DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
CE102 ENGINEERING MECHANICS
QUIZ 2

Date: 01-04-2019 Maximum Marks: 10
Time: 09.30 pm – 10.30 pm

Read the questions carefully. Show the steps clearly and mark the final answers. Assume suitable additional data, if required, and state the same clearly. Both questions carry equal weightage.

1. The uniform **6-kg** slender rod rests on the top centre of the **3-kg** block as shown in **Figure 1**. If the coefficients of static friction at the points of contact are μ_A = **0.4** and μ_B = μ_C = **0.6**, determine the largest couple moment **M** which can be applied to the rod without causing motion of the rod. Assume acceleration due to gravity **g** = **10 m/s²**.

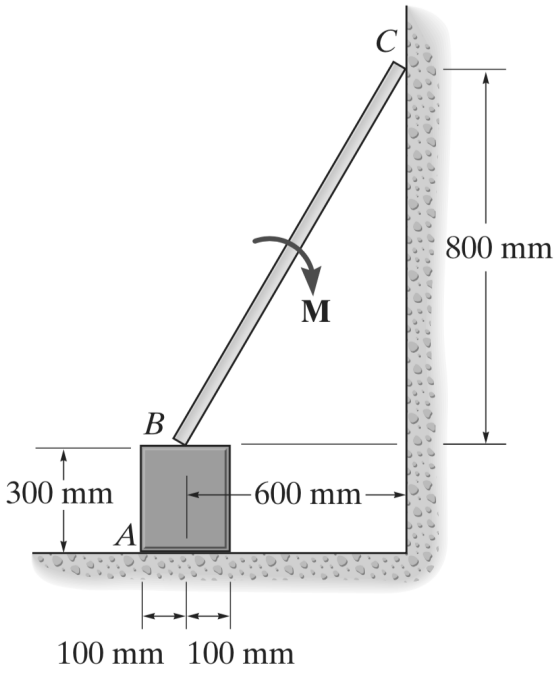


Figure 1

2. Determine the force in member ***DK*** of the overhead sign truss shown in **Figure 2**. Clearly state if this member is in tension or compression. ***U*** and ***V*** are hinge and rocker connections, respectively. For simplicity, neglect any friction force between the rocker and the ground below.

