

## Science-1A Lab: Week 2, Wednesday, January 20, 2021

This lab is designed to help everyone get 100 points for the Calculations Test. A practice Calculations Test is on my website at

<https://yosemitefoothills.com/Science-1A/QuizAndTestPractice/PracticeCalculationsTestAndSolutions.pdf> .

Pages 2-4 of this note walk you through those practice calculations.

My goal is for all students to be able to correctly calculate the answers to that practice test with multiple do-overs and help from me and others. Once that practice test is mastered, You are to do the "real" test that I hope you will then be able to do correctly without help. If not, do-overs will be allowed with feedback from me. Everyone needs to end up knowing how to do those calculations.

This would be easy to teach if everyone, including me, had the same type of scientific calculator. Unfortunately, there are a great variety of calculators. I have had my favorite for 35 years, an HP-41C, that none of you will have, so there is no point in describing it.

I bought a calculator to loan to students. It was the cheapest I could find (\$8.00 from amazon.com), a "Helect H1002 2-line Engineering Calculator". It is shown at the right. I does the job, but I have no reason to feel that it is better than any other cheap scientific/engineering calculator.

Many of you have TI or Casio calculators that are probably "better" in many ways. Last Spring, before school went online in March, I was able to do this "Calculations Test" lab in person. It took the whole lab period to make sure that everyone in the section could do the Calculations test with their calculator. The problem was that the great variety of calculators had significant differences, and they all differed from my trusty HP-41C.

How can I do this online? Well, I'll start with a video where the use of three different kinds of calculators is explained while doing a problem involving scientific notation. Please watch this video at <https://www.youtube.com/watch?v=6EmmbyDMmMg> , and see if you can connect the behavior of one of the calculators shown with your calculator.

The following table attempts to summarize the explanations in that video and includes my Helect calculator:

Calculator Model	Num Style	Making $\times 10^x$	Unary Minus
TI-84 Plus CE	mode	2nd EE	(-)
Casio fx-991ES PLUS	MODE	$\times 10^x$	(-)
Sharp EL-501X	F $\leftrightarrow$ E	Exp	+/-
Helect H1002	MODE	EXP	(-)

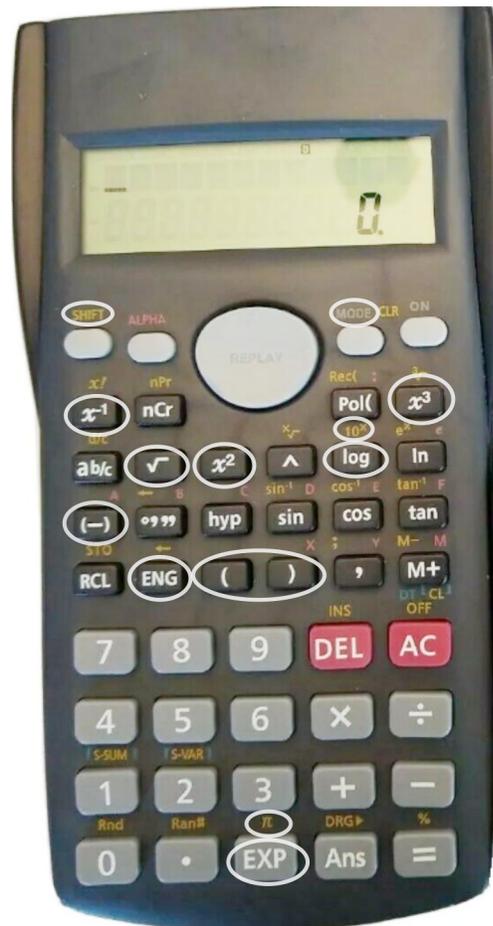
Be sure to use the "Unary Minus" (-), not the subtraction key, to make a number negative.

Also, be sure to use 2nd EE,  $\times 10^x$  or Exp when entering the power of 10 part of the scientific notation.

As he explains, using the multiply X instead of one of the "Making  $\times 10^x$ " keys will lead to an error when entering numbers in scientific notation.

Also, at the end, he explains a common mistake you must be careful to avoid.

**Added Notes:** For Casio fx-9750G Calculator, see <https://www.youtube.com/watch?v=cr91HYfms4U> .



Also see "Casio Calculator Fractions to Decimals (and back)" at <https://www.youtube.com/watch?v=OvvuuWQzqJw> for how to get out of the terrible fraction display mode Casio calculators use.

Next, I will do the Practice Calculations Test linked to at the top of this note while listing each key I poke **on the calculator shown above. Your calculator will likely operate with some differences, but seeing how this one works should help you figure out your calculator.**

In the following formulas, use  $G = 6.67 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}$  and  $c = 3.00 \times 10^8 \text{ m/s}$ .

