King Fahd University of Petroleum & Minerals
DEPARTMENT OF CIVIL ENGINEERING

CE 201 STATICS (102)

Second Major Exam

Tuesday 10/5/2011
7:00 p.m. → 9:30 p.m.

Name : Key Solution **I.D. # :** .....

SECTION #: [ ]

Question	Points	Grade
1A	15	
1B	15	
2	20	
3	25	
4	25	
TOTAL	**100**	

Good luck !

Question # 1A (15 points)

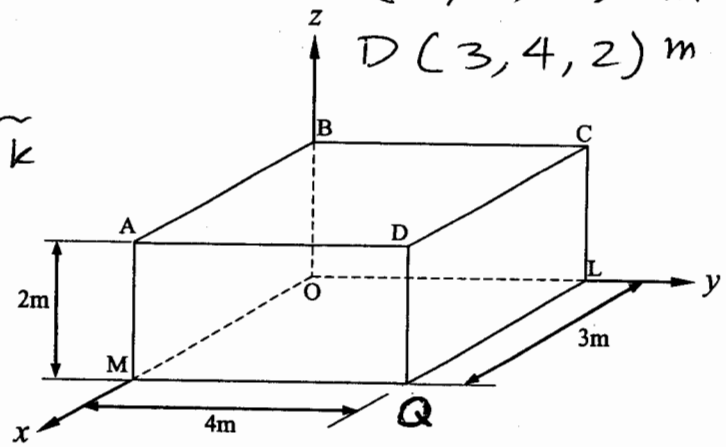
In the box shown below; Force $|\tilde{F}| = 50^{N}$ is directed from point (C) towards point (A):

4% a) Write the force $(\tilde{F})$ in Cartesian form.

5% b) Find the moment of force $(\tilde{F})$ about point (Q).

6% c) Find the moment of force $(\tilde{F})$ about axis (OD).

A (3, 0, 2) m
C (0, 4, 2) m
Q (3, 4, 0) m
D (3, 4, 2) m



Solution:

a) $\tilde{r}_{CA} = 3\tilde{i} - 4\tilde{j} + 0\tilde{k}$

(2) $|\tilde{r}_{CA}| = \sqrt{3^2+4^2} = 5^{m}$

$\tilde{u}_{CA} = 0.6\tilde{i} - 0.8\tilde{j}$

(2) $\tilde{F} = |\tilde{F}|\tilde{u}_{CA} = \boxed{30\tilde{i} - 40\tilde{j} + 0\tilde{k}}\ N$

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b) $\tilde{r}_{QA} = 0\tilde{i} - 4\tilde{j} + 2\tilde{k}$

(2)

(3) $\tilde{M}^{F}_{Q} = \tilde{r}_{QA} \times \tilde{F} = \begin{vmatrix} \tilde{i} & \tilde{j} & \tilde{k} \\ 0 & -4 & 2 \\ 30 & -40 & 0 \end{vmatrix} = \boxed{80\tilde{i} + 60\tilde{j} + 120\tilde{k}}\ N\cdot m$

$|M^{F}_{Q}| = 156.2^{N\cdot m}$

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c) $\tilde{r}_{OD} = 3\tilde{i} + 4\tilde{j} + 2\tilde{k}\ (m)$ $\quad |r_{OD}| = 5.4^{m}$

