# ASEN 3112 STRUCTURES: LAB 1 DESCRIPTION - Fall 2016

**(Version Subject to Minor Changes)**

## Bring this Document to Lab Demos and to Group Experiments

### I. SUMMARY

The first experimental lab involves testing two circular *thin wall* sections, one closed and one open, under applied torque, using the Instron Torsion Module purchased in 2009 by ITLL. The purpose of the tests is to verify and correlate the analytical theory with strain and twist-angle measurements.

The experimental procedure will be explained during one-hour demos to be given at ITLL on Friday September 16 at 1 pm and 3pm, and on Monday September 29 at 3pm. **Attendance to demos is mandatory** since learning to handle delicate equipment is important part of the lab. The Instron machine is permanently located on a table at ITLL Plaza level 2B by 2B 07 (West side), in the vicinity of Labstation 20A. Group experiments will be carried out there. However, all three demos will be conducted at the recitation room, ITLL 1B50.

Groups listed in Addendum IV should organize after the demos as described in **Getting Started** below. Groups repeat the experiment during September 20–26. After running the experiment each group prepares and submits a report. The report is due on Tuesday October 4 at class time.

### II. GROUPS, LOGISTICS AND TIMETABLE

#### II.1 Timetable

This lab spans September 16–26 with group reports due on Tuesday October 4. The calendar is summarized in Figure 1. Guidelines for writing the report are provided in Section IV.

***Important: (1) Attendance to lab demos & group experiments is mandatory (50% lab score deductions are taken for unjustified absence, see Sec IV.2) (2) All students must have a computer account on ITLL***

| Monday | Tuesday | Wednesday | Thursday | Friday |
|---|---|---|---|---|
| | | | | **Sep 16**<br>**Exp Proc Demos @ ITLL 1B50**<br>**1pm & 3pm** |
| **Sep 19**<br>**Exp Proc Demos @ ITLL 1B50 3pm** | **20**<br>Lec Torsion (OTW)<br>RQ#3<br>**Group experiments** | **21**<br>**Group experiments** | **22**<br>Lec Torsion (CTW)<br>**Group experiments** | **23**<br>Recitations (2)<br>**Group experiments** |
| **Sep 26**<br>Recitation (1)<br>**Group experiments** | **27**<br>Lec Beam defl<br>RQ#4 | **28** | **29**<br>Lec Beam defl<br>HW#4 due | **30**<br>Recitations (2) |
| **Oct 3**<br>Recitation (1)<br>Midterm 2 review | **4**<br>Lec Beam defl<br>HW#5 due<br>**Lab 1 report due** | **5** | **6**<br>Midterm exam 2 | **7**<br>**Exp Proc Demos**<br>**Lab 2**<br>**1pm & 3pm** |

Figure 1. Timetable for ASEN 3112 experimental Lab 1.

### II.2 Getting Started

To carry out the experiments groups have been formed from the roster under the constraint that all members of each group are enrolled in the same Lab section, to facilitate organization and reduce signup conflicts. The composition of the groups is listed in Addendum IV, at the end of this document.

The experimental procedure demos will be held at these date/times:

- Friday Sep 16 at 1pm and 3pm for students in Sections 011 and 012.
- Monday Sep 19 at 3PM for students in Section 013.

Attendance is mandatory and will be taken at the start of each demo. Demos will be held at the recitation room, ITLL 1B50. Group tests will be done at ITLL 2B Plaza by 2B 07. **Groups should meet before or after their session and get organized** as follows.

1. **The group signs up for a one-hour slot**. Available slots are shown in Addendum III of this document as guide. A sign-up sheet will be posted on the **Module Reservation Board** at the ITLL Plaza, Level 1B, located on the hallway between rooms 1B50 (Active Learning Center) and 1B60 (Module Storage Room). Write the group ID, for example "Group 14." Slots are allocated on a first come, first serve basis.
2. **Each group selects a leader**. The group leader is responsible for coordinating report preparation. If the group decides to do peer evaluation the gropu leader compiles the results and appends it to the report; see IV.2. The group leader also acts as contact person with the instructors or TAs should questions arise about the Lab. Note: a group may select different leaders for other Labs.

