Measuring Acceleration

S3 Physics

The Equation

$$\text{Acceleration} = \frac{\text{change in velocity}}{\text{time for change}}$$

$$a = \frac{\Delta v}{t}$$

where Δ is the change

$$\Delta v = v - u$$

change in velocity=final velocity- starting velocity

so

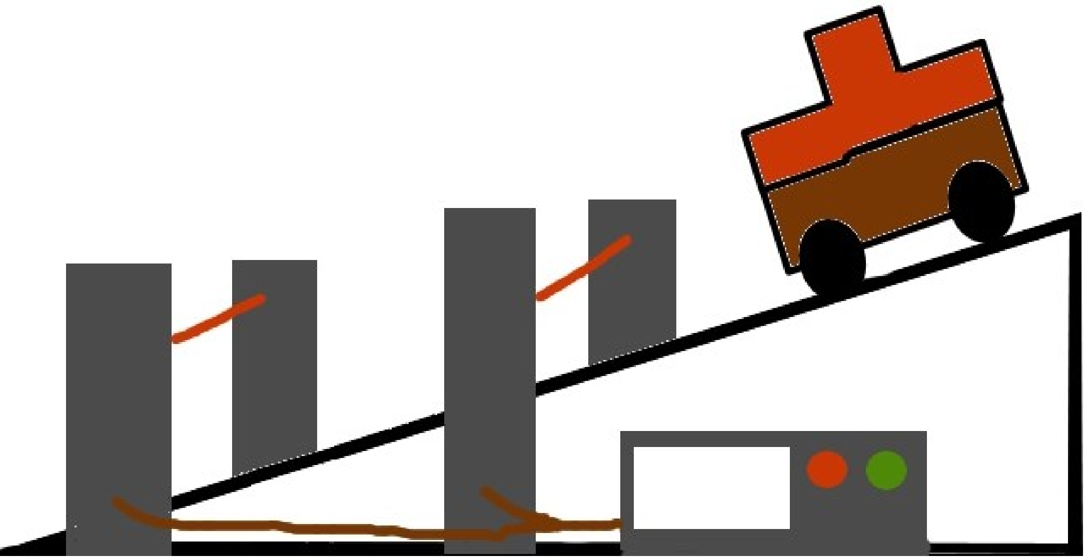
$$\text{acceleration} = \frac{\text{final velocity- starting velocity}}{\text{time for change}}$$

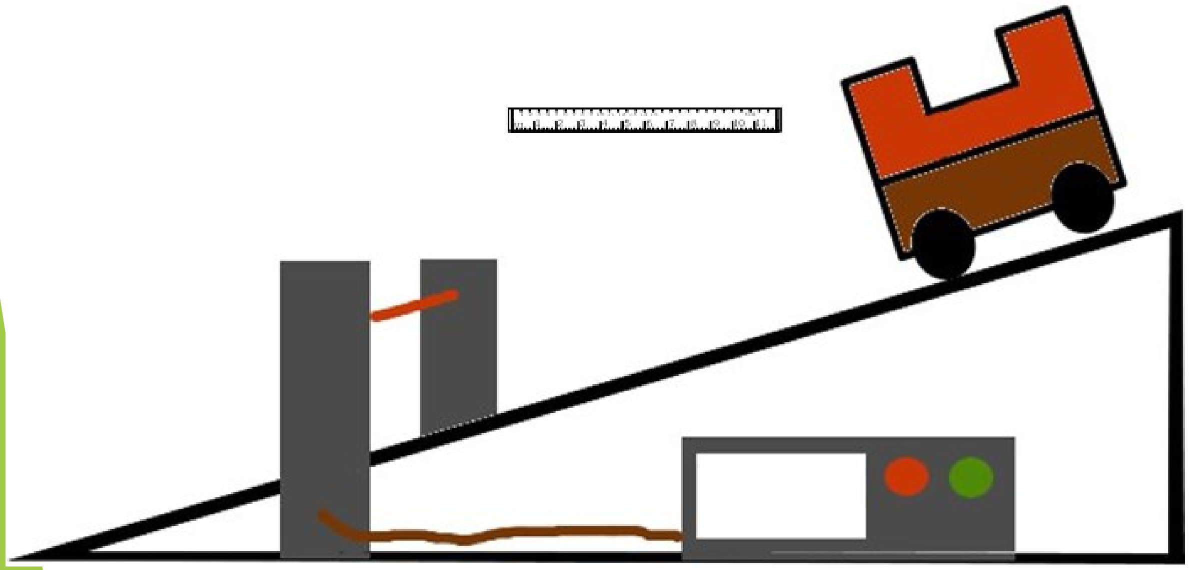
$$a = \frac{v - u}{t}$$

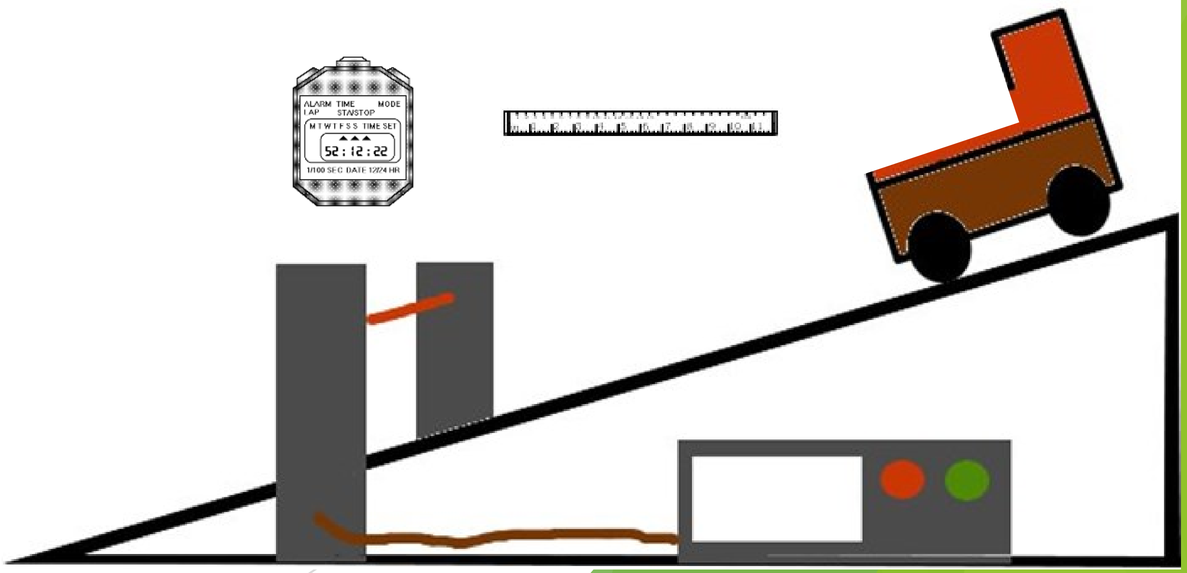
TASK

Describe how you could measure the acceleration of a small vehicle as it runs down a slope in the laboratory.

