Lesson Plans   CMST Institute

8-12-2004

Physics Lesson

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Grade level(s)/Subject taught:11th and 12th /Physics and Math B

Objectives: Students will use Interactive Physics software and TI-83/84 graphing calculators to study parabolic functions, quadratic equations and motion in two dimensions. Using a simulation of a golf ball in flight, students will manipulate the velocity of the golf ball and/or its angle of launch. They will observe the effects of these changes on the shape of the parabola produced, on the quadratic equations describing the parabola, and on the height, distance traveled and total time of flight of the golf ball. Students will then write quadratic equations from the data.

MATHEMATICS:
We will use Interactive Physics, Excel and the graphing calculator for mathematical modeling/multiple representation to provide a means of presenting interpreting, communicating and connecting mathematical information and relationships.

New York State Mathematics standards addressed in this lesson:
3b,c,d   4a,d, j, l,   7b,e,fg,h,i,o,

SCIENCE – PHYSICS SETTING/PHYSICS
Standard 4 – KEY Idea 5: Energy and matter interact through forces that result in changes in
                                             motion.

Performance Indicator 5.1: Students can explain and predict different patterns of the motion of
                                             objects.

Topic 5 Major Understandings:
   1. The path of a projectile is the result of the simultaneous effect of the horizontal and vertical
      components of its motion each of which acts independently (5.1f).
   2. A projectile's time of flight is dependent upon the vertical component of its motion (5.1g).
   3. The horizontal component determines the displacement of the projectile and its time in flight
      5.1h).

MST Standard 1 – Key Idea 1, M1.1: Students will interpret diagrams (of two dimensional
        motion) and use (mechanics) equations to solve for unknown variables.

MST Standard 6 – Models 2.1: Students will modify the (golf ball) simulation and predict the
        effects of changing variables (such as the velocity and club angle) on the ball's two dimensional
        motion.

MST Standard 6 – Models 2.2: Students will use technology (TI-83/84 graphing calculators) to
        facilitate collecting, analyzing and presenting results of the model changes.

DAY 1

Bell-work: (10 minutes)

The lesson will begin with a 10 minute quiz which involves solving 4 quadratic equations, one using the quadratic formula, one by factoring, one by completing the square and one using the graphing calculator. Question # 5 will ask students to find the coordinates of the vertex and the maximum height for a given quadratic equation. Students will receive a maximum of 25 points.

MATHEMATICS LESSON (30 minutes)

Students will now learn to write equations to fit data by following the procedure below.

Sample problem) Write an equation for the following data points:

$$\{(-7, -2) (-6, 3) (-4, 7) (-2, 3) (-1, -2)\}$$

Step 1: Clear List 1 and List 2 by pressing **STAT 4 2ⁿᵈ** L1 **, 2ⁿᵈ** L2 **ENTER.** Then clear any equations by pressing **Y= CLEAR ENTER.**

Step 2: Input the data by pressing **STAT ENTER.** Input the **(x)** values in List 1 and the **(y)** values in List 2.

Step 3: Display a scatter plot of the data by pressing **2ⁿᵈ STAT PLOT 1**. Highlight "On" and the scatter plot, and make sure that Xlist is L1 and Ylist is L2. Then press **ZOOM 9** to adjust the viewing window.
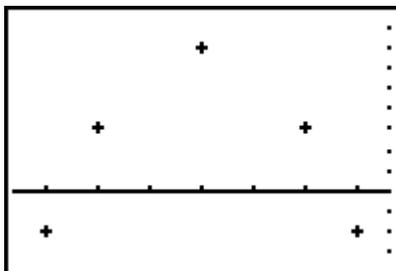
Step 4: Press **STAT** **>** **5** **ENTER** to obtain the equation above.

Step 5: Graph the quadratic regression to see if it is a perfect fit for the data. Press **Y=**
▼ VARS 5 ► ► 1 GRAPH. The r value, or the **correlation coefficient,** indicates
the closeness of the fit of this equation. When r = 1, the equation is a perfect fit for
the data. The closer to 1 the better the equation fits the data.

