Extended essay in physics engineering essay

The purpose of this essay is to compare and evaluate the effect of the initial velocity and launch height in the horizontal distance covered by a glider. The aim is to find out the optimal velocity required by a glider to cover the maximum distance when it is present at different heights. The recorded values are also compared to predicted values of the glider when it is in a vacuum, which is when the only forces acting on the moving glider is gravity. These predicted values are obtained from a projectile motion model developed for an object with the same mass as the glider.

The data is recorded on a home-made launcher powered by weights and using a paper plane as a glider. The horizontal distance travelled by the glider is recorded and the uncertainties are determined using the Law of Averages.

Despite uncertainties stemming from the Lift and Drag coefficients and the fact that many parameters are unaccounted for, the variables which have the most effect have been accounted for; the other parameters do not have a significant effect on the flight and thus can be ignored.

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Introduction:

I have had a keen interest in physics and in construction, along with a fascination with flight. This passion of mine has led to a vision of mine to improve the functioning of various machines around me. This is why I have chosen to study the gilding motion of a glider.

Humans are able to generate knowledge and ideas easily due to improved transportation and communication services. These services allow the convenient and quick conveyance of people, materials and ideas. However current transportation consumes a lot of natural and social resources which are not unlimited and whose extraction results in problems arising from the planet. Thus it is critical that methods be developed to conserve these resources.

This led me to compare the effect of the force applied and the launch height have on the flight distance of a glider and the question, how does the Force applied and the launch height of a delta wing glider affect its glide distance and how does it compare to the predicted distances when the plane is launched in a vacuum (projectile motion).

This research was conducted with the purpose of determining methods of reducing the fuel requirements and economic costs of modern aerial transport. Gliders are able to use fluid mechanics of the air to generate lift and to cover distances. Granted that gliders require a certain height to be effective, once it reaches significant height it can cruise over large distances and land without any fuel consumption. This reduces the fuel requirements of the flight by almost half as constant thrust is not required. The environmental and economic gains from this study are thus very significant.

Theory

Delta Wing

Pic : The HAL Tejas has a Delta Wing

http://en. wikipedia. org/wiki/File: Lca1. jpg (as on 23. 07. 2012)The Delta wing is a wing design or Planform in the shape of a triangle. It is named after the Greek letter Delta (Î”). The paper plane design used in this experiment has a delta wing shape. Such wings are used in situations when high speed and maneuverability is needed, as in Fighter Aircraft. Such a shape is structurally stronger than other wing designs and will not break under the large stresses caused in such conditions. File: Lca1. jpg

Reynolds Number

The viscosity of the fluid greatly affects the movement of objects as viscous fluids apply more frictional forces. The Reynolds number is the ratio between inertial forces of the object and the viscous forces of the fluid. At low Reynolds numbers the inertial forces are ignored because they are insignificant compared to the viscous forces and the opposite can be considered at high numbers. However the viscosity cannot be ignored when in contact with solids like the glider wing because the solid particles cannot slip around each other. This can generate a thin layer of frictional strain around the solid called the boundary layer.

Stokes Law

Stokes law is a relation between the Viscosity of a fluid and the Drag force acting on a spherical object passing completely through it. The relation compares the size and speed of the object to the drag force due to viscosity which is given by where Fd is the drag force, µ is the dynamic viscosity, R is the radius of the object. This is based on the assumption that the spherical object has smooth surfaces around which a fluid has Laminar flow. It is the basis of the Drag Equation. In the equation, 2Ï€R can be replaced with the orthographic area of an object to derive its Form Drag Force. (Bar-Meir, 2011)

Drag Equation

This is used to calculate the force of drag experienced by an object passing through a fully enclosing liquid. The equation is where Ï is the mass density of the fluid, v is the velocity of the object, A is the orthographic area of the object and Cd is the drag coefficient of the object.