Many different ways



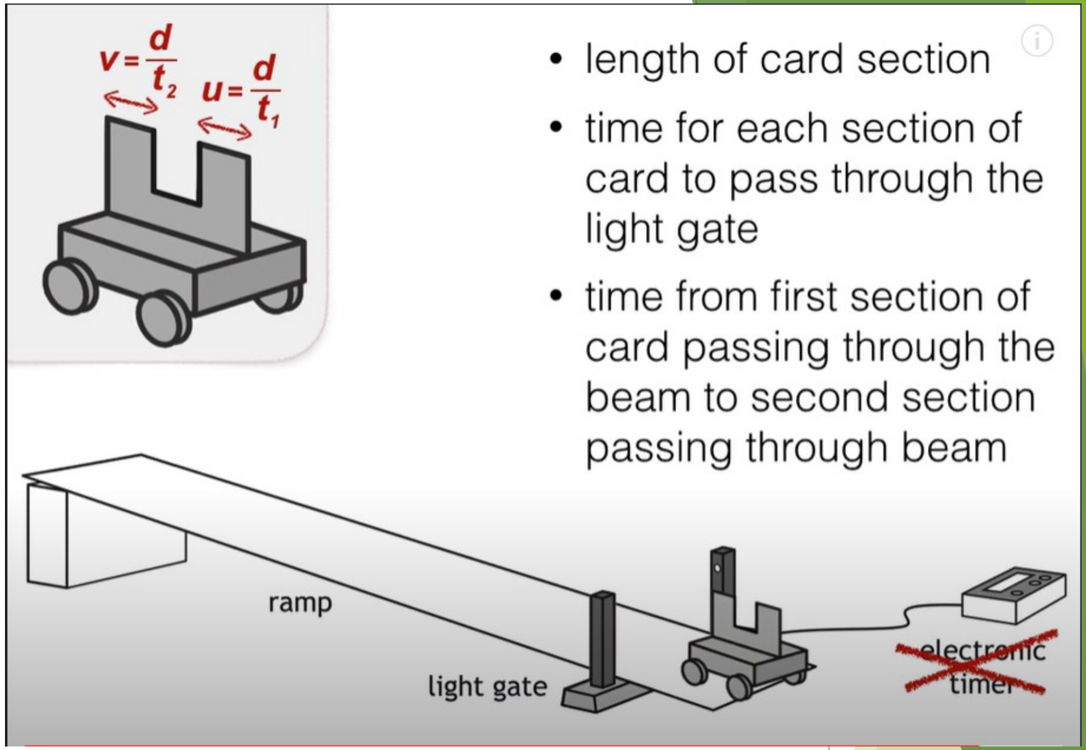


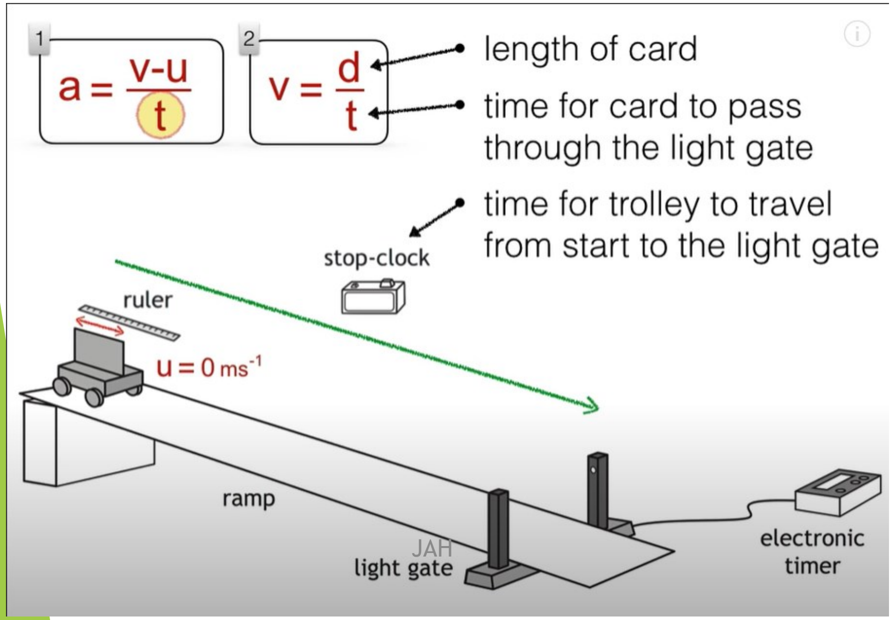


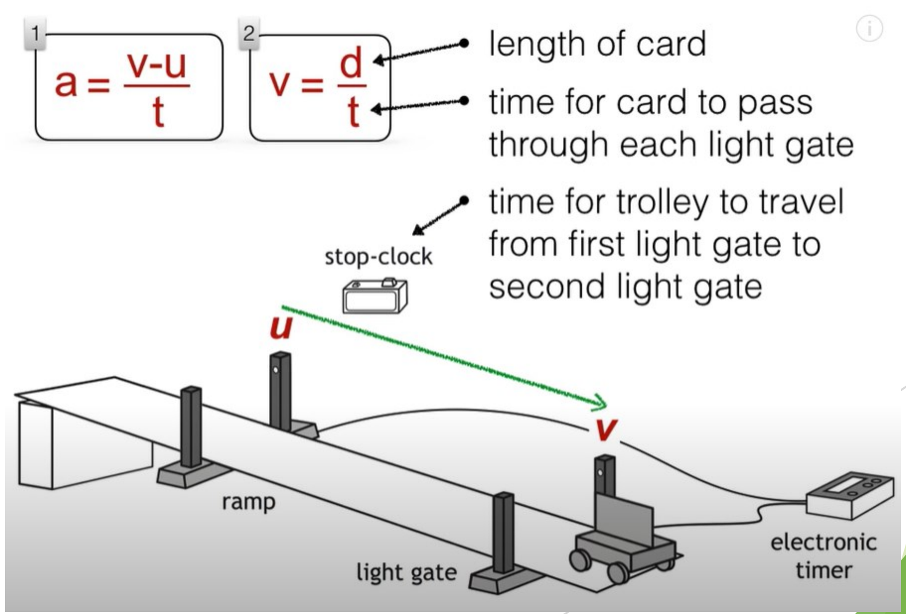
Note to the teacher
Go through this next slide before doing the experiments

https://www.youtube.com/watch?v=YUqwdD73610

- There are different ways to measure acceleration here are a few.







Don’t measure acceleration we calculate it!

We don’t measure *v* and *u* we calculate

them from

- $u=s/t$
  - Where
    - s = length of the card
    - t= time for the vehicle to pass through the top light gates.
- $v=s/t$
  - Where
    - s = length of the card
    - t= time for the vehicle to pass through the bottom light gates.

We also need to know the time it took the car to go between the light gates.

- Or v=s/t where s= length of second piece of card, and t is the time for the vehicle to pass through the light gate.

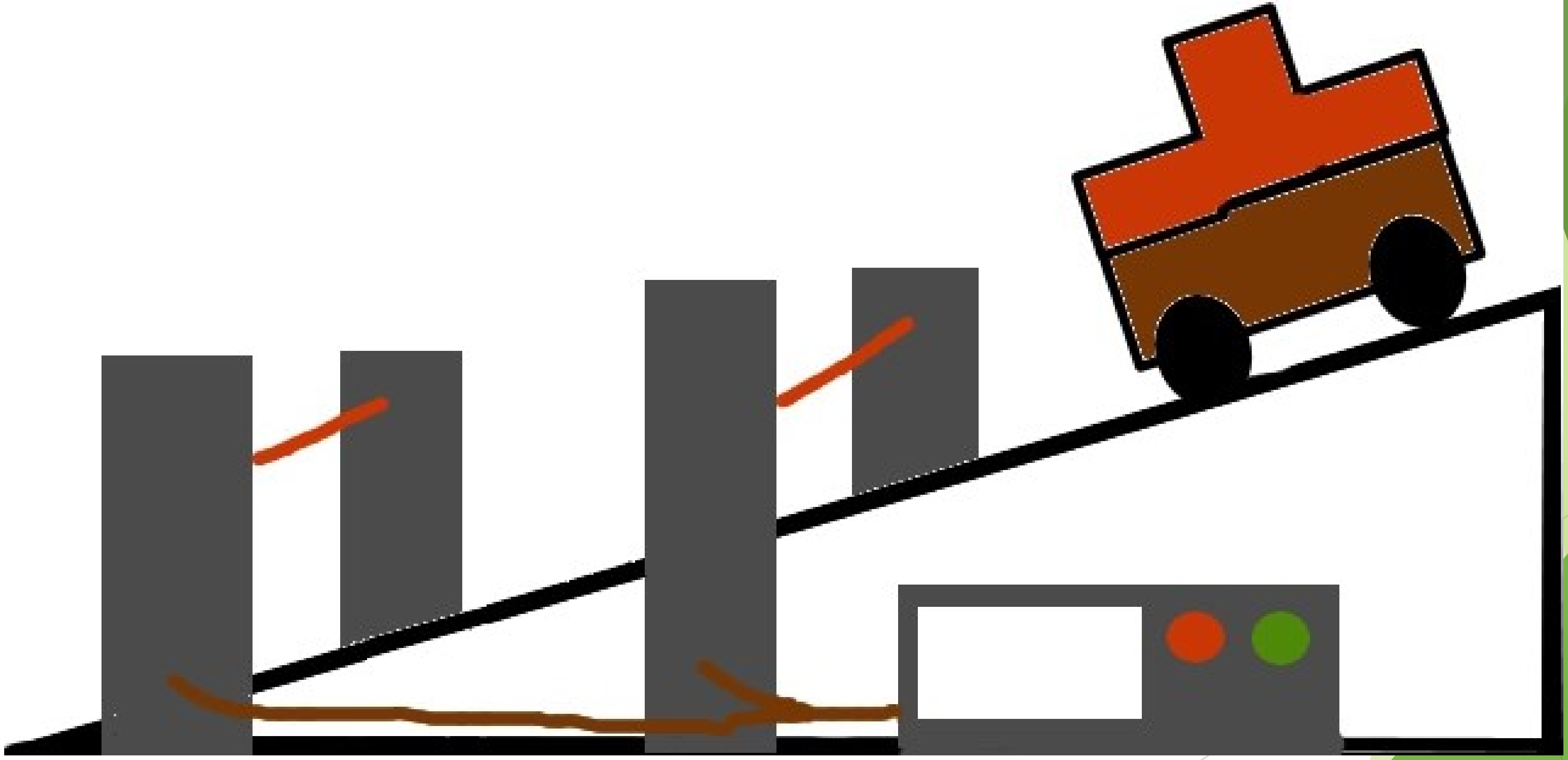
Measuring acceleration with the ALBA RANGER

