FIRST LIGHT ACADEMY

HELIOS PROVING GROUNDS

State of the Arc

Field manual & student work packet

Arc smarter, not harder.

Calculate a flight, test it in the Academy, then explain the result. Follow the tutorial from horizontal release to angled shots and different landing heights.

CADET _____ CLASS _____

INSTRUCTOR _____ DATE _____

Five core activities / three optional investigations / two calculation questions per worksheet page. Each question has a horizontal G.U.E.S.S. work table.

Print on Letter paper in portrait orientation at actual size. Keep first Solve answers visible when correcting. This packet follows the Academy and Practice Range.

READ BEFORE TRAINING

How to use the range

1 / Choose an exercise

From the title, select Enter academy. Start with Learn to Play, or choose any angled lesson. Skip tutorial returns to mode selection. Open practice bypasses the guided introduction.

2 / Calculate with G.U.E.S.S.

Read the coordinates, gravity and launch conditions. Work left to right through Givens, Unknowns, Equation, Substitute and Solve. The Solve entry is your prediction. Enter that result in the game.

3 / Record and launch

For an angled shot, enter both components and select Record and check components. Use the checked values for time and distance. Select Record prediction, then Release ordnance or Fire artillery.

4 / Observe and compare

Use Pause flight, Resume flight and playback speed as needed. Field notes and browser interruptions pause the flight. Compare observed results with your first answers. A faster playback does not change the physical flight.

5 / Correct without erasing

Use Try another prediction or Revisit components. Keep first work visible on paper and label corrections. Finish this lesson marks the current lesson complete. Skip does not. Written explanations stay on paper; numerical first answers and later attempts are stored separately on this browser.

Find your page

Activity	Open in the game	Page
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Practice selectors stay locked during a flight. Use the matching world and exercise before entering a new prediction. Browser records are not a substitute for keeping this paper packet.

REFERENCE DESK / G.U.E.S.S.

Two components. One clock.

Use SI units, +x to the right and +y upward. Gravity g is a positive magnitude; $a_y = -g$. Vertical displacement is $\Delta y = y - y_0$. The stopwatch begins at release or firing. Ignore wind and air resistance in every world.

World	Moon	Academy	Mars	Earth
g (m/s^2)	1.6	2.0	3.7	9.8

$v_x = v \cos \theta$ / $v_{y0} = v \sin \theta$

Resolve a launch angle measured above horizontal; use degrees.

$\Delta y = v_{y0}t - \frac{1}{2}gt^2$ / $\Delta x = v_x t$

Solve vertical motion for time; then use the same time horizontally.

$v_y = v_{y0} - gt$ / $t_{apex} = v_{y0} / g$

At the apex $v_y = 0$; v_x and downward acceleration remain.

$y_{max} = y_0 + v_{y0}^2 / (2g)$

Maximum y coordinate, measured from the same datum as y_0.

$t = [v_{y0} \pm \sqrt{(v_{y0}^2 - 2g\Delta y)}] / g$

For a raised reachable level, test both roots. Arrival here means the later crossing, with $v_y < 0$.

Worked paper model / follow the columns

An Earth release from 19.6 m has $v_{y0} = 0$. Find fall time. These demonstration numbers differ from the game release.

Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve
$y_0 = 19.6$ m $y = 0$ m $v_{y0} = 0$ m/s $g = 9.8$ m/s^2	t in seconds	$\Delta y = v_{y0}t - \frac{1}{2}gt^2$	-19.6 m = -4.9 $m/s^2 \times t^2$ $t^2 = 4.00$ s^2	t = 2.00 s Choose positive time.

Equation first. Numbers second. Units throughout.

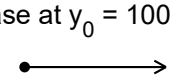
Retain calculator precision until the final result. Enter about 0.1 s and 1 m precision for flight predictions, and 0.01 m/s for components. Do not use $t = 2v_{y0}/g$ for unequal landing heights.

A01 / TUTORIAL COMPANION

Horizontal release

Open: Learn to Play

Release at y_0 = 100 m with v_x = 16 m/s and v_{y0} = 0. Landing plane: y = 0 m. Use Academy g = 2.0 m/s^2.



Target y = 0 m

Launch y_0 = 100 m / +x right, +y up / geometry sketch, not to scale

1 / Find flight time t to y = 0 m.

Givens	Unknowns	Equation	Substitute	Solve

2 / Find horizontal distance Δx during that flight.

Givens	Unknowns	Equation	Substitute	Solve

Observed / checked results: _____

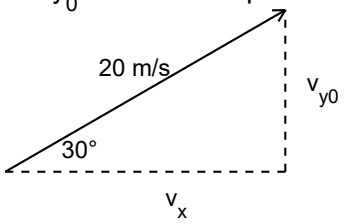
Explain: Why must the vertical equation be solved before the horizontal distance? Would changing only horizontal speed change the fall time?

A02 / TUTORIAL COMPANION

Resolve the launch

Open: Start angled launch / Resolve the components

Launch at y_0 = 20 m with speed 20 m/s at 30° above horizontal. Target level: y = 20 m. Use Academy g = 2.0 m/s^2.



Angle measured from horizontal. The dashed sides are components of one launch velocity.

1 / Find the horizontal launch velocity v_x.

Givens	Unknowns	Equation	Substitute	Solve

2 / Find the initial vertical velocity v_{y0}.