### II.3 Lab Reports

Each group prepares and submits a lab report, which is due at the start of class on Tuesday October 4. Instructions for this report are given in Section IV of this document. Grading weights are given in Addendum I.

## III. EXPERIMENT DESCRIPTION

### III.1 Operational Instructions

Please refer to the operational procedures for the Instron Torsion Module in setting up the apparatus. Procedural instructions for the test are given in Addendum VI, which is printed as a separate document. **A TA must be present during each group's time slot to supervise the process**.

### III.2 The Closed Thin Wall Specimen (a.k.a. Closed Tube)

This specimen is identified as CTW, for Closed Thin Wall. It is the commercial circular tube depicted in Figure 2. (Module grips are not shown in this Figure.) **English units are used throughout this lab.** The material is stock aluminum tube purchased at McGuckin's. It is also called the "closed tube" in the sequel for brevity. Nominal exterior dimensions are: exterior diameter $D_e = 3/4$ in, exterior radius $R_e = \frac{1}{2} D_e = 3/8$ in, and uniform wall thickness $t = 1/16$ in. The shear modulus of this material is $G \approx 3.75 \times 10^6$ psi. For the test $L$ is taken as the extensometer gage length in inches provided in Addendum VI, which is printed as separate document.

The specimen is instrumented with a torsional extensometer, as described in the **Experimental Procedure** document.

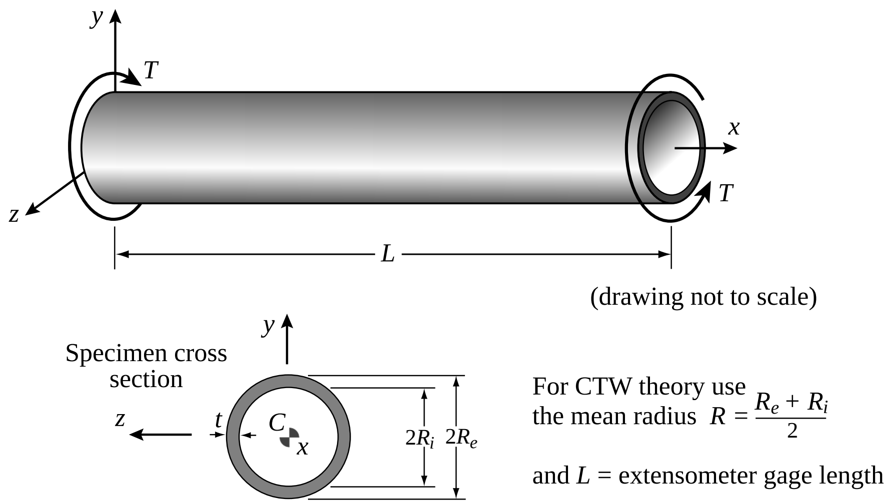


Figure 2. CTW specimen: Torqued circular tube. This Figure (in PDF) may be downloaded from the public web site "Labs" link.

Figure 3. Photos of CTW specimen. This Figure (in PDF) may be downloaded from the public web site "Labs" link.

This specimen is to be subjected to torque levels from $T_0 \approx 0$ lbs-in (calibration level) up to $T_{max} \approx 400$ lbs-in. At that level the maximum shear stress reaches roughly 8620 psi, which provides a safety factor of about 2.3–2.6 against yield. Two sets of measurements are to be recorded at increasing torque levels:

(a) The shear strain $\gamma$ in degrees over the gage length of the extensometer. This strain may be converted to microradians ($\mu$). If the strain is small (which can be assumed if the specimen is not taken beyond yield), the twist angle $\phi$ over the length $L$ is $\phi = \gamma\, L/R_e$, where $R_e$ is the exterior tube radius.

(b) The torque recorded by the Instrom machine.

