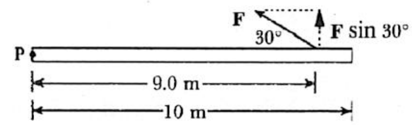
9. $F = 55$ N, $d = 9.0$ m



$\tau_{CC} = F{\cdot}d \sin\theta = (55)(9.0) \sin 30° = 247.5 \approx 250$ N·m
(counter-clockwise)

10. a) F_C

$\tau = F{\cdot}d \sin\theta$
Since force F_C has the longest lever arm, the torque produced by F_C is the greatest.

b) F_A

$\tau = F{\cdot}d \sin\theta \qquad F = \dfrac{\tau}{d \cdot \sin\theta}$

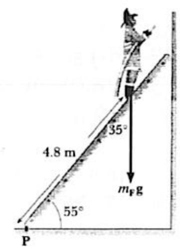
The magnitude of torque required to loose the bolt is constant. Since force F_A has the shortest lever arm, it must be the greatest to loose the bolt.

When the line-of-action of the force passes through the pivot, no rotation will occur at all ($\tau = 0$), and so it is impossible to loose the bolt by exerting F_D.

c) Force F_E produces a clockwise torque.

11. $m_F = 70$ kg, $d = 4.8$ m

$\tau_C = (m_F g){\cdot}d \sin 35° = (70)(9.8)(4.8)(\sin 35°) = 1889 \approx 1.9 \times 10^3$ N·m (clockwise)



12. a) $\Sigma\tau_P = 0$ N·m

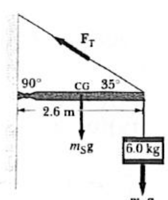
The metre stick is in rotational equilibrium, and so the sum of the torques about point P is zero.

b) $\Sigma\tau_Q = 0$ N·m

Since the metre stick is in rotational equilibrium, the sum of the torques about point Q is zero.

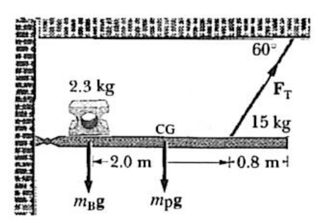
Note: If an object is in rotational equilibrium, the sum of the torques about any pivot point is zero.

13. $m_C = 6.0$ kg, $m_S = 1.8$ kg, $d_{CG} = 1.3$ m, $d_B = 2.6$ m



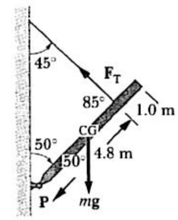
$\Sigma\tau = 0$: $\tau_{CC} = \tau_C$
$(F_T)(d_B) \sin 35° = (m_S g)(d_{CG}) + m_C g(d_B)$
$(F_T)(2.6) \sin 35° = (1.8)(9.8)(1.3) + (6.0)(9.8)(2.6) \qquad F_T = 118 \approx 120$ N

14. $m_B = 2.3$ kg, $m_P = 15$ kg, $d_B = 1.2$ m, $d_{CG} = 2.0$ m, $d_T = 3.2$ m



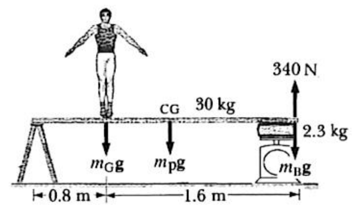
$\tau_{CC} = \tau_C$
$(F_T)(d_T) \sin 120° = (m_B g)(d_B) + (m_P g)(d_{CG})$
$(F_T)(3.2) \sin 120° = (2.3)(9.8)(1.2) + (15)(9.8)(2.0)$
$F_T = 115.8 \approx 120$ N

15. $F_T = 1300$ N, $d_{CG} = 2.9$ m, $d_T = 4.8$ m



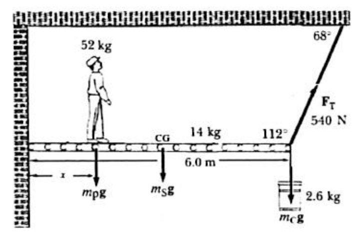
$\tau_{CC} = \tau_C$
$(F_T)(d_T) \sin 85° = (mg)(d_{CG}) \sin 50°$
$(1300)(4.8) \sin 85° = (m)(9.8)(2.9) \sin 50°$ $m = 286 \approx 290$ kg

16. $m_P = 30$ kg, $m_B = 2.3$ kg, $F_N = 340$ N
$d_G = 0.8$ m, $d_{CG} = 1.2$ m, $d_B = 2.4$ m, $d_N = 2.4$ m