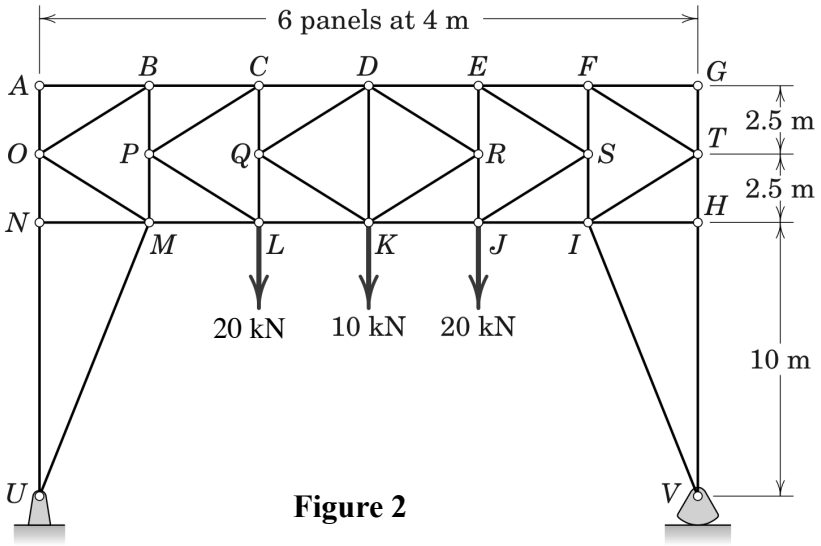


Figure 2

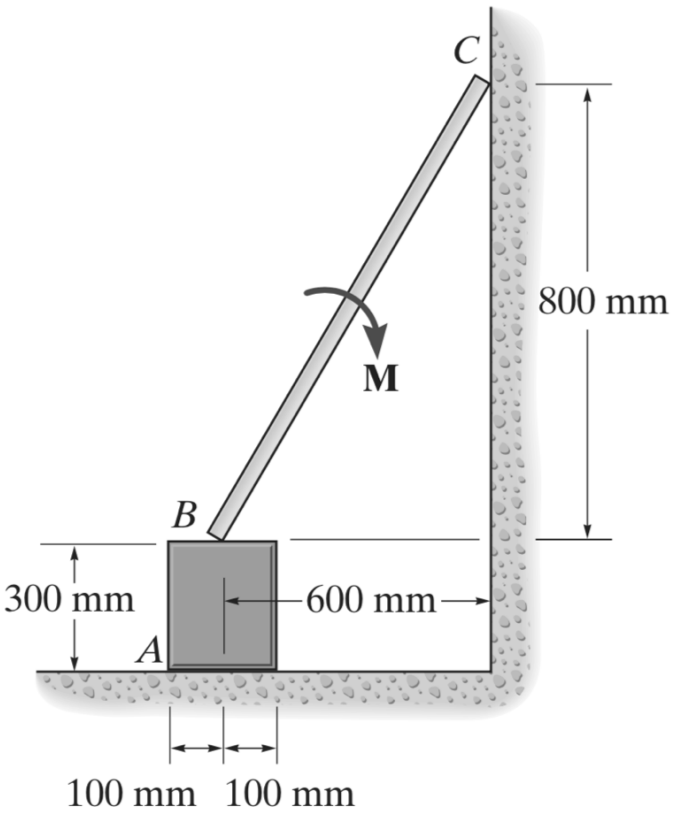
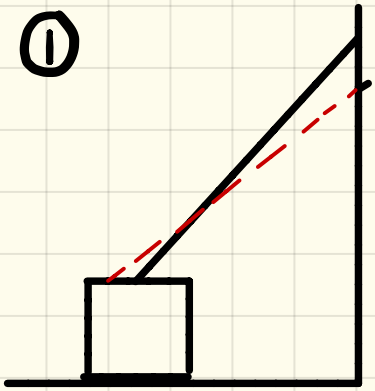


