Name___________________________

Round your uncertainty to two digits, and the answer to that place. (?)

1. Adding or subtracting

23.5 ± 0.4	127 ± 5
$\underline{+\ 42.6 \pm 0.7}$	$\underline{-\ 98 \pm 2}$

2. Multiplying and/or dividing:

With % uncertainty

$9 \pm 5\%$	$12 \pm 3\%$	$119 \pm 12\%$	$209 \pm 7\%$
$\underline{\times\ 7 \pm 3\%}$	$\underline{\times\ 4 \pm 11\%}$	$\underline{\div\ 17 \pm 4\%}$	$\underline{\div\ 19 \pm 5\%}$

With absolute uncertainty:

7.8 ± 0.5	7.35 ± 0.09	312 ± 2	22.6 ± 0.9
$\underline{\times\ 8.4 \pm 0.3}$	$\underline{\times\ 2.23 \pm 0.03}$	$\underline{\div\ 11 \pm 1}$	$\underline{\div\ 1.78 \pm 0.05}$

3. Powers

$(15.0 \pm 2.5)^2$ $(2.75 \pm 0.12)^4$ $\sqrt{17.0 \pm 2.1}$ $\sqrt[4]{1250 \pm 113}$

IB Physics
FA 1.1 - Uncertainty

Name__________________________

Do these calculations – express the answer as a result and an uncertainty. For the multiplication and division, round the uncertainty to two places, and round the answer to match the decimal place of the uncertainty. **<u>You must memorize the formulas for this!</u>**

When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

$(2.4 \pm 0.1) + (4.5 \pm 0.3) = ?$ 6.9±.4	$(7.2 \pm 0.5) - (3.1 \pm 0.4) = ?$ 4.1±.9
$(7.3 \pm 0.2) \times (9.5 \pm 0.2) = ?$ 69.4±3.4	$(12.7 \pm 0.5) / (3.1 \pm 0.2) = ?$ 4.10±.43
$(9 \pm 5\%) \times (7 \pm 8\%) = ?$ (Give a percent uncertainty) 63±13%	$(56 \pm 2\%) / (7 \pm 3\%) = ?$ (Give a percent uncertainty) 8±5%
$(9.0 \pm 0.2)^2$ 81.0±3.6	$\sqrt{}(25 \pm 2)$ 5.00±.20?

Uncertainty –
Any measurement or value in Physics will have an uncertainty. Here's how to estimate that uncertainty:

- Measuring with a ruler: The uncertainty is ± half the smallest division on the ruler. If you measure something that is 12.4 cm long with a ruler that has mm divisions, then your uncertainty is ± .5 mm or ± .05 cm so you would say 12.4 ± .05 cm
- Using a digital readout: The uncertainty is ± the last digit. If you have an ammeter that reads 1.56 Amps, it would be 1.56 ± .01 Amps.
- Multiple trials of something with random error: You could say that it is the average, ± range/2. If you did 3 trials for the rocket lab, and a rocket stayed up in the air for 5.23, 5.25, 5.12, and 5.36 seconds, you could say that it is 5.24 (the average) ± 0.12 (the range/2, i.e. (5.36-5.12)/2).

Directions: The answers are on the side. (Uncertainties should be rounded to 1 or 2 sig figs, and the number of decimal places in the answer should not exceed the limit of the uncertainty)

Adding or subtracting – the uncertainty of a sum or difference is the sum of the uncertainties

25.2 ± 0.7	13.1 ± 0.2	23.12 ± 0.01	24 ± 2	21.3 ± 0.5
6.87 ± 0.03	+ 12.1 ± 0.5	- 16.25 ± 0.02	+ 127 ± 5	- 21.1 ± 0.1
151 ± 7				
0.2 ± .6??				

Multiplying and/or dividing – if $y = ab/c$, then $\Delta y/y = \Delta a/a + \Delta b/b + \Delta c/c$ (Δ reads uncertainty of) Round uncertainty to two sig figs.