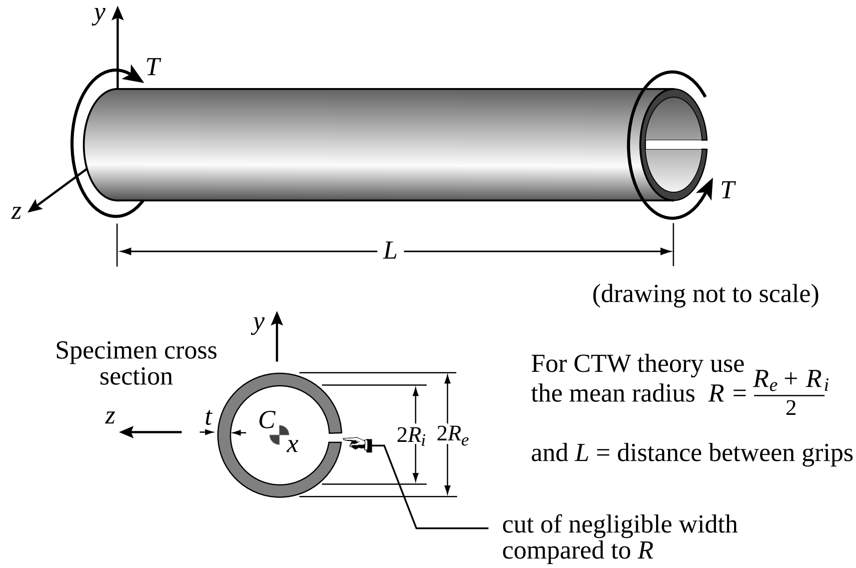


Figure 4. OTW specimen: Torqued circular tube with longitudinal cut. This Figure (in PDF) may be downloaded from the public web site "Labs" link.

### III.3. The Open Thin Wall Specimen (a.k.a. Slitted Tube)

This specimen is identified as OTW, for Open Thin Wall. It is the same commercial tube used in the previous test with a longitudinal cut along its length. See Figures 4–5. It is also called the *slitted tube* in the sequel for brevity. Nominal cross section dimensions are the same as before. The cut width is to be assumed negligible compared to the cross section radial dimension. The material properties are the same as those of the CTW specimen. For the test $L$ is taken as the extensometer gage length in inches, which is provided in the experimental procedure document.

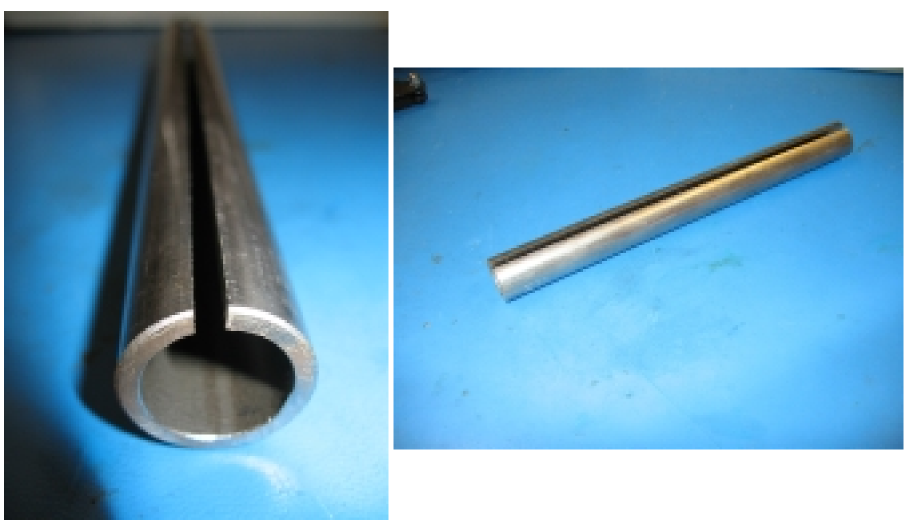

Figure 5. Photos of slotted tube (OTW) specimen. Later replaced by one with 7-in-long slot to reduce grip end effects. This Figure (in PDF) may be downloaded from the public web site "Labs" link.

