Interactive Applications of Microsoft Excel in a Virtual Lab

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Why Microsoft Excel 2007 Software?

- Excel 2007 software system is one of Microsoft Office product and is used extensively in high speed micro-computers such as IBM and Mac based PCs [1]
- These microcomputers are versatile class-room tools to teach undergraduate/graduate science and engineering curriculum [2]
- Microcomputer machines employ several software systems such as Excel, Access, Word, PowerPoint, Groove, InfoPath, OneNote, Outlook, Publisher, FrontPage etc. [1]
- Microsoft Excel is the second most used software system for undergraduate/graduate teaching and research in colleges, universities, scientific labs, private companies, businesses and banks in our country [1-4]

Why Microsoft Excel 2007 Software?

- Frequent adoption of internet technologies in undergraduate/graduate natural and medical science and engineering curricula
- International/National conferences to enhance and share the knowledge gained with other educators and researchers [1, 2]
- Use of Internet technologies to interactively teach in undergraduate and graduate classroom setting or during distant learning in virtual universities
- Internet has become very effective teaching tool for the natural, engineering and medical science curricula [2]

Main Objectives of Presentation

- Use of Microsoft Software Excel 2007 [1-4] for teaching college & university level curricula in the following disciplines:

  1. Business and finance applications in college and university class-room setting
  2. To compute Individual Retirement Accounts (IRAs)
  3. Math and statistics application principles
  4. Bio-medical sciences
  5. Computational physics and physics education
  6. Computer science education

Development of Interactive Applications with Excel 2007

Application principles discussed in my presentation:

- Car and mortgage payment calculations for business and finance majors/instructors
- IRA accounts for employees working in America
- Statistical analysis of virtual data of four sections taught in our University
- Model Mendel's Laws of heredity [5, 6] for recessive genes for biology instructors/majors

Development of Interactive Applications with Excel 2007 (contd.)

- Some interesting and important interactive applications to perform simulations of projectile motion in resistance free media
  - Launching of a cruise missile from an airplane to hit a target on ground for physics education, computational physics and engineering majors (application principle concerning deterministic problems)
- Study of random process of rolling of two or more dice in a casino game for a statistical or probabilistic problem in computer science education

Excel Built-in Functions Used in Interactive Applications

- Payment function: PMT(rate, nper, pv, [fv], [type])
- Future Value function: FV(rate, nper, pmt, [pv]. [type])
- Sum function: SUM(A1:A100)
- Average function: AVERAGE(A1:A100)
- Maximum function: MAX(A1:A100)
- Minimum function: MIN(A1:A100)
- Median function: MEDIAN(A1:A100)
- Counting of digits/words: COUNT() or COUNTA(A1:A100)
- Standard Deviation function: STDEV(A1:A100)
- Pseudo-random number generating function: RAND( )
- Lookup functions:

  VLOOKUP(lookup_value, table_array, col_index_num, [range_lookup])
  HLOOKUP(lookup_value, table_array, col_index_num, [range_lookup])

Business and Finance Applications

Basic Financial Functions in Business and Finance Applications	
PMT Function - The Purchase of Your New Car	
Purchase Price	$19,999
Manufacturer Rebate	$1,000
Down Payment	$3,000
Amount to Finance	$15,999
Interest Rate	1.0%
Term (years)	5
Your Monthly Car Payment	**$273.48**
FV Fuction - Investing for Retirement	
Your Annual Contribution	$1,200.00
Your Company's Annual Contribution	$1,200.00
Total Contribution	$2,400.00
Rate of Return	5.5%
Years of Contributing	40
Total Amount of Retirement Fund	**$327,853.47**
Author: Dr. Singh, SUNY Fredonia	

Monthly Home Mortgage Loan Payment Application

Monthly Mortgage Loan Payment			
Amount Financed	$150,000		
Starting Interest	5.50%		
Number of Years	30	15	
Interest Rate	**Monthly Payment**		**Difference**
5.50%	$851.68	$1,225.63	$373.94
6.50%	$948.10	$1,306.66	$358.56
7.50%	$1,048.82	$1,390.52	$341.70
8.50%	$1,153.37	$1,477.11	$323.74
9.50%	$1,261.28	$1,566.34	$305.06
10.50%	$1,372.11	$1,658.10	$285.99
11.50%	$1,485.44	$1,752.28	$266.85
12.50%	$1,600.89	$1,848.78	$247.90
13.50%	$1,718.12	$1,947.48	$229.36
14.50%	$1,836.83	$2,048.25	$211.42
15.50%	$1,956.78	$2,150.99	$194.21
16.50%	$2,077.72	$2,255.56	$177.84
Financial Consultant: Dr. G. Singh			

