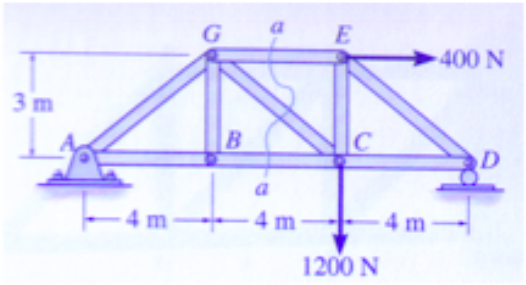
Brief concept:

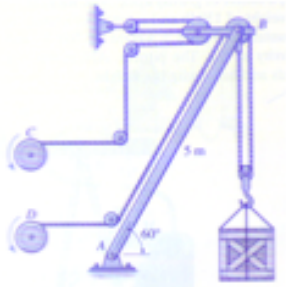
Frames and machines are defined as rigid bodies comprising of at least one multi-force member. **Frames are designed for supporting loads and usually stationary, while machines are designed to modify and transmit forces. It is very important to have a correct free body diagram.**

When drawing FBDs, it is useful to first identify two-force members and label of their unknowns. Doing this provides for less complicated FBDs, fewer equilibrium equations that need to be written and fewer unknowns to be determined.

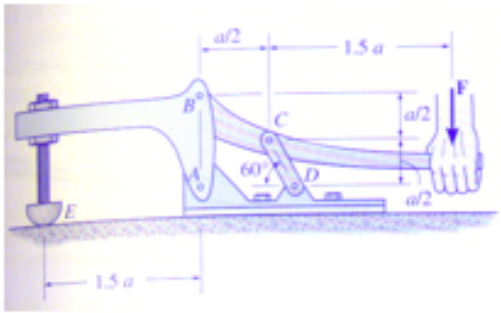
Brief concept:



Trusses

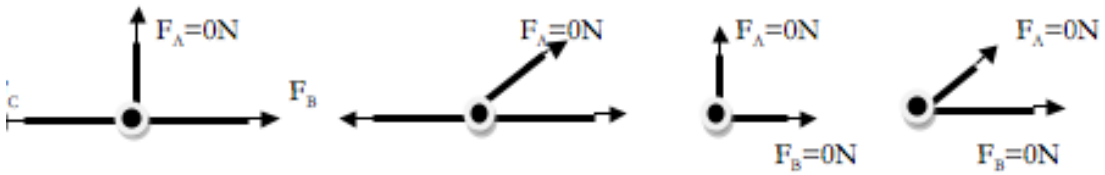


Frames



Machines

ERO-FORCE MEMBERS

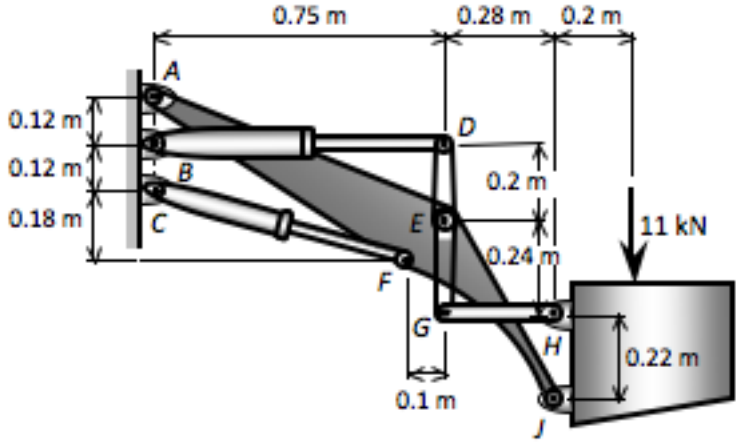


Examples:

EXAMPLE: MACHINES

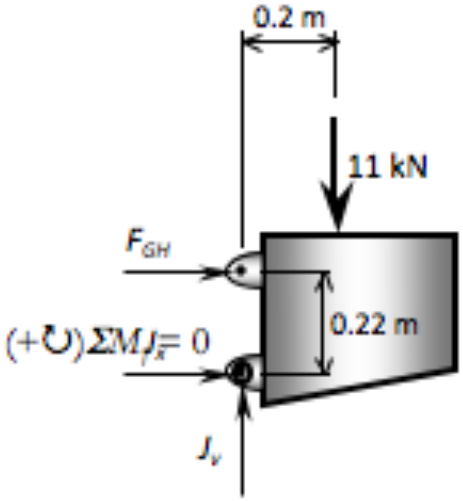
QUESTION 1

Determine the force in hydraulic cylinders *BD* and *CF* for the mechanism shown in **Figure** to support the 11 kN load. State whether the cylinders are in tension or compression.



Examples:

member *HJ*



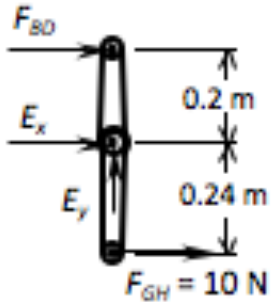
$(+\circlearrowleft)\Sigma M_J = 0$

$11(0.2) + F_{GH}(0.22) = 0$

$F_{GH} = -10$ N

$\therefore \quad F_{GH} = 10$ N ← (tension)

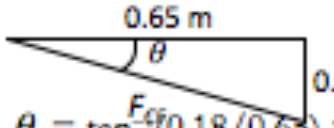
member *DEG*



$10(0.24) - F_{BD}(0.2) = 0$

$F_{BD} = 12$ N → (compression)

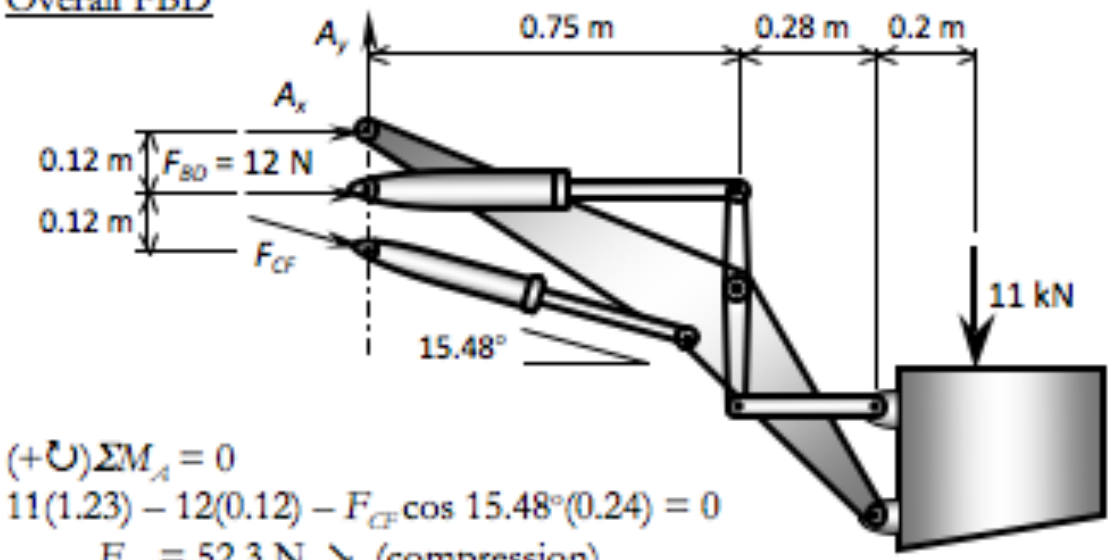
determine angle for F_{CF}



$\theta = \tan^{-1}(0.18/0.65) = 15.48°$

Examples:

Overall FBD



$(+\circlearrowleft)\Sigma M_A = 0$

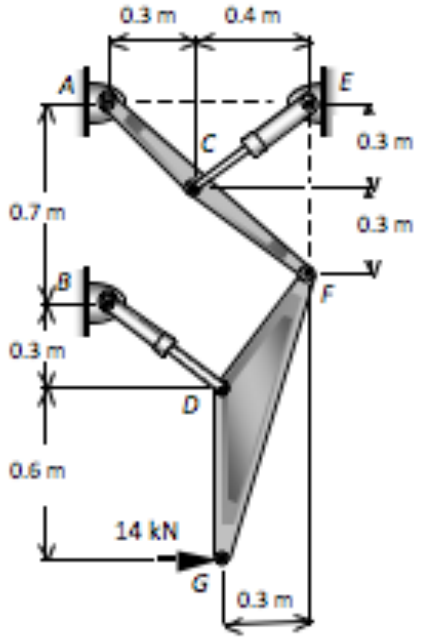
$11(1.23) - 12(0.12) - F_{CF}\cos 15.48°(0.24) = 0$

$F_{CF} = 52.3$ N ↘ (compression)

Examples:

QUESTION 2

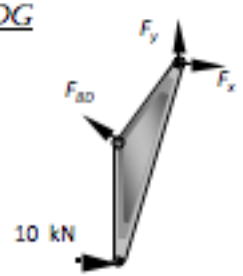
Determine components of the reaction at A and the force in hydarulic cylinders BD and CE when a 14 kN force is applied at G of the mechanism shown in **Figure**. State whether the cylinders are in tension or compression.



Examples:

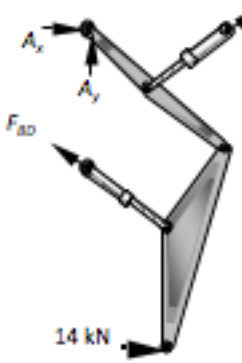
Solution

FDG



$(+\circlearrowleft)\ M_F = 0$
$F_{BD}(4/5)(0.4) + F_{CE}(3/5)(0.3) - 14(1) = 0$
$0.32\,F_{BD} + 0.18\,F_{BD} - 14 = 0$
$F_{BD} = 28$ kN (T)

Overall FBD



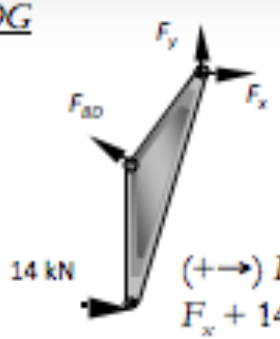
$(+\circlearrowleft)\ M_A = 0$
$F_{BD}(4/5)(0.7) - F_{CE}(3/5)(0.7) - 14(1.6) = 0$
$0.56(28) - 0.42\,F_{CE} - 22.4 = 0$
$F_{CE} = -16$ N (C)

$(+\rightarrow)\ F_x = 0$
$A_x + F_{CE}(4/5) - 28(4/5) + 14 = 0$
$A_x + (-16)(4/5) - 28(4/5) + 14 = 0$
$A_x - 12.8 - 22.4 + 14 = 0$
$A_x = 21.2$ kN ($\rightarrow$)

$(+\uparrow)\ F_y = 0$
$A_y + F_{CE}(3/5) + 28(3/5) = 0$
$A_y + (-16)(3/5) + 28(3/5) = 0$
$A_y - 9.6 + 16.8 = 0$
$A_y = -7.2$ kN ($\downarrow$)

Examples:

FDG

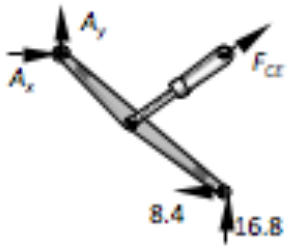


$(+\circlearrowleft)\ M_F = 0$
$F_{BD}(4/5)(0.4) + F_{CE}(3/5)(0.3) - 14(1) = 0$
$0.32\,F_{BD} + 0.18\,F_{BD} - 14 = 0$
$F_{BD} = 28$ kN (T)

$(+\rightarrow)\ F_x = 0$
$F_x + 14 - 28(4/5) = 0$
$F_x = 8.4$ kN $(\rightarrow)$

