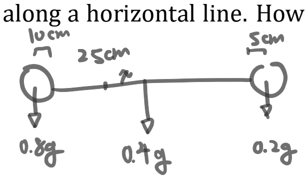
Assignment #2

Physics 2 Spring 2020
Instructor: Prof. Dirk Bouwmeester
Due: 04/12/20 5pm PST

Comments: Each problem is worth three points. If the problem has multiple parts the points breakdown is delineated in the problem.

1 A Steel Rod and Two Spheres

A uniform steel rod has mass 0.400 kg and length 50.0 cm and is horizontal. A uniform sphere with radius 10.00 cm and mass 0.800 kg is welded to one end of the bar, and a uniform sphere with radius 5.00 cm and mass 0.200 kg is welded to the other end of the bar. The centers of the rod and of each sphere all lie along a horizontal line. How far is the center of gravity of the combined object from the center of the rod?



$0.4x + 0.2(30+x) = (35-x)0.8$

$6 + 0.6x = 28 - 0.8x$

$1.4x = 22$

$x = \frac{110}{7} \approx 15.71$

2 Ladder Resting Against a Wall

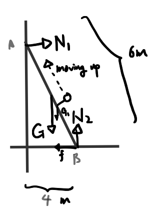
A uniform ladder 6.0 m long rests against a frictionless, vertical wall with its lower end 4.0 m from the wall. The ladder weighs 180 N. The coefficient of static friction between the foot of the ladder and the ground is 0.40. A man weighing 700 N climbs slowly up the ladder. Start by drawing a free-body diagram of the ladder. (a) What is the maximum friction force that the ground can exert on the ladder at its lower end? (b) What is the actual friction force when the man has climbed 1.0 m along the ladder? (c) How far along the ladder can the man climb before the ladder starts to slip?

Each part is 1 point $h = \sqrt{6^2 - 4^2} = 2\sqrt{5} \approx 4.472$

max possible $f = N_2\mu = (G_1+G)\mu$

$= 880 \times 0.4$

$= 352\ N$



b) assume equilibrium, $f = N_1$

$2\sqrt{5} \times N_1 = 700 \times \frac{4}{6} + 180 \times 2$

$f = 184.85$

c) after distance x climbed equilibrium breaks

at equilibrium

Moment:

about A: $180 \times 2 + (4 - \frac{4x}{6}) \times 700 + 2\sqrt{5} f = 4N_2$

about B: $180 \times 2 + \frac{4x}{6} \times 700 = 2\sqrt{5} N_1$

Force:

y: $G_1 + G = N_2$

x: $f = N_2\mu = N_1$

when $N_1 > f$, equilibrium breaks

$\frac{2G + G_1\frac{4x}{6}}{h} > (G_1+G)\mu$

$2G + G_1\frac{4x}{6} > 352 \times 2\sqrt{5}$

$x > 1214.19 \times \frac{6}{4G_1}$

$x > 2.602$

hence 2.602 m

3 Load Supporting Steel Post

A vertical, solid steel post 39 cm in diameter and 3.30 m long is required to support a load of 9900 kg. You can ignore the weight of the post. What are (a) the stress in the post; (b) the strain in the post; and (c) the change in the post's length when the load is applied?

Each part is 1 pt.

stress $= \frac{9900\,g}{\pi(\frac{0.39}{2})^2} = 812989.8\ Pa \approx 8.1 \times 10^6$

strain $= \frac{\text{stress}}{\text{young's modulus}}$

$= \frac{8.1 \times 10^6}{2.0 \times 10^{11}}$

$= 4.05 \times 10^{-5}$

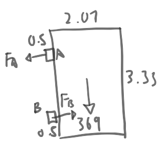
strain $= \frac{\Delta l}{l}$

$\Delta l = 4.05 \times 10^{-5} \times 3.3$

$\Delta l = 1.3365 \times 10^{-4}$

4 A Door and Two Hinges

A door 2.07 m wide and 3.33 m high weighs 369 N and is supported by two hinges, one 0.50 m from the top and the other 0.50 m from the bottom. Each hinge supports half the total weight of the door. Assuming that the door's center of gravity is at its center, find the horizontal components of force exerted on the door by each hinge.



hinge A as pivot

$(3.33-1)F_B = 369 \times \frac{2.07}{2}$

$(3.33-1)F_A = 369 \times \frac{2.07}{2}$

$F_A = F_B \approx 163.9$ N

(Direction defined separately on diagram)

