F-Chart Software

No. 47, Fall 2024

EESy Solutions

Engineering Equation Solver Newsletter

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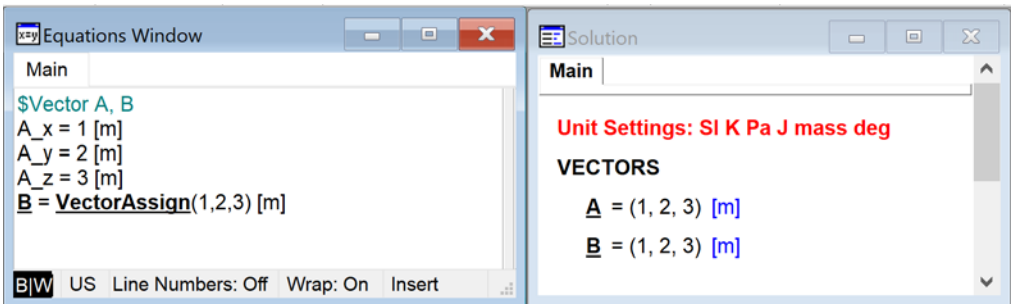
Welcome

This is the 47th issue of EESy Solutions, a newsletter that provides news, tips, and other updates for users of the Engineering Equation Solver software. This issue discusses the addition of vector variables to EES. Vector variables have two (*x* and *y*) or three (*x*, *y*, and *z*) components depending on whether they are 2D or 3D vectors. Functions to define and manipulate vectors have been added to EES as well as plotting capability to visualize vectors. This issue also discusses the EESyGrader utility which automates the process of opening, running, and grading many EES submissions in a class. EESyGrader allows a computer science class type of approach to assignments where students are provided answers to test cases while they are doing the assignment and then graded based on their program's ability to solve other cases.

EES has been commercially available for more than two decades. Previous issues of EESy Solutions, they can be downloaded from https://fchartsoftware.com.

Vector Variables

Vectors are useful in many areas of engineering. Starting with EES version 11.840, vector variables can be defined in EES. EES variables are declared to be vectors with the **$Vector** directive, followed by the names of each variable. Each variable that is defined as a vector in this way will have three scalar components that are designated with the subscripts _x, _y, and _z. The **$Vector2D** directive works the same way except that variables defined in this way have only two scalar components (_x and _y). Vector variables can be assigned one component at a time or all at once using the **VectorAssign** command.



*The vectors **A** and **B** in EES. The vector **A** is assigned component by component while the vector **B** is assigned using the **VectorAssign** command.*

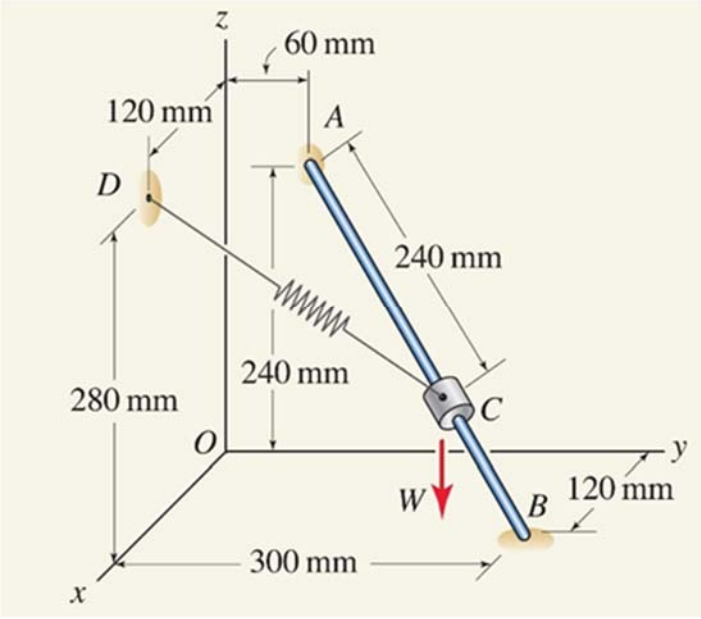
Vector Functions

Each component of a vector can be accessed and manipulated in the same way as for any other EES scalar variable. In this way it is possible to carry out any vector operation manually. However, there are a number of vector functions that make it easy to manipulate vector variables. Some of these are listed below.