Here the Ranger sends out pulses of sound / ultrasound. The sound waves reflect off the object and the reflected waves return to the ranger.

If the pulses are returning after a longer time what does this tell you about the vehicle?

What about the pulses reflecting in a shorter time?

Measuring acceleration with two light gates and a single mask

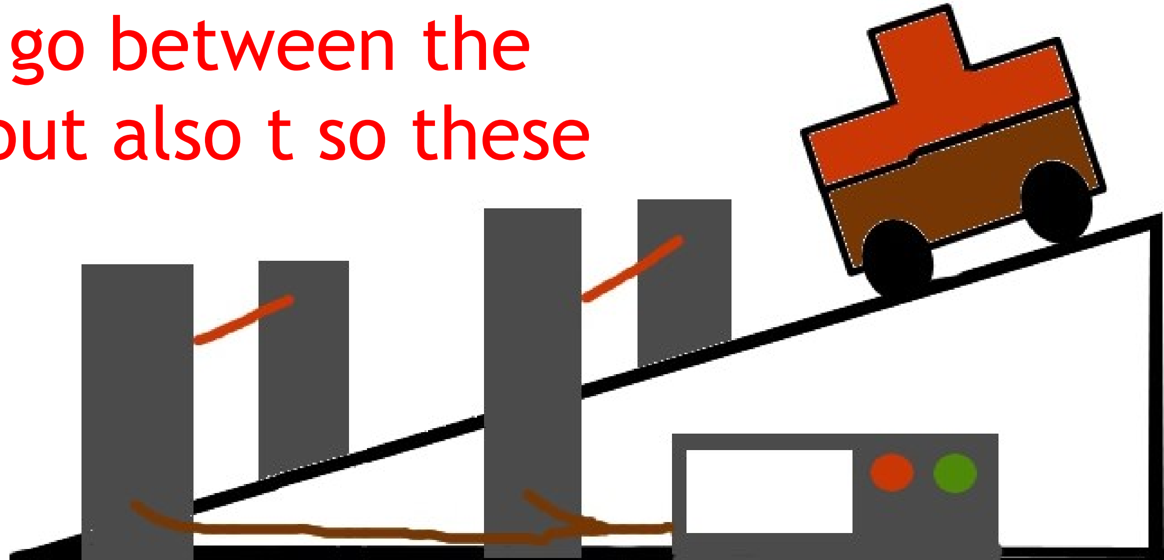


Does it matter how far apart the light gates are?

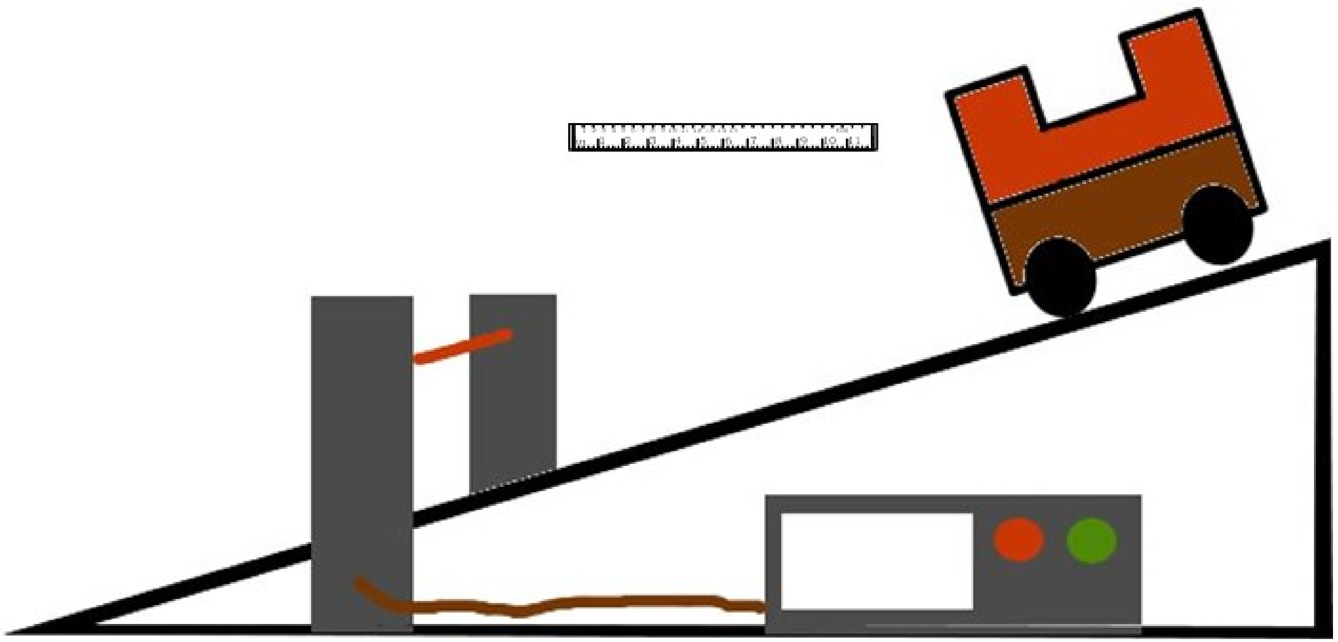
Surely the further apart the light gates the greater the value of v.

No it doesn't matter how far apart the light gates are if the acceleration down the slope is constant

Yes the further apart the light gates the greater the value of v but the longer it takes to go between the light gates. If a=v-u/t then v is greater but also t so these two cancel and a remains constant.

