Department of Civil Engineering, IIT Bombay
CE 102 Engineering Mechanics – Mid-Semester Exam

Date: February 20, 2008 **Max. Marks: 100**

Note: State clearly all assumptions you have made, if any. Draw clear Free Body Diagram(s). If you make multiple attempts, cancel out the one(s) you do not want to be graded. Only the first non-cancelled attempt encountered will be graded. .

Time: 2 hours

****

1. A horizontal platform *CD* carries a truck of weight *Q* and is rigidly welded to the vertical bar *AB*, which is hinged at the top to the horizontal lever *BFG* (Fig. 1). Determine the weight *Q* of the truck if a known weight *W* hanging at *G* holds the platform and its load in equilibrium as shown. The weight of the empty platform is just balanced by lever *GB*.

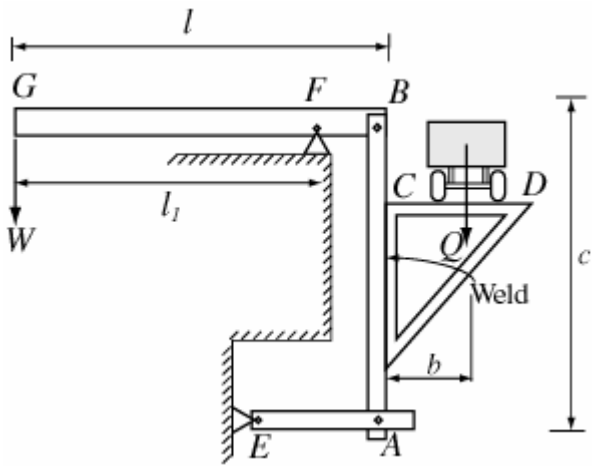


Fig. 1

2. Determine the forces in bars *1* and *2* of the plane truss supported and loaded as shown in Fig. 2; $\angle CAB = \angle DBA = 60^O$; $\angle CBA = \angle DAB = 30^O$.

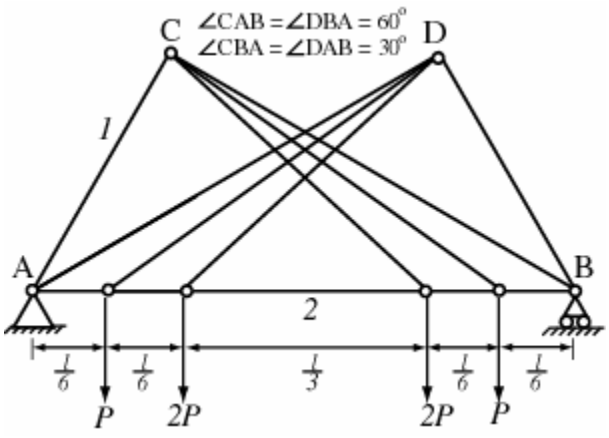


Fig. 2

3. Two bars *AB* and *OD*, which are pinned together at *C*, form the diagonals of a horizontal square *AOBD* (Fig. 3). The ends *A* and *O* are attached to a vertical wall by ball and socket joints. Point *B* is supported by a cable *BE*, and a vertical load *P* is applied at *D*. Find the components of the reactions at *A* and *O*.

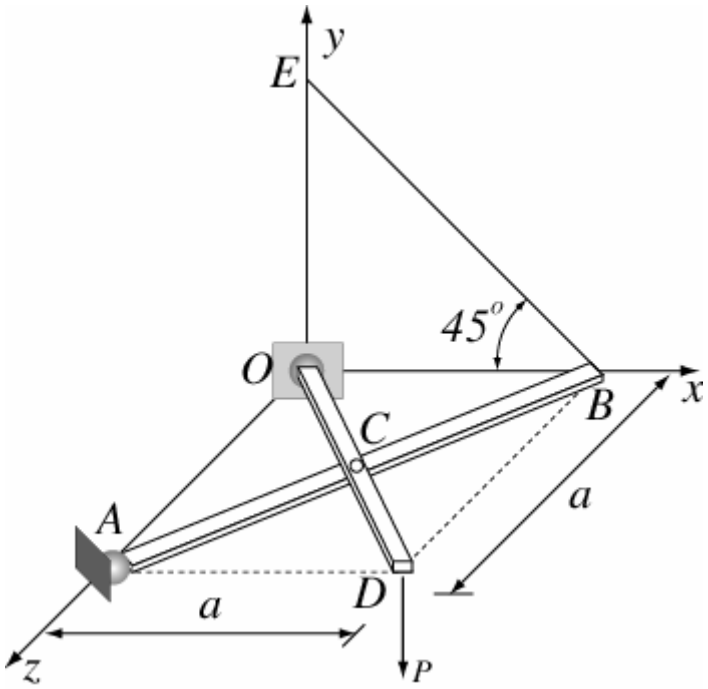


Fig. 3

4. The force *P* is applied normal to the diametral surface of the 25-kg semi cylinder (Fig. 4). As *P* is gradually increased, the cylinder is observed to slip on the horizontal surface when θ reaches 32^0. Calculate the coefficient of static friction μ_s and the force *P* when slipping begins.

