

3.032 Problem Set 1

Fall 2007

Due: Start of Lecture, 09.14.07

1. The I35 bridge in Minneapolis collapsed in Summer 2007. The failure apparently occurred at a pin in the gusset plate of the truss supporting the bridge span, at a time when the loads on the bridge span were unequal due to construction crews working on the westbound side. We'll treat a simplified section of this truss (Fig. 1a) to consider whether this unbalanced load could have generated enough force for the truss to fail. We will examine the truss section denoted by the dotted lines, and replace the gusset plate with a pin joint.

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Figure 1a: Bridge truss with gusset plates at pins.

On the day of the bridge failure, construction crews occupied the westbound lanes (right side of Fig. 1b). Let F be the forces acting on the truss members by the regular traffic and $2F$ be the forces acting on the truss by the heavier construction equipment. Taking into account the average mass of a car to be 1362 kg, we can estimate F to be ~ 13.35 kN.

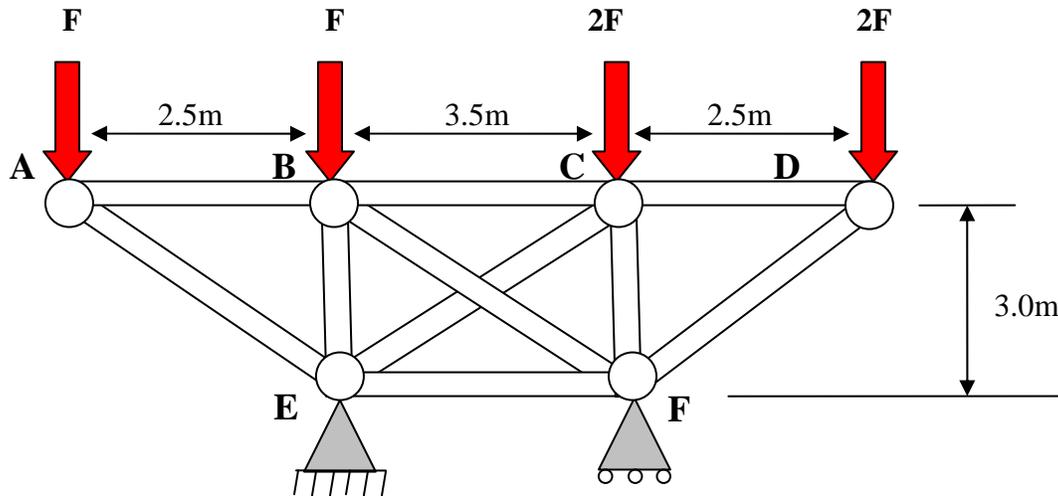


Figure 1b: Schematic of truss section with pin-loaded joints and supports.

- (a) Determine the reaction forces at supports E and F. Show any free-body diagrams used in your calculations.
 - (b) Determine the forces in members AB and AE. Draw all the free-body diagrams you use in your calculations and show whether the forces on the members you calculate are in tension or compression.
 - (c) The diagonal members BF and EC are called counters, thin cables that are designed to be loaded only in tension. It is known that the support pins at E and F will fail if any of the counters is under a tensile force greater than 10 kN. From the loading on the truss described above, determine the forces on each of the members BF and EC and state which, if any, of the pins will fail. Show all the free-body diagrams associated with your calculations.
2. The MIT varsity diving team is practicing their back flips on the Z-center's diving boards (Fig. 2). The diving boards have a total length of 3 m, width of 0.5 m, and thickness of 0.1 m. The core of the boards is made of a Douglas fir wood with an estimated Young's modulus E of 0.6GN/m^2 . Let us approximate the diving board as a clamped-free beam, neglecting the springboard support at the midspan of the diving board and the weight of the diving board.



Image courtesy flickr user Bret Arnett.

Figure 2: Z-center diving boards.

