STATE OF THE ARC / EARTH PROJECTILES

Trajectory Training Manual

Earth flight school

Animated training and worksheet questions
Earth g = 9.8 m/s^2
No wind or air resistance

NAME _____ CLASS _____

DATE _____ TEACHER _____

Use this packet alongside your 2 Dimensional Motion notes. Complete each section after the matching notes. Every cluster has one shared situation and linked questions; the printed evidence is enough to work without a device.

Section	Notes slides	Pages
E1 / Two directions, one flight	2-8	3-4
E2 / Plan a carrier delivery	9-10	5-6
E3 / Add and compare vectors	11-18	7-8
E4 / Resolve the launch velocity	19-22	9-10
E5 / Follow an angled projectile	23-31	11-12
E6 / Compare launch angles	32-34	13-14
E7 / Read the graph as evidence	35	15-16

Open the Academy, then Earth trajectory training. The on-screen question IDs match this packet. Select a section independently or work in order. Use the matching paper-page link in the lesson.

Keep your first response visible. Use a different line or colour for corrections. Paper responses, later revisions and game outcomes are different kinds of evidence.

Print portrait Letter at actual size. Two questions per worksheet page. E1/E2 use horizontal-flight T-charts. E4 has a component example; E5 has separate apex and landing T-charts. Other calculations use horizontal G.U.E.S.S. boxes; explanations and sketches have ruled space. Teacher answers are in a separate key.

REFERENCE / USE EQUATIONS AFTER THE MATCHING NOTES

Use the same clock

+x points right and +y points up. g = 9.8 m/s^2 is a positive magnitude; a_y = -9.8 m/s^2. The stopwatch begins at release. A projectile is treated as a point at the labelled centre. Artwork does not set its launch height or collision radius.

Horizontal release / slides 2-10

v_{iy} = 0; a_x = 0; v_{fx} = v_{ix}; a_y = -9.8 m/s^2
$\Delta y = v_{iy} t + \frac{1}{2} a_y t^2$; $\Delta x = v_{ix} t$; $x = x_0 + \Delta x$
d means displacement: final position minus initial position.
Find time vertically, then use that same time horizontally.

Vectors and components / slides 11-22

Add arrows tip to tail. The resultant joins the first tail to the final tip.
$v_{ix} = v_i \cos\theta$; $v_{iy} = v_i \sin\theta$; $v_i = \sqrt{(vix^2 + viy^2)}$
Angles here are measured above +x. Use degree mode.

Angled flight / slides 23-31

$v_y = v_{iy} - gt$. At the apex v_y = 0, while v_x and a_y remain.
$t_{up} = v_{iy}/g$; $H = v_{iy} t_{up} - \frac{1}{2} g\, tup^2$
For equal launch and landing heights only: T = 2tup; $R = v_{ix} T$.
Apex interval: v_{fy} = 0, dy = H. Whole flight: dy = 0, $v_{fy} = -v_{iy}$.

Graph evidence / slides 32-35

Slope of x-t gives v_x; slope of v_y-t gives a_y.
Signed area under v_x-t gives Δx; signed area under v_y-t gives Δy.
A spatial x-y path is different from a time graph.

Worked method / different numbers from your questions

A payload falls from rest through 4.9 m on Earth. Find the falling time.

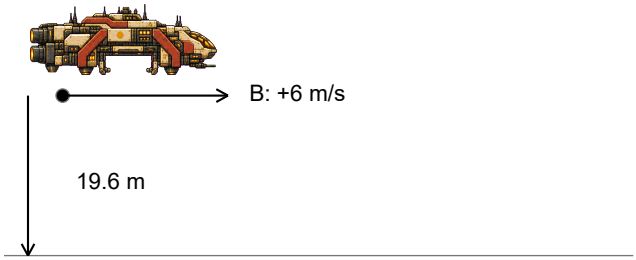
Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve
Δy = -4.9 m v_{iy} = 0 a_y = -9.8 m/s^2	t (s)	$\Delta y = v_{iy} t + \frac{1}{2} a_y t^2$	-4.9 = 0 - 4.9t^2 t^2 = 1.0 s^2	t = 1.0 s Use the future time.

Write the equation before substituting. Keep calculator precision until the final answer, then include units. A review mark or match win is not a correctness score.

