STORM THE CASTLE B

2011 Science Olympiad

Wolfgang Bauer
bauer@pa.msu.edu
517 884 5515
http://www.pa.msu.edu/~bauer/
The General Idea

• Launch a projectile (provided by the judge)
  • as far a possible
  • as accurately as possible
• Design and build a “device” to do this
• Use only gravitational potential energy contained in a counterweight (provided by the judge) to supply the initial kinetic energy for the projectile
The Device

• Must fit in $\left( 75 \, \text{cm} \right)^3$ cube
  • before launch
  • after launch
  • but **NOT** necessarily during launch

• Cannot store and release other energy forms besides that contained in the counterweight

• Cannot be anchored to the ground

• Must have a trigger that
  • extends out of the launch area
  • cannot be dangerous
Stuff Provided by Judge

- 3 projectiles (all identical)
  - $20 \text{ g} < m < 60 \text{ g}$
  - $d < 6 \text{ cm}$
- Counterweight
  - $1 \text{ kg} < M < 3 \text{ kg}$
  - Hook on top
  - Fits into $(15 \text{ cm})^3$ cube
- Target
  - Open top
  - Minimum size $(20 \text{ cm})^3$ cube
The Arena

• \((2 \text{ m})^2\) launch area
  • Device can be moved around by team inside the area after each shot
  • No part of device can extend out of launch area before or after launch

• No team member can be in launch area during launch
The Actual Competition

- Team has **three shots** and no practice shot
- Team can take up to 5 minutes
- Before 1\textsuperscript{st} shot team must announce the target distance (in integer number of meters)
- If the target is hit, the team can ask to move the target (presumably further …) before the next shot
- The **two best** of the three shots **count**
Scoring

• Highest score wins!
• All distances are measured in m
• Launch Score (LS) = TD – A + B
  • TD = Target Distance (integer number!)
  • A = Accuracy = distance from projectile first impact to target center
  • B = Bonus = 0.1 · TD, awarded if the target is hit on first impact and the projectile stays in it
• Graph Score (GS), max 12
• Penalty: 3 for each infraction
• Final Score = Sum of two best LS + GS – Penalties
• Tie breaker: best LS
Example

• Team puts target at 12 m and misses it by 2 cm on first shot, the hits it with second shot (projectile stays in), then moves target to 13 m and misses it by 55 cm; no penalties, perfect graphs

• Score
  • LS1 = 12 – 0.02 = 11.98
  • LS2 = 12 – 0 + 0.1·12 = 13.2
  • LS3 = 13 – 0.55 = 12.45
  • Final Score = 13.2 + 12.45 + 12 – 0 = 37.65
Final thoughts

- Maximize projectile range => launch angle 45°
- Theoretical maximum projectile range

\[ R_{\text{max}} = \frac{v_0^2}{g} = \frac{2K_0}{mg} \leq \frac{2\Delta U}{mg} = \frac{2Mgh}{mg} = 2h \frac{M}{m} \]

\[ h \leq 0.75 \text{ m} - 0.15 \text{ m} = 0.6 \text{ m} \]

- If you have a choice between two different target distances, pick the larger one
  - Say, your device can hit a maximum range of 13.8 m
  - TD = 13 => Launch score = 13 – 0.8 = 12.2
  - TD = 14 => Launch score = 14 – 0.2 = 13.8
  - TD = 15 => Launch score = 15 – 1.2 = 13.8