31.6 ± 3.8	5.10 ± 0.2	3.12 ± 0.05	484 ± 2	137 ± 9
3.59 ± 0.15	x 6.20 ± 0.5	x 1.15 ± 0.03	÷12.0 ± 1	÷ 1.78 ± 0.05
40.3 ± 3.5				
77.0 ± 7.2				

(These are easy - % uncertainties are fractional uncertainties, so just add the %)

12% — 0. What is the percent uncertainty of the area of a rectangle if the length is uncertain by 5%, and the width by 7%

9% — 1. What is the percent uncertainty of the volume of a cube if the sides each have a percent uncertainty of 3%?

15% — 2. A sphere has a radius with an uncertainty of 5%, what is the percent uncertainty of the volume?

Powers – if $y = a^n$, then $\Delta y/y = |n\Delta a/a|$ (Δ reads uncertainty of) Round uncertainty to two sig figs.

$(12.6 \pm 1.2)^2$	$(3.4 \pm .1)^3$	$\sqrt{(16 \pm 3)}$	$\sqrt[3]{(343 \pm 31)}$
159 ± 30.	39.3 ± 3.5	4.00 ± .38?	7.00 ± 0.21

Word problems (the test isn't like these : -)

21.2 ± 1.3 m/s — 0. A car goes 45 ± .5 m in 2.12 ± 0.11 seconds. What is the speed of the car, and what is the uncertainty of the speed?

14.7 ± .8 m^2
.77? — 1. What is the area (with uncertainty) in square meters of a rectangular room that measures 3.5 x 4.2 m where both measurements have an uncertainty of .1 m?

140.4 ± 6.0 cm — 2. A staircase has 12 steps, each one being 11.7 ± .5 cm high. What is the total height of the staircase with uncertainty? (Add twelve together…)

1.2 ± 1.3 cm
Yes — 3. One board is 24.1 ± .5 cm long, and another is 25.3 ± .8 cm long. How much longer is the second than the first? Could the first possibly be longer?

452.4 ± 7.5 cm^2 — 4. What is the area (with uncertainty) of a circle that is 12.0 cm ± .1 cm in radius? (area = πr^2 so that is $\pi x r x r$)

589 ± 68 cc — 5. A sphere has a radius of 5.2 ± .2 cm. What is its volume in cubic centimeters? ($V = 4/3\pi r^3$)

Group Quiz 2.3 – Linear Kinematics

Name_______________________________

1. A car going 11.0 m/s accelerates at 0.890 m/s/s for 15.0 s. How far does it go in this time?

2. A runner accelerates from rest at 3.40 m/s/s to a final velocity of 9.40 m/s. What distance do they go?

3. A tennis ball cannon rolls to a stop covering a distance of 3.80 m in 7.20 s. What was its initial velocity?

4. A car covers 113 m accelerating at 0.640 m/s/s for 14.0 s. What was its initial velocity?

5. A car covers 212 m in 13.0 seconds, and is going 14.0 m/s at the end. What is its acceleration during this time?

6. A car going 20.0 m/s accelerates at 0.920 m/s/s. What time does it take to cover 123 m?

7. An airplane reaches a speed of 52.0 m/s from rest on a runway that is 890. m long. What is its speed when it has gone only 100. m down the runway?

8. A train decelerates from 32.0 m/s to 21.5 m/s in 41.0 seconds. What time did it take it to cover 500. meters from the beginning?

IB Physics
FA 2.3 - Basic Kinematics

Name__________________________

Round to the correct significant figures, circle your answers, and label them with units. **You must memorize the kinematics formulas for this!**
When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1. A car has an acceleration of 1.20 m/s/s for 3.50 seconds, at the end of which it is going 24.0 m/s. What was its initial velocity?

2. A car moves 214 m with an acceleration of 4.80 m/s/s in 6.00 seconds. What was its final velocity?

3. A dragster starts from rest and moves 180. m in 4.30 seconds. What is its acceleration?

4. A bike coasts from 12.5 m/s to rest in a distance of 27.2 m. What is its acceleration?

5. An airplane coasts with a uniform acceleration from 92.5 m/s to rest over a distance of 624 m. What was its velocity when it had covered only 200. meters of that distance?

Practice for 2.3

On a separate sheet of paper, show your work. List your knowns (suvat), show which formula you are going to use, and show the knowns in that formula.

