International Baccalaureate

Extended essay cover

Candidates must complete this page and then give this cover and their final version of the extended essay to their supervisor.

Candidate session number	[redacted]
Candidate name	[redacted]
School number	[redacted]
School name	[redacted]
Examination session (May or November)	May
Year	2012

Diploma Programme subject in which this extended essay is registered: Physics

(For an extended essay in the area of languages, state the language and whether it is group 1 or group 2.)

Title of the extended essay: Investigating the rotational motion of a can filled with a liquid

Candidate's declaration

This declaration must be signed by the candidate; otherwise a grade may not be issued.

The extended essay I am submitting is my own work (apart from guidance allowed by the International Baccalaureate).

I have acknowledged each use of the words, graphics or ideas of another person, whether written, oral or visual.

I am aware that the word limit for all extended essays is 4000 words and that examiners are not required to read beyond this limit.

This is the final version of my extended essay.

Candidate's signature: [redacted] Date: 236/01/2012

Supervisor's report and declaration

The supervisor must complete this report, sign the declaration and then give the final version of the extended essay, with this cover attached, to the Diploma Programme coordinator.

Name of supervisor (CAPITAL letters) ______________

Please comment, as appropriate, on the candidate's performance, the context in which the candidate undertook the research for the extended essay, any difficulties encountered and how these were overcome (see page 13 of the extended essay guide). The concluding interview (viva voce) may provide useful information. These comments can help the examiner award a level for criterion K (holistic judgment). Do not comment on any adverse personal circumstances that may have affected the candidate. If the amount of time spent with the candidate was zero, you must explain this, in particular how it was then possible to authenticate the essay as the candidate's own work. You may attach an additional sheet if there is insufficient space here.

Extended Essay

is a talented student with a marked interest in physics. In the context of his extended essay, he investigated the effect of fluid inside a rolling can moving down an incline. He analyzed the related motion using a motion detector facing down the ramp. extracted several pieces of relevant information in an attempt to answer his research question. In addition, he was really wondering what would be the effect of ice within the can to amplify the effect of non-uniform mass distribution. Finally, it is worth noting tha is in English B and consequently, it has been more challenging for him than for a native speaker to translate his findings in English.

This declaration must be signed by the supervisor; otherwise a grade may not be issued.

I have read the final version of the extended essay that will be submitted to the examiner.

To the best of my knowledge, the extended essay is the authentic work of the candidate.

I spent 4 hours with the candidate discussing the progress of the extended essay.

Supervisor's signature: ______________ Date: 26/1/2012

Assessment form (for examiner use only)

Candidate session number

Achievement level

Criteria	Examiner 1	maximum	Examiner 2	maximum	Examiner 3
A research question	1	2	1	2	
B introduction	2	2	0	2	
C investigation	2	4	3	4	
D knowledge and understanding	2	4	2	4	
E reasoned argument	2	4	2	4	
F analysis and evaluation	2	4	2	4	
G use of subject language	2	4	1	4	
H conclusion	1	2	1	2	
I formal presentation	3	4	3	4	
J abstract	2	2	1	2	
K holistic judgment	2	4	3	4	
Total out of 36	21		19		

ne of examiner 1: ______ Examiner number:
PITAL letters)

ne of examiner 2: ______ Examiner number: ______
PITAL letters)

ne of examiner 3: ______ Examiner number: ______
PITAL letters)

IB Cardiff use only: **B:** ✓

IB Cardiff use only: **A:** 104833 **Date:** 21/05

International School Of Brussels: Extended Essay

Year 2011-2012
Candidate Number:

Word count: 3994/4000

Investigating the rotational motion of a can filled with a liquid

(down a ramp)

Abstract:

This essay studies the rotational motion along an inclined plane in an attempt to answer the question: “How could the motion of a can filled with a liquid be described?”. The rotational motion of a can filled with a liquid (See Fig.1 page 4) is compared to the rotational motion of a hollow cylinder with its mass spread uniformly around the edge (See Fig.4 page 9). The comparison is used because these two motions are very similar. The differences analysis explores all the effects brought to the motion by the liquid in the cylinder.

RQ

RQ but in an abstract

During the experiment, the motion of a cylindrical can with different amounts of water in it going down an incline has been recorded. Then the final speed of hollow cylinders with different radius going down the same incline is computed. The first test made between these two motions is the comparison of the speeds of the two different rotational motions. The second step has been to compare the motion graphs of these motions. My last experiment consisted in analysing the rotational motion of the same cylinder filled with water but this time filled with ice. The goal of this experiment is to amplify the effects of having a mass which is not distributed uniformly around the side of the cylindrical object.

what is recorded? how recorded? (computed? assuming) RQ is about a fluid..

"how was done" analysis

The experiments results have been quite interesting. The liquid is making friction in the container which slows down the object. The liquid will make different friction depending on its viscosity. Secondly, the object is going faster with more or less 50% of water filled in it. It is due to the moment of inertia created by the disposition of the water in the can. At last, the object is having variations in its motion. This is due to the water going up and down. The consequences of this are changing acceleration and velocities during the incline.

concl.

different liquids used?

2nd element: incomplete, unclear..

Abstract: 1/2

Abstract words count: 297 words

Table of Contents

Generic

4. Introduction

The specific question of this paper is “How the motion of a can filled with a liquid can be described?”. In other words, we are going to investigate the motion of a cylinder filled up with a liquid (See Fig1). Instinctively, we know that when this kind of object is rolling without slipping, it will have a different motion than a normal can.

in what context? Prominent RQ vague RQ

"empty"?

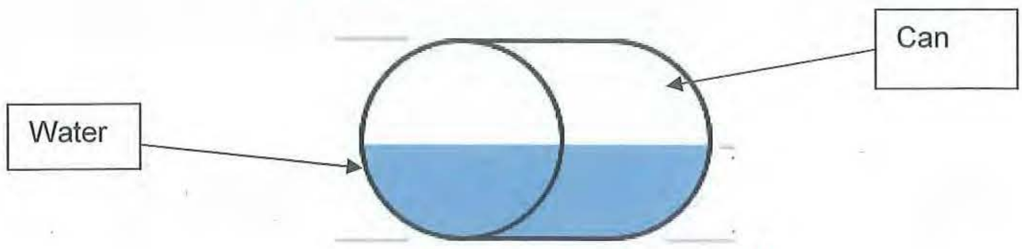


Fig.1[1] label

The goal of this work is to understand clearly, and to explore the patterns that can be seen in this particular rotational motion. still vague

The whole essay is based on this motion investigation, the analysis of the motion itself and then the comprehension of its effect by comparison with other motion. It also includes the explanation of everyday life scenarios using these effects.

which one? comparing what? RQ: 1/2

At first sight the subject chosen for this paper can look simple. But it is not what it seems to be. The physic course is rich, physics has so many subjects and surprisingly a lot of them are unknown. This subject is related to: “rotational motion”. Even if the question looks already quite restrained, there are a lot of different possible approaches to the investigation. It is possible to analyse the motion of a can with different density of liquid in it; or with a different amount of liquid in it; or the comparison of a liquid moving in the cylinder and a mass stuck on the bottle side... The phenomenon is of great interest because it can be related to other physics topics, like centripetal motion, translational motion and also because these effects are present in everyday life. For example, the famous technique consisting of making an egg spin in

what is the focus of RQ?

[1] *Tank Schematic: Horizontal Cylinder*. N.d. N.p., n.d. Web. 1 Nov. 2011. <http://www.calculatorsoup.com/calculators/construction/tank.php>.

order to see if it is cooked or not. These subjects reveal that they are more complex than they seem to be.

Significance of investigation
intro: 0/2 / significance/worthiness: ok
physics principles: none

5.Theory

The relevant principles of physics related to the topic are principally the following, the different energies present in rotational motion as the translational kinetic energy: the gravitational potential energy, the rotational kinetic energy; the law of conservation of energy; the moment of inertia. They are all defined below.

- a number of these are not "principles"
- how/which principles relate to the event

The translational kinetic energy:

An object in motion has the ability to do work and thus can be said to have energy. The energy of motion is called Kinetic energy, from the Greek letter word kinetikos, meaning "motion". The translational kinetic energy of an object can be described as: $\frac{1}{2}mv^2$.[2]

no need

what is what

rotation of center of mass...