E1 / NOTES SLIDES 2-8 / PREDICT AND CALCULATE

Two directions, one flight

Two identical test payloads start 19.6 m above level ground. A is dropped with $v_x = 0$; B is released horizontally at +6 m/s. Both start with $v_y = 0$. Earth g = 9.8 m/s^2; no wind or air resistance.



A: vx = 0; B: vx = +6 m/s

Given geometry only; not to scale

t (s)	A: v_y (m/s)	B: v_y (m/s)
0	0	0
0.5	-4.9	-4.9
1	-9.8	-9.8

E1.1 / Study the worked x/y T-chart for B from release to just before ground contact. Explain why v_{iy} is zero but v_{fy} is still unknown. This is guided work.

Quantity	Horizontal x	Vertical y
v_i (m/s)	+6 / given	0 / horizontal release
v_f (m/s)	+6 / same as v_{ix}	? / not calculated
a (m/s^2)	0 / no horizontal force	-9.8 / gravity down
d (m)	? / not calculated	-19.6 / 0 - 19.6
t (s)	? / the same unknown flight time in both directions	

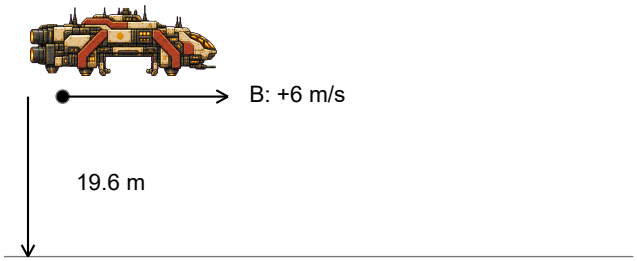
E1.2 / Use the shared table to predict which payload lands first. Which travels farther horizontally? Support both predictions with evidence.

First response stays visible. After testing, add a correction or explain agreement beside your work.

E1 / NOTES SLIDES 2-8 / EXPLAIN AND EXTEND

Two directions, one flight

Two identical test payloads start 19.6 m above level ground. A is dropped with $v_x = 0$; B is released horizontally at +6 m/s. Both start with $v_y = 0$. Earth g = 9.8 m/s^2; no wind or air resistance.



A: vx = 0; B: vx = +6 m/s

Given geometry only; not to scale

t (s)	A: v_y (m/s)	B: v_y (m/s)
0	0	0
0.5	-4.9	-4.9
1	-9.8	-9.8

E1.3 / Use the v_y-t evidence from 0 to 1.0 s to calculate vertical acceleration, including its sign and units.

Givens	Unknowns	Equation	Substitute	Solve

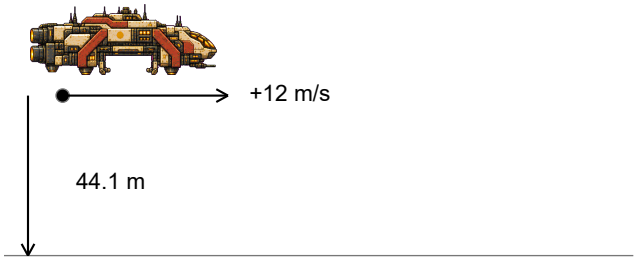
E1.4 / C has v_x = +12 m/s with the same release height and v_{iy}. Predict how its flight time and horizontal displacement compare with B. Explain.

First response stays visible. After testing, add a correction or explain agreement beside your work.

E2 / NOTES SLIDES 9-10 / PREDICT AND CALCULATE

Plan a carrier delivery

A carrier releases a test payload horizontally at (10, 44.1) m with speed +12 m/s. The landing surface is y = 0. A delivery marker is at x = 100 m. Use Earth g = 9.8 m/s^2 and no wind or air resistance.



Release x = 10 m; marker x = 100 m

Given geometry only; not to scale

Given information	Value
Release x	10 m
Height above ground	44.1 m
Horizontal release speed	+12 m/s
Marker x; ground y	100 m; 0 m

E2.1 / Complete the x/y T-chart, then calculate the time from release to first ground contact. Show the vertical equation before substituting.

Quantity	Horizontal x	Vertical y
v_i (m/s)		
v_f (m/s)		
a (m/s^2)		
d (m)		
t (s)	Shared flight time: _____	

Vertical equation and substitution:

E2.2 / Calculate horizontal displacement and final x for the original release. Explain why those numbers differ.