Individual Retirement Account (IRA) Application

The Value of an IRA (Individual Retirement Account)

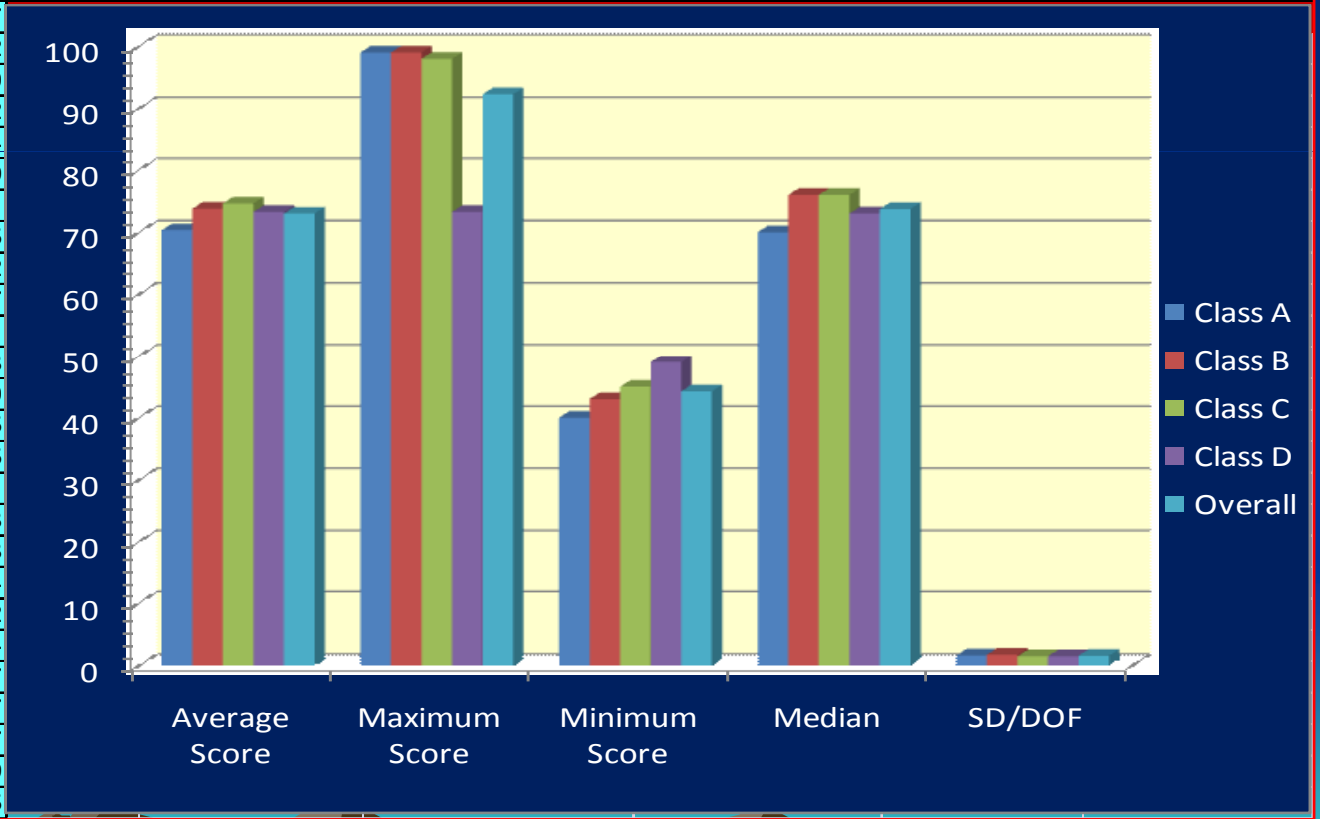
Annual Contribution	$3,000							
	Yearly Interest Rate							
Years Contributing	5.00%	6.00%	7.00%	8.00%	9.00%	10.00%	11.00%	12.00%
20	$99,197.86	$110,356.77	$122,986.48	$137,285.89	$153,480.36	$171,825.00	$192,608.50	$216,157.33
21	$107,157.76	$119,978.18	$134,595.53	$151,268.76	$170,293.59	$192,007.50	$216,795.43	$245,096.21
22	$115,515.64	$130,176.87	$147,017.22	$166,370.27	$188,620.01	$214,208.25	$243,642.93	$277,507.75
23	$124,291.43	$140,987.48	$160,308.42	$182,679.89	$208,595.82	$238,629.07	$273,443.65	$313,808.68
24	$133,506.00	$152,446.73	$174,530.01	$200,294.28	$230,369.44	$265,491.98	$306,522.45	$354,465.72
25	$143,181.30	$164,593.54	$189,747.11	$219,317.82	$254,102.69	$295,041.18	$343,239.92	$400,001.61
26	$153,340.36	$177,469.15	$206,029.41	$239,863.25	$279,971.93	$327,545.30	$383,996.31	$451,001.80
27	$164,007.38	$191,117.30	$223,451.47	$262,052.31	$308,169.40	$363,299.83	$429,235.91	$508,122.02
28	$175,207.75	$205,584.33	$242,093.07	$286,016.49	$338,904.65	$402,629.81	$479,451.86	$572,096.66
29	$186,968.14	$220,919.39	$262,039.59	$311,897.81	$372,406.07	$445,892.79	$535,191.56	$643,748.26
30	$199,316.54	$237,174.56	$283,382.36	$339,849.63	$408,922.62	$493,482.07	$597,062.63	$723,998.05
31	$212,282.37	$254,405.03	$306,219.12	$370,037.60	$448,725.65	$545,830.27	$665,739.52	$813,877.82
32	$225,896.49	$272,669.33	$330,654.46	$402,640.61	$492,110.96	$603,413.30	$741,970.87	$914,543.16
33	$240,191.31	$292,029.49	$356,800.28	$437,851.86	$539,400.95	$666,754.63	$826,587.67	$1,027,288.34
34	$255,200.88	$312,551.26	$384,776.29	$475,880.01	$590,947.03	$736,430.10	$920,512.31	$1,153,562.94
35	$270,960.92	$334,304.34	$414,710.64	$516,950.41	$647,132.26	$813,073.11	$1,024,768.66	$1,294,990.49

