Solved by the instructors who put the problems
(Coordinated course)

Question # 1 (25 points) In the cube shown below, each side is (2^m) long:-

(10 points) Part (A):

a) Represent force ($\tilde{F}$) in Cartesian form, if it is directed from (A) to (D) and has a magnitude of (30^N).

b) Find the moment of force ($\tilde{F}$) from part (a) above, about axis (BG).

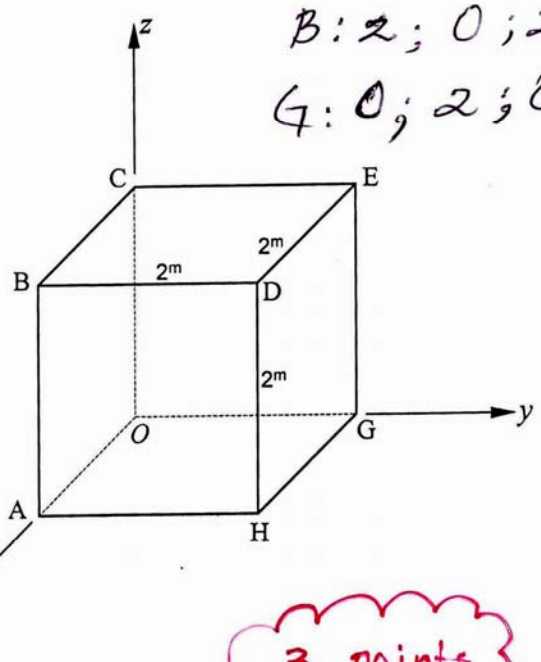
(a)

A : 2 ; 0 ; 0 (m)

D : 2 ; 2 ; 2 (m)

B : 2 ; 0 ; 2 (m)

G : 0 ; 2 ; 0 (m)



$$\tilde{r}_{AD} = 0\tilde{i} + 2\tilde{j} + 2\tilde{k}$$

$$|\tilde{r}_{AD}| = \sqrt{4+4} = 2.828^m$$

$$\tilde{u}_{AD} = \frac{\tilde{r}_{AD}}{|\tilde{r}_{AD}|} = 0\tilde{i} + 0.707\tilde{j} + 0.707\tilde{k}$$

3 points

$$\tilde{F} = |F|\,\tilde{u}_{AD} = 0\tilde{i} + 21.21\tilde{j} + 21.21\tilde{k}$$

(b)

$$\tilde{r}_{BG} = -2\tilde{i} + 2\tilde{j} - 2\tilde{k}, \quad |\tilde{r}_{BG}| = \sqrt{4+4+4} = 3.464^m$$

1 point

$$\tilde{u}_{BG} = -0.577\tilde{i} + 0.577\tilde{j} - 0.577\tilde{k}$$

$$|\tilde{M}^F_{BG}| = \tilde{u}_{BG} \cdot \tilde{r}_{BA} \times \tilde{F} = \begin{vmatrix} -0.577 & 0.577 & -0.577 \\ 0 & 0 & -2 \\ 0 & 21.21 & 21.21 \end{vmatrix}$$