$(+\uparrow)\ F_y = 0$
$F_y + 28(3/5) = 0$
$F_y = -16.8$ kN $(\downarrow)$

ACF



$(+\circlearrowleft)\ M_A = 0$
$8.4(0.6) - 16.8(0.7) - F_{CE}(3/5)(0.7) = 0$
$5.04 - 11.76 - 0.42\,F_{CE} = 0$
$F_{CE} = -16$ N (C)

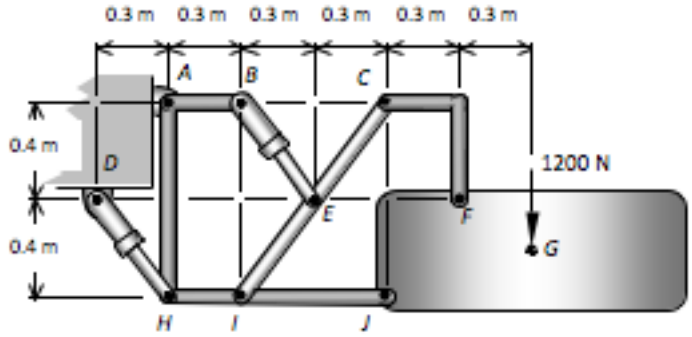
$(+\rightarrow)\ F_x = 0$
$A_x - 16(4/5) - 8.4 = 0$
$A_x = 21.2$ kN $(\rightarrow)$

$(+\uparrow)\ F_y = 0$
$A_y - 16(3/5) + 16.8 = 0$
$A_y = -7.2$ kN $(\downarrow)$

Examples:

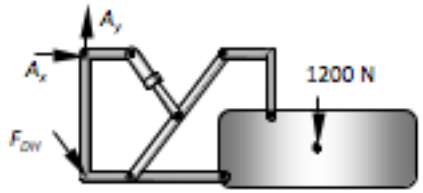
QUESTION 3

The mechanism shown in **Figure** is used to support a 1200 N load at *G*. Determine components of the reaction at *A* and the force in hydraulic cylinders *DH* and *BE*, and state whether the cylinders are in tension or compression.

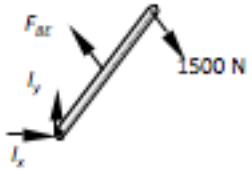


Solution

Overall FBD



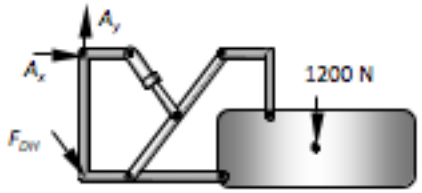
IEC



Examples:

Solution

Overall FBD

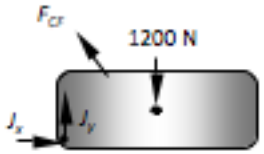


$(+\circlearrowright)\quad M_A = 0$
$1200(1.5) - F_{DH}(3/5)(0.8) = 0$
$F_{DH} = 3750$ N (C)

$(+\rightarrow)\quad F_x = 0$
$A_x + 3750(3/5) = 0$
$A_x = -2250$
$A_x = 2250$ N ($\leftarrow$)

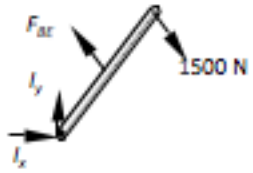
$(+\uparrow)\quad F_y = 0$
$A_y - 3750(4/5) - 1200 = 0$
$A_y = 4200$ N ($\uparrow$)

JFG



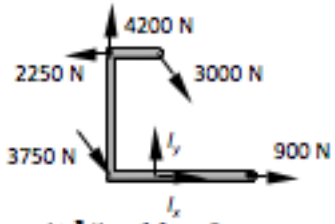
$(+\circlearrowright)\quad M_J = 0$
$1200(0.6) - F_{CF}(3/5)(0.4) - F_{CF}(4/5)(0.3) = 0$
$720 - 0.24\,F_{CF} - 0.24\,F_{CF} = 0$
$F_{CF} = 1500$ N (T)

