Whiteboard: 1/60, f5.6, iso 1000, **WB Use Grey Card**, Manual Audio at level 11, focal length ½ way to ∞. H4n **INPUT @ 95%** gain.

BBB 1/60, f5.6, iso 320, **WB Use Grey Card**, Manual Audio at level 11, focal length ½ way to ∞. H4n **INPUT @ 95%** gain.

BBB Check Horizontal Level & Billy's Lights!! Middle line at bottom 1/3 of desk & remember Billy and Bo chair locations!

Title: Harnessing the Power of Spreadsheets in Physics – zoom at 250%

Mr.p: Good morning. In my opinion, physics students have to know how to use a spreadsheet program to analyze lab data. That's why I call it, "Harnessing the Power! Of the spreadsheet." [intro]

Billy: Yeah! **Bobby: Okay. Bo: That's kind of weird.**

Mr.p: I am going to demonstrate by using the 2016 version of Excel. However, there are all sorts of other spreadsheet programs like Numbers, Sheets, NeoOffice. They all have similar functionalities, so

this demo should be useful no matter what program you use. Let's start with a basic experiment. Let's say we have a cart on an incline. The initial velocity of the cart is zero, we are adjusting the displacement of the cart, and measuring the time it takes to traverse the displacement. We will eventually graph displacement as a function of change in time. Let's start by inputting the information into our spreadsheet. These rectangular boxes are called "cells" and each cell is labeled with a letter in the x-direction and a number in the y-direction. In other words the first cell is A1. In A1 let's put "Change in Time (s)". "Change in Time"

labels the data in this column as the change in time and the parenthetical “s” tells us the units for the change in time are seconds. And we can input all of the data we collected for the change in time. [input data] That data looks strange aligned to the right of the cell, so I can click in the upper left corner to select all the cells in the worksheet and then click on this icon to center all the text in the worksheet. … Be careful to notice the tabs at the top because they change the menu of icons. The text alignment buttons are under the “home” tab. {hear Bobby} Yes Bobby?

Bobby: (Mr. p?) … We could use “delta t” instead of

"change in time", correct?

Mr.p: Sure, we could use delta t. Delta is a Greek symbol, so we would need to go to Insert → Symbol and then search for the Greek letter "delta". You could write either change in time or delta t, they mean the same thing. … Next lets add a column with our displacements in centimeters. {displacement (cm)} Our first displacement was 10 centimeters and each trial after that increased the displacement by 10 centimeters. So, there is an easy way to input that data and it requires we use an equation via the equal sign. In cell B3, which is directly below B2, we type an equal sign and then

click on cell B2. Notice how this adds B2 to our equation. Then we can type plus 10 to add 10 centimeters to the original 10 centimeters in B2.

Bo: That seems kind of dumb. We could've just typed in 20, instead of equals B2 plus 10. Typing 20 would've taken less time.

Mr.p: Sure. However, we can now select cell B3 and bring the pointer or cursor to the lower right corner of the cell. Notice how the cursor icon changes which indicates we can now click and drag all the way down to "drag and fill" the repeated equation. Clearly, this takes less time than typing in all the data, right?

Bo: I guess so.

Mr.p: “Drag and fill” copies and pastes the equation and it uses a relative reference which means the equation always uses the cell directly above the cell with the equation in it. {illustrate} There is a lot we can calculate from here. Let’s start with the average velocity in centimeters per second. {average velocity (cm/s)} Billy, how do you think we could calculate that?

Billy: Well, I bet we could use the equal sign to do an equation. The equation for average velocity is displacement over change in time. So in cell C2 type equals cell B2 and then divided by, which is

the forward slash, and then cell A2.

Mr.p: That is correct Billy. Notice you can either type in the cell name “A2” or you can click on the cell using the cursor. And again, we can select the cell we want to use to “drag and fill”, bring the cursor to the lower right corner, and click and drag down to “drag and fill” the equation.

Bo: Rather than typing “Average Velocity” for the heading of this column of data, could we use v with a subscript of “avg” for velocity average?

Mr.p: Sure. The way you would do that is by typing v and then “avg” without a space. Then we need to change the format of just the “avg” text to

"subscript". So we select just "avg" and then go to Format → Cells. Then we select the radio button next to "subscript". That changes the format of "avg" to subscript. {hear Billy} Yes Billy?

Billy: (Mr.p?) Why did we need to put the parenthetical "s" in the column heading, couldn't we have just put "s" next to all of our numbers?

Mr.p: Ah, yes. Notice what happens when we do that. Adding the "s" makes it so the equations no longer work because the spreadsheet program assumes what is in the cell is text and not a number, and it won't perform calculations on text. That is why we put the units at the top of each column instead of in

the cell with the data. … Does anybody see something currently wrong with our data?

- Bo: Nope.
- Bobby: … Significant figures. There is no way we know the average velocity to … what is that? … 10 sig figs?

