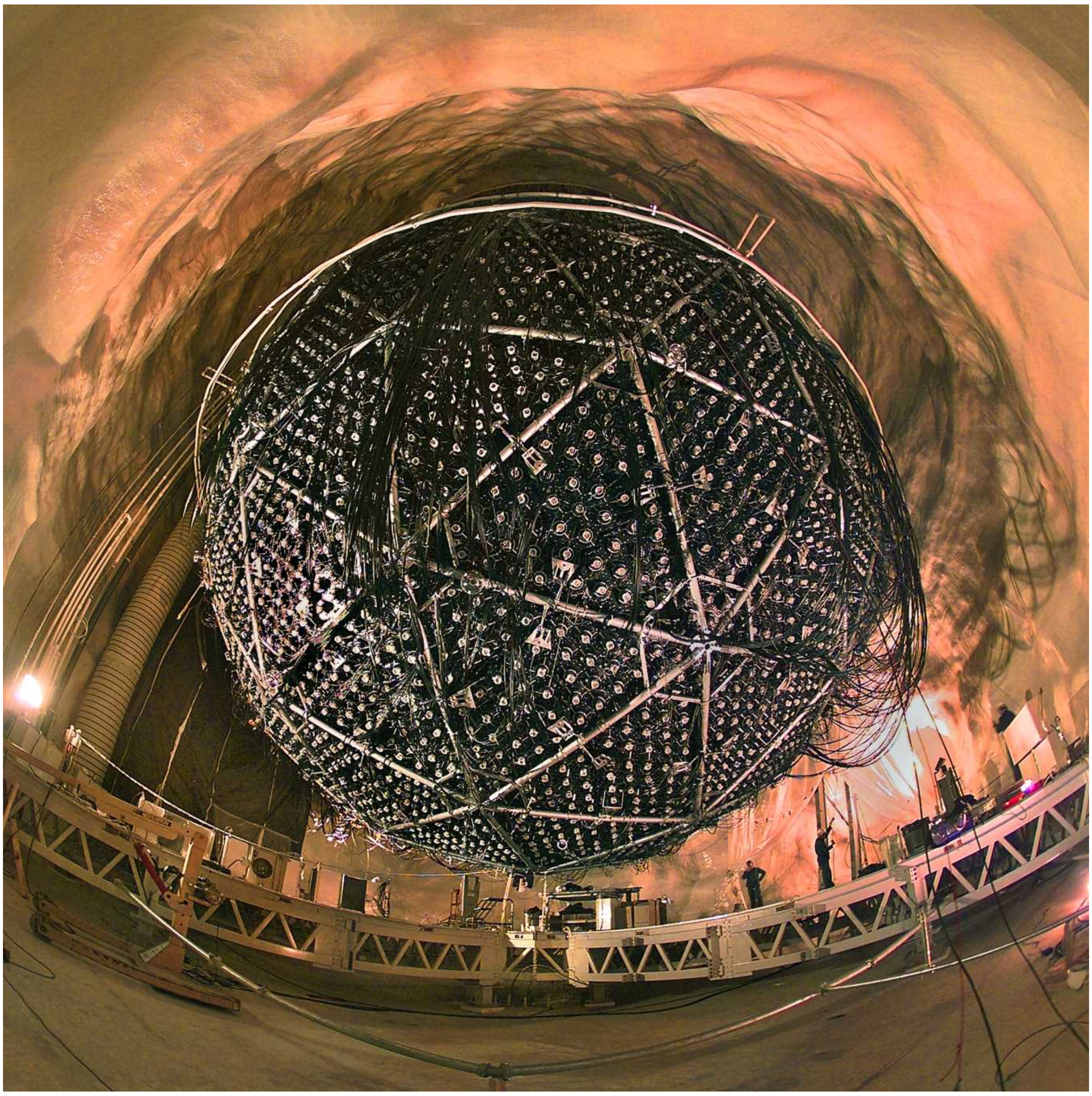
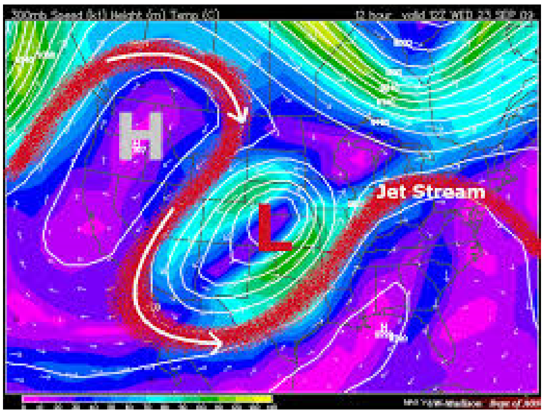
Modeling Physics

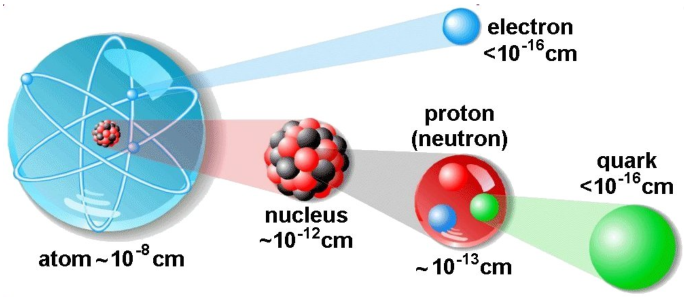
- Modeling in science and mathematics is an extremely important for:
  - > Predictions (stocks, weather, hospital patients).
  - > Determining the structure of objects we cannot sense (interior of Earth or stars, ultrasonic sounds, atoms).
  - > Analyze changes in variables.
- Models are created through graphing collected or mathematically generated data.
- In any field of science there are people who work towards modeling the nature - both the Earth and the entire universe.
- Models are always changed and updated to reflect new data, or new discoveries.
  - > Standard Solar Model, for example, was greatly fine-tuned with data from the Sudbury neutrino observatory.