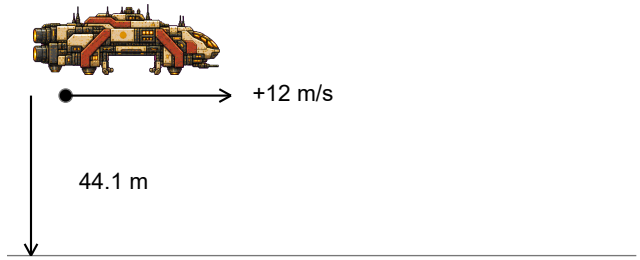
Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

First response stays visible. After testing, add a correction or explain agreement beside your work.

E2 / NOTES SLIDES 9-10 / EXPLAIN AND EXTEND

Plan a carrier delivery

A carrier releases a test payload horizontally at (10, 44.1) m with speed +12 m/s. The landing surface is y = 0. A delivery marker is at x = 100 m. Use Earth g = 9.8 m/s^2 and no wind or air resistance.



Release x = 10 m; marker x = 100 m

Given geometry only; not to scale

Given information	Value
Release x	10 m
Height above ground	44.1 m
Horizontal release speed	+12 m/s
Marker x; ground y	100 m; 0 m

E2.3 / Calculate the release x needed to land at the x = 100 m marker with the same height and velocity.

Givens	Unknowns	Equation	Substitute	Solve

E2.4 / A second carrier travels at +24 m/s from the same height. Calculate its flight time and displacement. Explain what changed.

Givens	Unknowns	Equation	Substitute	Solve

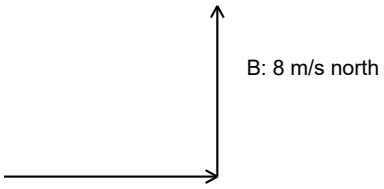
First response stays visible. After testing, add a correction or explain agreement beside your work.

E3 / NOTES SLIDES 11-18 / PREDICT AND CALCULATE

Add and compare vectors

A calibration display combines two velocity vectors: A = 6 m/s east and B = 8 m/s. Compare B directed east, west and north. These are vector-addition diagrams, not changes in gravity or a second push on a projectile.

Perpendicular trial: add tip to tail



Draw the resultant yourself.

Trial	Vector A	Vector B
Same direction	6 m/s east	8 m/s east
Opposite	6 m/s east	8 m/s west
Perpendicular	6 m/s east	8 m/s north

E3.1 / Find the resultant magnitude and direction for the same-direction and opposite-direction trials.

Givens	Unknowns	Equation	Substitute	Solve

E3.2 / For B northward, draw the tip-to-tail triangle. Calculate resultant magnitude and angle north of east.

Givens	Unknowns	Equation	Substitute	Solve

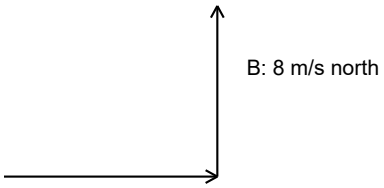
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E3 / NOTES SLIDES 11-18 / EXPLAIN AND EXTEND

Add and compare vectors

A calibration display combines two velocity vectors: A = 6 m/s east and B = 8 m/s. Compare B directed east, west and north. These are vector-addition diagrams, not changes in gravity or a second push on a projectile.

Perpendicular trial: add tip to tail



Draw the resultant yourself.

Trial	Vector A	Vector B
Same direction	6 m/s east	8 m/s east
Opposite	6 m/s east	8 m/s west
Perpendicular	6 m/s east	8 m/s north

E3.3 / Which magnitudes could result from these same two vectors: 1, 2, 10, 14 or 16 m/s? Justify using the minimum and maximum.

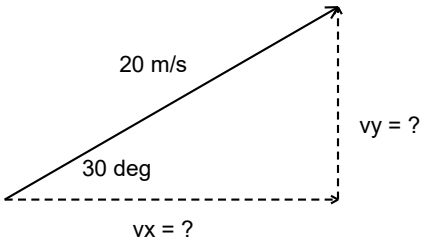
E3.4 / Explain why changing the angle between A and B changes the resultant even though neither vector changes length. Include a labelled sketch.

First response stays visible. After testing, add a correction or explain agreement beside your work.

E4 / NOTES SLIDES 19-22 / PREDICT AND CALCULATE

Resolve the launch velocity

A stationary training cannon launches at 20 m/s, 30° above horizontal. The diagram shows the launch velocity and its two perpendicular components. Earth g = 9.8 m/s^2 applies after launch; this component calculation uses the initial vector.



