ME 304 – Finite Element Analysis, Fall 2019
Assignment: Linear Springs

Estimated time to completion: 3-4 hours.

Suggestion: do not use a calculator on homework unless essential. No calculators will be allowed on quizzes or examinations in this course, so practice without a calculator. If it is difficult now, it won't be easy on exams; practice ***will*** make it easier. The following complexity of arithmetic should be second nature to engineers:

20/5 = 100/3000 = 20*5 = 24/60 = 2*60 /4 = etc.

Regarding format: as always, you must follow the standard homework format. However, for pure mathematical work (such as most work in this assignment), there will be no assumptions. Refer to the ME Student Reference page (link on the course web page). If you have questions, ask.

1. Educational Purpose: *Learn to open Workbench at the University of Portland and to become familiar with basic structural analysis.*
   - Open ANSYSIS Workbench 19 (via UP's virtual desktop.up.edu, Engineering Kiosk, Mechanical Engineering).
   - Read and work through sections 1.1.1 through 1.1.3 (H-H Lee…the *Finite Element Simulations* book).

Things to note: Section 1.1.3 asks you to prepare engineering data. There are four elastic constants available, although all four are defined by entering values for only two of them: Young's modulus and Poisson's ratio. For ***linear elastic isotropic materials***, bulk modulus (K) and shear modulus (G) can be derived from Young's modulus (E) and Poisson's ratio (ν) – see the table below. If you are having trouble accessing/finding ANSYS, don't get frustrated; ask. Ask your colleagues, ask your instructor…ask. Computers can be very frustrating if you don't know where to find things…

2. In words, describe/define bulk modulus (K) and shear modulus (G) (google may be helpful).

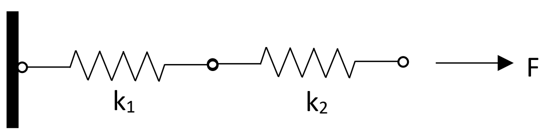
Relations among Elastic Constants for Isotropic Materials

Table 2.2 | Relations among the Elastic Constants for Isotropic Materials

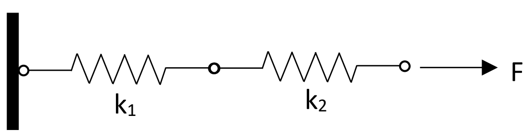
Elastic Constants	In Terms of: E, ν	E, G	K, ν	K, G	λ, μ
E	$=E$	$=E$	$=3(1-2\nu)K$	$=\dfrac{9K}{1+3K/G}$	$=\dfrac{\mu(3+2\mu/\lambda)}{1+\mu/\lambda}$
ν	$=\nu$	$=-1+\dfrac{E}{2G}$	$=\nu$	$=\dfrac{1-2G/3K}{2+2G/3K}$	$=\dfrac{1}{2(1+\mu/\lambda)}$
G	$=\dfrac{E}{2(1+\nu)}$	$=G$	$=\dfrac{3(1-2\nu)K}{2(1+\nu)}$	$=G$	$=\mu$
K	$=\dfrac{E}{3(1-2\nu)}$	$=\dfrac{E}{9-3E/G}$	$=K$	$=K$	$=\lambda+\dfrac{2\mu}{3}$
λ	$=\dfrac{E\nu}{(1+\nu)(1-2\nu)}$	$=\dfrac{E(1-2G/E)}{3-E/G}$	$=\dfrac{3K\nu}{1+\nu}$	$=K-\dfrac{2G}{3}$	$=\lambda$
μ	$=\dfrac{E}{2(1+\nu)}$	$=G$	$=\dfrac{3(1-2\nu)K}{2(1+\nu)}$	$=G$	$=\mu$

For the following problems, F is the force within the spring, δ is the change of length of the spring, and k is the spring constant; $F=k\delta$. The springs are attached to an immovable support at the left.

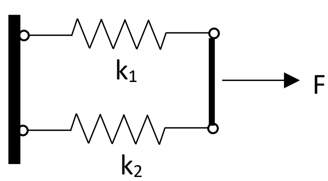
3. Given two springs in series as shown below, determine the change in length of each individual spring (δ_1, δ_2) and the total change in length (δ_{tot}). F=100kN, k_1=10kN/mm, k_2=20kN/mm



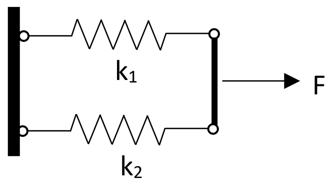
4. Given two springs in series as shown below, determine the force in the springs. δ_{tot} = 5mm, k_1=30kN/mm, k_2=20kN/mm



5. Given two springs in parallel as shown below. They are attached in such a way as the length of spring 1 always equals the length of spring 2 ($\delta_1 = \delta_2 = \delta_{tot}$). Determine the change in length of the springs. F=100kN, k_1=10kN/mm, k_2=20kN/mm



6. Given two springs in parallel as shown below. They are attached in such a way as the length of spring 1 always equals the length of spring 2. Determine the force, F.
   $\delta_1 = \delta_2 = \delta_{tot}$ = 5mm, k_1=30kN/mm, k_2=20kN/mm



7. Determine the spring constant, k, of a 10 inch long, 1 inch diameter steel prismatic bar, axial load.
8. When engineers solve a complicated problem, it is good practice to first solve a simpler but similar problem to provide a way of checking "reasonableness" of the complex solution. For the next problem (problem 9), let's approximate the tapered plate as a plate with same thickness but a constant width of 125mm. In other words, determine the change in length of a 1000mm long aluminum plate ($E \approx$ 70GPa = 70kN/mm^2), 5 mm thick by 125mm wide with a 1kN axial load.
9. One technique engineers use to "double check" answers is to solve the same problem two different ways. Determine the change in length of a 1000mm long tapered flat aluminum plate that is 5mm thick and has a 1kN axial load applied. The left side of the plate is 150mm wide, and the right side is 100mm wide. Solve this problem using:
   a. Calculus (integrate). Is the answer similar to the previous question (problem 8)?
   b. Numerically, using Excel. (include printout of the spreadsheet, and written work showing the content and results of the spreadsheet). See link on the course web page: "Excel homework requirements."
   c. Compare the two answers – discuss the differences.
   d. What is the spring stiffness of the plate?