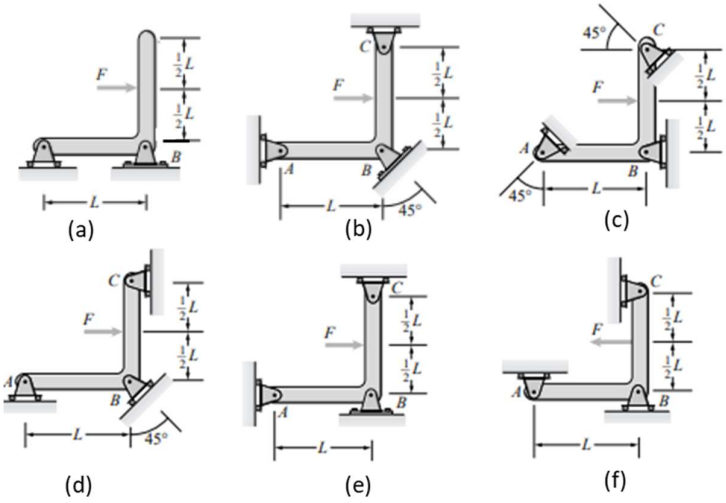
BASIC ENGINEERING MECHANICS (ME11003)

Tutorial 2: 2D and 3D Equilibrium

Take g =9.81 m/s2 wherever relevant

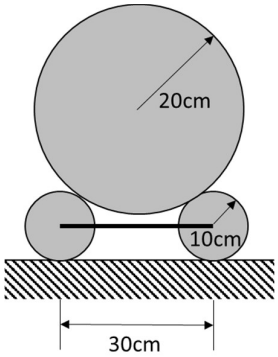
Q1. Carefully study the constraints and applied load in the L-shaped member and determine whether the member is properly or improperly supported.



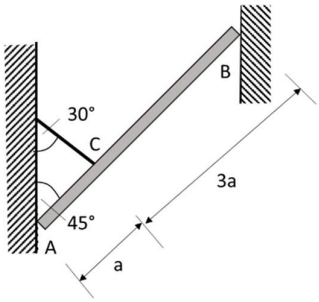
Ans:

a.) Properly constrained
b.) Improperly constrained
c.) Properly constrained
d.) Improperly constrained
e.) Improperly constrained
f.) Properly constrained

Q2. A cylinder of weight 4 kg and radius 20 cm lies on top of two cylinder each having weight 1 kg and radius 10 cm. the small cylinders are connected by a wire S of length 30 cm as shown. Assuming all surfaces are smooth, determine the contact forces and tension in the wire



Ans: *Contact force between large and small cylinder: 22.655 N*
Contact force between small cylinder and floor: 29.430 N
Tension in the thread: 11.327 N



Q3. A homogeneous beam (length 4a, weight G) is suspended at C by a rope. The beam touches the smooth vertical walls at A and B. Find the resultant of forces in the rope and the contact forces at A and B

Ans: $S = \frac{2\sqrt{3}}{3}G;\ A = \frac{1+\sqrt{3}}{4}G;\ B = \frac{3-\sqrt{3}}{12}G$

Q4. A 200 kg crate is to be moved to the right. To achieve this, the horizontal component of the force exerted on the crate must be equal to 0.35 times the normal force exerted by the crate on the floor. Which of the two methods will lead to the desired objective with lower applied force

Option 1: By applying a force at 20° degree with respect to the ground as shown in figure A
Option 2: By tying a rope to the ground and applying vertical force as shown in figure B

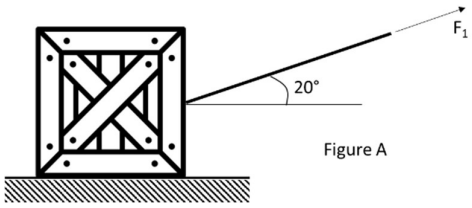


Figure A

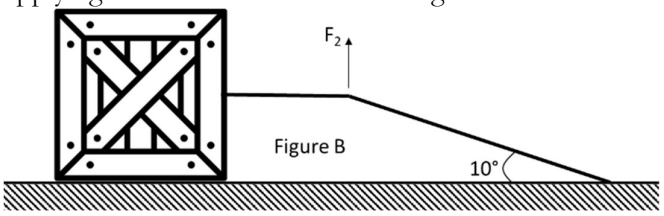
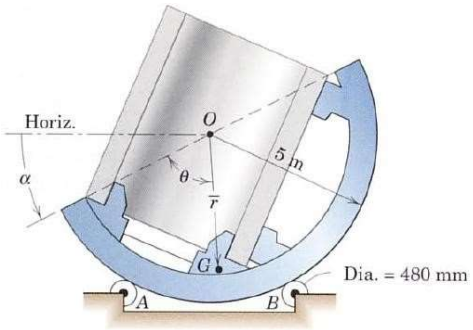