(2) $\tilde{u}_{OD} = 0.56\tilde{i} + 0.74\tilde{j} + 0.37\tilde{k}$

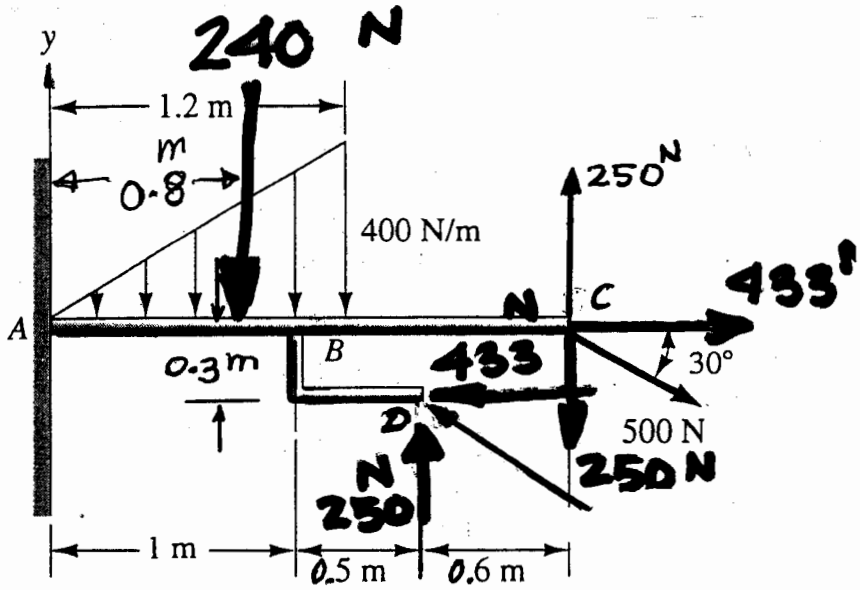
(1) $\tilde{r}_{DC} = -3\tilde{i} + 0\tilde{j} + 0\tilde{k}$

(3) $|\tilde{M}^{F}_{OD}| = \tilde{u}_{OD} \cdot \tilde{r}_{DC} \times \tilde{F} = \begin{vmatrix} 0.56 & 0.74 & 0.37 \\ -3 & 0 & 0 \\ 30 & -40 & 0 \end{vmatrix}$

$= \boxed{44.56\ N\cdot m}$

Question # 1B (15 points)

Reduce the system of forces on beam (ABC) into a single force and a single couple at point (A).



Solution

$400 \times 1.2 \times \frac{1}{2}$

$= 240^{N}(\downarrow)$ (3)

$\pm\rightarrow \sum F_x = 433 - 433 = 0$ (3)

$+\uparrow \sum F_y = 250 - 240 = 10^{N}\ (\uparrow)$ (3)

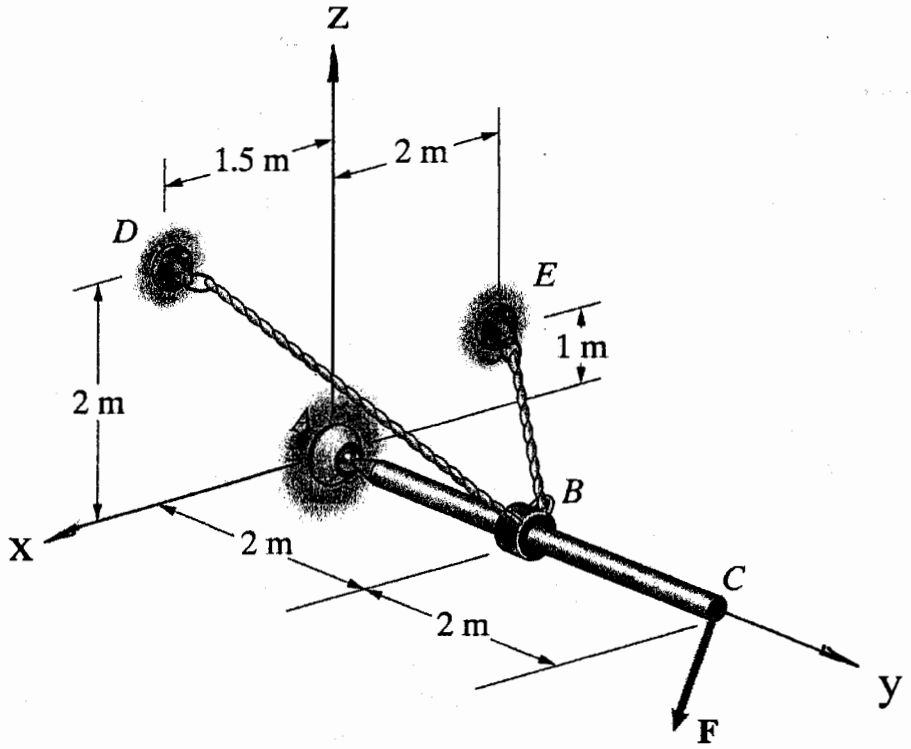
$\circlearrowleft^{+}_{A} \sum M_A = 250 \times 1.5 - 433 \times 0.3 - 240 \times 0.8$

$= 375 - 130 - 192$ (6)

$= 53.0\ N.m\ (\circlearrowleft^{+})$

Problem 2 (20 points)