Drag Coefficient

The drag coefficient is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid. A lower drag coefficient indicates the object will have less aerodynamic or hydrodynamic drag. The drag coefficient is always associated with a particular surface area. The drag coefficient of any object combines the effects of Form Drag and the frictional force between the object and particles in the fluid. It is obtained after the Drag force on an object is experimentally measured and defined as where A is the Area considered. (Chanson, 2009)

Aspect Ratio of a Wing

The Aspect Ratio of a Wing is defined as the square of the wing span divided by the wing area. It is a measure of how long and sleek a wing is. The wings with the lower aspect ratio must push down with a greater force to generate the same lift as wings with a higher aspect ratio, as it would have to deflect the air by a much greater amount. This greater deflection increases the drag in the form of Lift-Induced Drag. Therefore, planes with a high aspect ratio require less energy for lift and are thus more energy efficient. (HITSS, 2011)

However it is not possible for all lanes to have a high aspect ratio as wings with a high aspect ratio are not structurally strong and may break due to excessive stress at high speeds. Due to the less drag, they are not capable of making tight maneuvers required in stunt planes and military fighters. Wings with a low aspect ratio like wings with a large width or delta wings are more practical as they can be used to store fuel tanks, landing gear and other systems. Some Airfields also specify a maximum wingspan which they can accommodate.

Glide Ratio

The wings on a glider have to produce enough lift to balance the weight of the glider. The faster the glider goes the more lift the wings make. If the glider flies fast enough the wings will produce enough lift to keep it in the air. However, the wings and the body of the glider also produce drag, and they produce more drag the faster the glider flies. The speed can reduce due to friction with the air or when the glider goes into a climb. There is no engine in a glider to generate thrust so the pilot must use different ways to increase speed like angling the glider downward, trading altitude for speed.

The Glide ratio is the potential distance a glider can cover compared to the altitude it has to drop. For example, a Glide Ratio of 2: 1 says that the glider will travel for 2 Units Length when it reduces its altitude by 1 Unit Length. Modern gliders can have a Glide ratio of about 60: 1 and most commercial Jetliners are about 14: 1. (Brain & Adkins, 2001)

Simple Projectile Motion

Simple Projectile Motion is the parabolic curve which would predict the motion of the paper plane if gravity was the only force acting on it after its launch. Although this is not the case, it serves as a basis of any flying object. In order to calculate the position of any projectile, the launch angle and the launch velocity must be known. (Tsokos, 2004)

In the horizontal direction, x-axis, the velocity will not change as no force is acting in that direction. Thus it will be the x-component of the initial velocity of the projectile, which can be determined by. Since there is no acceleration, the projectile gets displaced by a fixed amount per unit time; this displacement can be obtained by.

The Velocity in the vertical direction is constantly changing because of acceleration due to gravity. The initial velocity of the projectile in the y-axis is given by. From this the vertical velocity after any time t can be given by, where g is the acceleration due to gravity. The position of the projectile can be determined to be.

To find the path of a projectile, the equations for the x and y displacements can be combined to give the equation of a parabola.

Variables Considered

Independent Variables: http://2. bp. blogspot. com/-4HTYhEZa0GE/TXqoKFlNiMI/AAAAAAACAeE/OjBW_Ai47CQ/s1600/diy_paper_plane_03. jpg

Height of launch

Force applied during launch

Dependent Variables:

Distance covered by the plane

Controlled variables:

Weight of the airplane

Dimensions of the plane

Angle of launch of the airplane

Uncontrolled Variables:

Effect of wind on the plane

Alignment of wings in the paper plane

Fig Design of the paper gliders used.

http://www. damncoolpictures. com/2011/03/how-to-build-cool-paper-planes. html (As on 29. 07. 2012)

Equipment Description and Methodology

Pre-Experimental Decisions

Pic : The bottom of the launcher showing the Pulley Mechanism which generates the force to launch the planes (Photo Credits Vanmayi Shetty, CVSL)One of the decisions I had to make before conducting the experiment was the design of the paper plane I was going to use. The launcher would damage and disfigure the plane due to the forces during take-off so the plane design should be easily reproducible. I chose paper as the material because it is convenient to obtain and easy to make many planes because it is produced in standardized sizes and thickness. I chose A4 size Bond Paper and cut each sheet into two halves and used the half for each plane. I also had to choose a design for the plane. I chose the delta wing Paper Rocket design which is very popular as I could easily make them.

Equipment

Paper planes

A large number of paper planes are made using half A4 size paper each. This is done so that all planes have the same weight and it will not affect their flight. The basic design of the planes is given in Fig 1. This is done such that irregularities of the plane caused during the launch and its landing can be removed as an undamaged identical plane is used to collect each set of data.