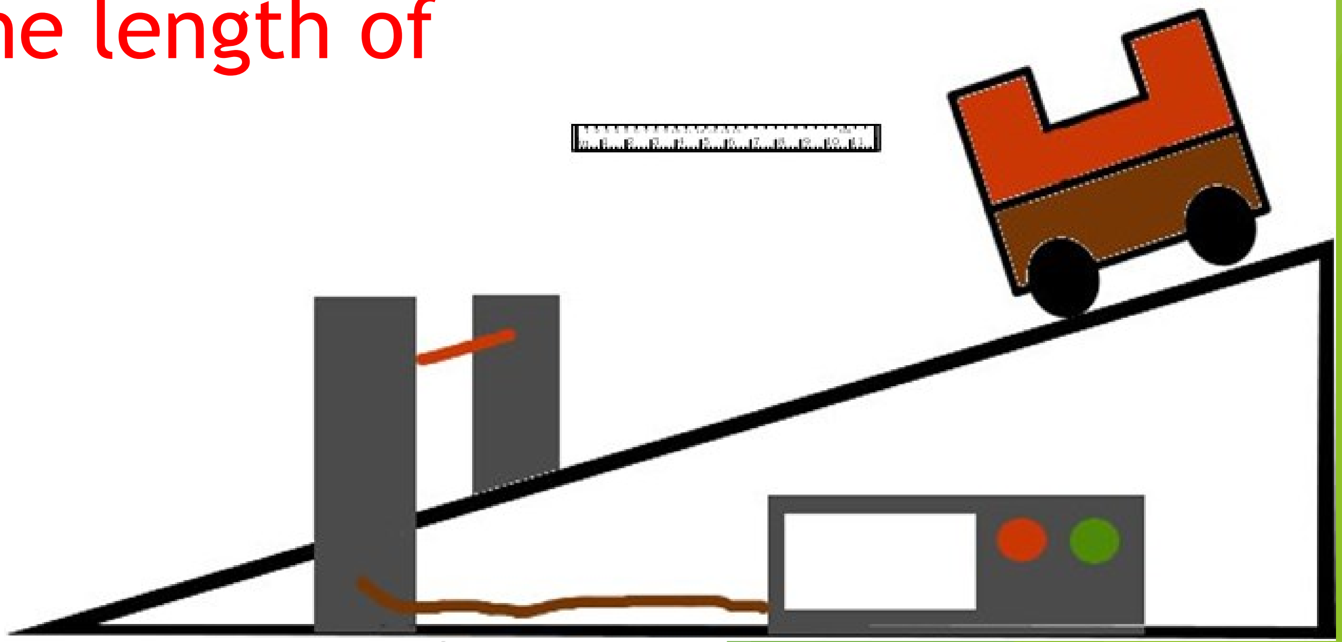


Measuring acceleration with only one light gate



How can we only use 1 light gate to find acceleration?

Yes the vehicle has a double MASK. *u* and *v* are still taken from the time it takes the mask to pass through the light gate and we need to measure the length of the mask.

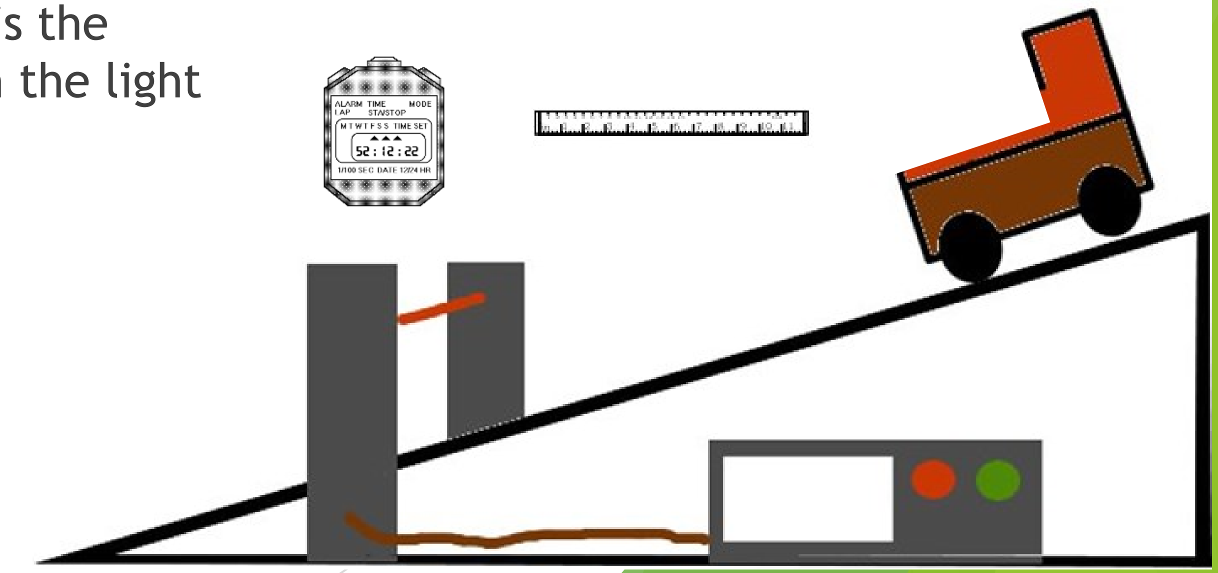


Measuring Acceleration

- You can measure acceleration in the lab with EITHER one single mask and two light gates or a double mask and one light gate.
- Whichever way the experiment is conducted the measurements that need to be made are:
  - Width of the mask or masks.
  - Time for first light beam to be broken.
  - Time for second light beam to be broken.
  - Time between the breaks in the light beam to be measured.

Measuring acceleration from rest

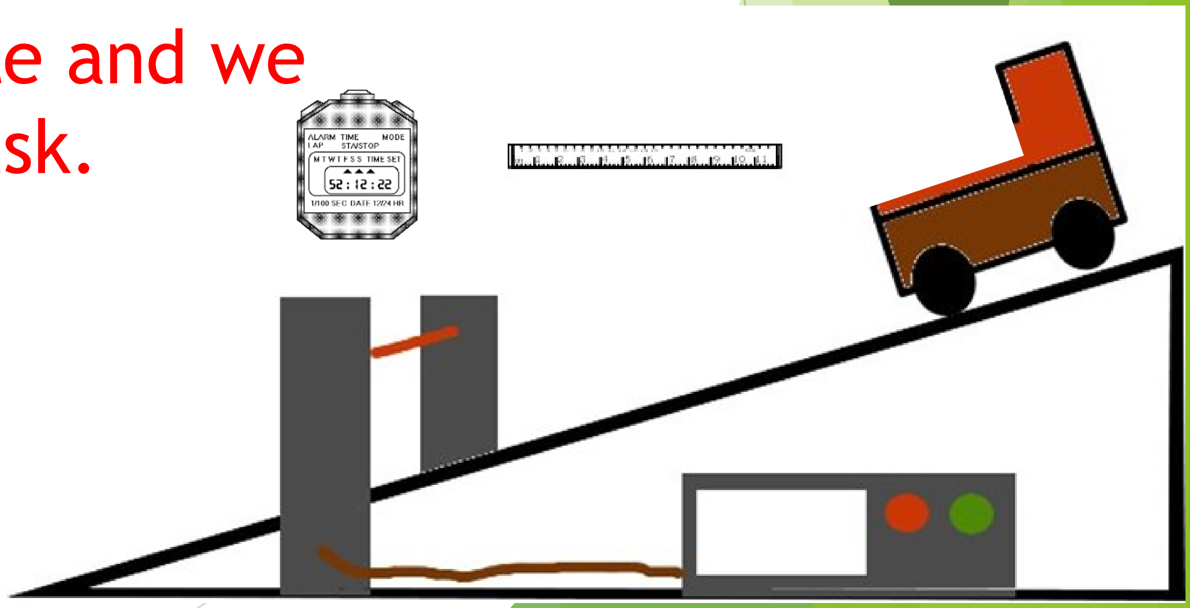
- If the vehicle is starting from rest then u does not need to be physically measured.
- A stopwatch can be used to time the vehicle from the time of release until the mask cuts the light gate
- The time for the mask to break the light beam allows the final velocity to be calculate from v=s/t where s is the length of the mask and t the time to pass through the light gate.



How can we only use 1 light gate and a single mask to find acceleration?

Here we take *u*, the starting velocity as zero, so we don’t need to measure that.

We time how long the vehicle takes to travel to the light gate. *v* is found from the time it takes the mask to pass through the light gate and we need to measure the length of the mask.