The gravitational potential energy:

It is the energy associated with forces that depend on the position or configuration of an object relative to the surroundings. In the case of the gravitational potential energy an object has potential energy because of its position relative to the Earth. It can be defined as the product of the object's weight *mg* and its height *y* above some reference level: mgh.[3]

'h'

(more important is mg(Δh))

The rotational kinetic energy

An object rotating about an axis is said to have rotational kinetic energy. The rotational kinetic energy of an object is given by the expression:

[2, 3, 4 and 5] 1.Giancoli, Douglas C. "Rotational Motion." *Physics Giancoli PRINCIPLES WITH APPLICATIONS*. Ed. Douglas C Giancoli. Sicth Edition ed. N.p.: Pearson International Edition, 2005. 194- 225. Print.

no need for basic physics

$I = \sum_{i=1}^{k} (\Delta m)_i r_i^2$ ...

c.o.m.: not necessarily

the — of rotation

$\frac{1}{2} I \omega^2$. Where I is the moment of inertia about an axis through the center of mass and ω is the angular velocity about this axis.[4]

The law of conservation of energy

If only conservative forces are acting, the total mechanical energy of a system neither increases nor decreases in any process. It stays constant, it is conserved.[5]

theoretical background
def^n of ω, α, τ
$\tau = I\alpha = rF_{\perp}$
$\omega = \tau(\Delta\theta)$ ... ; mechanics of friction due to motion of liquid ...

The moment of inertia

In classical mechanics, moment of inertia, also called mass moment of inertia, rotational inertia, polar moment of inertia of mass, or the angular mass, (SI units kg·m²) is a measure of an object's resistance to changes to its rotation. It is the inertia of a rotating body with respect to its rotation. The moment of inertia plays the same role in rotational dynamics as mass does in linear dynamics, describing the relationship between angular momentum and angular velocity, torque and angular acceleration, and several other quantities.[6]

? of angular velocity => angular acceleration ($\tau = I\alpha$)

very incomplete explanation..

-> Smaller the moment of inertia of an object is, greater the velocity is.

In what sense? – linear, rotational ?

6.Methodology

generic

In order to investigate the subject accurately, all the information about the motion of a can filled with water is recorded in experiments and labs. The independent variable in the experiments is going to be the percentage of volume in the cylinder occupied by water. Then the following step is to compare these data with the motion theory already known, that is the rotational motion of a hollow cylinder.

? ... ? dependent variable ?

A hollow cylinder has been chosen to be compared with our can filled with water because we want to isolate the liquid effects in the motion.

why not compare with a similar empty can ?

C

[6] Addison-Wesley, Goldstein H. "Classical Mechanics." *Wikipedia*. Ed. Jimmy Wales. jimmy wales, n.d. Web. 18 Nov. 2011. <http://en.wikipedia.org/wiki/Moment_of_inertia>.

The water in the cylindrical can is the only difference between the two motions; therefore the differences seen between the two motions are caused by this liquid being in the can. As well as a mass difference

7.Experiment

Globally this experiment looks like that (see fig.2)

why disk? not a can? not a cylinder (hollow)? ...

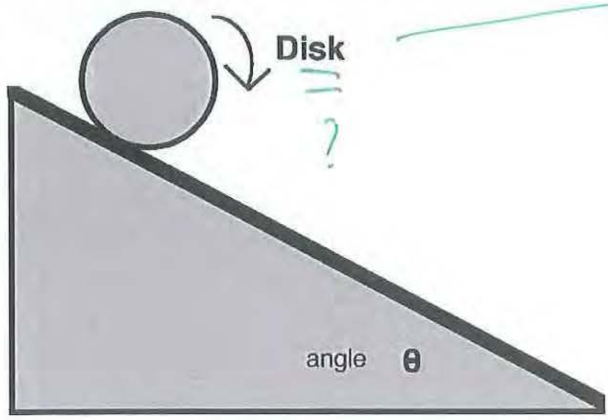


Fig.2 label

$x(t) \rightarrow$ $v(t) \rightarrow$ $a(t)$

The aim is to have all useful information about this particular motion. For that, we need to have the displacement of the object at any time during all its movement in the incline. This information is used to make graphs of its motion, velocity and acceleration. Moreover these data help us to find correlation between the two motions. For example, the final velocity of the can could be ~~find~~ out, and then compared to the theoretical value of the speed of a hollow cylinder rotational motion in the same circumstances. It is considered that the object mass is continuously and uniformly around the edge of the cylinder. ∧ Variable mass

filled with water.. ?

what about mass of water .. uniform distrib.?

For this experiment rather simple environment is used to achieve accurate data. It means that the incline, the percentage of the can' volume occupied by water, the length of the ramp path... all these factors affecting the motion can be measured easily. The ramp is going to have 5° of inclination. The volume in the can occupied by water is each time increased by 10 %. The length of the ramp path is: 2 metres +- 5cm because they are due to the ruler uncertainties. The "y" component representing the height of the top of the incline is the only number rounded. The reason of this is the fact that the size of this side depends on the others side size and angle. It is 17.4321cm and it is rounded up at 17.5 to have an easy number to measure while setting up the experiment.

Why? (2.00 ± 0.05) m G

?

17.4

The independent variable is the quantity of water in the can, the percentage of volume occupied in the can by the water. Obviously, the dependant variables are the displacement and the time. To increase the accuracy 3 trials have been made for each quantity of water. For each trial the can has been emptied and filled up again with the corresponding amount of water. A(t)

(c)

Diagram of the experiment: lack of clarity (G)

why not use a protractor? .. more precise?

a?
A : 2 m; b: 200 cm; c: 17.5 cm; || This seems to say a, b both equal 2m
A: 90° ; B: 85°; C: 5°

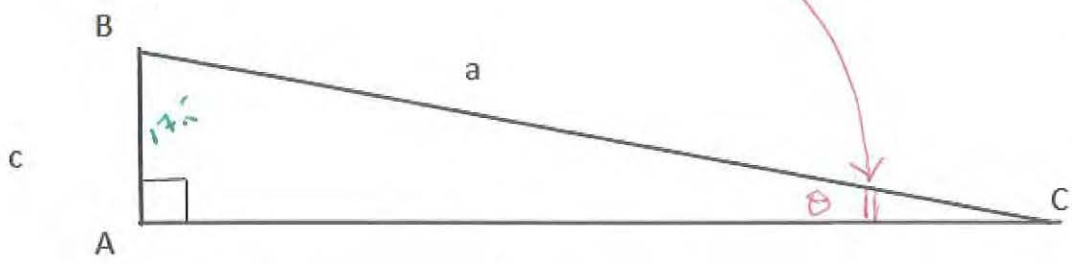


Fig.3

$\sin\theta = c/a$
$\rightarrow \theta = \sin^{-1} 17.5/200$
$= 5°$
should be proved

7.1Raw data

The raw data of my experiment are all the graphs and data about the motion of the can. Each quantity has its own table of data, graph of displacement over time, velocity over time and acceleration over time.

Some of them are in the appendix. - present a sample here
- set-up, probe used ...

7.2Speed comparison

$v_i = 0$?
$s = $?

The first step in the subject comprehension is to compare the final velocity of the object with the theoretical value that a hollow cylinder should have after rolling along the same incline.

The hollow cylinder velocity can be computed by using the law of conservation of energy which states:

(I) Number equations

$$E_{k1} + E_{p1} + E_{g1} = E_{K2} + E_{p2} + E_{g2} \quad (1)$$

Explain terminology (principle) (9)

→ $\frac{1}{2} Mv^2 + \frac{1}{2} I\,\omega^2 + Mgh$ (E at the top) = $\frac{1}{2} Mv^2 + \frac{1}{2} I\,\omega^2 + Mgh$ (E at the bottom)

The moment of inertia of a hollow cylinder is:

all symbols to be defined & clear (G)

$$\frac{1}{2} M(R_1^2 + R_2^2)$$

Where R_1 corresponds to the inner radius non-occupied by water (See Fig.4).

R_1 used in equation

use a diagram illustrate h and c.o.m. position

$mg(\Delta h) = \frac{1}{2} mv^2 + \frac{1}{2} I\omega^2$

$v = \omega r$

$I =$

(show understanding of what it is ...

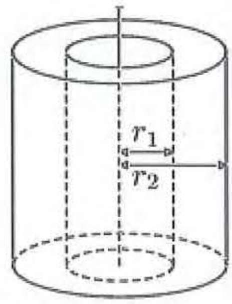
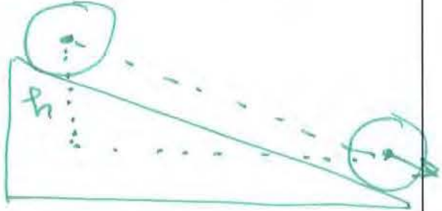


Fig4[7]



.

With the moment of inertia, the equation looks like that (assuming no air resistance):

$$(\tfrac{1}{2} Mv^2)_1 + (\tfrac{1}{2} [\tfrac{1}{2} M(R_1^2 + R_2^2)]\,\omega^2)_1 + (Mgh)_1 = (\tfrac{1}{2} Mv^2)_2 + (\tfrac{1}{2} [\tfrac{1}{2} M(R_1^2 + R_2^2)]\,\omega^2)_2 + (Mgh)_2 \quad (2)$$

The total energy at the top of the incline	The total energy at the bottom of the incline

not used

The Greek letter "ω" stands for the angular velocity and if the object is sliding without slipping: "ω" = v/R (NB: the R used here is the full radius of the can). ?