This specimen is to be subjected to torque levels in the range: $T_0 = 0$ lbs-in (calibration level) up to $T_{max} \approx 20$ lbs-in. **This range is much smaller than for the CTW specimen**. At that torque level the maximum shear stress is about 7800 psi, which provides a safety factor of approximately 2.8 against yield. Note, however, that stress concentrations will occur at the slot ends, even after rounding the tips. The measurements of applied torque $T$ and shear strain $\gamma$ are like those described for the closed tube in III.2. The recovery of the twist angle, however, is different: $\phi = \gamma\, L/t$ instead of $\phi = \gamma\, L/R_e$.

### III.4. What To Compare

For each specimen, the theory vs. experiment comparison involves:

(a) The shear strain $\gamma$ predicted by the appropriate TW torsion theory compared with measured values. Addendum II provides help for working out the theory-versus-experiment comparison. Plot the measured $T$ (lbs.in) versus $\gamma$ (micros) along with theoretical values in the same diagram.

(b) The measured torque rigidity, given by

$$GJ = \frac{TL}{\phi}$$

obtained from the test values of $\phi$ versus $T$. Plot $GJ$ versus $T$. This gives an idea of the quality of the test, since the $GJ$ given by theory is constant for any torque in the linear regime. If grip slip occurs during the test, the measured $GJ$ may show significant variations as $T$ varies. Note that the physical dimension of $GJ$ is force times length squared, e.g., lbs . in$^2$ in English units.

## IV. WRITING A REPORT

### IV.1. Organization

Reports are due Tuesday October 4 at class time. **The report must be word processed**. The main body should not exceed 6 pages (this excludes Appendices, Title Page and TOC page). It should include:

**Title Page**. Describes Lab, lists the name of the team members and identifies the group leader. A short Table of Contents as second page is optional but recommended.

**Objective**. A summary description of the lab objective (one or two paragraphs). This could also be titled **Summary** or **Introduction**.

**Experimental Procedure**. A summary of the experimental and data acquisition setup. There is no need to include a detailed operational description, because that is covered in Addendum VI, which is printed as a separate document.

**Theoretical Analysis**. Development of the theoretical formulas used to predict the measured values. Should be succint, giving appropriate references to sources insofar as possible, rather than trying to develop those in detail. It should conclude by plugging in the actual numerical values to obtain the theoretical formulas needed for the two theory vs. experiment comparisons described in III.4.

**Data Reduction and Presentation**. Summary of measurement results, and comparison with theoretical predictions derived in the **Theoretical Analysis** section. It is recommended that the data be organized as a table with one row for each of the selected measurements in each experiment, and five columns: torque, predicted $\gamma$, measured $\gamma$, predicted $GJ$ and measured $GJ$. By “selected measurements” it is meant representative values of the torque level, but at least three should be shown, so that linearity and zero-offset can be checked. Detailed measurement records should not be included here but may be attached as a report Appendix. However, plots generated from the data should be put in this section to confirm linearity and calibration.

**Discussion**. A discussion of the agreement between theory and experiment, pointing out and trying to explain sources of discrepancies if any.

**Conclusions**. One or two paragraphs summarizing your conclusions. Include here any suggestions on how to improve the experiment. Comment on how useful the test was as a tool to understand the topic of torsion.

**References**. List of references cited in the body of the report, e.g. the textbook, torsion handout or operational handout. References should be cited in the text by numbers enclosed in square brackets. Example: "the CTW stress formula provided in page 4 of [3] is used."

Reports are graded for both technical content (roughly 2/3) and presentation (roughly 1/3). More details on grading weights are given in Addendum II. Individual scores are also weighted by the "contribution grading' submitted by the group leader.

**Note**. For sections such as **Objective** it is recommended to follow a key rule of technical writing: **context before content**. That is, briefly state what the lab goals are and which approach was followed to meet the goals, before entering into the technical description.