IEC



$(+\circlearrowright)\quad M_I = 0$
$1500(3/5)(0.8) + 1500(4/5)(0.6)$
$- F_{BE}(3/5)(0.4) - F_{BE}(4/5)(0.3) = 0$
$720 + 720 - 0.24\,F_{BE} - 0.24\,F_{BE} = 0$
$F_{CF} = 3000$ N (T)

check using *BAHIJ*

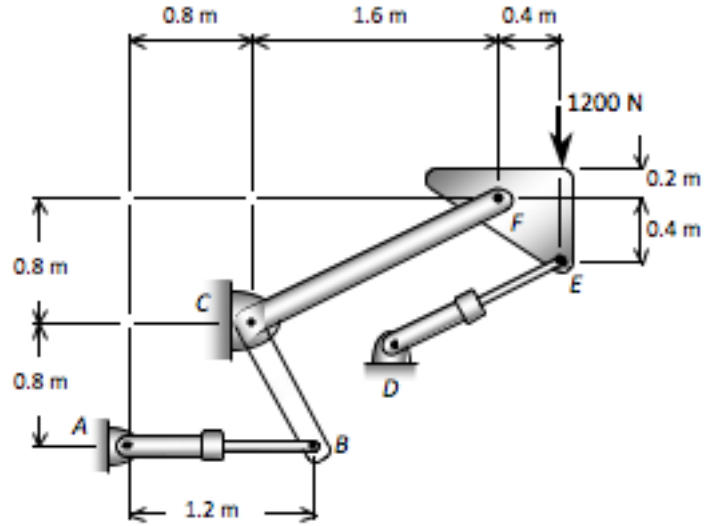


$(+\circlearrowright)\quad M_J = 0$
$3000(3/5)(0.8) - 2250(0.8)$
$+ 4200(0.3) - 3750(4/5)(0.3) = 0$
$1440 - 1800 + 1260 - 900 = 0$

Examples:

QUESTION 4

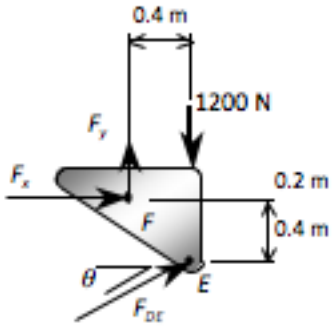
The mechanism shown in **Figure** is used to support the 1200 N load. Determine the force in the two identical hydraulic cylinders *AB* and *DE*, and components of the reaction at pin *C* for the system to maintain equilibrium. Hydraulic cylinder *DE* is parallel to *CF*.



Examples:

Solution

FE

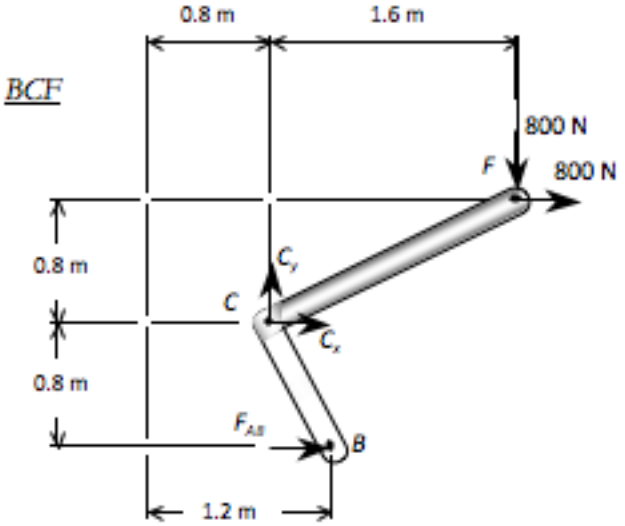


$(+\circlearrowright)\ M_F = 0$
$1200\ (0.4) - F_{DE} \sin\theta\ (0.4) - F_{DE} \cos\theta\ (0.4) = 0$
$\theta = \tan^{-1} 0.5 = 26.6°$
$480 - 0.1791\ F_{DE} - 0.358\ F_{DE} = 0$
$F_{DE} = 894\ \text{N}$

$(+\rightarrow)\ F_x = 0$
$F_x + F_{DE} \cos\theta = 0$
$F_x = -800\ \text{N}\ (\leftarrow)$