Explain clearly & fully with help of a diagram

In our case the equation looks like that:

diagram illustrating all Rs (G)

[7] *Tank Schematic: Horizontal Cylinder.* N.d. N.p., n.d. Web. 1 Nov. 2011. <http://www.calculatorsoup.com/calculators/construction/tank.php>.

- annular cylinder

$0 + 0 + Mgh = ½\, Mv^2 + ½\, [½\, M(R_1^2 + R_2^2)](v/R)^2 + 0$

➔ $Mgh = ½\, Mv^2 + ½\, [½\, M(R_1^2 + R_2^2)](v/R)^2$

The M's are cancelled and then the result that we obtain is:

not proper style / language (G)

➔ $gh = ½\, v^2 + ¼\, (R_1^2 + R_2^2)\, (v/R)^2$

➔ $gh = v^2\, [\, (\, ½ + ¼\, (R_1^2 + R_2^2)\,)\, /\, R^2\,]$

(G) ➔ $\underline{v =} \sqrt{(R^2gh)\, /\, [\, ½\, +\, ¼\, (R^21 + R^2)]}$

$R = R$?

Values of R, R1, R2 used here?

["=SQRT((9.81*0.1743)/(1/2+1/2*((1/2)*(R1^2+R2^2)*1/5.2^2)))[8] ||

This is one example of the formula put in excel to compute the theoretical speed.]

? The moment of inertia of the hollow cylinder has been chosen because it is the only moment of inertia varying with the radius. Anyway, the moment of inertia chosen does not matter if it corresponds to the object. It means that the moment of inertia of a thin hoop is equal to the moment of inertia of a hollow cylinder having its inner radius equal to the total radius. Additionally, the moment of inertia of a solid cylinder is the same as the moment of inertia of a hollow cylinder having its inner radius of zero and total radius "x". ✓

It can be proved by this demonstration:

Moment of inertia of a thin hoop: MR^2

no need

Moment of inertia of a hollow cylinder: $\frac{1}{2}M(R^21 + R^2)$ (G)

When R1 is equal to R because the hollow cylinder is empty, the equation becomes: $\frac{1}{2}M(2R^2)$ therefore -> MR^2 ✓

I.E.:

c.o.m. of the can (D)

The speed of the can with no water in it rolling along an incline can be computed as:

explain ... (D)

[8] Appendix

$mgh = \frac{1}{2}(mr^2)\omega^2 + \frac{1}{2}mv^2$

$mgh = \frac{1}{2}(mr^2)\frac{v^2}{r^2} + \frac{1}{2}mv^2$

mass cancels out ... ; . . . .

if can sliding: $v^2 = 2gh$ if not... derive this expression ±? fraction of mm... measured with?

$\Rightarrow v^2 = gh$??

$= h$ all units should be in S.I

After the two meters of incline at 5°, so 17.43 cm of "y" component:
$v = \sqrt{9.81 \times 0.1743} = 1.307\ ms^{-1}$

m s⁻¹

diagram with cylinder / can ...

And with $\frac{1}{2}M(R^2 1 + R^2)$

no need for this

➔ $v = \sqrt{(R^2 gh)} / [\ ½ + ¼\,(R^2 1 + R^2)]$
$= \sqrt{(5.2^2 x\ 9.81\ x\ 0.1743)} / [\ ½ + ¼\,(5.2^2 + 5.2^2)]$
$= 1.307\ ms^{-1}$
➔ The speeds values are the same.

Moment of inertia of solid cylinder : ½ MR²

values of R1, R2 have not actually been quoted yet

Moment of inertia of a hollow cylinder: $\frac{1}{2}M(R^2 1 + R^2)$

no need for all this it seems; not RQ

When R1 equal 0 because the hollow cylinder is full, the equation becomes: $\frac{1}{2}MR^2$. Therefore, it is the same moment of inertia as a solid cylinder.

page 9

XXX distribution of water a key factor

Now in order to compute the hollow cylinder's final speed, the inner radius R_1 is essential (See fig4). More we compare it to a case where the can has a high percentage of water in it, more it decreases. To calculate the inner radius we have to know how much space a certain percentage of water will occupy: ?

muddle between upper/lower case

With zero percent of water; the radius of the cylinder is $r_1 = 5.2$ cm and consequently $R_2 = 5.2$ cm . The height of the cylinder is 9.6 cm. The volume of a cylinder is:

D

2 s.f.s

$$(\pi \times R^2) \times H$$

s.f.s. ?

In our case we have:

$$(\pi \times 5.2^2) \times 9.6 = 815.5\ cm^3$$

G

diagrams here of actual empty can water filled can partially filled can ...

Volume of the cylinder with 10 percent occupied:

$r_0 = 5.2$ cm (2 sig. figs) on p 11

4 sig figs?

$81\cancel{5}^{6}.5 - 81.6 = 734\ cm^3$

Sig. fig.? ** present clearly your model & assumptions

Therefore:

10% $\pi \times r^2 \times 9.6 = 733.957\ cm^3$

paint can ... clean paint can?

➔ $r_1 = 4.933$ cm — this assumes an equal-thickness layer of water over the inside of the cylinder

-When 20 % of the volume will be occupied by water, the radius of the paint will be: What PAINT ??

Total volume is= 652.407 cm^3; $\pi \times r^2 \times 9.6 = 652.407$

➔ $r_1 = 4.65$ cm — 3 sig fig ... (F)

20%

-When 30 % of the volume will be occupied by water, the radius of the paint will be:

Total volume is = 570.45 cm^3; $570.45 = \pi \times r^2 \times 9.6$

➔ $r_1 = 4.34$ cm

30%

-When 40 % of the volume will be occupied by water, the radius of the paint will be:

Total volume is = 488.9 cm^3; $488.9 = \pi \times r^2 \times 9.6$ — 2 sig fig

-> $r_1 = 4.02\cancel{6}$ cm

S.D. error

no need to repeat all these calculations ⇒ use a data table

-When 50 % of the volume will be occupied by water, the radius of the paint will be:

Total volume is = 407.35 cm^3; $407.35 = \pi \times r^2 \times 9.6$

-> $r_1 = 3.675$ cm

-When 60 % of the volume will be occupied by water, the radius of the paint will be:

Total volume is = 325.8 cm^3; $325.8 = \pi \times r^2 \times 9.6$

$\rightarrow r_1 = 3.287$ cm

-When 70 % of the volume will be occupied by water, the radius of the paint will be:

Total volume is = 244.25 cm^3; $244.25 = \pi \times r^2 \times 9.6$

$\rightarrow r_1 = 2.846$ cm

-When 80 % of the volume will be occupied by water, the radius of the paint will be:

Total volume is = 162.7 cm^3; $162.7 = \pi \times r^2 \times 9.6$

$\rightarrow r_1 = 2.323$ cm 4 sig ? ? F

-When 90 % of the volume will be occupied by water, the radius of the paint will be:

Total volume is = 81.15 cm^3; $81.15 = \pi \times r^2 \times 9.6$ 2 sig fig

$\rightarrow r_1 = 1.64$cm

Obviously when 100 % of the volume is occupied by water, the inner radius is zero

Repetitive and unnecessary: after 1 calculation, the rest could be given in a table (as p.14)

Summary:

Number all tables

units?

4 sig fis ...

volume occupied	R1	R2	Theoretical speed
0	5.2	5.2	1.307
10	4.933	5.2	1.324
20	4.65	5.2	1.341
30	4.34	5.2	1.360
40	4.026	5.2	1.378
50	3.675	5.2	1.398
60	3.287	5.2	1.418
70	2.46	5.2	1.456
80	2.323	5.2	1.462
90	1.64	5.2	1.485
100	0	5.2	1.509;

Table # __ : label

Experimental values...

This graph summarises all the final velocity of the can after 2 metres of incline and their uncertainties

± maximized by taking $(x_{max} - x_{min})/2$ ...

ms^{-1}

Percentage of water in the can	trial 1 (ms^{-1})	trial 2 (ms^{-1})	trial 3 (ms^{-1})	Average (ms^{-1})	absolute uncertainties	
0	1.265	1.235	1.226	1.242	0.023	
10	1.207	1.285	1.201	1.231	0.054	± 0.044
20	1.307	1.251	1.285	1.281	0.03	
30	1.324	1.417	1.365	1.368	0.049	
40	1.355	1.4	1.406	1.387	0.032	± 0.026
50	1.362	1.458	1.451	1.423	0.061	
60	1.439	1.539	1.479	1.485	0.054	
70	1.613	1.455	1.464	1.510	0.103	
80	1.452	1.606	1.52	1.526	0.08	
90	1.475	1.52	1.631	1.542	0.089	
100	1.545	1.622	1.577	1.581	0.041	
					0.056	

Average of all the uncertainties

Table: label

reference?

? More the speed increases, the bigger are the uncertainties (that can be seen in the table above).