$G$  is a universal constant for gravitation used in Example 1, and  $c$  is the speed of light in a vacuum used in Examples 2, 3 and 4.

1. Calculate the gravitational force in newtons using the formula  $F = G \frac{m_1 m_2}{d^2}$  where,

$m_1 = 5.3 \times 10^{23} \text{ kg}$ ,  $m_2 = 64.9 \text{ kg}$  and  $d = 8.3 \times 10^8 \text{ m}$ .

$$F = \left( 6.67 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2} \right) \frac{(5.3 \times 10^{23} \text{ kg}) \cdot (64.9 \text{ kg})}{(8.3 \times 10^8 \text{ m})^2} = 3.330 \times 10^{-3} \text{ N}$$

(Note: I have left off the unnecessary alternative answer of 3.330 mN given in the solution sheet.)

I start by setting the MODE to SCI with 4 significant digits:

**MODE MODE MODE 2 4**

On my loaner calculator, hitting the MODE key the first time gives the choices "COMP SD REG" with a number below each to choose one. I ignore those choices, and hit the MODE key a second time, getting the choices "Deg Rad Gra" with choice numbers below them. Those are to change the measurement of angles which we will not use in this class. Hitting the MODE key a third time, gives the choices "Fix Sci Norm" for "Fixed point number style", "Scientific notation number style", and "Normal number style (a mix of Fixed and Scientific)". We want to choose Sci which has a number 2 below it. We select Sci by pressing the 2 key. It then wants to know how many significant digits it should show. We want 4, so we press the 4 key. The calculator remembers these settings even after it is turned off.

Now, we do the actual calculation:

**6.67 EXP (-) 11 X 5.3 EXP 23 X 64.9 ÷ ( 8.3 EXP 8 ) x<sup>2</sup> =**

It then shows  $3.330^{-03}$  for the answer which is its way of saying  $3.330 \times 10^{-3}$ . You, of course, need to show all the units (N, kg, and m) in your calculation setup and the N unit for the answer to this calculation.

2. Calculate the dimensionless relativistic factor  $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$  where  $v = 2.8 \times 10^8 \text{ m/s}$ .

$$\gamma = \frac{1}{\sqrt{1 - \frac{(2.8 \times 10^8 \text{ m/s})^2}{(3.00 \times 10^8 \text{ m/s})^2}}} = \frac{1}{\sqrt{1 - \left( \frac{2.8 \times 10^8 \text{ m/s}}{3.00 \times 10^8 \text{ m/s}} \right)^2}} = 2.785$$

**1 ÷ √ ( 1 - 2.8 EXP 8 x<sup>2</sup> ÷ 3 EXP 8 x<sup>2</sup> ) =**

or you can do

**1 ÷ √ ( 1 - ( 2.8 EXP 8 ÷ 3 EXP 8 ) x<sup>2</sup> ) =**

It then shows  $2.785^{00}$ , its way of saying  $2.785 \times 10^{00}$  which we know is just  $2.785 \times 1 = 2.785$  as explained in Section 2 (Exponent Rules) of the Algebra Refresher handout at <https://yosemitefoothills.com/Science-1A/Handouts/Week-01/AlgebraRefresher.pdf>).

The MODE key can be used to switch out of scientific mode to see the number directly with 3 digits to the right of the decimal point ("Fixed point mode") by doing:

**MODE MODE MODE 1 3**

You shouldn't need to do that in this course, sticking with scientific notation (SCI mode with 4 significant figures) should be fine throughout the course. Reporting 2.785 or  $2.785 \times 10^0$  for your answer is fine, but you should not report  $2.785^{00}$  since that style is specific to the calculator, not to mathematics.

In this example, the answer is dimensionless, it has no units because the velocity units cancel. You must still write those m/s units in the setup, however, because they are part of the velocity values.

**3. Using  $E=mc^2$ , calculate the energy in joules released when  $3.7 \times 10^{-3}$  kg is converted to energy.**

$$E = (3.7 \times 10^{-3} \text{ kg}) \cdot \left( 3.00 \times 10^8 \frac{\text{m}}{\text{s}} \right)^2 = 3.33 \times 10^{14} \frac{\text{kg} \cdot \text{m}^2}{\text{s}^2} = 3.330 \times 10^{14} \text{ J}$$

(Again, I have left off the other alternative answers that can just cause confusion at this point.)

After having done the previous calculations, this one is easy:

**3.7 EXP (-) 3 X 3 EXP 8 x<sup>2</sup> =**

It shows the answer as  $3.330^{14}$ , its way of saying  $3.330 \times 10^{14}$ . You must write your answer as  $3.330 \times 10^{14} \text{ J}$  and not forget the kg and m/s in the calculation setup. Also, don't forget the square or you will end up with the wrong value and with units of  $\frac{\text{kg} \cdot \text{m}}{\text{s}}$  which are not the same as joules.