VectorMag(A)	Provides the magnitude of the vector **A**.
VectorAngle_X(A)	Provides the angle between the x-axis and the vector **A** (also _Y and _Z).
VectorAssignPolar(Mag, A_x, A_y**)**	Creates a vector of magnitude Mag with angles relative to the x and y axes of A_x and A_y, respectively.
VectorCross(A, B)	Provides the cross product of vectors **A** and **B**; this result is a vector (for 3D vectors) or scalar (for 2D vectors).
VectorCross_i(A, B)	Provides the x-component of the cross product of vectors **A** and **B** (also _j and _k).
VectorDot(A, B)	Provides the dot product of vectors **A** and **B**.
VectorUnit_i	Creates a vector that is the unit vector in the x-direction (also _j and _k).
VectorZeros	Creates a vector that is zeros in each direction.

Vector Example

This example is from the book *Statics and Dynamics, Third Edition* by Gray, Costanzo, Witt and Plesha (McGraw Hill, 2023). Bar AB is straight and is fixed in space. Spring CD has 3 N/mm stiffness and 200 mm unstretched length. If there is no friction between collar C and bar AB, determine the weight W of the collar that produces the equilibrium configuration shown and the reaction force on the rod.



Example 3.8 from Gray et al., Third Edition (McGraw Hill,

Vector Example (cont.)

The problem inputs include the spring constant and unstretched length.

```
k = 3 [N/mm]                    "spring stiffness"
L_0 = 200 [mm]                  "spring unstretched length"
```

We will start by defining the coordinates of points A, B, and D. These coordinates each have an x, y, and z component and therefore can be conveniently defined using the **VectorAssign** function.

```
$Vector A, B, C, D
A = VectorAssign(0, 60, 240) [mm]     "coordinates of point A"
B = VectorAssign(120, 300, 0) [mm]    "coordinates of point B"
D = VectorAssign(120, 0, 280) [mm]    "coordinates of point D"
```

The position vector that defines the bar is determined from

$$\vec{r}_{AB} = B - A.$$

Point C is displaced from point A by a distance r_{AC} = 240 mm in the direction defined by $\vec{r}_{AB}$

$$C = A + r_{AC}\frac{\vec{r}_{AB}}{|\vec{r}_{AB}|}.$$

The position vector corresponding to the spring is

$$\vec{r}_{CD} = D - C.$$

These vector equations can be easily entered into EES using the vector variables **r_AB**, **C** and **r_CD**

```
$Vector r_AB, r_AC, r_CD
r_AB = B - A                          "position vector r_AB - corresponding to the bar"
C = A + 240 [mm]*r_AB/VectorMag(r_AB) "coordinates of point C"
r_CD = D - C                          "position vector r_CD - spring"
```

The magnitude of the spring force is given by

$$F_{CD} = k\left(|\vec{r}_{CD}| - L_0\right)$$

The spring force is in the direction defined by $\vec{r}_{CD}$

$$\vec{F}_{CD} = F_{CD}\frac{\vec{r}_{CD}}{|\vec{r}_{CD}|}.$$

The force due to the weight is in the vertical downwards direction

$$\vec{W} = -W\,\hat{k}.$$

Vector Example (cont.)

```
magF_CD = k*(VectorMag(r_CD) - L_0)          "magnitude of spring force"
$Vector F_CD, W
F_CD = magF_CD*r_CD/VectorMag(r_CD)          "spring force"
W = -magW*VectorUnit_k                       "weight force"
```

The sum of the spring force and weight must be zero when projected in the direction of the frictionless rod,

$$\vec{F}_{CD} \cdot \frac{\vec{r}_{AB}}{|\vec{r}_{AB}|} + \vec{W} \cdot \frac{\vec{r}_{AB}}{|\vec{r}_{AB}|} = 0$$