Equation: $y = -1x^2 - 8x - 9$
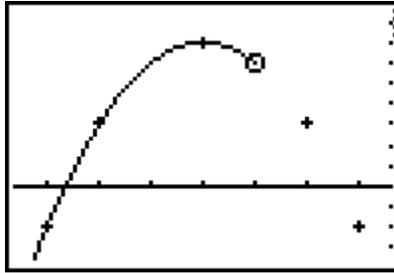
Step 6: Find the maximum height(y) using the **TRACE** button and find the roots of the
equation (where x = zero).

Assessment: Repeat **steps 1 – 6** for the following data. Find the equation, maximum
height and roots. {(0, -1) (1, 2) (2, 3) (3, 2) (4,-1)}

Suggested Rubric:
[5] $y = -1x^2 + 4x - 1$, max-height = 3 and roots x = {0.26, 3.72}.
[4] Correct equation, max-height and one root correct.
[3] Correct equation, either max-height or roots correct but not both.
[2] Incorrect equation, either max-height and one root correct.
[1] Appropriate max-height only or one root
[0] A zero response is completely incorrect, irrelevant or incoherent response.

Day 2

INTEGRATED LESSON

Students have difficulty connecting the similarities between disciplines. In this lesson we
are attempting show the connection between using quadratic equations in mathematics
and physics. They will be able to compare the two equations $y = ax^2 + bx + c$ and

$$d_x = v_{ix}t + \frac{1}{2}a_xt^2.$$

The Challenge: Which is the best golf club to use to get a hole-in-one?

Scenario: One of the most important factors in improving a person's golf game is the wise choice of which club to use when playing a shot. To aid in this selection, each golf club is numbered relative to the angle at which the face of the club hits the ball. The larger the club number, the larger is the angle and the higher and shorter the shot is likely to be. Launching a golf ball produces a parabolic-type trajectory that can be described in terms of horizontal and vertical components. Different clubs will produce higher or lower trajectories, will keep the ball in the air for longer or shorter times and will influence the distance at which the ball will travel. In this activity, we plan to have our students simulate a hole in one using various golf clubs and velocities when playing a simulated golf game using Interactive Physics software. Once a hole in one is obtained, they will export the data from the path of the golf ball (a parabola) to an Excel spreadsheet. Students will then record 10 – 15 data points (height vs range) on a provided worksheet. The data will be placed in the graphing calculator where the students will find the quadratic (motion) equation for the parabola. The maximum height achieved by the ball as well as the ball's flight time and its displacement to reach the hole will also be found.

Guided Practice:

Step 1: Observe the screen. Find the Velocity slider, the Angle slider, the RUN, STOP, RESET and ERASE TRACK buttons, and the LIST OF CLUBS and their angles.

Step 2: You will select a velocity and an angle based on your choice of club and set the values with the respective sliders.

Step 3: Run, Stop, Reset and Erase Track for each simulation. REMEMBER, you are trying to get a "hole-in-one"!!

Step 4: When you have found a correct club and velocity to achieve your goal, RESET the simulation so that it can be run by the EXCEL program.

TO COLLECT THE PROJECTILE DATA INTO AN EXCEL WORKSHEET:

Step 1: On the IP simulation screen, go to the Main Tool Bar and click on FILE, scroll down and click on EXPORT.

Step 2: On the EXPORT SCREEN, NAME the file and click the EXPORT button. NOTE that the simulation runs automatically.

Step 3: Move IP screen to the left and double click on the EXCEL application on desktop.

Step 4: On the EXCEL SCREEN, go to Main Tool Bar and click on FILE, scroll down and click on OPEN.

Step 5. On the EXCEL OPEN SCREEN, type in FILE NAME used in Step 2, and in next line below highlight ALL FILES.

Step 6: Go back up to top of the EXCEL OPEN SCREEN and click once on the "excel" folder –Your filename should appear, click on file name, click on OPEN button, then on the screens that follow, click on NEXT, NEXT, FINISH.