Measurements	Calculations
t_1 time to pass first light gate	$u = \frac{l}{t_1}$
t_2 time to pass second light gate	$v = \frac{l}{t_2}$
t_3 time between light gate	$a = \frac{v - u}{t_3}$
Length of mask	l

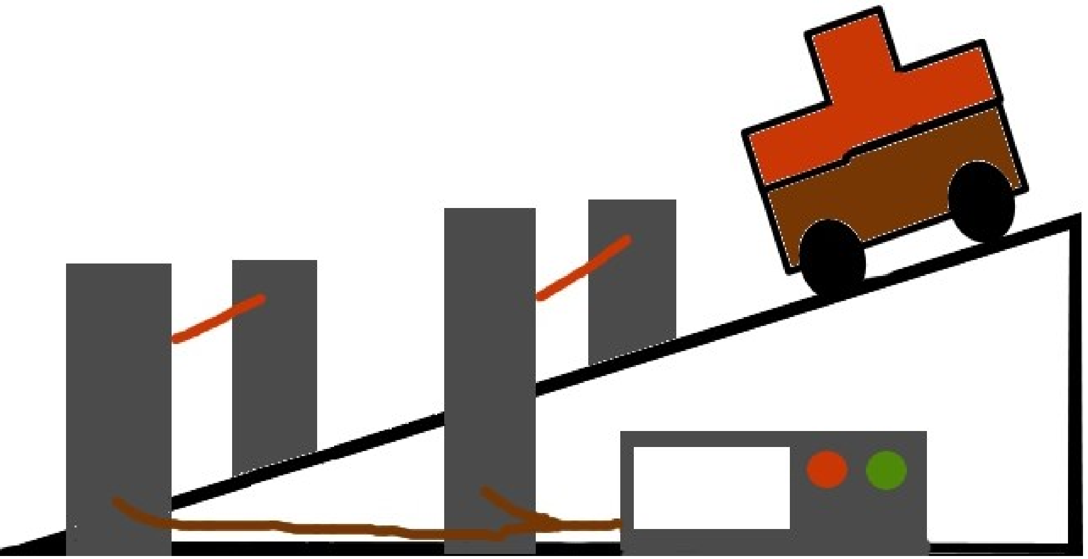
Now we need to try it and see what works and what doesn't

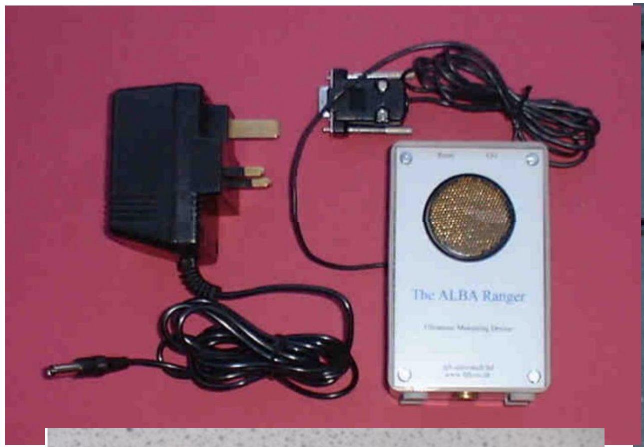
- Set up each method and find the value of the acceleration down the slope three times by each method.

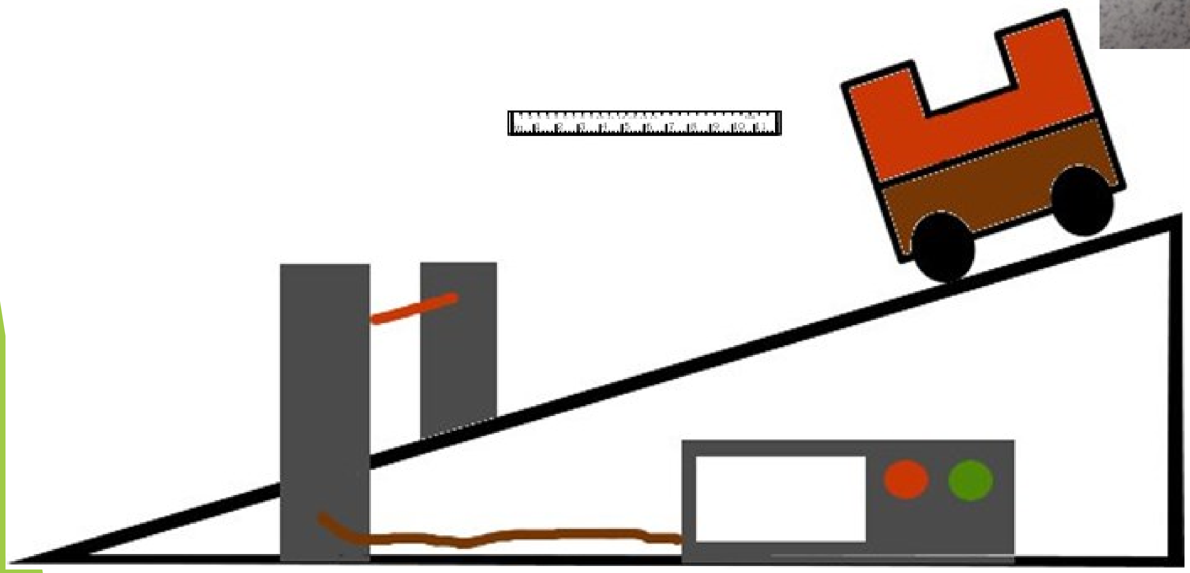
- Record **all** of your measurements

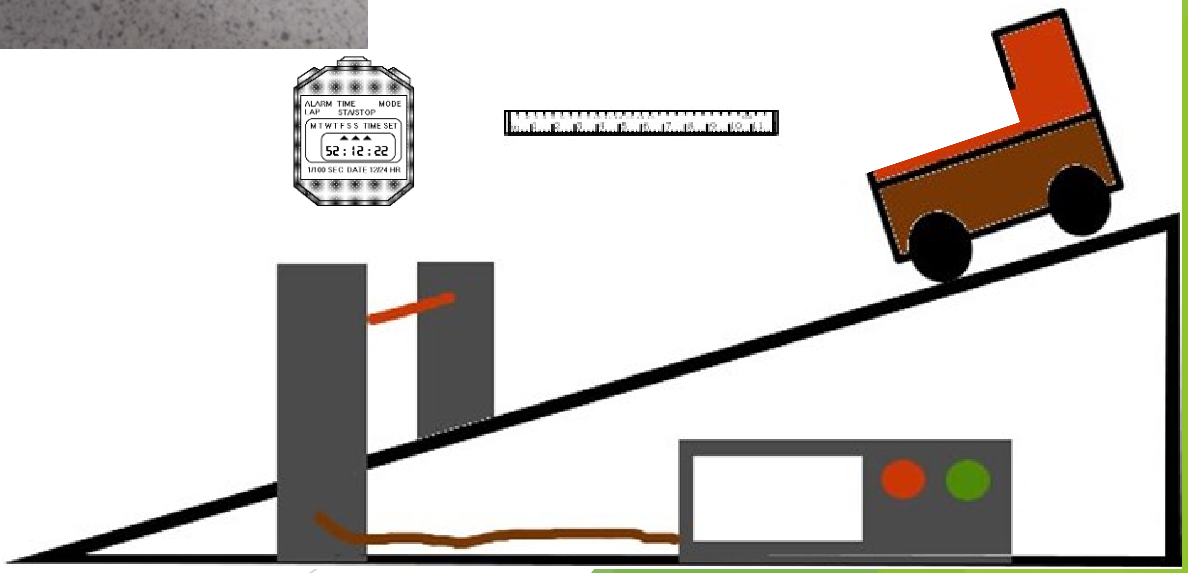
- **Evaluate** each method, discussing what is easy or hard to set up, which measurements are easy or hard to take and which measurements do you think are reliable. How confident do you feel that your answer tells you the exact value for the acceleration of your vehicle down the slope?