Statistical Analysis Application

Interactive Statistical Analysis of Virtual Data From Four Classes in CSIT 104

Class A	Class B	Class C	Class D
44	84	83	80
74	84	55	86
53	66	57	80
97	43	98	95
59	86	78	72
77	45	59	97
61	86	78	87
55	93	45	52
93	67	74	50
50	79	48	62
79	89	90	64
58	84	48	89
65	90	73	51
74	81	59	95
45	99	56	92
46	96	59	77
66	53	50	71
73	65	79	58
48	96	89	50
79	90	88	85
97	71	63	85
55	91	94	51
66	67	49	78
64	76	65	58
66	95	51	94
74	93	79	92
58	43	91	94
94	95	74	97
80	43	79	67
52	55	64	67
92	47	79	89
80	98	69	65

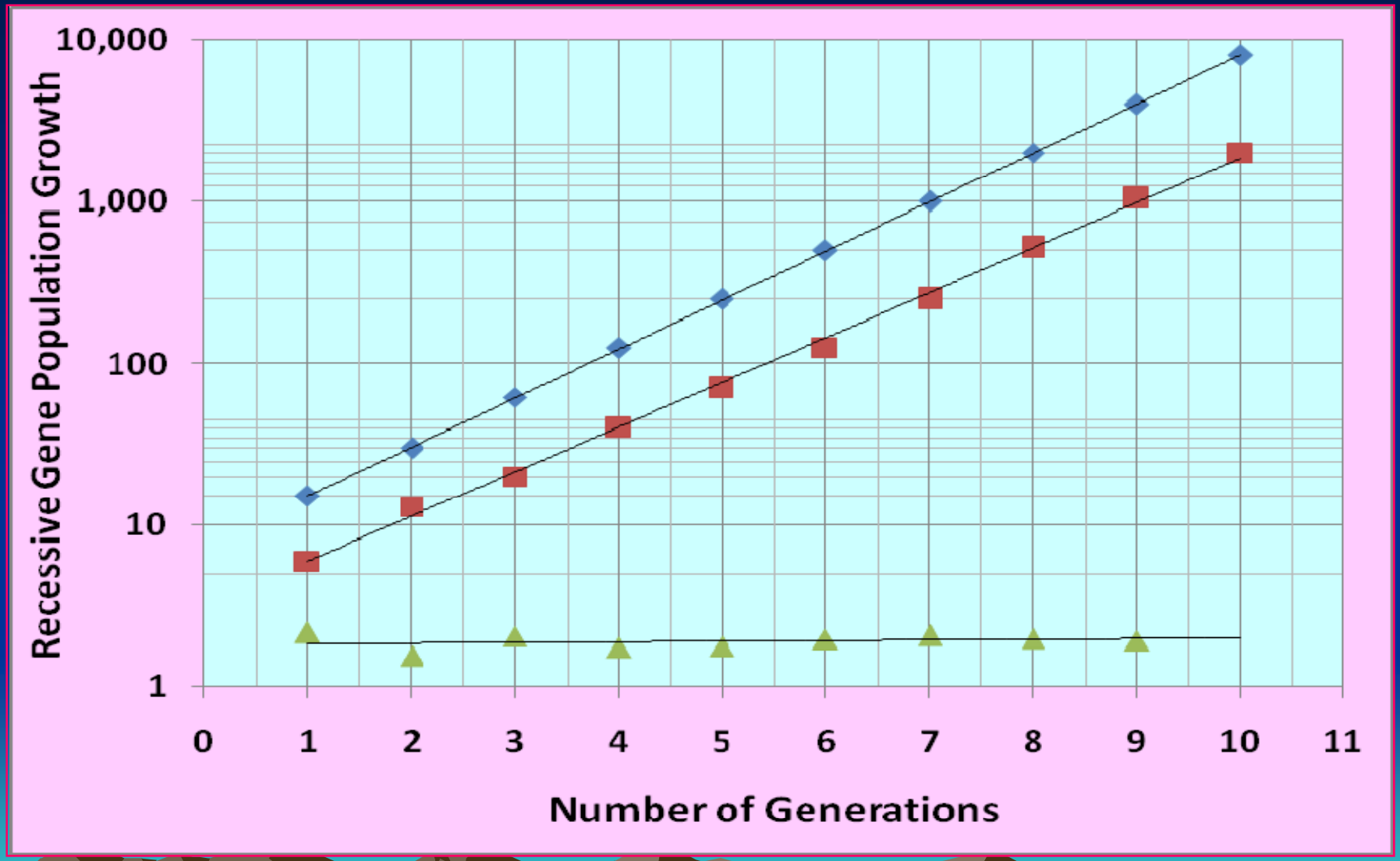
	Average Score	Maximum Score	Minimum Score	Median	SD/DOF
Class A	70	99	40	70	1.622
Class B	74	99	43	76	1.751
Class C	75	98	45	76	1.499
Class D	73	73	49	73	1.517
Overall	73	92	44	74	1.597



Few Simulation Results of Recessive Gene Population Growth

Female Gene	Male Gene	Baby	Recessive	Recessive Genes			
dominant	dominant	dominant	0	Generation	Trials	Babies	Ratio
recessive	recessive	recessive	1	1.0	15	4	2
recessive	dominant	dominant	0	2.0	30	9	2
dominant	recessive	dominant	0	3.0	62	17	2
dominant	recessive	dominant	0	4.0	125	34	2
recessive	recessive	recessive	1	5.0	250	63	2
recessive	dominant	dominant	0	6.0	500	123	2
dominant	recessive	dominant	0	7.0	1000	245	2
recessive	dominant	dominant	0	8.0	2000	508	2
recessive	recessive	recessive	1	9.0	4000	1014	2
recessive	dominant	dominant	0	10.0	8000	2042	2
recessive	recessive	recessive	1	11.0	16000	4089	

Overtime Population Growth



Examples of Projectile Motion in Physics

- Launching of a cruise missile from an air plane to hit an enemy post/target
- Motion of a space shuttle or a 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 of a golf ball with golf club
- Firing of a bullet from a gun or a 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 a ball game
- Finally, study of projectile motion in a physics lab

Theory and Algorithm of Projectile Motion

Components of velocity **v**(*x*, *y*, *t*), acceleration **a**(*x*, *y*, *t*), force **F**(*x*, *y*, *t*), **r**(*x*, *y*, *t*) position vectors in 2D-space are:

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

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

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

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

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

Theory and Algorithm of Projectile Motion

- Eqs. (4) and (5) are called *kinematic equations* of projectile motion
  - Employed these equations to simulate projectile trajectory
  - Under simplest assumption of no air resistance
  - Using boundary conditions: $a_x = 0$, $a_y = g = -9.80$ m/s^2, $v_y = V$, $v_{0y} = V_0$, $y = H'$, and $y_0 = H_0$
  - Thus, Eq. (4) and Eq. (5) could be written along y-axis as

$$V = V_o + gt, \qquad (6)$$

$$H' = H_o + V_o t + 0.5gt^2. \qquad (7)$$

- Used these equations to simulate projectile's exact velocity V and exact height H' at a given instant of time

Interactive Simulation of Projectile Motion

- Cell formulas for simulating exact velocity and exact height in Excel should be typed as:

$$V = V_o + g*A2 \quad (8)$$

$$H' = H_o + V_o*A2 + 0.5*g*A2\text{^}2 \quad (9)$$

- Here V_o = 0 m/s and H_o = 100 m is respective value of initial velocity and initial height of projectile in *y*-direction
- A2 = 0.0125 s represents relative cell reference for an infinitesimal change in the time interval, *dt*
- Memorized in Excel by something called "*Defined Name*" [1-4]

Interactive Simulation of Projectile Motion

- Depicting only first 27 simulated values of exact velocity, *V* and exact height, *H'*, of projectile motion in slide # 20 [1]
- Computed height *H* is always a little less than the exact height *H'*
- For 99% of simulated data points, magnitude of percent error between simulated height and actual height is < 2.0%
- Accuracy in computed projectile height is pretty good, which further proves that chosen time interval dt = 0.0125 s almost satisfies necessary and sufficient condition of differential calculus that in the limit of infinitesimal time interval, $\Delta t \rightarrow 0$ for the projectile motion

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

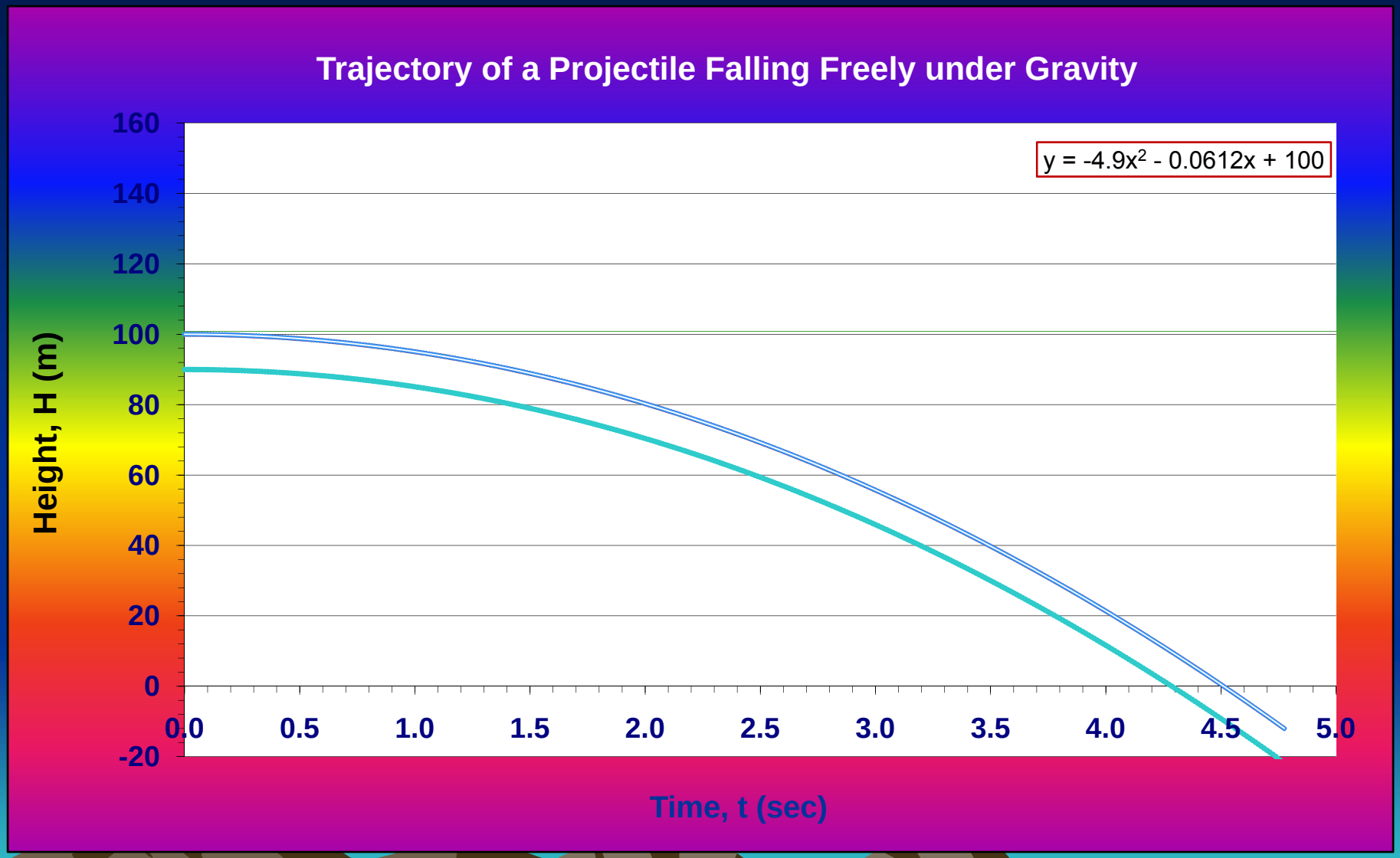
- Horizontal range, R, of projectile during its time of flight t = 4.775, assuming a constant speed of airplane, $V_{airplane}$ = 500 miles/hour along x-axis, can be obtained
- Using initial boundary conditions: x = R, $a_x = 0$, $x_0 = 0$ and $v_{0x} = V_{airplane}$: in Eq. (4)