Step 7: View your data and complete the worksheet provided by recording the data points.

t	Vx	Vy	|V|	Vθ	t	x	t	y
Velocity of Circle 3					X-Position of Circle 3		Y-Position of Circle 3	
0	5.592	8.29	10	0	0	0	0	0.431
0.125	5.592	7.065	9.01	0	0.125	0.699	0.125	1.39
0.25	5.592	5.839	8.085	0	0.25	1.398	0.25	2.197
0.375	5.592	4.613	7.249	0	0.375	2.097	0.375	2.85
0.5	5.592	3.387	6.538	0	0.5	2.796	0.5	3.35
0.625	5.592	2.161	5.995	0	0.625	3.495	0.625	3.697
0.75	5.592	0.935	5.67	0	0.75	4.194	0.75	3.89
0.875	5.592	-0.29	5.599	0	0.875	4.893	0.875	3.931
1	5.592	-1.516	5.794	0	1	5.592	1	3.818
1.125	5.592	-2.742	6.228	0	1.125	6.291	1.125	3.551
1.25	5.592	-3.968	6.857	0	1.25	6.99	1.25	3.132
1.375	5.592	-5.194	7.632	0	1.375	7.689	1.375	2.56
1.5	5.592	-6.42	8.514	0	1.5	8.388	1.5	1.834
1.625	5.592	-7.645	9.472	0	1.625	9.087	1.625	0.955

GOLFING "A HOLE IN ONE"
Data Collection Worksheet
Flight Angle _____

Time (.1 second)	Height (y)	Range (x)
0.00	0.00	0.00
	0.00	

Analyzing the Data using Graphing Calculator
to Write Equation

Step 1: Clear List 1 and List 2 by pressing **STAT 4 2nd L1 , 2nd L2 ENTER.** Then clear any equations by pressing **Y= CLEAR ENTER.**

Step 2: Input the data by pressing **STAT ENTER.** Input the **range (x)** values in List 1 and the **height (y)** values in List 2.

Step 3: Display a scatter plot of the data by pressing **2nd STAT PLOT 1**. Highlight "On" and the scatter plot, and make sure that Xlist is L1 and Ylist is L2. Then press **ZOOM 9** to adjust the viewing window.

Step 4: Press **STAT ≥ 5 ENTER** to obtain equation.

Step 5: Graph the quadratic regression to see if it is a perfect fit for the data. Press **Y= ▼ VARS 5 ► ► 1 GRAPH.** The r value, or the **correlation coefficient,** indicates the closeness of the fit of this equation. When r = 1, the equation is a perfect fit for the data. The closer to 1 the better the fit.

Step 6: Write equation.

Step 7: Use the **TRACE** to find the two roots of the equation and the maximum height.

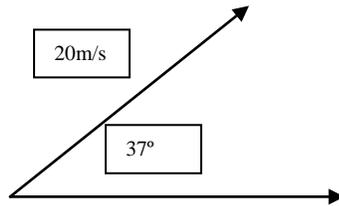Roots (solutions) _____, _____

Maximum height _____

Range _____

DAY 3

PHYSICS LESSON:

Bellwork(10 min): The students' prior knowledge of vectors, parabolas and quadratic equations will be assessed with the following bellwork assignment.

> 1. Calculate the x and y components of the following resultant.

2. Solve the following quadratic equation for distance, d_x, when $a_x=0$, t=25 and $v_{ix}=100$m/s.

$$d_x = v_{ix}\, t + 1/2 a_x\, t^2$$

'