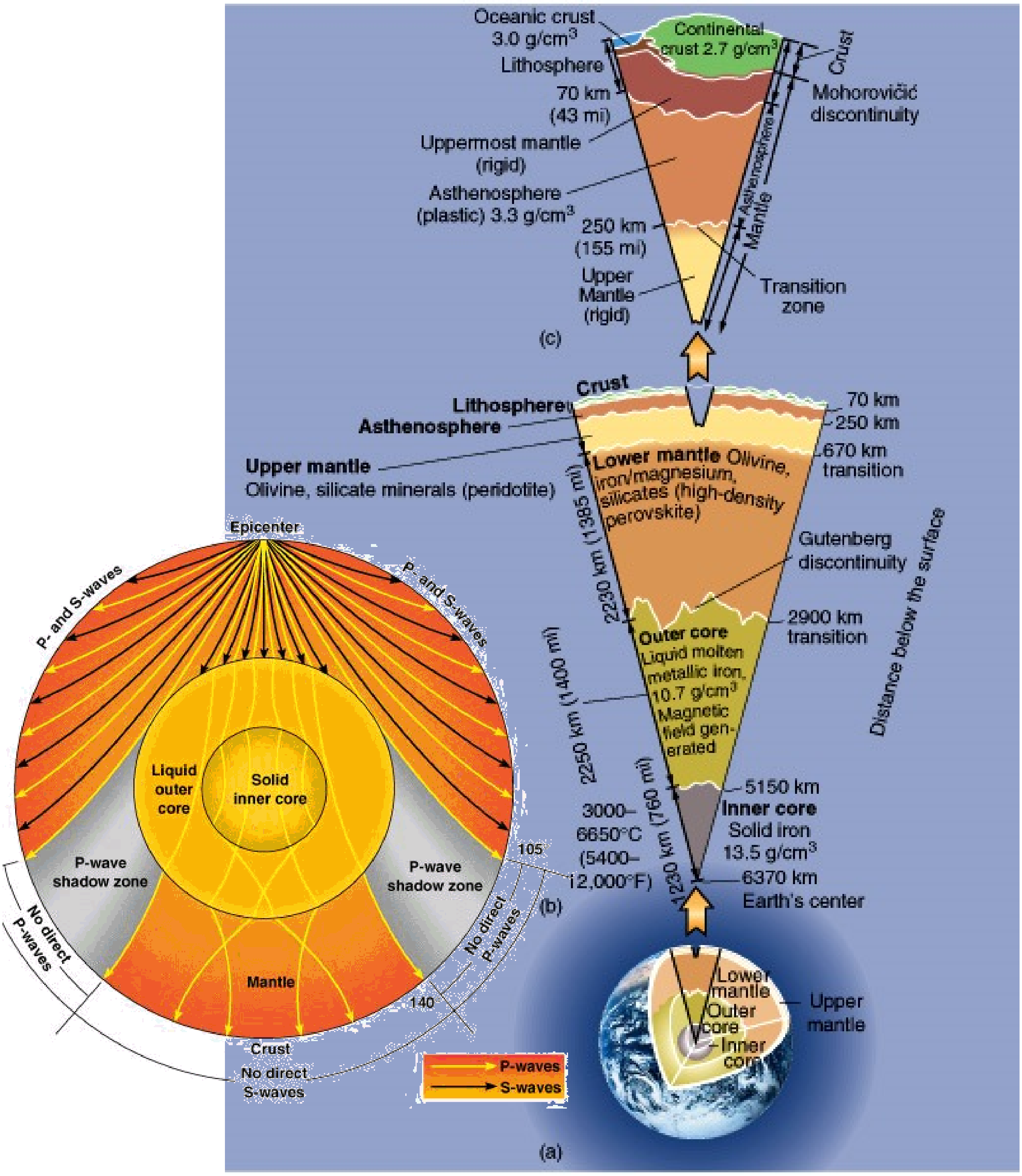


March 10, 2014

Modeling Physics - Examples







