AME 101, Fall 2017
Midterm exam #2 review
11/16/2017

80 minutes allowed. The exam is open book *to the extent of the printed version of the course lecture notes, your own notes, homework assignments and solutions and the optional Wickert textbook only.* Calculators are allowed, but not any other electronic devices. The material covered on the exam will emphasize stresses/materials and fluid mechanics (Chapters 5 and 6) but may include Units and Scrutiny (which are **always important*)*** as well. The material covered in Chapters 5 and 6 includes

Stresses and strains, material properties

- Stress = (Force on a material) / (Area of material that has to withstand this force) – units force/area, like pressure
- Normal stress (σ): stress **perpendicular** to a particular imaginary plane drawn through a point in the material
- Shear stress (τ): stress **parallel** to a particular imaginary plane drawn through a point in the material
- Strain (ε): fractional amount of elongation or contraction in a material caused by a stress $\equiv \Delta L/L$, where L = length of material without stress, ΔL = change in length due to stress
- Elastic material: a material with a linear relationship between stress and strain, *i.e.*, $\sigma = \varepsilon E$ where E is called the elastic modulus
- Elastic modulus relates mostly to the attractive force between the atoms/molecules in the material; the units of E are also force/area
- Yield, ultimate, fracture stresses depend only partially on this attractive force; these stresses also depend strongly on the grain size and structure
- Poisson's ratio (ν), i.e. $\nu \equiv -(\Delta d/d)/(\Delta L/L)$, Δd = change in diameter due to stress
- Relationships between normal and shear stresses (stress is actually a 3 x 3 matrix) – principal (maximum and minimum) stresses, maximum shear stress
- Pressure vessels – hoop and longitudinal stress, end caps
- Bending of beams – moments, stresses
- Buckling of columns

Fluid mechanics

- Hydrostatic pressure $P(z) = P(0) - \rho gz$ (if z is defined positive upward)
- Buoyant force $F = (\rho_f - \rho_o)gV$
- Bernoulli's equation – relates pressure (P), velocity (v) and elevation (z) (defined positive upward in this case) for an <u>incompressible</u> (ρ = constant) fluid (generally, in a pipe or duct) for <u>steady flow</u> when <u>viscosity is unimportant</u>.
- Viscosity effects
    - Definition of dynamic (μ) and kinematic (ν) viscosity
    - Reynolds number $Re = vL/\nu$ - measure of the importance of viscosity
- Lift and drag coefficients
- Navier-Stokes equations – $\mathbf{F} = d(m\mathbf{v})/dt$ applied to a fluid
- Laminar and turbulent flow – flows are always turbulent when Re is high enough, but the transition Re depends on the type of flow

- Drag coefficient for spheres and cylinders with laminar and turbulent flow
- Friction factor (f) and pressure drop in pipes with laminar and turbulent flow
  - Moody diagram – incompressible fluid, constant diameter pipe, steady flow
- Compressible flow – when the fluid density (ρ) cannot be considered constant, which happens in a gas when the Mach number (M) is not << 1
  - $M = v/c$, where c = sound speed = $(\gamma RT)^{1/2}$
  - Isentropic flow equations – special case with steady flow, reversible (no viscosity, no shock waves) and adiabatic (no heat transfer)

Last year's 2nd midterm (problems should look familiar…) (average was 72.3/100)

Problem #1 (stresses and materials) (30 points total)

A hollow cylinder 10 feet long has an outside diameter of 2 inches and a 1 mm thick wall. The yield stress of the wall material is 5×10^3 lbf/in^2 in tension, 1.5×10^3 lbf/in^2 in compression, and 1×10^3 lbf/in^2 in shear.

(a) (15 points) At what pressure difference would this cylinder fail (due to the stress exceeding the yield stress of the material) if the high pressure were inside the cylinder? Would it fail in tension, compression or shear?
(b) (15 points) At what pressure difference would this cylinder yield if the high pressure were outside the cylinder? Would it fail in tension, compression or shear?

Problem #2 (stresses and materials; fluid mechanics) (50 points total)

(a) (10 points) If the hollow cylinder of Problem 1 is placed in a 50 mi/hr crosswind (wind direction perpendicular to the axis of the cylinder), calculate the Reynolds number for the flow of air over the outside of the cylinder (Use Table 4 for the properties of air).
(b) (15 points) Calculate the drag force (in lbf) on the cylinder.
(c) (5 points) This drag force divided by the cylinder length is the loading (w) on the cylinder. Treating the cylinder as a uniformly-loaded beam, what is maximum bending moment (M) (units of ft lbf) in the beam?
(d) (10 points) What is the maximum normal stress (in units of lbf/in^2) in the cylinder wall material with this beam loading?
(e) (10 points) If the maximum deflection at the center of this beam is 0.1 inch, what is the elastic modulus (E) of the cylinder wall material?

Problem #3 (fluid mechanics) (20 points total)

(a) (5 points) If the hollow cylinder of Problem 1 were a pipe with air flowing through it at a speed of 50 mi/hr, what is the Reynolds number of this flow?
(b) (15 points) What would the pressure drop (ΔP) be for this flow through the pipe in units of lbf/in^2, assuming the pipe wall is very smooth?