3. Solve the following quadratic equation for distance (height), d_y, when $v_{iy}=0$, t=25s, ay=9.8m/s$^{2.}$

$$d_y = v_{iy}t + 1/2 a_y t^2$$

4. The diagram at the right is the general path
of a projectile fired at an angle. On the diagram,
   A) draw and label the path of another projection
       fired at a greater initial velocity but at the
       same angle.
   B) draw and label the representing a projectile
       traveling at an initial velocity slower than
       the first.
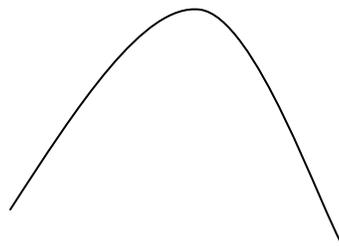
Lesson on Motion in Two Directions (15 min): We would start the lesson by showing an example of a parabola/trajectory produced from the golf ball flight simulation. With tracking, we would explain/show that the curve of the parabola is produced by a series of points representing the changing velocities of the ball.
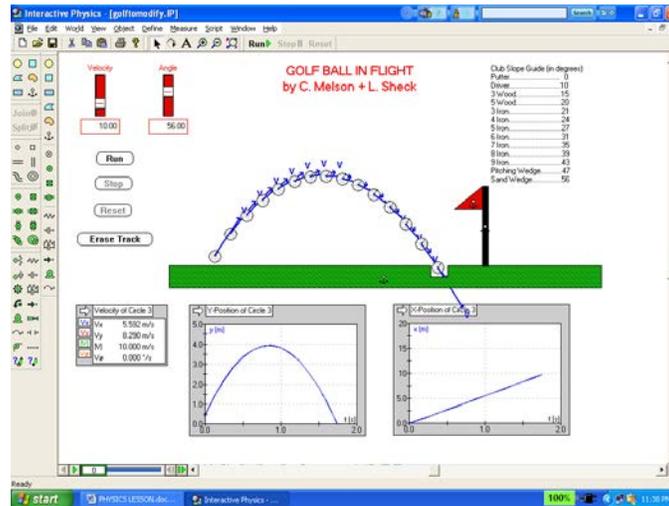
Using the diagram below, we would then explain that each velocity represented by a point on the curve is actually the result of the motion of the ball moving simultaneously in both the vertical and the horizontal directions. The vertical component (Vy) is affected by gravity that slows the ball down as it rises until eventually the ball has no vertical velocity and stops/pauses before falling back down toward earth. The horizontal component (Vy) remains at constant velocity/uniform motion.
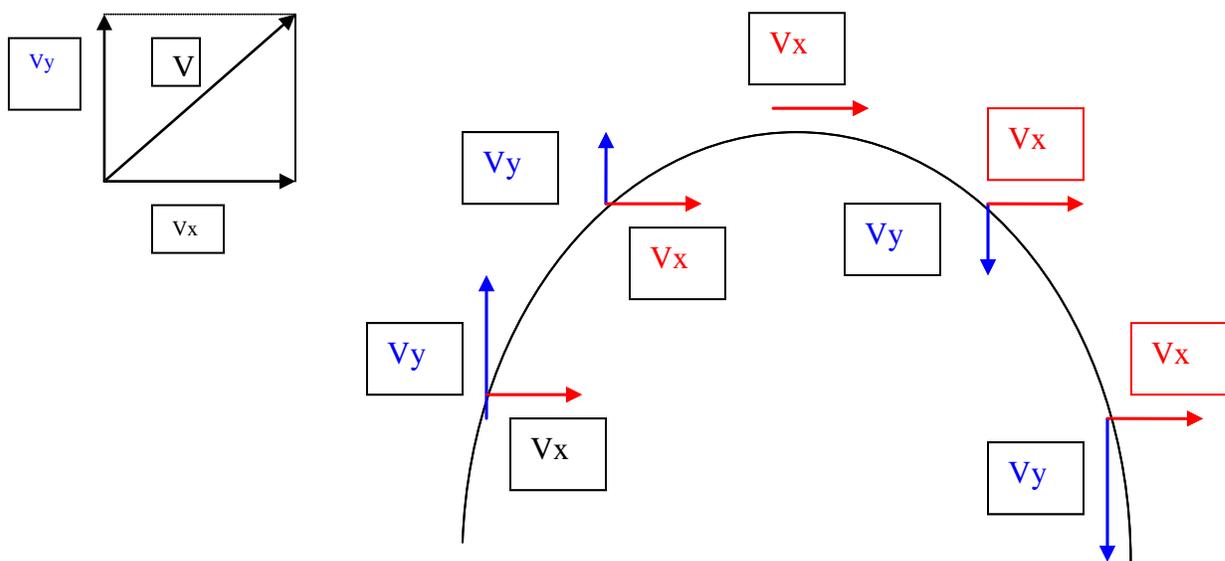
The solving of a projectile/motion in two dimensions problem would then be discussed as a four step method based on our knowledge of vectors, parabolas and quadratic equations.