Many different ways

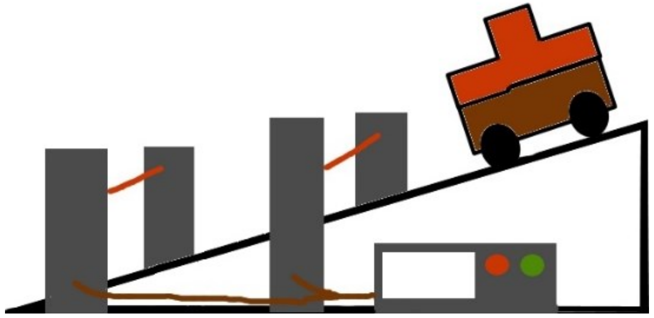








Method 1

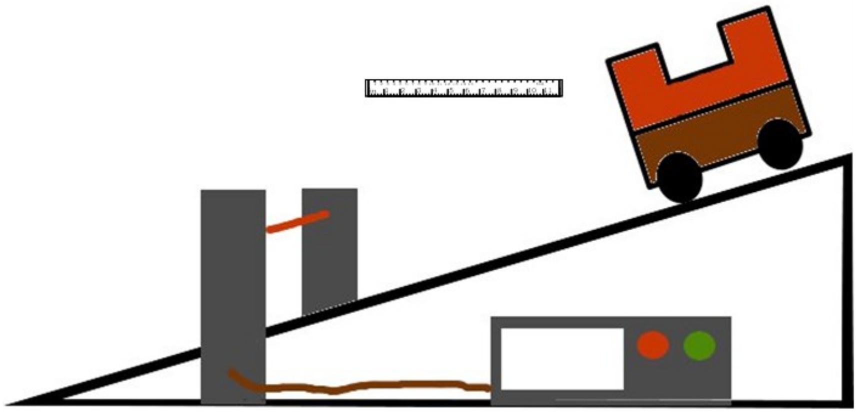


Pros	Cons
No handheld stopwatch	Mustn’t put light gate right at the bottom
Could cope with a high acceleration	Masks both have to be the same width
Consistent results (most of the time)	Sometimes hard to get through both light gates
Doesn’t matter how far apart the light gates are	Don’t put light gates right at the bottom

very consistent

u (m/s)	v (m/s)	t (s)	a (m/s^2)
0.49	0.83	0.78	0.45
0.47	0.83	0.77	0.46
0.52	0.85	0.74	0.45
0.36	0.77	0.89	0.47
0.55	0.88	0.71	0.46

Method 2

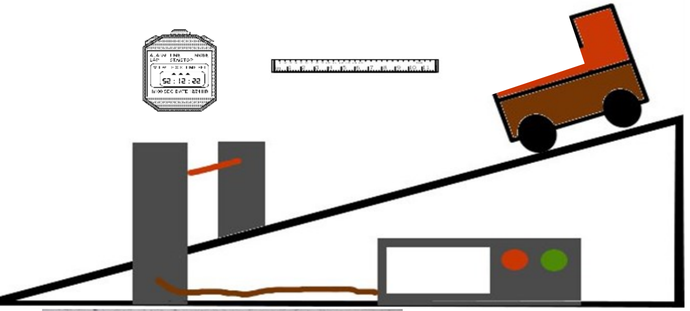


Pros	Cons
No handheld stopwatch	Mustn't put light gate right at the bottom
No problem with trolley going through 2 sets of light gates	Masks both have to be the same width
Could cope with a high acceleration	
No issues with setting the correct height.	

Quite consistent

u (m/s)	v (m/s)	t (s)	a (m/s²)
0.66	0.91	0.08	3.34
0.72	0.97	0.07	3.42
0.79	1.03	0.07	3.74
0.80	1.07	0.07	3.68
0.78	1.05	0.07	3.75

Method 3

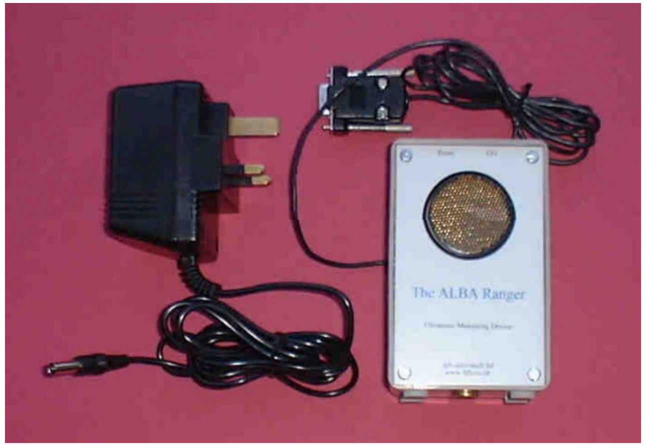


Pros	Cons
No mask so no problems with straight edges	Hand held stopwatch so problems with reaction time
Very easy to set up	light gate must be placed where the vehicle is still accelerating
	Needed the track so car went through light-gate
	Only some vehicles will go through the light-gate

Not very consistent

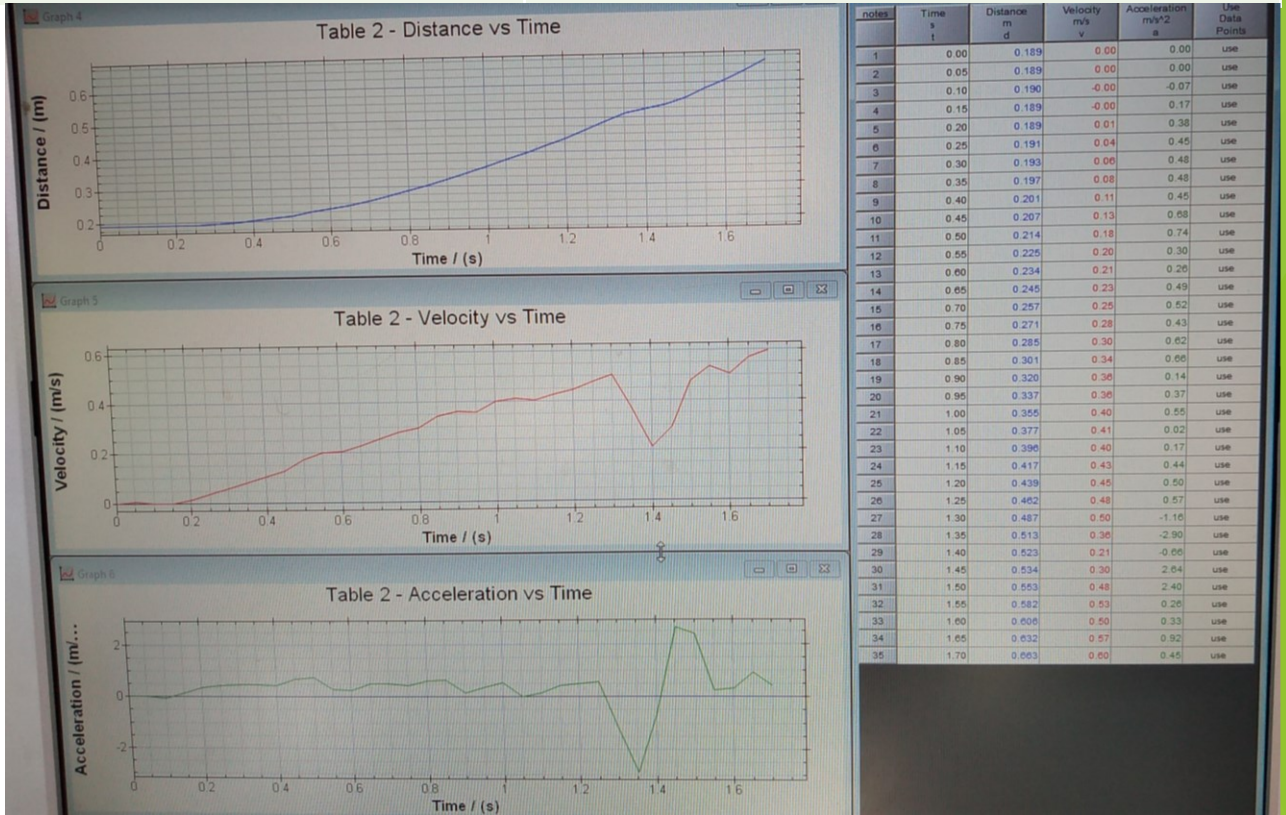
u (m/s)	v (m/s)	t (s)	a (m/s^2)
0	1.8	0.49	3.7
0	1.71	0.40	4.3
0	1.85	0.33	5.6