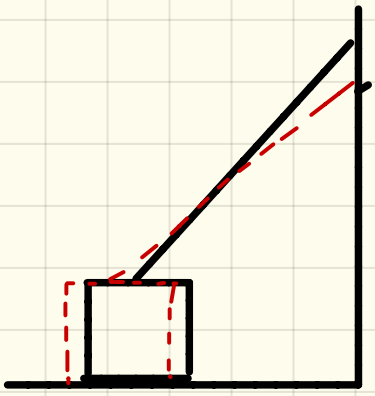
Figure 1

Three modes of slippage

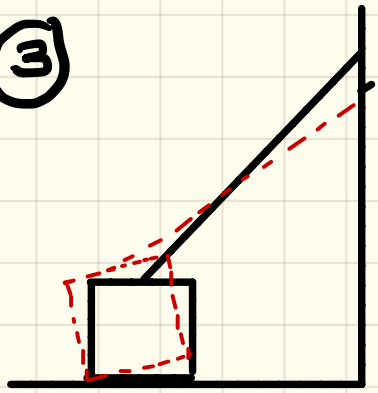
①



②



③

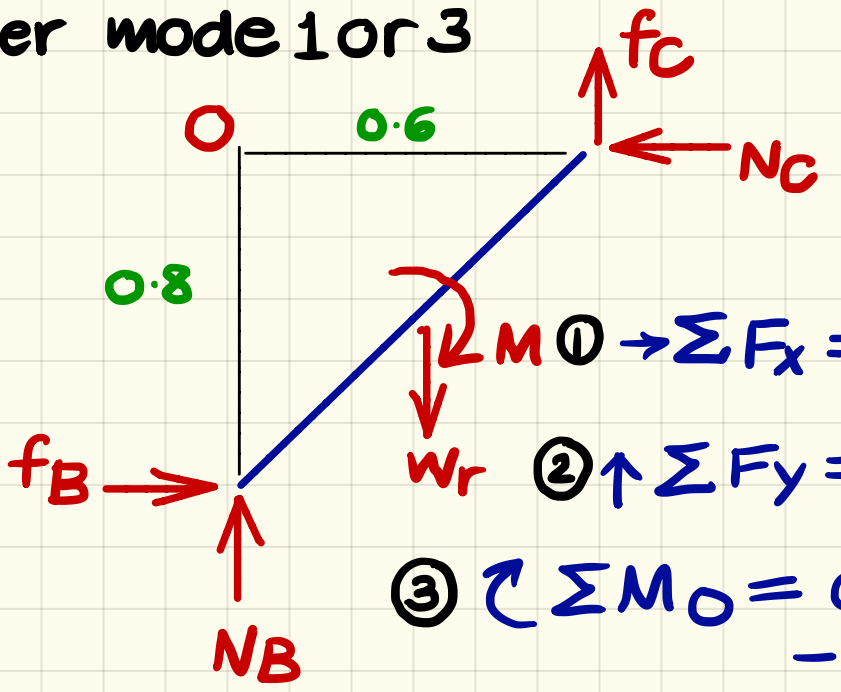


$\frac{b}{2h} = \frac{0.2}{2 \times 0.3} = 0.33 < \mu_A$ (0.4)

Topple before slide

Either mode - ① or ③

Either mode 1 or 3

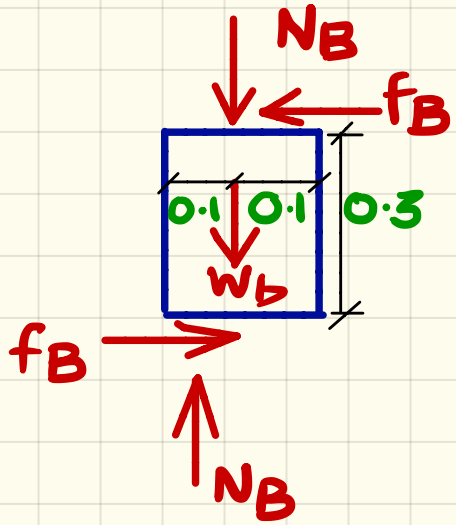


Friction direction as shown either in mode 1 or 3

① $\rightarrow \Sigma F_x = f_B - N_C = 0$

② $\uparrow \Sigma F_y = N_B + f_C - W = 0$

③ $\circlearrowleft \Sigma M_O = 0.8 f_B + 0.6 f_C - 0.3 W_r - M = 0$



Assume Mode-1

$f_C = \mu_C N_C, \; f_B = \mu_B N_B$

$\mu_B N_B = N_C$

$N_B + \mu_C \mu_B N_B = W_r$

$N_B = \dfrac{W_r}{1 + \mu_C \mu_B} = 44.12\,N$

$0.8 \mu_B N_B + 0.6 \mu_C \mu_B N_B - 0.3 W_r - M = 0$

$W_r \left[\dfrac{0.8 \mu_B}{1 + \mu_C \mu_B} + \dfrac{0.6 \mu_C \mu_B}{1 + \mu_C \mu_B} - 0.3 \right] - M = 0$