$$R = tV_{airplane} = 1067 \text{ m} \qquad (10)$$

Here R is the distance where the projectile will hit a target on the ground and in present study, R = 1.07 km,

- R can be increased either by increasing airplane's speed with respect to ground or by imparting some initial thrust to projectile at launch time or by a combination of both

Plot of projectile height, *H* versus time, *t*



Two Slide Bars to Change Initial Boundary Conditions

1

2

- Used two slider bars to perform simulations with different initial velocity V_0 of projectile and at a different initial height H_0 of the airplane
- Slide bar 1 represents an instantaneous initial height of projectile
- Slide bar 2 shows initial velocity of projectile at launch time

Interactive Simulations of Nine Dice

- Simulation of data was done using a built-in *pseudo number generating function* called RAND( )
- Can generate all kinds of fractional numbers between 0 and 1
- Cell formula to create non-zero random numbers for rolling of nine dice should also include a factor of 6 to take into account the fact of six faces of a dice
- Factor of unity is added to generate pseudo random excluding zeros
- Random numbers generated for nine rolling dice are given in Table on slide # 26 [1]

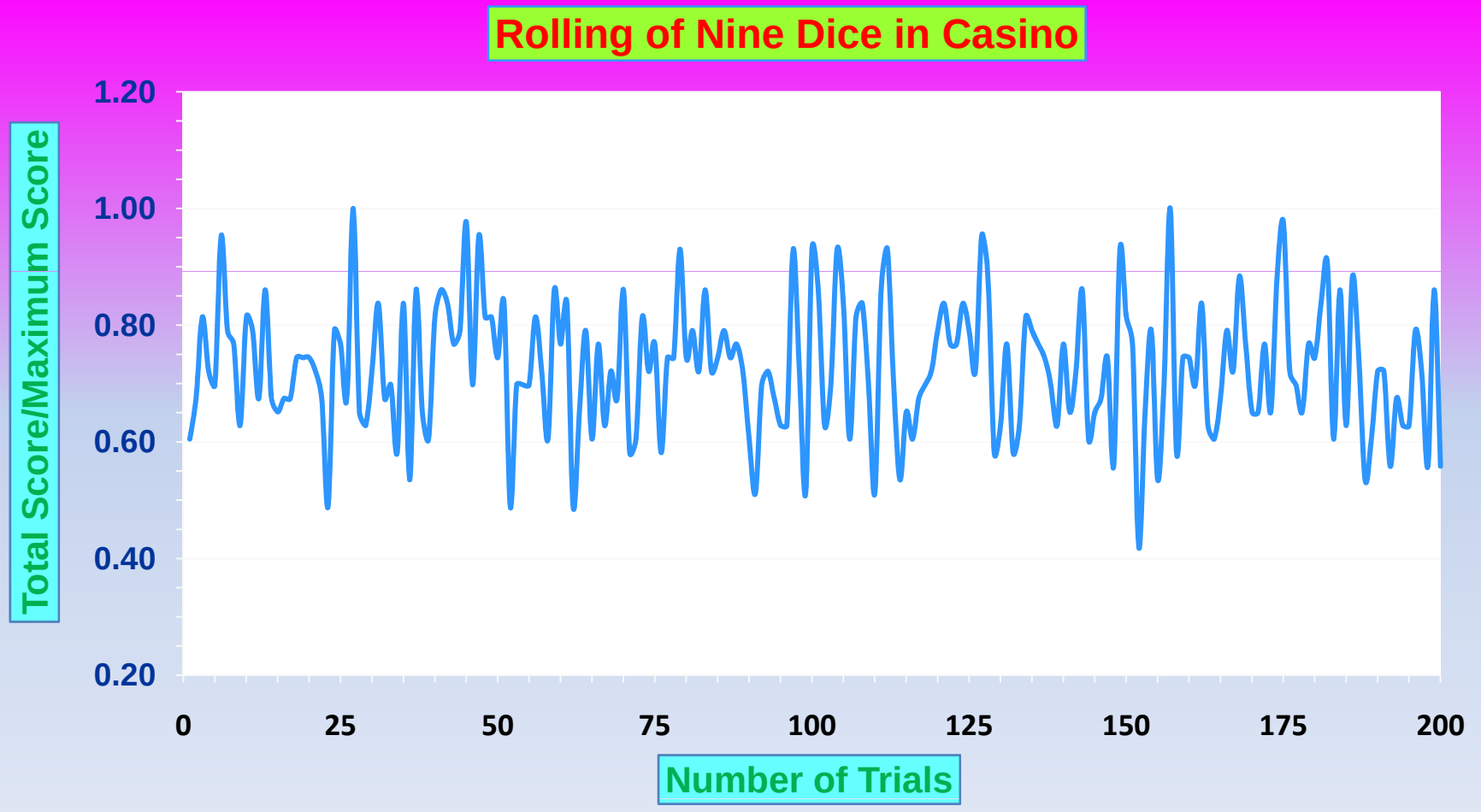
Interactive Simulations of Nine Dice

- Random numbers thus generated for nine rolling dice are given in first nine columns of slide # 25
- Column ten shows the sum total of scores obtained for all nine dice in a single trial
- Eleventh column represents a ratio of sum total score of all nine dice in one row to the maximum score among all 200 data sets in column ten
- If one double clicks any cell of generated data, and then hits *ENTER* key on keyboard, all simulated random numbers for nine dice changes instantaneously
- Consequently, total score in a single row normalized with the maximum score of tenth column data values also changes

Simulated Number of Dots on one of Six Face of Nine Rolling 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

Plot of Ratio of Total Score in one Row to Maximum Score as a Function of Trials



