LEARN BY DEFENDING / FIELD NOTES

Hold the Line

Defend a Sol Heirs outpost through 11 waves. Inspect, calculate, predict, fire and review. Use the on-screen G.U.E.S.S. workspace or these paper notes. Keep your first answer when you make corrections.

NAME _____ CLASS _____ DATE _____

Your defense	Current rules
Base and cannons	Base: 10 HP. C1 at x = 85 m; C2 at x = 140 m.
Ground launches	Flat, indestructible terrain. Both heights = 0. Earth g = 9.8 m/s^2.
Orders	1-124 m/s; 5-80 degrees. Each cannon may Fire or Hold. No reloads.
Damage at landing	Direct hit: 2 HP. Nearby blast: 1 HP, within 18 m beyond a target bracket.
Waves 1-3	Start with range; then predict a fixed advance. No flight-time calculation required.
Waves 2-3	Predict, advance once, then aim. Robots stop throughout the shot.
Wave 4	Introduce flight time with stationary targets.
Waves 5-11	Robots keep moving during flight. Lead targets, coordinate hits and beat sentry charges.

Follow the same cycle on screen and on paper

1. Inspect the target coordinates and the cannon launch position.
2. In Waves 2-3, predict the announced advance; press Advance robots once.
3. Choose each cannon's speed, angle and Fire or Hold order.
4. Record a prediction, use paper, or choose observation.
5. Resolve the shot and compare predicted and observed values in Review.
6. Keep your first answer; explain a correction before your next shot.

Early turns end one second after the last landing; Hold takes one simulated second. From Wave 5, orders run for 16 simulated seconds; airborne rounds continue next turn. Planning is untimed. Menus and interruptions pause action; playback speed changes presentation only.

Full coaching steps back to short prompts in Waves 6-9 and independent defense in Waves 10-11. Show full coaching restores help. Hints progress from equation to substitution to solution. Skip guidance never marks completion.

Review separates damage from calculation accuracy. Checks allow ±1.2% of the reference magnitude or ±0.06 in its units, whichever is larger. Keep extra digits until your final answer. Error clues suggest what to recheck; first answers stay preserved.

WAVE 1 / STATIONARY PRACTICE

Find the range

Two damaged robots stand at x = 210 m and x = 300 m. Each has 1 HP, stays still and cannot hurt the base. C1 launches from x = 85 m; C2 holds. Launch and landing heights are both zero. Use g = 9.8 m/s^2 and degree mode.

1 / Find the required horizontal range from C1 to the first robot. Explain why its coordinate, 210 m, is not the range.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

2 / For 35 m/s at 45 degrees, calculate range and landing x. Then find the speed at 45 degrees needed to reach the second robot at x = 300 m.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

$R_{required} = x_{target} - x_{launch}$. $R = v^2 \sin(2\theta) / g$. Landing $x = x_{launch} + R$. At 45 degrees, sin(90 degrees) = 1, so $v = \sqrt{(Rg)}$. Keep full calculator values until the final answer. Givens, Unknowns, Equation, Substitute and Solve run left to right.

Observed landing: first shot x _____ m; second shot x _____ m.
What stayed the same, and what did you change?

WAVE 2 / ADVANCE, THEN STOP

Predict the advance

A damaged Cyclops begins at x = 280 m and advances 20 m left each turn. It has 1 HP. C1 is at x = 85 m. Calculate before pressing Advance robots. After this one advance, the robot remains stopped while you aim and fire.

3 / Write the signed displacement for the announced advance. Predict the robot's new x after its first advance.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

4 / Use the new position to calculate the required range from C1. Find a launch speed at 45 degrees that reaches the stopped robot. Use g = 9.8 m/s^2.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

$x_{new} = x_{now} + \Delta x$. A leftward displacement is negative. Subtract the cannon position to find range, then use $v = \sqrt{(Rg)}$ at 45 degrees. The advance happens once per turn, regardless of how many cannons fire.

Observed robot x _____ m; observed shell landing x _____ m.
Compare both with your first prediction and explain any correction:

WAVE 3 / TWO CANNONS

Different advance distances

A damaged Cyclops starts at x = 300 m and advances 20 m left per turn. A damaged Spine runner starts at x = 380 m and advances 40 m left. Both have 1 HP and stop during shots. C1 is at x = 85 m; C2 is at x = 140 m.