That means that the kind of error affecting the movement could be computed as a percentage error. The percentage of all the points can be calculated roughly by a rule of three, by dividing "100" by "1.41" and then multiplying it by "0.056".

Average of all the points: 1.41

Average of all the uncertainties: 0.056

$$(100/1.41)\times 0.056 = \underline{3.97\%}$$

This answer means that we could consider the uncertainties for each point to be 3.~~97~~%. 4%

F

... better to look at the beginnings of the event carefully before averaging values

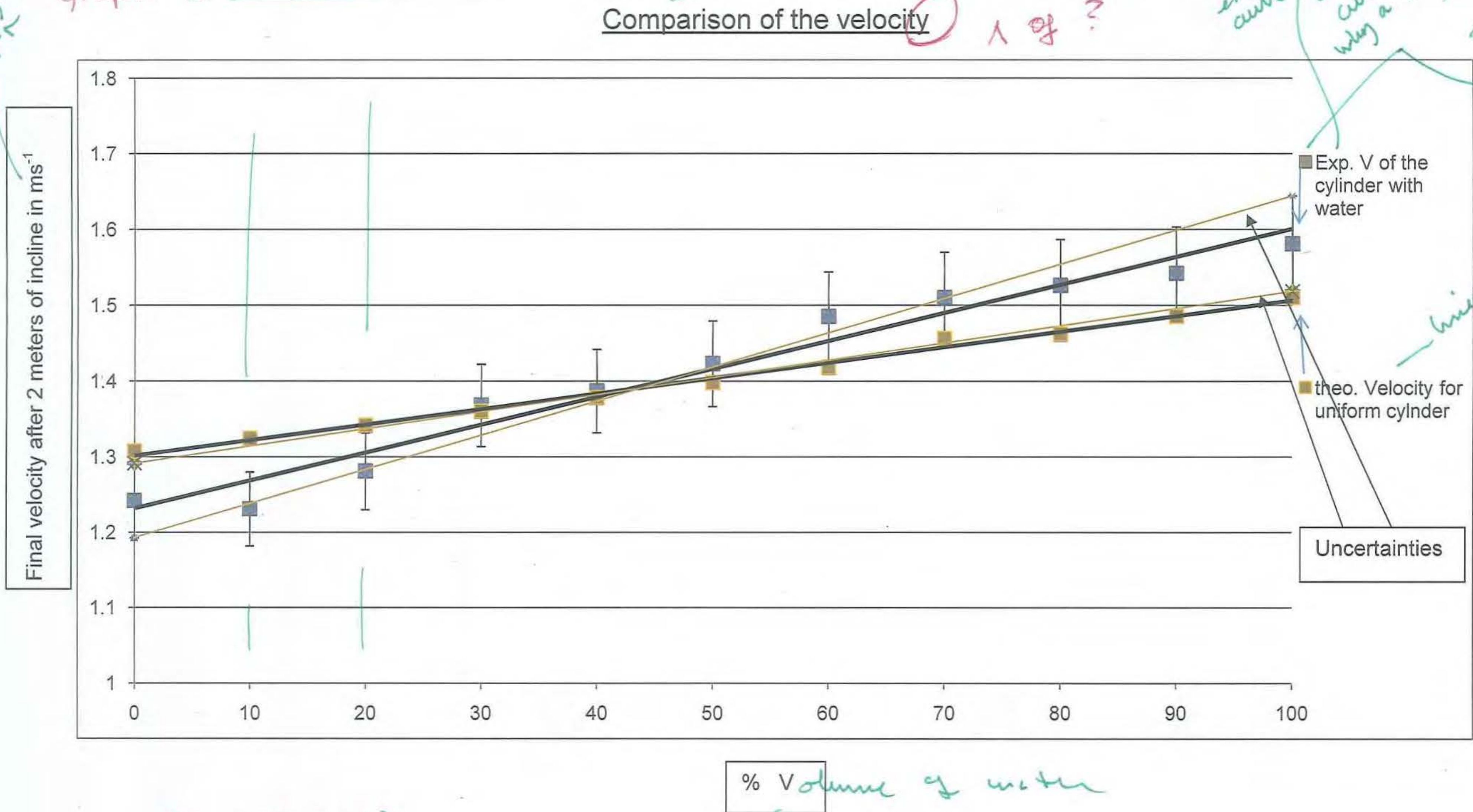
see comment on page 14

I

F

Graph 1. label

?



ms^{-1}

∧ of ?

experimental curve → there is a clear S-shape curve visible: why a forced straight line?

colour..

linear

olume of water

(in words

(complete grid)

Equation of the lines:

Theoretical velocity of the uniform cylinder:

$Y = 0.002x + 1.2316$

actually an S shape curve on graph

Experimental values of the velocity of the can with water in it:

$Y = 0.0037x + 1.3016$

7.3Interpretation of results

G

Similitude:

1) Both, the theoretical values and the experimental values of final velocity are increasing with volume of water in the can.

Explanation:

The object is under the gravitational force thus it is normal that its speed is increasing. BUT velocity is independent of mass for translational motion

Differences:

1) *We can see a significant speed reduction for the second point of the experimental value. The can speed is higher when there is no water in it than when there is 10% of water in it.*

Explanation:

- Without water in the container, the can is going faster than when there is just 10 percent of water, 80 ml. That means the water makes the can go slower. The water is probably making friction in the can and reducing the total energy at the end because it makes that some of the total energy becomes friction which is thermal energy or noises. Moreover, to prove it, we can see that the second point of the experimental points is the only one which does not include the speed of the hollow cylinder in its uncertainties. ??

much more to it...

how water behaves inside the can as it rolls down the incline?

D

2) The slope of the experimental point's equation is steeper than the theoretical point equation slope. At more or less 50% of water the can looks to be as fast as if the mass was uniformly around the edge and then at 80%, even faster.

Explanation:

- The moment of inertia of our object created by the disposition of the water in the cylinder is smaller than the moment of inertia of a hollow cylinder. Consequently the speed is greater.

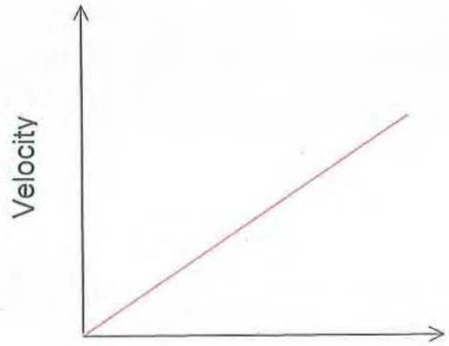
8.Comparison of the graphs shape

The next step of the analysis is the comparison of the experimental graphs shape obtained, and the theoretical graphs shape. This step has the goal to look more precisely at how the object is moving along the path. Firstly, it determines how the motion of a hollow cylinder looks like along the incline of the experiment. Then it looks closely at how the can filled up with water moves along the same incline according to the obtained graphs. After that, the differences between the two different motions are explored. It helps us to understand some observations made above.

Theoretical values

As the net force exerting on the object does not change (gravitational force), the "velocity over time graph" looks roughly like that:

what about mass variations?



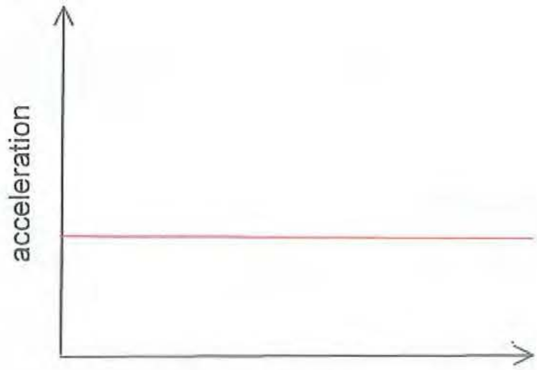
Time

The graph could not start at the origin because the motion recorder starts recording a bit before the object is dropped.

