STORM THE CASTLE B

2011 Science Olympiad

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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 $(75\ cm)^3$ 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

- $(2\ m)^2$ 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 1st 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 = **T**arget **D**istance (integer number!)
  - A = **A**ccuracy = distance from projectile first impact to target center
  - B = **B**onus = 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 missies 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

$$R_{\max} = \frac{v_0^2}{g} = \frac{2K_0}{mg} \le \frac{2\Delta U}{mg} = \frac{2Mgh}{mg} = 2h\frac{M}{m}$$

$$h \le 0.75\ \text{m} - 0.15\ \text{m} = 0.6\ \text{m}$$

- 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