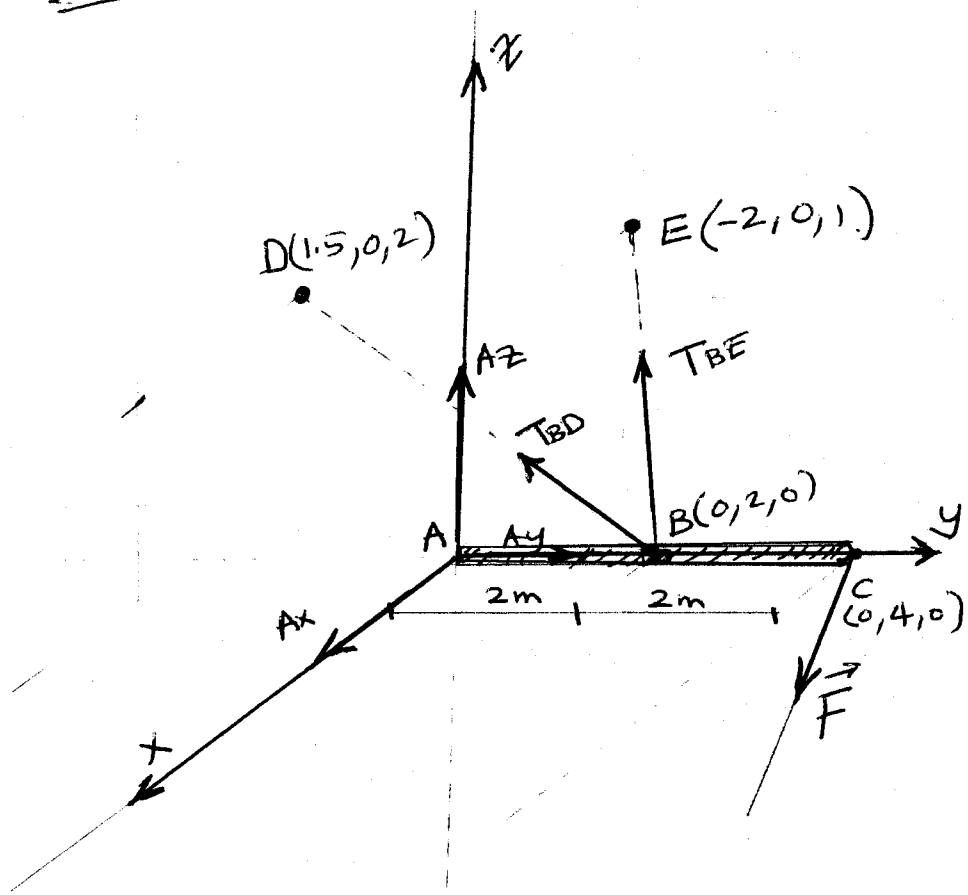
The force **F** acting on the boom ABC at C point in the direction of the unit vector (+ 0.767**i** + 0.512**j** - 0.384**k**) and its magnitude is (80 kN). The boom is supported by a ball and socket at A and the cables BD and BE. The collar at B is fixed to the boom. Determine the tension in the cables and the reactions at A.



Problem 2 (Solution)

(20)

FBD (2)



$$\vec{F} = 80(0.767\vec{i} + 0.512\vec{j} - 0.384\vec{k})\ N$$

$$= 61.36\vec{i} + 40.96\vec{j} - 30.72\vec{k}\ (N) \quad (1)$$

$\vec{r}_{BE} = -2\vec{i} - 2\vec{j} + \vec{k}$ (1/2) $\Rightarrow$ $|r_{BE}| = 3\ m$ (1/2)

$\vec{u}_{BE} = -0.67\vec{i} - 0.67\vec{j} + 0.33\vec{k}$ (1/2)

$\vec{r}_{BD} = 1.5\vec{i} - 2\vec{j} + 2\vec{k}$ (1/2) $\Rightarrow |r_{BD}| = 3.202\ m$ (1/2)

$\vec{u}_{BD} = 0.468\vec{i} - 0.625\vec{j} + 0.625\vec{k}$ (1/2)

$\vec{T}_{BE} = T_{BE}(\vec{u}_{BE}) = T_{BE}(-0.67\vec{i} - 0.67\vec{j} + 0.33\vec{k})$ (1)