$\tau_{CC} = \tau_C$
$(F_N)(d_N) = (m_G g)(d_G) + (m_P g)(d_{CG}) + (m_B g)(d_B)$
$(340)(2.4) = m_G(9.8)(0.8) + (30)(9.8)(1.2) + (2.3)(9.8)(2.4)$
$m_G = 52$ kg

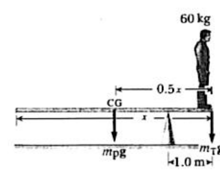
17. $m_P = 52$ kg, $m_S = 14$ kg, $m_C = 2.6$ kg, $F_T = 540$ N
$d_{CG} = 3.0$ m, $d_C = 6.0$ m, $d_T = 6.0$ m



$\tau_{CC} = \tau_C$
$(F_T)(d_T) \sin 112° = (m_P g)(x) + (m_S g)(d_{CG}) + (m_C g)(d_C)$
$(540)(6.0) \sin 112° = (52)(9.8)(x) + (14)(9.8)(3.0) + (2.6)(9.8)(6.0)$
$x = 4.8$ m

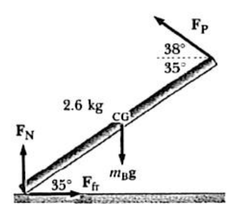
The painter cannot fetch the paint can. The maximum distance that the painter can walk out on the scaffold is 4.8 m.

18. $m_P = 40$ kg, $m_T = 60$ kg, $d_T = 1.0$ m, $d_{CG} = (0.5x - 1.0)$ m



$\tau_{CC} = \tau_C$
$(m_P g)(d_{CG}) = (m_T g)(d_T)$ $(40)(9.8)(0.5x - 1.0) = (60)(9.8)(1.0)$
$x = 5.0$ m

19. $m_B = 2.6$ kg, $d_P = d$, $d_{CG} = 0.5d$

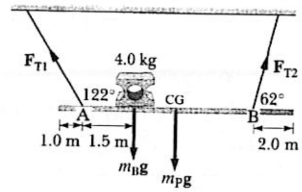


pivot: the bottom of the beam
$\tau_{CC} = \tau_C$
$(F_P)(d_P) \sin 73° = (m_B g)(d_{CG}) \sin 55°$
$(F_P)(d) \sin 73° = (2.6)(9.8)(0.5d) \sin 55°$ $F_P = 10.91$ N

$\Sigma F_x = 0$
$F_{fr} = F_P \cos 38° = (10.91) \cos 38° = 8.6$ N

20. $m_P = 50$ kg, $m_B = 4.0$ kg

pivot: point A
$d_B = 1.5$ m, $d_{CG} = 4.0$ m, $d_T = 7.0$ m



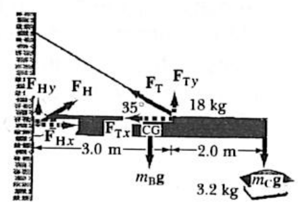
$\tau_{CC} = \tau_C$
$(F_{T2})(d_T) \sin 118° = (m_Bg)(d_B) + (m_Pg)(d_{CG})$
$(F_{T2})(7.0) \sin 118° = (4.0)(9.8)(1.5) + (50)(9.8)(4.0)$
$F_{T2} = 326.6 \approx 330$ N

Solution I: Using two pivot points
pivot: point B
$d_B = 5.5$ m, $d_{CG} = 3.0$ m, $d_T = 7.0$ m

$\tau_{CC} = \tau_C$
$(m_Bg)(d_B) + (m_Pg)(d_{CG}) = (F_{T1})(d_T) \sin 122°$
$(4.0)(9.8)(5.5) + (50)(9.8)(3.0) = (F_{T1})(7.0) \sin 122°$ $\quad F_{T1} = 283.9 \approx 280$ N

Solution II: $\Sigma F = 0$
$\Sigma F_x = 0$, $\Sigma F_y = 0$
$F_{T1} \sin 58° + F_{T2} \sin 62° = m_Bg + m_Pg$
$F_{T1} \sin 58° + (326.6) \sin 62° = (4.0)(9.8) + (50)(9.8)$ $\quad F_{T1} = 284.0 \approx 280$ N

21. $m_B = 18$ kg, $m_C = 3.2$ kg, $d_{CG} = 2.5$ m, $d_T = 3.0$ m, $d_C = 5.0$ m