$\Rightarrow$ **$M = 12.71\,N$**

Check for tipping in mode-3

$$(W_b + N_B)0.1 - \underbrace{\mu_B N_B}_{f_B} \times 0.3$$

$= -0.52$ } tips

④ $(W_b + N_B)0.1 - f_B \times 0.3 = 0$

$\Rightarrow f_B = \frac{1}{3}(W_b + N_B)$, $f_B = N_C$

$f_C = \mu_C N_C = \frac{\mu_C}{3}(N_B + W_b)$

Using ①, ② and ③

$N_C = \frac{1}{3}(N_B + W_b)$, $N_B + \frac{\mu_C}{3}(N_B + W_b) = W_r$

$$N_B = \frac{W_r - (\mu_C/3)W_b}{1 + \mu_C/3} = 45N$$

$$f_B = \frac{1}{3}\left(\frac{W_b + W_r}{1 + \mu_C/3}\right), = 25N$$

$$f_C = \frac{\mu_C}{3}\left(\frac{W_b + W_r}{1 + \mu_C/3}\right) = 15N$$

$$M = 0.8f_b + 0.6f_C - 0.3W_r$$

$M = 11\ N.m$, Check $f_B/N_B = 25/45 = 0.55 < \mu_B$

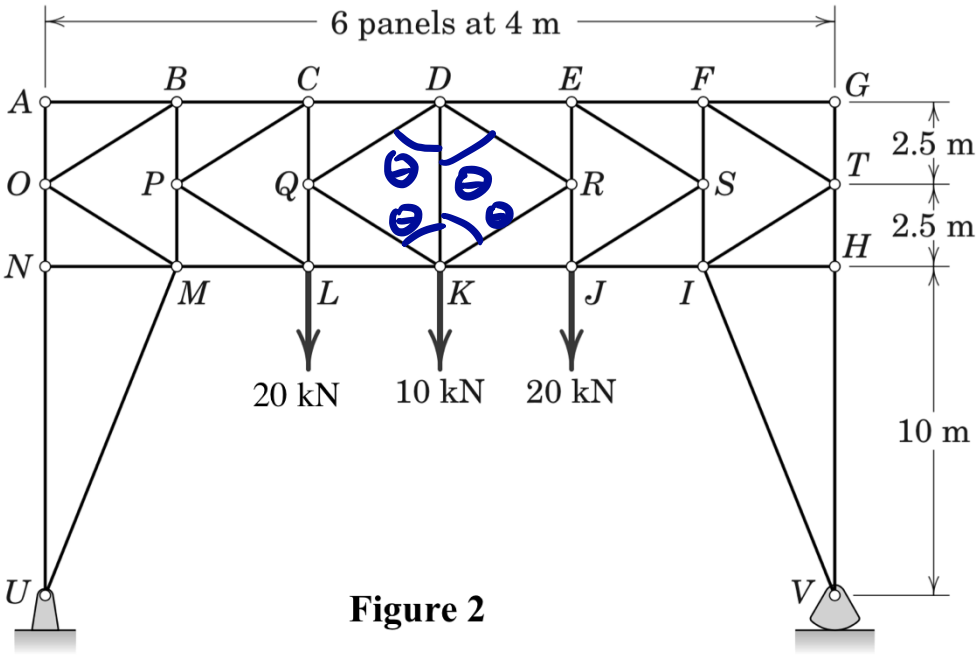


Figure 2

Solution :-1

Assume members in tension

Joint Q: $\rightarrow \Sigma F_x = 0 \Rightarrow F_{QD} = -F_{QK}$

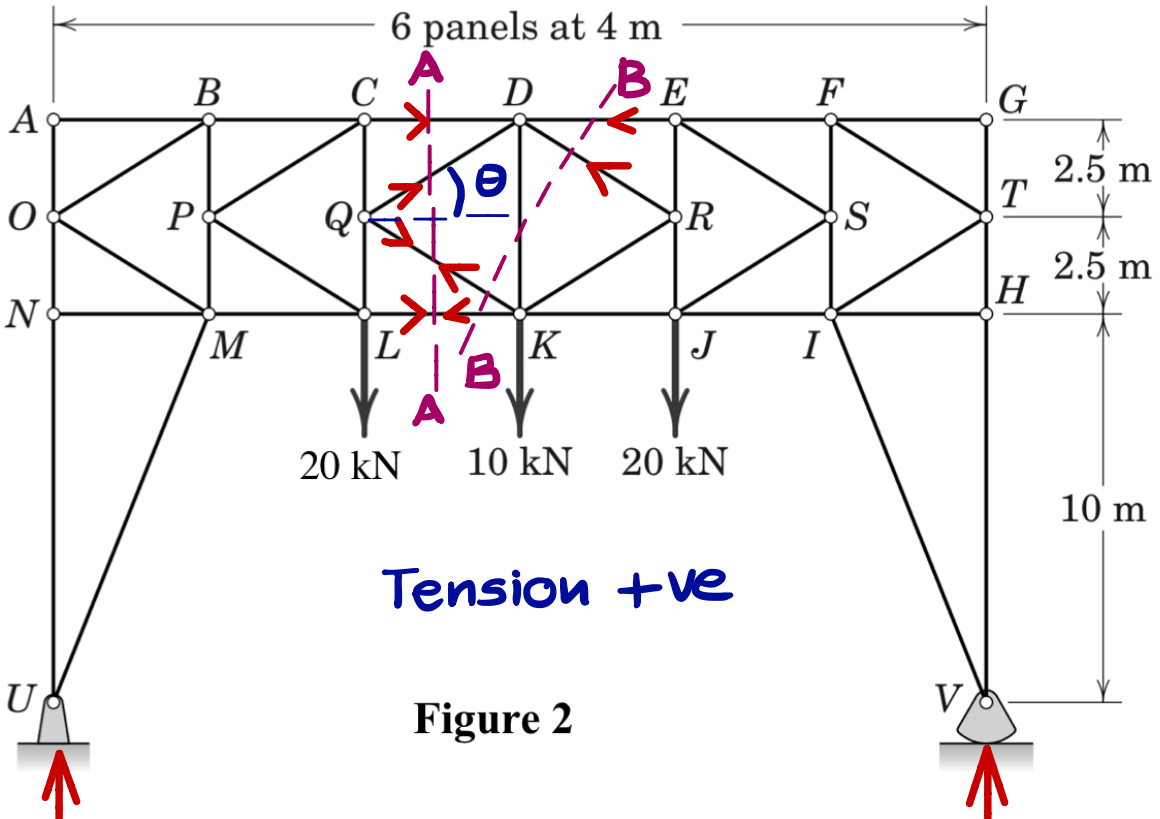