$$= -24.5 \ N.m$$

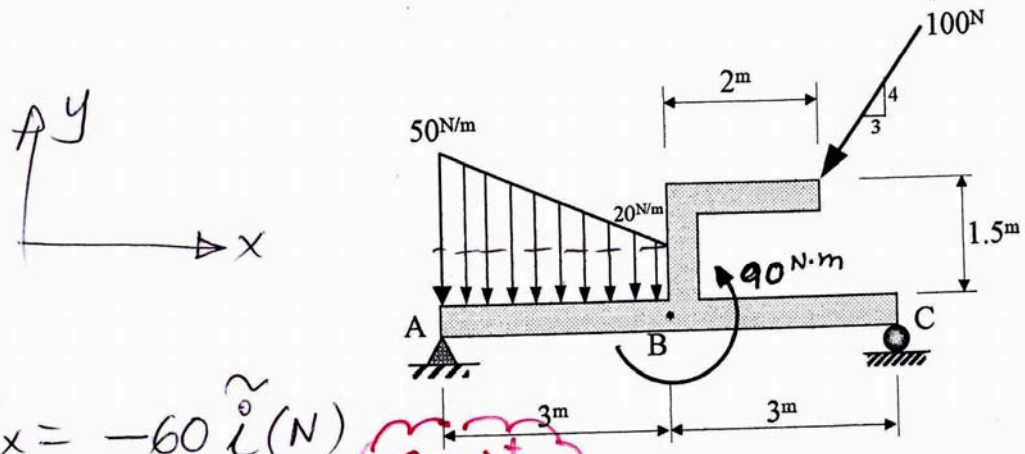
5 points

$$\tilde{M}^F_{BG} = -14.13\tilde{i} + 14.13\tilde{j} - 14.13\tilde{k} \ N.m.$$

4 points

(15 points) **Part (B):**

Reduce the system of applied forces and moment on beam (ABC) below, into a single force and single moment at point (A).



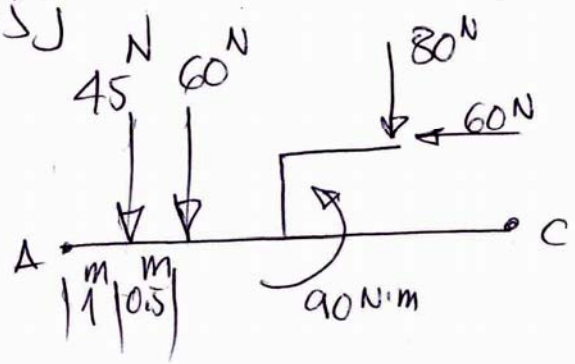
$$\Sigma F_x = -60\,\tilde{i}\,(N)$$

3 points

$$\Sigma F_y = -80\tilde{j} - 60\tilde{j} - 45\tilde{j}$$

$$= -185\,\tilde{j}\,(N)$$

5 points



$$\Sigma M_A = 90 + 60\times1.5 - 80\times5 - 60\times1.5 - 45\times1$$

$$= 90 + 90 - 400 - 90 - 45$$

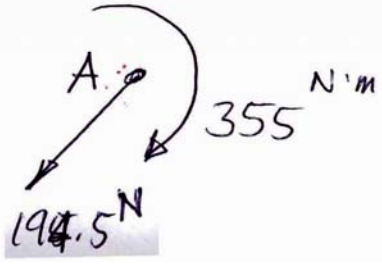
$$= -355\,\tilde{k}\,(N\cdot m)$$

6 points

$$\tilde{F} = -60\,\tilde{i} - 185\,\tilde{j}$$

$$|\tilde{F}| = 194.5\ N.$$

1 point



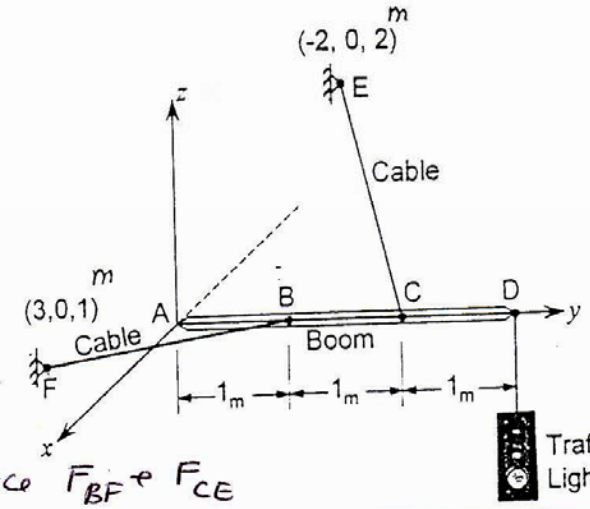
Question # 2 (25 points)

Boom (ABCD) is used to support a traffic signal which weighs (300 N). The boom is supported by a ball and socket at (A) and cables (BF) & (CE). Find the forces of the two cables, and the support reaction at (A).

Solution :

A(0,0,0)
B(0, 1, 0)
C(0,2,0)
D(0, 3,0)
E(-2,0, 2)
F(3, 0, 1).