Method 4



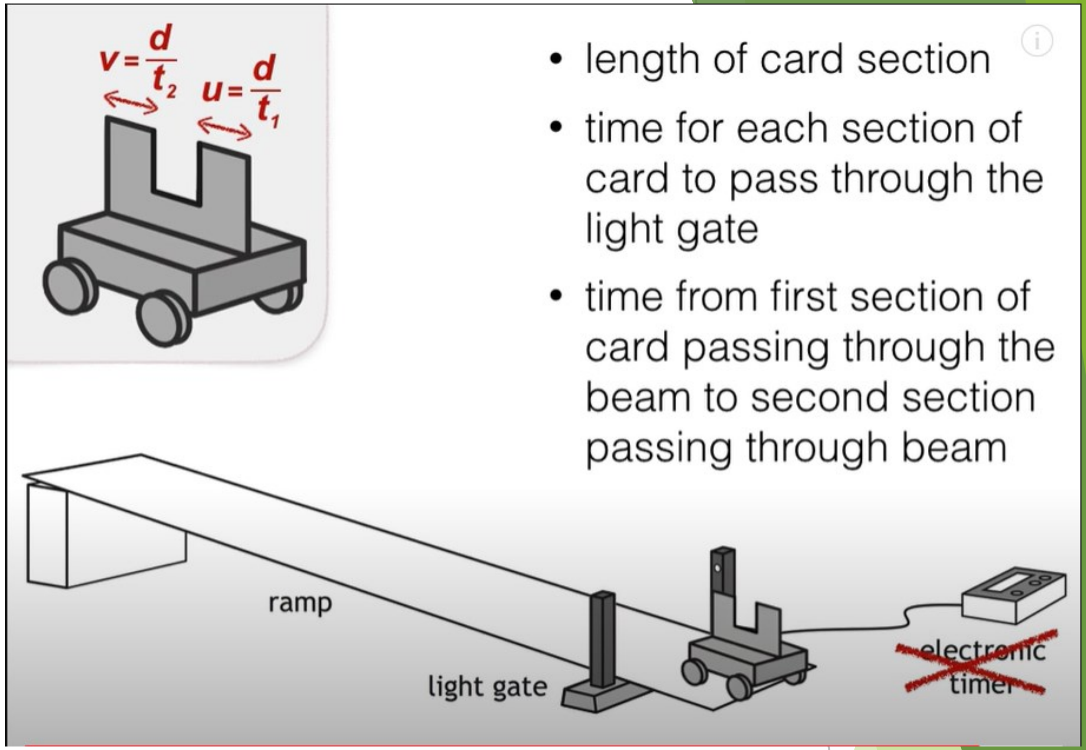
Pros	Cons
Instantaneous displacement/ velocity and acceleration	Flat surface must allow the ranger to reflect off it all the way down the slope
	High air/resistance drag
	Results are harder to interpret

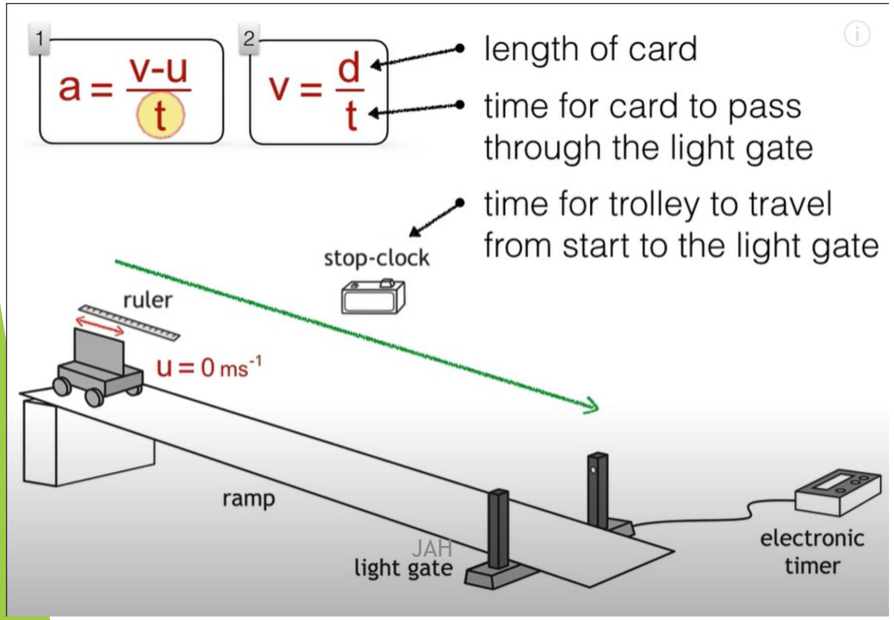
Nice displacement graph, OK v-t graph a bit rough for the a-t graph

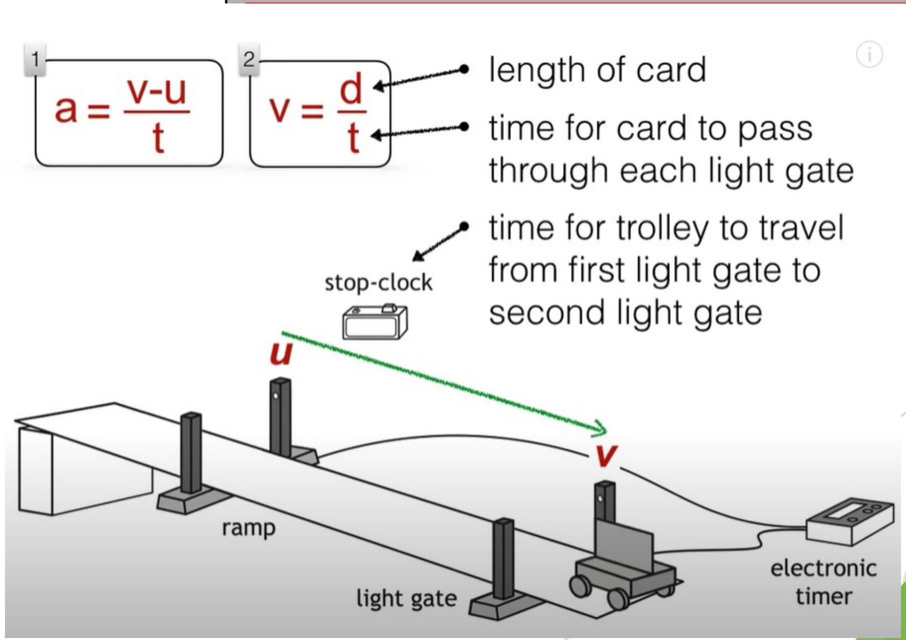


https://www.youtube.com/watch?v=YUqwdD73610

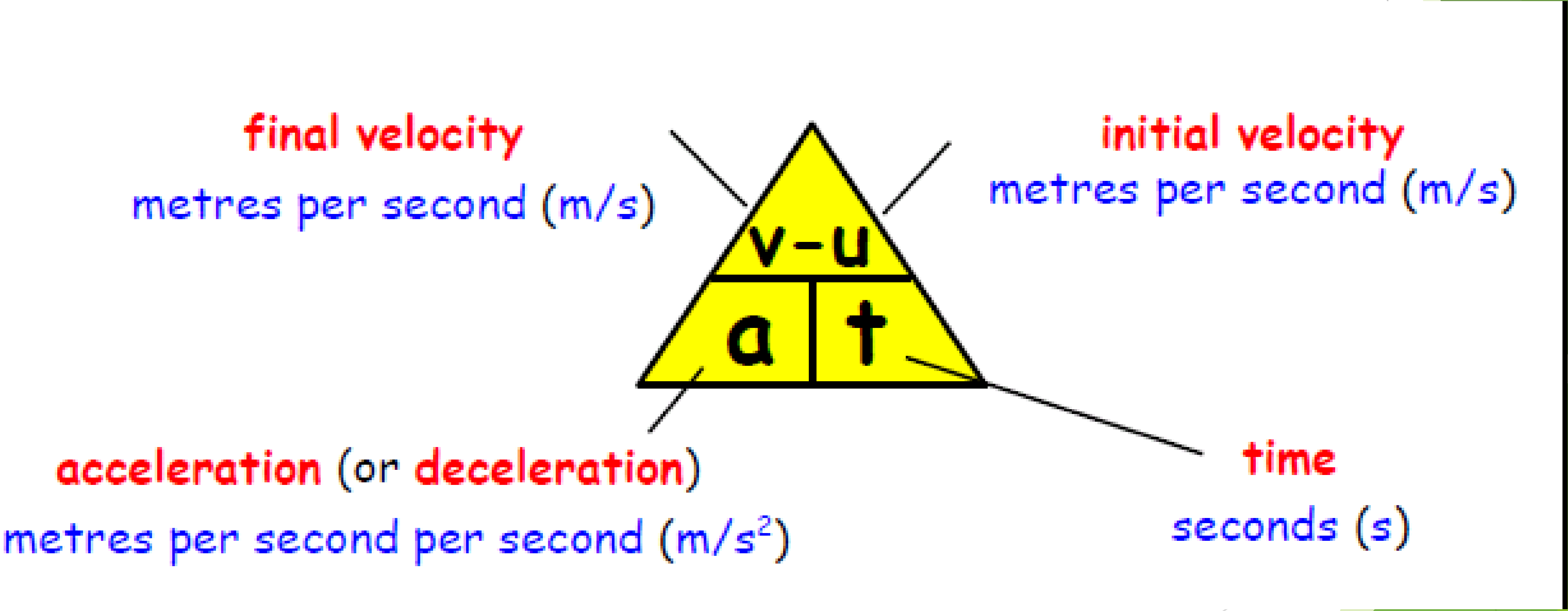
- There are different ways to measure acceleration here are a few.