Figure B

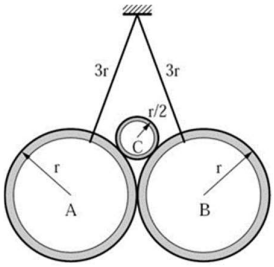
Ans: *Option 1: force needed is 648.441N; Option 2: force needed is 120.663N*

Problems taken from various sources. Figures not own.

Q5. A special jig consists of an 80 Mg sector mounted on a line of rollers at A and a line of rollers at B. One of the rollers at B is a gear which meshes with a ring of gear teeth on the sector so as to turn the sector about its geometric center O. When α=0, a counter-clockwise torque of 2460 Nm must be applied to the gear at B to keep the assembly from rotating. When α=30^{O}, a clockwise torque of 4680 Nm is required to prevent rotation. Locate the mass center G of the jig by calculating $\bar{r}$ and θ. Note that the mass center of the pipe section is at O.



Ans: $r = 367mm;\ \theta = 79.8°$

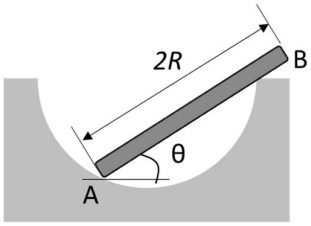


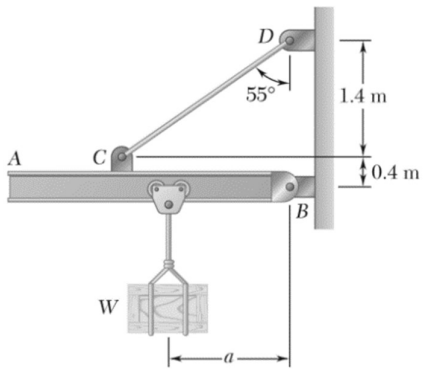
Q6. Two identical smooth tubes A and B, each of weight W, are suspended at their ends by cords of equal length. A third tube C of weight WC = 0.8W is placed between A and B. Determine the greatest weight of C that can be supported without upsetting equilibrium.

Ans: $W_C = 0.8W$

Q7. A uniform rod AB of length 2R rests inside a hemispherical bowl of radius R as shown. Neglecting friction, determine the angle θ corresponding to equilibrium.

Ans: $\theta = 32.53°$





Q8. A 50-kg crate is attached to the trolley-beam system shown.

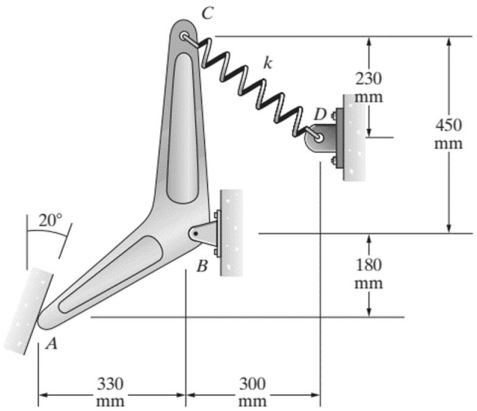
i.) Determine the angle which the resultant at B makes with the horizontal without solving the equilibrium equations when a = 1.5 and when a = 3m.

ii.) Determine the tension in cable CD and the reaction at B, when a = 1.5 m and a = 3m.

Ans: *when a = 1.5, angle of resultant at B with horizontal is 26.556°, T_{CD}=498.99N, T_B=456.96N*
when a = 3, angle of resultant at B with horizontal is 5.729°, T_{CD}=998.18N, T_B=821.76N

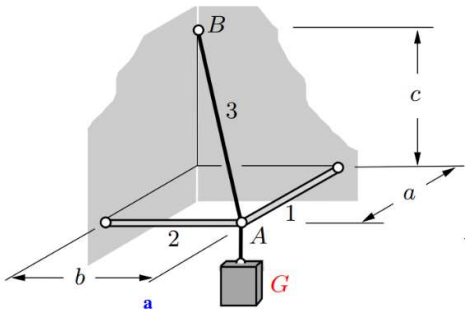
Q9. The unstretched length of the spring CD is 350 mm. Suppose that you want the lever ABC to exert a 120-N normal force on the smooth surface at A. Determine the necessary value of the spring constant k and the resulting reactions at B.