Light = 300N
A = Ball+Socket
Find. Reaction of A, Force F_{BF} & F_{CE}



(3) $\vec{r}_{CE} = -2\vec{i} - 2\vec{j} + 2\vec{k}$ $\quad r_{CE} = \sqrt{12} = 3.464\ m$

$\vec{u}_{CE} = -0.577\vec{i} - 0.577\vec{j} + 0.577\vec{k}$

$\vec{F}_{CE} = -0.577\,F_{CE}\,\vec{i} - 0.577\,F_{CE}\,\vec{j} + 0.577\,F_{CE}\,\vec{k}$

(3) $\vec{r}_{BF} = 3\vec{i} - 1\vec{j} + 1\vec{k}$ $\quad r_{BF} = \sqrt{11} = 3.32\ m$

$\vec{u}_{BF} = 0.904\vec{i} - 0.301\vec{j} + 0.301\vec{k}$

$\vec{F}_{BF} = F_{BF}(0.904\vec{i} - 0.301\vec{j} + 0.301\vec{k})$

(3) $\vec{r}_{AB} = 0\vec{i} + 1\vec{j} + 0\vec{k}$; $\vec{r}_{AC} = 0\vec{i} + 2\vec{j} + 0\vec{k}$, $r_{AD} = 0\vec{i} + 3\vec{j} + 0\vec{k}$

(2) $\vec{r}_{AB} \times \vec{F}_{BF} \longrightarrow 0.301\,F_{BF}\,\vec{i} - 0\vec{j} - 0.904\,F_{BF}\,\vec{k}$

(2) $\vec{r}_{AC} \times \vec{F}_{CE} \longrightarrow 1.154\,F_{CE}\,\vec{i} - 0\vec{j} + 1.154\,F_{CE}\,\vec{k}$

(2) $r_{AD} \times \vec{F}_{D} \longrightarrow -900\,\vec{i} + 0\vec{j} + 0\vec{k}$

(3) ΣM_A

$\vec{i} \rightarrow 0.301\,F_{BF} + 1.154\,F_{CE} - 900 = 0$ -- (1)

$\vec{j} \rightarrow 0 - 0 + 0 = 0$ (2)

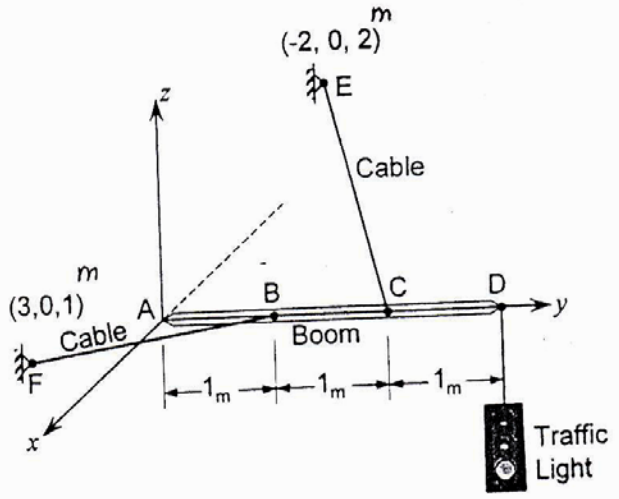
$\vec{k} \rightarrow -0.904\,F_{BF} + 1.154\,F_{CE} + 0 = 0$ (3)

add (1) + (-3) $\longrightarrow 1.2\,F_{BF} - 900 = 0 \;\therefore\; F_{BF} = 750\ N$.

From (3) $\longrightarrow F_{CE} = \dfrac{0.904(750)}{1.154} = 587.5\ N$.

Question # 2 (25 points)

Boom (ABCD) is used to support a traffic signal which weighs (300^{N}). The boom is supported by a ball and socket at (A) and cables (BF) & (CE). Find the forces of the two cables, and the support reaction at (A).



Continue Solution.