Case	Given information	Angle reference
A	20 m/s at 30°	above +x
B	v_x = 12; v_y = 16 m/s	find θ above +x
C	v_x = 6.0 m/s; θ = 30°	above +x

Worked component example / different numbers

For 10 m/s at 30 deg: v_{ix} = 10 cos 30 deg = 8.66 m/s; v_{iy} = 10 sin 30 deg = 5.00 m/s. Now use case A below.

E4.1 / Calculate v_{ix} and v_{iy} for case A. Label them on a right-triangle diagram.

Quantity	Given or calculated value
v_i	20 m/s
θ	30 deg above +x
v_{ix}	_____ m/s
v_{iy}	_____ m/s

Equation and substitution:

E4.2 / For case B, calculate the initial speed and angle above horizontal.

Quantity	Given or calculated value
v_{ix}	12 m/s
v_{iy}	16 m/s
v_i	_____ m/s
θ	_____ deg above +x

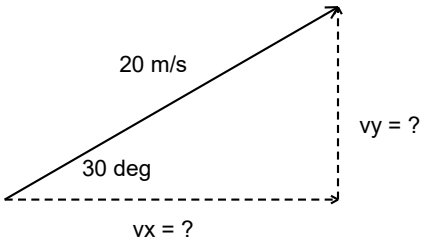
Equation and substitution:

First response stays visible. After testing, add a correction or explain agreement beside your work.

E4 / NOTES SLIDES 19-22 / EXPLAIN AND EXTEND

Resolve the launch velocity

A stationary training cannon launches at 20 m/s, 30° above horizontal. The diagram shows the launch velocity and its two perpendicular components. Earth g = 9.8 m/s^2 applies after launch; this component calculation uses the initial vector.



Case	Given information	Angle reference
A	20 m/s at 30°	above +x
B	v_x = 12; v_y = 16 m/s	find θ above +x
C	v_x = 6.0 m/s; θ = 30°	above +x

E4.3 / For case C, find the full initial speed and the initial vertical component.

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

E4.4 / Change case A to 60° while keeping 20 m/s. Calculate both components and explain the changes.

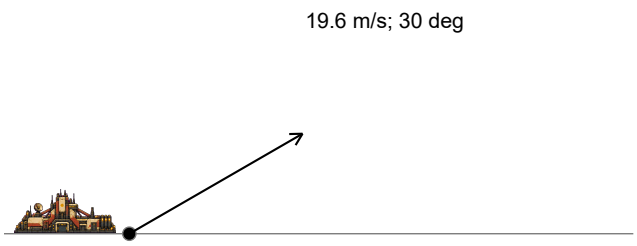
Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

First response stays visible. After testing, add a correction or explain agreement beside your work.

E5 / NOTES SLIDES 23-31 / PREDICT AND CALCULATE

Follow an angled projectile

A stationary test cannon launches at 19.6 m/s, 30° above horizontal, from (0, 0) m. It returns to the same elevation with no earlier collision. Use Earth g = 9.8 m/s^2; neglect air resistance and wind. The marked point defines launch, independent of sprite size.



Launch y = landing y = 0 m

Given geometry only; not to scale

Quantity	Horizontal	Vertical
Initial velocity	19.6 cos 30°	19.6 sin 30°
Acceleration	0 m/s^2	-9.8 m/s^2
At apex	find v_x	$v_y = 0$
Whole-flight displacement	range	0 m

E5.1 / Resolve the 19.6 m/s launch velocity into initial x and y components.

Quantity	Given or calculated value
v_{ix}	_____ m/s
v_{iy}	_____ m/s

Equation and substitution:

E5.2 / Complete a launch-to-apex T-chart. Calculate time to apex and maximum height above launch.

INTERVAL: LAUNCH TO APEX / +x right, +y up

Quantity	Horizontal x	Vertical y
v_i (m/s)		
v_f (m/s)		
a (m/s^2)		
d (m)		
t (s)	Shared flight time: _____	

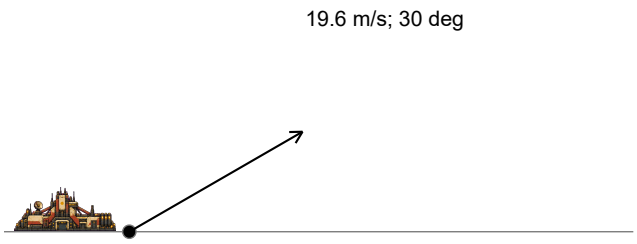
Equations, substitution and reasoning:

First response stays visible. After testing, add a correction or explain agreement beside your work.

