



Your Name: RUINA

Section day & time: _____

TA name & section #: _____

"SOLUTIONS"

T&AM 202 Prelim 1

Tuesday Oct 1, 2002

This version last edited September 30, 2002.

3 problems, 100 points, and 90 minutes (+ 60 extra).

Please follow these directions to ease grading and to maximize your score.

- a) No calculators, books or notes allowed. A blank page for tentative scrap work is provided at the back. Ask for extra scrap paper if you need it.
- b) Full credit if
- $\swarrow \nearrow$ →free body diagrams← are drawn whenever force or moment balance is used;
 - correct vector notation is used, when appropriate;
 - ↑→ any dimensions, coordinates, variables and base vectors that you add are clearly defined;
 - ± all signs and directions are well-defined with sketches and/or words;
 - | reasonable justification, enough to distinguish an informed answer from a guess, is given;
 - * you clearly state any reasonable assumptions if a problem seems *poorly defined*;
 - work is I.) neat,
II.) clear, and
III.) well organized;
 - your answers are TIDILY REDUCED (Don't leave simplifiable algebraic expressions.);
 - your answers are boxed in; and
 - » unless otherwise stated, you will get full credit for, instead of doing a calculation, presenting Matlab code that would generate the desired answer. To ease grading and save space, your Matlab code can use shortcut notation like " $R_{Ax} = 18$ " instead of, say, " $RAX = 18$ ".
- c) Substantial partial credit if your answer is in terms of well defined variables and you have not substituted in the numerical values. Substantial partial credit if you reduce the problem to a clearly defined set of equations to solve.

Problem 1: _____/_____

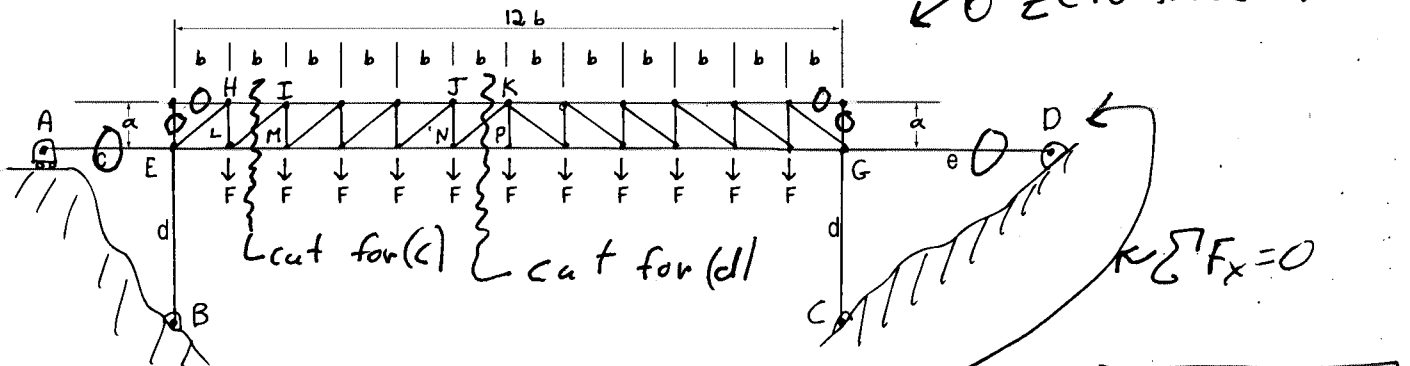
Problem 2: _____/_____

Problem 3: _____/_____

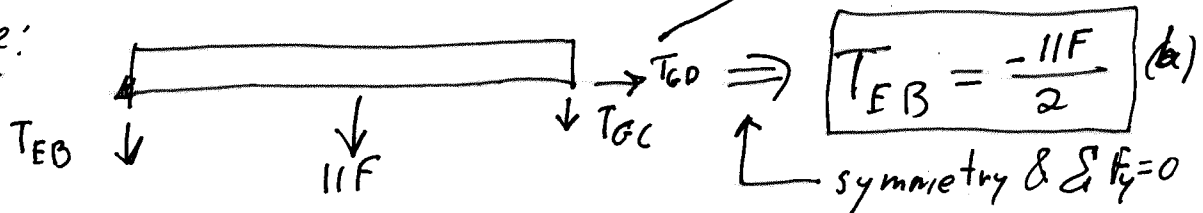
TOTAL: _____/100

1) (35 pts) The 2D truss shown consists of 12 diagonally braced rectangles (each a high and b wide). Thus the slope of the diagonal elements is a/b . The whole structure is supported by 4 bars (with lengths c, d , and e as marked). The loading is idealized as 11 identical loads F shown. Give your answers in terms of some or all of a, b, c, d, e and F .