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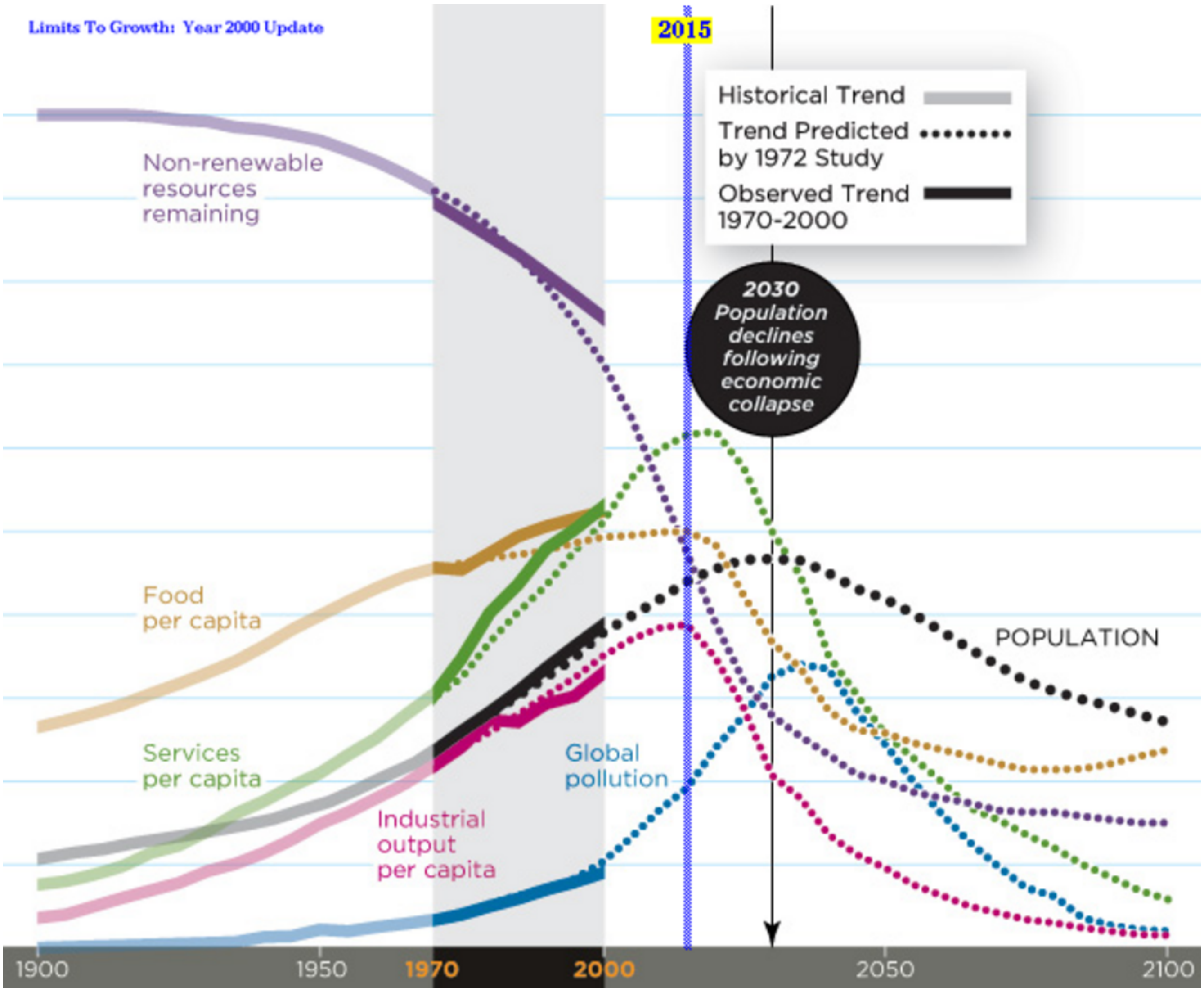
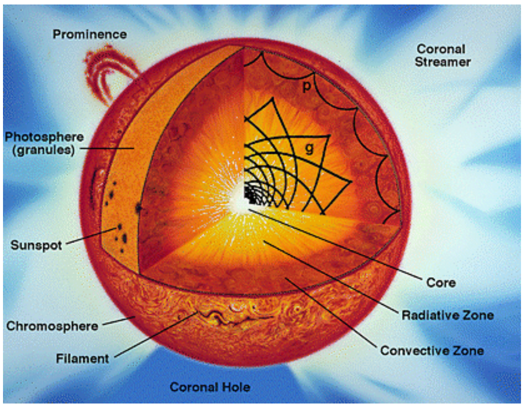


