INDIAN INSTITUTE OF TECHNOLOGY KHARAGPUR

Date of Examination: 18.09.2015(FN) **Time: 2 hours**
Mid Semester Examination (Autumn) **Full Marks: 90**
Subject No. ME10001 **Subject Name: MECHANICS**
No. of students: 700

Instructions: ***Answer all SEVEN questions. Any data, if not furnished, may be assumed with justification.***

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1. The weld at A, shown in Fig.1, can support a maximum of 2.5 kN of force along each of the n and t directions and a maximum moment of 1350 Nm. Determine the allowable range for the direction θ of the 2.7 kN force applied at B. The angle θ is restricted to $0^0 \le \theta \le 90^0$. *(8)*

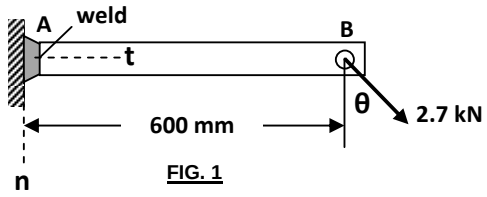


FIG. 1

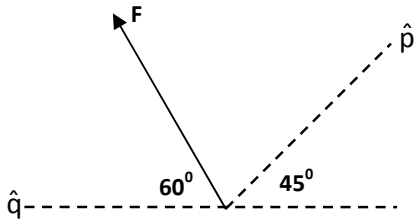


FIG. 2

2. With reference to Fig.2, **(a)** determine the components of the force F = 800 N along $\hat{p}$ and $\hat{q}$ axes and **(b)** the projections of the force F on $\hat{p}$ and $\hat{q}$ axes. *(7)*

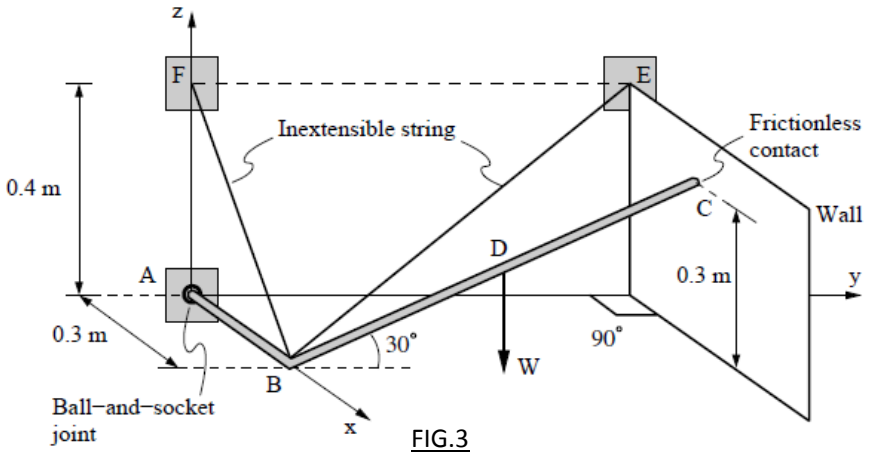


FIG.3

3. A massless L-shaped frame ABC with ∠ABC=90° is suspended as shown in Fig.3. A vertical force W is applied at D, where |BD|= |DC|. **(a)** Draw the free body diagram of the frame ABC**. (b)** For a load W=100N, determine the wall reaction at C for equilibrium. **(c)** For some load W, if the magnitude of the wall reaction at C is 20 N, find the tension in the string BE for equilibrium. **(d)** If the reaction at the ball-and-socket joint at A is $60\hat{i}$ N, determine the force W for equilibrium. *(15)*

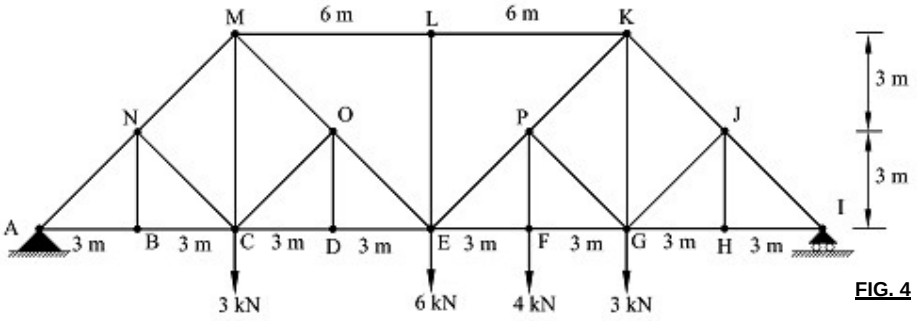


FIG. 4

4. For the truss shown in Fig.4, determine **(a)** the ground reaction at the hinge A, **(b)** force in the members CD, ML and EF (indicating tension or compression) and **(c)** all the zero-force members in the truss. *(15)*