	Regular one step or two step problems:
11.2 m	1. A Pirate Ship accelerates uniformly from 1.80 m/s to 5.60 m/s with an acceleration of 1.25 m/s/s. What was its displacement?
8.28 m/s	2. A lemur going 3.45 m/s accelerates at 1.52 m/s/s for 3.18 s. What is its final velocity?
-8.85 m/s/s	3. A giant lizard stops in 5.85 m in 1.15 s. What was its acceleration?
12.4 s	4. A tuna going 2.35 m/s accelerates at 0.208 m/s/s covering a distance of 45.0 m. What time did it take?
7.27 m	5. A lemming speeds up from rest to 5.19 m/s in 2.80 s. What is its displacement during this time?
21.6 m/s	6. An accident scene detective knows that a car with a deceleration of -7.14 m/s/s was brought to rest in 32.8 m. What was the initial velocity?
-1.22 m/s/s	7. What is the acceleration of an ATV that goes from 12.0 m/s to 7.50 m/s in 3.68 s?
41.9 m	8. A XC runner accelerates uniformly for 8.20 s at 0.540 m/s/s having a final velocity of 7.32 m/s. What is their displacement during this time?
22.8 m/s	9. A racecar accelerates at 5.13 m/s/s for 3.35 s covering a distance of 105 m. What was its initial velocity?
21.9 m/s	10. A car avoiding an accident is brought to rest over a distance of 56.0 m in 5.12 s. What was its initial velocity?
-4690 m/s/s	11. A baseball going 38.0 m/s decelerates to rest over a distance of 0.154 m. What was its deceleration? (It's big)
-2.01 m/s/s	12. A car goes from 27.2 m/s to 14.7 m/s in 6.23 s. What is its acceleration?
458 m	13. A train going 45.0 m/s decelerates at -2.17 m/s/s for 17.9 s. What is its displacement during this time?
4.36 m/s	14. A hamster going 2.7 m/s accelerates uniformly for 6.52 s, covering a distance of 23.0 m. What was its final velocity? (it's riding a hamster scooter)
2.33 s	15. A car is going 15.0 m/s after having decelerated at -6.25 m/s/s over a distance of 52.0 m. What time did it take?
-25.1 m/s	16. A hot pocket accelerating at -9.81 m/s/s from rest falls downward -32.1 m. What is the final velocity?
18.2 m/s	17. A car accelerates uniformly for 8.70 s with a final velocity of 31.5 m/s over a distance of 216 m. What was its initial velocity?
2.39 s	18. A car that can brake at -8.92 m/s/s will take what time to decelerate from 33.1 m/s to 11.8 m/s?
81.6 m	19. A rollercoaster car going 8.60 m/s decelerates at -0.215 m/s/s for 11.0 s. What was its displacement during this time?
47.1 s	20. A space probe is going 615 m/s after having decelerated at -0.147 m/s/s over a distance of 29,100 m. What time did it take?
	Two-part kinematics problems:
39.2 m	21. A dragon accelerates from 1.13 m/s to 3.60 m/s in 4.13 seconds. Over what distance could it accelerate from rest to 6.85 m/s if it had the same acceleration?
4.98 s	22. A car accelerates uniformly from rest, covering 65.0 m in 5.62 seconds. What time would it take the same car to go from 8.90 m/s to 29.4 m/s if it had the same acceleration?
7.73 m/s	23. A runner covers 21.5 m accelerating uniformly from rest to 9.94 m/s. What was their speed when they had covered only 13.0 m?
2.84 s	24. A train decelerates from 35.0 m/s to 22.0 m/s in 42.0 seconds. What time did it take it to cover 98.0 meters from the beginning?
17.5 s	25. A car accelerates from rest to 23.0 m/s over a distance of 231 m. What time would it take it to accelerate from rest to 20.0 m/s if it accelerated at the same rate?

Group Quiz 2.4 – Free Fall

Name______________________________

Use the acceleration of gravity to be 9.81 m/s/s, and use the convention that downward quantities are negative.

1. A rock falls from rest from a 23.0 m tall cliff. What time does it take to reach the ground? What is the velocity of impact?

2. An air rocket leaves the ground with an initial velocity of 34.2 m/s, and returns to the ground at the same elevation. What height does it reach before coming down? What time does it take to reach the top? What is its total time in the air?