### IV.2. Individual Contribution Evaluation and Deductions for No-Show

The group leader submits along with the report a separate "grading sheet" rating the contribution of each team member on a scale of 0 to 100%. *Please staple this sheet to the report as last page to avoid misplacing*. A score of 100% indicates that the member contributed the expected share to the experiment and to the preparation of the report. The scores are normally assigned by *peer evaluation*, using the same procedures followed in the ASEN 200x sophomore courses. The group leader is responsible for tabulating and submitting the results of the peer evaluation.

Alternatively, the group may decide to hace the GL directly assign the scores, but peer evaluation is recommended.

A no-show at the lab demos, without justification, will be penalized by a deduction of 50% from the group score. A no-show at group experiments, without justification, is deducted 50%. A no-show at both is deducted 100%. Students that miss one or both events on account of a bona-fide reason, such as a medical emergency or unavoidable absence, should contact instructors or TAs as soon as possible.

# Addendum I. Report Grading

The score assigned to the lab report includes technical content (65%) and presentation (35%). This is a more detailed breakdown of the weights:

| Category | Weight | Score | Contribution |
|---|---|---|---|
| Objective | 0.05 | | |
| Experimental procedure | 0.10 | | |
| Theoretical analysis | 0.15 | | |
| Data reduction & presentation | 0.20 | | |
| Discussion | 0.10 | | |
| Conclusions | 0.05 | | |
| Organization | 0.05 | | |
| Flowthrough | 0.10 | | |
| Style | 0.05 | | |
| Grammar | 0.05 | | |
| Spelling & typos | 0.05 | | |
| Referencing | 0.05 | | |
| Total | 1.00 | | overall score |

“Flowthrough” measures smoothness of reading from start to finish and correlation of material from section to section, as well as adherence to guidelines of technical writing.

The score within each category ranges from 0 to 100%. For example if the score for “theoretical analysis” is 80%, it contributes $0.15 \times 80 = 12\%$ to the overall score. This group score is then multiplied by the “contribution factor” assigned by in the submitted participation grading sheet.

# Addendum II - Hints on Theory Steps

**Closed Thin Wall (CTW) Specimen**. Geometric data: mean tube radius $R$, wall thickness $t$, and extensometer gage length $L$. Material data: $G$. Measure applied torque: $T$. Measured shear strain $\gamma$ given by extensometer. This can be converted to twist angle by $\phi = \gamma\, L/R_e$, where $R_e$ is the *external specimen radius*. Using CTW theory (Lecture 9) find analytically $\gamma$ in terms of $T$. For the enclosed area $A_e$ and moment of inertia $J$ use $R$ instead of $R_e$. Note: first obtain and write down all expressions keeping $G$, $R$, $t$, $L$, $T$, $\gamma$ and $\phi$ as variables, *then* plug numbers.

**Comparing CTW Approximation To Exact Theory**. The closed circular tube happens to be covered by the exact theory for Torsion of Circular Sections presented in Lecture 7. For the tested closed tube, recompute the data above using formulas (7.7), (7.9) and (7.11) of that Lecture. Note that now $\gamma = \gamma_{max}$, which happens at the exterior radius because the extensometer is placed on the *outside* surface of the tube. Therefore you should use the outer (exterior) radius $R_e$ in the formulas for $\tau_{max}$ and $\gamma_{max} = \tau_{max}/G$. Compare to values obtained above using the CTW approximation, and comment on their accuracy. Does the specimen qualify as a thin-wall section?

**Open Thin Wall (OTW) Specimen**. Geometric, material and extensometer gage length same as for the closed tube. Assume gap width of cut is negligible. Measured shear strain $\gamma$ given by extensometer. This can be converted to twist angle by $\phi = \gamma\, L/t$, where $t$ is the wall thickness (note the difference from the CTW formula given above). For the OTW theory "rectify" the slitted cross section, neglecting the cut width.