Modeling Physics - Examples

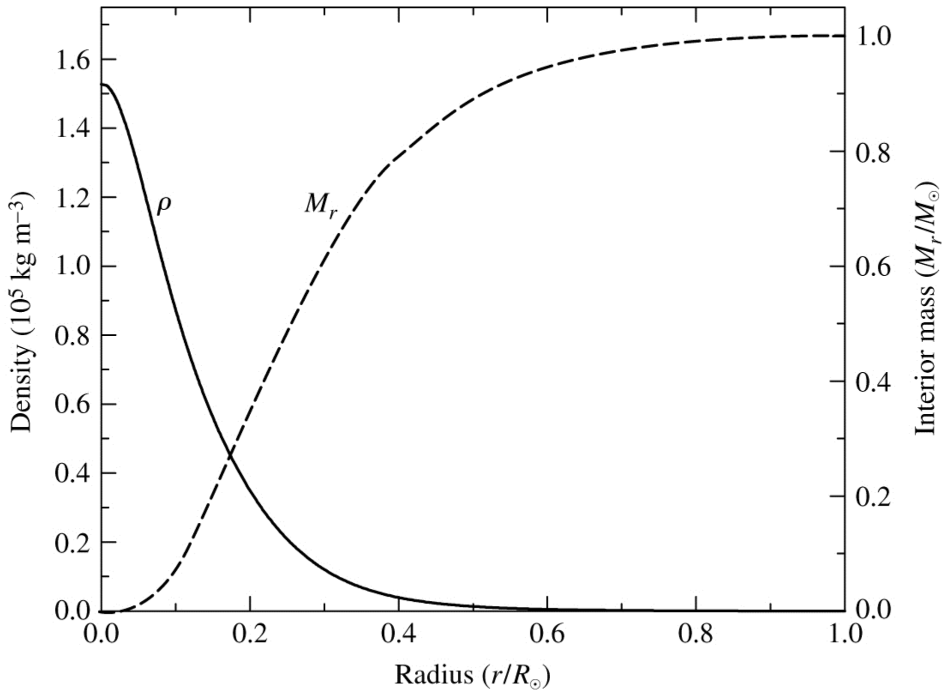


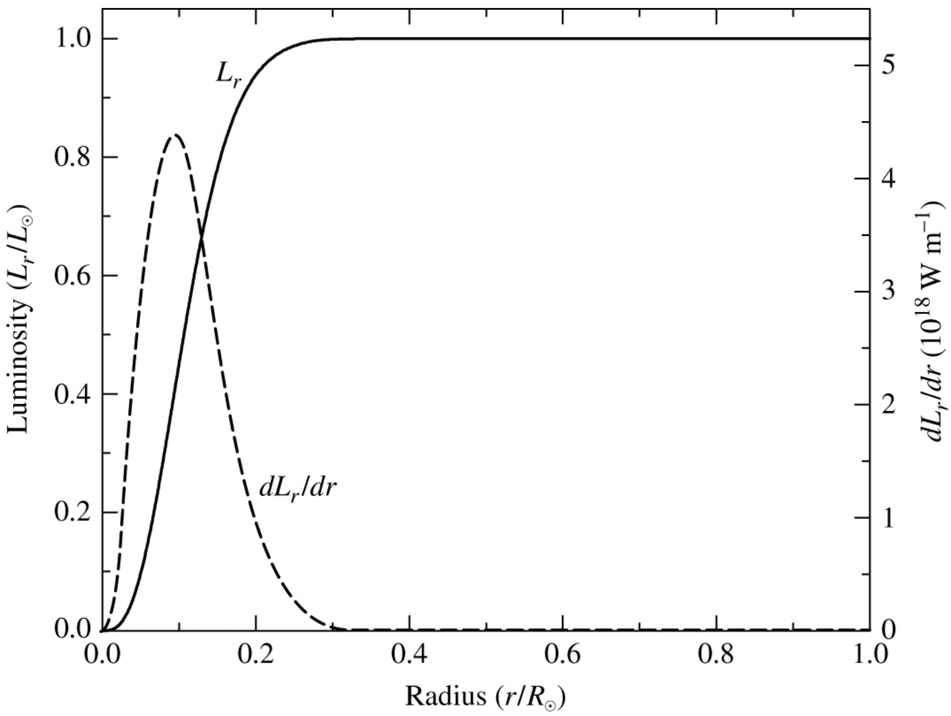
$$\frac{dP}{dr} = -\frac{GM\rho}{r^2}$$

$$\frac{dP}{dr} = -\frac{4\pi G\rho^2 r}{3}$$

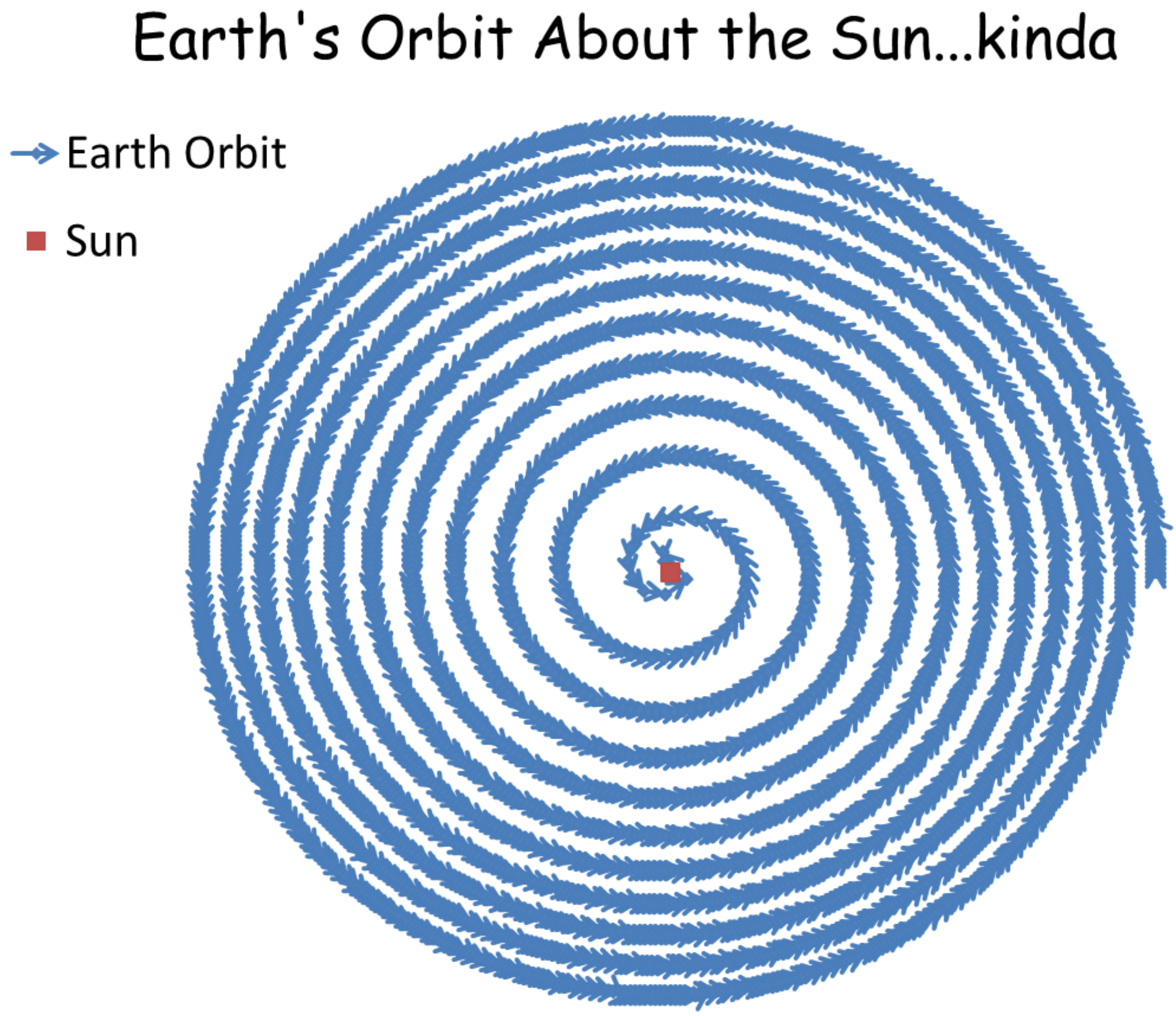
$$P(r) = \int_r^R \frac{4\pi G\rho^2 r}{3} dr$$