(This graph assumes no air resistance)

And the acceleration looks like that:

(see appendix at 0%)



Time

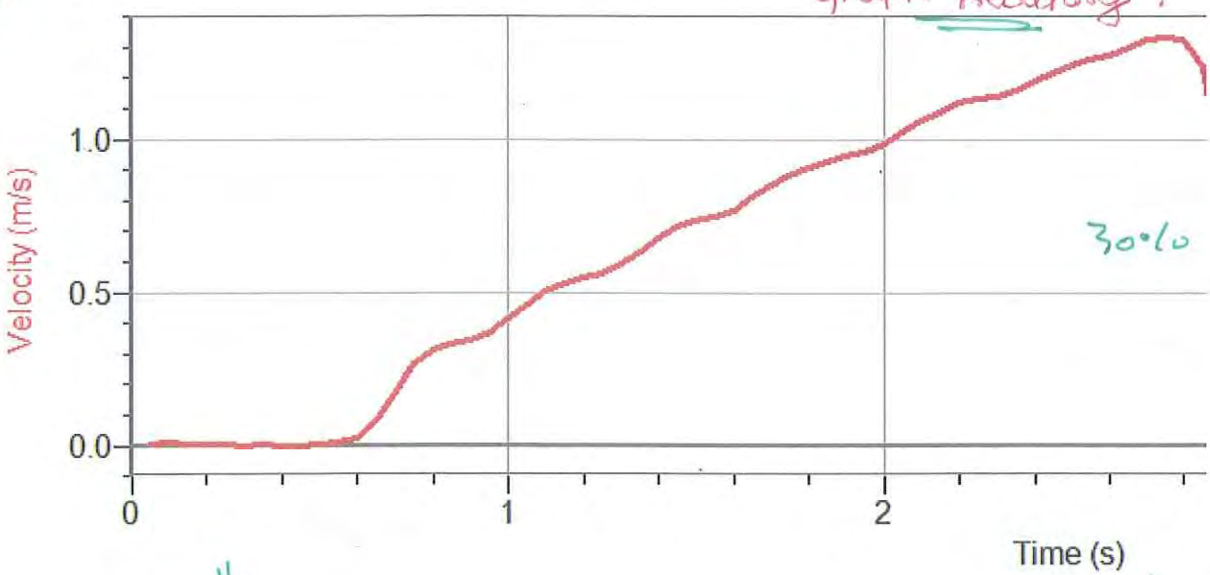
The acceleration is always related to the gravitational force and the incline doesn't change.

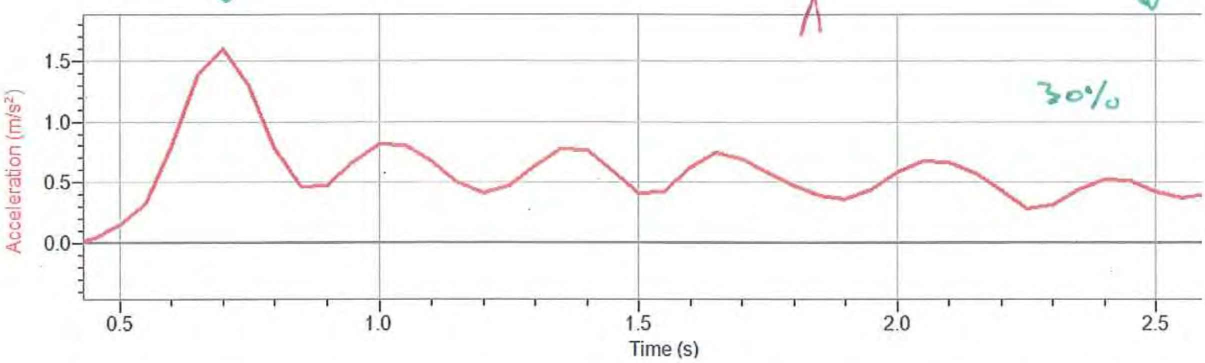
should look first at the "0%" graph x(t), v(t), a(t)

Graph 2

Experimental values.

Graph heading?





This is the graph of the can velocity when there is some water in it. (The example is taken when there is 30% percent of the maximum water in the can).

Observations:

1) *"At the beginning of the incline the object has a high acceleration during a small amount of time."*

repeated at 60%, 90% (affirmative)

Explanation:

Maybe it is due to the fact that the motion recorder was too close to the object at the beginning of the incline, thus the recording wasn't precise enough.

Not a valid explanation in terms of physics

2) *"The theoretical velocity and the experimental velocity are increasing with time"*

Explanation:

The object is under the gravitational force thus it is normal that its speed is increasing. Explain this ; clear explanation that friction was not balanced.

C

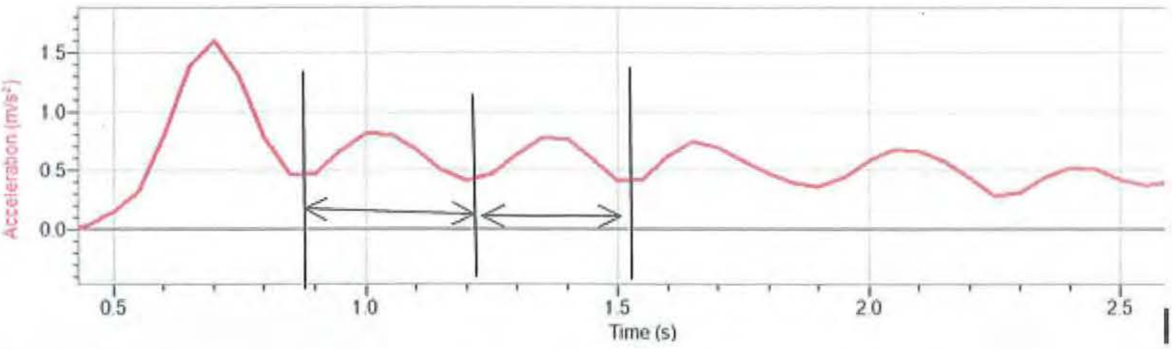
3) *"There are some variations of the acceleration in the incline, they have sinusoidal shape."*

=> oscillations of acceleration

Explanation:

The liquid in the container is moving up and down, and because it is moving in arc of a circle the change in velocity have sinusoidal shapes.

These periods can be measured:



T = +- 0.3 s explain

$\omega = 2\,\pi / T = 21\ s^{-1}$ q?

During the experiment no correlations between the variations and the can characteristics could be found.

q? G

what about physics to start with... with oscillation of any water inside can?

4) *"These variations are less significant with time"*

=? damping ...

Possible explanation:

what does your theoretical model assume?

There are two factors in this phenomenon. The major effect is the fact that we can consider the rotational motion of the can becoming higher at the end, so the liquid is naturally pushed to the edge of the can. Thus the can is losing this effect of water moving up and down. The second factor is the fact that the net force magnitude acting on the object decreases with time, because the friction force magnitude increases with velocity which increases with time.

significantly ...?

5) *"The average acceleration is decreasing with time"*

Possible explanation:

This pattern is due to the fact that the net force acting on the can will eventually result to zero, the reason is that the gravitational force component will equal the friction force made by the can going down the incline.

more investigation is required to justify or not the model proposed re distribution of water inside the can as it rotates starting from rest → hitherto highly limited

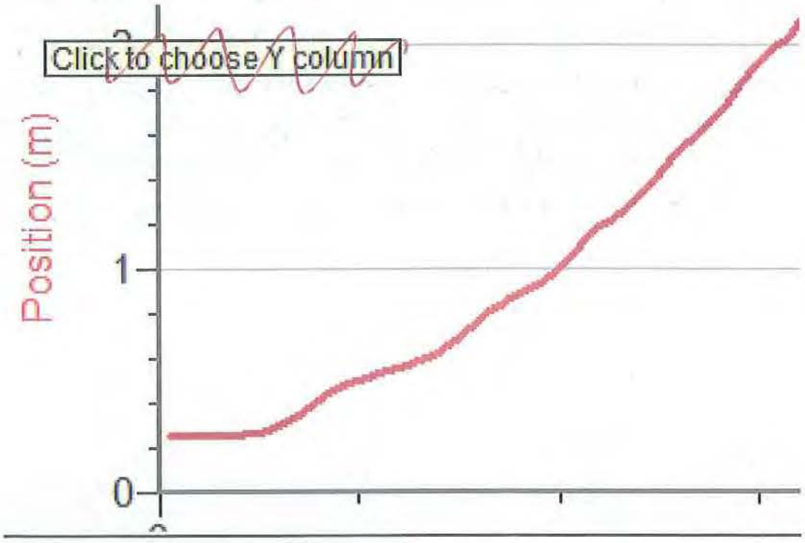
9.Further investigation

Another test has been done to support the observation that the variations of acceleration are due to the fact that the liquid is going up and down. To prove this: the same amount of water put in the can for the graph above (30% of water); has been filled up in the can. Then the can has been lain down on its side, in a fridge like in a fig1. The water froze and became ice, it got stuck on the side of the can. Then the motion of the new can has been recorded along the same incline used for the first test. The goal is to amplify the effects of having a mass on a side of the cylinder.[9]

another RQ

Results:

Position over time



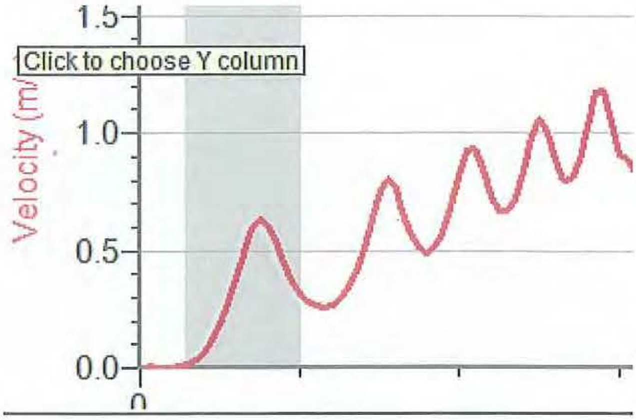
Graph number

scale ?

