CIV102F Assignment #2: September 14th, 2025

Due: September 21, 2025 at 11:59 pm (all sections)

General Instructions

[Update] The requirements of Assignment #2 and onward have changed based upon a request from the Division of Engineering Science. Short solutions to assignments will be posted after the due date. Assignment #1 is not subject to these changes. Assignments will now be released on Sundays at 11:59 pm.

- There are **six (6) questions** in this assignment. **Only one (1) question will be graded.**
- **For this assignment, the question to be graded is question #3.**

- Students are **not** required to complete and submit the entire question set. You are, however, strongly encouraged to proactively complete the set every 1-1.5 weeks to obtain consistent practice and develop a routine. **This forms great preparation for your final exam and weekly quizzes!**

- Submissions which do not contain a serious attempt to solve the question to be graded will receive a grade of 0.

- Intermediate steps must be provided to explain how you arrived at your final answer. Receiving full marks requires **both** the correct process and answer.

- All final answers must be reported using **slide-rule precision** (i.e., four significant figures if the first digit is a “1”, three otherwise), and **engineering (or scientific) notation** for very large or very small quantities.

- Submissions must be prepared **neatly** and be formatted using the requirements discussed in the updated course syllabus. Marks will be deducted for poor presentation of work.

Assignment-Specific Instructions

- When material properties are not provided in the question, you can use the table of material properties in Appendix A of the course notes if needed. If you have any questions, you can come to TA office hours or send quick emails to ask us!

Slide-Rule Precision Reminders

The following information is taken from the CIV102 Fall 2025 Quercus site (subject to updates): click here.

Example Scenario	Final Answer	Justification
Area of an Euclidean circle with a radius of 1 m?	3.14 m^2.	The number π has a decimal representation of 3.14159265... that is infinitely long. **Since it starts with a "3" and not a "1", we express it using three significant digits: 3.14.**
Hypotenuse length of a right-angled Euclidean triangle, with legs of 1 m each?	1.414 m.	The exact length comes from the Pythagorean theorem: $\sqrt{1^2+1^2}=\sqrt{2}$. The square root of 2 is irrational and has a decimal representation of 1.41421356... that is also infinitely long. **Since it starts with a "1", we express it using four significant digits: 1.414.**
Speed of light in a vacuum, expressed in m/s?	3.00 x 10^8 m/s (scientific notation; exponent is 8). 300. x 10^6 m/s (engineering notation; exponent is a multiple of 3).	A commonly quoted value is 299,792,458 m/s. This is a large number! To express it with 3 significant digits, let's use scientific notation. You can also use engineering notation, if you want! Ensure the **coefficient of the 10^n has 3 significant digits. The exponent, n, is an integer.**
Hydrogen atom radius (approximate), expressed in m?	5.30 x 10^{-11} m (scientific notation; exponent is -11). 53.0 x 10^{-12} m (engineering notation; exponent is a multiple of 3).	From various online sources, the approximate size is 53 picometres (53 trillionths of a metre), which is also called the "Bohr Radius". This is a very small number! Ensure the **coefficient in front of the 10^n has 3 significant digits. The exponent, n, is an integer.**
Density of water, expressed in kg/m^3?	1000. kg/m^3 (common). 1.000 x 10^3 kg/m^3 (also acceptable, but takes longer to write).	In some cases, "1000" is interpreted as having 1 significant digit, or 4 significant digits. To be certain, you can place a decimal after the last zero, like "1000." to indicate that you intend for all the digits to be considered significant. **On quizzes and/or assignments, the safest option is to use the "1000." format.**
What if the final answer is an exact, whole number?	10 people, 314 apples, 3 oranges, 420 bricks, 117634 strands of string, etc.	**Whole numbers can be reported as-is, following the context of the question.** There is no need to format answers as "10.00 people", "314. apples", "3.00 oranges", "420. bricks", "1.176 x 10^5 strands", etc.
Mathematical expressions?	Examples include $F/6$, $3x+2$, $\sqrt{2GM/r}$, etc. Using slide rule precision, we would have $0.1667F$, $3.00x+2.00$, and $1.414\sqrt{GM/r}$.	**If not explicitly stated, then slide-rule precision should be used for all coefficients.** Depending upon the context of the question, it will be **explicitly stated** whether the answer should be reported using slide-rule precision or can be kept in an exact mathematical form.
Complex-valued answers?	One example is the principal square root of the imaginary unit: $\sqrt{i}=0.707+0.707i$.	Complex numbers, $z=a+bi$, consist of a real part, a, and an imaginary part, b. The imaginary unit is defined as the principal square root of negative one: $i=\sqrt{-1}$ and $i^2=-1$. **Both the real part and the imaginary part** should be expressed using slide-rule precision.