$$P(r) = \frac{2\pi G\rho^2}{3}(R^2 - r^2)$$



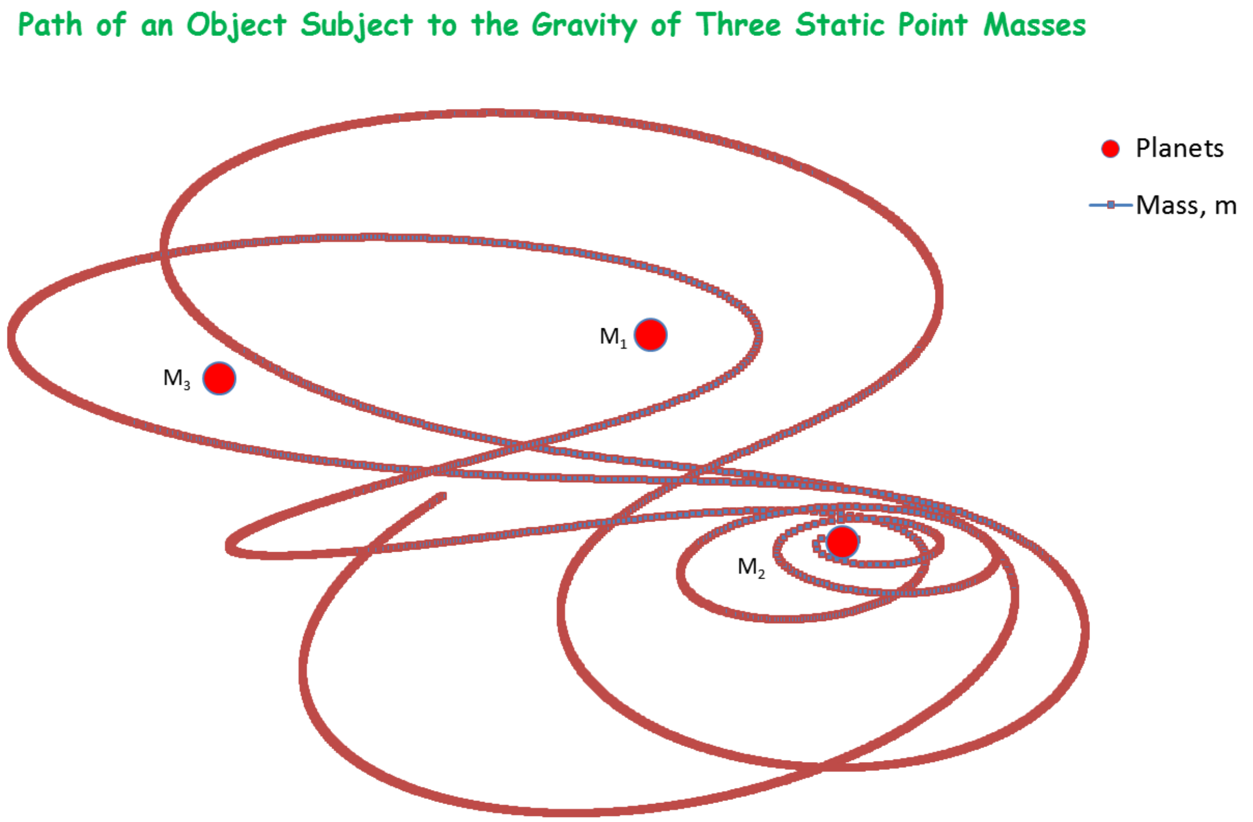


Modeling Physics



Simulated 5.3 years by calculating the position of the earth every 13.9 hours (3344 data points).

Modeling Physics



Unrealistic for objects in space (scale is not accurate). 3496 data points with dynamic variables calculated every 0.6 seconds giving a time frame of 35 minutes.

Graphical Modeling of Motion

- Most of the time when solving a physics equation we only calculate what is happening to an object at that very specific instant in time.
- For the next week or so you will learn how to model an object's motion over a period of time. For this we will use Excel to generate data at specific time intervals.
  - > You will learn how to create and manage basic formula's and scatter plots in Excel.
  - > Save and back up your work frequently. We will come back to modeling in our Forces unit.