$\vec{T}_{BD} = T_{BD}(\vec{u}_{BD}) = T_{BD}(0.468\vec{i} - 0.625\vec{j} + 0.625\vec{k})$ (1)

$\vec{A} = A_x\vec{i} + A_y\vec{j} + A_z\vec{k}$ (1/2)

$\Sigma F = 0 \qquad \vec{A} + \vec{T}_{BE} + \vec{T}_{BD} + \vec{F} = 0$

$$A_x\vec{i} + A_y\vec{j} + A_z\vec{k} + T_{BE}(-0.67\vec{i} - 0.67\vec{j} + 0.33\vec{k})$$

$$+ T_{BD}(0.468\vec{i} - 0.625\vec{j} + 0.625\vec{k})$$

$$+ 61.36\vec{i} + 40.96\vec{j} - 30.72\vec{k} = 0$$

(2) (1)

$\Sigma F_x = 0$

$$A_x - 0.67\,T_{BE} + 0.468\,T_{BD} + 61.36 = 0 \quad -(1)$$ (1/2)

$\Sigma F_y = 0$

$$A_y - 0.67\,T_{BE} - 0.625\,T_{BD} + 40.96 = 0 \quad -(2)$$ (1/2)

$\Sigma F_z = 0$

$$A_z + 0.33\,T_{BE} + 0.625\,T_{BD} - 30.72 = 0 \quad -(3)$$ (1/2)

$\vec{r}_{AB} = 2\vec{j}$ (m) (1/2) $\qquad \vec{r}_{AC} = 4\vec{j}$ (m) (1/2)

$\Sigma M_A = 0$ (1)

$$\vec{r}_{AB} \times (\vec{T}_{BE} + \vec{T}_{BD}) + \vec{r}_{AC} \times \vec{F} = 0$$

$$\begin{vmatrix} i & j & k \\ 0 & 2 & 0 \\ -0.67T_{BE} & -0.67T_{BE} & 0.33T_{BE} \end{vmatrix} + \begin{vmatrix} i & j & k \\ 0 & 2 & 0 \\ 0.468T_{BD} & -0.625T_{BD} & 0.625T_{BD} \end{vmatrix}$$ (1) (1)

$$+ \begin{vmatrix} i & j & k \\ 0 & 4 & 0 \\ 61.63 & 40.96 & -30.72 \end{vmatrix} = 0$$ (1)

$$i(0.67\,T_{BE}) + k(2(0.67)\,T_{BE})$$
$$+ i(2(0.625)\,T_{BD}) + k(-2(0.468)\,T_{BD})$$
$$+ i(-4(30.72)) + k(-4(61.63)) = 0$$

(1) ✓

$\Sigma M_X = 0$

$$0.67\,T_{BE} + 1.25\,T_{BD} - 122.88 = 0 \quad \text{—(4)}$$

(1/2)

$\Sigma M_Z = 0$

$$1.34\,T_{BE} - 0.936\,T_{BD} - 246.52 = 0 \quad \text{—(5)}$$

(1/2)

multiply —(4) × 2

$$1.34\,T_{BE} + 2.5\,T_{BD} - 245.76 = 0 \quad \text{—(4)}$$
$$-1.34\,T_{BE} \pm 0.936\,T_{BD} \pm 246.52 = 0 \quad \text{—(5)}$$

Subtract

$$3.436\,T_{BD} + 0.76 = 0$$

$T_{BD} = 0$ kN	(1/2) ✓
$T_{BE} = 183.4$ kN	(1/2) ✓

Substitute in eqns (1), (2) and (3)