E5 / NOTES SLIDES 23-31 / EXPLAIN AND EXTEND

Follow an angled projectile

A stationary test cannon launches at 19.6 m/s, 30° above horizontal, from (0, 0) m. It returns to the same elevation with no earlier collision. Use Earth g = 9.8 m/s^2; neglect air resistance and wind. The marked point defines launch, independent of sprite size.



Launch y = landing y = 0 m

Given geometry only; not to scale

Quantity	Horizontal	Vertical
Initial velocity	19.6 cos 30°	19.6 sin 30°
Acceleration	0 m/s^2	-9.8 m/s^2
At apex	find v_x	$v_y = 0$
Whole-flight displacement	range	0 m

E5.3 / Complete a launch-to-landing T-chart. Calculate total flight time and horizontal range. State why doubling the ascent time is valid here.

INTERVAL: LAUNCH TO LANDING / +x right, +y up

Quantity	Horizontal x	Vertical y
v_i (m/s)		
v_f (m/s)		
a (m/s^2)		
d (m)		
t (s)	Shared flight time: _____	

Equations, substitution and reasoning:

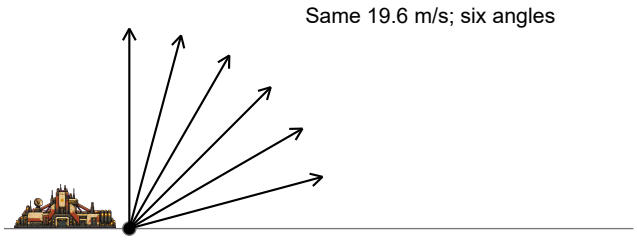
E5.4 / At the apex, state v_x, v_y, a_x and a_y. Evaluate the statement: “The projectile stops and has no acceleration at the top.”

First response stays visible. After testing, add a correction or explain agreement beside your work.

E6 / NOTES SLIDES 32-34 / PREDICT AND CALCULATE

Compare launch angles

Six separate launches use 19.6 m/s at 15°, 30°, 45°, 60°, 75° and 90°. Each starts and lands at y = 0, with Earth g = 9.8 m/s^2 and no wind, air resistance or intervening obstacles. Angle is the only changed variable.



Launch y = landing y = 0 m

Given geometry only; not to scale

Trial pair	Initial speed	Landing elevation
15° and 75°	19.6 m/s	same as launch
30° and 60°	19.6 m/s	same as launch
45° and 90°	19.6 m/s	same as launch

E6.1 / Calculate total flight time and range for 30° and 60°. Compare the results.

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

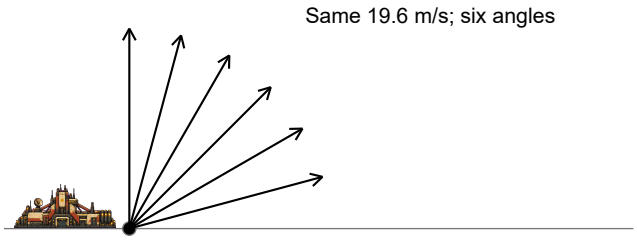
E6.2 / Predict which listed angle gives maximum range and which gives maximum height. State the conditions that make the comparison valid.

First response stays visible. After testing, add a correction or explain agreement beside your work.

E6 / NOTES SLIDES 32-34 / EXPLAIN AND EXTEND

Compare launch angles

Six separate launches use 19.6 m/s at 15°, 30°, 45°, 60°, 75° and 90°. Each starts and lands at y = 0, with Earth g = 9.8 m/s^2 and no wind, air resistance or intervening obstacles. Angle is the only changed variable.



Launch y = landing y = 0 m

Given geometry only; not to scale

Trial pair	Initial speed	Landing elevation
15° and 75°	19.6 m/s	same as launch
30° and 60°	19.6 m/s	same as launch
45° and 90°	19.6 m/s	same as launch

E6.3 / At 45°, calculate the range at 19.6 m/s, then at twice that speed. Compare using components and flight time.