[9] Some small part of this paragraph are inspired by a site:
Dixon, David. *Wikihow*. N.p., n.d. Web. 22 Nov. 2011. <http://www.wikihow.com/Tell-If-Eggs-Are-Raw-or-Hard-Boiled>.

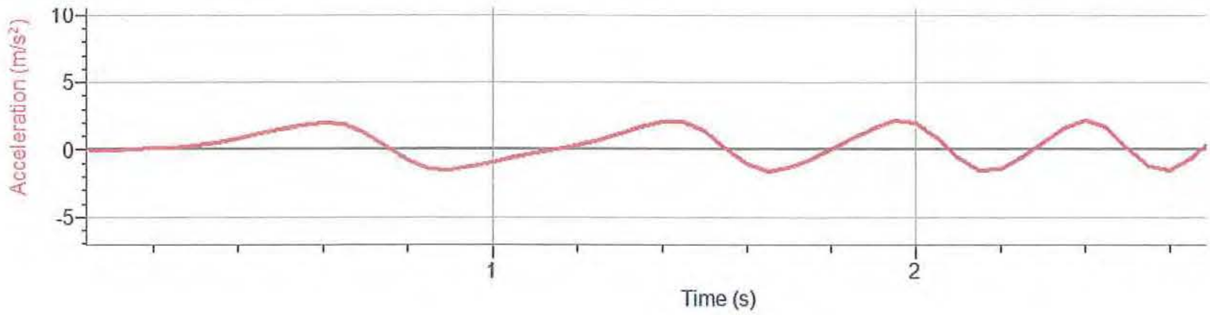
Not cited in Bibliography

Velocity over time



^ label axis ; scale ?

Acceleration over time



Findings

As it is seen the variations in these graphs are much bigger than the variations of the studied motion. Thus, they exist because the mass is stuck on the side of the cylinder.

no new insight into the question

This experiment proves us that if the mass of an object is not uniformly around the edge; the object will not have a constant acceleration.

physics reason? how?

1/2 (lack of consistency with reality) ..

10.Conclusion of the findings and evaluation

This investigation has led to several interesting observations. First of all, the fact that the liquid in the cylinder creates friction with the side of the cylinder itself, it has for consequences to slow down the general motion of the cylinder. This effect can be assumed to be greater if the viscosity of the liquid in the cylinder is higher. Secondly, having a cylindrical

of water? if syrup?

container filled up with more than fifty percent of water seems to be faster than a hollow cylinder with the same amount of mass uniformly distributed around the edge. The possible reason is the fact that the water makes the moment of inertia of the cylinder smaller and therefore increases the speed as explained during the results analysis. Thirdly, this motion has variations in its acceleration, consequently in its velocity and its motion. This is due to the fact that the liquid is moving up and down in the can. This effect is smaller when there is not a lot of water in it (less than 20 %) or if there is too much (more than 70 %). Additionally, this effect decreases whenever the velocity of the can increases. Relating to the third observation, these variations are even bigger if the mass is stuck on the side of the cylinder.

- diagrams
- [illegible]

There are certain limitations to this investigation. The variations acting on the velocity of the can could be observed. The velocity after two meters of incline was recorded. One of the biggest limitations is the fact that this velocity recorded after two meters was maybe at a minimum or at a maximum on the sinusoidal variations of acceleration. That means that there are some possibilities that the velocity recorded was just at the moment where the object was going faster or inversely, slower. Therefore, it gives us a bigger range of uncertainties than the chosen one. The impact of this effect has been a bit reduced by the fact that we did three trials. Another important point is the fact that it wasn't possible to see clearly if the object wasn't slipping during any moment of the incline.

The possible improvement of this investigation could be to do it on a bigger scale. The complexity of all the effects, the understanding of the size of the period of the variations... to understand all this factors clearly, the experiment should include more derivations and expands. For example the incline should be much bigger, for example, 20 meters. There should have been much more trials in order to reduce completely the variations of velocity effect.

Theory needs to be in much more depth.

G: scales missing on graphs;
language not always precise;
equations not numbered;
SI units not always used.

I: illustrative material not always
numbered;
some errors in referencing

language: key helpful symbols missing; unit symbols not always well written; use of symbols not consistent; use of a number of vague terms or expressions; a series of symbols not identified; lack of precision in definition of some other symbols; subscripts not properly used; units missing in some tables;

presentation: not well organized, not easy going reading the essay; poor numbering and labelling of graphs and tables; layout, appearance not very good; some graphs in appendix should be in core of essay; biblio/citation not complete;

historic judgment: even though questionable, a model is proposed; interesting topic; challenge under estimated; lack of investigation (on internet ..); initiative taken with the ice-in-can very good and revealing;

10.Utilisations of the effects in our life

which means ?

The egg:

Everybody knows that if you want to know if an egg is cooked or not you just have to make it spin. If the egg is cooked it will spin correctly and if the egg is not cooked it won't spin. However, if we turn the raw egg long enough we could make it spin just as well as the hard-boiled one. This technique is based our observations. The variations in the velocity that we observed are the liquid moving in the container; in this case the liquid in the egg is moving and changing the center of gravity. Eventually if we turn the egg long enough, as we have seen, these variations will calm down and the raw egg will be able to spin.

no mention of c.o.g. or c.o.m. in the essay

Further research and improvements:

Explanation of the use of water in a fluid coupling.

X: limited investigation

11.Bibliography

Work not cited missing in Bibliography

1.Giancoli, Douglas C. "Rotational Motion." *Physics Giancoli PRINCIPLES WITH APPLICATIONS.* Ed. Douglas C Giancoli. Sicth Edition ed. N.p.: Pearson International Edition, 2005. 194- 225. Print.

? *Hollow cylinder.* N.d. N.p., n.d. Web. 9 Oct. 2011. <http://en.wikipedia.org/wiki/List_of_moments_of_inertia>.

not cited in essay

Tank Schematic: Horizontal Cylinder. N.d. N.p., n.d. Web. 1 Nov. 2011. <http://www.calculatorsoup.com/calculators/construction/tank.php>.

Addison-Wesley, Goldstein H. "Classical Mechanics." *Wikipedia*. Ed. Jimmy Wales. jimmy wales, n.d. Web. 18 Nov. 2011. <http://en.wikipedia.org/wiki/ Moment_of_inertia>.