SAVE

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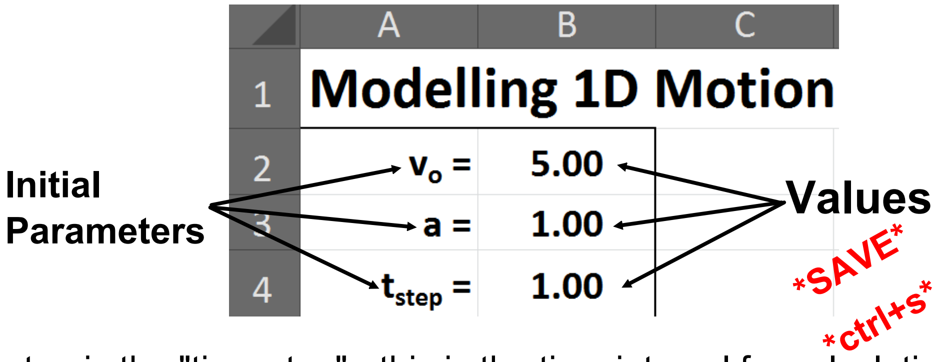
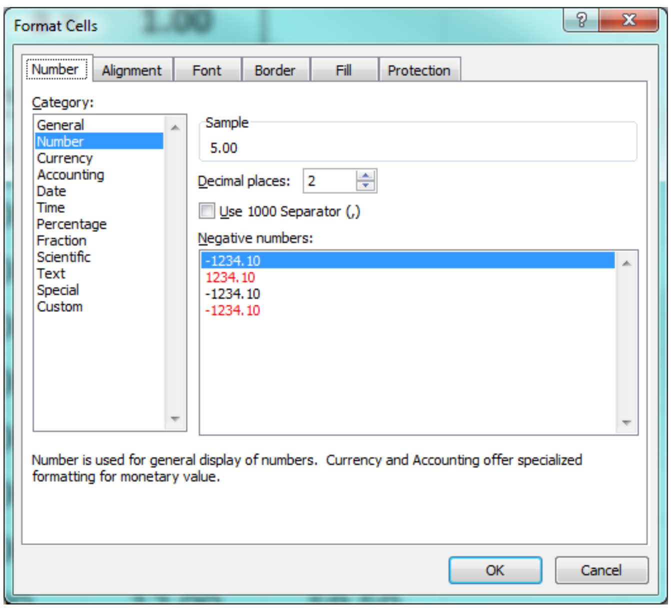
Set Up - Excel Tutorial

- Open Excel
- Type initial parameters and its value in the adjacent cell.

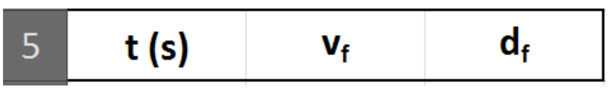


- t_{step} is the "time step" - this is the time interval for calculating the object's instantaneous motion. This is the most important parameter in our modeling.

- Keep your work organized with good formatting. Found under the "font" and alignment sub-tabs.
  > Note the use of subscripts (select text then right-click, choose format cells, check the subscript box under the "font" tab).
  > Cells with parameter symbols are right-aligned.
  > Values are centered and display two decimal places (select cells then right-click, format cells, find the decimal places under the "number" tab).



- Create column headings for the data that will be generated.
  > We will assume all values are in proper SI base units.
  > When labeling graphs we must include units.



- Below each heading enter the appropriate formula.
  - > We will start all of our modeling at time 0.0, type 0.0 in cell A6.
  - > In Excel the cell address takes the place of the variables used in formulas.

SAVE
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For example, in B6 type: =B2+B3*A6

$$v_o + at$$

The "=" sign is very important, it tells Excel we are inputing a formula and not just text.

In C6 type: =B2*A6+0.5*B3*A6^2

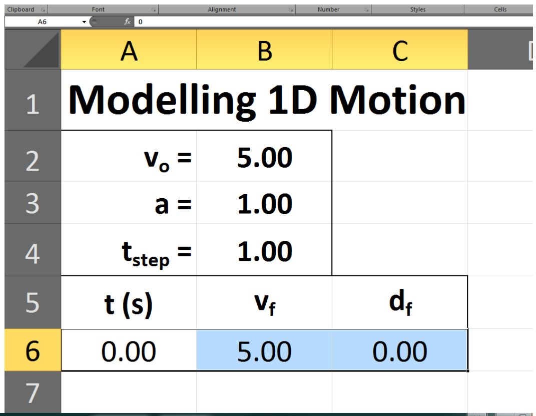
$$v_o t + \tfrac{1}{2}at^2$$

The first row of data becomes:

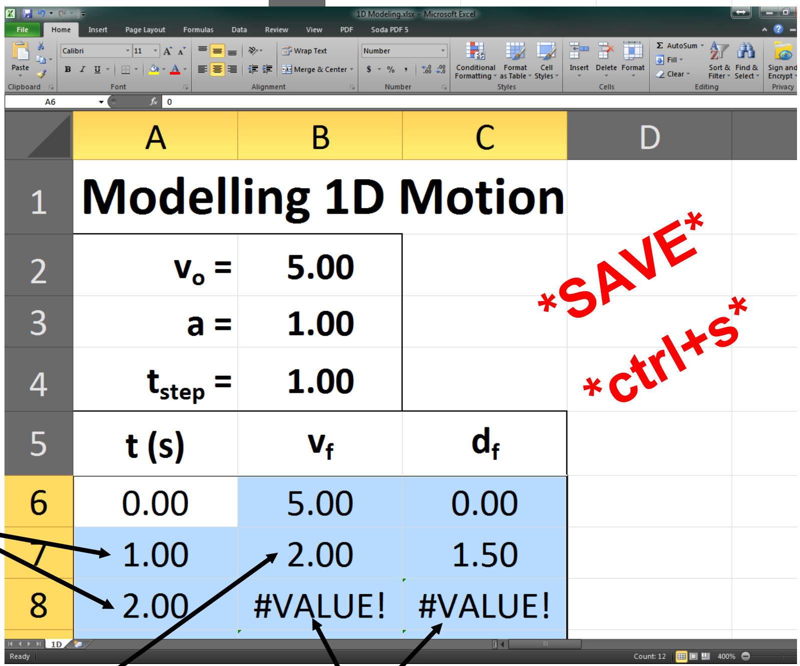
5	t (s)	v_f	d_f
6	0.00	5.00	0.00

- This is where the power of Excel kicks in. By selecting the cells of which we want more data, we can copy the forumlas down the columns.
- BIG HOWEVER, Excel automatically adjusts the cell row numbers each time - we do not want every variable to change for each calculation. See the next page for an explanation.