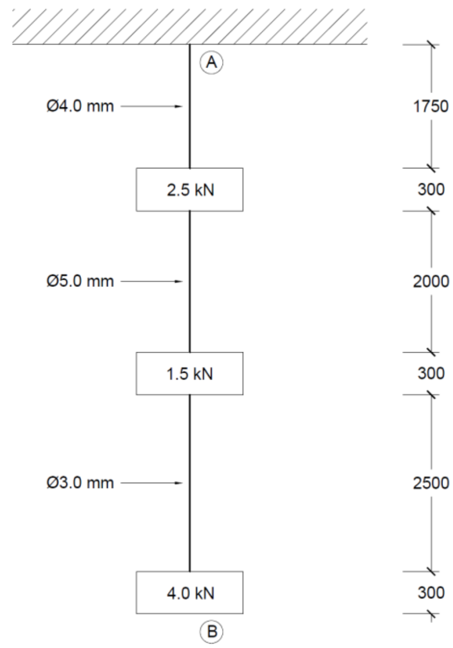
1. The *undeformed* lengths of the system of cables and blocks are shown on the right. The top, middle, and bottom cables are made from Carbon Fibre, Aluminum Alloy, and High Alloy Steel, respectively. Assume that the blocks are rigid and that the cables are weightless.

Note: All measurements provided are in mm, and ⌀ denotes a diameter measurement (i.e. ⌀4.0 mm = 4.0 mm diameter).

a. What is the total length of AB, including the deformation due to all of the loads?

b. Calculate the total energy stored in the three cables.

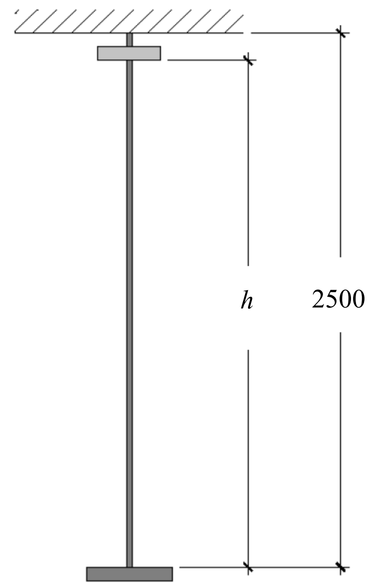
c. Among these three cables, which is…
   i. The cheapest,
   ii. The lightest,
   iii. The strongest, and
   iv. The toughest?



2. The longest suspension bridge span in the world up until March 2022 was the main span of the Akashi Kaikyo bridge in Japan, completed in 1998. This record was since taken by the 1915 Çanakkale Bridge, which spans the Dardanelles located in northwestern Turkey. In this assignment, we will focus on the Akashi Kaikyo bridge (see image below) and save the Çanakkale Bridge for another time.

For the Akashi Kaikyo bridge, its central span is 1,991 metres long (one half-hour walk from one end to the other), and the deck is 36 m wide. The drape of the main cables between the towers and the centre of the bridge is 201.2 metres. The two main cables which support the deck are to be made of a collection of small wires 5.23 mm in diameter, each with a rupture stress of 1,770 MPa. Suppose we are asked to perform a preliminary design of the main cables of this bridge. If the total load which the deck must carry is 27.5 kPa (kN/m^2), calculate the number of wires needed in each cable if the *required factor of safety against rupture* is 2.20.