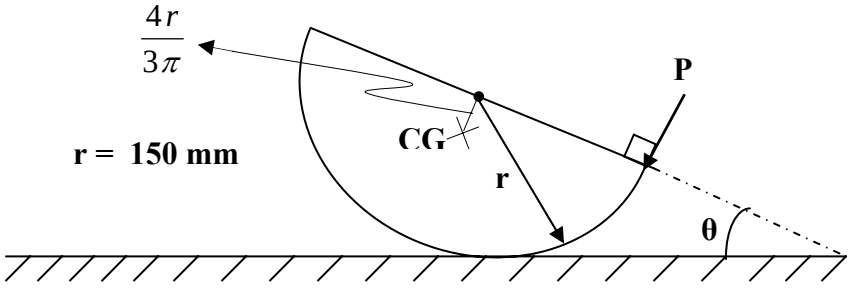
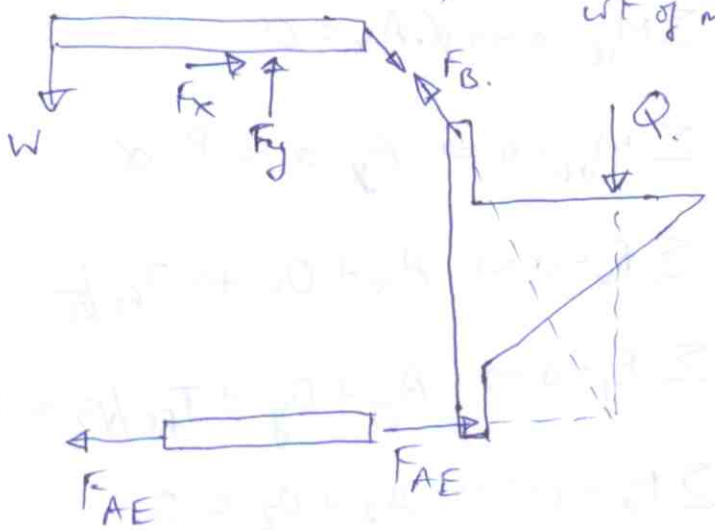


Fig. 4

CE102 Midsem Sol. Spring 2008.

P.1 (Without truck, system is balanced → equivalent to neglecting self wt of members)



AE → 2 Force member.

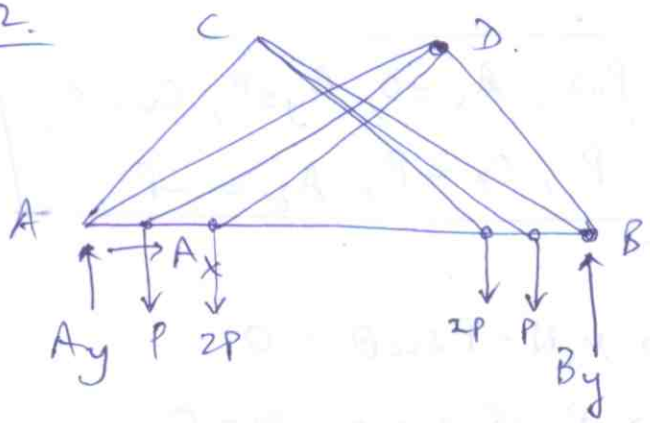
BCDA → 3 Force member.

$\Rightarrow F_{By} = Q.$, $F_{Bx} = F_{AE}$

$\Sigma M_F = 0 \Rightarrow W = \dfrac{F_{By}(L-L_1)}{L_1}$

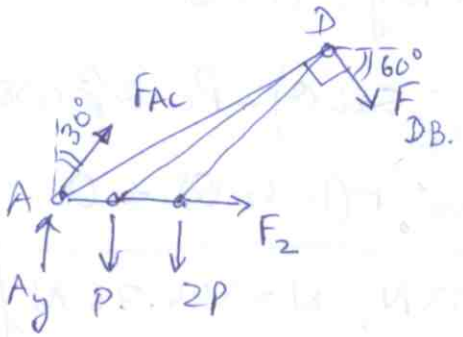
$$\Rightarrow \boxed{W = Q\left(\frac{L}{L_1} - 1\right)}$$

P.2.