3. A baseball is popped up and caught at the same elevation 8.32 seconds later. What time did it spend going up? What was its initial velocity? What two velocities does it have when it reaches an elevation of 60.0 m? What time does it take from when it leaves the bat to when it reaches 60.0 m on the way **up**? What time does it take from when it leaves the bat to when it reaches 60.0 m on the way **down**?

4. A ball is thrown **downwards** from an 18.2 m tall building at a speed of 6.82 m/s. What is its velocity of impact with the ground? What time does it take to reach the ground?

5. A ball is thrown upward from the top of a 12.4 m tall tower, and strikes the ground 3.80 s later. What was its initial upward velocity? With what velocity does it strike the ground?

6. An air rocket leaves the ground and strikes a 9.50 m tall light tower on the way down with a speed of 6.20 m/s. What was its initial velocity leaving the ground? What time did it spend in the air?

IB Physics
FA 2.4 – Free Fall Kinematics

Name___________________________

Round to the correct significant figures, circle your answers, and label them with units. Ignore air friction and use the convention that down is negative. g = 9.81 m/s/s. **You must memorize the kinematics formulas for this!**

When you have finished this, go to the website and check your answers. If you got a problem wrong, cross it off on the front, and do it correctly on the back.

1-3: An air rocket is launched vertically upward at a velocity of 28.0 m/s.

1. What time will it take to reach the top? What is the greatest height it reaches? What total time will it be in the air?

2. What will be its position and velocity 4.20 s after it is launched?

3. What time will elapse before it is at an elevation of 27.0 m on the way up? on the way down?

4-5: A baseball is popped up to a height of 24.1 m above the bat.

4. What velocity did it leave the bat going upwards? What time will it spend in the air before it reaches the level of the bat again?

5. What two velocities does it have at an elevation of 18.0 m above the bat?

Free Fall Practice Problems from 2.4

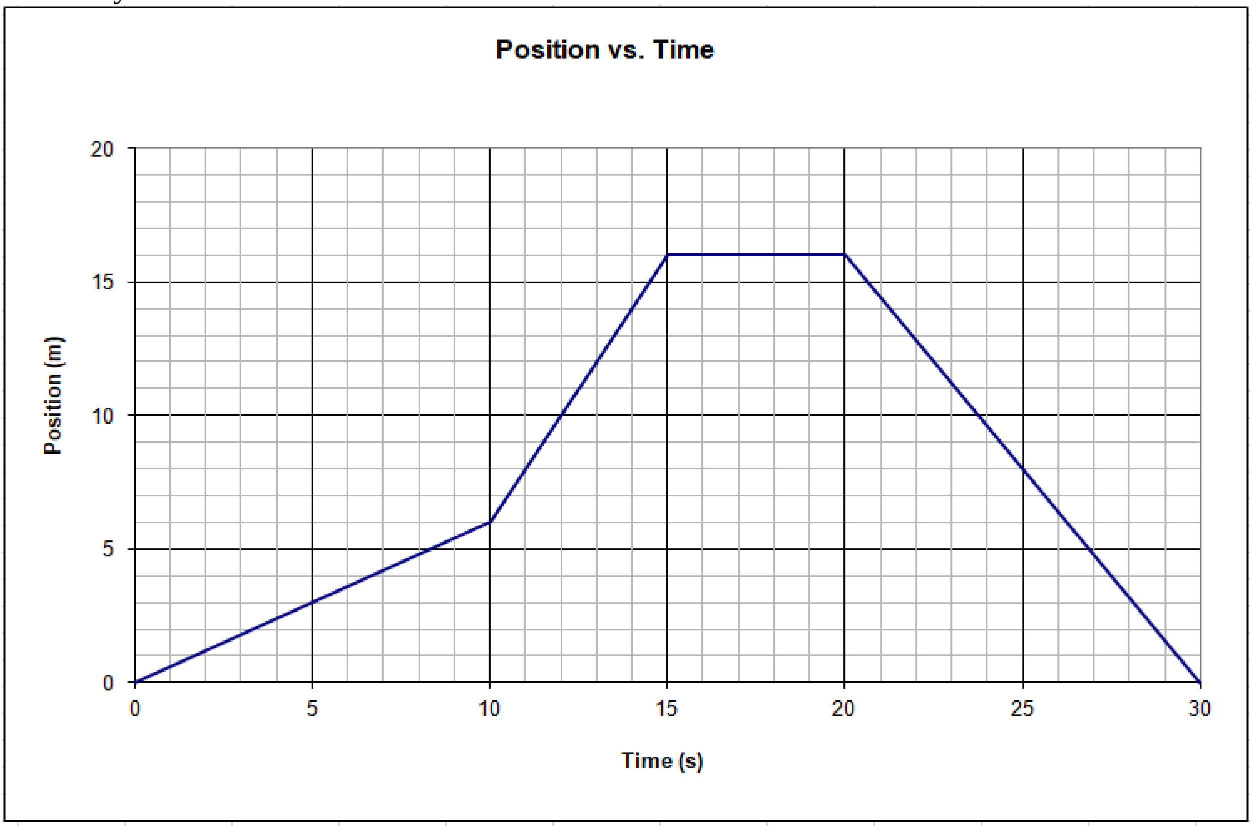
On a separate sheet of paper, show your work. List your knowns (suvat), show which formula you are going to use, and show the knowns in that formula. Round to the correct significant figures, ignore air friction and use the convention that down is negative. g = 9.81 m/s/s