3. A 2,500-mm long steel wire made of low alloy steel is attached to a sturdy ceiling and has a rigid catch-plate securely attached to the bottom (see the image on the right). The diameter of this wire is 6 mm throughout its height. A 4-kg rigid mass is dropped onto the catch plate from a height *h*. Strain-hardening effects may be neglected. You may also neglect the self-weight of the wire, the self-weight of the catch plate, air resistance effects, and the thicknesses of both the dropped mass and the catch plate. This wire also has a rupture strain of 0.25 mm/mm.



a. What is the impact velocity of the dropped mass just before it hits the catch plate, expressed as an algebraic expression? (No need to use slide-rule precision here… exact expressions for part a) are perfectly fine!)

b. What is the maximum value of *h* which does not cause any permanent deformations in the wire?

c. If $h = 2.2$ m, what is the maximum force experienced by the wire at any point during the drop?

d. If $h = 2.2$ m, calculate the maximum extension of the wire caused by the weight landing on the catch-plate.

e. If the mass is repeatedly dropped from a height of $h = 2.2$ m, then the wire will eventually rupture. How many drops can the wire sustain before rupturing?

4. Suppose that the steel wire shown near the bottom of this page has a stress-strain curve described by the following piecewise function definition:

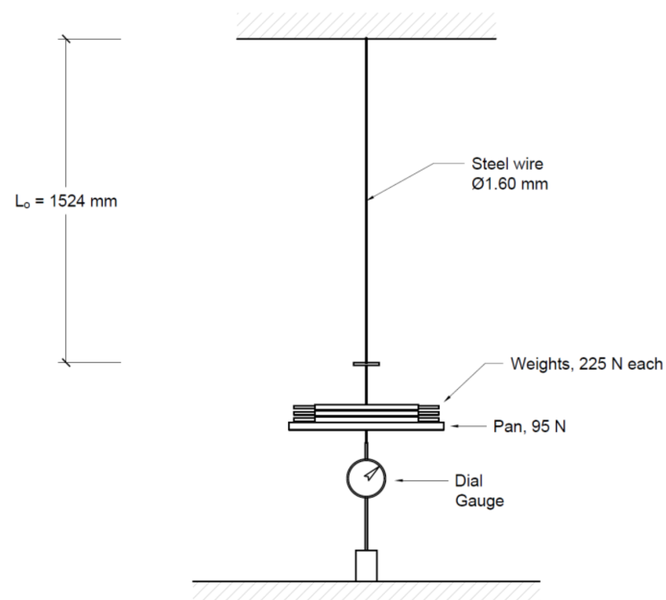
$$\sigma_s = \begin{cases} E_s \varepsilon_s & 0.000 \le \varepsilon_s \le 0.002 \\ \sigma_{yield} & 0.002 \le \varepsilon_s \le 0.040 \\ 4000(\varepsilon_s - 0.040) + \sigma_{yield} & 0.040 \le \varepsilon_s \le 0.065 \\ \sigma_{ult} & 0.065 \le \varepsilon_s \le 0.100 \\ -1500(\varepsilon_s - 0.100) + \sigma_{ult} & 0.100 \le \varepsilon_s \le 0.200 \end{cases}$$

In the above equations, suppose E_s = 200,000 MPa, σ_{yield} = 400 MPa and σ_{ult} = 500 MPa. For the following sub-questions, assume that a wire with the geometry described in the figure below is being tested to determine its stress-strain behaviour.

