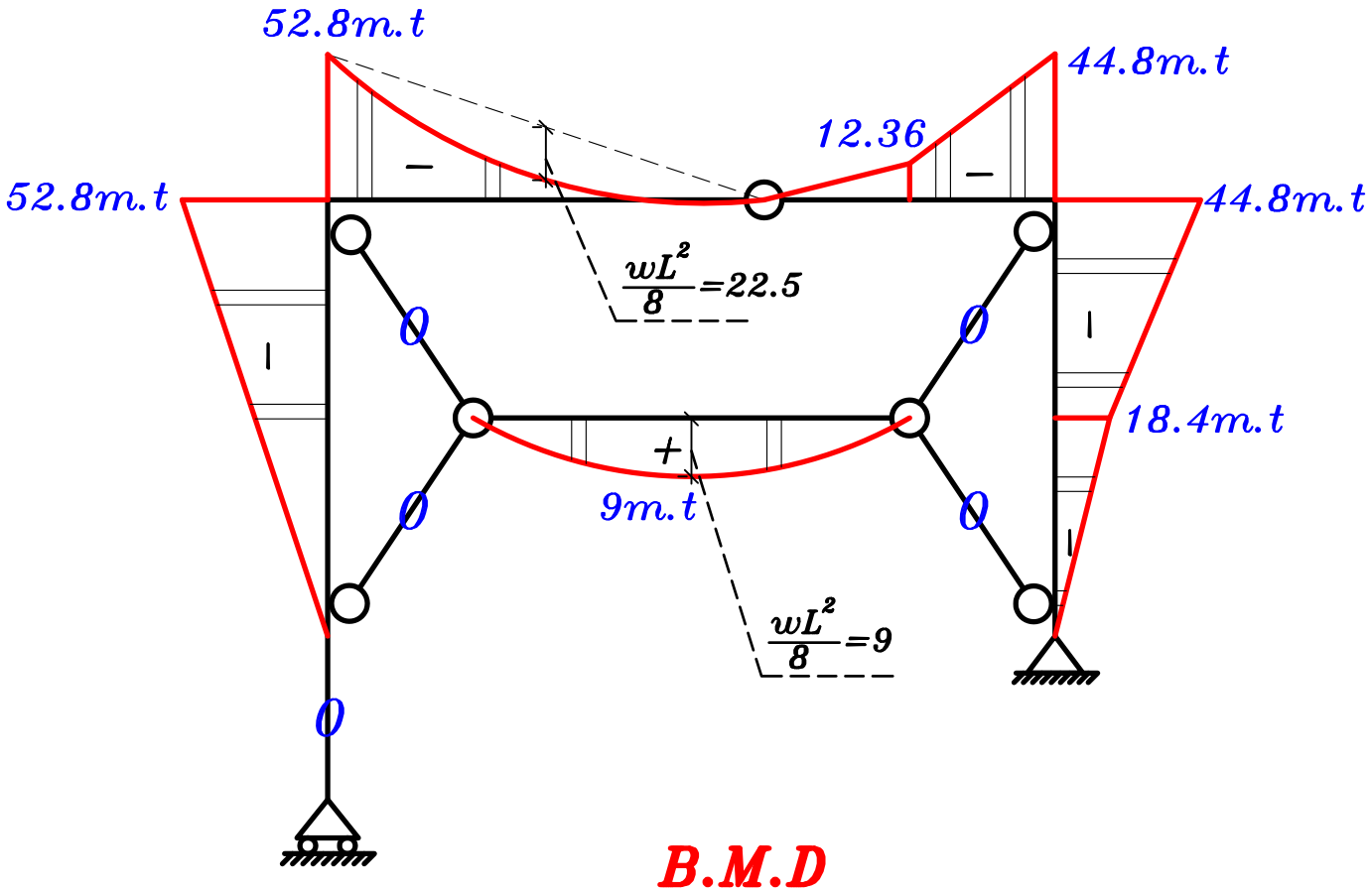


S.F.D



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