- Select cells.
- Place cursor at the bottom right corner of the selection.
- Drag down as many rows as desired.



Excel, we have a problem!



Time auto-incremented. We do not want this, we want to control the increments.

How can v_f be smaller than v_o if the acceleration is positive?!

Excel encountered text in a cell it thinks is numerical.

Look at the formulas in row 8:

B8: =B4+B5*A8 C8 =B4*A8+0.5*B5*A8^2

not v_o,

v_o is cell B2

not acceleration,

acceleration is cell B3

- **As said in class, to analyze an object's motion we usually don't change our initial conditions (or parameters).**
  > **We must tell Excel to do just that!**

- Don't worry about the "bad" data, we will copy over it.
- Enter the following in cell B6 and C6:

B6: =$B$2+$B$3*A6

SAVE
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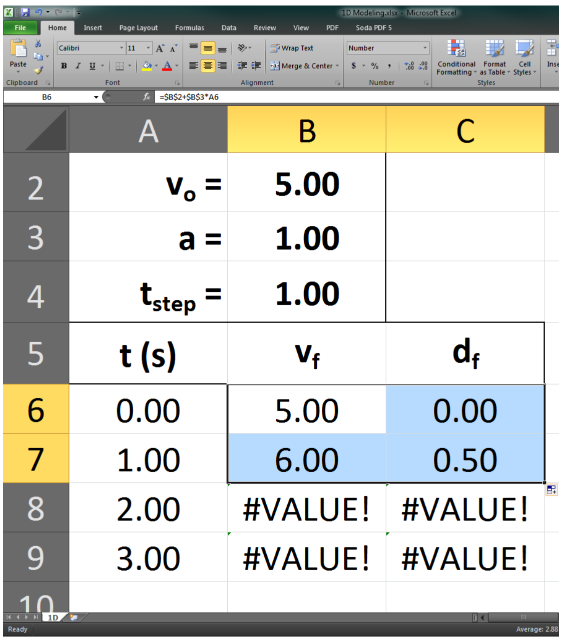
C6: =$B$2*A6+0.5*$B$3*A7^2

The "**$**" tells Excel not to change the row or column it comes before. Since there is a "**$**" before the column letter and row number each formula will read v_o from **B2** and ***a*** from **B3**.



	A	B	C
2	v_o =	5.00	
3	a =	1.00	
4	t_{step} =	1.00	
5	t (s)	v_f	d_f
6	0.00	5.00	0.00
7	1.00	6.00	0.50
8	2.00	#VALUE!	#VALUE!
9	3.00	#VALUE!	#VALUE!
10			

- Once entered, copy only those two cells down one row only.
- Now edit the time column to our desired step. Enter the following in A7:

=A6 + $B$4

- This formula adds the **time step** to the previous time value in the cell above it.
- Row 7 now contains all the correct formulas to generate our data.
- Select the three cells in row seven and copy them down to row 16 (the first 10 seconds).

You should have the following (may need to format the cells to have two decimal places):

	A	B	C
1	**Modelling 1D Motion**		
2	**v_o =**	**5.00**	
3	**a =**	**1.00**	
4	**t_{step} =**	**1.00**	
5	**t (s)**	**v_f**	**d_f**
6	0.00	5.00	0.00
7	1.00	6.00	5.50
8	2.00	7.00	12.00
9	3.00	8.00	19.50
10	4.00	9.00	28.00
11	5.00	10.00	37.50
12	6.00	11.00	48.00
13	7.00	12.00	59.50
14	8.00	13.00	72.00
15	9.00	14.00	85.50
16	10.00	15.00	100.00

- Once setup the power of the model is that we can enter new initial parameters and the formulas will automatically be recalculated.
  - » Change v_o, ***a***, and t_{step}.
  - » Generate more data by copying the formulas.

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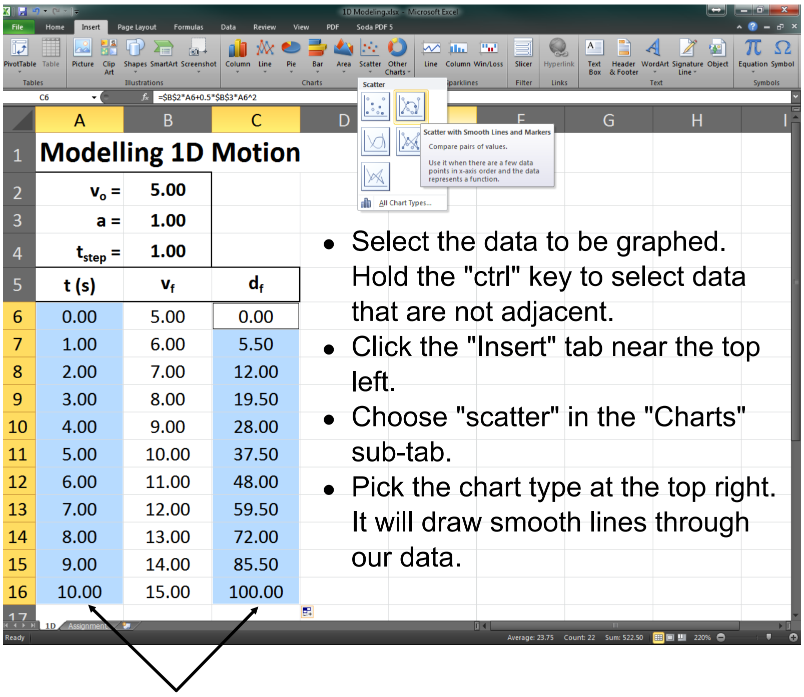
Graphing Scatter Plot Data in Excel