ALL Forces

$$\vec{F}_{CE} = -338.7\,\vec{i} - 338.7\,\vec{j} + 338.7\,\vec{k}$$

(3)
$$\vec{F}_{BF} = 678\,\vec{i} - 225.7\,\vec{j} + 225.7\,\vec{k}$$

$$\vec{F}_{D} = 0\,\vec{i} + 0\,\vec{j} - 300\,\vec{k}$$

$$\vec{F}_{A} = F_x\,\vec{i} + F_y\,\vec{j} + F_z\,\vec{k}$$

(4)
$\Sigma F_x = 0 \longrightarrow F_x = -339.3\ N$ (Ax)

$\Sigma F_y = 0 \longrightarrow F_y = 564.4\ N$ (Ay)

$\Sigma F_z = 0 \longrightarrow F_z = -264.4\ N$ (Az)

(25)

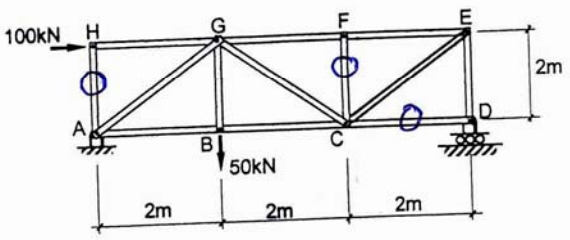
Question # 3 (25 points)

(5 points) Part (A):

List all the zero-force members in the truss below.

Zero-force members

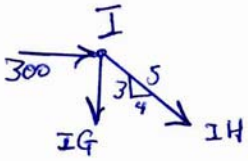
AH ②
CF ①
CO ②



(10 points) Part (B):

Using the Method of Joints, find forces in members: (IH), (IG), (GH) & (GE).

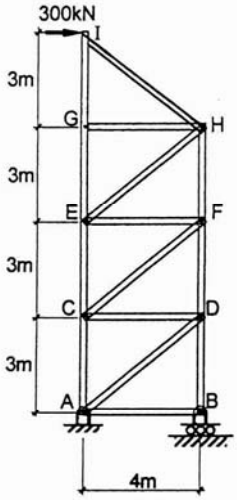
Joint I:



$\Sigma F_x = 0$: $300 + \frac{4}{5} IH = 0$

$IH = -375\ kN$

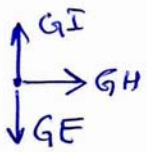
$\boxed{IH = 375\ kN\ (C)}$ (3)



$\Sigma F_y = 0$: $IG + \frac{3}{5} HI = 0$

$\boxed{IG = 225\ kN\ (T)}$ (3)

Joint G:

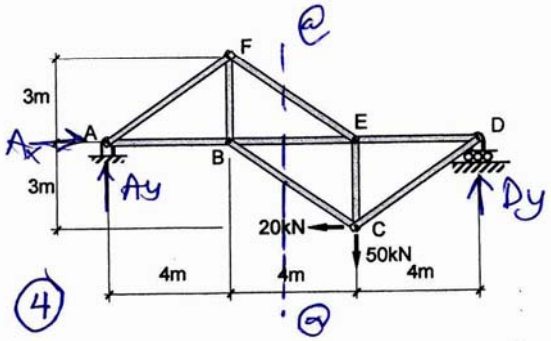


$\boxed{GH = 0}$ (2)

$\boxed{GE = GI = 225\ kN\ (T)}$ (2)

(10 points) **Part (C):**

For the truss shown below; Using the Method of Sections, find the force in member (FE).



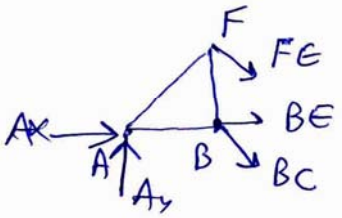
$\sum M_{@A} = 0 \; +\circlearrowleft$

$-20(3) - 50(8) + D_y(12) = 0$

$D_y = 38.33 \text{ kN}$

$\sum F_y = 0 \qquad A_y = 11.67 \text{ kN}$

Consider section (a-a) — left hand side.