Givens	Unknowns	Equation	Substitute	Solve

Checked components: v_x _____ m/s v_{y0} _____ m/s

Explain: Why does the horizontal component use cosine and the vertical component use sine? Which component is larger at 30°?

A03 / TUTORIAL COMPANION

Return to muzzle height

Open: Start angled launch / Make a flight prediction

Launch at y_0 = 20 m with speed 20 m/s at 30° above horizontal. Target level: y = 20 m. Use Academy g = 2.0 m/s^2.



Launch y_0 = 20 m / +x right, +y up / geometry sketch, not to scale

First complete the component check. Retain full-precision component values for subsequent calculations.

1 / Find the nonzero flight time back to y = 20 m.

Givens	Unknowns	Equation	Substitute	Solve

2 / Find horizontal distance Δx at that return.

Givens	Unknowns	Equation	Substitute	Solve

Observed / checked results: _____

Explain: Why is t = 0 not the landing answer? Is the projectile stationary at its apex?

A04 / TUTORIAL COMPANION

A lower landing

Open: Start lower landing

Launch at y_0 = 20 m with speed 20 m/s at 30° above horizontal. Target level: y = 0 m. Use Academy g = 2.0 m/s^2.



20 m/s at 30°

Target y = 0 m

Launch y_0 = 20 m / +x right, +y up / geometry sketch, not to scale

First complete the component check. Retain full-precision component values for subsequent calculations.

1 / Find arrival time at y = 0 m. Use signed Δy.

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

2 / Find horizontal distance Δx to the lower landing.

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

Observed / checked results: _____

Explain: Why does $t = 2v_{y0}/g$ underestimate this flight time? Compare the ascent and descent.

A05 / TUTORIAL COMPANION

A higher landing

Open: Start higher landing

Launch at y_0 = 20 m with speed 20 m/s at 30° above horizontal. Target level: y = 24 m. Use Academy g = 2.0 m/s^2.



Launch y_0 = 20 m / +x right, +y up / geometry sketch, not to scale

First complete the component check. Retain full-precision component values for subsequent calculations.

1 / Find both times at y = 24 m. Identify the descending time.

Givens	Unknowns	Equation	Substitute	Solve

2 / Find horizontal distance Δx at the descending arrival.

Givens	Unknowns	Equation	Substitute	Solve

Observed / checked results: _____

Explain: How does the sign of v_y identify the upward and downward crossings? Why does the shell not stop at the first crossing?

A06 / OPTIONAL INVESTIGATION

Compare gravity

Open: Practice / Horizontal release / Earth, then the other worlds

Release at y_0 = 100 m with v_x = 16 m/s and v_{y0} = 0. Landing plane: y = 0 m. For question 1 use Earth g = 9.8 m/s^2; for question 2 use Moon g = 1.6 m/s^2.



Target y = 0 m

Launch y_0 = 100 m / +x right, +y up / geometry sketch, not to scale

1 / On Earth, find flight time and horizontal distance.

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

2 / Repeat for the Moon. Compare the two flights.

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

Observed / checked results: _____

Explain: Rank the worlds by flight time and distance. Explain the ranking using gravity rather than the artwork.

A07 / OPTIONAL INVESTIGATION

Investigate the apex

Open: Practice / Angled / same landing height / Academy

Launch at y_0 = 20 m with speed 20 m/s at 30° above horizontal. Target level: y = 20 m. Use Academy g = 2.0 m/s^2.

Keep apex answers on paper. To start playback, enter the full-flight time and distance from A03; do not enter apex time as landing time.



Launch y_0 = 20 m / +x right, +y up / geometry sketch, not to scale

First complete the component check. Retain full-precision component values for subsequent calculations.

1 / Find elapsed time from firing to the apex.

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

2 / Find maximum y and both velocity components at the apex.

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

Observed / checked results: _____

Explain: At the apex, which quantities are zero: v_x, v_y or a_y? Explain how the shell can still move.

A08 / OPTIONAL INVESTIGATION

Two crossings on Earth

Open: Practice / Angled / higher landing height / Earth

Launch at y_0 = 20 m with speed 20 m/s at 30° above horizontal. Target level: y = 24 m. Use Earth g = 9.8 m/s^2.



Launch y_0 = 20 m / +x right, +y up / geometry sketch, not to scale

First complete the component check. Retain full-precision component values for subsequent calculations.

1 / Find both times at y = 24 m and v_y at each crossing.

Givens	Unknowns	Equation	Substitute	Solve

2 / Use the descending time to find arrival distance Δx.

Givens	Unknowns	Equation	Substitute	Solve

Observed / checked results: _____

Explain: Both times solve the height equation. What makes just one of them the arrival requested in this exercise?

REUSABLE WORK PAGE / MAKE EXTRA COPIES

Keep the reasoning. Revise the shot.

Use one box set for a new calculation and one for a correction or another trial. Keep your original Solve result visible. Record the world, exercise, givens and units each time.

1 / Activity _____ World _____ Quantity to find _____

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

Observed result / reason for revision: _____

2 / Activity _____ World _____ Quantity to find _____

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

Observed result / reason for revision: _____

Before you finish

Check signs, units, degree mode, launch and target heights, and the chosen time root. Explain a discrepancy before repeating the flight. Repeating an answer is not the same as explaining it.