Microsoft Excel Software Usage for Teaching Science and Engineering Curriculum

Gurmukh Singh and Khalid Siddiqui

Department of Computer and Information Sciences

State University of New York at Fredonia

Fredonia, NY 14063

singh@fredonia.edu

CIT-08, Genesee Community College, Batavia

May 27-29, 2008

Main Objectives of Presentation

- Use of Microsoft Software Excel 2003/2007 Software for teaching college and university level curriculum in science and engineering for college undergraduates
- Microsoft Excel Software targeted for undergraduate students in computational physics and physics education
- Computer science and bio-medical sciences
- Perform simulations of a projectile such as a missile launched from an airplane to hit a target on ground for physics majors
- Rolling of nine dice with six surfaces in a casino game for computer science majors

Why Microsoft Excel in College?

- Development and advancement in high speed micro-computers such as IBM and Mac based PCs
- Portable laptops as versatile class-room tools to teach undergraduate science and engineering curriculum
- Microcomputer machines employ several software systems such as Excel, Access, Word, PowerPoint, Groove, InfoPath, OneNote, Outlook, Publisher, FrontPage etc.
- Object oriented computing languages like C++, C#, Visual Basic (VB), Java Script, SQL etc.
- Such software systems are extensively used for undergraduate, graduates teaching in colleges, scientific labs, private companies, businesses and banks in world

Why Microsoft Excel 2007 in College?

- Adoption of internet technologies in undergraduate science and engineering curricula
- International/National conferences to enhance and share the knowledge gathered with other educators and researchers
- Use of Internet technologies to interactively teach in undergraduate and graduate classroom setting or during distant learning in virtual universities, which is a very effective teaching tool for the science and engineering curricula

Examples of Projectile Motion in Physics

- Launching of a cruise missile from an air plane to hit an enemy post
- Motion of a space shuttle or rocket from launching pad
- Firing an artillery shell to destroy an enemy post
- Firing of a cannon ball from a cannon
- Hitting of a baseball with baseball bat
- Hitting a golf ball with golf club
- Firing of a bullet from a gun or pistol
- Shooting of an arrow with a bow during hunting
- Punting of a football during ball game
- Kicking of a football during kick off in ball game
- Study the projectile motion in a physics lab

1. Theory and Algorithm of Projectile Motion

Components of projectile velocity **v**(*x,y,t*), acceleration **a**(*x,y,t*), vecor force **F**(*x,y,t*), **r**(*x,y,t*) position vector in two-dimensional space are:

$$v_x = \frac{dx}{dt} \qquad v_y = \frac{dy}{dt}. \qquad (1)$$

$$a_x = \frac{dv_x}{dt}, \qquad a_y = \frac{dv_y}{dt} \qquad (2)$$

$$F_x(x, v_x, t) = ma_x, \quad F_y(y, v_y, t) = ma_y \qquad (3)$$

$$x = x_0 + v_{0x}t + \frac{1}{2}a_x t^2, \quad y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2 \qquad (4)$$