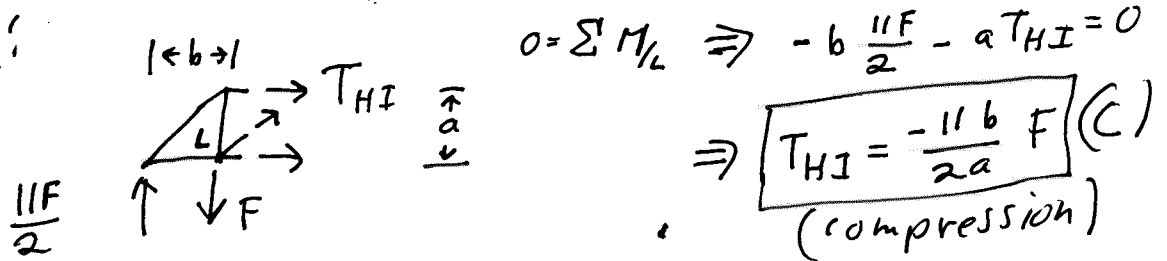
- On the figure below clearly mark all the zero-force members (put a '0' on the middle of each bar that has a 'bar force' of zero).
- Find the 'bar-force' in bar EB.
- Find the 'bar-force' in bar HI.
- Find the 'bar-force' in bar JK. [Hint: Use the method of sections and, to reduce calculations, replace a group of the F forces with a single equivalent force.]



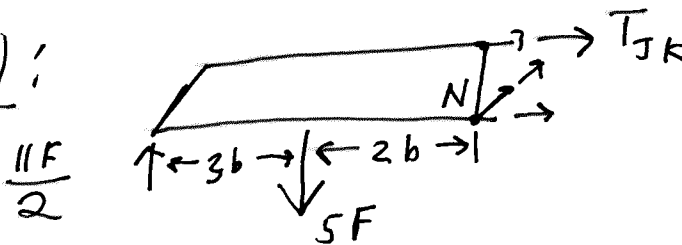
Whole structure:



section for (c):



section for (d):



$$0 = \sum M_{/N} \Rightarrow (-5b)\left(\frac{11F}{2}\right) + (2b)(5F) - a T_{JK} = 0$$

$$+b\left(-\frac{55F}{2} + 10F\right) = a T_{JK}$$

$$\boxed{T_{JK} = -\frac{35b}{2a} F} \quad (d)$$

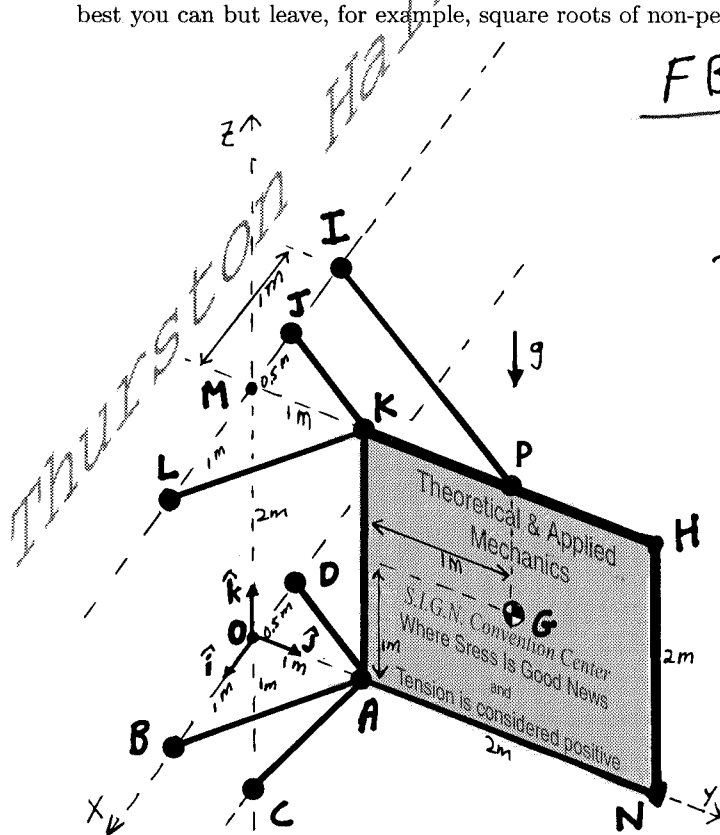
(compression)

(Note JK has more than 3 times the compression of HI.)