Pic : The top of the launcher showing the holder for the paper plane (Photo credits Vanmayi Shetty, CVSL)Launch Mechanism

A wooden board was taken and a long, thin vertical piece was cut out from its center. A set of weights is used to apply the initial force on the plane. At the end of this slit a pulley is placed. A slightly triangular piece of cardboard is taken and attached to the end of the spring; the paper plane will be loaded on this to be launched. A thread connecting this triangular holder and the weights passes through the pulley. To apply the force the weights are allowed to free fall and this force is transferred onto the plane after its direction is changed by the pulley and thread. The force applied on the plane will be the force on the weights, that is.

Experimental Procedure

The Initial launch height of the plane is determined. The distances covered by the plane from this height while varying the force is recorded. Then this process is repeated using different launch heights.

Multiple straight readings were taken and their flight paths were plotted and compared to the path predicted by the projectile motion formula of the same mass of the paper plane. This is done to find out the path of the paper plane when only gravity is acting on it.

Calculations

This Data is compared to the predicted distances of the plane when no forces are acting on it other than the force require to launch it and gravity; that is the predicted distance covered when an object with the same mass as the plane is launched in a vacuum on earth. This is the projectile motion of the object. In this projectile motion, launching force is in the direction perpendicular to the direction of gravity and parallel to the ground, thus the angle of this force is 0° and it can be ignored from these equations.

Fig : Diagram showing the change in direction of force from the vertical direction of gravity to the horizontal direction to launch the planeTo calculate these predicted distances, the projectile motion is divided into two aspects, its vertical motion and horizontal motion. The time taken for the projectile to reach the ground depends on its vertical motion, which is due to gravitational acceleration. This time taken is determined using the formula where m is the mass of the projectile, g is acceleration due to gravity and h is the height from which the plane is launched. The distance travelled by the plane is the distance covered by the horizontal motion of the projectile within the time the plane takes to reach the ground, giving the formula where v is the initial velocity in the horizontal direction. Combining these two formulas the equation obtained is. Since the planes and the weights are connected by a thread passing through a pulley, the force applied on the plane is the same as the force applied by gravity on the weights, which is determined by where is the mass added to the thread. This force acts on the plane as it is in the launcher which is 35cm in length. The acceleration a on the plane is determined by where m is the mass of the projectile and the final velocity of the plane on the launcher is obtained by which when combined with the previous equation gives. When this velocity formula is combined with the projectile motion formula derive earlier the formula for the distance covered by the projectile can be obtained as .

Assumptions

Following are some assumptions made when performing this experiment. Only situations that match these assumptions can be modeled.

The acceleration due to gravity is assumed to be 10 ms-2.

The motion of the plane is in only two axes, height and the direction it was launched in. It does not rotate, turn or move outside the plane formed by these two axes.

The energy stored in the launcher is completely transferred into the plane; no energy is lost due to aspects like, but not included to, friction between moving parts in the launcher, friction between the launching board and the plane, etc.

The launcher remains stable and fixed in a direction perpendicular to gravity during launch and does not shake.

Results

These readings were taken after launching a paper plane made of Bond Paper, of half A4 size. The plane had a wing span of 5cm from tip to tip and a tail height of 5 cm and mass of 3. 19 g. The error in the launch height is ±0. 05m which is due to unavailability of equipment which provide even increase in the height.

Tabulated Data

Launch Height = 0. 75 m

Tabulated Data:

Sl. No

Weight applied (g)

Force (N)

Distance (cm)

1st reading

2nd reading

3rd reading

Average

1

100

1

92

105

102

99. 667

2

150

2

110

115

109

111. 333

3

200

3

125

122

117

121. 333

4

250

4

113

118

112

114. 333

5

300

5

102

99

97

99. 333

Error Calculation:

Sl. No

1st Reading

2nd Reading

3rd Reading

Average

Range

Error

1

92

105

102

99. 667

8

± 4. 0

2

111

116

107

111. 333

9

± 4. 5

3

127

121

116

121. 333

11

± 5. 5

4

113

118

112

114. 333

6

± 3. 0

5

102

99

97

99. 333

4

± 2. 0

The Average Error in the distance covered is ±3. 8 cm

Launch Height = 1. 00 m

Tabulated Data:

Sl. No

Weight applied (g)

Force (N)

Distance (cm)

1st reading

2nd reading

3rd reading

Average

1

100

1

126

131

135

130. 667

2

150

2

137

150

145

144. 000

3

200

3

171

172

169

174. 000

4

250

4

156

148

145

149. 667

5

300

5

140

132

124

131. 333

Error Calculation:

Sl. No

1st Reading

2nd Reading

3rd Reading

Average

Range

Error

1

126

131

135

130. 667

9

± 4. 5

2

137

150

145

144. 000

13

± 6. 5

3

151

142

139

174. 000

12

± 6. 0

4

156

148

145

149. 667

12

± 6. 0

5

140

132

124

131. 333

16

± 8. 0

The Average Error in the distance covered is ±6. 2 cm

Launch Height = 1. 25 m

Tabulated Data:

Sl. No

Weight applied (g)

Force (N)

Distance (cm)

1st reading

2nd reading

3rd reading

Average

1

100

1

115

128

116

119. 666

2

150

2

178

162

181

173. 667

3

200

3

202

213

206

207. 000

4

250

4

178

171

186

178. 333

5

300

5

151

148

168

155. 667

Error Calculation:

Sl. No

1st Reading

2nd Reading

3rd Reading

Average

Range

Error

1

115

128

116

119. 666

13

± 6. 5

2

178

162

181

173. 667

19

± 9. 5

3

202

213

206

207. 000

11

± 5. 5

4

178

171

186

178. 333

15

± 7. 5

5

151

148

168

155. 667

20

± 10

The average error in the distance covered is ±7. 8 cm

Launch Height = 1. 50m

Tabulated Data:

Sl. No

Weight applied (g)

Force (N)

Distance (cm)

1st reading

2nd reading

3rd reading

Average

1

100

1

144

155

158

152. 333

2

150

2

190

180

185

185. 000

3

200

3

213

226

229

221. 667

4

250

4

196

208

203

202. 333

5

300

5

171

159

166

165. 333

Error Calculation:

Sl. No

1st Reading

2nd Reading

3rd Reading

Average

Range

Error

1

144

155

158

152. 333

14

± 7. 0

2

190

180

185

185. 000

10

± 5. 0

3

213

226

229

221. 667

16

± 8. 0

4

196

208

203

202. 333

12

± 6. 0

5

171

159

166

165. 333

12

± 6. 0

The average error in the distance covered is ±6. 4 cm

Launch Height = 1. 75m

Tabulated Data:

Sl. No

Weight applied (g)

Force (N)

Distance (cm)

1st reading

2nd reading

3rd reading

Average

1

100

1

163

171

176

170. 000

2

150

2

206

218

221

215. 000

3

200

3

248

239

253

246. 667

4

250

4

218

211

203

210. 667

5

300

5

164

185

179

176. 000

Error Calculation:

Sl. No

1st Reading

2nd Reading

3rd Reading

Average

Range

Error

1

163

171

176

170. 000

13

± 6. 5

2

206

218

221

215. 000

15

± 7. 5

3

248

239

253

246. 667

14

± 7. 0

4

218

211

203

210. 667

15

± 7. 5

5

164

185

179

176. 000

21

± 10. 5

The average error in the distance covered is ±7. 8 cm

Graphical Representation:

Other Qualitative observations:

The gliding action of the plane was most prominent when the plane was launched at 2 N Force. At lower forces, although some glide was observed, it did not cause a significant increase in the glide distance because it is possible that the plane hit the ground before it could take effect.

Similar observations were made when higher forces were applied; the gliding action was not very significant. In this case it could be because the initial speed of air around the wings is too much to generate significant lift. By the time the speed of the plane reduces to a magnitude which generates significant lift, it hits the ground.

In these situations, the plane does not follow a gliding motion, instead following a projectile motion. The graph of the glide distance moves closer to the graph showing the predicted motion of a body the same mass of the plane. This shows that tendency of the plane to follow a projectile motion is directly proportional to the difference of magnitude of applied force to 2N. Due to this, the longest distance covered by the plane is when the force is about 2N.

Conclusions

Results

For a glider to cover the maximum distance, it should be at a speed which is high enough to generate significant lift but not a very high velocity so that the drag can be minimized. For the paper plane used, it can be concluded that this optimal speed is approximately 22ms-1, which is the speed at which the plane leaves the launcher when 2N of force is applied.