or, multiplying through by $|\vec{r}_{AB}|$

$$\vec{F}_{CD} \cdot \vec{r}_{AB} + \vec{W} \cdot \vec{r}_{AB} = 0$$

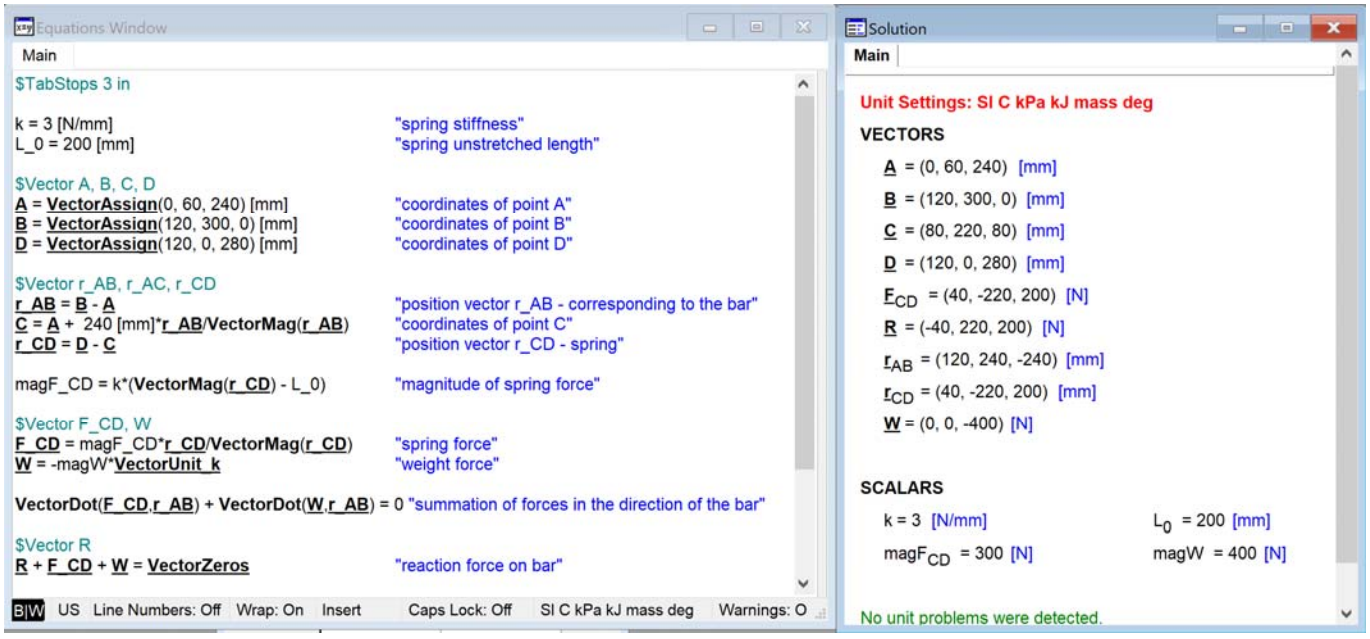
```
VectorDot(F_CD,r_AB) + VectorDot(W,r_AB) = 0 "summation of forces in the direction of the bar"
```

The reaction force on the rod is obtained by enforcing that the sum of forces on the collar must be zero

$$\vec{F}_{CD} + \vec{W} + \vec{R} = \vec{0}$$

```
$Vector R
R + F_CD + W = VectorZeros                   "reaction force on bar"
```

The resulting Equations and Solution Windows are shown below. Solving leads to magW = 400 N and **R** = (-40, 220, 200) [N].