$A_x = 61.5$ kN	(1/2) ✓
$A_y = 81.92$ kN	(1/2) ✓
$A_z = -29.80$	(1/2) ✓

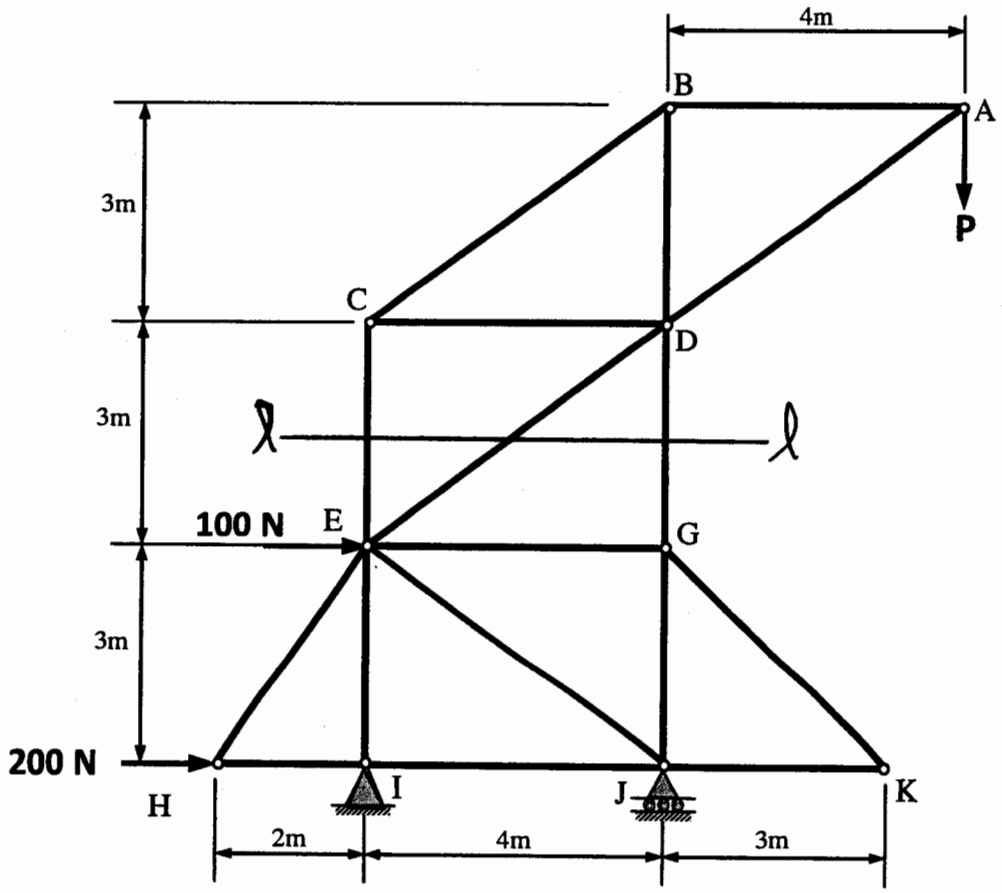
Question # 3 (25 points)

In the truss shown below, determine

5 pts. A) all **zero-force members** (***by inspection***);
(*Each wrong answer takes the points of a correct answer.*)

8 pts. B) the force in member **BD** by the **method of joints** (Express the answer in terms of P); (*No credit will be given if another method is used.*)

12 pts. C) the **maximum force** (**P**) which can be applied safely, if the maximum allowable forces in members CE, DE & DG are 500 N in tension and 900 N in compression. Use the **method of sections.** (*No credit will be given if another method is used.*)



Problem # 3:

(pts) Solution

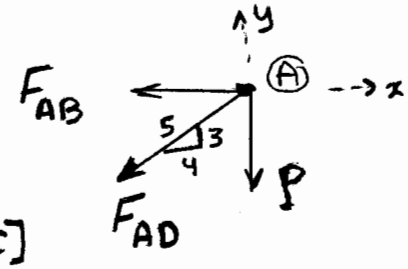
A) Zero-force members

KG, KJ, GE, HE [also DE, but not by inspection]

(5) ① ① ① ②

B)

(1) FBD of joint (A)



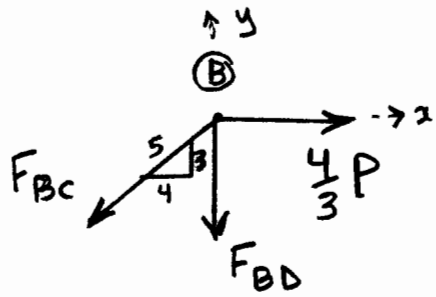
(1) $+\uparrow \Sigma F_y = 0 \Rightarrow$

(1) $-P - F_{AD}\left(\frac{3}{5}\right) = 0 \Rightarrow F_{AD} = \frac{5}{3}P$ [C]

(1) $\pm\rightarrow \Sigma F_x = 0 \Rightarrow -F_{AB} - \left(-\frac{5}{3}P\right)\left(\frac{4}{5}\right) = 0$

$\Rightarrow F_{AB} = \frac{4}{3}P$ [T]

(2) FBD of jonit (B)