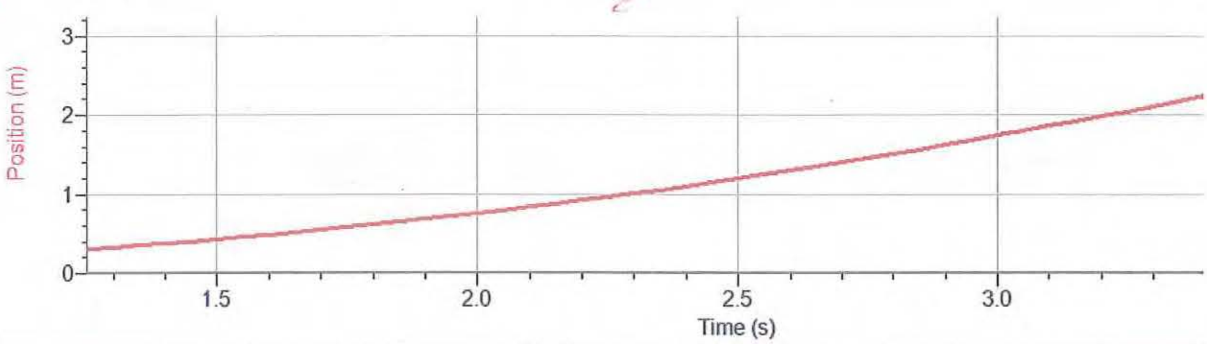
not part of EE here

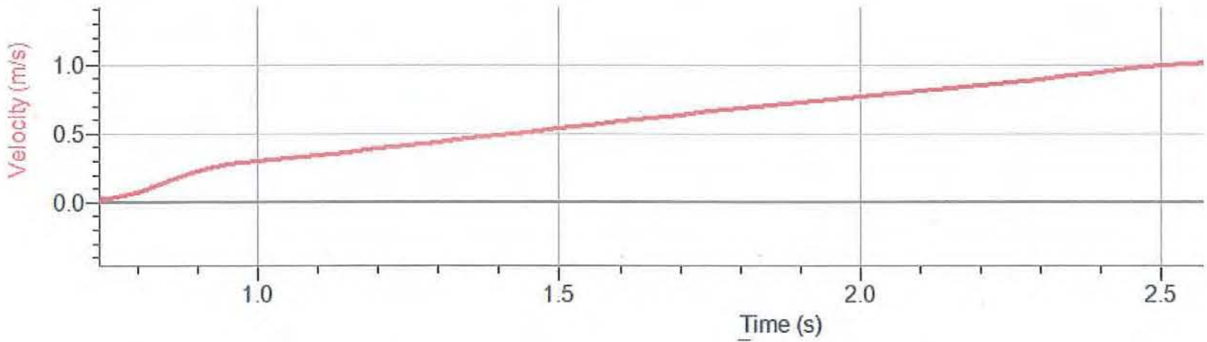
13.Appendix

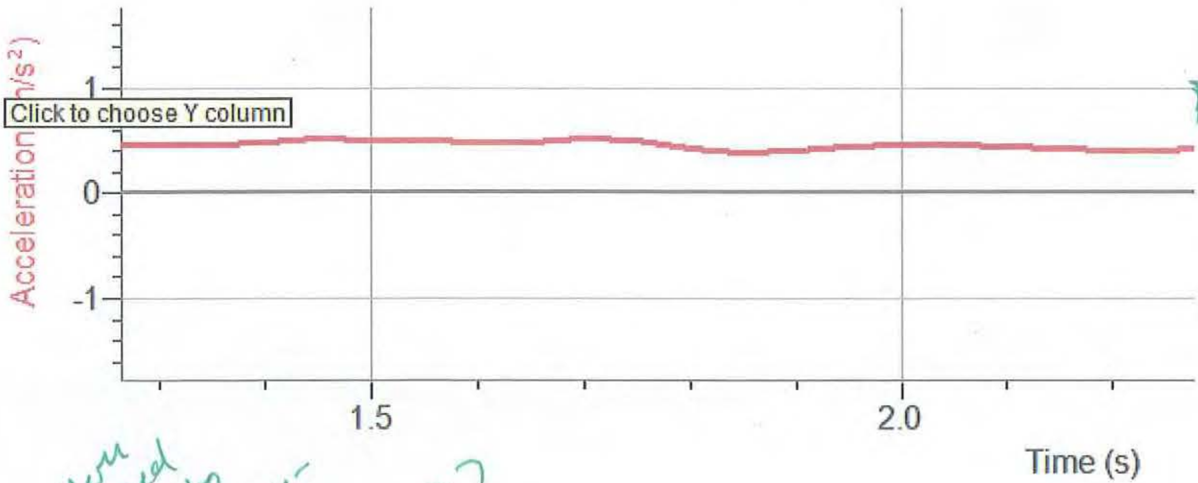
Separate page

Not marked.

0% of water:



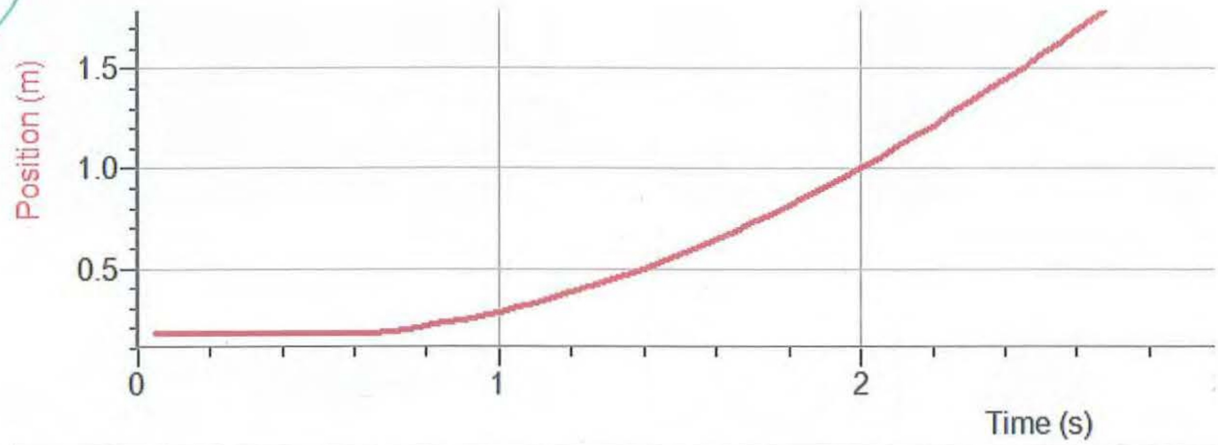


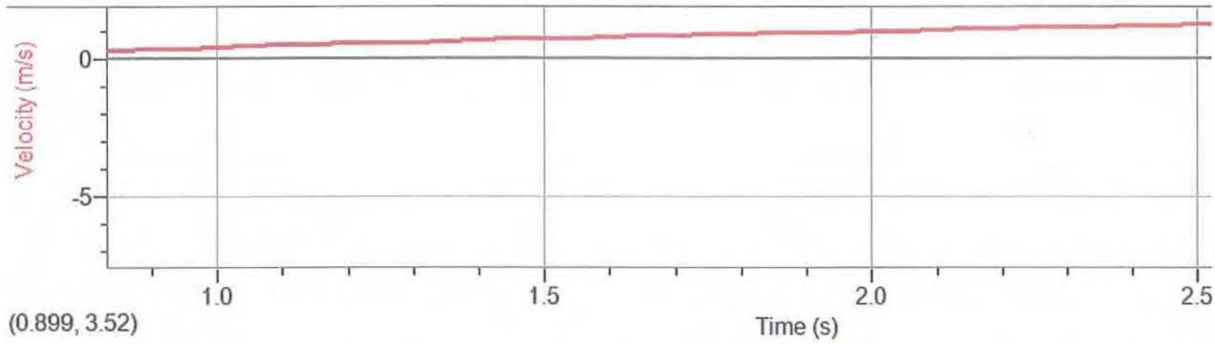


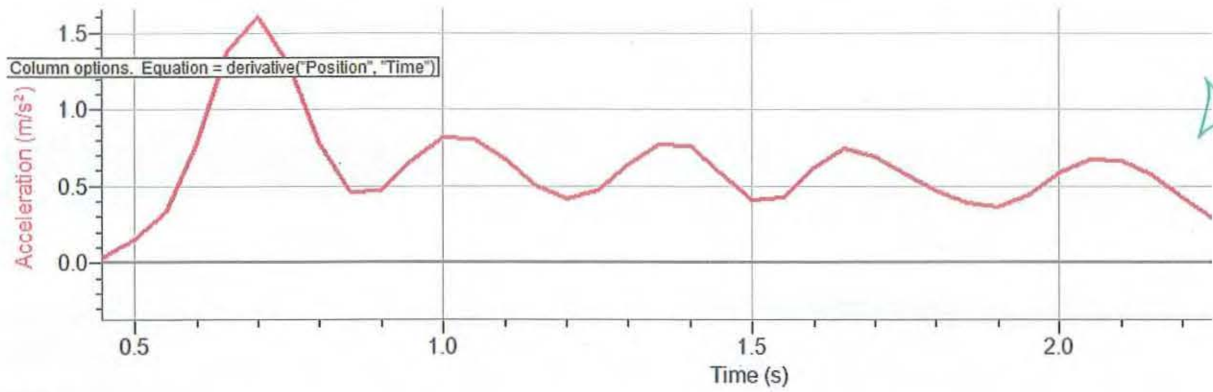
0%

how do you know speed is equal to a value corresponding to a displacement of 2,00 m ??

30%


Position (m)
1.5
1.0
0.5
0
1
2
Time (s)

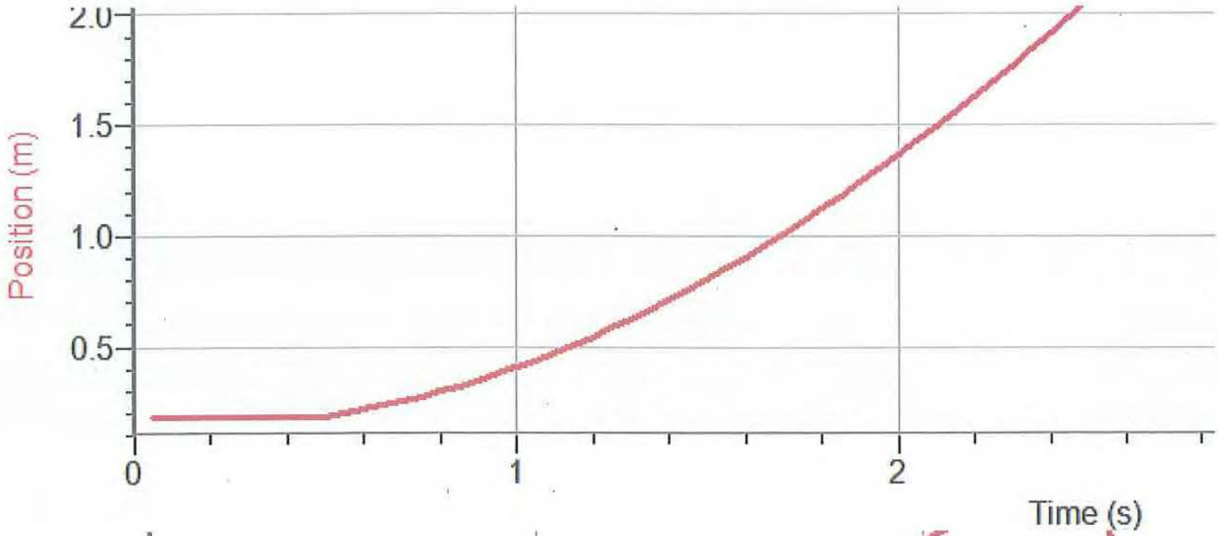

Velocity (m/s)
0
-5
1.0
1.5
2.0
2.5
(0.899, 3.52)
Time (s)