Interactive Simulations of Nine Dice

- Slide # 26 displays a graph of 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)
- Obtained for a patient with some defect in his/her heart caused by an irregular heart-beat
- Interactive plot has, in general, one or two peaks with a maximum value equals unity, and remaining peaks always have values less than unity
- Location of maximum peak values and nature of plot change with a new simulation, indicating pretty interesting application of Excel 2007 for computer science and medical undergraduates

Concluding Remarks

Interactive applications of Excel 2007 [1-4] software system has several important implications in mathematics, business and finance, statistics, biological and medical sciences, computational physics and physics education, computer science as well as in engineering curriculum:

- Business and finance majors, college/university instructors can calculate monthly car payment, home mortgage payment and future value of an investment like individual retirement account (IRA) funds in 401K plan
- Statistical analysis can also be done with Excel 2007
- Simulation of projectile motion and rolling of nine dice could be performed with Excel software system
- In biological and medical sciences, it is possible to empirically model Mendel's Laws of heredity for recessive genes of hybrid Pisum species [5,6]

Concluding Remarks (contd.)

- Physics students would learn how to simulate basic concept of projectile motion under action of constant gravitational acceleration with no air resistance [1]
- Computer science students could visualize real time application of this fundamental concept of physics in a virtual laboratory.
- Further, interactive application involving rolling of nine dice in a casino game gives a nice example of statistical and computer science problem in virtual lab [1]
- Medical students can have an idea of irregular heart-beat of a patient suffering from heart attack or stroke, from the simulations of nine rolling dice

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