# Addendum III. Available Time Slots For Group Tests

**(Subject to Adjustment if necessary)**

***ASEN 3112 Fall 2016 - Lab #1 (Torsion) Sign-up Planning***

The non-shaded slots are available for group tests. These are shown for planning purposes. Sign-up on the **Module Experiment Reserve Board**, located on the hallway about half-way between Rooms 1B50 and 1B60. Sign up sheet will be available by Thursday 9/15 afternoon. More details below.

| | Tu 9/20 | Wed 9/21 | Th 9/22 | Fri 9/23 | Mo 9/26 |
|---|---|---|---|---|---|
| 9:00-10:00 | | | | | |
| 10:00-11:00 | | | | | |
| 11:00-12:00 | | | | | |
| 12:00- 1:00 | | | | | |
| 1:00- 2:00 | | | | | |
| 2:00- 3:00 | | | | | |
| 3:00- 4:00 | | | | | |
| 4:00- 5:00 | | | | | |
| 5:00- 6:00 | | | | | |

- Lab times are on a first come, first served basis, so it is to your advantage to get signed up as early as possible. If you have any problems or questions see the TAs or the instructor personally
- Lectures for ASEN 3111, 3112, and 3113 are blocked.
- Sign-up by writing your group #, e.g. "Group 7"
- Contact addresses:<br>TA: Clemence Bacquet: Clemence.Bacquet@colorado.edu<br>TA: Leng Khoo Leng.Khoo@colorado.edu<br>TA: Dimitri Kratigger: Dimitri.Krattiger@colorado.edu<br>LC: Trudy Schwartz: Trudy.Schwartz@colorado.edu<br>LA: Keegan Sotebeer: Keegan.Sotebeer@colorado.edu

# Addendum IV - Lab 1 Groups

**Composition of the Groups** As of Sep 12, 2016.

**GROUPS FOR ASEN 3112 EXPERIMENTAL LAB #1 - FALL 2016 AS OF 9/12/16**

The Lab #1 description document will be distributed to the class of Tu Sep 13
Please bring to demos on Fri 9/16, @ 1 & 3pm, and Mo 9/19 @ 3pm.
Attendance to demos is mandatory. No recitations that day.

Each group: (1) selects a Group Leader, and (2) signs for a 1-hr experiment during 9/20 to 9/26 on the Module Reservation Board of ITLL, which is located across the hallway from ITLL 1B50. The sign up sheet will be posted by Sep 15 afternoon.