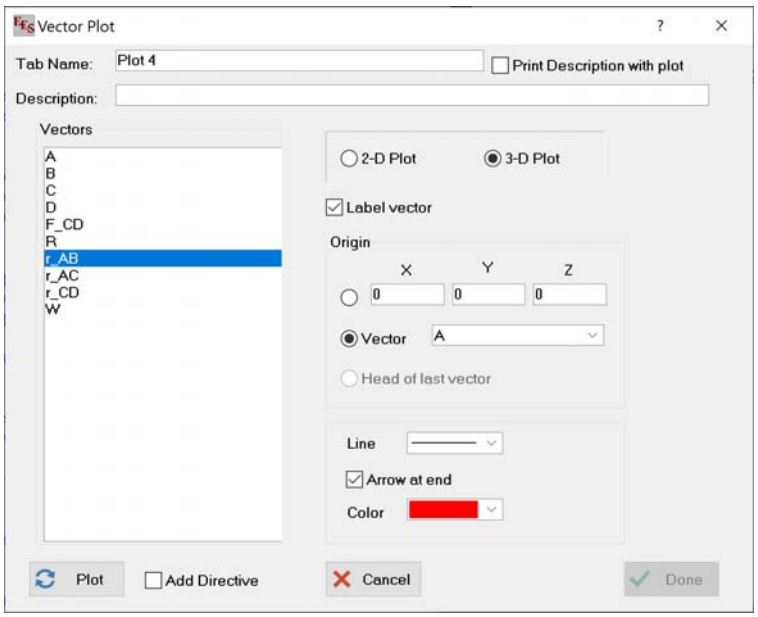


Equations and Solutions Window for Vector Example

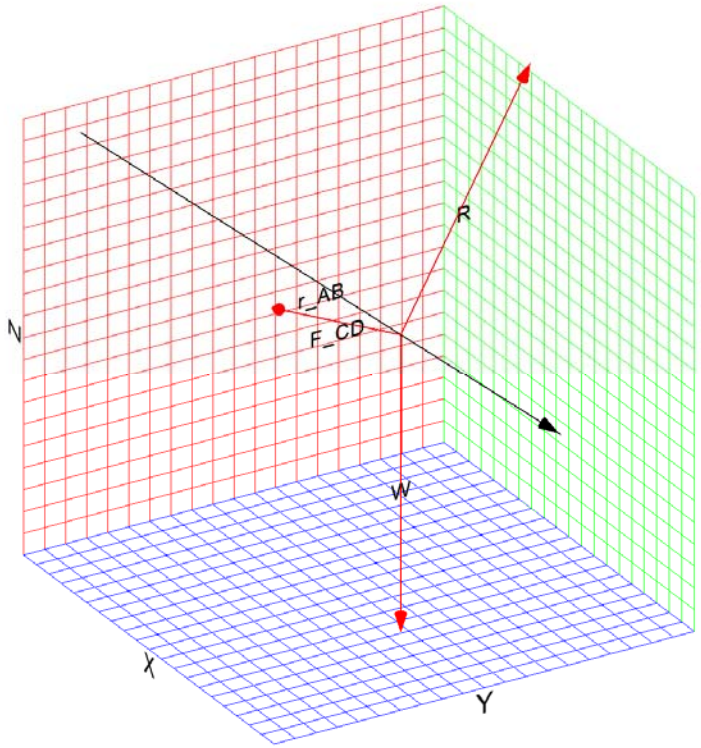
Vector Plots

Vectors in EES can be used to make vector plots that help visualize vectors in either 2D or 3D. Vector plots are complicated by the need to specify not only the vector but also its origin. To make a vector plot, select New Plot Window from the Plots menu and then Vector Plot from the fly-out menu.

Select either the 2-D or 3-D plot radio button and then select the vectors to be plotted (one at a time) and add them to your vector plot by clicking the Plot button. For each vector, you can specify its origin in one of three ways: by entering the coordinates, by specifying a vector, or by specifying that it be placed at the head of the last plotted vector (for all but the first vector). The figure at the right shows the selections required to plot the position vector **r_AB** starting at coordinate **A**. When you have added all of the vectors you want in your plot, select Done. The figure below shows the rod (**r_AB**) as well as the 3 forces on the rod (**W**, **F_CD**, and **R**) from the previous example.



*Vector Plot Dialog with selections to plot the vector **r_AB** starting at coordinate **A**.*

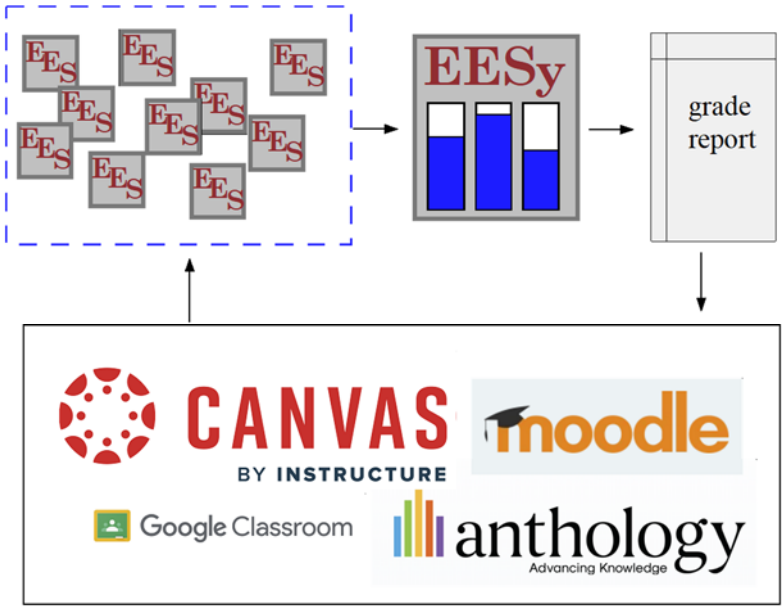


*Vector Plot showing the rod (**r_AB** starting at coordinate **A**) with the three forces on the rod (**W**, **F_CD**, and **R** starting at coordinate **C**)*

EESyGrader (for Academic License)

Student enrollments continue to increase which makes careful grading of homework assignments more and more burdensome. However, students learn best by doing problems and they need to work through many homework assignments in order to gain proficiency in any engineering discipline.