Mr.p: Correct. We need to change the number of sig figs we are displaying. Start by selecting the data you want to change the display of and then click on these two buttons to increase or decrease the number of digits displayed. I would argue we know the displacement to the nearest millimeter, so we can display to the tenth of the centimeter. We can

do the same thing with the average velocity. I would argue that three sig figs seems to be a reasonable number to display. {hear Bobby} Yes Bobby?

Bobby: (Mr. P?) Why do you keep saying “display”? It looks to me like we are changing the number, not just the “display” of the number.

Mr.p: Ah, right. It is important to realize we are not changing the number itself, but rather just changing the number displayed. The spreadsheet does not round the number to what is displayed; it just changes what you see. … Okay, now let’s make a graph or chart. Click on the “Insert” tab because we are going to insert a chart. To the right of where it

says “recommended charts” there are chart type options. Typically in physics we use an “ X Y scatter” chart, so we click on that and typically we use a scatter chart that does not have lines between the data points, so let’s choose that one. At this point the program tried to figure out what data we wanted, however, it did not guess correctly. We will deal with the data in a moment, however, let’s first decide where we want the chart to be. We can drag it over to the right so it does not cover any of our data or we can move it to a different sheet. To move the chart, select the chart and then click on the “Chart Design” tab and then the Move Chart button.

Then we can move the chart to its own sheet rather than keeping it as an object in our original sheet. Notice we now have a sheet with the data and a sheet with the chart. If you have a lot of data or want to print the chart large and on its own page, this may be the way to go, however, because we don't have that much data for this experiment, I am going to move the chart back to being an object in our original sheet. … Okay, now we need to select our source data for the chart. With the chart selected, again select the "Chart Design" tab, and click the "select data" button. You can see the program decided to add two data series

"displacement" and "velocity average". I find the easiest thing to do here is to remove all the data so we can start new. So click the "minus" button twice to remove the two data series. Now chose "add" to add a data series to the chart. If you have multiple data series, it can be helpful to give the series a name, however, because we will only have one data series for this chart, I am not going to name it. Now, we need to decide what goes on our y and x axes. We are going to graph displacement as a function of change in time. Can anyone tell me what we need to put on the y and x axes?

- Bobby: … I think it is always y as a function of x,

right?

- Billy: Yea. It's always y as a function of x, so if we are graphing displacement as a function of change in time…
- Bo: Then displacement goes on the y-axis and change in time goes on the x-axis.

Mr.p: Right. So, for the x values, click on the button to the right of where it says "x values" and this collapses the dialogue box so you can more easily access the data. Click and drag to select the change in time data. Note you need to select the data only, do not include the "change in time" header. In my experience, including the header

sometimes confuses the spreadsheet program. Again, just select the data. Once you have selected just the data, press return to open the “select data source” dialogue box again. And repeat the process for the y-axis values. Click the button to the right of Y Values, select just the displacement data for the y-axis, and click “return” to return back to the “select data source” dialogue box. And then click “OK” to finish selecting your data. And there is our data in chart form.

- Bobby: … I feel like the graph is missing some things.
- Bo: Yeah.

- Billy: And it looks like one of those data points is wrong. The data point at about 2.1 seconds does not seem to follow the general trend of the rest of the data.

Mr.p: Sure. Let's start with the errant data point. It looks like that data point is where the change in time is 2.088 seconds and the displacement is 120 cm. … Oh, will you look at that? When I go back to my original, hand written data, it turns out I accidentally typed in that change in time incorrectly. The change in time is actually 2.880 seconds and not 2.088 seconds. Oops, that's my bad. Let me fix that. {fix} Oh, and will you look at

that? Fixing the change in time also fixes the average velocity for that data point and fixes the graph. It looks like, if you make an error and then fix it, the change propagates through the entire spreadsheet. How about that?

- Bobby: I bet he did that on purpose.
- Bo: I bet he's going to say harnessing the power now.

Mr.p: That is how you Harness the Power of a Spreadsheet!

Billy: Yes! Harness the Power!! **Bobby and Bo: {react}**

Mr.p: Okay, now back to the fact that our chart is

missing some things. With the chart selected, we can click on the “Chart Design” tab and then “”Add Chart Element’ and there are several options. Let’s add “Primary Horizontal” and “Primary Vertical” axes titles. Rather than “Axis Title” we should add what variable is on each axis and include its units. For example, on the y-axis we have displacement in centimeters, on the x-axis we have change in time in seconds. … I don’t feel this chart needs a title, so let’s remove that. … I also don’t feel like the legend is adding anything, so let’s remove that as well. … Okay, now let’s add a best fit line or a best fit curve, in this program it is called a “trendline”. So

let's add a "trendline". I find the best way to do this is to select "more trendline options"; this presents you with more options to chose from. It defaults to a "linear" trendline. I would suggest selecting the radio button to "display equation on chart". This displays the equation for the best-fit line or trendline. In addition, if applicable, you should select the radio button to "set y-intercept to zero". Notice the original best-fit line equation is in the slope intercept form of a line, y equals m x plus b, or the y value equals slope times the x value plus the y-intercept. Selecting "set y-intercept equal to zero" forces b, or the y-intercept to equal zero.