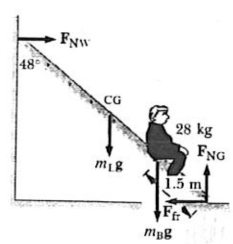
$\tau_{CC} = \tau_C$
$(F_T)(d_T) \sin 35° = (m_Bg)(d_{CG}) + (m_Cg)(d_C)$
$(F_T)(3.0) \sin 35° = (18)(9.8)(2.5) + (3.2)(9.8)(5.0)$ $\quad F_T = 347.4$ N

$F_{Tx} = F_T \cos 35° = 284.6$ N $\quad F_{Ty} = F_T \sin 35° = 199.3$ N
$F_{Hx} = F_{Tx} = 284.6$ N

$\Sigma F_y = 0$
$F_{Hy} + F_{Ty} - m_Bg - m_Cg = 0$
$F_{Hy} + 199.3 - (18)(9.8) - (3.2)(9.8) = 0$ $\quad F_{Hy} = 8.46$ N

$F_H = \sqrt{{F_{Hx}}^2 + {F_{Hy}}^2} = \sqrt{(284.6)^2 + (8.46)^2} = 284.7 \text{ N} \approx 280 \text{ N}$

22. $m_B = 28$ kg, $m_L = 14$ kg, $d_{CG} = 2.5$ m, $d_B = 1.5$ m, $d_L = 5.0$ m



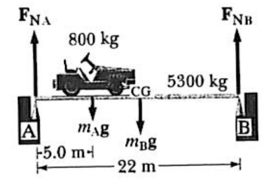
$\Sigma\tau = 0$: $\tau_{CC} = \tau_C$
$(m_Bg)(d_B) \sin 48° + (m_Lg)(d_{CG}) \sin 48° = (F_{NW})(d_L) \sin 42°$
$(28)(9.8)(1.5) \sin 48° + (14)(9.8)(2.5) \sin 48° = (F_{NW})(5.0) \sin 42°$
$F_{NW} = 167.6$ N

$\Sigma F_x = 0$ $\quad F_{NW} - F_{fr} = 0$ $\quad F_{fr} = F_{NW} = 167.6$ N

$\Sigma F_y = 0$
$F_{NG} - m_Bg - m_Lg = 0$ $\quad F_{NG} - (28)(9.8) - (14)(9.8) = 0$ $\quad F_{NG} = 411.6$ N

$F_{fr} = \mu \cdot F_{NG}$ $\quad 167.6 = \mu(411.6)$ $\quad \mu = 0.41$

23. a) $m_A = 800$ kg, $m_B = 5300$ kg



pivot: point A
$d_A = 5.0$ m, $d_{CG} = 11$ m, $d_L = 22$ m

$\Sigma\tau = 0$: $\tau_{CC} = \tau_C$
$(F_{NB})(d_L) = (m_Ag)(d_A) + (m_Bg)(d_{CG})$
$(F_{NB})(22) = (800)(9.8)(5.0) + (5300)(9.8)(11)$
$F_{NB} = 27751.8 \approx 2.8 \times 10^4$ N

Solution I: Using two pivot points
pivot: point B
$d_L = 22$ m, $d_A = 17$ m, $d_{CG} = 11$ m

$\Sigma\tau = 0$: $\tau_{CC} = \tau_C$
$(m_Ag)(d_A) + (m_Bg)(d_{CG}) = (F_{NA})(d_L)$
$(800)(9.8)(17) + (5300)(9.8)(11) = (F_{NA})(22)$ $\quad F_{NA} = 32028.2 \approx 3.2 \times 10^4$ N

Solution II: $\Sigma F = 0$
$\Sigma F_x = 0$, $\Sigma F_y = 0$
$F_{NA} + F_{NB} = m_Ag + m_Bg$
$F_{NA} + 27751.8 = (800)(9.8) + (5300)(9.8)$ $\quad F_{NA} = 32028.2 \approx 3.2 \times 10^4$ N

b) As the automobile approaches support B, the lever arm about pivot A increases and the clockwise torque increases. For the system to remain in rotational equilibrium, the counter-clockwise torque must increase and the reaction force exerted by support B must increase ($\Sigma\tau = 0$). If the reaction force of support B increases, the reaction force of support A decreases because the system must remain in translational equilibrium as well ($\Sigma F_y = 0$). In conclusion, for the system to remain in static equilibrium, the net torque and the net force of the system must be zero.