$F_A = -163.9$

$F_B = 163.9$

5 Supporting a Broken Leg

A therapist tells a 64 kg patient with a broken leg that he must have his leg in a cast suspended horizontally. For minimum discomfort, the leg should be supported by a vertical strap attached at the center of mass of the leg–cast system. To comply with these instructions, the patient consults a table of typical mass distributions and finds that both upper legs (thighs) together typically account for 21.5% of body weight and the center of mass of each thigh is 18.0 cm from the hip joint. The patient also reads that the two lower legs (including the feet) are 14.0% of body weight, with a center of mass 69.0 cm from the hip joint. The cast has a mass of 5.55 kg, and its center of mass is 78.0 cm from the hip joint. How far from the hip joint should the supporting strap be attached to the cast?

m_u $\quad$ m_L

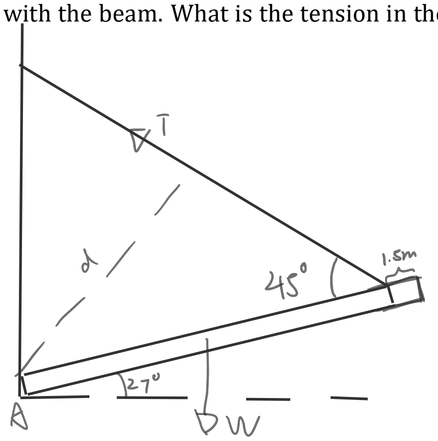
$\frac{21.5\% m}{2}$, $7\% m$

$$x = \frac{\frac{21.5\% m}{2}(18) + 7\% m(69) + 5.55 \times 78}{\frac{21.5\%}{2}m + 7\% m + 5.55}$$

$x = 51.2$ cm or 0.512 m

6 Beam Supported by Cable

A uniform, 6.9-m-long beam weighing 5180 N is hinged to a wall and supported by a thin cable attached 1.5 m from the free end of the beam. The cable runs between the beam and the wall and makes a 45° angle with the beam. What is the tension in the cable when the beam is at an angle of 27° above the horizontal?



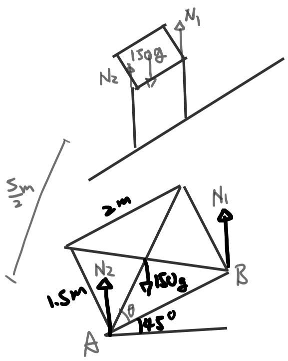
set pivot at A

$T \times (6.9-1.5)\sin(45°) = 5180\,(3.45)\cos(27°)$

$T = 4170$ N

7 To Pivot or Not to Pivot

Ross and Chandler are carrying a 150 kg crate up a flight of stairs. The crate is 2.0 m long and 1.5 m high, and its center of gravity is at its center. The stairs make a 45.0° angle with respect to the floor. The crate also is carried at a 45.0° angle, so that its bottom side is parallel to the slope of the stairs. If the force each person applies is vertical, what is the magnitude of each of these forces? Is it better to be the person above or below on the stairs?



A as pivot

$\theta = \arctan(\frac{3}{4})$

$150g \times \frac{5}{4} \times \cos(\arctan(\frac{3}{4}) + 45) = 2\cos(45)\,N_1$

B as pivot

$150g \times (2\cos(45) - \frac{5}{4}\cos(\arctan(\frac{3}{4}) + 45)) = 2\cos(45)N_2$

$N_1 = 183.9375$

$N_2 = 1288$

Above is better

8 Stress on the Shin Bone

The compressive strength of our bones is important in everyday life. Young's modulus for bone is about 1.4 1010 Pa. Bone can take only about a 1.0% change in its length before fracturing. (a) What is the maximum force that can be applied to a bone whose minimum cross-sectional area is 3.0 cm^2 ? (This is approximately the cross-sectional area of a tibia, or shin bone, at its narrowest point.) (b) Estimate the maximum height from which a 70 kg man could jump and not fracture his tibia. Take the time between when he first touches the floor and when he has stopped to be 0.030 s, and assume that the stress on his two legs is distributed equally.

(a) is 1 point, (b) is 2 points $\frac{1}{100\times100} \Rightarrow 10^{-4}$

$F = YA\frac{\Delta l}{l}$

$= 1.4\times10^{10} \cancel{/} (3\times10^{-4}) \times 1\%$

$= 4.2\times10^{4}N$ for 1 leg

$v^2 = u^2 + 2as$

$v = \sqrt{2gh}$

$F = \frac{70 \times \sqrt{2\times9.81} \times \sqrt{h}}{0.03}$

$\frac{2\times4.2\times10^4 \times 0.03}{70} = \sqrt{2gh}$

$v = 36$

$\frac{36}{2\times9.81} = h$

$h = 66.06m$