49.0 m 31.0 m/s 32.4 m	1. A Turkey is shot straight up and remains in the air for a total (up <u>and</u> down) time of 6.32 s before coming down again to the same elevation. What is the greatest height it reaches? What was its initial velocity? What is its displacement exactly 5.00 seconds after it is launched?
19.2 m 1.98 s 3.65 s	2. A frozen pot pie is launched upwards at 19.4 m/s, and lands at the same elevation from which it was launched. To what height does it rise before going back down again? What time does it take to reach the very highest point? What time elapses between release, and the pie being 5.50 m above the release point on the way down?
-9.66 m/s 31.7 m	3. A lemon is launched upwards at 28.0 m/s. It goes up, and on the way down it strikes the top of a 35.2 m tall light tower. With what velocity does it strike the light tower? What is its displacement 4.15 seconds after it is launched?
25.6 m/s 33.4 m -17.9 m/s	4. A flaming digital air rocket is launched vertically upwards, and is in the air for a <u>total</u> (up <u>and</u> down) of 5.22 s, before striking the ground again. At what velocity was it launched? What height did it reach? What was its velocity at an elevation 17.0 m as it was going <u>down</u>?
11.2 m/s 2.29 s 1.01 m	5. A chicken nugget is thrown upwards and reaches a height of 6.45 m above its release point, and is caught at the same elevation from which it was thrown. What was its initial velocity? What total time is the nugget in the air? What is its position 2.20 seconds after it is released?
-15.9 m/s 1.20 s	6. A gourd is thrown downward from the top of a 12.0 m tall building at a velocity of -4.12 m/s. With what velocity will it strike the ground? What time will it take to reach the ground?
42.0 m/s 84.6 m 7.30 s	7. A watermelon is launched straight upwards, and strikes the ground at the same elevation from which it is launched. It goes to a maximum height of 89.7 m before coming down. What was its initial velocity leaving the ground? What is its displacement 5.30 s after it leaves the ground? What time will it take from when it is launched to when it reaches an elevation of 45.0 m on the way down?
11.7 m/s -21.8 m/s	8. A projectile is thrown vertically upward from the top of a 17.2 m tall building and strikes the ground 3.42 s after it is released. What was its initial velocity? With what velocity does it strike the ground?
14.7m 2.86 s	9. A hot pocket is thrown vertically upwards at 17.0 m/s, and lands on a roof on the way down that is 8.50 m tall. What height does it reach? What time does it take to hit the roof on the way down?
13.5 m/s -7.82 m/s	10. A giant sloth throws a ball upward from the ground, and it comes down on top of a 6.12 m tall building in 2.17 s What is the ball's initial upward velocity? With what velocity does it strike the roof?

Name____________________

Graphs of Motion - Answer the questions below it, and show any calculations you made. Don't freak out if you don't get my exact answer – you should be within 0.1 or 0.2 of the right answer.

1. The position of a car is shown on the graph below. Answer the questions below it, and show any calculations you made.



This is a position question – you can just read the graph

a) What is the car's position at 15 seconds? 25 seconds? How about 6 s? 26 s?

b) At what time(s) is the car at 8 m? 16 m? 5 m?

