COMPUTATIONAL PHYSICS WITH SPREADSHEET – II

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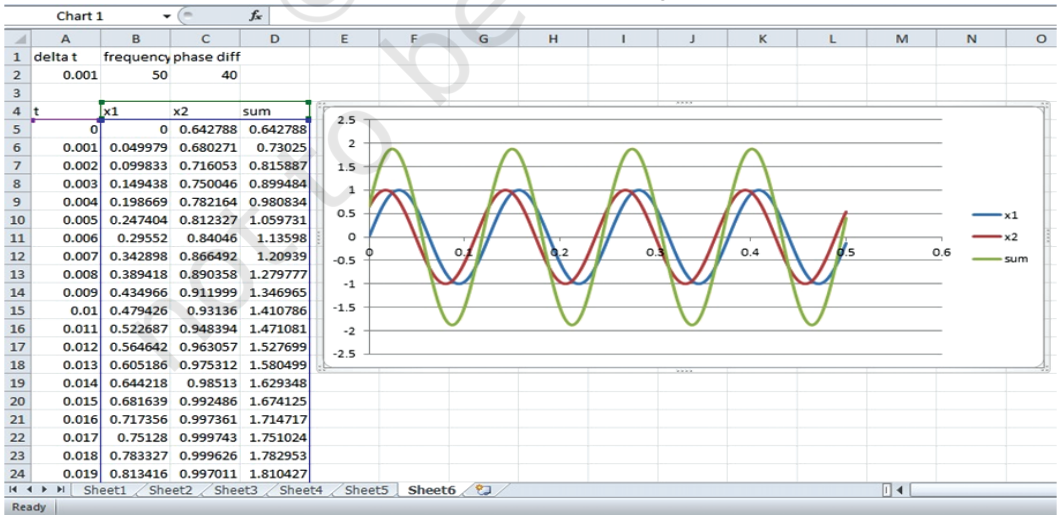
In the first two articles of the series, we have discussed the use of EXCEL as a tool to understand graphs and variations of physical quantities with respect to each other based on equations. In this article, we go one step further to show how to understand phenomena that deal with variation with respect to time and space are understood using EXCEL. When students are taught the superposition of waves, they are merely shown the graphs of how these waves add in space (stationary waves) and in time (beats formation). These graphs are merely abstract representations unless they can draw or are shown how to draw. This calculation becomes very time-consuming unless we can use computers. Now this power is accessible to most students on their mobile, and MS-EXCEL is free for android users. In this article, we show how to study the formation of beats and stationary waves with the help of MS-EXCEL. How to use EXCEL is already discussed in the first article of the series

Keywords: Addition of two waves, Formation of beats, formation of stationary waves

Addition of SHM

When two simple harmonic motions of the same frequencies are added, the total is also a simple harmonic motion with a phase difference equal to the average phase of the two-component waves.

It is instructive to see that by changing the phase difference between the two waves, how the phase difference and the amplitude of the sum change.



t	x1	x2	sum
0	0	0.642788	0.642788
0.001	0.049979	0.680271	0.73025
0.002	0.099833	0.716053	0.815887
0.003	0.149438	0.750046	0.899484
0.004	0.198669	0.782164	0.980834
0.005	0.247404	0.812327	1.059731
0.006	0.29552	0.84046	1.13598
0.007	0.342898	0.866492	1.20939
0.008	0.389418	0.890358	1.279777
0.009	0.434966	0.911999	1.346965
0.01	0.479426	0.93136	1.410786
0.011	0.522687	0.948394	1.471081
0.012	0.564642	0.963057	1.527699
0.013	0.605186	0.975312	1.580499
0.014	0.644218	0.98513	1.629348
0.015	0.681639	0.992486	1.674125
0.016	0.717356	0.997361	1.714717
0.017	0.75128	0.999743	1.751024
0.018	0.783327	0.999626	1.782953
0.019	0.813416	0.997011	1.810427

Fig.1

Formation of Beats

To see the formation of beats, we take two waves as

First Wave: $y_1 = sint$, and Second Wave $y_2 = sin(1.1t)$:

Superposition gives: $y = y_1 + y_2$:

Here we have chosen: $\omega_1 = 1.0$ and $\omega_2 = 1.1$

We generated this data using MS EXCEL. Say first x value (in this case, zero) is in cell C5. Then type '=SIN(t)' and ' =SIN(1.1*t)' in D5 and E6 respectively and enter. Type = D5 + E5' in F5. After the value is generated, please select the box and drag + sign on the lower right corner of the box by bringing the mouse cursor at it and generating data for each value of x. Selecting all four data columns, choosing the appropriate plot generates the wave pattern.