Symmetry (in load & structure)

$\Rightarrow A_y = B_y = 3P$, $A_x = 0$.



$AD = l\cos 30°$

$\Sigma F_y = 0 \Rightarrow \cancel{A_y} - \cancel{P} - \cancel{2P} - F_{DB}\cos 30 + F_{AC}\cos 30 = 0$

$\Rightarrow F_{DB} = F_{AC} = F_1$ (as expected from symmetry)

$\Sigma M_A = 0 \Rightarrow F_{DB}\, l\cos 30 + P\frac{l}{6} + 2P\frac{l}{3} = 0$

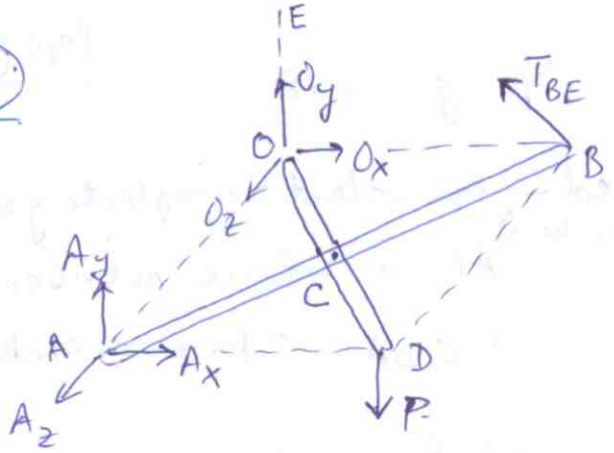
$\Rightarrow F_1 = F_{DB} = -\frac{5}{6}(\cos 30°)^{-1}P = -0.9622P$ ◀ (Compressive)

$\Sigma F_x = 0 \Rightarrow F_2 + F_{DB}\sin 30 + F_{AC}\sin 30 = 0$

$\Rightarrow F_2 = -2F_1\sin 30 = -F_1 = 0.9622P$ ◀ (Tensile)

$$\boxed{\begin{aligned} F_1 &= 0.9622P\ (C) \\ F_2 &= 0.9622P\ (T) \end{aligned}}$$

P.(3)



$\Sigma M_{oA}=0 \Rightarrow T_{BE}/\sqrt{2} \cdot a = P \cdot a$

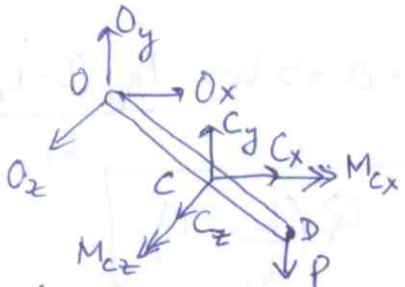
$\Sigma M_{oE}=0 \Rightarrow a \cdot A_x = 0$

$\Sigma M_{oB}=0 \Rightarrow A_y \cdot a = P \cdot a$

$\Sigma F_x=0 \Rightarrow A_x + O_x = T_{BE}/\sqrt{2}$

$\Sigma F_y=0 \Rightarrow A_y + O_y + T_{BE}/\sqrt{2} = P$

$\Sigma F_z=0 \Rightarrow A_z + O_z = 0$

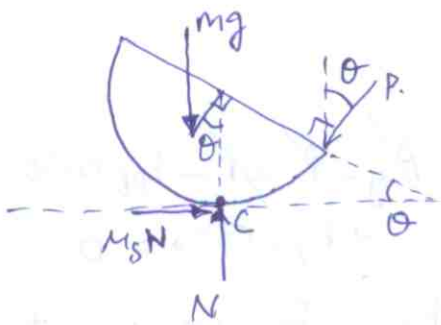


Take FBD of arm OCD.
Note that C is a hinge.

$\Sigma M_{Cy}=0 \Rightarrow (O_x - O_z)\frac{a}{2} = 0$

Solving above 7 eqns $\rightarrow$ $T_{BE} = P\sqrt{2}$, $A_x = 0$, $A_y = P$, $O_x = P$, $O_y = -P$, $O_z = P$, $A_z = -P$.

P4



$\Sigma F_x=0 \Rightarrow M_s N - P\sin\theta = 0$

$\Sigma F_y=0 \Rightarrow P\cos\theta + mg - N = 0$

$\Sigma M_C=0 \Rightarrow mg\left(\frac{4r}{3\pi}\sin\theta\right) - P\cos\theta\,(r\cos\theta) + P\sin\theta\, r(1-\sin\theta) = 0$

Solving above 3 eqns $\Rightarrow$ $P = 117.33\,N$, $N = 344.76\,N$, $M_s = 0 - 180$