EN130: Structural Analysis

Exam I
Wednesday, March 23, 2005

Division of Engineering
**Brown University**

NAME: _____

General Instructions

- No collaboration of any kind is permitted on this examination.
- You may consult your own written lecture notes and homework solutions during the course of this exam, but no other material. **PRINTED OR XEROXED NOTES ARE NOT PERMITTED**
- Write all your solutions in the space provided. No sheets should be added to the exam.
- Make diagrams and sketches as clear as possible, and show all your derivations clearly. Incomplete solutions will receive only partial credit, even if the answer is correct.
- If you find you are unable to complete part of a question, proceed to the next part. Use symbols to represent results from proceeding part if need be.

Please initial the statement below to show that you have read it

By affixing my name to this paper, I affirm that I have executed the examination in accordance with the Academic Honor Code of Brown University.
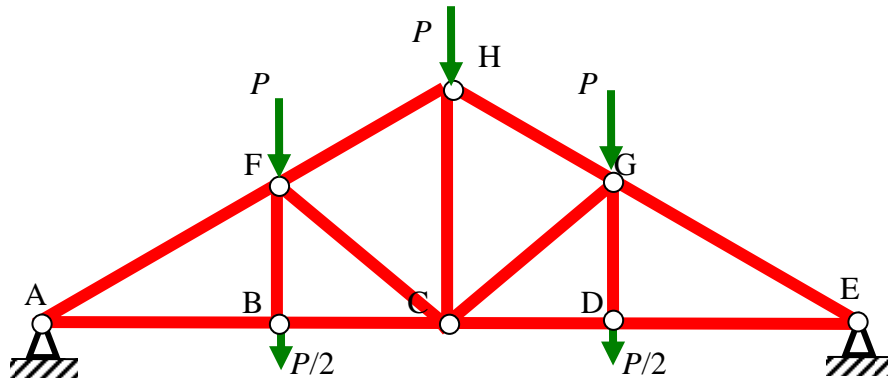
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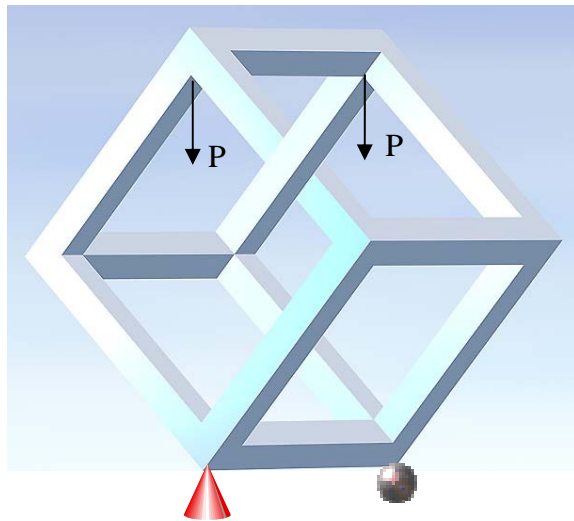
1-8 (16 points)   _____

9   (9 points)   _____

TOTAL (25 points)_____

Analyze This!!

Multiple Choice/Short Answer Problems. Write your answer to each problem in the space provided. Only the answer will be graded.

**Problems 1 and 2 refer to the roof truss shown below. *P*>0.**

1. Under the loads shown, member BF:
(a) is in tension
(b) is in compression
(c) is a zero-force member
(d) cannot be determined without further information.

ANSWER _____(2 points)

2. According to Maxwell's law,
(a) The truss shown above is statically determinate
(b) The truss shown above is a mechanism
(c) The truss shown above is statically indeterminate
(d) Bang, bang Maxwell's silver hammer came down upon her head….