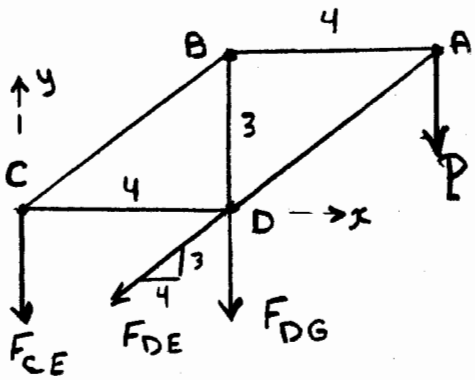
(1) $\pm\rightarrow \Sigma F_x = 0 = \frac{4}{3}P - F_{BC}\left(\frac{4}{5}\right)$

$\Rightarrow F_{BC} = \frac{5}{3}P$ [T]

(2) $+\uparrow \Sigma F_y = 0 = -F_{BD} - \frac{5}{3}P\left(\frac{3}{5}\right) \Rightarrow$

$F_{BD} = -P \Rightarrow \underline{F_{BD} = P}$ [C]

(3) C) Section l-l is made and the FBD of the upper part is chosen.



(1) $\pm\rightarrow \Sigma F_x = 0 \Rightarrow F_{DE} = 0$

(1) $+\circlearrowleft \Sigma M_D = 0 = F_{CE}(4) - P(4)$

$\Rightarrow F_{CE} = P$ [T]

(1) $+\uparrow \Sigma F_y = 0 = -P - P - F_{DG}$

$\Rightarrow F_{DG} = -2P = 2P$ [C]

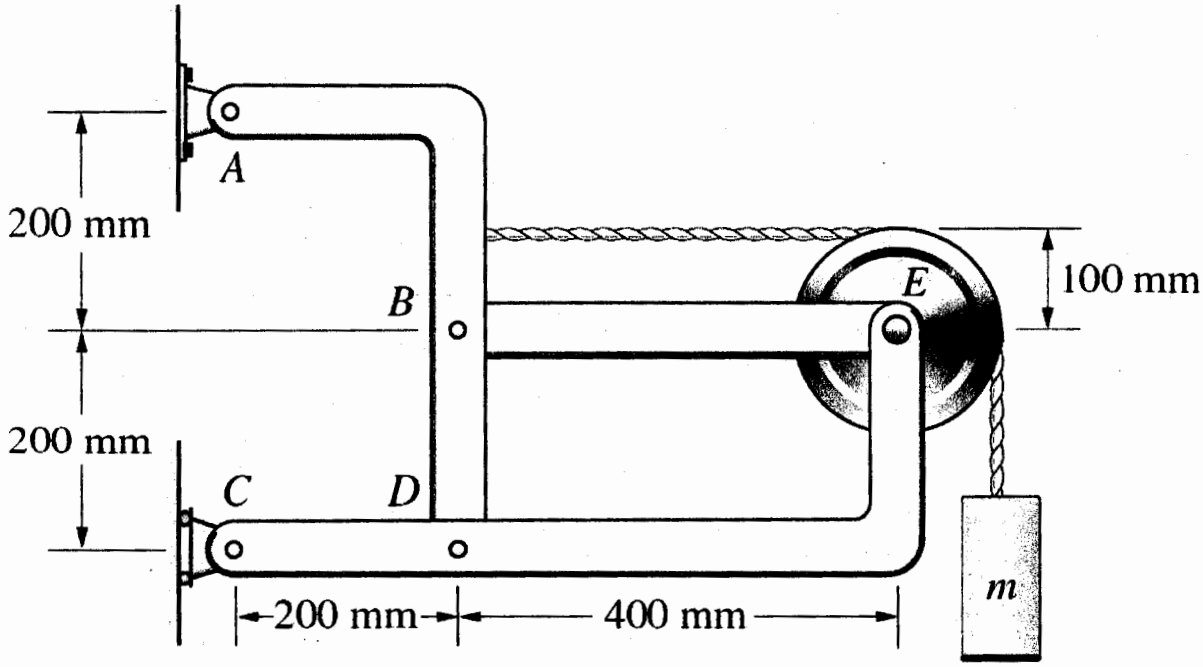
(2) Max. $T = P \Rightarrow$ set $P = 500 \Rightarrow P^{(1)}_{max} = 500\ N$