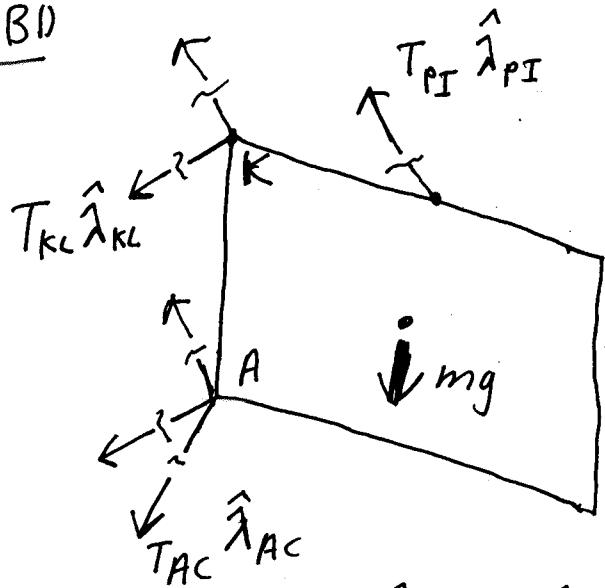
2) (35 pts) The 100 kg, 2 m square, uniform sign KHNA is held up by 6 bars.

Structure and geometry clarifications: The sign is held vertically, 1m in front of, and orthogonal to a vertical wall. Each bar holding the sign has a ball-and-socket joint both where it attaches to the sign and where it attaches to the wall. The points L, M, J, I, K, P and H lie in the same horizontal plane that includes the top edge of the sign. The points M, O, and C lie on a vertical line that is coplanar with the sign. Points B, O, D, A, and N lie in a horizontal plane shared with the bottom edge of the sign. The center of mass of the sign is at G. $g = 10 \text{ N/kg}$.

- Find the 'bar force' in bar AC [hint: $\Sigma F_z = \{\Sigma \mathbf{F}\} \cdot \hat{\mathbf{k}} = 0$].
- Find the "bar force" in bar PI [hint: $\Sigma M_{AK} = \{\Sigma \mathbf{M}_{/A}\} \cdot \hat{\mathbf{k}} = 0$].
- Find the "bar force" in bar KL. [The numerical answer is not especially tidy. Simplify it as best you can but leave, for example, square roots of non-perfect squares.]



FBD



Geometry:

$$\hat{\lambda}_{AC} = \frac{-\hat{j} - \hat{k}}{\sqrt{2}}$$

$$\hat{\lambda}_{KL} = (\hat{i} - \hat{j})/\sqrt{2}$$

a) $0 = (\Sigma \mathbf{F}) \cdot \hat{\mathbf{k}} = \Sigma F_z \Rightarrow -mg + T_{AC} \hat{\lambda}_{AC} \cdot \hat{\mathbf{k}} = 0$

$$T_{AC} = \frac{mg}{((-\hat{j} - \hat{k})/\sqrt{2}) \cdot \hat{\mathbf{k}}} = -\sqrt{2} mg \Rightarrow \boxed{T_{AC} = -1000\sqrt{2} \text{ N}} \text{ (a)}$$

compression

b) $\Sigma M_{AK} = 0 \Rightarrow \boxed{T_{IP} = 0}$ (b) All other forces intersect axis or are || to axis.

c) $\Sigma M_{BA} = 0 \Rightarrow (\mathbf{r}_{AK} \times (T_{KL} \hat{\lambda}_{KL})) \cdot \mathbf{r}_{BA} + (\mathbf{r}_{AG} \times (-mg \hat{\mathbf{k}})) \cdot \mathbf{r}_{BA} = 0$

$$[(2m \hat{\mathbf{k}}) \times \frac{(\hat{\mathbf{i}} - \hat{\mathbf{j}})}{\sqrt{2}}] \cdot (\frac{1}{2} \hat{\mathbf{i}} + \hat{\mathbf{j}}) T_{KL} + [1m(\hat{\mathbf{i}} + \hat{\mathbf{k}}) \times (-\hat{\mathbf{k}})] \cdot (\frac{1}{2} \hat{\mathbf{i}} + \hat{\mathbf{j}}) mg = 0$$

$$\frac{2(\hat{\mathbf{j}} + \hat{\mathbf{i}})}{\sqrt{2}} \cdot (\frac{1}{2} \hat{\mathbf{i}} + \hat{\mathbf{j}}) T_{KL} + (-\hat{\mathbf{i}}) \cdot (\frac{1}{2} \hat{\mathbf{i}} + \hat{\mathbf{j}}) mg = 0$$