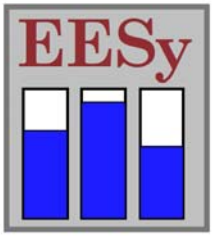
The EESyGrader program provides a solution to this problem. Students submit their EES files to your normal Learning Management System. These submissions can be downloaded to a directory where the EESyGrader program opens each one and grades them according to a rubric (i.e., a set of rules) that you have set up. The results are summarized in a grade report that can be uploaded to your Learning Management System.



Learning Management System

Students work on problem...

...and can get help if they do not obtain test case answers



EESyGrader opens EES file and solves it for a different case

Students submit working EES file

EESyGrader streamlines your ability to grade problems that were done using the Engineering Equation Solver (EES) software. By automating the grading process your time or your student assistant's time can be redirected from grading to helping students via office hours, problem solving sessions, and online discussion forums.

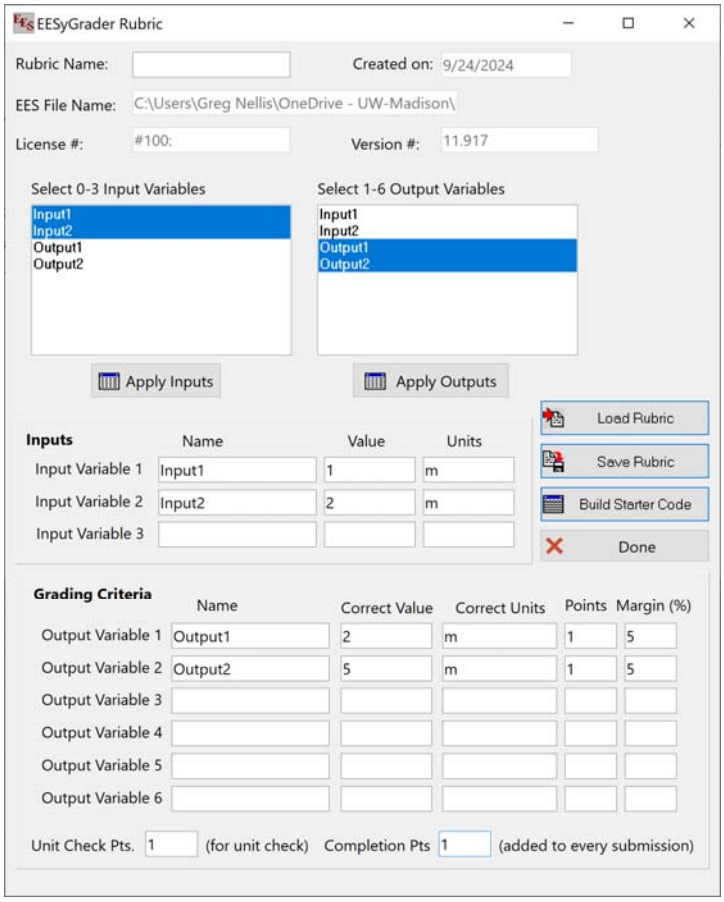
EESyGrader provides a tool for instructors to automatically grade EES programs submitted by students. EESyGrader integrates with your Academic License of EES provided that your AUS is up to date and is currently configured to work with the Canvas Learning Management System.

The EESyGrader program can be downloaded at no charge at:
https://fchartsoftware.com/ees/eesygrader.php.
A current subscription to Academic Update Service is required.

