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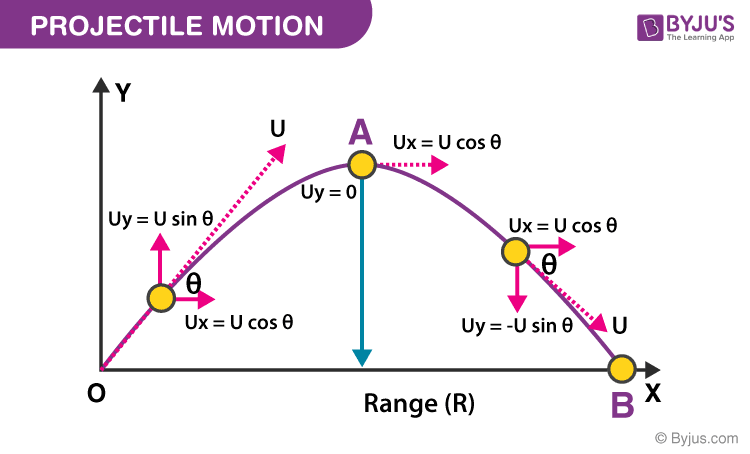
DATE 13 September 2021 Section J

**Report Sheet for Experiment 1: Projectile Motion**

**Abstract**

In this experiment, the projectile motion and its position, velocity, and acceleration are extensively investigated. With a variety of launching angle, different initial velocity, maximum height, acceleration, and horizontal distance of same height can tremendously differ. A simultaneous change in both speed and height makes a change in kinetic and potential energy which the conservation of the sum of two is also discussed. Possible error of the calculated values is considered to come from the motion blur of the recorded video, the negligible of the air resistance, and most heavily on the mis-calibration of length for the software.

**Introduction**

 Projectile motion is occurred when an object moves in the space with a uniformly distributed field, in this case, gravitational force from the Earth. The object will have an acceleration in one direction and move at a constant velocity in the others. By solving the equations of motions, the trajectory if the projectile would be downward parabola as depicted below.

[2]

**Theoretical Background**

In one-dimensional motion, if the system moves at a constant velocity, the displacement will be linearly dependent on the time spent according to the equation as follows:

Moreover, if there is a constant acceleration, there will be a constant change in velocity leading to a second-powered effect on the x-displacement:

In two-dimensional motion of a uniform field of force, for instance, gravitational field, the trajectory will be downward parabolic because of the acceleration occurred from the field. For example, an object is launched at an angle from the horizontal axis with an initial velocity u in a gravitational acceleration g. The vertical distance will be:

On the other hand, there is just a constant velocity in the horizontal direction

By combining above two equations, the relationship between y-x is achieved as follows:

Moreover, to calculate the distance R, the time spend during the vertical move is needed.

Total mechanical energy can be described as the summation of the kinetic and potential energy as:

Where m is the mass, v is the instantaneous velocity, g is the acceleration due to gravity, and h is height

**Methods**

1. Fix the launcher tightly on the table
2. Setup the camera so that the recording plane is parallel to the plane of projectile motion and place a bar of known length for further calibration
3. Start recoding video while launching the ball
4. Acquire the position of the ball at times from the Physics View program
5. Find velocity from the changed distance by some periods of time
6. Graph the position of the object in both axes versus time and fit with the equation
7. Repeat process 3 to 6 with various angle of the launching

**Chart, scatter chart

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v\_y = -11.00t+0.69 ; R2 = 0.9936

v\_y = -10.04t+1.13 ; R2 = 0.9867

v\_y = -22.00t+2.96 ; R2 = 0.9889

e

d

c

**b**

a

y = -5.44t2+0.51t+0.05 ; R2 = 0.9994

y = -5.17t2+1.01t+0.05 ; R2 = 0.9990

y = -11.17t2+2.75t+0.15 ; R2 = 0.9973

x = 1.77t+0.10 ; R2 = 0.9993

x = 1.46t+0.06 ; R2 = 1

x = 2.02t+0.09 ; R2 = 1

**Chart

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y = -1.67x2+0.60x. ; R2 = 0.9973

y = -2.43x2+0.99x ; R2 = 0.9990

y = -2.69x2+1.85x-0.01 ; R2 = 0.9985

30

45

60

v\_x = 1.77 ; R2 = 0.55

v\_x = 1.44 ; R2 = 0.56

v\_x = 1.97 ; R2 = 0.57

Figure 1 displays the motion of the object. a) and b) shows the x and y positions vs time, respectively, and c) combines the y position as a function of x. d) depicts the derivative of displacement as the velocity inn x and y axes respectively.