$$v_x = v_{0x} + a_x t, \quad v_y = v_{0y} + a_y t \qquad (5)$$

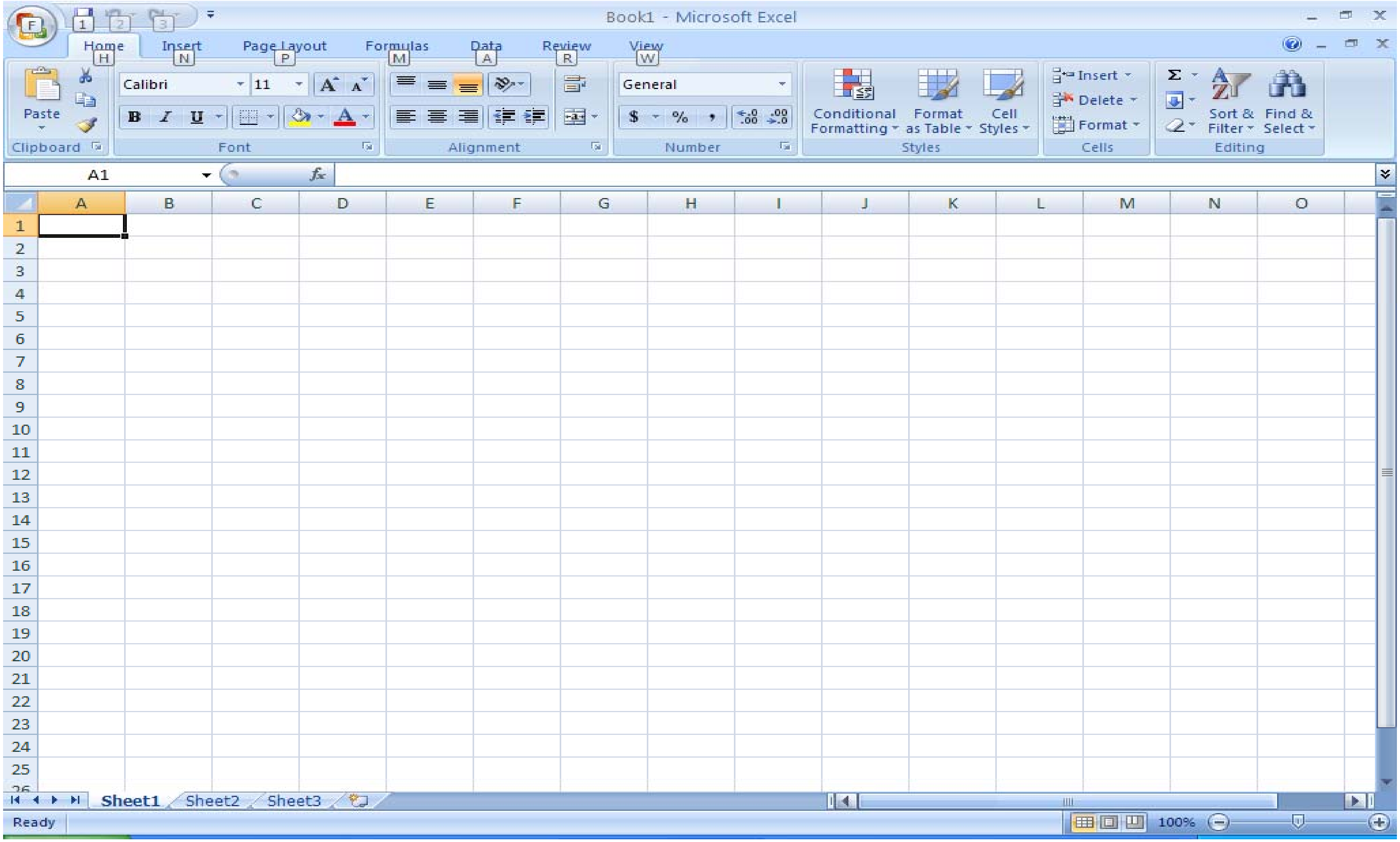
Theory and Algorithm of Projectile Motion (contd.)

where x_0, y_0 and v_{0x}, v_{0y} are initial position coordinates and initial components of velocity of projectile along *x*- and *y*-directions, respectively. Eq. (4) and Eq. (5) are called *kinematic equations* of projectile motion. We employed these equations to simulate the projectile trajectory under action of gravity with the simplest assumption of no air resistance and implemented boundary conditions for the present problem (i.e. $a_x = 0$, $a_y = g = -9.80$ m/s^2, $v_y = V$, $v_{0y} = V_0$, $y = H$, and $y_0 = H_0$), so that Eq. (4) and Eq. (5) could be written as follows along *y*-axis

$$V = V_o + gt,\ H' = H_o + V_o t + 0.5gt^2. \qquad (6)$$

These equations will be used in to simulate the projectile motion to simulate its exact velocity *V* and exact height *H*' at a given instant of time.