ANSWER _____(2 points)

3. You are running a 3-D finite element truss analysis program to calculate the deflections in the 3-D bicycle frame shown. Joints D and E are constrained to have no displacement; joint A is constrained to have no displacement in the **j** direction. The program bombs. Explain **briefly** how you would adjust the problem statement and input file.
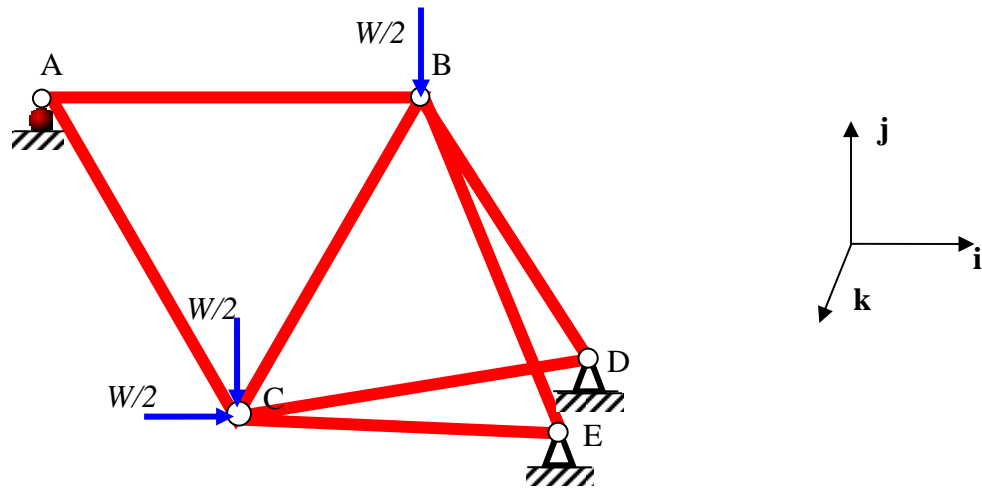
Answer: (2 points)

Problems 4 and 5 refer to the two trusses shown below. The cross sectional areas of the members are shown in the figures. The internal forces in the members are denoted by F_{AB}^{I}, F_{BC}^{I} and F_{AB}^{II}, F_{BC}^{II}.
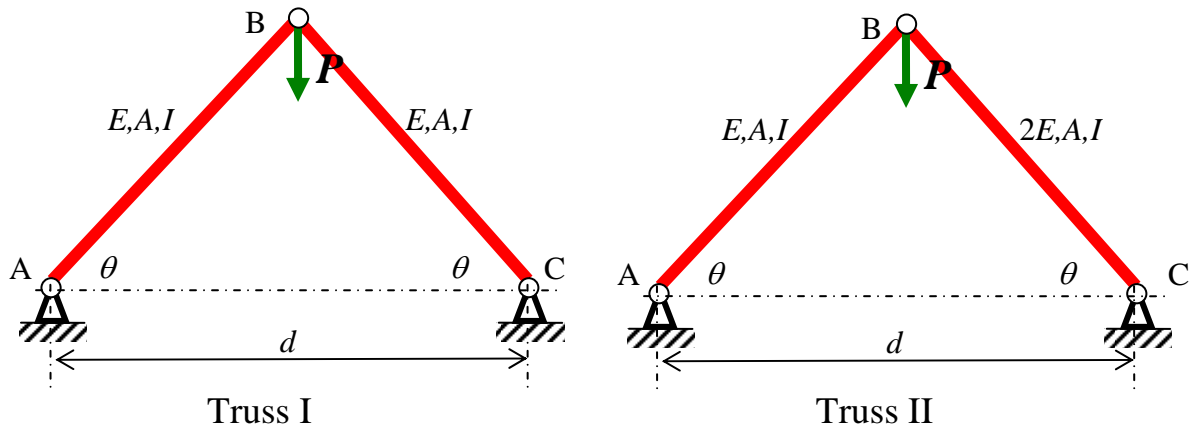
Truss I

Truss II

4. Which of the following is true?

(a) $\left|F_{BC}^{I}\right| < \left|F_{BC}^{II}\right|$

(b) $\left|F_{BC}^{I}\right| > \left|F_{BC}^{II}\right|$

(c) $\left|F_{BC}^{I}\right| = \left|F_{BC}^{II}\right|$

(d) Insufficient information

ANSWER _____(2 points)

5. Let P^{I} and P^{II} be the loads that induce buckling in truss I and truss II, respectively. Which of the following is true?