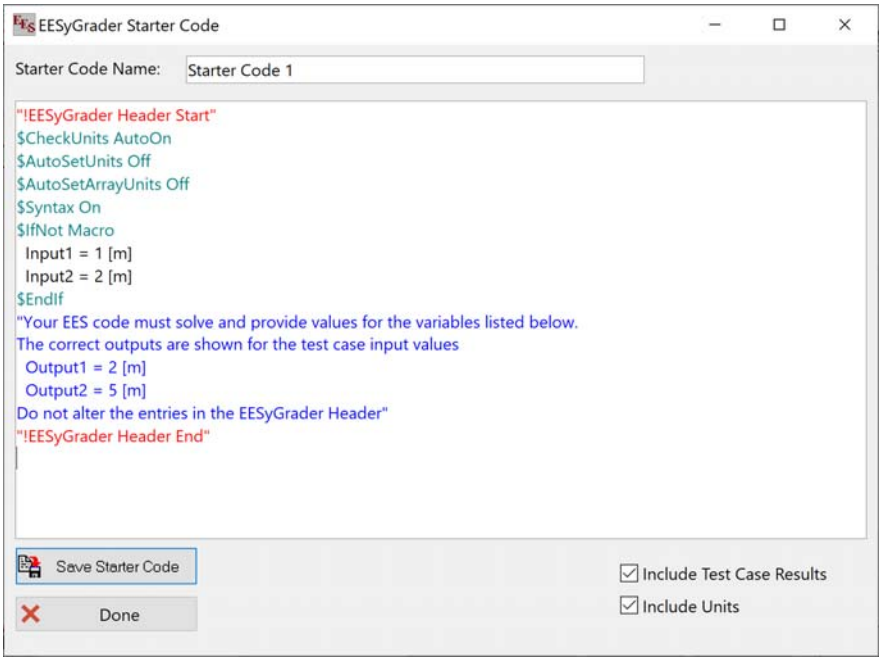
EESyGrader (cont.)

In order to be effective from a pedagogical standpoint, this process requires two things. First, students need to have some way of knowing if they are understanding the material while they are doing the homework. This is accomplished by providing students with the answers for a test case that they can use to see if their EES program produces the right answers. Second, once the students turn in their homework as an EES file, EESyGrader provides an automated method for opening all of the student submissions and solving them using a set of conditions that are different than the test case to be sure that the problems were actually solved correctly.

The process starts by generating a homework assignment for whatever class you are teaching. The homework assignment will involve some input parameters (Input1, Input2, etc.) and will lead to the calculation of some answers or outputs (Output1, Output2, etc.). The next step is developing an EES solution to the homework problem that includes these input and outputs. Select EESyGrader from the Options menu and create a rubric that defines the inputs and outputs.



EESyGrader Dialog



EESyGrader Starter Code

The EESyGrader dialog can automatically generate a starter EES code for you so that it can be distributed to your students. The starter EES code provides the naming convention that must be followed by the students and, optionally, the answers for a test case that allows them know if their code is working, giving them time to clear up any problems they have by getting help using whatever mechanisms you have set up for that purpose. You can also use the EESyGrader Dialog to set up a rubric that uses a different set of inputs and outputs for grading purposes.

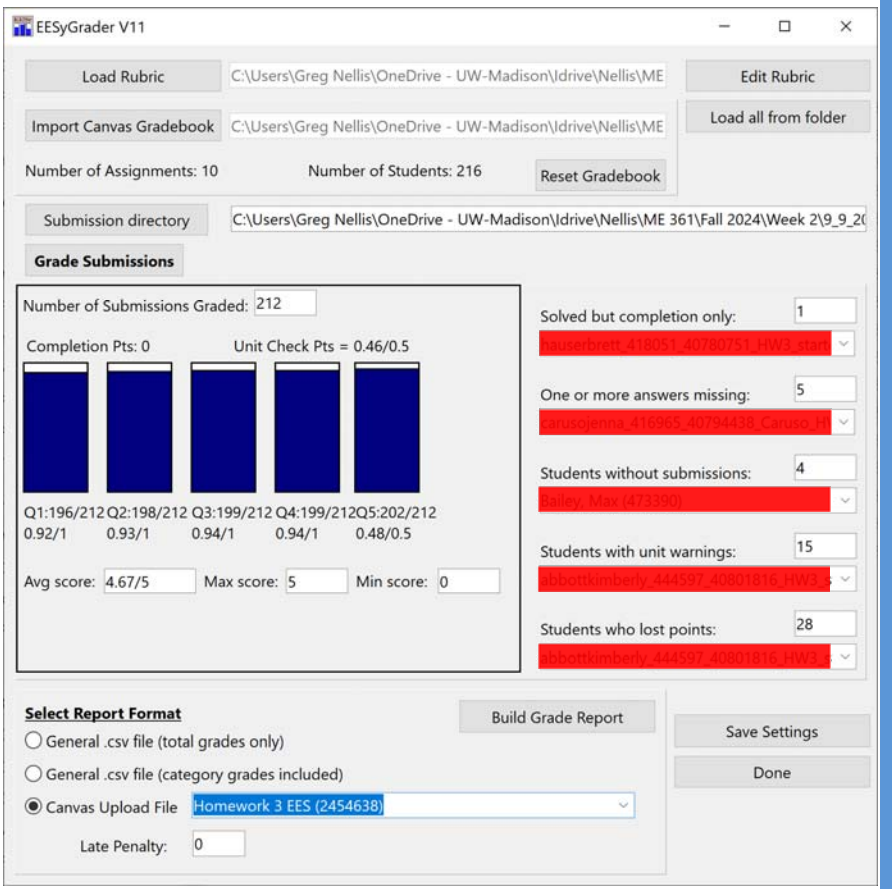
EESyGrader (cont.)