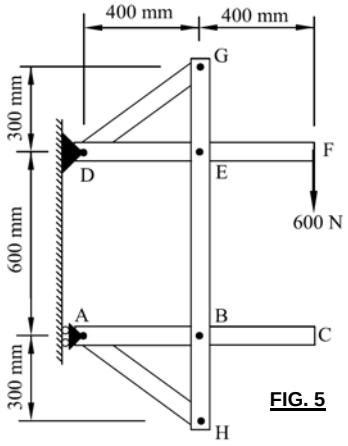


FIG. 5

5. For the frame and loading shown in Fig.5, **(a)** determine the ground reaction at A and **(b)** components of all forces acting on the member GEBH. Neglect the weights of the members. *(15)*

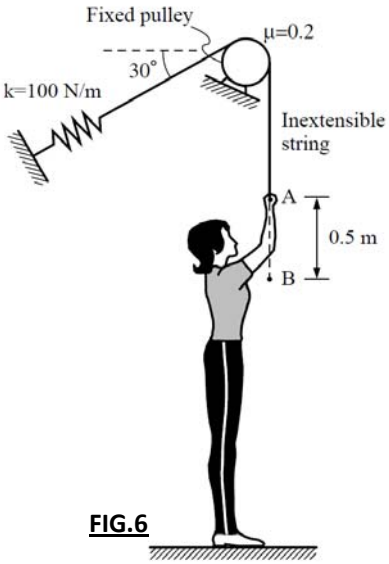


FIG.6

6. An athlete pulls vertically down the handle of an exercise machine by 0.5m from A to B as shown in Fig.6. The spring is unextended when the handle is at the position A. The coefficient of friction between the string and the fixed pulley is μ=0.2. **(a)** Determine the tension in the vertical section of the string when the handle reaches B. **(b)** If with the handle at position B, she starts reducing the tension in the string (vertical section), determine the value of tension when the handle just starts moving upwards towards A. *(15)*

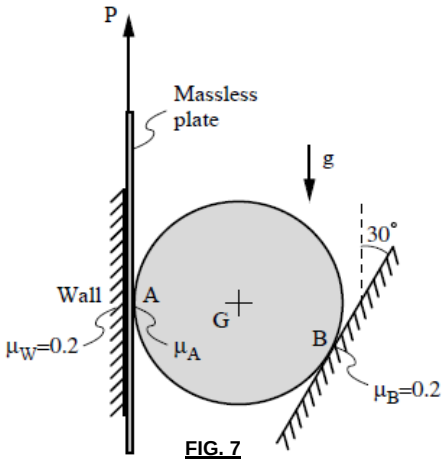
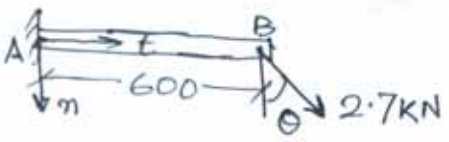


FIG. 7

7. A homogeneous cylindrical roller of weight *W*=100N is placed against a thin massless plate, as shown in Fig. 7. The coefficient of friction at contact B is μ_B=0.2 and at the wall contact μ_{wall}=0.2. **(a)** Draw the free body diagram of the roller. **(b)** When the plate is pulled up vertically as shown, determine the minimum coefficient of friction required at contact A so that the roller rolls at A and slips at B. **(c)** If μ_A=0.3, determine the minimum force *P* required to pull the plate up. *(15)*

Answers – Midterm – Autumn (2015)
(MECHANICS – ME10001)

A1



$F_t = 2.7\times10^3 \times \sin\theta \le 2.5\times10^3$ ··· (1)

$F_n = 2.7\times10^3 \times \cos\theta \le 2.5\times10^3$ ··· (2)

$M_A = 2.7\times10^3 \times \cos\theta \times 0.6 \le 1350$ (3)

From (1) $\theta = 67.81^\circ$ $F_n = 2.7\times10^3 \times \cos 67.81^\circ = 1.02\,KN$ – valid.

