

**AME 101, Fall 2016**  
**Midterm exam #2 review**  
**11/17/2016**

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 ( $\sigma$ ): stress **perpendicular** to a particular imaginary plane drawn through a point in the material
- Shear stress ( $\tau$ ): stress **parallel** to a particular imaginary plane drawn through a point in the material
- Strain ( $\epsilon$ ): fractional amount of elongation or contraction in a material caused by a stress  $\equiv \Delta L/L$ , where  $L$  = length of material without stress,  $\Delta L$  = change in length due to stress
- Elastic material: a material with a linear relationship between stress and strain, *i.e.*,  $\sigma = \epsilon E$  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 ( $\nu$ ), *i.e.*  $\nu \equiv -(\Delta d/d)/(\Delta L/L)$ ,  $\Delta d$  = 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  $P(z) = P(0) - \rho g z$  (if  $z$  is defined positive upward)
- Buoyant force  $F = (\rho_f - \rho_o) g V$
- Bernoulli's equation – relates pressure ( $P$ ), velocity ( $v$ ) and elevation ( $z$ ) (defined positive upward in this case) for an incompressible ( $\rho = \text{constant}$ ) fluid (generally, in a pipe or duct) for steady flow when viscosity is unimportant.
- Viscosity effects
  - Definition of dynamic ( $\mu$ ) and kinematic ( $\nu$ ) 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 ( $\rho$ ) cannot be considered constant, which happens in a gas when the Mach number (M) is not  $\ll 1$ 
  - $M = v/c$ , where  $c = \text{sound speed} = (\gamma RT)^{1/2}$
  - Isentropic flow equations – special case with steady flow, no friction, no shock waves

**Last year's 2<sup>nd</sup> midterm (problems should look familiar...) (average was 75.5/100)**

**Problem #1 (units) (25 points total)**

The Weber number ( $We$ ) is a measure of the relative importance of kinetic energy to surface energy in a flow with an interface (e.g., between liquid water and air in a water droplet.) Its definition is  $We \equiv \rho v^2 d / \Sigma$ , where  $\rho$  = density of liquid,  $v$  = flow velocity,  $d$  = droplet diameter and  $\Sigma$  is the surface tension (units force/length).

- (6 points) Calculate the value of  $We$  for a falling water droplet in a cloud with  $d = 0.01$  inch,  $v = 10$  miles/hr and  $\Sigma = 0.070$  Newtons/m.
- (6 points) Calculate the Reynolds number based on diameter  $d$  of this falling droplet. (Use the viscosity of air, not water, in the calculation for  $Re$ .)
- (13 points) It is desired to simulate the flow around this falling droplet in air with mercury ( $\Sigma = 0.486$  Newtons/m,  $\rho$  from the table of fluid properties in Chapter 6) as the liquid in a laboratory experiment. What droplet  $d$  (in inches) and fluid speed ( $v$ ) (in feet per second) would be required to have the same Weber and Reynolds numbers as determined in parts (a) and (b)? (In both cases the liquid droplet is falling in air).

**Problem #2 (stresses and materials) (40 points total)**

A 6061-T6 aluminum pipe (see Table 2 of the lecture notes for properties) has a diameter of 5 cm, a wall thickness of 1/8 inch and a length of 10 feet. Assume that the aluminum has the same yield strength in tension, compression and shear.

- (10 points) What is the maximum pressure this pipe could hold without yielding?
- (10 points) If instead this pipe is used as a beam, what is the maximum distributed load ( $w$ , units lbf/ft) that could be applied without yielding?
- (10 points) If **both** of the loads from parts (a) and (b) were applied simultaneously, what would the maximum shear stress in the pipe be? (Assume that somehow the pipe didn't yield).
- (10 points) If instead of applying the loads in parts (a) and (b), the pipe were oriented vertically and used as a column, what is the maximum load (in lbf) that the pipe could support without buckling? Assume both ends of the column are tightly clamped.

**Problem #3 (fluid mechanics) (35 points, 5 points each part)**

Ronney Chemicals, Inc. has invented a new fluid, called PDR™, that has **all** the same properties as water except that **its dynamic viscosity ( $\mu$ ) is twice that of water**. In particular, the density ( $\rho$ ) of PDR™ is the same as water. If PDR™ were used instead of water, state whether each of the following would increase, decrease or remain the same, and if there is a change, would the change be a factor of more than, less than, or exactly a factor of 2. **No credit without explanation!**

- (a) Hydrostatic pressure at the bottom of a 100 m deep lake.
- (b) The net buoyant force acting on an object with density ( $\rho_o$ ) of  $500 \text{ kg/m}^3$ .
- (c) Velocity at the exit of a nozzle decreasing from 4 inches to 2 inches diameter with a pressure decrease of  $60 \text{ lbf/in}^2$ , assuming Bernoulli's equation applies.
- (d) Reynolds number of the flow around a sphere (same sphere diameter ( $d$ ) and velocity ( $v$ ) for both fluids)
- (e) Drag force on a sphere at very low Re (same sphere diameter ( $d$ ) and velocity ( $v$ ) for both fluids)
- (f) Pressure drop ( $\Delta P$ ) in a pipe at very low Re (same diameter ( $d$ ), length ( $L$ ), roughness ( $\epsilon$ ) and velocity ( $v$ ) for both fluids)
- (g) Pressure drop ( $\Delta P$ ) in a pipe at very high Re (same  $d$ ,  $L$ ,  $\epsilon$  and  $v$  for both fluids)