Joint R: $F_{RD} = -F_{RK}$

Joint D: $\downarrow \Sigma F_y = (F_{QD} + F_{DR})\cos\theta + F_{DK} = 0$

Joint K: $\uparrow \Sigma F_y = (F_{QK} + F_{RK})\cos\theta + F_{DK} - 10 = 0$

This implies: $2F_{DK} - 10 = 0$

$$\Rightarrow \boxed{F_{DK} = 5\,\text{kN (T)}}$$



Tension +ve

Figure 2

25kN By Symmetry 25kN

Joint Q : $F_{QD} = -F_{QK}$

Section AA and left section

$$\uparrow \Sigma F_y = 25 + F_{QD} \times \sin\theta - F_{QK}\sin\theta - 20 = 0$$

$$\Rightarrow 5 - 2F_{QK}\sin\theta = 0$$

$$\Rightarrow F_{QK}\sin\theta = \frac{5}{2}\ kN$$

By Symmetry: $F_{DR}\sin\theta = -\frac{5}{2}\ kN$

section BB left part

$$\uparrow \Sigma F_y = F_{DR}\sin\theta + F_{QK}\sin\theta + F_{DK}$$

$$-10 - 20 + 25 = 0$$

$$\Rightarrow \quad \left(-\frac{5}{2} + \frac{5}{2}\right) + F_{DK} - 5 = 0$$

$$\Rightarrow \quad \boxed{F_{DK} = 5\,kN}$$