$M_A = 611.88\,Nm$ – valid.

From (2) $\theta = 22.19^\circ$ $F_t = 2.7\times10^3 \times \sin 22.19 = 1.02\,KN$ valid.

$M_A = 1500\,Nm$ – Not valid.

From (3) $\theta = 33.56^\circ$ $F_t = 1.49\,KN$ valid.

$F_n = 2.25\,KN$ Valid.

∴ Range of θ is $33.56^\circ \le \theta \le 67.81^\circ$

alternative.

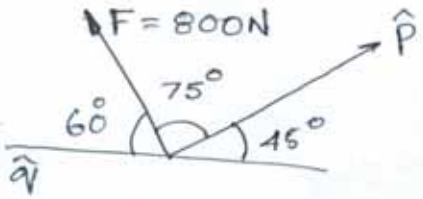
From (1) $\theta = 67.81^\circ$ ∴ $67.81 \ge \theta \ge 0^\circ$

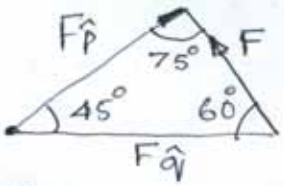
From (2) $\theta = 22.19^\circ$ ∴ $90^\circ \ge \theta \ge 22.19^\circ$.

From (3) $\theta = 33.56^\circ$ ∴ $90^\circ \ge \theta \ge 33.56^\circ$.

∴ Range of θ is $33.56^\circ \le \theta \le 67.81^\circ$

A2





a) $\dfrac{F_{\hat{p}}}{\sin 60^\circ} = \dfrac{F_{\hat{q}}}{\sin 75^\circ} = \dfrac{F}{\sin 45^\circ}$

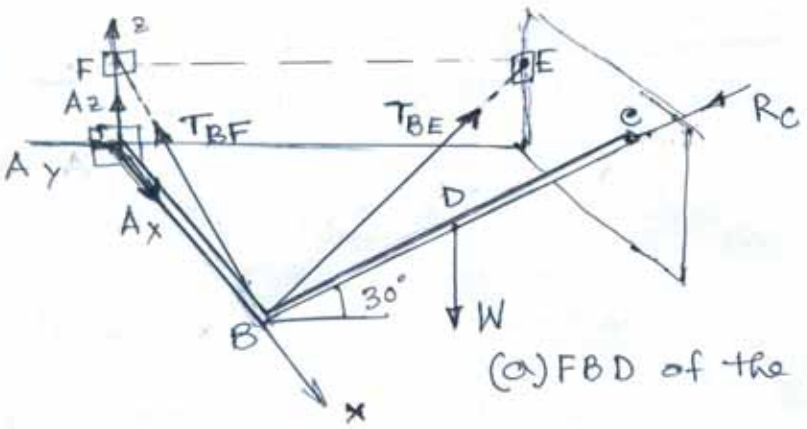
∴ $F_{\hat{p}} = \dfrac{800 \times \sin 60}{\sin 45^\circ} = 979.8\,N$

$F_{\hat{q}} = \dfrac{800 \times \sin 75}{\sin 45^\circ} = 1092.8\,N$

b) F on $\hat{p} = 800\cos 75^\circ = 207.06\,N$

F on $\hat{q} = 800\cos 60^\circ = 400\,N$.

A3



(a) FBD of the structure

(b) $\Sigma M_{AB} = 0$, only W and R_C will contribute.

$M_{AB} = M_B \cdot i$

$= \left[BD\sin 30^\circ j \times W(-K) + 0.3K \times R_c(-j)\right] \cdot i = 0$.

$= (-0.26Wi + 0.3R_C i) \cdot i = 0 \quad \therefore R_C = 86.6N$

(c) Moment about AE will have contribution from R_C and tension in BE.