(a) $P^{I} < P^{II}$

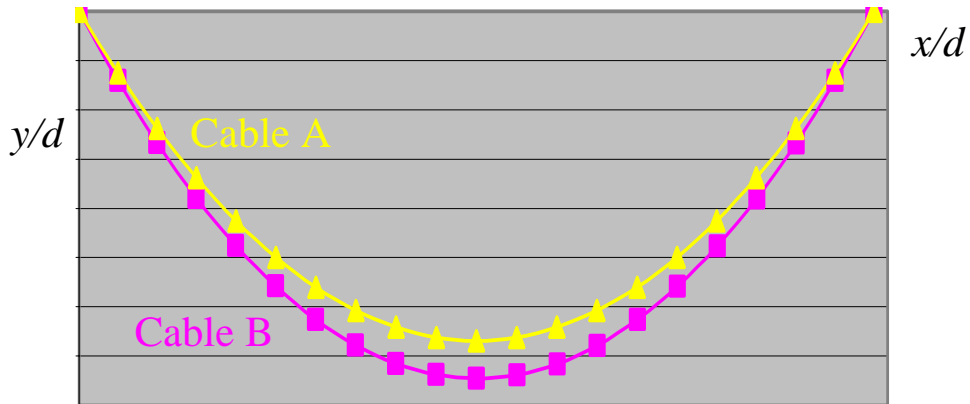(b) $P^{I} > P^{II}$

(c) $P^{I} = P^{II}$

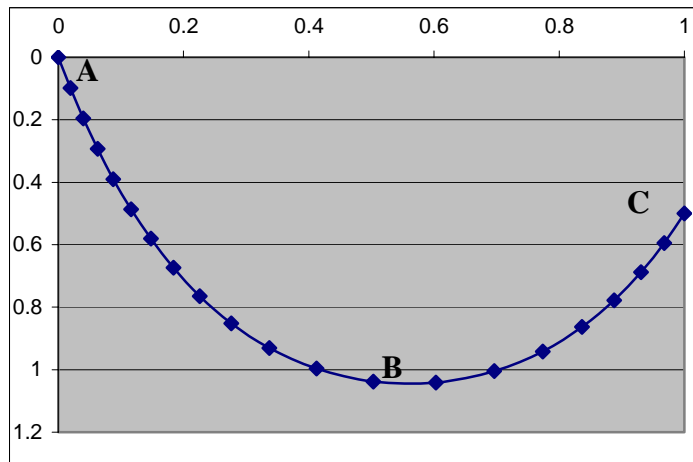(d) Insufficient information.

ANSWER _____(2 points)

6. Two inextensible cables are hung between fixed points $(x,y)=(0,0)$ and $(x_e,y_e)=(d,0)$. The cables have equal weight. Cable A has length L_A, cable B has length L_B, with $L_A<L_B$. The maximum tensions in each cable are given by T_{max}^A and T_{max}^B. Which of the following is true?