Fig. 1: Typical Excel 2007 Interface, Home Tab on



Interactive Simulation of Projectile Motion

Eq. (6) is used to simulate projectile motion using Microsoft Excel 2007 [5]. A cell formula in Excel always starts with an equals sign (=), and thus the corresponding cell formulas of Eq. (6) for simulation of exact velocity and height should be typed in Excel spreadsheet as

$$V = V_o + g\text{*A2} \qquad (7)$$

$$H' = H_o + V_o\text{*A2 + 0.5*g*A2^2} \qquad (8)$$

where V_o = 0 m/s and H_o = 100 m is the value of initial velocity and height of the projectile in y-direction, and A2 = dt = 0.0125 s represents the relative cell reference for a change in time interval, dt, which is memorized in Excel by some thing called "*Defined Name*" [5] and its value may exist in a different cell, whose cell reference could be used in Eq. (7) and Eq. (8) for the current simulation work.

Interactive Simulation of Projectile Motion

We are depicting only the first forty simulated values of velocity, *V* and computed height, *H'*, of the projectile in Table I. Also given in this Table is the exact height of the projectile and % error in height. The computed height *H* is always a little less than that of the exact height *H'*. For 93% of the simulated data points, the magnitude of percent error between simulated height and actual eight is $< 4.0\%$, which indicates that the accuracy in computed values of projectile height is pretty good, which further proves that the chosen time interval $dt = 0.0125$ s almost satisfies the necessary and sufficient condition of differential calculus that in the limit of infinitesimal time interval, $\Delta t \rightarrow 0$ for the projectile motion.

Table 1: Partial Results of Interactive Simulation

Serial #	Time (sec)	Velocity (m/s)	Calculated Height (m)	Exact Height (m)	% Error in Height (m)
1	0.0000	0.0000	100.0000	99.5406	-0.4594
2	0.0125	-0.1225	99.9985	99.9992	0.0008
3	0.0250	-0.2450	99.9954	99.9969	0.0015
4	0.0375	-0.3675	99.9908	99.9931	0.0023
5	0.0500	-0.4900	99.9847	99.9878	0.0031
6	0.0625	-0.6125	99.9770	99.9809	0.0038
7	0.0750	-0.7350	99.9678	99.9724	0.0046
8	0.0875	-0.8575	99.9571	99.9625	0.0054
9	0.1000	-0.9800	99.9449	99.9510	0.0061
10	0.1125	-1.1025	99.9311	99.9380	0.0069
11	0.1250	-1.2250	99.9158	99.9234	0.0077
12	0.1375	-1.3475	99.8989	99.9074	0.0084
13	0.1500	-1.4700	99.8806	99.8898	0.0092
14	0.1625	-1.5925	99.8607	99.8706	0.0100
15	0.1750	-1.7150	99.8392	99.8499	0.0107
16	0.1875	-1.8375	99.8163	99.8277	0.0115
17	0.2000	-1.9600	99.7918	99.8040	0.0123
18	0.2125	-2.0825	99.7657	99.7787	0.0130
19	0.2250	-2.2050	99.7382	99.7519	0.0138
20	0.2375	-2.3275	99.7091	99.7236	0.0146
21	0.2500	-2.4500	99.6784	99.6938	0.0154
22	0.2625	-2.5725	99.6463	99.6624	0.0161
23	0.2750	-2.6950	99.6126	99.6294	0.0169
24	0.2875	-2.8175	99.5774	99.5950	0.0177
25	0.3000	-2.9400	99.5406	99.5590	0.0185

Horizontal Range of Projectile Motion

For 99% of the simulated values, magnitude of percent error between computed height and actual height is < 2.0%, which indicates that the accuracy in computed values of projectile height is pretty good.

The magnitude of horizontal range, R, of projectile during its time of flight t = 4.775, assuming a constant speed of airplane, V_{airplane} = 500 miles/hour along x-axis, can be obtained from kinematic equation Eq. (4) by using the initial boundary conditions, i.e., x = R, $a_x = 0$, $x_0 = 0$ and $v_{0x} = V_{\text{airplane}}$:

$$R = tV_{\text{airplane}} = 1067 \text{ m} \qquad (9)$$

R is the distance where the projectile will hit a target on the ground. In the present problem, R = 1.07 km, which can be increased either by increasing airplane's speed with respect to ground or by imparting some initial thrust to the projectile at launch time or by a combination of both.