- (a) If the average weight of a student standing on the free-end of the board is about 155 lbs, how much will the board deflect? Note that, in the US, “weight” is commonly stated in units of mass [pounds, or lbs] instead of force, and state your solution in SI MKS units.
 - (b) Draw a free-body diagram of the diving board, again neglecting the spring board near the midspan for simplicity, and determine all reaction forces and moments for the “typical diver” in (a).
3. Bundles of protein filaments inside tissue cells are structural elements that can generate contractile force against the materials to which they adhere. Figure 3 shows struts called “stress fibers” that extend from one end of the cell to the other. These fibers are made of crosslinked, filamentous actin, with an average diameter of $2\ \mu\text{m}$ and an effective “stiffness” E of $16\ \text{kN/m}^2$.

If we assume the connections at either end of the stress fiber can be modeled as pins, how much force P would the cell need to generate to buckle the longest of these stress fibers?

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http://www.biology.arizona.edu/Cell_bio/tutorials/cytoskeleton/graphics/microfilament.gif.

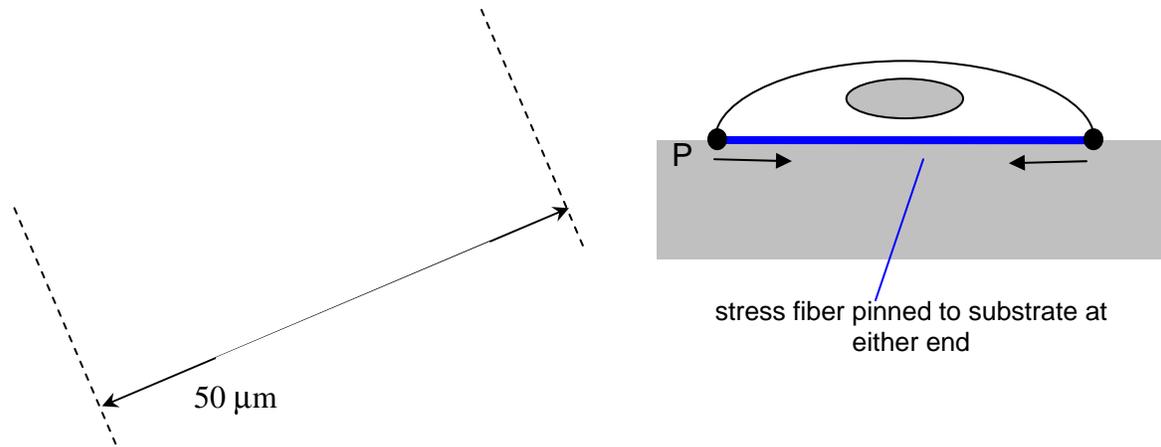


Figure 3: Structural elements of cells under axial end-loads.

4. A U.S. based company was in charge of designing MIT's new physics lab, near the new DMSE headquarters in Bldg 6. They used 30-ft long, wide-flanged structural steel beams for the floor joists to carry the distributed weight of the rooms above. The actual weight distribution is shown in Fig. 4, which is different from what they anticipated, so they want to know where to add an extra support to minimize the shear force and bending moment on this beam. This week, you'll get started on that calculation.

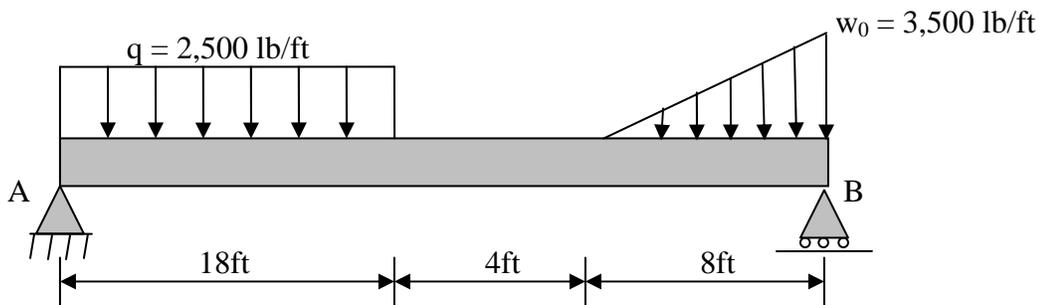


Figure 4: Floor joist beam of new MIT physics building.

- Being a US-based engineer, the first step to analyzing the beam is to convert all units from the US architects to SI MKS units. Perform these conversions.
- Draw a free-body diagram of the beam and calculate the reaction forces at A and B.