Before the due date, students submit their EES files rather than a print out or a pdf to your learning management system and you can download them all as a zip file and then unzip them into a directory for grading.

In order to grade the submissions, you will first load your rubric into the EESyGrader application. You can modify aspects of your grading scheme, such as how many points are assigned to each of the answers and whether you want to assign points for unit checking or give each submission some completion points. Once you are happy with your rubric, EESyGrader will use it to grade the student submissions and prepare a report that shows how students performed on each question as well as a list of student files that had various issues. You can optionally investigate these specific EES programs further by double clicking on the files in these lists.

Finally, a grade report is generated. The grade report can be a simple csv file consisting of each EES file name and the associated grade. Alternatively, if you are using the Canvas learning management system, EESyGrader can generate a compatible grade report that can be uploaded directly into Canvas.

The objective of EESyGrader is to give students in large enrollment class more access to instructional help by freeing up grading time so that it can be repurposed for activities that are more impactful for student learning like office hours and problem-solving sessions. The ability of the application to quickly generate a test case that is different from the grade case allows students to know before they turn in their homework assignment whether they have conceptual issues. This is the point in time where they are motivated to get help.



EESyGrader Application

Recent Changes to EES

- The Incompressible Substance library is no longer included in the EES folder but instead it is loaded from our website when needed.
- The **AddPlotText** macro command allows the name, value, and units of an EES variable to be placed on a plot. The text item can optionally be automatically updated.
- The **MessageWindow** macro command suspends a macro until one of three buttons is pressed allowing the EES file to be viewed and manipulated while the macro is suspended.
- Thermodynamic and transport properties for LPG (liquefied petroleum gas) and ideal gas combustion gas mixtures (CombustionGas_100, _200, and _400) have been added.
- Property data for molten salt (20NaCl_40KCl_40MgCl2) have been added.
- The **Students_t_function** returns the probability that a value falls within a normal probability distribution.
- Thermodynamic and transport properties for R444A have been added.
- The **$DefineUnits** directive allows a new unit to be defined or an existing unit to be redefined.
- Syntax Highlighting now includes a default option that displays functions and keywords in a consistent manner.
- The **StdAtm_1976** procedure provides the temperature and pressure of the atmosphere as a function of elevation.
- The **$ModifyAxis** directive allows the characteristics of the axes of an existing plot to be modified.
- Open Tab and Save Tab popup menus are provided for Equation Window Tabs which allows the contents of a tab to be saved as either a .txt file or an .EESTab file which retains variable information.
- The **$Warnings Off /Last** directive will can limit the display of warnings to those that only occur during the last iteration.
- A new variable can be added to your EES code from the Parametric Table by selecting the *** New Variable *** option from the variable list in the New Table dialog.

F-Chart Software

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Instant Update & Technical Service

EES uses a different model for updating than most other programs. Each time that there is a change in the EES program, either to correct a problem or to add a new feature, the version number is incremented by 0.001 and the latest version of EES is placed on our website. Although the program has become very robust and stable, there have been many new versions of EES released since the last EESy Solutions was distributed.

Any user who has a current subscription to our Instant Update & Technical Service (IUTS) or Academic Update Service (AUS) can download the current version. All new Commercial and Professional licenses of EES are provided with a one year subscription of this service. The cost to continue IUTS or AUS after the first year is ~20% of the current cost of the program per year, provided that it is renewed within 12 months after expiration. Contact us if you wish to re-subscribe to IUTS or AUS.