$(+\uparrow)\ F_y = 0$
$F_y - 1200 + F_{DE} \sin\theta = 0$
$F_y = 800\ \text{N}\ \uparrow$

BCF



$(+\circlearrowright)\ M_C = 0$
$800(0.8) + 800(1.6) - F_{AB}\ (0.8) = 0$
$640 + 1280 - 0.8\ F_{AB} = 0$
$F_{AB} = 2400\ \text{N}$

$(+\rightarrow)\ F_x = 0$
$C_x + 800 + 2400 = 0$
$C_x = -3200\ \text{N}\ (\leftarrow)$

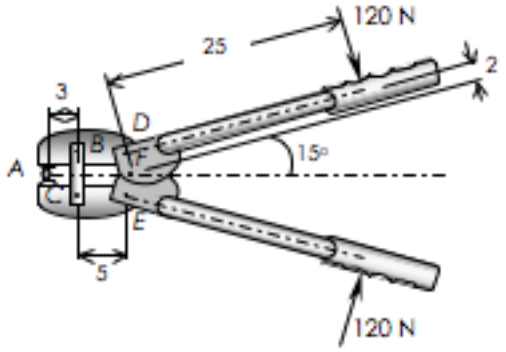
$(+\uparrow)\ F_y = 0$
$C_y - 800 = 0$
$C_y = 800\ \text{N}\ \uparrow$

Exercises:

EXERCISE: MACHINES

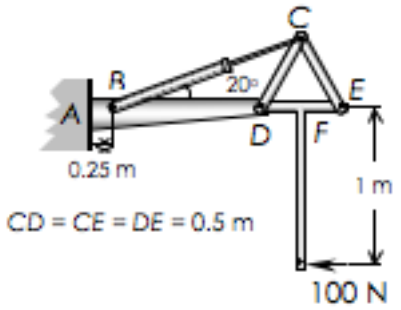
QUESTION 1

120 N forces are exerted on wire cutter as shown. Determine the forces acting on the wire. All dimensions in cm. (A = 5659N)



QUESTION 2

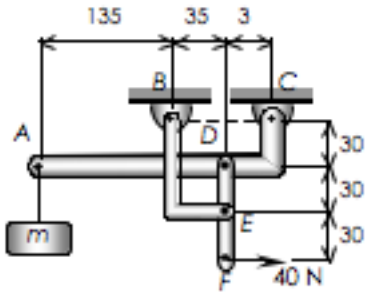
The mechanism shown in the figure is used to support the 100 N load at *G*. Determine the force acting on the two force member *CE* and the hydraulic cylinder *BC* for this instant.
(F_{CE}= 231N (T), F_{BC}= 311N (T))



Exercises:

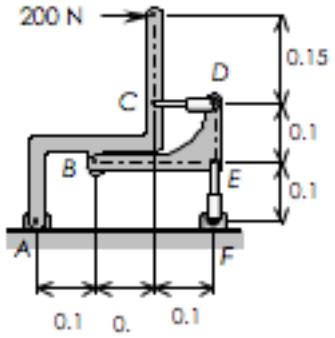
QUESTION 3

The frame in the figure is used to support the mass *m* at end *A*. Determine the mass *m* (in kg) if a 40 N force is applied at *F*. All dimensions in cm. (*m* = 2.71kg)



QUESTION 4

The mechanism shown is used to support the 200 N horizontal force at *D* by adjusting hydraulic cylinders *CE* and *FG*. Determine all components of forces acting on member *ABC* for the position shown. All dimensions in metres. (A_x = 200N(<), A_y = 233N (^) , B_x = 47N (>), B_y = 233N (^), F_{CD} = 47N (C))



Exercises:

QUESTION 5

The figure shows a 180 kg adjustable platform *AB* used to raise a 550 kg crate with centre of gravity at *G*. Determine the force in the two–force member *BC* and hydraulic cylinder *DF* and state whether they are in tension or compression. All dimensions in cm. (F_{BC} = 2656N (C), F_{DF} = 5825N (C))