Ans: *Spring constant, k= 3380 N/mm The magnitude of the reactions at B is 212.33N*

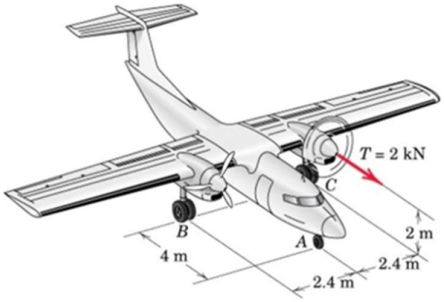


Problems taken from various sources. Figures not own.

Q10. A structure consists of two bars 1 and 2 and a rope 3 (weights negligible). It is loaded in A by a box of weight G. Determine the forces in the bars and in the rope.



Ans: $S_3 = G\frac{\sqrt{a^2+b^2+c^2}}{c}$; $S_1 = -G\frac{a}{c}$; $S_2 = -G\frac{b}{c}$

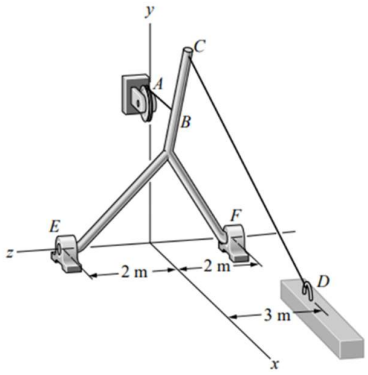


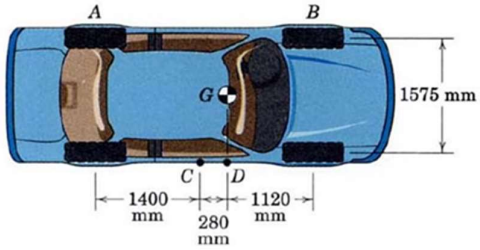
Q11. During a test, the left engine of the twin-engine airplane is revved up and a 2 kN thrust is generated. The wheels at B and C are braked in order to prevent motion. Determine the change in the nominal values of the normal reaction forces at A, B and C compared to their nominal values with the engine turned off.

Ans: *ΔN_A =1000 N, $\Delta N_B = \Delta N_C$ =-500 N*

Q12. The crane's cable CD is attached to a stationary object at D. The crane is supported by the bearings E and F and the horizontal cable AB. The tension in cable AB is 8 kN. Determine the tension in the cable CD.

Ans: *T_{CD} = 6.54 kN*



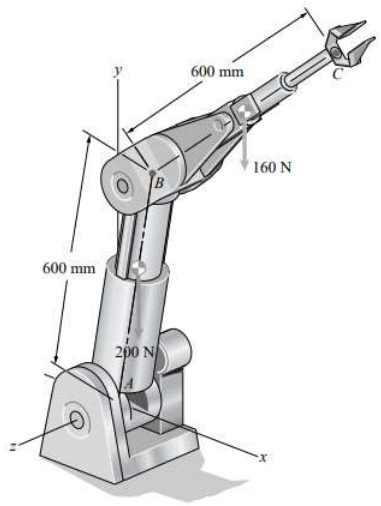


Q13. For a car of mass 1600 kg, two different locations C and D are considered for a single jack. In each case, the entire right side of the car is lifted just off the ground. Determine the normal reaction forces at A and B, and the vertical jacking force required in each case.