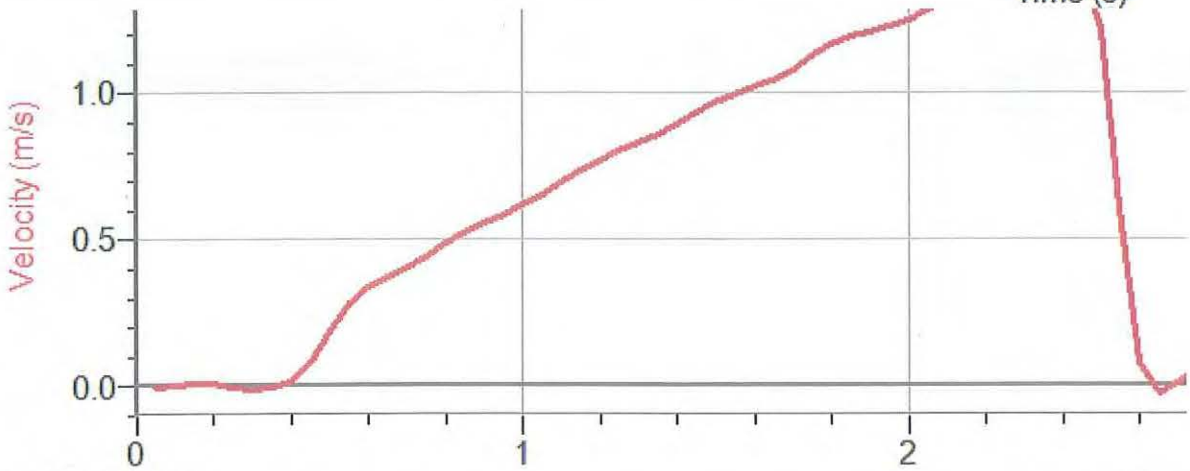

Column options. Equation = derivative("Position", "Time")
Acceleration (m/s²)
1.5
1.0
0.5
0.0
0.5
1.0
1.5
2.0
Time (s)

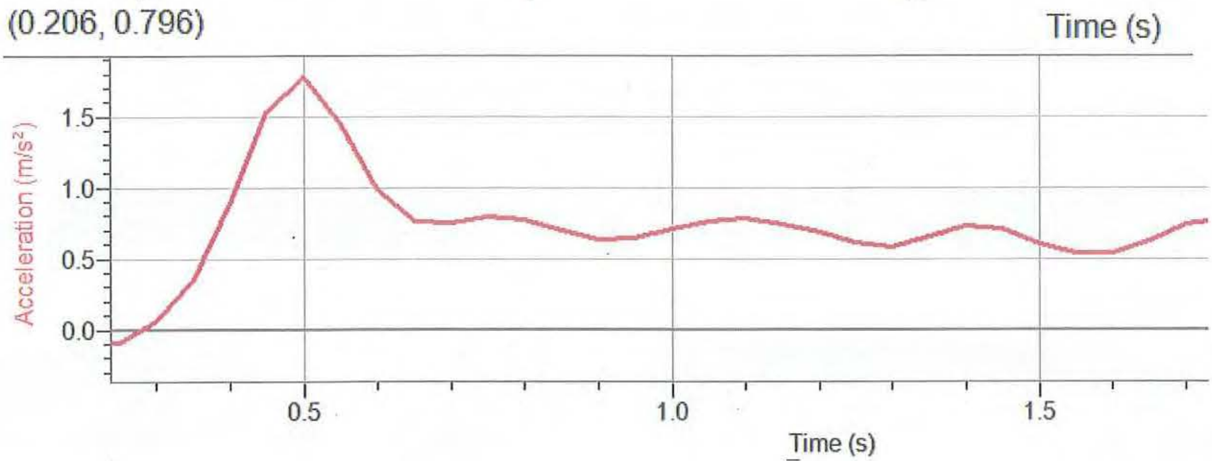
30%

60%

60%

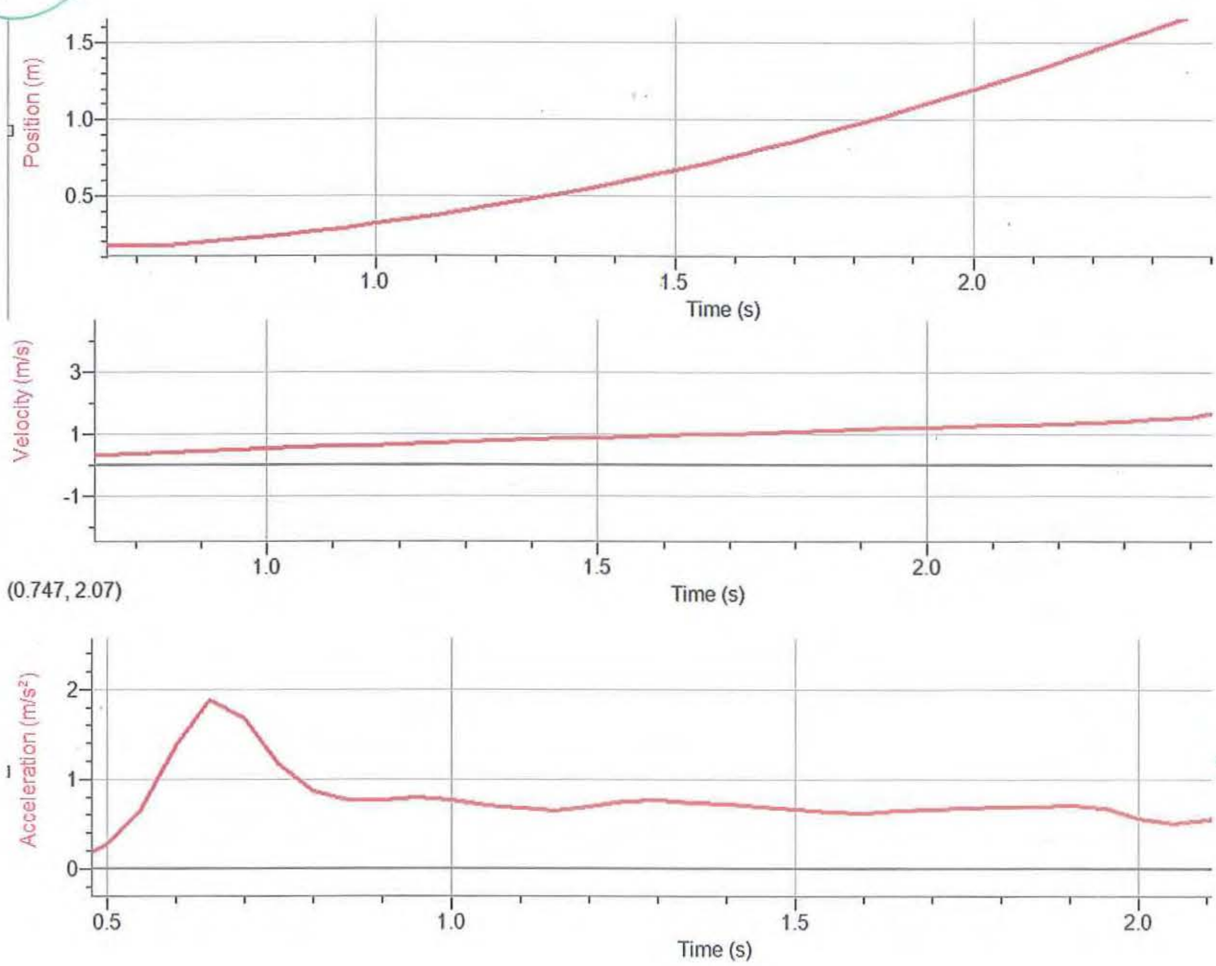

Position (m)
2.0
1.5
1.0
0.5
0
1
2
Time (s)


Velocity (m/s)
1.0
0.5
0.0
0
1
2
Time (s)


(0.206, 0.796)
Acceleration (m/s²)
1.5
1.0
0.5
0.0
0.5
1.0
1.5
Time (s)

60%

90%



Position (m)
1.5
1.0
0.5
1.0
1.5
2.0
Time (s)
Velocity (m/s)
3
1
-1
1.0
1.5
2.0
(0.747, 2.07)
Time (s)
Acceleration (m/s²)
2
1
0
0.5
1.0
1.5
2.0
Time (s)

90%