Calculating Acceleration

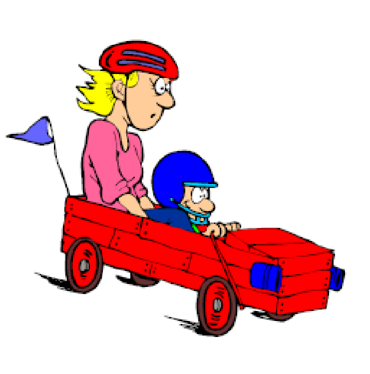


Acceleration

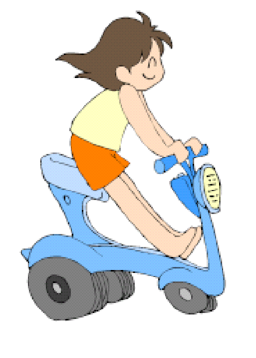
1. A Jaguar can reach 27 m/s from rest in 9.0 s, calculate its acceleration.
2. The space shuttle reaches 1000 m/s, 45 s after launch. Calculate the acceleration.
3. A car reach 30 m/s from a speed of 18 m/s in 6 s. calculate its acceleration.
4. A train moving at 10 m/s increases its speed to 45 m/s in 10 s. calculate its acceleration.
5. A bullet travelling at 240 m/s hits a wall and stops in 0.2 s. Calculate its acceleration.
6. A car travelling at 20 m/s brakes and slows to a halt in 8 s. Calculate its acceleration, it ought to be a negative value!

In each case, calculate the **acceleration** of the vehicle:

(a) Farmer Jones' tractor starts from rest and increases its velocity to 8 m/s to the right in 10 s.

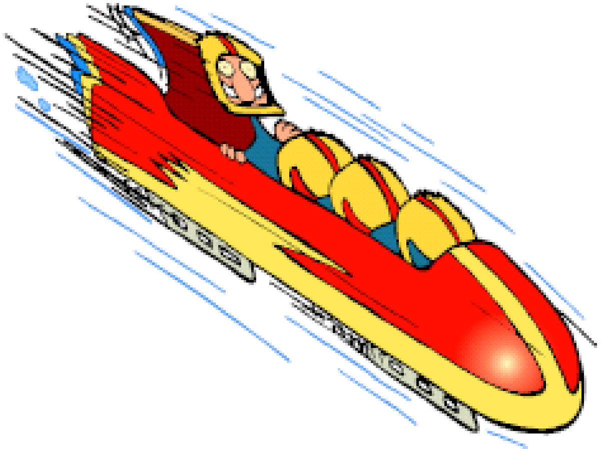


(b) In their go-kart, Jill and her Mum increase their velocity from rest to 6 m/s to the right in 12 s.



(c) On her motor scooter, Dominique takes 5 s to increase her velocity from 3 m/s to 13 m/s to the right.

(d) Mike's motorbike takes 5 s to increase in velocity from 10 m/s to 30 m/s to the right.



20) As a bobsleigh reaches a steep part of track, its velocity increases from 24 m/s to 36 m/s down the slope. This happens in 0.4 s.

Calculate the acceleration of the bobsleigh during this time.

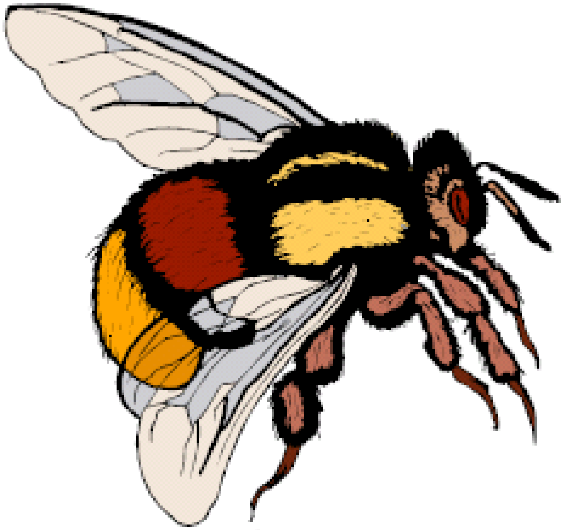
21) An arrow hits a stationary target with a velocity of 50 m/s to the right and comes to rest in 0.1 s.

Calculate the deceleration of the arrow once it hits the target.

22) Starting from rest, a fireman slides down a pole with an acceleration of 1.2 m/s^2 downwards. His velocity at the bottom of the pole is 3.6 m/s downwards.

Calculate the time taken to slide down the pole.

23) A bee, decelerating at 0.7 m/s^2 to the right, decreases its velocity from 6.7 m/s to 2.5 m/s to the right.

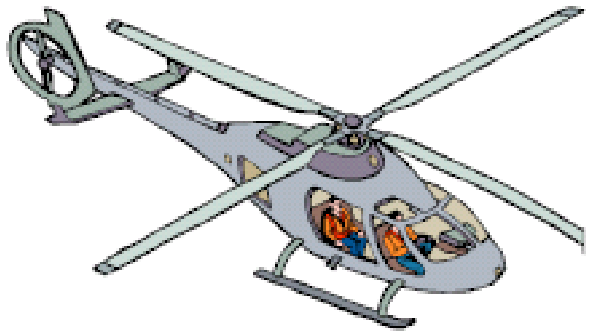


What time does this take?

24) When a stationary rugby ball is kicked, it is in contact with a player's boot for 0.05 s. During this short time, the ball accelerates at 600 m/s^2 at 45° above the horizontal ground.

Calculate the velocity with which the ball leaves the player's boot.

25) A helicopter is flying at 35 m/s to the right. It then decelerates at 2.5 m/s^2 to the right for 12 s.

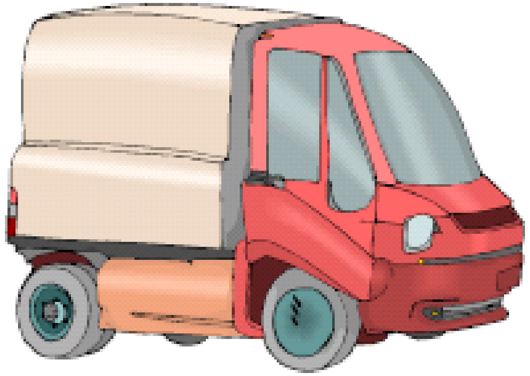


Calculate the velocity of the helicopter after the 12 s.

26) The velocity of a conveyor belt which is moving to the right is increased to 2.8 m/s by accelerating it at 0.3 m/s^2 to the right for 4 s.

Calculate the initial velocity of the conveyor belt.

27) A van decelerates at 1.4 m/s^2 to the right for 5 s. This reduces its velocity to 24 m/s to the right.



Calculate the van's initial velocity.