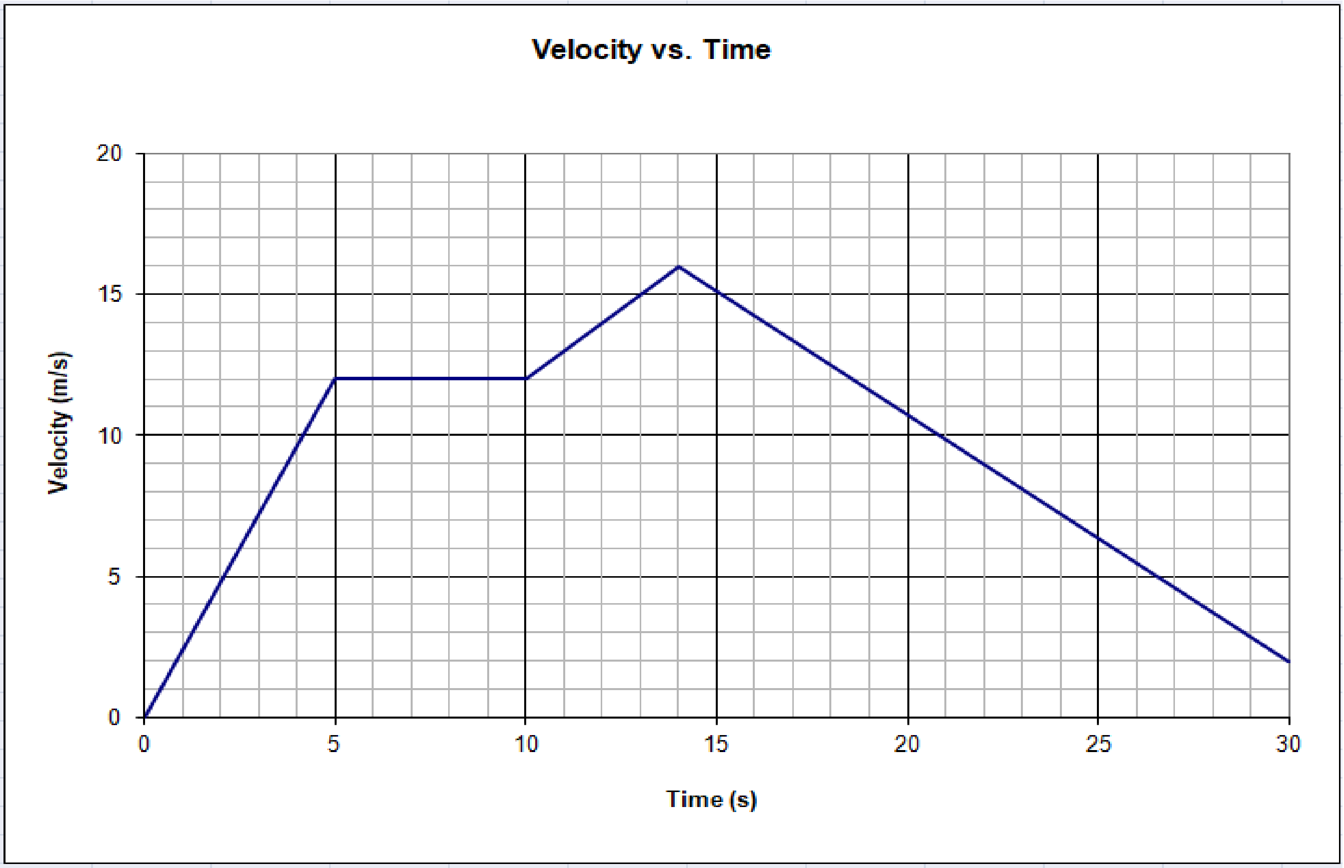
The next few questions are about velocity. Velocity is slope on this kind of graph.

c) What is the velocity at 5 seconds? (Use the whole line segment to find the slope – from 0 – 10 s)

d) What is the velocity at 12 seconds? at 17 seconds? At 25 seconds? (Use the whole line segment)

Answers: (a: 16 m, 8 m, ≈3.6 m, ≈6.3 m) (b: 11 s and 25 s, 15 s-20 s, 8.3 s and 26.9 s) (c: 0.60 m/s) (d: 2.0 m/s, 0.0 m/s, -1.6 m/s)

2. – This is a velocity vs. time graph for a different car.