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

E6.4 / Identify both complementary-angle pairs in the table. Explain why two launches can have equal range but different apex heights and flight times.

First response stays visible. After testing, add a correction or explain agreement beside your work.

E7 / NOTES SLIDES 35 / PREDICT AND CALCULATE

Read the graph as evidence

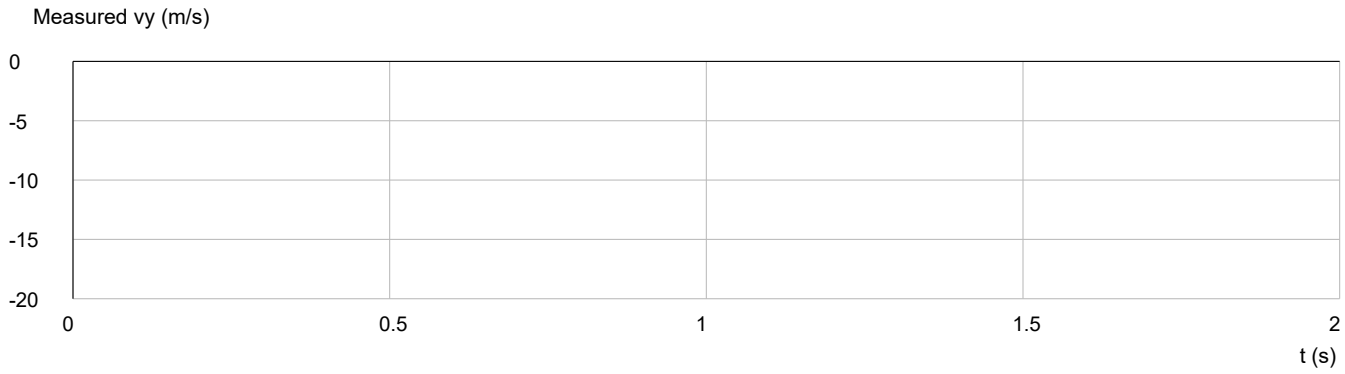
The table is supplied classroom data for a payload released from rest, sampled in separate timing trials. Downward measured speeds have been assigned negative v_y because +y is upward. These values include measurement variation; they are not exact game telemetry. The animated comparison is an ideal drop from 19.6 m.

Plot the table on the large grid below.

Choose a best-fit line that represents the overall trend. Keep units and the upward-positive sign convention visible.

Falling time t (s)	Measured v_y (m/s)
0	0
0.5	-4.8
1	-9.9
1.5	-14.6
2	-19.7

E7.1 / Plot the supplied data on the graph. Draw a best-fit straight line and explain why negative v_y is appropriate.



E7.2 / Use two widely separated points on your best-fit line to calculate its slope. State the physical quantity and units.

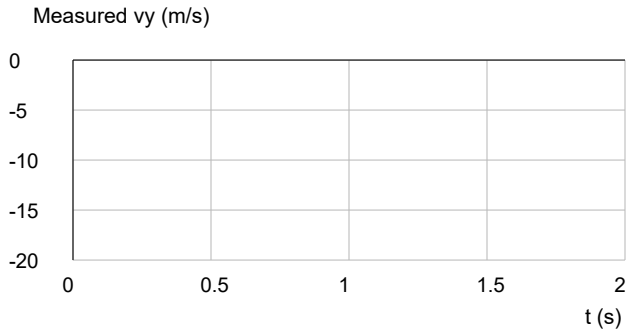
Givens	**U**nknowns	**E**quation	**S**ubstitute	**S**olve

First response stays visible. After testing, add a correction or explain agreement beside your work.

E7 / NOTES SLIDES 35 / EXPLAIN AND EXTEND

Read the graph as evidence

The table is supplied classroom data for a payload released from rest, sampled in separate timing trials. Downward measured speeds have been assigned negative v_y because +y is upward. These values include measurement variation; they are not exact game telemetry. The animated comparison is an ideal drop from 19.6 m.



Falling time t (s)	Measured v_y (m/s)
0	0
0.5	-4.8
1	-9.9
1.5	-14.6
2	-19.7

E7.3 / Calculate percent error between the magnitude of your slope and 9.8 m/s^2. Show the comparison clearly.

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

E7.4 / Compare the supplied measurements with the ideal simulation. Use numerical evidence and describe one measurement limitation.

First response stays visible. After testing, add a correction or explain agreement beside your work.