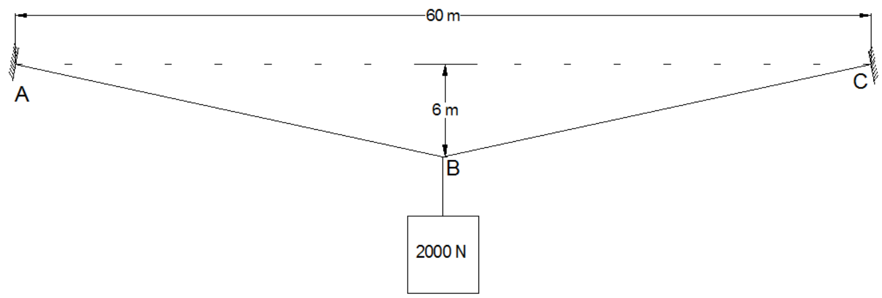
a) Plot the relationship between the wire tension P and the elongation Δ if the wire was tested by gradually stretching the wire in small increments of Δ and measuring the tension in the wire. The graph does not need to be to scale along the Δ axis but should highlight all **key** points. This testing methodology is called *displacement control*.

b) On the same graph, plot the relationship between the wire tension P and the elongation Δ if the wire was tested by placing 225 N weights onto the 95 N loading pan and then measuring the change in length (i.e. in the same manner as the demonstration in tutorial 2). This testing methodology is called *force control*.

c) Explain the differences in results. Which experimental method would be preferred if one was trying to measure the "full" stress-strain curve of the material?



5. (Optional.) When performing structural analysis, we typically calculate the stresses in the structure assuming the initial geometry of the structure does not change due to the applied loads. This is usually a reasonable assumption because these deformations are typically small. However, sometimes these deflections are large and need to be considered as they modify how the load is carried – these are called ***second-order effects***. We will perform a basic second-order effect analysis on this mass-wire system:



Steel wire ABC has a diameter of 3 mm and an ultimate tensile strength of 1,500 MPa. The geometry shown above is the initial geometry of the wire system. Points A and C are fixed in place and do not move. Point B is located in the middle between point A and point C. Please answer the following questions.

a) Calculate the forces and stresses in wires AB and BC.
   i. How much longer does each wire become due to the applied load?
   ii. How far does the 2,000 N load move downwards?
   iii. What is the factor of safety of this structure?

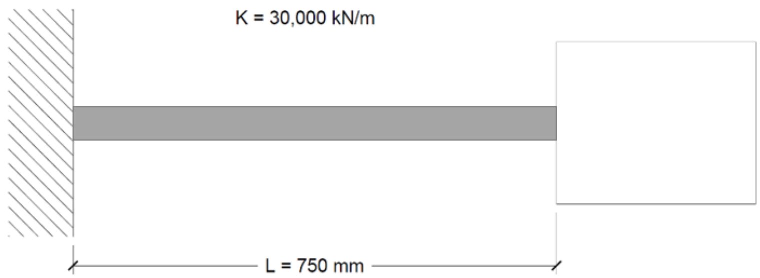
b) Because the wires have gotten longer, the geometry of the system has changed, which has caused the tension in the wires to change as well.
   i. Re-calculate the forces and stresses in wires AB and BC using the deformed lengths of AB and BC you calculated in part a) to define the system's geometry.
   ii. Has the factor of safety increased or decreased?

c) Using the stresses calculated in part b), calculate the length of wires AB and BC caused by carrying the 2,000 N load.
   i. Are these values consistent with the lengths used to compute the stresses?
   ii. Based on your answer, estimate how much the 2,000 N load has moved downwards.

d) Comment on the differences between an analysis using the initial geometry only and an analysis which includes second-order effects. Can you think of an example where neglecting second-order effects may be **dangerous?**

6. In class, we learned about Hooke's law and the engineering definitions of stress and strain. Using this information, we can derive the spring constant, "K", for a system by adjusting the choice of material and geometry.

a. For the rectangular prism member shown below (in dark gray), calculate the cross-sectional area **and** volume of material required to obtain the specified value of K for each of the three materials suggested below.
   i. Low alloy steel.
   ii. Aluminum alloy.
   iii. Carbon fibre.



b. Identify the material among the options presented in part a) which should be used to manufacture…
   i. The cheapest equivalent spring,
   ii. The lightest equivalent spring,
   iii. The strongest equivalent spring,
   iv. and the toughest equivalent spring.

c. If we use a hydraulic load cell to apply a force of 3,000 kN to each spring that was constructed in part a), which spring would deform the least?