Co-ordinates: A(0,0,0), B(0.3,0,0), C(0.3, 0.52, 0.3)
E(0, 0.52, 0.4)

$BE = (-0.3i + 0.52j + 0.4K)$; $\hat{BE} = (-0.416i + 0.721j + 0.555K)$

$AC = 0.3i + 0.52j + 0.3K$

$M_{AE} = M_A \cdot K = 0$

$\left[(0.3i + 0.52j + 0.3K) \times -20j + 0.3i \times T_{BE}(-0.416i + 0.72j + 0.555K)\right] \cdot K = 0$.

$\therefore T_{BE} = 27.74N$.

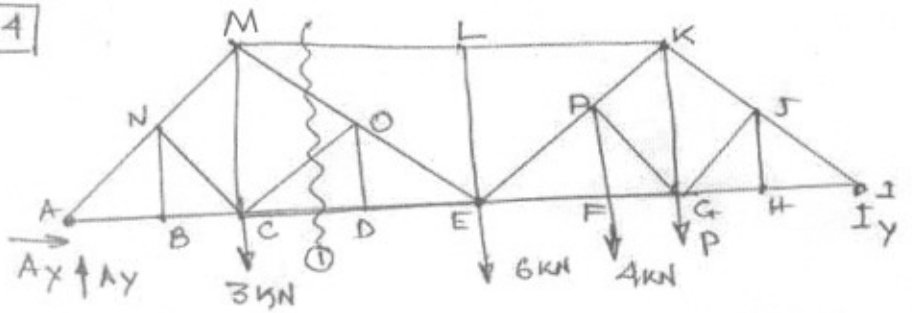
(d) $\Sigma M_{FE} = 0$, only R_A and W will contribute.

$M_{FE} = (M_E \cdot j) = 0$; $FD = 0.3i + 0.26j - 0.25K$.

$= \left[-0.4K \times 60i + (0.3i + 0.26j - 0.25K) \times W(-K)\right] \cdot j = 0$

$\left[-24j + 0.3Wj\right] \cdot j = 0 \quad \therefore W = 80N$

A4

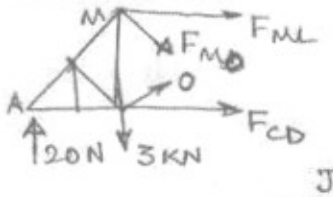


(a) $A_x = 0$; $A_y \times 24 = 3\times18 + 6\times12 + 4\times9 + P\times6$ $[\Sigma M_I = 0]$, $P = 3KN$

$\therefore A_y = 7.5KN$.

(b) Zero force members : NB, NC, CO, OD, LE, GJ and JH

(c) Section-1.

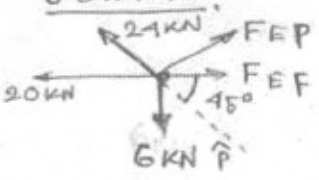


$\Sigma M_M = 0$; $20\times6 - F_{CD}\times6 = 0$ $\therefore F_{CD} = 20KN$ (T)

$F_{MO}\cos45^\circ + 3KN - 20KN = 0$ $\therefore F_{MO} = 24.04KN$ (T)

$F_{ML} + F_{MO}\sin45^\circ + F_{CD} = 0$ $\therefore F_{ML} = 37KN$ (C)

Joint E.

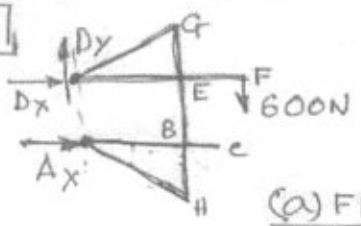


$\Sigma \hat{P} = 0$.

$F_{EF}\cos45^\circ + 6\sin45^\circ - 24 - 20\cos45^\circ = 0$

$\therefore F_{EF} = 48\ KN$ (T).

A5



(a) FBD.

(b) $\Sigma M_B = 0$

$600\times800 - A_x\times600 = 0$

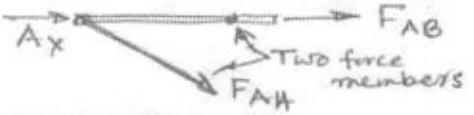
$\therefore A_x = 800N$.