You may modify these waves with different frequencies by changing ω_2 to some other value and seeing its effect.

In all first graphs that depict waves y_1 and y_2. The second graph shows the superposition of the two together.

It can be seen that the amplitude of the superposition varies from maximum to minimum in time

$$\frac{1}{n_1 - n_2} = \frac{2\pi}{w_1 - w_2} = 20\pi = 62.84$$

Table 1

t	y_1 = sin(t)	y_2 = sin(1.1*t)	$y = y_1 + y_2$
0	0	0	0
0.1	0.099833	0.109778	0.209612
0.2	0.198669	0.21823	0.416899
0.3	0.29552	0.324043	0.619563
0.4	0.389418	0.425939	0.815358
0.5	0.479426	0.522687	1.002113
0.6	0.564642	0.613117	1.177759
0.7	0.644218	0.696135	1.340353
0.8	0.717356	0.770739	1.488095
0.9	0.783327	0.836026	1.619353
1	0.841471	0.891207	1.732678
1.1	0.891207	0.935616	1.826823
1.2	0.932039	0.968715	1.900754
1.3	0.963558	0.990105	1.953663
1.4	0.98545	0.999526	1.984976

1.5	0.997495	0.996865	1.99436
1.6	0.999574	0.982154	1.981728
1.7	0.991665	0.955572	1.947236
1.8	0.973848	0.917438	1.891286
1.9	0.9463	0.868215	1.814515
2	0.909297	0.808496	1.717794
98	-0.57338	0.833742	0.26036
98.1	-0.65231	0.889317	0.237007
98.2	-0.72472	0.934143	0.209423
98.3	-0.78989	0.967677	0.177788
98.4	-0.84717	0.989514	0.142348
98.5	-0.89598	0.999389	0.103412
98.6	-0.93584	0.997185	0.061347
98.7	-0.96635	0.982926	0.01658
98.8	-0.9872	0.956787	-0.03041
98.9	-0.99819	0.919081	-0.07911
99	-0.99921	0.870266	-0.12894
99.1	-0.99024	0.810932	-0.17931
99.2	-0.97138	0.741795	-0.22958
99.3	-0.94281	0.663691	-0.27912
99.4	-0.90482	0.577565	-0.32726
99.5	-0.8578	0.484457	-0.37334
99.6	-0.8022	0.385494	-0.4167
99.7	-0.73858	0.28187	-0.45671
99.8	-0.66759	0.17484	-0.49275
99.9	-0.58992	0.065696	-0.52423
100	-0.50637	-0.04424	-0.55061