To cover the maximum distance, there should be a balance between the Lift forces and the drag forces acting on the plane. The lift force reduces the vertical movement of the plane and allows the horizontal motion to cover more distance; the drag force reduces the speed of the horizontal motion and reduces the distance covered. However, the magnitude of both forces increases with an increase in speed although not at the same rate. Thus for the mass and wingspan of a given plane, the optimal velocity varies so as to cover the most possible distance. As seen from the data collected from the paper plane, the relation between the force applied and the distance covered forms a parabolic arc when plotted on a graph, with the optimal force at the peak of the parabola.

The chart above shows the distance covered when the force and the launch height was varied. This clearly shows that the maximum distance is covered at 2N force. Another trend this graph shows is that the distance covered is also proportional to the height from which it was launched. This change is elaborated in the next graph which plots the distance covered and launch height when 2N Force is applied.

The above chart shows that these two values are directly proportional to each other within a certain margin of error. The gradient of the chart is 1. 52 cm/m. This gives the glide ratio of the paper plane used. When both units are converted into the same unit, the gradient is approximately 1. 5. Thus the glide ratio is approximately 1. 5: 1, which says that when the plane is gliding, for every unit of height lost by the plane it gains 1. 5 units of distance covered.

Limitations

A major problem while performing this experiment was launching the planes. It is difficult to have the same launch throughout the experiment while varying the forces and launch heights. It is difficult to get a stable platform to place the launcher while maintaining fixed intervals between the values of initial height measured. Although fixed variables were maintained, stability was sacrificed. Keeping the launcher fixed and leveled during launch was a challenge. Highly unstable launches were not recorded but the recorded launches were also slightly unstable and this poses problems when forming trends between two variables because the other variables are not very accurately recreated.

The planes do tend to turn left or right, adding a third dimension to this two dimension study. No matter how much care is taken, it is impossible to hand make exactly symmetrical paper planes. The turns are caused when the two wings are not exactly equal in their size and weight. Flights which had drastic turns were ignored and not recorded.

The drag and lift coefficients are considered constant in the experiment but they vary as the velocity of the paper plane changes. For the purpose of this essay, they were considered as constants as the main purpose of the essay was to compare launch height, Distance covered and force applied. Although the Lift and drag will change as the force applied is varied, they will change by the same amount no matter the launch height or distance covered. Due to the laboratory limitations the Drag and Lift could not be determined. However, if it could be possible to explore these variables, the current models could be easily adapted and brought to a much higher level of precision.

The launch angle is a significant aspect of both gliding and projectile motion that was unfortunately not explored in my study. Another aspect which was not measured was the changing position of the glider with respect to time. These aspects can be studied when appropriate equipment is available for use. If the Value of my model is to increase, these should be the next aspects of study

Appendix

Symbols used

Symbol

Description

Mass of the object

Acceleration

or

Velocity at a fixed point in time, or average velocity during the period observed

Initial Velocity of object during observation period

Final Velocity of object during observation period

Time period during observation period

Distance covered by object during observation period

Force applied on an object

Friction force due to drag in the air

Dynamic viscosity of the fluid medium

Radius of a circular object passing through a fluid

Mass density of a fluid

The orthographic area of the object

The drag coefficient of an object passing through a fluid

The horizontal component of any variable related to motion which is filled in the box

The vertical component of any variable related to motion which is filled in the box

Acceleration due to gravity, assumed to be 10ms-1

Height of the object from the ground, vertical component of distance from the ground

Raw Data

Launch Height = 0. 75m

Sl. No

Weight applied (g)

Distance (cm)

1st reading

2nd reading

3rd reading

1

100

92

105

102

2

150

110

115

109

3

200

125

122

117

4

250

113

118

112

5

300

102

99

97

Launch Height = 1. 00 m

Sl. No

Weight applied (g)

Distance (cm)

1st reading

2nd reading

3rd reading

1

100

126

131

135

2

150

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150

145

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200

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172

169

4

250

156

148

145

5

300

140

132

124

Launch Height = 1. 25 m

Sl. No

Weight applied (g)

Distance (cm)

1st reading

2nd reading

3rd reading

1

100

115

128

116

2

150

178

162

181

3

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213

206

4

250

178

171

186

5

300

151

148

168

Launch Height = 1. 50m

Sl. No

Weight applied (g)

Distance (cm)

1st reading

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3rd reading

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226

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196

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5

300

171

159

166

Launch Height = 1. 75m

Sl. No

Weight applied (g)

Distance (cm)

1st reading

2nd reading

3rd reading

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171

<