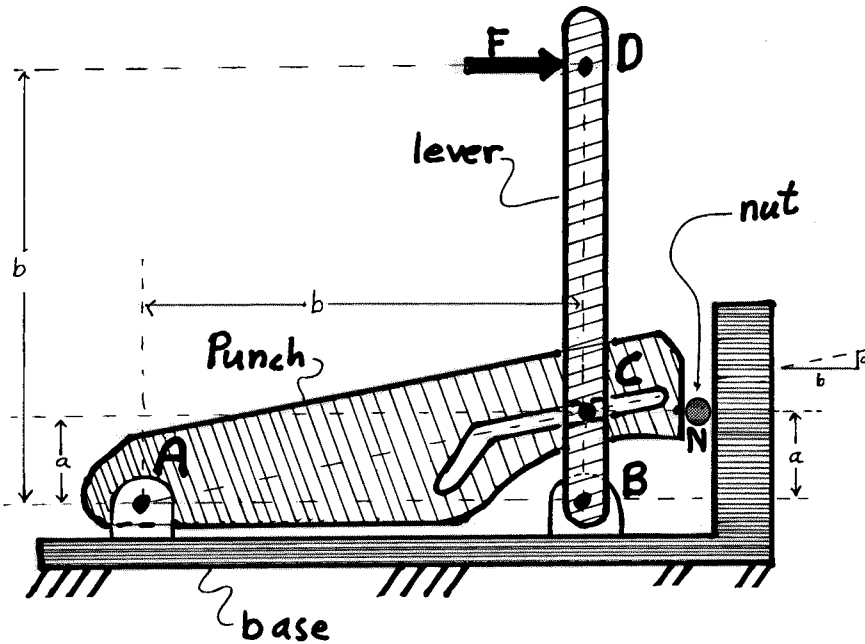
$$\frac{3 T_{KL}}{\sqrt{2}} - \frac{mg}{2} = 0 \Rightarrow \boxed{T_{KL} = \sqrt{2} mg / 6 = \frac{\sqrt{2} 1000}{6} \text{ N}} \text{ (c)}$$

(Tension)

3) (30 pts) The proposed nutcracker design consists of two moving parts: a lever hinged to the fixed base at B and a punch hinged to the fixed base at A. All joints and slots are assumed to have negligible friction.

Mechanism and geometry clarifications: The vertical lever has a pin at C and a horizontal force F applied at D. The punch has a slot in which the lever pin slides at C. The slot is parallel to the line AC. The spherical nut is cracked by being squeezed between the vertical surface of the punch at N and the vertical surface attached to the base. Point N at the left edge of the nut is level with the sliding pin at C. The horizontal distance from C to N does not enter the solution, but assume it is c if you need it for an intermediate calculation.

Quantities: $F = 10 \text{ lb}$, $a = 2 \text{ in}$, $b = 10 \text{ in}$.

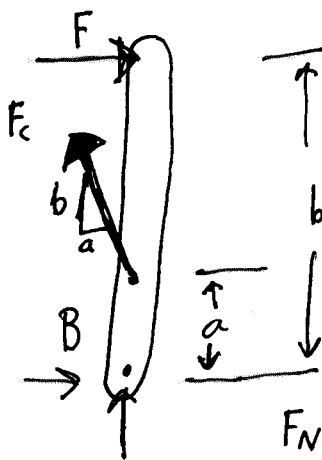


a) (25 pts) Find the force acting on the nut at N. A number is desired (i.e., so many lb force). [Hint: Only substitute in numbers when you have a formula for your answer in terms of a , b and F .]

b) (5 pts) The answer to (a) is conspicuous in its being either much smaller than F , very similar to F , or much bigger than F . Which is it? Explain, in words, why.

Part (b) will be graded independently of part (a). The best possible answer will generate an approximate answer formula for the force at N using next-to-no equations.

FBDs:



$$\sum M_B = 0 \Rightarrow -bF + a \left(\frac{a}{\sqrt{a^2+b^2}} F_c \right) = 0$$

$$\Rightarrow F_c = \frac{b\sqrt{a^2+b^2}}{a^2} F \quad (1)$$

$$\sum M_A = 0 \Rightarrow aF_N - \sqrt{a^2+b^2} F_c = 0$$

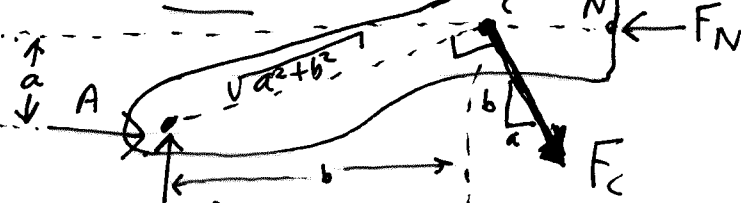
$$\Rightarrow F_N = \frac{\sqrt{a^2+b^2}}{a} F_c$$

$$= \frac{\sqrt{a^2+b^2}}{a} \left(\frac{b\sqrt{a^2+b^2}}{a^2} \right) F$$

$$= \frac{b(a^2+b^2)}{a^3} F$$

$$F_N = \frac{10 \cdot (2^2 + 10^2)}{2^3} = 130 \cdot 10 \text{ lb} = \boxed{1300 \text{ lb} = F_N}$$

Punch:



(b) There are 3 mechanical advantages each about a factor of 5: The lever ACB, the slope at C and the jamb (toggle) of ACN. So $F_N \approx 5^3 F \approx 125 F$.