From the equation 9 deriving the relationship between the initial velocity, angle of launching, and gravity, the horizontal distance can be calculated as summarized in the Table 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Angle of Launching (Degree)** | **Vx,0 (m/s)** | **Vy,0 (m/s)** | **V0 (m/s)** | **R (m)** |
| **30** | 1.851 | 0.719 | 1.986 | 0.348116 |
| **45** | 1.334 | 1.134 | 1.751 | 0.312404 |
| **60** | 1.499 | 2.699 | 3.088 | 0.841853 |

Table 1 displays the initial velocity and its axial components, and R (horizontal distance with the same height as launching) of three launching angles

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Time(s) | Kinetic | Potential | Total E. | Kinetic | Potential | Total E. | Kinetic | Potential | Total E. |
| 30 | | | 45 | | | 60 | | |
| 0 | 0.00544 | 0.00065 | 0.00609 | 0.00423 | 0.00102 | 0.00525 | 0.01316 | 0.00244 | 0.01560 |
| 0.03333 | 0.00336 | 0.00084 | 0.00420 | 0.00273 | 0.00169 | 0.00442 | 0.01217 | 0.00433 | 0.01651 |
| 0.06666 | 0.00425 | 0.00079 | 0.00504 | 0.00319 | 0.00205 | 0.00524 | 0.00509 | 0.00542 | 0.01051 |
| 0.1 | 0.00415 | 0.00046 | 0.00462 | 0.00335 | 0.00229 | 0.00563 | 0.00720 | 0.00623 | 0.01343 |
| 0.13333 | 0.00471 | -0.00019 | 0.00453 | 0.00303 | 0.00211 | 0.00513 | 0.00621 | 0.00650 | 0.01271 |
| 0.16666 | 0.00637 | -0.00116 | 0.00521 | 0.00301 | 0.00169 | 0.00469 | 0.00497 | 0.00596 | 0.01093 |
| 0.2 | 0.00779 | -0.00251 | 0.00528 | 0.00391 | 0.00084 | 0.00475 | 0.00646 | 0.00487 | 0.01133 |
| 0.23333 | 0.00899 | -0.00414 | 0.00485 | 0.00524 | -0.00024 | 0.00500 | 0.01056 | 0.00325 | 0.01381 |
| 0.26666 | 0.01279 | -0.00628 | 0.00651 | 0.00678 | -0.00169 | 0.00509 | 0.01801 | 0.00081 | 0.01882 |
| 0.3 |  |  |  | 0.00926 | -0.00361 | 0.00565 | 0.02396 | -0.00244 | 0.02152 |
| 0.33333 |  |  |  | 0.00850 | -0.00542 | 0.00308 | 0.03789 | -0.00677 | 0.03112 |
| 0.36666 |  |  |  |  |  |  | 0.04634 | -0.01164 | 0.03469 |

Table 2 displays the Kinetic, Potential, and total mechanical energy of all three launching angles

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c

**b**

a

Figure 2 displays the Kinetic, Potential, and total mechanical energy of motions of three launching angles including a) 30, b) 45, and c) 60

**Discussion**

According to Figure1.a and 1.b, the trajectory components in x and y directions of the ball, as expected in the equations four, have a dependence on the time linearly and quadratically, respectively. Furthermore, in x direction, there is no acceleration occurring because of the zero net force acting on the object in this direction, leading to a horizontal fitting line of x\_velocity and time. Distinctively, in y direction, parabolic motion in distance was observed, resulting in a negative slope of y\_velocity vs time graph which its slope can be referred to the acceleration due to gravity (g=-9.81 m/s2). The results have the fitted acceleration of -11.00, -10.44, and -22.00 m/s2, from the ascending angle of launching. The error can be calculated as:

and 6.42%, 124.26% for the two remaining angles. The case of 30 and 45, their error can result from the measuring of the distance at the very beginning. With the video capture, the motion blur of the camera can cause blurry image which is hard to pinpoint the exact center of the ball, therefore, the distance is imprecise. Nonetheless, a hundred percent error of the 60 launching might be an outlier which presumably can happen from the change length calibration during set-up.

A picture containing text, person, indoor

Description automatically generatedFigure 3 displays the motion blur occurring during the measurement of distance in the software

The initial velocity of the balls is summarized in Table 2. They are calculated with their velocity components in x and y direction as:

The magnitudes are not the same for each experiment, as the error night come from measuring distances in a motion blurred video record or the mis-calibration of length during set up which was explained above. Also, the effect of air resistance is not yet considered in this experiment. The velocity can be compared with the fitted intercept of the x\_velocity vs time graph in Figure 1.d

|  |  |  |  |
| --- | --- | --- | --- |
| Angle of launching(degree) | v\_0 from Table2 | v\_0 from Figure1.d | %error |
| 30 | 1.986 | 1.77 | 12.2% |
| 45 | 1.751 | 1.44 | 21.6% |
| 60 | 3.088 | 1.97 | 56.7% |

Table 3 summarizes the initial velocity values and their error.

In projectile trajectory, when consider the maximum horizontal an object can move, the distance R can be derived like in equation 9. If we wonder about the optimal angle to maximize the R distance, the only parameter regardless of the initial velocity which should be kept constant as a control, the value of should be maximized at 1 as the angle equals to 45. However, the result does not go along with the theoretical value by having 60 as the longest, longer than 30and 45.

In figure 2, the conversion between potential and kinetic energy can be analyzed with the total mechanical energy being conserved, especially in the case of 30and 45 launching angles. During the decrease in y distance of the object falling downward, the potential energy decrease, however, the kinetic energy increases with in increased speed while the E is still conserved.

**Reference**

1. <https://genphylab.kaist.ac.kr/labs/general-physics-lab-1/projectile-motion/manual>
2. <https://byjus.com/physics/projectile-motion/>