Fig. 2: A plot of projectile height, *H* versus time, *t*

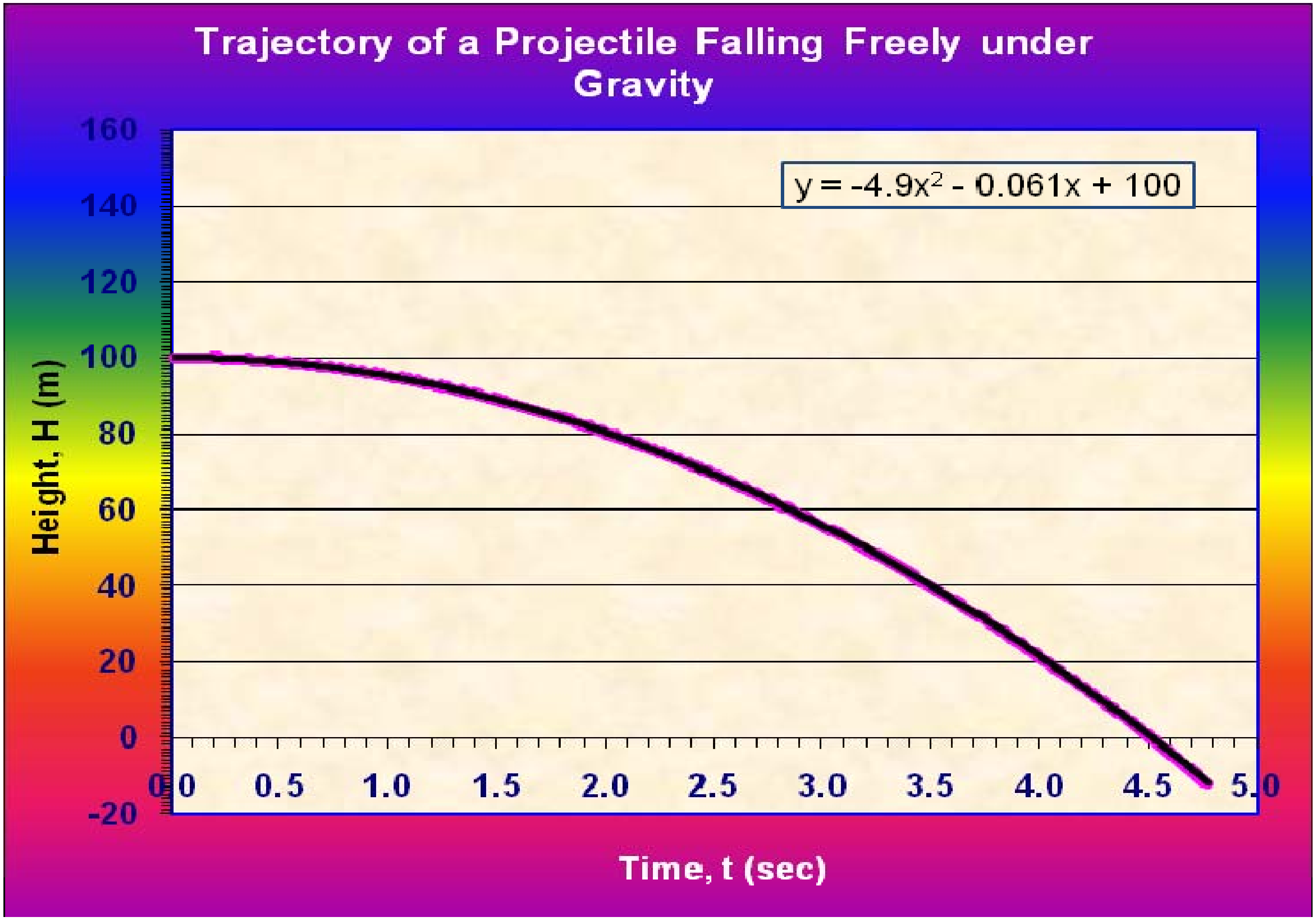


Fig. 3: Two slide bars to change initial boundary conditions

1
2

Two slider bars are used to perform simulations with different initial velocity V_0 of the projectile and at a different initial height H_0 of the airplane. Slide bar 1 represents the instantaneous initial height of the projectile, whereas slide bar 2 shows the initial velocity of the projectile at launch time. The initial height, H_0 and initial velocity, V_0 of the projectile can be increased or decreased by clicking on right or left hand side arrow existing on each end of a slide bar.