Step 1: Find the V_x and V_y components of the initial velocity using

$$V_x = V_i\cos(\theta) \quad \text{and} \quad V_y = V_i\sin(\theta)$$

Step 2: Find the total time of flight by solving the following equation for time, t.

$$d_y = v_yt + 1/2at^2 \quad \text{where } dy = 0 \text{ (Note that the height of the trajectory is 0}$$
when it lands
and $a = g = -9.8m/s^2$ (acceleration due to gravity)

Step 3: Find the maximum height of the trajectory using the same equation as above.

$$d_y = v_yt + 1/2at^2 \quad \text{where } a = g = -9.8m/s^2$$
and t = time of flight from second step/2 (Remember symmetry of the parabola)

Step 4: Find the horizontal distance (the range) that the trajectory traveled by solving the same equation as above except for dx.

$$d_x = v_{ix}t + 1/2a_x t^2 \quad \text{where } a = 0 \text{ and } t = \text{entire time of flight}$$

Using the four step method outlined above, we would model how to solve the following problem and engage our students' help with each step.

SAMPLE PROBLEM: Consider a golfer who swings at a golf ball such that the ball has an initial velocity of 4.47m/s at an angle of 66°above the green.

a) Sketch a drawing of the motion of the ball.

b) Find the initial x and y velocity components.

c) Find how long it will take for the ball to land.

d) Find how high the ball flew in the air.

e) Find the range of the ball.

PROBLEM SOLVING and ASSESSMENT (15 min):

1. ON YOUR OWN NOTEBOOK PAPER, solve the following projectile problem using the four step method outlined above. SHOW EQUATIONS AND ALL SUBSTITUTIONS!!

Problem: A golfer swings at a golf ball that leaves the green at a velocity of 15m/s at an angle of 27º.

a) Sketch a drawing of the motion of the ball.
b) Find the initial x and y velocity components.
c) Find how long it will take for the ball to land.
d) Find how high the ball flew in the air.
e) Find the range of the ball.

2. Using the INTERACTIVE PHYSICS SIMULATION OF THE FLIGHT OF A GOLF BALL,

a) Select an angle and velocity, run the simulation with tracking and sketch (in red) the path the ball follows on your notebook paper.
b) Now keep the angle constant but change the velocity to a higher value. Run the simulation and sketch (in blue) the path the ball follows on the same diagram.
c) Predict the path the ball will follow if a lower value velocity is used. Sketch (in green) the path the ball might follow on the same diagram.
d) Verify your prediction by running the simulation with a lower value velocity. Sketch (in orange) the path the ball follows on the same diagram.
e) Generalize and explain in writing the effect that changing the velocity of the ball has on the flight time of the ball, the height the ball reaches in the air and the distance the ball will fall from the tee.

3. Using the INTERACTIVE PHYSICS SIMULATION OF THE FLIGHT OF A GOLF BALL,

a) Select an angle and velocity, run the simulation with tracking and sketch (in red) the path the ball follows on your notebook paper.
b) Now keep the velocity constant but change the angle to a higher value. Run the simulation and sketch (in blue) the path the ball follows on the same diagram.
c) Predict the path the ball will follow if a smaller angle is used. Sketch (in green) the path the ball might follow on the same diagram.
d) Verify your prediction by running the simulation with a smaller angle. Sketch (in orange) the path the ball follows on the same diagram.
e) Generalize and explain in writing the effect that changing the angle of the ball has on the flight time of the ball, the height the ball reaches in the air and the distance the ball will fall from the tee.

Suggested Rubric: Students will be evaluated with a score from 5 to 0 for each task listed in the table below.

Target	Acceptable			Unacceptable		
	5	**4**	**3**	**2**	**1**	**0**
Student shows satisfactory understanding of bellwork review of vectors, quadratic eqs. and parabolas.						
Student could correlate relationship between simulation parabola and the parabola discussed in terms of velocity						
Student wrote satisfactory description of motion in two dimensions in his/her notebook.						
Student copies four-step method for solving projectile problems.						
Student completes sample problem satisfactorily.						
Student completes assessment - Problem 1 - Simulation Problem 2 - Simulation Problem 3						
Student can predict the effect on height of the projectile, on time in air and its range when velocity is changed.						
Student can predict the effect on height of the projectile, on time in air and its range when angle is changed.						
Student can explain the golf ball simulation in terms of two dimensional motion.						