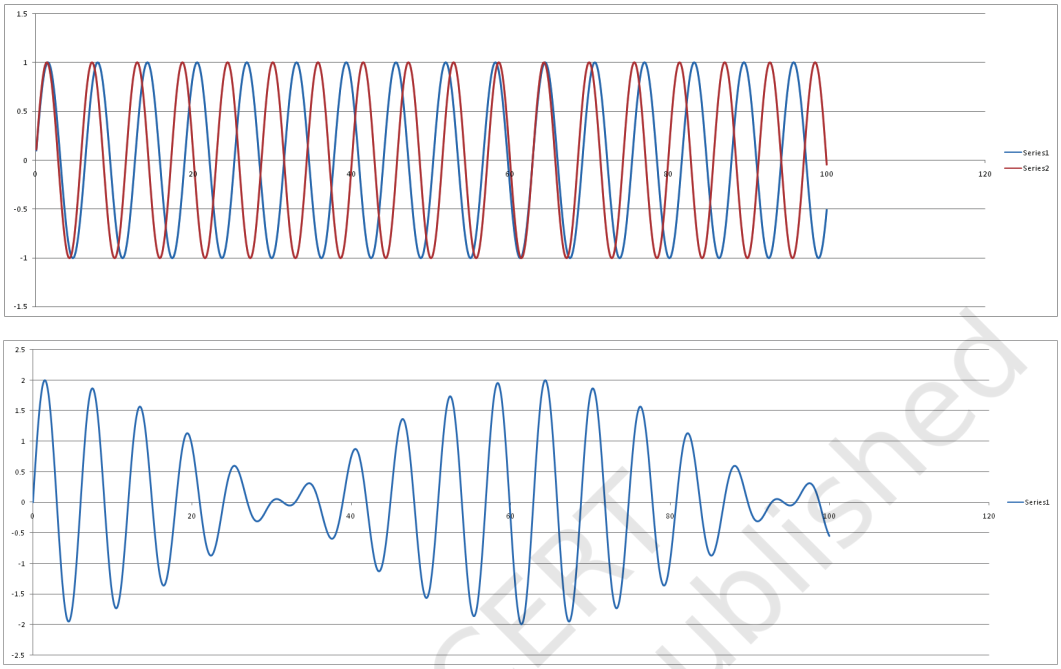


Fig.2

Students may take n_2/n_1 as some number other than 1.1 and see what happens to the beats pattern.

Formation of Stationary Waves

Incident Wave: $y_1 = 2\sin(\omega t+\pi x+0.2)$, Reflected Wave :$y_2 = 2\sin(\omega t-\pi x+0.2=\pi)$ Superposition gives: $y = y_1 + y_2 = 4\sin\pi x \cos(\omega t+0.2)$ Here we have chosen : $\lambda = 2$

We have taken the incident wave like the one travelling in negative x-direction and reflected at x = 0 by a rigid boundary (this brings an additional phase of 180°.

We generated this data using MS EXCEL. Say, first x value (in this case, zero) is in cell E6. Then type '=-2*SIN(3.142/4 - 3.142*E6+0.2)' and ' =2*SIN(3.142/4 + 3.142*E6+0.2)' in F6 and G6, respectively and enter. Type '= F6 + G6' in H6. After the value is generated, please select the box and drag + sign on the lower right corner of the box by bringing the mouse cursor at it and generating data for each value of x and selecting all four data columns, x, y_1 and y_2, and choosing appropriate plot generates the wave pattern. Repeat this at different time instants. In the end, we have a plot of all eight standing waves within one time period, showing what it looks like.

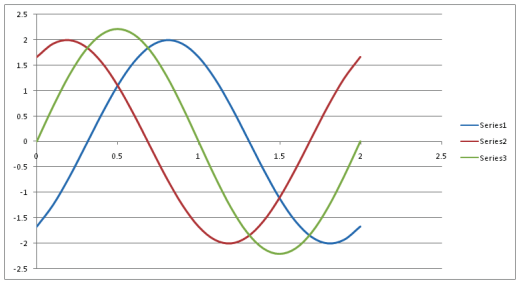
You may modify these waves with different phases by changing 0.2 additional phase to some other value and seeing its effect. You may make this extra phase 0 and see the effect on all the waves. In all first eight graphs that depict waves at a different instant, 1st series is an incident wave, 2nd

series is a reflected wave, and 3rd series is a superposition of the first two. The last graph shows all eight superpositions together. If one takes double or, say, 20 such graphs within one time period, it may generate a loop itself where individual superposed waves may not get noticed.

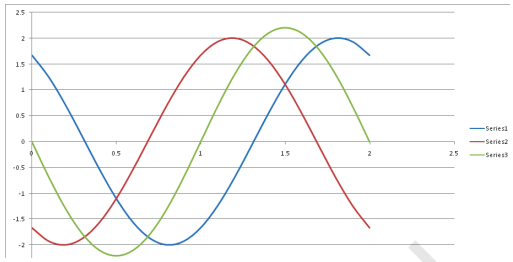
Table. 2

	theta = 0.7855	**at T/8**	**PI=3.142**
x	y^1= 2*sin(theta + PI*x+0.2)	Y^2 = - 2*sin(theta - PI*x+0.2)	$y = y^1+y^2$
0	1.667096836	-1.667096836	0
0.1	1.926955785	-1.24400886	0.682946924
0.2	1.998142361	-0.69911731	1.299025051
0.3	1.873686534	-0.085773685	1.787912849
0.4	1.56577404	0.535968226	2.101742266
0.5	1.104553253	1.105232339	2.209785591
0.6	0.535183288	1.566280783	2.10146407
0.7	-0.086587621	1.873971317	1.787383696
0.8	-0.699880549	1.998177301	1.298296751
0.9	-1.244646673	1.92673746	0.682090787
1	-1.667546771	1.666646623	-0.000900148
1.1	-1.92717379	1.243370842	-0.683802948
1.2	-1.99810709	0.698353954	-1.299753135
1.3	-1.87340144	0.084959734	-1.788441706
1.4	-1.565267038	-0.536753076	-2.102020114
1.5	-1.103873984	-1.105911241	-2.209785225
1.6	-0.53439826	-1.566787265	-2.101185526
1.7	0.087401542	-1.874255789	-1.786854246
1.8	0.700643673	-1.998211909	-1.297568236
1.9	1.245284279	-1.926518816	-0.681234537
2	1.667996431	-1.666196134	0.001800296