$\theta = \tan^{-1}3/4$

$\sin\theta = 0.6$

$\cos\theta = 0.8$

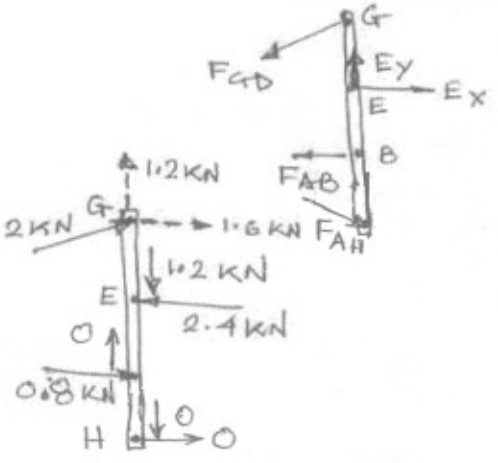
(c) FBD of ABH.



$F_{AH} = 0$

$F_{AB} = -A_x = -800N$

FBD of GEBH



$\Sigma M_E = 0$

$F_{GD}\cos\theta \times 300 - F_{AB}\times600 = 0$

$\therefore F_{GD} = -2000N = -2KN$

$F_{GD}\sin\theta - E_y = 0$ $\therefore E_y = -1200N = -1.2KN$

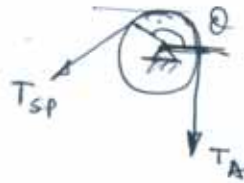
$E_x - F_{AB} - F_{GD}\cos\theta = 0$

$E_x = F_{AB} + F_{GD}\cos\theta$

$= -800 - 2000\times0.8$

$= -2400N = -2.4KN$.

A6



$T_{SP} = 100 \times 0.5 = 50\,N$

$\theta = \frac{2\pi}{3}$ (angle of wrap)

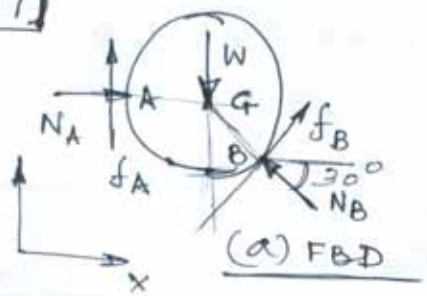
(a) $T_{AB} > T_{SP}$ $\therefore T_{AB}/T_{SP} = e^{(0.2 \times \frac{2\pi}{3})}$

$\therefore T_{AB} = 76\,N$

Part(b) $T_{SP} > T_{AB}$ $\therefore T_{SP} = T_{AB}\, e^{(0.2 \times 2\pi/3)}$

$\therefore \underline{T_{AB} = 32.9\,N}$

A7



(a) FBD

(b) $\mu_B = 0.2$, $\mu_W = 0.2$.

$\Sigma M_G = 0$; $f_A = \mu_B N_B$.

$\Sigma F_y = 0$; $f_A + f_B \cos 30^\circ + N_B \sin 30^\circ - W = 0$

$\left(\mu_B + \mu_B \frac{\sqrt{3}}{2} + \frac{1}{2}\right) N_B = W$

$\therefore N_B = \underline{114.5\,N}$

$\Sigma F_x = 0$; $N_A + f_B \sin 30^\circ - N_B \cos 30^\circ = 0$

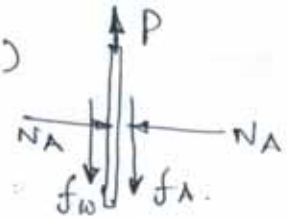
$N_A = (\cos 30^\circ - \mu_B \sin 30^\circ) N_B$

$= \underline{87.71\,N}$

$\therefore \mu_A \geq \frac{f_A}{N_A} = \frac{\mu_B}{(\cos 30^\circ - \mu_B \sin 30^\circ)}$

$= \underline{0.261}$ $(\mu_A\,min)$

(c)



$P = f_W + f_A$

$\mu_A = 0.3 > \mu_A(min) = 0.261$

$\therefore f_B$ prevails

Slip at B and roll at A.

$\therefore P = f_W + f_A = \mu_W \times N_A + f_B$

$= (0.2 \times 87.7 + 0.2 \times 114.5)\,N$

$= \underline{40.44\,N}$