This is a velocity question – you can just read the graph.
a) When is the velocity 12 m/s? What is the highest velocity it has? What is the velocity at 20.0 s?

The next question is an acceleration question. Acceleration is the slope of a velocity graph.
b) What is the acceleration at 3 seconds? at 6 seconds? at 12 seconds? at 25 seconds? Use the whole line segment to calculate the slopes.

These are displacement questions. Displacement is the area under this kind of graph.
c) What is the displacement of the car between 5 and 10 seconds?

d) What is the displacement of the car between 0 and 5 seconds?

e) What is the displacement for the whole graph? (0-30 s)

Answers: (a 5-10s and 18.6s, 16 m/s, 10.8 m/s) (b 2.4 m/s/s, 0, 1 m/s/s, -0.875 m/s/s) (c 60 m) (2d 30 m) (e 290 m)

IB Physics

Measuring the Initial
Velocity of an Air Rocket

You can measure the initial velocity of an air rocket by firing it straight up into the air and timing how long it takes to reach the earth again. **If you need help with this there is a website for this lab with videos**

Materials:

1. Get a launch platform, a bicycle pump, a nose cone, a rocket body, and four different sizes of thrust washers. (Super, High, Medium, and Low) Locate yourself at least 30 feet from the nearest group, or hard surface.

Design

2. Your goal is to measure the initial velocity of the air rocket as it leaves the launch pad from the time it is in the air. This is tricky because the launch is always unpredictable – so the timer's reaction time introduces a **systematic** error. Clever students estimate this error and add it to the average of time. You need to decide how many trials of each washer to do, how to time, and how to correct for the timer's reaction time. There is also random trial to trial error. (Not every launch is the same.) **Write a brief sentence on how you dealt with this systematic error**

Data Collection and Processing

3. •**Create a nice data table for your raw data.** Include in your table **labels**, **units** and **uncertainty**. You will have to calculate the uncertainty for each washer from the trials. The uncertainty for multiple trials of a washer is $\pm\frac{range}{2}$ where the range is Max-Min. This trial to trial error is actual **random** error intrinsic to the timing method and the apparatus itself.

Your data table should: •be a **table** (draw lines around it) •have the **units** labeled •have the **uncertainty** of each thrust washer's data in it. Watch the online videos if this makes no sense to you.

4. •Calculate one initial launch velocity from the **average** of your trials for each washer. It would be appropriate to add the timer's reaction time to the average to arrive at the total time the rocket is in the air. (Remember – at **½ the total time** in the air the final velocity is 0, so you know v, a and t) •Show each of these calculations.

5. •Also **calculate the uncertainty of this velocity** from the uncertainty of time.

(use the relation $\frac{\Delta u}{u} = \frac{\Delta t}{t}$ - that the fractional uncertainty of the time is the same as that of the velocity) •Show each of these calculations.

6. •Create an appropriate **graph** to present your calculated **velocities**. (**Computer generated**, or by hand **on graph paper**…) **Be sure that the graph starts with 0 (zero) on the y-axis**. Your graph should reflect the uncertainty of the velocity you calculated.

Conclusion and Evaluation

7. •Evaluate the procedure as per IB criteria:
   - Cite what your velocities were (all 4) and write a sentence or two about any patterns that emerged
   - List 2-3 main sources of error present in the procedure and equipment used
   - Suggest improvements to mitigate the identified sources of error

IB Moving Plots

Here you will use a 60Hz tape timer to make position and velocity v time graphs of an object in free fall. (or nearly in free fall)
If you need help with this there is a website for this lab with videos

Getting a Tape:

1. **You and one partner** will need a mass, a spark timer kit and some masking tape. You may work in a group larger than two to gather data, just get a different tape for every two people at least.
2. Cut a 1.3 m length of expensive silver timer tape, and feed it from the top through the tape timer, so that about 5 cm or so sticks through the bottom. Have one person stand up on a chair holding the tape near the other end (way up high), and have the other person clip the 0.5 kg mass to the other end. (If it slides off, try putting a bit of masking tape on the timer tape on that end) Pull the mass up as high as you can, turn the timer on, wait until the mass stops swinging, and have the person on the chair release the mass so it falls into the sandbox on the floor.