Okay, now I am going to move the equation to make it easier to read. And clicking back on the trendline brings back the “format trendline” options. {hear Billy} Yes Billy?

- Billy: (Mr.p?) That trendline does not approximate the data very well.
- Bo: And the trendline does not go through the origin, even though you said we “set the y-intercept equal to zero.”

Mr.p: Right, okay. Let’s deal with Bo’s observation first. Realize the trendline does not, by default, extrapolate beyond the data, it only interpolates between the data. In other words, the trendline

defaults to only displaying within the horizontal axis bounds of the known data. That is why the trendline does not extend to the left beyond our data all the way to the origin. … With regards to the trendline not approximating our data, that is because when the acceleration of the object is constant, the relationship between displacement and change in time is not linear, it is actually a polynomial of order two. Notice when we change our trendline option to “polynomial of order 2”, the trendline approximates our data extremely well.

Billy: Wow, it really does. That cool! **Bobby: Yep.**

Bo: Sure.

Mr.p: Just a little bit more about the physics of this best-fit line or trendline. The spreadsheet program displays the trendline equation with dummy “y” and “x” variables because it does not know what is on our y and x axes. However, we know displacement is on the y-axis and change in time is on the x-axis, therefore this best-fit line equation is actually displacement equals 12.5 times change in time squared plus 5.25 times change in time. This equation represents the relationship between displacement and change in time for our particular experiment.

- Billy: Oh boy, so we could use that equation to

determine the displacement of the cart for any change in time. All we have to do is plug the change in time into the equation and bam! We have the answer!! That is awesome!

- Bobby: Wow. **Bo: That is pretty cool.**

Mr.p: Yes, it is pretty cool, because it's physics. And that equation is actually one of our uniformly accelerated motion equations; displacement equals velocity initial times change in time times one half acceleration times change in time squared.

- Bobby: Uh, wait a second. I thought the initial velocity was zero in the experiment. That equation shows the initial velocity as 5.25 centimeters per

second. Why is that?

Mr.p: Very nice Bobby. That discrepancy shows that there must be experimental error, which there always is. … Okay, if you think this is harnessing the power of a spreadsheet, imagine if you are doing something like this!!!! Ooh Ahh AHHH! {Numerical Modeling excel file}

BBB: Ahh. Eek. Uh. What? Yes! Yipee.

Mr.p: A few other items you may need to know. To multiply a number use the asterisks. {2*130 =}… To get an exponent, use the “caret” symbol. Just so you know that is spelled C A R E T not C A R R O T. Just so you know, I did not realize I was spelling

caret incorrently until I was looking it up for this video. {10 cubed = & square root of 10 = } … In order to get pi in a spreadsheet you need to type the four characters P I start parenthesis and end parenthesis. Those four characters in order are treated as the number pi. {2pi =} … Be careful to use parenthesis when necessary. For example, four divided by two times two is not the same as four divided by the quantity two times two. … And the last thing is printing. Notice what happens when we click on “file” and then “print”, this defaults to printing in portrait orientation and it does not print the gridlines that display in the spreadsheet. … So

let's add lines to our data table by selecting the whole table and then adding borders by clicking on the "format" tab, selecting "cells", selecting the "border" tab and then choosing to add borders to both the "outside" and "inside" of all of our cells. … Then let's click on "file" and "page setup", change the orientation to "landscape" and adjust the scaling to fit everything to 1 page wide by 1 page tall. … Now when I go to print, notice we can see the data table better and everything fits on one page, which is really helpful. Clearly you need to adjust the print scaling depending on the amount of data, however, this is something you should always

adjust before printing. … Okay, I am sorry, however, there is one more thing we need to discuss. I showed only one way to do everything we did in this video; however, there are often many ways to get to the various dialogue boxes. For example, if you right click or two finger tap on the middle of the chart, it brings up a contextual menu where you can choose “select data” to bring up the “select data source” dialogue box. … You can right click or two-finger tap on the trendline itself to bring up a contextual menu where you can chose “format trendline” to bring up the format trendline dialogue box. … You can right click or two-finger tap on a

cell to bring up a contextual menu where you can select “format cells” to bring up a “format cells” dialogue box. … I highly recommend you become familiar with the contextual menus that come up when you right click or two-finger tap on items. Contextual menus are menus of options that change depending the context of what is selected. Contextual menus can be very helpful. … Also notice the symbol to the right of “format cells” in the contextual menu. This shows you that the keyboard shortcut for “format cells” is command 1. If you have a cell selected and press both the command and 1 keys at the same time, the “format

cells” dialogue box pops up. Keyboard shortcuts for operations you perform repeatedly can really save time. … Okay. I am finally done. I am sorry this took so long, but I had a lot to say about Harnessing the Power of a Spreadsheet! … Thank you very much for learning with me today, I enjoyed learning with you.