Ans: *<u>at C:</u> N_A =2354.4 N, N_B =5493.6N, <u>at D:</u> N_A =3139.2 N, N_B =4708.8 N*

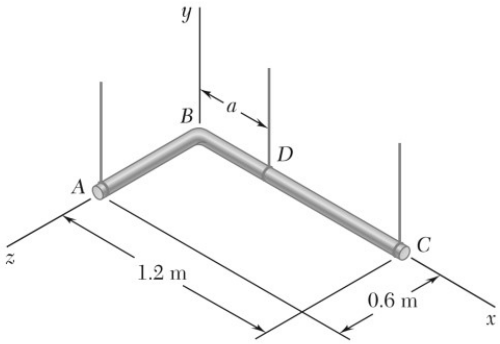
Q14. The robotic manipulator is stationary and the y axis is vertical. The weights of the arms AB and BC act at their midpoints. The direction cosines of the centreline of arm AB are cos θ_x = 0.174, cos θ_y = 0.985, cos θ_z = 0, and the direction cosines of the centreline of arm BC are cos θ_x = 0.743, cos θ_y = 0.557, cos θ_z =-0.371. The support at A behaves like a built-in support. Determine all the reactions at A.

Ans: $A_x = 0, A_y = 360N, A_z = 0$
$M_{Ax} = 17.81\ N.m, M_{Ay} = 0, M_{Az} = 62.81\ N.m$

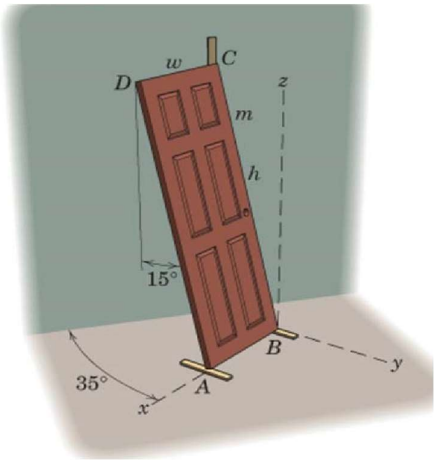


Problems taken from various sources. Figures not own.

Q15. Two steel pipes AB and BC, each having a mass per unit length of 8 kg/m, are welded together at B and supported by three wires. For the pipe assembly shown, determine (a) the largest permissible value of "*a*" if the assembly is not to tip, (b) the corresponding tension in each wire.



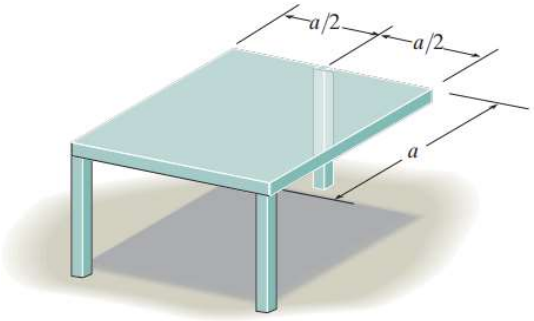
Ans: $a = 0.480m$, $T_A = 23.5\ N$; $T_D = 117.7\ N$



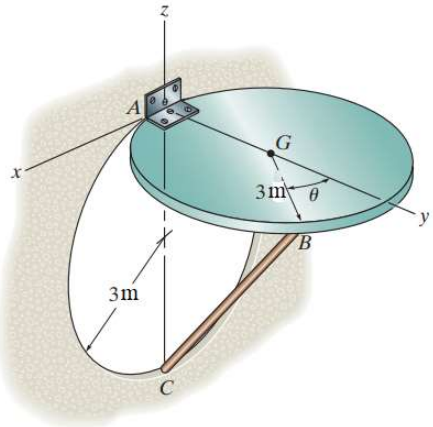
Q16. A homogeneous door of mass m, height h and width w is leaned against a frictionless wall and on a rough floor. The door is in contact at A and B on the floor and is in contact at C on the vertical wall. Determine y and z components of the floor reactions and normal reaction at C.

Ans: $C_N = 0.164mg$
$A_y = -0.024mgh/w$
$A_z = mg(0.5 + 0.091h/w)$
$B_y = mg(0.024h/w - 0.134)$
$B_z = mg(0.5 - 0.091h/w)$

Q17. A uniform square table having a weight W and sides a is supported by three vertical legs. Determine the smallest vertical force P that can be applied to its top that will cause it to tip over



Ans: P = 0.5W



Q18. The circular door has a weight of 55 kg and a center of gravity at G. Determine the x, y, z components of reaction at the hinge A and the force acting along strut CB needed to hold the door in equilibrium when θ = 90°

Ans: A_x = -269.775 N;
A_y = -269.775 N
A_z = 0;
M_{AY} = 1618.65 N.m
M_{AZ} = 0
F_{CB} = 660.8016

Problems taken from various sources. Figures not own.