Analyzing the Tape:

1. Tape a meter stick to the table, and tape your timer tape next to it at both ends so the first clear dot is at the 0 cm end of the meter stick.
2. Write down, measuring to the nearest millimeter, where the dots fall on the meter stick. These numbers should increase from 0 to almost 100. Do not measure between the dots.
3. In Google Sheets, make a column that is labeled Time (s), and have it be every 60th of a second. (0, 0.01666, 0.03333, 0.05000, 0.06666, etc.) There is a quick way to do this that I will show in the video. In the second column labeled Position (cm) type in your positions of your dots, starting with the first dot at 0 cm, and ending with a number close to 100 cm. In your third column labeled Velocity (cm/s), make a formula that is the distance traveled in the last 1/60th of a second, divided by the elapsed time (1/60th s) This will look like "=(B3-B2)*60". You will have one fewer of these than positions, and this will start next to the second position.
4. Make **two** nice **x-y scatter** graphs: (Vertical vs. Horizontal)
   a. Distance (cm) vs time (s) – choose the smooth line graph, label the axes etc., and make it a separate sheet. Add a second order polynomial trendline, and label it with the equation.
   b. Velocity (cm/s) vs. time (s) – choose the points only, and you could put this graph on the same page as the data to save paper. Add a "Linear" trend line to this graph, displaying the equation on the graph.

Write up:

Tangent Lines: Pick a smooth part of the distance vs. time graph. •Draw a long tangent line with a ruler to a smooth part of the curve. The line should go off the plot frame at both ends. •By using the coordinates read from your axes of where your tangent line enters and exits the plot frame, find the slope of the line you drew. Show this calculation on the graph itself. •Your tangent line is tangent at a certain point in time. Read this from the time axis of your graph. How does that slope compare the velocity at that time you calculated in the data table? (Compare the slope of the tangent line to the velocity at that time read from the values you calculated in step 4 above – the velocity column.)

Do this for two points on the graph. Each person should do their very own unique tangent line.

(Over) Analysis of the data: We will find the acceleration of the mass four different ways, as well as determine what the exponent is:

A. Polynomial model on position graph: A spreadsheet will show your equation in the form $y = Ax^2 + Bx + C$. Our formula is $s = ut + {}^1/_2at^2$ where $u = 0$, so from the Excel polynomial, C and B should be 0 or thereabouts (don't worry if they are not) but most importantly, A (The coefficient of x^2) will be ${}^1/_2a$ - half the acceleration of the mass. So double A, (the coefficient of x^2) and you have the acceleration from this model. **State the value for acceleration obtained this way.**

B. Slope of velocity graph: This one is easy – the slope of the velocity vs. time graph **is** the acceleration. **State the value for acceleration obtained this way.**

C. Log-Log: Make a new sheet and paste the time and position data in there. Create two new columns – one of the natural log of time "Ln(time)" and one that is the natural log of distance "Ln(distance)". Make a graph of Ln(distance) vs Ln(time) and put a linear model through it and display the equation on the chart. Since we think the position is going to be a power function distance = ${}^1/_2at^2$, then Ln(distance) = Ln(${}^1/_2a$) + 2Ln(time) so we will get a graph that has a slope of 2 (or we should) and a y intercept of Ln(${}^1/_2a$). **Use the log log graph to determine the exponent, and also the value for acceleration (From the y-intercept, right?)**.

D. Linearization: At this point we think the exponent for the power function of distance is 2, but we really want to make IB happy, so let's linearize the data. Since we think that position = ${}^1/_2at^2$, if we graph position vs t^2, we ought to get a straight line with a slope of ${}^1/_2a$. Make a new sheet, paste the distance and time data in it, and insert a column after time that is the time squared. Graph position vs. time squared. Stick a best fit line through it and display the equation. **State the value of the acceleration from the equation of the line.**

•Write a sentence where you state what the acceleration is using all four ways (From A, B, C and D) of calculation, and compare them. Are they close?