(a) $T_{max}^A < T_{max}^B$

(b) $T_{max}^A > T_{max}^B$

(c) $T_{max}^A = T_{max}^B$

(d) Insufficient information
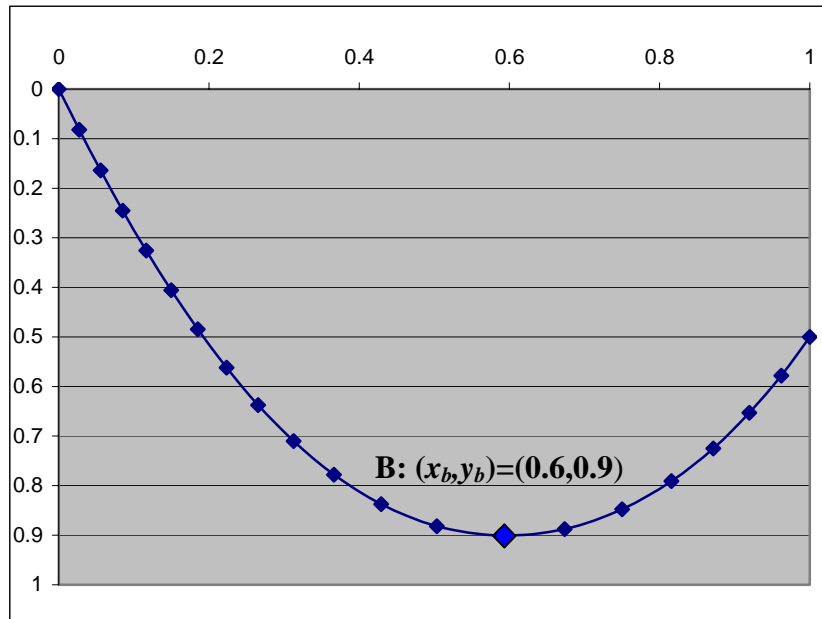
ANSWER _____(2 points)

7. An inextensible cable is hung between fixed points $(x,y)=(0,0)$ and $(x_e,y_e)=(1,0.5)$ as shown. At which point is the cable tension highest?

(a) Point A

(b) Point B

(c) Point C

(d) Insufficient information

ANSWER _____(2 points)

5

8. An inextensible cable is hung between fixed points $(x,y)=(0,0)$ and $(x_e,y_e)=(1m,0.5m)$ as shown. The cable carries a load $w(x)=1$ Newton/meter **distributed evenly across its span**. The cable shape is shown below. The maximum sag occurs at point B and is found to be 0.8 meters, occurring a distance 0.6 meters from the right endpoint.


B: $(x_b, y_b) = (0.6, 0.9)$

The tension in the cable at point B is
- (a) $T_B = 0.185$ Newtons
- (b) $T_B = 0.2$ Newtons
- (c) $T_B = 0.5$ Newtons
- (d) $T_B = 1$ Newton
- (e) None of the above

ANSWER _____(2 points)

9. In this problem, you will analyze the out-of-plane stiffness of the Shimano WH-M540 front wheel, which has 8 pairs of radial spokes. Assume that the wheel rim (radius R) and hub (height $2h$) are effectively rigid compared with the spokes. Each spoke has unstretched length $L_0 = \sqrt{R^2 + h^2}$, area A, and Young's Modulus E.

The geometry is shown below. The origin of the coordinate system is in the midplane of the wheel and the hub length is $2h$. The position vectors of nodes 9 and 10 are therefore $\mathbf{r}_9 = h\mathbf{k}$ and $\mathbf{r}_{10} = -h\mathbf{k}$. Node 1 has position $\mathbf{r}_1 = R\mathbf{j}$, node 3 $\mathbf{r}_3 = R\mathbf{i}$, etc.