$\sum M_{@B} = 0 \; +\circlearrowleft$

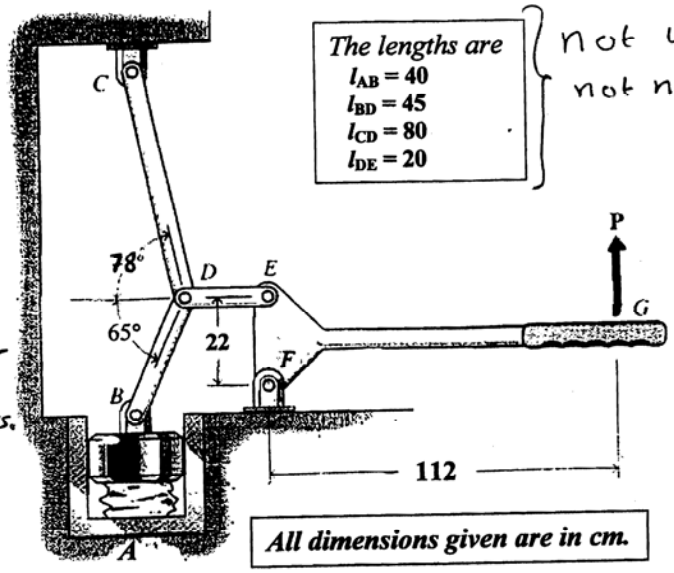
$-A_y(4) - FE\left(\frac{4}{5}\right)(3) = 0$

$FE = -19.5 \text{ kN}$

$FE = 19.5 \text{ kN (C)}$

Question # 4 (25 points)

In the mechanism shown below, the ***vertical force*** needed to crush the cans between A and B in its current configuration is **600 N**. What is the required force **P**?
Comparing **P** *with the 600-N force, what conclusion can you make?*



The lengths are
$l_{AB} = 40$
$l_{BD} = 45$
$l_{CD} = 80$
$l_{DE} = 20$

not used ⇒ not needed !!

Solution:

Note that DB, DC, and DE are two-force members.

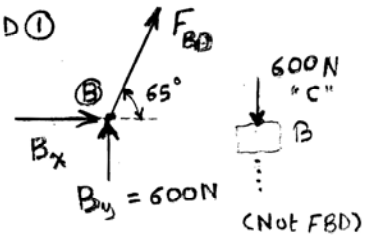
(Pts)

(3) FBD① [B]

$+\uparrow \Sigma F_y = 0 \Rightarrow$

$F_{BD} \sin 65^\circ + 600 = 0 \Rightarrow$

(3) $F_{BD} = -662.03 = 662.03 \text{ N «C»}$

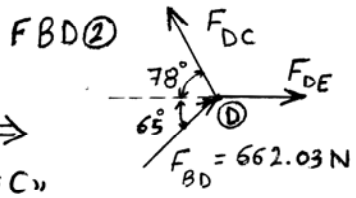


(3) FBD② [D]

$+\uparrow \Sigma F_y = 0 \Rightarrow$

(3) $662.03 \sin 65^\circ + F_{DC} \sin 78^\circ = 0 \Rightarrow$

$F_{DC} = -613.40 = 613.40 \text{ N «C»}$



(4) $\pm \rightarrow \Sigma F_x = 0 = F_{DE} + 662.03 \cos 65^\circ + 613.40 \cos 78^\circ$

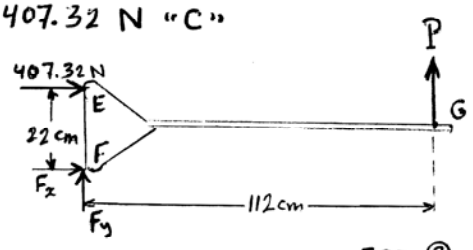
$\Rightarrow F_{DE} = -407.32 = 407.32 \text{ N «C»}$

(4) FBD③ [EFG]

$+\circlearrowleft \Sigma M_F = 0 \Rightarrow$

$P(112) - 407.32(22) = 0$

(3) $\Rightarrow \boxed{P = 80.0 \text{ N}}$



(2) **Conclusion:** The 80-N force at G produced the 600-N force at B. This is the "job" of such a mechanism. It transmits & alters/modifies/amplifies **loads**.