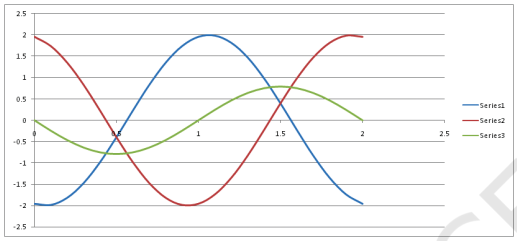
At t = T/8



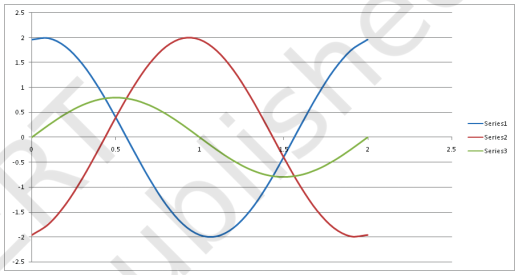
At t = $\frac{5}{8}$ T



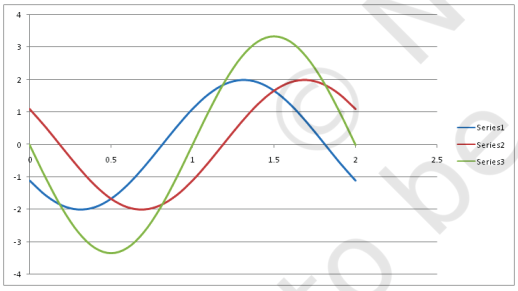
At t = T/4



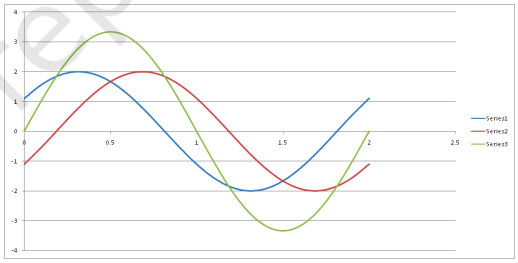
At t = 3T/4



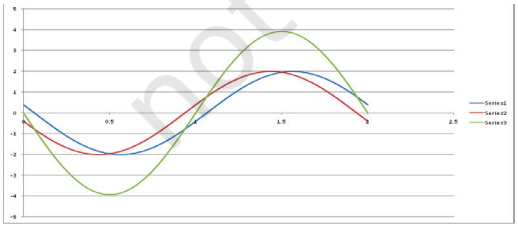
At t = 3T/8



At t = 7T/8



At t = T/2



At t = T

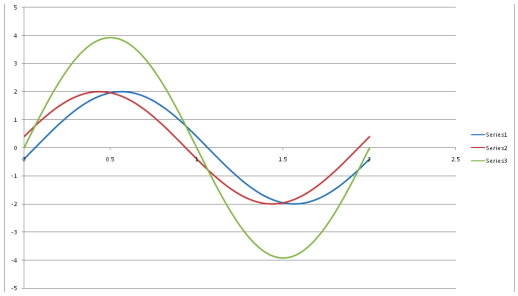


Fig.3

The figure below shows all eight superposed waves simultaneously. If the frequency is more than 10 Hz, we see all superpositions simultaneously, making them appear as loops of lengths λ/2. This is as seen below.

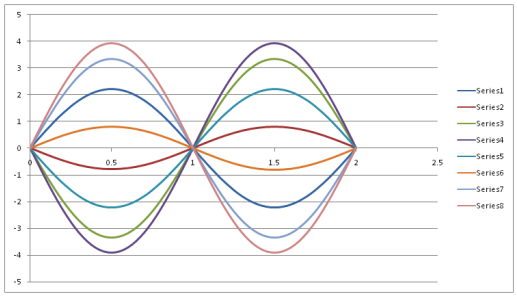


Fig. 4

Students may try taking more than 8 slices of the time period and try to understand the pattern better.

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