ENGINEERING SCIENCES 120

INTRODUCTION TO THE MECHANICS OF SOLIDS

Quiz 1

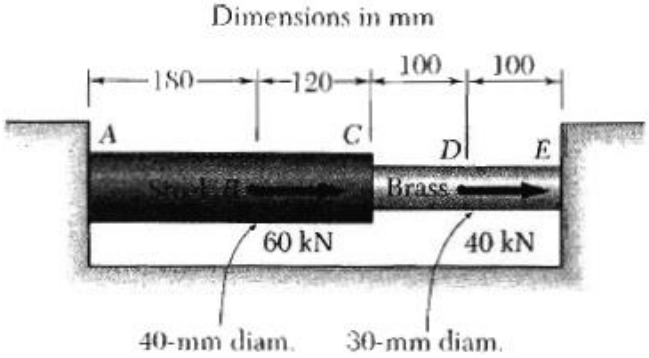
March 8, 2013

Length: 53 minutes

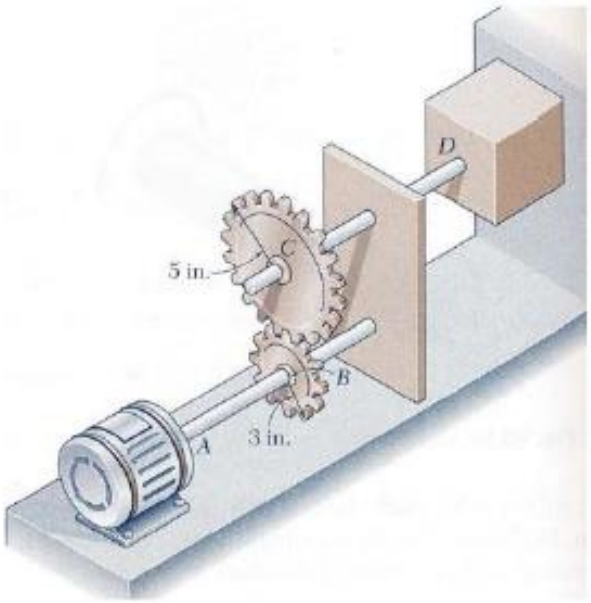
You are allowed to use a calculator when solving the problems, as well as the equation sheet posted on the web site. Please make sure your answers are clear and legible. No credit will be given if we cannot read an answer or figure out how you derived it! All questions are weighted equally. You only have to solve the first three problems, but you will get extra credit if you attempt the bonus problem.

1. We would like to estimate how much the Empire State building sags under its own weight. To get some idea, we are going to model the building as a tall rectangular column of constant cross section made out of concrete. Assume Young's modulus E of concrete is 30 GPa and the density ρ of concrete is 2400 kg/m^3. The roof height L of the Empire State Building is 381 m, ignoring the antenna spire, as that is negligible compared to the rest of the building. (a) Determine the normal stress in the concrete caused by the weight of the building as a function of height, (b) determine the deflection of the top of the building as a result of its own weight, (c) what shape building would you need to ensure that the stress in the concrete is constant? Such a building could in theory be of unlimited height. A qualitative argument here is fine, but it is also possible to derive a formula for the cross-sectional area of the building as a function of height.

2. Two cylindrical rods, one of steel and the other of brass, are joined at C and restrained by rigid supports at A and E. For the loading shown and knowing that E_S = 210 GPa and E_B = 120 GPa, determine (a) the reactions at A and E and (b) the deflection of point C. If the temperature is then raised by 100°C and knowing that α_S = 13 x 10^{-6} K^{-1} and α_B = 19 x 10^{-6} K^{-1}, determine (c) the deflection of point C assuming there is no plastic flow.



3. The two solid shafts and gears shown are used to transmit 15 kW from the motor at *A* operating at a speed of 1260 rpm to a machine tool at *D*. Knowing that the maximum allowable shear stress is 50 MPa, determine the required diameter of (a) shaft *AB* and (b) shaft *CD*.



Bonus question (extra credit!)

A cooling tube having the cross section shown is formed from a sheet of stainless steel of 3 mm thickness. The radii $c_1 = 150mm$ and $c_2 = 100mm$ are measured to the centerline of the sheet metal. Knowing that a torque of magnitude T = 3kNm is applied to the tube, determine (a) the maximum shearing stress in the tube, (b) the magnitude of the torque carried by the outer circular shell. Neglect the dimensions of the small opening where the outer and inner shells are connected.