2. Interactive Simulations of Nine Rolling Dice

To simulate rolling of nine dice in a casino game, we employ latest version of Microsoft Excel 2007 and use a built-in *pseudo number* generating function, RAND( ), which can generate fractional numbers between 0 and 1. As none of the faces of a dice has marked with zero a dot, one is should include this fact while generating the random numbers. Cell formula to create non-zero random numbers for the rolling of nine dice should also include a factor of 6, which is multiplied by the function RAND( ) to take into account the fact of six faces of a dice, and a factor of unity is added to it to exclude zero value generated random numbers. The random numbers thus generated for nine rolling dice are given in Table 2 in its first nine columns.

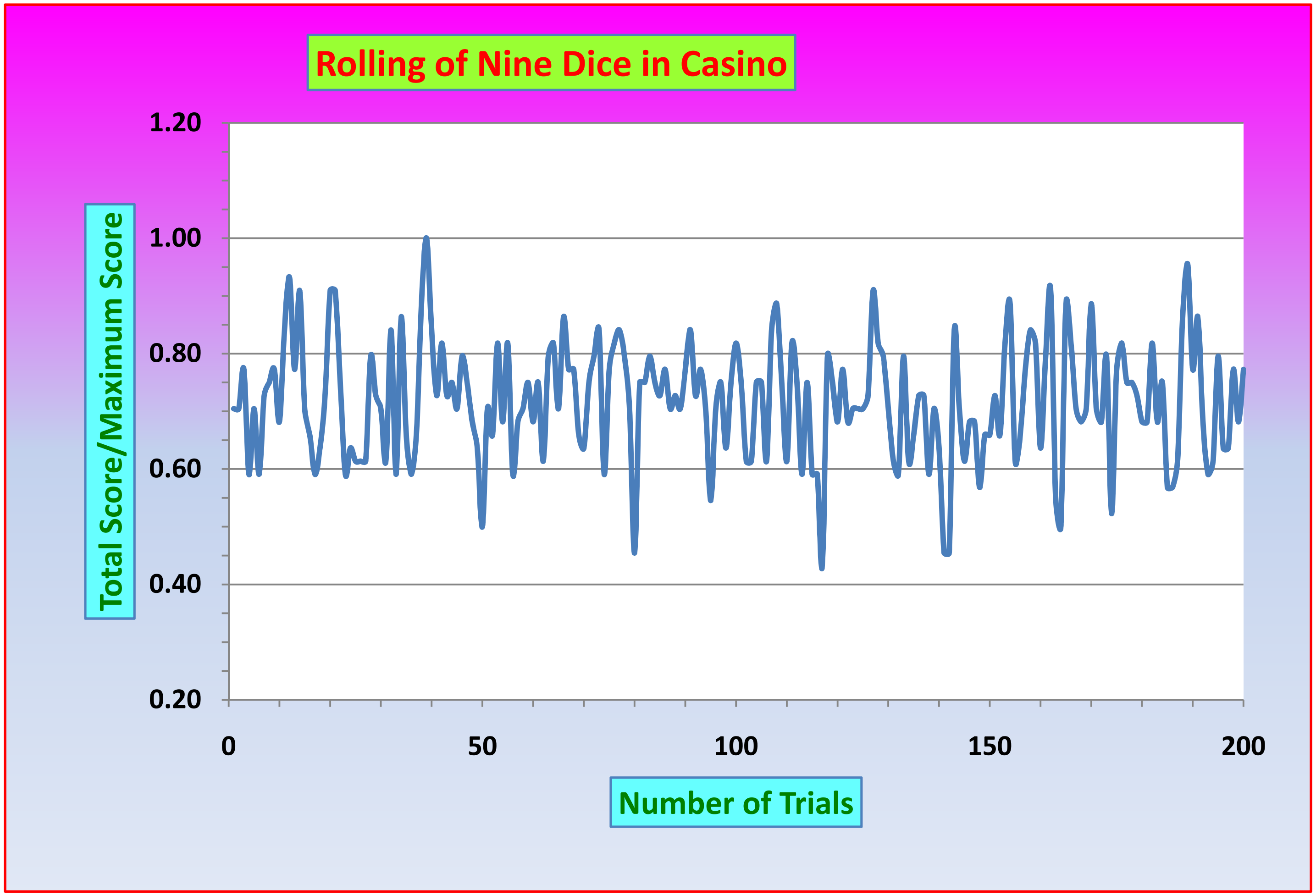
Interactive Simulations of Nine Rolling Dice

