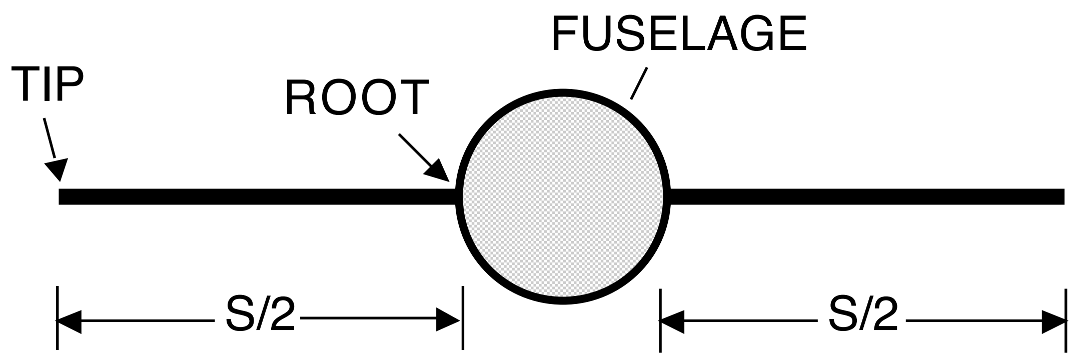
Unified Engineering Problem Set **Lectures: M4, M5, M6*(look-ahead)***
Week 3 Fall, 2007 **Units: M1.2, M1.3*(look-ahead)***

M3.1 ***(15 points)*** In this problem, we consider the new Boeing 787 and learn about the modeling of the lift on a wing in order to consider the loads acting on the structure. The 787 has approximate values for the gross takeoff weight of up to 540,000 pounds and for a wing half-span of 100 feet. The overall weight can be considered to act at the center of the *fuselage*. The half-*span* of the wing is the distance from the *root* (where the wing connects to the *fuselage*) to the *tip*. (See the simple diagram of the geometry below.)



For the purposes of structural analysis, we can model an airplane wing in two dimensions as a linear structural member of length s/2 (the half-*span*) emanating from the *root* as shown above. Consider the fuselage to be a point for this initial structural consideration **(not too comfortable for the passengers!)**. The *lift* (pressure differential between the top and bottom surfaces) on the wing can be represented as a *lineload* and thus has dimensions of [force/length]. We can consider different possible models for the lift distribution that may be connected to aerodynamic analysis: (1) constant along the *span* of the wing; (2) linear variation along the *span* of the wing with its maximum value at the *root* and with a value of zero at the *tip*; (3) linear variation along the *span* of the wing with its maximum value at the *root* and with a value at the *tip* of half that at the root; (4) quadratic variation along the *span* of the wing such that Lift = $b - ax^2$ with its maximum value at the *root* and with a value of zero at the *tip*. For each case, assume that in steady flight, each wing must provide sufficient *lift* to support half the total weight.

We work to see how the model for *lift*, as one might get from fluid/aerodynamic analysis, changes the following results. For each of the four lift models:

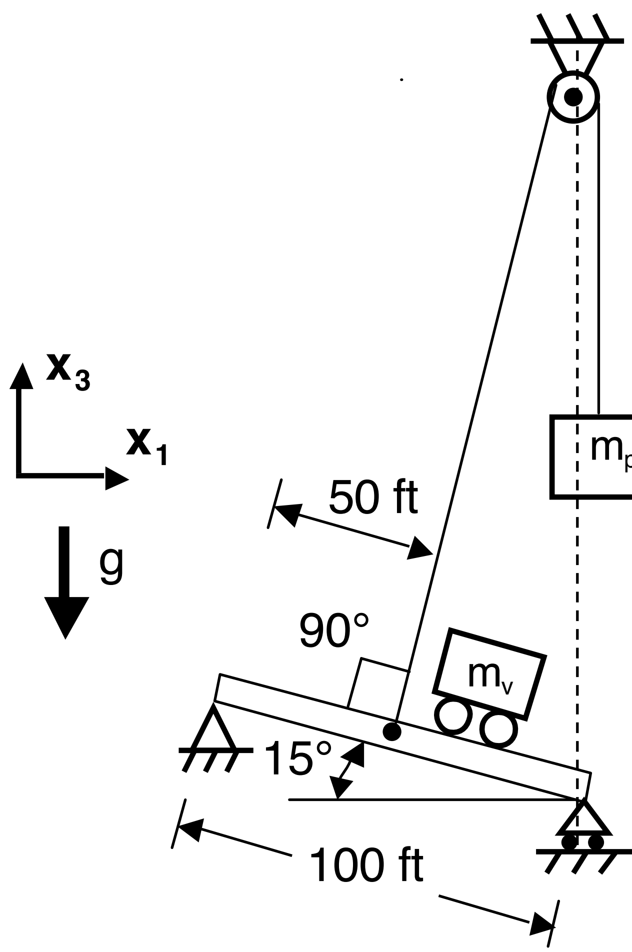
(a) Draw this configuration showing all loads.

(b) Determine the maximum magnitude of the lineload of lift and where it occurs.

(c) For one wing, determine the equipollent force system at the root for the lift.

M3.2 *(15 points)* **SOME LOOK-AHEAD:** ***Use M1.3 notes, CDL 1.7, 1.8***

A 100-foot long "bridging structure" with a 15° incline is modeled as a 100-foot long beam pinned at the upper end and attached via a roller at the lower end. This support configuration is known as *simply-supported*. A vehicle of mass, m_v, can move anywhere along this beam. In addition to the vehicle, the beam has a cable attached to it at the midpoint. This cable is perpendicular to the beam and goes through a pulley, with a radius of r, attached by a pin to an overhead support directly above the roller support. At the other end of the cable is a suspended mass, m_p. The overall situation is illustrated in the accompanying figure.



(a) Draw the free body diagram for this situation (choose any location, a_v, for the vehicle).

(b) If possible, determine the reaction forces as a function of the point on the beam at which the vehicle is located.

(c) With the vehicle at any location, determine if the mass hanging from the cable can be changed in such a way that the reaction(s) at the roller is(are) zero. Clearly explain your reasoning.

(d) The overhead cable is now removed and a pin support replaces it at the beam midpoint. Draw the free body diagram for this case and then determine the reaction forces or, if the reaction forces cannot be exactly determined, clearly explain the reasons for that.