Shimano WH-M540
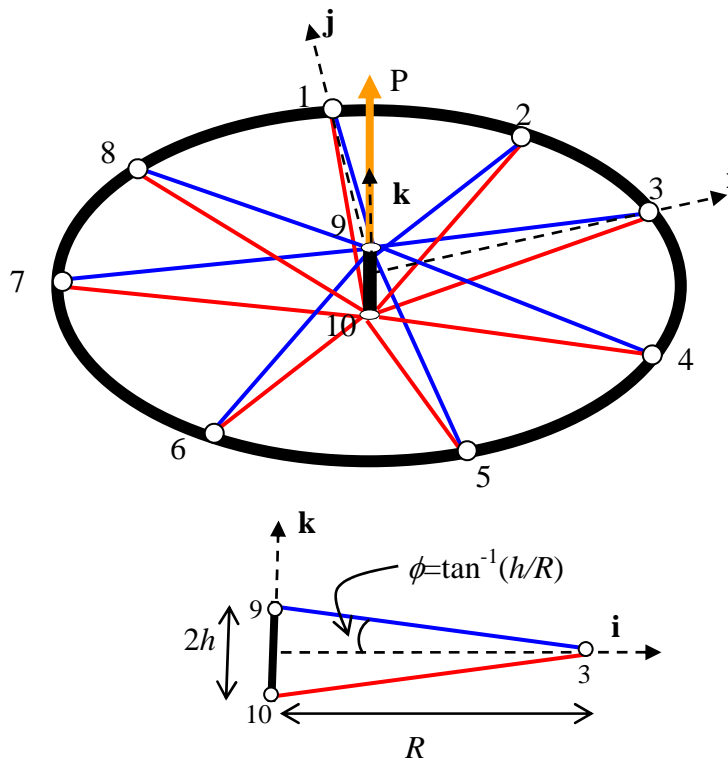
A load P is applied to the hub (node 9) in the $\mathbf{k}$-direction. As a result, nodes 9 and 10 undergo corresponding displacements $(u_1^{(9)}, u_2^{(9)}, u_3^{(9)}) = (u_1^{(10)}, u_2^{(10)}, u_3^{(10)}) = (0, 0, u_z), \quad u_z \ll L_0.$

a. Find the potential energy of the loaded wheel (elastic energy of the spokes + the load) as a function of the hub displacement u_z and any of the parameters P, E, A, R, and h. Assume $u_z \ll L_0$. (2 points)

$\phi = \tan^{-1}(h/R)$

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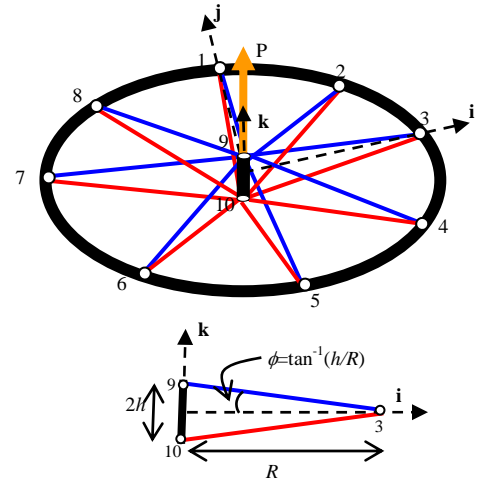
b. Find the hub displacement u_Z as a function of P, E, A, h, and R. (2 points)
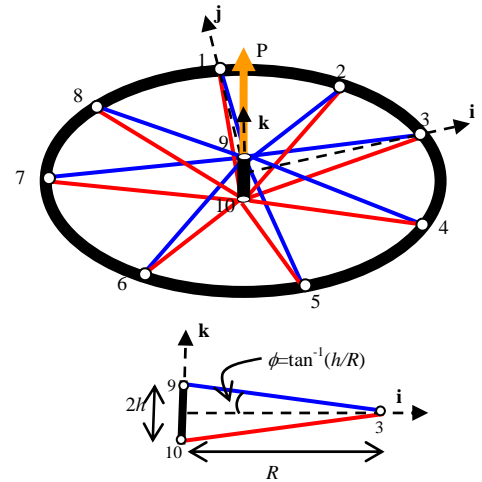
c. Find the force in the spokes as a function of P, E, A, h, and R. (2 points)

d. Suppose you want to take into account the hub elasticity. The hub is made from the same material (Young's modulus E) and has cross sectional area of $A_h=16A$. Does $(u_1^{(9)}, u_2^{(9)}, u_3^{(9)}) = (u_1^{(10)}, u_2^{(10)}, u_3^{(10)}) = (0, 0, u_z)$ still hold? Write the potential energy of the wheel (spokes, hub, and load) as a function of the displacement components of nodes 10 and 11. The answer may also involve the parameters P, E, A, h, and R. (3 points)