v_o =	5.00	
a =	1.00	
t_{step} =	1.00	
t (s)	v_f	d_f
0.00	5.00	0.00
1.00	6.00	5.50
2.00	7.00	12.00
3.00	8.00	19.50
4.00	9.00	28.00
5.00	10.00	37.50
6.00	11.00	48.00
7.00	12.00	59.50
8.00	13.00	72.00
9.00	14.00	85.50
10.00	15.00	100.00

- Select the data to be graphed. Hold the "ctrl" key to select data that are not adjacent.
- Click the "Insert" tab near the top left.
- Choose "scatter" in the "Charts" sub-tab.
- Pick the chart type at the top right. It will draw smooth lines through our data.

Left-most column is defaulted to the horizontal axis. Right-most the vertical axis. Axis data is editable.

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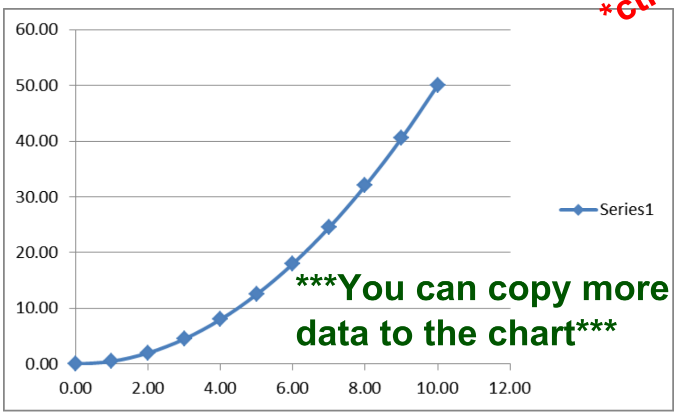
You get the following:



*****You can copy more data to the chart*****

- Charts can be edited with the "Chart Tools" tab that comes up. The "Chart Layouts" sub-tab will be important in labeling your graphs.
- Right-clicking on your graph data brings up options as well (you can rename your series, for example).

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Your turn:

- Create a graph of v_f versus t.
- Explore the "Chart Layout" sub-tab to label and title your graph.
- Change the series name to read "Red Car"
- Charts are automatically updated if your data changes. Change your initial parameters.

Modeling 1D Motion - Assignment

March 2014

Instructions

- You can work in groups of up to three.
- All generated data, graphs, and answers to questions are to be typed in MS Word and submitted by Friday, March 14th. (anything in Excel can be copied into Word)

Part 1 - Analyzing the Motion of Two Cars

- West ⟵⟶ + East

Red Car	Blue Car	
v_o = 7.50 m/s	v_o = -15.00 m/s	t_{step} = 0.5 seconds for each car.
a = -1.50 m/s^2	a = 1.50 m/s^2	

1. Generate $\boldsymbol{v_f}$ and $\boldsymbol{d_f}$ data for the first 20 seconds (include time 0.00).
2. Graph the **d_f vs t** data for each car on the same set of axis.
3. Graph **v_f vs t** data for each car on the same set of axis.
   > Choose chart layouts that lets you edit all titles.
   > You may want to play with the gridline and axis settings.

Analysis Questions - Graph of **d_f vs t**

1. In what direction did each car start driving?
2. At what time did each car change direction?
3. At what time was each car back at the starting position?
4. How far from the starting position did the car's cross paths? At what time did this happen?
5. Calculate the total distance traveled by each car (may want equation editor in Word).
6. Calculate the average speed and velocity of each car (use equation editor in Word).

Analysis Questions - Graph of **v_f vs t**

1. At what time did each car change direction? Does this match your answer to #1 above?
2. Calculate the slope of the red and blue lines. How do the slopes relate to your initial parameters?
3. Calculate the area between the red line and time axis for the first 5 seconds. Compare your answer to the position of the red car at 5 seconds.
4. Do the same as #3 but for the blue car at 10 seconds.
5. Do the same as in #3 but for the red car's final 15 seconds.
6. Add your answer to #5 with that of #3. Compare your answer to the position of the red car at 20 seconds.
7. Add the absolute value of #5 to that of #3. Compare that to total distance traveled by the red car.

Part 2 - Modeling the Changing Motion of an object.

Create a graphical model of **v_f** and **d_f** verses **time** (0.5 second time steps) for the following motion information (use a scatter plot with straight lines):

$0 \le t \le 5$	$5 \le t \le 10$	$10 \le t \le 15$
v_o = -12.0 m/s	Holds a content velocity	a = -2.0 m/s^2
a = 4.0 m/s^2		

Attachments

Complex Orbit.xlsx