(2) Max. $C = 2P \Rightarrow$ set $2P = 900 \Rightarrow P^{(2)}_{max} = 450\ N$

(2) Choose $\min(P^{(1)}_{max}, P^{(2)}_{max}) \Rightarrow \underline{P^{allow}_{max} = 450\ N}$ (« P_{safe} »)

Question # 4 (25 points)

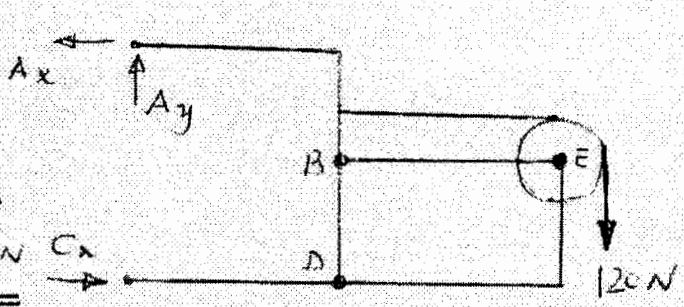
The weight of cylinder (m) is (120 N). Determine the forces on all the members of the frame.



KEY SOLUTION FOR Q 4 (CE 201 MAJOR EXAM II)

(3) FBD of the entire frame

Equations for entire frame:



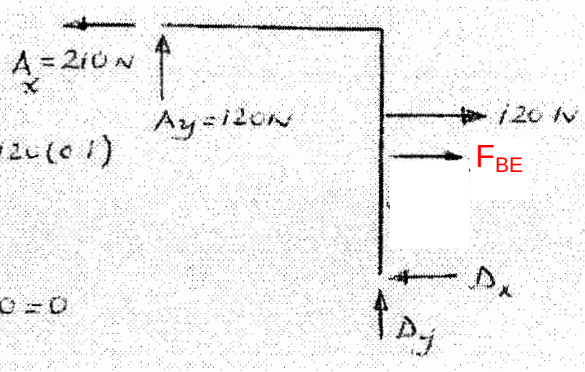
(+2) $\overset{+}{\rightarrow} \Sigma F_x = 0$; $-A_x + C_x = 0 \Rightarrow \underline{A_x = C_x}$

(2) $+\uparrow \Sigma F_y = 0$, $A_y - 120 = 0 \Rightarrow \underline{A_y = 120\ N}$

(2) $\overset{+}{\curvearrowleft} \Sigma M_C = 0$; $A_x(0.4) - 120(0.7) = 0 \Rightarrow \underline{A_x = 210\ N} \Rightarrow \underline{C_x = 210\ N}$

Analyze ABD,

(2) FBD for ABD



$\overset{+}{\curvearrowleft} \Sigma M_B = 0 \Rightarrow$

$-D_x(0.2) - 120(0.2) + 210(0.2) - 120(0.1)$

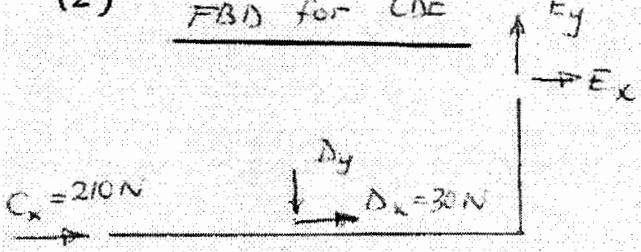
(2) $\Rightarrow \underline{D_x = 30\ N}$

$\overset{+}{\rightarrow} \Sigma F_x = 0$; $-210 + 120 + F_{BE} - 30 = 0$

(2) $\Rightarrow \underline{F_{BE} = 120\ N}$

(2) $+\uparrow \Sigma F_y = 0$; $120 + D_y = 0$ *

(2) FBD for CDE



Analyze CDE

(2) $\overset{+}{\rightarrow} \Sigma F_x = 0$; $210 + 30 + E_x = 0$

$\Rightarrow \underline{E_x = -240\ N}$

(2) $\overset{+}{\curvearrowleft} \Sigma M_D = 0$; $E_y(0.4) - (-240)(0.2) = 0$

$\underline{E_y = -120\ N}$

(2) $+\uparrow \Sigma F_y = 0$, $E_y - D_y = 0 \Rightarrow -120 - D_y = 0$

$\underline{D_y = -120\ N}$