The random numbers thus generated for nine rolling dice are given in Table 2 in its first nine columns. Column ten shows the sum total of scores obtained for all the nine dice in one trial. Eleventh column represents the ratio of sum total score of all nine dice in one row to the maximum score among all 200 data values in column ten of Table 2. If one double clicks any cell of generated data, and then hits the *ENTER* key on the keyboard, all simulated random numbers for nine dice will change instantaneously and consequently, the total score in a single row normalized with the maximum score of the tenth column data values will also change.

Table 2: Simulated value of number of dots on the six faces of each dice in rolling of nine dice

Dice 1	Dice 2	Dice 3	Dice 4	Dice 5	Dice 6	Dice 7	Dice 8	Dice 9	Total	Total/Max
3	4	1	3	5	3	3	6	3	31	0.70
4	6	3	6	2	3	3	3	1	31	0.70
3	4	2	5	4	4	4	6	2	34	0.77
6	5	1	1	1	3	5	3	1	26	0.59
5	1	3	6	1	6	5	1	3	31	0.70
4	1	2	2	2	6	2	1	6	26	0.59
4	4	6	4	2	2	3	5	2	32	0.73
3	6	1	6	6	1	2	3	5	33	0.75
2	1	3	4	5	5	4	6	4	34	0.77
2	6	1	4	4	3	4	4	2	30	0.68
2	6	1	1	5	6	5	6	5	37	0.84
6	1	6	6	5	1	6	4	6	41	0.93
4	1	6	5	5	4	2	4	3	34	0.77
3	6	5	5	4	3	3	5	6	40	0.91
6	5	4	3	1	3	2	6	1	31	0.70
1	1	6	2	3	2	3	5	6	29	0.66
1	5	2	2	2	1	6	1	6	26	0.59
5	2	3	1	2	5	4	2	4	28	0.64
1	3	4	1	6	6	5	4	2	32	0.73
3	5	3	5	6	4	6	4	4	40	0.91
5	1	6	6	4	6	3	6	3	40	0.91
6	3	6	1	3	4	6	2	2	33	0.75
1	1	1	6	2	5	2	2	6	26	0.59
4	3	3	1	4	3	2	2	6	28	0.64

Fig. 4: A plot of ratio of total score in one row to the maximum score as a function of number of trials



Interactive Simulations of Nine Rolling Dice

In Fig. 4, we display a graph of this normalized total score as a function of number of trials. This graph has several peaks and valleys and it looks like the replica of an Electrocardiograph (ECG), which is obtained for a patient with some defect in the heart causing an irregular heart-beat. The interactive plot of Fig. 4 has in general, one or two peaks with a maximum value equals unity, and the remaining peaks always have values less than unity. The location of the maximum peak values and the nature of the plot changes with each new simulation, showing pretty interesting application of Excel 2007 for computer science and medical undergraduates.

Concluding Remarks

In conclusion, we may emphasize that the present paper has quite important implications both in physics as well as in computer science and medical science curriculum:

(i) In physics the students will learn how to employ software system such as Excel 2007 [1, 5] to simulate the basic concept of projectile motion under the action of constant gravitational acceleration with no air resistance

(ii) Whereas in computer science, they could visualize the real time application of this fundamental concept of physics in a virtual laboratory.

(iii) In addition, medical students can have an idea of irregular heart-beat of a patient suffering from heart attack or stroke, which has been proven with the help of a plot of normalized total score as a function of the number of trials from the simulations of nine rolling dice.