| | | | |
|---|---|---|---|
| **Group 1** (Sec 11) | **Group 2** (Sec 11) | **Group 3** (Sec 11) | **Group 4** (Sec 11) |
| Agramonte Moreno, Abdiel | Alvarenda, Glenda | Aronson, Ryan | Baertsch, Jorgen |
| Cuther, John | Bishop, Amber | Baker, Brett | Boyd, Brendan |
| Hakulin, Robert | Dunbar, Grant | DiGiacomo, Kyle | Flaherty, Haleigh |
| Larsen, Reidar | Mezich, Andrew | Hutchinson, Benjamin | Johnson, Abigail |
| Setiawan, Nikolas | O'Neill, Nathaniel | Lieberman, Pierce | Kelly, Samuel |
| Sorensen, Lucas | Schira, Zachary | Sheahan, Corwin | McIntire, Lauren |
| **Group 5** (Sec 11) | **Group 6** (Sec 11) | **Group 7** (Sec 11) | **Group 8** (Sec 11) |
| Bui, Thanh | Anwar Deen, Syamimah | Kondor, Gregory | Cenedella, Nicholas |
| Castillo, Gabriel | Derevyanko, Sergey | LaBonde, Charles | Jafari, Rod |
| Johnson, Alexander | Hawthorne, Cassidy | Levigne, Nathan | Larson, Sarah |
| Lee, Kent | Lyke, Owen | Mast, Harrison | Lynch, Ryan |
| Ortega, Angel | Reilly, Christine | Norman, Justin | Owens, Kelsey |
| Ursetta, Jake | Sieira, Pol | Stanco, Anthony | Robak, Matthew |
| | | Toelkes, Zachary | Tyler, Rachel |
| **Group 9** (Sec 12) | **Group 10** (Sec 12) | **Group 11** (Sec 12) | **Group 12** (Sec 12) |
| Alvey, Justin | Arnold, Andrew | Andrada, Rolf | Beavers, Caleb |
| Astarita, Mattia | Blay, Ryan | Charland, Cody | Cott, Brandon |
| Feu Vidal, Jose | Duong, George | Funk, Matthew | Geraghty, Ian |
| Pulido, Gerardo | Gangopadhyay, Rishab | Growley, Samantha | Mellinkoff, Benjamin |
| Stoffle, Matthew | Holton, Jesse | Reynolds, Zachary | Sherman, Sage |
| Taylor, Nicholas | Mitchell, Jakob | Suykerbuyk, Savant | Teigen, Lucas |
| **Group13** (Sec 12) | **Group 14** (Sec 12) | | |
| Cooke, Ian | Droste, Lucas | | |
| Crouse, Jacoib | Folsom, Richard | | |
| Markle, Mason | Levandoski, Andrew | | |
| Roe, Cavan | Normile, Mathew | | |
| Sundahl, Brandon | Viets, Alec | | |
| Thurmes, Nicholas | | | |
| **Group 15** (Sec 13) | **Group 16** (Sec 13) | **Group 17** (Sec 13) | **Group 18** (Sec 13) |
| Bertman, Alex | Anderson, Dalton | Brock, Darin | Ellingson, Sean |
| Harrmann, Kennedy | Colic, Alija | Chidambaram, Olagappan | Greer, Daniel |
| Johnsrud, Torfinn | Isaacs, Tristan | Hriday, Ankit | Lee, Nolan |
| McKernan, Matthew | Polakiewicz, Severyn | Hutchinson, Leina | Moore, Nicholas |
| Williams, Justin | Shepherd, Owen | Romano, Jaquelyn | Pestolesi Jr., Thomas |
| | Wiemelt, Nicholas | Winoker, Alexander | Swindell, Alexander |
| **Group 19** (Sec 13) | **Group 20** (Sec 13) | **Group 21** (Sec 13) | **Group 22** (Sec 13) |
| Brusky-Hyland, Joshua | Barrett, Ian | Harrell, Jacob | Lux, Andrew |
| Collins, Daniel | Jenkins, Jeffrey | Kravchuk, Kirill | Mitchell, TR |
| Kerry, Connor | Jordan, Forrest | Margalit, Guy | Morgan, Ethan |
| Landis, Mary | Nguyen, James | Ortiz, Brian | O'Donnell, Samuel |
| Loefgren, Ian | Wall, Ryan | Stokley, Dawson | Stout, Selby |
| Sample, Kristyn | Zuzula, Edward | | |

# Addendum V - Student Email Addresses To Facilitate Group Coordination

**ROSTER OF ASEN 3112-011: STRUCTURES, AS OF 9/5/16**

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Left # is position in full roster.

**ROSTER OF ASEN 3112-012: STRUCTURES, AS OF 9/5/16**

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|---|---|---|---|
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| 9. | Astarita, Mattia | Mattia.Astarita@colorado.edu | 12 |
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| 29. | Crouse, Jacob | Jacob.Crouse@colorado.edu | 12 |
| 33. | Droste, Lucas | Lucas.Droste@colorado.edu | 12 |
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| 42. | Geraghty, Ian | Ian.Geraghty@colorado.edu | 12 |
| 44. | Growley, Samantha | Samantha.Growley@colorado.edu | 12 |
| 49. | Holton, Jesse | Jesse.Holton@colorado.edu | 12 |
| 70. | Levandoski, Andrew | Andrew.Levandoski@colorado.edu | 12 |
| 78. | Markle, Mason | Mason.Markle@colorado.edu | 12 |
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Note: Addendum VI, which describes the test procedure, is provided as a separate document.