The units of the calculation produced  $\frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$  which we know from the last page of our Equation Sheet is the same as the unit joule, J. It is necessary to write either  $\frac{\text{kg} \cdot \text{m}^2}{\text{s}^2}$  or J with your answer, but which one to write is your choice.

Units are discussed in Section 4, Measurement Units, of the Algebra Refresher at page 5 of <https://yosemitefoothills.com/Science-1A/Handouts/Week-01/AlgebraRefresher.pdf>.

**4. Using  $\lambda = \frac{c}{f}$ , calculate the wavelength in meters of a photon that has a frequency of  $5 \times 10^{15} \text{ Hz}$ .**

$$\lambda = \frac{3.00 \times 10^8 \text{ m/s}}{5 \times 10^{15} \text{ Hz}} = 6.00 \times 10^{-8} \frac{\text{m/s}}{1/\text{s}} = 6.00 \times 10^{-8} \text{ m}$$

(Again, I have left off the alternative answers that can just cause confusion at this point.)

The following calculator operations produce this answer:

**3 EXP 8 ÷ 5 EXP 15 =**

It shows the answer  $6.000^{-08}$  which you should write as  $6.000 \times 10^{-8} \text{ m}$ .

The units in this case need a little explanation. On the last page of your Equation Sheet, you will find the following line which shows that Hz is the same as 1/s :

**hertz                      Hz=1/s                      frequency, cycles per second**

So in the above calculation Hz is replaced by 1/s. Then, the per seconds at the top and bottom cancel leaving just meters for the units of the answer.

The final two questions involve the chemical measure of acidity, pH. It is based on a "log" scale where something 10 times stronger, is 1 unit bigger. Earthquakes are also measured like this. A Richter Scale 7 earthquake shakes 100 times more than a Richter Scale 5 earthquake.

For historical reasons, the pH scale has a minus sign which serves to confuse students, but the idea is similar, just in reverse. Instead of measuring shaking of the earth, it measures concentrations of hydrogen ions ( $H^+$  which immediately become hydronium ions  $H_3O^+$ ). A pH 4 acid has 100 times as many hydrogen ions per liter as a pH 6 acid. The equations connecting pH and the concentration of hydrogen ions (written as  $[H_3O^+]$ ), are given under the Chapter 11 heading on the 4th page of the Equation Sheet as

$$pH = -\log_{10}[H_3O^+] \quad [H_3O^+] = 10^{-pH}$$

**5. Acetic acid, the active ingredient in vinegar, has a pH of 4.756. Calculate the concentration in mol/L of hydronium ions in vinegar using  $[H_3O^+] = 10^{-pH}$ .**

$$[H_3O^+] = 10^{-pH} = 10^{-4.756} = 1.754 \times 10^{-5} \text{ mol/L}$$

The keys to use on the calculator for this are

**SHIFT 10<sup>x</sup> (-) 4.756 =**

which produces  $1.754^{-05}$  so that the proper answer is  $1.754 \times 10^{-5} \text{ mol/L}$ . This calculation will always produce a concentration with units of mol/L even though one normally consider pH to have no units. This is a peculiarity of chemistry history.

**6. The concentration of hydronium ions in household ammonia is  $[H_3O^+] = 2.34 \times 10^{-12} \text{ mol/L}$ . Calculate the pH of household ammonia using  $pH = -\log_{10}[H_3O^+]$ .**

$$pH = -\log_{10}[H_3O^+] = -\log_{10}(2.34 \times 10^{-12} \text{ mol/L}) = 11.63$$

**Note: pH has no units, but must be calculated from a  $[H_3O^+]$  value that has units of mol/L.**

The keys to use on the calculator for this are

**(-) log 2.34 EXP (-) 12 =**

which produces  $1.163^{01}$  so that the proper answer is  $1.163 \times 10^1 = 11.63$ , without any units.

A video showing how to use a couple of other calculators to calculate pH from molar concentrations is at <https://www.youtube.com/watch?v=wTrH4IR58IE>.

**To get the lab points do the following:**

First try doing the Practice Calculations Test discussed above using your calculator. If you run into trouble, get help from someone, including e-mailing me if necessary.

When you feel confident that you can do all 6 of those questions, open the e-mail with the Subject '**Your Calculations Test - Open only when Practice Test is mastered**' and work out its values. Send me an e-mail of your results, including any units, and identify your model of calculator. If you get them right, you get your Calculations Test and lab points, if not, I will try to guide you in how to get the right answer so that eventually you will get all your points. For just this test, do-overs are OK because I want everyone to know how to use their calculators to get the numeric answers to our future quizzes and tests which will no have do-overs.