5 / Predict both positions after their first advance. Find the range from C1 to the Cyclops and from C2 to the runner.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

6 / If both robots survive, predict their positions after the second advance. Recalculate the same two cannon-to-target ranges. Explain why the second ranges are shorter.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

Use $x_{new} = x_{now} + \Delta x$ once each turn. Use the last position for the next advance, or add both displacements to the starting position. Fire and Hold both lead to a new advance next turn. A robot reaching x = 40 m damages the base once.

C1 order _____ C2 order _____

Observed landings and evidence for my next choice:

WAVE 4 / STATIONARY TARGETS AGAIN

Time in the air

Return to stationary robots at x = 210 m and x = 300 m. Now introduce flight time. C1 launches from (85, 0) m at 35 m/s and 45 degrees. Landing height is zero and g = 9.8 m/s^2. C2 holds for this example.

7 / Resolve the initial launch velocity into horizontal and vertical components. Use degree mode and include units.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

8 / Calculate the flight time, then use horizontal velocity × time to find range and landing x. Check that the range agrees with the equation used in Wave 1.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

$v_x = v \cos \theta$; $v_{y0} = v \sin \theta$. For equal heights, $T = 2v_{y0} / g$. $R = v_x T$, which agrees with $R = v^2 \sin(2\theta) / g$. Use full calculator values until the final answer.

Flight time: predicted _____ s; observed _____ s. Landing x _____ m.
Why do both range methods agree?

WAVES 5-6 / CONTINUOUS MOTION

Lead a moving robot

New rule: robots keep moving while rounds fly. Wave 5 begins with a damaged Cyclops at x = 220 m moving at -2 m/s. Reuse C1 at 35 m/s and 45 degrees. Wave 6 introduces Spine runners moving at -4 m/s.

9 / Use the flight time from Wave 4 to find the Cyclops's displacement and position when the shell lands. Compare this with your calculated shell landing x.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

10 / At the start of Wave 6, the first runner is at x = 320 m. Choose cannon orders, calculate flight time and predict both the runner position at landing and the shell landing x.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

$x_{robot} = x_{now} + v_{robot} T$. Use the same T for the robot and the shell. A candidate shot may miss: keep the first prediction, then adjust one firing value and explain why. Your prediction does not steer the shell.

Cannon _____ Speed _____ m/s Angle _____ degrees
Observed: target x _____ m; landing x _____ m; flight time _____ s.

WAVES 7-8 / PRIORITY TARGETS

Armor and arrival times

The Pillbug crawler has 4 HP, moves at -1 m/s and deals 3 base damage if it reaches x = 40 m. A direct hit removes 2 HP; a nearby blast removes 1 HP. Combine cannon orders or plan a follow-up. Robots keep advancing while damaged.

11 / At the start of Wave 7, the crawler is at x = 300 m. Find its displacement and time to x = 40 m if it is not stopped.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

12 / Wave 8 starts with a Cyclops at 315 m (-2 m/s), a runner at 390 m (-4 m/s) and a crawler at 450 m (-1 m/s). Find each time to x = 40 m. Which arrives first, and where will it be after 10 s?

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

$\Delta x = x_{final} - x_{now}$; $t = \Delta x / v_x$. Compare urgency with remaining HP and breach damage. The slowest robot is not always safe to ignore. There are no automatic base repairs between waves.

Priority target _____ C1 order _____ C2 order _____
After firing: target HP _____ Base HP _____. Evidence for my next choice:

WAVES 9-11 / RANGED ENEMIES

Beat the charge

A Cannon sentry has 3 HP. It moves left at 2 m/s, stops at x = 160 m and charges for 20 s. Its shot travels 125 m to x = 35 m for 1 base damage. Wave 9 introduces one alone; Wave 10 combines armor and a sentry; Wave 11 brings two sentries with a nearby runner.

13 / Wave 9 starts with the sentry at x = 192 m. Find the time to its firing line, then the total time until its first launch if it is not disabled.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

14 / From (160, 0) m, the sentry fires at 35 m/s, 45 degrees above horizontal toward the left. Find flight time, range and landing x. Then find total time from wave start until the base is hit. Use g = 9.8 m/s^2.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

$T = 2v \sin \theta / g$; $R = v^2 \sin(2\theta) / g$. Leftward landing $x = x_{launch} - R$. Disabling a sentry before launch cancels the attack; an airborne shell still arrives. It recharges for 12 s before the next 20 s charge. Planning and pause freeze countdowns.

Which cannon orders can arrive before the launch deadline, and why?